A review of Australian wind farm noise assessment procedures

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ABSTRACT

With the increase in wind energy projects in Australia over the past decade, most Australian States now have a wind farm noise assessment procedure either approved or in draft. Given that wind turbines operate under windy conditions and vary in noise level with the wind, these procedures necessarily vary from typical noise assessment methodologies applied to industry and transport sources. While there are differences between the wind farm noise assessment procedures within each State, in all cases the methodologies employed for the assessment of overall A-weighted noise levels are based on a modified version of that prescribed in the UK document ETSU-R-97 *The Assessment and Rating of Noise from Wind Farms*. With a higher level of attention around wind farm noise in comparison to other environmental noise sources and with some proposed assessment procedures in draft format, it is prudent to review these assessment procedures and consider their suitability. This paper reviews the approaches taken in the procedures to the assessment of wind farm and background noise, establishment of assessment criteria and the consideration of wind farm noise character. It is demonstrated that, while the assessment methodologies may appear fairly similar, relatively minor differences in procedure can have a significant impact on a noise assessment or developed noise objective.

1. INTRODUCTION

With the increase in wind energy projects in Australia over the past decade, most Australian States now have a wind farm noise assessment procedure either approved or in draft. Given that wind turbines operate under windy conditions and vary in noise level with the wind, these procedures necessarily vary from typical noise assessment methodologies applied to industry and transport sources, and, generally, all follow a similar methodology. However, there are differences within the methodologies employed within each State which, although they appear minor, can impact on the outcome of an assessment. This paper reviews the approaches taken to the assessment of wind farm and background noise, establishment of assessment criteria and the consideration of wind farm noise character. The methodologies are compared to understand how different States are regulating wind farm noise.

2. WIND FARM NOISE ASSESSMENT PROCEDURES

A range of wind farm noise assessment procedures exist in Australia, with some having been in place for a number of years and others very new and/or in draft format. While broadly similar, there are differences that exist between each that warrant consideration. In reviewing these procedures, this paper focusses on the assessment procedures applied to non-involved residences, which are those where the landowner does not host wind turbines on their property. Different noise assessment procedures, and less stringent criteria, are generally applied to the residences of host landowners who receive payment for wind turbines on their land.

2.1 ETSU-R-97

Although this paper is primarily focussed upon Australian wind farm noise assessment procedures, it is appropriate to start by considering the procedure implemented in the UK's ETSU-R-97 *The Assessment and Rating of Noise from Wind Farms* (DTI, 1996), as the procedure employed within this document is the basis for Australian procedures. In ETSU-R-97, assessment criteria for wind farms are set across a range of wind speeds with reference to both a minimum absolute criterion and the existing environment. ETSU-R-97 is still applied within the UK but is now supplemented by additional guidance provided by the Institute of Acoustics (IoA, 2013) to standardise assessments.

Background noise levels are established by measuring A-weighted $L_{90,10min}$ noise levels over a period of, typically, at least two weeks. Noise levels are plotted with wind speed measured at a height of 10 m above ground at a reference location, and a best fit regression curve is determined for the dataset. An example of this is shown in Figure 1. ETSU-R-97 originally required background noise data to be collected up to a wind speed of 12 m/s but this was based on older stall-regulated wind turbines and, with modern pitch-regulated turbines, data is only required up to the wind speed at which the turbines reach maximum sound power level, generally 7 to 8 m/s at 10 m height (IoA, 2013).

