The Cape Bridgewater Wind Farm Noise Study – Sensitisation, and Cause & Effect

In 2014 a noise study was undertaken at three houses in proximity to the Cape Bridgewater Wind Farm, in south-west Victoria, Australia, with a specific brief to undertake measurements to determine certain wind speeds and certain sound levels that related to disturbances reported by specific local residents. Resident's diaries used throughout the eight week monitoring period describe the severity of three different impacts: noise, vibration and sensation on a ranking of 1 to 5. The sensation index when married up with the speed and output of the windfarm identified a cause-and-effect where for higher levels of sensation specific operating modes of the windfarm were identified as causing the greatest level of disturbance.

Six adult residents (three households) have lodged complaints with the wind farm operator in relation to noise disturbance with one household abandoning their property three years ago with the two other households abandoning their property after the completion of the study. The wind farm operator claims that the wind farm is acoustically compliant with the permit conditions which are expressed in terms of the A-weighted value. Yet despite acoustic this, the six residents have lodged hundreds of noise complaints.

In mid-2013 as a result of documented evidence in relation to a screeching noise from the turbines an investigation by the operator revealed an issue with brakes for the yaw mechanism (for the rotating hub assembly). A public apology was made by the company for the “screech” and they stated that the issue had been resolved. The residents' noise complaints continued.

As a result of a subsequent community consultative process, including input from a Federal Senator representing the state of Victoria, an undertaking was given by the wind farm operator to conduct an acoustic survey by an acoustician selected by the residents.

Originally the residents requested a team of independent acousticians to undertake an acoustic survey similar to that carried out for the Shirley windfarm study but the wind farm operator restricted the survey to one acoustician. The residents selected the author to undertake the study.

In view of observations and measurements at other wind farms, the proposal for the study nominated full sound spectrum measurements inside and outside dwellings, a diary format to be filled in by the residents during the monitoring period, measurements on the wind farm in relation to identification of various sources of emission, and for the operator to provide the wind farm data with respect to power output, wind speed and wind direction from the turbines.

Timing around the conduct of the monitoring was to coordinate with a planned shutdown over a two week period to undertake cabling work at the Main substation, associated with the addition of a further stage of the wind farm complex in the same region.

With the planned shutdown occurring, it was considered appropriate to include the shutdown period in the study so as to determine the ambient noise at the three residential locations under various wind conditions, not just low wind situations where the turbines were either not turning or not producing power.

During the course of the monitoring it was found that the shutdown for the high voltage cabling work occurred for some 10 days where the wind farm was shut down around 6:30 AM in the morning to start up some 12 hours later, and one occasion some 48 hours later.

The brief from the wind farm operator for the study was to:

> ***Undertake noise and vibration monitoring to determine certain wind speeds and certain sound levels that related to disturbances reported by specific local residents.***

The specific brief was an entirely different approach to looking at wind farm noise. It did not look to permit conditions or a nominated threshold, and more importantly it was not a health study. It was a detailed acoustical investigation of disturbances being reported by residents from three homes, and the acoustic environment inside and outside those homes.

Prior to undertaking the testing regime the residents trialled a diary format used by the South Australian EPA with respect to the Waterloo wind farm [2] that reported only noise events. The participants in the study found the diary was inadequate.

An alternative severity ranking method used for a UK wind study [3] was considered more appropriate by the residents, but there was difficulty in expressing the disturbance in terms of noise. Discussions with the residents indicated that apart from noise, there are issues of vibration both in terms of continuous and intermittent pulses, and also that there were disturbances which were not directly attributed to noise or vibration. As a result the concept of sensation was added to the diary format in addition to noise and vibration.

As set out in the study report [1] sensation was considered to encompass headache, pulsations or pressurisation detected in the head or parts of the body. During the study it became apparent that many of the sensation descriptions also included fatigue, and sleep disturbance.

By use of the diary format periods of increased levels of disturbance were found to relate to certain operations of the wind farm (first part of the brief) which were identified as:

- when the turbines were seeking to start to generate power
- when the turbines were at maximum power, and the wind strength was increasing such that there was a de-powering of the blades, and
- changes in power of 20% or more for about an increase or a decrease in the wind speed.

Contrary to reports in the media, the residents for the majority of the time could not see the operation of the turbines whilst inside their dwellings in the day – unless they went to windows that had an outlook to the turbines.

