Comments on the SA EPA Waterloo Wind Farm Environmental Noise Study 2013

The following document is an analysis of the recent "Waterloo Wind Farm Environmental Noise Study" conducted by the South Australian Environmental Protection Agency (SA EPA). Overall, the report is well-written and reflects awareness of current international guidelines on low frequency noise and infrasound. The use of specialised low frequency microphones and multi-layered windshields (in some cases) indicates that attempts have been made to ensure that the infrasound and low frequency noise is measured as accurately as possible. The inclusion of local weather station data, indoor measurement data and noise diary entries shows that there has also been an attempt to surpass the baseline requirements of the EPA guidelines. Finally, the large amount of information in the report has been succinctly summarised in tables and figures.

On the other hand, the EPA found "no evidence linking the noise from the wind farm to adverse impacts on residents" and there are several reasons why this conclusion may have been reached erroneously. These include certain limitations of the current guidelines as well as aspects of the study that could have been improved. In some cases, interpretation of the data has led to generalisations that are not well backed up by the supporting figures.

It is clear that the study undertaken by the EPA was comprehensive and complex. There are many ways of analysing and interpreting the data and the comments below are intended only to indicate the areas where I believe the analysis and interpretation could be improved. The intention of my comments is to offer alternative interpretations of the data that I believe are valid and that do not result in the same conclusion of "no significant noise impact" that was reached by the EPA.

1. General Comments

1.1. Noise criteria

While there is significant discussion in the EPA report of the low frequency indoor limit proposed by the Danish guidelines as well as the third-octave indoor limit recommended by DEFRA, compliance is nevertheless determined based on the 40 dB(A) outdoor limit specified in the EPA guidelines (2009). It is not clear whether the EPA has used L_{Aeq} values or L_{A90} to determine compliance as this has not been explicitly stated. Wind farm noise can be significantly underestimated using L_{A90} levels due to the unsteady nature of the noise. The peaks that are associated with unsteady effects such as amplitude modulation are not present for 90% of the time and hence their disturbance potential is never evaluated.

Compliance is determined based on a regression analysis that effectively "averages" the range of noise levels for a given wind speed. This means that a considerable number of 10-minute-average data points may lay above the regression line of best fit even though the wind farm is still considered to be compliant. This is particularly problematic if those instances occur at night time during stable atmospheric conditions when the contrast between wind farm noise and ambient noise is greatest (Van den Berg, 2004). At night time, annoyance and sleep disturbance effects are also likely to be most

critical. The reliability of the regression analysis could be improved by separating the results into daytime and night time and plotting separate regression curves.

A further limitation in the guidelines can be seen by comparing Figure 18 (a) and (b) for the "North East" residence. Plotting the measured sound pressure level (SPL) against wind speed at hub height shows compliance (Figure 18 (b)) whereas plotting against local wind speed shows non-compliance (Figure 18 (a)). However, it is often the case that the wind behaviour at hub height and in the vicinity of the residence bear no relation to one another, therefore Figure 18(a) appears to be the better choice for determining compliance. This argument is further supported by the better curve fit which has been attained in Figure 18 (a) compared to Figure 18 (b).

It should be noted that the SA EPA guidelines contain many references to work that was carried out in the late 1990s and the most recent reference was published in 2004. Hence, it is reasonable that these guidelines could be reviewed to take into consideration research work done since then and current international best practice guidelines.

1.2. Shutdowns

There were a total of 6 shutdowns during the measurement period. All shutdowns occurred during the day with the exception of one from 5:10 am to 6 am. For the purpose of evaluating the impact of the wind farm on the community, I believe that it would have been more appropriate for the shutdowns to have occurred between the hours of 12 am and 5 am. During the night, people are trying to sleep and this time also represents the greatest contrast between ambient noise and wind turbine noise, due to the absence of other sources such as traffic and farming machinery. This would give more confidence that any excess noise above the background noise would be due to the wind farm. Moreover, it was mentioned that many files that were obtained during shutdown had to be discarded due to indoor noise sources not associated with the wind farm. For example, at the "North East" and "South East" residences, 4 out of 6 files could not be relied upon due to indoor interferences. Between the hours of 12 am and 5 am, it would be expected that indoor noise would be at a minimum since most people are sleeping during this time.

