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2016 WL 1725990
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United States District Court,
D. Oregon,
PORTLAND DIVISION.

Daniel Brian Williams, Plaintiff,
v.
Invenergy, LLC, an Illinois Corporation;
and Willow Creek Energy, LLC, a
Delaware Corporation, Defendants.

Case No.: 2:13-CV-01391-AC
|
Signed 04/28/2016

OPINION AND ORDER

ACOSTA, Magistrate Judge.

*1 Plaintiff Daniel Brian Williams ("Williams") brings claims for private nuisance alleging Defendants Invenergy, LLC ("Invenergy") and Willow Creek Energy, LLC ("Willow Creek") (collectively "Defendants") are denying him the use and enjoyment of his home in Morrow County, Oregon. Williams contends Defendants' wind-turbine facility (the "Willow Creek Wind Facility"), which is situated near Williams's home, emits audible noise, vibration, light, and low-frequency infrasound which causes him anxiety and disturbs his sleep. Defendants move for partial summary judgment and, in the alternative, move to exclude the testimony of Williams's expert witnesses to the extent they intend to testify that low-frequency infrasound causes adverse health effects in humans. Upon careful review of the record, the court grants in part and denies in part Defendants' motion to exclude Williams's expert testimony. The court also grants in part and denies in part Defendants' motion for partial summary judgment.

Background

I. Factual Background

In early 2005, the Morrow County Planning Board ("Morrow County") granted Defendants a conditional use permit ("CUP") to build and operate the Willow Creek Wind facility. (Declaration of Steven Rizzo in Support of Defendants' Motion for Partial Summary Judgment ("Rizzo PSJ Decl.") Ex. 1 at 1.) Defendants were required to comply with twenty-one conditions to operate the Willow Creek Wind Project. (Rizzo PSJ Decl. Ex. 2 at 1.) Notably, the CUP required Defendants to "[c]omply with OAR 340 Division 35 standards relative to wind facilities and the appropriate sections of the Morrow County Noise Ordinance." (*Id.*)

The wind farm went operational in early 2008, and individuals with homes nearby immediately began complaining about the noise and vibration produced by the wind turbines. (McCandlish PSJ Decl. Ex. 2, 3, 4.) Shortly after the wind turbines began generating power, Williams started experiencing health problems. (Rizzo PSJ Decl. Ex. V.) Although Williams's primary complaint was sleep disturbance, he also experienced irritability, anxiety, nausea, dizziness, headaches, and at least one anxiety attack. (*Id.* at 2.) Williams primarily linked his symptoms to the deep, "pulsating, throbs of intermittent and constant audible sound" generated by the wind turbine. (*Id.* at 4.) He alternatively described the sound as "like a jet/train that isn't coming or going. Just there." (*Id.*) Eventually, Williams moved out of his home to escape the wind turbine noise. (*Id.* at 5.)

Upon learning of the complaints, Defendants met on several occasions with Williams and other local residents to discuss the local residents' concerns about the manner Defendants' were operating the wind-turbine facility. At these meetings, the parties discussed how much audible noise the turbines could lawfully produce while remaining in compliance with the CUP. (McCandlish PSJ Decl. Ex. 2 at 2.) Defendants initially expressed their belief that the applicable noise ceiling was 50 dB. Williams and the other concerned residents disagreed; they contended the state-imposed limit was 36 dB and urged Defendants to comply with that standard. Eventually, Defendants' agreed to conduct a noise test at properties surrounding the Willow Creek Wind Facility to determine whether they were in compliance with relevant noise standards. (McCandlish PSJ Decl. Ex. 17.) The "preliminary noise level survey" found regular, albeit minor, noise exceedences at various locations near the wind farm, particularly at wind speeds of 9 meters per second or more. (McCandlish PSJ Decl. Ex. 17.)

II. Procedural Background

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***2** Upon learning that Defendants were out of compliance with the conditional use permit, Williams and the other local residents instituted administrative proceedings with the Morrow County Planning Board in an attempt to have the violations remedied. (Rizzo PSJ Decl. Ex. 9 at 2.) Initially, the Morrow County Planning Board determined Defendants were in violation of the noise limitations in the CUP at multiple residences near the wind facility, and concluded Defendants "should have six months to bring the facility into compliance." (*Id.* at 3.) The parties appealed the board's decision to a Morrow County court, who remanded the case back to the Morrow County Planning Commission so the commission could "adopt findings in support of its decision and specify a procedure by which Invenergy could bring the Willow Creek Energy Facility into compliance with the noise standards within the six month deadline." (*Id.*)

On remand, the planning commission found:

> (1) that the evidence shows the facility violates the noise standard at times at three petitioners' residences (Eaton, Williams and Mingo) and at a fourth residence in some wind conditions (Wade), (2) the wind standard is an objective standard rather than a subjective standard and is either met or not met, "black and white," (3) future data collection should be done by a third party with Invenergy paying the cost, (4) Invenergy should have six months to bring the facility into compliance, and (5) to comply with the noise standard, total noise (combined noise from background sources and the facility) may not exceed 36 decibels (dBA).

(*Id.* at 4.) The parties again appealed the planning board's decision to a Morrow County Court, who adopted the planning board's decision in full. (*Id.*) In turn, the parties appealed the court's decision to the Oregon Land Use Board of Appeals ("LUBA"), which concluded the county court's decision was not supported by adequate findings or substantial evidence. (*Id.*) LUBA also concluded there were two separate methods for establishing whether Defendants complied with relevant noise standards, either of which were applicable to gauge compliance with the state noise standards. LUBA remanded the case back to the Morrow County court because "[b]oth the planning commission's and the county court's decision had erroneously suggested that, in defending against the allegations of noise standard violations, Invenergy is limited" to one method. (*Id.* at 4-5.)

On remand, the Morrow County Court concluded that Defendants violated the noise standards only at Williams's home, "but that those violations were not serious or significant enough to warrant either revoking the [CUP] or taking further action to require that those violations be corrected." (*Id.* at 5.) Williams and his neighbors again appealed to LUBA, who affirmed the county court's decision in full. (*Id.* at 20-21.)

On August 9, 2013, Williams filed a complaint in this court for common law trespass, common law nuisance, and nuisance per se. (Dkt. No. 1.) His complaint asks for an award of $5,000,000 in non-economic damages, $171,000 in economic damages, $5,000,000 in punitive damages, fees and costs, and a "permanent injunction enjoining Invenergy from creating noise exceedences." (Dkt. No. 1 at 13.) Defendants moved to dismiss Williams's claims for failure to state a claim. *Williams v. Invenergy, LLC*, Civ. No. 3:13-cv-01391-AC, 2014 WL 7186854, at *1 (D. Or. Dec. 16, 2014). In a December 16, 2014 Opinion and Order, the court concluded Williams failed to state claims for trespass and nuisance *per se*, but held his common-law nuisance claim could proceed based on his theory that the wind turbines created audible noise, low-frequency infrasound, light, and vibration which interfered with Williams's use and enjoyment of his property. *Id.* at *21.

Defendants have now filed a motion for partial summary judgment and a *Daubert* motion to exclude testimony by three of Williams's expert witnesses.

III. Overview of Williams's Expert Opinions

***3** Williams retained four experts to testify in this case. Defendants move to exclude only three from offering their testimony. The following section contains a brief description of the Rule 26 expert report for each contested expert.

A. James Report

Upon filing his lawsuit, Williams retained Richard James ("James") as an expert witness to assist in

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taking measurements in and around Williams's home, to determine the audible noise and infrasound, or wave phenomena "sharing the physical nature of sound but with a range of frequencies below that of human hearing," present and attributable to the wind turbines. (Declaration of Steven Rizzo in Support of Motions for Summary Judgment and for Alternative Request for a *Daubert* Hearing ("Rizzo Daubert Decl.") Ex. A at 1; *Infrasound*, THE AMERICAN HERITAGE DICTIONARY OF THE ENGLISH LANGUAGE (5th ed. 2000)) Williams also retained James to testify regarding the general causal relationship between acoustic outputs produced by wind turbines and adverse health effects in humans. (*Id.*)

James's report begins with an introduction wherein James states his credentials and briefly describes his findings regarding the low-frequency sound emitted by the Willow Creek wind turbines. (*Id.*) James explains that the turbines emit a "sound signature" consisting of "a series of tones that start in the very low infrasound range below 1Hz at a frequency that is linked to the rotation speed of the turning hub and blades." (*Id.*) He further explains that "the blade pass tone has harmonics that also appear as tones" which accompany the tone immediately produced by turbine. (*Id.*)

After James describes his testing methods and instrumentation, James states three opinions related to Williams's case. (*Id.*) First, James opines that, "there is sufficient information from ... studies to associate the operation of utility scale wind turbines that produce strong ... blade pass tones and harmonics inside a home as a cause of the reported adverse health effects or inability to remain in one's home." (*Id.* at 3.) In support of this conclusion, James cites two documents. First, he cites the minutes from the "Wisconsin Brown County Board of Health's [October] 14, 2014 hearing which summarizes the supporting research conducted by this author and others for the Shirley Wind utility ...." (*Id.*) Second, James cites "peer reviews" of the Cape Bridgewater Acoustic Testing Program ("Cape Bridgewater ATP"), "a study conducted in Australia by Steve Cooper" which purportedly "linked the cause of the complaints and sensations not associated with audible sounds experienced by the test subjects while in their homes in the presence of the wind turbine signature (WTS)." (*Id.*) In particular, he cites two documents produced by Acoustician Steve Schomer which summarize the Cape Bridgewater ATP and discuss the implications thereof. (*Id.*)

James's second opinion is that, based on review of the topography surrounding Williams's home, "there is a clear line of sight (sound) from the region of the blades where sounds are emitted and the Williams's home and property where the immissions are received." (*Id.* at 4.) James based this conclusion on information obtained from Willow Creek, the Federal Aviation Administration, and Google Earth. (*Id.*) Lastly, James opines in his third opinion that the measurements taken in Williams's home evidence the presence of a Wind Turbine Signature ("WTS"), including low-frequency infrasound. (*Id.*) According to James, these sound-pressure levels are similar to those produced by other wind farms, and "supports [James's] opinion hat the infrasound associated with the WTS is sufficient to cause a person who is sensitive to these adverse health effects to similarly vacate his or her home as Mr. Williams has also done." (*Id.*)

B. Punch Report

***4** Williams also retained audiologist Jerry Punch ("Punch") as an expert witness in this case. (Rizzo Daubert Decl. Ex. T.) Pursuant to his duties as an expert, Punch submitted a Rule 26 expert-witness report (the "Punch Report"). (*Id.*) In that report, Punch recounts his lengthy career and comprehensive list of publications. Punch thereafter explains that, based on his pre-existing knowledge, his review of a symptom questionnaire completed by Williams, and his review of portions of the evidentiary record, including depositions and the James Report, he came to twelve conclusions regarding the effect of industrial-scale wind turbines. (*Id.* at 4.) Punch concludes that wind turbines:

> (1) produce low-frequency noise and infrasound that is acoustically unique and more disturbing than other sources of industrial or transportation noises,??
>
> (2) produce noise low-frequency noise and infrasound [*sic*] that cannot be easily masked by wind noise, closed windows, external noises such as fans, hearing protection devices or sleeping in a typical residential basement,??
>
> (3) produce infrasonic energy whose harmful effects on humans can be explained by physiological mechanisms

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of the inner ear, even though infrasound is not perceived as sound,??

(4) result in complaints of annoyance in substantial percentages of persons who live near them, which, in turn, can lead to stress, sleep disturbance, and other health disorders, with sleep disturbance being the most frequent health complaint,??

(5) result in symptoms of nausea or motion sickness in some people,??

(6) produce noise that results in a wide variety of health effects for a non-trivial percentage of residents,??

(7) produce adverse health effects that are not typically well correlated with A-weighted sound levels,??

(8) emit noise levels that exceed 32-35 dBA, which according to the World Health Organization (WHO, 2009), is a threshold level above which sleep disturbance and other adverse health effects occur in a substantial portion of the population (See Exhibit E),??

(9) lead to health effects that cannot be explained by either visibility or psychological expectations alone, and??

(10) can result in physiological responses directly linked to stress, changes in hormonal levels, slight alterations in brain-wave (EEG) activity, notable alterations in inner-ear physiology, and cardiovascular illnesses,??

(11) at Wisconsin's Shirley Wind project have been declared a human health hazard by the Brown County Board of Health, and??

(12) have been shown at the Cape Bridgewater Wind Farm in Melbourne, Victoria, Australia, to produce unpleasant sensations in exposed residents; those sensations, which include headache, dizziness, and nausea, were synchronized with operational conditions of the turbines, following a period of non-operation in which the sensations subsided.

(*Id.*) Punch attached to his report the symptom questionnaire, a document published by the World Health Organization regarding the relationship between audible noise levels and human behavior, including sleeping, the Schomer review of the Cape Bridgewater ATP, and a lengthy reference list.

C. Ironside Report

Williams's third expert is Dr. Keith Ironside, Jr. ("Dr. Ironside"), a medical doctor and board certified sleep specialist who operates the Oregon Sleep Center in Hermiston, Oregon. (Rizzo Daubert Decl. CC at 1, 8.) Dr. Ironside interviewed Williams about his symptoms and the circumstances surrounding those symptoms. (*Id.* at 1.) In his report, Dr. Ironside observes that Williams experienced "loss of sleep when he hears the wind turbines" and "awakens on days the wind mills are going feeling anxious." (*Id.*) Dr. Ironside further writes that Williams's sleep disturbances were often associated with "a fast heart rate." (*Id.* at 2.)

***5** Dr. Ironside assessed that Williams was a "non-sleepy person" due to his score of 2 out of 24 on the "Epworth sleepiness scale." (*Id.* at 3.) After consulting the International Classification of Sleep Disorders, 3rd edition, Dr. Ironside diagnosed Williams with "short-term insomnia disorder." (*Id.* at 6.) Williams's insomnia, Dr. Ironside opined, could not "be explained in this case purely by inadequate opportunity to sleep," but was properly attributed to "the noise of the wind turbines ...." (*Id.*) Dr. Ironside also concluded that vibrations produced by the wind turbines had an effect "on his autonomic nervous system ...." (*Id.*)

At deposition, Dr. Ironside testified that he had is "not an expert in infrasound or ... an audiologist," and had little experience with infrasound. (Rizzo Daubert Decl. Ex. DD at 6.) When asked whether it was his expert opinion that infrasound caused Williams's insomnia, Dr. Ironside responded, "I can't differentiate from infrasound and plain sounds based on [Williams's] history." (*Id.*) In fact, Dr. Ironside admitted at deposition that he has read about infrasound "only in passing," but has experienced infrasound twice in his life, once when a lion roared in his ear as a child and later when he experience tachycardia immediately preceding an earthquake in San Francisco. (*Id.* at 6.) However, following his deposition, Dr. Ironside reviewed the James Report and penned a letter to Williams's attorney in which he decisively concludes that "it is my opinion that to a reasonable degree of medical probability within my field of sleep medicine that the infrasound generated by industrial wind turbines operating closest to Mr. Williams'[s] home is a substantial contributing factor to Mr. Williams'[s] insomnia." (Rizzo Daubert Decl. Ex. EE at 1-2.)

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Legal Standards

I. Motion to Exclude under *Daubert*

The Federal Rules of Evidence ("Rules") provide:

> A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if: (a) the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue; (b) the testimony is based on sufficient facts or data; (c) the testimony is the product of reliable principles and methods; and (d) the expert has reliably applied the principles and methods to the facts of the case.

FED. R. EVID. 702. Under Rule 702, the district court is tasked with the gate-keeping function assigned by *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993) ("*Daubert I*"), to determine the admissibility of expert witness testimony. *Kumho Tire Co., Ltd. v. Carmichael*, 526 U.S. 137, 141, 147 (1999). "Faced with a proffer of expert scientific testimony, then, the trial judge must determine at the outset ... whether the expert is proposing to testify to (1) scientific knowledge that (2) will assist the trier of fact to understand or determine a fact in issue. This usually entails a preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue." *Daubert I*, 509 U.S. at 592-93 (footnote omitted). An expert's "bald assurance of validity is not enough." *Daubert v. Merrell Dow Pharm., Inc.*, 43 F.3d 1311, 1316 (9th Cir. 1995) ("*Daubert II*"). *Daubert*, which originally applied only to the testimony of "scientists," has been extended to apply to the testimony of engineers and other experts who possess technical and specialized knowledge. *Kumho Tire*, 526 U.S. at 141.

***6** In *Daubert I*, the Supreme Court articulated factors to consider when determining if an expert's testimony is admissible under Rule 702. Trial courts undertaking the *Daubert* analysis must determine: (1) whether the theory, technique, and background knowledge the expert applies is generally accepted in the relevant scientific community; (2) whether the research supporting the expert's conclusion has been subjected to peer review and publication; (3) whether the expert's theory can be and has been tested; (4) whether standards exist to control the operations of the expert's methods; and (5) whether the known or potential rate of error is acceptable. *Daubert I*, 509 U.S. at 593-94. The inquiry, however, is a flexible one, with the focus solely on the principles and methodology used, not on the conclusions they generate. *Id.* at 594; *see also Claar v. Burlington N. R. Co.*, 29 F.3d 499, 502 (9th Cir. 1994) (the district court is "both authorized and obligated to scrutinize carefully the reasoning and methodology" underlying the expert's testimony); *Tyson v. Ore. Anesthesiology Group, P.C.*, Case No. 03-1192-HA, 2008 WL 2371420, at *15 (D. Or. June 6, 2008) (finding inadmissible expert conclusions that were "vague and inadequately supported with specific, relevant statistical analysis").

However, the court's analysis is not constrained to an inflexible application of *Daubert* factors. *Daubert I*, 509 U.S. at 594; *Kumho Tire*, 526 U.S. at 147-153. As the Supreme Court observed, *Daubert's* factors "may or may not be pertinent in assessing reliability.... The conclusion, in our view, is that we can nether rule out, nor rule in, for all cases and for all time the applicability of the factors mentioned in *Daubert*.... Too much depends upon the particular circumstances of the particular case at issue." *Id.* at 150 (citations and internal quotations omitted). As a result, the court may consider other factors germane to the expert's opinion, and the factors listed in *Daubert* may not be reasonable measures of reliability of expert testimony in a particular case. *Id.*

A threshold question in determining the admissibility of expert testimony is whether the proffered testimony will assist the trier of fact. *Daubert I*, 509 U.S. at 592. Expert witness testimony is unnecessary unless the subject matter "is beyond the common knowledge of the average lay person." *U.S. v. Hanna*, 293 F.3d 1080, 1086 (9th Cir. 2002) (quotation marks omitted). Rulings on the admissibility of expert testimony under Rule 702 are committed to the sound discretion of the trial court. *Gen Elec. Co. v. Joiner*, 522 U.S. 136, 141-42 (1997). Thus, "even if [the expert] testimony may assist the trier of fact, the trial court has broad discretion to admit or exclude it."

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Beech Aircraft Corp. v. U.S., 51 F.3d 834, 842 (9th Cir. 1995) (per curiam) (quotation marks omitted).

II. Motion for Summary Judgment

A court should grant a motion for summary judgment "if the movant shows that there is no genuine dispute as to any material fact and the movant is entitled to judgment as a matter of law." FED. R. CIV. P. 56(a). The moving party bears the burden of establishing that no issue of fact exists and that the nonmovant cannot prove one or more essential elements of a claim or defense. *Celotex Corp. v. Catrett*, 477 U.S. 317, 324 (1986). If the movant meets his burden, the nonmovant must "go beyond the pleadings [ ] by her own affidavits ... [to] designate specific facts showing that there is a genuine issue for trial." *Id.* (internal quotation marks omitted). On summary judgment, the court is bound to view all facts in a light most favorable to the nonmovant and must draw all justifiable inferences in the nonmovant's favor. *Narayan v. EGI, Inc.*, 616 F.3d 895, 899 (9th Cir. 2010).

Discussion

Defendants move for summary judgment, for partial summary judgment, and for exclusion of Williams's expert testimony. Williams opposes Defendants' motions and argues that, even if the court excludes his expert testimony, his nuisance claims survive. The court will first address Defendants' *Daubert* motion. Thereafter, the court will consider whether Defendants are entitled to summary judgment on Williams's claim for private nuisance. If his claims survive summary judgment, the court will then address whether he is barred as a matter of law from recovering injunctive relief and punitive damages.

I. Motion to Exclude under *Daubert*

***7** Defendants move to exclude the expert opinions of James, Punch, and Ironside. According to Defendants, the anticipated testimony of these three experts is not based on scientific knowledge and is not reliable under the test articulated in *Daubert I*. Williams contends his experts have reliably applied generally accepted scientific principles to establish causation in his case. After careful review of the record, the court grants in part and denies in part Defendants' *Daubert* motion, and will exclude all expert testimony regarding the causal link between turbine-generated infrasound and adverse human health effects.

A. James

Williams engaged James to testify primarily about two issues. First, James will testify that the windmills near Williams's home produce audible noise and infrasound which is measurable inside Williams's home. Second, James will testify regarding the general causal element of Williams's infrasound claim: that the noise and infrasound produced by the wind turbines caused Williams adverse health effects and annoyance which drove him to move out of his home.

Defendants move to exclude James's opinion under *Daubert*. They argue: (1) The materials upon which James relies lack scientific reliability; (2) James is not qualified to testify on causation; (3) James did not employ reliable methodology to reach his conclusions; and (4) James's opinion that infrasound is harmful to humans lacks scientific reliability. Williams disputes each of Defendants' arguments and contends James's scientific methods are reliable in theory and application.

1. Reliability of Foundational Materials

Defendants argue the materials upon which James relies to inform his causation testimony lacks scientific reliability. Because James's opinion lacks the requisite reliability required of expert testimony, Defendants contend the court should exclude James's testimony in its entirety. Specifically, Defendants contend the Brown County Board of Health Meeting Minutes, the Cape Bridgewater ATP, the Schomer review of the Cape Bridgewater ATP, and the N.D. Kelley Paper do not exhibit "good science" which may be relied upon to form opinions about the affect of wind farms on humans. Williams argues James is a seasoned expert in the field of acoustics who has encountered reliable scientific literature throughout his career which informs his opinions in this case. Because this is typical in scientific and academic fields of study, Williams contends James's testimony should be admitted.

The primary goal of the *Daubert* analysis is to determine whether the expert witness's testimony reflects "scientific knowledge." *Daubert II*, 43 F.3d at 1315. Proponents typically meet their burden of demonstrating "scientific

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knowledge" by showing that their methods constitute "good science." *Id.* Moreover, to the extent the witness's opinions arise out of pre-existing research or knowledge, the expert must "explain precisely how they went about reaching their conclusions and point to some objective source — a learned treatise, the policy statement of a professional association, a published article in a reputable scientific journal or the like — to show that they have followed the scientific method, as it is practiced by (at least) a recognized minority of scientists in their field." *Id.* at 1319. Due to the requirements of Rule 702, assuring the reliability of the expert's foundational knowledge, experience, and research is an essential aspect of the court's gatekeeping function on a *Daubert* motion. FED. R. EVID. 702. As such, the court must occasionally go beyond the expert's own research and scrutinize the foundational studies and literature which inform the expert's conclusions. *See Daubert II*, 43 F.3d at 1315 (stressing the importance of "scientific knowledge" based on "reliable treatises" and scientific research which predates the litigation in which the expert testifies).

a. Brown County Board of Health

***8** Attached to James's expert report as Exhibit 2(a) is a document entitled "Minutes of Brown County Board of Health meeting including Motion" (the "Brown County Minutes"). (Rizzo Daubert Decl. Ex. B.) The Brown County Minutes are the written minutes for an October 14, 2014 meeting of the Board of Health for Brown County, Wisconsin. (*Id.*) The primary topic of the meeting is to consider taking action against the "Shirley Wind Project" near Glenmore, Wisconsin due to the alleged health effects experienced by individuals living in the area. The meeting begins with members of the board of health reciting portions of a study performed by James on the Shirley Wind Project, including the following conclusion:

> [I]t is reasonable to conclude that the adverse health effects reported by members of the Shirley community are linked to the operation of the Shirley Wind Project wind turbines. While there may still be debate about the precise mechanism that causes these sounds to induce the symptoms; it is clear from this study, and others conducted in different parts of the world by other acousticians, that acoustic energy emitted by the operation of modern utility scale wind turbines is at the root of the adverse health effects.
>
> Following the Precautionary Principle, it is concluded that operation of the Shirley Wind [P]roject is exposing the community members to acoustic energy that can be linked to the reported adverse health effects, is similar to other historical problems with other infrasound noise sources, and that the only method available to protect the community's health is to not operate wind turbines close to homes. For that to occur, either the utility must terminate operations or it should operate with a buffer zone between the wind turbines and the closest residential properties. Given that the recent study shows people reporting adverse health effects at distances of four miles this could require purchase of many of the properties in the community.

(Rizzo Daubert Decl. Ex. B at 3.) James's data associated with his research on the Shirley Wind Project is not attached to or otherwise contained in the minutes. (*Id.*) Following recitation of portions of James's study, the board opened the meeting up to hear comments from the public. (*Id.* at 3.) The relevant portion of the meeting concluded with approval of a parliamentary motion, "[t]o declare the Industrial Wind Turbines at Shirley Wind Project in the town of Glenmore, Brown County, WI a human health hazard for all people (residents, workers, visitors, and sensitive passerby) who are exposed to infrasound/low frequency noise and other emissions potentially harmful to human health." (*Id.* at 13.)

Defendants contend this is not a scientific document which may serve as a foundation for scientific knowledge, and that the portions of James's study referenced in the Brown County Minutes may not serve as foundational scientific knowledge because no data is attached from which a third party could confirm or disprove James's conclusions. Williams, however, declares Defendants' argument a "straw man" and contends the Brown County Minutes were never intended to be a "scientific paper" or "demonstration of science." Instead, Williams contends the Brown County Minutes were "included as a demonstration of how medical practitioners, including a medical doctor trained and experienced in clinical work with patients, use their personal knowledge and skills to associate complaints to a cause." (James Decl. ¶ 11.)

The court agrees with Defendants that the Brown County Minutes do not constitute "scientific knowledge" and may not serve as a foundational document to explain the conclusions James reaches in his expert report. In James's

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Rule 26 report, he cites the Brown County Minutes to support the proposition that a causal relationship exists between industrial wind turbines and adverse health effects in humans. However, James's data is not included in the Brown County Minutes, and the Minutes do not reflect any other scientific method which demonstrates the type of "good science" which should form the basis for an expert witness's knowledge. The Minutes are not a published scientific paper subject to the scrutiny of the scientific community. Nor are the Minutes properly described evidencing medical diagnosis or clinical decision making where medical professionals make unbiased treatment decisions to address the symptoms of individual patients. The Brown County Minutes are best described as the documenting the political process surrounding an issue of public concern in Brown County, Wisconsin. This is particularly evident given that a majority of the minutes are devoted to documenting public comments by concerned citizens at the meeting. As such, the Brown County Minutes are not scientific knowledge which may serve as a foundational basis for James's expert opinion.

b. The Schomer Review of Cape Bridgewater ATP

***9** In support of his opinion on general causation, James also cites "two statements issued by Dr. Paul Schomer" which he describes as "peer reviews of a study conducted in Australia by Steve Cooper ...." (Rizzo Daubert Decl. Ex. A at 3.) The first statement ("Schomer I"), briefly describes the "Cape Bridgewater Acoustic Testing Program" case study conducted by Steve Cooper in Victoria, Australia. (McCandlish Daubert Decl. Ex. 1 at 30.) Schomer then proclaims, with little explanation or additional reasoning, that the study conclusively proves the causal relationship between wind turbine operations and adverse health effects in humans. (*Id.*) Thereafter, Schomer warns that "some will undoubtedly argue that a correlation does not show cause and effect." (*Id.*) He labels this argument as "groundless" and "creative logic" which relies on the postulation that "some other thing like an unknown 'force' that simultaneously causes the wind turbine power being generated and symptoms such as nausea, vertigo, and headaches to change up and down together." (*Id.*)

The second document, which Schomer issued on February 20, 2015, serves as a response to certain criticisms of the Cape Bridgewater study and Schomer I. (Declaration of Attorney James E. McCandlish in Support of Plaintiff's Response to Defendants' Motions for Partial Summary Judgment or Alternative Request for a *Daubert* Hearing ("McCandlish Daubert Decl.") Ex. 1 at 32.) Among other criticisms, Schomer responds to the critique that the Cape Bridgewater study was not a "medical study," and that Schomer is not qualified to opine on the epidemiological relationship between acoustic stimuli created by wind turbines and adverse health effects in humans. (*Id.*) Schomer contends this criticism is unwarranted, and that he and the author of the Cape Bridgewater ATP are not holding out their conclusions as "medical conclusions." (*Id.*) He proceeds to analogize the causal relationship shown in the study to the relationship between some individuals' consumption of beans and the digestive gas created by those individuals thereafter:

> The Cooper study is a variation of how one "discovers" the relationship: beans in – gas out. Cooper examines three possible inputs: sound level of the receivers (six subjects), the vibration levels at the receivers, and the power output of nearby turbines. Cooper's outputs are the periodic observations by each subject as to the degree by which they feel they are being affected by wind turbines, specifically at the time they are giving these observations. The cause and effect is found between the input, the turbine power, and the outputs, subject's judgments as to the degree they are being affected at the time.... [T]he processes inside the body are not explained; [so] nothing "medical" is dealt with.

(*Id.*)

The court agrees with Defendants that the Schomer documents do not represent reliable "scientific knowledge" which James may use as a foundation for his expert conclusions. First, the Schomer documents are not a scientific study. Schomer includes no independent data or analysis of the Cape Bridgewater ATP. Instead, he summarizes the study and offers a brief defense of Cooper's work without critical analysis or any discussion of the study's limitations. There is no evidence Schomer's documents were published in a reputable journal or have otherwise been peer reviewed by respected acousticians in the scientific community. Third, the opinions expressed by Schomer are not "scientific." They are not supported by citation to corroborating studies or even explained in much detail. Schomer's thoughts, as expressed in these documents, consists primarily of unsupported conclusions which are not suitable to serve as a basis for "scientific knowledge."

Because the Schomer's review documents lack scientific reliability, they do not establish a definitive causal relationship between infrasound and adverse health effects. Thus, to the extent James bases his causal theory on the Schomer documents, those opinions lack scientific reliability and are not helpful to the court, and will be excluded.

c. Cape Bridgewater Acoustic Testing Program

***10** Although James does not cite directly to it in his expert report, Defendants move to exclude James's causation testimony to the extent it relies on the Cape Bridgewater ATP. (Rizzo Daubert Decl. Ex. F.) Defendants argue that the Cape Bridgewater ATP lacks scientific reliability because the author's methods were not scientific, and the author himself concedes that the study has too many limitations to conclusively establish causation.

In the Cape Bridgewater ATP, acoustician Steven Cooper ("Cooper") was retained by the company operating a wind-turbine project in Victoria, Australia to study the effects of the wind turbines on six local residents. (*Id.*) Cooper began by taking broad-spectrum sound and sound-pressure measurements in and around three homes located between 650m and 1600m from a wind turbine. (*Id.*) He then compared that data to operations data provided by the company operating the wind turbines to identify the audible and inaudible frequencies associated with the turbines' operation (the "Wind Turbine Signature"). (*Id.*) Finally, Cooper had six test subjects who self-reported turbine-associated symptoms record their experiences in a diary every few hours. (*Id.*)

The subjects were instructed to record their observations over the course of ten weeks regarding the observable noise and vibration produced by the wind turbines. (*Id*) They were also instructed to record the type and severity of the "sensation" they felt at the time of the diary entry. (*Id.*) The author defined "sensation" as (1) headache; (2) pressure in the head, ears, or chest; (3) ringing in the ears; (4) tachycardia; and (5) a sensation of heaviness. (*Id.*) Ultimately, statistical comparisons of the three sets of data showed an association with subjects experiencing a "high severity" of sensation when one of the following conditions was present: (1) "when the turbines were seeking to start (and therefore could drop in and out of generation);" (2) "an increase in power output of the wind farm in the order of 20%;" (3) "a decrease in the power output of the wind farm in the order of 20%;" and (4) " ... when the turbines were operating at maximum power and the wind increased above 12 m/s." (*Id.* at 167.) However, there "were at times other instances of high severity of [sensation] not fitting the above four scenarios." (*Id.*) Moreover, the author was able to find no association between the subjects' feeling of "sensation" with the decibel measurements intended to capture the audible volume of the noise produced by the turbines. (*Id.*) Based on that comparison, the author surmised that the "sensation" among subjects was caused not by audible noise, but by low-frequency infrasound which is below the human hearing threshold. (*Id.*)

i. Acoustic Outputs and WTS

James relies on the Cape Bridgewater ATP for two scientific propositions. First, he cites the Cape Bridgewater ATP in his rebuttal report for the proposition that, through broad-spectrum sound-pressure measurements, one can demonstrate the existence of a Wind Turbine Signature ("WTS"). The Wind Turbine Signature is the set of acoustic outputs and the associated harmonic frequencies created by the operation of a particular type of wind turbine. The court concludes this is reliable scientific knowledge under *Daubert*. First, the method of identifying the frequencies emitted by a wind turbine appears to be generally accepted in the field of acoustic sciences. James, Schomer, Salt, and even Defendants' expert have utilized some form of the methods applied by Cooper in the Cape Bridgewater ATP for determining the WTS of other wind turbines.

***11** Second, although other portions of the Cape Bridgewater ATP have not been subjected to meaningful peer review, the methods Cooper applies to show the

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WTS have been subject to "true peer review." Legal commentators have articulated two types of peer review, "true peer review," and "editorial peer review." *See* *Valentine v. Pioneer Choir Alkali Co., Inc.*, 921 F. Supp. 666, 675 (D. Nev. 1996) (citing Effie J. Chan, *The "Brave New World" of Daubert: True Peer Review, Editorial peer Review, and Scientific Validity*, 70 N.Y. U. L. Rev. 100 (1995) (note)). "Editorial peer review" is the process by which reputable scientific journals choose which articles it will publish. *Valentine*, 921 F. Supp. at 675. Editorial peer review is not necessarily a good measure of the scientific reliability for a study, as "the average [peer-reviewing] referee spends less than two hours assessing an article submitted" to a journal. *Id.* Moreover, the editorial peer review process is rife with the internal politics of academia. *Id.*

"True peer review" on the other hand, is the process by which an author's peers review the author's methods and attempt to replicate the results through retesting. *Id.* Some have labeled true peer review "the essence of science." *Id.* Here, Cooper's methods for measuring the acoustic outputs of the Cape Bridgewater wind turbines, and his articulation of the WTS, have been reviewed by acousticians around the world and successfully replicated. It is clear that, due to its replicability, this method has become generally accepted in the acoustician community.

Third, Cooper's methods are capable of empirical verification as demonstrated by their continued use in the acoustician community. Finally, Defendants do not contend that the margin of error lies within an unacceptable limit. Therefore, the court will accept James's testimony about measuring acoustic outputs of wind turbines and creation of a WTS to the extent that testimony is based on the Cape Bridgewater ATP.

ii. Causation

James also cites the Cape Bridgewater ATP for his opinion that wind turbine acoustic outputs have a causal relationship to human adverse health effects, but the author of Cape Bridgewater ATP articulated significant shortcomings of the study as it relates to proving causation. First, the study's methods were not scientifically rigorous and are not generally accepted in the scientific community. The author of the study concedes that there were significant reporting abnormalities which affected the reliability of some data. At first, the test subjects did not understand their duty to fill out diaries every one-to-two hours. It was only part of the way through the study that they began filling out their diaries as intended. Moreover, the author noted that there "were significant issues in terms of instrumentation," and cautioned future researchers against relying on manufacturers data to record measurements. (*Id.* at 170.) Second, the subject pool was small, and the individuals in the subject pool were not selected at random. Instead, the subjects of the study were self-selected based on their own pre-existing reactions to wind turbines. Thus, "the findings must be considered as **preliminary** and warrant[ ] further detailed studies of the scientific rigor necessary for the purpose of confirming/verifying" the study's findings. (*Id.* at 185) (emphasis original).

In addition, when analyzing "sensation" data, the author failed to analyze large amounts of data. Of the data collected, Cooper wrote only about the reports of level four and level five "sensations." (Rizzo Daubert Decl. Ex. F at 126.) Subjects reported "441 Sensations classified as severity ranking 4, and 81 as severity ranking 5." (*Id.*) Cooper analyzed 323 level 4 and 5 responses against the turbine power output data. However, Cooper did not analyze the level four data against the noise and infrasound data because "the degree of time involved in analysing [*sic*] the data ... would be significant." (*Id.*) Moreover, thirty of the eighty-one level-five responses were not analyzed because the corresponding noise measurements were unavailable. (*Id.*) Due to the statistical methods involved, most notably the analysis of only six self-selected participants with pre-existing symptoms, Cooper specifically recognizes that it is not a reliable scientific basis to establish causation, and specifically provides that there "is not enough data from this study to justify any change in regulation." (*Id.* at 230.) Another limitation noted by Cooper was that this "study did not include any testing in relation to sleep disturbance or health effects." (*Id.* at 229.)

***12** Here, the *Daubert* factors weigh against accepting James's causation opinion to the extent it is premised on the Cape Bridgewater ATP. As the court has discussed, the statistical and methodological abnormalities present in this study show Cooper's methods were not generally accepted in the scientific community to definitively prove causation. Instead, Cooper's study is best described as a "case study," which does not provide sufficient statistical reliability to constitute scientific evidence. *Casey v. Ohio Medical Prod.*, 877 F. Supp. 1380, 1384 (N.D. Cal. 1995). The existence of statistical and methodological abnormalities also lessens the importance of the study's replicability. Even though it is replicable, the replicating study would lack scientific reliability. Further, there is no evidence Cape Bridgewater ATP has been published in a reputable scientific journal. James contends that the Schomer documents constitute a “peer review” of the study, but the court is not convinced that Schomer's non-critical and non-analytical endorsement of the Cooper study constitutes the type of rigorous peer review which lends itself to scientific reliability. Accordingly, the court will not admit James's opinion on causation to the extent it is based on the findings of the Cape Bridgewater ATP.

d. N.D. Kelley Paper

Defendants move to exclude James's causation testimony to the extent it is premised on the paper “A Proposed Metric for Assessing the Potential of Community Annoyance from Wind Turbine Low-Frequency noise Emissions” by N.D. Kelley (the “Kelley Study”). In the Kelley Study, Kelley sought to quantify the “annoyance” felt by subjects when they were exposed to extremely low-frequency sound. (Rizzo PSJ Decl. Ex. J at 1.) Kelley placed the subjects in a room and in an adjacent room, put a speaker which would emit sounds below the range of audible frequencies in humans. (*Id.* at 5-6.) He also put measures in place to prevent associated audible noise from confounding the results. The subjects then recorded their “annoyance” level as they were exposed to various frequencies. (*Id.*)

Kelley found that “people do indeed react to a low-frequency noise environment” and registered “annoyance” for very low frequencies, even when the standard, A-weighted decibel level was low. (*Id.* at 8.) As a result, he concluded that the standard A-weighted decibel “measurements are not an adequate indicator of annoyance when low frequencies are dominant.” (*Id.*)

However, like James's other sources, the Kelley study has significant scientific shortcomings. First, Kelley takes data from only seven subjects. He admits that the “experiment would have to be repeated with a much larger number of evaluators (population) to confirm” his results as scientific knowledge. (*Id.* at 8.) Moreover, there is no evidence the Kelley study was published in a reputable scientific journal or that it was subject to any manner of peer review. Finally, even if these methodological deficits were not present, the Kelley study would not be reliable scientific evidence of a causal relationship between wind turbine infrasound and adverse health effects in humans because Kelley studied only whether low frequencies produce “annoyance” in those exposed to them. The study does not support the proposition that wind-turbine infrasound is capable of producing broader adverse health effects, including anxiety, panic attacks, and sleeplessness.

Because James does not cite any foundational literature which supports his causation opinion, the court concludes James's opinion lacks the indicia of scientific knowledge necessary for the court to consider it under Rule 702. Therefore, the court will exclude James's conclusions regarding the causal relationship between infrasound produced by wind turbines and adverse health effects.

2. Qualification to Testify on Causation

Defendants next argue that, because James does not have the qualifications to opine on causation based on his education and work experience, the court should exclude his causation testimony. Williams disagrees, and contends James's long career as an acoustician who studies sound-pulses produced by industrial equipment qualifies him to opine on general causation. The court agrees with the Defendants.

***13** James received a Bachelor's degree in mechanical engineering from General Motors Institute with a focus on “Noise Control Engineering.” (McCandlish Daubert Decl. Ex. 1 at 8.) He served as an adjunct instructor at Michigan State University from 1985 to 2013, and as an adjunct professor at Central Michigan University from 2012 to 2015. (*Id.*) Currently, James is the principal consultant and founder of E-Coustic Solutions. (*Id.*) He has a long career studying the noise and sound-pressure produced by industrial wind turbines. However, he is not a doctor or epidemiologist. As a result, he does not have the training to opine that the infrasound and audible noise created by wind turbines activates physiological mechanisms in the body which produce adverse health effects.

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3. Reliability of Methodology

Defendants also move to exclude James's testimony regarding three additional opinions: (1) that wind turbines produce broad-spectrum sound pressure, including audible noise and infrasound; (2) that generally accepted scientific methods may be applied to measure those acoustical outputs; and (3) that James was able take measurements inside Williams's home to capture the acoustical output, or Wind Turbine Signature of the wind turbines located nearby. The court disagrees, and concludes James has the qualifications and experience to offer each opinion, and that he reliably applied reliable scientific methods in this case to take acoustical readings inside Williams's home.

James has the qualifications and experience to opine on acceptable methods for measuring the broad-spectrum sound pressure and identifying the Wind Turbine Signature. James testifies in his Declaration that "the methodologies I use, full-spectrum recordings using instruments with appropriate sensors for the type of sound to be recorded and subsequently analyzed have been used by acousticians for at least 40 to 50 years." (James Decl. ¶ 8.) These methods are utilized in each study and case study cited in the record, including the Cape Bridgewater ATP and others. (*See* McCandlish Daubert Decl. Ex. 1 at 76-213.) It is clear these methods are capable of repetition, and that they are based on objective measures (Hz and dB, among others) which lend to its scientific reliability. Defendants offer no reason to reject James's opinions regarding the fact of turbines' acoustical output, or that those outputs may be measured and quantified. Therefore, the court will allow James to offer his opinions on those subjects.

Defendants last contend James did not apply reliable methods in this case to take accurate acoustic measures in Williams's home. Specifically, they contend James did not visit the property, did not set up the equipment, and cannot establish a "chain of custody" for his instrumentation which suggests the data could have been manipulated. The court disagrees.

James thoroughly explains in his declaration that, due to the nature of the instruments used, the data would reflect any manipulation of the equipment. He testifies that "[s]afety/security features are part of he system," including a "GPS component that logs the location" of the testing equipment. (James Decl. ¶ 10.) "Any attempt to relocate the system would be documented in a time stamped log file." (*Id.*) Moreover, James instructed Williams to set the equipment up in an empty bedroom where it would be undisturbed by the noise associated with people moving around the room. (*Id.*) Aside from speculation, Defendants offer no evidence that James's methods led to abnormalities or anomalies in the data. Therefore, this portion of their motion is denied.

4. Conclusions

After careful review of the record and briefs, the court concludes that James may testify: (1) that wind turbines produce broad-spectrum acoustic outputs, including audible noise and infrasound, that can be measured; and (2) that he reliably applied generally-accepted methodology to measure the broad-spectrum sound pressure present in Williams's home. James's testimony on these points is based on generally-accepted methods and reliable scientific knowledge; the methodology is testable and replicable; and to the extent acousticians have repeatedly replicated these methods, they have been subject to "true peer review" in the scientific community. Moreover, there is no indication that these methods were applied in an unreliable fashion by James.

***14** However, the court concludes James may not testify that these broad-spectrum acoustic stimuli produce adverse health effects in humans. James is neither a medical professional nor an epidemiologist, and the sources he cites in his Rule 26 report do not constitute reliable treatises or contain "objective, verifiable evidence ... based on 'scientifically valid principles" linking turbine-created infrasound to adverse health effects. *Daubert II*, 43 F.3d at 1138. Nor does James cite material which has "been subjected to normal scientific scrutiny through peer review and publication." *Id.* He relies exclusively on case studies, which at least one court in this district concluded "are universally regarded as an insufficient scientific basis for a conclusion regarding causation because case reports lack controls." *Hall v. Baxter Healthcare Corp.*, 947 F. Supp. 1387, 1411 (D. Or. 1996) (citing *Casey*, 877 F. Supp. at 1384, among others). While "[c]ausation can be proved even when we don't know precisely *how* the damage occurred," James does not come forward in this case with "sufficiently compelling" scientific proof to support his opinions on causation. *Daubert II*, 43 F.3d at 1314.

It is wholly possible that the adverse health effects articulated in the literature James cites are caused by infrasound and other acoustic outputs of wind turbines. However, the court does not concern itself during a *Daubert* analysis on the accuracy of the expert's results. Instead, the court must consider whether the methods used and sources relied upon are "scientifically reliable." The record before the court does not support Williams's contention that James's causation opinion is scientifically reliable. Therefore, the court excludes James's opinions on general causation.

B. Punch

Defendants move to exclude Punch from testifying regarding the general causal connection between wind-turbine acoustic outputs and adverse health effects in humans. They contend Punch: (1) did not apply reliable methodology to assess Williams's symptoms; and (2) based his opinions on unreliable and unscientific literature. Williams contends Punch applied reliable methodology, and has thoroughly justified his opinions by citing to dozens of studies and papers.

1. Reliable Methodology

Defendants argue Punch did not apply reliable methodology because he based his opinions in part on Williams's explanation of his symptoms in a questionnaire, which Defendants describe as unreliable. Punch used an eight-page questionnaire to "understand Williams'[s] complaints, what they were, the circumstances as to when they arose, when they subsided, frequency, duration and intensity ...." (Punch Decl. ¶ 3(a).) The questionnaire is eight pages long and is divided into three sections. (Rizzo Daubert Decl. Ex. V.) The first section asks the participant to check a box next to any of seventy-two symptoms that "have begun, or have become noticeably worse, after the industrial wind turbine project began operation" and asks the participant to describe the symptoms in detail on a separate page. (*Id.*) "Section 2" of the questionnaire asks the subject to answer a series of questions about the subject's symptoms, the subject's belief in the cause of those symptoms, and whether certain variables lessen or enhance the subject's symptoms. (*Id.* at 3-5.) "Section 3" contains a set of "miscellaneous" questions. (*Id.* at 6-8.)

Punch did not personally interview Williams or any other witness in this case, but he reviewed other data on the record. (Punch Decl. ¶ 3.) He reviewed the deposition testimony of Williams, Williams's neighbor, and Williams's ex-girlfriend, which Punch cross-checked against Williams's responses in the questionnaire. (Punch Decl. ¶ 3(a).) Punch also reviewed the acoustic data collected by James and Invenergy's expert, Robert O'Neal. (Punch Decl. ¶ 15(b).)

The Defendants contend the questionnaire is unreliable because it is "designed to encourage the subjective reporting of non-specific symptoms" which may be attributable to other causes and "does not permit wind farm complainants to express a difference in symptoms when wind turbines were on or off." The court disagrees with both critiques. First, there is nothing suggestive or leading about the questionnaire. Section 1 of the questionnaire allows the subject to pick from among seventy-two symptoms. No emphasis is placed on any one symptom or group of symptoms, and nothing in the explanations that precede the checklist or the or questions that follow are suggestive of which symptoms the subject should "check." In fact, aside from the fact it was developed by Punch and James, Defendants identify nothing in the questionnaire which shows it is suggestive or unreliable.

***15** Defendants also argue the questionnaire is unreliable because it "does not permit wind farm complainants to express a difference in symptoms when wind turbines were on or off." Again, the court disagrees. The second page of "Section 1" provides a space for the subject to describe their symptoms in detail. (Rizzo Daubert Decl. Ex. V at 2.) Moreover, the questions in Section 2 and Section 3 allow ample opportunity for the subject to explain differences in symptomatology during operation or non-operation of the wind turbines. (*Id.* at 3-6.) Williams even explains in question (a) that "[s]leep losses start and stops [*sic*] when I am around the turbines and they are turning. See my deposition." (*Id.* at 3.) Therefore, the court will not exclude the questionnaire or Punch's opinions thereof.

To the extent Defendants sought to argue that questionnaires are an unreliable methodology for documenting a subject's complaints, the court also

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disagrees. Punch testifies that "though a survey interview is not considered experimentation, it is regarded by the scientific community as a form of standard self-report research that is useful in gathering information about an individual's attitudes, opinions, symptoms, personal experiences or traits and beliefs." (Declaration of Jerry Punch, PHD, in support of Plaintiff's Response to Defendants' Motions for Partial Summary Judgment or Alternative Request for a *Daubert* Hearing ¶ 15.) Defendants offer no reason to discount this testimony or otherwise reject the use of questionnaires in general. Therefore, Defendants' motion is denied on this point.

2. Scientific Reliability of Causation Opinion

Defendants challenge the scientific reliability of Punch's opinion on general causation. Their arguments can be grouped into two rough categories. First, they argue Punch does not have the qualifications to opine on general causation without resorting to documentary and empirical support. Second, Defendants argue the support Punch cited in and attached to his expert report does not constitute "scientific knowledge." Because Punch does not cite to adequate scientific sources to support his opinions on causation, the court should exclude his expert opinion on that point under *Daubert*.

a. Qualifications

Defendants contend Punch may not opine on causation solely on the basis of his qualifications. The court agrees. Punch's qualifications are impressive, to be sure. After earning his bachelors degree in psychology from Wake Forrest University, he earned a masters degree in Audiology and Speech Pathology from Vanderbilt University and a Ph.D. in Audiology from Northwestern University. (McCandlish Daubert Decl. Ex. 2 at 7.) He has served as a clinical audiologist, an assistant professor at two universities, an associate professor at Indiana University School of Medicine, a tenured associate professor at Michigan State University, Chair of the Audiology and Speech Sciences at Michigan State University, and director of the research division at the American Speech-Language-Hearing Association, among other positions. (*Id.* at 8.) Punch has also taught a litany of classes at the university level and written many published, editorially peer-reviewed articles. (*Id.* at 8-12.) However, Punch is neither a medical doctor nor an epidemiologist who could opine on the cause of Williams's symptoms solely on the basis of these qualifications. Therefore, for Punch's causation testimony to be admissible under *Daubert*, he must support his causation opinion with reference to foundational literature which establishes the causal relationship through the application of "scientific knowledge."

b. Support from Scientific Literature

Defendants next contend Punch's causation opinion is not supported by "scientific knowledge" because the literature on which he bases that opinion consists of unreliable case studies and unproven hypotheses which have not been peer reviewed. In particular, they question the scientific reliability of three documents: (1) the 2009 book *Wind Turbine Syndrome*, by Nina Pierpont ("Pierpont"); (2) "A Theory to Explain Some Physical Effects of the Infrasonic Emissions at Some Wind Farm Sites," by Schomer, Edreich, Pamidighantam, and Boyle (2015) ("Schomer et al."); and (3) "Responses of the Ear to Low Frequency Sounds, Infrasound and Wind Turbines" by Salt and Hullar (2010). Williams contends these articles are but a small portion of the literature which supports Punch's conclusions, and the court should deny Defendants' motion.

***16** The court already has explained that the Brown County Minutes, the Schomer Critique, and the Cape Bridgewater ATP are scientifically unreliable and do not prove causation. Similarly, the Pierpont and Schomer et al publications do not constitute "scientific knowledge." For both pieces, the authors collected anecdotal data on the symptoms of self-selected individuals living near wind turbines who had already reported symptoms the subjects themselves had linked to the presence of wind turbines. In the case of Pierpont's case study, the author "chose a cluster of the most severely affected and most articulate subjects [she] could find." (Rizzo Daubert Decl. Ex. X at 16.) She cautioned that her sample size and methods cannot establish a "gradient of effects with a gradient of exposure" and "is not an epidemiologic sample." (*Id.*) Similarly, Schomer et al caution that "[t]his paper presents a theory upon which needed investigations can go forward," and although the authors present an interesting theory regarding the physiological mechanisms which could cause the health

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effects purportedly associated with exposure to industrial wind turbines, there is no accompanying statistical analysis which demonstrates causation to any degree of scientific reliability. Without comparing the statistical prevalence of adverse health effects near wind turbines to that of the broader community, or to data taken before the wind turbines became operational among the same study participants, the court cannot conclude that Williams's experts adequately demonstrate causation.

The Ninth Circuit's analysis in *Daubert II* is instructive on this point. 43 F.3d at 1313. There, the plaintiff sued Dow Pharmaceuticals claiming that her child's birth defects were caused by the plaintiff's use of Bendectin, an anti-nausea drug manufactured by the defendant. *Id.* The Plaintiff submitted expert-witness reports which opined that a causal relationship existed between the drug and the birth defects. *Id.* Thus, the court was tasked with determining whether the expert-witness reports reflected "scientific knowledge." *Id.* The court began its analysis by observing that "[c]ausation can be proven even when we don't know precisely *how* the damage occurred, if there is sufficiently compelling proof that the agent must have caused the damage *somehow.* One method of proving causation in these circumstances is to use statistical evidence." *Id.* (emphasis original). The court explained further:

> To evaluate the relationship between Bendectin and [birth defects], an epidemiologist would take a sample of the population and compare the frequency of birth defects in children whose mothers took Bendectin with the frequency of defects in children whose mothers did not. *See DeLuca,* 911 F.2d at 946. The ratio derived from this comparison would be an estimate of the "relative risk" associated with Bendectin. *See generally* Joseph L. Fleiss, *Statistical Methods for Rates and Proportions* (2d ed. 1981). For an epidemiological study to show causation under a preponderance standard, "the relative risk of limb reduction defects arising from the epidemiological data ... will at a minimum, have to exceed '2.' " *DeLuca,* 911 F.2d at 958. That is, the study must show that children whose mothers took Bendectin are more than twice as likely to develop limb reduction birth defects as children whose mothers did not.

Daubert II, 43 F.3d at 1321 (footnote omitted).

Here, neither the Pierpont nor Schomer information constitutes an epidemiological study or shows a significant statistical relationship between turbine-generated infrasound and adverse health effects. The third article, by Salt and Hullar, supports its theory of causation by demonstrating that some low-frequency sounds simulate hair-cells in the cochleas of guinea pigs. However, the Salt and Hullar article, like Punch's other exhibits, fails to demonstrate the statistical relationship between low-frequency wind-turbine infrasound and human health effects. Similar to *Daubert II*, the court cannot ignore the lack of statistical or epidemiological evidence to prove Williams's theory of causation.

Williams also argues that the court should allow Punch to testify on causation because he was able to produce significant support for his opinion in his declaration. Punch's Declaration includes several string citations to various papers and studies which purportedly support his opinion. However, Punch did not cite these authorities in his expert witness report, and there is no evidence Invenergy was made aware of these sources prior to depositions. Rule 26 requires that an expert witness attach to his or her report "any exhibits that will be used to summarize or support" the expert's opinions. FED. R. CIV. P. 26(a)(2)(B) (iii). Failure to do so may be ground for exclusion because, as Judge Aiken reasoned in *McClellan v. I-Flow Corp*, 710 F. Supp. 2d 1092, 1029 (D. Or. 2010), "it is not defendants' responsibility to track down documents that purportedly support the opinion of plaintiffs' expert; it is plaintiff's duty to disclose the relevant documents or accept the consequences for failing to do so." The court agrees with Judge Aiken's observation, and concludes Punch's causation testimony should be excluded for failure to attach scientifically reliable supportive documents, or citations to such documents, to his expert report.

***17** In the absence of scientific evidence showing general causation, the court also concludes Punch may not testify about the hypotheses of Pierpont, Schomer et al, and Salt regarding the physiological mechanisms underlying the alleged causal relationship. Each author refers to their proposal as a "hypothesis" or "theory." However, none of these hypotheses or theories has been subject to experimental testing. As the Ninth Circuit reasoned in *Claar*, "scientists whose conviction about the ultimate conclusion of their research is so firm that they are willing to aver under oath that it is correct prior to performing the necessary validating tests could properly be viewed by the district court as lacking the objectivity that is

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the hallmark of the scientific method." 29 F.3d at 503. Therefore, the court concludes Punch may not opine on the relationship between wind-turbine infrasound and human adverse health effects or the prevailing hypotheses regarding the physiological mechanisms underlying that alleged causal relationship.

c. Admissible Subjects of Testimony

Although Punch may not testify that non-audible infrasound and other low-frequency sound pulses cause adverse health effects, Defendants do not challenge Punch's qualification or expertise to testify regarding the audible noise created by wind turbines and the causal relationship between that noise and sleep disturbance. Punch cites literature which discusses the link between audible noise levels and "annoyance" or disturbance, including the executive summary of a report issued by the World Health Organization ("WHO"). The WHO is a reputable organization, and Defendants produce no reason to question the scientific reliability of the WHO paper. Therefore, Punch may reference this "scientific knowledge" to support his opinion that wind turbines produce audible noise which may disturb individuals and interfere with sleep.

C. Ironside

Defendants challenge the opinion of Dr. Ironside that infrasound was a cause of Williams's short-term insomnia. They contend Dr. Ironside has neither the qualifications nor the expertise to offer such an opinion. The court agrees. Dr. Ironside admitted at deposition that he was not an expert in infrasound and could not parse the relative contribution of audible noise and infrasound to Williams's sleep disturbance. Dr. Ironside's anecdotal experience with infrasound produced by a lion's roar and an earthquake does not qualify him to opine on causation. The only outside source Ironside relied upon was the James Report. As the court discussed *supra*, James does not demonstrate in his report that his opinions on general causation between infrasound and adverse health effects reflect "scientific knowledge." Thus, the James report may not be relied upon by experts in other fields as authoritative evidence in support of a particular conclusion. Dr. Ironside's opinion that Williams's short-term insomnia was caused, in whole or in part, by infrasound produced by the wind turbines is not scientifically reliable and thus not helpful to the court. Accordingly, it is excluded under *Daubert*.

However, Defendants do not move to exclude Dr. Ironside's testimony to the extent he intends to testify regarding the causal relationship between audible noise produced by the wind turbines and Williams's sleep disturbances. Given Dr. Ironside's speciality in sleep medicine and the typical factors associated with sleep disturbance, the court concludes he may provide this opinion to the court.

II. Motion for Summary Judgment

Defendants contend they are entitled to summary judgment or partial summary judgment in three ways. First, they contend Williams cannot prove a prima facie case of nuisance without his expert witnesses's testimony on causation. Second, they argue Williams's nuisance claim predicated on the turbine's flashing lights is preempted and otherwise not legally cognizable. Third, Defendants argue Williams cannot recover punitive damages and injunctive relief as a matter of law.

A. Proof of Causation

***18** Defendants argue that, because the court granted their *Daubert* motion in part, they are entitled to summary judgment because Williams cannot prove the causal element of his claim. Williams contends he can establish his claims even without expert testimony.

"Any person whose property or personal enjoyment thereof is affected by a private nuisance, may maintain an action for damages therefor." OR. REV. STAT. § 105.505. Whether an activity constitutes a nuisance "depends upon its effect upon an ordinary reasonable man, that is, a normal person of ordinary habits and sensibilities." *York v. Stallings*, 217 Or. 13, 20-21 (1959). The "interference with the use and enjoyment of land is not actionable unless it is substantial and unreasonable." *Aldridge v. Saxey*, 242 Or. 238, 243 (1965). However, "all that need be established is that the annoyance is regarded as harmful to the health or comfort of ordinary people." *Seagraves v. Portland City Temple*, 269 Or. 28, 32 (1974). To determine whether the activity at issue constitute a nuisance, courts consider: (1) the location and character o the neighborhood; (2) the extent and frequency of the injury; and (3) the effect upon the enjoyment of life, health and property. *Aldridge*, 242 Or. at 243. However, a plaintiff may recover damages

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only for those injuries which are "causally linked" to the nuisance. *See Lunda v. Matthews*, 46 Or. App. 701, 709 (1980) (Awarding emotional distress damages because the nuisance would offend a reasonable person and "[a]ny anguish plaintiffs suffered is causally linked to their concern over the affects of the defendants' trespass and the resulting nuisance.").

Here, Williams contends that Defendants' operation of the Willow Creek Wind Facility have interfered with the use and enjoyment of his property because the audible noise, vibration, light, and infrasound emitted by the wind turbines causes him stress, anxiety, and loss of sleep. The court has already concluded that, under *Daubert*, Williams's experts may not opine on the causal relationship between low-frequency infrasound and adverse health effects in humans. Therefore, Williams cannot prove infrasound interferes with the enjoyment of his property and cannot prove his nuisance claim on that basis. Therefore, Defendants are entitled to summary judgment on Williams's nuisance claim to the extent it is premised on infrasound produced by the Willow Creek wind turbines.

However, Williams's claims are not based exclusively on nuisance caused by infrasound, and the record contains ample evidence to create a genuine issue of material fact on whether the audible noise, light, and vibration produced by the Willow Creek wind turbines constitutes a nuisance. Williams has introduced the testimony of both lay witnesses and expert witnesses which links audible noise, light, and vibration with Williams's sleep disturbance, stress, and anxiety.

To the extent Defendants contend Williams cannot prove his claims without expert testimony, they are mistaken. In *Seagraves*, the court rejected the defendant's argument that objective measurements or expert statements were necessary to prove a nuisance claim. 269 Or. at 32. The court continued, "[t]he cases are legion in which the extent of the interference with reasonable use and enjoyment attributable to a noise has been established by the evidence of witnesses describing the character and effect of the noise." *Id.* The same principle applies to vibration and light, which are readily perceptible to the ordinary person. Therefore, to the extent Defendants' moved for summary judgment on Williams's nuisance claim based on the audible noise and vibration, that motion is denied.

B. Nuisance based on "Flashing Lights"

***19** Defendants next argue Williams's nuisance claim based on the wind-towers' flashing lights is preempted by federal law and not cognizable under Oregon law. In response to Defendants' arguments, Williams withdrew his claim premised upon the disturbance caused by the flashing lights on the wind-turbine towers. Therefore, this claim is dismissed with prejudice.

C. Punitive Damages

Defendants next move for summary judgment on Williams's claims for punitive damages. They contend no reasonable jury could find Williams is entitled to punitive damages by the clear and convincing evidence because: (1) Williams cannot create a genuine issue of material of fact on whether Defendants acted with the requisite culpability; and (2) Defendants engaged in good-faith efforts to mitigate the alleged nuisance. Williams contends that, despite the heightened burden of proof, he can demonstrate a genuine issue of material fact on whether Defendants acted maliciously and deceptively, thus entitling him to punitive damages.

In Oregon, a plaintiff may prove he or she is entitled to punitive damages "by clear and convincing evidence that the party against whom punitive damages are sought has acted with malice or has shown a reckless and outrageous indifference to a highly unreasonable risk of harm and has acted with a conscious indifference to the health, safety and welfare of others." OR. REV. STAT. § 31.730. Although the type of conduct necessary to implicate a punitive damages award depends significantly on the type of case at issue, courts typically hold that an award of punitive damages is proper where the defendant acted with "malice," in an "aggravated" manner, or acted "willfully" "wantonly," or "recklessly." *Andor by Affatigato v. United Air Lines, Inc.*, 303 Or. 505, 512-513 (1987).

In nuisance actions, punitive damages are recoverable where the defendant acted with an "aggravated disregard of the rights of others and where the violation of societal interests is sufficiently great and of a kind that sanctions would tend to prevent." *Senn v. Bunick*, 40 Or. App. 33, 41 (1979) (internal quotation marks omitted). The defendant need not exhibit an intent to injure the plaintiff. *Id.* In fact, the Oregon Supreme Court has observed that:

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> punitive damages serve the function to deter enterprises from accepting the risks of harming other private or public interests by recklessly substandard methods of operation at the cost of paying economic compensation to those who come forward to claim it. Such operations may well be wholly impersonal with respect to any victim, indeed conducted with the hope that no harm will occur, and they may not involve a culpable attitude on the part of any one person responsible for the management of the enterprise; yet this court has held that such lack of managerial culpability alone does not foreclose punitive damages.

Andor by Affatigato, 303 Or. at 514 (quoting *Schmidt v. Pine Tree Land Dev.*, 291 Or. 462, 466 (1981) (internal citations omitted)). However, punitive damages are not available in cases where the defendant acted only in good faith. *Senn v. Bunick*, 40 Or. App. 33, 42 (1979). "Obviously, awarding punitive damages against a defendant who took pains to avoid encroachment [on the plaintiff's rights], and who honestly and reasonably believed he was not encroaching [on those rights], would not promote societal interests by deterring others in the future." *Id.*

***20** Here, Williams has introduced evidence which could suggest Defendants engaged in deception while dialoging with Williams and other concerned neighbors about the applicable noise limits, and continued to operate despite knowing they were violating ths state-mandated noise standards. Shortly after local residents complained to Invenergy about the audible noise produced by the wind turbines, Invenergy hired acoustic consultants to conduct a noise study of the residences surrounding the wind farm. The noise study demonstrated as early as March 25, 2009 that there were noise exceedences at Williams's home. (Declaration of Attorney James E. McCandlish in Support of Plaintiff's Response to Defendants' Motions for Partial Summary Judgment ("McCandlish PSJ Decl.") Ex. 16 at 2.) The evidence shows that Willow Creek continued to operate despite this knowledge.

Moreover, the evidence demonstrates that Willow-Creek representatives misrepresented the applicable standards in an attempt to convince them to drop their complaints against Willow Creek. David Iadarola, the Willow Creek project manager, testified that at the time he discussed the noise levels with residents, he was aware Defendants were required to comply with the state-mandated noise limit of 36 dB. (McCandlish PSJ Decl. Ex. 26 at 4.) However, Williams and his neighbor Michael Eaton testified that, at their meeting with Iadarola, he claimed Defendants needed only to keep the noise below the county-imposed limit of 50 dB. (McCandlish PSJ Decl. Ex. 25 at 6-7, Ex. 27 at 3.) The witnesses contend that, when they raised their concern that Defendants needed to comply with the 36 dB limit, Iadarola responded that he "didn't read it that way" and that "we got 50 [dB], County allows 50 [dB], we're at 50 ...." (McCandlish PSJ Decl. Ex. 27 at 3; Ex. 25 at 6.)

Further, the record contains evidence which, when viewed in a light most favorable to Williams, could suggest Defendants employed deceptive and manipulative testing methods to determine the true noise levels at Williams's residence. First, Williams produces an email in which the consultant Invenergy hired to conduct noise tests wrote, "[w]e need to end up conducting a test which will demonstrate compliance with the particular standard ...." (McCandlish PSJ Decl. Ex. 10 at 1.) Although this statement is ambiguous, and alone may not demonstrate the culpability necessary to justify punitive damages, other emails between the consultant and Defendants' representatives tend to support the proposition that Defendants or their consultants manipulated reporting of sound-test data. In a June 12, 2009 email, the consultant writes:

> A quick plot of Eaton's L1 shows almost all L1's are less than the 75 dBA limit. There are a few exceedance [*sic*]. I agree that L1 has no place here from an acoustic standpoint. If you want to say something like "the wind turbine section of the code focuses on L10 and L50 and therefore L1 was not analyzed" –I am ok with that. Proceed that way?

(McCandlish PSJ Decl. Ex 18 at 1.) This email suggests that some sound-measurements were collected and analyzed, but Defendants or their agents chose not to report that data because, by their own admission, it was "going to give [them] heartburn." (*Id.*) When viewed in a light most favorable to Williams, the evidence on the record creates a genuine issue of material fact regarding

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whether Defendants exhibited "aggravated disregard" of Williams's right to use and enjoy his property.

Defendants argue Williams cannot recover punitive damages because he can prove only *de minimis* violations of the DEQ noise regulations. Although compliance with relevant regulations is evidence in the defendant's favor, the standard for whether a condition constitutes a nuisance is not tied directly to governmental standards governing noxious conditions. *See Lunda v. Matthews*, 46 Or. App, 701, 707 (1980) ("Conformance with pollution standards does not preclude a suit in private nuisance"). Instead, the primary question in a nuisance action is whether the allegedly noxious condition would interfere with a reasonable individual's ability to use and enjoy his or her property. *Id.* Similarly, whether Williams is entitled to punitive damages depends not on whether Defendants maliciously and recklessly violated the DEQ violations, but whether they maliciously and recklessly interfered with Williams's right to enjoy his property. *Id.*

***21** Lastly, Defendants contend Williams cannot prove the requisite state of culpability because they took good faith efforts to mitigate the noise, including a state-of-the-art system which automatically monitors the turbine noise levels and shuts down certain turbines in the event of a noise exceedence. Again, this is evidence which Defendants may use to rebut Williams's contention that Defendants acted recklessly and maliciously, but it is not determinative. *See McElwain v. Georgia-Pacific Corp*, 245 Or. 247, 252-254 (1966) (affirming an award of punitive damages against the operator of a mill where the defendant took significant remedial steps because they knew prior to constructing the mill "that the mill would cause damage to adjoining property"). Therefore, this portion of Defendants' motion is denied.

D. Injunctive Relief

Defendants argue they are entitled to summary judgment on Williams's claim for injunctive relief because it is an "extraordinary remedy" which should be granted only where the plaintiff cannot be sufficiently compensated by remedies at law. Alternatively, Defendants contend an injunction would be inappropriate in this case because the hardship created by an injunction would be disproportionate to the benefit resulting to Williams. The court disagrees.

In Oregon, the court may award injunctive relief only where there is a likelihood of substantial and immediate irreparable injury and there are insufficient remedies at law to compensate the plaintiff for his or her injury. *G.C. & K.B. Inv., Inc. v. Wilson*, 326 F.3d 1096, 1107 (9th Cir. 2003). In nuisance cases, an injunction should not be issued as a matter of course. *York v. Stallings*, 217 Or. 13, 22 (1959). Instead, whether to issue an injunction "is subject to the sound discretion of the court." *Id.* The Oregon Supreme Court has also established a "comparative injury doctrine," whereby the "court may refuse an injunction in certain cases where the hardship caused to the defendant by the injunction would greatly outweigh the benefit resulting to the plaintiff." *Id.*

However, injunctive relief is not an uncommon remedy in nuisance cases, and by their very nature, nuisance cases are seldom resolved through legal remedies alone. *Jewett v. Deerhorn Ent., Inc.*, 281 Or. 469, 479 (1978). As the Oregon Supreme Court held in *Jewett*, "[i]t would be unreasonable to require the plaintiffs to further endure the nuisance while the defendant experiments" with cost-effective remedial measures. *Id.* When issued, these injunctive remedies must be tailored to remedy the plaintiff's injury. *Lunda*, 46 Or. App. at 711. Notably, injunctive relief must "restrict defendants from operating [the alleged nuisance] at such times and in such manner as would unreasonably interfere with plaintiffs' use and enjoyment of their property." *Id.*

Here, the Defendants do not meet their burden of demonstrating they are entitled to judgment as a matter of law on Williams's claim for injunctive relief. First, they cite no evidence suggesting legal remedies would be sufficient to compensate Williams for his injury in the event he succeeds at trial. Defendants also fail meet their burden of showing that imposing an injunction would result in a burden disproportionate to Williams's benefit. They produce no testimony, financial analysis, or other evidence which shows an injunction would be at all burdensome. Therefore, this portion of their motion for summary judgment is denied.

Conclusion

For the aforementioned reasons, the court GRANTS in part and DENIES in part Defendants' Motion for Partial Summary Judgment and Alternative Request for

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a *Daubert* Hearing (Dkt. No. 97). The court GRANTS that motion to the extent it seeks to exclude expert testimony regarding the causal link between turbine-produced infrasound and adverse human health effects. Consequently, because Williams cannot create a genuine issue of material fact that infrasound impaired his ability to use and enjoy his land, his nuisance claim premised on the effects of infrasound is dismissed and the court GRANTS Defendants' motion for partial summary judgment on that issue. Williams's nuisance claims based on noise and vibration remain at issue.

***22** Further, pursuant to Williams's withdrawal of his nuisance claim based on the flashing lights on the wind-turbine towers, the court GRANTS Defendants' motion for partial summary judgment on that claim. The court DENIES Defendants' motion for partial summary judgment on Williams's claims for punitive damages and injunctive relief. Therefore, this case shall proceed to trial on Williams's claims for nuisance based on the audible noise and vibration produced by the Willow Creek wind turbines, punitive damages, and injunctive relief.

IT IS SO ORDERED.

This 28 th day of April, 2016.

All Citations

Not Reported in F.Supp.3d, 2016 WL 1725990

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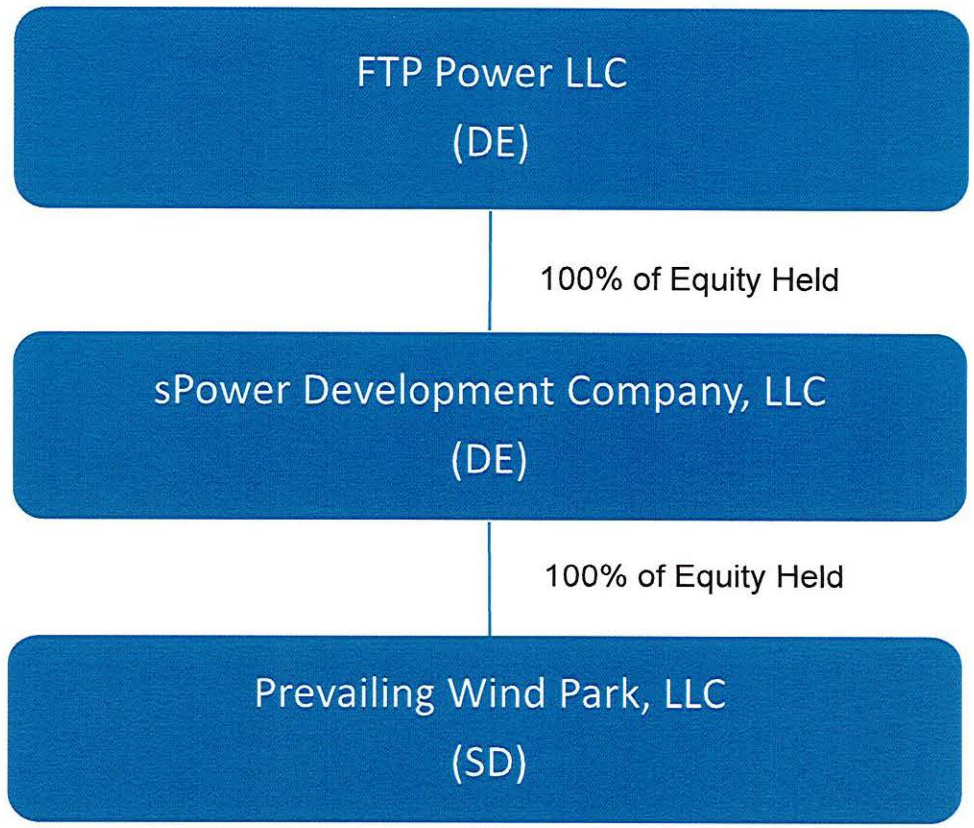
Ownership Structure of Prevailing Wind Park, LLC (formed 9/27/17)



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Prevailing Wind Park Project
Turbine Number Key

Construction ID[1]	Turbine No.[2]
1A.01	21
1A.02	33
1A.03	54
1A.04	36
1A.05	50
1A.06	46
1A.07	47
1B.08	18
1B.09	20
1B.10	25
1B.11	51
1B.12	30
1B.13	56
1B.14	55
2A.15	5
2A.16	3
2A.17	1
2A.18	2
2A.19	6
2A.20	4
2A.21	13
2B.22	7
2B.23	12
2B.24	9
2B.25	8
2B.26	15
2B.27	22
2B.28	16
3A.29	17
3A.30	29
3A.31	23
3A.32	48
3A.33	57

[1] This column includes the turbine numbers included in Exhibit A3-2 (Updated Shadow Flicker Analysis) and Exhibit A10-2 (Updated Sound Study). These identifiers will be used during Project construction.

[2] This column includes the turbine numbers identified on Exhibit A14-2 (Revised Layout) Exhibit and I29, Attachment 4-2.

Prevailing Wind Park Project
Turbine Number Key

Construction ID[1]	Turbine No.[2]
3A.34	40
3A.35	32
3A.36	26
3B.37	24
3B.38	41
3B.39	45
3B.40	37
3B.41	39
3B.42	58
3B.43	49
4A.44	28
4A.45	10
4A.46	11
4A.47	34
4A.48	14
4A.49	31
4B.50	27
4B.51	52
4B.52	53
4B.53	35
4B.54	42
4B.55	44
4B.56	43
4B.57	38
5A.58	60
5A.59	61
5A.60	62
5A.61	63
5A.62	64

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http://dx.doi.org/10.5665/sleep.5326

Effects of Wind Turbine Noise on Self-Reported and Objective Measures of Sleep

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Study Objectives: To investigate the association between self-reported and objective measures of sleep and wind turbine noise (WTN) exposure.
Methods: The Community Noise and Health Study, a cross-sectional epidemiological study, included an in-house computer-assisted interview and sleep pattern monitoring over a 7 d period. Outdoor WTN levels were calculated following international standards for conditions that typically approximate the highest long-term average levels at each dwelling. Study data were collected between May and September 2013 from adults, aged 18–79 y (606 males, 632 females) randomly selected from each household and living between 0.25 and 11.22 kilometers from operational wind turbines in two Canadian provinces. Self-reported sleep quality over the past 30 d was assessed using the Pittsburgh Sleep Quality Index. Additional questions assessed the prevalence of diagnosed sleep disorders and the magnitude of sleep disturbance over the previous year. Objective measures for sleep latency, sleep efficiency, total sleep time, rate of awakening bouts, and wake duration after sleep onset were recorded using the wrist worn Actiwatch2® from a subsample of 654 participants (289 males, 365 females) for a total of 3,772 sleep nights.
Results: Participant response rate for the interview was 78.9%. Outdoor WTN levels reached 46 dB(A) with an arithmetic mean of 35.6 and a standard deviation of 7.4. Self-reported and objectively measured sleep outcomes consistently revealed no apparent pattern or statistically significant relationship to WTN levels. However, sleep was significantly influenced by other factors, including, but not limited to, the use of sleep medication, other health conditions (including sleep disorders), caffeine consumption, and annoyance with blinking lights on wind turbines.
Conclusions: Study results do not support an association between exposure to outdoor WTN up to 46 dB(A) and an increase in the prevalence of disturbed sleep. Conclusions are based on WTN levels averaged over 1 y and, in some cases, may be strengthened with an analysis that examines sleep quality in relation to WTN levels calculated during the precise sleep period time.
Keywords: actigraphy, annoyance, multiple regression models, PSQI, sleep, wind turbine noise
Citation: Michaud DS, Feder K, Keith SE, Voicescu SA, Marro L, Than J, Guay M, Denning A, Murray BJ, Weiss SK, Villeneuve PJ, van den Berg F, Bower T. Effects of wind turbine noise on self-reported and objective measures of sleep. *SLEEP* 2016;39(1):97–109.

Significance
This study provides the most comprehensive assessment to date of the potential association between exposure to wind turbine noise (WTN) and sleep. As the only study to include both subjective and objective measures of sleep, the results provide a level of insight that was previously unavailable. The absence of an effect of WTN on sleep is based on an analysis of self-reported and objectively measured outcomes in relation to long term outdoor average sound levels. Knowledge in this area may be strengthened by future research to consider the potential transient changes in WTN levels throughout the night, which may influence subtle measures of sleep not assessed in the current study.

INTRODUCTION

Sleep loss has been implicated in a variety of negative health outcomes[1] including cardiovascular abnormalities,[2] immunological problems,[3] psychological health concerns,[4] and neurobehavioral impairment that can lead to accidents.[5] Sleep loss may be related to total sleep time restriction and/or reduced sleep quality in the sleep time obtained. Sleep disorders such as insomnia and obstructive sleep apnea are associated with an increased incidence of hypertension, heart failure, and stroke.[6,7]

Sleep can clearly be disrupted with noise.[8] It has long been recognized that electroencephalography (EEG) arousals can be induced with external environmental stimuli, but are modulated by sleep state.[9] The World Health Organization (WHO) Guidelines for Community Noise recommend that, for continuous noise, an indoor sound level of 30 dB(A) should not be exceeded during the sleep period time to avoid sleep disturbance.[10] More recently, the WHO's Night Noise Guidelines for Europe [11] suggest an annual average outdoor level of 40dB(A) to reduce negative health outcomes from sleep disturbance even among the most vulnerable groups.

Sleep can be measured by subjective and objective means[12] although due to the fundamental nature of unconsciousness in this state, people are unable to introspect on their sleep state. As such, an individual may surmise the quality of his or her sleep, with descriptions of what his or her presumed sleep was like, periods of awakening, and consequences of the state. However, sleep state misperception is a common clinical phenomenon, whereby patients with some degree of insomnia may report much worse quality of sleep than what actually occurred.[13] Subjective interpretation of sleep state is thus subject to biased reporting from the individual and therefore subjective and objective measures of sleep are frequently discordant. Therefore, objective physiological measures of sleep can provide a more accurate reflection of what actually happened during an individual's sleep and form the basis of an

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unprejudiced understanding of the actual biological effect of factors such as noise on sleep.

Although the current study is the first to include objective measures in the assessment of sleep quality in the context of wind turbine noise (WTN) exposure, the psychological experience of the individual must be considered, though this factor may be more prone to subjective interpretation. Numerous subjective scales of sleep have been devised. The Pittsburgh Sleep Quality Index (PSQI)[14] is a measure of the subjective experience of sleep that has had detailed psychometric assessment,[15] validation in numerous populations,[16–18] and is one of the most common subjective methodologies used in sleep research.

The PSQI has been administered in a study to compare subjective sleep quality among 79 subjects living near two different wind farms wherein it was reported that sleep quality was worse among the group living closer to the wind turbines.[19] Pedersen[20] found that self-reported sleep disturbance for any reason from any source was inconsistently related to the level of WTN. Bakker et al.[21] showed that self-reported sleep disturbance was correlated to WTN level, but when noise annoyance from wind turbines was brought into a multiple regression, sleep disturbance appeared to be highly correlated to the annoyance, but not to WTN level and only annoyance was statistically correlated to WTN level. This is consistent with the study by van den Berg et al.[22] wherein noise annoyance was reported as a better predictor of self-reported sleep disturbance than noise level for transportation, industrial, and neighbor noise.

Several studies have provided objectively measured assessments of transportation noise-induced sleep disturbance.[23–26] Although it is clear that noise is among the many factors that contribute to sleep disturbance [23,24,27,28] there has been no study to date that has provided an assessment of sleep disturbance in the context of WTN exposures using objective measures such as actigraphy.

The current study was designed to objectively measure sleep in relation to WTN exposure using actigraphy, which has emerged as a widely accepted tool for tracking sleep and wake behavior.[29,30] The objective measures of sleep, when considered together with self-report, provide a more comprehensive evaluation of the potential effect that WTN may have on sleep.

This study was approved by the Health Canada and Public Health Agency of Canada Review Ethics Board (Protocol #2012-0065 and #2012-0072).

METHOD

Sample Design

Target population, sample size, and sampling frame strategy

Several factors influenced the determination of the final sample size, including having adequate statistical power to assess the study objectives, and adequate time allocation for collection of data, influenced by the length of the personal in-dwelling interview and the time needed to collect the physical measures. Overall statistical power for the study was based on the study's primary objective to assess WTN-associated effects on sleep quality. Based on an initial sample size of 2,000 potential dwellings, it was estimated that there would be 1,120 completed survey responses. For 1,120 survey responses there should be sufficient statistical power to detect at least a 7% difference in the prevalence of sleep disturbances with 80% power and a 5% false positive rate (Type I error). There was uncertainty in the power assessment because the current *Community Noise and Health Study*, was the first to implement objectively measured endpoints to study the possible effects of WTN on sleep. How these power calculations applied to actigraphy-measured sleep was also unknown. In the absence of comparative studies, a conservative baseline prevalence for reported sleep disturbance of 10% was used.[31,32] Sample size calculation also incorporated the following assumptions: (1) approximately 20% to 25% of the targeted dwellings would not be valid dwellings (i.e., demolished, unoccupied seasonal, vacant for unknown reasons, under construction, institutions, etc.); and (2) of the remaining dwellings, there would be a 70% participation rate. These assumptions were validated (see response rates and sample characteristics related to sleep).

Study locations were drawn from areas in southwestern Ontario (ON) and Prince Edward Island (PEI) where there were a sufficient number of dwellings within the vicinity of wind turbine installations. The ON and PEI sampling regions included 315 and 84 wind turbines, respectively. The wind turbine electrical power outputs ranged between 660 kW to 3 MW (average 2.0 ± 0.4 MW). All turbines were modern monopole tower design with three pitch-controlled rotor blades (~80 m diameter) upwind of the tower and most had 80 m hub heights. All identified dwellings within approximately 600 m from a wind turbine and a random selection of dwellings between 600 m and 11.22 km were selected from which one person per household between the ages of 18 and 79 y was randomly selected to participate. The final sample size in ON and PEI was 1,011 and 227, respectively. Participants were not compensated in any way for their participation.

Wind turbine sound pressure levels at dwellings

Outdoor sound pressure levels were estimated at each dwelling using both ISO 9613-1[33] and ISO 9613-2[34] as incorporated in the commercial software CadnaA version 4.4.[35] The resulting calculations represent long-term (1 y) A-weighted equivalent continuous outdoor sound pressure levels (LAeq). Therefore, calculated sound pressure levels can only approximate with a certain degree of uncertainty the sound pressure level at the dwelling during the reference time periods that are captured by each measure of sleep. The time reference period ranges from 1–7 d (actigraphy), to 30 d for the PSQI and the previous year for the assessment of the percentage highly sleep disturbed. Van den Berg[36] has shown that, in the Dutch temperate climate, the long-term average WTN level for outdoor conditions is 1.7 ± 1.5 dB(A) below the sound pressure level at 8 m/sec wind speed. Accordingly, a best estimate for the average night-time WTN level is approximately 2 dB(A) below the calculated levels reported in this study.

Calculations included all wind turbines within a radius of 10 km, and were based on manufacturers' octave band sound power spectra at a standardized wind speed of 8 m/sec and favorable sound propagation conditions. Favorable conditions assume the dwelling is located downwind of the noise source, a

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stable atmosphere, and a moderate ground-based temperature inversion. Although variations in wind speeds and temperature as a function of height could not be considered in the model calculations due to a lack of relevant data, 8 m/sec was considered a reasonable estimate of the highest noise exposure conditions. The manufacturers' data were verified for consistency using on-site measurements of wind turbine sound power. The standard deviation in sound levels was estimated to be 4 dB(A) up to 1 km, and at 10 km the uncertainty was estimated to be between 10 dB(A) and 26 dB(A). Although calculations based on predictions of WTN levels reduces the risk of misclassification compared to direct measurements, the risk remains to some extent. The calculated levels in the current study represent reasonable worst-case estimates expected to yield outdoor WTN levels that typically approximate the highest long-term average levels at each dwelling and thereby optimize the chances of detecting WTN-induced sleep disturbance. The few dwellings beyond 10 km were assigned the same calculated WTN value as dwellings at 10 km. Unless otherwise stated, all decibel references are A-weighted. A-weighting filters out low frequencies in a sound that the human auditory system is less sensitive to at low sound pressure levels.

In the current study, low-frequency noise was estimated by calculating C-weighted sound pressure levels. No additional benefit was observed in assessing low frequency noise because C- and A-weighted levels were so highly correlated. Depending on how dB(C) was calculated and what range of data was assessed, the correlation between dB(C) and dB(A) ranged from r = 0.84 to r = 0.97.[37]

Background nighttime sound levels at dwellings

As a result of certain meteorological phenomena (atmospheric stability and wind gradient) coupled with a tendency for background sound levels to drop throughout the day in rural/semi-rural environments, WTN can be more perceptible at the dwelling during nighttime.[38–41] In Canada, it is possible to estimate background nighttime sound pressure levels according to the provincial noise regulations for Alberta, Canada,[42] which estimates ambient noise levels in rural and suburban environments. Estimates are based on dwelling density per quarter section, which represents an area with a 451 m radius and distance to heavily travelled roads or rail lines. When modeled in accordance with these regulations, estimated levels can range from 35 dB(A) to 51 dB(A). The possibility that exposure to high levels of road traffic noise may create a background sound pressure level higher than that estimated using the Alberta regulations was considered. In ON, road noise for the six-lane concrete Highway 401 was calculated using the United States Federal Highway Administration (FHWA) Traffic Noise Model[43] module in the CadnaA software.[35] This value was used when it exceeded the Alberta noise estimate, making it possible to have levels above 51 dB(A).

Data Collection

Questionnaire administration and refusal conversion strategies

The questionnaire instrument included modules on basic demographics, noise annoyance, health effects, quality of life, sleep quality, sleep disorders, perceived stress, lifestyle behaviors, and prevalence of chronic disease. To avoid bias, the true intent of the study, which was to assess the community response to wind turbines, was masked. Throughout the data collection, the study's official title was: *Community Noise and Health Study.* This approach is commonly used to avoid a disproportionate contribution from any group that may have distinct views toward wind turbines. Data collection took place through in-person interviews between May and September 2013 in southwestern ON and PEI. After a roster of all adults aged 18 to 79 y living in the dwelling was compiled, a computerized method was used to randomly select one adult from each household. No substitution was permitted; therefore, if the targeted individual was not at home or unavailable, alternate arrangements were made to invite them to participate at a later time.

All 16 interviewers were instructed to make every reasonable attempt to obtain interviews, which included visiting the dwelling at various times of the day on multiple occasions and making contact by telephone when necessary. If the individual refused to participate, they were then contacted a second time by either the senior interviewer or another interviewer. If, after a second contact, respondents refused to participate, the case was coded as a final refusal.

Self-reported sleep assessment

Long-term self-reported sleep disturbance included an assessment of the magnitude of sleep disturbance experienced at home (of any type for any reason) over the past year. Participants were requested to describe their level of sleep disturbance at home over the past year using one of the following categories: "not at all," "slightly," "moderately," "very" or "extremely," where the top two categories were collapsed and considered to reflect "highly sleep disturbed." For the purposes of this analysis the bottom three categories reflect "low sleep disturbance." These categories and the classification of "highly sleep disturbed" is consistent with the approach adopted for annoyance[44] and facilitates comparisons to self-reported sleep disturbance functions developed for transportation noise sources.[45] Data were collected on prevalence of diagnosed sleep disorders. In addition, participants completed the PSQI, which provided an assessment of sleep quality over the previous 30 d. The seven components of the PSQI are scored on a scale from 0 (better) to 3 (worse); therefore the global PSQI is a score ranging between 0–21, where a value of greater than 5 is thought to represent poor sleep quality.[14,16–18]

Objectively measured sleep

An Actiwatch2® (Philips Healthcare, Andover, MA, USA) sleep watch was given to all consenting and eligible participants aged 18 to 79 y who were expected to sleep at their current address for a minimum of 3 of the 7 nights following the interview. There were 450 devices at hand that were cycled throughout the study. In order to receive the device, respondents also needed to have full mobility in the arm on which the watch was to be worn. Respondents were asked to wear the device on their wrist during all hours of the day and night for the 7 d following their interview. The Actiwatch2® provides key information on sleep patterns (based on movement), including timing and duration of sleep as well as awakenings, and has been compared with polysomnography in some patient samples,[46] but does not replace polysomnography due to imperfect sensitivity and specificity for detecting wake periods. However, this tool can provide reasonable estimates for assessing subjects objectively for more prolonged periods of time than conventional assessment tools, with minimal participant burden.[47] The devices were configured to continuously record a data point every 60 sec for the entire 7 d period. Data analysis was conducted using Actiware® Version 5.1[48] with the software set to default settings (i.e., sensitivity setting of medium and a minimum minor rest interval size of 40 min). With these settings an epoch of 40 counts (i.e., accelerometer activity above threshold) or less is considered sleep and epochs above 40 counts are considered wake. However, any given epoch is scored using a 5-epoch weighting scheme. This procedure weighs the 2 epochs adjacent to the epoch in question. The 5-epoch weighting is achieved by multiplying the number of counts in each respective epoch by the following: 1/25, 1/5, 1, 1/5, 1/25, whereby an average above 40 indicates "awake" for the central epoch. The sleep start parameter was automatically calculated by the Actiware® software determined by the first 10 min period in which no more than one 60 sec epoch was scored as mobile. An epoch is scored as mobile if the number of activity counts recorded in the epoch is greater than or equal to the epoch length in 15 sec intervals (i.e., in a 60 sec epoch an activity value of 4 or higher). Endpoints of interest from wrist actigraphy included sleep efficiency (total sleep time divided by measured time in bed), sleep latency (how long it took to fall asleep), wake after sleep onset (WASO) (the total duration of awakenings), total sleep time, and the number of awakening bouts (WABT) (during a sleep period). The WABT data was analysed as the rate of awakening bouts per 60 min in bed.

To help interpret the measured data, respondents were asked to complete a basic sleep log each night of the study. The log contained information about whether the respondent slept at home or not, presence of windows in the room where they slept, and whether or not the windows were open. After the 7 d collection period, respondents were asked to return the completed sleep log with the actigraph in a prepaid package.

Statistical Methodology

The analysis follows the description in Michaud et al.,[49] which provides a summary of the study design and objectives, as well as a proposed data analysis. Briefly, the Cochran Mantel-Haenszel chi-square test was used to detect associations between self-reported magnitude or contributing sources of sleep disturbance and WTN exposure groups while controlling for province. Because a cut-off value of 5 for the global PSQI score provided a sensitive and specific measure distinguishing good and poor sleep, the PSQI score was dichotomized with the objective to model the proportion of individuals with poor sleep quality (i.e., PSQI > 5).[14] As a first step to develop the best model to predict the dichotomized PSQI score, univariate logistic regression models only adjusting for WTN exposure groups and province were carried out. It should be emphasized that variables considered in the univariate analysis have been previously demonstrated to be related to the modeled endpoint and/or considered by the authors to conceptually have a potential association with the modeled endpoint. The analysis of each variable only adjusts for WTN category and province; therefore, interpretation of any individual relationship must be made with caution.

The primary objective in the current analysis was to use multiple regression models to identify the best predictors for (1) reporting a PSQI score greater than 5; and (2) the actigraphy endpoints. All explanatory variables that were statistically significant at the 20% level in the univariate analysis for each respective endpoint were considered in the multiple regression models. To develop the best model to predict each endpoint of interest, the stepwise method, which guards against issues of multicollinearity, was used for multiple regression models.

The stepwise regression was carried out in three different ways wherein the base model included: (1) WTN exposure category and province; (2) WTN exposure category, province, and an adjustment for individuals who reported receiving personal benefit from having wind turbines in the area; and (3) WTN category and province, stratified for those who received no personal benefit.

For the analysis of PSQI, multiple logistic regression models were developed using the stepwise method with a 20% significance entry criterion and a 10% significance criterion to remain in the model. The WTN groups were treated as a continuous variable, giving an odds ratio (OR) for each unit increase in WTN level, where a unit reflects a 5 dB(A) WTN category. The Nagelkerke pseudo R^2 is reported for logistic regression models.

Repeated-measures data from all wrist actigraphy measurements were modeled using the generalized estimating equations (GEE) method, as available in SAS (Statistical Analysis System) version 9.2 PROC GENMOD.[50–52] Univariate GEE regression models only adjusting for WTN exposure groups, province, day of the week, and the interaction between WTN groups and day of the week were carried out. The interaction between WTN and province was significant for the total sleep time outcome in the univariate models, but was no longer significant in the multiple GEE regression model. Therefore, the base model for the multiple GEE regression models included only WTN category, province, and day of the week. The same stepwise methodology that was applied to build the PSQI models was used to develop multiple GEE regression models for each actigraphy endpoint. The within-subjects correlations were examined with different working correlation matrix structures (unstructured, compound symmetry, and autoregressive of first order). An unstructured variance-covariance structure between sleep nights was applied to all endpoints with the exception of sleep latency, where compound symmetry was used. The advantage of the GEE method is that it uses all available data to estimate individual subject variability (i.e., if 1 or more nights of data is missing for an individual, the individual is still included in the analysis).

The wrist actigraphy endpoints of sleep efficiency and rate of awakening bouts do not follow a normal distribution, because one is a proportion ranging between 0 and 1 (sleep efficiency) and the other is a count (awakening bouts). Therefore, to analyze awakening bouts a Poisson distribution was assumed. The

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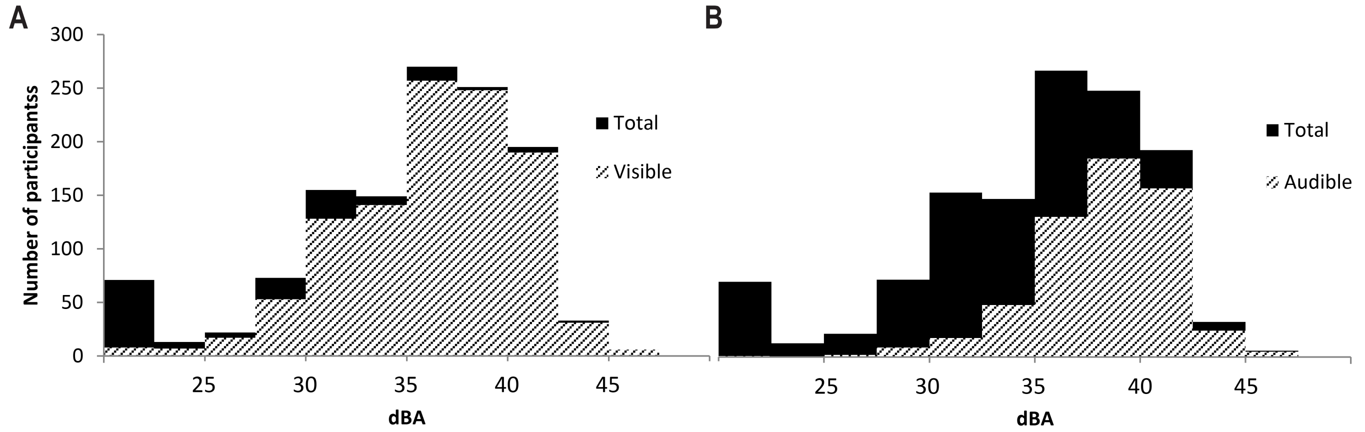

Figure 1—Histogram showing the distribution of participants as a function of calculated outdoor A-weighted wind turbine noise levels. **(A)** The number of participants who self-reported on the questionnaire that wind turbines were visible from anywhere on their property. **(B)** The number of participants who self-reported that wind turbines were audible from inside or outside their home.

number of awakening bouts was analyzed with respect to the total time spent in bed and is reported as a rate of awakening bouts per 60 min in bed. Sleep efficiency, sleep latency, and WASO were transformed in order to normalize the data and stabilize the variance.[53–55] In the GEE models, statistical tests were based on transformed data in order to satisfy the normality and constant variance assumptions. Because back-transformation was not possible for some endpoints, the arithmetic mean (least squares mean [LSM]) is presented for all endpoints.

All regression models for PSQI and actigraphy endpoints were adjusted for provincial differences. Province was initially assessed as an effect modifier. Because the interaction was not statistically significant for any of the multiple regression models, province was treated as a confounder in the models with associated adjustments, as required. Statistical analysis was performed using SAS version 9.2. A 5% statistical significance level was implemented throughout unless otherwise stated and Tukey corrections were applied to account for all pairwise comparisons to ensure that the overall Type I (false positive) error rate was less than 0.05.

Actigraphy Data Screening

The sleep actigraphy file consisted of 4,742 nights of actigraphy measured sleep (i.e., sleep nights) data from 781 participants. The following adjustments to the file were made to account for data that could not be processed: removal of sleep nights with no data (n = 15), data where the dates from the sleep watch and sleep log diary did not match (n = 61), recordings beyond 7 d (representing data collected off wrist or during return shipment) (n = 56), nights with shift work (n = 630), and data related to sleep nights away from home (n = 132). Removal of these data supported the objective to relate sleep behavior to noise exposure from wind turbines at the participants' dwelling. Sleep starting after 05:00 with awakening on the same day before 18:00 was considered day sleep and removed from the analysis (n = 70). One participant was removed where there appeared to be a watch malfunction (i.e., indicated nearly constant sleep). The final sample size consisted of 3,772 sleep nights and 654 participants. Any sleep that started after midnight, but before 05:00 was re-coded and considered as sleep for the previous night to avoid having two sleep observations for the same night. For the remaining data, all available data was used whether the person wore the watch for 1 d or for the maximum 7 d.

RESULTS

Wind Turbine Sound Pressure Levels at Dwellings

Calculated outdoor sound pressure levels at the dwellings determined by ISO 9613-1[33] and ISO 9613-2[34] reached levels as high as 46 dB(A). Results are considered to have an uncertainty of ± 4 dB(A) within distances that would have the strongest effect on sleep (i.e., ~600 m). Figure 1 illustrates the distribution of participants as a function of WTN levels and identifies the number of participants who reported wind turbines were visible from anywhere on their property (panel A) and audible (panel B) while they were either outside or inside their dwelling.

Background Nighttime Sound Pressure Levels

Modeled background nighttime sound (BNTS) levels ranged between 35 and 61 dB(A) in the sample. Average BNTS was highest in the WTN group 30–35 dB(A) and lowest in areas where modeled WTN levels were between 40–46 dB(A).[37] In the univariate analysis of global PSQI, the proportion of people with poor sleep (i.e., global scores above 5) was statistically similar among the BNTS levels (P = 0.9727). For actigraphy, BNTS levels were only statistically significant for the endpoint WASO (P = 0.0059), where it was found that individuals in areas with louder BNTS levels tended to have longer durations of awakenings. WASO increased from 50.7 min (95% confidence interval [CI]: 46.9, 54.4) in areas with < 40 dB(A) BNTS to 67.2 min (95% CI: 57.0, 77.5) in areas with ≥ 55 dB(A) BNTS levels (see supplemental material).

Response Rates and Sample Characteristics Related to Sleep

A detailed breakdown of the response rates, along with personal and situational variables by WTN category, is presented by Michaud.[37] Of the 2,004 potential dwellings, 1,570 were valid and 1,238 agreed to participate in the survey (606 males,

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Table 1—Self-reported magnitude and contributing sources of sleep disturbance.

Variable	Wind Turbine Noise, dB(A) < 25	25–30	30–35	35–40	40–46	Overall	CMH P value[a]
n	83	95	304	519	234	1,235	
Self-reported sleep disturbance n (%)							
Not at all	29 (34.9)	44 (46.3)	112 (36.8)	208 (40.1)	85 (36.3)	478 (38.7)	
At least slightly[b]	54 (65.1)	51 (53.7)	192 (63.2)	311 (59.9)	149 (63.7)	757 (61.3)	0.7535
Highly[c]	13 (15.7)	11 (11.6)	41 (13.5)	75 (14.5)	24 (10.3)	164 (13.3)	0.4300
Source of sleep disturbance (among participants at least slightly sleep disturbed) n (%)							
n[d]	53	51	186	298	138	726	
Wind turbine	0 (0.0)	2 (3.9)	4 (2.2)	45 (15.1)	31 (22.5)	82 (11.3)	< 0.0001
Children	9 (17.0)	12 (23.5)	21 (11.3)	36 (12.1)	20 (14.5)	98 (13.5)	0.2965
Pets	7 (13.2)	12 (23.5)	9 (4.8)	45 (15.1)	22 (15.9)	95 (13.1)	0.3582
Neighbors	6 (11.3)	5 (9.8)	9 (4.8)	13 (4.4)	5 (3.6)	38 (5.2)	0.0169
Other	41 (77.4)	35 (68.6)	162 (87.1)	232 (77.9)	87 (63.0)	557 (76.7)	0.0128
Stress/anxiety	6 (11.3)	2 (3.9)	21 (11.3)	33 (11.1)	11 (8.0)	73 (10.1)	0.8938
Physical pain	11 (20.8)	9 (17.6)	50 (26.9)	48 (16.1)	18 (13.0)	136 (18.7)	0.0289
Snoring	5 (9.4)	6 (11.8)	17 (9.1)	20 (6.7)	12 (8.7)	60 (8.3)	0.4126

Participants were asked to report their magnitude of sleep disturbance over the last year while at home by selecting one of the following five categories: not at all, slightly, moderately, very, or extremely. Participants that indicated at least a slight magnitude of sleep disturbance were asked to identify all sources perceived to be contributing to sleep disturbance. [a]The Cochran Mantel-Haenszel chi-square test was used to adjust for provinces. [b]At least slightly sleep disturbed includes participants indicating the slightly, moderately, very or extremely categories. [c]Highly sleep disturbed includes participants who reported the very or extremely categories. The prevalence of reported sleep disturbance was unrelated to wind turbine noise levels. [d]Of the 757 participants who reported at least a slight amount of sleep disturbance, 31 did not know what contributed to their sleep disturbance. Of the remaining 726, at least one source was identified. Columns may not add to sample size totals as some participants did not answer questions and/or identified more than one source as the cause of their sleep disturbance.

Table 2—Summary of Pittsburgh Sleep Quality Index scores.

	Wind Turbine Noise, dB(A) < 25	25–30	30–35	35–40	40–46	Overall
Mean (95% CI)	6.22 (5.32, 7.11)	5.91 (5.05, 6.77)	6.00 (5.51, 6.50)	5.74 (5.33, 6.16)	6.09 (5.55, 6.64)	5.94 (5.72, 6.17)
n (%) score > 5[a]	40 (49.4)	45 (48.9)	138 (46.5)	227 (44.4)	106 (46.7)	556 (46.0)

[a]Pittsburgh Sleep Quality Index score above 5 is considered to represent poor sleep. CI, confidence interval.

632 females), resulting in a final overall response rate of 78.9%. Of the 1,238 participants, 1,208 completed the PSQI in its entirety (97.6%) and 781 participated in the sleep actigraphy portion of the study (63%). Sleep actigraphy participation rates were in line with projections based on an unpublished pilot study designed to assess different sleep watch devices and participant compliance. Participation rate was equally distributed across WTN categories.

The prevalence of reporting a diagnosed sleep disorder was unrelated to WTN levels (P = 0.3102).[27] In addition, the use of sleep medication at least once a week was significantly related to WTN levels (P = 0.0083). The prevalence was *higher* among the two lowest WTN categories (< 25 dB(A) and 25–30 dB(A)).[37] Factors that may affect sleep quality, such as self-reported prevalence of health conditions, chronic illnesses, quality of life, and noise sensitivity were all found to be equally distributed across WTN categories.[37,56] In response to the general question on magnitude of sleep disturbance for any reason over the past year while at home, a total of 757 participants (61.3%) reported at least a "slight" magnitude of sleep disturbance (includes ratings of "slightly," "moderately," "very" and "extremely"), with a total of 164 (13.3%) classified as "highly" sleep disturbed (i.e., either very or extremely). The levels of WTN were not found to have a statistically significant effect on the prevalence of sleep disturbance whether the analysis was restricted to only participants highly sleep disturbed (P = 0.4300), or if it included all participants with even a slight disturbance (P = 0.7535) (Table 1). When assessing the sources reported to contribute to sleep disturbance among all participants with even slight disturbance, reporting wind turbines was significantly associated with WTN categories (P < 0.0001). The prevalence was ≥ 15.1% among the participants living in areas where WTN levels were ≥ 35 dB(A) compared to ≤ 3.9% in areas where WTN levels were below 35 dB(A). However, wind turbines were not the only, nor the most prevalent, contributing source at these sound levels (see Table 1).

PSQI Scores

For the 1,208 participants who completed the PSQI in its entirety, the average PSQI score across the entire sample was

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5.94 with 95% confidence interval (CI) (5.72, 6.17). The Cronbach alpha for the global PSQI was 0.76 (i.e., greater than the minimum value of 0.70 in order to validate the score). Table 2 presents the summary statistics for PSQI as both a continuous scale and a binary scale (the proportion of respondents with poor sleep; i.e., PSQI above 5) by WTN exposure categories. Analysis of variance was used to compare the average PSQI score across WTN exposure groups (after adjusting for provinces). There was no statistical difference observed in the mean PSQI scores between groups (P = 0.7497) as well as no significant difference between provinces (P = 0.7871) (data not shown). Similarly, when modeling the proportion of respondents with poor sleep (PSQI > 5) in the logistic regression model, no statistical differences between WTN exposure groups (P = 0.4740) or provinces (P = 0.6997) were observed (see supplemental material).

Effects of Personal and Situational Variables on PSQI Scores and Actigraphy

A univariate analysis of the personal and situational variables in relation to the PSQI scores (logistic regression) and actigraphy (GEE) was conducted. The list of variables considered was extensive and included, but was not limited to, age, sex, income, education, body mass index, caffeine consumption, housing features, diagnosed sleep disorders, health conditions, annoyance, household complaints, and personal benefit (i.e., rent, payments or other indirect benefits through community improvements) from having wind turbines in the area. The analysis of these and several other variables in relation to the endpoints has been made available in the supplemental material.

Multiple Logistic Regression Models for PSQI

Table 3 provides a summary of the variables retained in the multiple regressions for the PSQI and actigraphy endpoints. A detailed description of the statistical results, including the direction of change and the pairwise comparisons made among the groups within each variable is available in the supplemental material.

Table 4 presents the results from stepwise multiple logistic regression modeling of the proportion of respondents with "poor sleep" (i.e., scores above 5 on the PSQI). The final models for the three approaches to stepwise regression as listed in the Statistical Methods section produced nearly identical results to one another. Therefore, results are only presented for the regression method where the variables WTN category, province, and personal benefit were forced into the model that fit the data well (Hosmer-Lemeshow test, P > 0.05). Using stepwise regression, the predictive strength of the final model was 37%. There was no observed relationship between the proportion of respondents with poor sleep and WTN levels (P = 0.3165).

Participants who had improved sleep quality after closing their bedroom window were found to have the same odds of poor sleep when compared to those who did not need to close their window (P = 0.0565). Participants who stated that closing their window did not improve sleep quality had higher odds of poor sleep in comparison with both those who had improved sleep quality after closing windows and those who did not need to close windows (P ≤ 0.0006, in both cases). Unemployed individuals had higher odds of poor sleep compared with those who were employed (OR [95% CI]: 1.55 [1.12, 2.15]).

Long-term sleep disturbance (of any type by any source) was included in the study because dose-response relationships have been published for this measure in relation to other community noise sources[45] and this endpoint provides a longer time reference period than the previous 30 d assessed using the PSQI. Those who reported a very or extremely high level of sleep disturbance (i.e., percentage highly sleep disturbed) by any source while at home had 6 times higher odds of poor sleep assessed with the PSQI (OR [95%CI]: 6.28 [3.46, 11.40]) when compared to those with no, slight, or moderate reported sleep disturbance. Finally, participants suffering from migraines/headaches, asthma, arthritis and a diagnosed sleep disorder (e.g., sleep apnea or insomnia) had higher odds of poor sleep when compared to those not suffering from these health and chronic conditions.

Sleep Actigraphy

The majority of participants (56%) wore the watch for the full 7 nights (mean number of days 5.77, SD = 1.85). The frequency across the days of the week was equally distributed (data not shown). Response rates for the actigraph were equally distributed across WTN exposure groups (P = 0.5585), although a higher proportion of participants were noted in PEI, in comparison to ON (P = 0.0008).

Table 5 presents the summary data for each sleep actigraphy endpoint analyzed. Although mean values appear stable between one sleep night to the next within an endpoint, the standard deviation is observed to fluctuate between sleep nights (data not shown). The observed correlations between the PSQI and the actigraphy endpoints are presented as supplemental material.

Multiple GEE Regression Models for Actigraphy

Multiple regression models for the five sleep actigraphy endpoints were developed. Variables that were associated with each endpoint (i.e., significant at the 10% level) are summarized in Table 3. Specific information on these variables, including the direction of change, P values, and pairwise comparisons has been made available in the supplemental material. Table 6 presents the LSM and the P values for the exposure of interest, the WTN exposure categories, obtained from the GEE regression models for the sleep actigraphy endpoints. Unadjusted results reflect the base model (including WTN, province, day of the week, and the interaction between WTN and day of the week) whereas adjusted results come from the multiple regression models obtained through the stepwise method and take into account factors beyond the base model. The level of exposure to WTN was not found to be related to sleep efficiency (P = 0.3932), sleep latency (P = 0.6491), total sleep time (P = 0.8002), or the number of awakening bouts (P = 0.3726). There was an inconsistent association found between WASO and WTN exposure where there was a statistically significant reduction in WASO time observed in areas where WTN levels were 25–30 dB(A), in comparison with < 25 dB(A) and 40–46

Table 3—Variables retained in multiple generalized estimating equations and multiple logistic regression models.

	Sleep Efficiency (%)	Sleep Latency (min)	Total Sleep Time (min)	WASO (min)	Rate of Awakening Bouts (per 60 min)	PSQI (scores > 5)
Base model						
WTN levels				++		
Province				+		+
Demographic variables						
Sex	++					
BMI group	+	++				
Age group		++				
Marital status					+	
Employment				++		++
Smoking status				++		
Caffeine consumption	++				+	
Education	++			++		
Situational variables						
Bedroom location				++		
Air conditioning unit in bedroom			++			
Bedroom on quiet side			+			
Bedroom window type			+			
Sleep improved by closing window						++
Closure of bedroom windows/other[a]		++				
BNTS level			++	++		
Audible rail noise						++
Audible aircraft noise				++		
Wind turbine related variables						
Complaint about wind turbines	+					
Personal benefits						++
Annoyance with blinking lights			++		++	
Personal and health related variables						
Self-reported sleep disturbance[b]						++
Sleep disturbed by pain			++		++	
Sleep disturbed by neighbors			++			
Sleep disturbed by other[c]						++
Annoyed by snoring						+
Sleep medication[d]				++		
Migraines						++
Dizziness						+
Chronic pain						+
Asthma		++				++
Arthritis						++
Diagnosed sleep disorder			+			++
Restless leg syndrome					++	

A summary of significant variables retained in multiple generalized estimating equations and multiple logistic regression models for objectively measured and self-reported sleep endpoints, respectively. The specific direction of change, level of statistical significance, pairwise comparisons between variable groups and full description of the variable names is provided in supplemental material. [a]The source identified by participants as the cause of closing bedroom windows to reduce noise levels was not road traffic, aircraft, rail or wind turbines. [b]Evaluates the magnitude of reported sleep disturbance at home from not at all to extremely, for any reason over the previous year. [c]The source identified by participants as contributing to their sleep disturbance was not wind turbines, children, pets or neighbors. [d]Use of sleep medication was note considered in the multiple regression model for PSQI since it is one of the seven components that make up the global PSQI score. +, ++ denotes statistically significant, $P < 0.10$, $P < 0.05$, respectively. BMI, body mass index; BNTS, background nighttime sound level; PSQI, Pittsburgh Sleep Quality Index; WTN, wind turbine noise.

Table 4—Multiple logistic regression model for Pittsburgh Sleep Quality Index.