Obviously when going outside the dwellings in the day, the operation of the turbines could be seen, but not at night, unless the moon was out.

Figure 18 and 19 in the study report [1] show the variation in the dB(A) level throughout the day with the reporting of noise, vibration and sensations for house 88 (where the turbines cannot be seen from inside the home) to show the change in sensation occurs throughout the day with relatively low wind speeds. The expanded view of the turbine output and the wind from the turbines themselves (not a met mast) show the first concept in the hypothesis. It is noted the internal background level is around 20 dB(A).

From both the internal or external A-weighted level versus the hub height high wind speed, or the power output of the wind farm, the study did not find any relationship to the reported disturbances.

The survey method required attendance by the author on a fortnightly basis to download the data from the various sets of instrumentation being used, and to discuss the survey results/observations of the residents, leading to the residents understanding the variations in the operation of the windfarm.

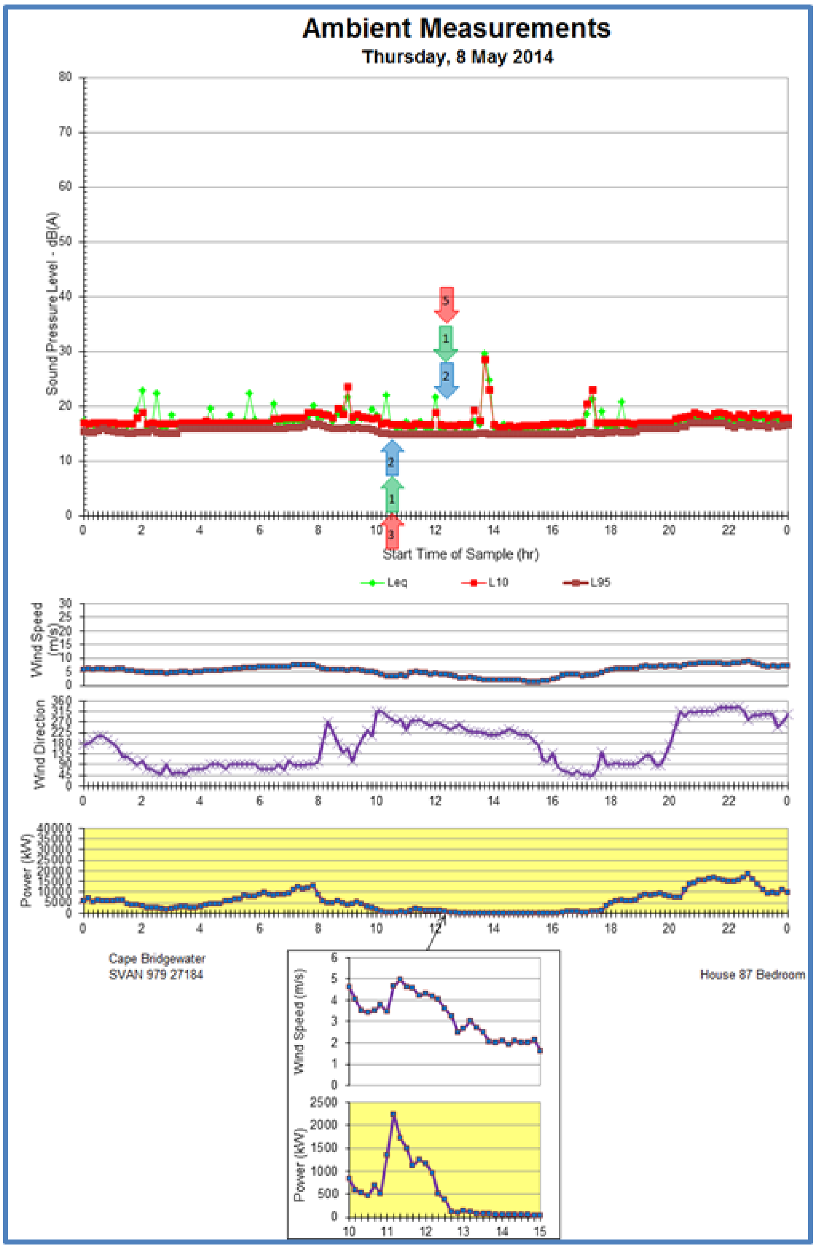


FIGURE 18: Internal Measurements (House 87): blue – noise, green – vibration and red - sensation

By concentrating on the high levels of sensation, the cause-and-effect of the specific operating windfarm conditions is consistent with the preliminary findings, however these had no relationship to the audible noise.