1.3. Listening to Audio Files

The EPA provides no information about the instrumentation that was used to listen to the audio files. It is stated that "low frequency content was not discernible subjectively when replaying audio records at actual levels." There is no description of how the EPA verified that the levels that they were replaying were exactly the same as those measured. If using headphones, the only way to verify this would be to use a head form with a microphone embedded in the ear. There are several reasons why the replayed levels would not be accurately reproduced and these include: self-noise of the instrumentation (headphones/computer), ambient noise in the listening room, frequency roll-off of the headphones and/or sound card and inaccurate amplification. The instrumentation self-noise and ambient noise in the listening room would act as a masking source, making any wind farm noise less perceptible. A frequency roll-off for the headphones and sound card would cause the replayed levels at lower frequencies to be softer and hence less perceptible. Reproducing the audio files with the correct amplification for all frequencies is a challenging task which requires an anechoic (or similarly quiet) room as well as highly-specialised equipment, and it is not clear that the EPA has access to such facilities and equipment.

The recommended methodology for listening to the audio files would be to replay them in an anechoic chamber with an appropriate speaker system. In this case a microphone would need to be positioned at the location of the listener to ensure that the noise had been reproduced with correct amplification at all frequencies. This would also be challenging since the frequency response of standard speakers rolls off at low frequencies, which means that a graphic equaliser capable of amplifying the very low frequencies would be needed. It should also be noted that most audio equipment is designed to operate in the audible range (20 Hz – 20 kHz) and would thus not be capable of reproducing sound outside of this frequency range.

Finally, there is no mention of the hearing ability of the individuals who were listening to the audio files.

1.4. Supplement to Listening

Since listening to audio files can be highly subjective, it is suggested that further analysis of the unweighted levels for specific measurement times should be carried out as well. The audibility threshold curve according to ISO 389-7 (2005) should be plotted to determine whether or not levels were perceptible in any third-octave bands according to a person with normal hearing. As wind farm noise is far from steady and the levels of perceptibility are for steady tones, it is thought by many researchers that the level of perceptibility for wind farm noise would be significantly lower than the published perceptibility levels.

In addition, investigation into the character of the noise should be carried out. It was stated that the noise was subjected to a "slight degree of modulation." However there have been no efforts to quantify the extent of the modulation to justify this subjective conclusion. Several researchers have suggested a relationship between amplitude modulation and increased annoyance (Pedersen & Waye, 2004; Van den Berg, 2004; James, 2012). Both the Draft NSW guidelines (2011) and the New Zealand guidelines (NZS6808, 2010) attach a 5 dB(A) and 6 dB penalty respectively where excessive amplitude modulation is identified. However, amplitude modulation is not even discussed in the EPA guidelines. Moreover, residents often describe wind turbine noise as thumping or rumbling and these descriptive terms reflect a regular change in the amplitude of the noise with time – amplitude modulation. Finally, there were many instances in the noise diaries from the EPA report where the noise was described as "Pulsing," which is clearly an indicator of amplitude modulation.

1.5. Low Frequency Noise (LFN) Measurements

The wind turbine noise spectrum at a residence located near a wind farm can be biased to lower frequencies due to propagation effects and poor attenuation by the housing structure. Such an unbalanced spectrum of sound can be more annoying (Blazier, 1997). In addition, room resonances and structural resonances occur at low frequencies, increasing the potential for annoyance. The EPA guidelines do not specify any limits for low frequency noise; therefore other standards were consulted (Danish EPA guidelines and Department of Food, Environment and Rural Affairs (DEFRA) proposed criteria). The EPA acknowledges that for the Danish criteria "the limit should be met inside of the houses and calculated as an average of the microphone indications measured at three points." Despite this, only one microphone was used in the recent EPA study. Pedersen *et al*. (2007) have found that a microphone measurement at a single position is not sufficient to properly characterise the noise in the room due to the existence of standing waves, which are particularly significant at low frequencies below 200 Hz. Recent results have shown that indoor measurements can vary by as much as 20 dB (Hansen *et al*., 2013) and this is in agreement with observations by Kelley (1987).