Variable	Groups in Variable[b]	Model: WTN, Province, and Personal Benefit Forced in PSQI[a] P value[c] (n = 933, R^2 = 37%, H-L P = 0.9252)[h]	OR (CI)[d]
WTN, dB(A)[e]		0.3165	0.93 (0.80, 1.07)
Province	PEI/ON	0.0810	1.46 (0.95, 2.25)
Personal benefit	No/Yes	0.0499	1.82 (1.00, 3.30)
Sleep improved by closing window (overall P value < 0.0001)	Yes	0.0565	1.41 (0.99, 2.00)
	No	< 0.0001	8.48 (3.11, 23.14)
	Did not need to close windows	Reference	
Employment	No/Yes	0.0085	1.55 (1.12, 2.15)
Audible rail noise	No/Yes	0.0380	1.56 (1.03, 2.37)
Reported cause for sleep disturbance			
Other[f]	Yes/No	< 0.0001	2.55 (1.86, 3.48)
Self-reported sleep disturbance[g]	High/Low	< 0.0001	6.28 (3.46, 11.40)
Annoyed by snoring	High/Low	0.0693	2.16 (0.94, 4.94)
Migraines	Yes/No	0.0062	1.76 (1.17, 2.64)
Dizziness	Yes/No	0.0696	1.46 (0.97, 2.20)
Chronic pain	Yes/No	0.0754	1.47 (0.96, 2.25)
Asthma	Yes/No	0.0166	2.01 (1.14, 3.56)
Arthritis	Yes/No	0.0497	1.45 (1.00, 2.10)
Diagnosed sleep disorder	Yes/No	0.0001	2.99 (1.71, 5.23)

[a]The logistic regression is modeling the probability of having a PSQI score above 5. [b]Where a reference group is not specified it is taken to be the last group. [c]P value significance is relative to the reference group. [d]OR (CI) odds ratio and 95% confidence interval based on logistic regression model. [e]The exposure variable, WTN level, is treated as a continuous scale in the logistic regression model. [f]The source identified by participants as the cause of closing bedroom windows to reduce noise levels was not road traffic, aircraft, rail or wind turbines. [g]Evaluates the magnitude of reported sleep disturbance at home from not at all to extremely for any reason over the previous year. [h]H-L P > 0.05 indicates a good fit. CI, confidence interval; H-L, Hosmer-Lemeshow test; ON, Ontario; OR, odds ratio; PEI, Prince Edward Island; PSQI, Pittsburgh Sleep Quality Index; WTN, wind turbine noise.

dB(A) WTN categories. This was because of a higher mean WASO time among participants from PEI living in areas where WTN levels were less than 25 dB(A) (data not shown).

DISCUSSION

The effects on health and well-being associated with accumulated sleep debt have been well documented.[1–5,57] The sound pressure levels from wind turbines can exceed the WHO recommended annual average nighttime limit of 40 dB(A) for preventing health effects from noise-induced sleep disturbance.[11] The calculated outdoor A-weighted WTN levels in this study reached a maximum of 46 dB(A), with 19% of dwellings found to exceed 40 dB(A). Within an uncertainty of approximately 4 dB(A), the calculated A-weighted levels in the current study can be compared to the WHO outdoor nighttime annual average threshold of 40 dB(A).[11,58] With the average façade attenuation with windows completely opened of 14 ± 2 dB(A),[58] the average bedroom level at the highest façade level, 46 dB(A), will be 32 ± 2 dB(A), which is close to the 30 dB(A) indoor threshold in the WHO's Guidelines for Community Noise.[10] Considering the uncertainty in the calculation model and input data, only dwellings in the highest WTN category are expected to have indoor levels above 30 dB(A) and thus sensitivity to sleep disturbance. However, with windows closed, indoor outdoor level difference is approximately 26 dB, which should result in an indoor level around 20 dB(A) in the current study.

Factors including, but not limited to, medication use, other health effects (including sleep disorders), caffeine consumption, and annoyance with blinking lights on wind turbines were found to statistically influence reported and/or actigraphically measured sleep outcomes. However, there was no evidence for any form of sleep disturbance found in relation to WTN levels. Studies published to date have been inconsistent in terms of self-reported evidence that WTN disrupts sleep,[59,60] and none of these studies assessed sleep using an objectively measured method. These inconsistent findings are

Table 5—Summary of Actiwatch2® data.

		Wind Turbine Noise, dB(A)				
		< 25	25–30	30–35	35–40	40–46
n (weekday, weekend)		(198, 78)	(200, 68)	(705, 273)	(1114, 420)	(526, 190)
Sleep Actigraphy Endpoint	**Sleep Night**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Sleep latency, min	Weekday	14.53 (23.31)	13.89 (23.08)	13.02 (26.14)	13.01 (23.05)	13.01 (22.83)
	Weekend	22.85 (37.01)	10.02 (15.86)	13.23 (22.47)	15.36 (36.13)	12.94 (26.96)
Sleep efficiency, %	Weekday	84.69 (6.59)	85.64 (7.84)	84.92 (7.56)	85.24 (7.83)	85.01 (7.03)
	Weekend	83.62 (7.93)	87.73 (5.46)	84.37 (8.39)	85.01 (7.96)	84.28 (8.47)
WASO, min	Weekday	58.58 (29.45)	50.43 (34.80)	54.99 (31.63)	52.63 (30.14)	55.50 (34.19)
	Weekend	60.49 (37.14)	48.57 (27.00)	58.28 (38.69)	54.11 (35.56)	56.60 (37.53)
Total sleep time, min	Weekday	455.24 (160.65)	447.70 (165.62)	448.88 (169.37)	445.76 (166.52)	448.38 (179.82)
	Weekend	468.12 (163.83)	462.21 (139.61)	457.15 (167.15)	448.63 (155.09)	442.85 (174.23)
Number of awakening bouts, count	Weekday	24.41 (9.49)	22.04 (10.04)	25.05 (13.53)	23.56 (9.86)	24.01 (9.81)
	Weekend	24.89 (10.00)	22.09 (8.76)	26.09 (13.01)	24.60 (10.54)	24.35 (10.22)
Time in bed, min	Weekday	536.05 (173.73)	521.39 (176.46)	526.53 (180.77)	520.55 (173.97)	524.48 (187.30)
	Weekend	559.85 (184.18)	526.99 (154.00)	540.13 (179.72)	527.18 (166.46)	522.57 (176.14)
Rate of awakening bouts per 60 min in bed	Weekday	2.83 (1.00)	2.64 (1.12)	2.94 (1.27)	2.82 (1.08)	2.89 (1.09)
	Weekend	2.77 (1.06)	2.60 (1.06)	2.97 (1.18)	2.87 (1.08)	2.93 (1.14)

SD, standard deviation; WASO, wake after sleep onset.

Table 6—Generalized estimating equations regression models for sleep actigraphy endpoints.

	Sleep Efficiency, %	Sleep Latency, min	Total Sleep Time,[d] min	WASO, min	Number of Awakening Bouts during Sleep
n	618	526	619	647	626
Sleep nights[c]	3,561	3,017	3,552	3,728	3,595
P value unadjusted[a]	0.2420	0.9051	0.7222	0.0655	0.2460
P value adjusted[b]	0.3932	0.6491	0.8002	0.0056	0.3726
Unadjusted[a] WTN, dB(A)	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**
< 25	84.71 (83.25, 86.17)	16.34 (11.40, 21.28)	458.00 (428.08, 487.93)	58.83 (52.78, 64.87)	24.26 (22.28, 26.25)
25–30	86.49 (85.12, 87.87)	12.34 (8.88, 15.80)	462.68 (427.47, 497.90)	49.11 (43.72, 54.50)	21.08 (19.14, 23.02)
30–35	84.82 (83.86, 85.78)	12.51 (10.54, 14.49)	464.00 (441.44, 486.57)	55.39 (52.04, 58.74)	24.57 (23.01, 26.14)
35–40	85.33 (84.60, 86.05)	13.02 (11.39, 14.65)	449.10 (433.95, 464.24)	53.08 (50.35, 55.80)	23.37 (22.40, 24.35)
40–46	85.01 (84.05, 85.98)	12.64 (10.50, 14.78)	445.78 (426.60, 464.96)	55.46 (51.45, 59.47)	23.84 (22.55, 25.13)
Adjusted[b] WTN, dB(A)	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**	**LSM (95% CI)[e]**
< 25	85.62 (83.97, 87.28)	15.08 (10.03, 20.13)	462.41 (407.97, 516.84)	62.00 (55.14, 68.85)	23.19 (20.58, 25.79)
25–30	87.28 (85.55, 89.01)	10.88 (6.45, 15.32)	453.43 (401.10, 505.76)	51.67 (44.14, 59.20)	20.57 (17.87, 23.26)
30–35	85.82 (84.52, 87.13)	9.95 (7.02, 12.87)	455.22 (406.72, 503.72)	56.11 (50.81, 61.42)	24.00 (21.26, 26.75)
35–40	85.97 (84.86, 87.08)	10.71 (7.88, 13.54)	466.12 (416.21, 516.02)	57.80 (52.36, 63.24)	22.56 (20.57, 24.56)
40–46	86.16 (84.84, 87.48)	10.92 (7.01, 14.82)	472.95 (422.09, 523.81)	62.06 (55.64, 68.48)	22.85 (20.68, 25.02)

[a]The base model for the multiple generalized estimating equations (GEE) regression models for all endpoints included wind turbine noise (WTN) exposure groups, province, day of the week, and the interaction between WTN groups and day of the week. [b]A complete list of the other variables included in each multiple GEE regression model based on the stepwise methodology is presented in Table 3. [c]Sample size for the adjusted GEE regression models. [d]The base model for total sleep time includes the interaction between WTN groups and province. [e]LSM, least squares means, for each group after adjusting for all other variables in the multiple GEE regression model and corresponding 95% confidence interval (CI). P values for both the adjusted and unadjusted models are based on the transformed variable in order to satisfy model assumptions of normality and constant variance.

not entirely surprising considering that sleep disturbance reported as a result of transportation noise exposure occurs at sound pressure levels that exceed WTN levels calculated in the current study.[27,28,45] Study results concur with those of Bakker et al.,[21] with outdoor WTN levels up to 54 dB(A), wherein it was concluded that there was no association between the levels of WTN and sleep disturbance when noise annoyance was taken into account.

The current study employed a wide range of self-reported and objectively measured endpoints related to sleep to provide a comprehensive assessment of the potential effects that WTN exposure may have on sleep. Self-reported diagnosed sleep disorders[37] and self-reported highly sleep disturbed for any reason were factors found to be unrelated to WTN exposure. Furthermore, taking medication at least once per week was more commonly reported among participants living in areas where WTN levels were below 30 dB(A). Scores on the PSQI, either analyzed as a proportion above 5, or as a mean score, were also unrelated to WTN level. Actigraphy-measured sleep latency, sleep efficiency, the rate of awakening bouts, and total sleep time were all found to be unrelated to WTN exposure. The only statistically significant finding found between WTN level and actigraphy was a reduced wake time after sleep onset among participants living in areas where WTN levels were 25–30 dB(A) and this was because of a higher WASO time at the lowest WTN category among PEI participants. The results of the current study do not support conclusions that exposure to WTN up to 46 dB(A) has any statistically significant effect on self-reported or objectively measured sleep. However, annoyance with blinking lights on wind turbines (used as aircraft warning signals) may be related to a higher rate of awakening bouts and reduced total sleep time.

This study has some important limitations. Objective measures of sleep were assessed for up to 7 d, whereas the PSQI and the reported highly sleep disturbed outcomes represent time periods of 30 d and 1 y, respectively. The concern is that 7 d of actigraphy may not represent long-term average sleep patterns. However, the selected time frame for actigraphy measures is typical, and supported in the literature and considered more than adequate for evaluating sleep in a nonclinical study sample.[30,61] If there were situational factors (e.g. an ill child) that made sleep worse in the actigraphy-assessed week, it would not be expected to bias against the effect of wind turbines on sleep, and in fact, would overstate the effect of recent situational events as compared to the long-term theoretical concern about WTN-induced sleep disturbance. As previously discussed, the analysis of actigraphy results was based on nightly average sleep patterns in relation to long-term WTN levels. Although WTN calculations would be expected to produce the highest sound pressure levels at the dwelling, they do not take into consideration the influence that night-to-night variations in outdoor WTN levels may have had on actigraphy results. Similarly, an analysis based on long-term average sound level does not fully account for transient deviations in WTN levels that could potentially interfere with sleep. An analysis based on a time-matched comparison between operational turbine data and actigraphy would permit a more refined assessment of the possible effect that night-to-night variations in WTN levels may have on sleep. These limitations extend to the fact that fluctuations in indoor sound levels during sleep remain unknown.

The possibility that wind turbine operators may have intentionally altered the output of their turbines in order to reduce potential WTN effects on sleep has been one of the concerns raised during the external peer review of this paper. When the *Community Noise and Health Study* was originally announced several months preceding data collection the study locations were unknown. Although awareness of the precise study locations would have become greater as data collection commenced, the deployment of the sleep watches took place over several months among a subsample of participants across the entire study sample. Furthermore, the reference period time for self-reported sleep disturbance was over the previous year and previous 30 d (PSQI). Finally, the subsets of sound power measurements were consistent with manufacturer-supplied data. In the authors' opinion, there is no evidence to suggest that wind turbine operators intentionally altered the output of their turbines to minimize potential effects on sleep at any point in the study.

CONCLUSIONS

The potential association between WTN levels and sleep quality was assessed over the previous 30 d using the PSQI, the previous year using percentage highly sleep disturbed, together with an assessment of diagnosed sleep disorders. These self-reported measures were considered in addition to several objective measures including total sleep time, sleep onset latency, awakenings, and sleep efficiency. In all cases, in the final analysis there was no consistent pattern observed between any of the self-reported or actigraphy-measured endpoints and WTN levels up to 46 dB(A). Given the lack of an association between WTN levels and sleep, it should be considered that the study design may not have been sensitive enough to reveal effects on sleep. However, in the current study it was demonstrated that the factors that influence sleep quality (e.g. age, body mass index, caffeine, health conditions) were related to one or more self-reported and objective measures of sleep. This demonstrated sensitivity, together with the observation that there was consistency between multiple measures of self-reported sleep disturbance and among some of the self-reported and actigraphy measures, lends strength to the robustness of the conclusion that WTN levels up to 46 dB(A) had no statistically significant effect on any measure of sleep quality.

The WHO's[11] health-based limit for protecting against sleep disturbance is an annual average outdoor level of 40 dB(A). This level was exceeded in 19% of the cases, but by no more than 6 dB(A) and as such represents a limit to detecting a potential effect on sleep. It is therefore important to acknowledge that no inferences can be drawn from the current results to areas where WTN levels exceed 46 dB(A). Likewise, assuming a baseline prevalence of 10%, the study was designed so that the statistical power would be sufficient to detect at least a 7% difference in the prevalence of self-reported sleep disturbance. A larger sample size would be required to detect smaller differences. The statistical power of a study design is a limitation that applies to all epidemiological studies.

Although it may be tempting to generalize the current study findings to other areas, this would have required random selection of study locations from all communities living near wind turbines in Canada. Despite the fact that participants in the study were randomly selected, the locations were not and for this reason the level of confidence one has in generalizing the results to other areas can only be based on a certain level of scientific judgment regarding the level of exposure and the similarity between the current study sample and others. Despite limitations in generalizing the results of this analysis beyond the study sample, the current study is the largest and most comprehensive analysis of both self-reported and objectively measured sleep disturbance in relation to WTN levels published to date.

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Close

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EXHIBIT
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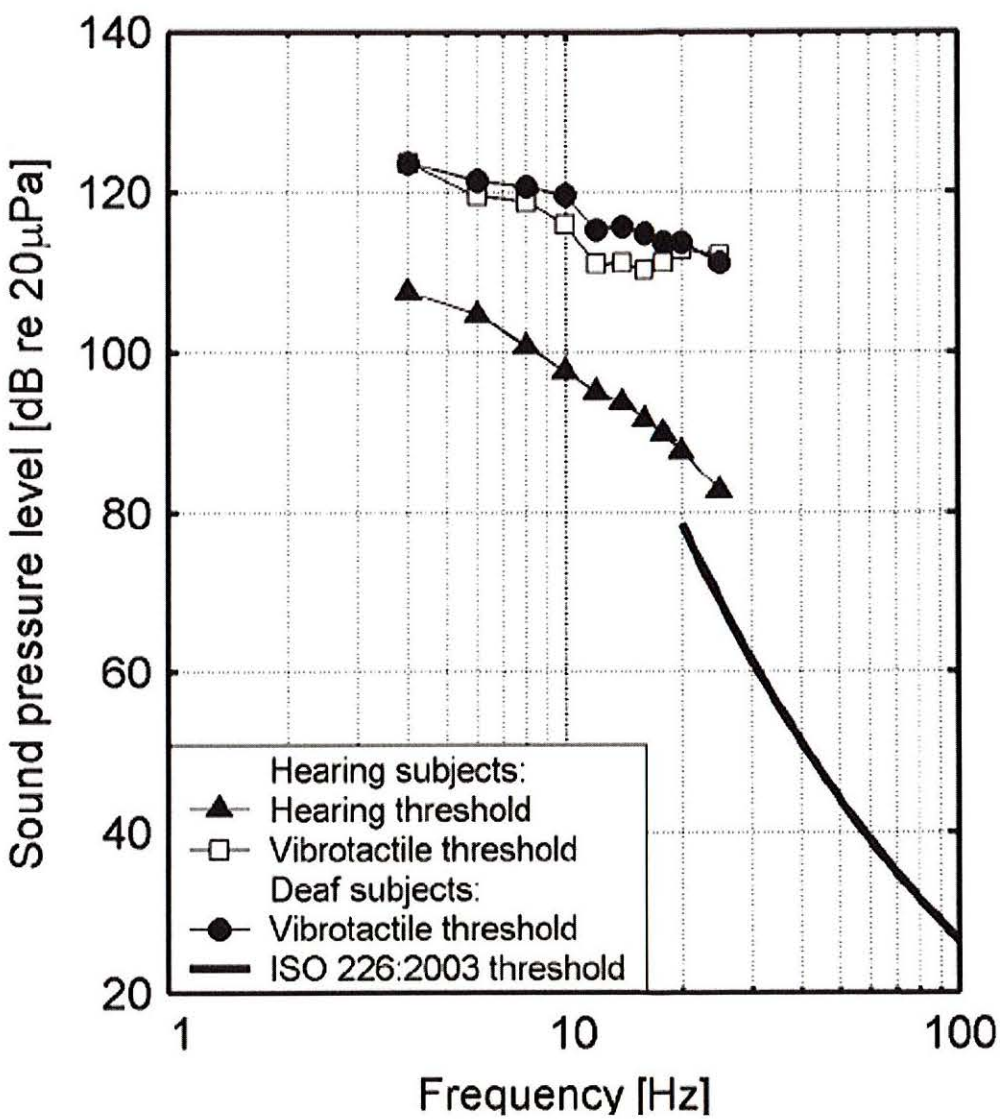
Hearing and vibrotactile thresholds as measured for hearing and deaf subjects by Landström et al. (1983).



IN THE COURT OF APPEALS OF IOWA

No. 16-2088
Filed November 8, 2017

SCOTT RUETER and TRICIA RUETER,
Plaintiffs-Appellants,

vs.

OSCEOLA WINDPOWER, LLC,
Defendant-Appellee.

Appeal from the Iowa District Court for Osceola County, Carl J. Petersen, Judge.

Scott and Tricia Rueter appeal the dismissal of their action for nuisance and negligence concerning the construction, placement, and operation of wind turbines owned by Osceola Windpower, LLC. **AFFIRMED.**

Steven Hamilton of Hamilton Law Firm, P.C., Storm Lake, for appellants.

William G. Beck and Sander J. Morehead of Woods, Fuller, Shultz & Smith, P.C., Sioux Falls, South Dakota, for appellee.

Considered by Vaitheswaran, P.J., and Doyle and Bower, JJ.

DOYLE, Judge.

Scott and Tricia Rueter appeal the dismissal of their action for nuisance and negligence concerning the construction, placement, and operation of wind turbines owned by Osceola Windpower, LLC (Osceola Windpower). The Rueters argue the district court abused its discretion in dismissing their petition for failing to comply with court orders and discovery rules. Because the district court did not abuse its discretion in dismissing the action, we affirm.

The genesis of this appeal was Osceola Windpower's installation of wind turbines near the Reuters' rural Osceola County home in 2008. Unhappy with the noise and disturbance the wind turbines caused, the Reuters filed a petition against Osceola Windpower in January 2010, alleging the wind turbines created a nuisance and seeking damages and injunctive relief. Litigation pended for nearly seven years without reaching trial.[1] In the final two years of litigation,

[1] The Rueters were initially represented by Gregg Owens. During Owens's representation, trial was originally scheduled to begin in May 2011 and was later rescheduled for dates in July 2012, February 2013, November 2013, July 2014, and January 2015. The record reveals Owens did nothing to otherwise advance the prosecution of the action during his representation. The Rueters did not propound discovery requests to Osceola Windpower in the first four years after filing the action. Although Osceola Windpower sent the Rueters discovery requests shortly after answering the petition, the Rueters' failure to answer led the court to grant Osceola Windpower's motion to compel discovery in September 2010.

After Owens left private practice in May 2014 and withdrew from representing the Rueters, Abby Walleck, Owens's former law firm partner, briefly represented them. Walleck designated five expert witnesses in June 2014 and served Osceola Windpower with the Rueters' first discovery requests.

In September 2014, Steven Hamilton made an appearance on the Rueters' behalf after Osceola Windpower filed its second motion for partial summary judgment. At that time, the Rueters amended their petition to add a claim for negligent construction, placement, and operation of the wind turbines. An October 2014 order granted a sixth continuance of trial, setting trial for September 2015. In a December 2014 order ruling on Rueters' motion to continue to avoid the application of Rule 1.944, the court noted, it was granting the continuance "on tenuous grounds as it appears that this entire proceeding has not been prosecuted by [the Rueters] with due diligence," and the court opined that "substitute counsel has attempted to rectify this situation." Trial was

Osceola Windpower filed three motions to dismiss the action based on the Rueters' failure to comply with court orders and the Iowa discovery rules. *See* Iowa Rs. Civ. P. 1.517(b)(3) (allowing the court to dismiss an action if a party fails to obey an order to provide or permit discovery), 1.945 (allowing a party to move to dismiss any action "if the party asserting it fails to comply with . . . any order of court"). The district court granted the third motion to dismiss in December 2016. The Rueters appealed.

We review the district court's order for an abuse of discretion. *See Troendle v. Hanson*, 570 N.W.2d 753, 755 (Iowa 1997). "An abuse of discretion consists of a ruling which rests upon clearly untenable or unreasonable grounds." *See id.* However, the range of the court's discretion narrows when it dismisses an action under rule 1.517. *See Kenall/Hunt Pub. Co. v. Rowe*, 424 N.W.2d 235, 240 (Iowa 1988). Dismissal is inappropriate in the absence of willfulness, fault, or bad faith. *See Wagner v. Miller*, 555 N.W.2d 246, 249 (Iowa 1996). Generally, a sanction of dismissal is only appropriate when a party has violated a court order; where the district court imposes the sanction of dismissal for something less, our supreme court has typically found an abuse of discretion. *See Suckow v. Boone State Bank & Trust Co.*, 314 N.W.2d 421, 426 (Iowa 1982) (analyzing cases).

The dispute at issue concerns the Rueters' failure to provide requested discovery concerning their calculation of damages. The district court entered an order in January 2015 resetting a new deadline requiring disclosure of this

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rescheduled twice thereafter—first for a date in March 2016 and then for a date in November 2016. The November 2016 trial date was removed from the calendar and never rescheduled due to the court's dismissal order.

information within ninety days. When the Rueters failed to provide the information as ordered, the district court entered an October 2015 order imposing monetary sanctions on Rueters' counsel for his failure to provide discovery. In February 2016, after the Rueters failed to inform Osceola Windpower of their updated damage calculation, the court ordered the Rueters to disclose an updated calculation within thirty days and warned that the Rueters were "dangerously close to overly frustrating the litigation process." Still, the Rueters failed to disclose and supplement the discovery requests as ordered by the court and as required by our rules. These failures delayed at least two witness depositions and, ultimately, the trial. In December 2016, after finding it "apparent" that the Rueters had violated the orders, the district court determined dismissal was warranted based on the Rueters "continual lack of prosecution" of the action.

On appeal, the Rueters attempt to downplay the seriousness of the failures to provide and supplement discovery responses, claiming the discovery violations only existed "in the mind of defense counsel." They also claim the only established violation "was a minor issue" of failing to provide answers to interrogatories concerning damages, which they claim was "inadvertent." We disagree with their characterization. In viewing the record before us, we ask whether the Rueters failed to comply with previous orders of the court and find they did. Whether the Rueters themselves did so willfully is irrelevant so long as their attorney's action—or inaction—may serve as the basis for the dismissal. *See Wagner*, 555 N.W.2d at 249. It is disingenuous to claim counsel's delinquent efforts to comply with the discovery rules and the prior court orders were merely oversight and inadvertent when Osceola Windpower had filed two previous motions to dismiss on this basis, the Rueters counsel had been sanctioned for his failure to comply with a prior court order, and the court had warned that the Rueters were "dangerously close" to frustrating the litigation process by failing to provide the discovery responses. Despite having multiple opportunities to comply, the Rueters failed to do so. On this record, there is substantial evidence to support the finding that the Rueters willfully failed to comply with the court's prior orders. *See id.* (finding plaintiffs' failure to comply with two court orders to answer interrogatories was substantial evidence of willful contemptuousness, supporting dismissal of the action). The fact that lesser sanctions were available is irrelevant. *See id*. So, too, is the fact that Osceola Windpower requested some of the continuances when it was the Reuters' failures that made the continuances necessary.

Because the failure to comply with the court's orders justifies the sanction of dismissal, the court did not abuse its discretion in ordering dismissal. We affirm.

AFFIRMED.

BEFORE THE SOUTH DAKOTA PUBLIC UTILITIES COMMISSION

DOCKET NO. EL18-026

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND PARK PROJECT

DIRECT TESTIMONY OF DARREN KEARNEY
ON BEHALF OF THE PUBLIC UTILITIES COMMISSION STAFF
September 10, 2018

EXHIBIT
Staff
S1

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EXHIBITS

I. INTRODUCTION AND QUALIFICATIONS

Q. State your name.

A. Darren Kearney.

Q. State your employer and business address.

A. South Dakota Public Utilities Commission, 500 E Capitol Ave, Pierre, SD, 57501.

Q. State your position with the South Dakota Public Utilities Commission.

A. I am a Staff Analyst, which is also referred to as a Utility Analyst.

Q. What is your educational background?

A. I hold a Bachelor of Science degree, majoring in Biology, from the University of Minnesota. I also hold a Master of Business Administration degree from the University of South Dakota.

Q. Please provide a brief explanation of your work experience.

A. I began my career in the utility industry working as contract biologist for Xcel Energy, where I conducted biological studies around various power plants, performed statistical analysis on the data collected, and authored reports in order to meet National Pollutant Discharge Elimination System (NPDES) permit requirements.

After two years of performing biological studies, I then transitioned into an environmental compliance function at Xcel Energy as a full-time employee of the company and became responsible for ensuring Xcel's facilities maintained compliance with the Oil Pollution Act of 1990. This involved writing Spill Prevention Control and Countermeasure (SPCC) plans and also ensuring Xcel's facilities maintained compliance with those plans. I was also responsible for the company's Environmental Incident Response Program, which involved training Xcel employees on spill reporting and response, managing spill cleanups, and mobilizing in-house and contract spill response resources.

I was in that role for approximately three years and then I transitioned to a coal-fired power plant at Xcel and became responsible for environmental permitting and compliance for the plant. Briefly, my responsibilities involved ensuring that the facility complied with all environmental permits at the plant, which included a Clean Air Act Title V Air Permit, a Clean Water Act NPDES permit, and a hazardous waste permit. I also drafted reports on the plant's operations for submission to various agencies as required by permit or law. After three years at the power plant, I left Xcel Energy to work for the South Dakota Public Utilities Commission (SD PUC).

I have been at the SD PUC for over five years now. During my employment with the PUC, I worked on a variety of matters in the telecom, natural gas, and electric industries. The major dockets that I worked on were transmission siting, pipeline siting, wind energy facility siting and energy efficiency programs. I also work on matters involving the Midcontinent Independent System Operator (MISO), specifically wholesale electricity market issues, transmission cost allocation and regional transmission planning. I also attended a number of trainings on public utility policy issues, electric grid operations, regional transmission planning, electric wholesale markets, and utility ratemaking.

My resume is provided as Exhibit_DK-1.

II. PURPOSE OF TESTIMONY

Q. On whose behalf was this testimony prepared?

A. This testimony was prepared on behalf of the Staff of the South Dakota Public Utilities Commission.

Q. What is the purpose of your direct testimony?

A. The purpose of my direct testimony is to discuss the Application review performed by Commission Staff, identify any issues or concerns with the representations made in the Application or by the Applicant, identify any outstanding concerns Staff has with Application, and provide recommended permit conditions.

III. REVIEW OF THE APPLICATION

Q. When did Prevailing Wind Park, LLC file its Application for a permit to construct the Prevailing Wind Park Project?

A. The Application was filed on May 30, 2018.

Q. Did you review Prevailing Wind Park, LLC's Application for a permit to construct the Prevailing Wind Park Project?

A. Yes. I also reviewed the figures, appendixes, discovery responses produced by all parties, Prevailing Wind's direct testimony, Prevailing Wind's supplemental testimony, and comments the PUC received from the public.

Q. Were other Staff involved in the review of the Application?

A. Yes. Staff Analyst Jon Thurber and Staff Attorney Kristen Edwards also assisted in reviewing the Application.

Q. Explain, in your words, the main role of the SDPUC Staff in the Application proceedings.

A. After receiving the Application filing, Staff completed a review of the contents of the Application as it relates to the Energy Facility Siting statutes, SDCL 49-41B, and Energy Facility Siting Rules, ARSD 20:10:22. Staff then identified information required by statute or rule that was either missing from the Application or unclear within the Application and requested Prevailing Wind Park to provide or clarify that information (see Exhibit_DK-2). Once interested individuals were granted party status, Staff also issued discovery to the intervenors to understand what concerns they had with the project (see Exhibit_DK-3).

Staff hired two consultants to assist with reviewing the Application. The first consultant, David Hessler, has expertise on noise emitted from wind turbines and noise modeling. The second consultant, David Lawrence, is a South Dakota licensed appraiser and has expertise regarding property valuation. These experts then completed their review and authored their testimony as filed in this docket.

Finally, Staff assisted intervenors and affected landowners by providing responses to numerous questions on the windfarm, the siting process at the PUC and the opportunities available for these individuals to be heard by the Commission. If the landowners had specific concerns with the wind farm, Staff often recommended that those individuals file comments in the docket for the Commission's review. Where appropriate, Staff also included some of the landowners' questions or concerns in Staff's data requests sent to Prevailing Wind Park to have them address the issue.

Q. What is the purpose of Staff's expert witnesses in this proceeding?

A. Given that some of the information submitted in the Application is technical in nature, Staff sought experts within their respective fields to assess the merits and deficiencies of the Application. Staff asked the experts to review the relevant portions of the Application, testimony, appendixes, data requests, and public comments that fall within their areas of expertise and identify any concerns they had with the material submitted.

Ultimately, Staff requested that the experts address whether or not the information submitted by Prevailing Wind Park aligns with industry best practices and if they agreed with the conclusions Prevailing Wind Park made regarding potential impacts from the project.

Q. Did Staff reach out to any other State Agencies for input?

A. Yes. Staff reached out to the South Dakota Game, Fish, and Parks (SD GF&P), the State Historic Preservation Office (SHPO), and the South Dakota Department of Health (SD DOH).

Q. Did any of those agencies communicate concerns to PUC Staff specific to the Prevailing Wind Park Project?

A. At the time of writing this testimony, no concerns specific to the Prevailing Wind Park Project were brought up by any of the agencies Staff reached out to.

Q. Why did PUC Staff not request SHPO and SD GF&P testify for the Prevailing Wind Park Project?

A. There are a few reasons why Staff did not request testimony from SHPO and SD GF&P. First, an Environmental Assessment (EA) is being completed by Western

Area Power Administration (WAPA) for the entire Prevailing Wind Park Project. It is Staff's understanding that the SD GF&P and SHPO were consulted for the EA and any comments those agencies may have on the project will be considered during that process. It should be noted that in the recent wind farm siting dockets, a federal EA was either not required or required for only a small portion of the project. In those cases, the PUC's siting docket was the only process available for the consideration of SD GF&P's and SHPO's comments and recommendations.

Second, the SD GF&P and SHPO have not communicated to Staff any concerns specific to the Prevailing Wind Park Project. As such, Staff is not aware of any issues or concerns that SD GF&P and SHPO have with the project that would need to be briefed.

Finally, the procedural schedule in this docket allows for Staff to present rebuttal witnesses. Should any issues arise that fall in the area of expertise of SD GF&P or SHPO, Staff is planning to present the appropriate agency as a rebuttal witness.

Q. Did Commission Staff request assistance from the South Dakota Department of Health in the review of the Application?

A. Yes. SDCL 49-41B-22(3) requires the Applicant establish that the Prevailing Wind Park will not substantially impair the health of the inhabitants. At the Public

Input Hearing and through written comments to the Commission, inhabitants have raised concerns regarding health impacts from wind facilities. Commission Staff believes the Department of Health is the appropriate State agency to assess the potential health impacts from the facility.

Q. Has the Department of Health commented on health impacts associated with wind facilities in other dockets?

A. Yes. For the Crocker Wind Farm (Docket EL17-028), the Department of Health provided Commission Staff with a letter stating that the Department of Health has not taken a formal position on the issue of wind turbines and human health. Further, they referenced the Massachusetts Department of Public Health and Minnesota Department of Health studies and identified those studies generally conclude that there is insufficient evidence to establish significant risk to human health. I included the Department of Health's letter as Exhibit_DK-4.

Q. What is the Department of Health's position on the health impacts associated with the Prevailing Wind Park Project?

A. On August 8, 2018, the Department of Health stated that it maintains the same position for the Prevailing Wind Park Project as previously provided for the Crocker Wind Farm. Since the letter was provided for the Crocker Wind Farm, the Department of Health has not become aware of any additional studies that would cause the Department to re-evaluate their position.

Q. Was Prevailing Wind Park, LLC's Application considered complete at the time of filing?

A. At the time of the filing, the application was generally complete. However, as identified above, Staff requested further information, or clarification, from Prevailing Wind Park that Staff believed was necessary to satisfy the requirements of SDCL 49-41B and ARSD 20:10:22. I would note that an applicant supplementing its original application with additional information as requested by Staff is not unusual for siting dockets.

Q. Based on your review of the Application, responses to Staff's data requests and Prevailing Wind Park, LLC's testimony, do you find the Application to be complete?

A. Yes. Staff found that Prevailing Wind Park provided information that addressed the information required by ARSD Chapter 20:10:22 and SDCL 49-41B. In my opinion, Prevailing Wind Park, LLC did an excellent job of preparing the Application, which resulted in fewer discovery questions issued from Staff.

Q. Did Commission Staff receive responses to discovery from all individuals granted party status?

A. Yes. Staff received discovery responses from all intervenors. The following section addresses a few of the requests that were made by the intervenors.

IV. Intervenor Concerns

Q. What is Staff's position on a 2-mile setback from non-participating residences?

A. While staff acknowledges that a 2-mile setback would provide more protection to non-participating residences, at this time there is insufficient evidence presented in the record for Staff to take a position on whether the 2-mile setback distance is appropriate in this docket. A setback distance of 2-miles would reduce noise impacts on non-participants, however I will note that Prevailing Wind Park's proposed turbine layout currently meets Staff witness David Hessler's suggested noise limit of 45 dBA.

Q. What is Staff's position on requiring a 1500 foot setback from property lines?

A. Based on the information Staff has reviewed in the docket thus far, Staff does not feel there is adequate evidence in the record to support a 1500 foot setback from property lines. However, requiring that setback distance would provide added protection for an individual's personal property or livestock in the event of ice throw or blade malfunction.

Q. What is Staff's position on reducing the noise limit to 35 dBA at nonparticipating residences and performing C-weighted noise modeling?

A. Staff's noise witness, Mr. Hessler, addresses Staff's position on these recommendations made by the intervenors in his testimony. In summary, Mr.

Hessler identifies that a 35 dBA noise limit would be extremely difficult for a wind project to meet and that C-weighted sound measurements would still not capture the infrasound noise levels that the intervenors are concerned about. As such, Staff does not support a proposed noise limit of 35 dBA and requiring C-weighted sound measurements/modeling.

Q. What is Staff's position on the health concerns associated with infrasound and low-frequency noise?

A. Staff takes no position on the health concerns associated with infrasound and low frequency noise. This position is derived from the SD Department of Health's letter identifying that they do not have a formal position on the issue. What is clear (and would likely not be contested by either side of the debate) is that wind turbines will result in a small percentage of population residing near the turbines being annoyed by the noise from the turbines.

Q. What is Staff's position on developing an operational plan to shut down turbines, or implementing noise reducing operations of turbines, located within 2 miles of a nonparticipating residence during nighttime hours?

A. At this time, Staff does not have evidence to justify requiring such a plan. This is based on the fact that the wind turbine sound study shows that the noise from the Prevailing Wind Park Project will be within the recommended limit provided by Mr. Hessler. However, should concerns be raised in the future with noise produced by certain turbines, implementing such a plan could be a good mitigation strategy if those turbines are found to exceed the noise limit.

Q. What is Staff's position on requiring a property value guarantee?

A. Staff does not support the recommendation for a property value guarantee. Based on past testimony the Commission has heard during recent wind farm siting dockets and Mr. Lawrence's direct testimony in this docket, the implementation of a property value guarantee would be extremely difficult to do. I will also note that a property owner who finds that the wind farm adversely impacted their property values can seek damages for that loss through the court system.

Q. One commenter expressed concerns regarding the potential adverse economic impact to his pheasant hunting business. What is Staff's position on this concern?

A. Staff included a question in its data requests to have Prevailing Wind Park address this concern (see Staff Data Request 2-9 in Exhibit_DK-2). Prevailing Wind Park's approach to address this concern was to reference studies that show the impact to upland game species, including ring-necked pheasants, is not biologically significant. Based on this, Prevailing Wind Park concludes that any expected economic impact to hunting businesses is expected to be very low.

The approach Prevailing Wind Park took is logical (where if birds are still present in the area then people continue to have the opportunity to hunt in the area). However, Staff is not entirely convinced that proves there will be no impact on hunting businesses as other factors may impact a hunter's decision to hunt in certain areas as well (e.g. scenery, quietness). A more-robust study on whether hunters are choosing to avoid hunting lodges/guiding services near turbines in favor of lodges/guides in areas without turbines would be needed. Staff is not aware of any such study and does not take a position on this issue.

Should the Commission find this potential impact to be of concern and Prevailing Wind Park's response not satisfactory, the Commission could request additional information to be produced during the hearing.

V. Outstanding Concerns and Recommended Permit Conditions

Q. Does Staff have any outstanding concerns at this time?

A. Yes. Staff has one concern regarding shadow flicker that is expected to occur at a nonparticipant (receptor REC-076). In Prevailing Wind Park's response to Staff Data Request 1-1 subpart d (see Exhibit_DK-2), it is identified that REC-076 is expected to experience 33.93 hours of shadow flicker per year. Prevailing Wind Park committed to shadow flicker being less than 30 hours per year and/or 30 minutes per day at currently inhabited non-participating residences in Charles

Mix County (see Charles Mix County Letter to PUC Staff in Exhibit_DK-3). Based on this information, turbines 9 and 12 are not meeting the commitment Prevailing Wind Park made to Charles Mix County. Prevailing Wind Park should address this concern prior to the evidentiary hearing.

While Staff has identified only the one concern at the time of writing this testimony, we have not reviewed the Intervenors' testimony as exhibits. If Staff finds any of the issues the Intervenors raise have merit, Staff will address those issues either by supplementing our direct testimony, through rebuttal testimony, or at the hearing.

Q. Does Staff recommend any permit conditions?

A. Staff will be working with Prevailing Wind Park to create a list of recommended permit conditions for Commission consideration. In response to Staff Data Request 2-22 subpart b (see Exhibit_DK-2), Prevailing Wind Park identified that they are generally willing to accept the conditions attached to the permit issued for Dakota Range (Docket EL18-003). Given this, Staff believes that we will be able to work with Prevailing Wind Park to develop permit conditions consistent with those ordered by the Commission in the past.

However, one permit condition that Prevailing Wind Park and Staff may differ on is the amount of funding required to be set aside in an escrow account for the decommissioning of wind turbines. In response to Staff Data Request 2-17 (see

Exhibit_DK-2), Prevailing Wind Park stated they recommend to using the partial resale decommissioning cost estimate of $786,000 for the entire project. Staff disagrees with using this amount and finds that the no resale decommissioning cost estimate of $2,938,000 should be used as the basis for funding an escrow account. The no resale cost estimate would provide added assurance and be the most conservative of the two cost estimates since the market (and prices) for salvageable wind turbine components could change over the next 30 to 50 years.

Q. Does this conclude your testimony?

A. Yes.

DARREN D. KEARNEY

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Darren.Kearney@state.sd.us

EDUCATION:

UNIVERSITY OF SOUTH DAKOTA, Vermillion, South Dakota
Beacom School of Business
Master of Business Administration (GPA 4.0) — *June 2013 – May 2015*

UNIVERSITY OF ST. THOMAS, Minneapolis, Minnesota
Opus College of Business
Pursued Master of Business Administration (GPA 3.95) — *November 2011 – December 2012*

UNIVERSITY OF MINNESOTA, Minneapolis, Minnesota
College of Biological Sciences
Bachelor of Science, Biology (GPA 3.347) — *December 2003*

EXPERIENCE:

SOUTH DAKOTA PUBLIC UTILITIES COMMISSION, Pierre SD
Utility Analyst — *February 2013 - Present*
- Ensured public utility company filings are in compliance with South Dakota statutes and regulations.
- Analyzed siting dockets, testified before the Commission, and worked on settlement agreements as appropriate.
- Analyzed energy efficiency, telecom tariff, telecom certificate of authority, electric service territory, and other electric dockets in order to form a position and make recommendations to the Commission on those dockets.
- Reviewed proposed EPA Clean Power Plan rules and authored comments in response to the proposed rules.
- Worked on MISO wholesale electric market, regional transmission planning, and cost allocation issues.
- Attended a number of trainings on electric grid operation, regional transmission planning, public utility policy issues, and ratemaking.

XCEL ENERGY, Minneapolis MN
Plant Environmental Analyst III — *October 2009 – February 2013*
- Reviewed power plant processes and made modifications as necessary to ensure the plant was in continued compliance with environmental permits and regulations.
- Coordinated environmental related testing (e.g. annual stack tests required by Air Permit/CAA).
- Worked on Title V Air Permit and NPDES Permit renewals/amendments.
- Reviewed plant air and water emissions data and generated compliance reports for Air and NPDES/SDS Permits.
- Performed plant compliance inspections/audits to ensure permits, policies, and procedures were properly executed.
- Provided environmental training to plant staff.
- Conducted root cause investigations on spills and permit non-compliance incidents, developed corrective actions to prevent incident reoccurrence, and then implemented the corrective actions as directed by plant management.
- Acted as point of contact during regulatory agency inspections and internal audits.
- Managed the facility's hazardous waste program for compliance with county waste rules and RCRA.

Environmental Analyst II — *August 2006 – October 2009*
- Subject matter expert for AST/UST compliance, the Oil Pollution Act of 1990 (SPCC) and Industrial Stormwater.
- Managed an Environmental Incident Response Program that involved coordinating spill cleanups and training individuals on reporting/cleanup requirements for oil/chemical spills and power plant permit non-compliance incidents.

ADECCO TECHNICAL, Edina MN
Contract Biologist - Xcel Energy Environmental Analyst — *June 2004 – August 2006*
- Developed monitoring plans, conducted field monitoring/sampling, performed statistical analysis on data collected, and authored reports for biological studies at Xcel Energy power plants as required by State and Federal Rules.
- Established knowledge of environmental permits and Federal, State, and Local environmental regulations.

ACHIEVEMENTS
- Academic: Beta Gamma Sigma International Honor Society (Business School)

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * * *	**APPLICANT'S RESPONSES TO STAFF'S FIRST SET OF DATA REQUESTS EL18-026**

Below, please find Applicant's responses to Staff's First Set of Data Requests to Applicant.

1-1) One non-participating receptor is listed as having thirty or more hours of shadow flicker per year, and two participating receptors are listed as having thirty or more hours of shadow flicker per year.

a. How many hours of shadow flicker per year are expected at the participating receptors?

Aaron Anderson: Shadow flicker at the participating receptors is shown in the following table for the GE 3.8-137 turbine, which, as noted in response to DR 1-3 below, is the turbine PWP has selected for the Prevailing Wind Park Project ("Project").

Receptor Name	Easting [m]	Northing [m]	Flicker Duration [hour/year]	Flicker Duration [max minutes/day]	Participating Status	County Name	Caused by WTG(s)
REC-046	570,892	4,766,384	45.38	75	Participating	Charles Mix	T61, T63, T64
REC-114	580,644	4,779,066	32.07	46	Participating	Bon Homme	T18, T46, T47

b. Has this information been communicated to the landowner and/or inhabitant? If so, how?

Bridget Canty: Prevailing Wind Park plans to discuss anticipated shadow flicker levels with the participating landowners who may have more than 30 hours of shadow flicker per year.

c. What mitigation will Applicant be employing or exploring?

Bridget Canty: Measures that may be employed to mitigate shadow flicker that exceeds 30 hours per year may include: installation of internal window coverings, external window awnings, or landscape plantings.

d. What turbine numbers are associated with the three receptors having more than thirty hours of shadow flicker per year?

Aaron Anderson: For the GE 3.8-137 turbine, the turbine numbers contributing to shadow flicker at the three receptors are shown in the table below.

Receptor Name	Easting [m]	Northing [m]	Flicker Duration [hour/year]	Flicker Duration [max minutes/day]	Participating Status	County Name	Caused by WTG(s)
REC-046	570,892	4,766,384	45.38	75	Participating	Charles Mix	T61, T63, T64
REC-076	573,024	4,775,138	33.93	51	Non-participating	Charles Mix	T9, T12
REC-114	580,644	4,779,066	32.07	46	Participating	Bon Homme	T18, T46, T47

1-2) Table 9-2 references shadow flicker at currently inhabited dwellings of non-participants. How was the inhabited status of a dwelling confirmed?

Bridget Canty and Jennifer Bell: In 2016, inhabited status of dwellings was determined by (1) reviewing aerial photography to determine location of residences in and around the project footprint; (2) reviewing aerials and drawing on local knowledge of the area to determine obvious occupied residences; (3) field verifying dwellings with indeterminate status; (4) contacting landowners to verify occupancy status; and (5) using tax rolls to determine ownership and addresses of residences. In 2018, the 2016 data set was updated first by reviewing aerial photography of each identified dwelling. Dwelling locations and occupancy status were then reviewed in the field during windshield surveys (i.e., observed from public roads).

1-3) When does Applicant anticipate knowing which turbine model will be used?

Peter Pawlowski: Prevailing Wind Park has selected the GE 3.8-137 wind turbine model for the Project.

1-4) Provide a copy of the standard lease/easement contract. Do any of the contracts differ in a material way?

Roland Jurgens/Robert Wilson: Prevailing Wind Park has entered into three types of agreements with landowners. All three agreement forms which are provided in response to this request are confidential. One is a standard Prevailing Wind Park lease and wind easement agreement that provides full rights for Prevailing Wind Park to place turbines and facilities on the property. The second is a "no turbine" lease, which provides for an easement for associated facilities only; additional permission is required before

Prevailing Wind Park would have rights to place a turbine on the property. *See* item 3 of "Blank No Turbine Lease" form. The third type is a wind easement and setback waiver, which does not allow placement of facilities on the property.

1-5) In section 8-2, a 500-foot shift allowance is requested. Would this distance be from the center point of the structure?

Bridget Canty: Yes, the 500-foot shift allowance is requested from the center point of each proposed wind turbine location.

1-6) Describe the $4.3 million contribution received from the State of South Dakota.

a. Provide a copy of the agreement.

Roland Jurgens: The Prevailing Wind Park applied to the Governor's Office of Economic Development South Dakota Reinvestment Payment Program ("RPP") and was approved for a reinvestment payment of up to $4,329,410 of sales and use taxes that the project will pay during construction. The RPP is available to assist companies in offsetting the upfront costs associated with relocating or expanding operations and/or upgrading equipment in South Dakota. The program allows for project owners to receive a reinvestment payment, not to exceed the South Dakota sales and use tax paid on project costs, for new or expanded facilities with project costs in excess of $20,000,000, or for equipment upgrades with project costs in excess of $2,000,000.

As noted in the enclosed meeting notes, on June 12, 2018, the Governor's Office of Economic Development approved a reinvestment payment for the Prevailing Wind Project of $4,329,310 not to exceed 65 percent of the state sales/use tax paid on eligible project costs. There is not an agreement associated with the approval.

b. Was this money in the form of a grant, tax relief, or some other form?

Bridget Canty: The Governor's Office of Economic Development RRP payment is in the form of a tax rebate.

c. Will Applicant be reevaluating the financial benefit to the State given this transaction?

Bridget Canty: Yes, the Applicant will submit the reevaluated financial benefit to the State in prefiled testimony.

1-7) To Applicant's knowledge, are there any existing wind turbines operating in South Dakota which are equal to or greater than the total height of the turbines that would be used for this Project?

Bridget Canty: Not at this time. However, it is our understanding that others within the wind development industry are or will be utilizing taller turbines for projects.

1-8) Does Applicant anticipate the fact that the turbines are a greater height than those in other recent applicants analyzed by the SD PUC would change or otherwise effect the ice throw analysis? Why or why not?

Bridget Canty: Ice shedding and ice throw occur under certain weather conditions that cause ice to build up on the rotor blades and/or sensors, slowing the rotational speed and potentially creating an imbalance in the weights of the individual blades. Turbine height has been shown to have a moderate impact on ice throw. In the Dakota Range docket, EL18 -003, the Commission found that with the 492-foot turbine proposed, "[t]he concern for ice shedding is typically within 300 feet of the turbine." *Final Decision and Order Granting Permit to Construct Wind Energy Facility; Notice of Entry, Attachment A* at 69 (July 23, 2018). This finding is consistent with a study conducted in Sweden from 2013 to 2016 (Lunden 2017), with total turbine heights of 140 meters (459 feet), found that 75% of the ice was found within one rotor diameter (90 meters) from the turbine tower, and 1% beyond 1.5 rotor diameter (140 meters).

Data collected by the Global Wind Energy Council (2014) indicate more than 268,000 turbines in operation by the end of 2014, and more have been constructed since. The lack of reported injury with this number of operational turbines is further indication that risk is low.

Prevailing Wind Park will use two methods to detect icing conditions on turbine blades: (1) sensors that will detect when blades become imbalanced or create vibration due to ice accumulation; and (2) meteorological data from on-site permanent meteorological towers, on-site anemometers, and other relevant meteorological sources that will be used to determine if ice accumulation is occurring. These control systems will either automatically shut down the turbine(s) in icing conditions (per the sensors) or Applicant will manually shut down turbine(s) if icing conditions are identified (using meteorological data). Turbines will not return to normal operation until the control systems no longer detect an imbalance or when weather conditions either remove icing on the blades or indicate icing is no longer a concern. Prevailing Wind Park will pay for any documented damage caused by ice thrown from a turbine.

1-9) Referring to Section 6.1.2 of the Application, please provide the source identifying the load growth of South Dakota and North Dakota is projected to be at least 2,100 MWs over the next 10 years.

Bridget Canty: The source identifying the load growth of the Dakotas is: Gotham, D.J., L. Lu, F. Wu, T.A. Phillips, P.V. Preckel, and M.A. Velastegui. 2016. 2016 MISO Independent Load Forecast. State Utility Forecasting Group, Purdue University, West Lafayette, Indiana. November. Prepared for Midcontinent Independent System Operator. Available at: https://www.purdue.edu/discoverypark/sufg/docs/publications/MISO%202016%20Independent%20Load%20Forecast%20Final.pdf

1-10) Referring to Section 6.3 of the Application, please provide the expected impact on the procuring utility's resource plan should the project not be operational by the end of 2019.

Peter Pawlowski: Basin Electric Power Cooperative ("Basin") has contracted for the full output of the Prevailing Wind Park. Basin provides power to its member distribution cooperatives that include the following cooperatives in South Dakota: East River Electric Power Cooperative, Bon Homme Yankton Electric Association, Butte Electric Cooperative, and Charles Mix Electric Association. We have requested additional information from Basin regarding this question, and will provide it once received.

1-11) Referring to Section 8.2 of the Application, please identify the 2 to 6 turbine locations that are considered the alternate locations.

Bridget Canty: Prevailing Wind Park has not identified which turbines will be alternates at this time. The purpose of including alternate locations is to allow flexibility to choose preferred locations as information from cultural resource surveys and site-specific geotechnical analysis is completed for the Project.

1-12) Referring to Section 8.3 of the Application, how does Prevailing Wind Park define "extent practicable" in the statement: "[f]ollowing completion of construction, the temporary crane paths would be removed, and the area would be restored, to the extent practicable"?

Bridget Canty: The phrase "extent practicable" should be removed from the identified sentence in Section 8.3. The revised sentence should read: "*Following completion of construction, the temporary crane paths would be removed, and the area would be restored*."

1-13) Referring to Table 9-1 of the Application, please explain why the interconnection distance is identified as being 0 miles for Location #1 when the Application identifies a 27-mile 115 kV transmission line will be constructed to interconnect with the Utica Junction Substation.

Roland Jurgens: The difference is attributable to the different interconnection points. The description of Location #1 in Table 9-1 was further refined through the Southwest Power Pool ("SPP") process. Originally, the Project was proposed to interconnect to WAPA's 230-kV transmission line within the footprint of the Project Area via a 100 to 200-foot tie line from the Project substation. However, it was later determined that configuration was not feasible and the point of interconnection was move to the current configuration, which specifies a 27-mile 115-kV line interconnecting at WAPA's Utica Junction Substation.

1-14) Referring to section 15.6.5 of the Application, please provide a copy of the NTIA determination.

Bridget Canty: A copy of the initial NTIA determination letter is attached. Prevailing Wind Park has followed up directly with the Department of Energy ("DOE") to identify any potential concerns it may have regarding radio frequency transmissions. If concerns remain, Prevailing Wind Park will discuss mitigation options with the DOE.

1-15) Referring to section 16.0 of the Application, please provide a copy of the Bon Homme county zoning ordinance applicable to large wind energy systems and copies of all conditional use permits received for the project.

Bridget Canty: A copy of the Bon Homme County Zoning Ordinance, including Article 17 which is specific to wind energy systems, is enclosed. Prevailing Wind Park submitted an application for a Large Wind Energy System Permit under Article 17 of the Bon Homme County Zoning Ordinance on August 2, 2018. Prevailing Wind Park expects to submit CUP applications for the Project turbines in Hutchinson County by August 15, 2018; a decision on the CUP applications is expected within 60 days of submission. Prevailing Wind Park will forward copies of CUPs for Hutchinson County following receipt. Prevailing Wind Park also received building permits from Charles Mix County, which does not have a zoning ordinance. Copies are enclosed.

1-16) Please provide GIS shape files for the project.

Jennifer Bell: Please see attached GIS shape files.

1-17) Please provide shadow flicker and noise maps that identify participating residences and non-participating residences.

Aaron Anderson and Chris Howell: Please see attached shadow flicker and noise maps for the GE 3.8-137, which have been updated as requested.

1-18) Please provide a revised Figure 9 that shows participating and non-participating residences.

Jennifer Bell: Please see attached figure, which has been updated as requested.

Dated this 3rd day of August, 2018.

By /s/ Mollie M. Smith____________________

Mollie M. Smith
Lisa A. Agrimonti
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UNITED STATES DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, D.C. 20230

JUN - 7 2018

Mr. B. Benjamin Evans, P.E.
Evans Engineering Solutions, LLC
524 Alta Loma Drive
Thiensville, WI 53092

Re: Prevailing Wind Project, Revision 1: Bon Homme, Charles Mix & Hutchinson Counties, SD

Dear Mr. Evans:

In response to your request on April 4, 2018, the National Telecommunications and Information Administration provided to the federal agencies represented in the Interdepartment Radio Advisory Committee (IRAC) the plans for the Prevailing Wind Project, Revision 1, located in Bon Homme, Charles Mix, and Hutchinson Counties, South Dakota.

After a 45+ day period of review, one Federal agency, the Department of Energy (DOE), identified concerns regarding blockage of their radio frequency transmissions. Energy's concerns are noted here:

> This project has the potential to affect operations of the DOE Western Area Power Administration, and turbine location data will be necessary for mitigation purposes. Energy requests that the developer coordinate directly with our Western Spectrum Program Manager:
>
> Scott E. Johnson, Sr. Telecom Engineer/Spectrum Program Manager
> US Dept. of Energy, Western Area Power Admin Headquarters, P. O. Box 281213, Lakewood, Colorado 80228-8213
> Phone: (720) 962-7380; Fax: (720) 962-4080; email: sjohnson@wapa.gov

While the other IRAC agencies did not identify any concerns regarding radio frequency blockage, this does not eliminate the need for the wind energy facilities to meet any other requirements specified by law related to these agencies. For example, this review by the IRAC does not eliminate any need that may exist to coordinate with the Federal Aviation Administration concerning flight obstruction.

Thank you for the opportunity to review these proposals.

Sincerely,

Peter A. Tenhula
Deputy Associate Administrator
Office of Spectrum Management

DEFINITIONS

Definitions

For the purpose of this Ordinance, unless otherwise stated, words used in the present tense include the future; the singular number includes the plural and the plural the singular; the word shall means mandatory, not discretionary; the word may is permissive; the word person includes a firm, association, organization, partnership, trust, company or corporation, as well as, an individual; the word lot includes the word plat or parcel; and the words used or occupied include the words intended, designed, or arranged to be used or occupied.

Terms

For the purpose of this Ordinance, certain terms or words used herein shall be interpreted as follows:

Accessory Use or Structure - A use or structure on the same lot with, and of a nature customarily incidental and subordinate to, the principal use or structure.

Actual Construction - Actual construction is hereby defined to include the placing of construction materials in permanent position and fastened in a permanent manner. Where excavation or demolition or removal of an existing building has been substantially commenced, preparatory to rebuilding, such excavation or demolition or removal shall be deemed to be actual construction, provided that work shall be carried on diligently.

Agriculture - The planting, cultivating, harvesting and storage of grains, hay or plants, fruits, or vineyards along with the raising and/or feeding of less than one thousand (1,000) animal units of livestock and/or poultry in an animal feeding operation as defined by this ordinance.

An animal feeding operation as defined by this ordinance is not considered an agricultural use. The processing and/or storage of raw agricultural products, including facilities such as grain elevators and ethanol plants, shall not be considered an agricultural use if such use constitutes the main or principal use on a lot or parcel.

Agriculture Product Processing Facility - A business activity customarily designed to process raw agricultural products into value added products. Agricultural processing facilities include, but are not limited to; feed mills, ethanol plants, and soy bean processing facilities.

All Weather Road - A roadway in which emergency vehicles and local traffic may pass at all times not to include severe weather events such as snow drifting and surface flooding. ***(Amended 11/3/15)***

Animal Feeding Operation - A facility where more than one thousand (1,000) animal units are stabled, confined, fed, or maintained in either an open or housed lots for a total of 45 days or more in any 12-month period and the open lots do not sustain crops, vegetation, forage growth, or post-harvest residues in the normal growing season. Two (2) or more facilities under common ownership are a single animal feeding operation if they adjoin each other (within one (1) mile), or if they use a common area or system for the disposal of manure. For the purpose of this ordinance animal units of differing species shall not be totaled to constitute an animal feeding operation as defined herein.

Animal Units - A unit of measure for livestock. One (1) animal unit is equivalent to:

1	feeder or slaughter beef animal;
.5	horse;
.7	mature dairy cattle;
.27	farrow-to-finish sows;
2.13	swine in a production unit (breeding, gestating and farrowing);
10	nursery swine less than 55 pounds;
2.5	finisher swine over 55 pounds;
10	sheep or lambs;
30	laying hens or broilers;
5	ducks; and
55	turkeys.

Animal Unit Conversion Table
A conversion table designed to integrate the definition of an animal feeding operation with the animal unit definition.

Animal Species	1,000 Animal Units
Feeder or Slaughter Beef Animal	1,000
Horses	500
Mature Dairy Cattle	700
Farrow to Finish Sows	270
Swine in a Production Unit	2,130
Nursery Swine Less than 55 Pounds	10,000
Finisher Swine Over 55 Pounds	2,500
Sheep	10,000
Laying Hens or Broilers	30,000
Ducks	5,000
Turkeys	55,000

Animal Waste Facility - A structure designed and constructed to store and/or process animal waste. Animal waste facilities include but are not limited to; holding basins, lagoons, pits and slurry stores.

Automobile-Machinery Service Station - Building and premises where motor fuel, oil, grease, batteries, tires, and parts may be supplied and dispensed at retail, and where, in addition, customary repair services may be rendered.

Board – The County Commission, Planning Commission, Board of Adjustment or other governmental body governing the district this ordinance refers to. ***(Amended 11/3/15)***

Buildable Area - The portion of a lot remaining after required yards have been provided.

Building - Any structure for the support, shelter and enclosure of persons, animals, chattels, or moveable property of any kind.

Campground - Any premises where two (2) or more camping units are parked or placed for camping purposes, or any premises used or set apart for supplying to the public camping space for two (2) or more camping units for camping purposes, which include any buildings, structures, vehicles or enclosures, used or intended for use or intended wholly, or in part, for the accommodation of transient campers for monetary gain.

Camping Unit - Any vehicle, tent, trailer or portable shelter used for camping purposes.

Commercial Trucking Terminal - A building or structure where seven (7) or more commercially licensed trucks or tractors are rented, leased, kept for hire, or stored or parked for compensation, or from which trucks or tractors, stored or parked on the property, are dispatched for hire as common carriers, and which may include warehouse space.

Conditional Use - A conditional use is a use that would not be appropriate, generally or without restriction, throughout the zoning district, but which, if controlled as to number, area, location or relation to the neighborhood, would promote the public health, safety, welfare, morals, order, convenience, appearance, prosperity or general welfare.

Construction – Any clearing of land, excavation, or other action that would adversely affect the natural environment of the site or route but does not include changes needed for temporary use of sites or routes for non-utility purposes, or uses in securing survey or geological data, including necessary borings to ascertain foundation conditions. ***(Amended 11/3/15)***

Domesticated Large Animals - Any animal that through long association with man, has been bred to a degree which has resulted in genetic changes affecting the temperament, color, conformation or other attributes of the species to an extent that makes it unique and different from wild individuals of its kind. For the purpose of this ordinance the definition shall include, but is not limited to, animals commonly raised on farms and ranches, such as cattle, horses, hogs, and mules.

Dwelling Unit - One (1) room, or rooms connected together, constituting a separate, independent housekeeping establishment for owner occupancy, or rental or lease on a weekly, monthly, or longer basis and physically separated from any other rooms or dwelling units which may be in the same structure and containing independent cooking and sleeping facilities.

Dwelling, Multiple Family - A residential building designed for, or occupied by, two (2) or more families, with the number of families in residence not exceeding the number of dwelling units provided.

Dwelling, Single Family - A detached residential dwelling unit other than a manufactured home designed for or occupied by one (1) family only.

Family - Any number of individuals living together as a single housekeeping unit, in which not more than four (4) individuals are unrelated by blood, marriage or adoption. This definition shall not include foster families as regulated by the State of South Dakota.

Farm, Ranch, Orchard - An area of twenty (20) acres or more which is used for growing usual farm products, vegetables, fruits, trees, and grain, and for the raising thereon of the usual farm poultry and farm animals such as horses, cattle, and sheep, and including the necessary accessory uses for raising, treating, and storing products raised on the premises; but excluding an Animal Feeding Operation.

The processing and storage of raw agricultural products, such as grain elevators and ethanol plants, shall not be considered a farm, ranch or orchard if such constitutes the main or principal use on the lot or parcel

Farm Building - All buildings and structures needed in agricultural operation, including dwellings for owners, operators, farm laborers employed on the farm, and other family members.

Farm Occupation - A business activity customarily carried out on a farm by a member of the occupant's family without structural alterations in the building or any of its rooms, without the installation or outside storage of any machinery, equipment or material other than that customary to normal farm operations, without the employment of persons not residing in the home, which does not cause the generation of additional traffic in the area. Farm occupations include, but are not limited to, seed sales and custom combining support facilities.

Farmstead - The area within or adjacent to the shelterbelt protecting the house and main buildings, including, the driveway and the land lying between the farmstead and the road.

Farm Unit - All buildings and structures needed in an agricultural operation, including dwellings for owners, operators, and other family members.

Fishery - As defined by South Dakota Administrative Rules, Sections 74:03:03:02 and 74:03:03:03 (August 8, 1994). Bon Homme County as described in Section 74:03:03:07. Lakes Bucholz, Clear, Cosby, Hieb, Kloucek, Schaefer and Tyndall Kids Pond (Section 74:03:03:03(6)) are warm water marginal fish life propagation waters and Lake Henry (Section 74:03:03:03(5)) is defined as warm water permanent fish life propagation waters. The Missouri River (Section 74:03:04:04 (1,4,7,8,11) domestic water supply, warm water permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters. Choteau Creek from Lewis and Clark Lake to S34, T96N, R63W as described in 74:03:04:04 (5,8) and Emanuel Creek from Lewis and Clark Lake to S20 T94N R60W are warm water semi-permanent fish life propagation waters and warm water marginal fish life propagation waters. Dry Choteau Creek as described in 74:03:04:04 (6,8) from Choteau Creek to S.D. Highway 50 is warm water marginal fish life propagation waters and limited-contact recreation waters.

Flammable or Combustible Liquids, or Hazardous Material - Flammable material is any material that will readily ignite from common sources of heat, or that will ignite at a temperature of 600°F or less. Flammable liquid is any liquid having a flash point below 100°F and having vapor pressure not exceeding forty (40) pounds per square inch (absolute) at 100°F. Combustible liquid is any liquid having a flash point at or above 100°F. Hazardous material includes any flammable solids, corrosive liquids, radioactive materials, oxidizing materials, highly toxic materials, poisonous gases, reactive materials, unstable materials, hypergolic materials, pyrophoric materials, and any substance or mixture of substances which is an irritant, a strong sensitizer or which generates pressure through exposure to heat, decomposition or other means.

Game Farm - An area of five (5) acres or more which is used for producing hatchery raised game and nondomestic animals for sale to private shooting preserves.

Game Lodge - A building or group of two (2) or more detached, or semi-detached, or attached buildings occupied or used as a temporary abiding place of sportsmen, hunters and fishermen, who are lodged, with or without meals, and in which there are more than two (2) sleeping rooms.

Grain Elevator - Grain storage facilities, which are the principal and primary use of the lot. Said facilities are generally equipped with devices for housing and discharging significant quantities of grain. This definition does not include normal farm product storage and warehousing facilities such as grain bins and where such storage is an accessory use to the parcel.

Habitable Residential Dwelling – A structure designed and constructed for residential purposes to which utilities such as water and electrical are either active or readily accessible upon the property. Structures currently not occupied shall be able to facilitate human occupation with minor repairs or renovations as determined by the Zoning Administrator. ***(Amended 11/3/15)***

High Voltage Transmission Line – A conductor of electric energy with a minimum voltage of 69 kilovolts and associated facilities. ***(Amended 11/3/15)***

Hobby Farm - An activity carried out in rural residential areas which include the planting, cultivating, harvesting and storage of grains, hay or plants, fruits, or vineyards.

The raising and feeding of livestock and poultry shall be considered as part of a hobby farm if the area, in which the livestock or poultry is kept, is two (2) acres or more in area for every two (2) domesticated large animals, and if such livestock does not exceed ten (10) animals; or the raising of livestock and poultry is incidental or supplemental to the residential use and is not primarily for the growing of crops or raising of livestock.

Home Occupation - A business activity customarily carried on in the home by a member of the occupant's family without structural alterations in the building or any of its rooms, without the installation or outside storage of any machinery, equipment or material other than that customary to normal household operations, without the employment of persons not residing in the home, which does not cause the generation of additional traffic in the street.

Horticulture - The science or art of cultivating fruits, vegetables, flowers, and plants.

Junkyard - A place where non recyclable waste, having no economic value, or waste which is recyclable, but has no chance of being recycled is deposited.

Kennel - Any place where dogs, cats, or other domesticated animals are housed, groomed, bred, boarded, trained, harbored, kept or sold for commercial purposes.

Large Wind Energy System or LWES – All WES facilities excluding Small Wind Energy Systems. ***(Amended 11/3/15)***

Lagoon - Any pond, basin, or other impoundment made by excavation or earthfill for storage or treatment of animal waste.

Lot - Land occupied or to be occupied by a building and its accessory building(s) having its principal frontage upon a public street or officially approved place.

Lot Depth - The average horizontal distance between the front and rear lot lines.

Lot Frontage - The portion of the lot nearest the street. For the purpose of determining yard requirements on corner lots and through lots, all sides of a lot adjacent to streets shall be considered frontage, and yards shall be provided as indicated under Yards in this article.

Lot Line - The legally defined limits of any lot.

Lot Width - The mean horizontal distance between the side lot lines of a lot measured at right angles to the depth or the same distance measured at the front building line.

Manufactured Home - A moveable or portable dwelling which is eight (8) feet or more in width and thirty-two (32) feet or more in length, constructed on a chassis, and which is designed to be towed, designed for year-round occupancy, primarily to be used without a permanent foundation, but which may sit on a permanent foundation, and designed to be connected to utilities. It may consist of one (1) or more units, separately transportable, but designed to be joined together into one (1) integral unit.

The following shall not be included in this definition:

a. Travel trailers, pickup coaches, motor homes, camping trailers, or other recreational vehicles.

b. Manufactured modular housing which is designed to be set on a permanent foundation, and which uses standard sheathing, roofing, siding, and electrical, plumbing, and heating systems.

Mobile Home - See Manufactured Home

Modular Home - A structure or building module that is manufactured at a location other than the site upon which it is installed and used as a residence; transportable in one or more sections on a temporary chassis or other conveyance device; and to be used as a permanent dwelling when installed and placed upon a permanent foundation system. This term includes the plumbing, heating, air conditioning, and electrical systems contained within the structure.

Navigable Waters - A body of water presently being used or is suitable for use for transportation and commerce, or if it has been so used or was suitable for such use in the past.

Open Sales Area - Any open land or area used or occupied for the purpose of displaying for sale new or secondhand merchandise, including but not limited to, passenger cars or trucks, farm machinery, construction machinery, motor scooters or motorcycles, boats, trailers, aircraft, and monuments.

Ownership Line - A line defining ownership of property under one owner of record

Person – An individual, partnership, joint venture, private or public corporation, association, firm, public service company, cooperative, political subdivision, Municipal Corporation, government agency, public utility district, consumer's power district, or any other entity, public or private, however organized. ***(Amended 11/3/15)***

Private Shooting Preserves - An acreage of at least one hundred and sixty (160) acres and not exceeding one thousand two hundred and eighty (1,280) acres either privately owned or leased on which hatchery raised game is released for the purpose of hunting, for a fee, over an extended season.

Property Line - The division between two (2) parcels of land, or between a parcel of land and the road.

Route – The location of a High Voltage Transmission Line between two end points. The route may have a variable width of up to 1.25 miles. ***(Amended 11/3/15)***

Salvage Yard - The use of more than one (1) acre of open storage on any lot, portion of lot, or tract of land for the sale, storage, keeping, or for the abandonment, dismantling, or wrecking of automobiles or other vehicles, machines, or parts thereof.

Semi-Portable Agricultural Structures - Anything which requires placement on the ground for agriculture related purposes. Semi-portable agricultural structures include, but are not limited to, feed bunks, calving, lambing, or farrowing sheds, and temporary grain storage facilities.

Shelterbelt - A barrier consisting of trees and shrubs that reduces erosion and protects against the effects of wind and storms. For the purposes of this ordinance a shelterbelt shall include ten (10) or more trees planted in a line, separated by a distance of forty (40) feet or less.

Shelterbelt Restoration - The removal and replacement of two (2) or more rows of trees or of trees totaling one-half (1/2) acre or more, whichever is greater, in an existing shelterbelt.

Small Wind Energy System or SWES – A WES facility with a single Tower Height of less than seventy-five (75) feet used primarily for on-site consumption of power. ***(Amended 11/3/15)***

Street Line - The right-of-way line of a street or road.

Structure - Anything constructed or erected which requires location on the ground, or attached to something having a fixed location on the ground. Among other things, structures include, but are not limited to, buildings and manufactured homes. This definition does not include semi-portable agricultural structures.

Swine, Farrow-to-Finish - An animal husbandry operation including all elements of an animal's life cycle and generally includes a single site operation with breeding, gestating, farrowing, nursery, feeder, and finisher stages of swine. The operation is viewed as a complete operation and is different from multi-site production methods

Swine, Feeder - A swine of an intermediate stage of growth; removed from a nursery facility at an approximate weight of fifty-five (55) pounds then sold and/or moved to a finishing unit.
Swine, Finish - A swine weighing between an approximate weight of fifty-five (55) pounds and the standard slaughter weight for the specific genetic makeup of the animal. This term shall also include replacement stock raised to an adult stage for the purposes of reproduction or show. A swine in a finishing unit may be part of either a single or multi-site production system.

Swine, Nursery - A young swine weaned from a sow and placed in a unit for the purpose of growth to an approximate weight of fifty-five (55) pounds. A swine in a nursery unit may be part of either a single or multi-site production system.

Swine, Production Unit - A swine unit primarily focused on the breeding, gestating, and farrowing of swine. This unit may include newly farrowed swine not yet weaned from the sow. A swine production unit may be part of either a single or multi-site production system.

System Height – The height above grade of the tallest point of the WES, including the rotor radius. ***(Amended 11/3/15)***

Tower Height – The height above grade of the fixed portion of the tower, excluding the wind turbine itself. ***(Amended 11/3/15)***

Turbine – The parts of the WES including the blades, generator and tail. ***(Amended 11/3/15)***

Used Vehicles Dealer - Any person who, for commission or with intent to make a profit or gain sells, exchanges, rents with option to purchase, offers or attempts to negotiate a sale or exchange of used vehicles or who is engaged in the business of selling used vehicles; or any person who sells five (5) or more used vehicles or offers for sale five (5) or more used vehicles at the same address or telephone number in any one calendar year.

Utility – Any person engaged in the generation, transmission or distribution of electric energy in this state including, but not limited to, a private investor owned utility, a cooperatively owned utility, a consumers power district and a public or municipal utility. ***(Amended 11/3/15)***

Variance - A variance is a relaxation of the terms of the zoning ordinance where such variance will not be contrary to the public interest and where, owing to conditions peculiar to the property and not the result of the actions of the applicant, a literal enforcement of the ordinance would result in unnecessary and undue hardship. As used in this ordinance, a variance is authorized only for area and size of structure or size of yards and open spaces; establishment or expansion of a use otherwise prohibited shall not be allowed by variance, nor shall a variance be granted because of the presence of nonconformities in the zoning district or uses in an adjoining district or because of conditions created by the landowner. All required setbacks are eligible for variances within the provisions of this Ordinance.

Vehicle - Any new or used automobile, truck, truck tractor, motorcycle, motor home, trailer, semi trailer, or travel trailer of the type and kind required to be titled and registered under Chapters 32-3 and 32-5 of SDCL, except manufactured homes, mobile homes, mopeds or snowmobiles.

Vehicle Dealer - Any person who, for commission or with intent to make a profit or gain, sells, exchanges, rents with the option to purchase, offers or attempts to negotiate a sale or exchange new, or new and used vehicles, or who is engaged wholly or in part in the business of selling new, or new and used vehicles.

Wind Energy System or WES – A commonly owned and/or managed integrated system that converts wind movement into electricity. All of the following are encompassed in this definition of system:

a) Tower or multiple towers, including foundations;
b) Generator(s);
c) Blades;
d) Power collection systems, including pad mount transformers;
e) Access roads, meteorological towers, on-site electric substation, control building and other ancillary equipment and facilities. ***(Amended 11/3/15)***

Yard - An open space at grade, other than a court or plaza, between a structure and the adjacent lot lines, unoccupied and unobstructed by any portion of a structure from the ground upward. All yards shall be measured from the property line or road right-of-way where applicable.

Yard, Front - An open, unoccupied space on a lot facing a street and extending across the front of the lot between the side lot lines. Measured from the road right-of-way to the structure.

Yard, Side - An open, unoccupied space on the same lot with a building situated between the building and sideline of the lot and extending through from the front yard to the required rear yard. Any lot line not the rear line or a front line shall be deemed a sideline.

Yard, Rear - An open, unoccupied space extending across the rear of a lot from one side lot line to the other side lot line.

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ARTICLE 1

JURISDICTION

Section 101 General

This Ordinance shall be known and shall be cited and referred to as "The Zoning Ordinance of Bon Homme County, South Dakota", to the same effect as if the full title were stated.

Section 103 Jurisdiction

The provisions of this Ordinance shall apply within the unincorporated areas of Bon Homme County, South Dakota, excluding the incorporated communities of Avon, Scotland, Springfield, Tabor, and Tyndall, as established on the map entitled "The Official Zoning Map of Bon Homme County, South Dakota".

Section 105 Provisions of this Ordinance Declared to the Minimum Requirements

In their interpretation and application, the provisions of this Ordinance shall be held to be minimum requirements, adopted for the promotion of the public health, safety, morals, or general welfare. Whenever the provisions of this Ordinance require a greater width or size of yards, courts or other spaces, or require a greater percentage of lot to be left unoccupied, or impose other higher standards than are required, in any other Ordinance, the provisions of this Ordinance shall govern. Wherever the provisions of any other ordinance require a greater width or size of yards, courts, or other open spaces, or require a greater percentage of lot to be left unoccupied, or impose other higher standards than are required by the provisions of this Ordinance, the provisions of such Ordinance shall govern.

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ARTICLE 2

APPLICATION OF DISTRICT REGULATIONS

Section 201 General

The regulations, set forth by this Ordinance within each district, shall be minimum regulations and shall apply uniformly to each class or kind of structure or land, except as hereinafter provided.

Section 203 Zoning Affects Every Building and Use

No building, structure, or land shall hereafter be used or occupied, and no building or structure or part thereof shall hereafter be erected, constructed, reconstructed, moved, or structurally altered except in conformity with all of the regulations herein specified for the district in which it is located.

Section 205 Performance Standards

No building or other structure shall hereafter be erected or altered, without obtaining a permit, to:

1. accommodate or house a greater number of families;
2. occupy a greater area of the lot; or
3. have narrower or smaller rear yards, front yards, side yards, or other open spaces.

Section 207 Yard and Lot Reduction Prohibited

No yard or lot existing at the time of passage of this Ordinance shall be reduced in dimensions or area below the minimum requirements set forth herein. Yards or lots created after the effective date of this Ordinance shall meet at least the minimum requirements established by this Ordinance.

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ARTICLE 3

ESTABLISHMENT OF DISTRICTS

Section 301 Districts Created

For the purpose of this Ordinance, there are hereby created four (4) types of districts by which the jurisdictional area defined in Section 103 shall be divided.

AG - Agricultural

RR - Rural Residential

PTR - Platted Town Site Residential

RC - Rural Commercial

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ARTICLE 4

OFFICIAL ZONING MAP AND BOUNDARY INTERPRETATION

Section 401 General

The County is hereby divided into zones, or districts, as shown on the Official Zoning Map, which, together with all explanatory matter thereon, is hereby adopted by reference and declared to be a part of this Ordinance. The Official Zoning Map shall be identified by the signature of the Chairman of the County Commissioners, attested by the Auditor, and bearing the seal of the County, under the following words: “This is to certify that this is the Official Zoning Map referred to in Section 401 of Ordinance No. 99-1 of Bon Homme County, South Dakota, as amended” together with the date of the adoption of this Ordinance.

Section 403 Zoning Map Changes

If, in accordance with the provisions of this Ordinance, changes are made in the district boundaries or other matter portrayed on the Official Zoning Map, such changes shall be entered on the Official Zoning Map promptly after the amendment has been approved by the County Commissioners, with an entry on the Official Zoning Map as follows: “on [date], by official action of the Bon Homme County Commission, the following [change] changes were made in the Official Zoning Map: [brief description of nature of change],” which entry shall be signed by the Chairman of the Commission and attested by the Auditor. No amendment to this Ordinance which involves matters portrayed on the Official Zoning Map shall become effective until after such change and entry has been made on said map.

No changes of any nature shall be made in the Official Zoning Map or matters shown thereon except in conformity with the procedures set forth in this Ordinance.

Any unauthorized change of whatever kind by any person or persons shall be considered a violation of this Ordinance and punishable as provided under Section 1503.

Regardless of the existence of purported copies of the Official Zoning Map which may, from time to time, be made or published, the Official Zoning Map which shall be located in the office of the Zoning Administrator shall be the final authority as to the current zoning status of land and water areas, buildings, and other structures in the County.

Section 405 Zoning Map Replacement

In the event that the Official Zoning Map becomes damaged, destroyed, lost or difficult to interpret because of the nature or number of changes and additions, the Bon Homme County Commission may, by resolution, adopt a new Official Zoning Map, which shall supersede the prior Official Zoning Map. The new Official Zoning Map may correct drafting or other errors or omissions in the prior Official Zoning Map, but no such correction shall have the effect of amending the original Official Zoning Map or any subsequent amendment thereof.

The new Official Zoning Map shall be identified by the signature of the Chairman of the County Commission, attested by the Auditor, and bearing the seal of the County, under the following words:

> "This is to certify that this Official Zoning Map supersedes and replaces the Official Zoning Map adopted [date of adoption of map being replaced] as part of Ordinance No. 99-1 as amended of Bon Homme County, South Dakota."

Unless the prior Official Zoning Map has been lost, or has been totally destroyed, the prior map or any significant parts thereof remaining, shall be preserved, together with all available records pertaining to its adoption or amendment.

Section 407 Rules for Interpretation of District Boundaries

Where uncertainty exists as to the boundaries of districts as shown on the Official Zoning Map, the following rules shall apply:

1. Boundaries indicated as approximately following the center lines of streets, highways, or alleys shall be construed to follow such center lines;

2. Boundaries indicated as approximately following platted lot lines shall be construed as following such lot lines;

3. Boundaries indicated as approximately following city limits shall be construed as following such city limits;

4. Boundaries indicated as following railroad lines shall be construed to be midway between the main tracks;

5. Boundaries indicated as following shore lines shall be construed to follow such shore lines, and in the event of change in the shore line shall be construed as moving with the actual shore line; boundaries indicated as approximately following the center line of streams, rivers, canals, lakes, or other bodies of water shall be construed to follow such center lines;

6. Boundaries indicated as parallel to or extensions of features indicated in subsections 1 through 5 above shall be so construed. The scale of the map shall determine distances not specifically indicated on the Official Zoning Map; and

7. Where physical or cultural features existing on the ground are at variance with those shown on the Official Zoning Map, or in other circumstances not covered by subsections 1 through 6 above, the Planning Commission shall interpret the district boundaries.

ARTICLE 5

AGRICULTURAL DISTRICT (AG)

Section 501 Intent

The intent of Agricultural Districts (AG) is to protect agricultural lands and lands consisting of natural growth from incompatible land uses in order to preserve land best suited to agricultural uses and land in which the natural environment should be continued and to limit residential, commercial, and industrial development to those areas where they are best suited for reasons of practicality and service delivery.

Section 503 Permitted Principal Uses and Structures

The following principal uses and structures shall be permitted in an Agricultural District (AG):

1. agriculture;
2. farm;
3. ranch;
4. orchard;
5. farm occupations;
6. public parks and public recreational areas;
7. farm buildings;
8. farm drainage and irrigation systems, flood control and watershed structures and erosion control devices meeting all county, state, and soil conservation district regulations;
9. manufactured homes;
10. historic sites;
11. veterinary services and kennels;
12. off-site and on-site signs;
13. cemeteries;
14. schools public and private;
15. campgrounds;
16. single-family dwellings;
17. additional farm dwellings;
18. churches;
19. rodeo grounds and arenas;
20. shelterbelts; and
21. stock dams.

Section 505 Permitted Accessory Uses and Structures

The following accessory uses and structures shall be permitted in an Agricultural District (AG):

1. roadside stands for sales of farm products, fish bait, and other approved products;
2. home occupations;
3. professional offices; and
4. accessory uses, not specifically regulated by ordinance and structures customarily incidental to permitted uses and structures when established within the space limits of this district.

Section 507 Conditional Uses

After the provisions of this Ordinance relating to conditional uses have been fulfilled, the Board of Adjustment may permit as conditional uses in an Agricultural District (AG):

1. utility substations, television, radio, and telephone relay stations;
2. airports;
3. automobile and equipment sales;
4. fairgrounds, race tracks, and amusement parks;
5. golf courses, country clubs, and golf driving ranges;
6. amphitheaters, stadiums, arenas, and fieldhouses;
7. go-cart tracks, riding stables, playfields, athletic fields, bowling alleys, swimming pools, permanent automobile parking;
8. agricultural product processing facilities;
9. grain elevators;
10. municipal sewage disposal and/or treatment sites, animal feeding operation lagoons and holding facilities;
11. commercial trucking terminals;
12. sales and auction yards and barns;
13. private or commercial outdoor recreation areas;
14. sanitary landfills and similar facilities;
15. wildlife and game production areas;
16. fireworks stands;
17. animal feeding operations;
18. bed and breakfast commercial operations;
19. game farms;
20. private shooting preserves;
21. game lodges;

22. extraction of sand, gravel, or minerals provided such uses meet requirements for conducting surface mining activities of SDCL 45-6B;
23. salvage yards/junk yards; and
24. any facility engaged in the manufacture, wholesale distribution, retail sale or storage of flammable or combustible liquids, or hazardous material.

Section 509 Classification of Unlisted Uses

In order to insure that the zoning ordinance will permit all similar uses in each district, the Board of Adjustment, upon its own initiative or upon written application, shall determine whether a use not specifically listed as a permitted, accessory or conditional use in a District shall be deemed a permitted, accessory or conditional use in one or more districts on the basis of similarity to uses specifically listed.

Section 511 Prohibited Uses and Structures

All uses and structures which are not specifically permitted as principal, accessory or conditional uses or approved as such within the provisions of Section 509 shall be prohibited from an Agricultural District (AG).

Section 513 Minimum Lot Requirements

1. The minimum lot area per single-family dwelling unit, manufactured or modular homes shall be five (5) acres.

2. The minimum lot frontage shall be two hundred and fifty (250) feet.

3. An additional dwelling unit may be allowed if they are to be occupied by other members of the family farm unit, the Board of Adjustment may reduce the required area following the procedures of a variance.

4. The Zoning Administrator may allow construction of single and multi-family dwelling units not in conformance with this provision only on those lands organized as a 501(d), non-profit religious and apostolic associations as described in the United States Tax Code. Prior to issuance of a building permit or permission to proceed said entity shall file the Articles of Incorporation and other requested documentation with the Zoning Administrator. Construction activities carried on under this provision shall be in conformance with all other provisions of this ordinance.

Section 515 Minimum Yard Requirements for Dwellings, Manufactured or Modular Homes

All yards must meet the following criteria as measured from the lot lines. This Section shall apply to all buildings and structures, including but not limited to decks, patios, and garages:

1. There shall be a front yard of not less than a depth of seventy-five (75) feet.

2. There shall be a rear yard of not less than a depth of twenty (25) feet.

3. There shall be two (2) side yards, each of which shall not be less than twenty-five (25) feet.

4. The Zoning Administrator may allow construction of single and multi-family dwelling units not in conformance with this provision only on those lands organized as a 501(d); non-profit religious and apostolic associations as described in the United States Tax Code. Prior to issuance of a building permit or permission to proceed said entity shall file the Articles of Incorporation and other requested documentation with the Zoning Administrator. Construction activities carried on under this provision shall be in conformance with all other provisions of this ordinance.

Section 517 Prohibition of View Obstruction

1. There shall be no obstruction, such as buildings, structures, grain bins, baled or stacked agricultural products, large rocks or rock piles, dead plant material, volunteer trees, and shelter belts that may cause view obstruction, snow build-up or safety hazards within seventy five (75) feet of the road right-of-way between the dates of November 1 and April 1.

2. The purpose of this Section is to keep the right-of-ways free and clear of snow build-up and, further, to promote traffic safety along road rights-of-way and at intersections.

Section 519 Animal Feeding Operations Performance Standards

1. Animal Feeding Operations shall submit animal waste management system plans and specifications for review and approval prior to construction, and a Notice of Completion for a Certificate of Compliance, after construction, to the South Dakota Department of Environment and Natural Resources.

2. Prior to construction, such facilities shall obtain a storm water permit for construction activities from the South Dakota Department of Environment and Natural Resources. The storm water plan required by the permit must be developed and implemented upon the start of construction.

3. All animal feeding operation's confinement and waste facilities shall comply with the following setbacks;

Public Wells	1,000 feet
Private Wells	250 feet
Operators Well	150 feet
Property Lines delineating a change in ownership	300 feet
Road Right-of-Ways	300 feet
Lakes, Rivers, Streams Classified as Fisheries	500 feet

4. Applicants must present a nutrient management plan, with the initial application documents, which will assure offensive odors, and runoff will be kept to a minimum.

   Examples of such management shall include at least:

   a. Proposed maintenance of holding ponds.

b. Nutrient transportation equipment free of leaks or spillage hazards.

c. Land application process and/or methods

d. Legal description and map of area to be utilized for nutrient application.

5. Animal waste facilities shall be located no closer than one (1) mile from any incorporated municipality or rural residential district.

6. Animal waste facilities shall be located no closer than one (1) mile from any residential dwelling, one dwelling unit is allowed on the facility site. The owner of a residential dwelling may request the Board of Adjustment to review the facility and the Board may, by variance, waive or decrease the required separation distance. An easement, approved by the States Attorney must then be recorded with the County Register of Deeds in order that any future owners can be informed.

7. Animal waste shall be transported no further than five (5) miles from the point of origination for land application.

8. Animal Feeding Operations shall have a minimum lot size of five (5) acres.

9. The Zoning Administrator will automatically transfer a conditional use permit for all land approved as a conditional use for the purpose of operating an Animal Feeding Operation if:

   a. The current owner notifies the Zoning Administrator and Secretary of the Department of Environment and Natural Resources at least thirty (30) days in advance of the proposed transfer date;

   b. The notice includes a written agreement between the existing and new owners containing a specific date for transfer of permit responsibility, coverage and liability between them; and

   c. The new owner or operator submits a Certification of Applicant Form to the County and DENR.

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ARTICLE 6

RURAL RESIDENTIAL DISTRICT (RR)

Section 601 Intent

The intent of Rural Residential Districts (RR) is to provide for residential uses of varying types and other compatible uses in a pleasant and stable environment.

Section 603 Permitted Principal Uses and Structures

The following principal uses and structures shall be permitted in a Rural Residential District (RR):

1. single-family dwellings;
2. multi-family dwellings;
3. manufactured homes;
4. modular homes;
5. horticulture;
6. churches, synagogues, and temples;
7. nursery, primary, intermediate, secondary schools and day care facilities;
8. public recreational and park facilities;
9. cemeteries;
10. utility substations;
11. long term care facilities;
12. medical and other health facilities; and
13. governmental services.

Section 605 Permitted Accessory Uses and Structures

1. home occupations and professional offices; and
2. accessory uses and structures normally appurtenant to the permitted uses and structures when established within space limits of this district.

Section 607 Conditional Uses

After the provisions of this Ordinance, relating to conditional uses have been fulfilled, the Board of Adjustment may permit as conditional uses in a Rural Residential District (RR):

1. convenience stores;
2. colleges and universities;

3. golf courses, fairgrounds, rodeo grounds, and country clubs;
4. campgrounds;
5. hobby farms;
6. retail sales;
7. automobile service stations; and
8. game lodges.

Section 609 Classification of Unlisted Uses

In order to insure that the zoning ordinance will permit all similar uses in each district, the Board of Adjustment, upon its own initiative or upon written application, shall determine whether a use not specifically listed as a permitted, accessory or conditional use in a District shall be deemed a permitted, accessory or conditional use in one or more districts on the basis of similarity to uses specifically listed.

Section 611 Prohibited Uses and Structures

All uses and structures which are not specifically permitted as principal, accessory or conditional uses or approved as such within the provisions of Section 609 shall be prohibited from Rural Residential Districts (RR).

Section 613 Minimum Lot Requirements

1. The minimum lot area shall be one acre for a single-family dwelling unit, manufactured or modular homes;

2. The minimum lot area for a multi-family dwelling unit shall be ten thousand (10,000) square feet per unit; and

3. The minimum lot width shall be one hundred fifty (150) feet.

Section 615 Minimum Yard Requirements

All yards must meet the following criteria as measured from the lot lines. This Section shall apply to all buildings and structures, including but not limited to decks, patios, and garages:

1. There shall be a front yard of not less than a depth of seventy-five (75) feet;

2. There shall be a rear yard of not less than a depth of twenty-five (25) feet; and

3. Each side yard shall not be less than twenty-five (25) feet

ARTICLE 7

PLATTED TOWN SITE RESIDENTIAL (PTR)

Section 701 Intent

The intent of Platted Town Site Residential Districts (PTR) is to provide for residential uses of all currently platted property within unincorporated town sites, such as the Apple Tree, Bon Homme, Dempster's Cove, and Running Water, and other compatible uses in a pleasant and stable environment.

Section 703 Permitted Principal Uses and Structures

The following principal uses and structures shall be permitted in a Platted Town Site Residential District (PTR):

1. single-family dwellings;
2. multi-family dwellings;
3. manufactured homes;
4. modular homes;
5. horticulture;
6. churches, synagogues, and temples;
7. nursery, primary, intermediate, secondary schools and day care facilities;
8. public recreational and park facilities;
9. cemeteries;
10. utility substations;
11. convalescent, nursing, and rest homes;
12. medical and other health facilities;
13. governmental services; and
14. game lodges.

Section 705 Permitted Accessory Uses and Structures

1. home occupations and professional offices; and
2. accessory uses and structures normally appurtenant to the permitted uses and structures when established within space limits of this district.

Section 707 Conditional Uses

After the provisions of this Ordinance, relating to exceptions have been fulfilled, the Planning Commission may permit as exceptions in Platted Town Site Residential Districts (PTR):

1. convenience stores;

2. colleges and universities;
3. golf courses, fairgrounds, rodeo grounds, and country clubs;
4. campgrounds;
5. hobby farms;
6. retail sales;
7. automobile service stations; and
8. grain elevators.

Section 709 Classification of Unlisted Uses

In order to insure that the zoning ordinance will permit all similar uses in each district, the Board of Adjustment, upon its own initiative or upon written application, shall determine whether a use not specifically listed as a permitted, accessory or conditional use in a District shall be deemed a permitted, accessory or conditional use in one or more districts on the basis of similarity to uses specifically listed.

Section 711 Prohibited Uses and Structures

All uses and structures which are not specifically permitted as principal, accessory or conditional uses or approved as such within the provisions of Section 709 shall be prohibited from Platted Town Site Residential Districts (PTR).

Section 713 Minimum Lot Requirements

1. The minimum lot area shall be two thousand five hundred (2,500) square feet for single family dwelling, manufactured or modular homes;

2. The minimum lot width shall be twenty-five (25) feet; and

3. The minimum lot depth shall be one hundred (100) feet.

Section 715 Minimum Yard Requirements

All yards must meet the following criteria as measured from the lot lines. This Section shall apply to all buildings and structures, including but not limited to decks, patios, and garages:

1. There shall be a front yard of not less than a depth of twenty-five (25) feet;

2. There shall be a rear yard of not less than a depth of five (5) feet; and

3. Each side yard shall not be less than five (5) feet.

ARTICLE 8

RURAL COMMERCIAL DISTRICT (RC)

Section 801 Intent

The intent of the Rural Commercial Districts (RC) is to provide commercial areas for those establishments which can function most satisfactorily in an area directly related to a major vehicular circulation route due to the nature of the merchandise handled and the display space required, particularly items requiring expansive display area such as motor vehicles, trailers, and farm implements; the method of transport required of the purchaser for the merchandise handled, particularly goods customarily traded in bulk such as lumber or feed requiring access for the customer to the sales area; primary dependence upon vehicular, as opposed to pedestrian, access such as drive-in facilities and all types of automotive and farm implement services; or the clientele toward which the establishments are primarily oriented.

Section 803 Permitted Principal Uses and Structures

The following principal uses and structures shall be permitted in a Rural Commercial District (RC):

1. retail sales;
2. wholesale sales;
3. funeral and crematory services and supplies;
4. agriculture;
5. farm products warehousing and storage;
6. refrigerated warehousing;
7. household goods warehousing and storage;
8. general warehousing and storage;
9. automobile and machinery sales, repair and services;
10. veterinary services;
11. contract construction services;
12. bus garaging and equipment maintenance;
13. motor freight terminals, garaging, maintenance;
14. libraries; museums, art galleries; planetaria; aquariums; historic and monument sites; auditoriums; exhibition halls; and arcades;
15. miniature golf, gymnasiums and athletic clubs, swimming pools, tennis courts, ice skating, roller skating;
16. parks;
17. theaters; stadiums; drive-in movies; arenas and field houses; race tracks; fairgrounds; amusement parks, golf driving ranges; go-cart tracks; golf courses and country clubs; riding stables; playfields and athletic fields; bowling; and swimming pools;

18. communication and utility uses;
19. automobile-machinery service stations;
20. motels; and
21. off-site and on-site signs.

Section 805 Permitted Accessory Uses and Structures

The following accessory uses and structures shall be permitted in Rural Commercial Districts (RC):

Accessory uses normally appurtenant to the permitted principal uses and structures when established in conformance within the space limits of this district.

Section 808 Conditional Uses

After the provisions of this resolution relating to conditional uses have been fulfilled, the Board of Adjustment may permit as conditional uses in the Rural Commercial Districts (RC):

1. other trade and service uses which are similar to the permitted principal uses and which are in harmony with the intent of this district;
2. campgrounds;
3. any facility engaged in the manufacture, wholesale distribution, retail sale or storage of flammable or combustible liquids, or hazardous material; and
4. grain elevators.

Section 809 Classification of Unlisted Uses

In order to insure that the zoning ordinance will permit all similar uses in each district, the Board of Adjustment, upon its own initiative or upon written application, shall determine whether a use not specifically listed as a permitted, accessory or conditional use in a District shall be deemed a permitted, accessory or conditional use in one or more districts on the basis of similarity to uses specifically listed.

Section 811 Prohibited Uses and Structures

All uses and structures which are not specifically permitted as principal, accessory or conditional uses or approved as such within the provisions of Section 809 shall be prohibited from Rural Commercial Districts (RC).

Section 813 Minimum Lot Requirements

1. The minimum lot area shall be one (1) acre.

2. The minimum lot width shall be one hundred and fifty (150) feet.

Section 815 Minimum Yard Requirements

1. There shall be a front yard of not less than a depth of seventy-five (75) feet;
2. There shall be a rear yard of not less than a depth of twenty-five (25) feet; and
3. Each side yard shall be not less than twenty-five (25) feet.

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ARTICLE 9

SUPPLEMENTARY DISTRICT REGULATIONS

Section 901 Accessory Buildings

No accessory building shall be erected in any required yard area and no separate accessory building shall be erected within five (5) feet of any other building.

Section 903 Erection of More than One Principal Structure on a Lot

In any district, more than one structure, housing a permitted or permissible principal use, may be erected on a single lot, provided, that yard and other requirements of this Ordinance shall be met for each structure as though it were on an individual lot.

Section 905 Shelterbelts

All shelterbelts shall be seventy-five (75) feet from the road right-of-way to the first row of trees.

Section 907 Recording of Conditions

All zoning agreements including conditions prescribed by the Board of Adjustment must be recorded at the Register of Deeds Office prior to issuance of a building permit.

Section 909 Signs

All land lying within one (1) mile of an incorporated municipality and adjoining a designated primary roadway or lying on the same side of the road and within one (1) mile of a currently established business located within the rural areas shall be designated rural commercial for the sole purpose of the construction and placement of signs, displays, and devices. Placement of said signs shall comply with SDCL 31-29 and ARSD 70:04:03.

Section 911 Right-of Way Obstructions

It shall be unlawful for any person to place any obstruction in a road right-of-way without prior written permission from the Bon Homme County Highway Superintendent. Said obstacles may include but are not limited to signs, fences, and trees. Temporary obstacles may be placed within six (6) feet of the traveled surface upon written authorization of the Highway Superintendent.

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ARTICLE 10

ADMINISTRATIVE PROCEDURE AND ENFORCEMENT

Section 1001 Bon Homme County Zoning Administrator

An administrative official who shall be known as the Zoning Administrator and who shall be designated by the Bon Homme County Commission shall administer and enforce this ordinance. They may be provided with the assistance of such other persons as the County Commission may direct.

If the Zoning Administrator shall find that any of the provisions of this Ordinance are being violated, they shall notify in writing the person responsible for such violations, indicating the nature of the violation and ordering the action necessary to correct it. They shall order discontinuance of illegal use of land, buildings or structures; removal of illegal buildings or structures or of illegal additions, alterations, or structural changes; discontinuance of any illegal work being done; or shall take any other action authorized by the Ordinance to insure compliance with or to prevent violation to its provisions.

Section 1003 Right of Entry

Whenever necessary to make an inspection to enforce any of the provisions of this ordinance, or whenever the Zoning Administrator or an authorized representative has reasonable cause to believe that there exists in any building or upon any premises an ordinance violation, the Zoning Administrator or an authorized representative may enter such building or premises at all reasonable times to inspect the same or to perform any duty imposed upon the Zoning Administrator by this ordinance, provided that if such building or premises be occupied, they shall first present proper credentials and request entry; and if such building or premises be unoccupied, they shall first make an reasonable effort to locate the owner or other persons having charge or control of the building or premises and request entry. If such entry is refused, the Zoning Administrator or an authorized representative shall have recourse to every remedy provided by law to secure entry.

When the Zoning Administrator or an authorized representative shall have first obtained a proper inspection warrant or other remedy provided by law to secure entry, no owner or occupant or any other persons having charge, care or control of any building or premises shall fail or neglect, after proper request is made as herein provided, to promptly permit entry therein by the Zoning Administrator or an authorized representative for the purpose of inspection and examination pursuant to this ordinance.

Section 1005 Bon Homme County Planning Commission

The Bon Homme County Commission shall appoint a Planning Commission of five (5) members; the total membership of which shall be an uneven number and at least one (1) member shall be a county commissioner. The term of each of the appointed members of the Planning Commission shall be for three to five years. When the Planning Commission is first appointed the lengths of the terms shall be varied so that no more than one-third (1/3) of the terms shall expire in the same year. Meetings shall be scheduled and held at the call of the Chairman, at such other times as the Planning Commission may determine. The Chairman, or in their absence, the Acting Chairman, may administer oaths and compel the attendance of witnesses. All meetings shall be open to the public.

Upon notification of a proposed revision, modification, change or amendment to the zoning ordinance or any part thereof the Planning Commission shall schedule a public hearing. Said public hearing shall not be less than ten (10) days after notice has been published in the County's legal newspapers. Any person may appear and request or protest the proposed change.

The Planning Commission shall keep a record of all proceedings, including minutes, showing the vote of each member upon each question, or if absent or failure to vote indicating such fact, and shall keep records of its examinations and other official actions, all of which shall be a public record and be immediately filed with the Zoning Administrator. The Planning Commission shall adopt from time to time, subject to the approval of the County Commission, rules and regulations, as it may deem necessary for the conduct of its affairs and to carry the appropriate provisions of this Ordinance into effect.

Section 1007 Bon Homme County Board of Adjustment

The Bon Homme County Planning Commission shall serve as the Board of Adjustment. The Board of Adjustment is hereby designated to hear all requests for variances, conditional uses and zoning appeals. The Board of Adjustment may, in specific cases to avoid unwarranted hardship which constitutes an unreasonable deprivation of use as distinguished from the mere grant of a privilege, make upon an affirmative vote of two-thirds (2/3) of the full membership of the Board of Adjustment, conditional uses or grant variances to the terms of the regulations or controls, subject to appropriate conditions or safeguards being adopted by the Board of County Commissioners.

The Zoning Administrator shall act as secretary to the Board of Adjustment when acting in zoning cases, but shall take no part in the deliberations. Meetings of the Board of Adjustment acting in zoning cases shall be held at the call of the Chairperson and at such other times, as the Board shall determine. Such Chairperson, or in his/her absence, the Acting Chairperson, may administer oaths and compel the attendance of witnesses.

All meetings of the Board of Adjustment shall be open to the public. The Board, acting in zoning appeal cases, shall keep minutes of its proceedings, showing the vote of each member upon each question, or if absent or failing to vote, indicating such fact, and shall keep records of its examinations and other official actions, all of which shall be immediately filed in the office of the Zoning Administrator and shall be a public record. The Board of Adjustment, acting in zoning appeals cases, shall adopt from time to time, subject to the approval of the County Commission, such rules and regulations as it may deem necessary to carry the appropriate provisions of this Ordinance into effect.

Section 1009 Bon Homme County Commission

The Bon Homme County Commission may amend, supplement, change, modify, or repeal any regulation, restriction, boundary, or enforcement provision established in the comprehensive plan or adjuncts thereto. The County Commission shall forward a copy of the proposed changes to the Planning Commission for public review. Upon receipt of the comments from the Planning Commission the County Commission shall publish a notice of public hearing no less than ten (10) days in advance in the County's legal newspapers. The Board of County Commissioners shall thereafter either adopt or reject such amendment, supplement, change, modification, or repeal. If adopted the Board of County Commissioners shall direct the Planning Commission to prepare a summary of the action. Upon completion of the summary the States Attorney shall review the same and direct the County Auditor to have said summary published once in the legal newspapers.

Section 1011 Building Permits Required

No building or other structure shall be erected, moved, added to, removed, demolished, burned, or use changed without a permit issued by the Zoning Administrator. No building permit shall be issued by the Zoning Administrator except in conformity with the provisions of this Ordinance unless they received a written order from the Board of Adjustment in the form of an administrative review, conditional use, or variance as provided by this Ordinance.

Concrete flatwork of less than five hundred (500) square feet shall be exempt from obtaining a building permit provided such work is done at or immediately above grade.

Section 1013 Applications for Building Permits, Conditional Uses and Variances

All applications for building permits, conditional uses and variances must be signed or approved in writing by the owner of record. In the event the owner of record has a binding purchase agreement contingent on the approval of the application, the potential purchaser may submit and sign all documents required for application. All building permit, conditional use and variance applications shall be accompanied by a site plan including but not limited to the following items; drawn to scale, including a north arrow, showing the property lines, actual dimensions and shape of the lot to be built upon, the exact sizes and locations on the lot of buildings already existing, if any; and the location and dimensions of the proposed building or alteration. Refer to document entitled Site Plan Requirements for a detailed example of site plan requirements.

The application shall include such other information as may be lawfully required by the Zoning Administrator, including: existing or proposed building or alterations; existing or proposed uses of the building and land; the number of families, housekeeping units, rental units, or animal units the building is designed to accommodate; conditions existing on the lot; and such other matters as may be necessary to determine conformance with, and provide for the enforcement of, this Ordinance.

One copy of the plans shall be returned to the applicant by the Zoning Administrator after they shall have marked such copy either as approved or disapproved and attested to the same by their signature on such copy. If a building permit is refused, the Zoning Administrator shall state the reasons for such refusal in writing. The Zoning Administrator shall retain the original and one copy of the plans, similarly marked. The issuance of a building permit, shall, in no case, be construed as waiving any provisions of this Ordinance.

Section 1015 Expiration of Building Permit, Conditional Uses and Variances

If the work described in any building permit, conditional use or variance application has not begun within one hundred and eighty (180) days or has not been substantially completed within two (2) years of the date of issuance thereof, said permit shall expire; it shall be canceled by the Zoning Administrator and written notice thereof shall be given to the persons affected. The notice shall state that further work as described in the canceled permit or application shall not proceed unless, and until, a new building permit, conditional use or variance application has been approved and all required fees have been paid.

Section 1017 Construction and Use to be as Provided in Application, Plans, Permits, and Application for Zoning Compliance

Building permits issued on the basis of plans and applications approved by the Zoning Administrator authorize only the use, arrangement, and construction set forth in such approved plans and applications, and no other use, arrangement or construction. Use arrangement, or construction at variance with that authorized shall be deemed a violation of this Ordinance, and punishable as provided by Section 1503 of this ordinance.

Section 1019 Schedule of Fees, Charges, and Expenses

The Bon Homme County Commission shall establish a schedule of fees, charges, and expenses and a collection procedure for variances, conditional uses amendments, appeals and other matters pertaining to this Ordinance. The schedule of fees shall be posted in the office of the Zoning Administrator and may be altered or amended only by the Bon Homme County Commission. Until all application fees, charges, and expenses have been paid in full, no action shall be taken on any application or appeal.

Section 1021 Building Permit in a Conspicuous Place

All building permits issued by the Zoning Administrator must be placed in a conspicuous location on the building site for the duration of the construction of work described.

Section 1023 Bad Actor Legislation

The Bon Homme County Commission may reject an application for any permit filed for a variance, conditional use or otherwise for the reasons and on the grounds set forth in SDCL 1-40-27, as revised and amended. Such rejection shall be based upon a specific finding by the Commission that the applicant has engaged in the activity identified in the aforesaid statute. The burden on the Commission to make the specific finding provided for herein shall be by a preponderance of the evidence.

ARTICLE 11

BOARD OF ADJUSTMENT
APPEALS, VARIANCES AND CONDITIONAL USES

Section 1101 Members, Terms, Meetings, Rules

The Bon Homme County Planning Commission shall serve as the Board of Adjustment. The Board of Adjustment is hereby designated to hear all requests for variances, conditional uses, and zoning appeals. The Zoning Administrator shall act as secretary to the Board of Adjustment when acting in zoning cases, but shall take no part in the deliberations. Meetings of the Board of Adjustment shall be held at the call of the Chairperson and at such other times as the Board shall determine. Such Chairperson, or in his/her absence, the Acting Chairperson, may administer oaths and compel the attendance of witnesses.

All meetings of the Board of Adjustment shall be open to the public. The Board shall keep minutes of its proceedings, showing the vote of each member upon each question, or if absent or failing to vote, indicating such fact, and shall keep records of its examinations and other official actions, all of which shall be immediately filed in the office of the Zoning Administrator and shall be a public record. The Board of Adjustment shall adopt from time to time, subject to the approval of the County Commission, such rules and regulations, as it may deem necessary to carry the appropriate provisions of this Ordinance into effect.

Section 1103 Appeals to Board of Adjustment, Record of Appeals, Hearing, and Stays

Any decision rendered by the Zoning Administrator may be appealed to the Board of Adjustment. An appeal stays all proceedings in furtherance of the action appealed from, unless the officer from whom the appeal is taken certifies to the Board of Adjustment after the notice of appeal shall have been filed with them, that by reason of facts stated in the certificate a stay would, in their opinion, cause imminent peril to life or property. In such case, proceedings shall not be stayed otherwise than by a restraining order which may be granted by the Board of Adjustment or by a court of record on application or notice to the officer for whom the appeal is taken and on due cause shown.

Section 1105 Board of Adjustment Hearings and Notice

Each session of the Board of Adjustment at which a hearing is held shall be a public meeting with notice of hearing to be published at least ten (10) days prior to the date of the hearing in the legal newspapers of the County.

Section 1107 Powers and Duties

The Board of Adjustment shall have the following powers and duties:

APPEALS:

A. The Board of Adjustment shall have the power to hear and decide appeals where it is alleged there is error in any order, requirement, decision or determination made by an administrative official or agency based on or made in the enforcement of any zoning regulation or any regulation relating to the location or soundness of structures or to interpret any map. An appeal will not be heard until:

1. The applicant or any other person aggrieved by the decision of an administrative official or agency shall file a written appeal with the Zoning Administrator within five working days of the decision.

2. The administrative official or agency from whom the appeal is taken shall forthwith transmit to the Board of Adjustment all the papers constituting the record upon which the action appealed was taken.

3. Written notice shall be given to the appellant seven days prior to meeting.

4. The appellant or an authorized agent shall be present at the meeting. Failure to provide a representative may constitute grounds for a denial.

5. The administrative official or agency shall present their decision to the Board of Adjustment for review.

6. The Board of Adjustment shall either uphold, overrule or amend the decision of the Zoning Administrator.

CONDITIONAL USES

B. The Board of Adjustment shall have the power to hear and decide, in accordance with the provisions of this ordinance, requests for conditional uses or for decisions upon other special questions upon which the Board of Adjustment is authorized by this ordinance to pass; to decide such questions as are involved in determining whether conditional uses should be granted; and to grant conditional uses with such conditions and safeguards as are appropriate under this ordinance, or to deny conditional uses when not in harmony with the purpose and intent of this ordinance. A conditional use shall not be granted by the Board unless and until:

1. A written application for a conditional use is submitted, indicating the section of this ordinance under which the conditional use is sought and stating the grounds on which it is requested.

2. Notice of public hearing shall be given at least ten (10) days in advance by publication in the legal newspapers of the County. The owner of the property for which conditional use is sought or his agent shall be notified by mail.

3. A notice shall be posted in a conspicuous place on or near the property upon which action is pending. Such notice shall be not less than seventeen (17) inches in height and eleven (11) inches in width with a white background and black letters not less than one (1) inch in height. Such posted notice shall be so placed upon such premises that it is easily visible from the road and shall be so posted at least seven (7) days before the date of such hearing. It shall be unlawful for any person to remove, mutilate, destroy or change such posted notice prior to such hearings.

4. The public hearing shall be held. Any party may appear in person, or by agent or attorney.

5. The applicant or an authorized agent shall be present at the hearing. Failure to provide a representative may constitute grounds for a denial.

6. The Board of Adjustment shall make a finding that it is empowered under the section of this ordinance described in the application to grant the conditional use, grant with conditions, or deny the conditional use, and that the granting of the conditional use will not adversely affect the public interest.

7. Before any conditional use is granted, the Board of Adjustment shall make written findings certifying compliance with the specific rules governing individual conditional uses and that satisfactory provision and arrangement has been made concerning the following, where applicable:

   a. ingress and egress to property and proposed structures thereon with particular reference to automotive and pedestrian safety and convenience, traffic flow and control, and access in case of fire or catastrophe;

   b. off-street parking and loading areas where required; with particular attention to the items in (a) above and the economic, noise, glare, odor or other effects of the conditional use on adjoining properties and properties generally in the district;

   c. refuse, waste and service areas, with particular reference to the items in (a) and (b) above;

   d. utilities, with reference to locations, availability, and compatibility;

   e. screening and buffering with reference to type, dimensions, and character;

   f. signs, if any, and proposed exterior lighting with reference to glare, traffic safety, economic effect and compatibility and harmony with properties in the district;

   g. required yards and other open spaces; and

   h. general compatibility with adjacent properties and other property in the district;

VARIANCES

C. The Board of Adjustment shall have the power to hear requests for variances from this Ordinance in instances where strict enforcement would cause unnecessary hardship, and to grant such variances only when the following provisions apply:

   1. No such variance shall be authorized by the Board of Adjustment unless it finds that the strict application of the ordinance would produce undue hardship; such hardship is not shared generally by other properties in the same zoning district

and the same vicinity; the authorization of such variance will not be of substantial detriment to adjacent property and the character of the district will not be changed by the grant of the variance; and the granting of such variance is based upon reasons of demonstrable and exceptional hardship as distinguished from variations for purposes of convenience, profit, and caprice.

2. No variance shall be authorized unless the Board of Adjustment finds that the condition or situation of the property concerning or the intended use of the property concerned, or the intended use of the property is not of so general or recurring a nature as to make reasonably practicable the formulation of a general regulation to be adopted as an amendment of this ordinance.

3. A variance from the terms of this ordinance shall not be granted by the Board of Adjustment unless and until a written application for a variance is submitted demonstrating that special conditions and circumstances exist which are peculiar to the land, structure, or building involved and which are not applicable to other lands, structures, or buildings, in the same district; that literal interpretation of the provisions of this ordinance would deprive the applicant of rights commonly enjoyed by other properties in the same district under the terms of this ordinance; that the special conditions and circumstances do not result from the actions of the applicant; and that granting the variance requested will not confer on the applicant any special privilege that is denied by this ordinance to other lands, structure, or buildings in the same district.

4. No non-conforming use of neighboring lands, structures, or buildings in the same district, and no permitted or non-conforming use of lands, structures or buildings in other districts shall be considered grounds for the issuance of a variance.

5. Notice of public hearing shall be given, as in Section 1107 (B)(2), (B)(3) above; the public hearing shall be held. Any party may appear in person or by agent or by attorney; the Board of Adjustment shall make findings that the requirements of this Section have been met by the applicant for a variance; the Board shall further make a finding that the reasons set forth in the application justify the granting of the variance, and the variance is the minimum variance that will make possible the reasonable use of the land, building, or structure; the Board of Adjustment shall further make a finding that the granting of the variance will be in harmony with the general purpose and intent of this ordinance, and will not be injurious to the neighborhood, or otherwise detrimental to the public welfare.