The report identifies there was no correlation of the usual noise level descriptors found in environmental assessments. However there was a high correlation of some acoustical descriptors with the wind speed.

Similarly the use of 1/3 octave band information did not find any relationship with the operations of the turbines, or the disturbance reported by the residents.

However looking at the narrow band components associated with the blade pass frequency and multiples of that frequency for the high levels of sensation, there were elevated levels of the infrasound components inside the dwellings which related to the higher levels of sensation.

Sensation 5 was a level of severe disturbance such that the residents wanted to leave, or actually left their dwellings. This level of disturbance was considered the worst-case scenario. For the limited data set available, the extreme high levels of sensation were analysed and found to have a trend/relationship with the discrete infrasound spectra from turbines that the author has named "wind turbine signature".

The narrowband infrasound signature at Cape Bridgewater is consistent with that found at other wind farms by researchers, such as at the Shirley windfarm in the US [4], Health Canada study in Ontario [5] and Adelaide University at Waterloo [6], in addition to previous measurements conducted by the author at other wind farms.

The identification of the wind turbine signature attributed directly to the wind farm was established by comparing the measured levels 20 to 30 minutes prior to the complete shutdowns, which was compared to measurements 30 to 45 minutes after the shutdown where the weather conditions over that period were found to be consistent on the day of concern. With multiple shutdowns over some 10 days there were a range of weather conditions and wind directions available for analysis.