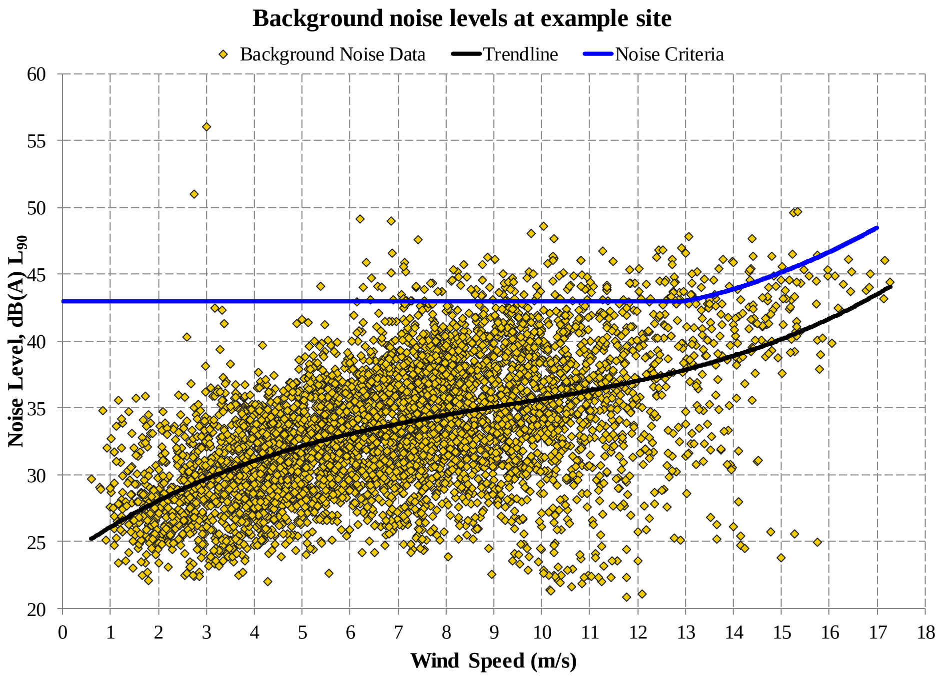

Figure 1: Determination of background noise level with wind speed

ETSU-R-97 sets separate noise assessment criteria for day and night time periods as is done in some Australian jurisdictions but only considers daytime amenity periods rather than the entire daytime period. Daytime amenity periods include evening and weekend periods. The noise criterion for each wind speed is the higher of the recommended absolute noise limit or the background level plus 5 dB. Interestingly, a higher absolute noise criterion is recommended for night time periods, 43 dB(A), then is recommended for daytime amenity periods, 35 to 40 dB(A). The example in Figure 1 has a 43 dB(A) base limit applied. The justification for this is that the primary focus during the night time is internal noise levels to prevent sleep disturbance, while the daytime criteria should be focussed on providing external amenity.

To measure wind farm noise post-construction of a wind farm, ETSU-R-97 specifies essentially the same procedure as the background noise measurements although recommends consideration of data gathered during downwind periods only, when the measurement location is downwind (±45˚) of the nearest turbine or group of turbines. The measurements may need to include periods of wind farm shutdown to allow correction for background noise where the measured noise levels are at or close to the noise criteria (IoA, 2014).

2.2 Victoria

The relevant wind farm noise assessment procedure in Victoria is that documented in New Zealand Standard NZS 6808:2010 (Standards New Zealand, 2010), although the planning approvals for a number of operating wind farms, and proposed sites with older planning approvals, still refer to the 1998 version of the Standard (Standards New Zealand, 1998). The changes between the two versions of the Standard are relatively minor, with the 2010 version adopting the L_{90} metric for the measurement of both background and wind farm noise, and specifying the wind speed reference height as the hub height of the turbines. The 1998 version adopted the L_{95} metric and did not specify a reference height, although it was common for a 10 m reference height to be adopted in Victoria.

NZS 6808:2010 requires essentially the same assessment approach to determining background noise levels as ETSU-R-97. There is no specific requirement by the Standard to assess night time background noise levels separately but it is normal for Victorian planning approvals to introduce an additional requirement for background noise levels with wind speed to be determined both for all data and just for that data collected during the night period (10 pm to 7 am). Once background noise levels are determined, the noise limit at non-involved residences is generally specified to be the higher of 40 dB(A) or the background level plus 5 dB for any wind speed. The only exception to the 40 dB(A) base limit in the 2010 standard is for areas where a “high amenity limit” may be considered warranted and a 35 dB(A) base limit should be considered. The Standard refers to “high amenity” areas in the context of the New Zealand planning system but, in Victoria, the common approach has been to only consider "high amenity" conditions for areas envisaged for rural living and not for farming areas mainly used for primary production.