6. The applicant or an authorized agent shall be present at the hearing. Failure to provide a representative may constitute grounds for a denial.

7. In granting any variance, the Board of Adjustment may prescribe appropriate conditions and safeguards in conformity with this ordinance. Violation of such conditions and safeguards, when made a part of the terms under which the variance is granted, shall be deemed a violation of this ordinance and punishable under Section 1503 of this ordinance.

8. Under no circumstances shall the Board of Adjustment grant a variance to allow a use not permissible under the terms of this ordinance in the district involved, or

any use expressly or by implication prohibited by the terms of this ordinance in said district.

D. The Board of Adjustment has the powers of a Zoning Administrator on Appeals and Reversing Decision of the Zoning Administrator.

In exercising the above-mentioned powers, the Board of Adjustment may reverse or affirm, wholly or partly, or may modify the order, requirement, decision or determination appealed from, and may make such order, requirement, decision, or determination as ought to be made, and to that end shall have all the powers of the officer from whom the appeal is taken.

The concurring vote of two-thirds (2/3) of the full membership of the Board of Adjustment shall be necessary to reverse any order, requirement, decision or determination of any such officer, or to decide in favor of the applicant on any matter upon which it is required to pass under this Ordinance or to effect any variation in this Ordinance.

E. Any persons, jointly or severally aggrieved by a decision of the Board of Adjustment, or any taxpayer, or any officer, department, board, or bureau of the County, may appeal to the Board of County Commissioners and by a majority vote reverse any decision of the Board of Adjustment. The applicant or any other person aggrieved by the decision of the Board of Adjustment shall file a written appeal with the County Auditor within five (5) working days of the Board of Adjustment decision. The County Auditor shall present the Board of Adjustment's decision to the Board of County Commissioners for review. Notice of the meeting shall be given as required by Section 1107 B(2) B(3). Review may be sought by a court of record of such decision, in a manner provided by the laws of the State of South Dakota.

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ARTICLE 12

DUTIES OF THE ZONING ADMINISTRATOR, BOARD OF COUNTY COMMISSIONERS AND COURTS ON MATTERS OF APPEAL

Section 1201 Duties of Zoning Administrator, Board of Adjustment, County Commission and Courts on Matters of Appeal

It is the intent of this Ordinance that all questions of interpretation and enforcement shall be first presented to the Zoning Administrator, and that such questions shall be presented to the Board of Adjustment only on appeal from the decision of the Zoning Administrator, and that such questions shall be presented to the County Commission only on appeal from the decision of the Board of Adjustment and that recourse from the decisions of the County Commission shall be to the courts as provided by law.

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ARTICLE 13

AMENDMENTS

Section 1301 Regulations

The regulations, restrictions, and boundaries set forth in this Ordinance may from time to time be amended, supplemented, changed, or repealed, provided that such modification or repeal in each instance be proposed in an Ordinance presented to the governing body for adoption in the same manner and upon the same notice as required for the adoption of the original Ordinance.

Prior to consideration of amending, supplementing, changing, modifying or repealing this Ordinance by the governing body, notice of public hearings shall be provided as follows:

1. If the proposed changes affect a particular piece of property a notice shall be posted in a conspicuous place on or near the property upon which action is pending. Such notice shall be not less than seventeen (17) inches in height and eleven (11) inches in width with a white background and black letters not less than one and one-half (1.5) inches in height. Such posted notice shall be so placed upon such premises that it is easily visible from the road and shall be so posted at least seven (7) days before the date of such hearing. It shall be unlawful for any person to remove, mutilate, destroy or change such posted notice prior to such hearings.

2. At least ten (10) days before the date of the Planning Commission hearing, the County shall have published in the County's legal newspapers a notice of the time, place, and subject matter of such hearing.

3. The Planning Commission shall hold the Public Hearing, review the proposed amendment(s) and make recommendations to the County Commission.

4. The applicant or an authorized agent shall be present at the meeting. Failure to provide a representative may constitute grounds for a denial.

5. At least ten (10) days before the date of the County Commission hearing, the County shall have published a notice of the time, place, and subject matter of such hearing in the County's legal newspapers.

6. The County Commission shall hold the Public Hearing, review the proposed amendment(s) and by Ordinance deny or pass the recommendations.

7. The applicant or an authorized agent shall be present at the meeting. Failure to provide a representative may constitute grounds for a denial.

8. If the changes are adopted the Planning Commission shall prepare a summary of the changes.

9. Once the summary is prepared the States Attorney shall review the changes and forward the changes to the County Auditor for publishing.
10. The summary of changes must be published once in the in the County's legal newspapers. The changes will take effect twenty (20) days after publication.

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ARTICLE 14

NON-CONFORMANCE

Section 1401 General

Within the districts established by this Ordinance or amendments that may later be adopted, there exists (a) lots, (b) structures, (c) uses of land and structures, and (d) characteristics of use which were lawful before this Ordinance was passed or amended, but which would be prohibited, regulated, or restricted under the terms of this Ordinance or future amendment; it is the intent to permit these nonconformities to continue until they are removed, but not to encourage their survival. It is further the intent that nonconformities shall not be enlarged upon, expanded, or extended, nor be used as grounds for adding other structures or uses prohibited elsewhere in the same district.

Nonconforming uses are declared to be incompatible with permitted uses in the districts involved. A nonconforming use of a structure, a nonconforming use of land, or a nonconforming use of structure and land in combination shall not be extended or enlarged after passage of this revised Ordinance by attachment on a building or premises of additional signs intended to be seen from off the premises, or by the addition of other uses, of a nature which would be prohibited generally in the district involved.

To avoid undue hardship, nothing in this Ordinance shall be deemed to require a change in the plans, construction, or designated use of any building on which actual construction was lawfully begun prior to the effective date of adoption or amendment of this Ordinance and upon which actual building construction has been carried on diligently. Actual construction is hereby defined to include the placing of construction materials in permanent position and fastened in a permanent manner. Where excavation or demolition or removal of an existing building has been substantially begun preparatory to rebuilding, such excavation or demolition or removal shall be deemed to be actual construction, provided that work shall be carried on diligently.

Section 1403 Nonconforming Lots of Record

In any district in which single-family dwellings are permitted, single-family dwelling and customary accessory buildings may be erected on any single lot of record at the effective date of adoption or amendment of this Ordinance, not withstanding limitations imposed by other provisions of this Ordinance. Such lots must be in separate ownership and not of continuous frontage with other lots in the same ownership. This provision shall apply even though such lots fail to meet requirements for area or width, or both, that are generally applicable in the district, provided that yard dimensions and requirements other than those applying to area or width, or both, of the lot shall conform to the regulations for the district in which such lot is located.

Variance of other yard requirements shall be obtained only through action of the Board of Adjustment.

Section 1405 Nonconforming Uses of Land or Land with Minor Structures Only

Where at the time of passage of this revised Ordinance lawful use of land exists, which would not be permitted by the regulations imposed by this Ordinance, and where such use involves no individual structure with a replacement cost exceeding one thousand (1,000) dollars, the use may be continued so long as it remains otherwise lawful, provided:

1. No such nonconforming use shall be enlarged or increased, nor extended to occupy a greater area of land than was occupied at the effective date of adoption or amendment of this Ordinance;

2. No such nonconforming use shall be moved, in whole or in part, to any portion of the lot or parcel other than that occupied by such use at the effective date of adoption or amendment of this Ordinance;

3. If any such nonconforming use of land ceases, for any reason, for a period of more than one (1) year, any subsequent use of such land shall conform to the regulations specified by this Ordinance for the district in which such land is located; and

4. No additional structure, not conforming to the requirement of this Ordinance, shall be erected in connection with such nonconforming use of land.

Section 1407 Nonconforming Structures

Where a lawful structure exists at the effective date of adoption or amendment of this Ordinance, that could not be built under the terms of this Ordinance by reason of restrictions on area, lot coverage, height, yards, its location on the lot, or other requirements concerning the structure, such structure may be continued so long as it remains otherwise lawful, subject to the following provisions:

1. No such nonconforming structure may be enlarged or altered in any way, which increases its nonconformity, but any structure or portion thereof, may be altered to decrease its nonconformity;

2. Should such nonconforming structure, or nonconforming portion of structure, be destroyed by any means, to an extent of more than seventy-five (75) percent of its replacement cost at the time of destruction, it shall not be reconstructed except in conformity with the provisions of this Ordinance; and

3. Should such structure be moved for any reason for any distance whatever, it shall thereafter conform to the regulations for the district in which it is located after it is moved.

Section 1409 Nonconforming Uses of Structures or of Structures and Premises in Combination

If the nonconforming use involving individual structures with a replacement cost of one thousand (1,000) dollars or more, or of structure and premises in combination, exists at the effective date of adoption or amendment of this Ordinance that would not be allowed in the district under the terms of this Ordinance, the nonconforming use may be continued so long as it remains otherwise lawful, subject to the following provisions:

1. No existing structure devoted to a use not permitted by this Ordinance in the district in which it is located shall be enlarged, extended, constructed, reconstructed, moved or structurally altered except in changing the use of the structure to a use permitted in the district in which it is located;

2. Any nonconforming use may be extended throughout any part of a building which was manifestly arranged or designed for such use at the time of adoption or amendment of this Ordinance, but no such use shall be extended to occupy any land outside such building;

3. If no structural alterations are made, any nonconforming use of a structure or structure and premises may, as a conditional use, be changed to another nonconforming use provided that the Board of Adjustment, either by general rule or by making findings in the specific case, shall find that the proposed use is equally appropriate or more appropriate to the district than the existing nonconforming use. In permitting such change, the Board of Adjustment may require appropriate conditions and safeguards in accordance with the provisions of this Ordinance;

4. Any structure, or structure and land in combination, in or on which a nonconforming use is superseded by a permitted use, shall thereafter conform to the regulations for the district, and the nonconforming use may not thereafter be resumed;

5. When a nonconforming use of a structure, or structure and premises in combination, is discontinued or abandoned for a period of more than one (1) year (except when government action impedes access to the premises), the structure, or structure and premises in combination, shall not thereafter be used except in conformity with the regulations of the district in which it is located; and

6. Where nonconforming use status applies to a structure and premises in combination, removal or destruction of the structure shall eliminate the nonconforming status of the land.

Section 1411 Uses Under Conditional Use Provisions are Conforming Uses

Any use, which is permitted as a conditional use in a district, under the terms of this Ordinance, shall be deemed a conforming use in such district without further action. A nonconforming use can never be allowed in a defined district without a change in the district definition or boundaries.

Permitted Principal Uses	Conditional Uses	Nonconforming
Allowed within defined district.	Allowed within defined district AFTER Board grants permission.	Never allowed within defined district without change in district definitions or boundaries.

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ARTICLE 15

VIOLATIONS, COMPLAINTS, PENALTIES, AND REMEDIES

Section 1501 Complaints Regarding Violations

Whenever a violation of this Ordinance occurs, or is alleged to have occurred, any person may file a complaint. Such complaint stating fully the causes and basis thereof shall be filed with the Zoning Administrator. The Zoning Administrator shall record properly such complaint with the Board of Adjustment and investigate and take action thereon as provided by this Ordinance.

If the Zoning Administrator shall find that any of the provisions of this Ordinance are being violated, they shall notify, in writing by certified mail with return receipt, the person responsible for such violations, indicating the nature of the violation and ordering the action necessary to correct it. The party responsible for the violation shall respond within seven (7) working days from receipt of the letter; otherwise, they will be considered in violation and punishable under Section 1503.

Section 1503 Penalties for Violations

The owner or agent of a building or premises in or upon which a violation of any provisions of this Ordinance has been committed or shall exist, or lessee or tenant of an entire building or entire premises in or upon which such violation shall exist, shall be guilty of a Class II misdemeanor and shall be punished by a fine not to exceed two hundred (200) dollars or imprisonment for not more than thirty (30) days in the County jail, or both, and in addition shall pay all costs and expenses involved in the case. Each day such violation continues shall be a separate offense.

Any architect, engineer, builder, contractor, agent or other person who commits, participates in, assists in or maintains such violation may each be found guilty of a separate offense and suffer the penalties herein provided.

In case any building or structure is erected, constructed, reconstructed, altered, repaired, converted, or maintained, or any building, structure or land is used in violation of this Ordinance, appropriate authorities of the county may institute any appropriate action or proceedings to prevent such unlawful erection, construction, reconstruction, alteration, repair, conversion, maintenance, or use; to restrain, correct or abate such violation; to prevent the occupancy of said building, structure or land; or to prevent any illegal act, conduct, business or use in or about such premises.

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ARTICLE 16

LEGAL STATUS PROVISIONS

Section 1601 Separability

Should any article, section, or provisions of this Ordinance be declared by the courts to be unconstitutional or invalid, such decision shall not affect the validity of this Ordinance as a whole, or any part thereof other than the part so declared to be unconstitutional or invalid.

Section 1603 Purpose of Sub-Titles

The sub-titles appearing in connection with the foregoing sections are inserted simply for convenience, to serve the purpose of any index and they shall be wholly disregarded by any person, officer, court or other tribunal in construing the terms and provisions of this Ordinance.

Section 1605 Repeal of Conflicting Ordinances

All ordinances or parts of resolutions in conflict with this Ordinance, or inconsistent with the provisions of this Ordinance, are hereby repealed to the extent necessary to give this Ordinance full force and effect.

Section 1607 Effective Date

This Ordinance shall take effect and be in force from and after its adoption

THIS PAGE RESERVED FOR FUTURE USE

ARTICLE 17

WIND ENERGY SYSTEMS (WES)

(Amended 11/3/15)

<u>Section 1701</u> <u>Intent</u>

The intent of this ordinance is to ensure that the placement, construction and modification of a Wind Energy System (WES) facility is consistent with the Bon Homme County's land use policies, to minimize the impact of WES facilities, to establish a fair and efficient process for review and approval of applications, to assure a comprehensive review of environmental impacts of such facilities, and to protect the health, safety and welfare of the County's citizens.

<u>Section 1703</u> <u>Authority and Jurisdiction</u>

South Dakota Codified Law 11-2-2 delegates the responsibility to the Board of County Commissioners of each county to adopt and enforce regulations designed for the purpose of promoting health, safety, and general welfare of the county.

<u>Section 1705</u> <u>Federal and State Requirements</u>

All WES facilities shall meet or exceed standards and regulations of the Federal Aviation Administration and South Dakota State Statutes and any other agency of federal or state government with the authority to regulate WES facilities.

<u>Section 1707</u> <u>Requirements for Siting Small Wind Energy Systems</u>

A Small Wind Energy System shall be a permitted use in all zoning districts subject to the following requirements:

a) Setbacks. The minimum setback distance between each wind turbine tower and all surrounding property lines, overhead utility or transmission lines, other wind turbine towers, electrical substations, public roads and **h*abitable residential dwellings*** shall be equal to no less than one point one (1.1) times the system height, unless written permission is granted by each affected person.

b) Access. All ground mounted electrical and control equipment shall be labeled or secured to prevent unauthorized access, and the tower shall be designed and installed so as to not provide step bolts or a ladder readily accessible to the public for a minimum height of eight (8) feet above the ground.

c) Lighting. A SWES shall not be artificially lighted unless such lighting is required by the Federal Aviation Administration.

d) Noise. SWES facilities shall not exceed forty-five (45) dBA, as measured at the closest neighboring ***habitable residential dwelling***. The level, however, may be exceeded during short-term events such as utility outages or wind storms.

e) Shadow Flicker. When determined appropriate by the County, a Shadow Flicker Control System shall be installed upon all turbines which will cause a perceived shadow effect upon a habitable residential dwelling. Such system shall limit blade rotation at those times when shadow flicker exceeds thirty (30) minutes per day or thirty (30) hours per year at perceivable shadow flicker intensity as confirmed by the Zoning Administrator are probable.

The permittees shall submit a report of predicted shadow flicker levels at habitable residential dwellings within one and one-half miles of proposed tower locations to the Board no less than forty five (45) days prior to commencing construction.

f) Appearance, Color, Finish. The SWES shall remain painted or finished the color or finish that was originally applied by the manufacturer, unless approved in the building permit.

g) Signs. All signs, other than the manufacturer's or installer's identification, appropriate warning signs, or owner identification on a wind generator, tower, building, or other structure associated with a SWES visible from any public road shall be prohibited.

h) Code Compliance. A SWES shall comply with all applicable state construction and electrical codes, and the National Electrical Code.

i) Utility Notification. No SWES shall be installed until evidence has been given that the utility company has been informed of the customer's intent to install an interconnected customer-owned generator. Off-grid systems shall be exempt from this requirement.

Section 1709 Permit Requirements

a) A building permit shall be required for the installation of a SWES.

b) The building permit shall be accompanied by a plot plan which includes the following:

1. Property lines and physical dimensions of the property;
2. Location, dimensions, and types of existing major structures on the property;
3. Location of the proposed SWES;
4. The right-of-way of any public road that is contiguous with the property;

5. Any overhead utility lines;
6. Wind system specifications, including manufacturer and model, rotor diameter, tower height, and tower type (monopole, lattice, guyed);
7. Tower foundation blueprints or drawings;
8. Tower blueprint or drawing;
9. Proof of notification to the utility in the service territory in which the SWES is to be erected, consistent with the provisions of 5(3)(h) herein; and
10. The status of all necessary interconnection agreements or studies.

c) Expiration. A permit issued pursuant to this ordinance shall expire if:

1. The SWES is not installed and functioning within twenty-four (24) months from the date the permit is issued; or
2. The SWES is out of service or otherwise unused for a continuous 12-month period.

Section 1711 Abandonment

A SWES that is out-of-service for a continuous 12-month period will be deemed to have been abandoned. The Board may issue a Notice of Abandonment to the owner of a SWES that is deemed to have been abandoned. The owner shall have the right to respond to the Notice of Abandonment within thirty (30) days from Notice receipt date. The Board shall withdraw the Notice of Abandonment and notify the owner that the Notice has been withdrawn if the owner provides information that demonstrates the SWES has not been abandoned.

If the SWES is determined to be abandoned, the owner of the SWES shall remove the wind generator from the tower at the Owner's sole expense within three (3) months of receipt of Notice of Abandonment. If the owner fails to remove the wind generator from the tower, the Board may pursue legal action to have the wind generator removed at the owner's expense.

Section 1713 Building Permit Procedure

a) An owner shall submit an application to the Board for a building permit for a SWES. The application must be on a form approved by the Board and must be accompanied by two (2) copies of the plot plan identified.

b) The Board shall issue a permit or deny the application within one month of the date on which the application is received.

c) The Board shall issue a building permit for a SWES if the application materials show that the proposed SWES meets the requirements of this ordinance.

d) If the application is approved, the Board will return one signed copy of the application with the permit and retain the other copy.

e) If the application is rejected, the Board will notify the applicant in writing and provide a written statement of the reason why the application was rejected. The applicant may reapply if the deficiencies specified by the Board are resolved.

f) The owner shall conspicuously post the building permit on the premises so as to be visible to the public at all times until construction or installation of the SWES is complete.

Section 1715 Violations

It is unlawful for any person to construct, install, or operate a SWES that is not in compliance with this ordinance or with any condition contained in a building permit issued pursuant to this ordinance. SWES facilities installed prior to the adoption of this ordinance are exempt.

Section 1717 Severability

The provisions of this ordinance are severable, and the invalidity of any section, subdivision, paragraph, or other part of this ordinance shall not affect the validity or effectiveness of the remainder of the ordinance.

Section 1719 Requirements for Siting Large Wind Energy Systems

A Large Wind Energy System as defined herein shall be a permitted use in all zoning districts subject to the standards identified within the following sections.

Section 1721 Mitigation Measures

a) Site Clearance. The permittees shall disturb or clear the site only to the extent necessary to assure suitable access for construction, safe operation and maintenance of the LWES.

b) Topsoil Protection. The permittees shall implement measures to protect and segregate topsoil from subsoil in cultivated lands unless otherwise negotiated with the affected landowner.

c) Compaction. The permittees shall implement measures to minimize compaction of all lands during all phases of the project's life and shall confine compaction to as small an area as practicable.

d) Livestock Protection. The permittees shall take precautions to protect livestock on the LWES site from project operations during all phases of the project's life.

e) Fences. The permittees shall promptly replace or repair all fences and gates removed or damaged by project operations during all phases of the project's life unless otherwise negotiated with the fence owner.

f) Roads

1. Public Roads. Prior to commencement of construction, the permittees shall identify all state, county or township "haul roads" that will be used for the WES project and shall notify the state, county or township governing body having jurisdiction over the roads to determine if the haul roads identified are acceptable. The governmental body shall be given adequate time to inspect the haul roads prior to use of these haul roads. Where practicable, existing roadways shall be used for all activities associated with the WES. Where practicable, all-weather roads shall be used to deliver concrete, turbines, towers, assemble nacelles and all other heavy components to and from the turbine sites.

2. The permittees shall, prior to the use of approved haul roads, make satisfactory arrangements with the appropriate state, county or township governmental body having jurisdiction over approved haul roads for construction of the WES for the maintenance and repair of the haul roads that will be subject to extra wear and tear due to transportation of equipment and WES components. The permittees shall notify the County Zoning Office of such arrangements.

3. Turbine Access Roads. Construction of turbine access roads shall be minimized. Access roads shall be low profile roads so that farming equipment can cross them and shall be covered with Class 5 gravel or similar material. Access roads shall avoid crossing streams and drainage ways wherever possible. If access roads must be constructed across streams and drainage ways, the access roads shall be designed in a manner so runoff from the upper portions of the watershed can readily flow to the lower portion of the watershed.

4. Private Roads. The permittees shall promptly repair private roads or lanes damaged when moving equipment or when obtaining access to the site, unless otherwise negotiated with the affected landowner.

5. Control of Dust. The permittees shall utilize all reasonable measures and practices of

construction to control dust during construction.

(g) Soil Erosion and Sediment Control Plan. The permittees shall develop a Soil Erosion and Sediment Control Plan prior to construction and submit the plan to the County Zoning Office no less than forty five (45) days prior to commencing construction. The Soil Erosion and Sediment Control Plan shall address the erosion control measures for each project phase, and shall at a minimum identify plans for grading, construction and drainage of roads and turbine pads; necessary soil information; detailed design features to maintain downstream water quality; a comprehensive re-vegetation plan that uses native plant species to maintain and ensure adequate erosion control and slope stability and to restore the site after temporary project activities; and measures to minimize the area of surface disturbance. Other practices shall include containing excavated material, protecting exposed soil, stabilizing restored material and removal of silt fences or barriers when the area is stabilized. The plan shall identify methods for disposal or storage of excavated material.

<u>Section 1723</u> <u>Setbacks</u>

a) Distance from currently occupied off-site residences, business and public buildings shall be not less than one thousand (1,000) feet. Distance from the residence of the landowner on whose property the tower(s) are erected shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater. For the purposes of this section only, the term “business” does not include agricultural uses.

b) Distance from right-of-way (ROW) of public roads shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater.

c) Distance from any property line shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater, unless appropriate easement has been obtained from adjoining property owner.

<u>Section 1725</u> <u>Electromagnetic Interference</u>

The permittees shall not operate the LWES so as to cause microwave, television, radio, or navigation interference contrary to Federal Communications Commission (FCC) regulations or other law. In the event such interference is caused by the LWES or its operation, the permittees shall take the measures necessary to correct the problem.

Section 1727 Lighting

Towers shall be marked as required by the Federal Aviation Administration (FAA). There shall be no lights on the towers other than what is required by the FAA.

This restriction shall not apply to infrared heating devices used to protect the monitoring equipment.

Section 1729 Turbine Spacing

The turbines shall be spaced no closer than is allowed by the turbine manufacturer in its approval of the turbine array for warranty purposes.

Section 1731 Footprint Minimization

The permittees shall design and construct the WES so as to minimize the amount of land that is impacted by the WES. Associated facilities in the vicinity of turbines such as electrical/electronic boxes, transformers and monitoring systems shall to the extent practicable be mounted on the foundations used for turbine towers or inside the towers unless otherwise allowed by the landowner on whose property the LWES is constructed.

Section 1733 Electrical Cables

The permittees shall place electrical lines, known as collectors, and communication cables underground when located on private property except when total distance of collectors from the substation require an overhead installation due to line loss of current from an underground installation. This paragraph does not apply to feeder lines.

Section 1735 Feeder Lines

The permittees shall place overhead electric lines, known as feeders, on public rights-of-way if a public right-of-way exists or immediately adjacent to the public right-of-way on private property. Changes in routes may be made as long as feeders remain on public rights-of-way or immediately adjacent to the public right-of-way on private property and approval has been obtained from the governmental unit responsible for the affected right-of-way. If no public right-of-way exists, the permittees may place feeders on private property. When placing feeders on private property, the permittees shall place the feeder in accordance with the easement(s) negotiated. The permittees shall submit the site plan and engineering drawings for the feeder lines to the Board no less than forty five (45) days prior to commencing construction.

Section 1737 Height from Ground Surface

The minimum height of blade tips at their lowest possible point shall be twenty-five (25) feet above grade.

Section 1739 Towers

a) Color and finish shall be as required by State and Federal regulations to include those of the Federal Aviation Administration

b) All towers shall be singular tubular design, unless approved by the Board.

Section 1741 Noise and Shadow Flicker

Noise level produced by the LWES shall not exceed forty five (45) dBA, average A-weighted sound pressure at the perimeter of occupied residences existing at the time the permit application is filed, unless a signed waiver or easement is obtained from the owner of the residence.

The permittees shall submit a report of predicted noise levels at habitable residential dwellings within one mile of proposed tower locations to the Board no less than forty five (45) days prior to commencing construction.

When determined appropriate by the County a Shadow Flicker Control System shall be installed upon all turbines which will cause a perceived shadow effect upon a habitable residential dwelling. Such system shall limit blade rotation at those times when shadow flicker exceeds thirty (30) minutes per day or thirty (30) hours per year at perceivable shadow flicker intensity as confirmed by the Zoning Administrator are probable.

The permittees shall submit a report of predicted shadow flicker levels at habitable residential dwellings within one and one-half miles of proposed tower locations to the Board no less than forty five (45) days prior to commencing construction.

Section 1743 Permit Expiration

The permit shall become void if no substantial construction has been completed within three (3) years of issuance.

Section 1745 Required Information for Permit Application

a) Boundaries of the site proposed for LWES and associated facilities on United States Geological Survey Map or another map as appropriate.

b) Map of easements for LWES.

c) Map of occupied residential structures, business and public buildings within one half mile of the proposed LWES site boundaries.

d) Preliminary map of sites for LWES, access roads and utility lines. Location of other LWES within five (5) miles of the proposed LWES site.

e) Project-specific environmental and cultural concerns (e.g. native habitat, rare species, and migratory routes). This information shall be obtained by consulting with the following agencies with evidence of such consultation included within the application

1. South Dakota Department of Game, Fish and Parks;
2. U.S. Fish and Wildlife Service; and
3. South Dakota State Historical Society

f) Project schedule

g) Mitigation measures

h) Status of interconnection studies/agreements.

Section 1747 Decommissioning

a) Cost Responsibility. The owner or operator of a LWES is responsible for decommissioning that facility and for all costs associated with decommissioning that facility and associated facilities. The decommissioning plan shall clearly identify the responsible party.

b) Useful Life. A LWES is presumed to be at the end of its useful life if the facility generates no electricity for a continuous period of twelve (12) months. The presumption may be rebutted by submitting to the Board for approval of a plan outlining the steps and schedule for returning the LWES to service within twelve (12) months of the submission.

c) Decommissioning Period. The facility owner or operator shall begin decommissioning a LWES facility within eight (8) months after the time the facility or turbine reaches the end of its useful life, as determined in 14(b). Decommissioning must be completed with eighteen (18) months after the facility or turbine reaches the end of its useful life.

d) Decommissioning Requirements. Decommissioning and site restoration includes dismantling and removal of all towers, turbine generators, transformers, overhead and underground cables, foundations, buildings and ancillary equipment to a depth of forty-two (42) inches; and removal of surface road material and restoration of the roads and turbine sites to substantially the same physical condition that existed immediately before construction of the LWES. To the extent possible, the site must be restored and reclaimed to the topography and topsoil quality that existed just prior to the beginning of the construction of the commercial wind energy conversion facility or wind turbine. Disturbed earth must be graded and reseeded, unless the landowner requests in writing that the access roads or other land surface areas be retained.

e) Decommissioning Plan. Prior to commencement of operation of a LWES facility, the facility owner or operator shall file with the Board the estimated decommissioning cost per turbine, in current dollars at the time of the application, for the proposed facility and a decommissioning plan that describes how the facility owner will ensure that resources are available to pay for decommissioning the facility at the appropriate time. The Board shall review a plan filed under this section and shall approve or disapprove the plan within six (6) months after the decommissioning plan was filed. The Board may at any time require the owner or operator of a LWES to file a report describing how the LWES owner or operator is fulfilling this obligation.

f) Financial Assurance. After the tenth (10^{th}) year of operation of a LWES facility, the Board may require a performance bond, surety bond, letter of credit, corporate guarantee or other form of financial assurance that is acceptable to the Board to cover the anticipated costs of decommissioning the LWES facility.

g) Failure to Decommission. If the LWES facility owner or operator does not complete decommissioning, the Board may take such action as may be necessary to complete decommissioning, including requiring forfeiture of the bond. The entry into a participating landowner agreement shall constitute agreement and consent of the parties to the agreement, their respective heirs, successors, and assigns, that the Board may take such action as may be necessary to decommission a LWES facility and seek additional expenditures necessary to do so from the facility owner.

Section 1749 Pre-construction Filing

At least forty-five (45) days prior to commencement of construction, the applicant/permittee shall submit reports of predicted noise levels, predicted shadow flicker levels, soil erosion and control plan, final maps depicting the approximate location of the proposed wind turbines, access roads and collector and feeder lines. Upon completion, the applicant shall also supply an "as-built" ALTA survey indicating that the proposed facilities are in compliance with the setbacks in the permit.

BUILDING PERMIT

Permit No. 2499 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: [signature]
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#26

BUILDING PERMIT

Permit No. 2498 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: [signature]
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#64

BUILDING PERMIT

Permit No. 2497 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: [signature]
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#61

BUILDING PERMIT

Permit No. 2496 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Lia Thonvold
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#63

BUILDING PERMIT

Permit No. 2495 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Lisa Fromwold

Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#62

BUILDING PERMIT

Permit No. 2494 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: [signature]
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#60

BUILDING PERMIT

Permit No. 2493 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Tronvold
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#45

BUILDING PERMIT

Permit No. 2492 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Ronwald
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance). #41

BUILDING PERMIT

Permit No. 2491 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Thonwald
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#49

BUILDING PERMIT

Permit No. 2490 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Thomeleel
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#58

BUILDING PERMIT

Permit No. 2489 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Lia Ramold
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#39

BUILDING PERMIT

Permit No. 2488 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Romwall
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#37

BUILDING PERMIT

Permit No. 2487 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Cromwell
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#12

BUILDING PERMIT

Permit No. 2486 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Lia Thomwald
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#8

BUILDING PERMIT

Permit No. 2485 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Ronwold
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#9

BUILDING PERMIT

Permit No. 2484 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Thanwald
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

BUILDING PERMIT

Permit No. 2483 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Pronwell
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#15

BUILDING PERMIT

Permit No. 2482 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Kronwald
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#22

BUILDING PERMIT

Permit No. 2481 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Romvold
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#23

BUILDING PERMIT

Permit No. 2480 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Ronwall
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#57

BUILDING PERMIT

Permit No. 2479 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Ronwold
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#48

BUILDING PERMIT

Permit No. 2478 issued by

Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Thorwald
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance). #40

BUILDING PERMIT

Permit No. 2477 issued by

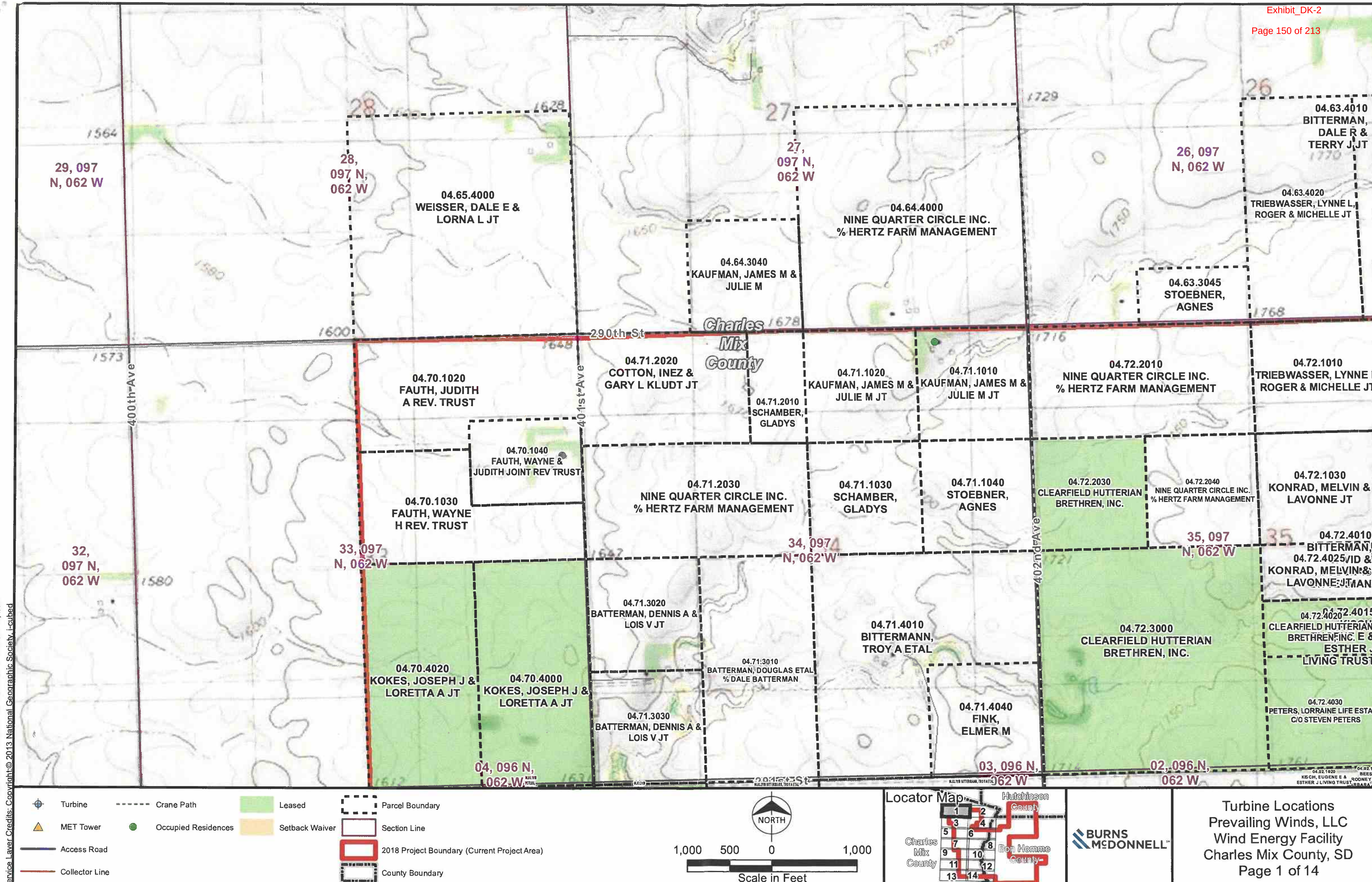
Charles Mix County, South Dakota

on 7-25-18

Signed: Gia Cronwold
Director of Equalization Office

(This permit must be placed in a conspicuous location on the building site for the duration of the construction of work described. --Section 4, Building Permit Ordinance).

#32



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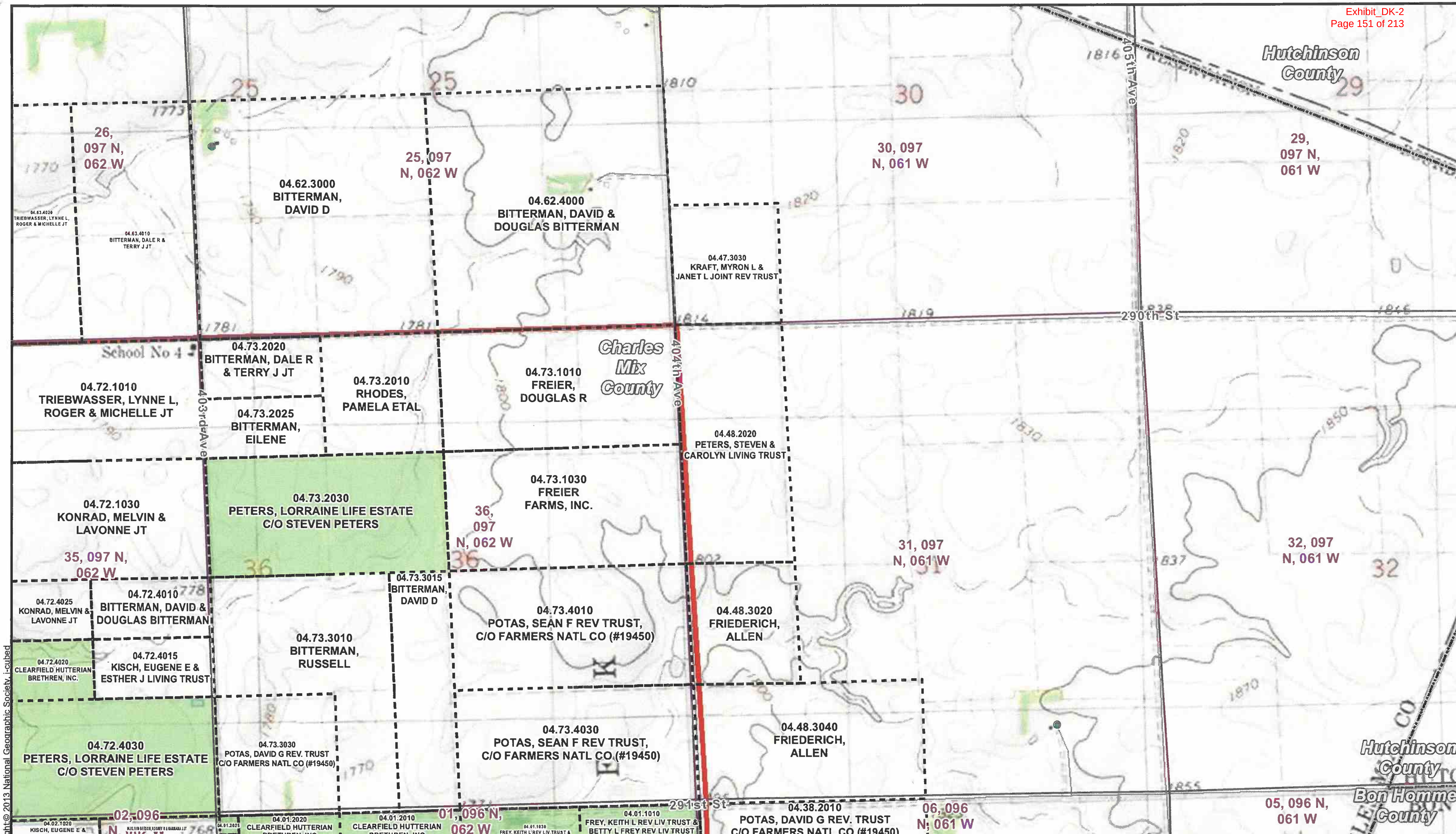
Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

Issued: 7/12/2018



Turbine	Crane Path	Leased	Parcel Boundary
MET Tower	Occupied Residences	Setback Waiver	Section Line
Access Road			2018 Project Boundary (Current Project Area)
Collector Line			County Boundary

NORTH

1,000 500 0 1,000
Scale in Feet

Locator Map

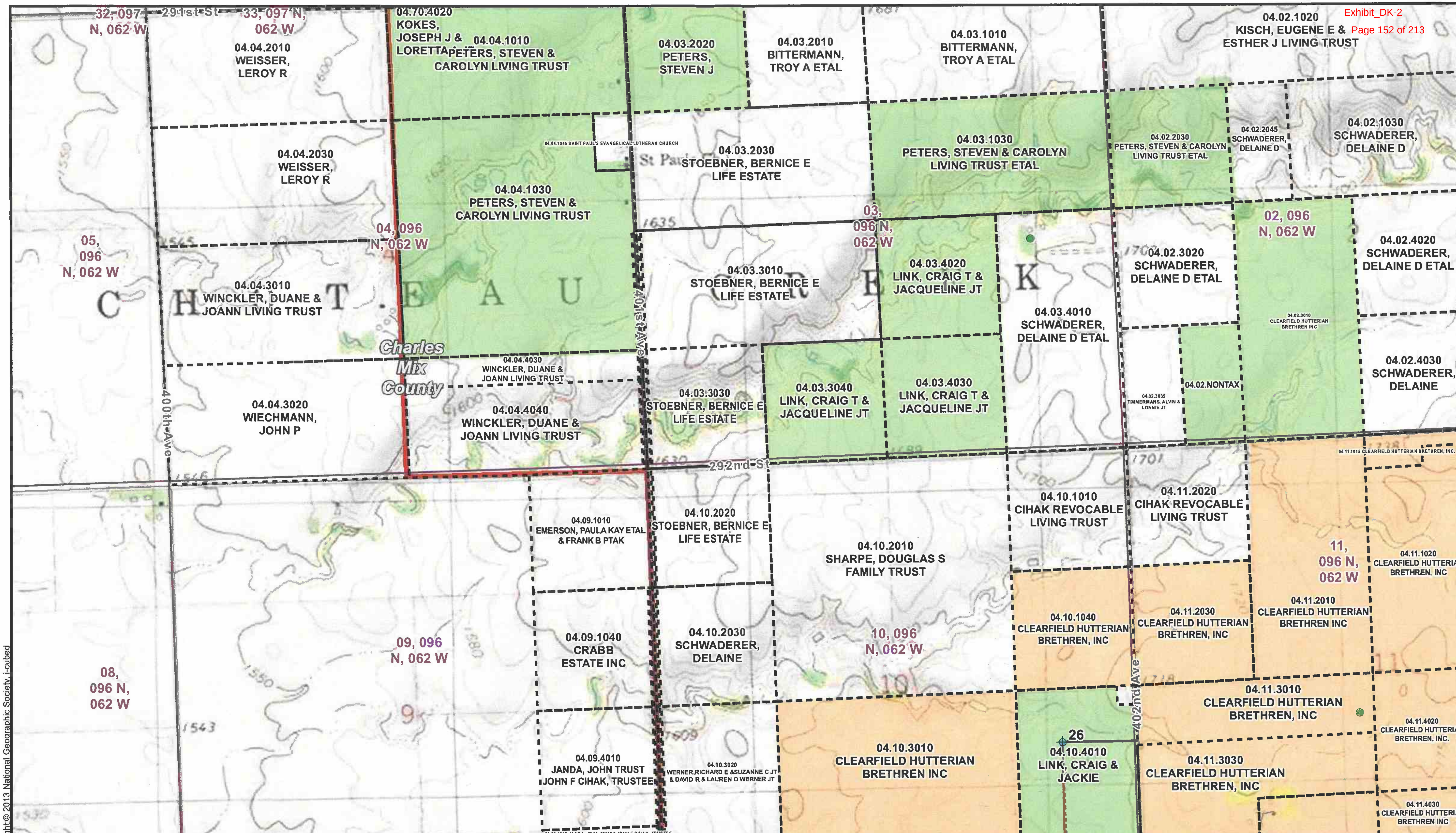
Hutchinson County
Charles Mix County
Bon Homme County

BURNS & McDONNELL

Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 2 of 14

Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

Issued: 7/12/2018



Turbine	Crane Path	Leased	Parcel Boundary
MET Tower	Occupied Residences	Setback Waiver	Section Line
Access Road			2018 Project Boundary (Current Project Area)
Collector Line			County Boundary

NORTH

1,000 500 0 1,000

Scale in Feet

Locator Map

Hutchinson County
Charles Mix County
Bon Homme County

BURNS & McDONNELL

Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
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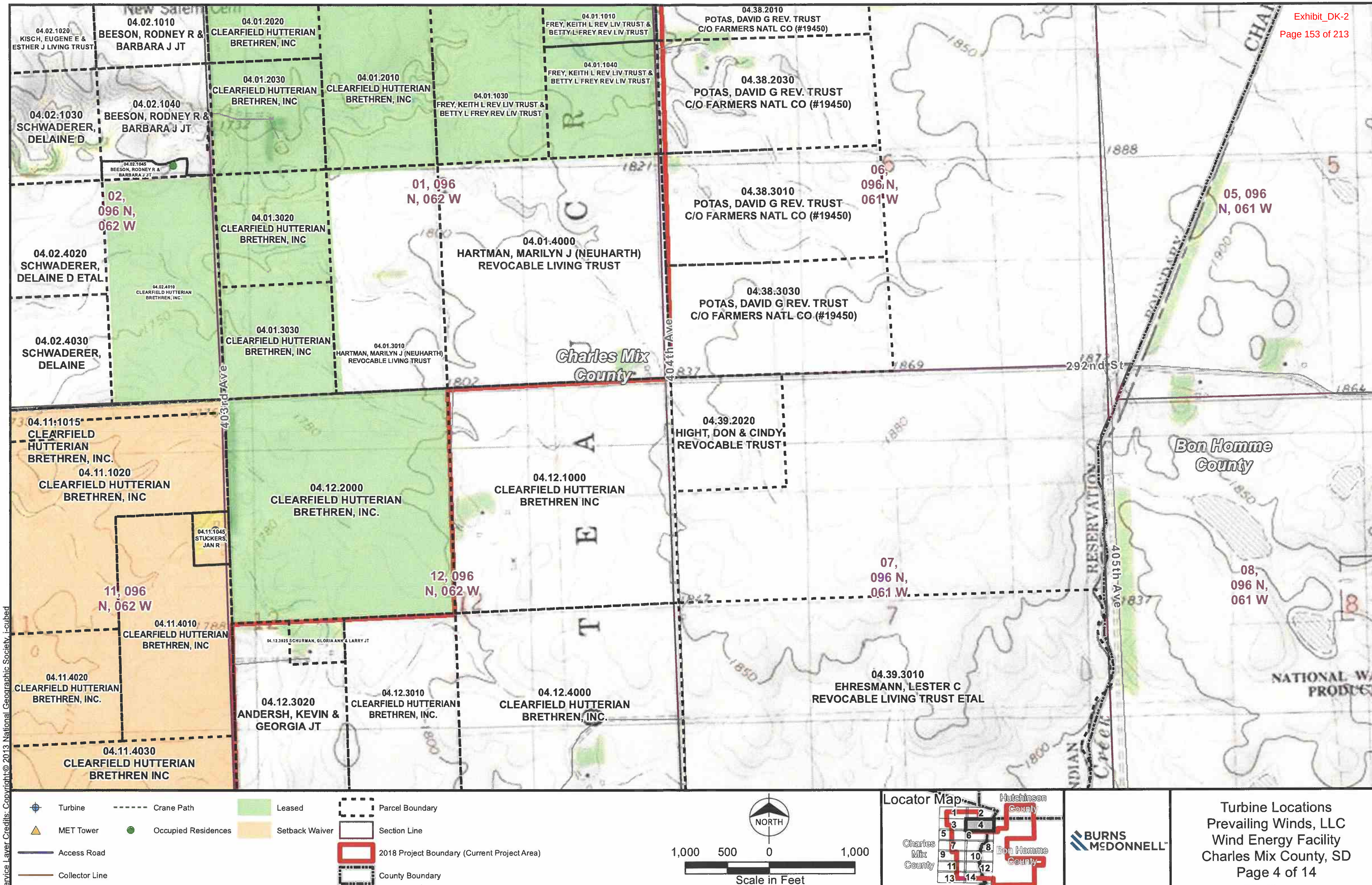
Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

Issued: 7/12/2018



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Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

Issued: 7/12/2018

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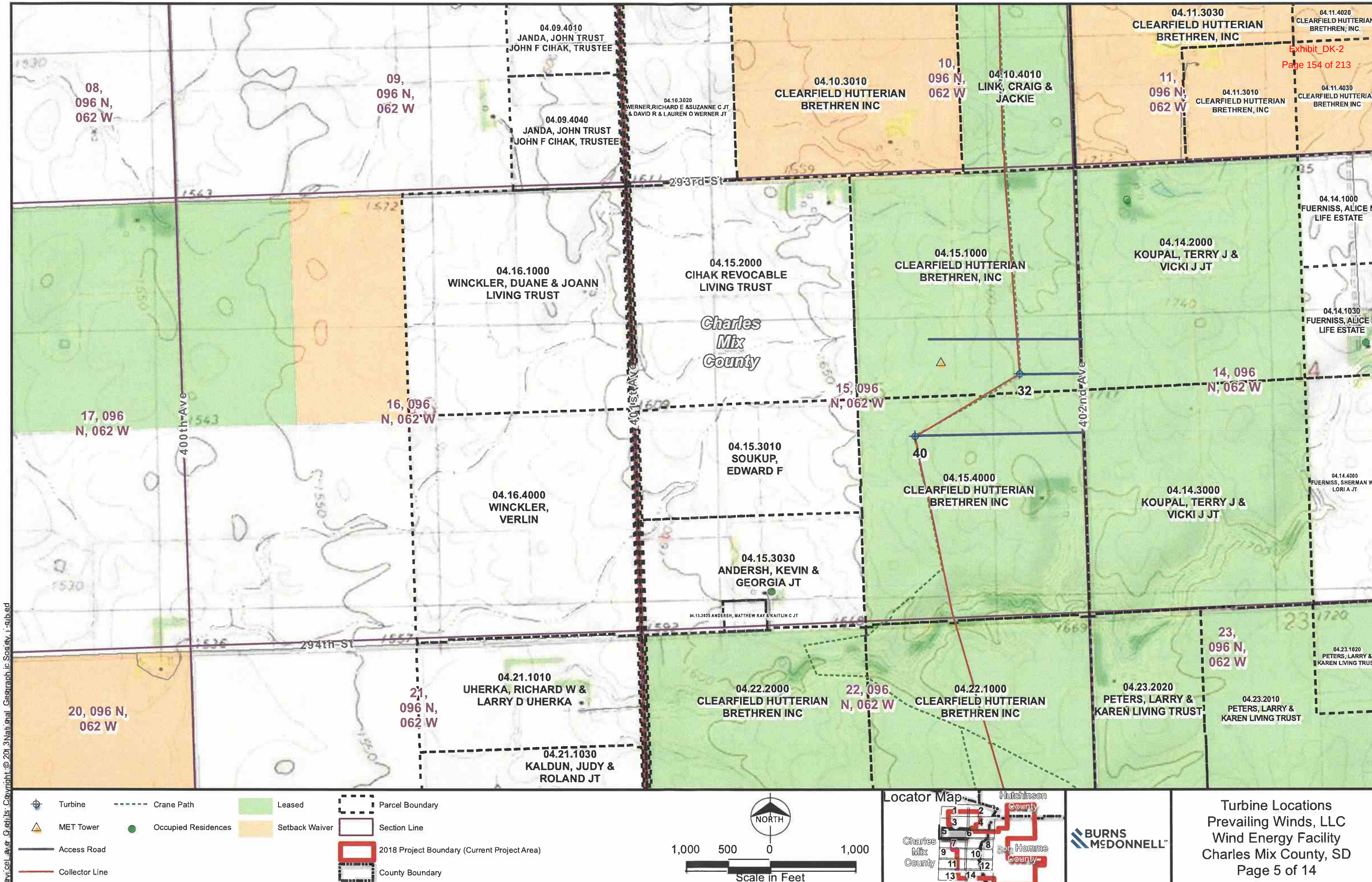

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Issued: 7/12/2018

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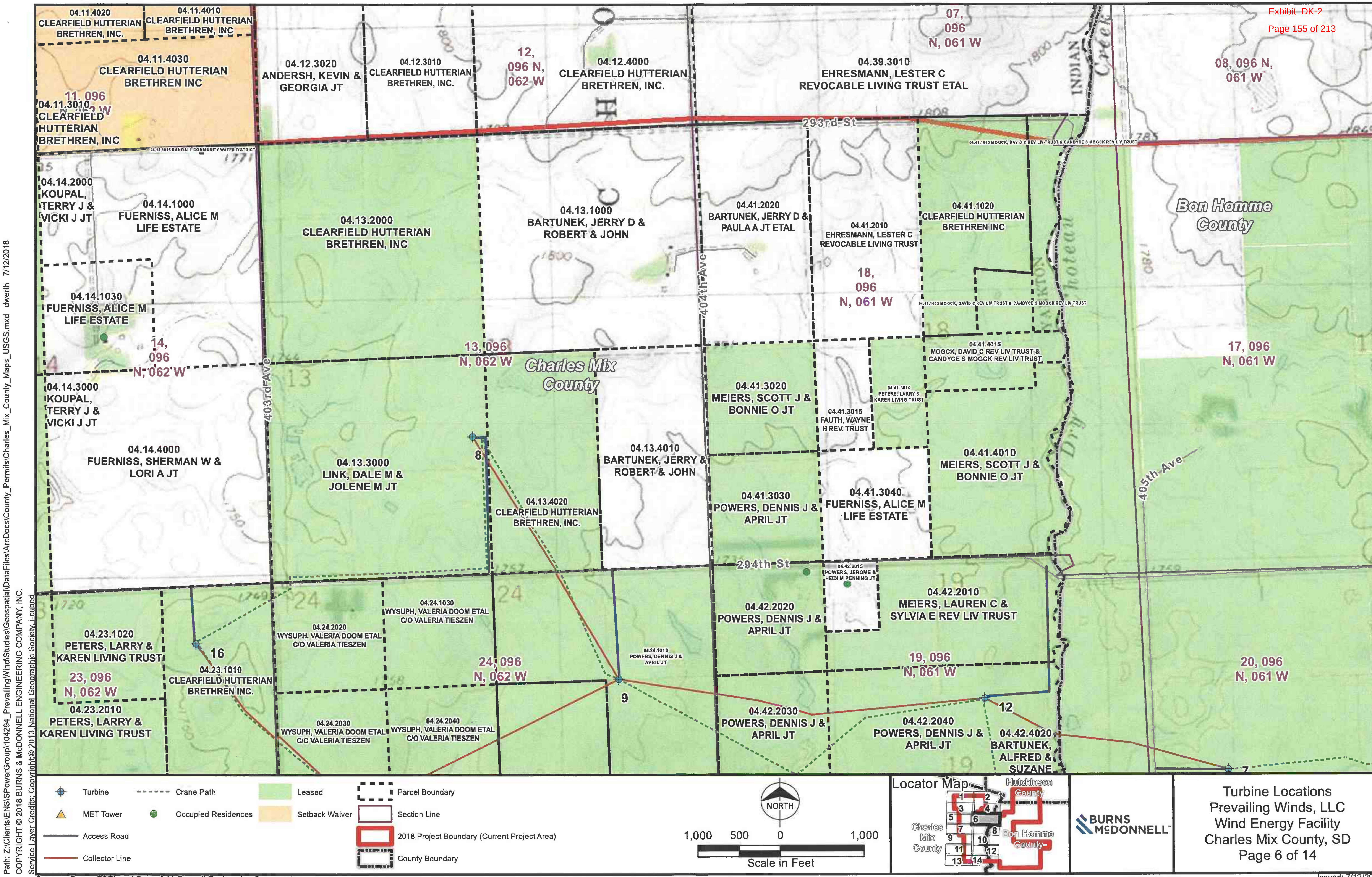
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04.11.4030 CLEARFIELD HUTTERIAN BRETHREN INC
11, 096 N, 062 W
04.11.3010 CLEARFIELD HUTTERIAN BRETHREN, INC
04.12.3020 ANDERSH, KEVIN & GEORGIA JT
04.12.3010 CLEARFIELD HUTTERIAN BRETHREN, INC.
12, 096 N, 062 W
04.12.4000 CLEARFIELD HUTTERIAN BRETHREN, INC.
07, 096 N, 061 W
04.39.3010 EHRESMANN, LESTER C REVOCABLE LIVING TRUST ETAL
INDIAN Creek
08, 096 N, 061 W
293rd St
04.14.1015 RANDALL COMMUNITY WATER DISTRICT
04.41.1040 MOGCK, DAVID C REV LIV TRUST & CANDYCE S MOGCK REV LIV TRUST
04.14.2000 KOUPAL, TERRY J & VICKI J JT
04.14.1000 FUERNISS, ALICE M LIFE ESTATE
04.13.2000 CLEARFIELD HUTTERIAN BRETHREN, INC
04.13.1000 BARTUNEK, JERRY D & ROBERT & JOHN
04.41.2020 BARTUNEK, JERRY D & PAULA A JT ETAL
04.41.2010 EHRESMANN, LESTER C REVOCABLE LIVING TRUST
04.41.1020 CLEARFIELD HUTTERIAN BRETHREN INC
Bon Homme County
18, 096 N, 061 W
04.41.1035 MOGCK, DAVID C REV LIV TRUST & CANDYCE S MOGCK REV LIV TRUST
04.14.1030 FUERNISS, ALICE M LIFE ESTATE
14, 096 N, 062 W
13, 096 N, 062 W
Charles Mix County
404th Ave
403rd Ave
04.41.4015 MOGCK, DAVID C REV LIV TRUST & CANDYCE S MOGCK REV LIV TRUST
17, 096 N, 061 W
04.14.3000 KOUPAL, TERRY J & VICKI J JT
04.41.3020 MEIERS, SCOTT J & BONNIE O JT
04.41.3010 PETERS, LARRY & KAREN LIVING TRUST
04.41.3015 FAUTH, WAYNE H REV. TRUST
04.14.4000 FUERNISS, SHERMAN W & LORI A JT
04.13.3000 LINK, DALE M & JOLENE M JT
8
04.13.4010 BARTUNEK, JERRY & ROBERT & JOHN
04.41.4010 MEIERS, SCOTT J & BONNIE O JT
405th Ave
Dry Choteau
YANKTON
04.13.4020 CLEARFIELD HUTTERIAN BRETHREN, INC.
04.41.3030 POWERS, DENNIS J & APRIL JT
04.41.3040 FUERNISS, ALICE M LIFE ESTATE
294th St
04.42.2015 POWERS, JEROME & HEIDI M PENNING JT
04.24.1030 WYSUPH, VALERIA DOOM ETAL C/O VALERIA TIESZEN
04.42.2010 MEIERS, LAUREN C & SYLVIA E REV LIV TRUST
04.24.2020 WYSUPH, VALERIA DOOM ETAL C/O VALERIA TIESZEN
04.42.2020 POWERS, DENNIS J & APRIL JT
04.23.1020 PETERS, LARRY & KAREN LIVING TRUST
16
04.23.1010 CLEARFIELD HUTTERIAN BRETHREN INC.
04.24.1010 POWERS, DENNIS J & APRIL JT
24, 096 N, 062 W
19, 096 N, 061 W
20, 096 N, 061 W
23, 096 N, 062 W
9
12
04.23.2010 PETERS, LARRY & KAREN LIVING TRUST
04.24.2030 WYSUPH, VALERIA DOOM ETAL C/O VALERIA TIESZEN
04.24.2040 WYSUPH, VALERIA DOOM ETAL C/O VALERIA TIESZEN
04.42.2030 POWERS, DENNIS J & APRIL JT
04.42.2040 POWERS, DENNIS J & APRIL JT
04.42.4020 BARTUNEK, ALFRED & SUZANE
7
Turbine
Crane Path
Leased
Parcel Boundary
MET Tower
Occupied Residences
Setback Waiver
Section Line
Access Road
2018 Project Boundary (Current Project Area)
Collector Line
County Boundary
NORTH
1,000 500 0 1,000
Scale in Feet
Locator Map
Hutchinson County
Charles Mix County
Bon Homme County
BURNS & McDONNELL
Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 6 of 14
Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.
Issued: 7/12/2018
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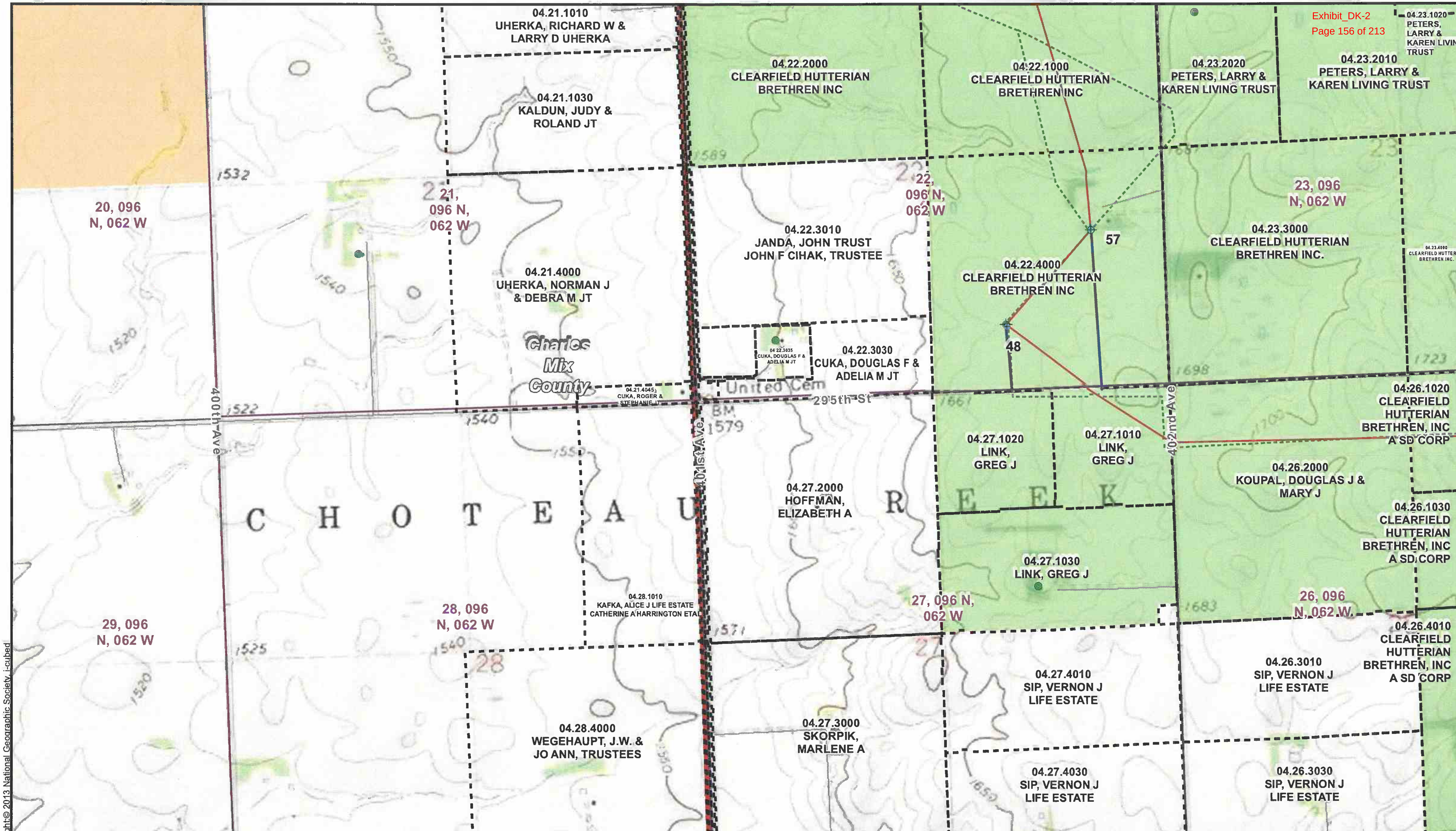

Turbine
MET Tower
Access Road
Collector Line
Crane Path
Occupied Residences
Leased
Setback Waiver
Parcel Boundary
Section Line
2018 Project Boundary (Current Project Area)
County Boundary

NORTH

1,000 500 0 1,000
Scale in Feet

Locator Map
Hutchinson County
Charles Mix County
Bon Homme County

BURNS & McDONNELL

Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 7 of 14

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Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

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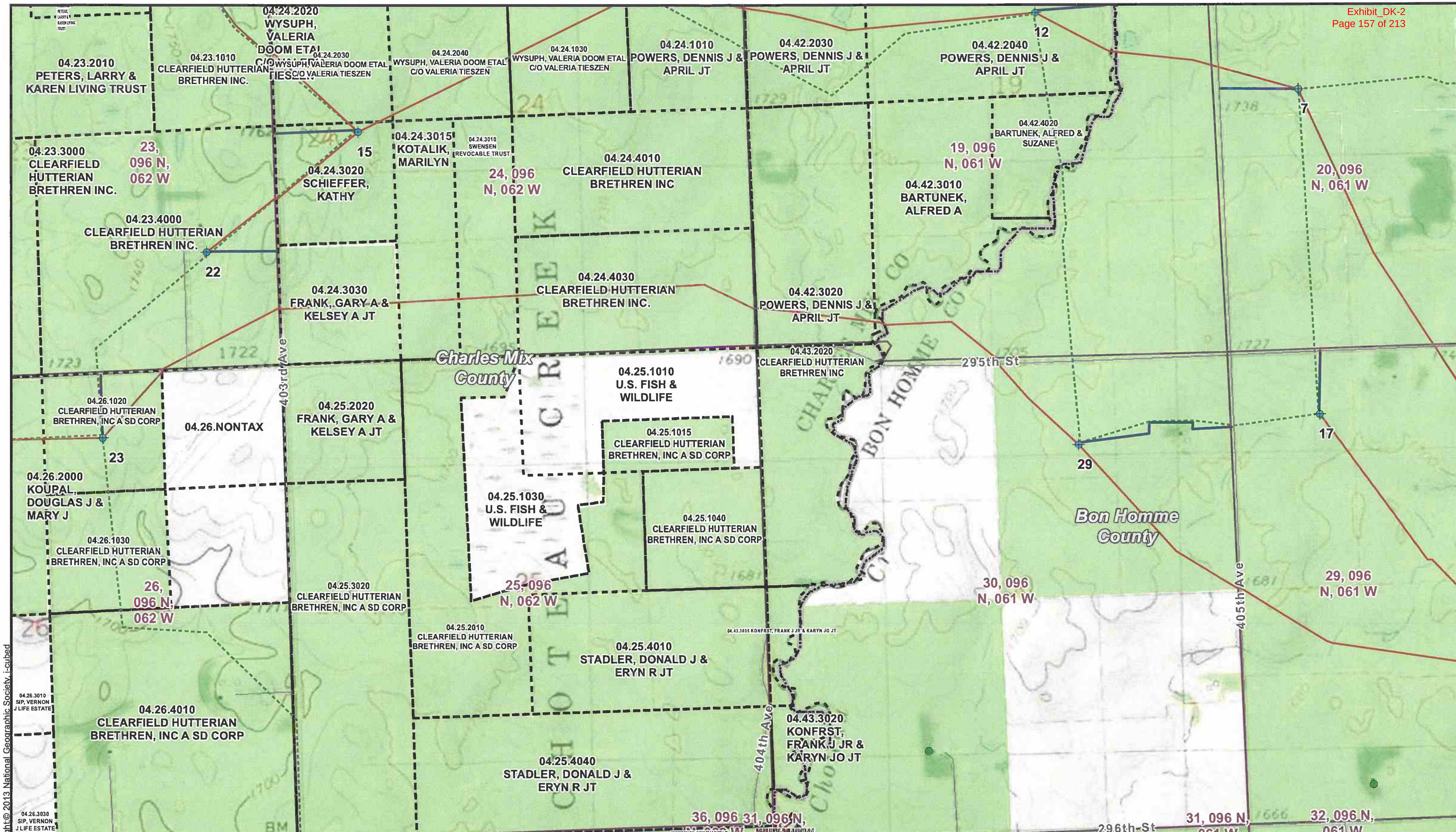


Turbine	Crane Path	Leased	Parcel Boundary
MET Tower	Occupied Residences	Setback Waiver	Section Line
Access Road			2018 Project Boundary (Current Project Area)
Collector Line			County Boundary

NORTH

1,000 500 0 1,000
Scale in Feet

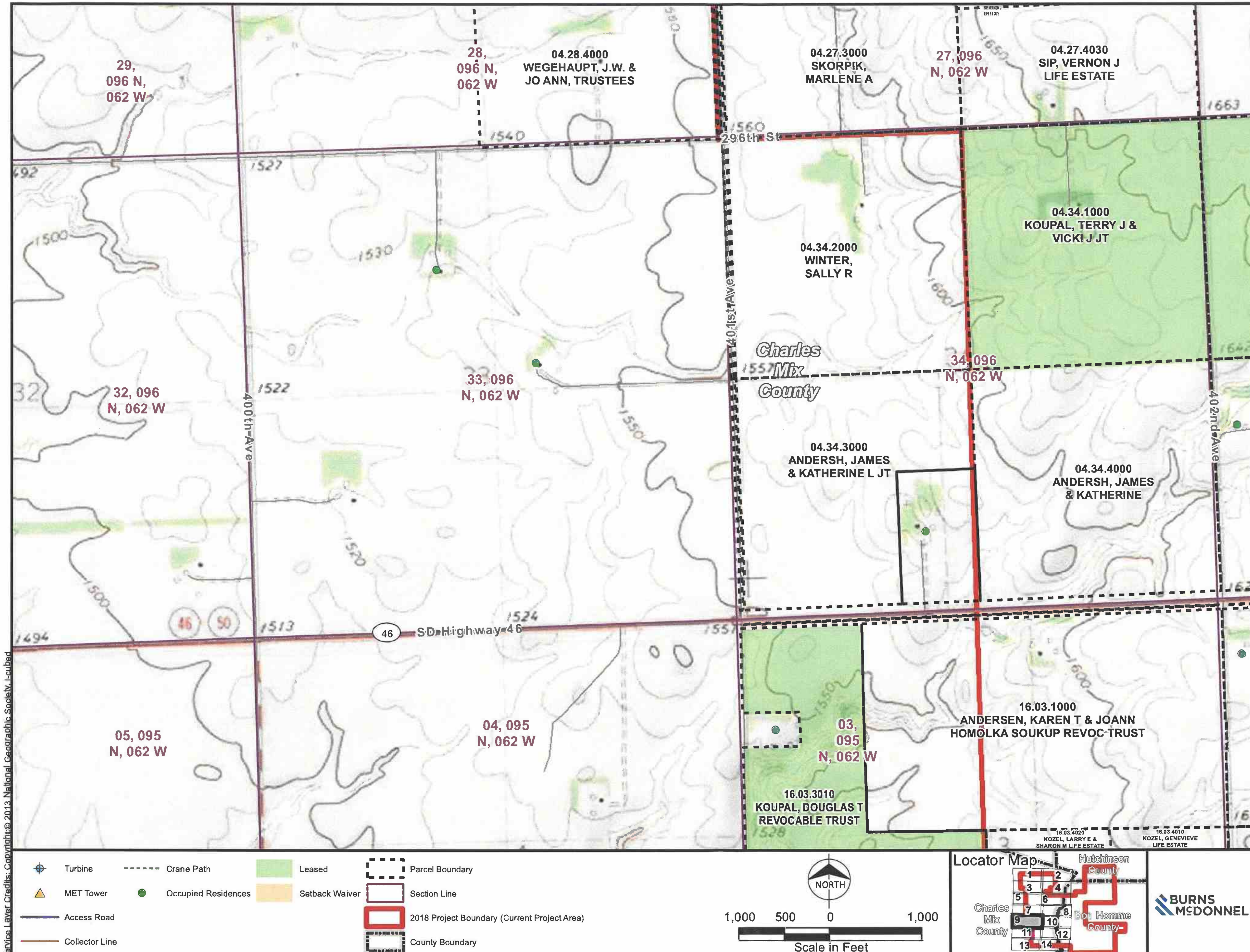
Locator Map
Hutchinson County
Charles Mix County
Bon Homme County
1 2 3 4 5 6 7 8 9 10 11 12 13 14

BURNS McDONNELL

Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 8 of 14

Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

Issued: 7/12/2018



Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 9 of 14

Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

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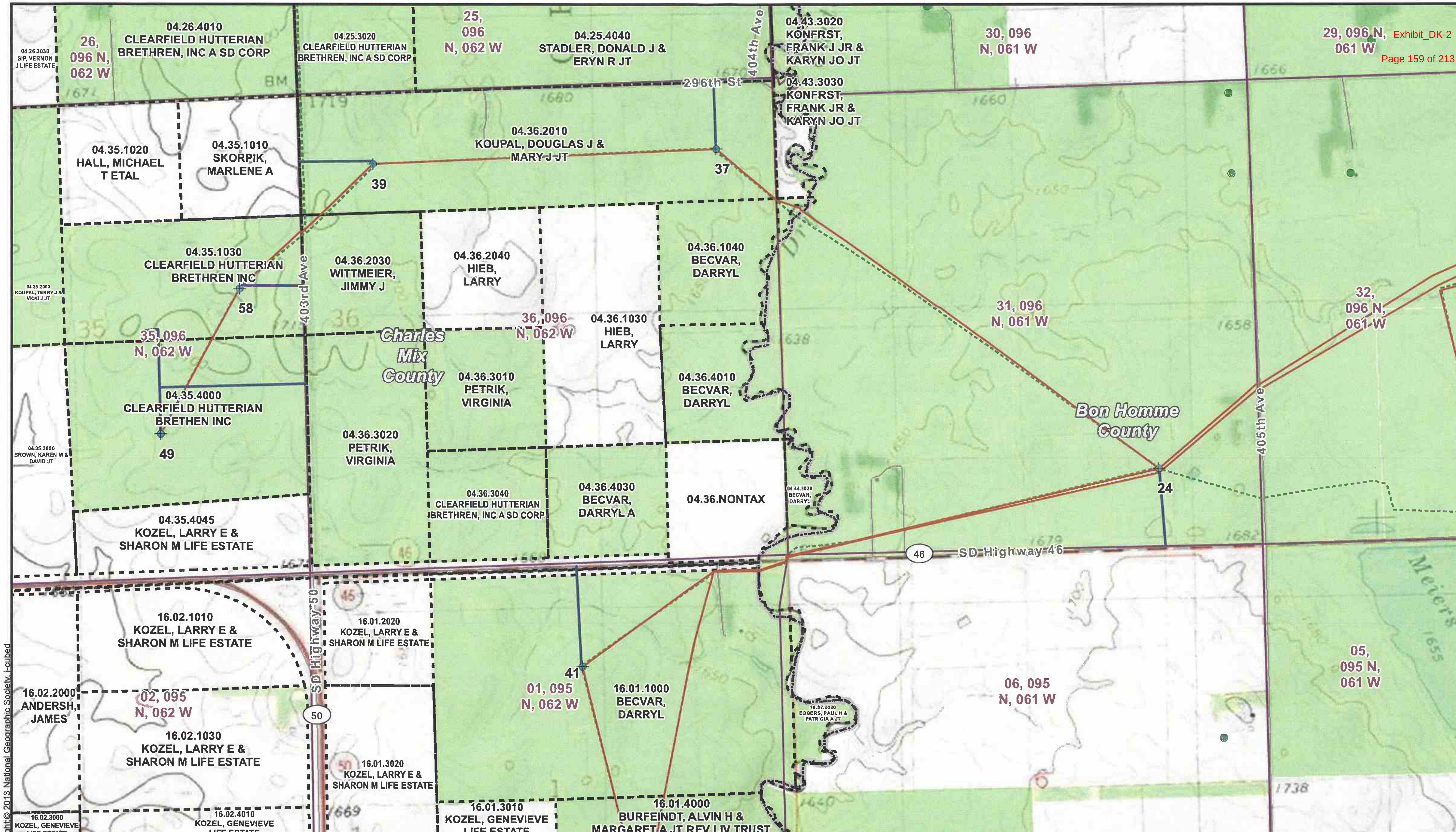

Turbine
MET Tower
Access Road
Collector Line
Crane Path
Occupied Residences
Leased
Setback Waiver
Parcel Boundary
Section Line
2018 Project Boundary (Current Project Area)
County Boundary

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Scale in Feet

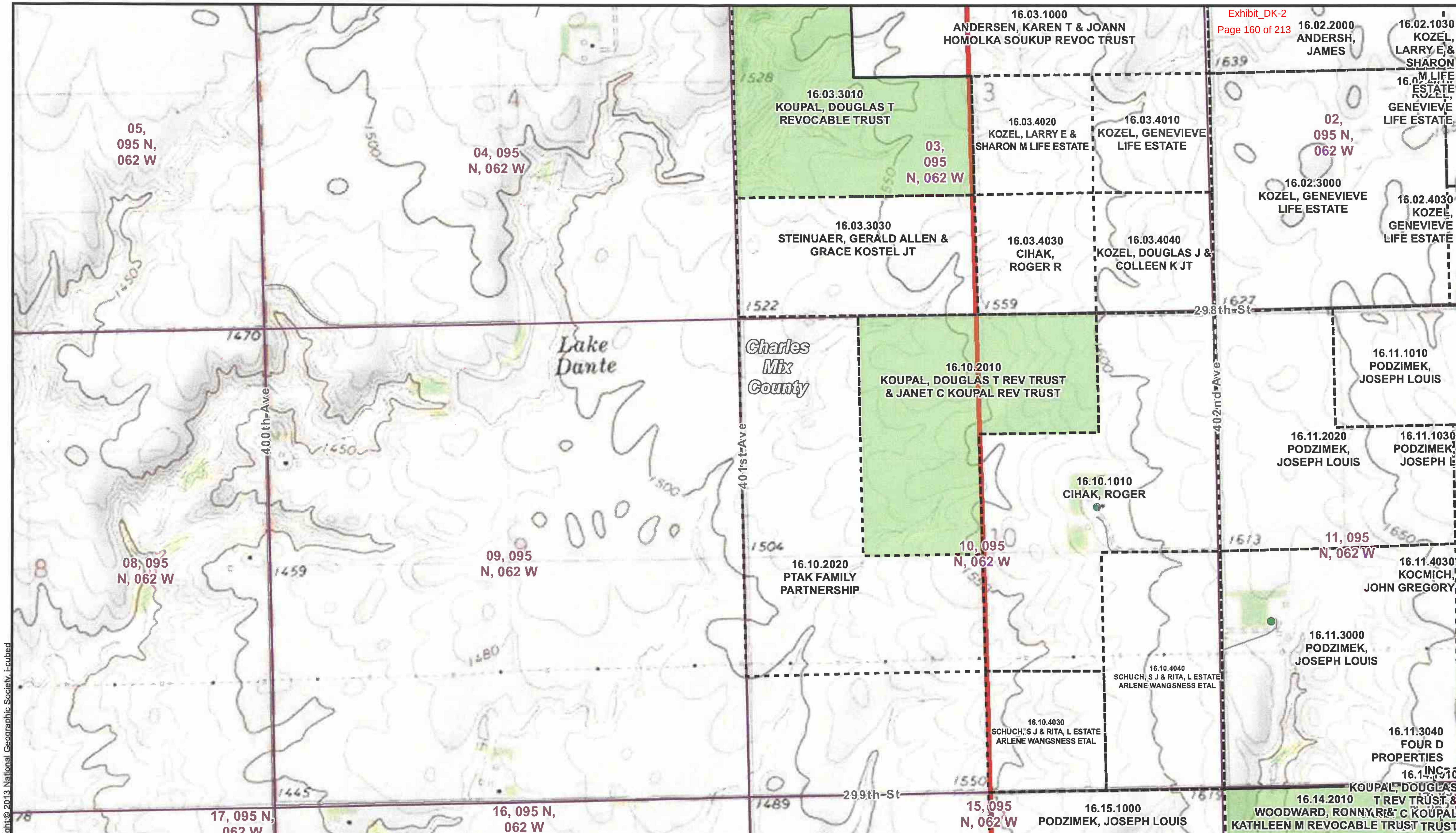
Locator Map
Hutchinson County
Charles Mix County
Bon Homme County
1 2 3 4 5 6 7 8 9 10 11 12 13 14

BURNS & McDONNELL

Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 10 of 14

Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

Issued: 7/12/2018



Turbine
MET Tower
Access Road
Collector Line
Crane Path
Occupied Residences
Leased
Setback Waiver
Parcel Boundary
Section Line
2018 Project Boundary (Current Project Area)
County Boundary

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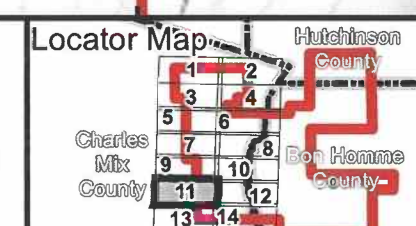
Scale in Feet

Locator Map



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Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
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Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

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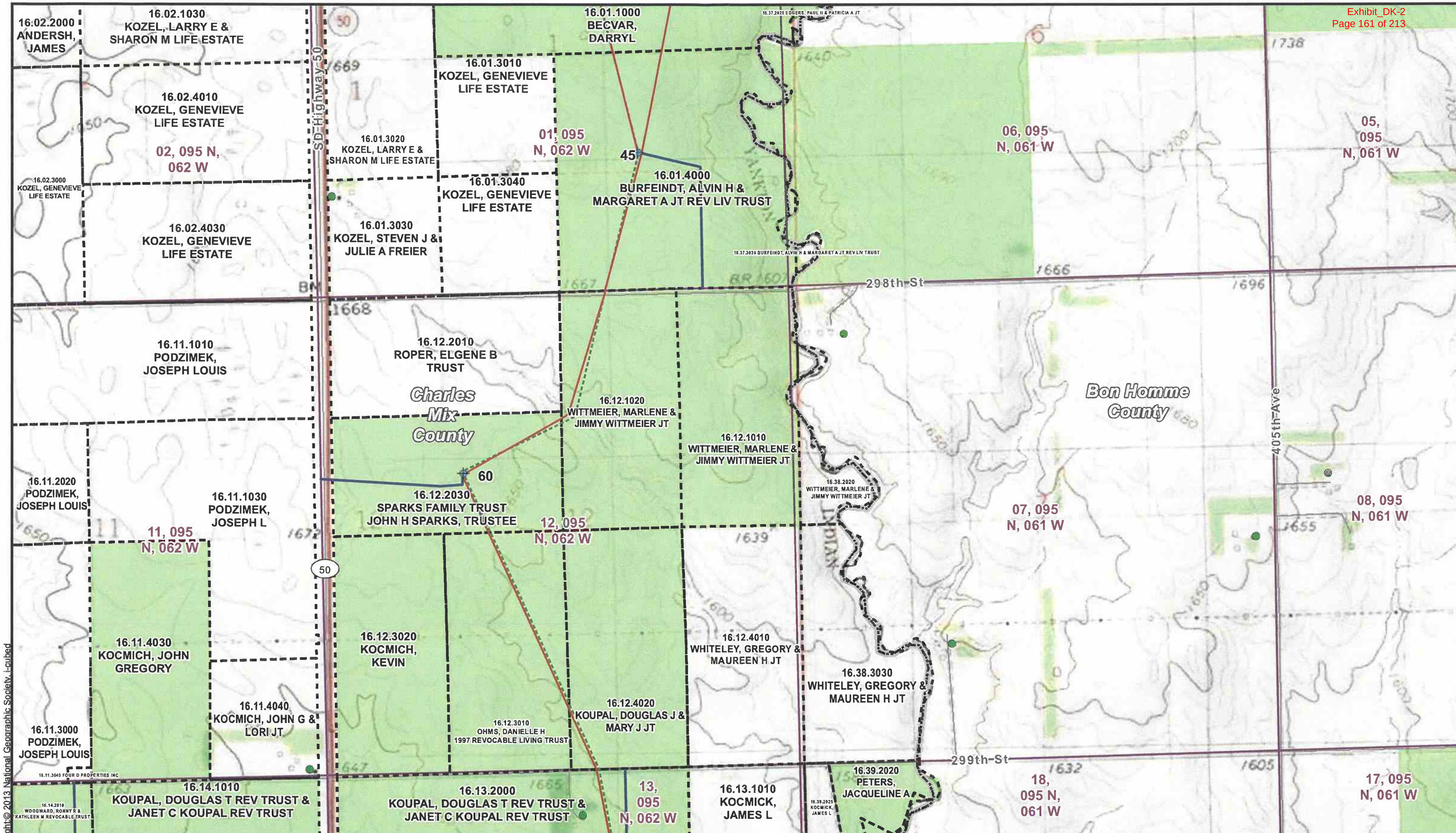

Turbine — Crane Path — Leased — Parcel Boundary
MET Tower — Occupied Residences — Setback Waiver — Section Line
Access Road — 2018 Project Boundary (Current Project Area)
Collector Line — County Boundary

NORTH

1,000 500 0 1,000
Scale in Feet

BURNS & McDONNELL

Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 12 of 14

Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

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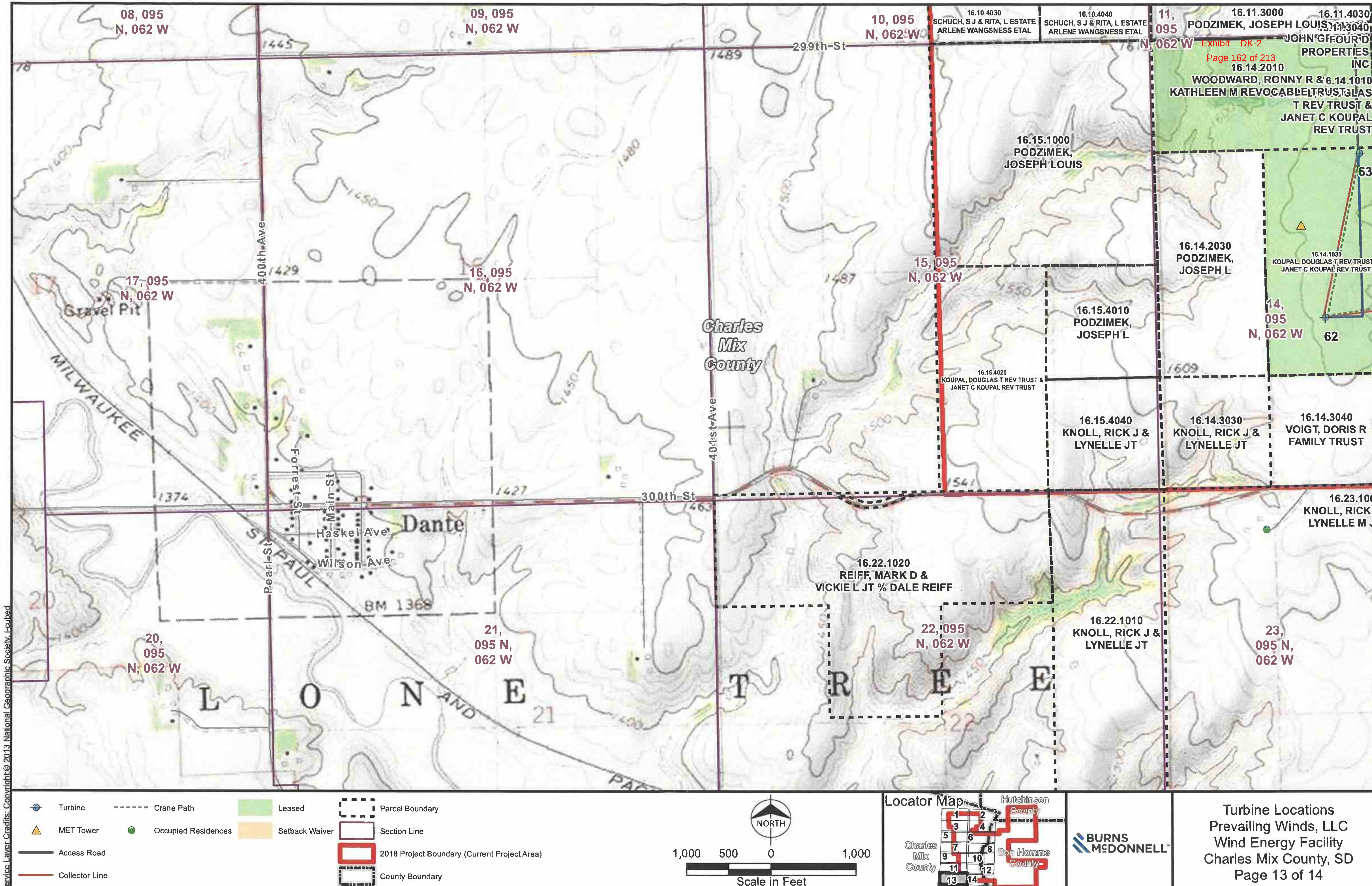

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Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 13 of 14

Source: sPower, ESRI, and Burns & McDonnell Engineering Company Inc.

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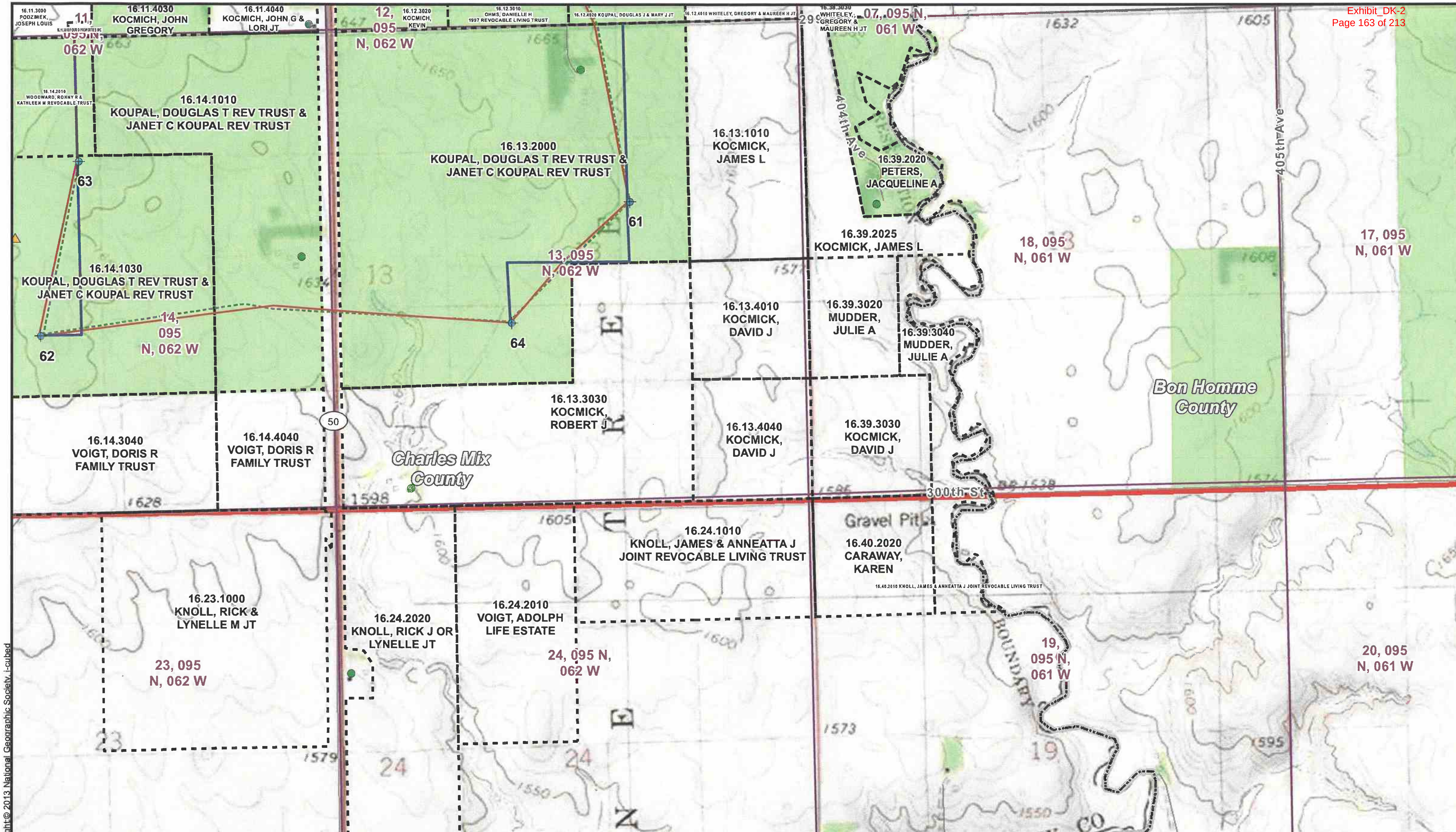

Turbine
MET Tower
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Crane Path
Occupied Residences
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Setback Waiver
Parcel Boundary
Section Line
2018 Project Boundary (Current Project Area)
County Boundary

NORTH

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Scale in Feet

Locator Map
Hutchinson County
Charles Mix County
Bon Homme County

BURNS McDONNELL

Turbine Locations
Prevailing Winds, LLC
Wind Energy Facility
Charles Mix County, SD
Page 14 of 14

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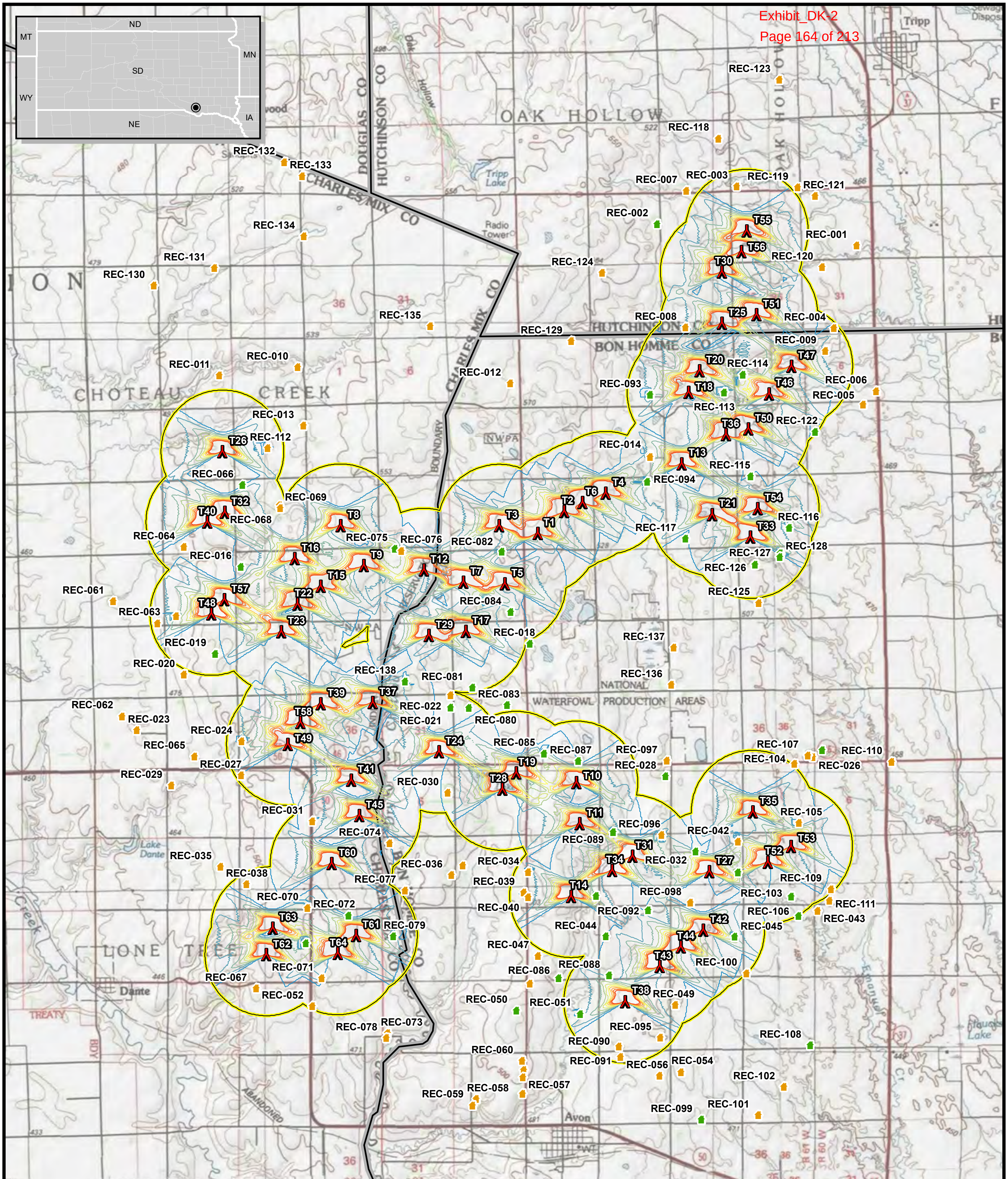


LEGEND

- County Boundary
- Wind Turbine
- Receptor, Participating
- Receptor, Non-participating
- Wind Turbine Buffer (1370m)

Shadow Flicker Vectors [hours per year]
0 10 20 30 40 50 60 70 80 90 100

REFERENCE

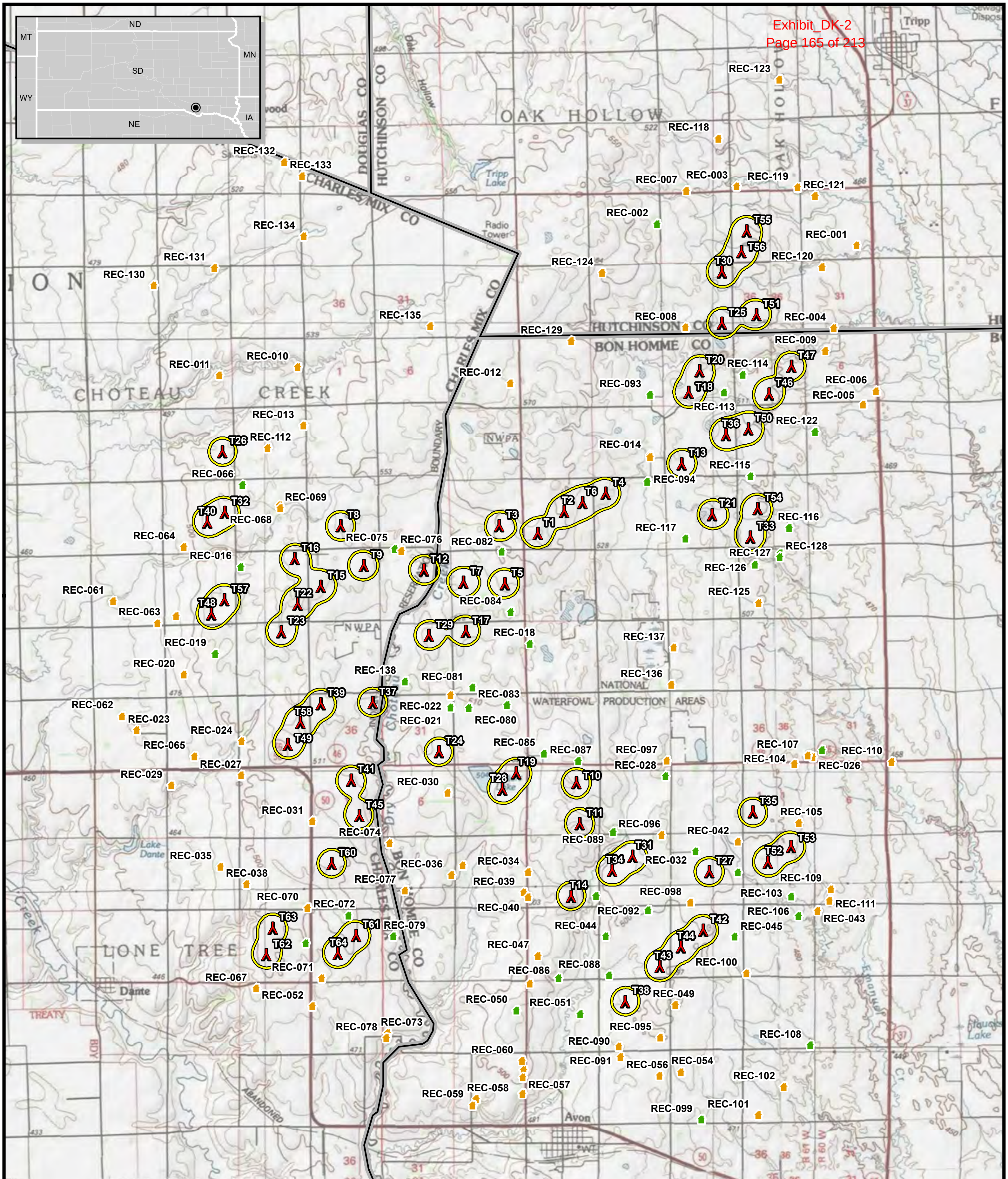
0 1 2 MILES
0 1 2 KILOMETERS
N

PREVAILING WIND PARK
Shadow Flicker Duration [Hr/Yr] - GE 3.8-137 Layout

LOCATION:	Charles Mix/Bonne Homme/Hutchinson Cty, SD
CLIENT:	Prevailing Wind Park, LLC
PROJ. NO.:	105644
CREATED:	07/23/2018

BURNS McDONNELL
www.burnsmcd.com

016513



LEGEND

County Boundary

Wind Turbine

Receptor, Participating

Receptor, Non-participating

45 dBA Limit, GE 3.8-137

REFERENCE

0 1 2

MILES

0 1 2

KILOMETERS

N

PREVAILING WIND PARK

45 dBA Contours - GE 3.8-137 Layout

LOCATION:	Charles Mix/Bonne Homme/Hutchinson Cty, SD
CLIENT:	Prevailing Wind Park, LLC
PROJ. NO.:	105644
CREATED:	08/02/2018

BURNS McDONNELL

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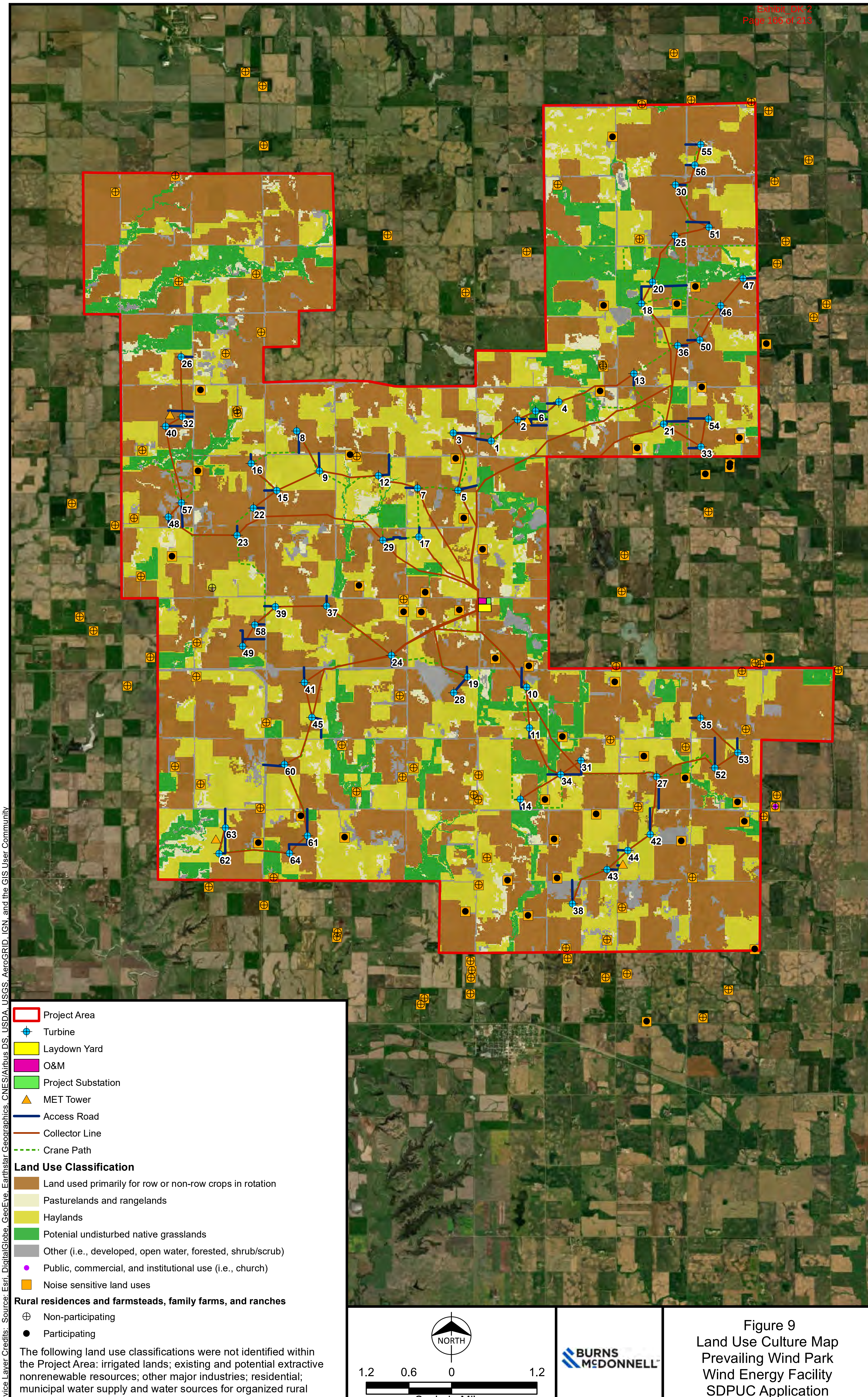

NORTH

1.2 0.6 0 1.2

Scale in Miles

BURNS & McDONNELL

Figure 9
Land Use Culture Map
Prevailing Wind Park
Wind Energy Facility
SDPUC Application

Source: ESRI, Burns & McDonnell Engineering Company, Inc., South Dakota GIS, NLCD, Prevailing Winds, LLC

Issued: 8/2/2018

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**PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC, FOR A WIND ENERGY FACILITY PERMIT FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * * *	**CERTIFICATE OF SERVICE** **EL18-026**

Lisa Agrimonti, of Fredrikson & Byron, P.A., hereby certifies that on the 3rd day of August, 2018, a true and correct copy of Applicant's Responses to Staff's First Set of Data Requests and this Certificate of Service were served electronically on the persons listed below:

Ms. Amanda Reiss Staff Attorney South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 Amanda.reiss@state.sd.us	Ms. Kristen Edwards Staff Attorney South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 Kristen.edwards@state.sd.us

<u>/s/ Lisa Agrimonti</u>
Lisa Agrimonti

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

EL18-026 - IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * *	**APPLICANT'S RESPONSES TO STAFF'S SECOND SET OF DATA REQUESTS** **EL18-026**

Below, please find Applicant's Responses to Staff's Second Set of Data Requests to Applicant.

2-1) Provide copies to Staff of all data requests served on Intervenors at the time of service, as well as the responses at the time of receipt.

Lisa Agrimonti: Prevailing Wind Park will provide Staff with the requested copies.

2-2) Provide copies to Staff of all of your answers to data requests from Intervenors at the time they are served on Intervenors.

Lisa Agrimonti: Prevailing Wind Park will provide Staff with the requested copies.

2-3) Refer to the Company's response to Staff Data Request 1-6c. Did the Applicant provide the revaluated financial benefit to the State in testimony submitted on August 10, 2018? If yes, please provide the reference. If no, please provide the evaluation of financial benefit to the State.

Bridget Canty: Prevailing Wind Park estimates that the net financial benefit to the state, minus the $4,329,410 in reinvestment funds granted from the Governor's Office of Economic Development ("GOED"), would total approximately $6.7 million. The reinvestment funds were granted through the Reinvestment Payment Program which is funded by the contractor excise taxes on the projects that the GOED brings to the State.

2-4) Refer to the Company's response to Staff Data Request 1-11. To promote transparency in this siting process, please provide the alternate turbine numbers if the Company was able to successfully construct GE 3.8-137 turbines in the preferred locations with the information the Company has available at this time.

Bridget Canty: Prevailing Wind Park recently identified potential alternate turbines: T38, T60, T61, T62, T63, and T64. The identification of alternate turbines is based on the best available information, and may change as additional information becomes available, e.g. site-specific soil conditions.

2-5) Refer to the Company's response to Staff Data Request 1-14. Please provide Western Area Power Administration's (WAPA) concerns, if any, once known.

Bridget Canty: In a letter dated August 21, 2018, WAPA identified a single turbine (T40) in Hutchinson County as potentially conflicting with radio transmission. PWP is surveying the specific radio transmission tower locations to determine what, if any, remedial action may be required.

2-6) Refer to the Company's response to Staff Data Request 1-15. Does the Applicant anticipate receiving a CUP from Hutchinson County prior to the evidentiary hearing in this proceeding on October 9, 2018? Please explain.

Bridget Canty: Yes. Prevailing Wind Park applied for CUPs for all properties with a turbine and/or other project facilities in Hutchinson County on August 14, 2018. Prevailing Wind Park expects Hutchinson County to issue a decision in early September 2018.

2-7) Refer to the Application, Section 3.1. Provide an update on the status of the Environmental Assessment, and a copy of the Environmental Assessment if it is available. Does the Company still anticipate WAPA will approve a final EA in fourth quarter 2018?

Jennifer Bell: The Environmental Assessment is being developed. Prevailing Wind Park now anticipates that WAPA approval of the final Environmental Assessment may occur in either 4th quarter 2018 or 1st quarter 2019.

2-8) Refer to the Application, Section 15.5, Shadow Flicker.

a. Provide the Applicant's definition and interpretation of a "Shadow Flicker Control System" in Section 1741 of the Bon Homme County ordinance.

Bridget Canty: Prevailing Wind Park interprets a "Shadow Flicker Control System" as mechanical and/or electrical measures that direct curtailment of turbines during pre-determined atmospheric conditions associated with shadow flicker.

b. Provide the Applicant's definition and interpretation of the following phrase in Section 1741 of the Bon Homme County ordinance: "When determined appropriate by the County …". When does the Applicant believe the County would determine it is appropriate to require a Shadow Flicker Control System? Will the County notify the Applicant through the conditional use permit whether the County will enforce Section 1741?

Bridget Canty: Prevailing Wind Park submitted an application for approval of a Large Wind Energy System with Bon Homme County on August 1, 2018 ("Application"). In the Application, Prevailing Wind Park committed to limit shadow flicker at non-participating residences to 30 hours per year. The County Board of Commissioners on August 21, 2018 determined that the Project was a permitted use and that the Project met the requirements in Bon Homme's Zoning Ordinance, Article 17, for a large wind energy system as proposed, without installation of a Shadow Flicker Control System.

c. Does Section 1741 apply to both habitable non-participating and participating dwellings? Explain.

Lisa Agrimonti: Section 1741 does not expressly distinguish between non-participating and participating dwellings. Regardless of its scope, the Bon Homme County Commission determined on August 21, 2018 that the Project as proposed was in compliance with Article 1741 of the Ordinance

d. Please explain why the discussion regarding mitigation focuses primarily on one non-participating receptor that exceed 30 hours per year, instead of all receptors that exceed 30 hours per year (3) and all receptors that exceed 30 minutes per day (25) for the GE 3.8-137 turbine, to comply with Section 1741 of the Bon Homme County ordinance.

Lisa Agrimonti: See response to 2-8(b).

e. Referring to the Shadow Flicker Study (Appendix N), please explain how receptors 009, 014, 015, 017, 032, 040, 041, 042, 045, 051, 082, 089, 093, 094, 096, 113, and 114, which have maximum expected shadow flicker duration greater than 30 minutes per day and/or greater than 30 hours per year, will comply with Section 1741 of the Bon Homme County Zoning Ordinance.

Lisa Agrimonti: See response to 2-8(b).

2-9) Refer to the Application, Section 20.1.2.1, Economic Impacts. What is the economic impact of the proposed Project on the hunting industry, specifically hunting guides? Provide studies to support for your response.

Bridget Canty: No impacts to upland game species are expected during construction. Collisions of game birds with wind turbines are typically quite low, relative to songbirds, and this effect is not expected to be significant either biologically or economically. If post-construction monitoring surveys determine that avian fatalities are significantly higher than predicted, Prevailing Wind Park will work with the United States Fish and Wildlife Service ("USFWS") and South Dakota Game Fish & Parks ("GF&P") to develop adaptive management measures to reduce impacts to an acceptable level. Studies of post-construction displacement of upland gamebirds in the Midwest indicate the impact for some species, including ring-necked pheasant, is not biologically significant; therefore the economic impact, if any, is expected to be very low. [1],[2] Big game may be temporarily displaced during construction, but are expected to return to the site during operations due to the abundance of suitable habitat; therefore, effects to big game are expected to be limited to the construction phase.[3]

2-10) Referring to Section 3.1 of the Bird and Bat Conservation Strategy, would Prevailing Wind Park be willing to conduct 2-years of post-construction fatality monitoring? If no, please explain why.

Bridget Canty: Yes.

2-11) Referring to Section 5.1 of the Bird and Bat Conservation Strategy, please explain the process for deciding what additional adaptive management measures should be implemented, if needed, and who decides what the appropriate measures are.

Bridget Canty: If needed, Prevailing Wind Park would determine the appropriate adaptive management measures to be implemented in coordination with the GF&P and the USFWS.

2-12) Referring to the Bird and Bat Conservation Strategy, is Prevailing Wind Park willing to provide results from all studies to the SD GF&P and the PUC? Further,

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[1] Dupuie, J.N. 2018. Ring-necked Pheasant Responses to Wind Energy in Iowa. Graduate Theses and Dissertations. Iowa State University. Available at: https://lib.dr.iastate.edu/etd/16346/

[2] Vodenhall, W.B. 2011. Location of Sharp-tailed Grouse and Greater Prairie Chicken Display Grounds in Relation to NPPD Ainsworth Wind Energy Facility, 2006-2011. Nebraska Game and Parks Commission. Available at: https://wind-energy-wildlife.unl.edu/download/Vodehnal_et_al_2011.pdf

[3] The Wildlife Society. 2007. Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat. Technical Review Committee on Wind Energy Facilities and Wildlife. Technical Review 07-2. Available at: http://wildlife.org/wp-content/uploads/2014/05/Wind07-2.pdf

will Prevailing Wind Park also coordinate with the SD GF&P to determine if adaptive management measures are needed and what measures should be implemented if necessary?

Bridget Canty: Prevailing Wind Park intends to provide copies of all studies to GF&P; copies of all studies were previously provided to the PUC as Appendices B through K to the PUC application. Yes, Prevailing Wind Park will coordinate with both USFWS and GF&P to develop adaptive management measures, if needed.

2-13) Referring to the Sound Study (Appendix M), would it be necessary to include the existing Beethoven Wind Project in the model to capture the cumulative noise impacts to receptors in or near the Project Area? If not, please explain why.

Chris Howell: I performed an analysis of the sound created by the Beethoven Wind Project turbines and the Prevailing Wind Park, which is enclosed as Attachment 2-13. The Analysis shows that the modeled sound from the existing Beethoven Wind farm exceeds 45 dBA at one receptor – REC 129. The modeled sound for REC 129 from the Beethoven Wind Farm is 46.2 dBA. When the two wind farms are modeled together, the sound at REC 129 is 46.3 dBA, showing that the Project would contribute only .1 dBA of sound. This added amount is acoustically negligible.

2-14) Referring to the Shadow Flicker Study (Appendix N), please explain if shadow flicker from the Beethoven project wind turbines in addition to the Prevailing Wind Park wind turbines could cause receptors to experience greater than 30hrs of shadow flicker per year.

Aaron Anderson: No. I evaluated shadow flicker at the Beethoven project wind turbines and the Prevailing Wind Park. No receptor that will experience shadow flicker from the Prevailing Wind Park would also experience shadow flicker from the Beethoven project.

2-15) Referring to page 18 of the RF Study (Appendix O), please identify if Prevailing Wind Park contacted the operators of the three point-to-multipoint microwave MAS facilities (NorthWestern Corporation and East River Electric Power Coop) to confirm the turbines will not adversely impact those facilities. If so, please provide documentation regarding those contacts.

Bridget Canty: Yes. Prevailing Wind Park sent a letter to the three MAS facilities on August 23, 2018. A copy of the letter is provided as Attachment 2-15.

2-16) What is the modeled noise level and shadow flicker at the Gramkow-Vesper Cemetery located at the intersection of 409th Ave. and 298th St. near turbine 35?

Chris Howell: The noise level of the Project at the Gramkow-Vesper Cemetery is 43.2 dBA for the GE 3.8-137 model.

Aaron Anderson: The shadow flicker level of the Project at the Gramkow-Vesper Cemetery is approximately 5 hours per year for the GE 3.8-137 model.