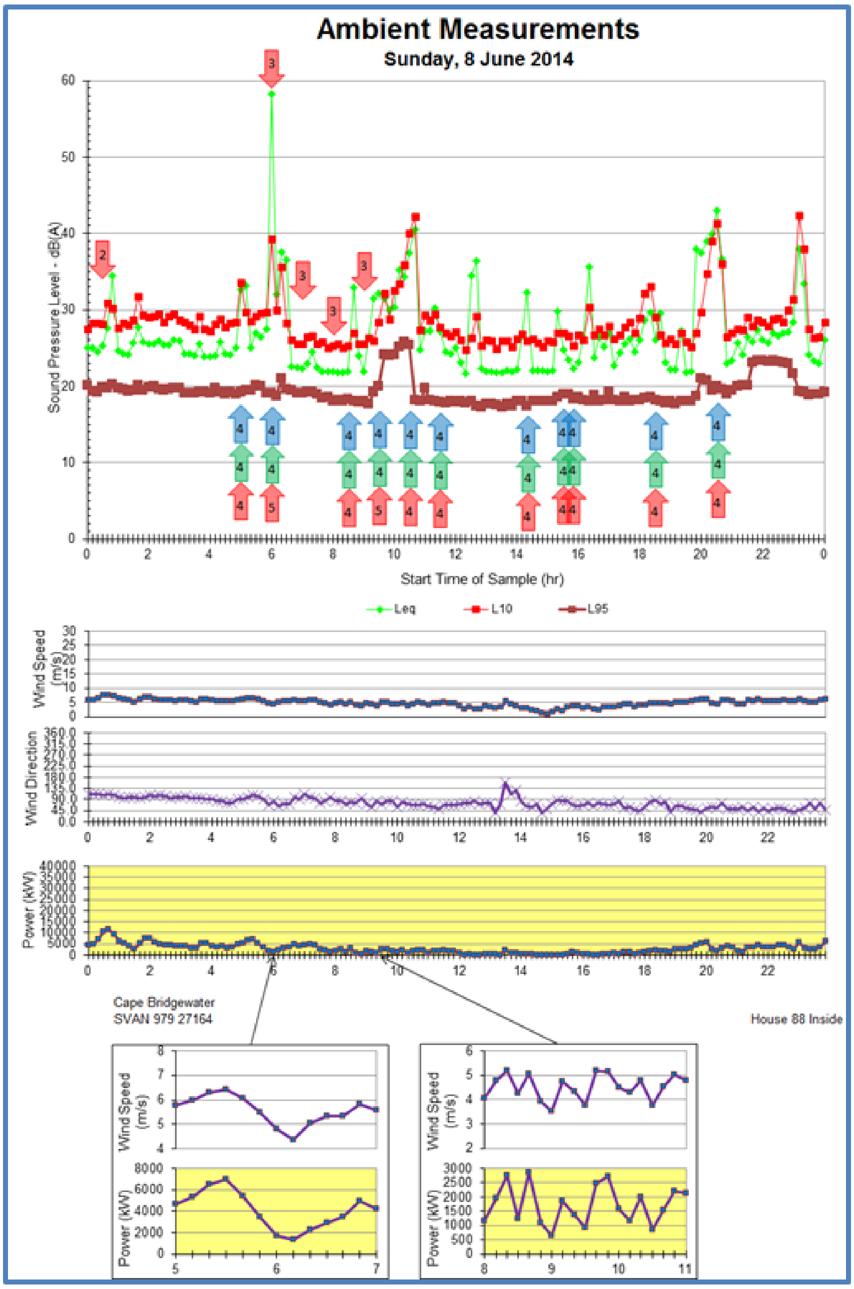


FIGURE 19: Internal Measurements (House 88): blue – noise, green – vibration and red - sensation

It is noted that the shutdowns were complete shutdowns, where the power to the wind farm was disconnected. This is in contrast to other shutdowns which has occurred in some testing, where the turbines are simply stopped for a period of time. If one uses the terminology of "temporary shutdown" to describe a situation that has the turbines stationary, there is ancillary equipment in the turbine towers that may still be operating. At Cape Bridgewater there were some cases where a turbine was in a temporary shutdown mode and the ventilation fans in the towers were found to be a source of noise radiation.

Figure 41 shows the narrow band (400 lines, 0 – 50 Hz) rms level signature for an ON – OFF test using an external ground plane, where the difference at 1600 metres from the nearest turbine is evident.

Figure 42 compares the 1/3 octave band versus the narrow band signals for the same results to show the 1/3 octave band information is of no assistance in investigation of wind turbine noise external to dwellings.

Figure 49 compares the wind turbine signature for sensation 5 (limited data) to sensation 2 and shows the difference in the levels and a slope that is similar to that found in other studies.

The levels for the infrasound components are all below the threshold of hearing. These measurement results relate directly to the reported disturbances. They are not an idea that somebody came up with such as "*If you can't hear it you can't feel it*" [7 – page 485] which is quoted.

The Cape Bridgewater study identified that the operation of the wind farm did relate to disturbance reported by the residents.