For post-construction measurements, an important distinction arises between NZS 6808:2010 and the other assessment procedures employed in Australia as the Standard does not require that post-construction assessments only consider noise levels measured under downwind conditions. Instead, it refers to a "representative range of wind speeds and directions" which is normally interpreted as the wind speeds and directions that occur during a monitoring campaign, which can extend from weeks through to months. If the same measurement location is used for both background and post-construction measurements, the Standard allows for determination of the wind farm noise level by logarithmically subtracting the background noise levels from the post-construction noise levels.

2.3 South Australia

Wind farms in SA are assessed according to the requirements of the SA Environment Protection Authority (EPA) *Wind farms environmental noise guidelines 2009* (SA EPA, 2009). The assessment procedure is largely the same as that employed in ETSU-R-97 and in Victoria, with background $L_{90,10min}$ noise levels measured over a period of weeks to obtain at least 2000 data points which are plotted against wind speed to determine background noise levels for each integer wind speed from cut-in to rated power of the nominated turbines. The base limits used in SA to establish criteria for non-involved residences are 35 dB(A), for predominantly rural living areas, or 40 dB(A) for predominantly primary production areas, as defined in the relevant Development Plan for the area. The vast majority of South Australian wind farms are located in primary production areas and therefore a 40 dB(A) base limit is generally applied.

Unlike ETSU-R-97, assessments in SA are carried out based on wind speeds measured at hub height and there is no separation of day and night time periods. However, the SA Guidelines do adopt the ETSU-R-97 procedure of requiring post-construction wind farm noise to be measured at a particular location during conditions when the location is downwind (±45˚) of the nearest turbine or group of turbines. The SA Guidelines sets a minimum requirement of 500 10-minute data points collected in a downwind direction for compliance monitoring.

2.4 New South Wales

Currently, the standard procedure in NSW is to use the 2009 SA Guidelines assessment procedures, with the procedure modified to include a base limit of 35 dB(A) rather than 40 dB(A). This procedure is stated in planning approvals for proposed wind farms and then adopted in EPA-issued licences for operating wind farms.

In August 2016, the NSW Department of Planning and Environment released a draft *Wind Energy: Noise Assessment Bulletin* (NSW DPE, 2016) for consultation. The draft Bulletin will essentially formalise the adoption of the 2009 SA Guidelines with the following modifications:

- A 35 dB(A) base limit will be applied in all areas. The draft Bulletin states that this is because rural land use zones in NSW "are often more densely settled than those of South Australia" and therefore the application of a higher 40 dB(A) base limit in farming areas is not considered justified.
- NSW-specific tonality and low frequency noise criteria are adopted and a specific approach to applying penalties to wind farm noise is proposed should these criteria be exceeded.

2.5 Queensland

The Queensland Department of Infrastructure, Local Government and Planning released the wind farm state code, contained within the *State Development Assessment Provisions* (Queensland DILGP, 2016), in July 2016. The code is supported by the *Wind farm state code – Planning guideline* (Queensland DILGP, 2016) which provides additional information related to the acoustic aspects of the code.

The Queensland code specifies separate day and night time criteria for wind farm noise at non-involved receivers, which involve a base limit of 37 dB(A) for day time (6 am to 10 pm) and 35 dB(A) for night time (10 pm to 6 am). Where it can be demonstrated that the background noise level plus 5 dB is higher than the base limit at a particular wind speed, then the criteria for that wind speed the background level plus 5 dB. Background noise levels are measured in accordance with the procedures in other States but determined separately for day and night time. The Queensland code does not specify a compliance monitoring procedure but it would appear reasonable to assume that a similar procedure would be adopted to those in SA and NSW.

2.6 Tasmania

The Tasmanian *Noise Measurement Procedures Manual* (DEPHA, 2008) has a brief section on wind farms that references NZS 6808. The assessment procedure in Tasmania would therefore be broadly equivalent to Victoria, although some of the additional requirements applied in Victoria, such as separate night time criteria, may not apply.

2.7 Western Australia

The WA Planning Commission released *Planning Bulletin No. 67* (WA Planning Commission, 2004), which provides guidance for noise assessment of wind farm developments. The Bulletin endorses the SA Guidelines procedures, although it is normal for the lower 35 dB(A) base limit to be applied in WA. As the Bulletin was released in 2004, there does appear to have been some assessments in WA that refer to earlier versions of the SA Guidelines while others refer to the 2009 SA Guidelines. The key impact this has had is that some wind farm noise assessments in WA reference noise criteria to 10 m height wind speeds (as required by earlier versions of the SA Guidelines) while others refer to hub height wind speeds as per the 2009 SA Guidelines.