2-17) In supplemental testimony, Peter Pawlowski represented that the Company is willing to establish an escrow account for decommissioning based upon costs provided in the testimony of Daniel Pardo. Provide the Company's estimate of the total amount that will be available in the account after thirty years of operation.

Bridget Canty: Prevailing Wind Park's consultant, Daniel Pardo/DNV GL provided an estimate for a "partial resale" value. Based on his calculations, the net cost of decommissioning would be approximately $786,000. Thus, the amount available in the escrow account after 30 years would equal $786,000, plus interest, unless the annual amount deposited were adjusted by the Commission.

2-18) What capacity factor did Applicant assume when calculating the tax benefits? How did Applicant determine this was the appropriate capacity factor?

Bridget Canty: Tax benefits resulting from both the Nameplate Capacity Tax and the Electric Production Tax were calculated based on the total generation capacity (in kilowatt hours) of the turbines. The preliminary calculations were based on use of 61 Vestas 3.6 MW turbines. Updated tax benefit calculations based on Prevailing Wind Park's decision to install 57 GE 3.8 MW turbines are shown in the following edited text from Section 6.1.3 of the application (footnotes omitted).

> The Project's use of only 45 acres within the larger Project Area would generate approximately $1.2 million annually in new income for landowners; approximately ~~$742,500~~ **$733,800** in new annual tax revenues for Bon Homme, Charles Mix, and Hutchinson counties, schools and townships[]; and approximately ~~$11.1~~ **$11** million in new tax revenues for State government[] from Project operations.

2-19) Refer to Ms. Canty's Supplemental Direct Testimony, Page 3, lines 65 – 82. Please discuss the Company's internal controls to ensure the Company has identified all residences in and around the study area for the applicable studies required in the Application.

Bridget Canty: As described in my Direct Testimony provided on August 10, 2018, a multi-step process of identifying occupied residences was conducted in 2016 and updated in 2018. After Prevailing Wind Park became aware that the Schoenfelder residence was missed during the 2018 review, the Company began an additional analysis, which includes review of the most current aerial photography to be followed by field verification of any residences. Prevailing Wind Park will update this response when this additional review is complete.

2-20) Refer to Mr. Pawlowski's supplemental testimony, Section III. Local Permitting Update. Provide the affidavit accepted by Charles Mix County, and documentation that supports the statement that commitments were responsive to the county's concerns.

Lisa Agrimonti: See enclosed Attachment 2-20.

2-21) Refer to Mr. Pawlowski's supplemental testimony, Section V. Aircraft Detection Lighting System.

a. Explain why the Company is installing ADLS when there is no County ordinance requiring the system.

Peter Pawlowski: sPower, after installing the first commercial system in the United States on its Pioneer Wind Park located in Converse County Wyoming, determined that where feasible sPower would include the ADLS system in their wind farm design. sPower, as a long-term owner and operator, prides itself in applying best practices for tower lighting and not just what may be required.

b. Is the Company aware of any circumstances where the FAA did not approve ADLS technology for a wind project? Provide examples and explain.

Peter Pawlowski: No. The Company is not aware of any such denial. However, the technology is new and, with sPower installing it for the first time in Wyoming, we are not sure how many (if any) applications have been made by companies other than sPower.

c. Explain why ADLS is considered a new technology by the Company. Does the FAA consider ADLS a new technology?

Peter Pawlowski: The FAA approved the first radar-based ADLS system for a wind farm in 2016 for the sPower Pioneer Wind Park in Converse County Wyoming, making this technology new for the implementation on a commercial basis for wind parks. ***See*** https://www.intelligent-aerospace.com/articles/2017/01/laufer-wind-radar-based-aircraft-detection-lighting-system-operational-on-wind-farm.html

d. What potential risks does ADLS present as a new technology? Explain and provide documentation.

Peter Pawlowski: The risk ADLS presents as a new technology is limited to two primary issues (1) the system growing unreliable over time and/or (2) the company making the equipment going out of business. The first can increase operational cost or cause the system to not function resulting in red blinking lights at night and wasted capital cost investment during construction. With respect to the second issue, sPower did in fact have the original manufacturer go out of business after installation and operation of the Pioneer Wind Park ADLS; however, the system functions to this day and sPower ensured contractually that sPower had the necessary rights to continue to maintain the ADLS system.

e. When was an ADLS implemented at the Pioneer Wind Park? Has sPower had any issues with the ADLS? If yes, please explain.

Peter Pawlowski: The ADLS system began operations shortly after October 27, 2016 at the Pioneer Wind Park when the FAA issued approval for the ADLS to operate. sPower has had some issue with the system involving failures at individual lights, resulting in the light turning on at night. The ADLS system has from time to time also experienced issues that have caused the system to go down; however, it is important to note that if the ADLS fails, then the original equipment manufacturer system operates as the default. sPower's experience has been such that we believe that ADLS is a good investment to make in our wind parks.

2-22) Refer to Mr. Pawlowski's supplemental testimony, Section VI. Other Project Commitments.

a. Is the Company willing to accept 250 feet, rather than the requested 500 feet, for turbine location flexibility? Please explain.

Peter Pawlowski: Yes.

b. Identify the permit conditions from Docket EL18-003 that the Company is unwilling to accept and explain why.

Peter Pawlowski: Prevailing Wind Park is generally accepting of all conditions that would apply to Prevailing Wind Park. For example, Condition 38 regarding decommissioning is specific to the off-taker in Docket EL18-003. Prevailing Wind Park is proposing some revisions to the conditions to reflect the specific circumstances relating to the Prevailing Wind Park and will provide a draft set of conditions to Staff for consideration.

2-23) Provide a map that shows the proposed turbines within 2 miles from the residence of Mr. Greg C. Hubner and Mrs. Marsha Hubner. Please provide a map similar to Page 88 of 156 of Staff Exhibit_JT-1 in Docket EL18-003 for Ms. Teresa Kaaz (http://puc.sd.gov/commission/dockets/electric/2018/EL18-003/exhibits/staff/s1.pdf).

Jennifer Bell: See enclosed Attachment 2-23.

2-24) Provide a map that shows the proposed turbines within 2 miles from the residence of Mr. Paul M. Schoenfelder and Mrs. Lisa A. Schoenfelder. Please provide a map similar to Page 88 of 156 of Staff Exhibit_JT-1 in Docket EL18-003 for Ms. Teresa Kaaz (http://puc.sd.gov/commission/dockets/electric/2018/EL18-003/exhibits/staff/s1.pdf).

Jennifer Bell: See enclosed Attachment 2-24.

2-25) Provide a map that shows the proposed turbines within 2 miles from the residence of Mr. Sherman Fuerniss. Please provide a map similar to Page 88 of 156 of Staff Exhibit_JT-1 in Docket EL18-003 for Ms. Teresa Kaaz (http://puc.sd.gov/commission/dockets/electric/2018/EL18-003/exhibits/staff/s1.pdf).

Jennifer Bell: See enclosed Attachment 2-25A (North) and Attachment 2-25B (South).

2-26) Provide a map that shows the proposed turbines within 2 miles from the residence of Ms. Karen D. Jenkins. Please provide a map similar to Page 88 of 156 of Staff Exhibit_JT-1 in Docket EL18-003 for Ms. Teresa Kaaz (http://puc.sd.gov/commission/dockets/electric/2018/EL18-003/exhibits/staff/s1.pdf).

Jennifer Bell: See enclosed Attachment 2-26.

2-27) Refer to Docket EL17-055, Pre-filed Exhibits filed by Crocker Wind Farm, LLC, Exhibit A15-7. Please provide a similar constraints map for the Prevailing Wind Park Project.

Bridget Canty: Please see enclosed Attachment 2-27.

2-28) At the public input hearing, Ms. Kelly Pazour voiced concerns that noise from wind turbines may adversely impact her daughter's bone anchored hearing aid (BAHA). Please provide an analysis as to whether or not the noise profile of wind turbines could interfere with the BAHA and include all supporting materials.

Dr. Mark Roberts: Based on my review of the human physiology and anatomy associated with the application of bone anchored hearing aids ("BAHA"), there is no scientific evidence that sounds generated by wind turbines would be perceived in any other manner than the sounds of everyday experience. There also is no evidence in the peer reviewed, published literature that the noise generated by wind turbines would cause adverse effects in individuals fitted with BAHA. Low frequency sounds are a normal part of our everyday experience and they have not been reported in the scientific literature as a problem for BAHA wearers. Testing of BAHA apparatus starts at 500 Hz, which is considerably higher than the 20 Hz and lower range that is often spoken of as a concern.

Dated this 30th day of August 2018.

By ***/s/ Lisa M. Agrimonti***

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Memorandum

BURNS McDONNELL
Attachment 2-13

Date: August 28, 2018

To: Prevailing Wind Park, LLC

From: Chris Howell, Burns & McDonnell

Subject: Prevailing Wind Park Sound Modeling with Beethoven Turbines

Prevailing Wind Park, LLC (Developer) is proposing to construct the Prevailing Wind Park near Avon, South Dakota, in Bon Homme, Hutchinson, and Charles Mix Counties (Project). The Project will consist of 57 to 61 wind turbines with a maximum nameplate capacity of up to 219.6 megawatts (MW), although output at the point of interconnection will be limited to a maximum of 200 MW. The wind turbine sites were analyzed for the proposed turbine model: General Electric (GE) 3.8-137. Directly north of the Project, NorthWestern Energy operates 43, 1.85-MW GE 1.85-87 wind turbines as part of the Beethoven Wind Farm. This sound assessment was completed to model sound levels of the Project, in combination with the existing wind farm.

Sound Modeling

Predicted sound levels were modeled using industry-accepted sound modeling software. The program used to model the turbines was the Computer Aided Noise Abatement (CadnaA), Version 2018, published by DataKustik, Ltd., Munich, Germany. The program is a scaled, three-dimensional program that takes into account air absorption, terrain, ground absorption, and ground reflection for each piece of noise-emitting equipment and predicts downwind sound pressure levels. The model calculates sound propagation based on International Organization for Standardization (ISO) 9613-2:1996, General Method of Calculation. ISO 9613-2, and therefore CadnaA, assesses the sound pressure levels based on the Octave Band Center Frequency range from 31.5 to 8,000 Hz. Compliance with the regulations for all turbines operating should ensure compliance for any combination of the turbines operating. Predictive modeling was conducted to determine the impacts from the new and existing turbines at the nearest occupied residences.

Acoustical modeling was conducted for the Project. Wind turbine nacelle heights and acoustical emissions were input into the model. The nacelles of the Project wind turbines are 110 meters high. The nacelles for the existing Beethoven turbines are 80 meters high. The sound emissions data supplied by GE was developed using the International Electrotechnical Commission (IEC) 61400-11 acoustic measurement standards. The expected sound power levels for the Project and representative sound levels for Beethoven turbines are displayed in Table 1.

Table 1: Maximum Sound Power Levels

Turbine	Height	Sound Power Level (dBA)									
		31.5	63	125	250	500	1000	2000	4000	8000	dBA
GE 3.8-137	110 m	78.5	86.8	92.6	96.4	99.4	102.1	102.0	93.7	79.2	**107.0**
GE 1.85-87*	80 m	69.3	81.4	91.0	99.0	102.3	101.1	96.8	88.1	74.0	**106.5**

*Actual specifications for the Beethoven Wind Farm turbines are unknown. Generic, representative GE data for similar turbines were used in this analysis.

Results

The maximum model-predicted cumulative L_{eq} sound pressure levels at each receiver (the logarithmic addition of sound levels from each frequency from every turbine) are included in Attachment 1. These values represent only the cumulative noise emitted by all wind turbines (Project turbines and Beethoven turbines) and do not include any extraneous noises (traffic, etc.) that could be present during physical noise measurements.

Beethoven Wind Farm was modeled based on conservative vendor data for GE 1.85-87 wind turbines. It is unknown if any of the Beethoven wind turbines have noise mitigation applied to them. Based on the conservative modeling assumptions, there is the potential for one receptor to exceed the 45-dBA limit, REC-129. At this receptor, the modeled existing sound level for the Beethoven Wind Farm by itself is 46.2 dBA. This level is directly attributable to the two Beethoven wind turbines near the receptor. When the two wind farms are modeled together, the sound level at REC-129 is predicted to be 46.3 dBA, showing that the Project would contribute only 0.1 dBA of additional sound. This added amount is acoustically negligible. The model results for the assumed Beethoven Wind Farm operating without the Project are shown in Attachment 1.

CJH

Attachment 1 – Predicted Sound Pressure Levels

Memorandum

Attachment 1 – Predicted Sound Pressure Levels

BURNS McDONNELL

Attachment 1 - Modeling Results

Attachment 2-13

GE 3.8-137, 110 m

Receiver	Coordinates Easting (m)	Coordinates Northing (m)	Base Elevation (m)	Modeled LAeq	Exceed 45 dBA? (Y/N)
REC-001	583178.93	4781949.36	473.94	24.7	N
REC-002	578731.00	4782428.97	540.99	36.9	N
REC-003	580506.89	4783273.92	505.27	34.0	N
REC-004	582678.66	4780104.52	480.03	32.4	N
REC-005	583326.78	4778396.84	476.81	27.5	N
REC-006	583615.28	4778695.43	471.94	26.2	N
REC-007	579386.45	4783171.84	519.65	34.2	N
REC-008	579364.54	4780122.78	515.18	38.6	N
REC-009	582485.70	4779597.03	481.47	34.3	N
REC-010	570706.40	4779232.69	531.85	30.6	N
REC-011	568954.92	4779049.93	516.88	23.0	N
REC-012	575450.96	4778869.67	571.47	43.8	N
REC-013	570834.43	4777923.92	539.22	34.9	N
REC-014	578568.31	4777265.47	526.35	38.3	N
REC-015	578578.94	4777228.45	526.13	38.5	N
REC-016	569437.95	4774776.35	523.53	38.9	N
REC-017	567999.72	4773683.50	489.60	36.8	N
REC-018	575893.85	4773069.05	525.25	32.5	N
REC-019	568870.35	4772837.61	510.51	36.3	N
REC-020	568170.58	4772373.09	491.63	30.5	N
REC-021	574122.73	4771641.66	507.46	35.0	N
REC-022	574117.98	4771913.43	508.31	34.7	N
REC-023	567115.19	4771132.04	470.89	-	N
REC-024	569455.79	4770885.60	499.55	34.2	N
REC-025	582409.59	4770691.28	486.10	26.3	N
REC-026	582205.90	4770538.43	489.18	27.7	N
REC-027	569450.78	4770122.57	499.25	32.0	N
REC-028	578915.96	4770106.59	519.65	30.5	N
REC-029	567890.47	4769896.98	472.42	19.1	N
REC-030	574057.84	4769738.20	530.58	35.9	N
REC-031	571038.40	4769099.63	510.51	36.6	N
REC-032	579594.58	4768433.69	507.46	40.2	N
REC-033	574388.42	4768112.11	502.26	29.5	N
REC-034	575856.91	4767968.51	509.35	34.3	N
REC-035	568988.11	4768088.17	487.50	27.6	N
REC-036	574139.54	4767903.27	507.06	28.6	N
REC-037	580534.75	4767955.77	497.42	40.6	N
REC-038	569570.52	4767693.73	493.87	33.1	N
REC-039	575753.59	4767511.52	511.25	33.5	N
REC-040	575853.92	4767408.85	513.56	34.3	N
REC-041	577365.54	4767429.45	496.85	41.4	N
REC-042	580534.93	4768649.62	501.93	40.0	N
REC-043	582314.18	4767105.01	476.98	30.8	N
REC-044	577581.91	4766535.38	501.37	35.6	N
REC-045	580459.53	4766528.35	495.27	37.9	N
REC-046	570892.00	4766384.10	500.34	39.9	N
REC-047	576071.91	4766099.10	511.58	28.5	N
REC-048	575888.47	4765484.03	507.46	26.2	N
REC-049	579136.06	4765003.57	501.37	36.3	N
REC-050	575594.26	4764877.78	513.56	22.9	N
REC-051	577014.96	4764806.12	483.08	32.6	N
REC-052	571034.71	4764976.49	483.08	32.4	N
REC-053	575751.76	4763553.72	504.89	18.1	N

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Attachment 1 - Modeling Results

Attachment 2-13

GE 3.8-137, 110 m

Receiver	Coordinates Easting (m)	Northing (m)	Base Elevation (m)	Modeled LAeq	Exceed 45 dBA? (Y/N)
REC-054	579261.02	4763508.83	493.92	26.2	N
REC-055	575738.19	4763383.18	501.37	18.7	N
REC-056	578784.40	4763423.45	495.27	26.8	N
REC-057	575728.70	4763020.56	496.19	-	N
REC-058	574689.98	4762905.51	489.18	-	N
REC-059	574608.88	4762765.31	484.23	-	N
REC-060	575719.36	4763758.78	507.46	19.6	N
REC-061	566590.17	4774005.26	470.89	25.5	N
REC-062	566794.52	4771446.01	467.84	-	N
REC-063	567575.59	4773523.26	480.49	32.1	N
REC-064	568169.85	4775221.75	493.83	37.5	N
REC-065	568402.45	4770548.21	483.08	24.8	N
REC-066	569474.73	4776605.15	525.75	39.1	N
REC-067	569782.41	4765373.88	493.98	36.1	N
REC-068	570301.18	4776152.11	533.82	36.3	N
REC-069	570320.63	4776086.07	530.62	36.4	N
REC-070	570930.65	4767169.47	502.79	37.7	N
REC-071	571246.87	4765598.42	488.81	38.5	N
REC-072	571847.73	4767001.23	507.46	41.7	N
REC-073	572712.41	4764371.30	476.98	25.2	N
REC-074	572760.45	4768609.65	494.96	35.3	N
REC-075	572875.14	4775183.93	528.80	39.5	N
REC-076	573023.77	4775137.74	528.80	39.9	N
REC-077	573104.39	4767558.79	488.61	31.1	N
REC-078	572689.83	4764269.58	472.84	24.7	N
REC-079	572840.24	4766532.05	483.08	35.8	N
REC-080	574527.24	4771635.20	508.86	34.0	N
REC-081	574606.23	4772084.46	513.56	34.0	N
REC-082	575265.41	4775117.32	552.59	41.9	N
REC-083	575384.42	4771695.61	513.56	32.3	N
REC-084	575459.57	4773771.95	533.47	39.2	N
REC-085	576210.31	4770611.18	524.57	38.1	N
REC-086	576537.52	4765598.06	498.89	30.2	N
REC-087	576971.43	4770447.24	531.85	40.8	N
REC-088	577659.69	4765661.22	489.18	38.1	N
REC-089	577747.37	4768859.92	513.80	40.5	N
REC-090	577878.24	4764078.53	490.80	32.8	N
REC-091	577915.85	4763844.06	489.18	30.5	N
REC-092	578531.67	4767119.28	501.56	37.6	N
REC-093	578575.67	4778618.52	525.75	37.4	N
REC-094	578514.65	4776677.36	519.65	38.0	N
REC-095	578804.05	4764274.93	501.37	32.8	N
REC-096	578827.98	4768793.31	520.74	37.4	N
REC-097	578943.49	4770454.51	519.65	29.0	N
REC-098	579475.34	4767289.07	507.32	40.3	N
REC-099	579720.64	4762441.83	480.38	-	N
REC-100	580720.17	4765706.10	489.18	32.2	N
REC-101	580991.94	4762540.89	476.98	-	N
REC-102	581560.41	4763175.20	470.14	-	N
REC-103	581721.12	4767420.32	484.05	35.9	N
REC-104	581794.35	4770381.50	494.21	30.1	N
REC-105	581890.50	4769063.10	495.27	40.1	N
REC-106	581882.94	4766984.50	478.66	32.1	N

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Attachment 1 - Modeling Results

Attachment 2-13

GE 3.8-137, 110 m

Receiver	Coordinates Easting (m)	Coordinates Northing (m)	Base Elevation (m)	Modeled LAeq	Exceed 45 dBA? (Y/N)
REC-107	582089.90	4770568.08	488.75	27.9	N
REC-108	582148.44	4764102.27	470.89	-	N
REC-109	582609.65	4767582.94	483.08	31.6	N
REC-110	583963.39	4770430.23	460.42	18.2	N
REC-111	582577.80	4767332.36	480.99	30.7	N
REC-112	570034.28	4777428.88	531.85	34.8	N
REC-113	580225.65	4778670.25	516.61	41.3	N
REC-114	580643.69	4779065.86	510.51	40.5	N
REC-115	580812.98	4776797.89	507.54	39.5	N
REC-116	581676.22	4775653.66	495.49	37.4	N
REC-117	579367.75	4775404.23	525.75	36.8	N
REC-118	580095.28	4784336.60	507.46	29.1	N
REC-119	581867.73	4783246.46	489.52	29.7	N
REC-120	582410.57	4781467.20	486.13	30.9	N
REC-121	582256.16	4783054.99	483.20	28.4	N
REC-122	582261.38	4777793.15	487.45	33.8	N
REC-123	581460.71	4785645.95	483.97	-	N
REC-124	577505.30	4781336.06	557.16	44.0	N
REC-125	580995.88	4773976.31	501.99	29.4	N
REC-126	580915.69	4774830.29	502.29	38.6	N
REC-127	581473.61	4775075.61	495.27	37.0	N
REC-128	581468.21	4774997.26	495.27	36.4	N
REC-129	576815.58	4779814.18	556.23	46.3	Y
REC-130	567502.00	4781060.00	502.37	-	N
REC-131	568850.00	4781446.00	523.04	-	N
REC-132	570408.00	4783811.00	527.44	22.5	N
REC-133	570806.00	4783497.00	538.25	24.9	N
REC-134	570845.00	4782153.00	543.29	30.2	N
REC-135	573665.00	4780153.00	564.37	42.6	N
REC-136	579049.00	4772150.00	519.65	-	N
REC-137	579104.00	4772978.00	519.65	17.9	N
REC-138	573105.45	4772224.12	513.56	37.1	N
Schoenfelder House	569781.24	4772133.60	510.51	35.5	N
Gramkow-Vesper Cemetery	580689.30	4768952.27	507.46	43.2	N

"-" represents no expected impacts at the receiver location

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Attachment 1 - Modeling Results

Attachment 2-13

Beethoven Only

Receiver	Coordinates Easting (m)	Coordinates Northing (m)	Base Elevation (m)	Modeled LAeq	Exceed 45 dBA? (Y/N)
REC-001	583178.93	4781949.36	473.94	-	N
REC-002	578731.00	4782428.97	540.99	36.1	N
REC-003	580506.89	4783273.92	505.27	22.3	N
REC-004	582678.66	4780104.52	480.03	-	N
REC-005	583326.78	4778396.84	476.81	-	N
REC-006	583615.28	4778695.43	471.94	-	N
REC-007	579386.45	4783171.84	519.65	32.3	N
REC-008	579364.54	4780122.78	515.18	27.6	N
REC-009	582485.70	4779597.03	481.47	-	N
REC-010	570706.40	4779232.69	531.85	30.2	N
REC-011	568954.92	4779049.93	516.88	-	N
REC-012	575450.96	4778869.67	571.47	43.8	N
REC-013	570834.43	4777923.92	539.22	34.0	N
REC-014	578568.31	4777265.47	526.35	25.7	N
REC-015	578578.94	4777228.45	526.13	25.5	N
REC-016	569437.95	4774776.35	523.53	-	N
REC-017	567999.72	4773683.50	489.60	-	N
REC-018	575893.85	4773069.05	525.25	-	N
REC-019	568870.35	4772837.61	510.51	-	N
REC-020	568170.58	4772373.09	491.63	-	N
REC-021	574122.73	4771641.66	507.46	-	N
REC-022	574117.98	4771913.43	508.31	-	N
REC-023	567115.19	4771132.04	470.89	-	N
REC-024	569455.79	4770885.60	499.55	-	N
REC-025	582409.59	4770691.28	486.10	-	N
REC-026	582205.90	4770538.43	489.18	-	N
REC-027	569450.78	4770122.57	499.25	-	N
REC-028	578915.96	4770106.59	519.65	-	N
REC-029	567890.47	4769896.98	472.42	-	N
REC-030	574057.84	4769738.20	530.58	-	N
REC-031	571038.40	4769099.63	510.51	-	N
REC-032	579594.58	4768433.69	507.46	-	N
REC-033	574388.42	4768112.11	502.26	-	N
REC-034	575856.91	4767968.51	509.35	-	N
REC-035	568988.11	4768088.17	487.50	-	N
REC-036	574139.54	4767903.27	507.06	-	N
REC-037	580534.75	4767955.77	497.42	-	N
REC-038	569570.52	4767693.73	493.87	-	N
REC-039	575753.59	4767511.52	511.25	-	N
REC-040	575853.92	4767408.85	513.56	-	N
REC-041	577365.54	4767429.45	496.85	-	N
REC-042	580534.93	4768649.62	501.93	-	N
REC-043	582314.18	4767105.01	476.98	-	N
REC-044	577581.91	4766535.38	501.37	-	N
REC-045	580459.53	4766528.35	495.27	-	N
REC-046	570892.00	4766384.10	500.34	-	N
REC-047	576071.91	4766099.10	511.58	-	N
REC-048	575888.47	4765484.03	507.46	-	N
REC-049	579136.06	4765003.57	501.37	-	N
REC-050	575594.26	4764877.78	513.56	-	N
REC-051	577014.96	4764806.12	483.08	-	N
REC-052	571034.71	4764976.49	483.08	-	N
REC-053	575751.76	4763553.72	504.89	-	N
REC-054	579261.02	4763508.83	493.92	-	N

BURNS McDONNELL

Attachment 1 - Modeling Results

Attachment 2-13

Beethoven Only

Receiver	Coordinates Easting (m)	Coordinates Northing (m)	Base Elevation (m)	Modeled LAeq	Exceed 45 dBA? (Y/N)
REC-055	575738.19	4763383.18	501.37	-	N
REC-056	578784.40	4763423.45	495.27	-	N
REC-057	575728.70	4763020.56	496.19	-	N
REC-058	574689.98	4762905.51	489.18	-	N
REC-059	574608.88	4762765.31	484.23	-	N
REC-060	575719.36	4763758.78	507.46	-	N
REC-061	566590.17	4774005.26	470.89	-	N
REC-062	566794.52	4771446.01	467.84	-	N
REC-063	567575.59	4773523.26	480.49	-	N
REC-064	568169.85	4775221.75	493.83	-	N
REC-065	568402.45	4770548.21	483.08	-	N
REC-066	569474.73	4776605.15	525.75	23.0	N
REC-067	569782.41	4765373.88	493.98	-	N
REC-068	570301.18	4776152.11	533.82	26.7	N
REC-069	570320.63	4776086.07	530.62	26.5	N
REC-070	570930.65	4767169.47	502.79	-	N
REC-071	571246.87	4765598.42	488.81	-	N
REC-072	571847.73	4767001.23	507.46	-	N
REC-073	572712.41	4764371.30	476.98	-	N
REC-074	572760.45	4768609.65	494.96	-	N
REC-075	572875.14	4775183.93	528.80	28.7	N
REC-076	573023.77	4775137.74	528.80	28.4	N
REC-077	573104.39	4767558.79	488.61	-	N
REC-078	572689.83	4764269.58	472.84	-	N
REC-079	572840.24	4766532.05	483.08	-	N
REC-080	574527.24	4771635.20	508.86	-	N
REC-081	574606.23	4772084.46	513.56	-	N
REC-082	575265.41	4775117.32	552.59	-	N
REC-083	575384.42	4771695.61	513.56	-	N
REC-084	575459.57	4773771.95	533.47	-	N
REC-085	576210.31	4770611.18	524.57	-	N
REC-086	576537.52	4765598.06	498.89	-	N
REC-087	576971.43	4770447.24	531.85	-	N
REC-088	577659.69	4765661.22	489.18	-	N
REC-089	577747.37	4768859.92	513.80	-	N
REC-090	577878.24	4764078.53	490.80	-	N
REC-091	577915.85	4763844.06	489.18	-	N
REC-092	578531.67	4767119.28	501.56	-	N
REC-093	578575.67	4778618.52	525.75	29.5	N
REC-094	578514.65	4776677.36	519.65	20.9	N
REC-095	578804.05	4764274.93	501.37	-	N
REC-096	578827.98	4768793.31	520.74	-	N
REC-097	578943.49	4770454.51	519.65	-	N
REC-098	579475.34	4767289.07	507.32	-	N
REC-099	579720.64	4762441.83	480.38	-	N
REC-100	580720.17	4765706.10	489.18	-	N
REC-101	580991.94	4762540.89	476.98	-	N
REC-102	581560.41	4763175.20	470.14	-	N
REC-103	581721.12	4767420.32	484.05	-	N
REC-104	581794.35	4770381.50	494.21	-	N
REC-105	581890.50	4769063.10	495.27	-	N
REC-106	581882.94	4766984.50	478.66	-	N
REC-107	582089.90	4770568.08	488.75	-	N
REC-108	582148.44	4764102.27	470.89	-	N

BURNS McDONNELL

Attachment 1 - Modeling Results

Attachment 2-13

Beethoven Only

Receiver	Coordinates Easting (m)	Northing (m)	Base Elevation (m)	Modeled LAeq	Exceed 45 dBA? (Y/N)
REC-109	582609.65	4767582.94	483.08	-	N
REC-110	583963.39	4770430.23	460.42	-	N
REC-111	582577.80	4767332.36	480.99	-	N
REC-112	570034.28	4777428.88	531.85	28.3	N
REC-113	580225.65	4778670.25	516.61	-	N
REC-114	580643.69	4779065.86	510.51	-	N
REC-115	580812.98	4776797.89	507.54	-	N
REC-116	581676.22	4775653.66	495.49	-	N
REC-117	579367.75	4775404.23	525.75	-	N
REC-118	580095.28	4784336.60	507.46	26.8	N
REC-119	581867.73	4783246.46	489.52	-	N
REC-120	582410.57	4781467.20	486.13	-	N
REC-121	582256.16	4783054.99	483.20	-	N
REC-122	582261.38	4777793.15	487.45	-	N
REC-123	581460.71	4785645.95	483.97	-	N
REC-124	577505.30	4781336.06	557.16	44.0	N
REC-125	580995.88	4773976.31	501.99	-	N
REC-126	580915.69	4774830.29	502.29	-	N
REC-127	581473.61	4775075.61	495.27	-	N
REC-128	581468.21	4774997.26	495.27	-	N
REC-129	576815.58	4779814.18	556.23	46.2	Y
REC-130	567502.00	4781060.00	502.37	-	N
REC-131	568850.00	4781446.00	523.04	-	N
REC-132	570408.00	4783811.00	527.44	22.5	N
REC-133	570806.00	4783497.00	538.25	24.9	N
REC-134	570845.00	4782153.00	543.29	30.2	N
REC-135	573665.00	4780153.00	564.37	42.6	N
REC-136	579049.00	4772150.00	519.65	-	N
REC-137	579104.00	4772978.00	519.65	-	N
REC-138	573105.45	4772224.12	513.56	-	N
Schoenfelder House	569781.24	4772133.60	510.51	-	N
Gramkow-Vesper Cemetery	580689.30	4768952.27	507.46	-	N

"-" represents no expected impacts at the receiver location

Attachment 2-15

From:	Ben Evans
To:	mark.maroney@northwestern.com; kirt.mayson@northwestern.com
Subject:	MAS Stations WNEY412 & WQON219
Date:	Tuesday, August 28, 2018 2:05:43 PM
Attachments:	WNEY412-WQON219 Google Maps.pdf

Re: Proposed Prevailing Wind Park Project in Southeast South Dakota

Dear FCC Licensee,

This letter is written in order to comply with a request from the South Dakota Public Utilities Commission (SD PUC) to contact FCC licensees of Multiple Address System (MAS) radio station transmitters located in or near a planned wind energy facility. Your MAS station master sites, call signs WNEY412 and WQON219, have been determined to be located roughly in the center of a wind turbine farm to be constructed by Prevailing Wind Park, LLC.

An application was recently submitted to the SD PUC for a facility permit for the Prevailing Wind Park project to be constructed between the communities of Tripp and Dante, in southeast South Dakota. The center of the project area is near the point where the counties of Bon Homme, Charles Mix and Hutchinson meet. It is proposed to construct 57 wind turbines, each with a maximum capacity of up to 3.8 megawatts. The turbine height will be 110 meters from ground to the blade hub and the length of the blades will be 68.5 meters (178.5 meters total height with one blade pointing straight upward).

The WNEY412 and WQON219 master sites, according to the FCC license, are 8.4 miles north of the community of Avon, on 294th Street, 0.33 mile east of 406th Avenue. Attached are two Google Earth maps showing the two MAS master sites and planned turbines surrounding them.

In addition to the turbines, the project will involve the construction of access roads, power generation collection lines and a collector substation.

As you may be aware, only the location of the master site of an MAS system is specified in the FCC license. The remote sites are not so specified. Thus, we were only able to ascertain the location of the master sites relative to the planned turbine sites. Although, interference to point-to-multipoint systems by wind turbines has generally not been a significant problem, it is appropriate to ascertain whether there would be turbine blockage between the master sites and any of the remote sites.

Regarding your FCC-licensed microwave paths in the area, we are aware that these paths need to be clear of planned turbines. We have plotted the Fresnel Zones of those paths on a GIS overlay to be used for turbine siting. If you would like a copy of the microwave impact report which shows no impact to your microwave paths, please contact me.

If you are concerned about potential harmful effects to your MAS system, please contact me (contact information below) to conduct a due diligence review. For this review, our due diligence team will require the geographic locations of all of the remote sites, which I trust you are willing to provide.

Thank you.

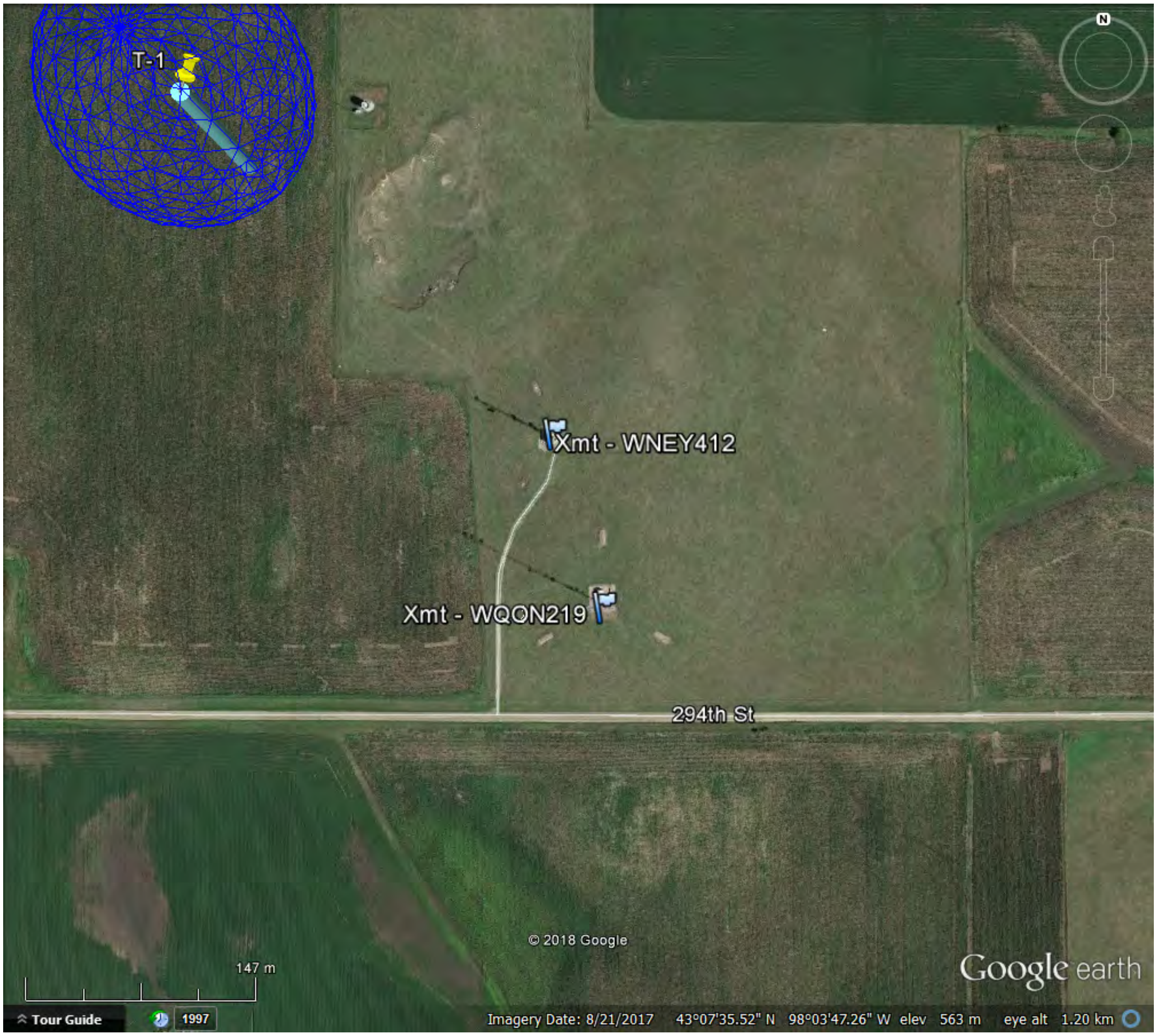
Regards,

B. Benjamin Evans
Engineering Consultant
Evans Engineering Solutions, LLC
524 Alta Loma Drive
Thiensville, WI, 53092
(262) 518-0178

Attachment 2-15

Google Map of WNEY412 & WQON219 MAS Sites

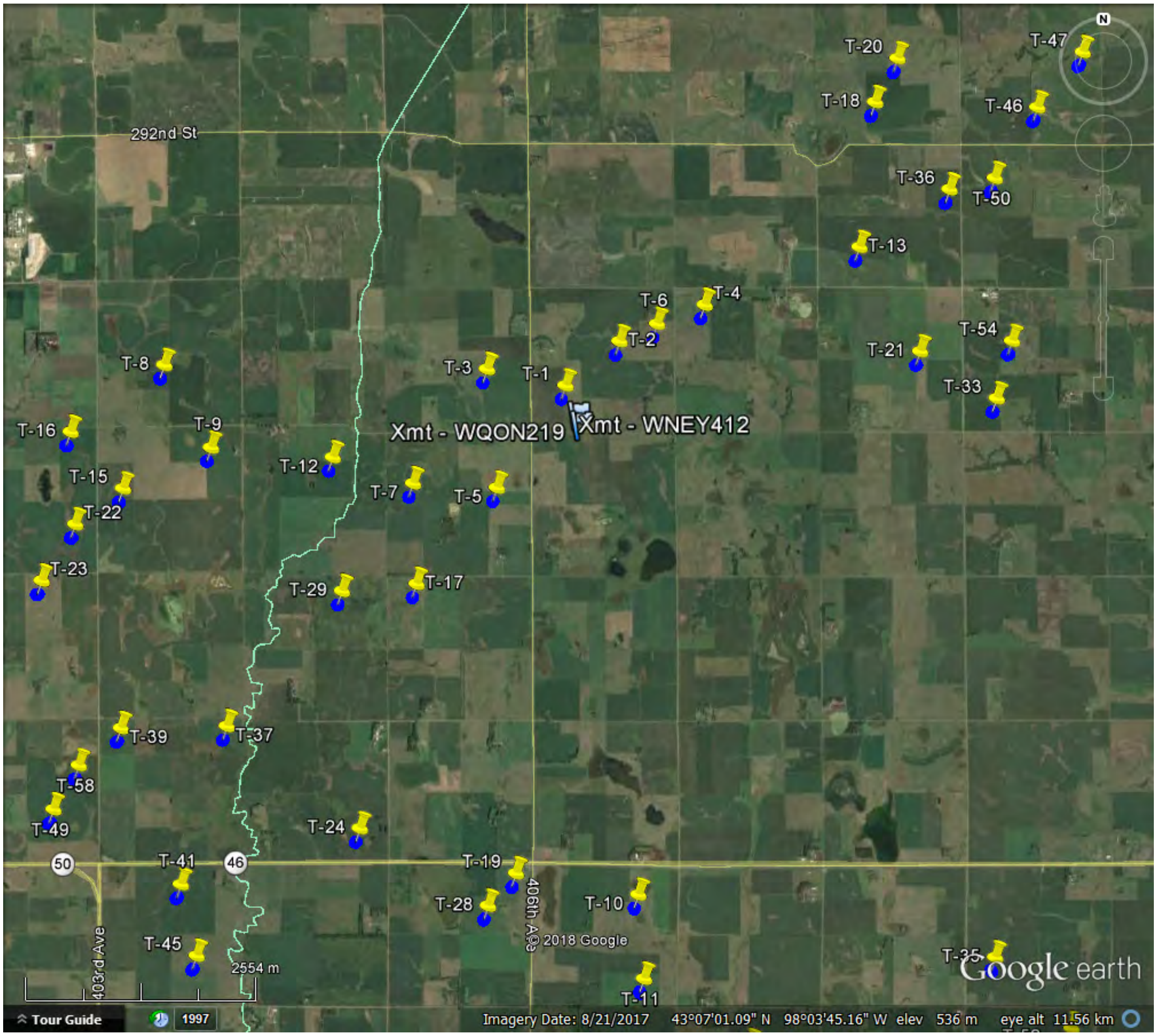
and Planned Nearby Turbine 1



Attachment 2-15

Google Map of WNEY412 & WQON219 MAS Sites

and Planned Surrounding Nearby Turbines



Attachment 2-15

From: Ben Evans
To: fcc-licensing@eastriver.coop
Subject: MAS Station WPND588
Date: Tuesday, August 28, 2018 2:30:57 PM
Attachments: WPND588 Google Maps.pdf

Re: Proposed Prevailing Wind Park Project in Southeast South Dakota

Dear FCC Licensee,

This letter is written in order to comply with a request from the South Dakota Public Utilities Commission (SD PUC) to contact FCC licensees of Multiple Address System (MAS) radio station transmitters located in or near a planned wind energy facility. Your MAS station master site, call sign WPND588, has been determined to be located roughly in the center of a wind turbine farm to be constructed by Prevailing Wind Park, LLC.

An application was recently submitted to the SD PUC for a facility permit for the Prevailing Wind Park project to be constructed between the communities of Tripp and Dante, in southeast South Dakota. The center of the project area is near the point where the counties of Bon Homme, Charles Mix and Hutchinson meet. It is proposed to construct 57 wind turbines, each with a maximum capacity of up to 3.8 megawatts. The turbine height will be 110 meters from ground to the blade hub and the length of the blades will be 68.5 meters (178.5 meters total height with one blade pointing straight upward).

The WPND588 master site, according to the FCC license, is 8.4 miles north of the community of Avon, on 294th Street, 0.33 mile east of 406th Avenue. Attached are two Google Earth maps showing the WPND588 master site and planned turbines surrounding it.

In addition to the turbines, the project will involve the construction of access roads, power generation collection lines and a collector substation.

As you may be aware, only the location of the master site of an MAS system is specified in the FCC license. The remote sites are not so specified. Thus, we were only able to ascertain the location of the master site relative to the planned turbine sites. Although, interference to point-to-multipoint systems by wind turbines has generally not been a significant problem, it is appropriate to ascertain whether there would be turbine blockage between the master site and any of the remote sites.

Regarding your FCC-licensed microwave paths in the area, we are aware that these paths need to be clear of planned turbines. We have plotted the Fresnel Zones of those paths on a GIS overlay to be used for turbine siting. If you would like a copy of the microwave impact report which shows no impact to your microwave paths, please contact me.

If you are concerned about potential harmful effects to your MAS system, please contact me (contact information below) to conduct a due diligence review. For this review, our due diligence team will require the geographic locations of all of the remote sites, which I trust you are willing to provide.

Thank you.

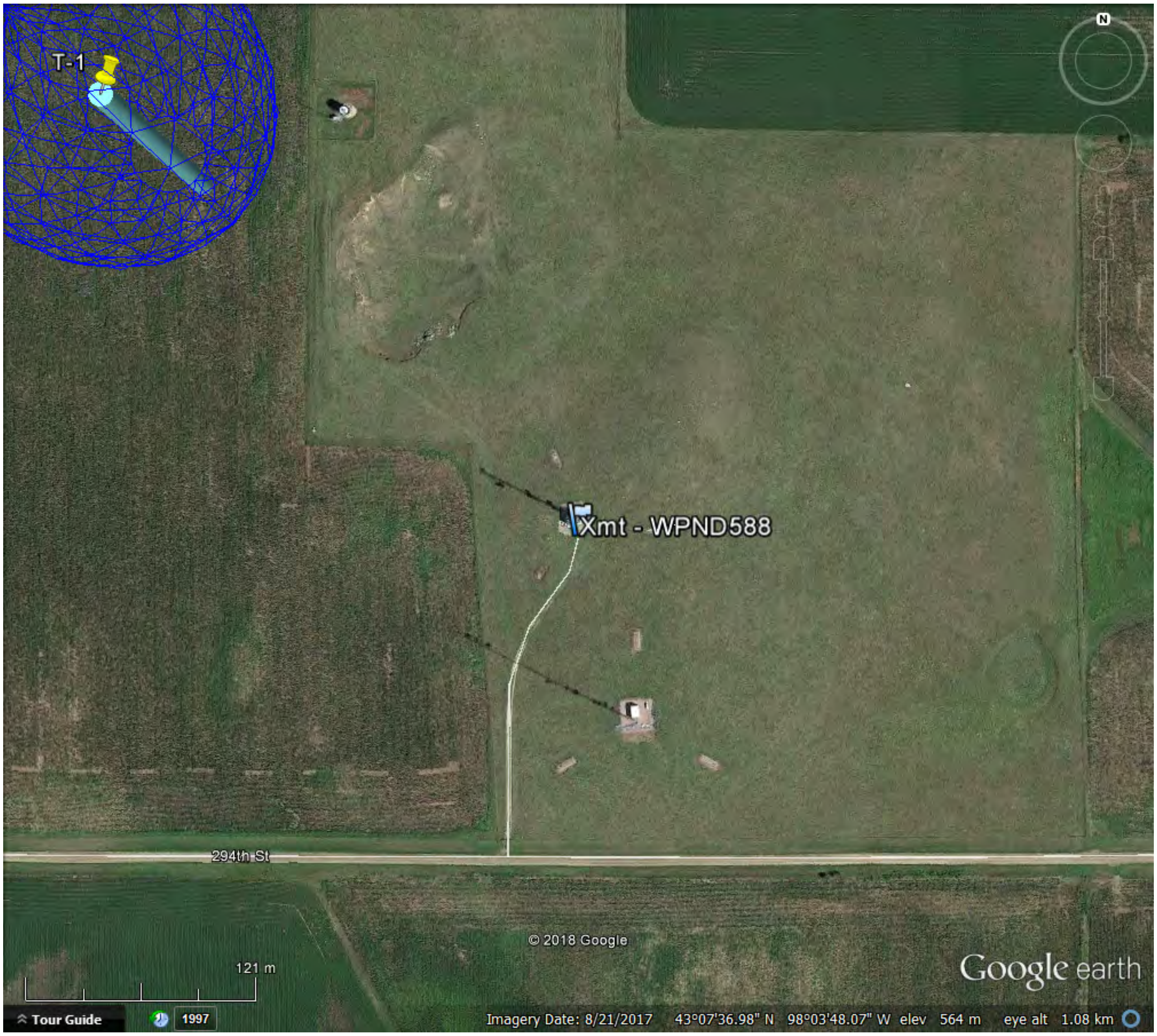
Regards,

B. Benjamin Evans
Engineering Consultant
Evans Engineering Solutions, LLC
524 Alta Loma Drive
Thiensville, WI, 53092
(262) 518-0178

Attachment 2-15

Google Map of WPND588 MAS Site

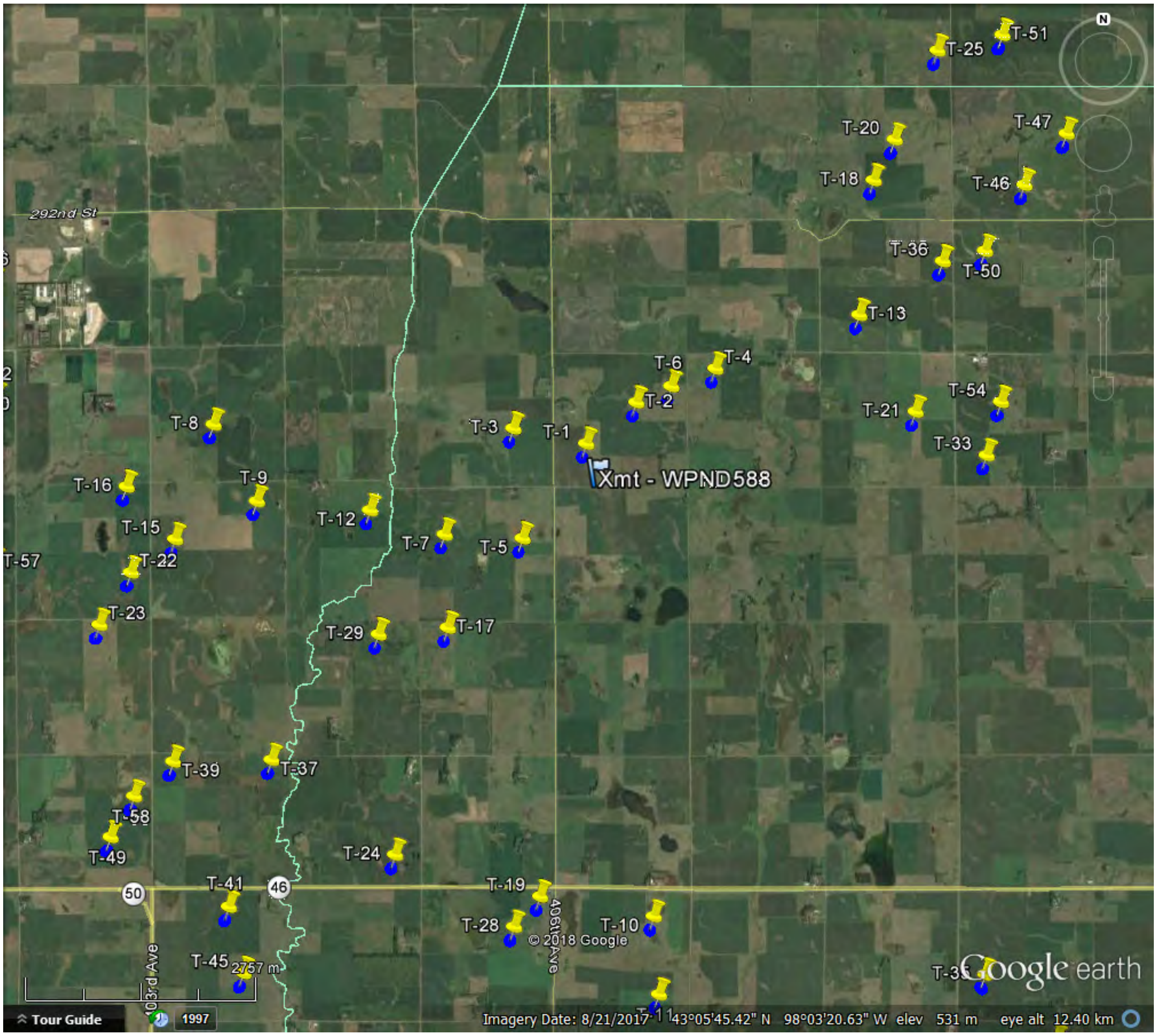
and Planned Nearby Turbine 1



Attachment 2-15

Google Map of WPND588 MAS Site

and Planned Surrounding Nearby Turbines



CHARLES MIX COUNTY
STATES ATTORNEY
PO BOX 370
LAKE ANDES, SOUTH DAKOTA 57356
605-487-7441

August 22, 2018

South Dakota Public Utilities Commission
500 East Capital Ave.
Pierre, SD 57501

RE: APPLICATION BY PREVAILING WIN PARK, LLC FOR A PERMIT OF WIND ENERTY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA FOR THE PREVAILING WIND EL 18-026

Dear SDPUC Commission:

This letter is to follow up the phone conversation we had concerning Charles Mix County, SD, and Keith Mushitz's notice of intervening party and the STATE'S FIRST SET OF DATA REQUESTS TO CHARLES MIX COUNTY

As I stated during that phone conversation, Charles Mix County by and through its Commission Chairman, Keith Mushitz, sought to be an intervening party in the above entitled action. In hind sight, I am not sure that was necessary. Applicant has met with the Charles Mix County Commission concerning its project and the concerns of that board Charles Mix County is presently not zoned. In these meetings, the Applicant listened to the county's concerns about parameters of the project. In the end, Applicant agreed to build the project in Charles Mix County in a manner that reflects the Commission's wishes, i.e., Tower Setbacks, Tower Noise (DB level), Shadow Flickering, etc.. The Applicant signed an Affidavit and provided the Commission with that document which outlines these commitments. A copy of that Affidavit is attached hereto.

Given that, the County's request to intervene was only to provide the SDPUC with notice this agreement, to provide the SDPUC with the parameters of the agreement and to request that the SDPUC consider implementing Charles Mix County parameters in the final permit, if given, to the Applicant.

Thus, Charles Mix County does not plan to take depositions, testify or present witnesses during the application process of Applicant. In fact, Charles Mix County has no intention of attending any of the hearings unless called upon.

Thank you very much for your office's guidance in helping Charles Mix County better understand the Application process.

Sincerely,

Scott J. Podhradsky
Deputy State's Attorney
Charles Mix County

Attachment 2-20

In the Matter of the Prevailing Wind Park Project in Charles Mix County, South Dakota

State of South Dakota)
) SS.
County of Charles Mix)

Affidavit of Peter Pawlowski

Peter C. Pawlowski, Vice President, Wind, Sustainable Power Group, LLC ("sPower") of the City of Salt Lake City, County of Salt Lake, State of Utah, being duly sworn on oath, deposes and states that the proposed Prevailing Wind Park will comply with the following requirements in Charles Mix County, South Dakota ("County"):

1. Prevailing Wind Park, LLC ("Prevailing Wind Park") is proposing to construct a wind energy system and associated facilities in Bon Homme, Charles Mix, Hutchinson and Yankton counties, South Dakota. As noted on its website, Basin Electric Power Cooperative has contracted to purchase the 200 megawatts of energy to be generated by the Project.[1] Up to 23 of the proposed turbines and associated facilities ("Project") would be located in Charles Mix County.

2. Prevailing Wind Park has been working cooperatively with the County to address questions regarding the Project.

3. Prevailing Wind Park is a wholly-owned subsidiary of sPower. In my position as Vice President, Wind, sPower, I am authorized to make commitments on behalf of Prevailing Wind Park.

4. Prevailing Wind Park hereby commits to the County Board of Commissioners that the Project will adhere to the following requirements:

   <u>Setbacks</u>.

   (a) Turbine tower distance from currently inhabited rural residence of a nonparticipating landowner shall be not less than three and a half (3.5) times the system height or two thousand feet (2,000) feet, whichever is greater. Turbine tower distance from the residence of the landowner on whose property the tower(s) are erected shall be not less than one thousand (1,000) feet.

   (b) Turbine tower distance from right-of-way of public roads shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater.

[1] https://www.basinelectric.com/About-Us/Organization/At-a-Glance/.

(c) Turbine tower distance from any property line shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater, unless a waiver has been obtained from adjoining property owner.

Noise. Noise from the wind turbines will not exceed 43 dBA at any existing nonparticipating residences and 45 dBA at existing participating residences, unless a signed waiver is obtained from the owner of the residence.

Shadow Flicker. Shadow flicker produced by the wind turbines will not exceed 30 hours per year and/or 30 minutes per day at currently inhabited residences of non-participants.

Lighting. The towers shall be lit using an Aircraft Detection Lighting System ("ADLS"), pending Federal Aviation Administration approval. The ADLS is designed to mitigate the impact of nighttime lights by deploying a radar-based system around a windfarm, turning lights on only when low-flying aircraft are detected nearby. The ADLS sends a signal to keep the light off until a plane is detected, then it stops sending the signal and the lights operate normally until the plane leaves the area and the off signal resumes.

Ice Detection. Prevailing Wind Park will use two methods to detect icing conditions on turbine blades: (1) sensors that will detect when blades become imbalanced or create vibration due to ice accumulation; and (2) meteorological data from on-site permanent meteorological towers, on-site anemometers, and other relevant meteorological sources that will be used to determine if ice accumulation is occurring. These control systems will either automatically shut down the turbine(s) in icing conditions (per the sensors) or Prevailing Wind Park will manually shut down turbine(s) if icing conditions are identified (using meteorological data). Turbines will not return to normal operation until the control systems no longer detect an imbalance or when weather conditions either remove icing on the blades or indicate icing is no longer a concern. Prevailing Wind Park will pay for any documented damage caused by ice thrown from a turbine

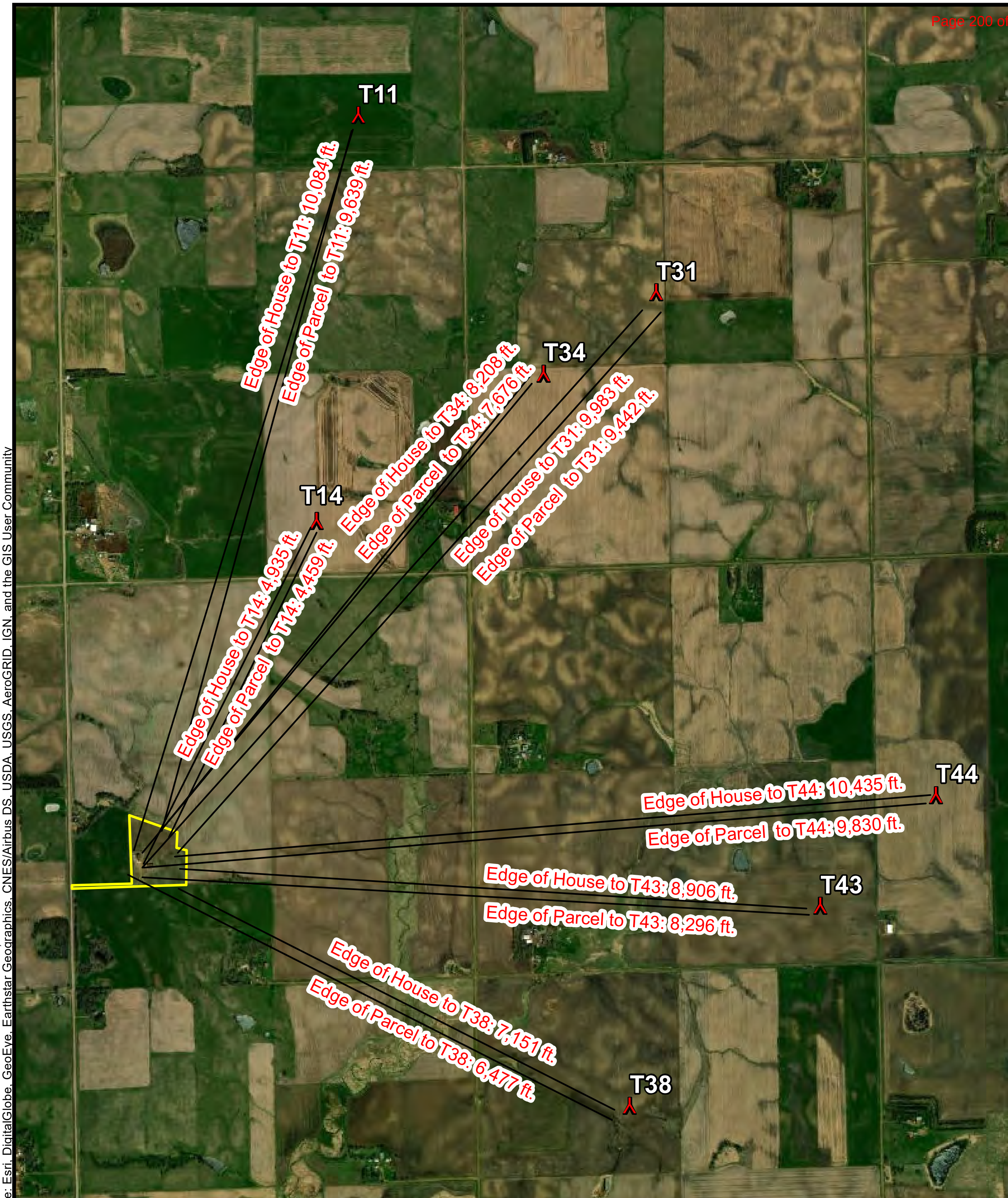
5. Prevailing Wind Park further commits to submitting this affidavit in the proceeding currently pending at the South Dakota Public Utilities Commission, *In the Matter of the Application by Prevailing Wind Park, LLC for a permit of a Wind Energy Facility in Bon Homme, Hutchinson and Charles Mix Counties*, Docket EL18-026.

Peter C. Pawlowski

Subscribed and sworn to before me this 9th day of August, 2018

Notary Public
Expires 4-19-2023

SEAL
SARA CLAYTON
Notary Public
SOUTH DAKOTA



Wind Turbine
Parcel Boundary

NORTH

1,700 850 0 1,700

Scale in Feet

BURNS McDONNELL

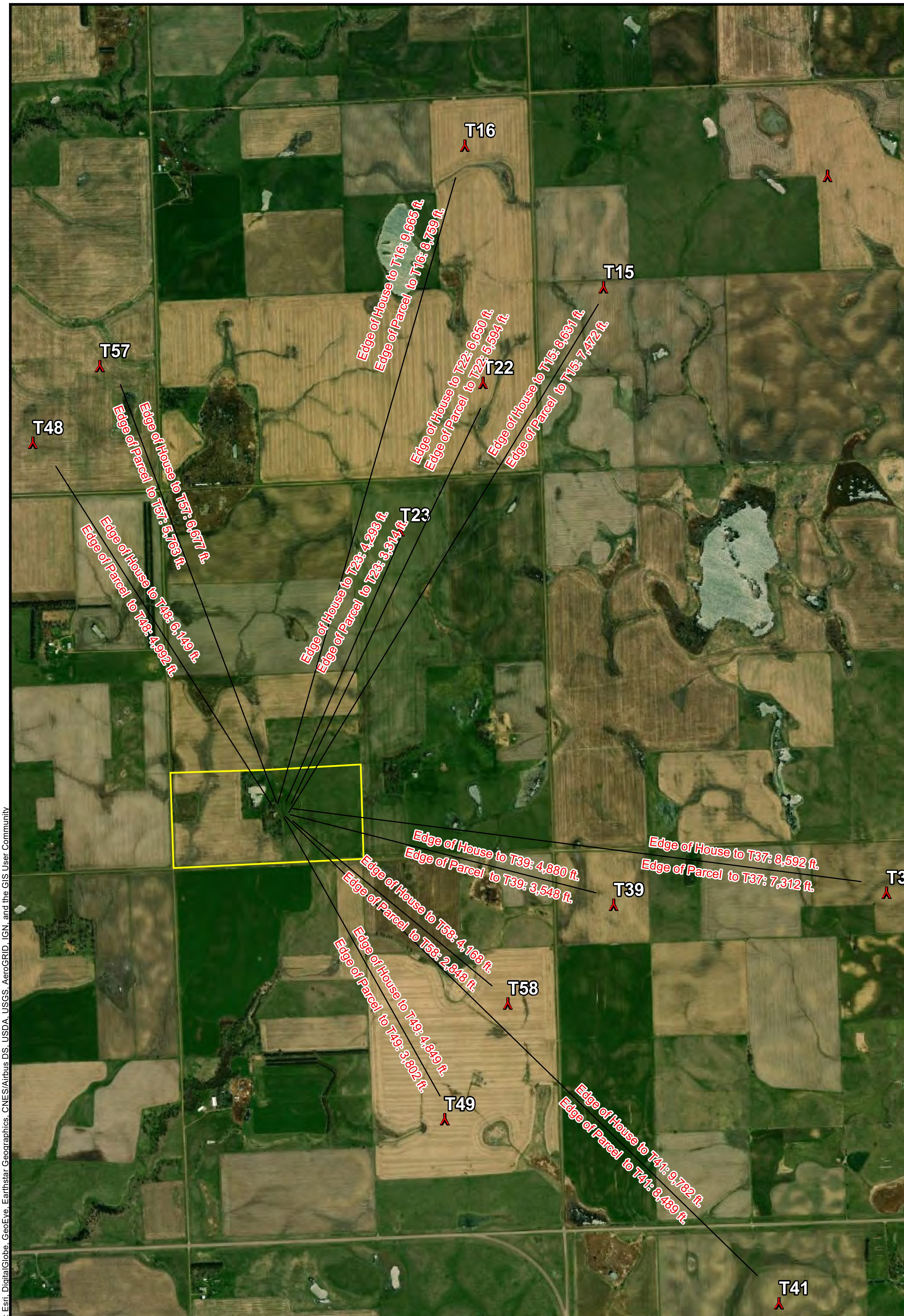
Hubner Residence
Bon Homme County
South Dakota

Path: Z:\Resources\Local\Clients\KCMIENS\SPowerGroup\104294_PrevailingWind\ArcGIS\Geospatial\DataFiles\ArcDocs\PUC Data Requests\HUBNER.mxd apwoehler 8/23/2018

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Source: ESRI, Burns & McDonnell, SPower

 Issued: 8/23/2018



Wind Turbine
Parcel Boundary

NORTH
1,240 620 0 1,240
Scale in Feet

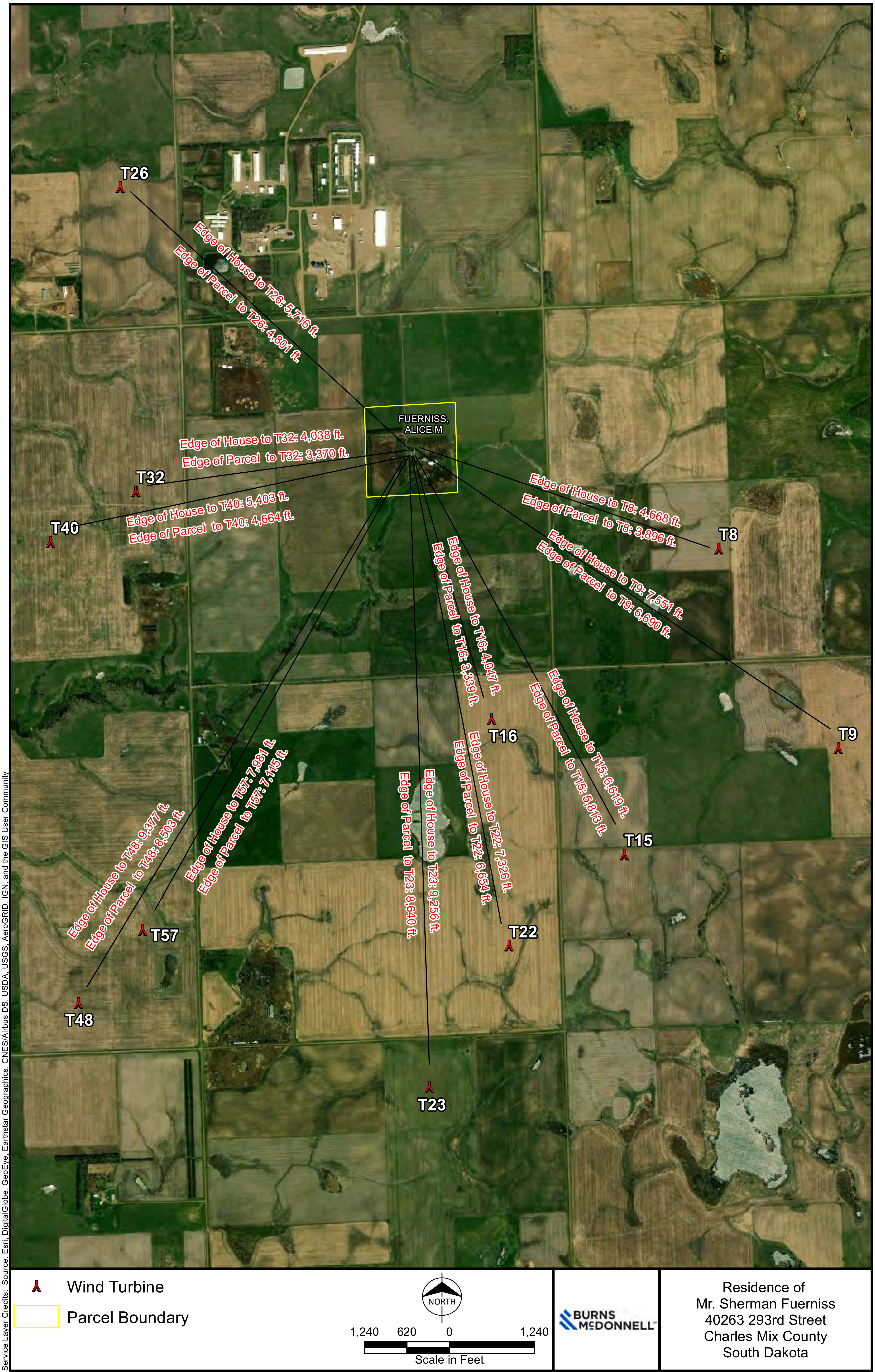
BURNS McDONNELL

Schoenfelder Residence
Charles Mix County
South Dakota

Path: Z:\Resources\Local\Clients\KCM\ENS\SPowerGroup\104294_PrevailingWind\ArcGIS\Geospatial\DataFiles\ArcDocs\PUC Data Requests\SCHOENFELDER2.mxd apwoehler 8/23/2018

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

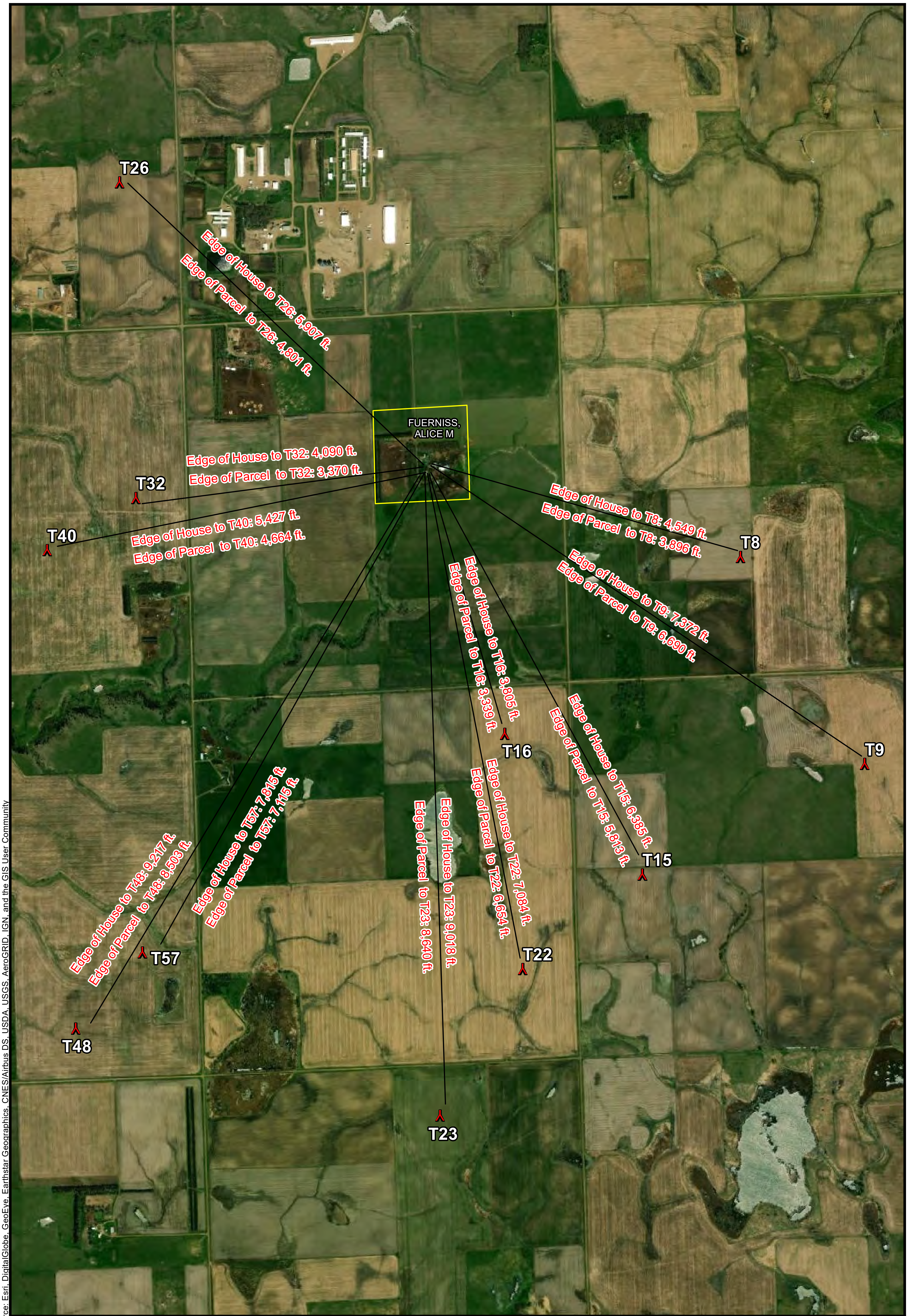
Source:
Issued: 8/23/2018



Residence of
Mr. Sherman Fuerniss
40263 293rd Street
Charles Mix County
South Dakota

Source:

Issued: 8/23/2018



Wind Turbine

Parcel Boundary

NORTH

1,240 620 0 1,240

Scale in Feet

BURNS McDONNELL

Residence of
Mr. Sherman Fuerniss
40265 293rd Street
Charles Mix County
South Dakota

Path: Z:\Resources\Local\Clients\KCM\ENS\SPowerGroup\104294_PrevailingWind\ArcGIS\Geospatial\DataFiles\ArcDocs\PUC Data Requests\Fuerniss_south.mxd apwoehler 8/23/2018

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Source:

Issued: 8/23/2018

BURNS McDONNELL

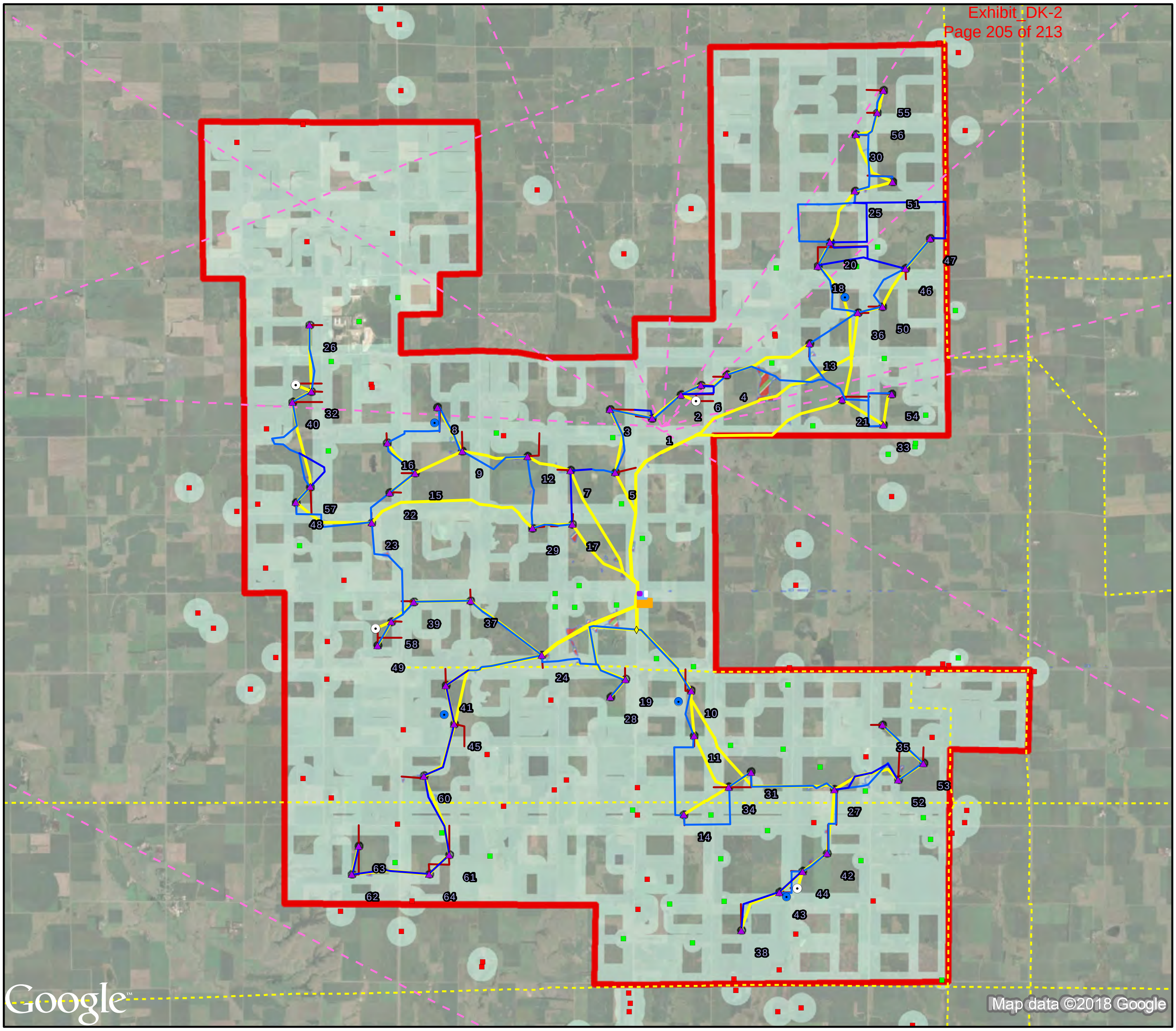
Residence of
Ms. Karen D. Jenkins
Hutchinson County
South Dakota

Path: Z:\Resources\Local\Clients\KCMIENS\SPowerGroup\104294_PrevailingWind\ArcGIS\Geospatial\DataFiles\ArcDocs\PUC Data Requests\Jenkins.mxd apwoehler 8/23/2018

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Source: ESRI, Burns & McDonnell, SPower

Issued: 8/23/2018



Multiple Counties, South Dakota

0 1 2 4 Miles

N

Prevailing Wind Park

Figure 1

Project Constraints Map (Overview)

Author: CIS

Date: 8/30/2018

Version: 1.0

Type: Exhibit

Proposed Facilities and Structures

- Preliminary Turbine Location
- Preliminary Permanent MET Tower
- Temporary MET Tower
- Junction Box
- Collection Line Paths
- Alternate Crane Path
- Primary Crane Path
- Turbine Access Roads
- Substation
- O&M Building
- O&M Grounds
- Laydown Yard

- Project Area Boundary
- 250 ft Micrositing Area

Existing Features

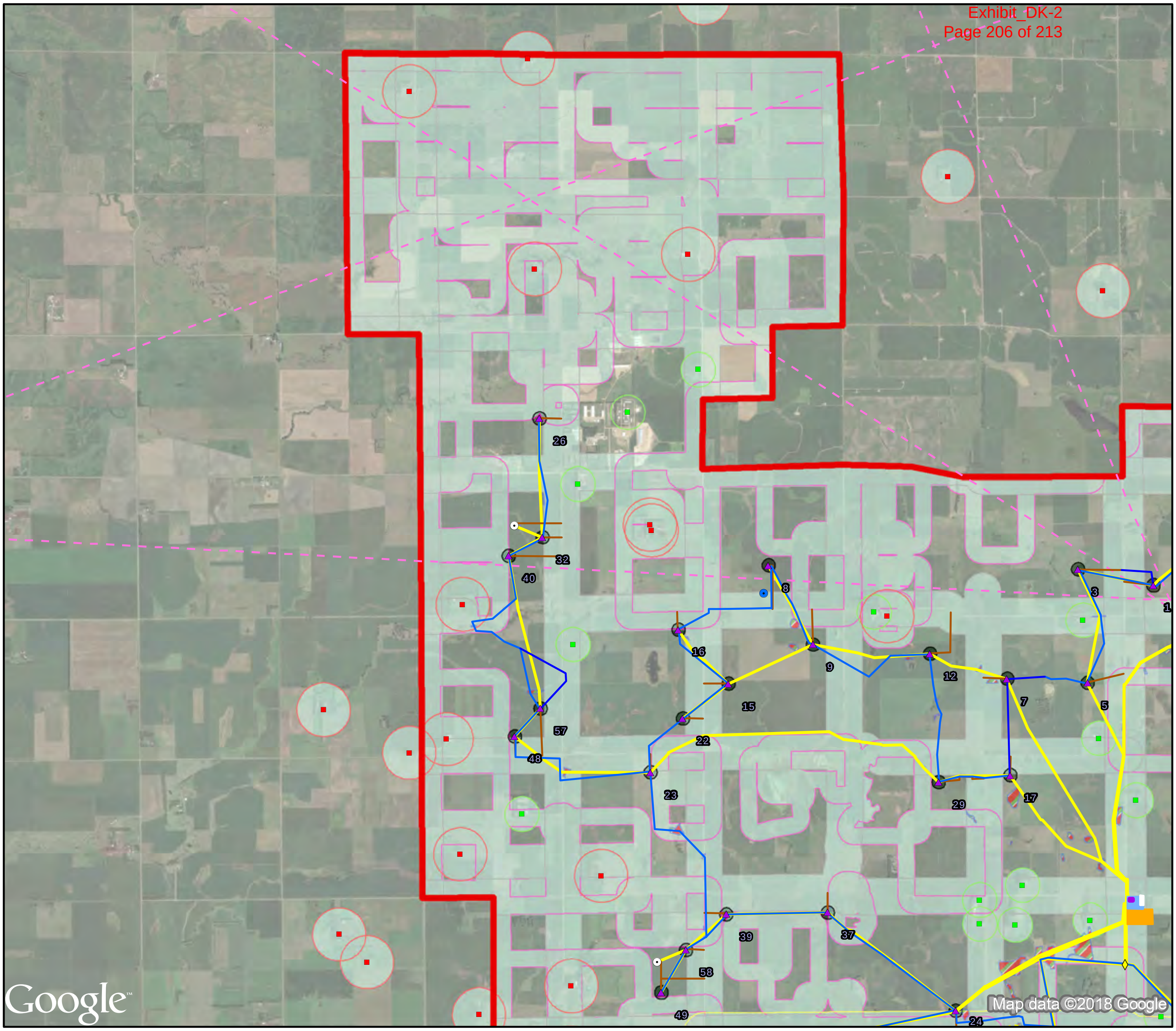
- Participating Residential Structures
- Non-Participating Residential Structures
- Existing Transmission
- Microwave Paths
- Wetland Area

Regulatory Setback Features

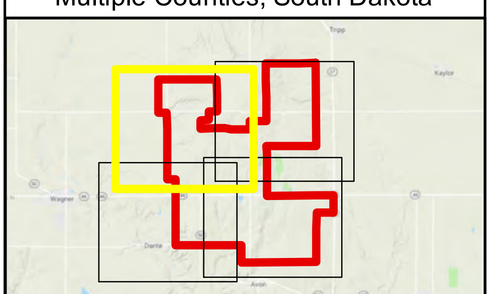
- Setbacks

Notes:
o 1. Turbines not drawn to scale
o 2. Turbine numbering is not sequential
o 3. Any turbine shifts within 250' will comply with 45 dBA noise setback and 30 hours per year shadow flicker guidance
o 4. Cultural Resource data is not included

S·POWER
An AES and AIMCo Company



Multiple Counties, South Dakota



0 0.5 1 2 Miles

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S·POWER
An AES and AIMCo Company

Prevailing Wind Park

Figure 1a

Project Constraints Map (Detailed)

Author: CIS
Date: 8/30/2018
Version: 1.0
Type: Exhibit

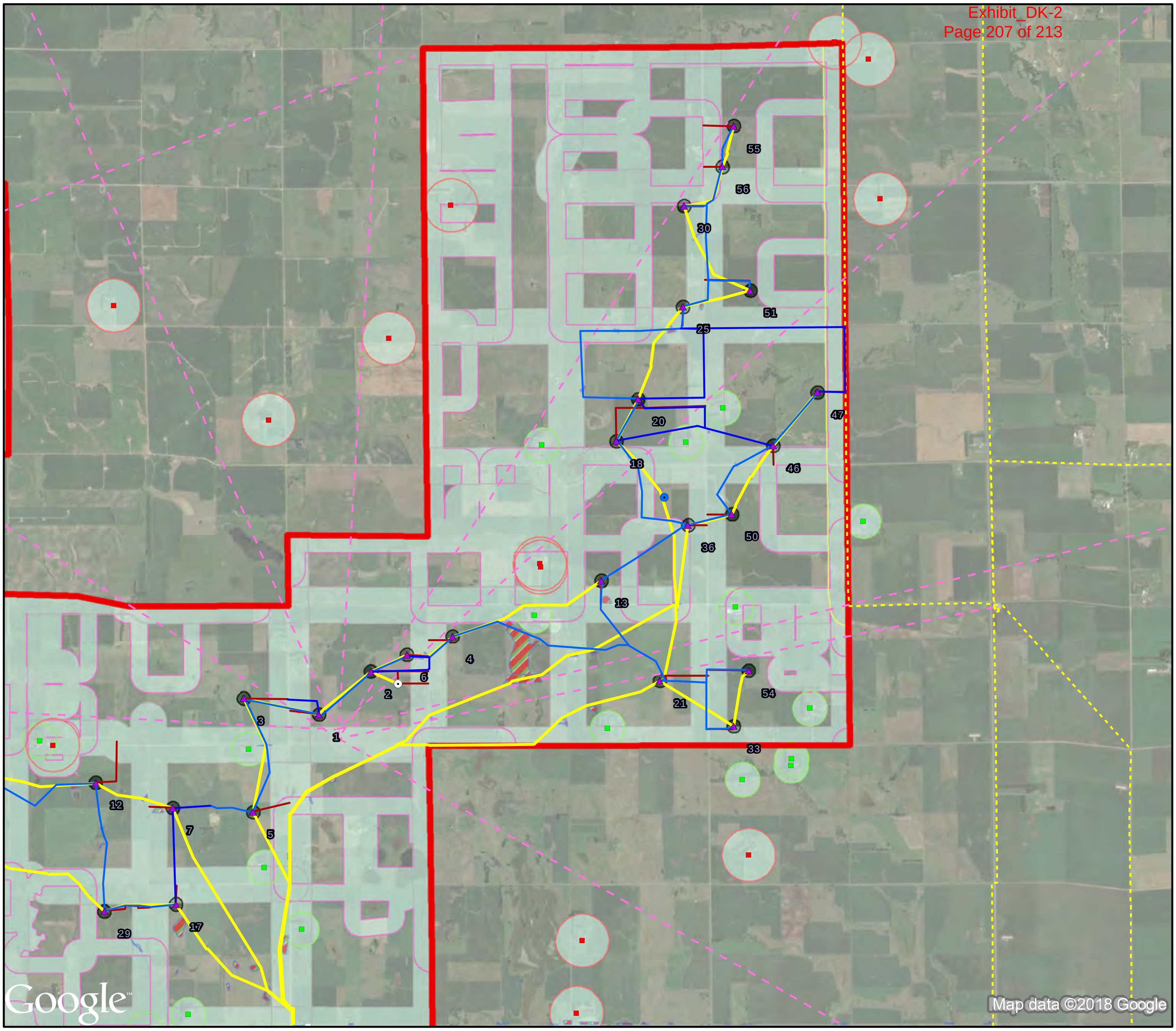
Proposed Facilities and Structures
- Preliminary Turbine Location
- Preliminary Permanent MET Tower
- Temporary MET Tower
- Junction Box
- Collection Line Paths
- Alternate Crane Path
- Primary Crane Path
- Turbine Access Roads
- Substation
- O&M Building
- O&M Grounds
- Laydown Yard

- Project Area Boundary
- 250 ft Micrositing Area

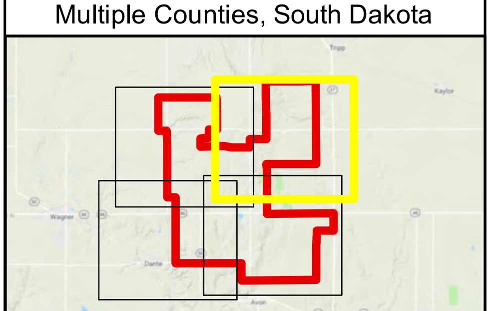
Existing Features
- Participating Residential Structures
- Non-Participating Residential Structures
- Existing Transmission
- Microwave Paths
- Wetland Area

Regulatory Setback Features
- Setbacks
- Public Roads (645 ft)
- Property Line (645 ft)
- Transmission Line (645 ft)
- Participating Residences (645 ft)
- Non-Participating Residences (1000 ft)

Notes:
- 1. Turbines not drawn to scale
- 2. Turbine numbering is not sequential
- 3. Any turbine shifts within 250' will comply with 45 dBA noise setback and 30 hours per year shadow flicker guidance
- 4. Cultural Resource data is not included



Multiple Counties, South Dakota



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Miles

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S·POWER
An AES and AIMCo Company

Prevailing Wind Park

Figure 1b

Project Constraints Map (Detailed)

Author: CIS
Date: 8/30/2018
Version: 1.0
Type: Exhibit

Proposed Facilities and Structures

- Preliminary Turbine Location
- Preliminary Permanent MET Tower
- Temporary MET Tower
- Junction Box
- Collection Line Paths
- Alternate Crane Path
- Primary Crane Path
- Turbine Access Roads
- Substation
- O&M Building
- O&M Grounds
- Laydown Yard

- Project Area Boundary
- 250 ft Micrositing Area

Existing Features

- Participating Residential Structures
- Non-Participating Residential Structures
- Existing Transmission
- Microwave Paths
- Wetland Area

Regulatory Setback Features

- Setbacks
- Public Roads (645 ft)
- Property Line (645 ft)
- Transmission Line (645 ft)
- Participating Residences (645 ft)
- Non-Participating Residences (1000 ft)

Notes:
o 1. Turbines not drawn to scale
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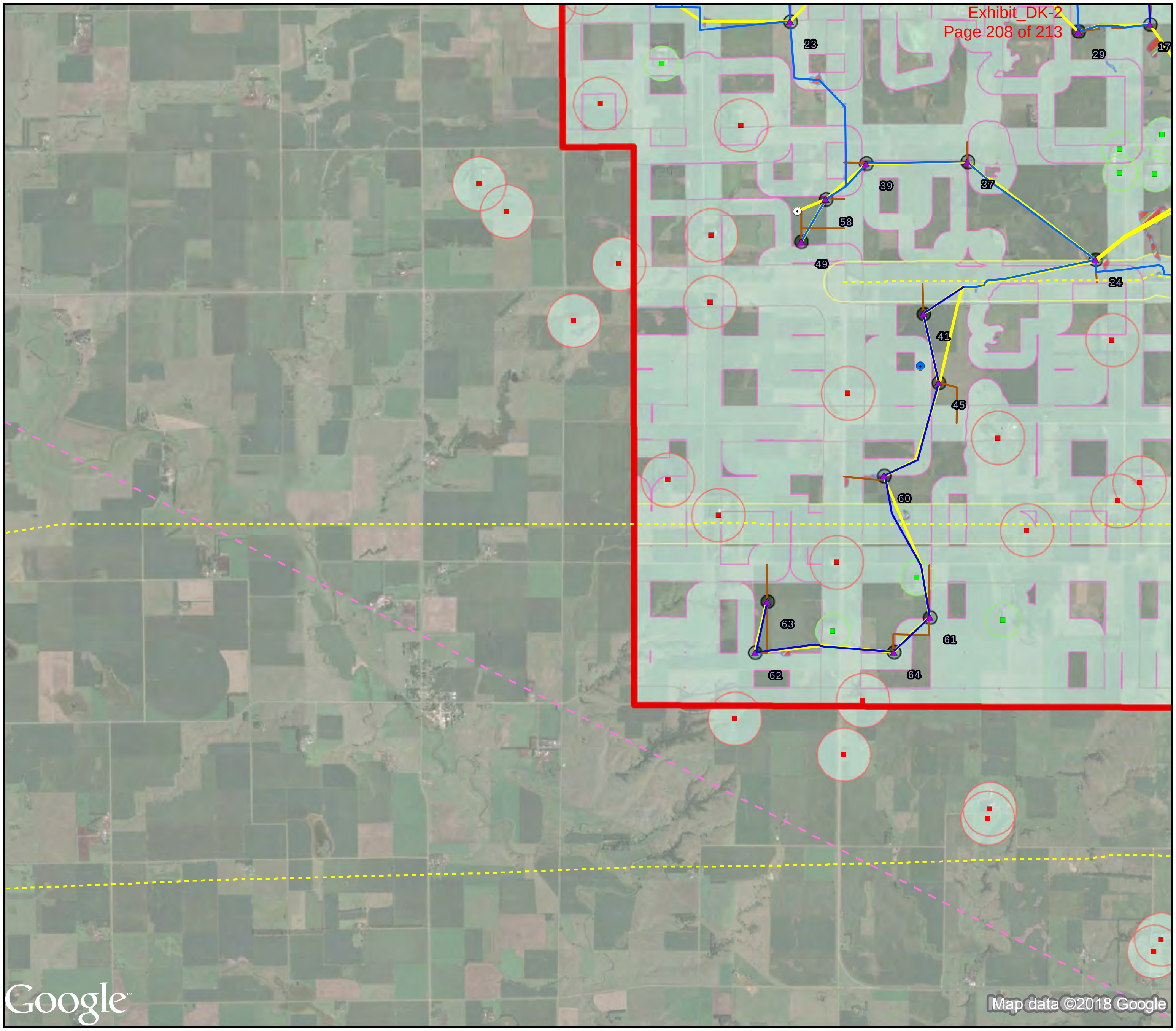
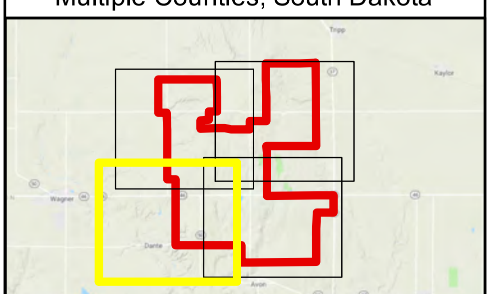
o 3. Any turbine shifts within 250' will comply with 45 dBA noise setback and 30 hours per year shadow flicker guidance
o 4. Cultural Resource data is not included



Multiple Counties, South Dakota



0 0.5 1 2 Miles

N

S·POWER
An AES and AIMCo Company

Prevailing Wind Park

Figure 1c

Project Constraints Map (Detailed)

Author: CIS
Date: 8/30/2018
Version: 1.0
Type: Exhibit

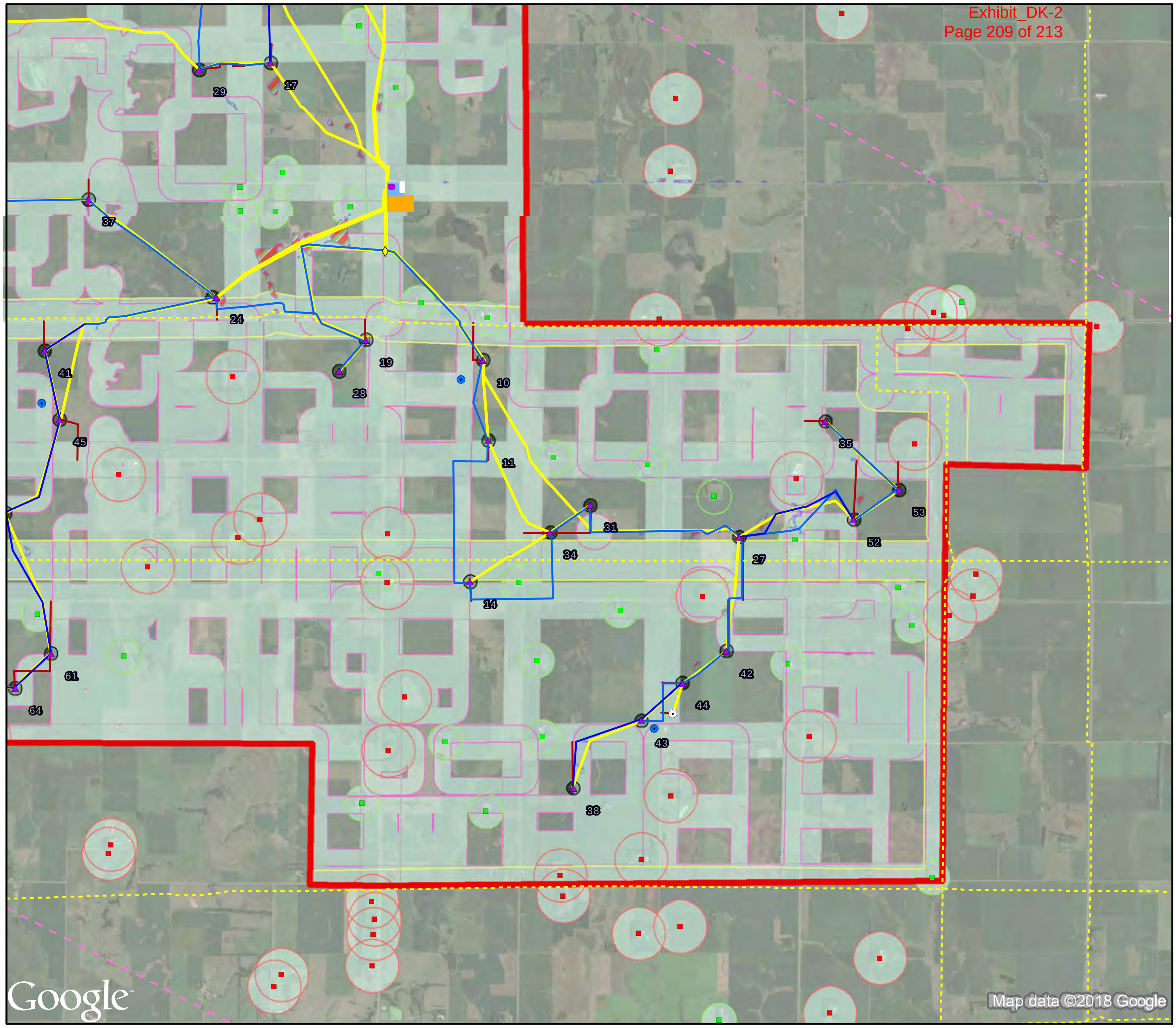
Proposed Facilities and Structures
- Preliminary Turbine Location
- Preliminary Permanent MET Tower
- Temporary MET Tower
- Junction Box
- Collection Line Paths
- Alternate Crane Path
- Primary Crane Path
- Turbine Access Roads
- Substation
- O&M Building
- O&M Grounds
- Laydown Yard

- Project Area Boundary
- 250 ft Micrositing Area

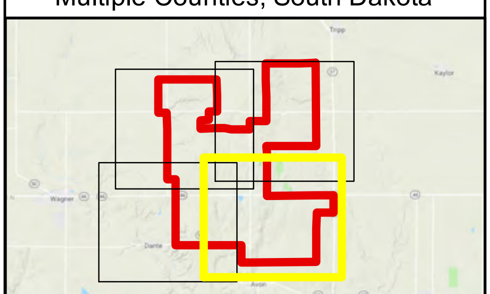
Existing Features
- Participating Residential Structures
- Non-Participating Residential Structures
- Existing Transmission
- Microwave Paths
- Wetland Area

Regulatory Setback Features
- Setbacks
- Public Roads (645 ft)
- Property Line (645 ft)
- Transmission Line (645 ft)
- Participating Residences (645 ft)
- Non-Participating Residences (1000 ft)

Notes:
o 1. Turbines not drawn to scale
o 2. Turbine numbering is not sequential
o 3. Any turbine shifts within 250' will comply with 45 dBA noise setback and 30 hours per year shadow flicker guidance
o 4. Cultural Resource data is not included



Multiple Counties, South Dakota



0 0.5 1 2 Miles

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S·POWER
An AES and AIMCo Company

Prevailing Wind Park

Figure 1d

Project Constraints Map (Detailed)

Author: CIS
Date: 8/30/2018
Version: 1.0
Type: Exhibit

Proposed Facilities and Structures
- Preliminary Turbine Location
- Preliminary Permanent MET Tower
- Temporary MET Tower
- Junction Box
- Collection Line Paths
- Alternate Crane Path
- Primary Crane Path
- Turbine Access Roads
- Substation
- O&M Building
- O&M Grounds
- Laydown Yard

- Project Area Boundary
- 250 ft Micrositing Area

Existing Features
- Participating Residential Structures
- Non-Participating Residential Structures
- Existing Transmission
- Microwave Paths
- Wetland Area

Regulatory Setback Features
- Setbacks
- Public Roads (645 ft)
- Property Line (645 ft)
- Transmission Line (645 ft)
- Participating Residences (645 ft)
- Non-Participating Residences (1000 ft)

Notes:
o 1. Turbines not drawn to scale
o 2. Turbine numbering is not sequential
o 3. Any turbine shifts within 250' will comply with 45 dBA noise setback and 30 hours per year shadow flicker guidance
o 4. Cultural Resource data is not included

**PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC, FOR A WIND ENERGY FACILITY PERMIT FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * * *	**CERTIFICATE OF SERVICE** **EL18-026**

Lisa Agrimonti, of Fredrikson & Byron, P.A., hereby certifies that on the 30th day of August, 2018, a true and correct copy of Applicant's Responses to Staff's Second Set of Data Requests to Applicant and this Certificate of Service were served electronically on the persons listed below:

Ms. Kristen Edwards Staff Attorney South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 Kristen.edwards@state.sd.us	Ms. Amanda Reiss Staff Attorney South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 amanda.reiss@state.sd.us
	Ms. Mollie Smith - Representing: Prevailing Wind Park, LLC Fredrikson & Byron, P.A. 200 S. 6th St., Ste. 4000 Minneapolis, MN 55402 msmith@fredlaw.com

/s/ Lisa Agrimonti
Lisa Agrimonti

64711627.1

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

EL18-026 - IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * *	**APPLICANT'S RESPONSES TO STAFF'S THIRD SET OF DATA REQUESTS** **EL18-026**

Below, please find Applicant's Responses to Staff's Third Set of Data Requests to Applicant.

3-1) Refer to Mr. Pawlowski's supplemental testimony, Section VI. Other Project Commitments, lines 135 through 138.

a. Which specific decommissioning cost estimate provided by Mr. Daniel Pardo, including page and line references to his testimony, should the Commission use to base the funding of the escrow account. Provide explanation and support for why this estimate is appropriate.

Peter Pawlowski: Reference Supplemental Direct Testimony of Daniel Pardo, page 2, lines 40 to 43. In his testimony, Mr. Pardo provides the results of his analysis in a partial resale scenario. Under that scenario, the estimated decommissioning cost is $13,790 per turbine. Further support for this estimate is provided in Exhibit 2, specifically information relating to "Scenario 2".

b. Provide the specific and complete escrow account condition that the Company is recommending.

Peter Pawlowski: Prevailing Wind Park proposes the following condition:

> At least 30 days prior to the start of construction, or as otherwise approved by the Commission, Applicant shall submit an escrow plan for Commission approval that is consistent with the escrow plan approved by the Commission in In the Matter of the Application by Crocker Wind Farm, LLC for a Permit of Wind Energy Facility and a 345 kV Transmission Line in Clark County, South Dakota, for Crocker Wind Farm, Docket EL17-055, Order Approving Escrow Plan (August 3, 2018).
>
> Pursuant to the escrow plan, the escrow account shall funded by the Applicant annually at a rate of $460 per turbine for a period of 30 consecutive years.

If the Applicant fails to execute the decommissioning requirement found in this Section ___ of the Conditions, the account is payable to the landowner as the landowner incurs and pays decommissioning costs.

3-2) Is the Company aware of any jurisdictions that require seller of real estate to disclose whether there are plans to construct wind turbines on an adjacent parcel of land? Please explain.

Peter Pawlowski: No, the company is not aware of any such requirement. However, the company records its leases in the applicable county recorder's office and, as such, they are publicly available and should be identified during a title search.

3-3) If Applicant or its contractor were to damage drain tile on a participant's property and the damage resulted in flooding and crop loss to a non-participating landowner's crop, how would the crop loss be remedied?

Mollie Smith/Peter Pawlowski: This request is a legal question, the analysis of which is highly dependent on the facts. Prevailing Wind Park will repair any damage to drain tile the Project causes on participants' land. Prevailing Wind Park has not had experience with any damages being asserted by non-participants' land due to drain tile damage on a participants' parcel and believes such damages are very unlikely to occur. However, should the Project cause flooding and crop loss damages on a non-participant's parcel, Prevailing Wind Park will fairly compensate the affected landowner.

Dated this 6th day of September, 2018

By *_/s/ Mollie Smith_*___________

Mollie M. Smith
Lisa A. Agrimonti
FREDRIKSON & BYRON, P.A.
Attorneys for Applicant
200 South Sixth Street, Suite 4000
Minneapolis, MN 55402
Phone: (612) 492-7270
Fax: (612) 492-7077

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PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC, FOR A WIND ENERGY FACILITY PERMIT FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * * *	**CERTIFICATE OF SERVICE** **EL18-026**

Roxanne Gangl, of Fredrikson & Byron, P.A., hereby certifies that on the 6th day of September, 2018, a true and correct copy of Applicant's Responses to Staff's Third Set of Data Requests and this Certificate of Service were served electronically on the persons listed below:

Ms. Kristen Edwards Staff Attorney South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 Kristen.edwards@state.sd.us	Ms. Amanda Reiss Staff Attorney South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 amanda.reiss@state.sd.us
Mr. Darren Kearney Staff Analyst South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 darren.kearney@state.sd.us	Mr. Jon Thurber Staff Analyst South Dakota Public Utilities Commission 500 E. Capitol Ave. Pierre, SD 57501 jon.thurber@state.sd.us

<u>/s/ Roxanne Gangl</u>
Roxanne Gangl

64801007.1

CHARLES MIX COUNTY
STATES ATTORNEY
PO BOX 370
LAKE ANDES, SOUTH DAKOTA 57356
605-487-7441

August 22, 2018

South Dakota Public Utilities Commission
500 East Capital Ave.
Pierre, SD 57501

RE: APPLICATION BY PREVAILING WIN PARK, LLC FOR A PERMIT OF WIND ENERTY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA FOR THE PREVAILING WIND EL 18-026

Dear SDPUC Commission:

This letter is to follow up the phone conversation we had concerning Charles Mix County, SD, and Keith Mushitz's notice of intervening party and the STATE'S FIRST SET OF DATA REQUESTS TO CHARLES MIX COUNTY

As I stated during that phone conversation, Charles Mix County by and through its Commission Chairman, Keith Mushitz, sought to be an intervening party in the above entitled action. In hind sight, I am not sure that was necessary. Applicant has met with the Charles Mix County Commission concerning its project and the concerns of that board Charles Mix County is presently not zoned. In these meetings, the Applicant listened to the county's concerns about parameters of the project. In the end, Applicant agreed to build the project in Charles Mix County in a manner that reflects the Commission's wishes, i.e., Tower Setbacks, Tower Noise (DB level), Shadow Flickering, etc.. The Applicant signed an Affidavit and provided the Commission with that document which outlines these commitments. A copy of that Affidavit is attached hereto.

Given that, the County's request to intervene was only to provide the SDPUC with notice this agreement, to provide the SDPUC with the parameters of the agreement and to request that the SDPUC consider implementing Charles Mix County parameters in the final permit, if given, to the Applicant.

Thus, Charles Mix County does not plan to take depositions, testify or present witnesses during the application process of Applicant. In fact, Charles Mix County has no intention of attending any of the hearings unless called upon.

Thank you very much for your office's guidance in helping Charles Mix County better understand the Application process.

Sincerely,

Scott J. Podhradsky
Deputy State's Attorney
Charles Mix County

In the Matter of the Prevailing Wind Park Project in Charles Mix County, South Dakota

State of South Dakota)
) SS.
County of Charles Mix)

Affidavit of Peter Pawlowski

Peter C. Pawlowski, Vice President, Wind, Sustainable Power Group, LLC ("sPower") of the City of Salt Lake City, County of Salt Lake, State of Utah, being duly sworn on oath, deposes and states that the proposed Prevailing Wind Park will comply with the following requirements in Charles Mix County, South Dakota ("County"):

1. Prevailing Wind Park, LLC ("Prevailing Wind Park") is proposing to construct a wind energy system and associated facilities in Bon Homme, Charles Mix, Hutchinson and Yankton counties, South Dakota. As noted on its website, Basin Electric Power Cooperative has contracted to purchase the 200 megawatts of energy to be generated by the Project.[1] Up to 23 of the proposed turbines and associated facilities ("Project") would be located in Charles Mix County.

2. Prevailing Wind Park has been working cooperatively with the County to address questions regarding the Project.

3. Prevailing Wind Park is a wholly-owned subsidiary of sPower. In my position as Vice President, Wind, sPower, I am authorized to make commitments on behalf of Prevailing Wind Park.

4. Prevailing Wind Park hereby commits to the County Board of Commissioners that the Project will adhere to the following requirements:

   Setbacks.

   (a) Turbine tower distance from currently inhabited rural residence of a nonparticipating landowner shall be not less than three and a half (3.5) times the system height or two thousand feet (2,000) feet, whichever is greater. Turbine tower distance from the residence of the landowner on whose property the tower(s) are erected shall be not less than one thousand (1,000) feet.

   (b) Turbine tower distance from right-of-way of public roads shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater.

---

[1] https://www.basinelectric.com/About-Us/Organization/At-a-Glance/.

(c) Turbine tower distance from any property line shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater, unless a waiver has been obtained from adjoining property owner.

Noise. Noise from the wind turbines will not exceed 43 dBA at any existing nonparticipating residences and 45 dBA at existing participating residences, unless a signed waiver is obtained from the owner of the residence.

Shadow Flicker. Shadow flicker produced by the wind turbines will not exceed 30 hours per year and/or 30 minutes per day at currently inhabited residences of non-participants.

Lighting. The towers shall be lit using an Aircraft Detection Lighting System ("ADLS"), pending Federal Aviation Administration approval. The ADLS is designed to mitigate the impact of nighttime lights by deploying a radar-based system around a windfarm, turning lights on only when low-flying aircraft are detected nearby. The ADLS sends a signal to keep the light off until a plane is detected, then it stops sending the signal and the lights operate normally until the plane leaves the area and the off signal resumes.

Ice Detection. Prevailing Wind Park will use two methods to detect icing conditions on turbine blades: (1) sensors that will detect when blades become imbalanced or create vibration due to ice accumulation; and (2) meteorological data from on-site permanent meteorological towers, on-site anemometers, and other relevant meteorological sources that will be used to determine if ice accumulation is occurring. These control systems will either automatically shut down the turbine(s) in icing conditions (per the sensors) or Prevailing Wind Park will manually shut down turbine(s) if icing conditions are identified (using meteorological data). Turbines will not return to normal operation until the control systems no longer detect an imbalance or when weather conditions either remove icing on the blades or indicate icing is no longer a concern. Prevailing Wind Park will pay for any documented damage caused by ice thrown from a turbine

5. Prevailing Wind Park further commits to submitting this affidavit in the proceeding currently pending at the South Dakota Public Utilities Commission, *In the Matter of the Application by Prevailing Wind Park, LLC for a permit of a Wind Energy Facility in Bon Homme, Hutchinson and Charles Mix Counties*, Docket EL18-026.

Peter C. Pawlowski

Subscribed and sworn to before me
this 9th day of August, 2018

Notary Public
Expires 4-19-2023

SEAL
SARA CLAYTON
Notary Public
SOUTH DAKOTA

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * *	**INTERVENORS' RESPONSES TO STAFF'S FIRST SET OF DATA REQUESTS TO INTERVENORS** **EL18-026**

Intervenors Gregg Hubner, Marsha Hubner, Paul Schoenfelder, and Lisa Schoenfelder ("Intervenors"), through counsel, provide the following Responses to PUC Staff's First Set of Data Requests to Intervenors.

1-1) Provide copies to Staff of all data requests served on Applicant at the time of service.

RESPONSE: This information will be provided.

1-2) Provide copies to Staff of all of your answers to data requests from Applicant at the time they are served on Applicant.

RESPONSE: This information will be provided.

1-3) Refer to SDCL 49-41B-22. Please specify particular aspect/s of the applicant's burden that the individuals granted party status intend to personally testify on.

RESPONSE: Intervenors are still evaluating the Application and Prevailing Wind Park LLC's ability to satisfy the provisions of SDCL 49-41B-22 and whether they will provide personal testimony on the same.

1-4) Refer to SDCL 49-41B-25. Identify any "terms, conditions, or modifications of the construction, operation, or maintenance" that the Intervenors would recommend the Commission order. Please provide support and explanation for any recommendations.

RESPONSE: Intervenors recommend a 2-mile setback from non-participating residences and a 1,500 ft. setback from a property line and public rights-of-way with waivers available for those who want them closer. Research shows the negative effects of wind turbines on people that live too close to turbines. In the book "Wind Turbine Syndrome" by Dr. Nina

Pierpont, MD, PhD, on page 254 she suggests a minimum of 2 mile setbacks. This book was written in 2009 when turbines were much smaller in megawatts and much shorter in size. There is no precedent for 586 ft. turbines. Attached as Exhibits 1-12 are various peer reviewed studies and articles on negative health effects. Intervenors are also concerned with ice-throws and malfunctioning turbines.

In Erik Johnson's public comments on the docket dated August 2, he says that 80% of the land in the footprint was signed up for the project. If that is the case, then a 2-mile setback for non-participants would be very easy to accommodate. If the Applicant has 80% of the land signed up, all it must do to make this work is move a few turbine locations.

Intervenors request the Aircraft Detection Lighting System which eliminates the red blinking lights at night.

Intervenors request a decommissioning bond paid for in its entirety prior to construction.

Intervenors request a liaison person or watchdog to monitor the project as it is being built to ensure compliance.

Intervenors request there should be no shadow flicker on non-participating residences, because shadow flicker presents a nuisance and the Applicant should not be permitted to create a nuisance.

1-5) Is there a specific objection (example health, blinking lights, sound) you have with respect to the Project? Please briefly explain.

RESPONSE: Intervenors are still evaluating the Application and their objections thereto. Presently, though, Intervenors are concerned with the sound, infrasound, and shadow flicker that will be created by the proposed turbines. The effects of infrasound are serious and documented. Studies show 35 decibels or less results in very few complaints. See also response to Data Request 1-4.

a. What, if anything, do you feel could be done to remedy that issue?

RESPONSE: 2-mile setbacks from non-participating residences and 1,500 ft. setbacks from a property line and rights-of-way (with waivers) and 35 decibel noise limit for non-participating residences.

1-6) Please list with specificity the witnesses the Intervenors intend to call. Please include name, address, phone number, credentials and area of expertise.

RESPONSE: Intervenors are still evaluating the Application and considering potential witnesses.

1-7) Do the you intend to take depositions? If so, of whom?

RESPONSE: Not at this time.

Dated this 30th day of August, 2018.

DAVENPORT, EVANS, HURWITZ & SMITH, L.L.P.

Reece M. Almond
206 West 14th Street – P.O. Box 1030
Sioux Falls, SD 57101-1030
Telephone: (605) 336-2880
Facsimile: (605) 335-3639
E-mail: ralmond@dehs.com
Attorneys for Intervenors Gregg Hubner, Marsha Hubner, Paul Schoenfelder, and Lisa Schoenfelder

CERTIFICATE OF SERVICE

The undersigned, one of the attorneys for Intervenors Gregg C. Hubner, Marsha Hubner, Paul M. Schoenfelder and Lisa A. Schoenfelder, certifies that a true and correct copy of Intervenors' Responses to Staff's First Set of Data Requests to Intervenors was served on August 30, 2018, via email, upon the following:

Ms. Kristen Edwards
kristen.edwards@state.sd.us
Ms. Amanda Reiss
Amanda.Reiss@state.sd.us
Staff Attorneys
South Dakota Public Utilities Commission
500 E. Capitol Ave.
Pierre, SD 57501

Dated this 30th day of August, 2018.