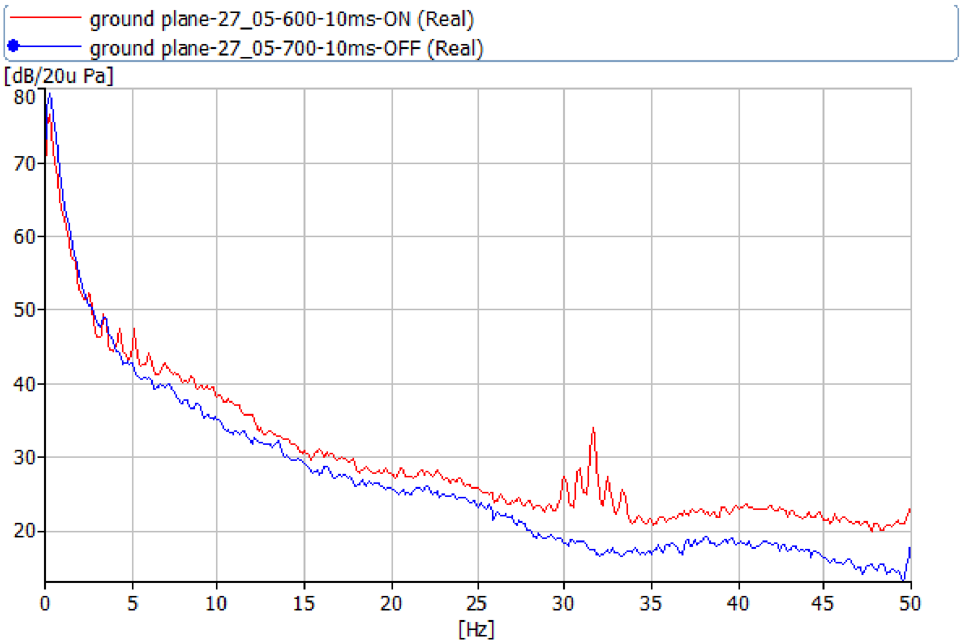


Figure 41: House 87 Results Wind Farm ON and OFF (0 – 50 Hz) – MODERATE WIND

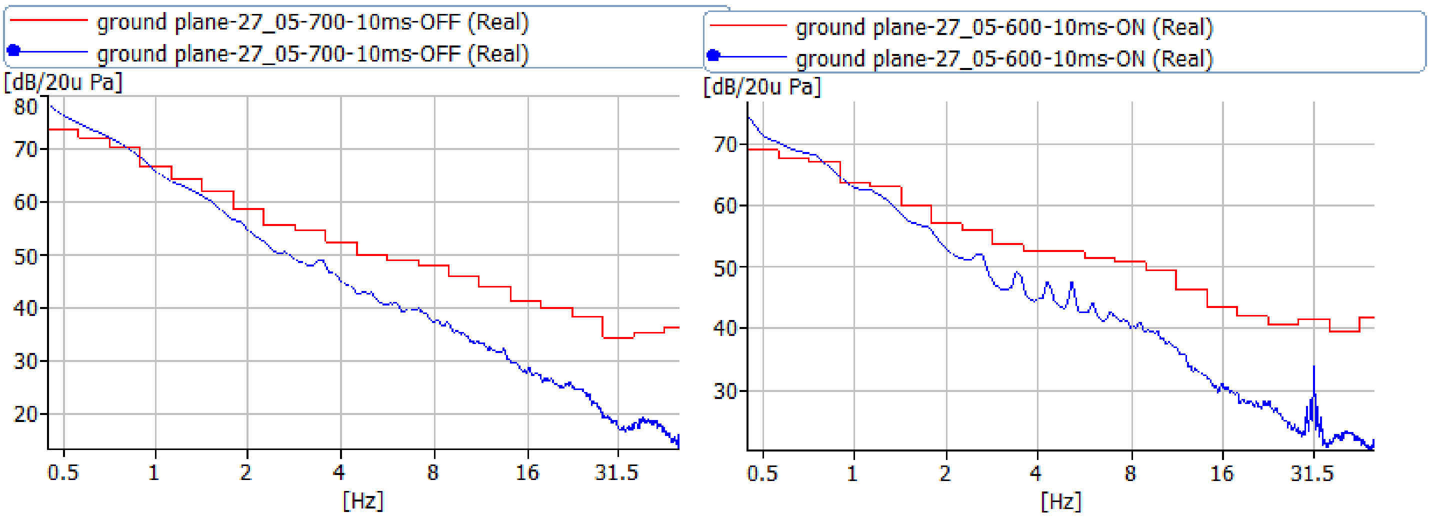


FIGURE 42: House 87 Results Wind Farm ON and OFF – MODERATE WIND

The study also identified the presence of the turbines (not operating) did result in vibration and sensation being detected even when the wind farm was completely shut down. Rather than publicly ridicule the residents perceiving such observations during a shutdown (as has occurred) the study found those intermittent sensations to be related to the occurrence of wind gusts, and suggested there are resonance effects of the blades/tower that are being excited in the infrasound region that cannot be heard but can be perceived.

The threshold of sensation in the infrasound region is below the threshold of hearing. That was established in the early 1980's by Kelley [8] and apparently lost by acousticians. The Kelley material resurfaced again after the author's measurements in May 2013 at Waterloo, where residents were requested to identify if they could detect the turbine operating (not hear them) inside their homes without looking outside. A similar result was found for people in a basement in the Shirley wind farm study.