2.8 Summary

Table 1 compares some of the primary aspects of the wind farm noise assessment procedures in Australia.

Table 1: Overview of wind farm noise assessment procedures in Australia

State	Base limit	Time periods	Wind direction for compliance assessment
Victoria	40 dB(A)[1]	24-hour period Night time assessment (10 pm to 7 am)	All directions
South Australia	40 dB(A)[1]	24-hour period only	Downwind ±45˚
New South Wales	35 dB(A)	24-hour period only	Downwind ±45˚
Queensland	37 dB(A) day 35 dB(A) night	Day (6 am to 10 pm) Night (10 pm to 6 am)	Not specified
Tasmania	40 dB(A)[1]	24-hour period only	All directions
Western Australia	35 dB(A)	24-hour period only	Downwind ±45˚

1. While Victoria and SA have provisions for a 35 dB(A) base limit in rural living areas, this is rarely applied.

3. THE ETSU PROCEDURE

The assessment of wind farm noise in all Australian States employs procedures that are largely based on the ETSU measurement procedure for both setting wind farm noise limits and measuring post-construction (compliance) noise levels. This offers consistency with procedures employed in the UK and New Zealand, and provides the ability for wind farm noise to be measured over a range of wind speeds at residential locations adjacent to a wind farm, which is typically expected by the community.

One aspect of the ETSU procedure that can lead to confusion with the community is that wind farm noise is not able to be measured and assessed for an individual 10-minute period. The procedure requires measurements to be carried out over a period of days, typically weeks, and compliance is not able to be assessed until the measured noise levels are analysed against wind speed. The measurement over a number of days is necessary because of the likelihood of individual measurements being influenced by extraneous noise given that wind farm noise levels are relatively low at residences and rarely above 40 dB(A). In this context, recent consideration by the Federal Government regarding "real-time" wind farm noise monitoring (Taylor, 2013) needs to have an understanding of how wind farm noise in regulated within Australia and that conventional "real-time" monitoring is unlikely to be feasible.

An alternative procedure that could allow for shorter-term or even "real-time" monitoring of wind farm noise could be to accept that the prediction methodologies employed for wind farms in Australia are accurate and to undertake compliance noise monitoring at the turbines themselves, or at a nearby intermediate location where the signal-to-noise ratio is higher, to essentially verify sound power levels. A procedure such as this is employed in countries such as Denmark and Germany, and has a distinct advantage in that the measurement result can clearly indicate whether compliance is achieved as the signal-to-noise ratio at the measurement location is high. By comparison, the ETSU procedures can often be influenced by extraneous noise near a residence such that an apparent non-compliant result may simply be the result of a change in background noise levels between pre- and post-construction measurements. It is also supported by evidence that indicates that the prediction methodologies used for wind farm noise within Australia are accurate (Evans and Cooper, 2012). However, such an alternative procedure would mean that it is possible that compliance measurements may not be conducted at all at houses near a wind farm, a result that is unlikely to be in line with the expectations of some community members.

4. BASE LIMITS

One of the most obvious differences between States is the variation in base limits, with most wind farms in SA and Victoria having a 5 dB higher base limit than those in NSW. While it should be noted that differences in noise limits within Australia are not unique to wind farms, a 5 dB difference in the base limit could have a significant impact on the allowable scale of a wind farm for which noise mitigation options are typically limited.

A previous study (Cook et al, 2012) showed, however, that the difference between a 35 dB(A) and 40 dB(A) base limit on a wind farm layout may not necessarily be equivalent to a 5 dB restriction. This is because wind turbines do not generally reach maximum sound power output until wind speeds of approximately 8 – 10 m/s at hub height, at which point background noise levels at residences may be above 30 dB(A) and therefore increasing the applicable noise criteria. The study by Cook et al analysed background noise levels collected at 60 residences and compared them to the sound power with wind speed curves for three typical wind turbine models, demonstrating that for the majority of residences there was no difference in outcome between a 35 dB(A) and 40 dB(A) limit. A 35 dB(A) limit only effectively resulted in a 3 to 4 dB more stringent criterion at 5-10% of residences.

