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23 November 2012

Dr Ian Holland
Secretary, Senate Environment & Communications committee inquiry into the renewable energy (wind farm noise) bill
PO Box 6100
Parliament House
Canberra ACT 2600
Via email: community.affairs.sen@aph.gov.au

Re: Reply to your email of 14 November, 2012

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Dear Ian,

I would like to take this opportunity to respond to the email referenced above. However, I should point out that our reply will not be a comprehensive or thorough response due to the length of the studies you have sent and the short timeframe allocated for our response.

In addition, I would point out that these three studies have very little, if any, relevance to the amendment being considered by the committee. The Committee's website clearly states,

"This is not an inquiry into wind farms, but an inquiry only into the terms of the Bill."

If a study does not demonstrate how a background +10dBA noise limit would affect people's health, then we would respectfully suggest that the study is outside the Terms of Reference of the Committee.

Nevertheless, a few points about each of the studies supplied in your email follows.

Effects of industrial wind turbine noise on sleep and health Michael A. Nissenbaum et.al. published in *Noise and Health* September-October 2012

A review of this paper has been written by Intrinsik Environment Sciences Inc. and is attached as Appendix A. The conclusion of the paper is as follows:

> **Overall Conclusion**
> Overall, in our opinion the authors extend their conclusions and discussion beyond the statistical findings of their study. We believe that they have not demonstrated a statistical link between wind turbines – distance – sleep quality – sleepiness and health. In fact, their own values suggest that although scores may be statistically different between near and far groups for sleep quality and sleepiness, they are no different than those reported in the general population. The claims of causation by the authors (i.e., wind turbine noise) are not supported by their data.

This review was written for the Canadian Wind Energy Association (CANWEA) which is clearly shown. This might lead a cynic to question its independence; however, at least the relationship with CANWEA is declared and transparent.

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On the other hand, Nissenbaum and Hanning are on the "Board of Directors" of the Advisory Group of the anti-wind farm lobbying group 'The Society for Wind Vigilance[1]'. Amani is a "Scientific Advisor" to the Advisory Group of the same organisation. None of these positions are disclosed in the Conflicts of Interest section of the paper, even though most readers would view such management positions in an anti-wind farm lobbying group to be, at least, a potential conflict of interest.

Infrasound from Wind Turbines Could Affect Humans by Alec Salt and James Kaltenbach, published in the *Bulletin of Science Technology & Society 2011*

Professor Chapman has written an assessment of The Bulletin of Science and Technology (BSTS). His assessment follows:

> *"In the past two years, an obscure allegedly "peer reviewed" research journal, the Bulletin of Science, Technology & Society has published a series of papers by authors who have anti-windfarm track records. The Bulletin has appeared erratically over the past few years. It was indexed between 1981-1995 by the Web of Science, the international scientific indexing platform which "covers over 10,000 of the highest impact journals worldwide, including Open Access journals and over 110,000 conference proceedings." But after 1995 it was dropped from the list of journals being indexed, generally a sign that indexing services regard a journal as having fallen below an acceptable scientific standard. In the 14 years it was indexed, a citation search conduced on 21 September 2012 shows that it published 961 papers that have been cited for a grand total of just 345 times - an average of 0.36 per paper --almost a homeopathic strength citation rate. Web of Science shows it has published only seven papers which have been cited 7 or more times, with the most cited paper in its history having been cited just 15 times. PubMed, the indexing service of the US National Library of Medicine also does not index the journal…*
>
> *In summary, this is a journal which cannot be described as low ranking in scientific research publishing. It is more accurately described as "unranking". All the papers in the journal on wind farms are only accessible by pay-per-view…*"

Therefore, it can be well argued that the BSTS is not a credible scientific journal.

With regards to the paper itself, there are several shortcomings with regards to the paper's methodology, but setting these aside, the paper only discusses *the possibility* that infrasound from turbines ***could*** affect human beings. The paper's concluding statement is hardly a statement proving anything:

> *"it is scientifically possible that infrasound from wind turbines could affect people living nearby"*

---

[1] http://www.windvigilance.com/home/advisory-group

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It logically follows from the paper's conclusion that it is also very possible that infrasound from wind turbines has no affect to people living nearby in any way. The paper simply floats a hypothesis that is not proved.

In contrast, as discussed in my testimony, the peer-reviewed acoustic study by Sonus published in *Acoustics Australia* measured and documented that infrasound levels from wind turbines are far, far below that which can be "heard" or perceived by human beings---even a few hundred metres away. *Acoustics Australia* is published by the Australian Acoustics Society and a copy of the Sonus paper is included as Appendix B.

Evaluating the impact of wind turbine noise on health-related quality of life by Daniel Shepherd et. al. published in ***Noise and Health*** Sept-Oct 2011

The Shepherd paper was reviewed by Fiona Crichton from the Department of Psychological Medicine, University of Auckland which is attached as Appendix C.

One of the key points made by Ms. Crichton is that,

> *"While there were differences detected between the groups in relation to satisfaction with the living environment, critically* ***there were no differences between the groups in terms of self-rated health and current illness****."*

The differences detected with regards to satisfaction with their living environment (and sleep patterns) could just as easily be caused by adverse TV and other publicity about the wind farm prior to the surveys as described by Ms. Crichton.

In any case, as with the Salt study, the Shephard study does not assert to have actually proved anything and merely represents a hypothesis rather than evidence of a causal relationship. The abstract states,

> *"Our data suggest that wind farm noise can negatively impact facets of HRQOL[Health-related quality of life]"*

To "suggest" something "can" have an impact is hardly a conclusive statement. As stated above, whatever small differences in survey results that exist between wind farm neighbours and the control group can just as easily be attributed to negative publicity and perceived issues---rather than actual acoustic impacts.

Therefore, the three studies cited in your email have substantial flaws, were published in less credible journals with questionable peer review processes, and/or do not actually provide any evidence of a causal link between wind turbines and detrimental health impacts. So, after reviewing these studies, I continue to stand by the statement made during my testimony that,

> *"I am not aware of any truly peer reviewed study in a reputable academic journal that proves a causal relationship between wind turbine noise and detrimental health impacts."*

Please feel free to contact me if you have any questions.