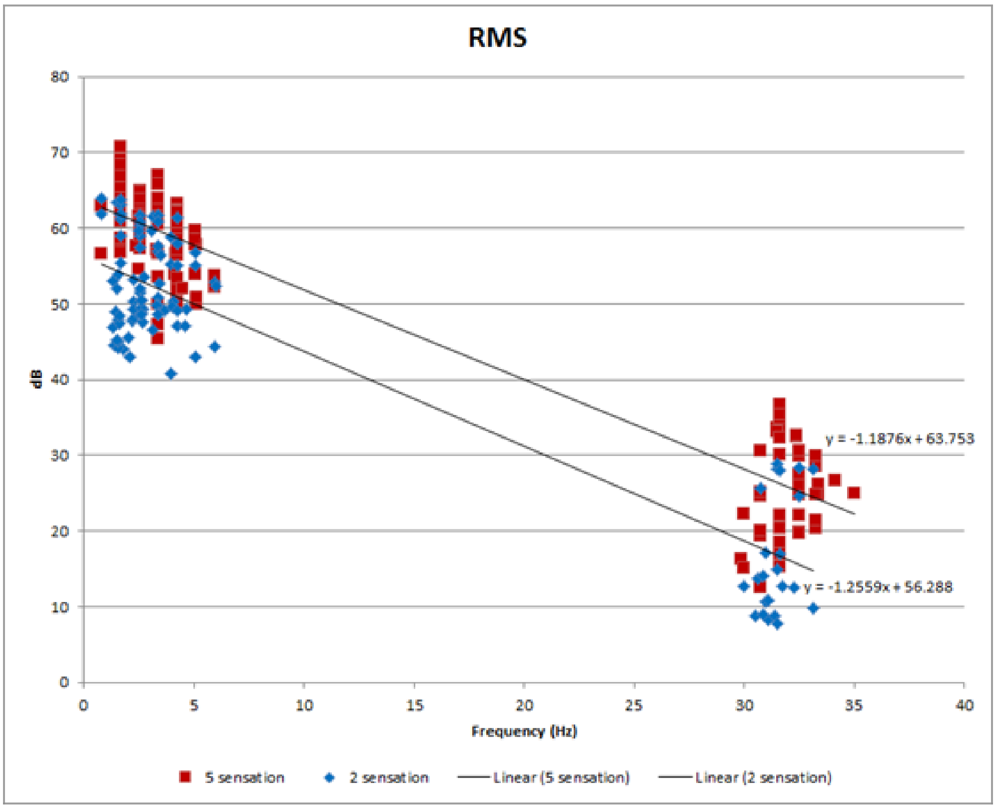


FIGURE 49: WTS and 31.5 Hz RMS components

The CBW study report utilised the slope of the infrasound components from the turbines, and presented the dB(WTS). Unfortunately the dB(WTS) is the property of the wind farm operator and no release has been given to use that term by the author.

It is proposed instead to use a new term (outside of that contract) as L (S-WT) of xx dB where the descriptor is Level of Sensation (Wind Turbine). This allows the use of Sensation (Gas Turbine), Sensation (Power station) and Sensation (Air Conditioning) to describe different sensation spectra.

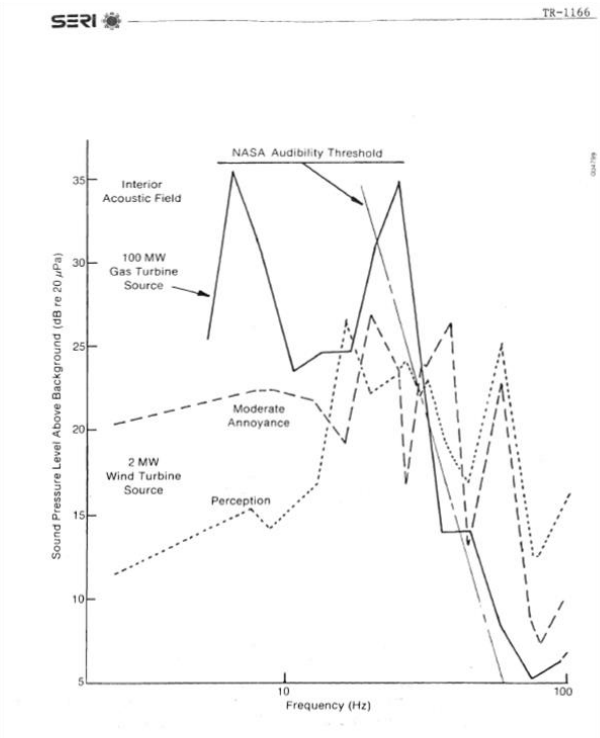
In considering the concept of the threshold of perception to operating wind turbines and other sources of infrasound there is the issue of a lower dose response relationship after chronic exposure. The residents in the CBW study have been exposed to the turbines for 6 years. They have a heightened sensitivity to infrasound than the residents at Waterloo or the Shirley wind farm, who were less chronically exposed at the time the measurements were taken.