It should be noted that the above study was based on background noise levels analysed over the full 24 hour period and it is likely that a change from a 40 dB(A) to 35 dB(A) base limit would have more of an impact on a wind farm layout where background noise levels are analysed separately for a night time period. Separate night time criteria are generally required in Queensland and, therefore, the 35 dB(A) base limit there may actually translate to a 5 dB more stringent criterion relative to SA. This is because background noise levels do not tend to increase as quickly with hub height wind speed at night time. However, the effect of changing from a 40 dB(A) to 35 dB(A) base limit is limited where noise levels are analysed over a 24 hour period as is the case in SA and as is proposed in NSW. That is, the application of a 35 dB(A) base limit to a site in SA does not necessarily result in a 5 dB more stringent criterion.

5. WIND DATA

A key factor in any wind farm noise assessment is the use of wind data, which is measured at a representative location at the wind farm site in 10-minute periods and correlated with measured noise levels across the assessment period to establish background noise levels and to conduct post-construction compliance monitoring.

5.1 Hub height versus 10 metre height wind speeds

One of the main differences between the original ETSU-R-97 assessment procedure and the Australian assessment procedures currently employed is that ETSU-R-97 references assessments to 10 m height wind speeds while almost all Australian assessment procedures now use hub height wind speeds. Given that most modern wind turbines proposed for future sites will have hub heights of no less than 80 m, and typically well above 100 m, the difference in wind speed between 10 m and hub height can be quite significant.

The complication that arises in using different wind speed reference heights relates to wind shear, which is the change in wind speed with height. Normally wind speeds increase with height but the rate of change can vary markedly with time and is not constant. Wind shear is normally quantified by a wind shear power law exponent, α:

$$V_1 = V_2(H_1/H_2)^{\alpha}. \qquad (1)$$

Where V_1 and V_2 refer to the wind speed at H_1 and H_2 respectively, and α is the power law exponent.

Figure 2 shows the measured wind shear at a particular wind farm site with both hub height wind speed and with time. It can be seen that at wind speeds below about 8 m/s, the wind shear can vary quite significantly, and tends to be highest during the night time periods.

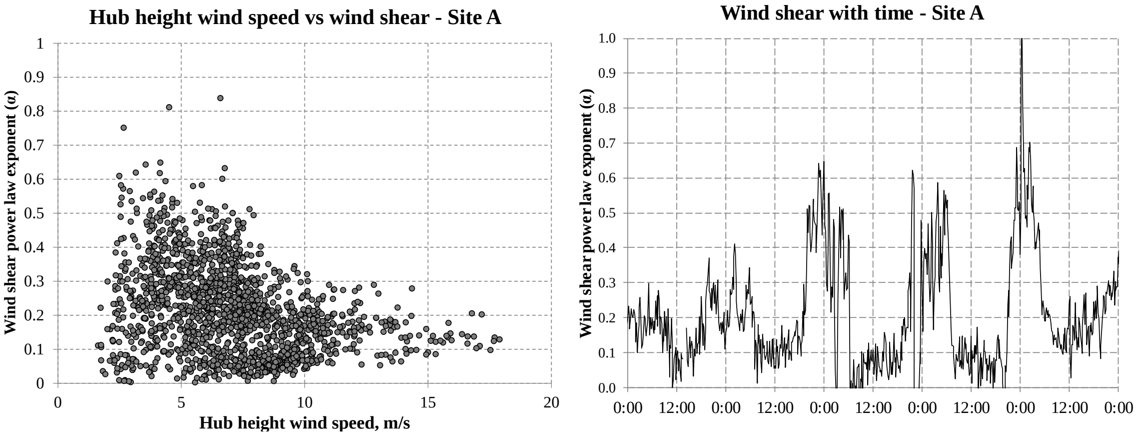

Figure 2: Wind shear measured at a wind farm site with hub height wind speed (left) and time (right)