Reece M. Almond
One of the Attorneys for Intervenors

Bulletin of Science, Technology & Society
http://bst.sagepub.com/

The Noise From Wind Turbines: Potential Adverse Impacts on Children's Well-Being

Arline L. Bronzaft

Bulletin of Science Technology & Society 2011 31: 291
DOI: 10.1177/0270467611412548

The online version of this article can be found at:
http://bst.sagepub.com/content/31/4/291

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On behalf of:
National Association for Science, Technology & Society

Intervenors' Responses to
Staff's First Set of Data Requests
EXHIBIT 1

Bulletin of Science, Technology & Society
31(4) 291–295

DOI: 10.1177/0270467611412548
http://bsts.sagepub.com

The Noise From Wind Turbines: Potential Adverse Impacts on Children's Well-Being

Arline L. Bronzaft[1]

Abstract

Research linking loud sounds to hearing loss in youngsters is now widespread, resulting in the issuance of warnings to protect children's hearing. However, studies attesting to the adverse effects of intrusive sounds and noise on children's overall mental and physical health and well-being have not received similar attention. This, despite the fact that many studies have demonstrated that intrusive noises such as those from passing road traffic, nearby rail systems, and overhead aircraft can adversely affect children's cardiovascular system, memory, language development, and learning acquisition. While some schools in the United States have received funds to abate intrusive aircraft noise, for example, many schools still expose children to noises from passing traffic and overhead aircraft. Discussion focuses on the harmful effects of noise on children, what has to be done to remedy the situation, and the need for action to lessen the impacts of noise from all sources. Furthermore, based on our knowledge of the harmful effects of noise on children's health and the growing body of evidence to suggest the potential harmful effects of industrial wind turbine noise, it is strongly urged that further studies be conducted on the impacts of industrial wind turbines on their health, as well as the health of their parents, before forging ahead in siting industrial wind turbines.

Keywords

health, cognition, language, learning, wind turbines, transportation, well-being

Introduction

Thirty-six years ago, when my then 8-year-old daughter learned I was looking at the impact of passing train noise on children's classroom learning, she asked me why I was conducting this study because it seemed obvious to her that passing train noise disrupting children's learning every 4 to 5 minutes for 30 seconds would affect their learning ability. I responded that someone had to demonstrate the impact of the noise on classroom learning with solid data, explaining the meaning of data to my daughter.

Assessing the Impacts of Noise on Children's Learning

My initial study on noise/learning link examined the impact of elevated train noise on reading ability in a school situated 220 feet from an adjacent elevated train structure. Eighty trains passed the school during the hours between 9 a.m. and 3 p.m. each weekday and disrupted the classes on the side of the building facing the tract every 4½ minutes for 30 seconds. The sound level in a classroom rose to 89 dBA from 59 dBA when the train passed, forcing the teacher to scream to be heard or to stop teaching until the train passed. In 1973, the New York Department of Air Resources reported that 11% of classroom teaching time was lost because of passing trains.

Reading scores were examined for 4 years comparing the scores of the children in the classrooms exposed to train noise with children attending classrooms on the quiet side of the building. Reading scores of children on the noisy side of the building lagged behind their peers on the quiet side from 3 months in the lower grades to as much as 1 year in the sixth grade. Whether the cause was the lost teaching time, the distraction of the trains, or the fact that the children took the tests in the noisy rooms, the fact remains that children in the noisy classrooms demonstrated poorer reading scores than children on the quiet side of the building. My results were published in a article in 1975 in the *Journal of Environment and Behavior* (Bronzaft & McCarthy, 1975).

Responding to Effects of Noise on Learning

The reaction to this study in New York City was overwhelming. Newspaper accounts of the study plus statements by public officials highlighted the findings broadly. This reaction made

[1]GrowNYC, New York, NY, USA

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it easier for me to approach the Transit Authority and ask the agency to select the tracks adjacent to P.S. 98 to test the effectiveness of rubber padding in quieting noisy elevated trains. When the pads were in place, the principal of the school and I asked the Board of Education to install noise abatement materials in three of the noisiest classrooms at P.S. 98. The noise reduction as a result of the two abatement techniques was 6 to 8 dBA. When asked to return to the school by a public official to conduct a study after the installation of noise abatement materials, I did so nervously. However, when I compared the reading scores of children in classrooms facing the tracks with those on the quiet side of the building, children on both sides of the building were reading at comparable levels. This study clearly demonstrated that when you correct a noise problem, children benefit (Bronzaft, 1981).

Research on Effects of Noise on Children's Learning Expands

Subsequent years saw additional research on the effects of noise on children's learning. Wachs and Gruen (1982) noted that noisy households can disrupt a child's development and warned parents about shouting and playing televisions and stereo systems too loudly. The U.S. Federal Interagency Committee on Aviation Noise (FICAN) concluded, after summarizing the findings of 20 studies, including my study in 1975, that aircraft noise can interfere with reading, speech acquisition, and noise (FICAN, 2000). Lercher, Evans, and Meis (2003) examined ambient neighborhood noises and found that chronic noise exposure was significantly related to poor incidental and intentional memory in children. S. A. Stansfeld et al. (2005) reported that an investigation of school children in the Netherlands, Spain, and the United Kingdom indicated that aircraft noise could impair cognitive development, especially reading comprehension. Recent studies by Matheson et al. (2010) and S. Stansfeld, Hygge, Clark, and Tamuno (2010) add to our knowledge of the adverse effects of road traffic and aircraft noise exposure on children's learning abilities, particularly in the school setting.

In my book *Top of the Class*, published in 1996, which examined the lives of high academic achievers, I learned from these high academic achievers that they were reared in homes that respected quiet (Bronzaft, 1996). Quiet areas were provided for them to read, study, and learn. Their parents tended not to discipline them with shouting and loud voices but rather used lowered, stern voices to correct their behavior. We could say that a quieter environment served these high academic achievers well.

Greater Awareness of Noise/Learning Link?

U.S. President Obama understands that noise can affect classroom learning. In a speech before Congress in February 2009, the President identified a young woman in the audience named Ty'Sheoma Bethea who attended a school in Dillon, South Carolina. In identifying the elements impeding on the learning in her classroom, he noted that "they have to stop teaching six times a day because the train barrels by their classroom." The American National Standards Institute in 2002 set acoustical standards for classrooms, stressing the importance of a proper acoustical school environment. In 2009, the House Education and Labor Committee of the U.S. Congress passed a bill that would introduce measures designed to reduce or eliminate exposure to classroom noise, as part of the Green High Performing School Facilities Act, but this legislation has not yet become law.

My daughter, now 44 years old, wonders why after years of research demonstrating a link between noise and children's learning, we need to conduct further research as suggested by the U.S. Federal Aviation Administration's (FAA) proposed study on the effects of aircraft noise on classroom learning (Airport Cooperation Research Program, Project Number 02-26). She believes there is enough research demonstrating an adverse effect of noise on learning and we should move, without hesitation, to creating quieter classroom environments rather than using funds to conduct further studies. Despite the fact that I serve on the Transportation Research Board committee that is overseeing the FAA-funded research on airport noise and children's schoolroom learning, I tend to agree with my daughter's conclusion. In 2011, there definitely is sufficient research linking noise to impaired learning and we should work toward improving the school learning environment.

Impacts on Children Beyond Learning

It should be pointed out even if the child were able to overcome the adverse effect of noise in the classroom, the need to do so may create stress and discomfort for the child, which in the long run can have an adverse effects on his or her health. In my 1974 study, the children interviewed expressed their unhappiness at the passing trains. One child, when interviewed for television, said, "I wish the trains wouldn't run anymore."

Noise has been associated with physiological problems in children. Studies on the adverse effects of loud sounds and noise on children's hearing have been well documented. Yet youngsters continue to expose themselves to loud video games, loud concerts, and so on. An example of the effects of long-term exposure to loud music is Pete Townshead, a member of the rock band "The Who," who has experienced hearing problems himself because of his exposure. Yet hearing loss is not the only physiological impact of noise. Evans and Lapore (1993) reviewed the nonauditory effects of noise and concluded that children living near or attending a school near a major airport were more likely to experience elevated blood pressure. Passchier-Vermeer and Passchier (2000) wrote that road traffic and aircraft noise have been found to affect children's cardiovascular system. The U.S. government over

30 years ago in its "Noise: A Health Problem" pamphlet stated that children in homes and schools exposed to aircraft noise had higher blood pressure than children in quieter environments (U.S. Environmental Protection Agency, 1978). Although this booklet pointed out back then that more studies were needed to strengthen this finding, it concluded with the statement that "this finding is cause for concern."

When Parents Are Stressed, Children May Suffer!

Another point that I would like to make concerning the impacts of noise on children's lives deals with the effects noise has on their parents. There are sufficient studies linking noise to adverse health effects (Bronzaft & Hagler, 2010) in adults. Even if we were to argue that the best data linking noise to well-being centers on a diminished quality of life rather than specific health ailments, as noted by the World Health Organization, then living near a noisy source would most likely diminish quality of life. Good health is not merely the absence of symptoms; it is the ability to experience a decent quality of life. Parents experiencing this poorer quality of life, or suffering from a noise-related ailment, may have less patience with their children and, as a result, express more anger at their misdeeds. I need not illustrate further how good parent-children relationships affect the health and well-being of children. If noise prevents a parent from getting a good night's sleep because of overhead aircraft, then one could expect this tired parent to be less able to deal with the obligations of parenthood.

Going Beyond Existing Findings on Noise Impacts

How does my discussion of the impacts of noise, largely measured on the dbA scale, on children's mental and physical health relate to the topic of wind turbine noise, including sound levels measured on the A scale as well as potential impacts from low-frequency sound. What I think we can learn from the research on the effects of noise on children is that before changes are made based on research findings, authorities demand solid data with huge samples. Occasionally, there are exceptions, as I experienced in the case of the New York Transit Authority and the New York City Board of Education actions to abate the noise at the school in which I had conducted my research on noise and learning. Although studies such as mine did influence the U.S. FAA to abate noise at schools lying within a designated noise area, it is difficult for schools to receive this abatement, largely because the noise metrics used by the FAA limit the numbers of schools that may be eligible. Thus, far too little has been done in the United States to lessen the effects of intruding noises from traffic, trains, and aircraft, despite a growing body of literature linking noise to adverse impacts on children's mental and physical health. With respect to wind turbine noise, the solid data we now have regarding the noise/health link in children should serve to warn about the potential harm of wind turbine noise and caution should be exerted before building industrial wind turbines near people's homes.

How Valid Are the Data in Support of Wind Turbines?

Before the academically reviewed journal articles are written and published, researchers explore problems employing observations and interviews. Before I conducted my research as noted above, parents of the children at P.S. 98 had long complained about the noise from the trains but no action was taken until after the findings of my research were published. However, I want to add that many public officials in New York City joined in our efforts to quiet the tracks next to the school and that hastened the abatement. Similarly, Dr. Pierpont (2009) was responding to resident complaints when she undertook her observations and interviews of residents living with wind turbine noise. Dr. Pierpont's observations, and those of other speakers who presented at the recent First International Symposium on the Global Wind Industry and Adverse Health Effects held in Ontario, Canada, are being questioned because they appear to be based on small numbers of residents. The validity and reliability of these observations are also being criticized because they lack comparisons with control groups. In the early days of psychology, Dr. Freud took careful notes on his patients' complaints and he relied on observations and interviews as he formulated his theory of human behavior. In time Dr. Freud, one of the great minds of the 20th century, developed a theory of human behavior, as well as a method to treat psychological problems. More traditional studies of his theories followed afterwards. Observations and interviews generally proceed questionnaires and testing that result in correlative data to be analyzed and evaluated.

The dismissal of the adverse effects of noise on residents living with wind turbine noise has largely come from the wind power industry, which has supported this claim with reports by acousticians, doctors, and engineers whom they have hired to write on the noise/health relationship. Yet there exist reports written by researchers that suggest that both the wind industry and governments in favor of wind turbine energy have erred in concluding that noise from wind turbines cannot affect physical and mental well-being. Dr. Frits van den Berg (2004), a Dutch physicist, claims that the methods used to predict the noise from large turbines are inappropriate and, thus, the conclusions drawn from findings based on these methods have to be questioned. Dr. van den Berg believes that the measurements of wind turbine noise near people's homes in quieter environments at night may be underestimated by as many as 10 dBA. Dr. van den Berg's conclusions have been supported earlier by Pedersen and Halmstad (2003). Studies such as these deserve to be examined more closely and, at the very least, suggest that additional studies be conducted to evaluate the impacts of wind turbine noise, including the low-frequency sounds, on individuals.

A Growing Interest in the Impacts of Wind Turbine Noise

Garret Keizer in his book *The Unwanted Sound of Everything We Want* (2010) states that while he is not an expert on wind turbine noise, he can still write as an individual who personally researched the issue of noise and wind power, including the works of van den Berg and Pedersen, for his book. He also personally visited residents in Maine who described how the wind turbine noise affected their lives. Mr. Keizer concluded that "wind turbines produce a devilishly complex form of noise that, combined with the imprudent siting of certain wind installations, is making some people sick." (p.221) Additionally, Mr. Keiser, in thinking about future environmental debates, states that "in debates over wind energy, noise will be front and center." (p.221)

In a *New York Times* article (Zeller, 2010), Mr. Zeller gives voice to residents who have had their quality of life diminished by nearby wind turbines, but then adds that "for the most extreme claims, there is little independent backing." Unfortunately, the only studies he cites are those from American Wind Energy Association, a trade group, and its Canadian counterpart, which concluded that "there is no evidence that the audible and sub-audible sounds emitted by wind turbines have a direct adverse physiological effects." The *New York Times* published two additional articles shortly afterwards (Wald, 2010; Wald & Zeller, 2010) on wind power energy. Additionally, President Barack Obama mentioned wind power as an alternative energy source that we must pursue in his State of the Union address in early January 2011. That Mr. Keizer's noise book, and the soon to be published book *Why Noise Matters* (Stewart, 2011), contain sections on wind turbine noise and that several stories on wind power have recently appeared in the *New York Times* indicate a both a growing interest in wind power as an alternative energy source as well as a source for potential harm from noise.

A Call for More Research

Yet this interest in harnessing wind power must be accompanied by research to resolve the issues of the potential harm of wind turbine noise on individuals living nearby. Research should also be conducted on the cost-effectiveness of harnessing the wind among other concerns. From past experience, I would venture to guess that the eagerness to move to wind power on the part of industry and governments internationally will result in a reluctance to support research that may conclude that caution is required when locating wind turbines close to residential communities. Of course, I speak from an American perspective where history has demonstrated how quickly Americans adopt new products, without requisite research on harmful effects, and how reluctantly they relinquish these products when evidence proves that they may be harmful. Similarly, when it comes to environmental concerns, the United States often errs on the side of industry, as noted by a *New York Times* editorial ("Questions About Fracturing," 2010), and proceeds with activities that might be harmful to the environment. In this editorial, the concern is hydraulic fracturing, which has been implicated in a number of water pollution cases. The drilling industry, like the wind power industry, states that its technology is "fundamentally sound" but the editorial adds: "We need more credible assurances this time." Yet the United States is most likely not alone in requiring *overwhelming* evidence to remove dangerous products or to proceed with dangerous technology.

Enough Evidence to Issue Warnings About the Hazards of Wind Turbine Noise

The U.S. Environmental Protection Agency released a booklet in 1978 that contained a section entitled "Special Effects on Children" and cited my research on the impacts of noise on children's classroom learning. The booklet in its final word section concludes: "It is finally clear that noise is a significant hazard to public health. Truly, noise is more than an annoyance." In 2009, the U.S. Environmental Protection Agency (http://www.epa.gov/air/noise.html) issued a pamphlet entitled "Say What" for middle school students, which states, "Noise can not only harm your hearing—it can also make it hard to concentrate while reading or doing homework, make you frustrated, prevent you from falling asleep, and make it hard to communicate with your family and friends."

Yet, despite declarative statements in government publications, and I could have added others to those cited above, the U.S. government is still assessing the impact of aircraft noise on children's learning and still thinking about passing legislation to quiet the nation's schools. With the American educational system falling behind the systems of other nations, especially evidenced in the lower number of people graduating from college, it is indeed egregious to allow our school children's education to be adversely affected by noise both inside and outside the school as well as the home. It would also be egregious to fail to consider the impacts of new sources of noise, for example, industrial wind turbines on their health.

Dr. William H. Stewart, the former Surgeon General of the United States, in a keynote talk to a 1969 Conference on Noise as a Public Health Hazard stated the following: "Must we wait until we prove every link in the chain of causation. In protecting health, absolute proof comes late. To wait for it is to invite disaster or to prolong suffering unnecessarily." I was taught that an ounce of prevention was worth more than a pound of cure. I believe we should explore the potential harmful noise effects of industrial wind turbines before we adopt this energy source; taking corrective action many years down the road, when the proof is overwhelming, would be, as Dr. Stewart says, "prolonging suffering unnecessarily."

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Bio

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Wind Turbine Noise

John P. Harrison[1]

Abstract

Following an introduction to noise and noise regulation of wind turbines, the problem of adverse health effects of turbine noise is discussed. This is attributed to the characteristics of turbine noise and deficiencies in the regulation of this noise. Both onshore and offshore wind farms are discussed.

Keywords

wind turbines, turbine noise, onshore and offshore noise propagation, noise regulation, turbulence

Introduction

The most common complaint about wind turbines is that they are noisy. There is audible noise perceived by the ear/brain system and the so-called inaudible infrasound felt by the body. The ear detects sound as pressure waves. The ear/brain system detects the loudness and pitch of the sound. The way the system works is that as the pressure in a sound wave increases by three times, the ear/brain combination perceives a doubling of the loudness. The ear/brain system for audible sound is effective from about 50 to 4,000 Hz with a gradual decrease in sensitivity at either end.

Engineers use a decibel scale to describe loudness as perceived. The scale is logarithmic to mimic the behavior of the ear. The scale is weighted to reflect the sensitivity of the ear to the frequency of the sound. The most common weighting is the A-scale. With this scale, familiar noises have approximate decibel levels as shown.

Background at night in a rural area:	25 dBA
Recommended bedroom level:	25 dBA
Living room:	40-45 dBA
A busy office:	60-65 dBA
Heavy street traffic:	90 dBA

An increase of 3 dBA is noticeable and an increase of 10 dBA is perceived as a doubling in loudness. Sound from extraneous sources is referred to as noise and is an annoyance and potential health problem.

The response to infrasound (<20 Hz) is not as well understood. However, there are receptors in the body for infrasound and it is detected at levels well below the audible sound threshold (Salt & Hullar, 2010).

Most noise regulations are derived from regulations designed for other noise sources, such as traffic or industry. However, anecdotal evidence and field studies suggest that turbine noise has a character that makes it far more annoying and stressful than other sources of noise at the same A-weighted sound level. The reasons for this are believed to include the amplitude modulation associated with the blade passage past the tower, the quiet rural environment in which turbines are placed, the turbulence of the air that blows past the blades, the variability of manufacture and assembly, the dominance of low frequencies in the received sound spectrum, and the association between the acoustic and visual impacts. This article reviews the annoyance and its impacts, the character of the turbine noise, and suggests revisions to regulations required to avoid adverse health effects.

Regulation of Wind Turbine Noise

Most jurisdictions have noise regulations to protect our environment from industrial, traffic, and other sources of noise. Regulation of wind turbine noise is used to determine the setback of turbines from homes and other sensitive receptors. For a review of regulations worldwide, see Orville Walsh (2010). The noise limit varies from 35 dBA for quiet regions of New Zealand and for nighttime in Germany to 50 dBA in many jurisdictions in the United States.

In Ontario, there is an Environmental Protection Act, which, among other thing, protects the health and the enjoyment of property of residents. As of September 2009, the limit for turbine noise at a sensitive receptor is 40 dBA. There is in addition a minimum setback of 550 meters from sensitive receptors. Typically, the ambient nighttime noise in a rural area is 25 dBA. The 15 dBA intrusion of the turbine noise above

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ambient corresponds to a sound three times as loud as the ambient, well above the 3 dBA detectability.

Ontario is now unique in allowing the noise limit to rise with the wind speed, up to 51 dBA at a wind speed of 10 m/s. The justification is based on masking noise from the wind. This is discussed further below.

Significance of Turbine Noise Regulation

It is usual when planning a wind farm to base the setback of the turbines from homes on the local noise regulation. Of course, there are many wind farms in unpopulated regions and noise is not a concern. However, in many cases turbines are being "shoe-horned" (Rolf Miller, Director of Wind Assessment at Chicago-based Acciona Windpower, quoted in Del Franco, 2011) in and noise is the dominant concern. The protocol is to base the siting of turbines on the prediction of the noise at a receptor. There is no routine testing for compliance postconstruction and therefore no feedback on the planning of future wind farms. In cases where complaints have led to noise audits that have demonstrated noncompliance, the receptors have been compensated but still no feedback.

There is routine software that starts with the coordinates of the proposed turbine sites and the turbine noise specifications and outputs noise contours for the area of the wind farm. The contour maps are drawn for a range of wind speeds. The noise specification is the sound power, with the total sound power from the extended source (the blades and nacelle) treated as a spherical source of area 1 m^2, as a function of the wind speed and sound frequency. The software uses a sound propagation algorithm such as ISO 9613-2. In turn, this algorithm requires a ground effect parameter and an atmospheric absorption parameter. The algorithm basically accounts for spherical spreading of the sound wave from the source, reflection and absorption by the ground, and frequency-dependent absorption by the atmosphere.

A typical result, expressed as sound pressure level in dBA as a function of distance of the turbine from a receptor, is shown in Figure 1. A turbine sound power level of 105 dBA was chosen for the example. The lower curve corresponds to a single turbine and the upper curve to 3 turbines equidistant from the receptor. Highlighted on the figure are regulated noise limits of 35 and 40 dBA.It is seen that a 40 dBA noise limit, calculated in this way, corresponds to a setback of about 500 meters. Rarely is a receptor overlooked by a single turbine. For three equidistant turbines, the 40 dBA limit corresponds to a setback of 800 meters. Seen in this light, it is clear that the 550 meters minimum setback specified by the Ontario Ministry of the Environment as part of the Green Energy Act turbine noise regulation is meaningless.

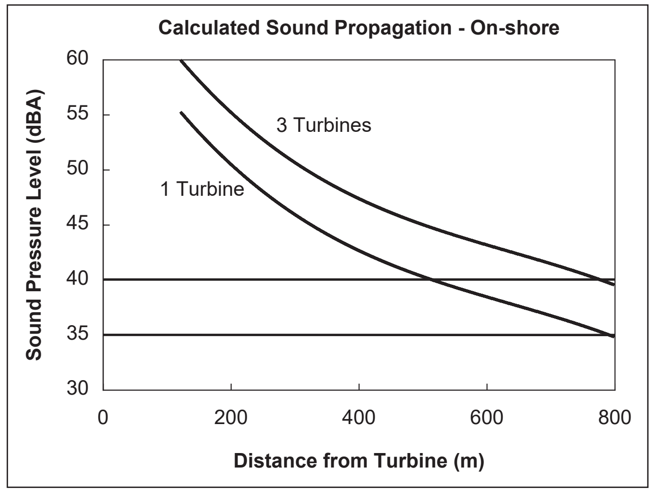

Figure 1. Predicted sound pressure level versus distance from turbine

Noise and Adverse Health Effects

Turbine noise causes annoyance, sleep disturbance and deprivation, and can result in adverse health effects (see, e.g., Frey & Hadden, 2007; Harry, 2007; McMurtry, 2009; Pierpont, 2010). On the basis of the study of widespread complaints of adverse health effects due to turbine noise, various health authorities have recommended setbacks in the range 1.5 to 2 kilometers from homes and other sensitive receptors. In addition to the "one on one" interactions between health professionals and complainants, there have been field studies of the annoyance caused by turbine noise. Perhaps the most significant are the Netherlands study recently reported by Pedersen, van den Berg, Bakker, and Bouma (2009) and the earlier Swedish studies reported by Pedersen and Persson Waye (2004, 2007); the significance is based on the size of the samples, the experience of the investigators and the intercomparison between the studies.

The results are summarized in Tables 1 and 2. The authors used five categories for the response to turbine noise of those survey respondents: did not notice, noticed but not annoyed, slightly annoyed, rather annoyed, and very annoyed. The sound level at the respondents' homes was calculated using ISO 9613-2. The resulting sound levels were checked against two other algorithms with no significant difference found (<1 dBA). A ground absorption parameter of 1 (perfectly absorbing) was used in the ISO calculation. This is the same value as used by Ontario, for instance.

It would appear that a noise limit of 40 dBA will result in annoyance (rather plus very annoyed) for about 20% of the population subject to that noise level. Again, for many wind farms in low-populated regions this is not a problem because there is no need to site to the noise limit. However, where rural populations are denser and where turbines are being "shoe-horned" in, this is a problem. Southern Ontario, Quebec,

Table 1. Respondents in Rural Sweden (*N* = 1095)

Noise (dBA)	Rather Annoyed (%)	Very Annoyed (%)	Total (%)
35-40	3	6	9
40-45	10	19	29

Table 2. Respondents in Rural Netherlands (*N* = 586)

Noise (dBA)	Rather Annoyed (%)	Very Annoyed (%)	Total (%)
35-40	14	6	20
40-45	7	18	25

Nova Scotia, and Prince Edward Island are obvious examples from Canada.

For comparison, it is interesting to note that Miedema and Vos (1998) found that just 2% to 4% of respondents were annoyed by traffic noise at the 40 dBA level.

Reconciliation Between Regulation and Adverse Health Effects

There is a problem. Noise regulation in the range 40 to 50 dBA allows turbines to be placed within 500 meters of homes and other sensitive receptors. Subsequently, in a significant fraction of such homes, residents are being annoyed, are suffering sleep deprivation and disturbance, and in many cases, are suffering adverse health effects. Yet for other noise sources the limit appears reasonable. We now know that turbine noise has characteristics that contribute to this situation. We also know that there are factors not considered when applying the noise regulations. Finally, there is a reluctance to test for compliance. One can understand the reluctance; each turbine costs about $5 million to put in place and unlike industrial machinery there is no possibility of shielding the noise at source. Nevertheless, regulation without compliance testing is unethical.

The characteristics of turbine noise that contribute to annoyance and sleep disturbance are as follows: The sound from turbines is amplitude modulated at the blade passage frequency. The modulation level is typically 3 to 5 dBA (van den Berg, 2005) but higher levels have been measured (Moorhouse, Hayes, von Hünerbein, Piper, & Adams, 2007). Two things arise: The peak sound is higher than the average used for noise regulation and the modulation enhances the audibility of the sound to such an extent that the turbine noise can be detected even when the sound is below ambient (Hanning, 2010). The noise emitted by a turbine is broadband; however, at a distance of 500 meters and more, the higher frequencies have been absorbed by the atmosphere so that it is predominantly low-frequency noise that reaches a receptor. This low-frequency noise enhances annoyance and is more readily able to penetrate walls and resonate inside rooms. Many people report a thumping, rumbling, or impulsive character to the turbine noise (e.g., Frey & Hadden, 2007; Harry, 2007); the reason is not clear.

Deficiencies With Present Noise Regulation

As noted above, the character of turbine noise makes it especially intrusive. This is exacerbated by the fact that wind turbines are sited in rural areas where the ambient noise level can be about 25 dBA. An intrusion of 15 dBA is too large. Germany has a nighttime noise limit of 35 dBA; this should be the international absolute maximum.

Also as noted above, the standard algorithm for predicting noise at a receptor is ISO-9613-2. But, this was never designed for turbine noise. The ISO manual is specific in limiting its use to noise sources close to the ground such as "road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources." Turbine noise derives from blades rotating, typically, between 35 to 125 meters above ground level. When used without compliance, testing the results of the predictions have little meaning.

The authors of noise prediction algorithms appreciate that there is uncertainty in the calculations. For instance, the manual for ISO 9613-2 puts the uncertainty at ±3 dBA for a source to receptor distance in the range 100 to 1,000 meters. The turbine makers know that there is variability in manufacture; this is put at ±1 or ±2 dBA. Combining these, the predictions can be no better than ±4 dBA. This uncertainty is ignored by the wind energy developers and by the regulatory authorities. This is despite the fact that the final siting plans are signed off by professional engineers and approved by professional engineers.

All prediction algorithms assume spherical spreading of the sound from the turbines. This is not necessarily always so. Sound propagation experiments over hard surface, such as water or packed sand, have demonstrated a transition from spherical to cylindrical spreading even for distances of less than 1 kilometer (Boué 2007; Hubbard & Shepherd, 1991). Packed snow would be another example of a hard surface. The cylindrical spreading is a result of refraction of sound in the atmosphere and channeling of sound between the atmosphere and the ground (Søndergaard & Plovsing, 2005).The distance at which the transition occurs depends on the wind speed and temperature gradients in the low atmosphere and will vary with time of year, time of day, and weather.

Turbines leave behind them a turbulent wake and a wind speed deficit. Turbulence is known to exacerbate turbine noise (Amiet, 1975; Moriarty, 2004; Moriarty, Guidati, & Migliore, 2004, 2005; Moriarty & Migliore, 2003; Romera-Sanz & Matesanz, 2008). Turbulence occurs naturally in the atmosphere but the wake turbulence can equal this natural turbulence out to 5 blade diameters (Barthelmie et al., 2003). Experiments with an isolated turbine at the National Renewable Energy Laboratory in the United States have demonstrated this excess noise for measured natural turbulence and compared it with turbulent inflow noise calculations (Moriarty, 2004). Below 200 Hz, the turbulent inflow noise dominates over all other aerodynamic sources for turbulent intensities above 10%. No account of this excess noise is included in any noise regulation.

The use of masking noise to justify an increase of the noise limit with wind speed was laid to rest by the pioneering work of van den Berg (2004). He argued that in a stable atmosphere there can be a large vertical wind speed gradient such that the turbine is generating power and noise while at ground level there is insufficient wind to generate masking noise. He supported his argument with meteorological tower wind speed measurements. At that time, only the Netherlands, New Zealand, and Ontario were permitting wind developers to use the masking noise allowance. The Netherlands and New Zealand have since dropped the allowance. Ontario persists but since October 2008 (Ministry of the Environment, 2008) does require that developers justify its use by making on-site wind speed gradient measurements. Needless to say, the developers are not able to justify its use. The pity of it is that so many wind farms have been built with setbacks based on the allowance years after van den Berg had so clearly made his case.

The Way Ahead

At a minimum, the following need to be introduced into noise regulation of wind turbines.

The noise limit needs to be reduced to 35 dBA at nighttime and, where applicable, reduced to 40 dBA for daytime. This is still intrusive in rural areas but will help bring setbacks to those recommended by health authorities. Wind energy and the wind industry have flourished in Germany with these regulations, despite a population density 20 times that of Ontario.

A penalty of 5 dBA needs to be added to the time-average predicted noise levels; this is to compensate for the enhanced audibility of the amplitude-modulated and impulsive character of turbine noise.

Uncertainty in design calculations is the norm in engineering practice. The ±4 dBA is real and should be tolerated in the noise prediction calculation. For the wind developers, erring on the side of caution could protect their very large investments when testing for compliance does become the norm.

A great deal is known about the excess noise due to turbulent inflow. Wind energy developers need to make test tower measurements of local natural turbulence and make calculations of wake turbulence to predict this excess noise.

Compliance is not so difficult. It is common practice to check for compliance in all manner of industrial situations. Atkinson & Rapley Consulting (2011), is association with Astute Engineering, in New Zealand has developed a fully automatic environmental noise measurement system. This is in service in New Zealand for compliance testing of wind turbine noise. Compliance testing is vital because it leads to reconsideration of noise prediction calculations. Where noise audits have been done, such as that at a home near Shelburne in Ontario, turbine noise well in excess of the noise limit has been demonstrated. In such cases, the wind energy company pays compensation or buys out the home-owner; no iterative use is made of the audit.

With the above changes to the regulation of noise: a 35 dBA nighttime noise limit, penalties of 5 dBA for the periodic or impulsive character of turbine noise, 4 dBA for uncertainty in noise prediction, and a penalty for turbulent inflow noise the setback from homes will approach the 1.5 to 2 kilometers recommended by health authorities.

Offshore Turbine Noise

At present there are no freshwater offshore wind farms and therefore no reported adverse health effects. Nevertheless, they are under consideration for Great Lakes both north and south of the border. It is our common experience that sound propagates readily over water and therefore it is expected that turbine noise will be a bigger problem for offshore wind farms. The science of noise from offshore wind turbines has been reviewed in a report for the Danish Ministry of the Environment (Søndergaard & Plovsing, 2005). They emphasize the "Swedish Model" (2001), which allows for a transition from spherical spreading to cylindrical spreading beyond a certain distance from the turbine. As noted above, the cylindrical spreading results from refractive reflection from the atmosphere and reflection from the water as a hard surface. The transition distance is a parameter that depends on the wind speed and temperature gradients.

This Swedish propagation model, for distances larger than a transition distance *d*, is written as

$$L = L_s - 20\log(r) - 11 + 3 - \Delta L_a + 10\log\left(\frac{r}{d}\right),$$

where L is the sound pressure level at the observer, L_s is the turbine sound power (e.g., 105 dBA), 11 is 10 log(4π), 3 is 3 dBA of ground reflection, ΔL_a is the integrated frequency dependent absorption coefficient, a function of r, and r is the distance from turbine hub to the observer. The second term on the right gives the spherical spreading and the final term corrects for cylindrical spreading beyond the distance d. Søndergaard and Plovsing (2005) have calculated the integrated absorption coefficient and show the result in figure 17 of their report. For instance, at a distance of 5 kilometers, it is 8 dBA. The transition distance for the onset of cylindrical spreading was uncertain but was assumed to be less than 1 kilometer.

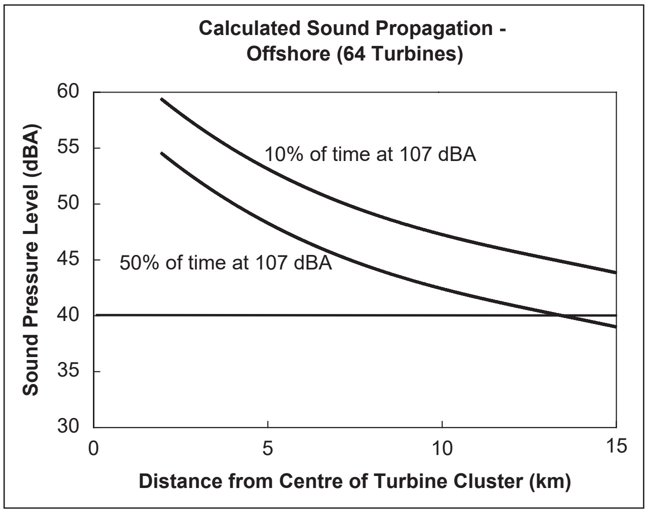

Figure 2. Predicted sound pressure level versus distance from group of 64 offshore turbines

The work of Søndergaard and Plovsing (2005) was followed up by sound propagation experiments over sea in the Kalmar Strait between Sweden and the Öland island in the Baltic Sea (Boué, 2007). The separation between source and receiver was 9.7 kilometers. Measurements of *average* sound transmission loss showed agreement with the Swedish propagation model with a transition distance of 700 meters for the break between spherical and cylindrical spreading. Furthermore, the measured TL(90), the transmission loss exceeded 90% of the time, was in agreement with the Swedish propagation model with the 200 meter transition distance. Therefore, Boué's measurements allow a reliable estimate of the sound pressure level as a function of distance over water from a turbine. Interestingly, Dickinson (2010) in New Zealand has found the break point of 750 meters for turbine noise propagation over land.

At large distances, such as 5 kilometers, the path difference between the direct and reflected pathways from turbine to receptor become small. For instance, at a distance of 5 kilometers, the path difference is equal to or less than a quarter wavelength for frequencies ≤1700 Hz. That is, for the spectrum of sound that reaches a receptor the direct and reflected sound waves add coherently. This adds 3 dB to the sound pressure level.

A numerical example demonstrates the difference between sound propagation over land and water. Figure 2 shows the predicted sound pressure level as a function of distance from a group of 64 offshore turbines. The example uses the Siemens 2.3 MW turbines, which reach their maximum sound power level of 107 dBA when the electrical power output is just 25% of the turbine nameplate power output. The wind farm will have some extension of course. The distance is the mean distance from the group. The lower curve is based on the average transition distance of 700 meters determined by Boué; the upper curve corresponds to the sound pressure level expected for 10% of the time that the turbines are operating at a capacity factor of 25% or greater. For the "worst case scenario" the setback of the wind farm needs to be 20 kilometers offshore.

Conclusion

Wind turbines are noisy and cause annoyance in about 20% of residents living within a distance considered acceptable by regulatory authorities. For many of this 20%, the annoyance and sleep disturbance leads on to adverse health effects. This is a far larger proportion than for those living with traffic and industrial noise at the same level. The annoyance and adverse health effects are attributable to the character of turbine noise and to deficiencies in noise regulations. Specifically, given the amplitude modulation, the allowed intrusion above ambient is far too high; there is no account taken of uncertainty in the prediction of noise at a home; there is no account taken for the excess noise caused by turbulent inflow, both natural and up-wind turbine wake; and the lack of compliance testing leaves the adverse health effects to compound from one completed wind farm to the next one being designed.

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Bio

John P. Harrison has expertise in the properties of matter at low temperatures with emphasis on high frequency sound waves (phonons). For the past 5 years he has studied wind turbine noise and its regulation. He has presented invited talks on the subject at 3 conferences, including the 2008 World Wind Energy Conference.

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Literature Reviews on Wind Turbines and Health: Are They Enough?

Brett Horner[1], Roy D. Jeffery[2], and Carmen M. E. Krogh[1]

Abstract

Industrial wind turbines (IWTs) are a new source of community noise to which relatively few people have yet been exposed. IWTs are being erected at a rapid pace in proximity to human habitation. Some people report experiencing adverse health effects as a result of living in the environs of IWTs. In order to address public concerns and assess the plausibility of reported adverse health effects, a number of literature reviews have been commissioned by various organizations. This article explores some of the recent literature reviews on IWTs and adverse health effects. It considers the completeness, accuracy, and objectivity of their contents and conclusions. While some of the literature reviews provide a balanced assessment and draw reasonable scientific conclusions, others should not be relied on to make informed decisions. The article concludes that human health research is required to develop authoritative guidelines for the siting of IWTs in order to protect the health and welfare of exposed individuals.

Keywords

wind turbines, adverse health effects, literature reviews

Introduction

Industrial wind turbines (IWTs) are promoted as a clean, renewable source of energy generation. In response to environmental concerns, many jurisdictions have incorporated IWT development as a component of their energy mix.

Noise regulations can have a significant impact on wind turbine spacing, and therefore the cost of wind generated electricity (Canadian Wind Energy Association, 2004). To obtain access to the transmission grid IWTs are being sited in close proximity to human habitation (Hornung, 2010). Some individuals are reporting experiencing adverse health effects resulting from living in the environs of IWTs.

The discussion presented in this article is based on the content and conclusions of some of the available literature reviews on the subject of IWTs and adverse health effects. This article is not a literature review. The intention is to consider the completeness, accuracy, and objectivity of the contents of some reviews.

While this article discusses some of commonly cited literature reviews produced in the past few years, it is not intended to be exhaustive. The literature reviews considered have been produced in North America and Australia.

There is no intention to focus on any author. Some (co) authors cited in this article have participated in more than one of the literature reviews considered.

Setting the Stage

IWTs are elevated sound sources visible from afar and hence intrude both visually and aurally into private space. IWTs are also a new source of community noise to which relatively few people have yet been exposed (Pedersen, Bakker, Bouma, & van den Berg, 2009).

There are reports of individuals experiencing adverse health effects attributed to exposure to IWTs in media reports, official reports (Hansard, 2009), and case studies (Harry, 2007; Krogh, Gillis, Kouwen, & Aramini, 2011; Nissenbaum, 2009; Phipps, Amati, McCoard, & Fisher, 2007; Pierpont, 2009; Shepherd, McBride, Welch, Dirks, & Hill, 2011; Thorne, 2011). Examples of reported adverse health effects include annoyance, sleep disturbance, stress or psychological distress, inner ear symptoms, headaches, excessive tiredness, and reduction of quality of life.

The World Health Organization (WHO, 1948) definition of health has been accepted by many jurisdictions including the Canadian federal, provincial, and territorial governments and health officials (Health Canada, 2004, vol. 1, p. 1-1): "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

IWT-induced annoyance, stress, sleep disturbance, other reported psychological or physiological symptoms and reduced quality of life constitute adverse health effects under the WHO definition of health.

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These reports have raised concerns that IWTs be sited in a manner that prevents negative health impacts. In recent years, a number of literature reviews on the subject of IWTs and adverse health effects have been convened in order to address these concerns.

Chatham-Kent Public Health Unit–Canada

In June 2008, the Chatham-Kent Public Health Unit released a literature review titled "The Health Impact of Wind Turbines: A Review of the Current White, Grey, and Published Literature." Some of the IWT issues discussed included structural and blade failure, ice throw, noise, shadow flicker, and construction injuries.

The literature review discusses the benefits of wind energy and informs the reader that the Chatham-Kent Official Plan states,

> It shall be the objective of Chatham-Kent to: encourage the development of wind energy systems for electricity production, as a source of renewable energy for the economic and environmental benefit of Chatham-Kent and the Province of Ontario.

Chatham-Kent Public Health Unit (2008) states that wind power has no harmful pollutants. However, one of the references cited to support this assertion, that is, WHO (2004), does acknowledge that IWT ". . . noise pollution may be a problem if turbines are situated close to centres of population."

Chatham-Kent Public Health Unit (2008) states, "Wherever possible, peer reviewed journals were utilized as the first information source in efforts to reduce potential bias" (p. 5) However, a number of relevant peer-reviewed articles available at the time of the literature review were omitted from the reference list. Examples include Pedersen and Persson Waye (2007, 2008), and G. P. van den Berg (2003). In addition, the literature review citations primarily include non–peer-reviewed references, many of which are produced for, or by, members of the wind energy industry. For example, numerous citations are from the works of the Canadian, American, British, and Danish wind energy associations or their listed members.

Chatham-Kent Public Health Unit (2008) acknowledges noise and sound can be annoying and states, "wind turbine noise is comparatively lower than road traffic, trains, construction activities, and industrial noise." However, it does not inform readers that IWT noise is found to be more annoying than other equally loud sources of noise including transportation noise and industrial noise or that sleep disturbance from IWT noise can occur (Pedersen & Persson Waye, 2004, 2007; F. van den Berg, Pedersen, Bouma, & Bakker, 2008).

Chatham-Kent Public Health Unit (2008) closes by stating,

> This paper concludes and concurs with the original quote from Chatham-Kent's Acting Medical Officer of Health, Dr. David Colby,
>
> In summary, as long as the Ministry of Environment Guidelines for location criteria of wind farms are followed, it is my opinion that there will be negligible adverse health impacts on Chatham-Kent citizens. Although opposition to wind farms on aesthetic grounds is a legitimate point of view, opposition to wind farms on the basis of potential adverse health consequences is not justified by the evidence.

Although Chatham-Kent's Acting Medical Officer (personal communication, May 6, 2009) is not the author of the literature review, he has stated that he endorsed it and takes full responsibility for the contents.

In a 2009 reference, the Acting Medical Officer of Health Chatham-Kent Health Unit stated,

> ... fluctuating aerodynamic noise is the cause of most noise complaints regarding wind turbines, as it is harder to become accustomed to fluctuating noise than to noise that does not fluctuate. The noise limits imposed by the Ministry of the Environment for wind turbines are designed to prevent noise issues but some wind turbines produce noise levels that may be irritating and even stressful to some people who are more sensitive to noise. Sleep disturbance can occur. Others exposed to the same noise levels may experience no difficulty. There is no evidence of direct effects to health by this level of noise but there could be indirect effects from annoyance-induced stress. (p. 3)

IWT-induced annoyance and sleep disturbance has been documented to occur at sound pressure levels permitted by Ontario IWT noise guidelines (Ministry of the Environment, Ontario, 2008; Pedersen & Persson Waye, 2004).

Notably, Chatham-Kent Public Health Unit (2008) omits discussion of amplitude modulation in modern upwind turbines, sleep disturbance, and annoyance-induced stress. The literature review cites Leventhall (2006), noting the reference discounts IWT infrasound as a health concern. However, Chatham-Kent Public Health Unit (2008) omits informing readers that Leventhall (2006) identified amplitude modulation as the noise which requires attention, both to reduce it and to develop optimum assessment methods.

Chatham-Kent Public Health Unit (2008) mentions research conducted by Dr. Nina Pierpont noting, "One cannot discount the information, yet it is prudent that generalizations from such limited data are avoided." Chatham-Kent Public Health Unit omits discussion of the specifics of Dr. Pierpont's research.

Dr. Pierpont's results were published in her 2009 book. She described an array of symptoms documented in her case study of individuals exposed to IWTs:

> Symptoms include sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering when awake or asleep. (p. 26)

Dr. Pierpont proposes a hypothesis regarding causation and acknowledges that additional research is required.

A 2010 presentation by the Acting Medical Officer of Health Chatham-Kent Health Unit states,

> Dr Pierpont has not made new discoveries.
>
> She is describing stress effects of low level noise, which occur with a small number of people.
>
> These effects have been published a number of times previously and are well known to those experienced at the "street level" of environmental noise problems.
>
> It appears that there is no specific Wind Turbine Syndrome, but there are stress effects from low levels of noise, either high frequency or low frequency noise, which affect a small number of people. It is the audible swoosh-swoosh which, when it occurs, is the cause, not infrasound or low frequency noise.

Minnesota Department of Health–United States

In May 2009, the Minnesota Department of Health Environmental Health Division released "Public Health Impacts of Wind Turbines." The literature review focuses predominately on IWT noise and vibration but also discusses IWT shadow flicker, that is, the casting of moving shadows on the ground as the wind turbine blades rotate.

A brief overview of the characteristics of sensory systems and sound is followed by a discussion of the characteristics of IWT noise. In addition, the literature review discusses specific IWT noise issues including difficulties in accurately modeling IWT noise levels, nighttime noise issues, effects of wind shear, modulation of aerodynamic noise, and low-frequency noise.

IWT shadow flicker is also discussed noting that it can cause annoyance and driver distraction, and can be an issue both indoors and outdoors when the sun is low in the sky. It notes flicker should not be an issue at distances over 10 rotational diameters or approximately 1,000 meters, which is a recommended setback distance. Detailed shadow flicker modeling is also recommended during the planning stage of an IWT project.

Studies of IWT impacts on people are summarized. The Minnesota Department of Health (2009) discusses both peer-reviewed literature and nonreviewed case reports which catalogued complaints of annoyance and other health impacts associated with IWTs. Case report summaries of Harry (2007), Phipps et al. (2007), The Large Wind Turbine Citizens Committee for the Town of Union (2008), and Pierpont (2009) are included in the literature review.

The Minnesota Department of Health (2009) notes that lower noise levels,

> . . . from wind turbines engenders annoyance similar to much higher levels of noise exposure from aircraft, road traffic and railroads. Sound impulsiveness, low frequency noise and persistence of the noise, as well as demographic characteristics may explain some of the difference. (pp. 19-20)

It states in its conclusion,

> The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headache are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise. Complaints appear to rise with increasing outside noise levels above 35 dB(A). It has been hypothesized that direct activation of the vestibular and autonomic nervous system may be responsible for less common complaints, but evidence is scant. (p. 25)

Minnesota Department of Health (2009) received a Notable Document Award for excellence in exploring topics of contemporary interest to legislators from the Legislative Research Librarians staff section of the National Conference of State Legislatures (National Conference of State Legislatures, 2010, http://www.ncsl.org/?tabid=16066)

AWEA/CanWEA Panel Review–United States/Canada

In response to publicized concerns that the sounds emitted from wind turbines cause adverse health consequences, industry trade associations, the American Wind Energy Association (AWEA), and Canadian Wind Energy Association (CanWEA), funded a literature review titled, "Wind Turbine Sound and Health Effects: An Expert Panel Review" (Colby et al., 2009).

The literature review focuses its discussion on IWT sound and does not address, in detail, other IWT impacts such as shadow flicker.

The Colby et al. (2009) Conclusions section states, "1. Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans." (p. 5-2). However, the contents of the literature review acknowledge IWT noise may cause annoyance, stress, and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms (p. 4-3, p. 4-10, p. 5-2).

Colby et al. (2009) lists symptoms which Dr. Nina Pierpont coined as "wind turbine syndrome" stating,

> Symptoms included sleep disturbance, headache, tinnitus, ear pressure, vertigo, nausea, visual blurring, tachycardia, irritability, concentration, memory, panic attacks, internal pulsation, and quivering.
>
> . . . these so called "wind turbine syndrome" symptoms are not new and have been published previously in the context of "annoyance" to environmental sounds. . . . The following symptoms are based on the experience of noise sufferers extending over a number of years: distraction, dizziness, eye strain, fatigue, feeling vibration, headache, insomnia, muscle spasm, nausea, nose bleeds, palpitations, pressure in the ears or head, skin burns, stress, and tension . . . (pp. 4-9, 4-10)

In reference to "wind turbine syndrome" symptoms Colby et al. (2009) coauthor Dr. Geoff Leventhall stated,

> I am happy to accept these symptoms, as they have been known to me for many years as the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise. . . . what Pierpont describes is effects of annoyance by noise—a stress effect, not the direct physiological effect which she claims, as it has been shown above that these claims are without substance. What Pierpont describes are simply the well known effects of persistent, unwanted noise, and use of the words "Wind Turbine Syndrome" should be discontinued, in order to avoid confusion. (*PSC Ref#121877 20: Wind Turbine Syndrome: An appraisal*, 2009, pp. 9-10)

The forgoing citations appear to contradict the Colby et al. (2009) conclusion that "Sound from wind turbines does not pose a risk of . . . any other adverse health effect in humans." (p. 5-2)

In March 2011, Dr. Leventhall testified under oath that the Colby et al. (2009) Conclusion "1" would be more clearly worded by adding the words, "direct physiopathological effects" (Erickson v. Director, Ministry of the Environment, 2011b), that is, sound from wind turbines does not pose a risk of hearing loss or any other direct physiopathological effect in humans. This addition of the words "direct physiopathological" is an important distinction which alters the fundamental meaning of one of the literature review's main conclusions.

The authors also conclude that "2. Subaudible, low frequency sound and infrasound from wind turbines do not present a risk to human health" (Colby et al., 2009, p. 5-2). However, the literature review also acknowledges that "No scientific studies have specifically evaluated health effects from exposure to low frequency sound from wind turbines" (Colby et al., 2009, p. 3-17). In the absence of specific scientific studies, it is difficult to draw a definitive conclusion.

In its discussion of IWT low frequency noise, Colby et al. (2009) states,

> According to a report of the National Research Council (NRC), low frequency sound is a concern for older wind turbines but not the modern type (National Research Council, 2007). (p. 3-17)

National Research Council (2007) does not appear to support the above statement. In reference to IWTs and low-frequency noise the National Research Council (2007) states,

> Low-frequency vibration and its effects on humans are not well understood. Sensitivity to such vibration resulting from wind-turbine noise is highly variable among humans. Although there are opposing views on the subject, it has recently been stated (Pierpont 2006) that "some people feel disturbing amounts of vibration or pulsation from wind turbines, and can count in their bodies, especially their chests, the beats of the blades passing the towers, even when they can't hear or see them." More needs to be understood regarding the effects of low-frequency noise on humans. . . . studies on human sensitivity to very low frequencies are recommended. (pp. 158-159, p. 176)

Colby et al. (2009) in their Conclusions state, "3. Some people may be annoyed at the presence of sound from wind turbines. Annoyance is not a pathological entity" (p. 5-2).

However, under oath Dr. Leventhall acknowledged that based on the information he had submitted, it would be fair to change Conclusion "3" from some people "may be" annoyed, to some people "will be" annoyed at the presence of sound from wind turbines. (Erickson v. Director, Ministry of the Environment, 2011b)

The final Conclusions states, "4. A major cause of concern about wind turbine sound is its fluctuating nature. Some may find this sound annoying, a reaction that depends primarily on personal characteristics as opposed to the intensity of the sound level." (p. 5-2)

However, Leventhall (2006, p. 34) discusses IWT amplitude modulation:

> Attention should be focused on the audio frequency fluctuating swish, which some people may well find to be very disturbing and stressful, depending on its level.

> The usual equivalent level measurements and analyses are incomplete, as these measurements are taken over a time period which is much longer than the fluctuation period and information on the fluctuations is lost. A time varying sound is more annoying than a steady sound of the same average level and this is accounted for by reducing the permitted level of wind turbine noise. However, more work is required to ensure that the optimum levels have been set.

Leventhall (2006) does not state that human response to amplitude modulation was primarily influenced by an individual's attitude but rather depends on its level/intensity. Consequently Conclusion "4" of Colby et al. (2009) appears to contradict Leventhall (2006).

In 2011, Dr. Leventhall affirmed the contents of Leventhall (2006) testifying there are no changes he would like to make to his 2006 article. (Erickson v. Director, Ministry of the Environment 2011b)

Colby et al. (2009) discuss how the first indication that an exposure might be harmful comes from the informal observations of doctors who notice a possible correlation between an exposure and a disease, then communicate their findings to colleagues in case reports, or reports of groups of cases (case series).

Based on its analysis of case reports, this literature review states in its Conclusions section,

> Panel members agree that the number and uncontrolled nature of existing case reports of adverse health effects alleged to be associated with wind turbines are insufficient to advocate for funding further studies. (Colby et al., 2009, p. 5-2)

However, Colby et al. (2009) limit their discussion to only two of the case studies available at the time of their publication. Case studies omitted from the literature review include the following: Krogh, Gillis, and Kouwen (2009), Nissenbaum (2009), Harry (2007), and Phipps et al. (2007).

Colby et al. (2009) suggests the "nocebo effect" may be a possible cause of reported IWT adverse health effects.

A keyword search of "nocebo" in *Noise and Health Journal* (as cited July 10, 2010), and WHO's *Guidelines for Community Noise* (Berglund, Lindvall, & Schwela, 1999) and *Night Noise Guidelines for Europe* (2009) yields no results. A keyword search of "nocebo" in peer-reviewed literature on the subject of human response to wind turbine noise returns no results. Research demonstrates individuals initially welcomed IWTs into their communities and the reported adverse impacts were unexpected (Krogh, 2011, p. 330).

National Collaborating Centre for Environmental Health–Canada

In January 2010, the National Collaborating Centre for Environmental Health (Canada), published an article, "Wind Turbines and Health" (Rideout, Copes, & Bos, 2010).

The first page contains a summary of findings and states, "The sound level associated with wind turbines at common residential setbacks is not sufficient to damage hearing, but may lead to annoyance and sleep disturbance" (p. 1).

This literature review also notes that "Annoyance and sleep disruption are common when sound levels are 30 to 45 dBA" (p. 4).

Citing Pierpont (2009), this literature review notes that a range of symptoms including dizziness, sleep disruption, and headaches have been attributed to wind turbines but it does not elaborate.

The literature review cites Colby et al. (2009) noting that IWT sound will not damage hearing. However, omitted is the Colby et al. (2009) acknowledgment that reported health effects are the result of stress from noise annoyance.

In earlier references, authors Copes and Rideout (2009a, 2009b) identified that IWT noise and/or aesthetics and/or shadow flicker may cause stress. However, these acknowledgments of stress are omitted from Rideout et al. (2010).

Both Rideout et al. (2010) and Copes and Rideout (2009a) list a number of key gaps. Some of the gaps identified include

- stress-induced health effects from noise, visual impact, shadow flicker
- health effects from long-term exposure to low levels of low-frequency sound
- practical measurement methods for attributing sound specifically to wind turbines
- impact of wind turbine sound on sleep physiology
- dizziness and migraine from shadow flicker
- risk of ice throw in regions where glaze ice is common (most research has focused on rime ice)
- research to measure the efficacy of currently used setbacks to prevent injury
- epidemiological data to assess health status before and after wind farm development

In spite of these acknowledged gaps Rideout et al. (2010) do not make an appeal for new research.

Chief Medical Officer of Health–Canada

On May 20, 2010, the Chief Medical Officer (2010a) of Health of Ontario released "The Potential Health Impact of Wind Turbines." This literature review discusses a number of IWT issues including the following: the main research data available to date on wind turbines and health, sound and noise, low-frequency sound, infrasound and vibration, sound exposure assessment, electromagnetic fields, shadow flicker, ice throw and ice shed, and structural hazards.

Chief Medical Officer of Health (2010a) cites "four cross-sectional studies, published in scientific journals, which investigated the relationships between exposure to wind turbine noise and annoyance in large samples of people (351 to

1,948) living in Europe near wind turbines" (p. 5). The literature review goes on to state that the studies found,

> The sound was annoying only to a small percentage of the exposed people; approximately four to ten per cent were very annoyed at sound levels between 35 and 45 dBA. (Chief Medical Officer of Health, 2010a, p. 6)

However, the Chief Medical Officer of Health (2010a) omitted results from Swedish studies, the respondents who were "rather" annoyed, and the respondents who reported annoyance when spending time outdoors at their dwelling. Therefore, based on a peer-reviewed body of research, reporting a range of at least 5% to 28% would have been more accurate (Pedersen et al., 2009; Pedersen & Persson Waye, 2004).

Of significance, a 2010 final draft report prepared for the Ontario Ministry of Environment states,

> The audible sound from wind turbines, at the levels experienced at typical receptor distances in Ontario, is nonetheless expected to result in a nontrivial percentage of persons being highly annoyed. As with sounds from many sources, research has shown that annoyance associated with sound from wind turbines can be expected to contribute to stress related health impacts in some persons. (Howe Gastmeier Chapnik Limited, 2010, p. 39)

Chief Medical Officer of Health (2010a) discusses Pierpont (2009) but omits discussion of other case studies including Nissenbaum (2009), Harry (2007), and Phipps et al. (2007). WindVOiCe (Krogh et al., 2009) is included in the reference list; however, there is no discussion of the Ontario-based health survey. Prior to the release of the literature review, the Chief Medical Officer of Health of Ontario, Dr. Arlene King, had been informed of the results of the Krogh et al. (2009) survey (Teleconference, 2009, November 23). Just prior to the release of the literature review the Office of the Chief Medical Officer of Health of Ontario was advised, by e-mail, of updated WindVOiCe results. At that time the survey documented approximately 100 Ontario residents reporting adverse health effects (Krogh, Gillis, & Kouwen, 2010).

Chief Medical Officer of Health (2010a) discusses the symptoms documented in Dr. Pierpont's case study, that is, "wind turbine syndrome" and concludes,

> While some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. (p. 10)

The use of the word "direct" by the Chief Medical Officer of Health (2010a) ignores the possibility of indirect adverse health effects from IWT noise. The lead author of this literature review acknowledged under oath that Chief Medical Officer of Health (2010a) only looked at direct links (Erickson v. Director, Ministry of the Environment, 2011a) and in addition, the report:

> . . . did not say that there is no sleep disturbance, it said that there is no direct link to the sleep disturbance. So if annoyance has caused the sleep disturbance, we are not saying that that could not have happened. (Erickson v. Director, Ministry of the Environment, 2011a)

Chief Medical Officer of Health (2010a) cites Colby et al. (2009) but does not disclose that this reference attributes "wind turbine syndrome" symptoms to be stress responses associated with noise annoyance. Chief Medical Officer of Health (2010a) omits discussion of potential stress impacts.

One of the main conclusions of the Chief Medical Officer of Health (2010a) is "The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct adverse health effects" (p. 6).

This statement that "other direct adverse health effects" will not be caused by exposure to wind turbine sound is not supported by the studies reviewed by the Chief Medical Officer of Health (2010a) which consider the relationship between residential exposure to IWT sound and human health.

Chief Medical Officer of Health (2010a) does acknowledge the unique characteristics of IWT noise, and the unique human response to IWT noise, stating, "Wind turbine noise was perceived as more annoying than transportation or industrial noise at comparable levels, possibly due to its swishing quality, changes throughout a 24 hour period, and lack of night-time abatement." (p. 6)

From various studies it follows that this swishing (modulation) is equivalent in annoyance to the unmodulated sound at an approximately 5 dB higher level (Pedersen & van den Berg, 2010).

Ontario Guidelines require a 5 dBA adjustment for other industrial noise that has amplitude modulation (Ministry of the Environment, Ontario, n.d.); however, there is no such adjustment for IWT amplitude modulation (Ministry of the Environment, Ontario, 2008). Chief Medical Officer of Health (2010a) does not address this disparity.

Chief Medical Officer of Health (2010a) also concludes,

> Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects (p. 10).

This conclusion is not supported by other references listed in the report of Chief Medical Officer of Health (2010a). For example, the literature review of Minnesota Department of

Health (2009) suggests that reported health effects are related to audible low-frequency noise.

Colby et al. (2009) acknowledge that "No scientific studies have specifically evaluated health effects from exposure to low frequency sound from wind turbines" (p. 3-17).

Furthermore, Chief Medical Officer of Health (2010a) acknowledges that the Ontario Ministry of the Environment had recently hired consultants to review low-frequency sound impacts from wind turbines and develop recommendations regarding low-frequency sound. The consultant's final draft report on IWT low-frequency noise and infrasound states that "There is a degree of disagreement and uncertainty in the literature of some of the subjects discussed in this review, and research efforts are ongoing" (Howe Gastmeier Chapnik Limited, 2010, p. 41) The report also acknowledges that IWT low-frequency noise can be an issue and recommends the adoption or development of a protocol to provide guidance for addressing such complaints (Howe Gastmeier Chapnik Limited, 2010).

Under oath the lead author of the report of Chief Medical Officer of Health (2010a) stated that

> . . . there is definitely recognition that low frequency sound could produce annoyance and the sensitivity to annoyance to low frequency sound could be greater than to audible sounds. (Erickson v. Director, Ministry of the Environment, 2011a)

Annoyance from audible low-frequency noise is acknowledged to be more severe in general. Low-frequency noise does not need to be considered loud for it to cause annoyance and irritation (DeGagne & Lapka, 2008). Low-frequency noise causes immense suffering to those who are unfortunate to be sensitive to it (Leventhall, 2003) and chronic psychophysiological damage may result from long-term exposure to low-level low-frequency noise (Leventhall, 2004). Some symptoms associated with exposure to low-frequency noise include stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, anxiety, heart ailments, and palpitation (DeGagne & Lapka, 2008; Leventhall, 2003; Schust, 2004).

The report of the Chief Medical Officer of Health (2010a) contains a section on Ontario IWT setbacks which states,

> Provincial setbacks were established to protect Ontarians from potential health and safety hazards of wind turbines including noise and structural hazards.

Analysis of this section suggests that the authors lack a thorough understanding of the existing Ontario IWT setbacks.

For example, Chief Medical Officer of Health (2010a) states,

> . . . a wind project with five turbines, each with a sound power level of 107dB, must have its turbines setback at a minimum 950 m from the nearest receptor.

The above use of the term *must* is incorrect. Ontario regulations permit IWTs to be sited as close as 550 m if the developer submits a report prepared in accordance with the publication of the Ministry of the Environment titled "Noise Guidelines for Wind Farms" (Environmental Protection Act, Ontario Regulation 359/09).

Chief Medical Officer of Health (2010a) also states that setbacks are based on modeling of sound produced by wind turbines and are intended to limit sound at the nearest residence to no more than 40 dB. It does not inform readers that Ontario IWT Noise Guideline permit in principle, levels up to 51 dBA at a residence 24 hours a day (Ministry of the Environment, Ontario, 2008). The 51 dBA permitted by Ontario guidelines is significantly higher than the 40 dB that the report of the Chief Medical Officer of Health (2010a) indicates is recommended to protect public health from community noise.

In 2011, when questioned about the 40 dB noise limit the lead author of the report of the Chief Medical Officer of Health (2010a) acknowledged that it was not developed based on IWT noise research but rather on traffic, rail, and aircraft noise. Furthermore, when asked to comment on the approved Ontario IWT noise limits of up to 51 dBA the lead author testified she would not like to speculate on numbers above 40 dBA (Erickson v. Director, Ministry of the Environment, 2011a).

Of interest, in 2009 the lead consultant of the report which led to the 2008 Ontario IWT noise guidelines declined to comment on IWTs and health stating,

> I am not a medical doctor or a psychoacoustician or a physiological acoustician. I am an acoustician from the engineering science perspective. So, to comment on health issues is outside my area of expertise. (personal communication, July 22, 2009)

The Chief Medical Officer of Health (2010a) acknowledges Ontario does not have a measurement protocol to verify actual IWT noise compliance with the modeled limits.

The Chief Medical Officer of Health (2010a) discusses IWT shadow flicker but limits the topic to photosensitive epilepsy noting that industrial turbines rotate at a speed below that which would trigger a seizure. However, the literature review does not mention that shadows cast by one turbine on another should not have a cumulative flash rate exceeding 3 per second (Harding, Harding, & Wilkins, 2008). Consideration of shadow flicker–induced annoyance is also omitted. As well, there is no mention that detailed shadow flicker modeling is a recommended practice (Minnesota Department of Health, 2009; National Research Council, 2007). The absence of Ontario regulations to minimize the impact of IWT shadow flicker is not addressed.

Wind turbine ice throw and structural failure are potentially severe public hazards to people or passing vehicles (Rideout et al., 2010). The Chief Medical Officer of Health (2010a) acknowledges that "injury is minimized with setbacks of 200 to 500 metres" but does not question the wisdom of Ontario's setbacks which permit wind turbines to be situated within approximately 50 m (blade length plus 10 m) of a public road, railways, and/or a nonparticipating property (Environmental Protection Act, Ontario Regulation 359/09).

Contributing authors reportedly commented that material that could have been included was left out of the report of the Chief Medical Officer of Health (2010a) (Jankowski, 2010).

Of interest, in previous works, some of the contributing authors of the report of the Chief Medical Officer of Health (2010a), acknowledge that IWT noise may cause annoyance and/or stress and/or sleep disturbance (Copes & Rideout, 2009a, 2009b; Rideout et al., 2010) and symptoms such as dizziness, headaches, and sleep disturbance are examples of the well-known stress effects of exposure to noise (Colby et al., 2009).

In addition to their literature review, the office of the Chief Medical Officer of Health of Ontario has produced other references on the topic of IWTs and health.

For example in October 2009, the Chief Medical Officer of Health of Ontario, issued a memorandum addressed to medical officers of Health and Environmental Health directors. The memorandum references the work of Dr. Copes stating that ". . . sound produced by wind turbines is sometimes found to be annoying to some people which may result in stress and sleep disturbance" (King, 2009).

The above acknowledgment that IWT noise annoyance may result in stress and sleep disturbance is omitted from the report of the Chief Medical Officer of Health (2010a).

Another document was prepared by the office of the Chief Medical Officer of Health and transmitted to Ontario medical officers of health by the chair of the Council of Ontario Medical Officers of Health on May 19, 2010 (personal communication, January 27, 2011). The document states,

> Although some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, available scientific evidence does not demonstrate a direct causal link to wind turbine noise. It is possible that these symptoms are a result of annoyance with the noise. (Chief Medical Officer of Health, 2010b)

The acknowledgment that it is possible that the reported symptoms such as dizziness, headaches, and sleep disturbance are the result of IWT noise–induced annoyance is another omission from the Chief Medical Officer of Health (2010a).

Salt and Hullar–United States

On June 16, 2010, Dr. Alec Salt and Dr. Timothy Hullar released their peer-reviewed literature review titled, "Responses of the ear to low frequency sounds, infrasound and wind turbines" (Salt & Hullar, 2010). This work was supported by a research grant from the National Institute on Deafness and Other Communication Disorders, National Institutes of Health.

Salt and Hullar (2010) discuss the physics of infrasound, the anatomy of the ear, the mechanics of low-frequency stimulation, and the mechanics of low-frequency stimulation. The literature review notes that most references dismiss IWT inaudible low-frequency noise or infrasound as an issue on the basis that the sound is not perceptible. However, the authors state that this perspective fails to take into account that the outer hair cells of the inner ear are stimulated at levels that are not heard. The authors note that this raises the possibility that exposure to the infrasound component of wind turbine noise could influence the physiology of the ear and more research is required before firm conclusions can be made.

Salt and Hullar (2010) state in their conclusions,

> Other sensory cells or structures in the inner ear, such as the outer hair cells, are more sensitive to infrasound than the inner hair cells and can be stimulated by low frequency sounds at levels below those that are heard. The concept that an infrasonic sound that cannot be heard can have no influence on inner ear physiology is incorrect.
>
> . . .
>
> Based on our understanding of how low frequency sound is processed in the ear, and on reports indicating that wind turbine noise causes greater annoyance than other sounds of similar level and affects the quality of life in sensitive individuals, there is an urgent need for more research directly addressing the physiologic consequences of long-term, low level infrasound exposures on humans (p. 8).

National Health and Medical Research Council–Australia

In July 2010, the National Health and Medical Research Council released a report titled "Wind Turbines and Health, A Rapid Review of the Evidence July 2010" (National Health and Medical Research Council, 2010a). In 11 pages this literature review discusses adverse health impacts of IWTs with a focus on the effects of infrasound, noise, electromagnetic interference, shadow flicker, and blade glint.

At the outset, the National Health and Medical Research Council (2010a) present the reader with a limited scope. It states,

> In particular the paper seeks to ascertain if the following statement can be supported by the evidence: There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines. This statement is supported by the 2009 expert literature review commissioned by the American and Canadian Wind Energy Associations. (Colby et al., 2009)

A National Health and Medical Research Council (personal communication, June 15, 2010) communication asserts that the literature review ". . . only uses the best available evidence, in the form of peer-reviewed scientific literature, to formulate its recommendations."

The contents of National Health and Medical Research Council (2010a) reveal a different reality. The quality of material cited in NHMRC (2010a) is questionable. For example, the literature review cites an internet posting contained on "croakey the Crikey health blog." At the same time a number of the existing relevant peer-reviewed articles relevant to IWTs and health were omitted from the reference list.

National Health and Medical Research Council (2010a) quotes Colby et al. (2009): "Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effects in humans." However, it does not advise the reader that Colby et al. (2009) also acknowledge IWT noise may cause annoyance, stress, and sleep disturbance.

National Health and Medical Research Council (2010a) also states,

> The opposing view is that noise from wind turbines produces a cluster of symptoms which has been termed Wind Turbine Syndrome (WTS).

The literature review omits the discussion that Colby et al. (2009) attribute the symptoms defined as "wind turbine syndrome" to be the stress effects of noise annoyance. While National Health and Medical Research Council (2010a) briefly mentions Dr. Pierpont's research it does not detail the documented symptoms and omits any discussion of other existing case studies.

National Health and Medical Research Council (2010a) states,

> . . . numerous reports have concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines

One of the references cited to support this statement is WHO (2004). However, WHO (2004) does not evaluate the health impacts of IWT infrasound or low-frequency noise.

National Health and Medical Research Council (2010a) relies on Minnesota Department of Health (2009); however, it omits disclosing that this literature review concludes that most available evidence suggests the reported health effects are related to audible low-frequency noise.

National Health and Medical Research Council (2010a) also relies on a citation from a fact sheet, which states, "Findings clearly show that there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health." Canada's federal health agency, Health Canada, responded to this fact sheet, stating, "In fact, there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health" (Health Canada, 2009).

National Health and Medical Research Council (2010a) also quotes a reference by HGC Engineering which states,

> While a great deal of discussion about infrasound in connection with wind turbine generators exists in the media there is no verifiable evidence for infrasound and production by modern turbines.

However, National Health and Medical Research Council (2010a) omits a reference by the same authors which acknowledges modern IWTs do produce infrasound (Howe Gastmeier Chapnik Limited, 2006). In addition, HGC Engineering stated in 2010 that modern IWTs produce infrasound which may be audible or inaudible (Howe Gastmeier Chapnik Limited, 2010).

National Health and Medical Research Council (2010a) concludes by stating,

> There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines. (p. 8)

The authors do not specify what the potential impacts on humans are nor do they provide specifics of the planning guidelines which will minimize the impacts.

In a public statement, National Health and Medical Research Council (2010b), affirms the need for research recommending ". . . relevant authorities take a precautionary approach and continue to monitor research outcomes." However, the literature review makes no appeal for new research.

Discussion

Complete, Accurate, and Objective

Literature reviews can be useful tools for summarizing existing literature related to a particular topic. In order to be considered reliable a literature review must be complete, accurate, and objective.

Literature reviews assessing the potential health impacts of a new exposure must evaluate the totality of the evidence. The use of terminology such as "direct physiopathological effects" or "direct causal links" limits the discussion. Failure to carefully evaluate potential indirect causal pathways and the psychological harm of IWT exposure represent errors of omission. Annoyance, sleep disturbance, cognitive and emotional response, and stress are health effects that occur through the indirect pathway (WHO, 2009, figure 4). The health outcomes associated with the indirect pathway are significant:

> Physiological experiments on humans have shown that noise of a moderate level acts via an indirect pathway and has health outcomes similar to those caused by high noise exposures on the direct pathway. The indirect pathway starts with noise-induced

disturbances of activities such as communication or sleep. (WHO, 2009, p. 138)

In January 2010, the NHS Knowledge Service of the U.K. National Health Service, released a critique of Colby et al. (2009) and concluded, "The link between psychological distress and physical symptoms has not been explored by this report." These observations are appropriate for the other literature reviews that omit an evaluation of the indirect pathway.

Most of the literature reviews discussed in this article share many of the same references. Some of the literature reviews indicate a preference for peer-reviewed research. However, due to the limited body of peer-reviewed literature, they ultimately rely predominately on citations from nonreviewed sources, case studies, and other literature reviews.

Many of the literature reviews omit evaluating most of the available case studies, limiting their discussion to Pierpont (2009). The practice of omitting the majority of case studies raises concerns of completeness and objectivity.

Authors have an inherent responsibility to ensure that they accurately reflect the contents of references cited. Literature reviews which inappropriately cite or misquote references should be viewed with caution.

Some governments have incorporated wind energy as a key component of their energy mix and economic policy. For example, the Ontario Government has passed legislation designed to encourage rapid implementation of renewable energy and has made substantial financial commitments to wind energy development (Government of Ontario, 2010; Green Energy and Economy Act, 2009). Reports, including internal government correspondence, document that some Ontario families reporting adverse health effects have abandoned their homes, or had their homes purchased by IWT developers (Braithwaite, 2009a, 2009b; Ministry of Environment, Ontario, internal e-mail, 2009). Other Ontario families reporting adverse health effects have been billeted by the local IWT developer for months at time (Hansard, 2009; Krogh et al., 2011). Ministry of Environment correspondence also describes how low frequency noise from Ontario IWT facilities resulted in annoyance, "sleep deprivation" and "uninhabitable" living conditions. (Ministry of the Environment, Ontario, internal emails, May 1, 2009, June 29, 2009). Another internal document cites a number IWT noise issues, including amplitude modulation, and concludes "It appears compliance with the minimum setbacks and the noise study approach currently being used to approve the siting of WTGs will result or likely result in adverse effects…" (Ministry of the Environment, Ontario, internal memorandum, April 9, 2010)

Meanwhile the Ontario Health Minister reportedly stated there is no evidence, whatsoever, that there is an issue related to turbines (Heath, 2010).

Claims of no evidence raise concerns regarding the objectivity of research initiatives convened by governments which have financial commitments to; or policies that support; the rapid implementation of IWTs.

Health Canada (2004) states, "Government's job is to provide citizens with accurate and appropriate information so that they can protect themselves" (p. 1-1). It follows that a literature review produced by public health officials should provide the public with complete and accurate information.

Arguably government health officials are not fulfilling their responsibilities to provide citizens with complete and accurate information if their literature reviews omit acknowledgments that IWT-induced annoyance or stress may be the cause of reported health effects.

The Acting Medical Officer of Health Chatham-Kent Health Unit and the Office of the Chief Medical Officer of Health have declined requests to meet with individuals reporting experiencing adverse health from IWTs (personal communications, 2009, 2011). The reluctance of public health officials to consult with individuals reporting health effects represents a significant obstacle to the advancement of knowledge on the issue.

In some cases, literature reviews with common contributing authors, were released only months apart but contain different contents and/or conclusions. These inconsistencies raise concerns of completeness, accuracy, and objectivity.

Literature review assertions that IWT regulations are protective of human health should be viewed with caution if, the authors misquote the regulations, acknowledge recommended noise limits are not designed for IWTs, or are unable to comment on maximum permitted IWT sound levels.

Conclusions presented in a literature review must be derived objectively based on the science available. A conclusion that states that the sound from IWTs does not pose a risk of any adverse health effect in humans is not scientifically credible.

NHS Knowledge Service (2010) discusses the contents of Colby et al. (2009) and concluded, "Overall, this review will probably not resolve this controversy as there was a lack of high-level evidence on which to base any solid conclusions."

Where Are We Now?

The current inventory of the peer-reviewed literature relevant to the topic of IWTs and adverse health effects is increasing. One of the main conclusions from the existing body of peer-reviewed literature is that IWT turbine noise is perceived to be more annoying than transportation noise or industrial noise at comparable sound pressure levels (Pedersen et al., 2009). In addition, a number of case studies have documented individuals living in the environs of IWTs who are reporting adverse health effects.

WHO (2001) has recognized the serious nature of noise: "The recognition of the noise as a serious health hazard as opposed to a nuisance is a recent development and the health effects of the hazardous noise exposure are now considered to be an increasingly important public health problem."

Annoyance is acknowledged to be an adverse health effect (Health Canada, 2005; Michaud, Keith, & McMurchy, 2005; Pedersen & Persson Waye, 2007; Suter, 1991)

Until recently, the serious health consequences of noise-induced annoyance have been underestimated. Maschke and Niemann (2007) confirm that chronic severe annoyance induced by neighbor noise must be classified as a serious health risk.

Of interest, several authors of IWT-related literature reviews accept the plausibility of the reported IWT health effects and acknowledge that IWT noise and/or visual impacts may cause annoyance and/or stress and/or sleep disturbance, which can have other consequences. It is also acknowledged that these adverse health effects can occur at common residential set-back and sound pressure levels.

Some authors conducting literature reviews have proposed plausible mechanisms suggesting that the health effects may be caused by IWT amplitude modulation, the lack of night-time abatement, temporal variability, audible low frequency noise, visual impact, shadow flicker, and economic impacts. Exposure to IWT infrasound is another plausible explanation. All these proposed mechanisms require appropriate investigation.

At this time the precise pathophysiological mechanism(s) for the reported adverse health effects is not settled but important new evidence is emerging. Recent references indicate that IWT noise issues such as amplitude modulation and audible low-frequency noise are becoming more significant as IWTs increase in size (Møller & Pedersen, 2011; Thorne, 2011). Recent recommendations to measure and monitor IWT low-frequency noise indicate advancement of our understanding of IWT noise issues (Howe Gastmeier Chapnik Limited, 2010; *The Social and Economic Impact of Rural Wind Farms*, 2011).

Leventhall (2004) notes ". . . authorities must accept that annoyance by low frequency noise presents a real problem which is not addressed by the commonly used assessment methods." It is now becoming apparent that the commonly adopted compliance-based noise audits, based on "A" weighted Leq, are unsatisfactory for amplitude modulation and low-frequency noise (Richarz, Richarz, & Gambino, 2011; Thorne, 2011).

In summary, some literature reviews provide a balanced assessment and attempt to draw reasonable scientific conclusions based on the totality of evidence. Other literature reviews lack completeness, accuracy, and objectivity and contribute little to inform the public about the potential health risks associated with living in the environs of IWTs. Literature reviews which contain errors of omission and/or errors of commission cannot be relied on to make informed decisions and should be amended or regarded with caution.

Conclusions

IWTs can cause harm to human health if they are sited too close to residents (Thorne, 2011; Krogh, 2011). This finding is confirmed in a July 2011 Ontario Environmental Review Tribunal Decision which also supports the value of additional research into the health impacts of IWTs. The Decision also expressed concern the precautionary principle had not been appropriately considered, noting Colby et al. (2009) and Chief Medical Officer of Health (2010a) are focused on direct health effects rather than the indirect pathway. (DeMarco & Muldoon, 2011 p. 195, p. 204, p. 205, p. 207).

Repetitive literature reviews are of little value when dealing with emerging technologies; particularly when there is an acknowledged lack of original research. Some authors acknowledge knowledge gaps (Minnesota Department of Health, 2009; Rideout et al., 2010) and that research is required (Salt & Hullar, 2010). At the other extreme, other authors specifically do not advocate for funding further studies (Colby et al., 2009). In their review of Colby et al. (2009) the NHS Knowledge Service (2010) concluded new studies are indeed needed and that these studies should include a careful evaluation of the psychological harms of noise exposure.

Our analysis indicates that while some of the literature reviews are helpful, none are sufficient to resolve the complex issues surrounding IWT health effects. Even the most recent of the literature reviews discussed, National Health and Medical Research Council (2010a), cannot be considered conclusive. In March 2011, the chief executive officer of National Health and Medical Research Council stated,

> We regard this as a work in progress. We certainly do not believe that this question has been settled. That is why we are keeping it under constant review. That is why we said in our review that we believe authorities must take a precautionary approach to this (*The Social and Economic Impact of Rural Wind Farms*, 2011)

WHO (Berglund et al., 1999) endorses the precautionary principle,

> In all cases, noise should be reduced to the lowest level achievable in a particular situation. Where there is a reasonable possibility that public health will be damaged, action should be taken to protect public health without awaiting full scientific proof.

A June 2011 Australian Senate committee investigating IWT and adverse health effects report recommended,

> . . . the Commonwealth Government initiate as a matter of priority thorough, adequately resourced epidemiological and laboratory studies of the possible effects of wind farms on human health. This research must engage across industry and community, and include an advisory process representing the range of interests and concerns. (*The Social and Economic Impact of Rural Wind Farms*, 2011)

The authors of this article acknowledge the urgent need for original independent third party research into the adverse health effects of IWTs. In the interim, the precautionary principle must be respected and IWTs should not be built in close proximity to human habitation and where reports of adverse health effects are being reported, the facility should be decommissioned until the situation is resolved.

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Wind Turbines Make Waves: Why Some Residents Near Wind Turbines Become Ill

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2 authors, including:

Magda Havas
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Wind Turbines Make Waves: Why Some Residents Near Wind Turbines Become Ill

Magda Havas[1] and David Colling[2]

Abstract

People who live near wind turbines complain of symptoms that include some combination of the following: difficulty sleeping, fatigue, depression, irritability, aggressiveness, cognitive dysfunction, chest pain/pressure, headaches, joint pain, skin irritations, nausea, dizziness, tinnitus, and stress. These symptoms have been attributed to the pressure (sound) waves that wind turbines generate in the form of noise and infrasound. However, wind turbines also generate electromagnetic waves in the form of poor power quality (dirty electricity) and ground current, and these can adversely affect those who are electrically hypersensitive. Indeed, the symptoms mentioned above are consistent with electrohypersensitivity. Sensitivity to both sound and electromagnetic waves differs among individuals and may explain why not everyone in the same home experiences similar effects. Ways to mitigate the adverse health effects of wind turbines are presented.

Keywords

wind turbine, dirty electricity, power quality, ground current, contact current, electrohypersensitivity, noise, infrasound, vibroacoustic disease, wind turbine syndrome

Introduction

With growing concern about climate change, the carbon budget, depletion of fossil fuels, air pollution from dirty coal, radiation from nuclear power plants, and the need for a secure energy supply, more attention and funding are being diverted to renewable energy. Among the various types of renewable energy, wind has received a lot of attention due, in part, to opposition from communities earmarked for wind turbines and from communities that have experienced wind turbines firsthand.

Some people who live near wind turbines report difficulty sleeping and various symptoms of ill health and attribute these problems to noise and shadow flicker—two elements they can perceive. Indeed the U.S. National Research Council (Risser et al., 2007) identify noise and shadow flicker as the two key impacts of wind turbines on human health and well-being.

Not all health agencies, however, recognize that sound waves from wind turbines may cause adverse health effects. Following a review of the literature, the Chief Medical Officer of Health for Ontario (2010), concluded

> that while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects, although some people may find it annoying.
>
> Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects.

What specifically is responsible for the illness reported near wind turbines is controversial; while some of this controversy is scientifically valid, some of it is politically motivated (Phillips, 2010).

It is intriguing that not everyone in the same home experiences symptoms, and the symptoms are not necessarily worse for those nearest the turbines. Indeed, the situation may be much more complex than noise and shadow flicker.

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Why do some people who live near wind turbines become sick while others feel no ill effects? What aspects of wind power generation and distribution are responsible for the health problems? What can be done to minimize adverse human biological and health effects? These are some of the questions addressed in this report.

Wind Turbines Make Waves

What aspects of wind power generation and distribution are responsible for the adverse health effects experienced by those who live near wind turbines?

The short answer to this question is that *wind turbines make waves*. They make pressure waves and electromagnetic waves. The pressure waves (or sound waves) generated by the moving turbines can be heard as noise and/or perceived as infrasound. The electromagnetic waves are generated by the conversion of wind energy to electricity. This conversion produces high-frequency transients and harmonics that result in poor power quality. These high frequencies can flow along the wires (dirty electricity) and along the ground, thereby causing ground current. These four types of waves—noise, infrasound, dirty electricity, and ground current—and shadow flicker are each likely to contribute to ill health among those who live near wind turbines.

Characteristics of Sound Waves and Electromagnetic Waves

Sound waves are longitudinal waves that require a medium for transport. They travel at the speed of sound (340 meters/second) through air and are much slower than electromagnetic waves that travel at the speed of light (300,000,000 meters/second) and can travel through a vacuum. Both sound waves and electromagnetic waves have a frequency (cycles per second) and an intensity (amplitude of the wave).

Frequency refers to the number of waves or cycles per second and is known as pitch for sound. The A above middle C, for example, is set to a frequency of 440 cycles per second (hertz, abbreviated as Hz). The audible range for the human ear is between 20 and 20,000 Hz. Frequencies below 20 Hz are referred to as "infrasound," and, although they cannot be heard, they can still have an effect on the body. Infrasound can travel much greater distances than higher frequency sound waves and could potentially reach and affect a much larger population.

The frequencies of electromagnetic waves, generated by wind turbines, fall within two ranges of the electromagnetic spectrum: extremely low frequency (ELF), below 1,000 Hz; and the lower range (kilohertz [kHz] to megahertz [MHz]) of the radio frequency radiation (RFR) band. Electromagnetic waves can enter homes by various paths: through the air, along wires, through the ground, and via plumbing and other metal structures. Electromagnetic waves travelling across the ground contribute to ground current.

Intensity is measured by the amplitude of the wave and, for sound, is measured in decibels (dB). Vibrations with the same frequency but different amplitude will sound the same, but one will be louder than the other. The decibel scale is logarithmic. A quiet bedroom is at 25 dB, conversation is around 60 dB, a rock group is at 110 dB, and the human threshold of pain is at 140 dB.

The intensity of electromagnetic waves is measured in various ways: electric field, magnetic field, voltage, current, and power density. The biological effects of electromagnetic energy are a function of frequency, intensity, and both the manner and the duration of exposure.

Pressure Waves: Noise

Most people who live near wind turbines and complain of ill effects blame the effects on the noise generated by the turbines (Frey & Hadden, 2007).

> Everything changed . . . when the wind turbines arrived . . . approximately 700 metres away from our property . . . Within days of the windfarm coming into operation we began to hear a terrible noise . . . The noise drove us mad. Gave us headaches. Kept us awake at night. Prevented us from having windows and doors open in hot weather, and was extremely disturbing.
>
> This noise is like a washing machine that's gone wrong. It's whooshing, drumming, constant drumming, noise. It is agitating. It is frustrating. It is annoying. It wears you down. You can't sleep at night and you can't concentrate during the day . . . It just goes on and on . . . It's torture . . . [4 years later] You just don't get a full night's sleep and when you drop off it is always disturbed and only like "cat napping." You then get up, tired, agitated and depressed and it makes you short-tempered . . . Our lives are hell.

The French National Academy of Medicine (Chouard, 2006) issued a report that concludes,

> People living near the towers, the heights of which vary from 10 to 100 meters, sometimes complain of functional disturbances similar to those observed in syndromes of chronic sound trauma . . .
>
> The sounds emitted by the blades being low frequency, which therefore travel easily and vary according to the wind . . . constitute a permanent risk for the people exposed to them . . .
>
> . . . sound levels 1 km from an installation occasionally exceeded allowable limits.
>
> . . . the Academy recommends halting wind turbine construction closer than 1.5 km from residences. (Translated from French)

Noise, especially at night, has been associated with an increase in stress hormones leading to hypertension, stroke, heart failure, and immune problems. It is discussed in greater detail elsewhere in this journal.

Pressure Waves: Infrasound

Repetitive noise can be disturbing, especially at night, when sound seems amplified. However, pressure waves at levels outside the range of human hearing can also have unpleasant side effects.

In Nova Scotia, one family was unable to remain in their home and blamed their loss of sleep and headaches on vibrations from 17 turbines (Keller, 2006).

> The d'Entremont family complained of noise and low frequency vibrations in their house after the wind turbines began operation in May 2005. The inaudible noise deprived his family of sleep, gave his children and wife headaches, and "made it impossible for them to concentrate." They now live nearby; if they return to their home, the symptoms return.
>
> Natural Resources Canada, which oversees funding for wind farm projects, found no problems with low-frequency noise or infrasound. The government report concludes that the measurements:
>
> indicate sound at infrasonic frequencies below typical thresholds of perception; infrasound is not an issue. (cited in Frey & Hadden, 2007)

Gordon Whitehead, a retired audiologist with 20 years of experience at Dalhousie University in Halifax, conducted tests and found similar results but came up with a different conclusion:

> They're [Natural Resources Canada] viewing it from the standpoint of an engineer; I'm viewing it from the standpoint of an audiologist who works with ears . . . The report should read that (the sound) is well below the auditory threshold for perception. In other words, it's quiet enough that people would not be able to hear it. But that doesn't mean that people would not be able to perceive it.
>
> " . . . low-frequency noise can affect the balance system of the ear, leading to a range of symptoms including nausea, dizziness and vision problems. It's not perceptible to the ear but it is perceptible. It's perceptible to people with very sensitive balance mechanisms and that's generally people who get very easily seasick.

Resonance may explain why infrasound is harmful at low intensities. Different parts of the human body have different resonance frequencies. When the external frequency generated by a wind turbine approaches the resonance frequency of a part of the human body, that body part will preferentially absorb the energy and begin to vibrate. For example, frequencies that affect the inner ear (between 0.5 and 10 Hz) can interfere with balance, cause dizziness or vertigo, contribute to nausea, and be experienced as tinnitus or ringing in the ears. According to the International Standards Organization (ISO Standards 2631), frequencies for the eye are between 20 and 90 Hz, head 20 and 30 Hz, chest wall 50 and 100 Hz, abdomen 4 and 8 Hz, and spinal column 10 and 12 Hz. Some of the symptoms documented at infrasonic frequencies (between 4 and 20 Hz) include general feeling of discomfort, problems with breathing, abdominal and chest pain, urge to urinate, lump in throat, effect on speech, and head symptoms (Frey & Hadden, 2007).

According to a report by the U.S. Air Force, Institute for National Security Studies, acoustic infrasound can have dramatic and serious effects on human physiology (Bunker, 1997).

> Acoustic, infrasound: very low frequency sound which can travel long distances and easily penetrate most buildings and vehicles. Transmission of long wavelength sound creates biophysical effects, nausea, loss of bowels, disorientation, vomiting, potential organ damage or death may occur. Superior to ultrasound because it is "inband," meaning it does not lose its properties when it changes mediums such as air to tissue. By 1972 an infrasound generator had been built in France, which generated waves at 7Hz. When activated it made the people in range sick for hours.

In a paper known as "The Darmstadt Manifesto," published in September 1998 by the German Academic Initiative Group and endorsed by more than 100 university professors in Germany, the German experience with wind turbines is described as follows (cited in Frey & Hadden, 2007):

> More and more people are describing their lives as unbearable when they are directly exposed to the acoustic and optical effects of wind farms. There are reports of people being signed off sick and unfit for work, there is a growing number of complaints about symptoms such as pulse irregularities and states of anxiety, which are known to be from the effects of infrasound [sound frequencies below the normal audible limit].

Infrasound is influenced by topography, distance, and wind direction (Rogers, Manwell, & Wright, 2006) and differs from home to home and room to room because each room is a distinct cavity with its own resonant frequency. Whether a door is open or closed can alter the effect.

The biological effects of low-frequency noise (20-100 Hz) and infrasound (less than 20 Hz) are a function of intensity, frequency, duration of exposure, and direction of the vibration.

Wind Turbine Syndrome and Vibroacoustic Disease

Exposure to low-frequency noise and infrasound may produce a set of symptoms that include depression, irritability, aggressiveness, cognitive dysfunction, sleep disorder, fatigue, chest pain/pressure, headaches, joint pain, nausea, dizziness, vertigo, tinnitus, stress, heart palpitations, and other symptoms. Not everyone has the same sensitivity. Those who experience motion sickness (car, boat, plane), get dizzy or nauseous on carnival rides, have migraine headaches, or have eye or ear problems may be particularly susceptible to low-frequency vibrations.

Two different “diseases” have been associated with low-frequency noise exposure and infrasound. They are wind turbine syndrome—coined by Pierpont (2009) in her book by the same name—and vibroacoustic disease (VAD). VAD is a whole-body, systemic pathology characterized by the abnormal proliferation of extracellular matrices and caused by excessive exposure to low-frequency noise (Castelo Branco & Alves-Pereira, 2004). These two “diseases” differ as described by Pierpont (2009).

> Wind Turbine Syndrome, I propose, is mediated by the vestibular system—by disturbed sensory input to eyes, inner ears, and stretch and pressure receptors in a variety of body locations. These feed back neurologically onto a person’s sense of position and motion in space, which is in turn connected in multiple ways to brain functions as disparate as spatial memory and anxiety. Several lines of evidence suggest that the amplitude (power or intensity) of low frequency noise and vibration needed to create these effects may be even lower than the auditory threshold at the same low frequencies.
>
> Vibroacoustic Disease, on the other hand, is hypothesized to be caused by direct tissue damage to a variety of organs, creating thickening of supporting structures and other pathological changes. The suspected agent is high amplitude (high power or intensity) low frequency noise. (p. 13)

VAD seems to be dose dependent, with symptoms becoming progressively worse with continued exposure. Three stages have been identified based on 70 aircraft technicians who, presumably, were exposed to much higher intensities of low-frequency noise than those who live near wind turbines (Castelo Branco, 1999, Castelo Branco & Alves-Pereira, 2004).

Stage 1: Mild, 1 to 4 years, slight mood swings, indigestion, heartburn, mouth/throat infections, bronchitis

Stage 2: Moderate, 4 to 10 years, depression, aggressiveness, pericardial thickening, light to moderate hearing impairment, chest pain, definite mood swings, back pain, fatigue, skin infections (fungal, viral, parasitic), inflammation of stomach lining, pain during urination, blood in urine, conjunctivitis, allergies

Stage 3: Severe, more than 10 years, myocardial infarction, stroke, malignancy, epilepsy, psychiatric disturbances, hemorrhages (nasal, digestive, conjunctive mucosa), varicose veins, hemorrhoids, duodenal ulcers, colitis, decrease in visual acuity, headaches, severe joint pain, intense muscular pain, neurological disturbances

Whatever name is given to the symptoms, the symptoms are real and can be caused by low-frequency sound waves and infrasound.

Electromagnetic Waves

One undesirable consequence of wind-generated electricity is poor power quality due to variable weather conditions, mechanical construction of the towers, and the electronic equipment used (Lobos, Rezmer, Sikorski, & Waclawek, 2008). Electricity in North America has a frequency of 60 Hz and is a sine wave when viewed on an oscilloscope (Figure 1). When a wind turbine generates electricity, the frequency must be converted to 60 Hz by power converters; that conversion generates a large spectrum of current and voltage oscillations leading to poor power quality (Lobos et al., 2008). Wind turbines can generate a wide range of frequencies—from less than 1 Hz (Lobos et al., 2008), with the majority of the frequencies in the kHz range associated with power conversion.

Dirty Electricity

High-frequency transient spikes that contribute to poor power quality, also known as dirty electricity, can flow along wires, damage sensitive electronic equipment, and adversely affect human and animal health.

After wind turbines were activated in Ripley, Ontario, several of the residents complained of ill health. Residents suffered from headaches, poor sleep, elevated blood pressure (requiring medication), heart palpitations, itching, ringing and pain in the ears, watering eyes, and pressure on the chest causing difficulty breathing. These symptoms disappear when the residents leave the area. Some residents were forced to move out of their homes because the symptoms were so severe. Locals complain of headaches and poor radio reception when they drive near these power lines.

One of the authors (DC) measured the power quality near several residences where people were unwell. The primary neutral-to-earth voltage (PNEV) is the electrical potential difference between the earth and the neutral wire on the primary distribution line, as shown in Figure 2. Measurements taken before wind turbines were installed and after they were installed and operating (Figure 3) clearly show the distortion (spikes on the waveform) generated by the wind turbines.

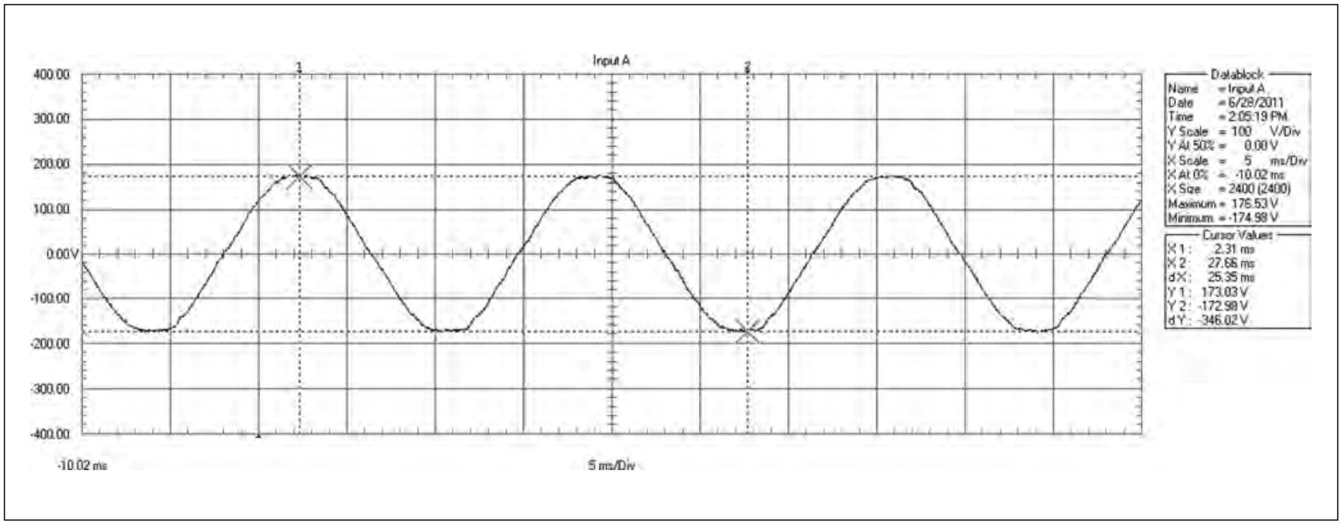

Figure 1. Good power quality exemplified by the 60-Hz sine wave

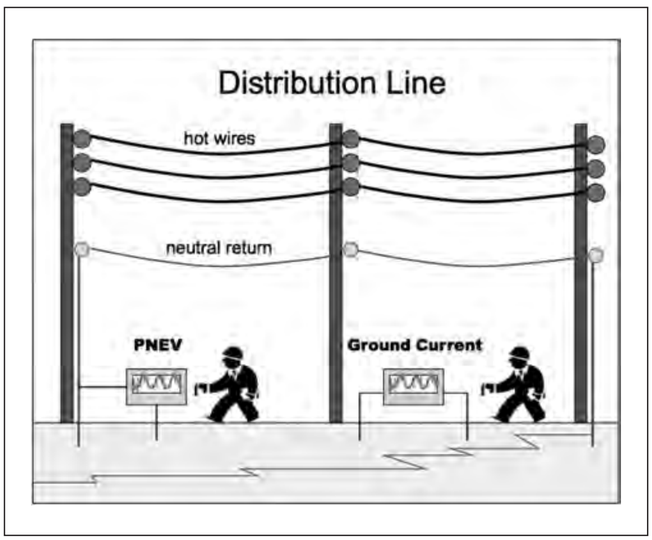

Figure 2. Diagram demonstrating how primary neutral-to-earth voltage (PNEV) and ground voltage measurements are taken

In this area, wind turbines are variable speed and are interconnected. The collection lines connecting the wind turbines to the substation are attached to the same utility pole as the home owners' lines.

According to one of the authors (DC; September 30, 2008),

> We had four families move out of their homes and now if I spend too much time in these homes I get the same symptoms, which is ear aches, ringing in the ears and pressure in the ears. [name removed] eventually buried a portion of the line but have only isolated the lines by insulators so it is better, however there is still some high frequency coming into the houses. The three families that now have buried lines are back in their homes, but things are far from ideal.

Dirty electricity in the kHz range affects human health; this has been shown in schools and homes in both Canada and the United States. Power quality can be improved both on electrical wires by using power line filters (Ontario Hydro, 1998) and inside buildings by using special surge suppressors or power filters that dampen the voltage spikes (http://www.stetzerelectric.com).

In one Wisconsin School that had "sick building syndrome," once power quality was improved, the health of both teachers' and students' improved. According to the school nurse, both staff and students have more energy, fewer allergies, and fewer migraine headaches, and asthmatics rely less on their inhalers (Havas, 2006a).

In a Toronto School, improvements in power quality were accompanied by improvements in teachers' health and students' behavior. Teachers were less tired, less frustrated, less irritable; they had better health and more energy; they had a greater sense of satisfaction and accomplishment; they were more focused and experienced less pain. Students' behavior also improved especially in the elementary grades (Havas, Illiatovitch, & Proctor, 2004). Similar results were reported in a placebo-blinded study in three Minnesota schools (Havas & Olstad, 2008).

Dirty electricity has been associated with increased risk of various types of cancers among teachers in a California school (Milham & Morgan, 2008), with higher blood sugar levels among diabetics, and with exacerbation of tremors and difficulty walking among those with multiple sclerosis (Havas, 2006b). People who are adversely affected by dirty electricity are classified as electrically hypersensitive.

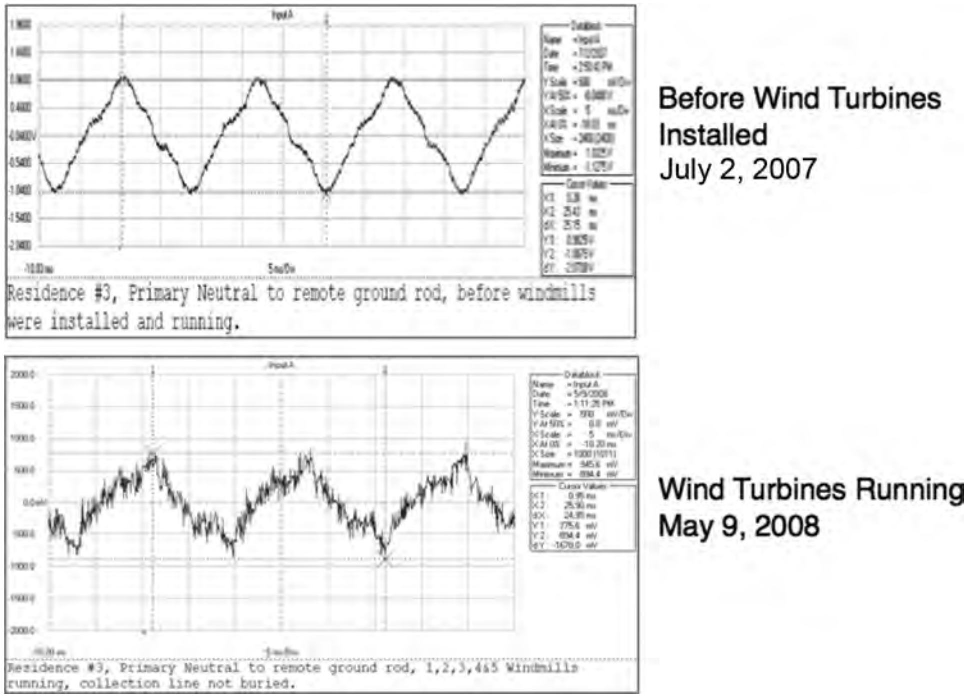

Figure 3. Primary neutral-to-earth voltage (PNEV) at Residence No. 3 in Ripley, Ontario, before wind turbines were installed (July 2, 2007) and when five wind turbines were operating (May 9, 2008)
Note. Collection line was not buried.

Ground Current

Just as dirty electricity can flow along wires, it can also flow along the ground resulting in ground current. Ground current (often measured as voltage and called stray voltage or tingle voltage) is a serious problem in certain locations and has been shown to adversely affect the health of farm families and the health and productivity of farm animals, especially dairy cattle.

The Ontario Federation of Agriculture (2007) provides information on symptoms experienced by farm animals, pets, and people who are exposed to tingle voltage as follows:

> Farmers and their families who suffer from immune disorders such as allergies or rheumatoid arthritis find their symptoms worsen or go into remission in close coordination with livestock symptoms. Periods of fatigue increase. Sleep disorders may increase.
>
> Cats leave the farm, become ill, cease to bear litters or have small, unhealthy litters, or die; coats are usually dull and shaggy and eyes are runny.
>
> Horses may paw the ground and shy away from watering or feeding troughs; behaviour and handling becomes more difficult.
>
> Pigs often take to ear and tail biting; mastitis and baby pig scours are common; piglet mortality may increase.
>
> Cattle lap water from the trough or bowl; feed in the bottom of the manger is not cleaned up; milk out is slow and uneven; cows are reluctant to enter the milk parlour and quick to leave; slow growth in calves and heifers; somatic cell counts are high; unexplained spontaneous abortions of calves; bulls become markedly more irritable.

According to the *National Electrical Safety Code (NESC) Handbook* (Clapp, 1997),

> When the earth returns were used in some rural areas prior to the 1960's, they became notorious offenders in dairy areas because circulating currents often cause both step and touch potentials.
>
> In some cases, they have adversely affected milking operations by shocking the cattle when they were connected to the milking machines, and have affected feeding. (p. 152)

According to Lefcourt (1991) in the U.S. Department of Agriculture book titled *Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems*:

> The effect of a transient voltage superimposed on the regular power voltage (dc or ac) is to cause a momentary

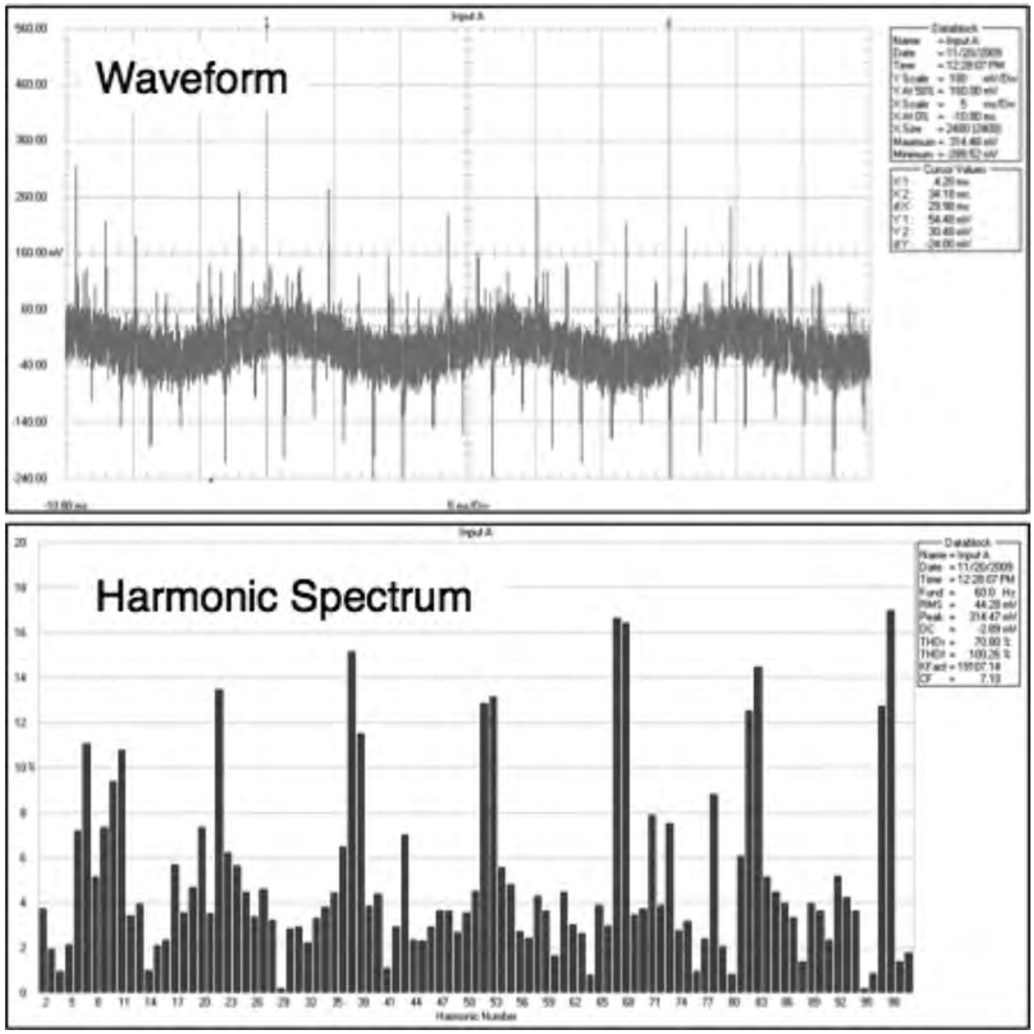

Figure 4. Ground voltage measured at the Palm Springs wind farm in California using 50 feet of copper wire attached to two metal rods in the earth
Note. The top graph shows the distorted 60-Hz waveform, and the bottom graph shows the harmonic frequencies. Data courtesy of Dr. Sam Milham.

> change in the waveform. When the transient causes the momentary voltage to be greater than normal, it may cause a transient current to flow in an animal. If the transient waveform has sufficient energy (magnitude and duration), there may be an animal response. (p. 63-64)

Indeed, dirty electricity flowing along the ground may be more harmful to farm animals than the 60-Hz ground current (Hillman et al., 2003):

> Cows were sensitive to harmonic distortions of step-potential voltage, suggesting that utility compliance with IEEE standards on dairy farms may need to be addressed.
>
> Power quality varied greatly from farm to farm and day to day. Milk production responses to changes in power quality varied inversely with the number of transient events recorded with event recorders, oscilloscope, and power quality meters. Harmonics often gave better estimates of electrical effects on milk production than voltage *per se*. (p. 19)

Do wind turbines generate ground current? They can if proper safeguards are not taken. Generally, this is a problem with power distribution once the energy leaves the turbine.

Figure 4 shows the waveform of ground voltage near an industrial wind farm in Palm Springs, California (as shown in Figure 5 photographs). The waveform distortion in Figure 3 and 4 are considerable when compared with Figure 1.

Figure 5. Wind farm in Palm Springs, California, showing (A) location of ground voltage readings; (B), view of wind turbines from the ground; and (C) view of wind turbines from the air
Note. Photograph A from Dr. Sam Milham. Photographs B and C from Google maps.

Burying the collection line may not eliminate the ground voltage but can improve power quality, as shown in Figure 6.

Just as animals are adversely affected by dirty ground current, so are people. If ground current enters a home via the plumbing, touching any part of the plumbing (e.g., faucet) induces a current in the body, known as contact current.

In one Ripley home, the frequency fingerprint (relative intensities of various frequencies) on the plumbing (sink to floor measurement) was similar to the PNEV, indicating that the source of the ground voltage was the wind turbines' collection line (Figure 7). In this home, the sink to floor contact current was calculated to be 400 microamperes (peak to peak based on 200 millivolts and 500 ohms), and this value is 22 times higher than levels associated with cancer according to Kavet, Zaffanella, Daigle, and Ebi (2000).

> "The absolute (as well as modest) level of contact current modeled (18 micro Amps) produces average electric fields in tissue along its path that exceed 1 mV/m. At and above this level, the NIEHS Working Group [1998] accepts that biological effects relevant to cancer have been reported in "numerous well-programmed studies." (p. 547)

Wertheimer, Savitz, and Leeper (1995) documented the link between ground current and cancer in Denver, Colorado. They found that leukemia risk increased by 300% among children exposed to elevated magnetic field from ground current that enters the home through conductive plumbing.

Electrohypersensitivity (EHS)

Why do some people who live near wind turbines become sick while others feel no ill effects?

Exposure to both pressure waves and electromagnetic waves is highly variable—spatially and temporally—as is sensitivity to these vibrations. Not everyone in the same home is going to have the same exposure or the same sensitivity. People who have balance problems, experience motion sickness, or have ear or eye problems are more likely to react to low-frequency sound vibrations. Those who are electrically hypersensitive are more likely to suffer from dirty electricity

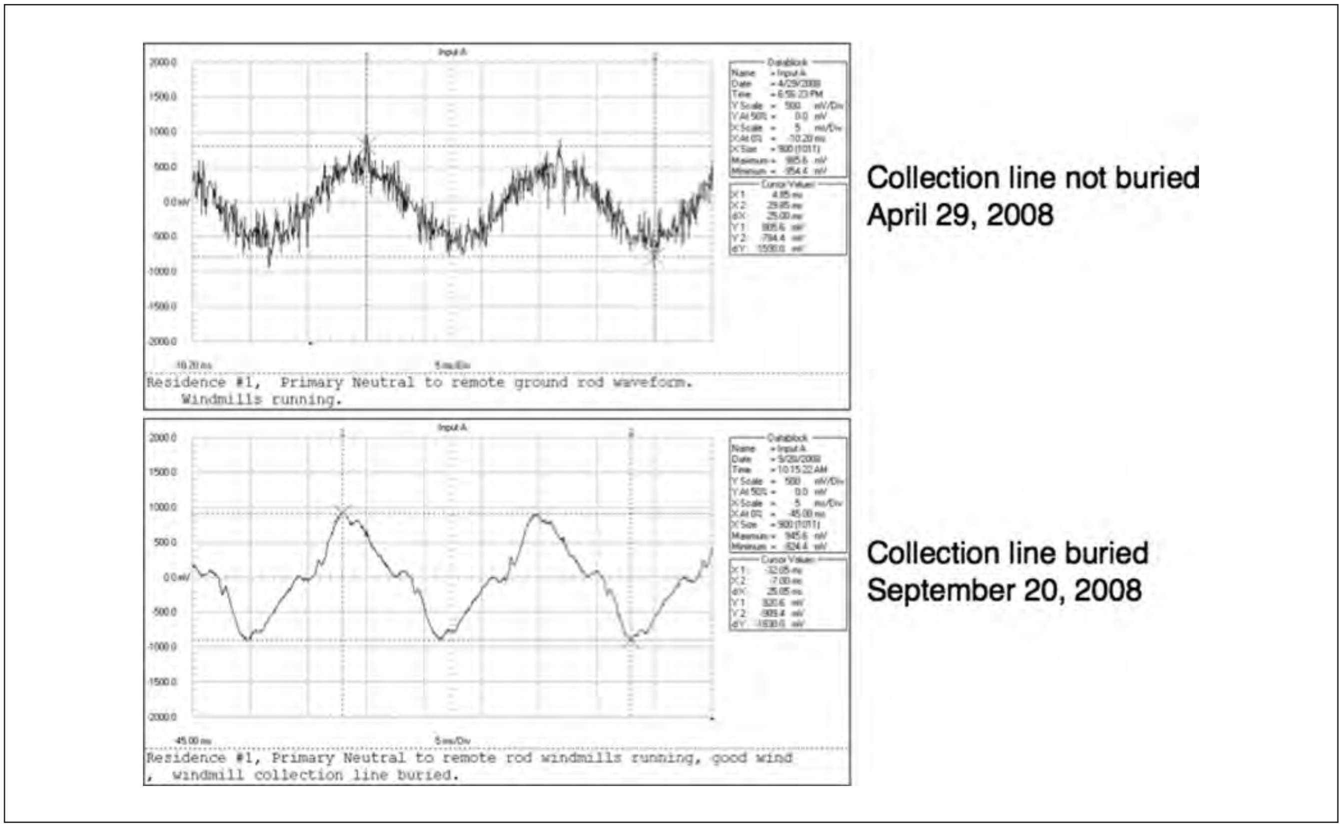

Figure 6. Primary neutral-to-earth voltage (PNEV) at Residence 1 in Ripley, Ontario, when wind turbines were operating
Note. Collection line from wind turbines was buried on September 20, 2008 (bottom graph), but not on April 29, 2008 (top graph).

and contact current. As a result, people living in the same home may have very different sensitivities and may respond differently to these vibrations.