Yours sincerely,

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Senior Development & Government Affairs Manager

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November 14, 2012

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Re: Intrinsik Review of Nissenbaum MA, Aramini JJ, Hanning CD. Effects of industrial wind turbine noise on sleep and health. Noise Health 2012; 12: 237-243

The October 29, 2012 edition of the journal Noise & Health includes the following paper:

> Nissenbaum MA, Aramini JJ, Hanning CD. Effects of industrial wind turbine noise on sleep and health. Noise Health 2012; 12: 237-243

The purpose of the Nissenbaum et al. work was to undertake an epidemiology study to investigate the relationship between reported adverse health effects and wind turbines among residents of two rural communities: Mars Hill and Vinalhaven, Maine, USA. Participants living 375 to 1400 m and 3.3 to 6.6 km were given questionnaires to obtain data about sleep quality (using the Pittsburgh Sleep Quality Index- PSQI), daytime sleepiness (using the Epworth Sleepiness Score- ESS) and general physical and mental health (using the SF36v2 health survey). Overall the authors reported that when compared to people living further away than 1.4 km from wind turbines, those people living within 1.4 km of wind turbines had worse sleep, were sleepier during the day and had worse mental health scores. Based on these findings the author's concluded that:

> *"…the noise emissions of IWTs disturbed the sleep and caused daytime sleepiness and impaired mental health in residents living within 1.4 km of the two IWT installations studied".*

This work and its findings are not new; earlier works by Nissenbaum about this investigation have been available on the internet since 2009. The work and findings of this publication have been reviewed in the Queen's Bench of Saskatchewan case McKinnon v. Martin (2010 – also referred to as the Red Lily case) and during the Ontario Environmental Review Tribunal (ERT) Erickson v. MOE (2011 – also referred to as the Kent Breeze case). Indeed, Nissenbaum and his coauthors provided a manuscript (Nissenbaum et al. 2011a) to the ERT in the Erickson v. MOE proceedings. At that time the manuscript was confidential in nature; however, in keeping with the rulings of the ERT order dated February 25, 2011, the manuscript was made part of the public record on February 27, 2012. This work was also presented as a conference proceeding in 2011 (Nissenbaum et al., 2011b) and subsequently reviewed and critically evaluated by an expert panel convened by the Massachusetts Department of Environmental Protection and Massachusetts Department of Public Health (MassDEP/MDPH, 2012).

The work in all three manuscripts is fundamentally the same: the study design, methodology, study population and statistical methods are all similarly reported. There are some variations in text but the fundamental conclusions reached by the authors remain consistent across the manuscripts. The primary change comes in the published version (Nissenbaum et al. 2012) with the inclusion of a limited amount of post-hoc noise data. As such we assert that the previous evaluations of this work remain valid.

For instance, the ERT (2011) wrote this of Nissenbaum et al. (2011a):

> *"Looking at the Appellants' evidence, the Tribunal found that strong statements about harm that will be caused were preceded by evidence that largely showed that harm "may" be caused. For example, with respect to the Nissenbaum Study and Dr. Aramini's application of it, there are enough uncertainties to lead the Tribunal to conclude that no proof of harm is present"*.

As well, the expert review panel convened for the MassDEP/MDPH (2012) stated this of Nissenbaum et al. (2011b):

> *"This study is somewhat limited by its size — much smaller than the Swedish or Dutch studies described above — but nonetheless suggests relevant potential health impacts of living near wind turbines. There are, however, critical details left out of the report that make it difficult to fully assess the strength of this evidence. In particular, critical details of the group living 3–7 km from wind turbines is left out. It is stated that the area is of similar socioeconomic makeup, and while this may be the case, no data to back this up are presented—either on an area level or on an individual participant level. In addition, while the selection process for these participants is described as random, the process of recruiting these participants by going home to home until a certain number of participants are reached is not random. Given this, details of how homes were identified, how many homes/people were approached, and differences between those who did and did not participate are important to know. Without this, attributing any of the observed associations to the wind turbines (either noise from them or the sight of them) is premature."*

Intrinsik also has concerns related to study design, methodology, sample size and administration of questionnaires to participants. These concerns were all raised in detail during the aforementioned legal proceedings and won't be repeated fully herein. With these points in mind, we urge readers of this scientific review to revisit findings of both the legal proceedings in Saskatchewan and Ontario, as well as other panel reviews, for complete details on their suppositions.

Notwithstanding these previous criticisms and study limitations, we were encouraged to see that the authors published their work in a peer-reviewed scientific journal. However, we do not believe that their findings support their conclusions. To that end we have prepared this brief scientific review of their published work in Noise & Health.

Findings

Sound Levels

For the first time in publishing this work the authors included sound levels with distance from the turbines. Information on the source of these sound levels is included in the second paragraph of the Study Sites and Participant Selection section of the article. The authors indicate that "*Simultaneous collection of sound levels during the data collection at the participants' residences was not possible, but measured IWT sound levels at various distances, at both sites, were obtained from publically available sources.*"

For Mars Hill the sound levels were reportedly extracted from the "*Sound Level Study, Compilation of Ambient and Quarterly Operations Sound Testing, and the Maine Department of Environmental Protection Order No. L-21635-26-A-N.*" However, Nissenbaum et al. do not provide the figures from which the data were obtained and simply state in the notes of Table 1 that: *"Values read or derived from report figures; accuracy +/- 50 m and +/- 1 Db"*. For Vinalhaven no reference, other than "*R and R, personal communication, 2011*" was provided for the sound measurements that were apparently collected as two-minute measurements over a single day in February 2011.

Given that the relationship between noise from wind turbines and health concerns is the fundamental premise of the study by Nissenbaum et al., it is surprising that the authors gave such little consideration to collection of actual sound data measurements at the study participant homes. The use of post-hoc sound data, visually obtained from figures in reports, is not scientifically defensible and should not have been used to draw conclusions about the findings of the questionnaires with distance from turbine locations. Given the nature of these data we believe that any results or conclusions related to sound levels at these facilities are not supported and the finding that "…*it is apparent that this value will be less than an average hourly LAeq of 40 dBA, which is the typical night time value permitted under the current guidance in most jurisdictions*" is not defensible.

We also believe that the title of the paper "*Effects of industrial wind turbine noise on sleep and health*" is not supported given the nature of the data presented. No evidence with respect to sound level (noise) and its effect on sleep and health has been presented in this paper and the authors could have more appropriately focused the title with respect to the distance, which is the variable that they actually investigated.

Sleep Outcomes
The study team administered two questionnaires related to sleep: the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS).