With respect to the establishment of noise criteria, the potential variation in wind shear does raise some concern. Previously, and as is still the case with ETSU-R-97, it was common to reference 10 m height wind speeds in noise assessments. This meant that there was a risk in the assessment procedure for a wind farm as the sound power level of the turbines is controlled by wind speeds at hub height which are not necessarily consistently related to wind speeds at 10 m height. If wind shear varies quite significantly across time, and this is not well quantified in the assessment, then there is a risk that a higher sound power than expected could occur for a given 10 m height wind speed. However, from the perspective of background noise at a receiver, the use of 10 m height wind speeds provided an advantage as these speeds are more likely to be related to wind speed at ground level, and therefore background noise at a receiver, than are hub height speeds. Changing the assessment procedure to reference hub height speeds, as has been done in all modern Australian assessment methodologies, removes the risk associated with underestimating the sound power level at a given wind speed but also means that background noise levels may not correlate as well with the wind speed in establishing background noise-based criteria for a particular residence.

Overall, any wind farm assessment procedure needs to balance the above two risks. A reasonable approach to balance the risks from a regulatory perspective could be to require the use of hub height wind speeds as a reference but also require that separate noise criteria are developed for the night time period. A higher wind shear will tend towards a lower background noise level for a given hub height wind speed and, as wind shear will generally be higher at night time, this procedure means that background noise levels are established for the time period when wind shear will be highest. This methodology is currently in use in Victoria, imposed as an additional assessment requirement within Planning Permits, and is also required by the recently released Queensland code.

5.2 Wind direction

An interesting difference between the methodology used in Victoria and that used in SA and NSW is that compliance monitoring conducted in Victoria considers all wind directions, whereas SA and NSW limit the assessment to those periods when a particular receiver is downwind ±45˚. This means that the wind farm noise level measured for a particular wind farm will be lower if assessed in accordance with Victorian procedures than if it was measured in accordance with South Australian procedures.

Figure 3 and Table 2 present the difference in the measured wind farm noise levels that were calculated at a particular site if data from all directions is considered or if data only from downwind ±45˚ is considered. The measurement site was approximately one kilometre from a large wind farm, with the measurements conducted over a period of over six months to obtain a wide range of directions. The measurement site was located in the middle of a paddock, such that extraneous noise was minimised as far as possible, with a range of analysis methodologies applied to exclude measurements that were influenced by extraneous noise as described in our 2014 paper (Cooper et al, 2014). The wind farm noise level has been determined over the wind speed range of 6 to 11 m/s at hub height, as that is the wind speed range over which wind farm noise can be more accurately determined for the all direction case. This is because the periods lowest measured wind farm noise levels at lower wind speeds were typically excluded as they were most likely to be influenced by extraneous noise.

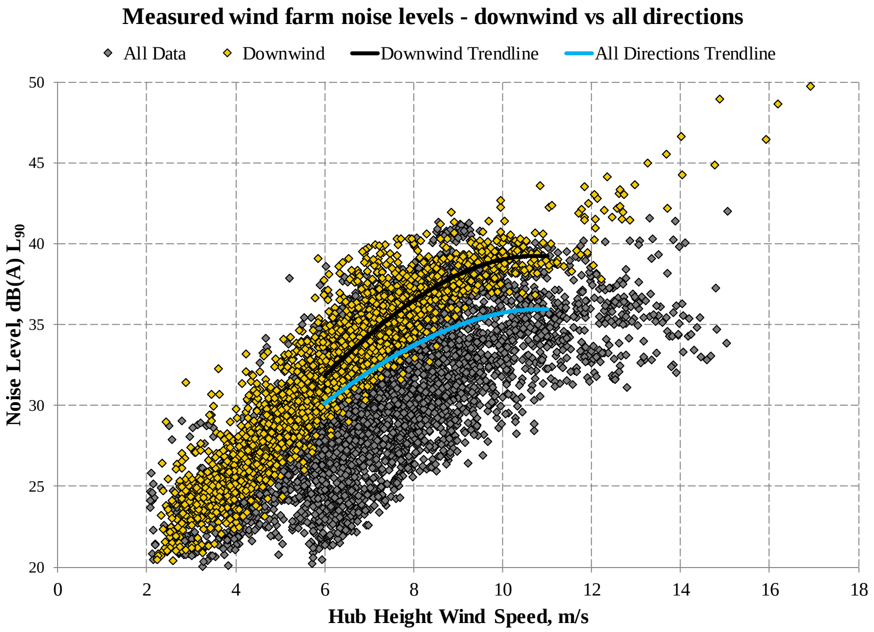

Figure 3: Measured wind farm noise levels for downwind directions and for all wind directions