Even though the EPA used only one microphone, there were still instances where the measured levels exceeded both the Danish guidelines and the DEFRA criteria. This was justified as allowable by the EPA on the basis that external wind noise contributed to the measurements. This further supports the argument outlined in Section 1.2 that the shutdowns should have been performed at night time. It has been found that stable conditions are much more likely to occur during the night, hence giving a greater contrast between wind speed at the microphone height and wind speed at hub height (Van den Berg, 2004). Nevertheless, careful observation of Figure 13 (c), Figure 21 (a), Figure 29 (a) and Figure 37 (a) for the "North", "North East", "West", and "South East" residences respectively, shows that the Danish guidelines were exceeded indoors, even for low wind speeds. But finally, as acknowledged by the EPA, the Danish low frequency guidelines require wind speed to be measured at a height of 10 m as the standard applies to wind speeds of 6 m/s and 8 m/s at this height. In the EPA study wind speed was measured at 4 m for the "West", "North East" and "South East" residences, at 2.2 m for the "North" and "Township" residences and not at all for the "East" residence. Therefore, it is difficult to come to any conclusions about the extent to which the wind farm contributed to non-compliance with the criteria because not enough data have been provided.

1.6. Wind Farm Power Output

Power output data are not provided in any of the tables and figures despite the fact that this information was made available to the EPA by the wind farm operator. While the wind speed at hub height gives an indication of how much power the wind farm may be producing, meteorological effects influence the actual value. Plotting the sound pressure level and power data on the same figure provides more insight into the relationship between these two variables.

1.7. Instrumentation Noise Floor

The noise floor of the instrumentation was not stated. It cannot be assumed that the noise floor is equivalent to the microphone noise floor (which was stated) as the data acquisition system can also add instrumentation noise. An excessive instrumentation noise floor could affect the slope of the regression curve.

1.8. Vibration

In answers to frequently asked questions, the EPA states that "vibration testing was not a part of the scope of this project. The monitoring locations are situated at high separation distances from the wind farm." The separation distances to the residences are in fact not high enough to preclude vibration from the analysis as we have found in our measurements (Hansen *et al*., 2013). Vibration can be caused by acoustic excitation of a housing structure and it is particularly perceptible in the infrasonic range or in the low-frequency range where the ear is less sensitive (Hubbard, 1982).

The fact that many residents recorded vibration as a source of annoyance suggests that vibration measurements should have been included in the EPA study for completeness.

1.9. Outdoor Measurement Positions

Positioning of outdoor microphones is important, particularly since there were many references to wind induced noise in the EPA study report. However, there are few pictures or diagrams of the instrument set-ups available in the report. One picture of the township site is shown and it can be seen that the microphones are in close proximity to buildings and a fence. Based on our own observations when

setting up at the same locations as the EPA, there were many other instances where microphones were placed in proximity to trees and buildings. In such positions, turbulence-induced noise is expected, particularly during windy conditions. This is important for the background levels which were measured whilst the wind farm was shutdown. The true background levels would be expected to be lower if the microphones were positioned adequately far from trees, houses and other obstacles due to reduced turbulence-induced noise.

According to the EPA guidelines, *"The microphone should be positioned 1.2–1.5 metres above the ground and* ***at least 5 metres from any reflecting surface*** *(other than the ground)."* It is also stated that "*care should be taken to ensure that the area is* ***not screened from the wind farm by house, shelter or other elements."*** At the township residence, the EPA sited their equipment within an area enclosed on all sides by a corrugated iron fence 1.4 m high, an iron shed, tanks, a shade structure, a metal ATCO hut and a masonry and weatherboard home. There was also a latticed tower supporting a television antenna within the enclosed area. The microphones were less than 5 m from any reflective surface and were screened from the turbines by the infrastructure mentioned above. The microphones and weather station can be seen in Figure 1 below.

Figure 1 – Picture of the EPA microphones and weather station at the "township" site.