The PSQI is a self-rated questionnaire meant to assess sleep quality and disturbances over a one month period. A global PSQI score >5 can be used to distinguish "good sleepers" from "poor sleepers". This is acknowledged within the Nissenbaum et al. (2012) paper in the Questionnaire Development section. Although there was a statistically significant difference between the mean PSQI scores in the near (7.8) and far group (6.0), it is important to remember that both of these average scores are greater than 5, which would qualify both groups as "poor sleepers". When one examines the reported "% of PSQI score >5" no statistical difference between the near and far groups was found (p=0.0745).

Moreover, the authors attempt to illustrate the relationship between PSQI and distance to the nearest wind turbine in Figure 1 (and ESS scores in Figure 2 and SF36 MCS scores in Figure 3). In all cases the regression lines had p values <0.05. Nissenbaum et al. appear to mistake these significant p values in the regression lines as being related to the relationship of the scores with distance. As with all regressions, the p values in these tests refer to the significance of the slope of the lines being greater than 0, rather than a relationship between variables. In fact in these types of regressions, as important, if not more important, is the r^2 value (coefficient of determination/goodness of fit). This value provides one with the ability to ascertain how well a regression line fits the scatter of data that it attempts to predict. The closer an r^2 is to 1.0, the better the fit of the data and the ability of a regression line to predict a future outcome.

The authors did not provide the r^2 values for any of the three figures nor did they present the slope equations for these lines. If one examines the figures it is revealed that there is considerable scatter of the values, especially in the 375-1400 m near group. For example the scatter of the resulting PSQI scores in the near group is between 1 and 18 and in the far group the range is 1 to 16. Visual examination reveals that one cannot predict the PSQI values from the slope of this line at any given distance. For example, between 600 and 900 m one could just as easily have a score of 19 as they would 1. Based on our experience it is unlikely that the r^2 for any of the three figures would provide reasonable fit to make these regression lines of any use in future predictions or even in predicting scores with distance in this study.

The Epworth Sleepiness Scale (ESS) is also a widely used self-administered questionnaire that can provide information about a person's general level of daytime sleepiness or average daily sleep propensity. According to the University of Maryland Medical Centre, Sleep Disorders Centre, an ESS score of 10 or more is considered sleepy and a score of 18 or more is considered very sleepy (http://www.umm.edu/sleep/epworth_sleep.htm).

Similar to the PSQI test, when completing the ESS test those living near turbines had significantly different scores than those in the far group (7.8 vs. 5.7); however, given that the threshold of sleepiness is a value of 10, on average neither group should be considered sleepy. Moreover, the "% with ESS score > 10" was not statistically different between the two groups (p=0.1313). While some individuals from both groups reported scores greater than 10 it needs to be highlighted that 10-20% of the general population report having ESS scores greater than 10 (http://epworthsleepinessscale.com/about-epworth-sleepiness/), similar to those found in the near and far groups in this study.

In their paper Nissenbaum et al. state that noise emitted by IWTs can affect sleep. However, their results do not support this statement. In fact, the authors state that "*The data on measured and estimated noise levels were not adequate to construct a dose-response curve*…" and no statistical analyses were conducted to assess this supposed relationship. Therefore, we do not believe that Nissenbaum et al. (2012) show any statistical difference in overall "poor" sleep quality or sleepiness between the groups.

Physical and Mental Health Outcomes

The SF36 test has been widely used within the quality of life scientific investigation field. The SF 36 is a multi-purpose, short-form health survey made up of 36 questions that yields an 8-scale profile of functional health and well-being scores as well as psychometrically-based physical and mental health summary measures and a preference-based health utility index (http://www.sf-36.org/tools/sf36.shtml).

It is important to note that the authors acknowledge that "*There was no statistically significant difference in PCS (p=0.9881).*" This means that respondents reported no difference in their Physical Component Summary score or physical well-being between the two groups. Nissenbaum et al. did show significantly decreased SF36 Mental Component Summary (MCS) scores between the near (42.0) and far (52.9) groups (p=0.0021). However, the conclusion that the reduced MCS score in some residents living near wind turbines is related to noise emissions is hypothetical and not support by the data. In the paper, neither sleep nor physical effects were related to noise levels, and no attempt was made to relate MCS score to sleep. Moreover, there was no significant difference (p=0.06) between the number of respondents that required psychotropic medications since the start of turbine operations for the two groups. Simply put Nissenbaum et al. show that some people in the vicinity of turbines reported lesser MCS scores than those living further away, but no underlying reason for this was conclusively established.

The authors pointed out that visual cue and attitude towards wind turbines *"are known to affect the psychological response to environmental noise"*. While this may be true, visual cue and attitude by themselves have been shown to be stronger drivers of psychological responses than a wind-turbine specific variable like sound itself (e.g., Pedersen 2004). Therefore, a conclusion that can be drawn from this study is that the self-reported health effects of people living near wind turbines can be likely attributable to physical manifestations from an annoyed state, rather than a wind-turbine specific factor like noise. Indeed, the weight of evidence in the wind turbine and human health literature points to a causal relationship between self-reported health effects and annoyance, which is to say annoyance brought on by the change in the local environment (i.e., a decrease in amenity) that wind turbines represent (Knopper and Ollson 2011).

Overall Conclusion

Overall, in our opinion the authors extend their conclusions and discussion beyond the statistical findings of their study. We believe that they have not demonstrated a statistical link between wind turbines – distance – sleep quality – sleepiness and health. In fact, their own values suggest that although scores may be statistically different between near and far groups for sleep quality and sleepiness, they are no different than those reported in the general population. The claims of causation by the authors (i.e., wind turbine noise) are not supported by their data.

Closure

The opinions in this scientific review are those of the undersigned who are independent scientific professionals and are not influenced by any contractual obligations. Drs. Knopper and Ollson will be submitting these comments as a Letter to the Editor to the journal Noise & Health for consideration for publication. If you have any questions please do not hesitate to contact the undersigned.