Table 2: Comparison of measured wind farm noise level with different procedures

Hub height wind speed, m/s	Measured noise level considering downwind ±45˚ only, dB(A)	Measured noise level considering all directions, dB(A)	Difference, dB(A)
6	31.8	30.1	1.7
7	34.4	32.1	2.3
8	36.5	33.7	2.8
9	38.1	35.0	3.1
10	39.0	35.7	3.3
11	39.2	36.0	3.2

The difference between the downwind and all direction noise levels reaches approximately 3 dB for wind speeds of 8 m/s and above. It is also apparent from Figure 2 that the measured noise levels vary by as much as 6 dB from the all direction trendline. By comparison, the downwind noise levels are typically within 3 dB of the downwind trendline. The lower levels in Figure 2 correspond to noise levels measured under upwind conditions, with an average 6 to 7 dB difference between downwind and upwind directions consistent with a previous study conducted at another site (Evans and Cooper, 2012a).

In the context of a wind farm, a 2 to 3 dB difference between assessment procedures, while it appears small, could correspond to the addition of a reasonable number of turbines to a site. However, it should be noted that this does not mean that wind farms in Victoria are generally sited much closer to residences than in SA. Wind farm noise predictions for proposed new wind farms are generally carried out using the ISO 9613-2 (ISO, 1996) prediction algorithm in all States, and this prediction methodology has previously been shown to give good agreement to the downwind measured noise levels (Evans and Cooper, 2012; IoA 2013). In fact, the predicted noise levels for the wind farm at which the measurements shown in Figure 2 were carried out are within 0.6 dB of the measured downwind trendline at all wind speeds. Therefore, Victorian wind farms will typically still be located to achieve compliance with the downwind noise levels but will have a buffer provided for compliance as compliance monitoring can consider noise levels measured under all directions.

Despite this, the preferable approach for wind farm regulations would be to require the compliance measurements to be carried out under downwind conditions. While this does reduce the margin of compliance in States referencing NZS 6808, such as Victoria, it offers the following benefits:

- Measuring noise levels under downwind conditions means that measurements can be repeated to obtain consistent results. When assessing noise levels over all wind directions, the measured levels will be highly susceptible to the directions that occur during a measurement campaign and can therefore vary with the season in which measurements are conducted. Seasonal variations in background noise also occur, with changes in vegetation and birds/insects, and are more likely to influence the measured noise level if all wind directions are considered rather than just downwind periods when wind farm noise is loudest.
- Measuring under downwind conditions offers consistency with the measurement procedures employed for industrial noise in most Australian States.
- The measured downwind noise levels typically agree well with predicted noise levels based on the standard prediction methodologies employed in Australia.

One drawback of the downwind procedure is that, if downwind conditions do not occur regularly for a particular residence, then it can be difficult to obtain the 500 data points required under the SA Guidelines procedure. This, however, can be treated on a case-by-case basis and long post-construction measurement campaigns are already typical for wind farms such that it is normally possible to obtain a reasonable amount of data for most wind directions.

6. SPECIAL AUDIBLE CHARACTERISTICS

Special audible characteristics is a term introduced to wind farm noise assessments in Australia through NZS 6808, which uses the term to describe potentially annoying characteristics such as tonality and amplitude modulation. It may also include low frequency noise in some contexts although this is not included in the definition in NZS 6808.

6.1 Tonality

Tonal noise from wind farms, if it occurs at a residential location, is subject to a penalty in all Australian States although differences exist in the tonality assessment methodologies applied. Table 3 provides a comparison of the tonality assessment methodologies employed in those States that have a specific procedure.