At the Working Group meeting on EMF Hypersensitivity in Prague, the World Health Organization (2004) described electrosensitivity as

> a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic, or electromagnetic fields (EMFs).
>
> Whatever its cause, EHS is a real and sometimes a debilitating problem for the affected persons, while the level of EMF in their neighborhood is no greater than is encountered in normal living environments. Their exposures are generally several orders of magnitude under the limits in internationally accepted standards.

Symptoms include cognitive dysfunction (memory, concentration, problem solving); fatigue and poor sleep; body aches and headaches; mood disorders (depression, anxiety, irritability, frustration, temper); nausea; problems with balance, dizziness, and vertigo; facial flushing, skin irritations, and skin rashes; chest pressure, rapid heart rate, and altered blood pressure; ringing in the ear (tinnitus); and nosebleeds. A comprehensive list of the symptoms is provided in Table 1.

In Sweden, EHS is recognized as a functional impairment (not as a disease). Between 230,000 and 290,000 Swedes (about 3% of the Swedish population) may be electrohypersensitive (Johansson, 2006). The number of people complaining of EHS seems to be increasing as is the medication sold to deal with the symptoms of insomnia, pain, fatigue, depression, and anxiety. By 2017, as many as 50% of the population may experience these symptoms (Hallberg & Oberfeld, 2006).

Some individuals may have a predisposition to EHS. Those who have experienced physical trauma to their nervous system (whiplash), electrical trauma in the form of multiple shocks or several severe shocks, and/or chemical exposure to mercury or pesticides are likely to be more electrically sensitive. Children, the elderly, and those with impaired immune systems are also likely to be more electrically sensitive.

It is not possible to determine which factors are contributing to ill health until appropriate monitoring is conducted and steps are taken to reduce exposure to the offending agents. Monitoring of both electromagnetic waves and pressure waves in homes where people report ill health is highly recommended as are the mitigation techniques mentioned below

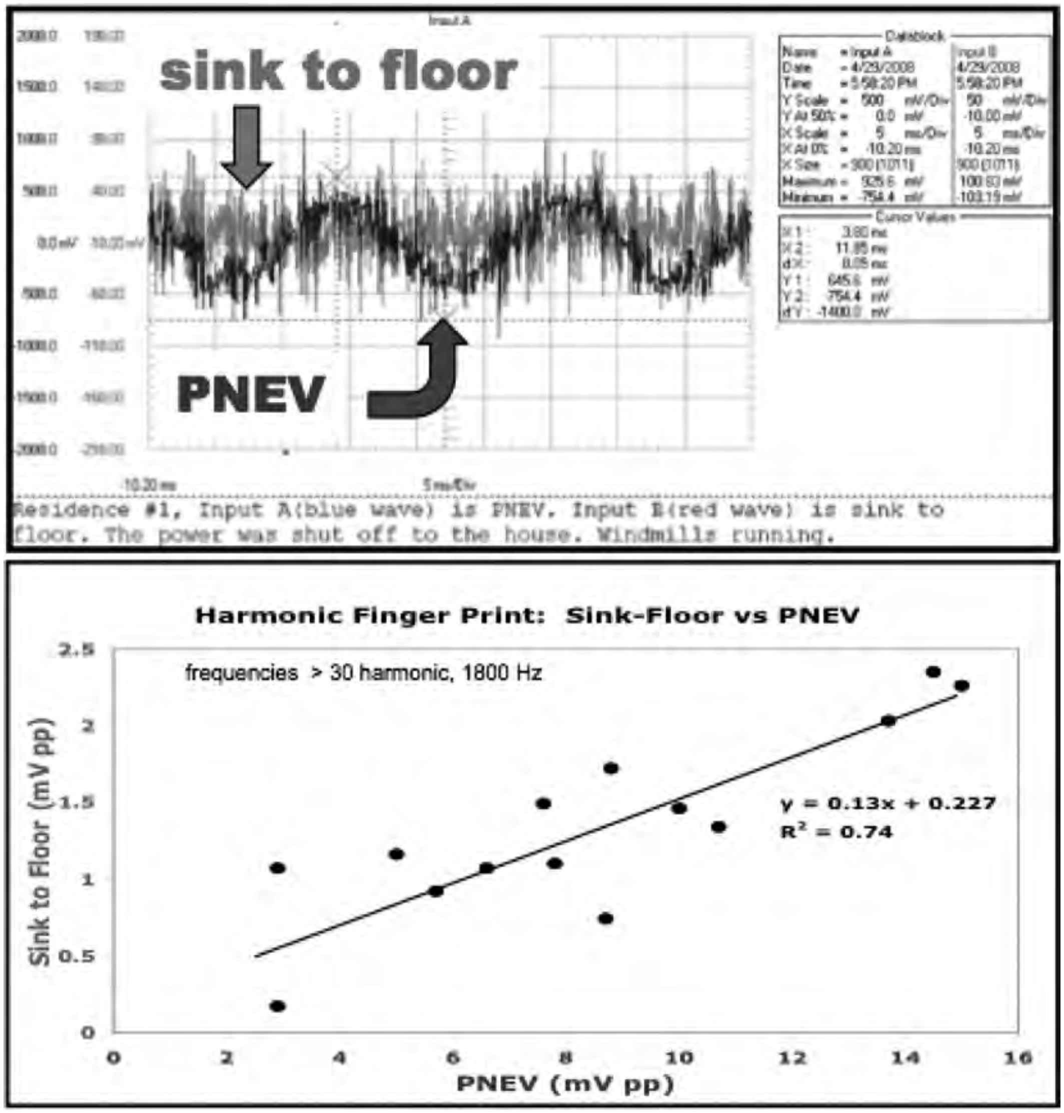

Figure 7. The primary neutral-to-earth voltage (PNEV) and the sink-to-floor voltage for Residence 1 in Ripley, Ontario (top graph), and the harmonic figure print for these voltages (bottom graph).

Recommendations

What can be done to minimize adverse biological and health effects for those living near wind turbines?

One obvious step is to eliminate or reduce exposure to the agent(s) causing the illness.

1. To minimize noise and exposure to infrasound, the following steps should be taken:
   a. Wind turbines should be placed as far away as possible from residential areas. The French National Academy of Medicine (Chouard, 2006) recommends 1.5 km from residential areas.
   b. Buffers can be constructed to disrupt pressure waves and to absorb or deflect sound waves in areas where turbines are closer to homes or where problems have been documented,
2. To improve power quality, the following steps should be taken:
   a. The electricity should be "filtered" at all inverters before it leaves the wind turbine. Ontario Hydro (1998) provides information on power line filters and other ways to improve power quality.
   b. The collector lines from the wind turbines should be attached to utility poles that do not provide power to homes.
   c. Power from the substation supplied by the wind turbines should be filtered before it is distributed to customers.

Table 1. Comprehensive List of Electrohypersensitivity (EHS) Symptoms (Bevington, 2010)

Auditory
earaches,
imbalance,
lowered auditory threshold,
tinnitus

Cardiovascular
altered heart rate,
chest pains,
cold extremities especially hands & feet,
heart arrhythmias,
internal bleeding,
lowered/raised blood pressure,
nosebleeds,
shortness of breath,
thrombosis effects

Cognitive
confusion,
difficulty in learning new things,
lack of concentration,
short / long-term memory impairment,
spatial disorientation

Dermatological
brown 'sun spots',
crawling sensations,
dry skin,
facial flushing,
growths & lumps,
insect bites & stings,
severe acne,
skin irritation,
skin rashes,
skin tingling,
swelling of face/neck

Emotional
anger,
anxiety attacks,
crying,
depression,
feeling out of control,
irritability,
logorrhoea,
mood swings,

Gastrointestinal
altered appetite,
digestive problems,
flatulence,
food intolerances

Genito-urinary
smelly sweat / urine,
urinary urgency,
bowel urgency

Musculoskeletal
aches / numbness
pain / prickling sensations in:
bones, joints & muscles in:
ankles, arms, feet
legs, neck,
shoulders, wrists,
elbows, pelvis,
hips, lower back,
cramp / tension in:
arms, legs, toes,
muscle spasms,
muscular paralysis,
muscular weakness,
pain in lips, jaws, teeth with amalgam fillings,
restless legs,
tremor & shaking

Neurological
faintness, dizziness,
'flu-like symptoms,
headaches,
hyperactivity,
nausea,
numbness,
sleep problems,
tiredness

Ophthalmologic
eyelid tremors/'tics',
impaired vision,
irritating sensation,
pain / 'gritty' feeling,
pressure behind eyes,
shiny eyes,
smarting, dry eyes

Other Physiological
abnormal menstruation,
brittle nails,
hair loss,
itchy scalp,
metal redistribution,
thirst / dryness of lips, tongue, eyes

Respiratory
asthma,
bronchitis,
cough /throat irritation,
pneumonia,
sinusitis

Sensitisation
allergies,
chemical sensitivity,
light sensitivity,
noise sensitivity,
smell sensitivity

   d. Wind power electrical substations that require power from an external source (electrical distribution network) must ensure that the power quality of this eternal source is not affected as this can result in power quality problems for customers connected to the same external power source.
   e. Nearby home owners may need to install power line filters in their homes if levels of dirty electricity remain high.
3. To reduce ground current/voltage, the following steps should be taken:
   a A proper neutral system (possibly a five-wire system) should be installed to handle the high-frequency return current in overhead lines (Electric Power Research Institute, 1995).
   b. Insulators can be placed between the neutral line and the grounding grid for the wind turbine.
   c. The collection lines from the wind turbine to the substation should be buried if the other techniques to minimize dirty ground current are ineffective.
   d. Local home owners may need to install stray voltage isolators near their transformers until the electric utility can resolve the problem (Hydro One, 2007).

If these steps are taken, improved quality of life and a feeling of wellness may return to some of the people adversely affected by nearby wind turbines.

Conclusions

A subset of the population living near wind turbines is experiencing symptoms of ill health. These symptoms are likely caused by a combination of noise, infrasound, dirty electricity, ground current, and shadow flicker. These frequencies can be highly viable spatially and temporally and are affected by distance; terrain; wind speed and direction; shape, size, and type of dwelling; type of power converters used; state of the electrical distribution line; type and number of grounding systems; and even the type of plumbing in homes. Furthermore, not everyone has the same sensitivity to sound and electromagnetic radiation nor do they have the same symptoms. The following symptoms seem to be quite common: sleeplessness, fatigue, pain, dizziness, nausea, mood disorders, cognitive difficulties, skin irritations, and tinnitus. To help alleviate symptoms in areas where wind turbines have been erected, remediation is necessary to reduce or eliminate both sound waves and electromagnetic waves. More research is required to help us better understand the relative importance of the various factors contributing to poor health. This type of information will enable a healthy coexistence between wind turbines and the people living nearby.

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Bios

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Industrial Wind Turbine Development and Loss of Social Justice?

Carmen M. E. Krogh

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Intervenors' Responses to
Staff's First Set of Data Requests
EXHIBIT 5

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Industrial Wind Turbine Development and Loss of Social Justice?

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Abstract

This article explores the loss of social justice reported by individuals living in the environs of industrial wind turbines (IWTs). References indicate that some individuals residing in proximity to IWT facilities experience adverse health effects. These adverse health effects are severe enough that some families have abandoned their homes. Individuals report they welcomed IWTs into their community and the negative consequences were unexpected. Expressions of grief are exacerbated by the emotional and physical toll of individuals' symptoms, loss of enjoyment of homes and property, disturbed living conditions, financial loss, and the lack of society's recognition of their situation. The author has investigated the reported loss of social justice through a review of literature, personal interviews with, and communications from, those reporting adverse health effects. The author's intention is to create awareness that loss of social justice is being associated with IWT development. This loss of justice arises from a number of factors, including the lack of fair process, the loss of rights, and associated disempowerment. These societal themes require further investigation. Research by health professionals and social scientists is urgently needed to address the health and social impacts of IWTs operating near family homes.

Keywords

wind turbines, adverse health effects, social justice, procedural justice, disempowerment, disturbed living conditions, impact statements, loss of home, societal themes

Introduction

It is recognized that there are many elements which define human health:

> At the Ottawa Conference in 1986, the World Health Organization, along with Health Canada (formerly Health and Welfare Canada) and the Canadian Public Health Association, agreed on the Ottawa Charter for Health Promotion. The Charter sees health in the context of the interaction between the person and the environment. It recognizes the elements of our social environment, including peace, shelter, education, food, income, social justice and equity as prerequisites for health. (Health Canada, 2004, vol. 1, p. 15)

Many articles regarding social justice are available in a variety of psychology and sociology journals and on the Internet; however, a simple definition of social justice seems elusive.

Shain (2011) in a communication with the author comments,

> While there is no one account of procedural justice upon which there is consensus, the criteria for what constitutes a fair procedure advanced by Leventhal (1980) enjoy considerable support and have been used in numerous research studies on the subject (Tyler, Boeckmann, Smith, & Huo, 1997).
>
> Leventhal (1980) proposes six key criteria that people use wittingly or otherwise in judging to what extent a decision-making procedure or process is just or fair:
>
> - *Consistency:* Equal treatment of persons across time and place
> - *Bias suppression:* Avoiding self-interest or ideological preconceptions
> - *Accuracy:* Using good, accurate information and informed opinions
> - *Correctability:* Opportunities for review and amendment
> - *Representativeness:* Everyone is involved in decision making who has a material interest in the outcome

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- *Ethicality:* Compatible with fundamental moral and ethical values

These criteria collectively amount to a definition of fair process.

As such, they resonate with Trebilcock's (1993) analysis of what causes breakdowns in contractual relationships: information failure and participation failure. And at a more philosophical level, they resonate with a working definition of fairness given by Shain (2001) following Rawls (2001) in his seminal treatise on *Justice as Fairness* (see also Rawls, 1971).

This definition sees fairness as "the recognition and reasonable accommodation of one another's legitimate interests, claims and rights." As such, fairness calls for a process in which people who are brought into relationships with one another are actively enjoined to make themselves aware of one another's interests, claims, and rights, to understand these as best they can, and to use their knowledge to arrive at best-fit solutions that accommodate all involved. This imperative applies not only to parties involved in personal and domestic relationships but also to those involved in community and commercial undertakings.

While this is a tall order, it is nonetheless the goal of procedural fairness. It also describes the antithesis of the situation we confront in connection with the licensing and siting of industrial wind turbines (IWTs).

These concepts set the stage to raise awareness of the issues associated with social justice and its effects on those living in the environs of IWTs.

Urgent research by health professionals and social scientists is required to further study this social phenomenon.

The Beginning

In January 2009, I began investigating reports of adverse health effects made by individuals living in the environs of IWTs. Over the course of more than 2 years I have been in communication with many of those experiencing physiological and psychological symptoms in Ontario, Canada and elsewhere globally. The descriptions of reported symptoms are consistent and based on individuals' reports, correlate with the onset of IWT facilities' operations.

An impact statement from early 2009 provoked my awareness that in addition to experiencing adverse health effects, there was evidence of a feeling of disempowerment and lack of process: "I trusted the wind energy companies"—"I can't believe the government is doing this to me." (S. M., personal communications, 2009, Ontario).

Many feel abandoned by the very procedural systems they believed would protect them. Through my research, I observed a progression of impacts starting with the identification of physiological and psychological symptoms and culminating with frustration, grief and anger, disempowerment, loss of trust, and an overall sense of social injustice.

When the health symptoms became apparent, there was an expectation that authorities and/or the IWT developer would resolve the issues. Individuals report their distress intensified when attempts to obtain recognition of their situation failed. An unexpected lack of response from a cross section of society, including government officials, industry, medical practitioners led to an exacerbation of their situation.

Failure to obtain recognition and resolution has resulted in some individuals seeking legal counsel, abandoning their home, or continuing to experience the adverse health effects, which ultimately, heightens the feelings of injustice.

Social well-being is acknowledged to be a determinant of health: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization [WHO], 1948). Many jurisdictions, including the Canadian federal, provincial, and territorial governments and health officials have accepted WHO's definition of health (Health Canada, 2004, vol. 1, p. 1-1).

Social Justice Violated

The WHO (2008) acknowledges the importance of social justice. It states, "Social justice is a matter of life and death. It affects the way people live, their consequent chance of illness, and their risk of premature death" (p. 3).

This statement set the stage for my presentation on social justice and IWTs (Krogh, 2010) given during the Society for Wind Vigilance, First International Symposium "The Global Wind Industry and Adverse Health Effects: Loss of Social Justice?"

The WHO (2008) final report on social determinants of health identifies three overarching principles:

1. Improve daily living conditions.
2. Tackle the inequitable distribution of power, money, and resources.
3. Measure and understand the problem and assess the impact of action.

Improve Daily Living Conditions

WHO (2008) states, "Different government policies, depending on their nature, can either improve or worsen health and health equity" (p. 110).

In response to environmental and economic concerns, some governments have adopted wind energy development as an alternative energy source (Green Energy and Economy Act, 2009; VisitDenmark, 2009). In some jurisdictions, implementation of IWTs has resulted in unexpected consequences. There are global reports of adverse health effects correlated with the onset of operations of IWTs (Harry, 2007; Krogh, Gillis, & Kouwen, 2011; Nissenbaum, 2009; Pierpont, 2009; Phipps, Amati, McCoard, & Fisher, 2007).

In several case series, respondents report experiencing a reduced quality of life. WindVOiCe, a self-reporting health survey from Ontario, Canada found that in addition to a plethora of symptoms, 113 of 131 respondents reported altered quality of life (Krogh et al., 2011). Similarly, in the United Kingdom, Harry (2007), 40 of 42 reported this as well.

In my presentation at the Society for Wind Vigilance International Symposium held in Ontario, Canada, I presented impact statements from a number of countries that described disturbed living conditions and adverse health effects (Krogh, 2010). One impact statement from Japan described how family members were sufficiently sleep disturbed by IWT noise they resorted to renting a second home in order to sleep. A family member from Germany described experiencing tachycardia, which intensified as the IWT speed increased.

References, both from peer-reviewed and other literature, acknowledge that IWTs may cause annoyance and/or stress and/or sleep disturbance (Colby et al., 2009; Keith, Michaud, & Bly, 2008; Minnesota Department of Health, 2009; Pedersen & Persson Waye, 2004, 2007; Rideout, Copes, & Bos, 2010; Thorne, 2010).

The Wind Turbine Noise (2011) post–conference report states,

> The main effect of daytime wind turbine noise is annoyance. The night time effect is sleep disturbance. These may lead to stress related illness in some people. Work is required in understanding why low levels of wind turbine noise may produce affects which are greater than might be expected from their levels.

Noise from IWTs is found to be more annoying than other sources of noise at comparable sound pressure levels (Pedersen, Bakker, Bouma, & van den Berg, 2009).

In everyday language, the term *annoyance* may be viewed by some as trivial; however, in the context of human health, annoyance is an adverse health effect (Health Canada, 2005). In 1991, Suter commented that

> "Annoyance" has been the term used to describe the community's collective feelings about noise ever since the early noise surveys in the 1950s and 1960s, although some have suggested that this term tends to minimize the impact. While "aversion" or "distress" might be more appropriate descriptors, their use would make comparisons to previous research difficult. It should be clear, however, that annoyance can connote more than a slight irritation; it can mean a significant degradation in the quality of life. This represents a degradation of health in accordance with the WHO's definition of health, meaning total physical and mental well-being, as well as the absence of disease. (p. 27)

Niemann and Maschke (2004) also comment on the significance of annoyance: "The result confirms the thesis that for chronically strong annoyance a causal chain exists between the three steps health–strong annoyance–increased morbidity" (p. 18).

The exact cause of IWT-induced adverse health effects is not fully understood. Plausible causes are not limited to but include amplitude modulation, temporal variability, lack of nighttime abatement, shadow flicker, and visual impact. Audible low-frequency noise has also been identified as one of the IWT noise characteristics that can be a contributing factor for annoyance (Minnesota Department of Health, 2009; Møller & Pedersen, 2010).

Reported symptoms associated with human exposure to IWT's include sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering when awake or asleep (Pierpont, 2009, p. 26).

Leventhall (2009) attributes these reported IWT symptoms as effects of "annoyance by noise" stating, "I am happy to accept these symptoms, as they have been known to me for many years as the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise."

The effects of low-frequency noise–induced annoyance and stress from various sources have been researched. "Regulatory authorities must accept that annoyance by low frequency noise presents a real problem . . ." and that "The claim that their 'lives have been ruined' by the noise is not an exaggeration . . ." (Leventhall, 2004).

DeGagne and Lapka (2008) note, "Unlike higher frequency noise issues, LFN is very difficult to suppress. Closing doors and windows in an attempt to diminish the effects sometimes makes it worse . . ."

Respite from the effects of low-frequency noise can require extreme measures: "Those exposed may adopt protective strategies, such as sleeping in their garage if the noise is less disturbing there. Or they may sleep elsewhere, returning to their own homes only during the day" (Leventhall, 2004).

In Ontario, personal communications with individuals residing in the environs of IWTs report their attempts to mitigate the low-frequency component of the noise by wearing ear protection day and night proved to be ineffective. To escape the noise, some report resorting to sleeping in vehicles, tents, trailers, basements lined with mattresses, garages, and at relatives or friends' homes. Others have bought or rented a second residence to obtain respite (G. W., personal communications, 2010; T. W., personal communications, 2011) or relocated with friends or family (T. K., personal communications, 2011). Some families have been billeted at the IWT developer's expense (Hansard, 2009, p. G-547). Others have abandoned their homes or been bought out by wind developers (Braithwaite, 2009a, 2009b). Buyouts by IWT developers have been reported in other parts of the globe (Rolfe, 2011).

An impact statement from Italy conveys the health and economic effects associated with having to leave their home:

". . . I had to abandon my home . . . because of the terrible symptoms. My house is worth nothing." (G. A., personal communications, 2010).

An individual representing a group of families testified before the Ontario Standing Committee on Green Energy and Green Economy Act and described how

> Each family has incurred additional costs from budgets for food, fuel, laundry and doctor visits while living away from our homes. Family events had to be held in restaurants. There is wear and tear on our vehicles. There is the extra cost of extensive phone bills from trying to get the problems fixed. There is the price of putting isolators on our homes to protect our families from the unfiltered power. There's the cost of going to meetings. There's loss of productivity due to sleep deprivation. A loss of three weeks from work occurred.
>
> Ontario common law and MLS rules and regulations set out for Ontario realtors all require full disclosure of factual information regarding properties offered for sale by owners. This means an owner is legally obligated to disclose any information known or expected about a property that may affect a buyer's decision to purchase a property.
>
> My real estate agent tells me our farm is unsellable. Our homes are unsellable or of zero value. Buying a second home to live in, which I've done—possible lawyer fees, possible appraisal costs. Our lives are upside down for the last 18 months, and how do you put a cost on that? This is like someone committing a crime, going to jail for, say, 10 years and then finding out after DNA tests, "Oh, you're innocent." How do you get that time back at our ages? (Hansard, 2009, p. G-548)
>
> P. C. from Ontario described the impacts to the family:
>
> Although we did not realize it at the time, November, 2008 was to be the beginning of the worst nightmare to affect our quality of life that we had and still have ever experienced. There was now a total of 33 industrial wind turbines within a 3 km radius of our house. With the whirling of the turbines came the destruction of personal, family and social life as we knew it. I was positive that the wind corporation and our government would fix the problem as soon as I told them that the noise of the turbines was affecting our health and our quality of life. I was wrong! Since May, 2009 I have been communicating with the wind corporation and with various ministries of our Ontario government (mostly MOE) explaining that the noise from the turbines often makes it impossible to sleep thus causing other health problems that are associated with lack of sleep and sleep disturbance. We also started often feeling our bed vibrate, our chest vibrate, our heart racing, headaches, nausea, pounding in the ears. We were told that mitigations are in place, we are still feeling the same ill effects (P. C., personal communications, 2011).

The impacts on P.C.'s family life have extended to an elderly mother who had to leave the affected home and adult children who were unable to visit:

> Our lives have been changed drastically . . . have been ruined. The building we live in is not a home because the 33 turbines within a 3 km radius have an adverse effect on the health of the people who live in this house and the turbines cause a loss of enjoyment of normal use of our property. The whooshing audible noise of the turbines is torture, it is often a continuous "on/off" whooshing noise often both inside and outside our house. In my opinion, our government pretends we do not exist. Our government caused this problem, we did not ask for it yet we suffer. We are moms, dads, grandpas, grandmas, children, babies, pregnant mothers . . . why have we become insignificant to the turbine corporations and to our provincial government? (P. C., personal communications, 2011)

Additional testimony has described negative health and societal impacts:

> We are quizzed or defending our health problems at community events such as hockey games, shopping or church. Dysfunctional community relations have been created by the wind project representatives and some community members trying to discredit the validity of our problems.
>
> The family unit for each family has deteriorated and has been torn apart. We begged for sleep, and four families were billeted by the wind company from their homes for 90 to 180 days in motels, hotels and a rooming house. The consistent stress has broken apart the family unit—no gatherings, few or no celebrations at home. At present, one family has purchased a separate residence to live in, and two others had to, at the expense of thousands of dollars, modify their hydro connection to try and live in their homes that they've lived in for 19 to 35 years.
>
> Due to concerns for the health of grandchildren, grandparents, older children, extended family members and friends, we all strongly discourage extended visits to our homes. We had to meet somewhere else other than our homes for celebrations. (Hansard, 2009, p. G-547)

While the data base of youth impact statements is limited, some young people are also negatively affected. A teenager reports having to leave home prematurely. This displacement and separation of family was destructive. The outcome is isolation from friends and family: “I am forced to sit back and say nothing as my own teachers teaches my classmates and peers that wind energy is flawless . . . I am forced to live away from home with my grandmother . . . I can never go home” (J. K., personal communications, 2010).

Tackle the Inequitable Distribution of Power, Money, and Resources

WHO (2008) states, “Empower all groups in society through fair representation in decision-making about how society operates, particularly in relation to its effect on health equity, and create and maintain a socially inclusive framework for policy-making” (p. 158).

Absence of fairness has been raised globally by individuals who are disturbed by some governments’ procedures for implementing a renewable energy policy. Rapid introduction of IWTs into rural communities has resulted in negative social impacts.

For example, in Ontario, the Green Energy and Economy Act (2009) was passed with the intention of streamlining the approval process for thousands of IWTs. The Act legislated a centralized decision-making process and removed jurisdictional authority from local municipalities (Gallant, 2011). The domino effect is that those living in the affected communities are unable to participate in meaningful consultation.

In Ontario, local communities no longer have planning authority to determine how or if renewable energy projects will be incorporated. As result, a significant number of local municipalities and counties have expressed concern and have requested that planning authority be restored to local governments. At the time of this article, 76 municipalities have expressed concerns regarding the development of renewable energy projects (Wind Concerns Ontario, 2011). The disempowerment of local councils and residents is perceived as a loss of democratic rights and social justice.

Section 2 of the Green Energy and Economy Act (2009) states, “This Act shall be administered in a manner that promotes community consultation.” However, in practice, the community consultation process does not include the right to approve or not approve IWTs in individual communities.

In a reported statement by former Minister of Energy and Infrastructure, George Smitherman: “We passed a law, and the law does not create an opportunity for municipalities to resist these projects just because they may have a concern” (Hendry, 2009).

Impact statements from other parts of the globe report concerns regarding IWT development and social impacts to the local community:

> We are Japanese concerning about wind farm developments. Big wind is destroying nature and local communities in Japan too. People near wind farms are suffering from low-frequency noise from the turbines. (Y. T. O., personal communications, 2010)

M. R. from Australia notes,

> . . . the social division; the slander, lies and intimidation; the anxiety that is caused by the health problems whether they are real or imagined. Again it is how dismissive the neighbours, authorities etc are, of the claims of people who have been affected. Then there is just the total destruction of small communities—pitching one faction against another; appearing to spread largesse when it is a farce; interference with the normal political processes in a small country town. (M. R., personal communications, 2010)

Another individual comments,

> Besides all the health problems, friendships, families and local communities have been destroyed forever. It’s so sad. Has the government stopped to think of the real cost in all this so called green energy. (M. O., personal communications, 2010)

A. R. reports,

> . . . the social dislocation that the wind farm has caused. There seems to be dismissal of any opinion that is contrary to the wind company, the government. . . . As dissenters, our rights as citizens of Australia have been eroded—they being the right to free speech and opinion, the right of association and thirdly the right to the benefits of our property’s that were meant to be protected under planning laws. This community is forever divided and mentally the wounds are incurable. (A. R., personal communications, 2010)

These sentiments reflect a perceived erosion of local democratic rights and loss of procedural justice.

During the course of several years, over 600 IWTs were commissioned in Ontario, Canada. Coinciding with these IWT developments were increasing reports of adverse health effects. After several years of IWT operations, correspondence from the Ministry of Environment, Ontario (2009) stated, “There is currently no scientifically accepted field methodology to measure wind turbine noise to determine compliance or non compliance with a Certificate of Approval limits.”

This lack of measurement and enforceability explained in part, why in spite of a growing number of complaints and requests for help, mitigation and resolution for those experiencing adverse health effects was elusive. Ontario, Canada residents' impact statements reflect frustration and disappointment:

> The wind developers get free access to all levels of the Ministry of Environment—when there are discussions about our noise study, we are excluded from the meeting.
>
> Who do you go to for help?—the government says it's ok—the industry says it's ok—society says it's ok. I follow all the rules—they call me a NIMBY. What can I do—the developer says it has a license and a right to put the turbines there.
>
> When people can't sleep, the developer always wins. The Ministry of Environment says they're in compliance, even when they aren't. It's not about justice—it's about procedures. (Personal group interviews by the author, 2010)

In Ontario, the Renewable Energy Approval (REA, 2009) process came into effect with the passing of the Green Energy and Economy Act. The REA is a fast tracking system with the intention to streamline the approval of renewable energy projects.

An individual may appeal a REA if they provide

> (d) a description of how engaging in the renewable energy project in accordance with the renewable energy approval will cause,
> (i) serious harm to human health, or
> (ii) serious and irreversible harm to plant life, animal life or the natural environment. . ." (Rules of Practice and Practice Directions of the Environmental Review Tribunal, (July 9, 2010), section 142.1 (s. d. ss. i, ii).

Originally, the Government of Ontario had proposed an even more onerous legal test in that the serious harm to human health would also have to be "irreversible" (Bill 150, 2009, Section 142.1 (3).

Concern has been raised that the process for filing an REA appeal is daunting for the average Ontarian. Those who wish to appeal an REA, must file one within 15 days. This time limit provides little time to organize an appeal. The appeal process has a number of steps with which an environmental lawyer might be familiar, but most residents would not. The legal requirement to prove that the renewable energy project will cause serious harm requires a comprehensive inventory of evidence, including testimony from expert witnesses.

Typically, an REA appellant would face the well-funded legal resources of the government and the project developer. The associated financial costs are a significant deterrent, which would discourage most individuals from filing an appeal.

In spite of these challenges, an appeal has been launched in Ontario, Canada, regarding the Kent Breeze project in Chatham Kent (The Canadian Press, 2011). At the time of writing this article, testimony by 26 appellant and respondent witnesses has been completed. The appeal hearing started February 1, 2011 and final submissions are scheduled for the end of May 2011.

People expressing legitimate concerns that IWT be sited to protect people from harm have been negatively characterized using preemptive stereotyping such as "those opposed to wind," "anti-wind farm activists," "detractors," "opponents," "beyond NIMBY" (Not In My Back Yard), and "BANANAS" (Build Absolutely Nothing Anywhere Near Anything), (Chatham Kent Public Health Unit, 2008; Colby, 2010; Colby et al, 2009; Kelahan & Purslane, 2009).

Martin (2009) reports on comments by the Premier of Ontario, Canada stating,

> He said the new Green Energy Act his government will enact is intended to prevent such barriers to green energy projects and the 50,000 jobs they bring. "We are going to find a way, through this new legislation, to make it perfectly clear that NIMBYism will no longer prevail," he told reporters at a luncheon gathering of the London chamber of commerce.

An impact statement in response to the Premier of Ontario's allegations of NIMBYism expressed an absence of fairness and stated, ". . . it lowered my sense of value and insulted my personal integrity—and it was coming from the highest office of my provincial government (S. M., personal communications, 2011). This individual's family was billeted by the IWT developer for months and ultimately has left their home of decades to live elsewhere.

The practice of using preemptive stereotyping labels such as NIMBYs demonstrates a lack of understanding of the health and social issues faced by individuals and their families. This lack of understanding results in increased feelings of injustice.

Based on my research, people initially welcomed IWTs into their communities and the adverse impacts were unexpected. Impact testimony reveals

> You need to know the problems with wind turbines and people living with them. I know you probably know me. You've probably seen my letters. When the wind turbines started up in early December, we had terrible noise issues, and it was pretty much instant. There were three nights straight we didn't sleep at all. . . . We had no thoughts that we were going to have problems. When the wind turbines were actually going up at our place in the summer, we were putting a double-car garage up at the same time. We had put in a new fence, a new deck, everything. We weren't

> expecting anything. We're not anti-wind, we're not anti-green. . . . When I hear people say, "There aren't problems," and "It's all in their heads," and "They're just unhappy because they don't have a turbine," I don't even know what to do. My government has not been helping. If you guys are going to go push more through—and then, because I came out and starting speaking, I've got people all over the province phoning me and saying, "Help us. We're not getting anywhere with our MPP. Nobody's listening to us." (Hansard, 2009, p. G-517)

Inconsistent government decisions can undermine Leventhal's (1980) criteria of equal treatment of persons resulting in a perceived discrimination.

For example, the Ontario, Canada, government has been inconsistent in its application of setback distances for IWTs. Currently, the on shore setback distances are 550 meters; however, it was proposed that off shore setbacks would be 5 kilometers (Ministry of Environment, Ontario, 2010). Spears (2010) reports regarding the Minister of Energy (Ontario):

> Minister Brad Duguid said the proposed guideline provides clarity to proponents of wind power projects and to people who may be affected by them. "I think it sets to rest the concerns of some moderate people who were concerned that if they go to the beach, they could be looking up at a huge wind turbine," he said in an interview.

Many Ontario rural residents were disturbed by the government's discrimination between the two groups—those living along a shore line and those living inland.

Measure and Understand the Problem and Assess the Impact of Action

WHO (2008) notes, "society must acknowledge when there is a problem monitor and initiate surveillance, then once the problem is identified, conduct research, and finally, take action" (chap. 16, p. 178).

Inconsistent information, including competing claims and denial of IWT adverse health effects has suppressed the stimulus to investigate the reports of those experiencing negative health and other negative impacts.

The Canadian Wind Energy Association's (CanWEA, 2008) website informs visitors: "Scientists conclude that there is no evidence that wind turbines have an adverse impact on human health."

The tactic of denying of health risks by industry has been employed in the past:

> In 1954, the industry established the Tobacco Industry Research Council. Its task was to reassure the public that the industry could responsibly investigate the smoking and health issue and that it could resolve any problems that were uncovered. The Council's real role, however, was "to stamp out bush fires as they arose." Instead of supporting genuine scientific research into the problems, it spent millions of dollars publicizing research purporting to prove that tobacco did not cause cancer. Its true purpose was to deliberately confuse the public about the risks of smoking. "Doubt is our product," proclaimed an internal tobacco industry document in 1969. "Spread doubt over strong scientific evidence and the public won't know what to believe." (Saloojee & Dagli, 2000)

The American and Canadian Wind Energy Association commissioned and funded panel report acknowledges that IWT noise may cause annoyance, stress, and sleep disturbance, which may have other consequences but then inexplicably states in the conclusion: "Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans." (Colby et al., 2009, p. 5-2)

A draft final report prepared for the Ontario Ministry of Environment states,

> The audible sound from wind turbines, at the levels experienced at typical receptor distances in Ontario, is nonetheless expected to result in a non-trivial percentage of persons being highly annoyed. As with sounds from many sources, research has shown that annoyance associated with sound from wind turbines can be expected to contribute to stress related health impacts in some persons. (Howe Gastmeier Chapnik Limited, 2010, p. 39)

The WHO (1999, p. xiii, 32) recognizes annoyance as a health effect. In terms of annoyance and stress from low-frequency noise in general it has been noted, "The noise, typically classed as 'not a Statutory Nuisance,' causes immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances" (Leventhall, 2003, p. 5).

An impact statement from Ontario reveals,

> This hum and vibration is not covered in the guidelines. There are no guidelines for interior noise in our house. When the winds are whipping up, and we can't sleep for days and days at a time, there's nothing. You phone the MOE and I cannot tell you how many times I heard, "We're in compliance. We're in compliance." They're in compliance. They're in compliance. In fact, they weren't in compliance. Finally, we dragged it out and got the acoustics study back. It's just been such a fight to get information. (Hansard, 2009, p. G-517)

In response to proposed Ontario requirements that IWT proponents ". . . be required to monitor and address any perceptible infrasound (vibration) or low frequency noise as a condition of the Renewable Energy Approval" (Renewable Energy Approval Regulation, June 9, 2009, p. 15), the CanWEA (2009b) stated, ". . . CanWEA submits that the proposed requirement for infrasound or low frequency noise monitoring as a condition of the REA be removed" (EBR Posting).

Individuals experiencing symptoms report the lack of recognition of their circumstances. An impact statement from G. M. (personal communications, 2010) in the United States reveals, "I am a victim of large IWTs . . . it is time that legislators and public health officials learn about and are held accountable for the terrible health affects inflicted on nearby residents . . ."

In the meantime, a local public health unit responded to an individual reporting IWT adverse health effects: "Our public health unit does not have the recourse, resources or expertise to monitor the health effects of turbines . . . To stray from this course, by pursuing such avenues, would be highly problematic" (B. A., personal e-mail communication, 2009). Ultimately, this individual's family home was purchased by the IWT developer. A nondisclosure clause prevents the family members from discussing specific details of their experience.

The Ontario Chief Medical Officer of Health's (2010) literature review states, "While some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects" (p. 10). However, the literature review does not adequately address effects of noise regarding the indirect pathway, which includes annoyance, sleep disturbance, cognitive and emotional response, and stress (WHO, 2009, p. 62, figure 4).

The health outcomes associated with the indirect pathway are significant:

> Physiological experiments on humans have shown that noise of a moderate level acts via an indirect pathway and has health outcomes similar to those caused by high noise exposures on the direct pathway. The indirect pathway starts with noise-induced disturbances of activities such as communication or sleep. (WHO, 2009, p.138)

The lack of evidence of IWT adverse health effects is cited as the rationale for not conducting health studies.

The industry trade association–sponsored panel report stated: "Panel members agree that the number and uncontrolled nature of existing case reports of adverse health effects alleged to be associated with wind turbines are insufficient to advocate for funding further studies" (Colby et al., 2009 p. 5-2). The president of CanWEA reportedly stated, "We don't support the implementation of an epidemiological study" (Avery, 2010).

At the same time, peer-reviewed scientific articles have identified the urgent need for research on human response to IWT sound (Pedersen, Bakker, Bouma, & van den Berg, 2009; Salt & Hullar, 2010).

In testimony at the Green Energy and Economy Act Standing Committee, Ontarians living in the environs of IWTs asked elected officials for understanding:

> I want everybody to live in my house. Nobody will live in it. I offer to everybody here: Come and live in my house, free.
>
> A government should take all the money we've given in taxes, use some of it to get the science people out there with no association with the wind industry at all—get out there and study this, and don't put up another wind tower or another wind project until you fix the problems. That's what good government does. Good government looks after its people. (Hansard, 2009, p. G-549)

It is expected that "Government's job is to provide citizens with accurate and appropriate information so that they can protect themselves" (Health Canada, 2004, p. 1-1).

A media report from the United Kingdom discussed the suppression of information regarding IWT health concerns: "Civil servants have suppressed warnings that wind turbines can generate noise damaging people's health for several square miles around." The media report cites a U.K. resident: "We abandoned our home. We rent a house about five miles away—this is our fourth Christmas out of our own home. We couldn't sleep. It is torture—my GP describes it as torture. Three hours of sleep a night is torture" (Leake & Byford, 2009).

The CanWEA states: "…findings clearly show there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health." (CanWEA, Revised: April 2009, p.3), However, Health Canada states "In fact, there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health". (Health Canada, 2009)

It was reported,

> Minister of Health Matthews also took on the question of whether the province will undertake a comprehensive health study on industrial wind turbines now that wind farms are becoming more abundant in Ontario thanks to the province's Green Energy Act.
>
> The short answer to the question of the possibility of a full-scale study is no.
>
> "There is no evidence, whatsoever, that there is an issue related to turbines," says Matthews, noting Ontario's Chief Medical Officer of Health completed

> a report, The Potential Health Impact of Wind Turbines, which shows there is no correlation between wind projects and ill health effects. (Heath, 2010)

In an apparent contradiction, the Premier of Ontario, Canada stated in the legislature:

> . . . we're now funding a research chair devoted to putting in place a longitudinal study so we can ensure that we are in fact not compromising the health of Ontarians. I think we're doing exactly what we need to do at this point in our history. (Hansard, 2010, p. 1032).

The $1.5 million in total funding for the research chair is distributed over a 5-year term (Council of Ontario Universities, 2010). In the meantime, IWT projects continue to be approved (Kent Breeze, 2010) and by the time the health research has been completed; more people are expected to be adversely affected.

Meanwhile, impact statements from existing IWT installations reveal chronic distress:

> I begged the Premier to help me, please help me.
>
> It's mental abuse—I will never be the same . . . I have lost all hope.
>
> We wait and wait for help—our hopes are dashed over and over—the problem is never solved.
>
> I write letters and keep hoping the next one will get us out of this. (Personal group interviews by author, 2010)

Similar comments are expressed in other parts of the globe:

> We still have the noise 4 years later and no one has done anything . . . No one came. No one rang, no one wrote. I am still waiting for someone to take some interest. They don't know the impact on our life. . . . They don't care. (L. C., personal communication, 2010)

Other impact statements describe additional negative social impacts, including the inability to earn a living:

> We have lost our health, our home, and no one cares . . . I had to quit my job, a job I dearly loved. (N. S., personal interview, 2010)
>
> I am a teacher, we are driven from our home of 31 years and I have to teach the social marketing about wind turbines to our youth. (S. M., personal interview, 2010)

G. W. from Australian reports a similar issue about livelihood:

> I've been living in [city y] for 25 years. I live and work from home. The nearest cluster of turbines is approximately 3.25 kilometres from my home. Since the operation of the . . . Windfarm I have suffered headaches, ear aches, ear pressure, head pressure, tinnitus, severe sleep disturbance and mood swings. All of which living in a tranquil bush environment I had never experienced before. These symptoms disappear when I am away from home. The symptoms present themselves again on my return home. These health issues have had a significant detrimental effect on my capacity to work as an artist. (G. W., personal communications, 2010).

In 2009, an increasing number of media reports documented some individuals in Ontario were experiencing adverse health effects from IWTs. In response to the lack of IWT vigilance monitoring in Ontario, volunteers established a self reporting health survey in March 2009. WindVOiCe (Krogh et al., 2011) follows the principles of Health Canada's *Canada Vigilance Programs* for reporting adverse events for prescription and nonprescription products, vaccines and other. Individuals do not have to prove the effect, only perceive it. Under Canada Vigilance, the pharmaceutical industry is obligated by law to submit any reported adverse health effects it receives to Health Canada (Health Canada, n.d.). This obligation to report adverse effects does not apply to wind energy development in Ontario.

The lack of a post–market monitoring methodology to measure wind turbine noise and its compliance with the Ontario IWT noise guidelines is a serious lapse in responsible and fair policy making.

In Ontario, the inability to measure IWT noise for compliance has resulted in a lack of mitigation and resolution for those reporting IWT adverse health effects and other associated societal impacts.

In 2010, after several years of IWT development and operation, the Ministry of Environment, Ontario, released a request for proposal (RFP):

> The Ministry requires a consultant to assist in the development of a measurement procedure to assess noise compliance of existing wind farms with the applicable SOUND level limits. The resulting procedure can be used both by operators of existing wind farms to assess compliance and by Ministry abatement staff in assessing compliance with noise limits. The measurement procedure must address two scenarios.
>
> - Assessment of compliance in a noise complaint situation
> - Assessment of compliance in the context of an acoustic audit. (MERX# 189608, 2010)

At the time of authoring this article, the protocol is still under development. In the meantime, individuals continue to report IWT adverse health effects which are not resolved.

Discussion

The impact statements in this article represent a small sample of a larger body of data acquired through the WindVOiCe health survey, official reports of debates, personal interviews, and other communication.

It is acknowledged that IWTs, if not sited properly, can adversely affect the health of exposed individuals. In addition to physiological and psychological symptoms there are individuals reporting adverse impacts, including reduced well-being, degraded living conditions, and adverse societal and economic impacts. These adverse impacts culminate in expressions of a loss of fairness and social justice.

The above impacts represent a serious degradation of health in accordance with commonly accepted definitions of health as defined by the WHO and the Ottawa Charter for Health Promotion.

Wind turbines are a new source of community noise to which relatively few people have yet been exposed (Pedersen et al., 2009). Public policy to adopt renewable energy as an alternative energy source has inspired governments to introduce measures to encourage rapid development. This has resulted in many IWTs being sited in close proximity to human habitation.

Ontario's Green Energy and Economy Act (2009) is reported to be designed to remove barriers to renewable energy development such as removal of local planning authority. The Act arguably erodes individual human and environmental rights. The Act is written such that a renewable energy development can be approved even if it will cause harm to human health and serious harm to plant life, animal life or the natural environment.

As discussed in the introduction, fairness can be defined as "the recognition and reasonable accommodation of one another's legitimate interests, claims and rights" (Shain, personal communication, 2011). Evidence indicates the rapid implementation of IWTs has circumvented fairness. My research demonstrates that IWTs were initially welcomed into communities. The reported adverse impacts were unexpected. Individuals initially believed there were systems in place that would resolve the problems. Instead, those adversely affected report receiving little if any recognition or reasonable accommodation of their legitimate interests, claims, and rights. A review of IWT development in Ontario indicates that the application of fair process and social justice criteria as proposed by Leventhal (1980) and WHO (2008) are not being achieved.

This subject provides research opportunities for clinicians and social scientists. There are unanswered questions about the risk of short and long term exposure to IWTs. The long-term health impacts to infants, children, and the unborn, family members, and workers such as farmers and technicians who live and work in close proximity to IWTs are unknown.

The long-term psychological, economic, and social impacts on families who have abandoned their homes or been bought out by IWT developers but are silenced by nondisclosure clauses are also unknown.

Conclusions

In Ontario, Canada, there is a suspension of critical appraisal and due process regarding IWTs. The lack of confidence in the political and regulatory systems will persist if governments and industry continue to deny the existence of adverse impacts from human exposure to IWTs.

Societies concerned with health place value on the individual: "A society that is concerned with health and health equity acknowledges the existence of all its citizens and the importance of their well-being" (WHO, 2008, p. 177).

Good governance implies that governments have a responsibility to correct policies that result in harm. Governments have the power to halt development of IWTs in close proximity to humans until authoritative human health research has been completed. Facilities where there are reports of adverse health effects should be decommissioned and health and quality of life restored.

The negative psychological effect of disempowerment interacting with the adverse health effects attributed to IWTs has intensified the negative synergy of justice lost. Impact statements indicate that the violation of procedural justice will not be easily forgotten.

It is expected that this topic will be explored by health care professionals, psychologists, and social scientists for decades to come.

Author's Note

I would like to express my appreciation to the many who have shared their experiences with me. Most of the author's research has been conducted in Ontario, Canada; however, effort has been made to include an international perspective.

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Bio

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WindVOiCe, a Self-Reporting Survey: Adverse Health Effects, Industrial Wind Turbines, and the Need for Vigilance Monitoring

Carmen M.E. Krogh, Lorrie Gillis, Nicholas Kouwen and Jeff Aramini

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WindVOiCe, a Self-Reporting Survey: Adverse Health Effects, Industrial Wind Turbines, and the Need for Vigilance Monitoring

Carmen M.E. Krogh[1], Lorrie Gillis[2], Nicholas Kouwen[3], and Jeff Aramini[4]

Abstract

Industrial wind turbines have been operating in many parts of the globe. Anecdotal reports of perceived adverse health effects relating to industrial wind turbines have been published in the media and on the Internet. Based on these reports, indications were that some residents perceived they were experiencing adverse health effects. The purpose of the WindVOiCe health survey was to provide vigilance monitoring for those wishing to report their perceived adverse health effects. This article discusses the results of a self reporting health survey regarding perceived adverse health effects associated with industrial wind turbines.

Keywords

Self-reporting, adverse health effects, industrial wind turbines, health survey, vigilance monitoring

Introduction

Many Ontarians living close to industrial wind turbines (IWTs) who believe they are suffering adverse health effects are hesitant to report their symptoms. Individuals report that this hesitancy is because of the manner in which their claims have often been discounted or ignored by the wind energy industry and government officials (Hansard, 2009, pp. G-516, G-547). As a result of a limited number who first came forward to report their symptoms, WindVOiCe was established in March 2009.

WindVOiCe is a self-reporting health survey that collects data about adverse health effects being reported by families living near IWTs. The WindVOiCe health survey follows the principles of Health Canada's *Canada Vigilance Programs*, which encourages all consumers in Canada to self-report perceived adverse health effects from prescription and consumer products, vaccines and other. Medical and health care practitioners are encouraged to report perceived adverse health effects to the *Canada Vigilance*. Consumers do not have to prove the effect, only perceive it. The pharmaceutical industry is obligated by law to submit any reported adverse health effects it receives to Health Canada (Health Canada, n.d.).

The objectives of WindVOiCe are to

document any changes in health outcomes among individuals living near IWTs

if documented, provide information to assess the need for large-scale controlled epidemiological studies and to establish evidence-based and safe residence setback distances.

Methods

Study Design and Participant Recruitment

This is a self-reporting survey based on perceived adverse health effects occurring with the onset of an industrial wind turbine facility.

The WindVOiCe survey questionnaire reproduced that of Harry (2007). The questionnaire is designed to collect basic demographic information and information on any new adverse health outcomes and changes to quality of life since the start of the respective IWT project (Appendix A). Health outcome observations included headaches and migraines, heart

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palpitations, excessive tiredness and sleep disturbance, stress and anxiety, depression, tinnitus, and hearing problems.

A Health Survey Contact Flyer was distributed starting in March 2009 to residents in five project areas where adverse health effects had been anecdotally reported (Appendix B): Melancthon Phase 1 and 2 (Shelburne), Canadian Hydro Wind Developers (Shelburne), Kingsbridge 1 Wind Power (Goderich), Kruger Energy Port Alma (Port Alma), Ripley Wind Power (Ripley), Enbridge Ontario Wind Farm (Kincardine), and Erie Shores Wind Farm (Port Burwell).

The Health Survey Contact Flyer was distributed by Canada Post and in some cases by volunteers who hand-delivered it to mailboxes in the areas where IWTs were situated. The opportunity to participate in the WindVOiCe project also involved distributing notices at community information sessions, by word of mouth, and via the Internet (The Society for Wind Vigilance, n.d.).

A confidential toll free telephone number and e-mail address were provided. Those who contacted the WindVOiCe survey team were assured of total confidentiality and anonymity. There were no restrictions placed on the distribution or access to the survey in communities with IWTs. Individuals experiencing adverse health effects and those who were not were encouraged to fill out and submit a health survey. Both hard copy and rarely, electronic copies, were sent on request. Each interested adult in the home was asked to complete a separate survey, with a minimum age of 18 years and fluency in English specified as requirements. The WindVOiCe health survey could not be used by anyone with any cognitive impairment.

Those interested in participating in the study were provided with the survey, a cover page giving general instructions (Appendix C) and a cover note with mailing instructions (Appendix D). Surveys were typically mailed to those wishing to participate and were returned by Canada Post.

Questionnaire Processing

The WindVOiCe Scrutinizer validated each returned survey. The survey contact lead and scrutinizer transferred results into an electronic database (Microsoft Office Excel 2003). Respondents were given the opportunity to include additional comments and these were transcribed exactly as stated. A strict protocol was employed to protect confidentiality and data integrity of the returned surveys.

Data Analysis

All analyses were performed using SAS 9.22 (2008, SAS Institute Inc., Cary, NC).

Descriptive analyses were performed to investigate and describe participant demographics and frequency of health outcome responses. The association between health outcomes and distance to nearest IWT was also investigated. Distance to the nearest IWT was assessed both as a categorical and continuous variable. Significance of associations when distance to nearest IWT was assessed as a categorical variable involved using Proc FREQ (Fisher's exact test). Significance of associations when distance to nearest IWT was assessed as a continuous variable involved using Proc GENMOD (logit link; binomial distribution). Age and gender were included in the Proc GENMOD model if significant at $p < .05$.

For the purpose of interpreting statistical significance, the following parameters were used:

$p < .05$ = significant
p .1 to .05 = moderately significant
$p > .1$ = not significant

Results

Data Preparation for Analysis

- Number of Ontario WindVOiCe survey participants = 109
- Responses of "maybe," "unsure," or "left blank," were all set to "No"
- Those reporting either Altered Health or Altered Quality of Life included = 102
- Four (4) participants were younger than 18 years and were removed.
- Two (2) participants were much further away from IWTs compared with the rest (5 kilometers) and were removed from further analysis given the distance gap.
- Distance to nearest IWT was divided into four groups based on natural break-points among the participants: 350 to 499 meters, 500 to 699 meters, 700 to 899 meters, and 900 to 2400 meters.

Participant Comments

Survey participants were given the opportunity to volunteer comments. A representative selection of comments is provided in Appendix E.

Discussion

A case report is a descriptive study of a single individual (case report) or small group (case series) in which the possibility of an association between an observed effect and a specific environmental exposure is based on clinical evaluations and histories of the individual(s). Because cases in a case series study are often self-identifying and population controls are lacking (as in this study), it is difficult to investigate and measure exposure–outcome relationships, and it is impossible

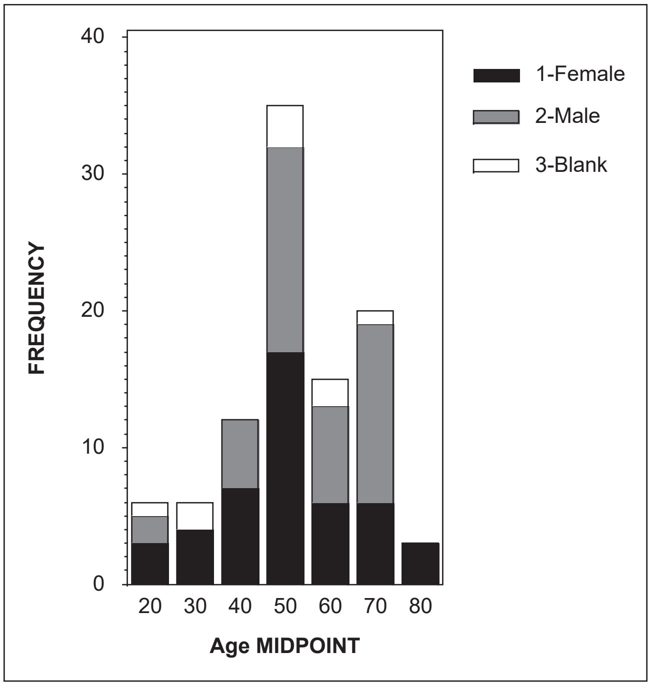

Figure 1. Age (years) and gender of participants
Age: mean = 52 years, range = 19-83 years. Gender: female = 52%, male = 48%.

to extrapolate results to the general population as selection bias is always a concern. That said, case reports (or case series) often provide the first indicators in identifying a new disease or adverse health effect from an exposure.

Study participants ranged in age from 19 to 83 years; there was approximately an equal number of males and females enrolled in the study (Figure 1); and the frequency of participants increased with closer distances to IWTs (Figure 2).

In total, 72% of participants reported increased symptoms of anxiety, stress, or depression since the start of their local wind project (Table 1), and not unexpectedly, mental distress was *not* associated with distance to nearest IWT. Distress likely played a major role in individuals self-identifying themselves for the study, and it is reasonable to assume that individuals experiencing distress because of IWTs for *whatever* reason (real or perceived adverse health effect, attitude, etc.) were more likely to participate in the study. Among study participants, the most common adverse health outcomes reported included sleep disturbance, excessive tiredness, and headaches.

Although it is not possible to compare participants to a control group in this study, it is possible to investigate relationships between exposure levels (as measured by distance to IWT) and outcomes *among* participants. Results suggest dose–response relationships between a number of adverse health outcomes and distance to IWTs, particularly sleep disturbance, excessive tiredness, and headaches (Figures 3-6). Modeling efforts suggested stronger relationships between adverse health events and log-distance to IWTs compared with linear distance. This mirrors the way in which sounds decays as it travels from source to receptor.

Discovering relationships between adverse health outcomes and log-distance (Figures 7-9) to IWTs among self-reported cases is a significant finding and supports the underlying hypothesis that living too close to IWTs can cause adverse health effects. If adverse effects were purely psychosomatic (i.e., the result of emotional distress and fear), one would expect the proportion of individuals self-reporting to increase closer to IWTs in this alternative hypothesis; but among those who did self-report, one would *not* expect dose–response relationships. Lack of a true cause–effect relationship should have resulted in relationships with distance to IWTs as seen with stress, anxiety, and depression (i.e., the primary drivers of self-reporting in this alternative hypothesis).

It is noted that the comments excerpted from the survey range from descriptions of altered quality of life and enjoyment of property, health issues related to noise, flicker and sleep disturbance, altered social and family interactions, concerns about property values and altered financial status, changes in pet and wildlife behavior, and concerns about the future. Some describe the impact on the family unit when a parent or spouse has been billeted at the developers' expense because of adverse health effects. These comments were voluntarily submitted by participants.

Conclusion

Self-reporting is an important research tool and frequently used by the research community. Examples of the use of self-reporting include peer-reviewed articles by Engstrom, Paterson, Doherty, Trabulsi, and Speer (2003), Meyer, McParlan, Sines, and Waller (2009), Zota, Aschengrau, Rudel, and Brody (2010), and Lim et al. (2010). In addition, self-reporting is encouraged with respect to breast cancer vigilance where women are encouraged to conduct routine breast examinations. This self-monitoring is used as an adjunct to other monitoring procedures such as mammograms and checkups by physicians.

It is important not to overinterpret results of a self-reporting case-series study. Outcome measures are crude, and the lack of a control group and potential selection bias prevents investigating traditional population-based epidemiological measures of association (e.g., odds rations, relative risk, etc.). Careful analysis of case-series data, however, can provide important initial indicators regarding underlying causal relationships, providing support for more thorough and larger scale epidemiology studies. Results of this study suggest an underlying relationship between IWTs and adverse health effects and support the need for additional studies.

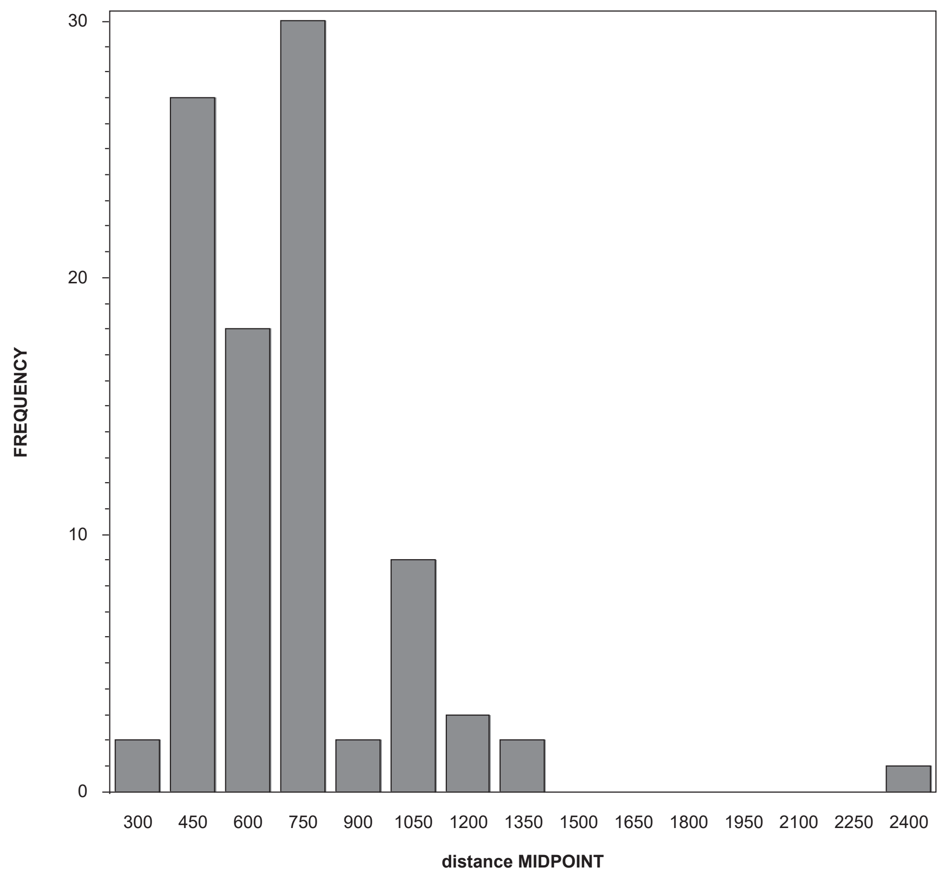

Figure 2. Distance of participants to nearest industrial wind turbine (meters)
Distance: mean = 707 meters, range = 350-2400 meters.

Table 1. Health Outcomes Results

		Distance Range From Residence to Nearest IWT in Meters (Mean)						
Parameter	All Participants	350-490 (428)	500-673 (587)	350-673 (506)	700-808 (769)	900-2400 (1154)	700-2400 (908)	p[a]
Number of responses	97	24	23	47	30	17	47	
Altered quality of life (%)	97	96	96	96	100	94	98	1.0000
Altered health (%)	90	93	96	94	87	82	85	.1908
Disturbed sleep (%)	69	78	78	78	60	59	60	**.0778**
Excessive tiredness (%)	76	89	83	86	63	71	66	**.0307**
Headaches (%)	62	74	65	70	60	41	53	**.0990**
Migraines (%)	13	22	13	18	13	0	9	.2358
Hearing problems (%)	35	22	57	38	27	41	32	.6706
Tinnitus (%)	56	59	61	60	33	41	51	.4179
Heart palpitations (%)	34	26	39	32	33	37	36	.6750
Stress (%)	69	74	57	66	70	76	72	.5189
Anxiety (%)	52	52	57	54	40	65	49	.6864
Depression (%)	41	44	48	46	33	41	36	.4099
Distress[b] (%)	72	74	61	68	73	82	77	.3735
Approached doctor (%)	38	37	39	38	40	35	38	1.0000

Note: Significant or moderately significant p values are in the boldfaced.
[a]Fisher's exact test.
[b]Distress = "Yes" if at least one of stress, anxiety, or depression reported as "Yes."

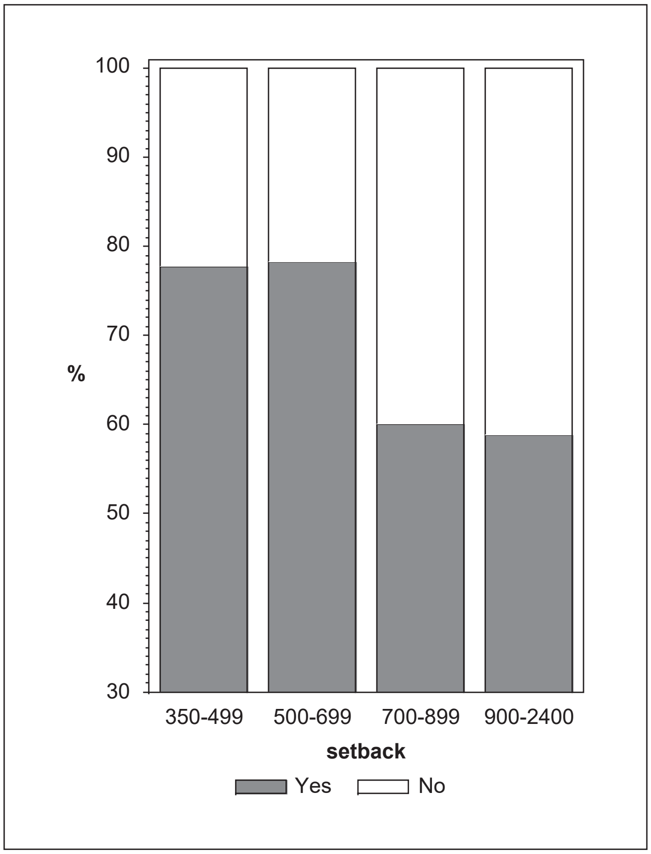

Figure 3. Sleep disturbance by distance (meters)

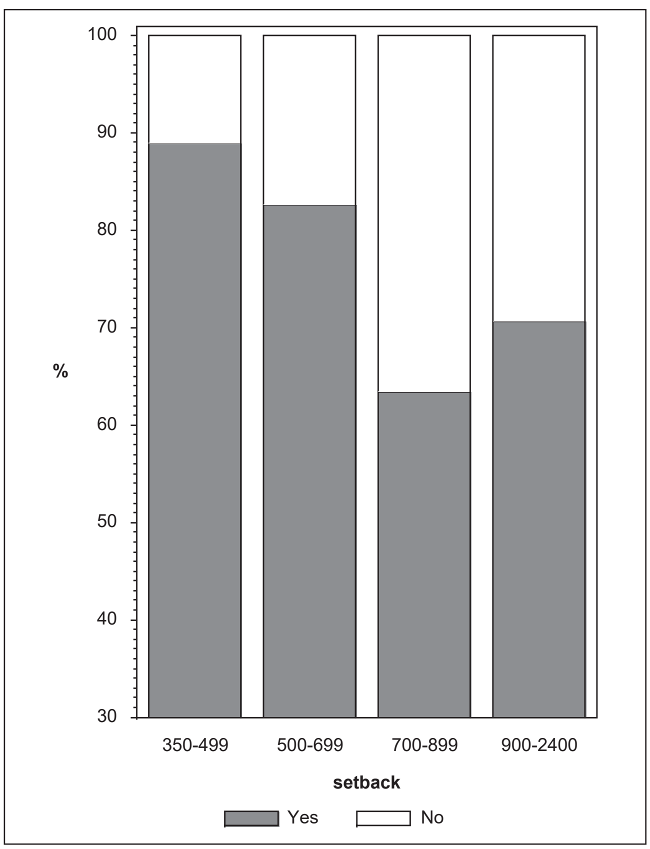

Figure 4. Excessive tiredness by distance (meters)

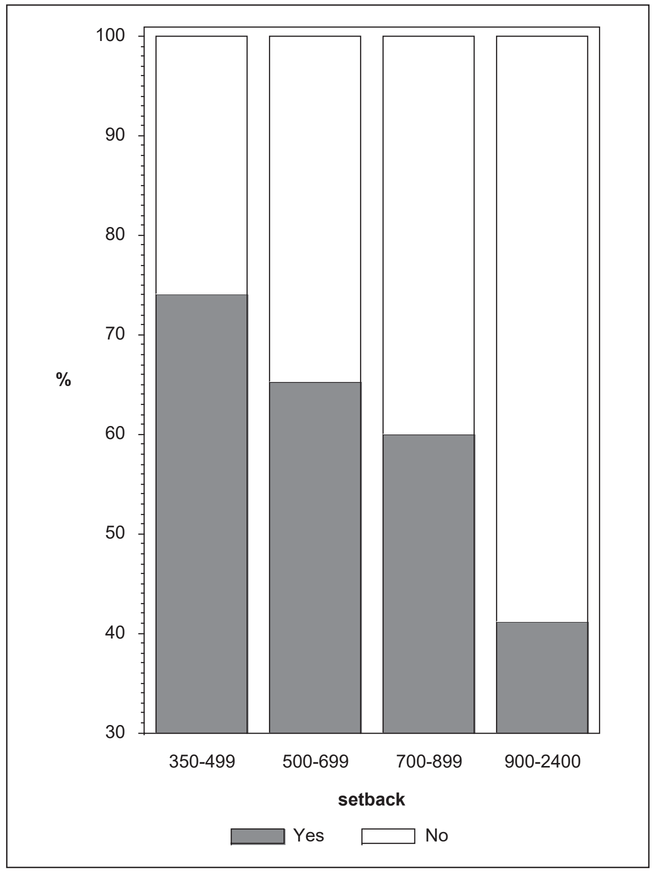

Figure 5. Headaches by distance (meters)

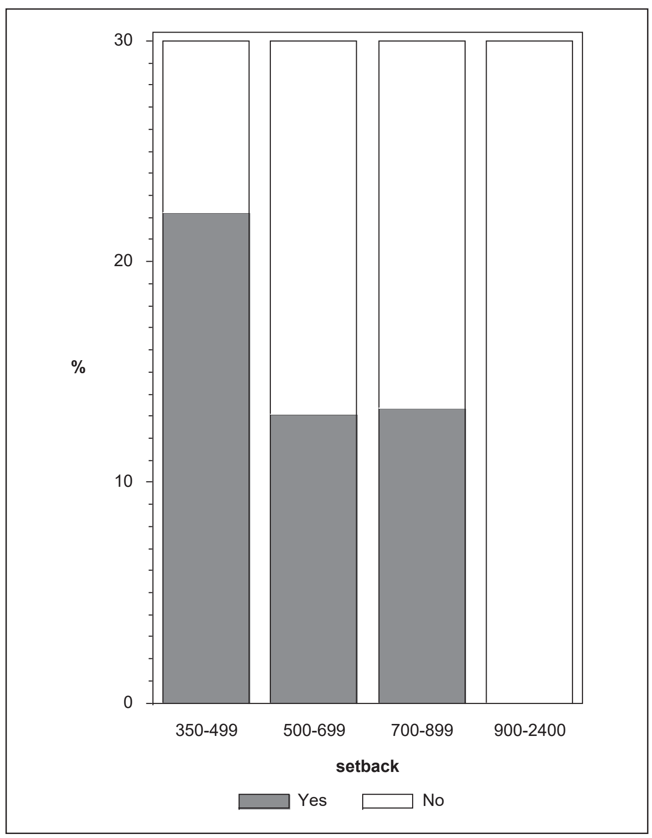

Figure 6. Migraines by distance (meters)

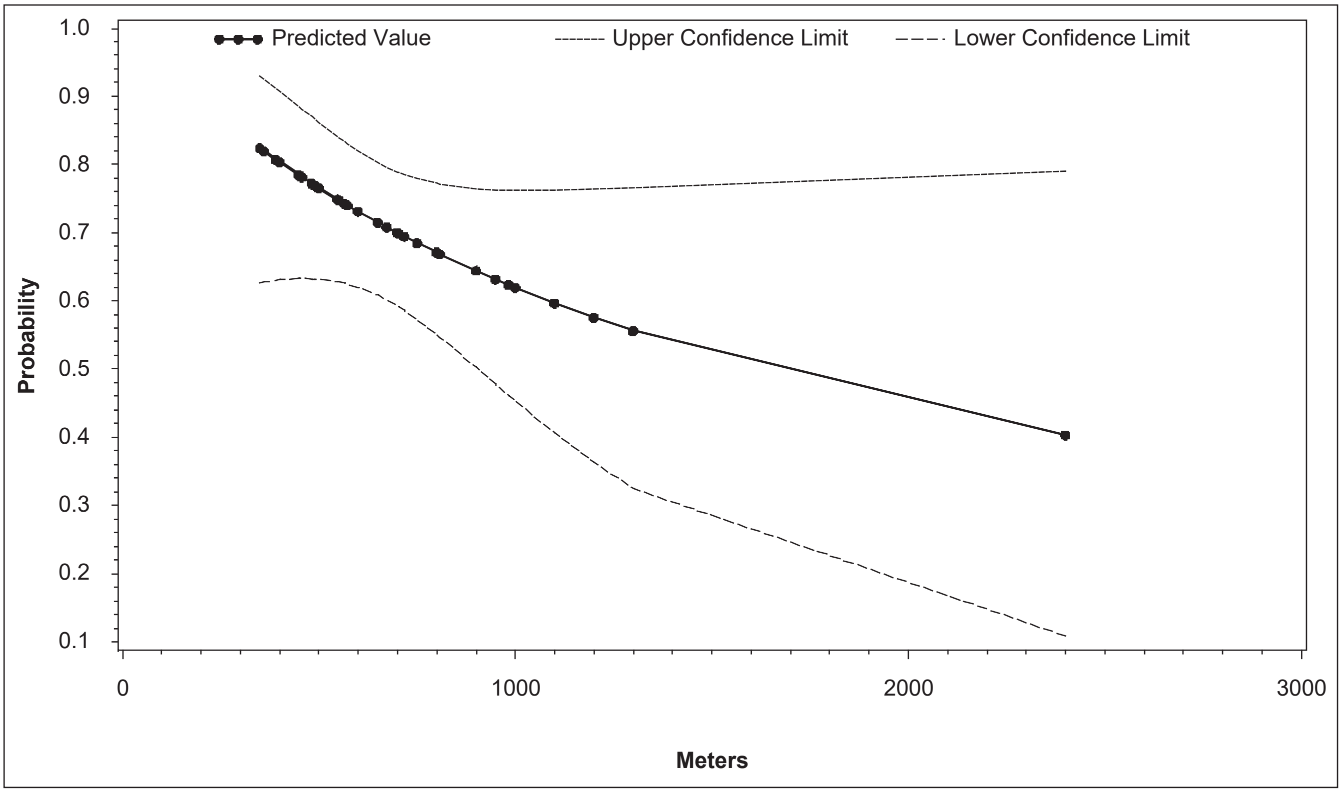

Figure 7. Predicted probability of sleep disturbance by distance to industrial wind turbine (95% upper and lower confidence limits)
Proc Genmod (logit link; binimoial distribution). Sleep = ln(distance) + sex + intercept. *p*(ln distance) = .1015.

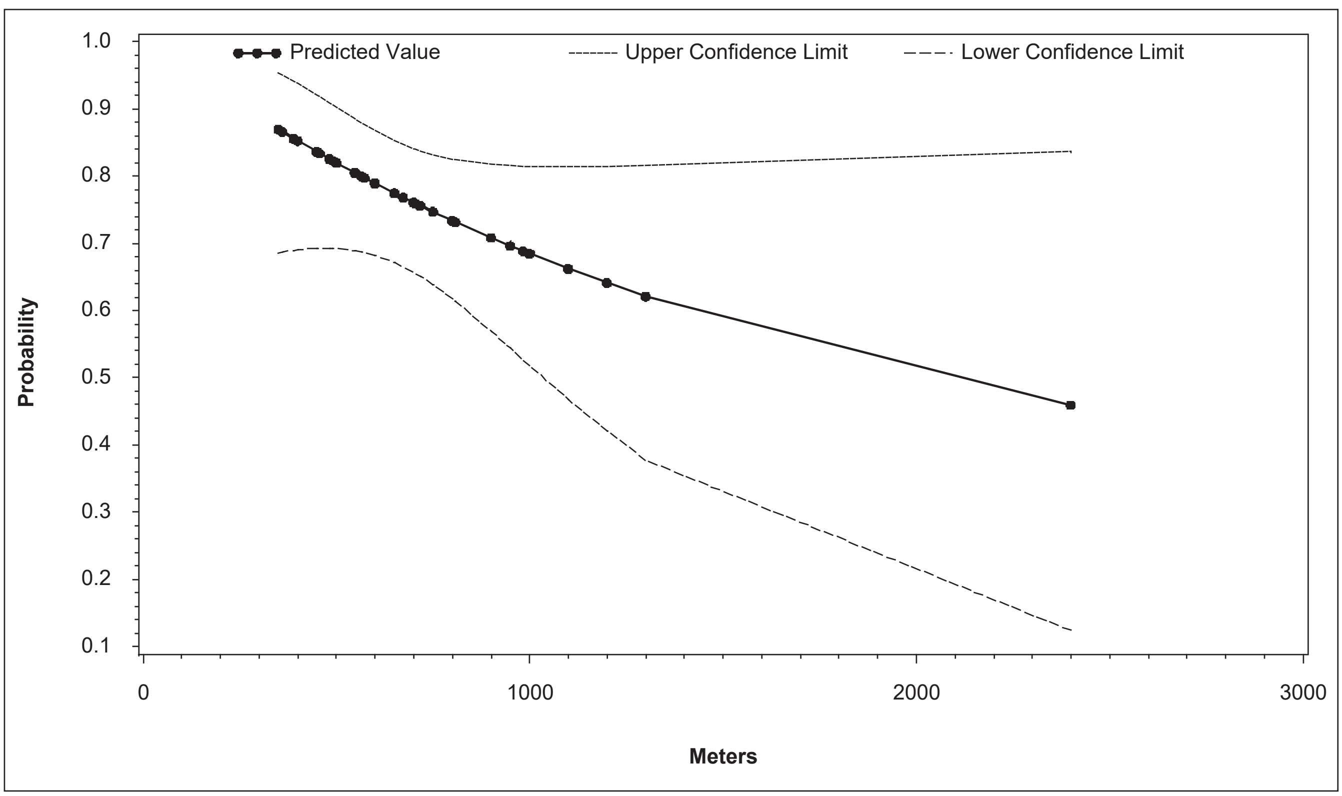

Figure 8. Predicted probability of excessive tiredness by distance to industrial wind turbine (95% upper and lower confidence limits)
Proc Genmod (logit link; binimoial distribution). Excessive tiredness = ln(distance) + sex + intercept. *p*(ln distance) = .1005.

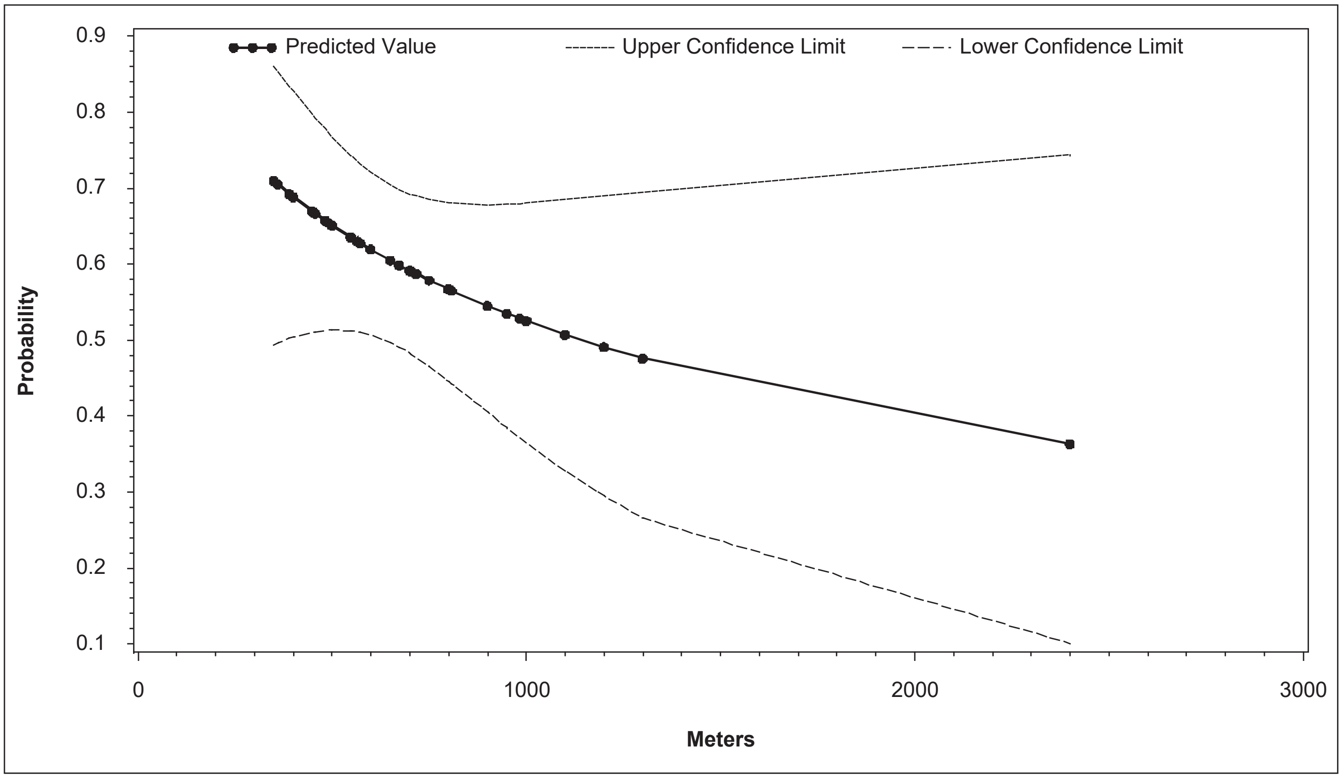

Figure 9. Predicted probability of headaches by distance to industrial wind turbine (95% upper and lower confidence limits)
Proc Genmod (logit link; binimoial distribution). Headaches = ln(distance) + sex + intercept. p(ln distance) = .1837.

Appendix A

WindVOiCe Survey Questionnaire

Adult survey questionnaire:
WindVoiCe (Wind Vigilance for Ontario Communities)

1) Name (preferred but optional)

2) Date of birth

Day _______ Month __________ Year ______________

3) Occupation ______________________
4) Address and/or postal code

5) Which wind farm is near your property?

6) How far away from your property is the nearest turbine?

7) How long have you been living at this property?

8) Do you feel that your health has in any way been affected since the erection of these turbines?

If yes, please answer the following
Do you feel that since living near a wind turbine/turbines you have experienced excess of the following symptoms (i.e., more than you did prior to living near these structures)?

Headaches	yes _____	no _____
Palpitations	yes _____	no _____
Excessive tiredness	yes _____	no _____
Stress	yes _____	no _____
Anxiety	yes _____	no _____
Tinnitus (ringing in ears)	yes _____	no _____
Hearing problems	yes _____	no _____

(continued)

Appendix A (continued)

Sleep disturbance	yes_____ no _____
Migraines	yes_____ no _____
Depression	yes _____ no _____
Other—please specify	

If you have answered yes to any of the above questions, have you approached your doctor regarding these symptoms?

yes _____ no _____

If yes, please state any tests and/or treatment initiated

9) Do you feel that your quality of life has in any way altered since living near wind turbines?

yes_____ no _____

10) If yes, could you please explain in what way you feel your life has been altered?

11) If you have any pets or livestock and have seen any changes in their behaviour since turbines have been erected, please describe

Appendix B

Health Survey Contact Flyer

WIND ENERGY CONCERNS?

Industrial wind turbine installations are becoming one of the most prolific forms of energy being put into use today.

Some residents living in the vicinity of a wind farm are suffering from adverse health effects and disturbed living conditions.

People from across Ontario who welcomed wind turbines into their community are now coming forward with questions and concerns and may not know where to turn.

If you, or anyone you know is having difficulty, please call *toll free 1-888-700-5655* or email *windaffects@gmail.com* Others are facing similar concerns.

Your call will be kept totally confidential.

Appendix C

Health Survey Cover Page

WindVOiCe (Wind Vigilance for Ontario Communities)

Questionnaire on Health/Disturbed Living Conditions

Some residents living in the vicinity of wind turbines are suffering from adverse health effects and disturbed living conditions.

Currently, there are no authoritative guidelines about how far away turbines should be placed from residences. We are collecting information so that we can advise those in authority about the impact wind turbines have had on some of our population.

Your name will be kept totally confidential.

How to use the questionnaire:

1. If more than 1 adult in the home is affected please have each adult fill out a separate questionnaire.
2. This questionnaire may be filled out by a person 18 years of age or older who is fluent in English. This questionnaire will NOT be used by anyone with any cognitive impairment.
3. Question 5)—please answer with project name and/or wind company name. Question 6)—please give estimate if exact number is unknown. Question 10)—open to any other life alterations you've noticed for yourself. Please, worried parents, use this space to describe any symptoms your children may show.

Lorrie Gillis
Health Survey
R.R. #4
Flesherton, Ontario N0C 1E0

Thank you for taking the time to fill out this questionnaire.

Appendix D

Health Survey Cover Note

Cover Note accompanying the survey with mailing instructions

Thank you for being part of this survey. Your participation gives voice to adverse health and living conditions to people living in close proximity to industrial wind turbines. Confidentiality of your personal information is assured. Results will go forward with no disclosure of any personal or identifying information. All surveys will be kept in locked storage at all times with extremely limited access for tabulation of data. Please return your completed survey to:

Lorrie Gillis
Health Survey
R.R. #4
Flesherton, Ontario N0C 1E0

Appendix E

Sample WindVOiCe Participant Comments

3

9) [other] High blood pressure 217/124

Had a foot that don't heal until I moved out of the house

Yes [contact doctor] Blood pressure, urine test, Doppler test, heart machine, on blood pressure pills now (Mavik 1 mg) Trandolapril [sp?]

10) [quality of life altered]

1. Had to move out of my home, just come home now to feed the cattle.
2. Our home can't be sold due to the problem per real estate agent.
3. Family events can't take place at home
4. Financial problems due to keeping two homes
5. Always sick, depressed and bad tempered when at home but when away for a short time feel much better. (Much better in the second house which I had to buy)
6. Had family problems until we moved out.
7. Feel no cares or believes us.

Bottom line:

They took life away as we knew it before the wind farm, same house value 0 sick all the time, financial stress now, world turned upside down.

11) 2 house dogs always sleeping, ear problems itching all the time. Moved the dogs out of house, now they are fine.

13

10) [quality of life altered] Everything in my life has changes since the town_x Wind Turbine Project company_x has been in operation. I feel my health has been compromised. I have felt generally unwell physically and mentally since March 24/08. Also sensitivity to white noise and sounds has increased. My ears are either humming or feeling pressure on them/heart palpitations continue usually while sleeping. My anxiety and stress levels continue to be high. We have discouraged our two daughters and son-in-law from visiting. They have also experienced health issues when visiting. The damage that has been done to my body—scares me what will happen in the future. At 60—I wanted to enjoy my retirement with reasonable good health and now everything has blown up in our faces. We spent 5 weeks in Florida Jan 26—March/09 improvement in health. Loss of enjoyment of working outside with flower beds and yard. Our property value has been greatly decreased. We are still having problems with electrical pollution. Constant reminder in every direction of our property—turbines. A very uncertain future!!

#18

8) [health affected] Yes—whenever I am there!

9) [other] [other] Pressure in my ears or ear aches tightness feeling in my head

[doctor visit] Not at this time, these symptoms only occur around the Wind Project and not at my own residence.

10) [quality of life altered] As a teacher who spends most of my summer relaxing at home& was disrupted in July/Aug 2008 when I would leave each night with my mother to drive 10 min to a hotel town z in because of the above symptoms. This is something she did for months, it was disruptful for the few weeks I did it, not a peaceful relaxing environment. In December 2008 when I arrived home to my parents on the first night for Christmas the pressure in my head and ears hurt so bad that I had difficulty sleeping and considered spending the rest of the week at a relative's home away from the wind turbines. These are regular occurrences when I visit, and now sometimes think twice before going as I don't know how bad it will be this time, which makes going home no longer relaxing and peaceful like it once was. I also worry on a daily basis for the health and well being of my parents who live through this daily and the negative health impacts and stress worries me greatly. It also causes me stress that the value of my family farm has dramatically been reduced due to these wind turbines.

11) Thank you for organizing this health survey. My family greatly appreciates it.

#34

[palpitations] pressure in chest, dull and stabbing pain in chest

9) [other] joint pain, numb face, dizziness, feeling cold a lot.

Yes, doctor is aware and looking for a referral to an environmental specialist—so far no luck—not sure what next step will be.

10) [quality of life altered] Along with the above symptoms—experiencing a general lack of wellness.

#40

Struck/heart palpitations

9) [other] Stress tests/blood tests too numerous to count.

10) [quality of life altered] I now live on drugs that don't seem to help.

11) Livestock were all sold off due to problems that could not be explained. (Nervousness)

(continued)

Appendix E (continued)

#41

10) [quality of life altered] Forced to sell our property, take less than what it was really worth!! This was due to health problems caused by the wind turbines.

11) Our dogs were nervous, as well as our four (4) ponies. We ended up taking our ponies to the auction barns and had them sold. Two of our dogs had to be put down!!

#46

9) [other] No. Problems with the above go away when I leave the (wind project) home.

10) [quality of life altered] I feel wound up when at home. I just cannot settle. Because of this I do not want to stay in our home or for that matter come home. The biggest change has been the effect on my Mom, sister and Dad's health, especially Mom. To see her suffering from health problems, getting sicker and sicker just pisses me off. It really bothers me a lot.

#50

9) [other] [tinnitus] pop when turbines come on and off.

[sleep disturbance] Do not sleep a full night. Wake up quite often.

[other] nasal cavity felt like I had allergies, but no mucus, irritable.

10) [quality of life altered] Personal—have found the changes in sleep patterns reduced energy levels, levels of patience and very frustrating and draining. Dec. on there were serious, angry arguments we normally do not have. I am *very worried* about my partner's, [wife], reduced sleep/rest, humming/ringing in her ears and continued deterioration of health. When [wife] had to live away from home it was hard. She is my partner and my love. We would always chat on family plans from food to finances. Our lives were upside down at all family levels when she was billeted by the windmill company wind_co_x from May 2008 to July 17th and AGAIN now. She is living at her Mom's in town_y a 30-minute drive away (on Dr. orders). On a very personal level I am like a widower and sad and lonely.

Generally—Our financial outlook for our property has changed. At present we cannot sell knowing the possible harm that someone may experience. This is a stressor we did not have prior to the turbines. I can't sleep with the bedroom window open in the summer for a cool breeze due to the roaring jet sound. (This was pleasant and cooling too.) I can't have a quiet sit on the deck without the jet or swoosh sound. And our phone has static on it which is not there when turbine were not here. CKNX am channel is staticy or weaker in the project area.

#58

10) The flicker from the turbines can be very annoying in the mornings. When I'm training horses for 3 to 4 hours the noise gets to you and you have to stop for awhile and go to the house. In the summer when windows are open you can hear them in the house. There is also some problems with some of the neighbours around me because of stray electricity. I have not had mine checked.

When the turbines are noisy, the horses always go to the far side of the barn.

#61

9) [other] Yes, doctor did blood tests, oral scope, prescribed sleeping pills, referred me to therapist and a nutritionist, sent me to a sleep clinic, I was vomiting blood.

10) [quality of life altered] We lived in this house for twenty years with the plan that we would pay it off, borrow money to purchase our retirement home and then sell the house to pay for the retirement home. We put the house up for sale the year before the turbines were built and real estate agents told us, people were worried about where the turbines would be placed and the house did not sell. Now the turbines are up and I can count 30 of them from my property. My wife and I can hear them when we are outside and we experience flicker when we are inside. We can see them through every window in the house in the daytime and we see the sea of red flashing lights every night. We live in a school house we took from being vacant for twenty years to a beautiful open concept home in a quiet country setting. Our friends and family have loved our home for years but now just shake their heads when they [see] what has happened here. Don't know what's going to happen to me in five years when I'm ready to retire if I can't sell my house.

#69

10) [quality of life altered] We bought this property to be away from the noise of the city and road traffic now all I hear is the windmills. I love to be outside, walking, hunting in our bush. Now all I hear is the windmills. Peace and quiet no longer exists. The rear of our house is all windows, at night all you see is the warning lights. It is driving me crazy. We had no say in the mills because we weren't getting one. The persons that got them get paid and don't live near them. I'm sure our property value has went down because of them. This summer will be the first time we can lay by our pool and I'm sure they will drive me.

#78

9) [other] [Doctor] Discussed symptoms with doctor twice. At this point we will further monitor my symptoms and discuss possible actions (tests, etc.)

10) [quality of life altered]This previously peaceful/quiet area was to be our retirement home. We are now considering changing our plans. Any further improvement to this property is on hold.

Depending on wind direction there is a loud pulsating, intrusive swooshing noise. I seem to sense a vibration in the air and at times I seem to sense the changing air pressure (like descending in an airplane.)

I spend 80% of my time in [turbine town x] and 20% in [town y]. When in [town y] I sleep better, less headaches and more relaxed.

#83

9) [other] nausea, muscle pain, irritability

10) [quality of life altered] To avoid morning flicker must have blinds or avoid rooms until it passes. When warm weather arrives noise from turbines will limit opening of windows especially at night for sleeping.

Will not enjoy evenings out of doors on decks due to all the Red Flashing lights and noise.

#88

9) [other] Have no family doctor. Went to emerg currently awaiting a CT scan.

10) [quality of life altered] Constant noise, constant headaches. Sleep disturbance since the wind towers have started.

We have recently put a 500′ addition on our home with large windows all around. Not only we get flickering from the towers we cannot open any windows due to the constant noise of the blades.

My occupation is a bookkeeper. These constant headaches are affecting my concentration, especially working with numbers. I work from my home. I simply cannot afford to be in ill health.

I can no longer sit on my back porch enjoying the beautiful sunsets. This was so relaxing to me. Now all I see is flickering blades and blinding red lights. The sunsets have disappeared into money hungry pockets of our government.

This area was once known as having the most beautiful sunsets in the world, now gone!

I now am a prisoner in my own home of 23 years.

This is not the future I wanted! That is why I bought this property 23 years ago. Now I am going to sell and start all over again. Extremely depressing!

11) My horses are nervous of the noise and do not focus on what they are doing. Instead they watch the windmills making this a danger when riding or training them. My dogs and cats want to stay in the house more now. This is very unusual for them.

#107

8) Biggest factor is the noise.

Unable to sleep with windows open at night and I'm a poor sleeper under good conditions. Find when I'm outside gardening or reading, the constant noise from the blades turning very irritating and I find I have a pressure in my ears that wasn't there prior to the last few months.

#110

8) [health affected] yes, (mostly mental health)

9) [other symptoms] cannot deal with noise

10) [quality of life altered]—cannot enjoy the outdoors and sounds of nature because of noise

hesitate to invite friends over

feel upset that we built our amazing energy efficient ICF home in an area full of horrible noise pollution.

feel violated

upset that my lonely elderly mother came to live with us to have a happier life but now has vertigo (we have not mentioned to her the possible correlation to windmills.)

feel like we should have known better!

we trusted township and [wind company]

#130

6) [distance from turbines] approx 400m but there are 10 of them within 1 mile of our home.

8) [health affected] YES—WITHOUT A DOUBT!!!

9) [symptoms] [palpitations] not sure, [excessive tiredness] I have trouble sleeping, [tinnitus] sometimes, I've just noticed it. [other] I don't know if it's palpitations or anxiety, but sometimes my heart races like it's going to jump out of my chest.

10) [life altered]

I now have great trouble getting to sleep in fact I now use sleeping pills, I never used to, EVER!!!

I can no longer enjoy my home outdoors, There is a constant "buzzing" that I cannot escape. The further that I walk onto my vacant land, the closer I get to the neighbors tower—these towers make me feel constantly stressed and I always am anxious or have a feeling of anxiety.

I worry about my plummeting real estate value, and if a bank will even renew my mortgage when its time.

I'm in a position that if I complain, I fear that my property value will fall even further. [identifying comment left out]

myself and other members of my family are now getting unexplained headaches, even my [age] year old daughter who has never had a headache prior to these towers coming online. I have a feeling of helplessness because I want to get away from the towers but we must remain due to the fact that we can't afford to abandon our home and move.

11) Our dog is restless constantly pacing

#133

9) [other symptoms] Lack of focus—Lack of Concentration—Memory loss—High Blood Pressure—Nausea—Feeling of Fullness in the Head—Fullness Feeling in the ears

[approached doctor] Weekly pain clinic and migraine treatments. Pain medication for migraine. Nausea medication. Anti-hypertensive medication. Anti-depressant medication. Several types of pain medication. Acupuncture and Chinese Medication. Acupuncture bi-weekly.

(continued)

Appendix E (continued)

10) [life altered]

1. Lost my career, which I loved dearly. It was a part of my life since age 18. *A huge loss*.
2. Lack of sleep has caused an enormous amount of stress; has impacted my everyday life from everyday appointments to social events + friendships; routines of living such as shopping, house cleaning, gardening; entertaining and family gatherings.
3. I was an avid reader but I cannot sit and concentrate to read a book.
4. I'm exhausted most of the time.
5. I feel tense all the time.
6. My ill health has become a major focus of my life and I fear a major fear of having a stroke!
7. I don't have people in my home anymore.
8. All our needed home renovations are on hold.

Author's Note

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Bios

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Occupational Health and Industrial Wind Turbines : A Case Study

Robert W. Rand, Stephen E. Ambrose and Carmen M. E. Krogh

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Occupational Health and Industrial Wind Turbines: A Case Study

Robert W. Rand[1], Stephen E. Ambrose[2], and Carmen M. E. Krogh[3]

Abstract

Industrial wind turbines (IWTs) are being installed at a fast pace globally. Researchers, medical practitioners, and media have reported adverse health effects resulting from living in the environs of IWTs. While there have been some anecdotal reports from technicians and other workers who work in the environs of IWTs, little is known about the occupational health sector. The purpose of this case study is to raise awareness about the potential for adverse health effects occurring among workers. The authors propose that there is a need for research regarding occupational worker exposure relating to IWTs.

Keywords

industrial wind turbines, occupational health, adverse health effects, case study

Industrial wind turbines (IWTs) are becoming more prolific worldwide. Ongoing technical support from engineers, technicians, and other personnel are required to maintain and operate the wind energy facility. As well, farm and other operators such as truck drivers are frequently exposed to the emissions associated with the operations of the wind turbines.

There is a paucity of information relating to the risks to occupational exposure. This article will report on an incident involving worker exposure. It is expected this case study will encourage research on this topic to ensure protection and mitigation of worker exposure.

Setting the Stage

The authors were commissioned to conduct a study at a wind turbine facility where residents were complaining about noise issues and adverse health effects. The complaints were correlated with the start of operations of two IWTs. The study was privately funded under a grant and was independent of any developer or group opposing IWTs.

The purpose of the study was to evaluate the presence or absence of sound in the low-frequency and infrasonic range. The primary area of interest was from 1 to 200 hertz.

Two IWTs were involved—one owned by the township and the other privately owned. Operation of the facilities started in 2010. Prior to the operation of the IWTs, there were no noise complaints such as those now being reported postoperation. The requests for mitigation ranged from complaints, to appeals to stop the noise, to requests for stays of operation with legal representation.

As a result of the complaints, the township capped the operations of its turbine so that at 10 meters per second wind speed at the hub, the turbine was shut off. This is reported to have provided some relief. However, the privately owned turbine was not capped and continued to operate.

The study took place over a 2-day period inside a home where people were experiencing serious adverse health effects. The home owners reported symptoms of nausea, dizziness, irritability, and cloudy thinking; had incurred falls and injury from loss of balance; and were severely affected to the point where abandoning the home was being considered. It is a custom-built, highly insulated, solidly constructed retirement home of 10 years. The home is 1,700 feet (520 meters) from the privately owned turbine and 4,200 feet (1,280 meters) from the township-owned turbine. The terrain is predominately gently rolling rural countryside with modest changes of elevation including glacial moraine, stream valleys, and sand quarries.

Technical Details and Conditions

The study took place over a 2-day period.

Weather Conditions During Study

The weather generally showed an early summer pattern with wind speeds at the hub of 20 to 25 m/s by midmorning. Ground wind speed was light during the day. At night, hub wind speed was light, with ground wind speed about zero

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and no background noise except that of distant traffic, which died off in the early hours of the day. Average wind shear at hub height was documented previously by two independent researchers at 0.47.

Day 1: Changeable with wind speeds 25 to 30 meters per second at the hub, gusting to more than 35 meters/second. Wind direction west–southwest. Barometer "low" and variable. Sunny and partly cloudy. Temperature 45 to 50 degrees Fahrenheit

Day 2: Sunny with wind speeds 15 to 20 meters per second at the hub, gusting to 25 to 30 meters/second. Wind direction west–southwest. Barometer "low" and rising during the day. Temperature 45 to 50 degrees Fahrenheit

Day 3: Winds stopped and the study concluded

Turbine Make and Model

Vestas V82, 1.65 megawatts, hub height 80 meters, diameter 82 meters. Both turbines were manufactured and shipped at the same time.

Distance From the Wind Turbine

Private home, 1,700 feet (520 meters).

Instrumentation

The table below lists the instruments used to perform the study.

Instrumentation list
Outdoor/indoor dual-channel system
Microphone: GRAS, Model 40AN, sn 27538
Preamplifier: Larson Davis, Model 2221, sn 0107
Microphone: Bruel & Kjaer, Model 4165, sn 844497
Preamplifier: Larson Davis, Model 902, sn 0235
Sound meter: Larson Davis, Model 824, sn 0914
Audio interface: Sound Devices USB Pre 2, sn HB0411005004
Acoustic calibrator: Bruel & Kjaer, Model 4230, sn 1103065
Digital audio recorder: M-Audio, Model Microtrack II, sn 138AOC8107245
Computer: Acer 5745 i3cpu, Win7; Spectraplus 5.0, sn 5879.
Roving and stepped distance measurement system
Microphone: Svantek, Model SV22, sn 4012682
Preamplifier: Svantek, Model SV12L, sn 5552
Sound meter: Svantek, Model 949 SLM, sn 6028
Acoustic calibrator: Larson Davis, Model CAL200, sn 2425
Digital audio recorder: Tascam, Model DR100, sn 0030486
Computer: Sony VAIO, Win7, Spectraplus 5.0

Method

Testing was performed primarily inside the home. At times sound measurements were taken simultaneously inside and outside the home. Particular attention was given to measurements below 20 hertz and included determining the noise reduction that occurred between the inside and outside values. Standards ANSI S12.9, ANSI S12.18, and ASTM E966-02 were used. In later analysis, data were digitally compensated for flat response to 1 hertz.

Study Results

Day 1

The authors were unable to prepare their instrumentation or acquire calibrated data from arrival to midnight due to encountering unexpected and severe adverse health effects similar to those described by the home owners. At midnight they left the house and conducted a series of stepped measurements at 275, 830, and 1340 feet (84, 253, and 408 meters) from the turbine. They concluded outdoor measurements due to rain and returned to the house at 1:50 a.m. Long-term recording was conducted indoors from 2 a.m. to 8 a.m. during sleeping hours.

Day 2

The authors left the house to have breakfast and experienced relief from symptoms once they were more than a mile away from the IWTs. They returned later and found that the symptoms returned almost as strongly as the previous day. They conducted a series of tests with inside–outside microphones during the afternoon with winds at the strongest of the day. The wind turbine noise controlled the outdoor sound levels at 42 to 44 dBA.

Day 3

The winds were calm in the morning and the nearest turbine was off. The authors found that the health symptoms were considerably lessened from the previous 36 hours. Recordings were made of the ambient sounds of the morning for comparison to turbine sound during later analysis. Sounds included vehicle operations in a quarry some distance away, distant and occasional local traffic, and birds, with sound levels 32 to 28 dBA.

Findings

Overall, there was a strong correlation between the wind speed, resulting wind turbine operation level, and severe adverse health effects (Table 1). The strongest effects were experienced indoors with hub height winds at 25 meters per second with gusts to 35 meters per second. The strongest correlation between physical symptoms and wind turbine acoustic emissions was judged to be the change in the modulated infrasonic sound level measured in dBG over a quiet background. Low background sound levels and infrasonic levels modulating or pulsing above 60 dBG were found to be

Table 1. Nearest Turbine Data and Adverse Health Effects at House Under Study

Hub wind speed (meters/second)	Industrial wind turbine output (kilowatt)	Study location	dBA	dBG	Symptoms experienced
25, gusts to 35	1,600-1,700	Indoors	NA	NA	Nausea, dizziness, irritability, headache, loss of appetite, inability to concentrate, need to leave anxiety
		Outdoors	NA	NA	Felt miserable, performed tasks at a reduced pace
18-20, gusts to 30	1,350-1,500	Indoors	18-20	51-64	Dizzy, no appetite, headache, felt miserable, performed tasks at a reduced pace. Desire to leave
		Outdoors	42-44	54-65	Dizzy, headache, no appetite. Slow. Preferred being outdoors or away
<6, calm	OFF	Indoors	18	39-44	Improvement in health. Fatigue and desire to leave
		Outdoors	32-38	49-54	Improvement in health. Fatigue and desire to leave

present when adverse health symptoms were also present. This was noted as consistent with the research findings of Salt and Hullar (2010) that certain structures in the inner ear are sensitive to infrasound and can be stimulated by low-frequency sounds at levels starting at 60 dBG, well below levels that can be heard. The stimulation is maximal at low background sound levels (e.g., indoors). The authors found that when the wind turbine modulating, pulsing infrasonic levels dropped below 60 dBG (nearest wind turbine OFF), there was improvement in health status.

Worker Exposure and Adverse Health Effects

The authors experienced severe adverse health effects during the study procedures. One author experienced a high degree of irritability within a few minutes of arriving at the home. This was not usual as the author is normally calm. The irritability rapidly progressed to loss of cognitive function to the point where there was an inability to perform routine tasks. Dizziness progressing to apparent vertigo occurred.

The second author experienced headache, loss of appetite, and anxiety and also was not able to perform routine tasks. He was unable to concentrate and had difficulty finishing a thought or sentence. There was a strong desire to leave the area to seek relief.

Overall, there was a loss of ability to perform tasks that were second nature. Simple tasks such as calibrating a meter, which were "automatic" functions due to 30 years of experience, were beyond the ability of the authors for some hours.

A summary of the impacts is that on Day 1 when the winds were high, the authors felt terrible and were debilitated and unable to perform simple tasks. On Day 2, when the winds were lower, the technicians felt a bit better but were still miserable and continued to have difficulty focusing on completing required tasks. On Day 3, with the turbine off, there was improvement in health status, but there remained a desire to leave the area.

In both cases, it took about 7 days for the recovery from the adverse health effects. One author was still experiencing some symptoms 7 weeks later.

Conclusion

Globally, there are reports of adverse health effects correlated with the onset of operations of IWTs (Harry, 2007; Krogh, Gillis, Kowen, & Aramini, 2011; Nissenbaum, 2009; Phipps, Amati, McCoard, & Fisher, 2007; Pierpont, 2009). Pedersen, van den Berg, Bakker, and Bouma (2009) and Pedersen and Waye (2004, 2007) have published peer-reviewed articles regarding the negative effects being reported.

There have been some anecdotal reports from technicians and workers in specialized fields such as electrical and engineering. In addition, there have been several anecdotal reports from other workers such as farmers and operators of heavy equipment (CK, personal communications, 2009 to 2011).

Those working in the environs of IWTs may be at risk for occupational exposure. Technicians and other workers such as farmers and IWT site staff employed for maintenance and other duties may be at risk to symptoms. Others at risk could include truck drivers and other equipment handlers.

This case study report is intended to raise the awareness of occupational health risks. There are unanswered questions about worker exposure. This will require independent research to determine the risks.

Authors' Note

Throughout this article, the term *author(s)* applies to Rand and Ambrose.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Bios

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Carmen M. E. Krogh, BScPharm, who provided health-related research and reference support, is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was a former Director of Publications and Editor in Chief of the *Compendium of Pharmaceutical and Specialties* (*CPS*), the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

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Infrasound From Wind Turbines Could Affect Humans

Alec N. Salt[1] and James A. Kaltenbach[2]

Abstract

Wind turbines generate low-frequency sounds that affect the ear. The ear is superficially similar to a microphone, converting mechanical sound waves into electrical signals, but does this by complex physiologic processes. Serious misconceptions about low-frequency sound and the ear have resulted from a failure to consider in detail how the ear works. Although the cells that provide hearing are insensitive to infrasound, other sensory cells in the ear are much more sensitive, which can be demonstrated by electrical recordings. Responses to infrasound reach the brain through pathways that do not involve conscious hearing but instead may produce sensations of fullness, pressure or tinnitus, or have no sensation. Activation of subconscious pathways by infrasound could disturb sleep. Based on our current knowledge of how the ear works, it is quite possible that low-frequency sounds at the levels generated by wind turbines could affect those living nearby.

Keywords

cochlea, hair cells, A-weighting, wind turbine, Type II auditory afferent fibers

Wind Turbines Generate Infrasound

The sounds generated by wind turbines vary widely, depending on many factors such as the design, size, rotor speed, generator loading, and different environmental conditions such as wind speed and turbulence (e.g., Jakobsen, 2005). Under some conditions, such as with a low wind speed and low generator loading, the sounds generated appear to be benign and are difficult to detect above other environmental sounds (Sonus, 2010).

But in many situations, the sound can contain a substantial low-frequency infrasound component. One study (Van den Berg, 2006) reported wind turbine sounds measured in front of a home 750 m from the nearest turbine of the Rhede wind farm consisting of Enercon E-66 1.8 MW turbines, 98 m hub height, and 35 m blade length. A second study (Jung & Cheung, 2008) reported sounds measured 148 to 296 m from a 1.5 MW turbine, 62 m hub height, 36 m blade length. In both these studies, which are among the few publications that report full-spectrum sound measurements of wind turbines, the sound spectrum was dominated by frequencies below 10 Hz, with levels of over 90 dB SPL near 1 Hz.

The infrasound component of wind turbine noise is demonstrated in recordings of the sound in a home with GE 1.5 MW wind turbines 1,500 ft downwind as shown in Figure 1. This 20-second recording was made with a microphone capable of recording low-frequency components. The sound level over the recording period, from which this excerpt was taken, varied from 28 to 43 dBA. The audible and inaudible (infrasound) components of the sound are demonstrated by filtering the waveform above 20 Hz (left) or below 20 Hz (right). In the audible, high-pass filtered waveform, the periodic "swoosh" of the blade is apparent to a varying degree with time. It is apparent from the low-pass filtered waveform that the largest peaks in the original recording represent inaudible infrasound. Even though the amplitude of the infrasound waveform is substantially larger than that of the audible component, this waveform is inaudible when played by a computer's sound system. This is because conventional speakers are not capable of generating such low frequencies and even if they could, those frequencies are typically inaudible to all but the most sensitive unless played at very high levels. It was also notable in the recordings that the periods of high infrasound level do not coincide with those times when the audible component is high.

This shows that it is impossible to judge the level of infrasound present based on the audible component of the sound. Just because the audible component is loud does not mean that high levels of infrasound are present. These measurements show that wind turbine sounds recorded inside a home can contain a prominent infrasound component.

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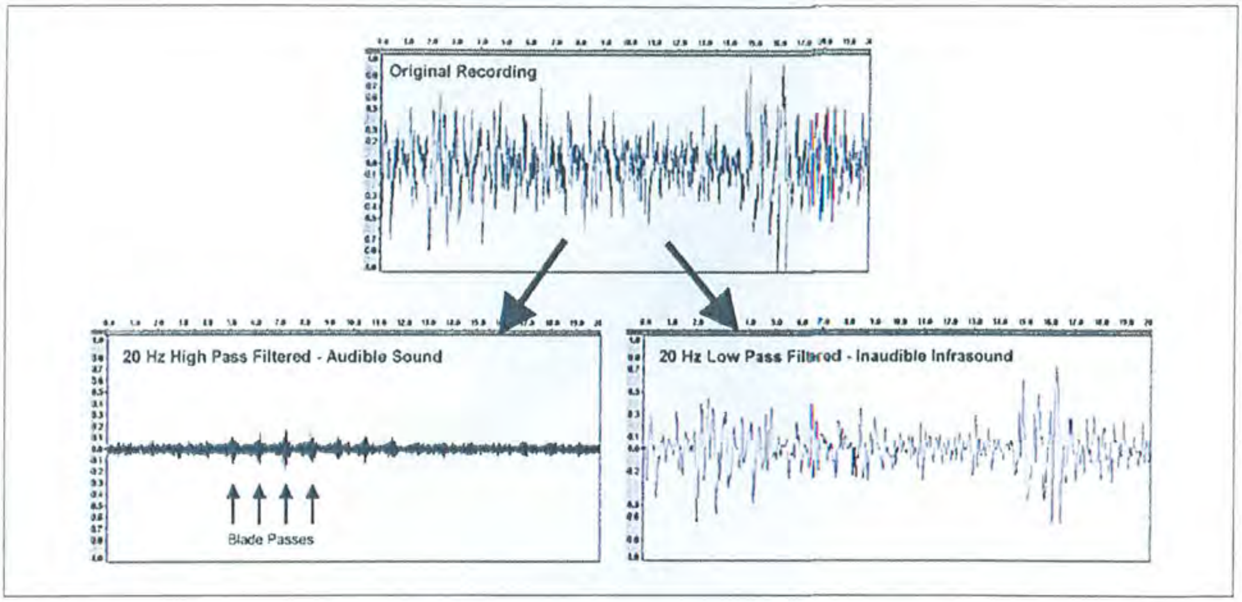

Figure 1. *Upper Panel:* Full-spectrum recording of sound from a wind turbine recorded for 20 seconds in a home with the wind turbine 1,500 ft downwind (digital recording kindly provided by Richard James). *Lower Left Panel:* Result of high-pass filtering the waveform at 20 Hz, showing the sound that is heard, including the sounds of blade passes. *Lower Right Panel:* Result of low-pass filtering the waveform at 20 Hz, showing the infrasound component of the sound

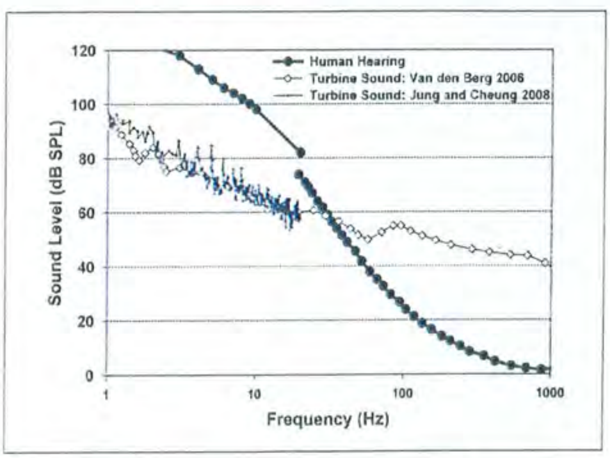

Figure 2. Wide band spectra of wind turbine sounds (Jung & Cheung, 2008; Van den Berg, 2006) compared with the sensitivity of human hearing (International Organization for Standardization, 2003, above 20 Hz; Møller & Pederson, 2004, below 20 Hz). The levels of sounds above 30 Hz are above the audibility curve and would be heard. Below 30 Hz, levels are below the audibility curve so these components would not be heard

Wind Turbine Infrasound Is Typically Inaudible

Hearing is very insensitive to low-frequency sounds, including those generated by wind turbines. Figure 2 shows examples of wind turbine sound spectra compared with the sensitivity of human hearing. In this example, the turbine sound components above approximately 30 Hz are above threshold and therefore audible. The sounds below 30 Hz, even though they are of higher level, are below the threshold of audibility and therefore may not be heard. Based on this comparison, for years it has been assumed that the infrasound from wind turbines is not significant to humans. Leventhall (2006) concluded that "infrasound from wind turbines is below the audible threshold and of no consequence." (p.34) Leventhall (2007) further stated that "if you cannot hear a sound you cannot perceive it in other ways and it does not affect you." (p.135)

Renewable UK (2011), the website of the British Wind Energy Association, quotes Dr. Leventhall as stating, "I can state quite categorically that there is no significant infrasound from current designs of wind turbines." Thus, the fact that hearing is insensitive to infrasound is used to exclude the possibility that the infrasound can have any influence on humans. This has been known for many years in the form of the statement, "What you can't hear can't affect you." The problem with this concept is that the sensitivity of "hearing" is assumed to equate with sensitivity of "the ear." So if you cannot hear a sound then it is assumed that the sound is insufficient to stimulate the ear. Our present knowledge of the physiology of the ear suggests that this logic is incorrect.