Yours sincerely,
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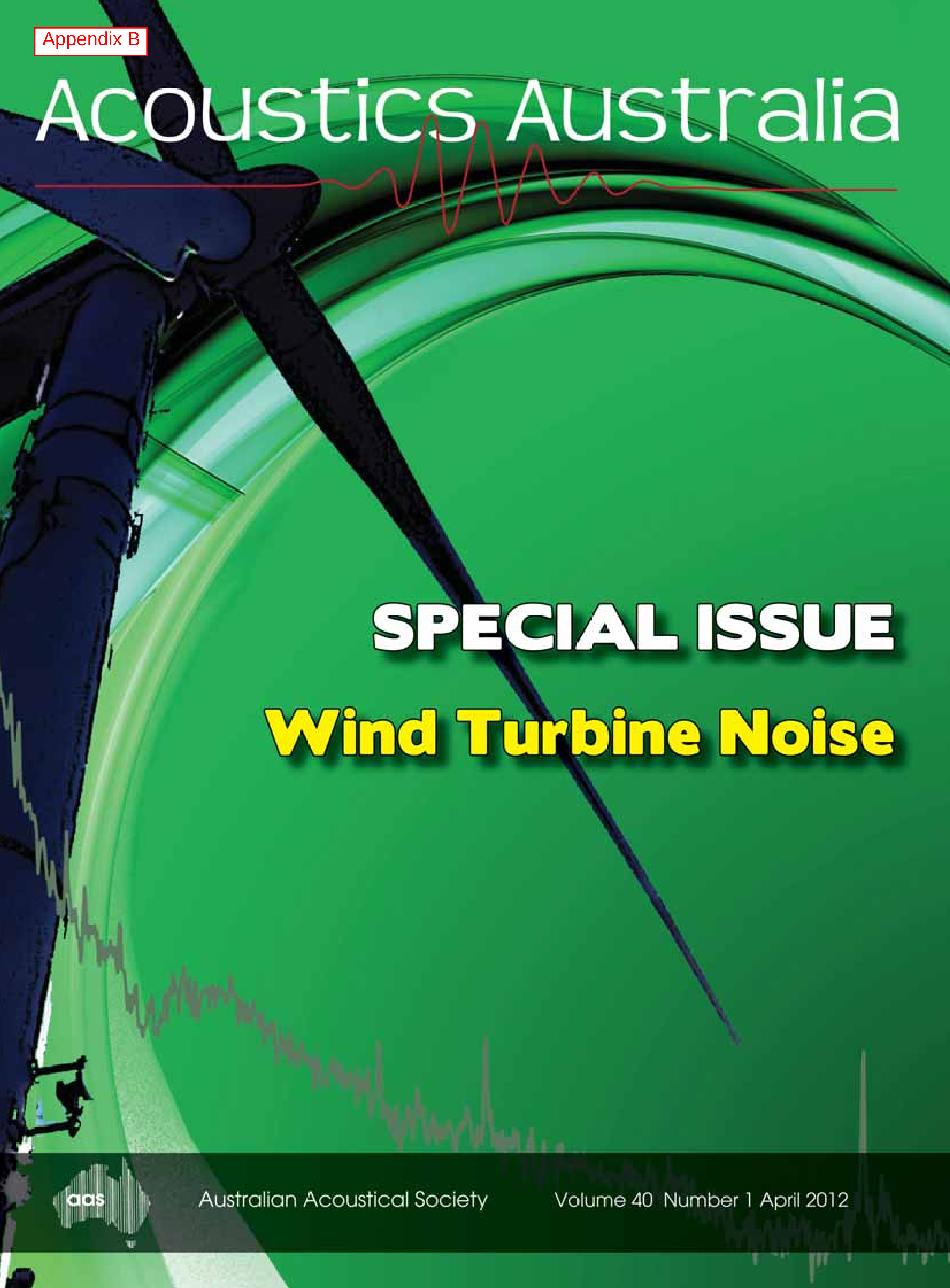
Appendix B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PAPERS

TECHNICAL NOTES

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MEASUREMENT AND LEVEL OF INFRASOUND FROM WIND FARMS AND OTHER SOURCES

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Infrasound is generated by a range of natural and engineered sources. The measurement of infrasound at low levels requires a specific methodology, as it is readily affected by even light surface breezes on the microphone. Such a methodology, based on measurements below the ground surface in a test chamber, has been developed to measure infrasound at two Australian wind farms and also in the vicinity of a beach, a coastal cliff, the city of Adelaide and a power station. The measured levels have been compared between each source and against the infrasound audibility threshold of 85 dB(G). The measured level of infrasound within the wind farms is well below the audibility threshold and is similar to that of urban and coastal environments and near other engineered noise sources.

INTRODUCTION

Infrasound is generally considered to be sound at frequencies less than 20 Hz and is often described as inaudible. However, sound below 20 Hz remains audible provided that the sound level is sufficiently high [1]. Infrasound is generated by a range of natural sources, including waves on the coastline, waterfalls and wind. It is also generated by a wide range of engineered sources such as industrial processes, vehicles, air conditioning and wind farms. The thresholds of audibility for infrasound have been determined in a range of studies [2]. The G-weighting has been standardised to determine the human perception and annoyance due to noise that lies within the infrasound frequency range [3]. A common audibility threshold from the range of studies is an infrasound level of 85 dB(G) or greater. The audibility threshold limit of 85 dB(G) is consistent with other European standards and studies, including the UK Department for Environment, Food and Rural Affairs threshold developed in 2003 [2], the UK Department of Trade and Industry study [4], the German Standard DIN 45680 [5] and independent research conducted by Watanabe and Møller [6].

There have been concerns raised in the community regarding the generation of infrasound by Australian wind farms. The generation of infrasound was detected on early international turbine designs, which incorporated the blades ‘downwind’ of the tower structure [7]. The mechanism for the generation was the blade passing through the wake caused by the presence of the tower. Modern wind turbines now locate the blade ‘upwind’ of the tower.

Australian States presently assess the noise from wind farms under a range of Standards and Guidelines [8-12]. These Standards and Guidelines do not provide prescriptive requirements for infrasound from wind farms due to the absence of evidence that infrasound should be assessed.

A specific methodology was developed to reduce the influence that even light surface breezes can have on the infrasound results. The methodology is based on measurements being conducted below the ground surface in a test chamber that is approximately 500mm square and 500mm deep. Infrasound was measured using this below ground methodology at two Australian wind farms, Pacific Hydro’s Clements Gap Wind Farm which has been operating in the mid-North of South Australia since 2010 and comprises 27 Suzlon S88 wind turbines, each with a rated capacity of 2.1 MW, and at the coastal Cape Bridgewater Wind Farm which has been operating since 2008 in south-western Victoria, and comprises 29 REpower MM82 wind turbines, each with a rated capacity of 2.0 MW. Infrasound was also measured in the vicinity of a beach, a coastal cliff, the city of Adelaide and a power station using the below ground methodology. This paper reports on the study that:

- Develops a methodology to measure infrasound that minimises the influence of wind on the microphone;
- Measures the levels of infrasound at a range of distances from a wind turbine, for two wind farms;
- Compares the results against recognised audibility thresholds; and
- Compares the results with infrasound measurements taken near natural sources, such as beaches, and engineered sources, such as a power station and general activity within the city of Adelaide.