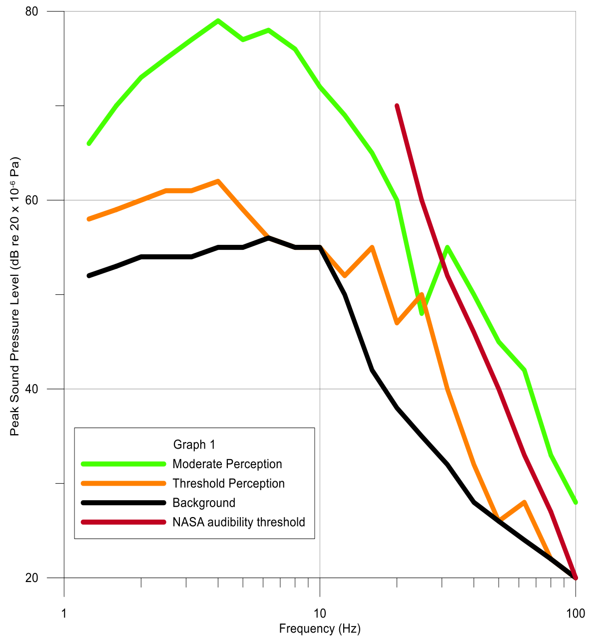
It may also be the case that the residents in the Kelley MOD-1 testing had a limited exposure. Whilst the Kelley material was expressed in peak values, obtained using instrumentation that would be considered very much out of date now, I have attempted to extract the relevant data from the report to show what was known back in the 1980s as a basis of persons newly affected.

Slide 7 is from the SERI report and shows the gas turbine to have infrasound components above the moderate annoyance and perception of the wind turbine.

The SERI report expresses the levels above the background, and is not directly comparable to the CBW report or the Shirley wind farm report.

From the SERI report the background level for the two houses can be obtained (they are different) to show the peak levels in the infrasound region are below the NASA audibility threshold – see slide 8.





Slide 7

Slide 8 SERI Perception Thresholds

DISCUSSION - IS INFRASOUND AN ISSUE?

What areas should we as acousticians look to undertake for further research into the impact of turbines?

Acousticians working in the real world are often called upon to solve problems that come about as a result of complaints. Having a background in industrial noise issues and licensed premises gives rise to odd hours and interesting projects that are not the standard fare of building acoustics or environmental matters such as road traffic, rail traffic or aircraft nose assessments of buildings.

There are quite a few cases of industrial noise complaints involving gas turbines, compressors and air conditioning matters that whilst having complaints about low frequency noise also included the presence of infrasound.

Whilst we didn't have the instrumentation to accurately view infrasound years ago, that didn't stop the complaints being addressed. In the 1980's the author was faced with complaints from the furnaces in a brick pit when on a low fire rate. One of our Universities had a lecturer that specialised in gas burners and airflow from jet engines. The use of high speed photography to film gas flames showed instability of the flame at the low fire rate.

The main frequency of disturbance was in the infrasound region. We adapted air conditioning duct attenuation concepts to the lower frequency by making labyrinth chambers with U shaped passages big enough to drive a fork lift truck that allowed the required air flow for combustion and solved the problem.

The acoustician working in the real world must take into consideration the large number of complaints generated in relation to wind farms. Even if one discounted 50 % of the complaints, people do not just complain about nothing.

The "if you can't hear it, you can't feel it" thought [7] was not scientifically studied (or at least presented in papers). We undertook tests using infrasound that can be generated between 8 Hz and 10Hz from large speaker combinations and found the "thought" of Leventhall and Johnson to be easily disproved.

Acousticians around the world responding to resident's complaints about wind farms are finding there are unique acoustic signatures with discrete infrasound components.

Maintaining a belief in limited studies carried out 20 or more years ago based upon a concept derived for small turbines and ignoring developments in instrumentation and bigger turbines, and maintaining the belief of only considering audible noise [9] does not favour the possibility of further investigation into what is the problem for the community, despite the moral and ethical obligations of acousticians to protect the well-being of the community.

Testing in houses in the real world using people already sensitised should be undertaken before laboratory studies

Discussions with major speaker manufacturers have some difficulty in producing the infrasound levels that have been measured in homes. Is the problem energy at the blade pass frequency, the harmonics of the blade pass frequency or the energy (vector) combination of all of the infrasound frequencies? Limiting the bandwidth of the generation of the signal for evaluation purposes is not the same as what is experienced by residents in the real world. This may be an area of investigation?