Positioning of weather stations is also important and it was noted that weather stations were often situated close to buildings and trees. Due to wake and turbulence effects, the true wind speed and direction would not be measured in such a position. On the lee side of a building, it would be expected that the wind speed would be lower since the building would provide shielding from the wind. The weather station at the "North" residence was very close to the residence which means that the true wind speed and direction was not measured there. The only consolation is that the microphones were next to the weather station and hence the wind speed and direction at the microphone locations were measured.

1.10. Lack of Correlation between Noise Diaries and Measurements

In several cases, it was found that whilst a surrounding group of diary respondents recorded many occasions when they considered the wind farm to have had an adverse impact on amenity, wind farm noise was not audible in the audio records "without significant amplification". The lack of correlation between the resident's perceptions and the EPA conclusions could be explained by the method that the EPA used for listening to the audio files as discussed in Section 1.3.

It is also possible that the residents at Waterloo may have become more sensitised to wind farm noise, which makes it more difficult to classify their response to it as typical (Moorhouse, 2005).

1.11. Discrepancies between Online and pdf Versions of EPA Report

The EPA's statement about the ***study not being valid for other wind farms*** and other residences is ***MISSING from the pdf report,*** but is still on the webpage which says:

"The conclusions of the study may not be valid for other wind farms, and may only be valid for the Waterloo Wind Farm under the specific conditions (eg weather, wind farm operating conditions, etc) under which the study was undertaken. It also may not necessarily be valid for all residences potentially affected by noise emission from the Waterloo Wind Farm."

It is confusing to leave this disclaimer out of the pdf version of the report since many people will be referring to the pdf version exclusively.

1.12. Errors

Referring to Figure 2 which follows, it can be seen that there is an error in the presentation of the data. This table is thus meaningless to the reader.

Table 35 Acoustic descriptors and analysis of audio records for diary return entries, North East site

No.	Inside			Outside						
	Infrasound, dB(G)	$L_{pA,LF}$, dB(A)	DEFRA	Infrasound, dB(G)	$L_{pA,LF}$, dB(A)	DEFRA	$L_{AF,90}$	L_{Ceq}	L_{Aeq}	$L_{Ceq}-L_{Aeq}$
1	24.2–61.7	36.3 – 63.4	4.6–39.0	86%	21.8–55.4	40.3–72.2	–1.3–26.7	20.9–34.7	14.9–53.3	69%
2	61.9	62.4	29.2	0%	46.4	70.3	23.9	37.3	40.6	0%
3	27.3–67.9	41.9–67.2	11.4–36.5	45%	35.7–51.4	59.0–76.4	13.0–26.6	28.8–43.8	29.7–47.3	0%
4	31.4	47.0	17.4	0%	41.7	56.8	15.2	30.7	31.6	0%

Figure 2 – Table 35 from EPA report, where values have been displaced

Table 30, page 95 in the pdf report shows that for the Township location, events 88 and 89 are both at 3:30 am but the wind speed and direction is different. The error is carried through to Table 31 on page 110, where the acoustic descriptors are also different.

No.	Resident	Neighbours	Date	Start time	End time	Wind			
						Local		Wind turbine generator	
						Speed, m/s	Direction, deg	Speed, m/s	Direction, deg
75	Yes	Yes	27/05/2013	22:30	N/A	0.0	0.0	6.8	36.3
76	Yes	Yes	28/05/2013	0:00	N/A	0.0	0.0	8.5	45.7
77	No	Yes	28/05/2013	17:10	N/A	0.0	0.0	3.7	53.1
78	Yes	No	28/05/2013	22:00	N/A	0.3	342.4	9.9	24.1
79	No	Yes	29/05/2013	8:30	N/A	0.7	357.1	15.4	339.3
80	No	Yes	29/05/2013	9:00	N/A	0.7	5.6	14	340.4
81	Yes	No	30/05/2013	16:50	N/A	2.2	31.8	10.4	22.5
82	Yes	No	31/05/2013	1:10	N/A	2.3	357.4	9.3	351
83	No	Yes	31/05/2013	9:30	N/A	0.0	0.0	4	352.8
84	No	Yes	5/06/2013	11:50	17.10	0.2–2.8	245.2–357.6	7.8–15.0	304.8–318.8
85	No	Yes	6/06/2013	13:50	14:30+	0.3–1.5	266.3–331.1	10.6–13.8	288.4–294.7
86	Yes	No	8/06/2013	5:30	N/A	0.0	0.0	6.3	42
87	No	Yes	8/06/2013	15:30	N/A	0.8	356.6	4.5	315.5
88	Yes	No	9/06/2013	3:30	N/A	0.0	315.0	3.7	356.2
89	No	Yes	9/06/2013	3:30	N/A	1.0	348.4	6.1	326.4