MEASUREMENT TECHNIQUE

Equipment

All measurements were conducted with a SVANTEK 957 Type 1 NATA calibrated sound and vibration analyser. The SVANTEK 957 Type 1 meter has a measured frequency response down to 0.5 Hz. A GRAS 40AZ ½” free field microphone with a frequency response of ±1dB to 1 Hz and ±2dB to 0.5 Hz was used with the SVANTEK meter. The meter and microphone arrangement is therefore suitable for measurement of noise levels in the infrasound range to the level of accuracy required for the assessment.

Microphone Mounting Method

A microphone mounting method is provided in IEC 61400-11 [13]. The method was developed to minimise the influence of wind on the microphone for the measurement of noise in frequencies higher than those associated with infrasound. This is achieved by mounting the microphone at ground level on a reflecting surface and by protecting the microphone with two windshields constructed from open cell foam. The method was not developed specifically for the measurement of infrasound, and wind gusts can be clearly detected when measuring in the infrasound frequency range using the above method. Therefore, this study has developed an alternative method to reduce the influence of wind on the microphone that would otherwise mask the infrasound from a particular source. A below ground surface method was developed based on a similar methodology [14]. This method has been adapted for this study, and includes a dual windshield arrangement, with an open cell foam layer mounted over a test chamber and a 90mm diameter primary windshield used around the microphone. The microphone mounting arrangement is depicted in Figure 1.

Verification of Technique

The below ground technique was analysed at a remote site away from wind farms, transport corridors and other appreciable noise sources and in very still conditions. The aim of the analysis was to determine the level of transfer of infrasound from outside to inside the chamber. The following procedure was used:

- A constant level of infrasound was generated using a tone signal generator and sub-woofer speaker (B&W Type ASW CDM), mounted 1m above the ground at a distance of 10m horizontally from the chamber. The lowest frequency that could be generated by the signal generator was 8 Hz and therefore the infrasound was generated at a number of discrete frequencies between 8 and 20 Hz.
- The infrasound was measured using the IEC 61400-11 above ground technique;
- The infrasound was measured using the below ground technique;
- The infrasound was measured without the tone signal generator operating to determine the ambient level of infrasound.

The measurement results are summarised in Table 1. The measured levels inside and outside of the chamber were consistent at all of the frequencies produced by the signal generator. The measurement of a constant source of infrasound in still conditions is the same above the ground as in the chamber using the technique described above.

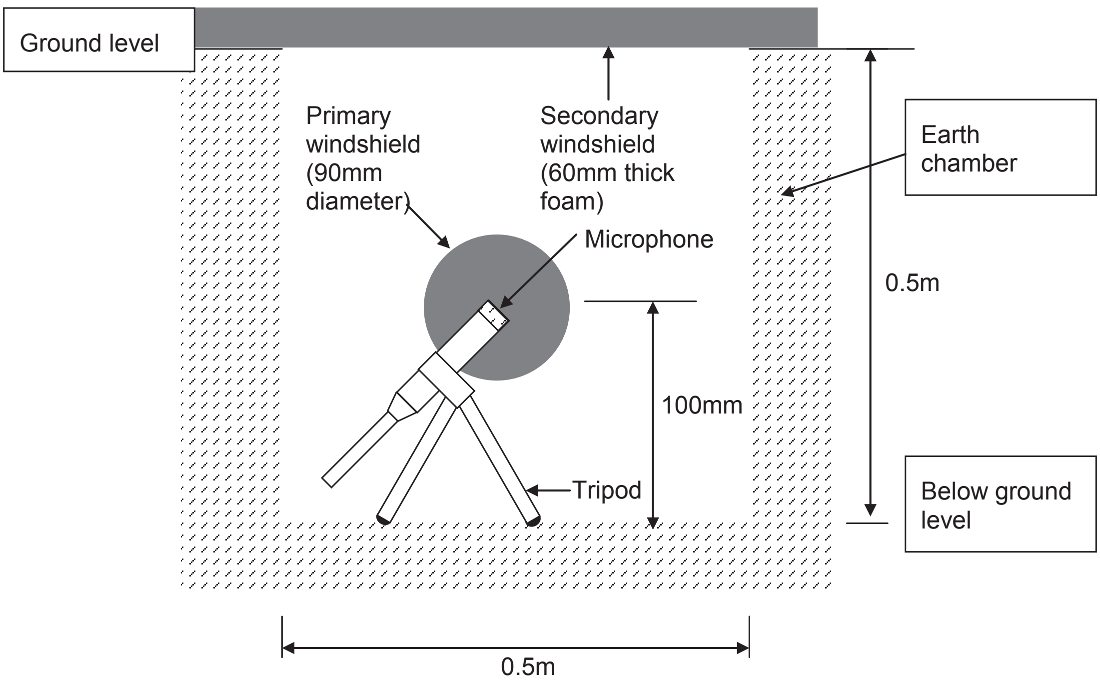

Figure 1. Schematic diagram of the microphone position (not to scale)

Table 1. Measurement at approximately 10m from the controlled source with no wind

Frequency (Hz)		8.00	10.0	12.5	16.0	20.0
Noise Level (dB)	Inside chamber	47	50	54	60	63
	Outside chamber	47	50	54	60	63
	Ambient level	39	38	39	39	37

RESULTS

Infrasound was measured at the Clements Gap Wind Farm and the Cape Bridgewater Wind Farm, using the below ground methodology. In addition, the level of infrasound was measured in the vicinity of a beach, a coastal cliff, a city and a power station using the same methodology. At Clements Gap Wind Farm, the infrasound was measured at distances of 85m, 185m and 360m from the base of a turbine in a downwind direction. The testing was conducted between approximately 7pm and 11pm on Tuesday 11 May 2010, under a clear night sky with a light breeze. Operational data indicates that the turbines were subject to hub height wind speeds of the order of 6 to 8m/s during the period of the testing. The wind speed at ground level was not measured.

At Cape Bridgewater Wind Farm, the infrasound was measured at distances of 100m and 200m from the base of a turbine in a downwind direction. The testing at the wind farm site was conducted between approximately 4am and 6am on Wednesday 2 June 2010, under a clear night sky with a light breeze. During the testing, the operational status of the turbines was constantly observed and confirmed. Measurements were conducted with both the turbines operational and with the turbine blades stationary.