The Ear Is Sensitive to Wind Turbine Infrasound

The sensory cells responsible for hearing are contained in a structure in the cochlea (the auditory portion of the inner ear) called the organ of Corti. This organ runs the entire length of the cochlear spiral and contains two types of sensory cells, which have completely different properties. There is one row

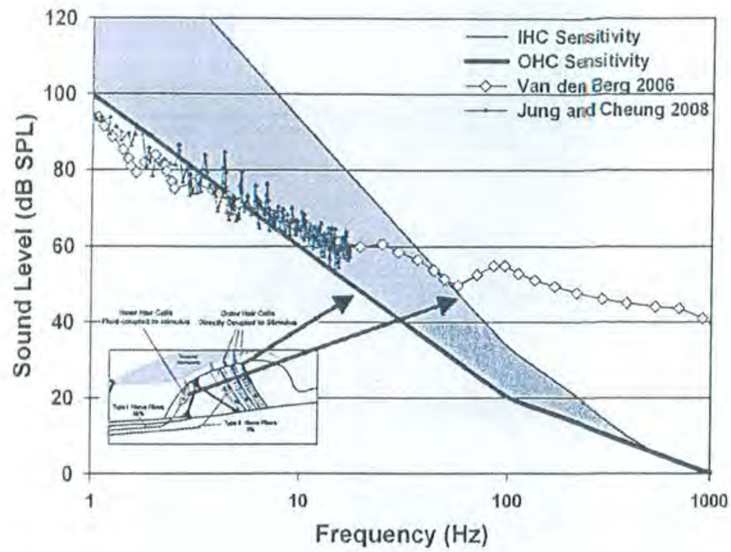

Figure 3. The thin line shows the estimated sensitivity of inner hair cells (IHC) as a function of frequency, which is comparable with the human audibility curve shown in Figure 2 and which is consistent with hearing being mediated by the IHC (based on Cheatham & Dallos, 2001). The thick line shows the estimated sensitivity of the outer hair cells (OHC), which are substantially more sensitive than the IHC. Sound components of the overlaid wind turbine spectra within the shaded region (approximately 5 to 50 Hz) are too low to stimulate the IHC and cannot therefore be heard but are of sufficient level to stimulate the OHC. The inset shows a cross section of the sensory organ of the cochlea (the organ of Corti) showing the locations of the IHC and OHC

of sensory inner hair cells (IHC) and three rows of outer hair cells (OHC) as shown schematically in the inset to Figure 3. For both IHC and OHC, sound-induced deflections of the cell's sensory hairs provide stimulation and elicit electrical responses. Each IHC is innervated by multiple nerve fibers that transmit information to the brain, and it is widely accepted that hearing occurs through the IHC. The rapidly declining sensitivity of hearing at lower frequencies (Figure 2) is accounted for by three processes that selectively reduce low-frequency sensitivity (Cheatham & Dallos, 2001), specifically the properties of middle ear mechanics, from pressure shunting through the cochlear helicotrema and from "fluid coupling" of the inner hair cell stereocilia to the stimulus (reviewed in detail by Salt & Hullar, 2010).

The combined effect of these processes, quantified by Cheatham and Dallos (2001), are shown as the "IHC sensitivity" curve in Figure 3. The last component attenuating low frequencies, the so-called fluid coupling of input, arises because the sensory hairs of the IHC do not contact the overlying gelatinous tectorial membrane but are located in the fluid space below the membrane.

As a result, measurements from the IHC show that they do not respond to sound-induced displacements of the structure but instead their amplitude and phase characteristics are consistent with them responding to the velocity of the stimulus. As stimulus frequency is lowered, the longer cycles result in lower stimulus velocity, so the effective stimulus falls by 6 dB/octave. This accounts for the known insensitivity of the IHC to low-frequency stimuli. For low frequencies, the calculated sensitivity of IHC (Figure 3) compares well with measures of hearing sensitivity (Figure 2), supporting the view that hearing is mediated by the IHC.

The problem, however, arises from the more numerous OHC of the sensory organ of Corti of the ear. Anatomic studies show that the sensory hairs of the OHC are embedded in the overlying tectorial membrane, and electrical measurements from these cells show their responses depend on the displacement rather than the velocity of the structure. As a result, their responses do not decline to the same degree as IHC as frequency is lowered.

Their calculated sensitivity is shown as the "OHC sensitivity" curve in Figure 3. It is important to note that the difference between IHC and OHC responses has nothing to do with frequency-dependent effects of the middle ear or of the helicotrema (the other two of the three components mentioned above). For example, any attenuation of low-frequency stimuli provided by the helicotrema will equally affect both the IHC and the OHC. So the difference in sensitivity shown in Figure 3 arises purely from the difference in how the sensory hairs of the IHC and OHC are coupled to the overlying tectorial membrane.

The important consequence of this physiological difference between the IHC and the OHC is that the OHC are stimulated at much lower levels than the IHC. In Figure 3, the portion of the wind turbine sound spectrum within the shaded region represents frequencies and levels that are too low to be heard, but which are sufficient to stimulate the OHC of the ear.

This is not confined to infrasonic frequencies (below 20 Hz), but in this example includes sounds over the range from 5 to 50 Hz. It is apparent that the concept that "sounds you can't hear cannot affect you" cannot be correct because it does not recognize these well-documented physiologic properties of the sensory cells of the inner ear.

Stimulation of OHC at inaudible, low levels can have potentially numerous consequences. In animals, cochlear microphonics demonstrating the responses of the OHC can be recorded to infrasonic frequencies (5 Hz) at levels as low as 40 dB SPL (Salt & Lichtenhan, in press). The OHCs are innervated by Type II nerve fibers that constitute 5% to 10% of the auditory nerve fibers, which connect the hair cells to the brainstem. The other 90% to 95% come from the IHCs. Both Type I (from IHC) and Type II (from OHC) nerve fibers terminate in the cochlear nucleus of the brainstem, but the anatomical connections of the two systems increasingly appear to be quite different. Type I fibers terminate on the main output neurons of the cochlear nucleus. For example, in the dorsal part of the cochlear nucleus, Type I fibers connect with fusiform cells, which directly process information received from the ear and then deliver it to higher levels of the auditory pathway. In contrast, Type II fibers terminate in the granule cell regions of the cochlear nucleus (Brown, Berglund, Kiang, & Ryugo, 1988). Some granule cells receive direct input from Type II fibers (Berglund & Brown, 1994). This is potentially significant because the granule cells provide a major source of input to nearby cells, whose function is inhibitory to the fusiform cells that are processing heard sounds. If Type II fibers excite granule cells, their ultimate effect would be to diminish responses of fusiform cells to sound. Evidence is mounting that loss of or even just overstimulation of OHCs may lead to major disturbances in the balance of excitatory and inhibitory influences in the dorsal cochlear nucleus. One product of this disturbance is the emergence of hyperactivity, which is widely believed to contribute to the perception of phantom sounds or tinnitus (Kaltenbach et al., 2002; Kaltenbach & Godfrey, 2008). The granule cell system also connects to numerous auditory and nonauditory centers of the brain (Shore, 2005). Some of these centers are directly involved in audition, but others serve functions as diverse as attentional control, arousal, startle, the sense of balance, and the monitoring of head and ear position (Godfrey et al., 1997).

Functions that have been attributed to the dorsal cochlear nucleus thus include sound localization, cancellation of self-generated noise, orienting the head and ears to sound sources, and attentional gating (Kaltenbach, 2006; Oertel & Young, 2004). Thus, any input from OHCs to the circuitry of the dorsal cochlear nucleus could influence functions at several levels.

A-Weighted Wind Turbine Sound Measurements

Measurements of sound levels generated by wind turbines presented by the wind industry are almost exclusively A-weighted and expressed as dBA. When measured in this manner, the sound levels near turbines are typically in the range of 30 to 50 dBA, making wind turbine sounds,

> about the same level as noise from a flowing stream about 50-100 meters away or the noise of leaves rustling in a gentle breeze. This is similar to the sound level inside a typical living room with a gas fire switched on, or the reading room of a library or in an unoccupied, quiet, air-conditioned office. (Renewable UK, 2011)

On the basis of such measurements, we would expect wind turbines to be very quiet machines that would be unlikely to disturb anyone to a significant degree. In contrast, the human perception of wind turbine noise is considerably different. Pedersen and Persson-Waye (2004) reported that for many other types of noise (road traffic, aircraft, railway), the level required to cause annoyance in 30% of people was over 70 dBA, whereas wind turbine noise caused annoyance of 30% of people at a far lower level, at around 40 dBA. This major discrepancy is probably a consequence of A-weighting the wind turbine sound measurements, thereby excluding the low-frequency components that contribute to annoyance. A-weighting corrects sound measurements according to human hearing sensitivity (based on the 40 phon sensitivity curve). The result is that low-frequency sound components are dramatically deemphasized in the measurement, based on the rationale that these components are less easily heard by humans. An example showing the effect of A-weighting the turbine sound spectrum data of Van den Berg (2006) is shown in Figure 4. The low-frequency components of the original spectrum, which resulted in a peak level of 93 dB SPL at 1 Hz, are removed by A-weighting, leaving a spectrum with a peak level of 42 dBA near 1 kHz. A-weighting is perfectly acceptable if hearing the sound is the important factor. A problem arises though when A-weighted measurements or spectra are used to assess whether the wind turbine sound affects the ear. We have shown above that some components of the inner ear, specifically the OHC, are far more sensitive to low-frequency sounds than is hearing. Therefore, A-weighted sounds do not give a valid representation of whether wind turbine noise affects the ear or other aspects of human physiology mediated by the OHC and unrelated to hearing. From Figure 3, we know that sound frequencies down to 3 to 4 Hz may be stimulating the OHC, yet the A-weighted spectrum in Figure 4 cuts off all components below approximately 14 Hz. For this reason, the determination of whether wind turbine sounds affect people simply cannot be made based on A-weighted sound measurements. A-weighted measurements are inappropriate for this purpose and give a misleading representation of whether the sound affects the ear.

Alternatives to A-weighting are the use of full-spectrum (unweighted), C-weighted, or G-weighted measurements. G-weighted measurements use a weighting curve based on the human audibility curve below 20 Hz and a steep cutoff above 20 Hz so that the normal audible range of frequencies is deemphasized. Although the shape of this function is arbitrary

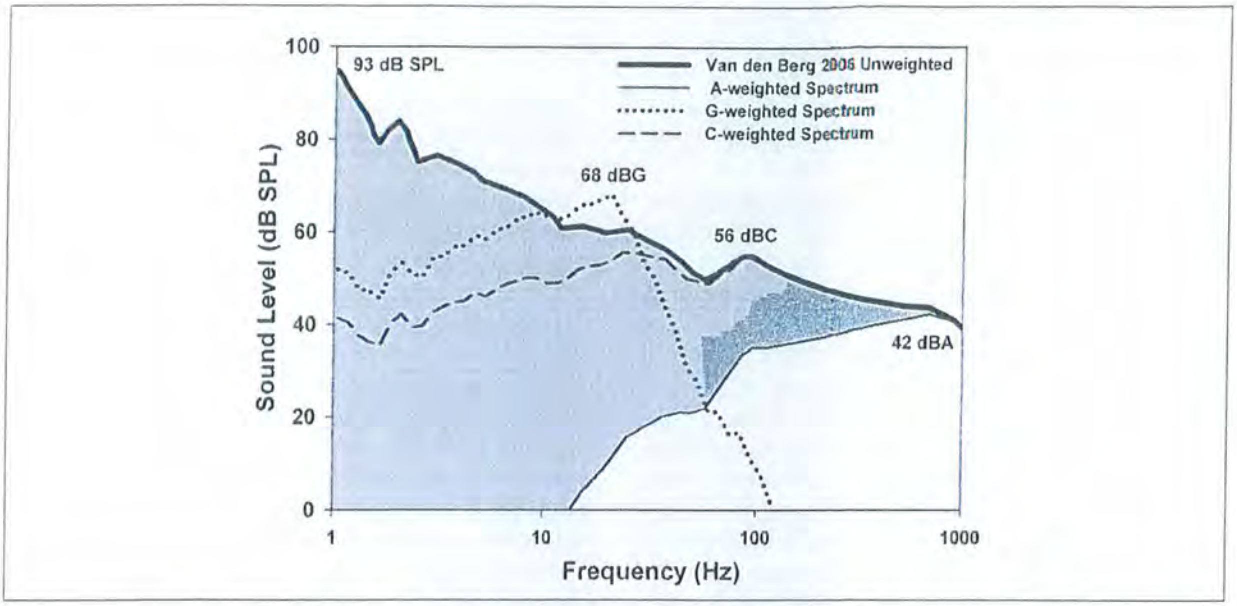

Figure 4. Low-frequency components of wind turbine sound spectrum (below 1 kHz) before and after A-weighting. The original spectrum was taken from Van den Berg (2006). The shaded area represents the degree of alteration of the spectrum by A-weighting. A weighting (i.e., adjusting the spectrum according to the sensitivity of human hearing) has the effect of ignoring the fact that low-frequency sounds can stimulate the OHC at levels that are not heard. Representing this sound as 42 dBA, based on the peak of the spectrum, ignores the possibility that low-frequency components down to frequencies as low as 5 Hz (from Figure 3) are stimulating the OHC. Also shown are the spectra after G-weighting (dotted) and C-weighting (dashed) for comparison

when hearing is not the primary issue, it does give a measure of the infrasound content of the sound that is independent of higher frequency, audible components, as shown in Figure 4. By applying the function to the normal human hearing sensitivity curve, it can be shown that sounds of approximately 95 dBG will be heard by humans, which agrees with observations by Van den Berg (2006). Similarly, by G-weighting the OHC sensitivity function in Figure 3, it can be estimated that sound levels of 60 dBG will stimulate the OHC of the human ear. In a survey of infrasound levels produced by wind turbines measured in dBG (Jakobsen, 2005), upwind turbines typically generated infrasound of 60 to 70 dBG, although levels above and below this range were observed in this and other studies. From Jakobsen's G-weighted measurements, we conclude that the level of infrasound produced by wind turbines is of too low a level to be heard, but in most cases is sufficient to cause stimulation of the OHC of the human ear. C-weighting also provides more representation of low-frequency sound components but still arbitrarily de-emphasizes infrasound components.

Is the Infrasound From Wind Turbines Harmful to Humans Living Nearby?

Our present understanding of inner ear physiology and of the nature of wind turbine sounds demonstrates that low-level infrasound produced by wind turbines is transduced by the OHC of the ear and this information is transmitted to the cochlear nucleus of the brain via Type II afferent fibers. We therefore conclude that dismissive statements such as "there is no significant infrasound from current designs of wind turbines" are undoubtedly false. The fact that infrasound-dependent information, at levels that are not consciously heard, is present at the level of the brainstem provides a scientific basis for the possibility that such sounds can have influence on people. The possibility that low-frequency components of the sound could contribute both to high annoyance levels and possibly to other problems that people report as a result of exposure to wind turbine noise cannot therefore be dismissed out of hand.

Nevertheless, the issue of whether wind turbine sounds can cause harm is more complex. In contrast to other sounds, such as loud sounds, which are harmful and damage the internal structure of the inner ear, there is no evidence that low-level infrasound causes this type of direct damage to the ear. So infrasound from wind turbines is unlikely to be harmful in the same way as high-level audible sounds.

The critical issue is that if the sound is detected, then can it have other detrimental effects on a person to a degree that constitutes harm? A major complicating factor in considering this issue is the typical exposure duration. Individuals living near wind turbines may be exposed to the turbine's sounds for prolonged periods, 24 hours a day, 7 days a week for weeks, possibly extending to years, although the sound level will vary over time with varying wind conditions. Although there have been many studies of infrasound on humans, these have typically involved higher levels for limited periods (typically of up to 24 hours). In a search of the literature, no studies were found that have come close to replicating the long-term exposures to low-level infrasound experienced by those living near wind turbines. So, to date, there are no published studies showing that such prolonged exposures do not harm humans. On the other hand, there are now numerous reports (e.g., Pierpont, 2009; Punch, James, & Pabst, 2010), discussed extensively in this journal, that are highly suggestive that individuals living near wind turbines are made ill, with a plethora of symptoms that commonly include chronic sleep disturbance. The fact that such reports are being dismissed on the grounds that the level of infrasound produced by wind turbines is at too low a level to be heard appears to totally ignore the known physiology of the ear. Pathways from the OHC to the brain exist by which infrasound that cannot be heard could influence function. So, in contrast, from our perspective, there is ample evidence to support the view that infrasound could affect people, and which justifies the need for more detailed scientific studies of the problem. Thus, it is possible that people's health could suffer when turbines are placed too close to their homes and this becomes more probable if sleep is disturbed by the infrasound. Understanding these phenomena may be important to deal with other sources of low-frequency noise and may establish why some individuals are more sensitive than others. A better understanding may also allow effective procedures to be implemented to mitigate the problem.

We can conclude that based on well-documented knowledge of the physiology of the ear and its connections to the brain, it is scientifically possible that infrasound from wind turbines could affect people living nearby.

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The Problems With "Noise Numbers" for Wind Farm Noise Assessment

Bob Thorne[1]

Abstract

Human perception responds primarily to sound character rather than sound level. Wind farms are unique sound sources and exhibit special audible and inaudible characteristics that can be described as modulating sound or as a tonal complex. Wind farm compliance measures based on a specified noise number alone will fail to address problems with noise nuisance. The character of wind farm sound, noise emissions from wind farms, noise prediction at residences, and systemic failures in assessment processes are examined. Human perception of wind farm sound is compared with noise assessment measures and complaint histories. The adverse effects on health of persons susceptible to noise from wind farms are examined and a hypothesis, the concept of heightened noise zones (pressure variations), as a marker for cause and effect is advanced. A sound level of LAeq 32 dB outside a residence and above an individual's threshold of hearing inside the home are identified as markers for serious adverse health effects affecting susceptible individuals. The article is referenced to the author's research, measurements, and observations at different wind farms in New Zealand and Victoria, Australia.

Keywords

wind farms, human perception, noise

Wind Farms Are a Unique Source of Noise

Wind farms and wind turbines are a unique source of sound and noise. The noise generation from a wind farm is like no other noise source or set of noise sources. The sounds are often of low amplitude (volume or loudness) and are constantly shifting in character ("waves on beach," "rumble-thump," "plane never landing," etc.). People who are not exposed to the sounds of a wind farm find it very difficult to understand the problems of people who do live near wind farms (Thorne, 2007). Some people who live near wind farms are disturbed by the sounds of the farms, others are not. In some cases adverse health effects are reported, in other cases such effects do not appear evident. Thus, wind farm noise is not like, for example, traffic noise or the continuous hum from plant and machinery. Wind turbines such as those proposed are large noise sources relative to dwellings, and like aircraft, sound emissions are transmitted via the roof and windows. Noise barriers at ground level are generally ineffective in screening or mitigation such sound (Thorne, 2011).

Wind has audible and subaudible characters. That is, measurement of wind sound will always present sound levels in the audible, low-frequency, and infrasonic frequencies. Sound in the low frequencies and infrasound frequencies can be heard if the sounds are loud enough. The sounds, however, may be perceptible rather than heard at relatively lower levels of "loudness."

Evidence produced in New Zealand concerning the West Wind and Te Rere Hau wind farms indicate that the adverse effects of wind farm noise are well documented. West Wind has recorded 906 complaints over a 12-month period. Te Rere Hau has recorded 378 complaints over an 11-month period. Waubra (Victoria, Australia) has a less well documented complaint history but, as recorded in this article, sufficient to identify issues.

Wind farm sound analysis presents three distinct issues:

- The identification of sound that can be directly attributed to the sound of the wind farm/turbines, measured as a background sound level, compared with the sound of the ambient environment without the presence of the wind turbines
- The sound of any special audible characteristics of the wind farm/turbines, such as distinct tonal complexes and modulation effects (amplitude and frequency) that may affect human health through sleep disturbance, for example
- The presence of any sound characteristics that may affect human health

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Sound from modern wind turbines is primarily due to turbulent flow and trailing edge sound, mechanical sound, and variations in infrasound (air pressure variations). Sound character relates to blade characteristics, blade/tower interaction, and mechanical noise and can be grouped into four main bands. The sound can be characterized as being impulsive and broadband, audible and inaudible (infrasonic):

- Infrasound below, 20 Hz (perceptible, normally inaudible)
- Low frequencies, 20 to 250 Hz
- Mid frequency, 250 to 2,000 Hz (broadly, although the higher level could be 4,000 Hz)
- High frequency, 2,000 to 20,000 Hz

Not all these frequencies can be heard by a person with "normal" hearing, as hearing response is unique to an individual and is age dependent as well as work and living environment dependent. It is important to note that infrasound can be "audible" to people with sensitive hearing (Thorne, 2011). Evidence briefly summarized in this article allows the conclusion that there is the potential for adverse health effects for individuals due to wind farm activity while living in their residences and while working on their farms within 3,500 meters of large-scale turbines. Wind farm activity that causes adverse health effects such as sleep disturbance, anxiety, stress, and headaches is a health nuisance, is objectionable, and is unreasonable.

Research indicates that "ordinary" wind has a laminar or smooth infrasound and low-frequency flow pattern when analyzed over short periods of time. Wind farm activity appears to create a "pulsing" infrasound and low-frequency pattern. These patterns are illustrated in sonograms in this article. The hypothesis derived from my research is that wind farm sound has an adverse effect on individuals due to this pulsing nature as well as audible noise due to the wind turbines. These effects may be cumulative.

The Problems With "Noise Numbers" for Wind Farm Noise Assessment

Analysis of "single-value" A-weighted wind farm background levels in the presence of ambient background levels (the real world) is extremely difficult to impossible. This observation is made on the basis of 5 years of monitoring wind turbines at different locales under widely different weather conditions. Figure 1 illustrates the issue: there are the separate sets of sound sources—local ambient, the turbines, and distant sources. It is not possible to separate out the contribution of each source once it is recorded as a single-value (e.g., the "background LA95" sound level or "time-average LAeq" sound level) at a specific location, such as a residence.

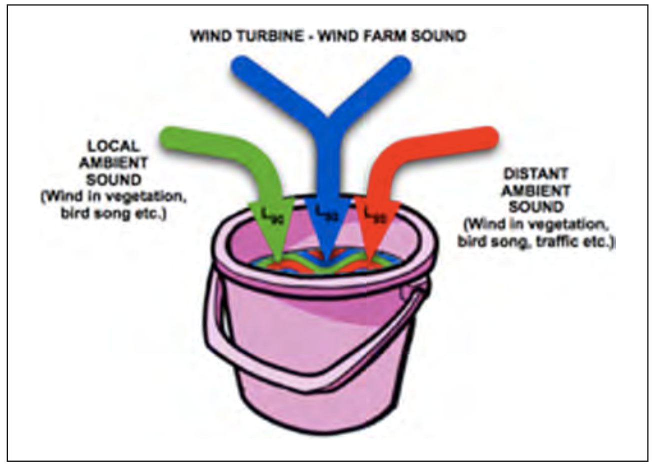

Figure 1. "Bucket of mixed sound" from different sources

By way of example, pour a glass of milk (noise specifically from wind farm activity) into a glass of water (the ambient sound around a residence). Add some extra water for distant sound (wind in trees, distant water pumps, etc.) that affects the background. Now remove the milk. Difficult? Impossible. The three components are completely intermingled. Unfortunately, the example holds true for whatever combination of "single-value" acoustical descriptors are used to describe wind farm mixed with ambient sound levels. A practical alternative is to identify a set of sounds that are specific to the wind farm that are not a characteristic of the receiving environment and reference these sounds. The levels are recorded as, for example, unweighted (*Z*) sound levels in third octave or 1/12 octave bands. Still difficult, but not impossible.

Obviously, loud levels of sound from a wind farm in excess of LAeq 35 dB may be measurable but still very difficult to prove as being the source of sound when mixed into sound from vegetation (wind in trees, for example).

Conversely, it is easy for people to hear wind farm noise within "ordinary" ambient sound.

It is on this fundamental issue that any standard or condition requiring a wind farm to comply with a specific compliance level will fail. The only possible way is to turn the turbines off, measure the ambient levels, turn the turbines on, measure the wind farm and ambient sound levels together, assess the variation and then come to some decision as to compliance. This procedure only applies to an audit process and fails, of course, if noise complaints are being investigated when the wind farm noise and the ambient sound are completely mixed together and the wind farm sound is not clearly dominant.

The problems with understanding the potential effects of the wind farm start with the sound level predictions often used to assess compliance against some form of guideline or legislation.

Prediction of Wind Farm Sound Levels

Sound level predictions are not "accurate"; they do not present the sound levels that will be heard at any one location at any one time. Rather, a prediction is a mathematical equation referenced to a lot of assumptions and uncertainties. Because of this, the predicted levels are also "uncertain." The art in prediction is to identify all the assumptions and uncertainties to present a realistic assessment under realistic daily conditions. This is extremely difficult to do and cannot be done with certainty using simple prediction methods such as ISO 9613-2:1996 *Acoustics-Attenuation of sound during propagation outdoors; Part 2 General method of calculation*.

Conversely, the prediction method can be used to provide an indication of expected sound levels over a long term of 12 months, for example.

To gain an initial understanding of the potential noise levels from a wind farm, it is common practice to prepare a noise map of the locality based on the 9 m/s turbine sound power information and residents living in the locale. Noise predictions do not tell the whole story, however. Meteorological conditions, wind turbine spacing, and associated wake and turbulence effects, vortex effects, turbine synchronicity, tower height, blade length, and power settings all contribute to sound levels heard or perceived at residences. In addition to this, the method of prediction has what is known as "uncertainty."

That is, the predicted values are given as a range, ±3 dB(A) at 1,000 meters for the most common prediction method with the predicted value being the "middle" of the range. The uncertainty increases with distance and the effect of two or more turbines operating in phase with a light/strong breeze blowing toward a residence. A variation of 6 to 7 dB(A) can be expected under such adverse conditions. Thus, on any given day the wind farm background LA95 or "source" time-average (LAeq) sound levels—assuming the wind farm is operating—could vary significantly in comparison with the predicted sound level. This is without the additional effect of any adverse wind effects or weather effects such as inversions.

A typical view from a residence toward the nearest towers approximately 1,800 to 2,200 meters to the south is shown in Photo 1. This shows the turbines side-on to the residence. The side-on angle of the blades allows the effect known as vortex shedding affect the residence. If the blades are full-on, as would be the case with a southwest breeze, the residence is affected by cumulative sound as well as wake and turbulence effects. The effects are potentially more noticeable on the land as there is no screening effect from the pressure changes that can occur. The wake effects are observable when the wind blows from one turbine to the other; the effects are not dependent on the direction of the turbines to the observer. The effect of the turbines at night can be seen in Photo 2.

Photo 1. Wind turbines as seen from a residence

Photo 2. Warning lights and visual effects, a local wind farm

Shepherd and Hubbard (1986) suggest that turbines "shift" from line source to point source decay characteristics at a separation distance of approximately 900 meters. Thus, a wind farm can be considered as a discrete line source consisting of multiple sources that can be identified by distance and spacing (blade swish, blade past tower, wake and turbulence interference effects, and vortex shedding). These sources are identifiable (see Photos 3 and 4). The imaging in Photo 3 shows the different sound levels from the blades of the two turbines.

The pattern in Photo 4 shows clearly the vortex shedding from the blade on the downstroke. The dominant source of sound is from the blades with an overall sound variation in the order of 2 dB(A). The measurements are taken at approximately 150 meters behind the turbine. Frequencies below 300 Hz can also be measured.

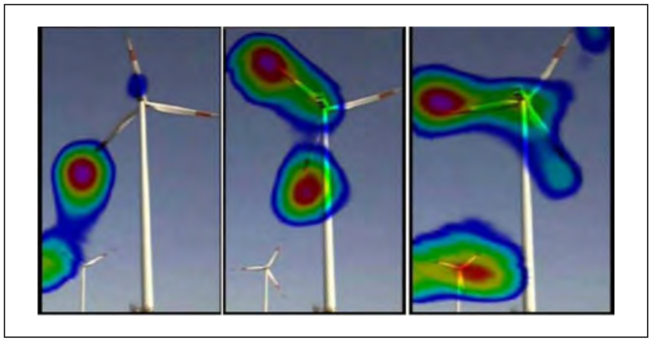

Photo 3. Acoustic photograph of sound sources from two turbines
Source. Acoustic Camera, "Multiple sources wind turbines 300Hz – 7kHz. avi" by permission from HW Technologies, Sydney.

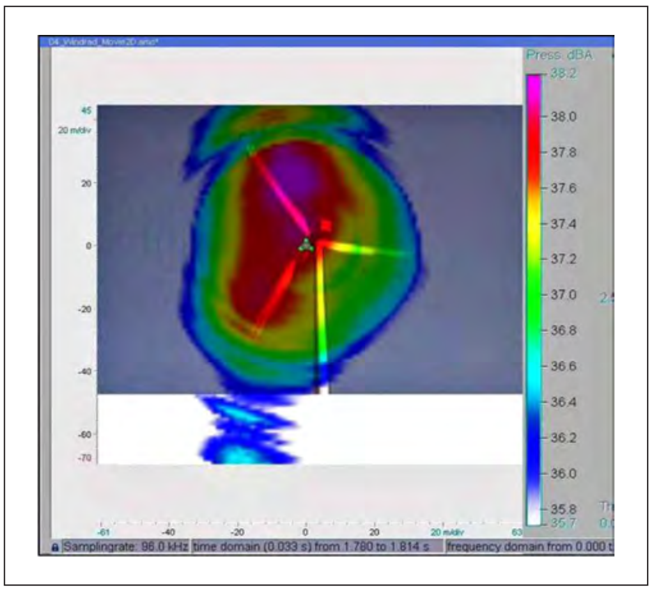

Photo 4. Acoustic photograph of sound sources from a turbine
Source. Acoustic Camera, by permission from HW Technologies, Sydney.

Wake effects are always created as highly turbulent air leaving a turbine interacts with lower speed air. A major wind turbine manufacturer recommends a distance of at least 5 rotor diameters between the wind turbines. Wake effects with pockets of lower speed air are present within 3 rotor diameters downwind and mostly dissipated at a distance of 10 rotor diameters. If a second turbine is situated within 10 rotor diameters of the first turbine, the blades of the second turbine can suddenly enter into a pocket of slower air in the wake caused by the first turbine. I. Shepherd (personal communication, 2010) concludes that increased sound levels will occur and the propagation distance in meters to a defined "criterion" or sound level can be calculated.

The vortex travels downwind in the form of a helix, rotating about its axis with each vortex replacing the previous one in space at approximately 1-second intervals—sometimes more, sometimes less depending on the speed of rotation and number of blades. The practical effect is to create heightened noise zones (HNZs).

It is hypothesized that an HNZ is the combined effect of directional sound and vibrations (wave trains) from the towers, the phase between turbines' blades, lensing in the air or ground, and interference between turbines' noise (audible) and vibration causing very localized patches of heightened noise and/or vibration. The wave train travels in time and the heightened peaks and troughs create a HNZ at an affected residence. The effect has been consistently measured at a residence 1,400 to 2,000 meters downwind from a row of turbines. The HNZ is directly affected by the design and operation of the wind farm (location and type of turbines, phase angles between blades) and wind conditions. These variables and the effects of wind shear are confounding factors that must also be taken into account when predicting the potential for noise from a wind farm.

The HNZs can be small in extent—even for low frequencies and infrasound—leading to turbine sounds "disappearing" and "appearing" in areas spaced only a few meters apart. The concept of HNZ goes a long way in explaining the problem of wind farm noise and its variability on residents. The other factor is the variability of the background sound levels as affected within the HNZs. The turbine sound levels have the effect of lifting the background (when in phase or acting together). The background drops when in the trough between the crest of the HNZ levels. However, this effect can change quite quickly depending on wind direction, temperature conditions, and turbine activity.

In summary, the prediction of wind farm sound levels at a receiver depends on a whole range of different assumptions and uncertainty, for example:

- The true sound power level of the turbine(s) at the specified wind speed
- The reduction in sound level due to ground effects
- The increase or reduction in sound level due to atmospheric (meteorological) variations and wind direction
- The variation due to modulation effects from wind velocity gradient
- Increase and reduction in sound levels due to wake and turbulence modulation effects due to turbine placement and wind direction
- Increased sound levels due to synchronicity effects of turbines in phase due to turbine placement and wind direction
- Building resonance effects for residents inside a dwelling

Wind farm noise level predictions can therefore be considered as only approximations of sound levels and cannot be given any weight other than this. The reasons are due to the highly complex nature of the sound created by each individual turbine and the cumulative effects of a number of turbines. Unfortunately, noise predictions are often taken as

Table 1. Average LA95 Sound Levels Recorded at Residence (Levels Rounded)

Date	LA95 Day, 7 a.m. to 6 p.m.	LA95 Evening, 6 p.m. to 10 p.m.	LA95 Night, 10 p.m. to 7 a.m.
October 15	—	35	—
October 16	37	40	32
October 17	34	32	36
October 18	29	26	27
October 19	29	29	25
October 20	34	31	29
October 21	34	29	31
October 22	30	31	33
October 23	32	25	36
October 24	33	35	26
October 25	38	—	—

being 100% true by naïve approving authorities. This sense is often bolstered by consultants claiming their predictions are "conservative" when in fact they are nothing of the kind. A conservative set of predictions includes all assumptions and uncertainties for different times of day/night, different weather/wind conditions, and the cumulative influence of the whole wind farm.

The situation becomes worse when the predicted levels are referenced to background sound levels as is the case with many wind farm guidelines, standards, and compliance requirements. These conditions are often called "background-plus" criteria where the compliance levels are determined against measured or predicted background sound levels.

Background Sound Levels

Background sound levels are the cornerstone of many acoustical standards dealing with wind farm noise. But what are background levels and how are they measured? Are they constant? Can anyone say with certainty that a background level measured at one location will be the same as in another nearby location? Does the wind affect the levels of background sound? How can wind turbine sound be identified in background sound?

These questions are answered by observations for a case study, "The Dean Report" (Thorne, 2010), taken at two different times in 2009 under different weather conditions. Although the residence is affected by wind turbine noise, a series of ambient and background sound levels were recorded in order to gain an indication of the levels within the locale. Ambient recordings were taken over the period October 15-30, 2009. Ambient A-weighted sound levels were measured generally in accordance with Australian Standard AS1055.1:1997. The ambient sound levels were recorded at 10-minute intervals over a 10-day period (see Table 1). Weather data (wind speed and direction, temperature, and humidity) were recorded for the same time period. Nighttime is recorded as from 10 p.m. the previous day to 7 a.m. on the nominal day.

Table 1 shows the wide range in sound levels at the residence. The levels, at approximately 2,000 meters from the turbines, show the impossibility of determining when or if the wind farm is exceeding a background level of 35 or 40 dB(A). It can be inferred that for some of the time the wind farm is in compliance but at other times it might not. The situation becomes more difficult if there is sufficient breeze to cause a significant lift in background levels.

Finally, if compliance depends on the presence—or not—of audible tones or modulation, then determination becomes near impossible without people to describe the character of the sound. Due to the nature of an operational turbine, modulation is a continuous feature of the wind farm under normal operational conditions—but the sound may not always be audible. In this case the residence is not occupied and the character of the sound—audible modulation in particular—cannot be determined "all the time" on the basis of personal physical observation. The background sound levels are often adjusted for special audible characteristics such as modulation or tonality. Modulation can, however, be determined from sound recordings from a calibrated sound level meter at a relevant time and place investigating the sounds of the wind farm.

The important compliance issue is, "How can special audible characteristics be measured in real time." The answer is, "With difficulty." Either of these two criteria requires full-time real-time monitoring in order for compliance to be proven or not proven at any affected residence.

Sound propagation varies significantly under different wind conditions and influences both the background levels and the character of the sound, especially:

- When there is a strong breeze at the turbines but no or little breeze at the residence
- When the prevailing breeze is blowing from the wind farm to the residence
- Under conditions of cool, clear evenings/nights/mornings when a mist (inversion) covers the ground

This latter condition is sometimes (in Australia) called the "van den Berg effect." It is a common condition and is explained further in this article. My own observations at operational wind farms at distances of around 1,400 meters show that sound levels are higher under calm or inversion conditions (cold clear night) at the observer than under unstable conditions (e.g., light breeze during the day). Sound levels under inversion conditions are often louder and clearer at observer locations. The effects of temperature inversion in the locale supports inversion (fog) conditions and enhanced and elevated sound levels at the residences are expected. Under stable or inversion conditions sound levels do not decay as quickly compared with unstable conditions.

Thus, the real sound levels from the wind farm may vary considerably within any 24-hour period, due to weather conditions. As with special audible characteristics, measurement

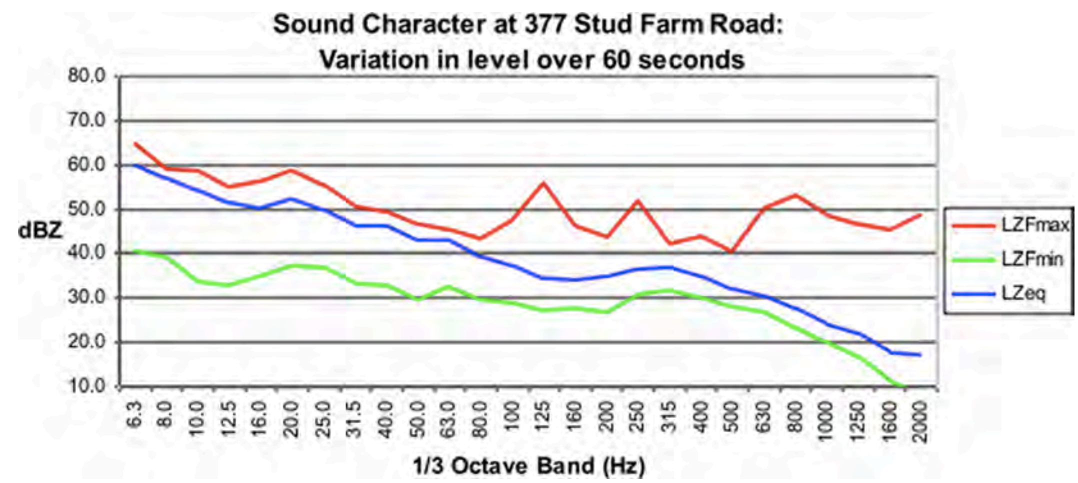

Figure 2. Variation in sound character over 60 seconds

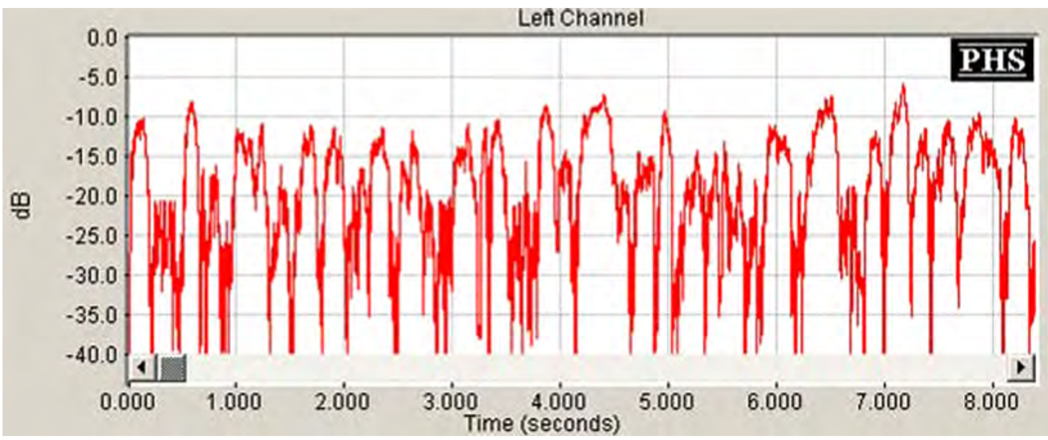

Figure 3. Pulse pattern from an operational wind farm

of wind farm noise for compliance requires full-time real-time monitoring in order for compliance to be proven or not proven at any affected residence. This applies to both audible and inaudible sound.

Audible Sound Character

The operation of the turbines to the southwest of the residence can be clearly heard at the residence. The sound on Thursday evening at 9:40 p.m., October 15, 2009, can be described as a steady rumble with a mixture of rumble-thumps. Wind in the trees or vegetation is not intrusive. Figure 2 presents the variation between maximum, minimum, and average (Leq) unweighted sound levels. Unweighted ("*Z*" weight sound levels) are referenced to assess the audibility of the sound.

In 60 seconds the sound character varies regularly by more than 20 dB; this level of variation will be audible. The generally accepted variation for a clear sense of audibility is 3 dB. Far finer detail is available by analyzing the sound into amplitude variation over the 60 seconds (see Figure 3). The figure shows the regular pulsing or modulation that is typical of blade passing the tower.

The background ambient sound levels for the assessment in Figure 2 references ambient levels recorded at the residence when the turbines were not operating. To confirm that a sound is audible to a person of "normal" hearing, an analysis of broadband sound such as the sounds recorded on the Thursday and illustrated in Figure 2 can be further analyzed for audibility. The higher the orange line is above the green line in Figure 4, the more clearly the signal can be heard. As a guide, a 3 dB shift can be readily heard. The sound is also compared against the hearing threshold level for a "normal" person.

From just this short survey it can be concluded that the wind farm was in noncompliance with a 40 dB(A) background criterion that includes a penalty for special audible characteristics. Sound from wind farms can be easily heard

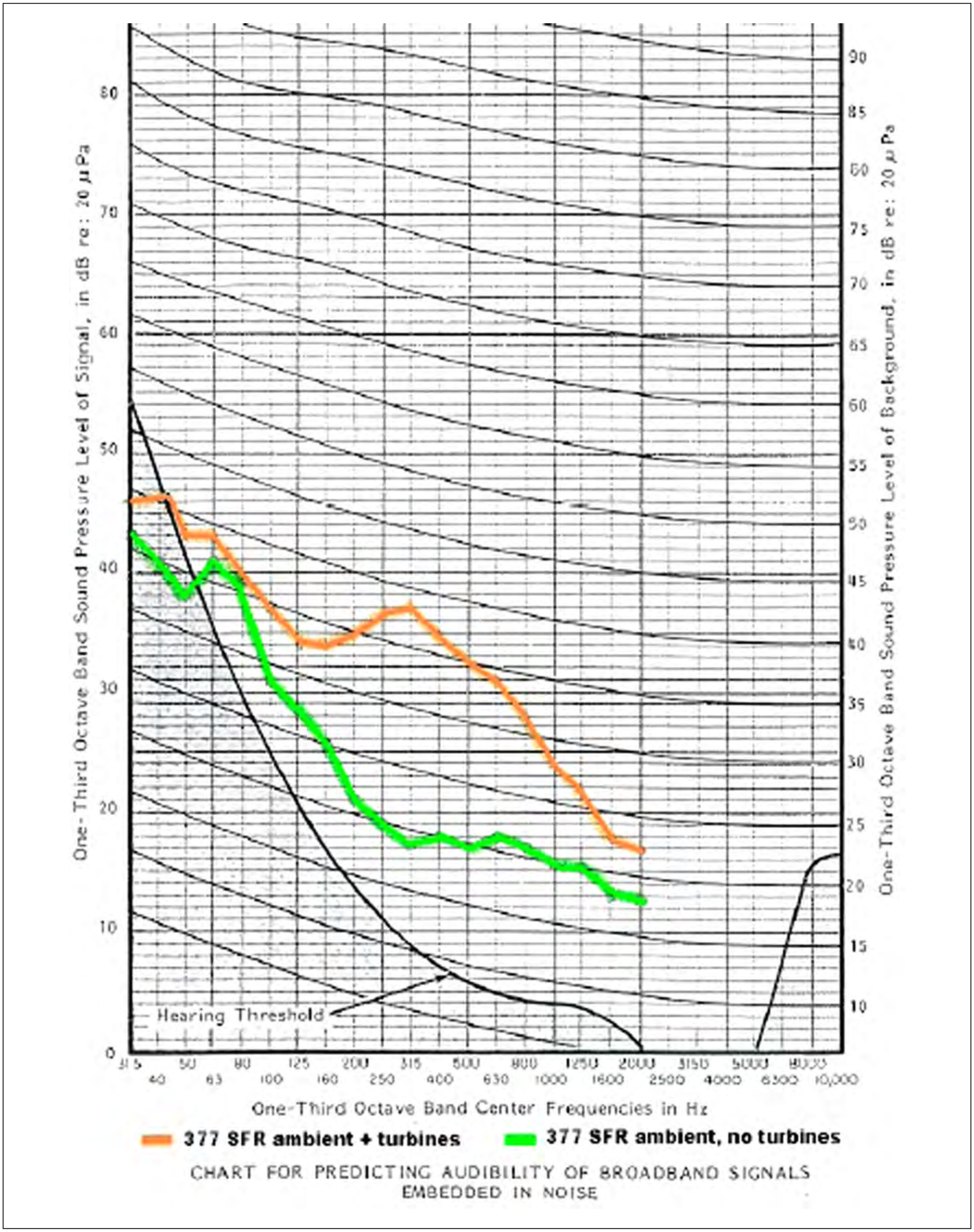

Figure 4. Audibility of wind turbines at a residence

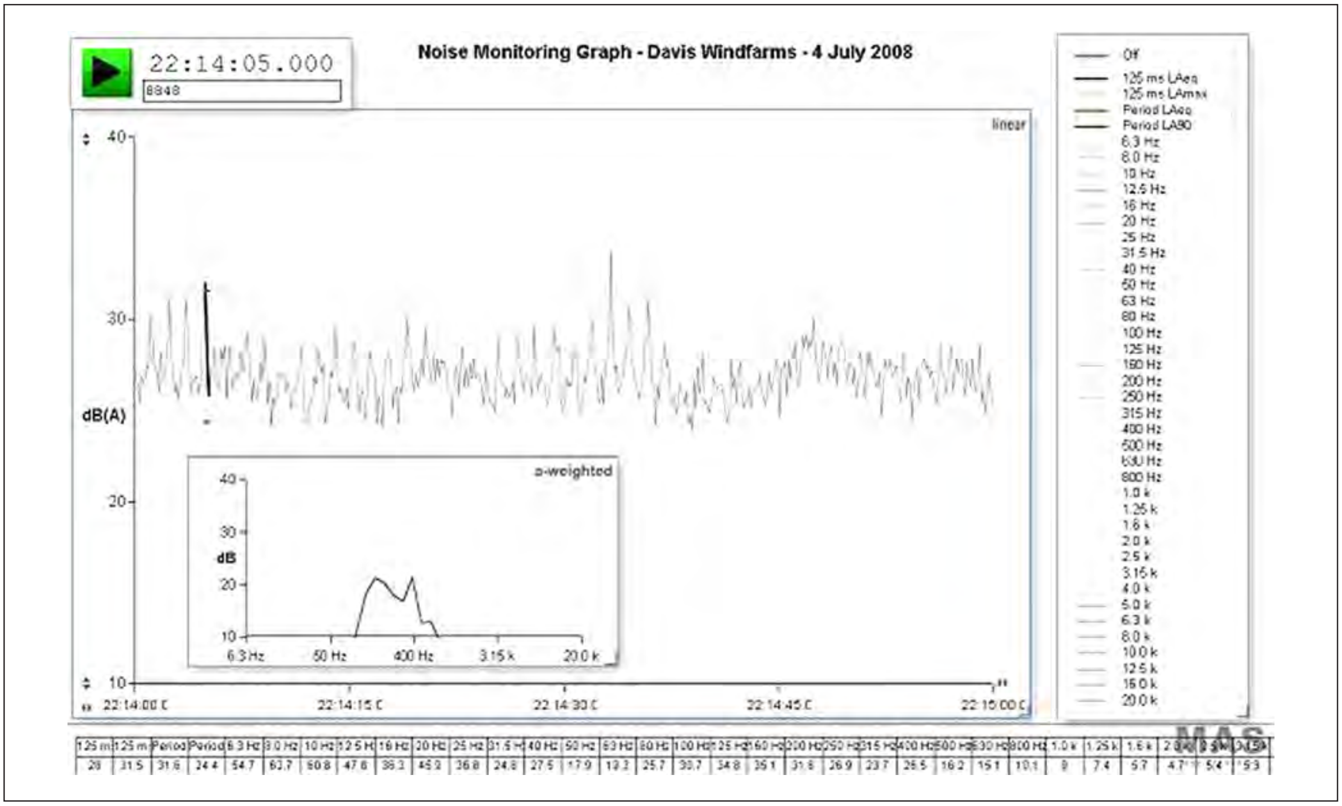

Figure 5. Sound of wind turbines at 930 meters, inside residence

at distances of 2,000 meters; such sound was measured as the background level over the range 29 to 40 dB(A) with conditions of calm to light breeze. The sound was modulating and readily observed and recorded. The sound can be defined as being both unreasonable and a nuisance. But in this case the sound is also causing adverse health effects to exposed residents. It is concluded that the reason for this is the effects of audible nuisance noise and infrasound.

Low-Frequency Sound and Infrasound

The issue of low-frequency sound and infrasound has been a controversial topic for many years. Figure 5 illustrates audible sound as well as both low-frequency and infrasound as heard inside a bedroom approximately 930 meters from a set of wind turbines. The modulating character of the sound is clearly defined in the first 5 seconds as a pattern of three spikes. The chart shows that low levels of sound are clearly audible inside a dwelling. The interior level for the 60 seconds is LAeq 31.6 dB. There are clear and distinctive audible, low-frequency, and infrasound levels. The residents (the United Kingdom) have vacated the dwelling.

In the Waubra case study, the sounds of the wind turbines were recorded at the residence and in the locale. Figures 6 and 7 illustrate the sound levels and character of the sound, including ambient wind, outside the residence. The initial survey was only for the time period 19:40 October 15, 2009, to 01:40 October 16, 2009. The wind dropped after 20:10 and the sound levels decreased.

The outdoor sound levels indicate fluctuating background (LA90, LA95) sound levels with significant variations in the "time-averaged" level, LAeq. The variations are not unusual. The LA95 level for the time period is 33.9 dB(A). The overall sound character shows slight variation between the time-averaged level, LZeq, and the maximum levels, LZmax, in each third octave band. The variation, however, is in the order of 6 dB or more in each band and this is audible.

The initial survey recorded the sound levels inside the residence. Figures 8 and 9 illustrate the sound levels and character of the sound, including ambient wind.

Figure 8 represents a time slice for the beginning of the survey when the sound of the turbines was audible outside. The inside background (LA90, LA95) sound levels are compared with the `time-averaged' level, LAeq. The consistency in level is not unusual for inside a home. The LA95 level for the time period is 17.4 dB(A). The average level is LAeq 32.5 dB. At 8 p.m., the wind dropped and the sound levels within the home decreased, with an average sound level of LAeq 18 dB, just above the background level.

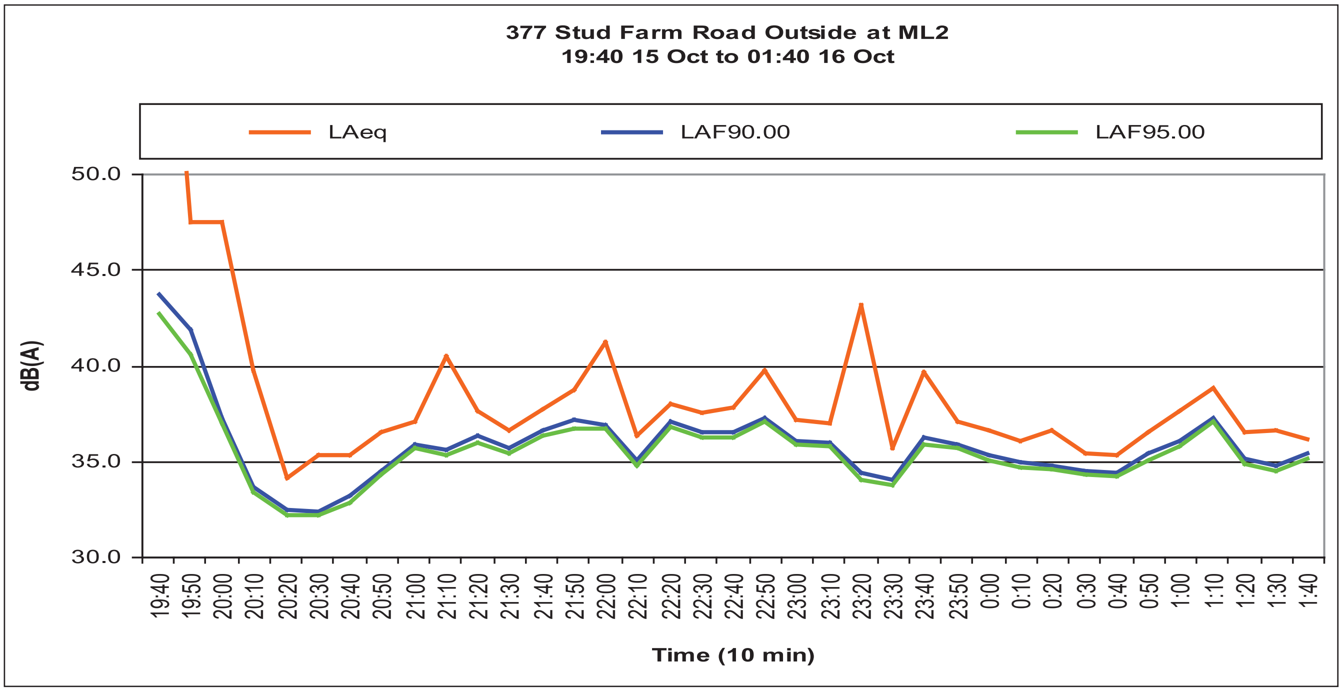

Figure 6. Outdoor sound levels for the initial survey

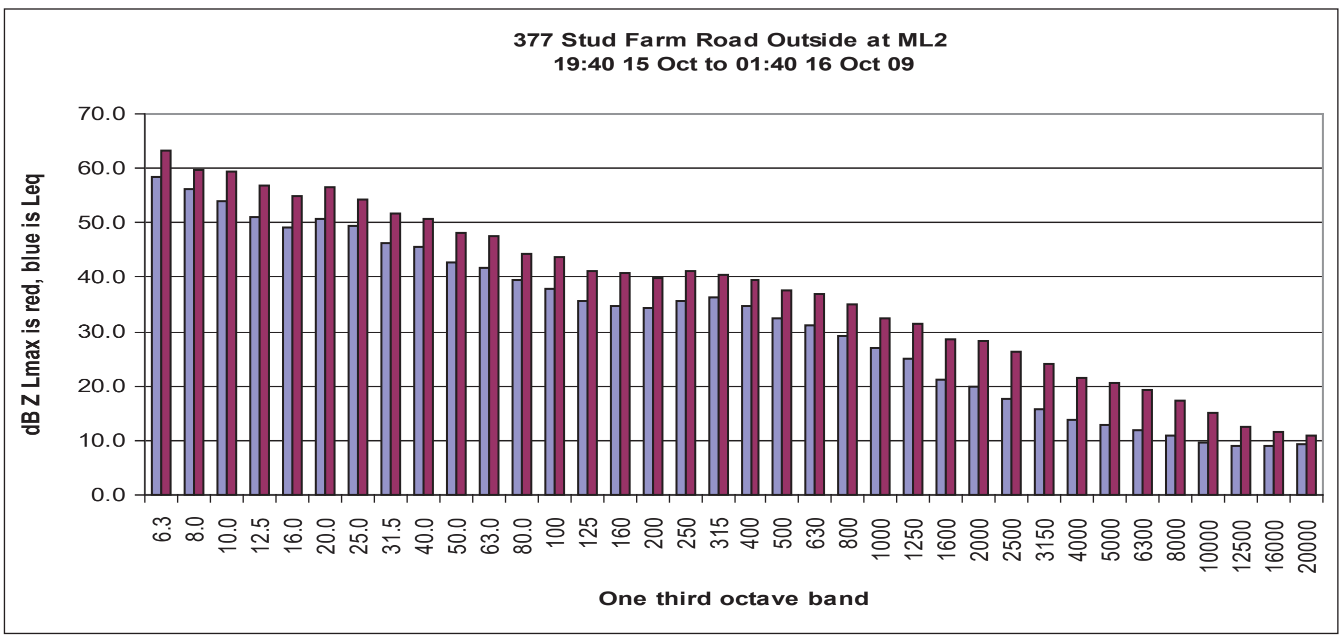

Figure 7. Outdoor sound character for the initial survey

The caution here is that sound levels vary significantly over very short (10 minutes, for example) periods of time. Thus, an assessment on an average longer-term level (Figure 8) may not truly represent the short-term effect of varying sound character (Figure 9).

The observation from Figure 9 is that the overall sound character shows substantial variation between the minimum level, LZmin, and the maximum levels, LZmax, in each third octave band. The variation is significant above 20 Hz because this is when the difference in sound levels becomes audible. The levels show the failure of A-weighted statistical levels in presenting the true sound character.

Sound levels were recorded inside the residence main bedroom over the time period 9:12 a.m. October 12, 2009, to 10:02 a.m. October 13, 2009 (see Figure 10). The wind farm was in operation at this time. The sound levels were

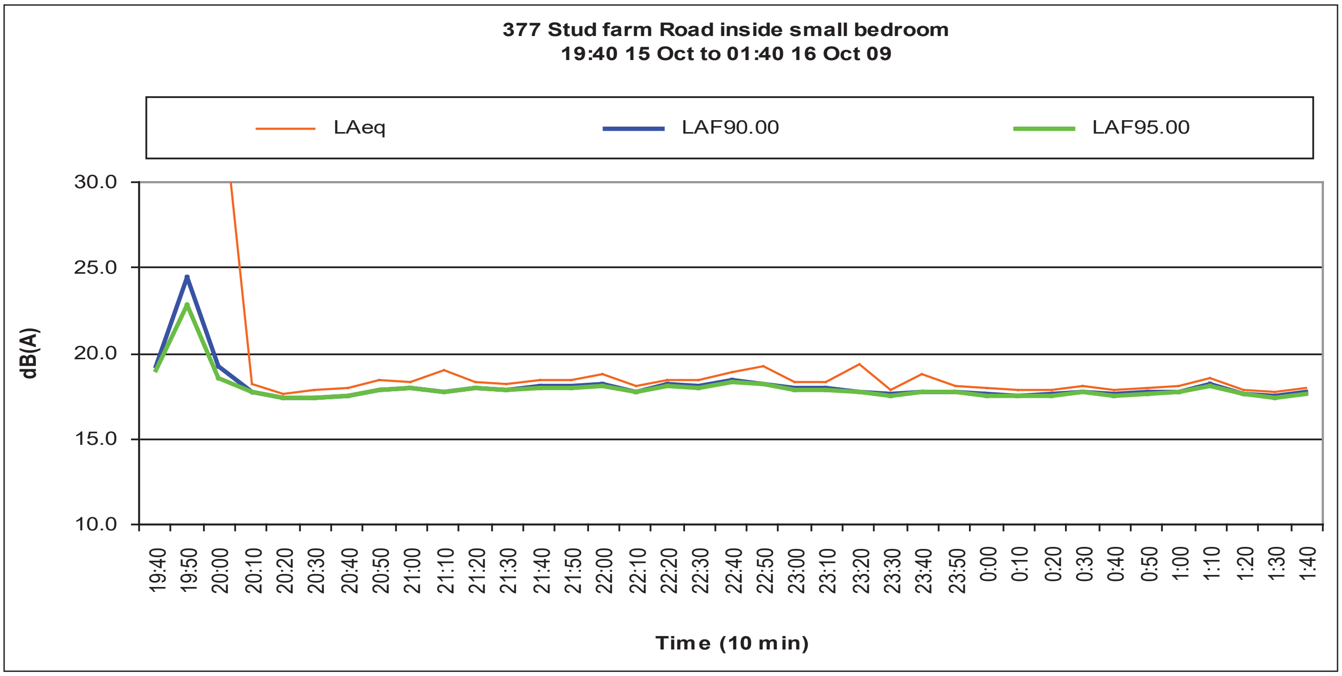

Figure 8. Indoor sound levels for the initial survey

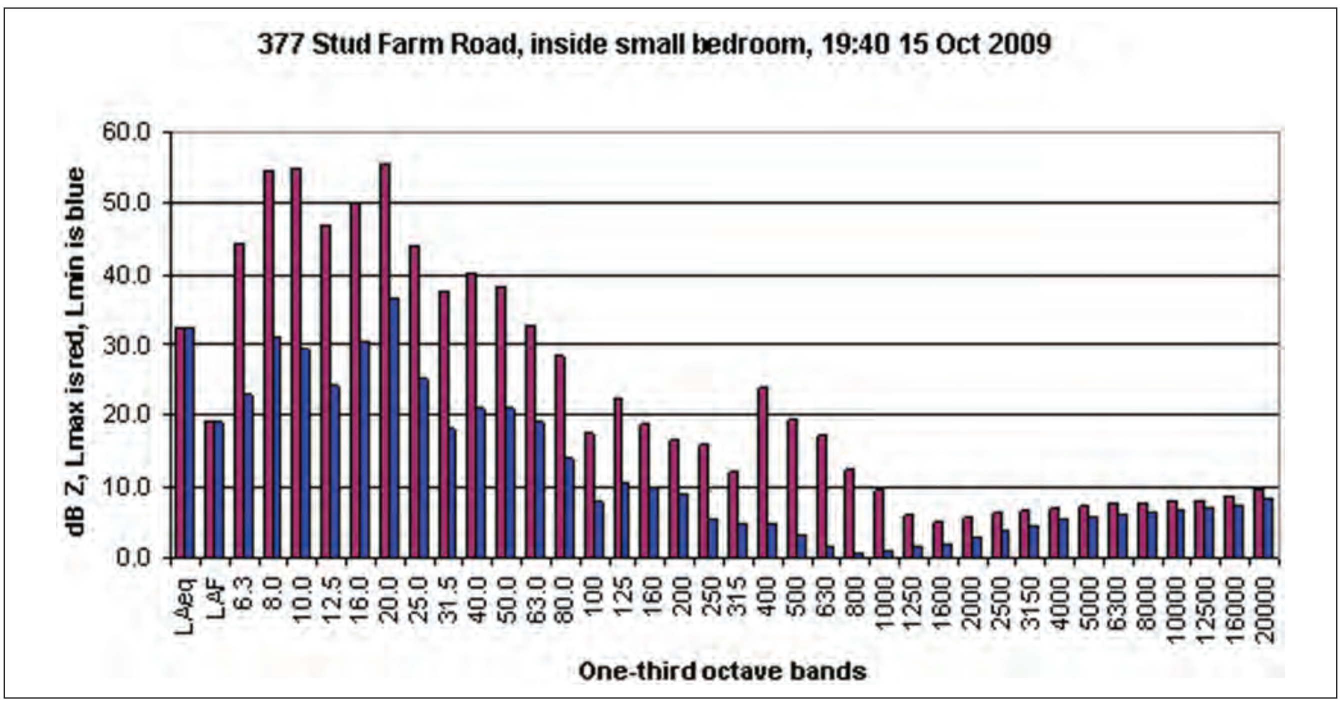

Figure 9. Indoor sound character for the initial survey

recorded in third octave bands every 30 seconds and the average levels for this time period are presented in the following. The SVAN sound level meter is able to record to a lower frequency compared with the Larson Davis 831 meter.

The character of the sound levels is similar to the time-average level *outside*, but there is significant variation between the levels in the two bedrooms. The point is to show that rooms in a residence can and will show significantly different characteristics. What may be inaudible or not perceptible in one room can be easily heard or perceived in another room on the same side of the house. The other concern is that the main bedroom appears to have little sound reduction from outside to inside. The recorded levels are with turbine activity and it is concluded that ambient and wind farm activity will be audible within the bedrooms.

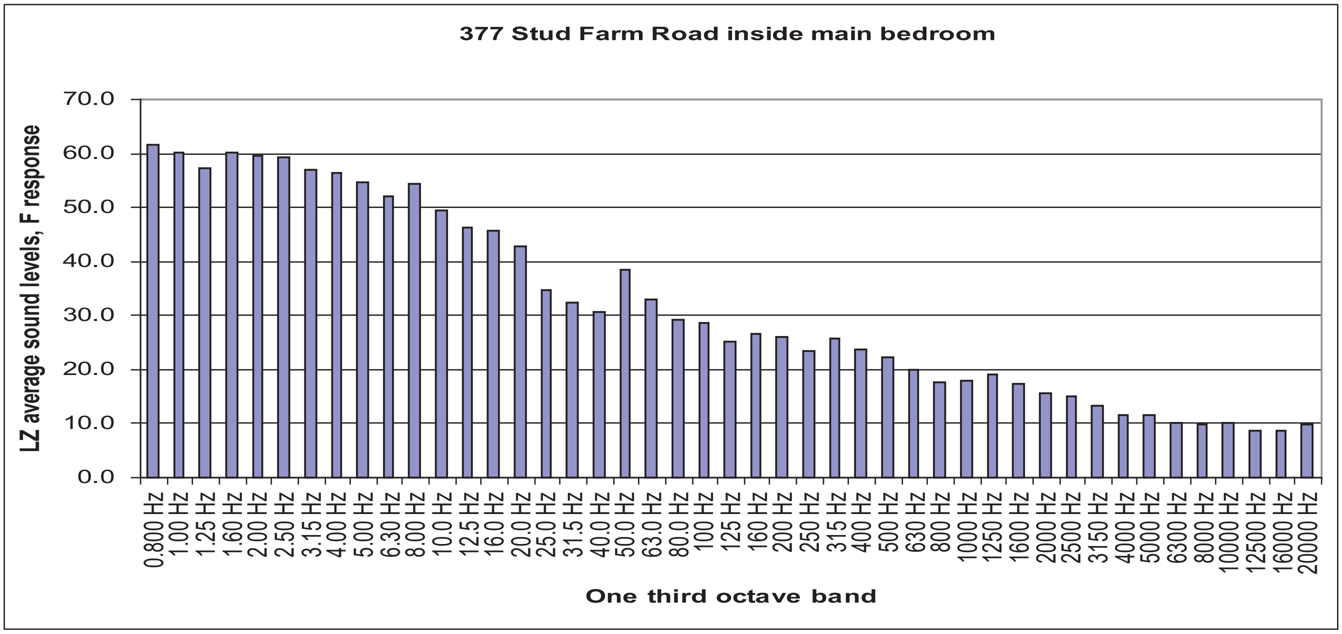

Figure 10. Indoor sound character (main bedroom)

Sonograms are presented to illustrate specific locations with and without turbine activity. The sonograms illustrate the presence of turbines even though the activity may not be audible. Different time segments are used to illustrate the effects. The important features are the following:

- The significant amount of sound energy in the low-frequency and infrasonic ranges.
- The variation of 20 dB between high and low values in the sonograms between the yellow bands and the purple bands. This variation is audible under observed conditions.

The overall levels in one third octave band charts are provided to illustrate the difference between maximum and minimum sound levels in the measurement time period. These correspond to the peak and trough values and give a "first-cut" assessment of whether or not audible modulation, audible tonality, perceptible modulation, or perceptible tonality may exist. Charts are provided as examples of the sound character. The sonograms are taken from recorded audio files that are 60 or 30 seconds in length. Hence, the displayed sonogram charts can differ from the one third octave band charts, which are calculated over a full 10 minutes.

The case study illustrates the difficulties in measuring and assessing wind turbine sound. Sound level criteria referenced to an A-weighted sound descriptor do not accurately describe the sound or perception of a wind turbine or a wind farm.

The study by Thorne (2010) records that wind turbine sound at the residence is perceptible and can be analyzed and assessed in a meaningful way.

The sound character of the wind farm is clearly different from the locale and indicates the presence of modulating sound. The sonograms and third octave band charts presented are provided to illustrate the character of the sound. The method developed by H. Bakker, Astute Engineering, New Zealand (personal communication, 2010) displays sound character, modulation, tonality, or tonal complexes through sonograms. These show sound at various frequencies over time as shown in Plate 1. They can be thought of like a sheet of music or an old pianola roll; the left axis is frequency—musical pitch—while the bottom axis is time. Amplitude and frequency modulation can be identified in the sonograms by distinctive regular patterning at 1-second (or longer or shorter) intervals. Tonality and tonal complexes can also be identified using sonograms. The color indicates the loudness in unweighted dB (SPL) with the color bar at the right providing a key to the "loudness" in decibels associated with each color. The values (−30 to 20, for example) on the right-hand side of the sonogram are decibel levels. Loud notes appear yellow or while; soft notes would appear purple or black. (In these sonograms, much of the color scale has been made black so that peaks stand out better.) Generally, the sonograms are not calibrated against measured sound level but present a comparison between peak and trough (maximum and minimum) levels in a short period of time. At the time of recording it is possible to include reference sound levels in order to assess the sonogram values against measured values.

There are two types of sonograms shown, one is for audible frequencies (20-1,000 Hz) and the other is for low frequencies (0.8-20 Hz), referred to as *infrasound*. The use of sonograms can show the presence of modulation. The rumble/thump of

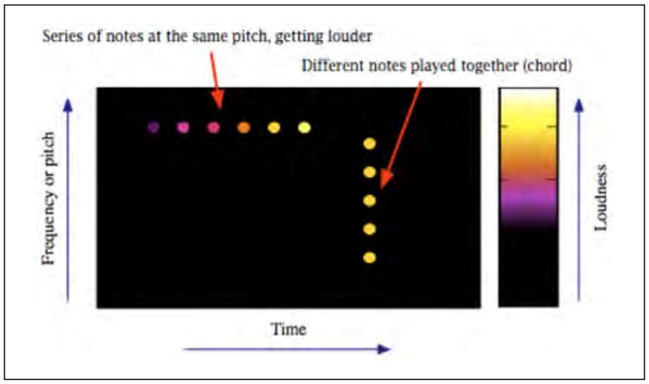

Plate 1. How to interpret a sonogram

wind turbine modulation has been demonstrated to exist in three geographically separate wind farms.

Sound Character at Residence, Plate 2

Plate 2 illustrates the sound of wind farm audible at 7:40 p.m. outside residence, as well as wind in trees, voices, setting-up activity, and a distant vehicle. The sonogram shows a distinctive 50 Hz tone from a nearby electrical source, as well as strong readings at 20 Hz, 16 Hz, and 6.3 Hz. These are indicator frequencies for potential adverse health response. The regular bands or modulations at around 1 Hz indicate wind turbine blade pass frequency. Higher frequency contents (800-5,000 Hz) not evident in the sonogram are evident in the third octave bands.

Sound Character at Residence, Plate 3

The audio file identifies wind and wind farm sounds. There are strong readings at 20 Hz, 16 Hz, and 6.3 Hz. These are indicator frequencies for potential adverse health response. The regular bands or modulations at around 1 Hz indicate wind turbine blade pass frequency. Higher frequency content (800-5,000 Hz) evident in the third octave band chart is not evident in the sonogram. Low-frequency content is evident in both the sonogram and the third octave band chart.

Sound Character at Residence, Plate 4

Wind farm not audible outside residence. The wind pattern is completely different from the previous two sonograms. There is a distinctive 90 Hz tone from an aircraft. Animal and bird noise provide the character. The strong readings at 20 Hz, 16 Hz, and 6.3 Hz have gone. The previous regular bands or modulations at around 1 Hz indicate wind turbine blade noise has gone and instead there are smooth bands of sound from "ordinary" wind flow.

Sound Character Between Two Sets of Turbines, Plate 5

The wind farm was audible at the measurement location as a distant rumble and some of the nearest visible turbines approximately 500 to 1,500 meters distant were moving slowly, as though they were starting up. The sound is similar to an aircraft overhead, although the sound was not from a plane. There are strong readings at 20 Hz and below on a regular basis although there was little or no breeze. The regular bands or modulations at around 1 Hz indicate wind turbine blade pass noise.

Sound Character Inside Residence, Plate 6

Sound levels measured inside a small bedroom. The audible sound character (200-400 Hz) is from distant voices within the house. Wind farm not audible outside residence: turbines to the north turning slowly, turbines to the south not turning. There are strong readings at 20 Hz and below on a regular basis. There was no ground-level breeze outside during the recording. There is evidence of normally nonperceptible infrasound and audible midrange frequencies within the bedroom.

Responses of Residents Living Near Wind Farms

Community noise exposure is commonly measured in terms of a noise exposure measure. Noise exposure is the varying pattern of sound levels at a location over a defined time period. The time period is most often 1 day (short term) or over weeks, months, or a year (long term).

The practical difficulty in locale measurements is that many of them are needed to describe a neighborhood. It is customary, therefore, to use a suitable single-number evaluation for community neighborhood noise exposure. Individuals, however, are different in their tolerance to specific sounds: there is a distinct duration-intensity relationship that varies depending on the character of the sound (Thorne, 2007).

There is no defined relationship that can predict when a noise is reasonable or unreasonable; for this to happen, the sound must be audible or perceptible to cause an adverse response in the person affected.

Previous wind farm investigations in New Zealand and Victoria, Australia, indicate that residences within 3,500 meters of a wind farm are potentially affected by audible noise and vibration from large turbines, such as those proposed. Residences within 1,000 to 2,000 meters are affected on a regular basis by audible noise disturbing sleep. Adverse health effects are reported and as these effects did not occur before the wind farms became operational a reasonable hypothesis is that the wind farm activity has a causal relationship (Thorne, 2007, 2011).

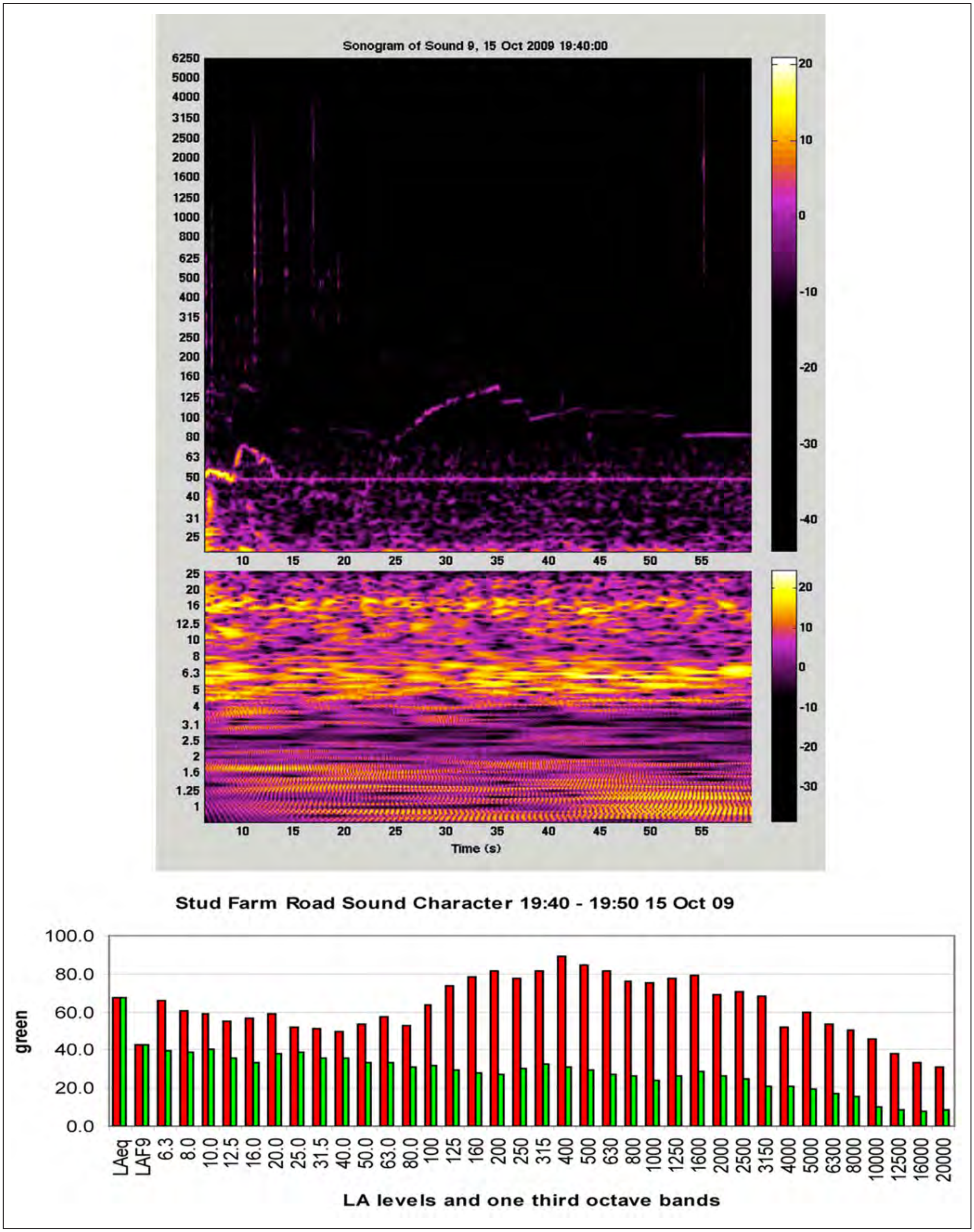

Plate 2. Sound of wind farm audible outside residence

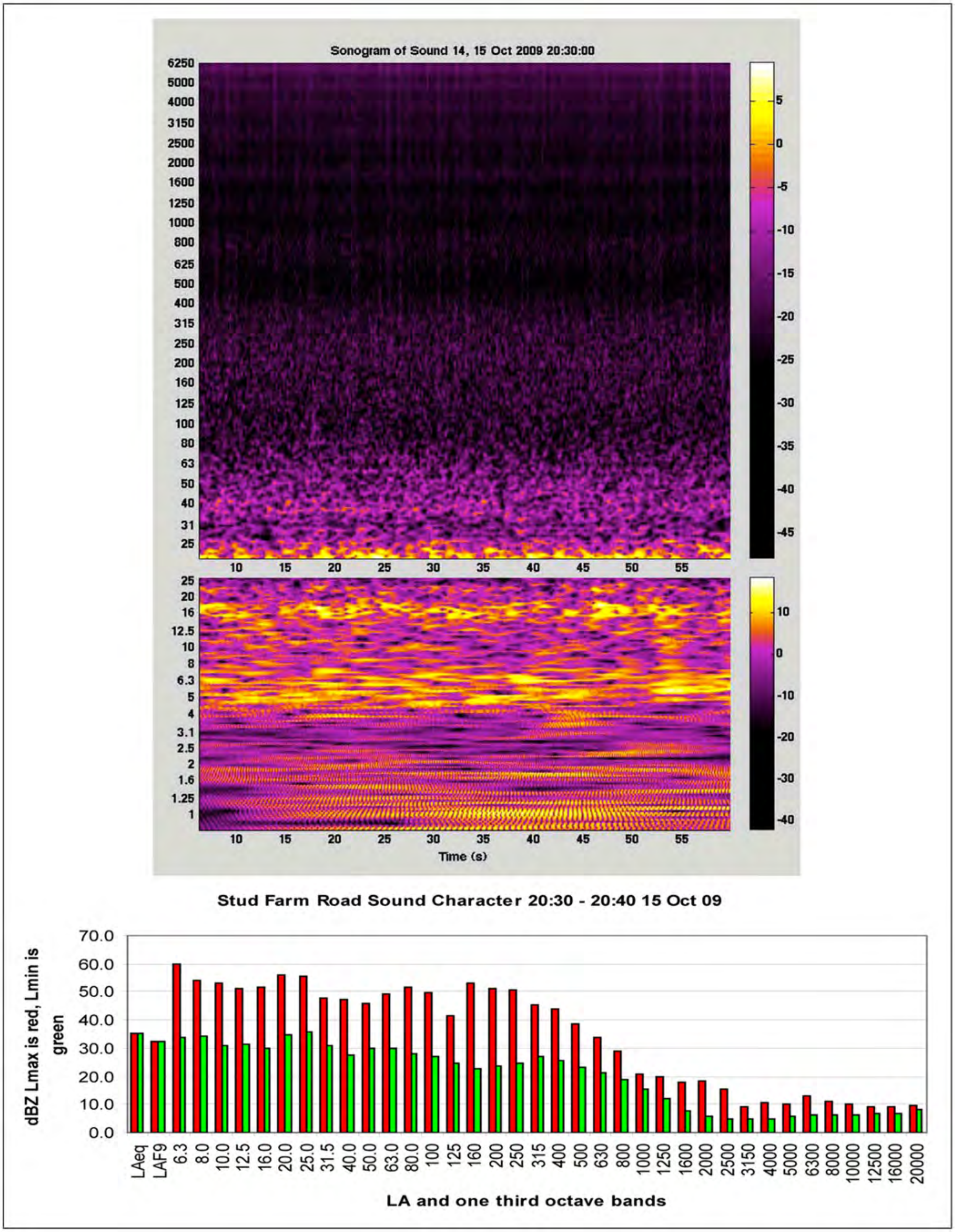

Plate 3. Sound of wind farm audible outside residence (low frequencies identified)

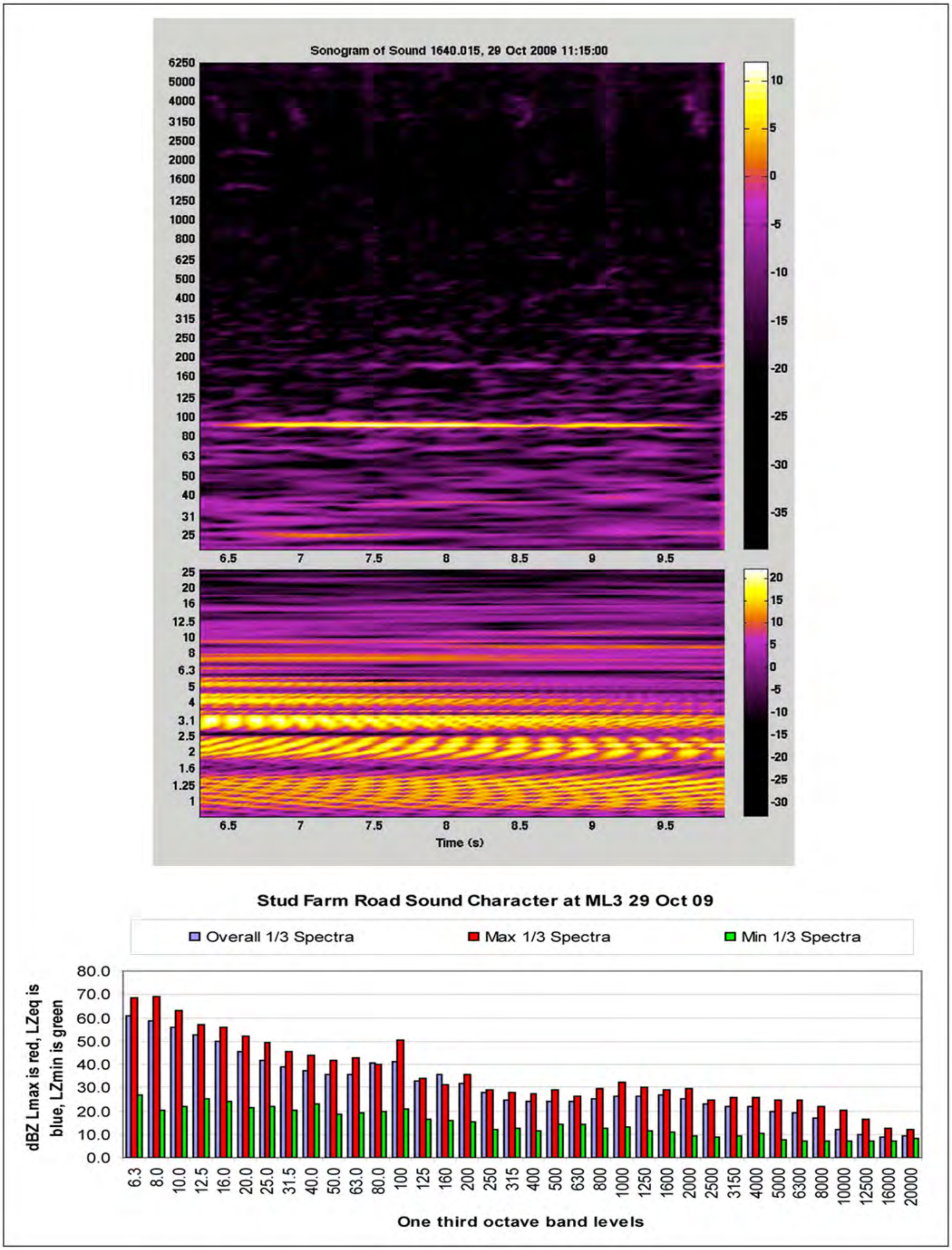

Plate 4. Sound of wind farm not audible outside residence

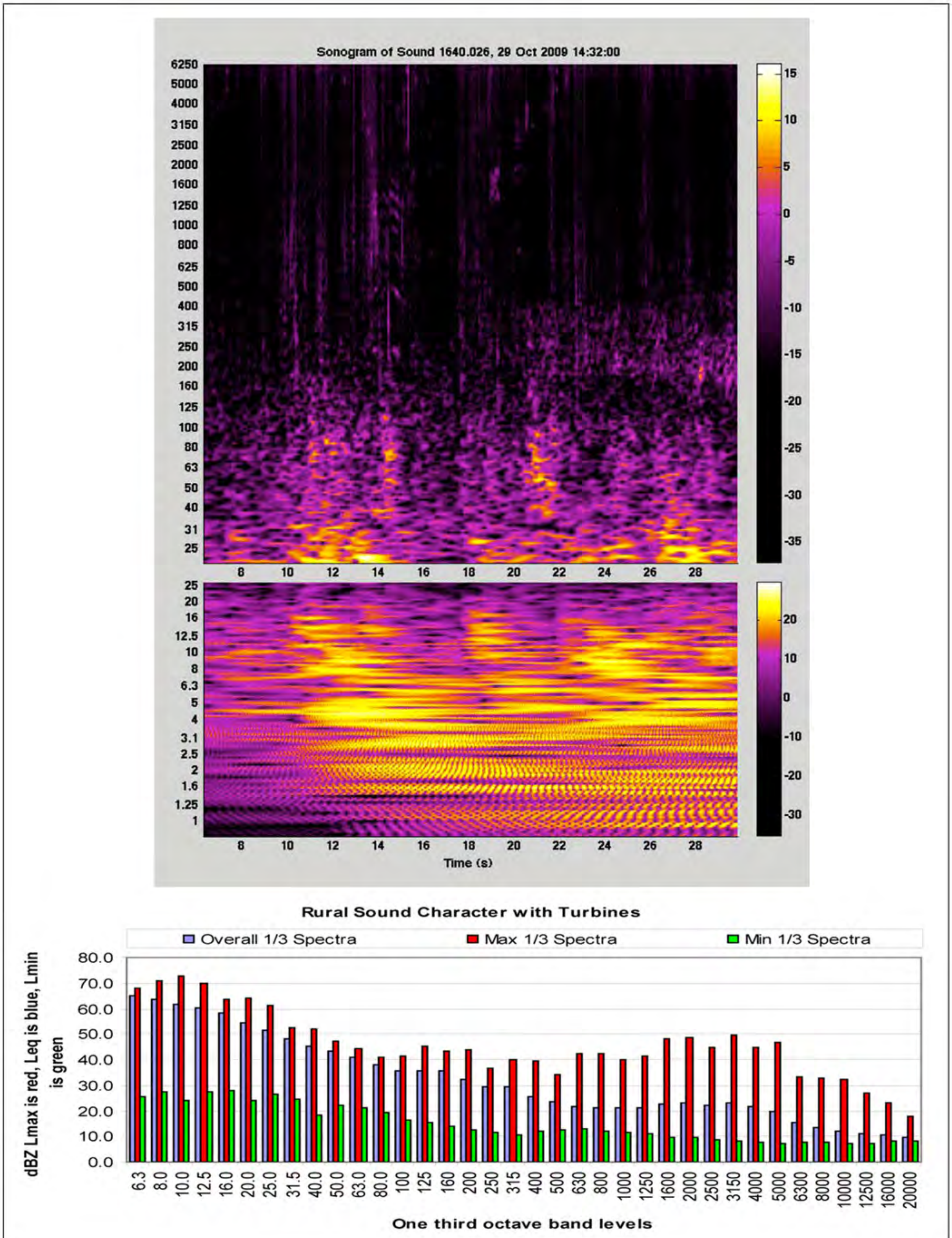

Plate 5. Sound character of wind farm turbines

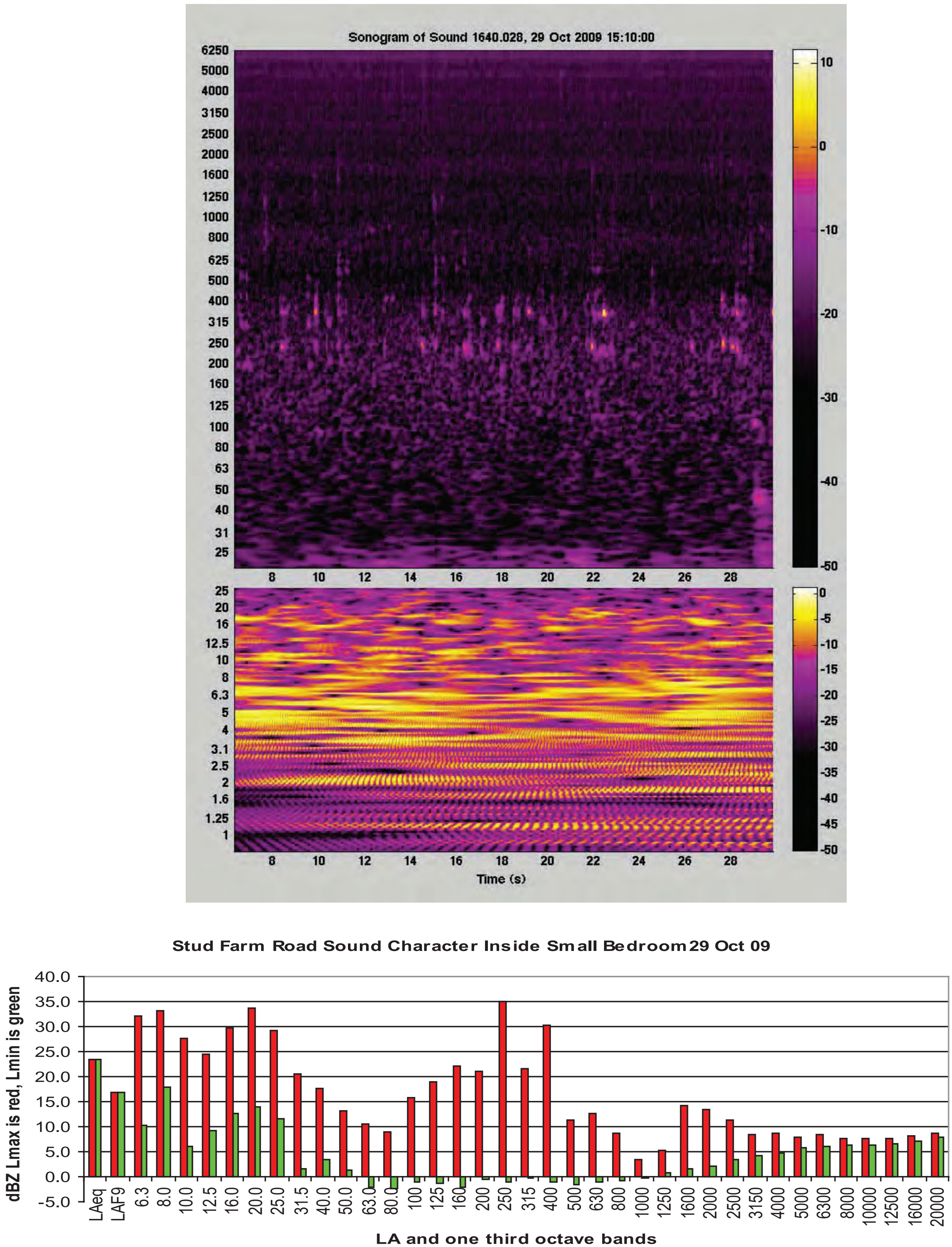

Plate 6. Sound character of wind farm inside a dwelling

The following three examples illustrate the effects of wind farms on residents living within the locale.

The Effects on People Living Near the Waubra Wind Farm, Victoria, Australia

The Waubra wind farm commenced operation in March 2009 in the Ballarat section and in May 2009 in the northern Waubra section. Within a short time nearby residents were becoming concerned about noise. By August 2009 adverse health effects were being reported. In September-October I interviewed five different families near the northern section of the wind farm, all of whom indicated some adverse reaction since the commissioning of a nearby wind farm earlier in the year. The families are all within approximately 1,000 to 2,000 meters of turbines and had at least two sets of turbines near to them. Under these circumstances, the residences are affected by wind farm activity over a range of wind directions. The interviews were preliminary in nature and standard psych and noise sensitivity tests were not conducted, nor were detailed health notes recorded.

Family A indicated headaches (scalp and around the head pressure), memory problems, and nausea when the turbines are operating. Symptoms include an inability to get to sleep and sleep disturbance, anxiety and stress, pressure at top and around head, memory problems, sore eyes and blurred vision, and chest pressure. When the turbines are stopped the symptoms do not occur. A difference in severity is recorded with different wind directions. A personal comment made states the following:

> I am having problems living and working indoors and outdoors on our property . . . problems include headaches, nausea, pain in and around the eyes, sleep disturbance, pain in back of head; we feel this is coming from generation of wind from wind farm as it is OK when turbines are stopped.

Family B indicated tinnitus, dizziness, and headaches since the turbines have started operating. The family also indicated sleep disturbance at night with the sound of the turbines interrupting sleep pattern, vibration in chest at times, and tiredness and trouble concentrating during the day. The family did not have problems sleeping when not at Waubra overnight.

Family C indicated that the noise coming from the turbines at night disturbed sleep. During the day there was noise that causes bad headaches, sore eyes causing impaired vision, earache, and irritability.

Family D indicated suffering from sleep disturbance, headaches, nausea, and tachychardia (rapid heart rate) since the turbines started operating.

Family E indicated that when the turbines were operating symptoms included feeling unwell, dull pains in the head (acute to almost migraine), nausea, and feeling of motion sickness. Symptoms at night when the turbines were in motion included sleep disturbance from noise and vibration (unable to get any meaningful deep sleep) and sleep deprivation leading to coping problems. The problems were reported as follows:

> Some days when the wind is in the north-east my eyes feel swollen and are being pushed out of the sockets. I have a buzzing in my ears. On these days I feel it very difficult to summon memory and difficult to concentrate.
>
> The sound of the turbines when functioning is on most days so intrusive that it affects my concentration and thought processes when performing complex tasks. I suffer from sleep interruption as a direct result of the noise, which then affects my ability to function at 100% the following day. One is aware of a throbbing in the head and palpitations that are in synchrony with the beat of the turbines and to a degree the flashing of the red lights. Because of this impact on my everyday life it causes me great stress and in turn great irritability.

Two families identified blade glint/flicker and the red warning lights on the top of each tower as an additional source of annoyance.

Statutory declarations (June 2010) concerning noise issues have been declared by residents affected by the Waubra wind farm. Noise from the turbines is being experienced by residents within approximately 1,000 meters of the nearest turbines and at distances of approximately 3,000 to 4,000 meters distant from the nearest turbines. The locales where the residents experience noise are shown in Plate W1. The noise and health effects experienced by residents are presented in Table W1.

The Waubra north and Ballarat locales are rural in nature with relatively low hills and rolling countryside. The northern section of the wind farm is illustrated in Plate W2. The locale is affected by southwest winds at turbine level but can be relatively calm at residences. The prevailing winds at Ballarat airport are shown in Figure W1. The measured wind directions are given to illustrate the importance of accurate wind data in predicting or assessing complaints.

The Effects on People Living Near the "West Wind" Wind Farm, New Zealand

The "West Wind" wind farm commenced operation in May 2009. From my observations at Makara, New Zealand, at a residence situated approximately 1,200 to 1,300 meters from 5 turbines and within 3,500 meters of 14 turbines there is known probability that the wind farm will exhibit adverse "special audible characteristics" on a regular basis resulting in sleep disturbance, annoyance, and stress.

The observations and measurements being recorded at Makara involve the residents taking notes of the noise heard when they are awakened. At the same time, a fully automated monitoring system records exterior audio as well as exterior and interior sound level data in summary levels and third octave band levels. This allows the generation of tracking

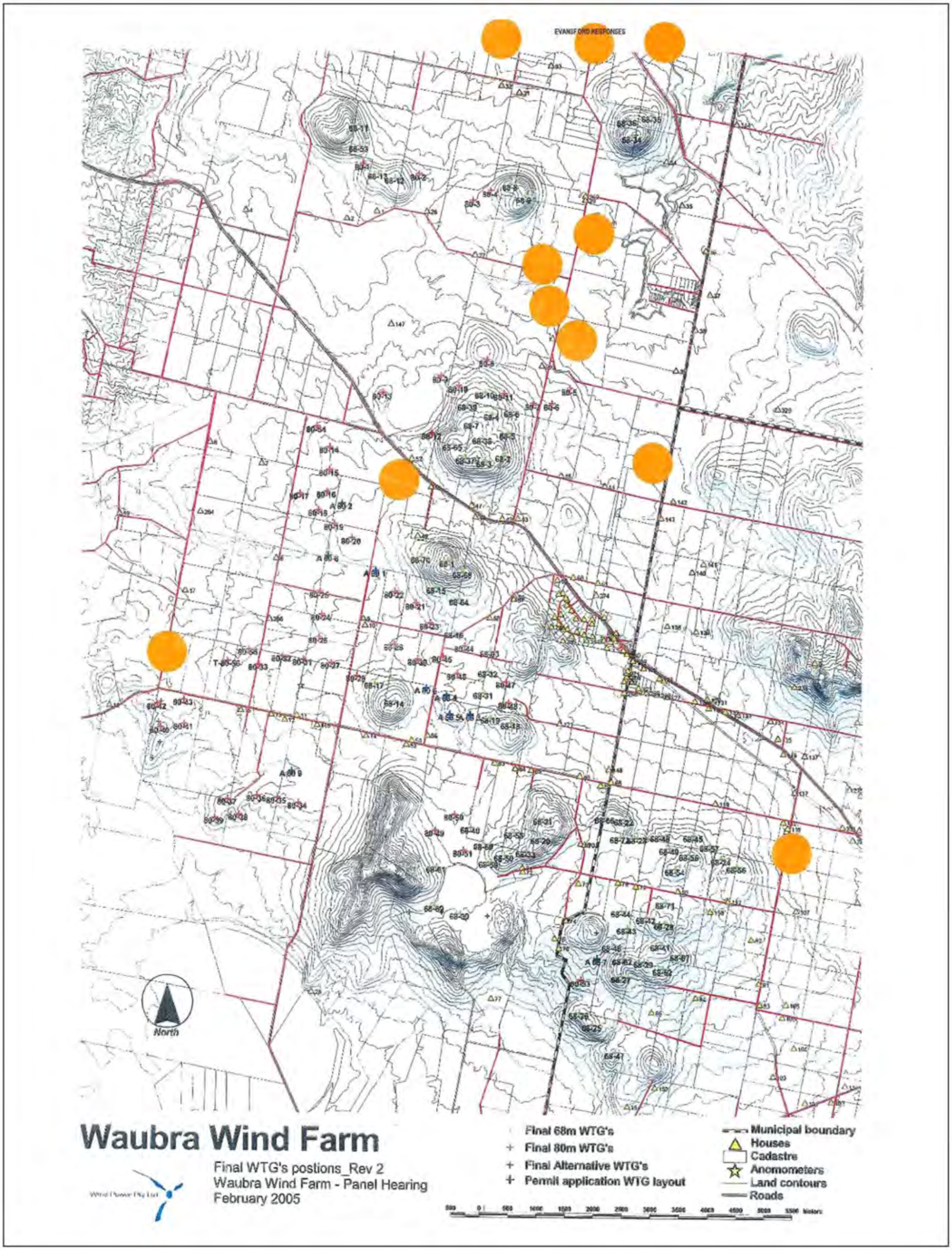

Plate W1. Locales in Waubra affected by Waubra wind farm turbine noise
Note. The locales affected by wind farm noise are identified by the orange circles.

Table W1. Waubra Wind Farm Perception and Complaint Analysis

Locale	Distance	Effects of Noise
1	1,500-2,500	Sleep disturbance, headaches, affects eyes and back of head, tinnitus. Worst affect is while working the farm. Heart pressure changes.
2	1,000	Sleep disturbance, headaches, high blood pressure.
3	1,000-1,300	Sore eyes and headaches when the turbines are operating.
4	1,250-3,000	Sleep disturbance. Affects people working on the farm. Headaches, earaches, blood pressure changes, and poor eye sight.
5	1,300-2,200	Insomnia, headaches, sore eyes, dizziness, tinnitus, and heart palpitations. Deteriorating health due to lack of sleep and stress levels. Unable to sleep through the night. Affects while working outside on the farm.
6	2,000-2,300	Headaches and pressure in ears when working on the farm.
7	550-1,400	Sleep disturbance, windows vibrate. Affects while working on the farm. Headaches, lack of sleep, major problem with flicker. Excessive noise under a strong southwest wind.
8	1,000-3,500	Headaches when working farm within 1500 meters of turbines. Dizziness when two turbines inline and in sync, effect went when approximately 300 meters out of alignment. Sleep awakenings and disturbed by pulsating swish. Heart palpitations, vibrating sensation in chest and body. Headaches while at home. Stress and depression.
9	3,500-4,300	Frequently suffer from headaches, tinnitus, irritability, sleepless nights, lack of concentration, heart palpitations. Turbines exhibit a loud droning noise and pulsating whoosh.
10	3,400-3,800	Headaches, ringing in ears when turbines are operating. Pressure in ears, heart palpitations, and anxiety attacks. Awaken at night, sleep disturbance.
11	3,000-4,600	Elevated blood pressure, heart palpitations, ear pressure and earache, disrupted sleep, increasing frequent headaches, head pressure, vibration in body, mood swings, problems with concentration and memory. Awaken at night, sleep disturbance.
12	1,000-1,200	Headaches, sickness, frequent sleep disturbance, very stressed. Affects personal life. Lights on turbines cause extreme distress. Ear pressure and loss of balance while working on the farm. Enormous pressure and stress on home and work.

Note. "Distance" is the distance in meters between the locale and the nearest turbines. The distances vary where turbines are in different directions surrounding the locale. Each locale contains one or more affected families. A common observation is that the adverse health effects noted did not exist before the wind farm commenced operation or diminish/disappear when not in the district affected by turbines.

data and sonograms for compliance and unreasonable noise assessment. The complaint data are retained by the City Council. Statistical data are retained by the wind farm operator and summarized for the Council. Audio data for real-time analysis of special audible characteristics are not recorded by either the Council or the wind farm operator. Audio data are recorded, however, by one affected resident.

In the period April 2009 to March 31, 2010, a total of 906 complaints were made to the Wellington City Council, New Zealand, concerning noise from the wind farm at Makara. These complaints were made by residents living near to and affected by the wind farm. An analysis of the complaint history was made by acoustical consultants working for the wind farm company. From 64 households in a population of approximately 140 occupied residences, 57% of the complaints were from 10 households and 79% were from 20 households.

The character of the 650 complaints was sorted by an independent researcher. Rumble, with 252 mentions, was the most common characteristic. Hum and thump are the next most common annoying sounds. In comparing complaints of noise outside to inside, of 650 complaints, only 23 specifically mentioned the noise as being outside.

In personal interviews at Makara, some residents identified nausea as a problem. In the most severely affected cases known, the residents have bought property and moved away from their farm.

Low-frequency sound and infrasound are normal characteristics of a wind farm as they are the normal characteristics of wind, as such. The difference is that "normal" wind is laminar or smooth in effect whereas wind farm sound is non-laminar and presents a pulsing nature. This effect is evident even inside a dwelling and the characteristics are modified due to the construction of the building and room dimensions. Of the indoor complaints, 4.5% specifically mentioned sleep disturbance.

The Makara complaints were limited to a small locale. Complaints were from the whole of the district, that is, a distance of approximately 12 km. The turbines are situated in both clusters and rows. The locale "Makara" is a small village and school affected by a cluster of approximately 14 turbines within 2,000 meters; the locale "South Makara" is a line of residences facing a line of 25 turbines within 2,000 meters over approximately 5 km. The issue is that turbine noise is known, it can be defined by character and distance, and it does have significant impact on a large number of people.

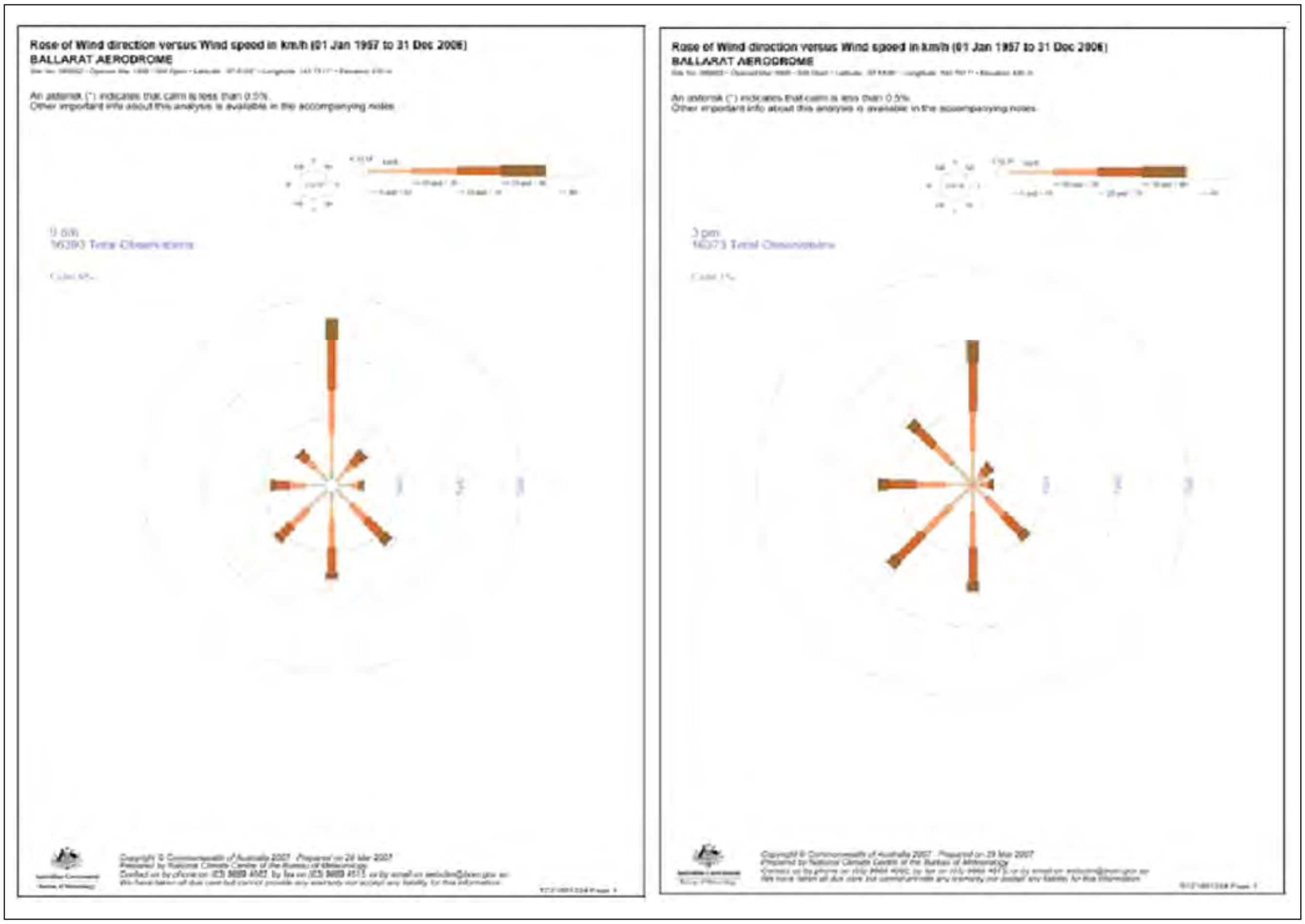

Figure W1. Wind rose, Ballarat Aerodrome, mid-morning and mid-afternoon

The turbines are Siemens 2.3 MW machines situated approximately 1,200 to 2,200 meters from residences.

Nausea and sleep disturbance were reported by one visitor to a residence 2,200 meters from the nearest turbine. The residents also complained about the visual nuisance caused by blade glint and flicker, as well as the red glow from the warning lights on top of each tower. A complaint (March 2010) about the operation of the wind farm expressed the following:

> We have had a persistent level of disturbance noise now for several hours throughout the evening that is now preventing us sleeping since 11:15 p.m. The predominant noise is a continuous loud booming rumble that is even more noticeable after a gust at ground level. When the wind noise drops, the background noise from the turbine continues and is also felt as a vibration being transmitted through the ground. Even with wind noise the vibrations in the house continue. The varying wind speed also causes a beating noise from the blades that occurs in cycles creating yet another form of noise disturbance.

A second resident said the following:

> We are 2 km away to the east and the thumping also penetrates our double glazing. The reverberation is somehow worse inside the house.

And a third resident said the following:

> We . . . get the low-frequency thump/whump inside the house, is very similar to a truck driving past or boy racers sub woofer 100 meters away . . . we have no line of sight turbines and the closest one in 1.35 km away. There are however 27 turbines within 2.5 km (which would apply for the whole village). The sound is extremely "penetrating" and while we have a new house with insulation and double glazing, the low-frequency modulation is still very evident in the dead of night. It is actually less obvious outside as the ambient noise screens out the sound.

The valley is affected by strong winds at turbine level but can be relatively calm at residences. The prevailing wind at

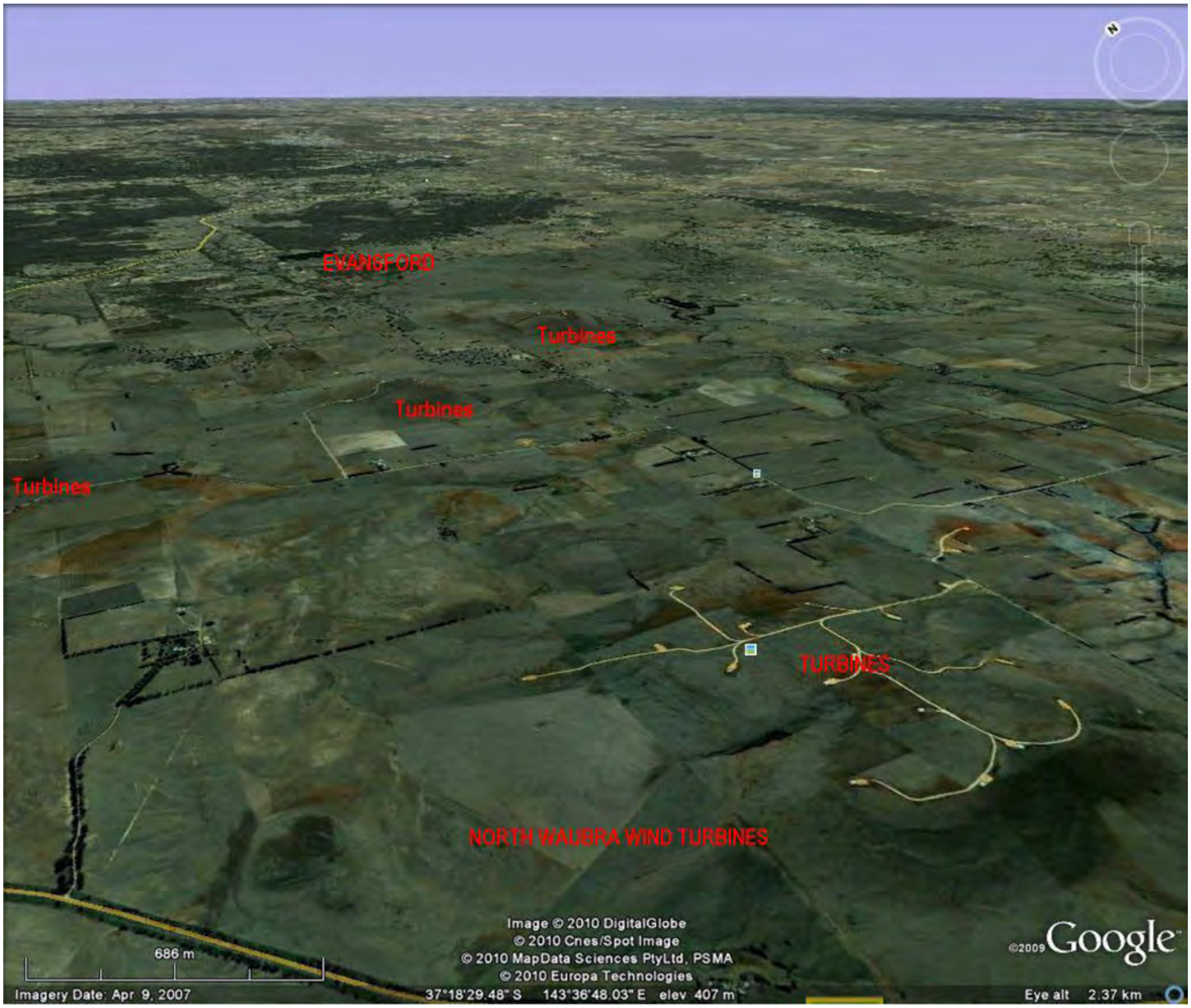

Plate W2. North Waubra locale, residents and the Waubra wind farm

the turbines' mast at 40 meters above ground is shown in Figure WW1. The measured wind directions are given to illustrate the importance of accurate wind data in predicting or assessing complaints.

The Effects on People Living Near the "Te Rere Hau" Wind Farm, New Zealand. In the period from May 2009 to March 31, 2010, a total of 378 complaints about noise were made to Palmerston North City Council, New Zealand, concerning the Te Rere Hau wind farm. The complaints were made by persons within approximately 2,300 meters south, 3,100 meters southwest, and 2,100 meters to the north of the center of the "97"-turbine wind farm. Complaints concerned both the loudness and character (grinding, swishing) of the sound from the turbines, a two-blade 500 kW design.

The Te Rere Hau wind farm complaints are important as they reflect the concerns of a rural community with relatively few people living within 3,500 meters of the center of the wind farm. Te Rere Hau is a densely packed design with wind turbines arranged in a grid pattern. In the 10 months for which records have been seen, 21 different residents complained about noise, with 2 residents logging more than 40 complaints each and a further 8 logging more than 10 complaints each. This indicates issues with wind farm placement and design that can be mitigated by careful consideration of turbine choice, turbine siting design, and

Table WW1. West Wind Perception and Complaint Analysis Till November 2009

Locale	Distance	Effects of Noise
1	1,200-1,300	Kept awake with turbine noise pulsing in bedroom. Sleep disturbance. Sounds not masked by wind in trees or stream.
2	1,200-1,300	Possible to hear and feel the turbines (20 of them) over usual household noises during the day and evenings. At night disturbs sleep patterns and affects health and well-being. Can hear the noise through the bed pillow. Sounds like a tumble dryer.
2	1,200-1,300	Can hear the turbines inside and outside the house during the day and at night. Disturbs sleep and affects health (tiredness). Family is stressed.
3	1,700	Sound is a rhythmic humming heard inside and outside the house during the day and at night. Northwest wind brings noise, southerly does not. Noise is highest when it is calm at the house but windy at the turbines. Turbines audible inside the home with TV on. Noise is a low hum.
4	1,750	When the wind is from the north to northwest the noise penetrates into the home. Persistent deep rumbling around 1-second interval and lasts for 10 to 20 seconds and then abates. Awakens and disturbs sleep. Generates annoyance and irritability.
4	1,700	Disturbs sleep. Turbines are heard when it is calm at the house and windy at the turbines. Annoyance, nausea, earaches, and stress.
5	2,100	Turbines audible in bedroom. Awaken and disturbs sleep. Creates pressure in head and headache. Feeling tired and distressed.
6	2,000	Northwest wind brings noise and disturbs sleep.
7	1,250	Northwest sound is constant thumping, pulsing. Cannot stand being in the house or around the property, sick feeling, headaches, tight chest. Can be heard at night cannot sleep, get agitated, and wound-up. Has ruined peace and tranquility.
7	1,250	Northwest wind, mild to wild, sound is constant thrumming. Noise is intensified in the house and more noticeable at night. Feeling of nausea precludes sleep. Disturbed and sleepless nights.
8	1,500-2,000	Turbine noise heard within the home. Severe sleep deprivation from interrupted sleep and lack of sleep. Fear of causing an accident on the farm due to lack of sleep. Noise at night is a southerly with a grinding rumbling sound. Noise from the northwest grinding a "plane takeoff" noise. Lot of ringing in ears. Easily heard above the background noise. Depression due to noise at night and lack of sleep.
9	750	Noise from the southerly winds rumbling, grinding all day and night. Trouble sleeping.
10	2,200	Regular sleep disturbance, sound like a plane. Louder inside the home than outside. Northwest wind thumping or rumbling sound, noise and vibration in the home (double glazed). Headaches. Low-frequency humming. Awakenings and sleep deprivation.