Table 3: Comparison of measured wind farm noise level with different procedures

State	Tonality assessment methodology
Victoria	NZS 6808:2010 makes reference to the reference methodology from ISO 1996-2 (ISO, 2007). Tonal audibility is calculated and a sliding penalty applied for audibilities greater than 4 dB up to a maximum penalty of 6 dB at audibilities of 10 dB or more.
SA	Makes reference to a procedure to be employed that is acceptable to the EPA such as IEC 61400-11 (IEC, 2012). The SA EPA has previously advised that tonal audibility should not exceed 0 dB when determined in accordance with IEC 61400-11.
NSW	The draft Bulletin makes reference to the simplified one-third octave band difference methodology from ISO 1996-2. A difference of 15 dB is required at low frequencies (125 Hz or less), 8 dB from 160 to 400 Hz and 5 dB above 400 Hz.

The SA Guidelines make reference to IEC 61400-11, which is a Standard used by wind farm manufacturers to test the sound power and tonality of wind turbines. Test reports for turbine models are provided in accordance with the IEC Standard, which provides a method for determining tonal audibility based on measurements approximately 120 m from a turbine, with an audibility of 0 dB or greater indicating a tone could be audible to the average listener. This tonal audibility calculation methodology can be adapted to residential locations to assess tonality at the receiver location. While this methodology has been used in SA to assess tonality (Cooper et al, 2013), it is important to be aware of the following aspects of the methodology:

- The IEC Standard only requires wind turbine manufacturers to assess tonality downwind (±15˚) and over a limited range of wind speeds. In the authors' experience, tonality from wind turbines, if it occurs, typically occurs outside of this range (Evans and Cooper, 2015). Therefore, a test report for a given wind turbine does not guarantee that no tonal noise will occur under other conditions.
- The IEC Standard offers no penalty scheme for tonality and the tonal audibility calculated under the IEC methodology will not be equivalent to that calculated using other methods such as that in ISO 1996-2.

In Victoria, NZS 6808:2010 is applied which makes reference to the ISO 1996-2 reference methodology for assessing tonality. Like the IEC Standard, this results in the calculation of tonal audibility, but also provides a sliding penalty scale for the assessment of tonal audibility. However, no guidance is given as to how to apply a penalty to a large range of measurements conducted in accordance with the ETSU methodology, only a percentage of which may contain a tone that warrants a penalty.

NSW applies the much simpler one-third octave band methodology from ISO 1996-2. While this is simpler to measure and assess, the results are typically not consistent with the more detailed reference methodology and tones that could warrant a 6 dB penalty under NZS 6808:2010 may not trigger a penalty under the one-third octave band methodology, particularly at low frequencies where a 15 dB difference to both adjacent bands is required (Evans & Cooper, 2015a). The NSW draft Bulletin does provide a methodology for applying the penalty to wind farm noise, with the 5 dB penalty applicable if it occurs for more than 10% of the assessment period. However, the precise extent of the assessment period for tonality and how tonal penalties are to be applied if tones are detected under non-downwind conditions remain unclear in the draft Bulletin at this stage.

6.2 Amplitude modulation

Excessive amplitude modulation is currently only referenced within NZS 6808:2010, which provides a methodology for assessing whether it occurs on a peak-to-trough basis. While all wind farm noise includes a level of amplitude modulation as part of its fundamental nature, excessive amplitude modulation has been noted as a concern at some sites in the UK and the Institute of Acoustics has recently developed a measurement methodology for excessive modulation (IoA, 2016). However, no penalty scheme has yet been proposed.

6.3 Low frequency noise

NSW has included criteria for low frequency noise in its draft Bulletin, which states that a 5 dB penalty would be applicable if it is shown that noise from the wind farm is repeatedly greater than 60 dB(C) when measured at a residence. The lack of specific criteria in other States is supported by findings of a recent Health Canada study that found that A-weighted and C-weighted wind farm noise levels were so highly correlated that regulating A-weighted noise levels was considered sufficient to address any concerns around C-weighted levels (Health Canada, 2014).

7. CONCLUSIONS

This paper presents a review of wind farm noise assessment procedures in Australia. While the assessment procedures, which are based on the UK ETSU methodology, appear similar, there are differences that require consideration with respect to base limits, wind speed measurement height and wind direction. In addition, the different tonality criteria applied around Australia can also result in changes in how any tonal noise is addressed. While it is normal for there to be differences in how noise from industry and the like is assessed between States, it is important that consultants and regulators understand the differences that exist for wind farm noise assessment procedures, particularly when developing or revising policy.

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