To determine the level of infrasound from natural sources, measurements using the below ground method were made at Cape Bridgewater 25m from the high waterline of a beach, at approximately 250m inland from a coastal cliff face and at 8km inland from the coast. To determine the level of infrasound from other engineered noise sources, measurements using the below ground method were conducted at a distance of approximately 350m from a gas fired power station as well as within the city of Adelaide at least 70m from any major road. The measured levels of infrasound are summarised in Table 2 and are shown graphically in one third octave bands in Figures 2, 3, 4 and 5.

Table 2. Measured levels of infrasound

Noise Source	Measured Level (dB(G))
Clements Gap Wind Farm at 85m	72
Clements Gap Wind Farm at 185m	67
Clements Gap Wind Farm at 360m	61
Cape Bridgewater Wind Farm at 100m	66
Cape Bridgewater Wind Farm at 200m	63
Cape Bridgewater Wind Farm ambient	62
Beach at 25m from high water line	75
250m from coastal cliff face	69
8km inland from coast	57
Gas fired power station at 350m	74
Adelaide CBD at least 70m from any major road	76

DISCUSSION

At the Clements Gap Wind Farm, the level of attenuation with increasing distance from the turbine is consistent with the theoretical reduction of 6dB for each doubling of the distance due to “hemispherical spreading” of the sound wave. This observation confirms that the measured levels were predominantly produced by the turbine. At the Cape Bridgewater Wind Farm, higher ambient noise levels (without the turbines operating) were encountered than at the Clements Gap Wind Farm and therefore the same attenuation with increasing distance was not observed. This indicates that the measured levels included a significant contribution of infrasound from the turbine at 100m but at a distance of 200m, the infrasound from other sources was at least as significant. The levels of infrasound from waves at a beach (in light swell conditions) and in the vicinity of a coastal cliff were in the same order of magnitude as the infrasound measured close to the wind turbines.

At 8km from the coast, the level of infrasound was significantly lower than levels observed in close proximity to the beach and the coastal cliff. The levels of infrasound in the city of Adelaide and in the vicinity of a gas fired power station were greater than the levels observed close to the wind turbines. The measured levels of infrasound from the wind turbines and all other natural and engineered sources were well below the 85dB(G) threshold of audibility.

CONCLUSIONS

A method for measuring infrasound from wind turbines has been successfully demonstrated. The method shows that wind turbines generate infrasound and that close to wind turbines, the level of infrasound is well below the audibility threshold of 85 dB(G). An attenuation rate of 6dB per doubling of distance from a single turbine was also demonstrated. Infrasound is prevalent in urban and coastal environments at similar levels to the level of infrasound measured close to a wind turbine.

ACKNOWLEDGEMENTS

Pacific Hydro commissioned Sonus to conduct a study with the aim of gaining a better understanding of the levels of infrasound from wind farms and more generally in the environment.