Note. "Distance" is the distance in meters between the locale and the nearest turbines. Each locale contains one or more affected families.

consideration of neighbors and long-term meteorological conditions. Plate TRH1 presents the impact of the wind farm on nearby residences. The number of complaints lodged by the residents is indicated in the plate. Table TRH1, for a single residence, illustrates the common thread of the noise problems found and the relationship to weather conditions. The residence is approximately 1,200 meters from the nearest row of wind turbines. The position of the wind farm on a plateau above the residences is illustrated in Plate TRH2. The measured wind directions are given in Plate TRH3 and illustrate the importance of accurate wind data in predicting or assessing complaints. The complaint numbers are very high for wind farms that supposedly are complying with their approval conditions. While the background levels may be achieved and this has yet to be proven, the wind farms are a significant source of unreasonable noise. The number and history of the complaints emphasizes the importance of buffer zones and wind farm design so noise can be mitigated by careful consideration of turbine choice, turbine placement, consideration of neighbors, and long-term meteorological conditions.

Real-World Noise Compliance Problem at a Wind Farm

The Te Rere Hau wind farm in New Zealand is presently the subject of a legal review of its compliance and the methodologies applied to measure background sound levels and compliance levels (*PNCC v. NZ Windfarms*, 2010). In brief, it is understood that specific issues raised are the following:

- The Te Rere Hau wind farm is being operated at levels higher than those predicted in the (wind farm) application
- The respondent has substantially underestimated the effects of the wind farm noise on the amenity of the area
- The AEE concluded noise from the wind farm would not exhibit special audible characteristics (i.e., clearly audible tones, impulses, or modulation of sound levels). This conclusion is inaccurate [reasons given]

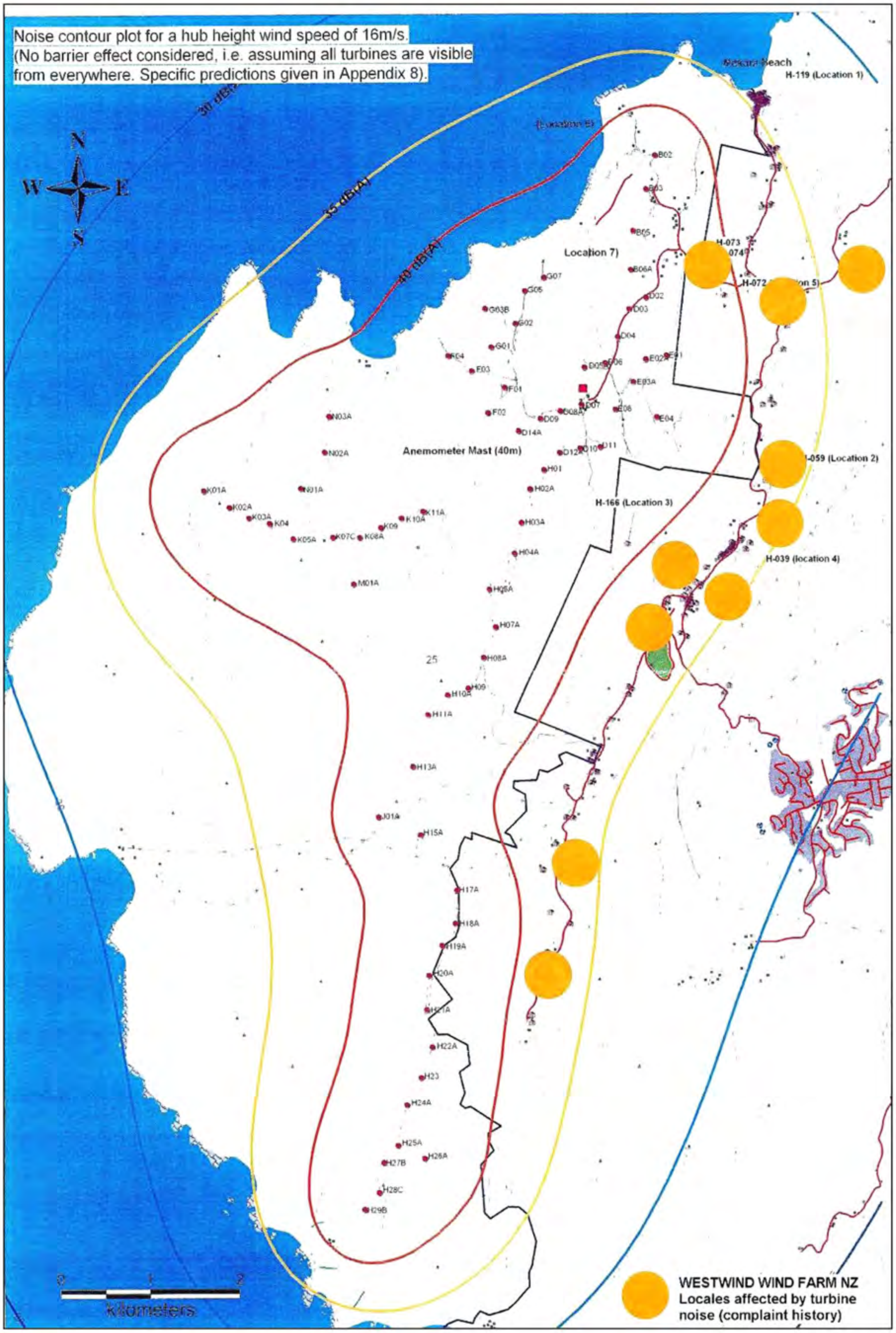

Plate WW1. Locales in Makara affected by "West Wind" wind farm turbine noise

Plate WW2. Makara Valley residents and the "West Wind" wind farm
Note. The turbines (marked in red) are situated on the top of the range and the residents are in the valley (Makara Village and blue squares)

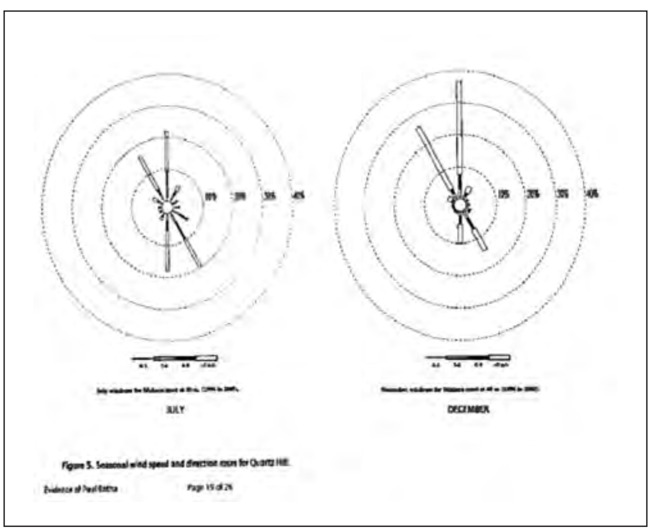

Plate WW1. Prevailing winds for Makara at the wind farm mast (40 meters)

- The actual experience of residents (located up to 2.18 km from the nearest turbines) and the number of complaints made to the Council indicating there are noise effects (which also exhibit special audible characteristics) being experienced at a significant number of local properties
- The actual results reported in the revised compliance report (April 2010) demonstrate the actual sound levels from the wind farm are significantly higher (up to 12.8 dBA higher) at the monitoring location under certain wind speeds and directions than predicted
- While monitored noise included noise from all sounds in the area (not just wind farm noise), the uncertainty as to the actual wind farm noise levels warrants further investigation. A new noise testing specification is the subject of the memorandum of December 21, 2010.

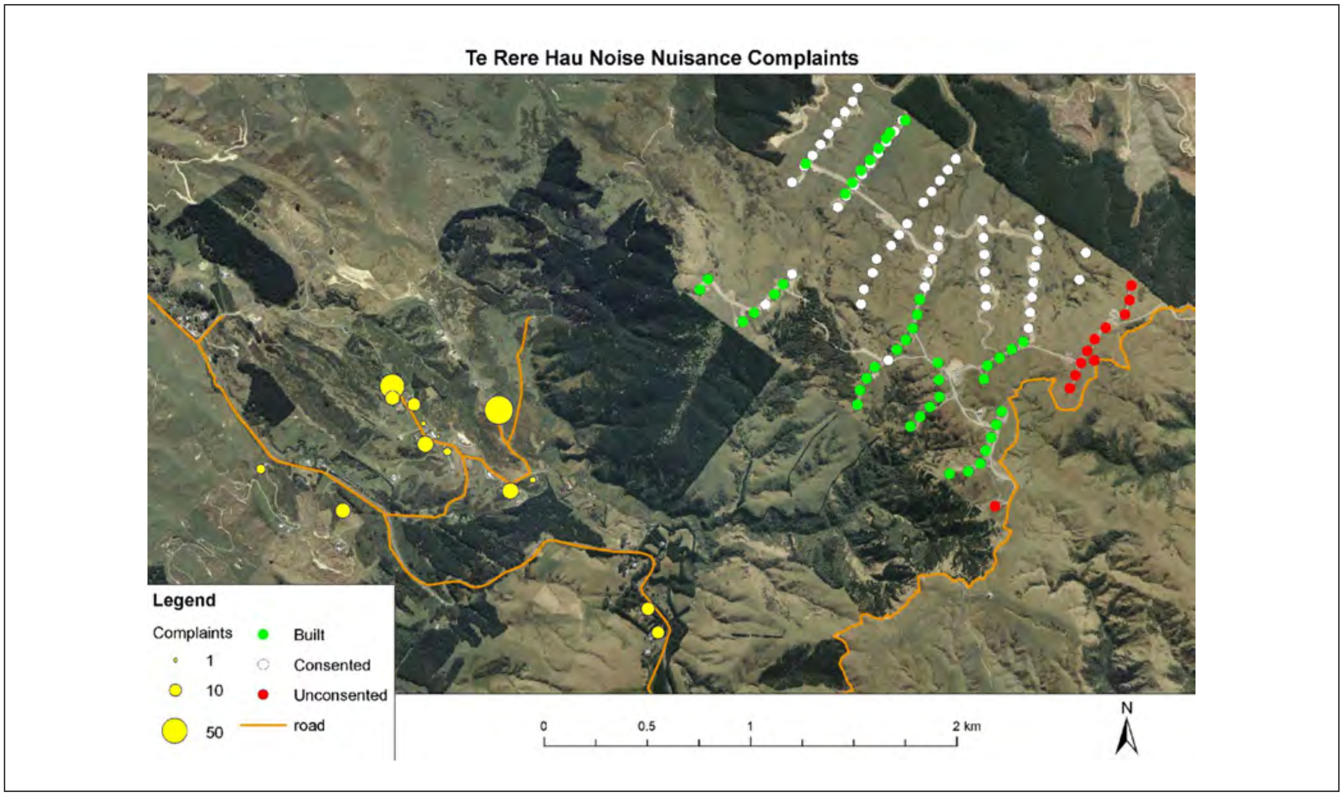

Plate TRH1. Te Rere Hau wind farm complaints by location

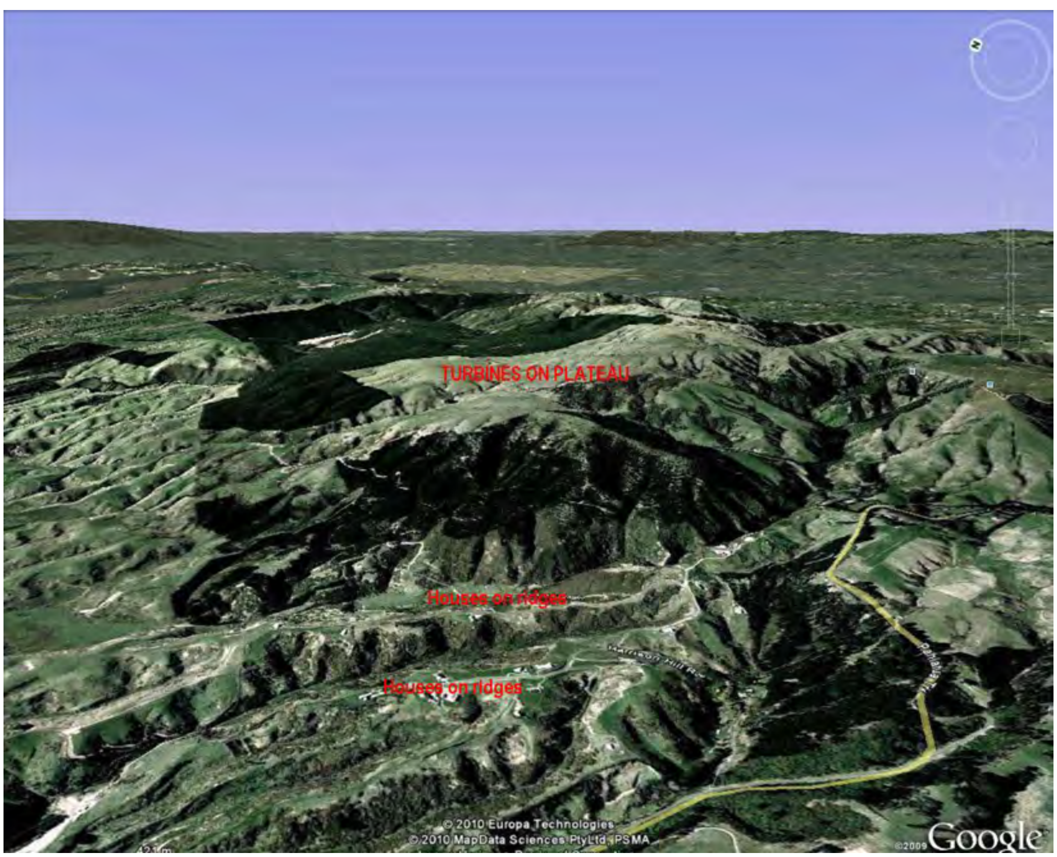

Plate TRH2. Te Rere Hau wind farm in relation to residences

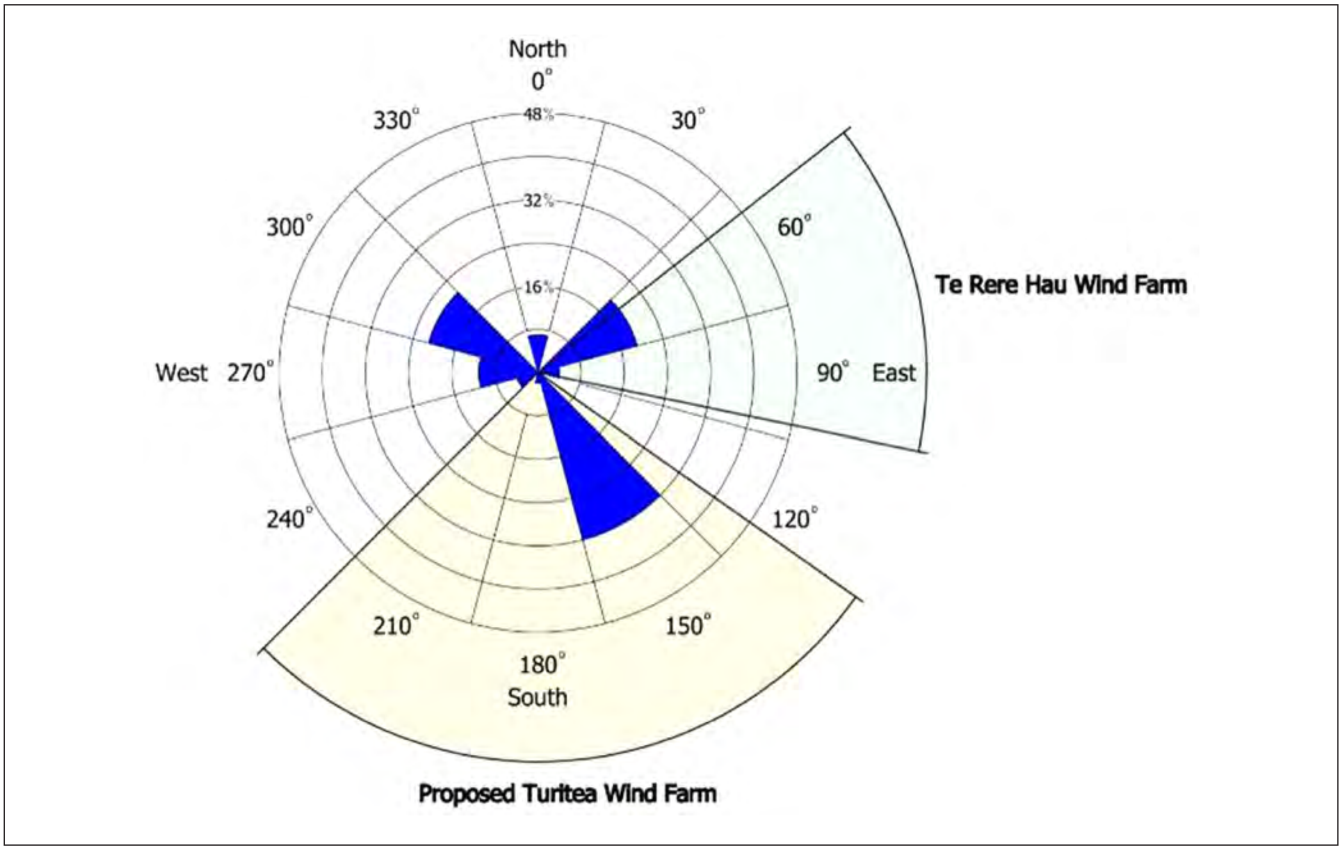

Figure TRH1. Wind Rose for May to September 2009 illustrating existing wind farm (Te Rere Hau) and effect from a proposed wind farm (Turitea) to the south

Conclusions

Personal perception of a sound is investigated through assessment of personal noise sensitivity, personal perception of the characteristics of the sound, and observable adverse health effects. Noise includes vibration in any form that can be "felt" by a person. There is, despite the differences in opinion as to cause, considerable agreement between the parties—residents, clinicians, and acousticians—as to observable health effects from unwanted sound. There are clear and definable markers for adverse health effects before and after the establishment of a wind farm and clear and agreed health effects due to stress after a wind farm has started operation. It is the mechanism of the physical or mental process from one to the other that is not yet defined or agreed between affected persons, clinicians, and psychoacousticians.

- It is concluded that, for the reasons given in this article, compliance criteria of a single value, such as 35 dB(A) measured as the equivalent level, LAeq; 40 dB(A) measured as the background level, LA95; or the "background plus 5dB" sound level, whichever is the greater are not acceptable. This is due to the general failure of approval conditions to provide clear and specific methodologies to measure wind farm sound under compliance testing conditions or under complaint conditions when turbine sound is part of the ambient sound.
- It is concluded that wind farms exhibit special audible characteristics that can be described as modulating sound, impulsiveness, or as a tonal complex. Compliance monitoring must include real-time measurement of special audible characteristics and infrasound.
- It is concluded that frequent short-term variations in air pressure (infrasound) may lead to adverse health effects in individuals.
- It is concluded that meteorological conditions, wind turbine spacing, and associated wake and turbulence effects, vortex effects, wind shear, turbine synchronicity, tower height, blade length, and power settings all contribute to sound levels heard or perceived at residences. Current noise prediction models are simplistic, have a high degree of uncertainty, and do not make allowance for these significant variables.
- It is concluded that noise numbers and sound character analyses are meaningless if they are not firmly linked to human perception and risk of adverse effects.

Table TRH1. Te Rere Hau Noise Complaints, August 2009 to February 2010, Single Residence

Date and Time	Wind Direction	Complaint
07/08/09, 5.45 p.m.		Noise from wind farm
20/08/09 6.55 a.m.	South-southeast	Wind farm loud this morning
20/08/09, 8.45 a.m.	South-southeast	Loud wind mills at 5.00a.m.
21/08/09, 6.32 a.m.	East	Wind farm noise
22/08/09, 12.51 p.m.	East	Medium strength, swooshing, and grinding, only ½ on
29/08/09, 8.45 a.m.	West	Very loud again today
15/09/09, 6.31 p.m.	East	Loud noise coming from wind farm
11/05/09, 10.48 a.m.	West	Light wind, wind farm extremely loud
21/11/09, 5.42 a.m.	West	WF too loud
05/08/09, 7.02 a.m.		Noise from Te Rere Hau this morning
09/08/09, 6.02 p.m.		Excessive noise Te Rere Hau
11/08/09, 1.03 p.m.		Windmills beeping noise every 2 minutes
04/09/09, 8.05 a.m.	East	Continuous noise last half hour
09/09/09, 11.24 a.m.	West	Started turbines 103 and 104, now noisy
11/09/09, 6.21 a.m.	North	Light northerly, noise since he got up
19/09/09, 10.49 a.m.	South	Very noisy again today
20/09/09, 8.13 a.m.	East	Loud noise
28/09/09, 7.15 a.m.	Northeast	Wind farm noise
07/10/09, 5.32 p.m.	West	Light wind, loud noise from wind farm
08/10/09, 7.42 a.m.	West	Light wind, swooshing noise this morning
09/10/09, 7.02 a.m.	Northeast	Light wind, wind farm really loud this morning
10/10/09, 9.59 a.m.	South	Light wind, would like to complain about noise
12/10/09, 7.48 a.m.	North	Light wind loud noise from wind farm
20/10/09, 3.53 p.m.	South	Loud noise at wind farm
08/11/09, 9.36 a.m.		Still, noise today
16/11/09, 7.25 a.m.	West	Lots of noise coming from wind farm this morning
17/11/09, 6.27 p.m.	West	Light wind, very loud tonight
20/11/09, 7.22 a.m.	West	Noise complaint
22/11/09, 7.16 p.m.	East	Light wind, wind farm very noisy
04/12/09, 6.18 a.m.	West	Noisy this morning
07/12/09 6.21 p.m.	West	Loud wind farm
09/12/09, 6.50 a.m.	West	Light wind, droning noise
15/12/09, 7.28 a.m.	South	Noisy wind turbines
19/12/09, 7.04 p.m.	West	Light wind noise from turbines over days whirring
25/12/09 8.59 a.m.	West	Light westerly, very loud today
16/01/10, 9.09 a.m.		Noise
17/01/10, 7.44 a.m.	South	Light-medium southerly wind farm quite loud today
17/01/10, 6.58 p.m.	South	Southerly wind, wind mill noise
18/01/10, 7.26 a.m.	Southeast	Medium wind, wind turbine noise last hour
18/01/10, 6.45 p.m.	East	Noise very bad
18/01/10, 10.54 p.m.	Southeast	Extremely loud
19/01/10, 7.28 p.m.	West	Turbines causing a lot of noise tonight
21/01/10, 8.21 p.m.	East	Loud noise from the turbines
25/01/10, 4.43 p.m.	East	Wind mill noise
26/01/10 8.12 a.m.	East	Medium wind, wind turbines making a lot of noise
28/01/10, 7.27 p.m.	East	Light wind, turbines are noisy again this evening
29/01/10, 10.21 a.m.	East	Loud noise from blades and mechanical noise
29/01/10, 6.12 p.m.	East	Med wind same noise as usual coming from turbines
02/02/10, 6.51 p.m.	East	Loud noise from wind farm
03/02/10, 7.19 p.m.	East	Noise from wind farm
04/02/10 7.01 a.m.	East	Noise loud this morning
05/02/10, 6.22 a.m.	East	Light, loud today
05/02/10, 5.57 p.m.	East	Light wind, same whirring gearbox noise as usual
07/02/10, 12.49 p.m.	Northwest	Excessive noise
08/02/10, 6.58 a.m.		Wind farm very loud this morning
08/02/10, 8.16 p.m.	East	Light wind
10/02/10, 7.11 a.m.	North	Te Rere Hau noisy this morning
15/02/10, 8.14 p.m.	East	Medium wind
16/02/10, 7.50 a.m.	East	Turbine noise in east direction at least hour

- It is concluded that no large-scale wind turbine should be installed within 2,000 meters of any dwelling or noise-sensitive place unless with the approval of the landowner.
- It is concluded that no large-scale wind turbine should be operated within 3,500 meters of any dwelling or noise-sensitive place unless the operator of the proposed wind farm energy facility, at its own expense, mitigates any noise within the dwelling or noise-sensitive place identified as being from that proposed wind farm energy facility to a level determined subject to the final approval of the occupier of that dwelling or noise-sensitive place.

In my opinion, based on my training, experience, measurements, and observations, serious harm to health occurs when a susceptible individual is so beset by the noise in question that he or she suffers recurring sleep disturbance, anxiety, and stress. The markers for this are (a) a sound level of LAeq 32dB outside the residence and (b) above the individual's threshold of hearing inside the home.

Declaration of Conflicting Interests

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Toward a Case Definition of Adverse Health Effects in the Environs of Industrial Wind Turbines: Facilitating a Clinical Diagnosis

Robert Y. McMurtry[1]

Abstract

Internationally, there are reports of adverse health effects (AHE) in the environs of industrial wind turbines (IWT). There was multidisciplinary confirmation of the key characteristics of the AHE at the first international symposium on AHE/IWT. The symptoms being reported are consistent internationally and are characterized by crossover findings or a predictable appearance of signs and symptoms present with exposure to IWT sound energy and amelioration when the exposure ceases. There is also a revealed preference of victims to seek restoration away from their homes. This article identifies the need to create a case definition to establish a clinical diagnosis. A case definition is proposed that identifies the sine qua non diagnostic criteria for a diagnosis of adverse health effects in the environs of industrial wind turbines. Possible, probable, and confirmed diagnoses are detailed. The goal is to foster the adoption of a common case definition that will facilitate future research efforts.

Keywords

case definition, clinical diagnosis, wind turbines, adverse health effects, symptoms

Introduction

On the last 3 days of October 2010, a groundbreaking meeting was held in the Waring House situated in Prince Edward County, Ontario (Society for Wind Vigilance, 2010). The focus of the symposium was the emerging issue of adverse health effects (AHEs) being experienced by people living in the environs of industrial wind turbines (IWTs).

These health effects appear to correlate with proximity to IWTs, the sound pressure level emitted by the IWTs, the frequency of the noise, the time of exposure, and individual response. The pattern of individuals' complaints demonstrates a striking similarity internationally in media reports and in physician-generated case series.

The issue of AHEs is of considerable complexity and has excited much controversy between proponents of the wind industry and those who have identified widespread media and Internet reports of AHEs in virtually all countries where IWTs have been erected (Gray, 2010; Jopson, 2010; Lam, 2009; Turkel, 2010).

The IWT proponents claim IWTs to be a promising green, clean, and free alternative source of electrical power and an ideal solution for reducing green house gases (Canadian Wind Energy Association, 2011; Nextera Energy Resources, 2010). Those who are concerned about IWT development too close to residences and who seek to prevent AHEs have a contrary view denying the foregoing claims and questioning the utility and safety of IWTs (Bryce, 2010; Gilligan, 2010).

This article will concentrate on the health aspects and the challenge of a case definition, leaving aside the debate surrounding economics, energy policy, lobbying, and social marketing, although all have a significant impact on government decision making.

Overview of Conference and Speakers

The purpose of the symposium was to promote a multidisciplinary dialogue on possible AHEs in an effort to advance the understanding of the genesis of complaints appearing globally. Among the goals of the symposium was a need to develop a case definition, which had been under discussion since June 2010.

The symposium attracted a multidisciplinary international group of speakers (14), including the disciplines of medicine (four specialties), acoustics, psychology, business, physics,

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epidemiology, policy analysts, pharmacy, law, statistics, and media (Society for Wind Vigilance, 2010). There was also an informal research meeting of the speakers joined by two family physicians and an occupational health physician where a debriefing of the symposium was held and future plans for research made.

Approximately 100 people attended the symposium including municipal and federal politicians, media, documentary filmmakers, as well as two members of a leading consulting group for the industry and two representatives from a wind power developer. There was a notable absence of any representatives from the Ontario provincial government.

Brief Summary of Presentations

The descriptions of the presentations below are highly abbreviated. The reader is referred to the Society for Wind Vigilance's website for more details.

Physics of IWTs and the resultant sound pressure level (SPL) are not adequately or consistently regulated. Based on experience with other noise sources, SPL clearly presents a health risk (Harrison, 2010; James, 2010; Walsh, 2010).

The human ear is perturbed by IWTs in quiet rural areas, potentially leading to neural remodeling and disorganization of neural pathways. It is more likely than not that the symptoms and signs associated with wind turbine syndrome are due to the sound energy emitted by IWTs. Low-frequency noise and infrasound will more likely than not be shown in subsequent research to be playing a major role in the genesis of wind turbine syndrome (Pierpont, 2010).

The outer hair cells of the cochlea respond to low frequency and infrasound. Sonic energy that is inaudible is perceived though not necessarily heard (except in sensitive people). What cannot be heard therefore may produce AHEs. This statement was made by Dr. Alex Salt, referring to his research using the standard animal model (guinea pig) for the study of human hearing (Salt, 2010).

Noise and infrasound during the day are capable of causing mood disorder, cognitive dysfunction, and learning and developmental problems in children. Stress and psychological distress are established findings of chronic exposure to noise. Chronic stress has serious physiological consequences (Bronzaft, 2010).

Nighttime noise compromises restorative sleep. Restorative sleep is a necessary condition for maintaining health and well-being. Chronic sleep disturbances (increased arousals and awakenings) and/or deprivation are established AHEs known to substantially increase the risk for chronic disease and premature death (Hanning, 2010).

Control studies comparing populations living near and far from IWT installations demonstrate a substantial and statistically significant difference in quality of life, mood disorders, and sleep disruption (Nissenbaum, 2010).

More than a hundred people in Ontario have self-identified as having AHEs using the Canada Vigilance protocol. AHEs with a very wide range of complaints were made, of which the most frequent are compromise of quality of life, sleep disruption, some living in the environs of IWTs leaving their homes temporarily or permanently in order to restore their health (Krogh, 2010). While some improvement in health status is achieved, follow-up has revealed that preexposure health status is not necessarily regained.

These findings are significant from a public health perspective for many reasons, including the findings the crossover and revealed preference in the WindVOiCe survey (Krogh et al., 2011). Crossover refers to the phenomenon of exacerbation and amelioration when near and far from wind farms, respectively. Revealed preference describes the act of leaving one's accustomed residence permanently or temporarily for significant periods of time in order to achieve restoration.

Legally there is evidence that the precautionary principle has not been respected by the governments who regulate and approve IWT installations in the absence of medical or health evidence establishing their safety (Gillespie, 2010). There is an urgent need to pursue research establishing dose-response curves as well as clinical research regarding psychological and physiological consequences (Bronzaft, 2010; Hanning, 2010).

There was a clear consensus among the foregoing presentations and from a wide variety of perspectives that AHEs are indeed occurring in relationship to people living in the environs of IWTs. In addition, an emerging consensus was evolving regarding a case definition that could be deployed by experts representing the many diverse disciplines in attendance. The importance of unifying the case definition for the purposes of research and future communications was clear.

Audience Response

The symposium featured a learned and diverse group of speakers as noted above. Attendees were able to witness and participate in a successful event of transdisciplinarity. Regardless of discipline, a unity of perspective was achieved. AHEs are clearly an issue for people living in the environs of wind farms. While the precise mechanism for the cause of AHEs remains to be elucidated, there is enough evidence to conclude IWTs represent a public health threat. Audience members were also highly supportive of a unified case definition.

Summary

The common denominator of the global reports of AHEs is the compromise of quality of life, restorative sleep, and psychological well-being.

There are many reports of AHEs in the environs of IWTs, including several case series (Harry, 2007). Unfortunately, no standard protocol for data gathering has been developed. This has lead to a wide variety of symptoms being reported and documented. This variance is exacerbated by the nonspecific nature of the complaints since the recorded symptomatology can arise from a wide variety of ailments and diseases.

The task of a case definition is to weight the unique elements of AHE/IWT to distinguish the clinical disorder from competing explanations. There are common themes found in the reports that are reflected in the first- and second-order criteria. There are few, if any, alternate explanations for the first- and second-order criteria other than AHE/IWT.

The third-order criteria serve the purpose of capturing the most commonly reported symptoms.

It is hoped that future reports will adopt a standardized protocol based on this case definition, which would facilitate future research and management of AHE/IWT.

Case Definition

The criteria for making an individual diagnosis of probable AHEs in the environs of IWTs are presented in the following paragraphs. The definition endeavors to be specific and sensitive. While the definition has not been validated formally in practice, it has proven useful. The case definition represents an important starting point for future international research collaboration. The genesis of the definition is based on a review of the literature and direct experience with those individuals experiencing AHE/IWT. It has been used to provide guidance to physicians and other primary health providers when they are asked to manage individuals following exposure to IWTs. The value of this proposal is based on the absence of a specific case definition either in the peer-reviewed or gray literature.

Diagnosis of Adverse Health Effects in the Environs of Industrial Wind Turbines

Possible adverse health effects. Report of a change in health status by people living within 5 km of a wind farm installation. Further confirmation is required to validate or exclude AHE/IWT by establishing a medical history that satisfies the criteria identified under "Probable Adverse Health Effects" below.

Probable adverse health effects.

1. First-order criteria (all four of the following must be present):
   (a) Domicile within 5 km of industrial wind turbines (IWT)
   (b) Altered health status following the start-up of, or initial exposure to, and during the operation of, IWTs. There may be a latent period of up to 6 months
   (c) Amelioration of symptoms when more than 5 km from the environs of IWTs
   (d) Recurrence of symptoms upon return to environs of IWTs within 5 km
2. Second-order criteria (at least three of the following occur or worsen after the initiation of operation of IWT):
   (a) Compromise of quality of life
   (b) Continuing sleep disruption, difficulty initiating sleep, and/or difficulty with sleep disruption
   (c) Annoyance producing increased levels of stress and/or psychological distress
   (d) Preference to leave residence temporarily or permanently for sleep restoration or well-being
3. Third-order criteria (at least three of the following occur or worsen following the initiation of IWTs):
   (i) Otological and vestibular
      (a) Tinnitus
      (b) Dizziness
      (c) Difficulties with balance
      (d) Ear ache
      (e) Nausea
   (ii) Cognitive
      (a) Difficulty in concentrating
      (b) Problems with recall or difficulties with remembering significant information
   (iii) Cardiovascular
      (a) Hypertension
      (b) Palpitations
      (c) Enlarged heart (cardiomegaly)
   (iv) Psychological
      (a) Mood disorder, that is, depression, anxiety
      (b) Frustration
      (c) Feelings of distress
      (d) Anger
   (v) Regulatory disorders
      (a) Difficulty in diabetes control
      (b) Onset of thyroid disorders or difficulty controlling hypo- or hyperthyroidism
   (vi) Systemic
      (a) Fatigue
      (b) Sleepiness

Confirmed adverse health effects. The confirmation of AHE/IWT is achieved by a clinical evaluation and physiological monitoring of individuals during exposure to IWT sonic energy or an accurate facsimile (recording or other imitative source of IWT sound). Ideally, sleep studies should be carried out in the home of people experiencing AHEs. The complex physiological monitoring equipment required for a sleep study is not readily made mobile. Accordingly, sleep studies need to be carried out in an established clinical sleep laboratory with a source of sonic energy that accurately reflects the person's exposure to IWTs.

The process may be simpler once controlled studies comparing possible victims with a nonexposed matched population are carried out. These studies could help determine the core physiological change(s) that is (are) likely occurring to those who live in the environs of IWTs.

The need to rule out alternate explanations is the responsibility of the licensed clinician. While adherence to the criteria has resulted in no false positive diagnosis to date further validation is required.

Differential Diagnosis

Consideration should be given to other stressors present in the community. The most obvious is the wind itself, which when associated with substantial barometric changes is known to cause a variety of symptoms. In this case, the onset of AHEs would not correlate with the establishment of a wind farm nor would the AHEs improve when leaving the environs of a wind farm.

A second possibility is a stressful home environment, which might lead to restoration being more likely away from home. A history for family stressors should be elicited and ruled in or out. Another distinguishing feature is the absence of correlation with IWTs starting up or being in operation.

Psychological issues and/or mood disorders may be simultaneously or independently present. A key differentiating point is the timing of the onset and the impact of being away from home and the environs of IWTs. Significant improvement away from the environs of wind turbines and revealed preference for sleeping away from home serve to distinguish between AHEs due to IWTs versus an independent cause. If the situation appears more complex then a referral to a clinical psychologist or psychiatrist might be considered.

Apart from the foregoing, there are very few if any imitative AHEs that can meet the three orders of criteria outlined above. However, the author invites critical commentary that might indicate a different conclusion.

Conclusions

1. A multidisciplinary symposium was held to address the possibility of adverse health effects in the environs of industrial wind turbines.
2. There was a consensus (unanimity) among the various experts that more likely than not, adverse health effects are occurring in the environs of industrial wind farms.
3. A case definition for adverse health effects in the environs of industrial wind turbines has been proposed based on the best available evidence. To date it has proven useful in clinical practice.
4. Further research is required to refine and validate the proposed definition and identify the simplest method by which to diagnose a confirmed case.

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Bio

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Mitigating the Acoustic Impacts of Modern Technologies: Acoustic, Health, and Psychosocial Factors Informing Wind Farm Placement

Daniel Shepherd[1] and Rex Billington[1]

Abstract

Wind turbine noise is annoying and has been linked to increased levels of psychological distress, stress, difficulty falling asleep, and sleep interruption. For these reasons, there is a need for competently designed noise standards to safeguard community health and well-being. The authors identify key considerations for the development of wind turbine noise standards, which emphasize a more social and humanistic approach to the assessment of new energy technologies in society.

Keywords

wind turbines, community noise, noise standards, health, sense of place

Introduction

The relationship between individuals or groups and their environment can be assessed from one or more perspectives. One approach is environmental psychology, which examines the effect of environmental parameters on the environment's inhabitants. Typically, the sorts of parameters scrutinized are those that are problematic in some way, and which adversely affect the well-being of those individuals found residing or operating within the confines of the environment. One example of a commonly cited environmental problem is noise (Proshansky, 1987), which traditionally has been judged more of a problem in high-density urban areas than rural or semirural (e.g., greenbelt) areas. In the past decade, a new source of noise has emerged in many rural and semirural areas across the world, noise associated with the operation of wind turbines.

Though considered a "green" source of renewable energy, wind turbines have their own environmental and social impacts and need to be sited with care and consideration in relation to the communities hosting them. Communities opposed to wind turbines argue that their health, amenity, and sense of place are compromised by turbine noise and visual impacts. Wind energy proponents argue that wind turbines provide communities with environment-friendly energy and economic opportunities. In between are the authorities overseeing the consent and compliance processes. There has been considerable public and academic debate over whether wind turbine noise poses a significant health threat to those living in their vicinity. It has been suggested that wind turbines can directly affect health via the emission of low-frequency sound energy (including infrasound), though this is currently an area of controversy (Pierpont, 2009; Salt & Timothy, 2010). Additionally, wind turbines may compromise health by producing sound that is annoying and/or can disrupt sleep. In this respect, turbine noise can be classified as community noise alongside industrial and transportation noise. When erected in rural settings, the visual impact of turbines can interact with turbine noise to exacerbate annoyance reactions (E. Pedersen & Persson Waye, 2004) and potentially reduce amenity (Pheasant, Fisher, Watts, Whitaker, & Horoshenkov, 2010).

Noise, as a social problem, is determined by a number of factors, some of which interact, some of which are acoustically related, and others which are not. This makes it very difficult to predict both individual and group responses to noise, which in turn hampers the development of noise standards. Factors influencing social reactivity to noise include the physical characteristics of the noise itself, the characteristics of the environment exposed to the noise (e.g., rural vs. suburban vs. urban), the type of human activities that the noise interferes with (e.g., rest, recreation, sleep, work), and the traits of the exposed individuals. The notion that living in the vicinity of a busy road, an airport, or a cluster of wind turbines can degrade health is, for some, a ridiculous proposition. For others, the invasion of their personal spaces by intrusive noise constitutes

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an abuse that severely degrades general health and well-being. This variability in response at the human level renders noise level an inadequate metric with which to safeguard community health, and in fact subjective evaluations of noise (e.g., intrusive, unnecessary) constitute a better predictor of aversive response than the noise itself (Flindell & Stallen, 1999). However, the inclusion of the human and social sides of the equation into noise guidelines remains an ongoing challenge (Maris, Stallen, Vermunt, & Steensma, 2007), and this criticism extends to noise standards that have "arguably" been developed to protect society from wind turbine noise. In this monograph, we list a number of points relevant to the placement of wind turbines near inhabited areas. The first cluster of points (Points 1 to 14) is general in nature, whereas the second cluster (Points 15 to 20) relates specifically to noise standards.

1. Wind Turbines Emit Noise

Noise is an unwanted sound that is judged undesirable, irritating, discordant with ones expectations, and/or that interferes with wanted sounds. Annoying or intrusive sound emanating from road, wind turbines, rail and air traffic, industries, construction and public works, or the neighborhood is known as community noise. Community noise is classified by the World Health Organization (WHO; 2011) as a common pollutant and health threat. Whether sited in isolation or in clusters, wind turbines produce audible sound to those living in their close vicinity. What distance defines "close vicinity" has yet to be determined, though Di Napoli (2011) reports that amplitude-modulated turbine noise can be heard up to 4 kilometers away from the source. Irrespective of distance, however, if the sound annoys, or disturbs the sleep of an individual, then the turbine(s) can be classified as noise generator(s).

People respond more negatively to man-made noise than natural noise (Nosulenko, 1990; E. Pedersen & Persson Waye, 2008), though some developers and supporters of wind energy claim that the sound emitted by wind turbines is congruent with natural habitats and is aesthetically pleasing. Sometimes developers and their contracted acousticians will compare wind turbine sounds to rustling leaves, flowing streams, or lapping waves. It follows then from these comparisons that turbine sounds cannot be considered noise in the formal sense as people generally do not find such sounds annoying or disruptive to sleep. In fact, the little research that has been undertaken on the sound properties of wind turbines concludes just the opposite (Pheasant et al., 2010; F. van den Berg, Pedersen, Bouma, & Bakker, 2008). Therefore, it must be acknowledged that wind turbines have the capacity to emit noise.

2. Spectrum Analyzers and Noise-Level Meters Do Not Mimic Human Hearing

Some acousticians mistakenly believe that if a band of acoustic frequencies are not represented in physical measurements of acoustic energy (e.g., on a spectrograph), then those frequencies cannot be perceived. However, for humans hearing is the most acute sense, and in controlled conditions a person with normal hearing can detect vibrations with an amplitude of less than half a nanometer: approximately one tenth the diameter of the hydrogen atom (Green, 1976). The range of sounds a properly functioning human ear can detect is likewise impressive, ranging from the smallest perceptible amplitude to amplitudes that are 10,000,000,000,000 times greater. Pertinently, our hearing processes are finely tuned to extract correlated patterns of acoustic activity from background noise and can far outperform any current technological devices claiming to perform the same function. Thus, wind turbine noise may be audible to a human even when the noise itself is lower than the ambient noise level (R. H. Pedersen, Von-Hunerbein, & Legarth, 2011; Siponen, 2011) and beyond the resolving power of modern equipment. Therefore, the limits of sound measurement apparatus relative to those of the human auditory system need to be acknowledged when judging acceptable limits of exposure to wind turbine noise.

3. The Subjective Nature of Noise

It has long been recognized that what is, and what is not, noise is highly subjective, and one person's noise can be another's music. Thus, noise pollution must be viewed as comparative to a certain extent, with substantial individual differences existing in relation to personal perception, sleep disturbance, annoyance, social context, and perceived control. As with other noise sources, we should expect individual variation with regard to the effects of wind turbine noise. However, it is a fallacy to argue that because only some suffer adverse effects while others do not, those who claim to be suffering effects must be "making them up." In the field of epidemiology, the differential susceptibilities of individuals are known as risk factors, and assuming that individuals of a population can be represented by the average characteristics of the population is known as the ecological inference fallacy. Although the WHO does acknowledge the existence of vulnerable groups, the noise levels presented in its Night Noise Guidelines for Europe (WHO, 2009) nevertheless rest on aggregate data that for the most part do not distinguish vulnerable from non-vulnerable groups. Such an approach, regrettably, constitutes an ecological inference fallacy.

Substantial individual differences are expected, and indeed found, when examining the effects of community noise on humans (Maris et al., 2007), including wind turbine noise (E. Pedersen & Persson Waye, 2008). Unfortunately, for policy makers there is no proportional relationship between annoyance or sleep disturbance and noise level, as these outcome factors will be influenced by characteristics associated with both the noise and the listener (Flindell & Stallen, 1999). Therefore, moderating factors, which include age, noise sensitivity, attitude, social context, coping styles, and mental health, need to be acknowledged and accounted for when judging the appropriateness of wind turbine sites close to residences.

4. Understand the Meaning of Health

Before considering any possible impact of wind turbine noise on health, an acceptable definition of health must be adopted. Such a task is not laborious however, as the WHO did precisely that during its formation in 1948. The WHO (1948) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

Thus, health refers not only to illness and "cuts-and-bruises" but also to well-being, quality of life, and amenity. In its 2008 World Health Report, the WHO recommitted itself to the concept of primary health care and acknowledged that good health exists not in the hospital but in society at large. At the social level, good health can be facilitated not only by the pursuit of healthy lifestyles (e.g., exercise and diet) but also by the provision of restful and restorative living environments (e.g., soundscapes). A prominent factor determining the restfulness of a living space is the level of privacy and intrusion by pollutants, including smell, air quality, and noise. In assessing the impacts of wind turbine noise, it is important to not only consider the potential of wind turbine noise to induce poor health but also its potential to compromise good health.

The health of a nation or group may be assessed using morbidity and mortality data and by using health status and health-related quality-of-life (HRQOL) data. The latter two approaches correlate highly with medical morbidity assessment, but instead of diagnosing particular symptoms or classifying health problems as the medical profession would, this approach has the value and advantage of examining factors that cause and/or result from a health disorder(s). These factors include physical health, psychological well-being, social support, and the environment. Such information is important both in the prevention and the treatment of health problems and in the assessment of treatment outcomes. It is now common practice in health research to incorporate measures of HRQOL, such that the U.S. Food and Drug Administration agency, for example, insists on such assessment in appraising all new pharmaceutical products (Glasgow & Emmons, 2007). Therefore, health status and HRQOL instruments would serve well to the studies of the effect of wind turbines on the health and well-being of nearby residents and in many ways are more practical and sensitive measures than those applied in medical appraisals.

5. Avoid the Argumentum Ad Ignorantiam

Wind turbines are a new source of community noise and as such their effects are only beginning to emerge in the literature. The recognition of a new disease, disorder, or threat to health usually follows a set pathway. First, doctors and practitioners attempt to fit symptoms into predefined diagnostic categories or else classify the complaints as psychosomatic. Second, as evidence accumulates, case studies begin to appear in the literature and exploratory research is undertaken to obtain better descriptions of the symptoms/complaints. Third, intensive research is undertaken examining the distribution and prevalence of those reporting symptoms, the factors correlating with the distribution and prevalence of those symptoms, and ultimately to cause-and-effect explanations as to why those reporting symptoms may be doing so.

Currently, the health and amenity impacts of wind turbines are only beginning to be elucidated and is caught somewhere between the first and second stages described above. Case studies (e.g., Harry, 2007; Krogh, Gillis, & Kowen, 2011; Pierpont, 2009) and correlational studies (e.g., E. Pedersen & Persson Waye, 2007; F. van den Berg et al., 2008) have already emerged in relation to the health effects of wind turbine noise, indicating that wind turbine noise, like traffic or aviation noise, has the potential to affect health and well-being. We can expect that, over the next decade, intensive research will be undertaken enabling more certain decisions to be made regarding wind turbine noise and health and the mechanisms that mediate the relationships between the two. Until that research is undertaken, however, an absence of data addressing cause-and-effect mechanisms does not equate to an absence of wind turbine noise impact (viz., *argumentum ad ignorantiam*).

6. Critically Interpret the Research

It is important to note that many studies reporting noise annoyance data are laboratory, as opposed to field, studies. If noise guidelines are informed by research predominantly undertaken in laboratories then they themselves lack ecological validity. That is, what is measured in a laboratory may not concord with measurements made in the actual environment. Additionally, older published data on wind turbine noise may involve turbines that are substantially fewer in number, smaller in size, and less noisy than modern wind turbine set ups, and so present findings that cannot be generalized to contemporary technology. Wind turbine noise research (actually nonsystematic literature reviews) has been conducted by industrial stakeholders in wind energy (e.g., Colby, 2009), which present results that likewise should be interpreted with caution. Wind turbine noise research, then, should be consulted with qualification and critique when considering wind turbine effects and not taken prima facie.

7. Determine Why Turbine Noise Is Especially Annoying

The characteristics of wind turbine noise have been well described from a social perspective (e.g., F. van den Berg et al., 2008, Table 7.23), either as a typical amplitude modulation (i.e., a 3-5 dB modulated "swish," audible in the near field) or an atypical amplitude modulation (i.e., >5 dB modulated "thump," audible in the far field). G. P. van den Berg (2004) shows that wind turbines produce noise with an impulsive character, and although the actual cause of the swishing or thumping has not yet been fully elucidated, it has been demonstrated that this swishing or thumping pattern is common with larger turbines (Stigwood, 2008) and may result from a fluctuating angle of attack between the trailing edge of the rotor blade and wind (Siponen, 2011). Furthermore, lower frequencies, which tend to be judged as more annoying than higher frequencies, become more salient during the transitions from swish to thump. In the far field, the less common two-bladed turbines, it should be noted, have a different noise profile characterized by an alternating thump without the swish.

Because wind is variable and not constant, wind turbine noise levels are also variable and inconsistent. Furthermore, the cyclic action of the turbine rotors serves to modulate noise level across time, producing a noise that can be perceived as repeating itself several times per second. This is unfortunate, as human senses act as contrast analyzers, responding to changes in sound rather than to the absolute level of the sound itself (Laming, 1986). Additionally, we are more sensitive to change in continuous noise (such as impulsive turbine noise) than to discrete auditory events (e.g., a passing car at night). Thus, wind variability will bring about noticeable changes in the level of turbine noise, irrespective of the aggregated level of that noise, and these changes in noise level due to wind speed fluctuations will make the noise more noticeable, especially so at night, when ambient sound levels reduce. Consequently, overall measures of sound level are not in themselves useful in predicting annoyance if those levels are dynamic (i.e., they change over time). In fact, the level of noise only explains 10% to 25% of an individual's response to noise (E. Pedersen & Persson Waye, 2008). When considering acoustical characteristics of turbine noise, however, overall noise level is usually chosen as the metric of importance whereas other aspects of the noise such as periodic amplitude modulation are ignored (Lundmark, 2011). Metrics describing the amplitude modulation characteristics of turbine noise, such as that proposed by T. H. Pedersen et al. (2011), should therefore be considered when judging the appropriateness of turbine placements.

8. Have Experts Working Within Their Field of Expertise

Although the contribution of acousticians can be critical in the measurement of noise at the physical level of description, there has been a noticeable trend in the field of public policy that, when the effects of wind turbine noise on society are being debated, acousticians are adopting the role of health experts. British physician Dr. Amanda Harry (2007) reports the alarming prevalence of acousticians giving evidence with regard to the health effects of sound emitted from wind turbines. She states that their "comments are made outside their area of expertise and should be ignored until proper medical, epidemiological studies are carried out by independent researchers" (p. 21). The message here is that acousticians reporting measured or predicted wind turbine noise levels should withhold commentary on likely health effects unless possessing suitable qualifications and can support their recommendations with quality research. As a corollary, health experts should not be commenting on acoustical matters without relevant qualification and the backing of quality research.

9. Reliance on Oversimplified Models

Though noise level itself explains only a small proportion of the variability found in the response to noise, it invariably carries the greater weighting and emphasis during wind turbine consent processes. Noise level metrics are usually predicted, though on occasion may be reported from other wind farms of a similar nature to that proposed or directly from the manufacturer's testing facilities. In relation to predicted levels, there are a number of factors influencing the predictions, and failing to sufficiently account for these factors can potentially produce either under- or overestimates of turbine noise. For example, depending on terrain and time of day, the effects of meteorological conditions on wind turbine noise can be in the order of 20 to 25 dB, with noise levels typically higher in spring than autumn due to temperature differences (Larsson & Öhlund, 2011). Terrain type is also important, and the predictions between open field and forest areas can differ by as much as 20 dB SPL, due to temperature and wind speed differences (Johansson & Almgren, 2011). Additionally, when the terrain impedes the wind close to dwellings then the wind's masking effect is reduced, and turbines located on higher ground may become more audible (Appelqvist & Almgren, 2011). Turbine noise depends on wind speed, which itself peaks between noon and 2:00 p.m. We can conclude that during this time of day the masking efficacy of wind is at its peak. Furthermore, thermal effects on atmospheric stratification can induce significant variability in wind gradients. Hence, wind speed can differ between ground and turbine hub height. Unfortunately, the most common reference of wind vertical profile used in modeling (IEC 61400-11) is appropriate only for flat terrain containing simple vegetation (Gianni, Bartolazzi, Mariani, & Imperato, 2011). Another important factor affecting noise level is the humidity- and temperature-dependent air absorption coefficient, in which lower values (e.g., 0.003 dB/m) yield more conservative estimates than higher values (e.g., 0.005 dB/m). Though these differences may appear subtle, selecting representative air absorption coefficient values are important as propagation through the air introduces random phase shifts due to atmospheric turbulence, which in turn influences noise levels. Additionally, when selecting an appropriate frequency weightings (e.g., dB(A) vs. dB(C)), one must consider that atmospheric sound absorption is greater for high as opposed to low frequencies (Siponen, 2011).

Current approaches to the modeling of sound propagation between multiple turbines assume statistical independence and sum the individual outputs of turbines in order to profile the impact of groups of turbines. Often this involves using manufacturer's technical data from a single turbine, but does not take into account the fact that multiple deterministic noise sources can add coherently. In the case of wind turbine installations, these noise sources include periodic modulating blade noise, low-frequency pulsations, and tones emanating from mechanical processes (Walker, 2011). The interactive effects of turbines may produce local "hotspots" or "heightened noise zones" (Bakker & Rapley, 2010) in which turbine noise can be amplified (and elsewhere attenuated) due to the superposition of multiple turbine acoustic waves. Hence, when predicting turbine noise levels using mathematical models, model complexity should not be sacrificed to simplify the calculation process.

10. Choosing the Right Metric

Another important factor when measuring or predicting wind turbine noise level is the range of exposure levels, that is, the minimum and maximum levels that are emitted by wind turbines. Noise measures based on energy summation and expressed as averaged values are not always sufficient when examining the health-related effects of noise. The WHO (1999) has repeatedly emphasized the importance of measuring peak values of noise fluctuations rather than averages. The inclusion of maximum levels is important as studies have consistently demonstrated that sleep disturbance is related to peak noise levels rather than aggregated measures (Morrell, Taylor, & Lyle, 1997). Thus, any measured or predicted noise levels used by acoustic experts must be accompanied by maximum levels, as sensitivity to the peaks of modulating noise waves are likely to better predict annoyance (Walker, 2011). Bolin and Karasola (2011), arguing against the use of aggregated measures when undertaking monitoring, claim that in order to present a "worst-case scenario," distributions representing the top 10% of the time average levels measured (i.e., dB LA_{10}) should be generated.

Further debate centers on the type of weighting that should be applied to noise measurements and predictions. Currently, standard practice in the wind turbine industry involves using A-weighted noise level estimates (i.e., dB(A)), though these may underestimate annoyance by failing to account for the degree of temporal variations and low-frequency content the measured noise contains. Siponen (2011), accounting for amplitude modulation and the low-frequency noise components in turbine noise, argues that A-weighted noise predictions underestimate the minimum distance required between wind turbines and inhabited dwellings. Instead, he advocates the use of a C-weighting, or else a corrected level based on the difference between C- and A-weightings.

Prior to the approval of a wind farm, it is common practice to assess the ambient (or background) sound levels and to compare these to, or combine them with, the predicted levels. Even this stage of noise level measurement has issues that require consideration, as extraneous factors such as time of year or equipment type can result in substantial overpredictions of ambient noise levels, up to 17 dBA in one study (Terlich, 2011). Seasonal effects such as insect noise can be lessened using weighting algorithms (Terlich, 2011), while decreasing the averaging time from the 1 minute recommended by IEC 61400-11 to around 10 seconds can help eliminate data contaminated by bird cries, pedestrian noise, or traffic noise (Ishibashi, Imaizumi, Ochiai, Inoue, & Yamada, 2011). Arguably, however, smaller durations around 100 milliseconds should be adopted as best practice, as the time averaged dB(A) levels recommended by the IEC 61400-11 (but see also its Appendix A5) fail to measure the amplitude modulation inherent in turbine noise (Lundmark, 2011).

11. Be Critical of Dose-Response Relationships

Many international standards for acceptable levels of community noise are based on the dose-response curve. This approach to establishing acceptable noise levels lacks validity and has been rightly lambasted by acousticians and health researchers alike (Fidell, 2003). The dose-response curve, constructed from dose-response data, plots (for example) noise annoyance as a function of noise level. Users of a dose-response curve define a level of noise annoyance that they are willing to accept and then, either graphically or numerically, derive a threshold by determining the level of noise that yields this predefined annoyance level. Figure 1A illustrates an actual theoretical dose-response curve produced by the Federal Interagency Committee on Aviation Noise (FICON) in the United States. Figure 1B is the same curve but with a shortened *x*-axis (now from 57 to 68 dB) accompanied by actual measurements of noise annoyance for aircraft noise. Note the incompatibility of the theoretical curve and the empirically derived data (data extracted from Fidell, 2003).

As Figure 1B shows, annoyance reactions to noise vary substantially and do not appear to be correlated with noise level. It can be concluded that the high variability between individuals and groups makes it difficult to model the relationship between noise and annoyance. Even though noise level is not a major determinant of noise-induced annoyance responses, plots such as Figure 2 are still used to determine acceptable noise levels. We can conclude from such data that the concept of a simple stimulus-response relationship is inadequate, and more attention needs to be paid to psychosocial factors when assessing the impact of wind turbine noise.

12. Dose-Response Curves and Criteria of Acceptable Harm

Using dose-response curves entails the establishment of an "acceptable harm" threshold, expressed in physical levels of the stimulus. The question is, at what level of noise does one estimate the threshold? In Australia, the criterion for aircraft noise is set at a point in which no more than 10% of the population would be severely affected. However, such criteria setting reflect a utilitarian approach to public health that is simply not sanctioned by modern society and are often arbitrary. Would we put an additive in the water that would benefit 90% of citizens and make the other 10% ill? These values need to be based on scientific validity and medical evidence but instead

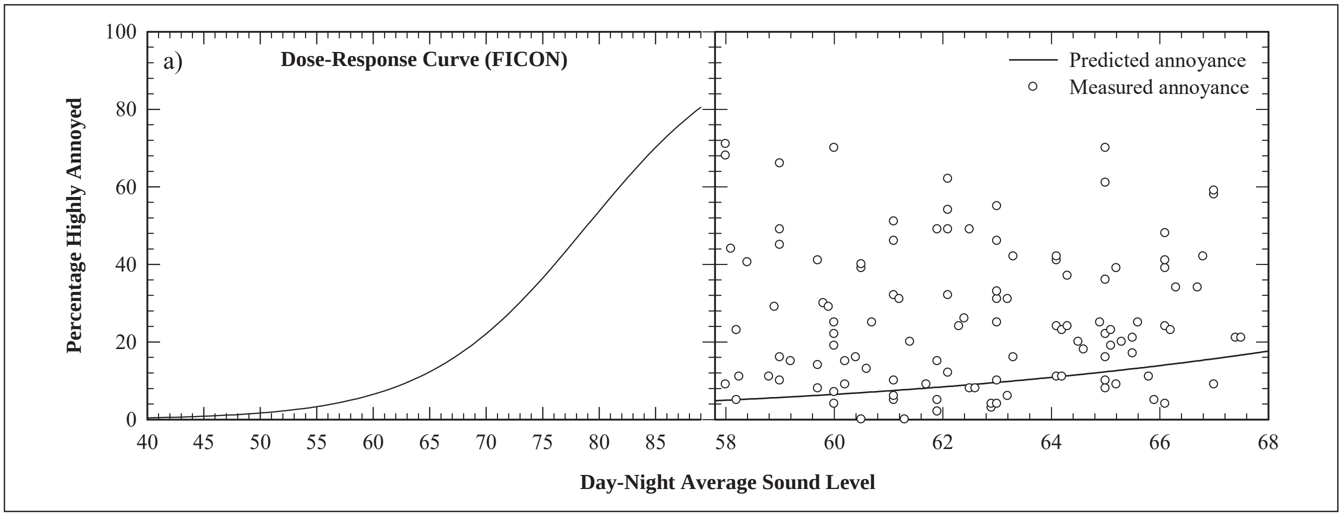

Figure 1. The dose-response function adopted by FICON (1992) to determine acceptable aviation noise levels (A) and actual measurements of aviation noise-induced annoyance in the vicinity of 60 and 65 dB LDN (B)
Note. Data reproduced with permission from Fidell (2003).

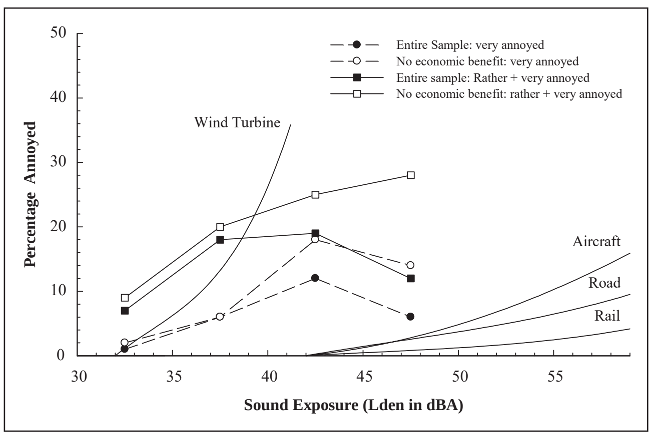

Figure 2. Annoyance plotted as a function of noise level for four theoretical models (rail, road, and air parameters: Miedema & Oudshoorm, 2001; wind turbine parameters: E. Pedersen & Persson Waye, 2004) and four sets of data obtained from Van der Berg et al. (2008, Tables 7.24 to 7.26)
Note. For the data, closed symbols are for the entire sample, whereas open symbols are for those who identified that they had no economic interest. Circles represent the percentage of "very annoyed" responses whereas squares represent the sum of "very annoyed" and "rather annoyed" responses.

are being set to reflect industrial objectives. The notion of acceptable harm then is one that needs to be debated at the societal level and, in relation to wind turbine noise, defined on a case-by-case basis with input from the communities hosting the turbines.

13. Noise Is a Social Problem, So Consider Approaches Other Than Level

Adopting noise level as the sole criterion of health impact makes little sense, given that (a) noise level is a poor predictor of the human response it elicits and (b) there has been a systemic failure in the prediction and measurement of wind turbine noise. In relation to the later, it is apparent that errors of prediction and measurement emerge due to inadequate methodology. For example, many of the wind turbine installations erected in New Zealand's Manawatu region were initially welcomed by residents who supported renewable energy (Martin, 2008). However, this initial enthusiasm was based on reassurances from the developers that turbine noise would not intrude into homes. The resulting lack of concordance between the predicted impacts of the noise and the actual impacts of the noise has since led to a rise in resistance to wind turbines in this region. Further evidence comes from a recent compliance report (Lloyd, 2010) undertaken on the Te Rere Hau wind turbine installation, also in the Manawatu region, that indicates that the complaints made by nearby residents regarding noise exposure are justified on the basis of recent noise level readings. Note that these readings are discordant with those originally predicted and do not comply with the original resource consent conditions. In 2011, court action against the wind farm operator was initiated by the Manawatu District Council.

Because of the discrepancies between predicted and actual noise levels, it may be more prudent to rely on evidence coming from individuals at established wind turbine installations than mathematical models heavily constrained by assumptions (see Points 9 and 10). Additionally, social-based approaches to wind turbine siting have actually been reported in the peer-reviewed literature (e.g., Gross, 2007; Maris et al., 2007), though incorporating these approaches into noise standards remain a challenge. Some countries, including Britain, Germany, and Canada, have negated noise level criteria and have instead adopted minimum setback distances between turbines and residential buildings. At this point in time, however, the use of setback distance is as controversial as the use of noise levels due to the lack of informing data.

14. Public Relations Should Consider the Social and Cultural Context

Invariably, the deployment of wind turbines creates winners (those who economically benefit) and losers (those who do not benefit and see the turbines as pollutants). Thus, it is important that the decision-making processes be perceived by all involved to be fair, or divided communities may ensue resulting in damaged relationships, degraded social well-being, and loss of sense of place. To this end, wind farm developers should not adopt an aggressive approach to decision-making processes, because in the past this has led to pronounced community divisions (Gross, 2007). Nor should they outwardly exploit their economic and political advantages over local opposition, as perceived procedural unfairness lessens social acceptance.

Maris et al. (2007) demonstrate that perceptions of procedural unfairness during the decision-making process, and insensitivity to the social context, can serve to increase subsequent noise-induced annoyance when the noise begins. Thus, public relations between developer and community can critically affect annoyance responses. An example of strained relationships within a community, and between community and wind turbine developer, can be found with the development of the Makara Wind Farm immediately north of Wellington, New Zealand's capital city. As part of the consent process, the developer was required to install a complaints line for the community to call if the noise became excessive. Thousands of calls were received in the first year, but the complaints themselves were never acted upon. A year later the wind turbine developer proposed to increase the wind farm into an adjacent area, which was opposed by the Makara Valley community. At subsequent consent hearings, the developer employed a marketing company to analyze complaints line data and use it against the Makara community. Such behavior resulted in indignation from the Makara community and would have likely increased annoyance to noise produced by the wind turbines already in operation.

The Use and Misuse of Noise Standards

A technical standard is a recognized norm or requirement, usually a formal document describing a standardized criterion, method, process, or practice. Standards may be developed at an international level, in which case they are classified as international standards, or locally by individual nations, in which case they are national standards. The process of agreeing to a technical standard is known as standardization. Standards have been an unqualified success in the field of engineering, science, and commerce. To stipulate a standardized procedure, test, definition, or specification is akin to creating a common language or frame of reference that facilitates communication and understanding between diverse groups. Noise standards exist to protect the public from noise and governments (local or central) from litigation and generally consist of regionally developed standards. That different nations have different noise standards indicates the impact of sociocultural and sociopolitical factors on noise acceptance. Because of their recent introduction, at least relative to other noise sources, wind turbines have developed rapidly in character, and consequently the development of noise standards specific to turbine noise has, for this reason and others besides, lagged.

The existence of a standard does not, unfortunately, presuppose that the standard itself is the correct procedure, test, definition, or specification. Nor does it guarantee that the standard is actually useful or effective. In fact, noise standards are evolving entities that are constantly undergoing review and change. In relation to noise and the public good, the WHO (1999), in identifying the inadequacies of noise emission standards, reports that existing trends in noise pollution are unsustainable. That noise standards are not necessarily definitive is further demonstrated by the lack of agreement that can exist among experts on standards or differences between standards. The differences of opinion surrounding the revision of the New Zealand standard for acceptable wind turbine noise (NZS6808) is testament to this (see, e.g., Chiles, 2010; Dickinson, 2009).

The classification of noise into broad ranges of frequency (e.g., low, medium, and high frequency) likewise illustrates the relative nature of noise standards. There appears to be a lack of universal agreement on this matter, and there are different standards in Germany (DIN 45680:1997), the United States of America (ANSI S12.9), Sweden (SOSFS 1996L17), and both Denmark and Holland. Given that the frequency content of the turbine noise is a contentious issue, and one that acousticians debate with some vigor, it can be argued that a common language is needed in order to advance these debates. In relation to the measurement of low-frequency noise, the international ISO-140-5 and the Swedish SP Info 1996:17 standards predict different noise level differences between outside and inside values (Lindkvist & Almgren, 2011). Thus, although useful, standards should not be treated as definitive authorities on where (or where not) wind turbines can be placed. A number of points relevant to the wind turbine noise standards are now made.

15. Standards Based on Standards

One can often encounter a Russian doll–type situation when examining noise standards, with many noise standards referencing other standards (which in turn may reference other standards) that may themselves not be fit for the purpose. For example, the international standard ISO9613 (Acoustics—Attenuation of sound during propagation outdoors) is used extensively in turbine noise standards (e.g., NZS6808:2010), yet it has been found to be inaccurate when applied to wind turbine noise (Bolin & Karasalo, 2011; Johansson & Almgren, 2011). It is thus of utmost importance to decompose standards into their constituent authorities and to examine each individually. The consequence of a noise standard relying on other inappropriate or ineffectual standards can result in flawed noise level predictions or inaccurate noise level readings during monitoring.

16. Reduce the Lag Between Practice and Reality

Technical and health standards are not updated quickly enough and perpetually lag behind research and technological developments. In England, wind turbine noise is predicted and assessed using standards that were developed for substantially shorter wind turbines (Davis, 2007). The WHO (1999), in their publication "Guidelines for Community Noise," acknowledges that their own noise recommendations are a work in progress and that there is still much to be done. Recently, there were calls from acoustical experts to update current American noise standards (Kryter, 2007), while an investigation by the Department of Health and Aging in Australia (Enhealth, 2004) has called for an immediate review of all noise guidelines, standards, and policies in light of the adverse health outcomes being associated with community noise. Thus, noise standards should have regular reviews in which they are updated, if necessary, to reflect technological advances and the latest findings in the field. For example, the period between the release of the New Zealand wind turbine standard (NZS6808:1998) and its revision (NZS6808:2010) is arguably too lengthy given the volume of research published during this period. Worse still is the British standard ETSU-R-97, which, despite being obsolete and there being repeated calls for a revision, remains in use.

17. Manage Conflicts of Interest

In some countries noise standards can be industry sponsored and as such lack sufficient input from stakeholders, social scientists, and health professionals. Failing to sufficiently declare conflicts of interests of those developing wind turbine noise standards can result in standards being endowed with more credibility than they deserve, or at a later date having their credibility impeached. Thus, all reasonable effort should be made to balance out groups involved with standard development, and all conflicts of interest should be explicitly declared. Wind turbine noise standards containing statements on acceptable noise levels should be developed with input from social organizations concerned with noise levels (e.g., the noise abatement society), and should clearly acknowledge that as a social problem, the mitigation of noise annoyance must necessarily include social factors.

18. The Nonequivalence of Noise Standards

When developing wind turbine noise standards, it is important that preexisting standards developed for other noise sources (e.g., road, rail, aviation) be applied with caution and qualification. For example, the Night Noise Guidelines for Europe developed by the WHO (2009) are based predominantly on road and aviation traffic data, yet are commonly cited in wind turbine consent applications. However, the unique physical characteristics of wind turbine noise (i.e., amplitude modulation), and the characteristics of those communities commonly exposed (i.e., rural and semirural dwellers), dictates that wind turbine noise is consistently judged more annoying than road, rail, or aviation noise (see Figure 2). The data plotted in Figure 2 suggests that the application of noise guidelines derived from aircraft, road, or rail data such as those published by the WHO should be accompanied by a 10 decibel (or more) subtraction in order to normalize it to the turbine context. In Italy, a generic national standard from noise regulation exists (DPCM 1/3/1991) that is not specific to turbine noise and is clearly inadequate to regulate the latest advances in turbine technology.

19. Domain-Specific Expertise

Wind turbine noise guidelines are often developed by teams of acousticians focusing on the physical measurements of noise, who later participate in the drafting of health impact clauses almost as an afterthought. For example, the aforementioned revision of the New Zealand standard (NZS6808:2010) had only a small proportion of health experts, and possibly as a result of this, only a small proportion of the standard was dedicated to health. We suggest that, regardless of noise source, measurement methodologies should be contained within a unique standard separate from those standards assessing health impacts. This would ensure that both measurement and health risk protocols would be developed by the experts in the field, and as such be fit for purpose.

20. Standards Are Not Weapons to Suppress Social Concerns

Noise standards can ironically be used to suppress "unwanted noise" coming from communities dissatisfied with noise levels. Giving a New Zealand example, a major regional newspaper (*The Manawatu Times*, 2005) reported the following statement from the owner of a newly established wind turbine installation: "It's a small number of people making a big noise about nothing" in response to locals complaining of a rumbling sound that "bombarded us with noise and vibration." The wind farm operator justified these comments on the basis of the advice they had received from their employed "health consultants," who were in fact acousticians providing information far beyond their expertise. These consultants justified their judgments by appealing to New Zealand's wind turbine noise standard (NZS6808), which had been sponsored and largely developed by umbrella organizations funded by wind turbine developers, including the owner.

Conclusion

Currently, environmental agencies, planning authorities, and policy makers in many parts of the world are demanding more information on the possible link between wind turbine noise and health in order to legislate permissible noise levels or setback distances. Concurrently, larger and noisier wind turbines are emerging, and consent is being sought for progressively larger wind turbine installations to be placed even closer to human habitats. However, the stimulus-response approach demanded by the bulk of these decision makers is misguided, and neither noise levels nor setback distances used in isolation are likely to be acceptable by society at large. Although noise standards can effectively and fairly facilitate decision-making processes if developed properly, the current standards on offer suffer severe conceptual difficulties. All this points to a need to incorporate social perspectives into the decision-making processes, though how this process itself can be standardized remains a challenge (but see Gross, 2007; Maris et al., 2007).

We have listed a number of important considerations that need to be addressed by environmental agencies currently deciding on the location of wind turbine installations. These various considerations can be grouped into broader categories, such as the credibility of procedures and players involved with standard development, the use of research to inform standards, critique of current approaches inherent in contemporary noise standards, and broader social factors. Ultimately, however, man-made noise is rarely perceived in a social vacuum (Maris et al., 2007), and acceptable levels of wind turbine noise should be a societal, and not a technological, decision one.

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Public Health Ethics, Legitimacy, and the Challenges of Industrial Wind Turbines: The Case of Ontario, Canada

Martin Shain[1]

Abstract

While industrial wind turbines (IWTs) clearly raise issues concerning threats to the health of a few in contrast to claimed health benefits to many, the trade-off has not been fully considered in a public health framework. This article reviews public health ethics justifications for the licensing and installation of IWTs. It concludes that the current methods used by government to evaluate licensing applications for IWTs do not meet most public health ethical criteria. Furthermore, these methods are contrary to widely held fundamental principles of administrative law and governmental legitimacy. A set of decision-making principles are suggested to address this situation that are derived from existing and emerging legal principles in Canada and elsewhere. These include the Precautionary Principle, the Least Impactful Means (Proportionality) Test, and the Neighbor Principle.

Keywords

public health ethics, wind turbines, legitimacy of government, licensing, decision rules

Introduction

The rationale for governmental support of industrial wind turbines (IWTs) as a viable form of alternate energy production emphasizes their "green" qualities. These qualities are said to include public health benefits because IWTs are claimed to produce less pollution than conventional energy sources. Consequently, we are told to expect less disease burden on the general public from IWTs than from fossil sources.

This assertion has been challenged in articles appearing in this issue (e.g., Bryce). Therefore, to this extent, the public health rationale itself must be reexamined.

But even if the net population health impact of IWTs were to be as claimed by their advocates and proponents, there is still a major problem with the rationale. This problem is only exacerbated by lack of data to support the green claim.

The problem is that even if the pollution-related public health *benefits* were established, there are also clear public health *risks* associated with IWTs. These risks accrue to a subpopulation of our society that suffers a range of negative health effects from IWTs, as documented in this issue.

The fact that such risks exist at all summons up a need for a risk-benefit analysis, which leads us into the deep waters of arguments predicated on utilitarian and contractarian principles.

The pursuit of these ideas leads us even further into a more fundamental debate on the nature and role of consent to governmental actions. Inevitably, this is the threshold to the very essence of political legitimacy.

In this article, the discourse of public health ethics will be used to parse arguments for and against IWTs in the broader context of governmental legitimacy.

A derived ethical/legal framework is proposed to help inform decision-making processes in governmental and commercial-industrial environments concerning the licensing and installation of IWTs.

Public Health Ethics

While some accounts of public health ethics see the mandate of public health as the maximization of welfare, other just as cogent accounts see it as an aspect of, or means of, producing social justice (Powers & Faden, 2006).

Both accounts, however, involve providing answers to the question: For whom is public health good?

This question assumes greater significance once it is acknowledged that many public health initiatives involve gains to some at the expense of losses to others in a context of

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governmental action backed up by the reality or threat of coercion. Familiar examples include the regulation of smoking, the required use of seat belts and helmets, immunization, and quarantine.

Sometimes, as in the case of wind turbines, the trade-off can be seen as one between asserted population health gains (e.g., net reductions in cases of fossil fuel induced respiratory and lung diseases) and negative impacts on the health of some individuals in specific communities (e.g., sleep loss induced states of anxiety, depression, headaches, extreme fatigue, diminished ability to concentrate, nausea, and other physiological effects including, albeit rarely, vibro-acoustic disease).

The descending gradient between impact on population health and individual health can be in some ways characterized as one of moral ascension: Some might argue that it is more obvious and heinous to expose a few to known immediate hazards in the service of the many who are presumed to benefit in the future from broadly applied social policies such as the proliferation of IWTs.

This type of trade-off, whether consciously or unconsciously applied, raises concerns about social justice and the fair distribution of benefits and burdens. But it has also been said that the conflation of public health with social justice blurs boundaries to such an extent that it ceases to have legitimacy as a definable discipline. As Faden and Shebaya (2010) state,

> One worry raised by this interconnectedness across spheres of social life and policy is that classifying something as a public health matter could be an effective way of taking it out of the realm of legitimate discussion. If the goal of protecting health is seen as clearly good, government actions aimed at securing health may be less scrutinized than actions aimed at more controversial ends, leaving public health officials with too much power and too little democratic accountability. . . . Public health ethics has to give serious consideration to the question: how exactly should the mandate of public health authorities be specified such that they do not run afoul of the requirements of legitimacy in a democratic political system? (p. 7)

This statement, however, raises a further issue to which it will be necessary to return in this article more than once. That is, although IWTs present public health issues, they are not regulated by public health agencies. Consequently, the concern raised by Faden and Shebaya (2010), while poignant in its own right, becomes even more worrying when the very protectors of public health are not even allowed into any kind of official debate about the impact of IWTs.

The following is an account of the ethical justifications typically used in connection with public health measures. Faden and Shebaya (2010) are drawn on for the organization of this section and for the basic outline of justifications used in public health ethics.

It is important to note that the need for justification arises often not from across the board concerns that public health measures may be illegitimate in some way so much as from a more particular concern that certain measures affect some members of society in adverse ways or that they benefit some at the expense of others.

Note too that the justifications outlined below are by no means sorted or capable of being sorted into wholly discrete categories, the boundaries of one sometimes blending into another.

Overall Benefit (Beneficence)

The argument is that public health is a good by definition, because most people benefit from it in one area or another. This is a net social gain type of argument.

The net gain argument is bolstered in modern economics by statistical models that seek to demonstrate population health benefits on an aggregated basis. These models often embed moral assumptions that are not always apparent under the guise of supposedly objective cost utility analyses. For example, the health of the elderly may be discounted as less valuable than the health of the young: the rights of those with "poor" health habits may be devalued in contrast to those who attend (and can afford to attend) health clubs and gyms and shop at high-end food stores (see, e.g., Brock, 2002; Gafni, 1991; Powers & Faden, 2006). And lurking in the shadows of cost utility analyses in the public health arena is the ever present specter of eugenics.

As Faden and Shebaya (2010) state,

> There is the risk that the findings emerging from these formal analyses will have determinative influence in policy circles. This risk is augmented by the increasing interest in attempting to empiricize moral considerations by measuring and aggregating the value preferences of the public about moral tradeoffs such as prioritizing by age or life-saving potential (Baker et al., 2008; Menzel et al., 1999; Nord, 1999). These aggregated preferences are then transformed into weights intended to incorporate moral values directly into the structure of the formal methodology, a move that is open to criticism on methodological as well as substantive grounds. (p. 17)

Applied to IWTs one can appreciate that green ideology could be "empiricized" to the point at which it trumps all other values in the development of wind energy policy.

Collective Efficiency

The argument is that in a complex society threatened by so many health risks from so many sources it is efficient for a central agency (public health) to oversee and regulate these risks because agencies organized according to specific issues could not hope to achieve the same level of proficiency.

While there is an intuitive appeal to this sort of argument, it fails to acknowledge the reality that public health concerns are often embedded in policies and practices that fall outside the sphere of public health agencies. IWTs are a leading example of this type of governmental dissonance. As noted above, the regulation of IWTs does not at present fall within an official public health remit in spite of the numerous and compelling claims advanced by various researchers in this issue.

Harm Prevention

The argument is that restriction or curtailment of the rights of a few can be justified only by prevention of harm to the many (Mill, 1869/1998).

This argument has been used in various public health and safety contexts but usually the contrast is between incursions on individual liberty (as in the case of compulsory seat belt or helmet use and no smoking in public places rules) and collective health benefits. In the case of IWTs, the contrast as noted already is between health benefits to the many versus health risks to a few, a situation to which the Harm Principle may not be best suited, although it must be said that advocates' claims for IWTs go beyond collective health benefits to embrace other putative social goods. These include increased freedom from reliance on nonrenewable energy sources. Insofar then as the contrast is between sacrificing the health of a few in the service of an anticipated bright energy future for the many, perhaps the Mills formulation is more useful. In this context, the prevention of harm to the many becomes a projected scenario in which the majority is "not harmed" by the perpetual threat that oil, gas, and even coal may run out or become inaccessible to us. Certainly, the trade-off is between a clear and evident loss to a few and the unknown, even vague probability of benefit to the many.

Paternalism

The argument is that government can interfere with the liberty or other rights of a few because it is ultimately in their best interests and certainly in the interests of the majority.

In the case of IWTs, the strong paternalistic case is made implicitly and sometimes explicitly that opponents are stupid, stubborn, or both because they do not know what is best for them in the long run. Their stupidity therefore disqualifies them from any further participation in the determination of their own fate.

A softer "libertarian" version of paternalism requires that until people are led to understand the benefits of the measures to which they are about to be unwillingly exposed they should not be subjected to them. Some argue that this is not paternalism at all but rather a form of participatory governance consistent with grassroots democracy. In any event, in this version people who did not accept that IWTs were likely to be a net benefit to them would not be obliged to consent to have them installed within a range accepted by the more prudential scientific community as likely to cause harm to their health.

Fairness

The argument is that in a democratic society we expect a relatively even social distribution of burdens when these are imposed and directed by government. Unequal distribution is unfair and therefore requires specific justification. In the case of IWTs, this justification might take the path of suggesting that all of us ultimately benefit from green energy in reduced pollution and eventually in freedom from reliance on nonrenewable fossil fuel sources. Consequently, harm to a few is justified by good for the many, which may even include the few who suffer in the short run but reap benefits in the end.

A particular problem arises in this context involving the disproportionate impact of certain public health measures on already disadvantaged groups. In the case of IWTs, this refers to those home and business owners who are economically disadvantaged to the extent that they do not have the option to sell and move from the location in which they are being harmed or expect to be harmed by the careless introduction of wind energy generators.

Again as Faden and Shebaya (2010) state,

> There is broad agreement that a commitment to improving the health of those who are systematically disadvantaged is as constitutive of public health as is the commitment to promote health generally (Institute of Medicine, Committee for the Study of the Future of Public Health, 1988; Nuffield Council on Bioethics, 2007; Powers & Faden, 2006, Thomas, Sage, Dillenberg, & Guillory, 2002). (p. 14)

Faden and Shebaya (2010) continue,

> When the burdens of a policy fall heavily on those who are already disadvantaged, the justificatory hurdle is particularly high. This concern is at the heart of many environmental justice controversies such as the locating of hazardous waste facilities and hazardous industries in low income communities and countries. (p. 16)

In other words, it is contradictory to the essence of public health ethics, at least insofar as it is grounded in fairness, to further disadvantage the already disadvantaged.

As we explore the further reaches of legitimacy in the next section of this article, fairness will be seen to take on an even more important role.

The Broader Canvas: Political Legitimacy, Social Justice, and IWTs

As noted earlier, public health ethics discourse as applied to IWTs is antecedent to a further-reaching discussion of political legitimacy. This connection is of vital importance in the case of IWTs because, as observed already, the regulation of IWTs does not fall within the public health remit but rather resides in other administrative bodies. Consequently, public health bodies have no direct control over the ways in which IWT installations are approved or sited. This dissociation of powers is in itself problematic and should be a matter of concern to all who govern in the name of the people. However, the issue of the public health impact of IWTs arises not only in the specific arena of institutional public health but also in the arena of political legitimacy generally.

Two fundamental questions of political legitimacy are the following: What gives government the right to govern in a democratic society in the first place? What gives it the ongoing right to coerce compliance with its laws and regulations?

These sound like simple if not simplistic questions but they have consistently eluded answers to which all can agree ever since people began to ask them.

Indeed, it is well to consider the context in which these questions were first asked in any really public and secular context, which was during the 17th century. Prior to that, natural law and divine right had been the source of the dominant accounts of political legitimacy and authority.

Early accounts of alternate sources of legitimacy concentrated on the nature of consent as the basis of political authority. Locke's treatise on the social contract is perhaps the best known of these accounts but there are many others that either elaborate on his thesis or challenge it (Peter, 2010). Essentially, however, Locke's account is based on not only "originating consent" (how government first got its mandate from the people) but on a form of ongoing majoritarianism. As Locke (1690/1990) wrote,

> Every man, by consenting with others to make one body politic under one government, puts himself under an obligation to every one of that society to submit to the determination of the majority, and to be concluded by it; or else this original compact, whereby he with others incorporates into one society, would signify nothing, and be no compact if he be left free and under no other ties than he was in before in the state of nature. (Locke, 1690/1990, p. 52f)

Modern descendants of earlier theories of consent now considered to be overly simplistic focus on notions of public reason and/or democratic approval drawing on the works of Kant and Rousseau, respectively (Peter, 2010).

One of the leading embodiments of these derived accounts is the seminal work of John Rawls (2001; see also Rawls, 1971), who grounds his theory of justice and legitimacy in fairness as a normative social practice.

This writer subscribes to Rawls's theory and declares his bias in this matter.

Fairness, as Rawls defines it, is to be not only a basis for everyday interactions among citizens but also the basis of interactions between government and citizens.

Fairness, as Rawls sees it, is the requirement to recognize and accommodate up to a standard of reasonableness the legitimate interests, claims, and rights of others.

Shain (2001) further articulates this requirement of fairness as it applies in domestic and institutional situations. Drawing on Trebilcock (1993), he identifies two impediments to the normative application of fairness as defined above: information failure and participation failure. Essentially, failures in these areas represent a failure of active consent, thus bringing full circle the links between fairness, legitimacy, and social justice.

The failure of information and participation are of particular relevance in the context of IWT installations where the alleged perfunctory adherence by government and proponents to regulated requirements for consultation with the public has attracted some harsh criticism.

Information and participation failure is abetted by any system of administrative law in which the principles of natural justice (e.g., let the other party be heard, the rule against bias, and the requirement of reasonableness) have become casualties. So much of what goes on under the auspices of administrative law is hidden from or ignored by the public to the point where the erosion of some of our most basic rights can go unremarked (Harlow, 2006).

So it is with IWTs, the story of which, in many jurisdictions, is representative of much that ails our system of administrative law. Anecdotal and deposition evidence from homeowners, community groups, and even municipalities in Canada and beyond frequently testify to the bankruptcy of the consultative process that should embody the principles of information sharing, transparency, and participation.[1]

Active consent to the rules and procedures that govern site location and installation of IWTs must be sought or obtained in a substantive way from those who are most likely to be affected by them, namely, residents in affected areas and the municipalities in which they live.

Fairness as an applied modern version of social contract theory calls for an active process in which all participants to a decision are engaged in ways that do not, without offer of compensation, advantage one party over another and in which there is an imperative to discover, acknowledge, and accommodate up to a standard of reasonableness one another's legitimate interests, claims, and rights.

In such a process, there are no preconceived "trump" values or considerations. For example, regulations under the Green Energy Act in Ontario cannot legitimately (according to a Rawlsian view) simply trump the claims and rights of subpopulations of citizens to the protection of their own and their families' health or enjoyment of their property based on some preconceived and unconfirmed notion of overall benefit to population health. However, that said, there are modern scholars who propose that there can be certain "preemptive" reasons that would allow governments to trump other considerations and interests if the authority behind the action were considered credible, rational, and legal enough for them to do so (see, e.g., Raz, 1986, 1995, 2006). The credibility of "preemptive" reasons, however, requires a virtually nonnormative Weberian account of legitimacy that is based on tradition, charisma, or some other kind of faith-based belief in the rightness of authority (Weber, 1918/1991; see also Weber, 1964). This is not considered to be mainstream thinking about the legitimacy of governmental action in Western democracies (Peter, 2010).

Various other critiques of consent as the basis of legitimacy see it as wishful thinking (e.g., Wellman, 1996) or as a delusion born of a desire to not acknowledge that many, now legitimate governments were born of violence (e.g., Hume, 1748/1965). Such arguments paved the way for the sorts of pragmatic, utilitarian justifications for public health measures that were scouted in the previous section.

Notwithstanding these objections to consent—in some form at least—as the basis of political authority and legitimacy, beliefs in its importance are probably the most current and widely held in our society today (Peter, 2010). We place a high value on the idea of consent in how we are governed even if in reality it is difficult to invest it with practical meaning. Effectively, consent is at the heart of how we create and honor contractual promises that extend beyond the realm of private transactions to that of state and civic governance. When we depart from the principle of consent, we feel obliged to give some account of how that can be justified, and eventually we return to the basic premise that it is desirable to place consent of the governed at the center of our communal life.

From the foregoing discussion and analysis, this writer proposes that Rawlsian fairness and its implied requirement of active consent emerge as the public health ethical principles most likely to serve the needs of a robust and legitimate democracy.

If that is taken as working assumption, what practical guidelines can be extrapolated from such principles to assist governments in the determination of criteria for approving IWT license applications?

In this regard, three emerging legal doctrines may be drawn on for assistance. These have roots in common law and in international law. They appear to be highly relevant to how we might usefully think about how IWT proposals can be fairly evaluated and judged. One doctrine—the Precautionary Principle—has been applied in an administrative law context in Canada already. The other two—the Neighbor Principle and the Least Impactful Means Test—remain to be fully articulated as such in an administrative law context but their emerging shape can be nonetheless discerned from recent cases.

These three doctrines are "before the fact" tools in that they are used to prevent harm from occurring in the first place.

A fourth doctrine—the Polluter Pay Principle—is an "after the fact" financial compensation tool that has long legal roots in all common law jurisdictions.

The Precautionary Principle

It was imported into Canadian law via the Supreme Court case of *Spraytech v. Hudson (Town)* [2001] 2 S.C.R. 241 from international law where it was originally approved by Canada in the Bergen Declaration of 1990. Subsequently, this doctrine has been embedded in several pieces of Canadian legislation including the Oceans Act, S.C. 1996, c. 31, Preamble (para. 6); Canadian Environmental Protection Act, 1999, S.C. 1999, c. 33, s. 2(1)(a); Endangered Species Act, S.N.S. 1998, c. 11, ss. 2(1)(h) and 11(1).

It means the following: When scientific evidence concerning the harm potential of a given industrial activity leaves room for doubt, that activity should not be undertaken. Proposed mitigating measures are not an adequate response, because if you do not know the nature or degree of risk you cannot prepare for its eventuation.

Some doubt surrounds the standard of care required by this principle. For example, how much harm could or should be reasonably foreseen if a risk eventuates? How big must the risk be to activate the principle? Currently, this principle is being tested in Ontario's legal and quasi-legal systems as it may be applied to IWT licensing. Such testing is likely to go on for some time. A recurrent issue appears to be the extent to which the Precautionary Principle that may be embedded in governing or parent statutes (such as Environmental Protection Acts) evaporates as delegated legislative vehicles such as regulations and administrative orders are created under its supposed authority.[2]

The Least Impactful Means Test

Evident from recent decisions of the Ontario Municipal Board, which is an administrative tribunal similar to many others in North America and the United Kingdom, this test means the following: State issuers of licenses should approve only those proposed methods of operation that will have the smallest social and environmental impact in pursuit of legitimate industrial objectives.

The Least Impactful Means Test is generically related to the Proportionality Test, which has currency in many countries including Canada. This test requires a form of ends-means analysis in which the requirement that the government provide justifications for statutes that infringe on protected rights is front and center (Beatty, 2004). In Canada, the Supreme Court case of *R. v. Oakes* [1986] 1 S.C.R. 103 is usually seen as the source of the proportionality test, which was stated as follows:

> First, the measures adopted must be carefully designed to achieve the objective in question. They must not be arbitrary, unfair or based on irrational considerations. In short, they must be rationally connected to the objective. Second, the means, even if rationally connected to the objective in this first sense, should impair "as little as possible" the right or freedom in question. Third, there must be a proportionality between the effects of the measures which are responsible for limiting the Charter right or freedom, and the objective which has been identified as of "sufficient importance."

As is apparent from the wording above, the test was developed to deal with infringements of the Canadian Charter of Rights and Freedoms by government actions such as law enforcement (as in the Oakes case) and law enactment (in other cases). Beatty (2004) shows convincingly, however, that in a number of countries, proportionality analysis is treated as a general principle of public law, applicable not only to constitutional law but also to administrative and even to international law questions.

However, Beatty is not alone in relating the proportionality test to the integrity of the rule of law. Harlow (2006) makes a similar connection in her consideration of the question whether or to what extent we can observe the emergence of a global administrative law with common principles and values. Central to such considerations is the question of when the State or its agencies can be held to be acting "ultra vires"—that is, beyond its legitimate powers and therefore unconstitutionally.

The marriage between the emerging jurisprudence of administrative tribunals in Ontario and the jurisprudence of the Supreme Court and the international community has not yet taken place. But the courtship is in progress and awaits only the brokerage and determination of creative lawyers to firm up the bond.

The Neighbor Principle

Also evident by deduction from recent Municipal Board decisions,[3] this is a common law legal doctrine that until recently applied only to claims of negligence in civil courts.

It means the following: basically, there is a legal duty of care to know enough about your neighbors to avoid doing predictable harm to their legitimate interests. A neighbor in this context is anyone who could be foreseeably affected by your acts or omissions. The standard of care is that of the reasonable person in the same situation.

However, the neighbor principle is now being referred to by implication in environmental cases where the expectation is raised that "reasonable" developers should know what social and environmental interests of their neighbors are foreseeably affected by their operations.

The relatively new concept of a "social impact zone" in municipal board jurisprudence (see examples of such decisions in Note 3) arguably requires developers to consider the foreseeable impact of their operations in certain defined areas. Ultimately, the Neighbor Principle takes its place within the framework of the Good Planning Test that pulls together all the expert information available to determine the extent to which proponents have discharged their duty to demonstrate no unacceptable or, in some cases, no negative impacts from their proposed operations.

This means that they should be aware of not only the commercial and business interests of neighbors but also of their reasonable social expectations of privacy, freedom from nuisance, and enjoyment of property. These are all "legitimate" interests.

It can be seen that all three aforementioned doctrines are allied to the Rawlsian concept of fairness as the recognition and reasonable accommodation of the legitimate interests claims and rights of others.

Indeed, it is this very concept of fairness that has the potential to unite the three doctrines into a coherent jurisprudence of social and environmental stewardship.

The Polluter Pay Principle

This well-established common law principle is evident from many Canadian cases including the Supreme Court case of *St. Lawrence Cement Inc. v. Barrette* [2008] SCC 64 and *Smith v. Inco* (2010) ONSC 3790 (CanLII). It is also enshrined in various forms of legislation.

It means that when an industrial operator is found to have caused loss to its neighbors it must compensate them for such loss regardless of whether there was negligence or not. This strict liability rule (a feature in many common law jurisdictions) has most recently been applied in a class action suit involving nickel contamination. The impact zone within which such losses will be considered varies from case to case.

Essentially, the polluter pay principle is a generic way of describing a class of private civil remedies that includes nuisance, trespass, and negligence. These are legal tools that are used in most cases after damage has been done except where injunctions and other interlocutory measures are used to stop harmful actions before they begin or while they are in progress. They really represent the failure of prevention.

Conclusion

A public health ethics analysis of how IWTs should be licensed and installed if the health of the few is to be balanced with, traded off or sacrificed for the health of the many, leads to the conclusion that the present methods of proposal evaluation need to be critically reviewed.

The only type of test that present methods would easily pass is "strong paternalism"—the argument that the State knows best. But this justification for public health measures enjoys little support in a free and democratic society.

With regard to the broader issue of governmental legitimacy and IWTs we are confronted with an even more profound problem. State actions that do not enjoy the active consent of the people—particularly of those whose health may be adversely affected by IWTs—are fundamentally suspect.

Administrative law systems that stray from the principles of natural justice held to underlie them are also suspect because such departures are in conflict with the Rule of Law.

Unfortunately, we do not find ourselves in this situation as a result of any one remediable action or default on the part of government but rather as a result of a gradual erosion of our collective capacity to hold government accountable.

IWT licensing procedures in whatever jurisdiction are a bellwether of the fate of democracy itself and therefore should be closely examined against the criteria suggested in this article, and in particular against the criterion of procedural fairness and active consent advocated by Rawls.

Several tools present themselves as proactive means of addressing perceived threats to procedural fairness and active consent: the Precautionary Principle, the Least Impactful Means Test (supported by the more general jurisprudence of the Proportionality Test), and the Neighbor Principle (drawn from the more specific requirements of the Social Impact Zone Test).

Converted into criteria for evaluation of IWT license applications, these principles and tests represent a formidable array of protections against arbitrary governmental action. That said, conversion into practical evaluative tools will require creative thinking and benign intent if we are to emerge with a more robust spine to our system of governance and administrative law.

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Notes

1. See also the Carmen Krogh article in this issue.
2. See, for example, the situation described in *Hannah v. Attorney General for Ontario*, 2011 ONSC 609.
3. Rockfort Quarry Hearing (2010) Ontario Municipal Board (Nov. 12th) PL000643, PL060448 (Campbell); Puslinch (Aikensville) Quarry Hearing (2010) Ontario Municipal Board (Jan. 19th) PL080489 (Jackson).

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Bio

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APPENDIX 2

Acoustic Group Pty. Ltd., Consulting Acoustical and Vibration Engineers.

Review of Draft Wind Farm Guidelines 42.4963.R2.ZSC

14th March 2012

EXECUTIVE SUMMARY

In late 2011 The Acoustic Group performed a desk-top review of the acoustic documents comprising the acoustic assessment for the Flyers Creek Wind Farm and conducted preliminary sound monitoring at an existing operational wind farm (the Capital Wind Farm) which was approved in New South Wales on the basis of similar analyses, guidelines and reports to that provided for the Flyers Creek Wind Farm. The assessment found deficiencies and inadequate information in the acoustic assessment of the Flyers Creek proposal such that the true acoustic impact of the proposed wind farm had not been presented to the community.

In the intervening period a set of Draft Wind Farm Guidelines have been issued by the NSW Department of Planning and Infrastructure (“the Department”) for public comment.

The Acoustic Group was requested by the Flyers Creek Wind Turbine Awareness Group to examine the Draft Wind Farm Guidelines with respect to acoustic issues. As there are no acoustic compliance reports for operational wind farms in NSW in the public domain, The Acoustic Group was also requested to conduct additional testing to assess the Draft Guidelines with respect to practical aspects of their application to operating wind farms.

The Draft Wind Farm Guidelines have identified that they closely follow the existing South Australian Guidelines in relation to the noise criteria. The problem for the broader community in comprehending the Guidelines is that from a noise perspective by definition, the Guidelines must be expressed in technical terms which are not readily understood by the community. The community therefore relies on the preparation by the Department of noise guidelines that set rigorous criteria and assessment procedures as well as a rigorous compliance regime. A reasonable person would expect that such Guidelines would be drawn from and based upon solid data and measurements. *Despite the fact that the Department has had the opportunity to scrutinize data and undertake scientific investigations of operating wind farms for the purpose of the Draft Guidelines, it has not done so.*

The Draft Wind Farm Guidelines set out measurement, assessment and compliance procedures which are likely to be unworkable in practice. This review highlights a number of outstanding issues in relation to noise impacts from wind farms that require the Draft Guidelines to be amended in order to safeguard the acoustic amenity of residents in areas where wind farms are proposed and where there has previously been no such noise source.

It is recommended that the proposed base criteria for wind farms be amended to 30 dB(A) when assessed under the worst case scenario. In particular, it is concluded:

1. There is no material or reference in the Guidelines supporting the use of 40 dB(A) as an acceptable amenity level in rural NSW. Examination of the Department’s compliance review

of the Capital Wind Farm confirms Leq levels when turbines are shut down which are significantly lower than 40dB(A) and which undermine this standard as an acceptable amenity.

2. The Draft Wind Farm Guidelines ignore "Offensive Noise." In so doing, the Guidelines set criteria which are inconsistent with the EPA's Industrial Noise Policy. Examination of noise data from the Capital Wind Farm confirms that the current Draft Guidelines will permit noise significantly above background level i.e. offensive noise which is likely to interfere unreasonably with a person's health, comfort or repose.
3. The base limit for wind farms should be 30 dB(A) when assessed under the worst case scenario. Testing establishes that this limit would be consistent with EPA guidelines for the protection of acoustic amenity in rural areas.
4. The Guidelines are vague and inconsistent in relation to the assessment of and measurement during temperature inversions. This undermines the efficacy of the noise criteria.
5. The use of the A-weighting filter is not sufficient to account for the audibility and annoying characteristics of wind farm noise. This is demonstrated with data obtained from the Capital Wind Farm, Woodlawn Wind Farm and Cullerin Range wind Farm.
6. The guidelines do not specifically require full spectrum noise monitoring inside residential properties. Data obtained demonstrates that such monitoring is essential to reflect noise impact and specific noise characteristics.
7. The Guidelines require more detailed acoustic analysis at the proposal stage to identify the effects of different weather scenarios. These scenarios are typically required for industrial noise assessments and in their absence, proper compliance monitoring is impossible.
8. The measurement procedure in relation to specific noise characteristics describes measurements conducted over a 10 minute period. This does not permit identification of these characteristics which are associated with swish, modulation, discrete tones and low frequency noise. This is demonstrated with analysis of data from operating wind farms. Criteria in relation to amplitude modulation are uncertain.
9. Examination of data demonstrates that compliance monitoring can only be effective with the provision of permanent noise monitoring within the wind farm, recording noise levels, wind speed and direction at receiver locations and recording wind speed and direction at hub height. The Guidelines do not, but should, provide for such permanent noise monitoring supplemented with temporary remote monitoring in real time to deal with complaints.
10. The provision of permanent noise monitoring data together with real time presentation of the wind speed and direction at the hub, the power output and operational status of individual turbines must be provided in the public domain to permit independent compliance testing. There is no provision for this in the Draft Guidelines.
11. Compliance procedures are ineffective. The Guidelines do not provide a clear indication of what triggers non-compliance. The specified effects of non-compliance are vague. There are no provisions requiring a cessation of operations if the wind farm is not compliant.

Retrieved from:

http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=YLfMeRzXkhs%3D&tabid=205&mid=1081&language=en-US

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND	* * * * * * * *	**RESPONSE TO** **STAFF'S FIRST SET OF DATA REQUESTS TO INTERVENORS** **EL18-026**

Below, please find my response to Staff's
First Set of Data Requests to Intervenors. Thank you for allowing me the extension to submit my response by August 24, 2018, at 5:00 pm.

1-1) Provide copies to Staff of all data requests served on Applicant at the time of service.
I will provide this information.

1-2) Provide copies to Staff of all of your answers to data requests from Applicant at the time they are served on Applicant.
I will provide this information.

1-3) Refer to SDCL 49-41B-22. Please specify particular aspect/s of the applicant's burden that the individuals granted party status intend to personally testify on.
I am in the process of reviewing the Application to find if it is sufficient to provide for the conditions set forth SDCL 49-41B-22. I have not decided if I will testify or not.

1-4) Refer to SDCL 49-41B-25. Identify any "terms, conditions, or modifications of the construction, operation, or maintenance" that the Intervenors would recommend the Commission order. Please provide support and explanation for any recommendations.

To be clear, I recommend that the Commission deny this application. I recommend this from my experience of the Beethoven Wind Farm from permitting, construction, to the operation of it, to date.

If the Commission will not deny the application, I recommend the condition of a 4-mile setback. My support is the fact that I live 3 miles from six Beethoven Wind Farm Industrial Wind Turbines and the height of 586 foot turbines as the Applicant has chosen is unprecedented and I believe will negatively impact my husband and myself without the 4 mile setback.

I request the ALDS which eliminates the alarming red blinking lights at night. If the FAA does not approve them, I recommend the application be denied.

The red blinking lights are meant to alarm. The red blinking lights on the Beethoven Wind Farm are a nuisance. To have an additional 57 turbines, many with the alarming red blinking lights will be result in a much bigger nuisance. The Applicant should be prevented from creating a nuisance.

I request a **Bat Detection** and Shutdown **System be installed on all Industrial Wind Turbines in this project. Bat fatalities negatively affect agriculture and the environment.**

I request a decommissioning bond, paid for up front. Once the Industrial Wind Turbines are up, they are up. Whether or not the proposed Industrial Wind Farm will be lucrative enough to produce the income to provide for a bond in ten years is not and cannot be proven.

I request a liaison person to monitor the project as it is being built to insure compliance and an avenue for those in the footprint to voice concerns and complaints. A project of this size must have a liaison.

I request a liaison person to monitor the project from the commencing of operation through the decommissioning. I have not been able to reach anyone to assist me when I have had concerns with the existing Beethoven Wind Farm.

I request there be no shadow flicker on non-participating residences, as shadow flicker presents a nuisance and the Applicant should be prevented from creating a nuisance.

I request a Guarantee of Property Value to be funded and developed by the Applicant, subject to approval of the Property Owner to protect residents in the footprint and buffer zone from financial loss should the residence become unlivable and / or unmarketable. The Applicants project will have serious financial implications on many of the residents in the footprint and the buffer zone.

1-5) Is there a specific objection (example health, blinking lights, sound) you have with respect to the Project? Please briefly explain.

The nuisance of red blinking lights as mentioned above in section 1-4. If the FAA will not approve the use of the ALDS the application should be denied.

Most concerning is sound, both audible and infrasound. There are many complaints about both audible and inaudible noise from Industrial Wind Turbines, they are well documented. The result of negative health effects to some residents from both audible and inaudible noise is also well documented.

Health, again the size of the Industrial Wind Turbines the Applicant has chosen is unprecedented. The area and range they will impact is unknown and will likely cause the loss of enjoyment of property, loss of use of property, loss of the residence to be inhabitable, and the marketability of property will be greatly diminished.

What, if anything, do you feel could be done to remedy that issue?

Deny the Application.

If the Commissioners will not deny the application, the Commission must then approve the Application with conditions that will truly protect the health, safety, and welfare of all of the residents living in and near the footprint.

Sound should not exceed 35 decibels for non-participating residences.

Setbacks should be 4-miles from a non-participating residence.

An ALDS must be installed. If the FAA does not approve an ALDS the application should be denied.

1-6) Please list with specificity the witnesses the Intervenors intend to call. Please include name, address, phone number, credentials and area of expertise.
I am still reviewing the Application and have not decided if I will call witnesses.

1-7) Do the you intend to take depositions? If so, of whom? **Not at this time.**

Dated this 24th day of August, 2018
Karen Jenkins
28912 410th Ave
Tripp, SD 57376
605-680-5646
jenkinskd55@gmail.com

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND	* * * * * * * *	**STAFF'S FIRST SET OF DATA REQUESTS TO INTERVENORS** **EL18-026**

Below, please find Staff's First Set of Data Requests to Intervenors. Please submit responses by August 22, 2018, at 5:00 pm, or promptly contact Staff to discuss an alternative arrangement.

1-1) Provide copies to Staff of all data requests served on Applicant at the time of service.
None served at this time.

1-2) Provide copies to Staff of all of your answers to data requests from Applicant at the time they are served on Applicant.
None received at this time.

1-3) Refer to SDCL 49-41B-22. Please specify particular aspect/s of the applicant's burden that the individuals granted party status intend to personally testify on.
1) Inaccuracies, errors, and omissions in the applicant's application and supplemental information may cause injury to the environment leading to the economic detriment of some inhabitants and businesses within and near the project as well as distressing other activities.
2) The applicant fails to substantially prove that placement of turbines twice as powerful as existing turbines and at distances even closer than existing turbines will not substantially affect the health, safety or welfare of either participating or non-participating inhabitants. Unless health, safety, and welfare have been quantitatively measured prior to construction the amount of substantial impairment can not be measured after. Personal health and well-being will be particularly emphasized.
3) There will likely be no future "orderly development" at all in the footprint of the facility if constructed as proposed.

1-4) Refer to SDCL 49-41B-25. Identify any "terms, conditions, or modifications of the construction, operation, or maintenance" that the Intervenors would recommend the Commission order. Please provide support and explanation for any recommendations.
The "terms, conditions or modifications" that would ameliorate nuisance, health, and negative financial concerns raised by the facility would be to simply deny the permit.
Should the permit be approved, full frequency spectrum analysis should be performed, including using the C-weighted scale (Broner and Leventhall 1983) not just modeling of projected dB(A) levels. The complete sound output needs to be accounted for not just the audible portion as with the dB(A) weighted scale. Dr. Alec Salt and colleagues,

Washington University School of Medicine, St. Louis have explained the effects of extremely low frequency sound on the inner ear leading to the distress of sleep disruption, sleep deprivation and subsequent adverse health effects. Larger and more powerful turbines produce an even larger proportion of low frequency noise than earlier smaller models. This needs to be accounted for by someone.

If appropriate sound power level studies are not implemented and standards set and enforced, an alternate condition for safety, health, and welfare would be setbacks of 2 miles from non-participating residences, businesses, churches, cemeteries, and schools with waivers for those so inclined and 1500 foot setbacks from property and right of way lines. All horizontal setback measurements need to be made to the tip of the blade when horizontal not to the center of the tower.

Aircraft Detection Lighting Systems should be installed. The air ambulances from the Sioux Falls hospitals make multiple trips to the Wagner hospitals every week at all hours of the day and night through the proposed facility area.

Shadow flicker should be eliminated at non-participating residences and business and should be reduced to 8 hours annually actual following the German model at participating residences so as not to imprison people their homes behind shuttered windows unable to use their own property.

Decommissioning monies should be made available in whole upfront and reevaluated every 2 years to account for inflation and other increasing costs. Decommissioning should include complete removal of all installed components not just visible portions.

1-5) Is there a specific objection (example health, blinking lights, sound) you have with respect to the Project? Please briefly explain.

a. What, if anything, do you feel could be done to remedy that issue?

Concerning sight, sound, health, and safety issues:

If constructed as proposed our horizon will be in constant motion when the wind blows except for about 60 degrees to the north. As someone susceptible to motion sickness and having suffered vertigo episodes within the last few months, this may well be an unbearable situation. Infrasound and low frequency noise from existing turbines may contribute to these issues as per Navy nauseogenic studies but I can not imagine that having larger turbines on all sides could possibly help.

Existing turbine noise is routinely audible at our residence at 1.25 miles distant. Note that applicant's sound study indicates that in 2 of 3 measurements at measuring points 1 and 2 there is audible sound from existing turbines at distances of approximately 2 miles. Again, being completely surrounded by larger turbines will not help the situation.

Both audible sound and inaudible low frequency noise are known to contribute to sleep disruption and sleep deprivation. The distress of sleep deprivation over time is known to cause physiological disruptions of several body systems. We already experience sleep problems. Being surrounded by more and larger turbines can not possibly help.

Possible remedies for these issues could include but are not limited to:

1) Not approving the permit.

2) Requiring 2 mile setbacks from habitable residences, businesses, churches, cemeteries, etc. with waivers if desired by participating landowners so as to protect by

distance from sound, inaudible noise, and sight disruption. All property and right of way line setbacks should be at least 1500 feet for safety from blade fragmentation and ice throw. For risk assessment it should be presumed that a person is always present at the property or right of way line.

3) Requiring 2 kilometer setbacks (as many European countries and Australian states have previously required 1000 meters for much smaller turbines as per summary by K. M. B. Haugen, Minnesota Department of Commerce) but from non-participating landowners property lines, along with noise limits of 25-40 dB(A) (again foreign country guidelines adjusted for turbine size per Haugen summary) at non-participating landowner property lines with lower values for measured quiet areas or 5 dB(A) or less above measured preconstruction ambient background noise levels with 5-15 dB penalties for tonality, impulsiveness, and modulation (Haugen summary) at the property line of non-participants so as not to imprison people in their homes unable to use or enjoy their entire property.

4) Further remedies to reduce audible sound and low frequency noise could include shutting down the entire facility from 7:00 pm to 7:00 am so that all inhabitants could sleep peacefully, shutting down all turbines within 2 miles of non-participating residences or 2 kilometers of non-participating owner property lines from 7:00 pm to 7:00 am, using Noise Reducing Operations (NRO) on all turbines from 7:00 pm to 7:00 am, or using NRO on turbines within 2 miles of non-participating residences or 2 kilometers of non-participating landowners property lines 24 hours a day.

Setbacks from property lines are stressed because our practice of animal husbandry requires working afoot on the majority of our property on a daily basis. Measurements to the residence are useless except for sleeping hours. No one should be denied the use of the entirety of their property.

1-6) Please list with specificity the witnesses the Intervenors intend to call. Please include name, address, phone number, credentials and area of expertise.

Potential witness other than self are unkown at this time.

1-7) Do the you intend to take depositions? If so, of whom?

Unknown at this time but doubtful.

21 August 2018

Sherman Fuerniss
40263 293rd Street
Delmont, So. Dak. 57330
605-779-5041
sol@midstatesd.net

Dated this 8th day of August 2018.

Amanda M. Reiss
Kristen Edwards
Staff Attorneys
South Dakota Public Utilities Commission
500 East Capitol Ave.
Pierre, SD 57501

SOUTH DAKOTA DEPARTMENT OF HEALTH

600 East Capitol Avenue | Pierre, SD 57501 P605.773.3361 F605.773.5683

Office of the Secretary

RECEIVED
OCT 13 2017
SOUTH DAKOTA PUBLIC UTILITIES COMMISSION

October 13, 2017

Public Utilities Commission Staff
SD Public Utilities Commission
Capitol Building, 1st floor
500 East Capitol Avenue
Pierre, SD 57501-5070

Re: PUC Docket EL17-028 - In the Matter of the Application by **Crocker Wind Farm, LLC** for a Permit of a Wind Energy Facility and a 345 kV Transmission Line in Clark County, South Dakota, for Crocker Wind Farm

Dear PUC Staff:

The South Dakota Department of Health has been requested to comment on the potential health impacts associated with wind facilities. Based on the studies we have reviewed to date, the South Dakota Department of Health has not taken a formal position on the issue of wind turbines and human health. A number of state public health agencies have studied the issue, including the Massachusetts Department of Public Health[1] and the Minnesota Department of Health[2]. These studies generally conclude that there is insufficient evidence to establish a significant risk to human health. Annoyance and quality of life are the most common complaints associated with wind turbines, and the studies indicate that those issues may be minimized by incorporating best practices into the planning guidelines.

Sincerely,

Kim Malsam-Rysdon

Kim Malsam-Rysdon
Secretary of Health

[1] http://www.mass.gov/eea/docs/dep/energy/wind/turbine-impact-study.pdf

[2] www.health.state.mn.us/divs/eh/hazardous/topics/windturbines.pdf