Another area of investigation based on our work over the years is that of the period of exposure.

Testing for one family near a wind farm in Waubra (In Victoria) by a number of acousticians has consistently found low frequency and infrasound signatures that occur at other wind farms.

However, the inquisitive nature of the noise control engineer in me asked questions of the family members (on an individual basis – with the approval of the family) to find that the wife noticed an effect the very first day the turbines were turned on. Within a month the wife was having disturbed sleep. The husband didn't understand the fuss until about 9 months after the turbines started and then had a problem with using his dedicated sitting position in the living room for watching television and reading. Over time the disturbance deteriorated.

The children (3 off) took a longer time to be adversely impacted with the youngest one (pre-teen) taking a further two years to be disturbed.

The SERI study used the MOD1 turbine (exposure period unknown). Figure 5 identifies the SERI threshold of perception, being higher than that obtained for sensitised residents (3 years) near the Waterloo wind farm.

We know the Cape Bridgewater residents had a six year exposure at the time of the testing. We should seek to ascertain the exposure period for the residents in the Shirley wind farm study to place their threshold levels in the context of sensitisation versus exposure periods.

CONCLUSION

It is unlikely that infrasound level inside dwellings in proximity to wind farms will be audible. The use of audibility as a defence in relation to adverse impacts or annoyance is irrelevant.

The proposition (that developed from an idea – not field or laboratory testing) that "*if you can't hear it, it can't affect you*" is not a scientific approach, is not supported by empirical scientific evidence, and must be dismissed.

Residents have reported disturbance and adverse impacts from the operation of wind turbines when such turbines cannot be heard, and the predicted exterior levels are below 35 dB(A) with internal dBA levels below 30 dB(A).

The concept of sensation has been found to be a better descriptor for disturbance than noise.

The diary concept developed for the Cape Bridgewater study included sensation, and found sensation to be the major factor for disturbance.

Plotting the diary information versus the noise level found no correlation or trend with the operation of the wind farm.

Plotting the diary information found a pattern of disturbance related to specific wind speeds and power output of the wind farm that demonstrated a cause and effect relationship.

The certain sound levels that were related to disturbance were found to be in the infrasound region, and related to the blade pass frequency and harmonics of that frequency, when assessed in narrow bands. Utilising 1/3 octave bands is of no assistance in identifying the wind turbine signature.

Testing at various wind farms has found a range of infrasound levels that have patterns associated with the operation of the turbines.

The results of the Cape Bridgewater study suggest further investigations of the cause and effect of reported adverse effects from turbines using dB(A) is of no assistance, but the use of the L(S-WT) descriptor determined from the CBW study may be of assistance.

It would appear that a dose-response exists, which leads to a greater degree of sensitivity to residents as the exposure period is increased. Any further studies into wind farm impacts should initially occur in their homes (before laboratory studies) and it is suggested must take account of the period of exposure for those residents.

1. "The Results of an Acoustic Testing Program, Cape Bridgewater Wind Farm", Dec 2014 http://waubrafoundation.org.au/resources/cooper-s-acoustic-group-results-cape-bridgewater-acoustic-investigation/
2. SA EPA, "Waterloo Wind Farm, Environmental noise study", November 2013
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4. Walker B, Hessler DM, Hessler GF, Rand R & Schomer P, " A Cooperative Measurement Survey and Analysis of Low Frequency and Infrasound at the Shirley Wind Farm in Brown County, Wisconsin", Report Number 122412-1, December 2012
5. MG Acoustics, "Analysis, Modeling, and Prediction of Infrasound and Low Frequency Noise from Wind Turbine Installation, Phase 2: Southern Ontario Site, Final Report", February 2014

6. Hansen K, Zajamsek B & Hansen C, "Comparison of the noise levels measured in the vicinity of a wind farm for shutdown and operational conditions", Internoise 2014, Melbourne

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8. Kelley N. D., McKenna H.E., Hemphill R.R, Etter C. L., Garrelts R. L. & Linn N. C. "Acoustic Noise Associated with the MOD-1 Wind Turbine: Its Source, Impact and Control, Soar Energy Research Institute, February 1985

9. Leventhall G, "Submission to the Select Committee on Wind Turbines, Application of regulatory governance and economic impact of wind turbines", May 2015