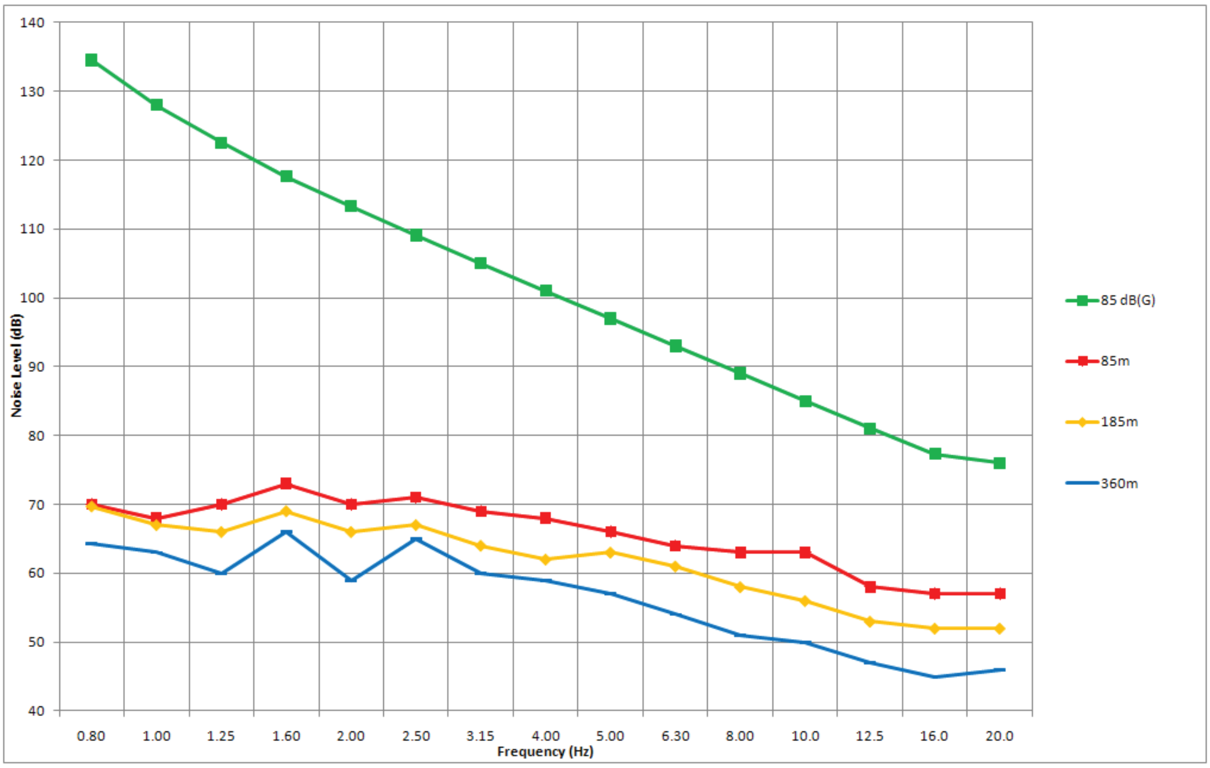

Figure 2. Measured levels of infrasound at Clements Gap Wind Farm

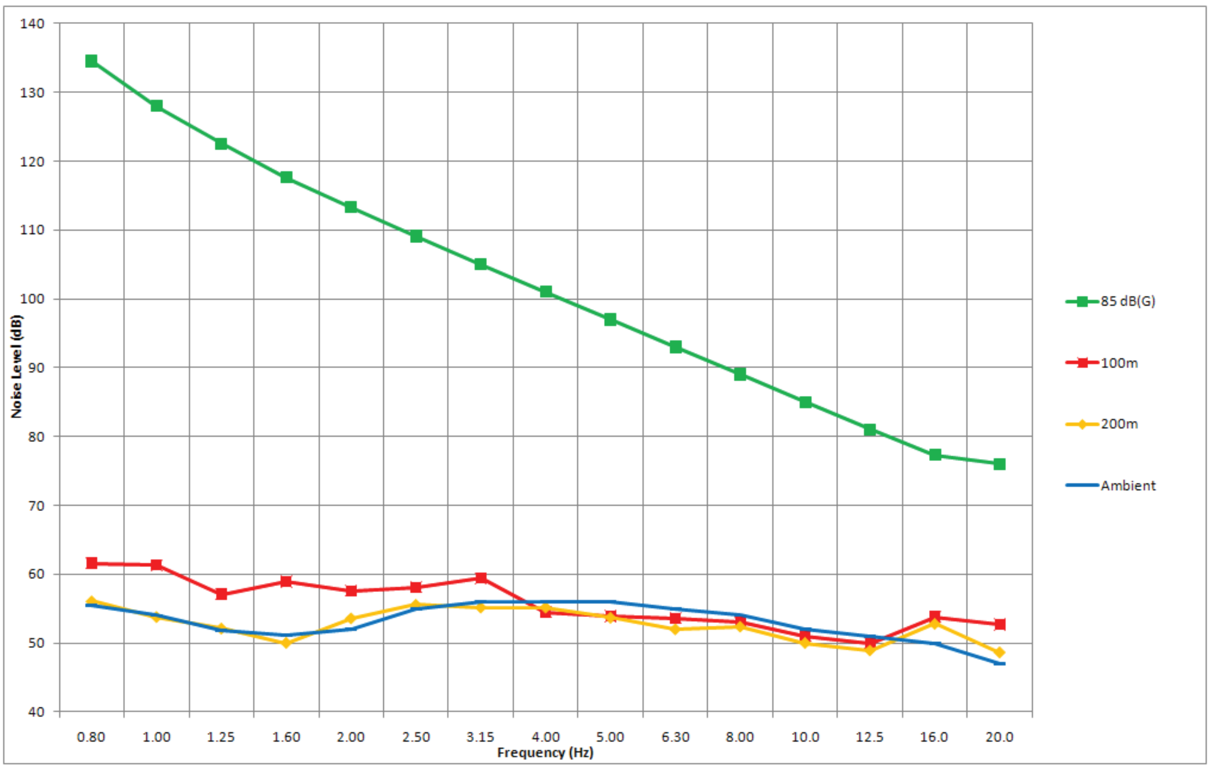

Figure 3. Measured levels of infrasound at Cape Bridgewater Wind Farm

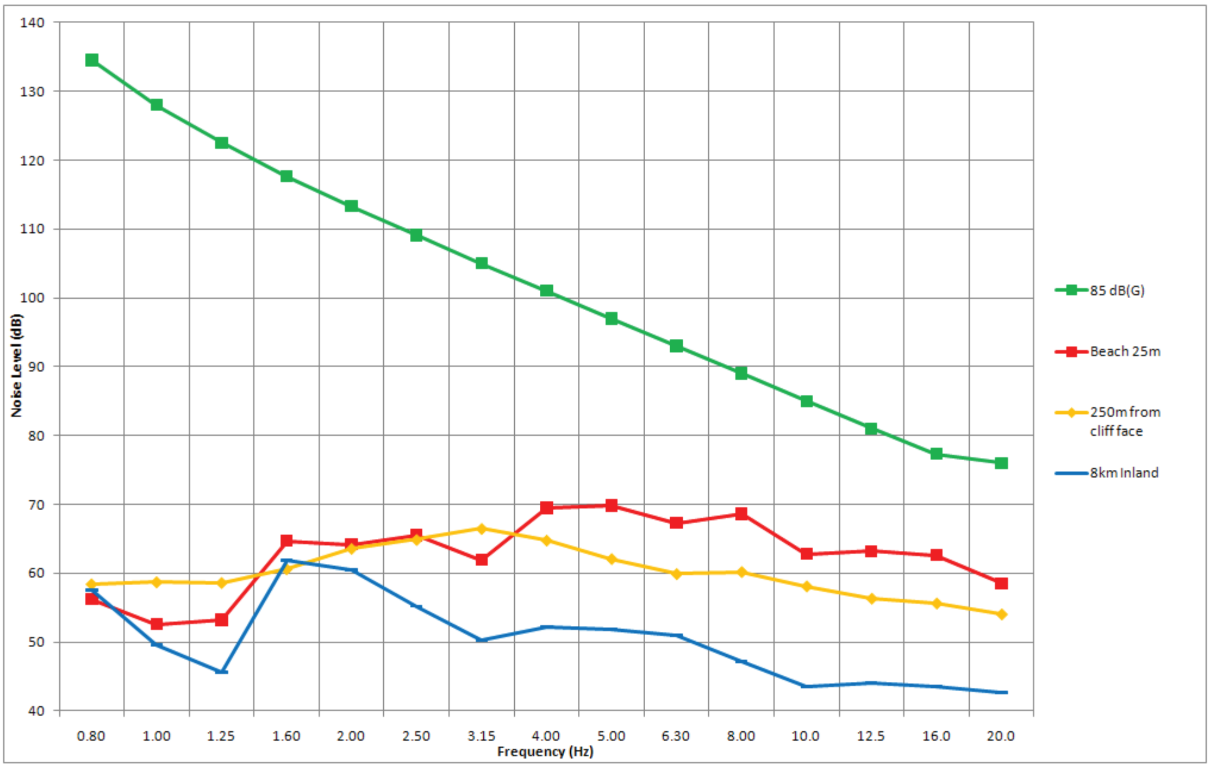

Figure 4. Measured levels of infrasound from natural sources

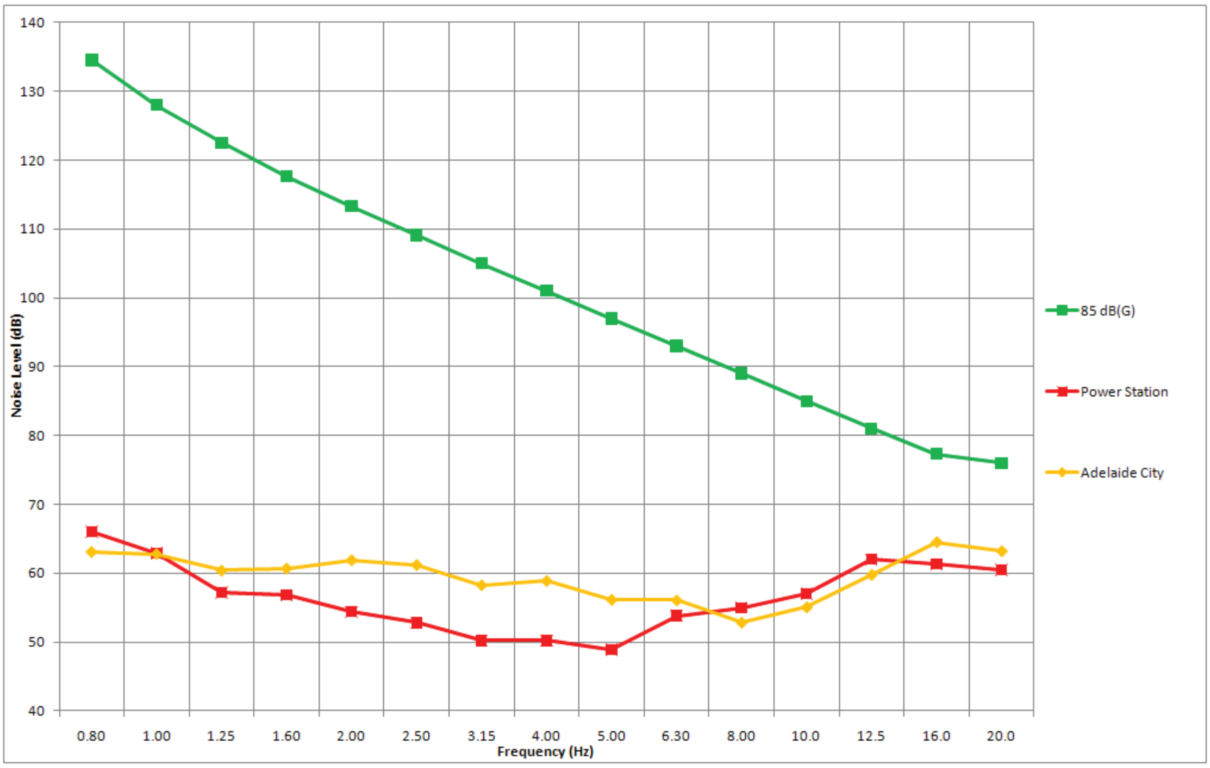

Figure 5. Measured levels of infrasound from engineered sources

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Appendix C

Comments on: Shepherd,D et al. Evaluating the impact of wind turbine noise on health---related Quality of life. Noise & Health 2011; 13:(54)333-9.

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The study was cross-sectional and used a non-equivalent comparison group. The wind farm sample was drawn from 56 houses and the control group from 250 houses. The researchers do not identify how many participants per household were recruited, however the final sample included 39 people in the wind farm group and 158 in the control group. While there were differences detected between the groups in relation to satisfaction with the living environment, critically **there were no differences between the groups in terms of self-rated health and current illness.**

The results of this study must also be interpreted in context. At the time this survey was distributed there had been some negative publicity about the wind farm in Makara. For instance a small number of people concerned about the wind farm publicly discussed their concerns on national free to air television (Campbell Live, TV3 9 August 2009). The 2010 survey was also distributed relatively soon after the wind farm was first operating in April 2009. For those living in proximity to wind farms, positive attitudes to wind farms have been shown to increase over time (Warren, Lumsden, O'Dowd, & Birnie, 2005). It is therefore unsurprising that the 39 people who responded to the survey were people feeling less satisfied with their living environment, than the control group, given that the wind farm was a relatively new feature of the landscape and there had been adverse publicity about effects of the wind farm on the living environment. The control group were unlikely to have experienced recent comparable change to their living environment, nor any related publicity affecting perceptions of their home environment. Evidence indicates that as time progresses and adverse publicity dwindles, satisfaction in the wind farm group will increase and perceptions of the Makara wind farm will become more positive (e.g. Warren et al., 2005).