Figure 3 – Table 30 from EPA report, where for item numbers 88 and 89, the wind speed and direction are different for the same measurement time.

No.	Inside			Outside							Spectrum shape/blade pass frequency	Audio records (inside/outside where available)
	Infrasound, dB(G)	$L_{pA,LF}$, dB(A)	DEFRA	Infrasound, dB(G)	$L_{pA,LF}$, dB(A)	DEFRA	$L_{AF,90}$	L_{Ceq}	L_{Aeq}	$L_{Ceq}–L_{Aeq}$		
87	48.1	13.6	0	56.3	32.1	1	31.3	52.8	35.8	17.0	Negative	Inside – mainly inaudible Outside – wildlife, substation, other noise sources
88	56.1	2.0	0	61.9	20.3	0	29.9	46.7	31.2	15.5	Negative	Inside – mainly inaudible Outside – machine, substation noise
89	46.3	5.4	0	55.5	29.8	1	31.7	48.5	42.8	5.7	Negative	Inside – wildlife, other noise sources Outside – wildlife noise, cars

Figure 4 – Table 31 from the EPA report, where the acoustic quantities for measurements 88 and 89 are different for the same measurement time.

2. More Specific Comments

2.1. Township

- The “township” residence was located such that it was in the “rural industrial zone” with an outdoor limit of 40 dB(A).
    - This residence is less than 100 m from the “rural living zone” which has an outdoor limit of 35 dB(A).
    - This house is therefore a poor representation of compliance in the “township” zone and thus another residence within the township should have been chosen instead. Alternatively, the 35 dB(A) limit could have been applied to this residence.

2.2. North

- Figures 17(a) and (b) show a notable increase in outdoor noise in the low frequency range for the downwind and downwind/crosswind conditions for the wind farm in operation compared to shutdown. The EPA attributes this to a higher relative wind speed during operation compared to shutdown.
    - To remove doubts about wind-induced noise contributions, the conditions for shutdown and operation should have been matched more accurately.
- Amplitude modulation is described as “slight” but this is subjective and was not quantified.

2.3. North East

- Inside levels were dominated by other sources during 4 shutdowns and thus only 2 shutdowns are useful for indoor comparison.
- The 50 Hz third-octave component is almost 20 dB greater during operation than shutdown for Downwind 2 (Figure 24 (b)). This third-octave frequency is also prominent for Downwind 1 “after” (Figure 25 (a)).
    - It would be useful to indicate whether or not this component would be perceptible.
- The EPA report states that “*Wind farm noise was audible in the amplified records at times, under dominantly downwind conditions inside or outside of the house, sometimes accompanied by rumbling or thumping character although not as distinctly as shown in records for the South East site. These periods were not indicated in the relevant diary returns.*”
    - We cannot rely on diary information to detect all events, sometimes people are busy, not home, tired, trying to sleep, unmotivated, etc.

2.4. West

- The outside microphone is surrounded by a few trees and vegetation
- Spectral analysis of event periods identified in noise diaries revealed a prominent 50Hz component inside the residence, generally under downwind conditions from the wind farm.
    - The EPA listened to these audio files with “significant amplification” and decided subjectively that there were no tonal or other characters which could be associated with the noise, which does not agree with our analysis.
- “Slight” rumbling and modulation could be heard for some of the indoor audio files.
    - This is a subjective analysis which is also highly dependent on the quality of the audio equipment used for listening.