Further, concern itself can have an effect on objective and subjective sleep quality. In a double blind experimental field study, participants from ten villages in various parts of Germany were exposed to sham signals and electromagnetic field signals from an experimental base station, while their sleep was monitored in their home environment over 12 nights (Danker-Hopfe et al., 2010). There was no evidence for direct short-term physiological effects of electromagnetic fields emitted by mobile phone base stations on sleep quality. However, results indicated a negative impact on objective and subjective sleep quality in subjects who were concerned that proximity to mobile phone base stations might negatively affect health. This study has particular relevance for research conducted in the Makara Valley (Shepherd et al., 2011). Adverse publicity about the Makara Valley wind farm aired on free to air television specifically dealt with concern about expected sleep disturbance from wind turbine noise (Campbell

Live, TV3 9 August 2009). Such publicity is likely to have created a negative impression of the Makara wind farm bound to create concern and tension within the community. It also gives an idea of what to expect as a result of living in the vicinity of wind farms e.g. sleep disturbance. Media reporting about health effects is very strongly related to corresponding symptom reporting, even when the information disseminated is erroneous (Faasse, Cundy, & Petrie, 2010). Such information appears to create specific health concerns, which has a priming effect, whereby people notice physical symptoms aligning with the information given (Winters et al., 2003). Where people are concerned about the health effects of an environmental agent they are inclined to monitor their physiological state and attribute their ordinary experience of symptoms to that environmental agent (Petrie et al., 2005). Epidemiological studies consistently indicate that sleep disturbance and fatigue is commonly experienced in the community (e.g. McAteer, Elliot, & Hannaford, 2011). For instance, evidence has shown 27% of New Zealand adults aged 20 to 59 years have a current sleep problem (Paine et al., 2005). Therefore, people concerned about noise induced sleep disturbance may begin to monitor their sleep patterns and erroneously attribute their normal sleep experience, which involves a level of disturbance, to noise emitted by wind turbines.

In addition, such concern may, in itself, interfere with sleep patterns, given a relationship between anxiety and insomnia (Jansson-Forjmark & Lindblom, 2008). Thus, there are a number of pathways by which people may attribute sleep disturbance to wind farm noise, without there being a direct relationship between noise exposure and sleep disturbance. It is also very important to be aware that objective and subjective measures of sleep disturbance are only modestly correlated (O'Donoghue, Fox, Heneghan, & Hurley, 2009). Therefore subjective measures of sleep disturbance measured in wind farm studies may not reflect actual sleep disturbance.