- It is suggested that the degree of amplitude modulation should have been quantified.

2.5. South East

- Inside levels were dominated by other sources during 4 shutdowns and thus only 2 shutdowns are useful for indoor comparisons.
- In Table 23, it can be seen that in the indoor level comparison between "shutdown" and "operational," there is a significant difference in the low frequency (10 – 160 Hz) A-weighted levels ($L_{pA,\ LF}$) compared to the A-weighted levels for the entire spectrum. During operation, the levels exceed the Danish standards by at least 5 dB(A). In addition, DEFRA criteria are met for all third-octave bands during shutdown but not at all during operation. The EPA attributes the differences to an increase in the wind speed before and after the shutdown of 1-2 m/s – an unlikely scenario – see below.
  - For Shutdown 6, the wind speed was 2.2 – 2.7 m/s which is approximately 1-2 m/s higher than for Shutdown 4 (0.9- 1.3 m/s). Yet, the outdoor $L_{pA,\ LF}$ for Shutdown 6 is 11 dB(A), which is 9 dB(A) below the Danish limit. The DEFRA criteria are also met for all third-octave bands for this case. However, when the turbines were operational, the DEFRA criteria were exceeded as described in detail above.
- The EPA report states that "*Relatively high values of acoustical descriptors acquired during some of the shutdown periods indicated that the natural environment and other unidentified sources were probably making significant contributions to noise levels during the study, including noise with substantial low frequency content. This suggested that the wind farm was not the dominant source*."
  - This is a generalisation and appropriate measures should have been taken to ensure that comparisons between "shutdown" and "operation" were made for the same local wind conditions.
- The EPA report states that "*Significant differences in the low frequency part of the spectrum (up to about 160Hz) were apparent for Downwind 2 and Crosswind conditions (Shutdowns 4–5)*."
  - This is however justified on the basis that differences were not so apparent for Shutdown 3 which was also downwind. On the other hand, the wind shear is higher for Shutdown 4 (downwind) compared to Shutdown 3, giving a greater contrast between wind farm noise and ambient noise.
    - Therefore a conservative approach would focus on Shutdown 4 results.
- For Downwind 2 there was a "prominent 50 Hz component."
  - Low frequency components below 50 Hz were not audible but nothing is mentioned for the 50 Hz component itself.
  - The 50 Hz component "may be attributable to the electrical substation."
    - Any instances of amplitude modulation at the blade-pass frequency would prove that this component is in fact attributable to the wind farm.
- The EPA report states that "*The character of noise can be described rather as 'rumbling' or 'thumping' which coincides with descriptions in some of the diary return records*."
  - This suggests the presence of amplitude modulation.
  - If a 5 dB(A) penalty was applied to these results, then it is possible that non-compliance could occur. Particularly as we have measured levels up to 38 dB(A) between 12 am and 5 am at this residence.
- The EPA report states that "*The wind farm was rarely the dominant noise source at the West site*"

- Since we are in the “South East” section, looks like a copy and paste.

- The EPA report states that “*The rumbling effect was more distinct inside the house when household noises do not interfere. The character may have related to contrast, since the house structure provides better attenuation of higher frequencies than the lower frequencies*.”
  - This is all true; the only question is why further investigation was not carried out?
- The EPA report states that “*The majority of events described in diary returns for the site were associated with a downwind direction from the turbines*.”
  - This suggests that the residents are reacting to wind farm noise.
- The EPA report states that “*It is possible that operation of the wind farm may cause increased annoyance to a sensitive listener at this site, if exposed for a long time period, possibly exacerbated by the presence of some degree of amplitude modulation*.”
  - Why is this acceptable? This should have been the subject of further investigation.

2.6. East

- The EPA report states that “*As expected, A-weighted sound pressure levels did not exhibit a good correlation with wind speeds measured at the turbines, since the noise was not controlled by the wind farm*.”
  - Given that there are several mentions in the report of the noise being controlled by vegetation, one would predict that the EPA would “expect” a good correlation between the A-weighted sound pressure level and wind speed. However, the above statement would support the theory that wind speed at the residences is not highly correlated with wind speed at the turbine hub.
- “Analysis of available audio records did not indicate any noise events that could be attributable to the wind farm.”
  - We have measured the blade-pass frequency and harmonics, tonal peaks and amplitude modulation at the blade-pass frequency at this location.

3. Conclusions

The wind farm is deemed compliant based on the existing EPA guidelines (2009). However, these guidelines allow for a significant number of measurement points in excess of the 40 dB(A) criteria. Moreover, the regression curve is plotted from data that are not affected by extraneous noise sources unrelated to the wind farm. Therefore at low local wind speeds, it is highly possible that the noise levels above 40 dB(A) can be attributed to the wind farm. At higher wind speeds, it is possible that the measurements are influenced by wind induced noise. On the other hand, results could have been compared for shutdown and operation for equivalent wind speeds and directions. The EPA attempted to do this; however in many cases the local weather conditions for shutdown and operation were not close enough to allow accurate comparison. This resulted in many occasions where the EPA suggested that increased low frequency noise for the operational state compared to shutdown could be attributed to wind-induced noise. This allowed a convenient excuse for exceeding the Danish guidelines and the DEFRA criteria.

To reduce the effects of wind-induced noise on the measurements, the shutdowns should have occurred at night time under stable conditions. Under these conditions, the wind speed at microphone height would be small or negligible, giving the greatest contrast between wind farm noise and ambient noise. Annoyance and sleep disturbance effects are also likely to be most critical at night time. In addition, noise sources indoors would have been minimised since the residents would likely be sleeping. This last

point is particularly relevant since many of the indoor measurements from the EPA study were affected by other sources and thus could not be relied upon.

In comparing measured indoor levels with the Danish guidelines, the EPA did not adequately follow the methodology in these guidelines. Most importantly, the EPA measured indoor levels at one position only whereas the Danish guidelines specify that the average sound pressure level for three locations should be determined. A microphone at a single position is not sufficient to adequately characterise the noise in the room which may vary by 20 dB. Additionally, wind speed and direction should be measured at 10 m to comply with this standard and data for wind speeds of 6 m/s and 8 m/s should be analysed exclusively. The EPA considered all wind speeds in their analysis and their weather station was located at a height of 4 m.

One of the most significant discoveries of the EPA investigation was that a “rumbling” or “thumping” noise was identified. However, it was mentioned that this noise was not discernible without “significant amplification.” On the other hand, there is no description of how the EPA verified that the levels they were replaying were exactly the same as those measured. Ensuring that the replayed levels were reproduced correctly requires specialised instrumentation and appropriate listening conditions. Many factors could contribute to an incorrect reproduction of the actual noise including self-noise of the instrumentation used for listening, ambient noise of the listening environment and frequency roll-off of headphones and sound card or speakers. These factors would contribute to masking of the replayed signal as well as unequal amplification across the frequency spectrum, which would cause the low frequency noise to be less perceptible.

It was also found that the spectrum associated with the “rumbling” or “thumping” noise showed a prominent peak in the 50 Hz third-octave band. The audibility threshold curve according to ISO 389-7 (2005) should have been plotted to determine whether levels in this third-octave band or other third-octave bands were perceptible to a person with normal hearing. Since amplitude modulation was also identified in the EPA study, allowances would also need to be made for an increase in annoyance potential as a result of modulation. Hence the level of perceptibility for wind farm noise would be significantly lower than the published perceptibility levels. The EPA did not attempt to quantify the amplitude modulation in any way nor relate it to any specific third-octave band. On the other hand, both the NZ standard (2010) and the draft NSW guidelines (2011) specify penalties for amplitude modulation. Since the character of this noise “coincides with descriptions in some of the diary returns” it is suggested that more work is required to determine if this noise source is causing annoyance.

Finally I do not believe that the EPA study has shown that the noise impact on residents from the Waterloo wind farm is insignificant. More detailed analysis of the data and analysis of the appropriateness of the existing EPA guidelines would in my opinion indicate a significant impact of the wind farm noise on local residents.

4. References

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