MICROPHONE WIND SPEED LIMITS DURING WIND FARM NOISE MEASUREMENTS

Jon Cooper[1] and Tom Evans[2]

[1]Resonate Acoustics, Level 1/23 Peel St, Adelaide SA 5000, Australia
Email: jon.cooper@resonateacoustics.com

[2]Resonate Acoustics, Level 4/10 Yarra St, South Yarra VIC 3141, Australia
Email: tom.evans@resonateacoustics.com

Abstract

Guidelines and Standards which set environmental noise criteria often include clauses which prescribe a limit as to the allowable wind speed during noise measurements. It is common practice for this limit to be 5 m/s at the microphone, although 3 or 10 m/s are sometimes also adopted. The purpose of this limit for general environmental noise measurements may be to limit wind induced background noise, adverse propagation affects, wind induced noise on the microphone, or a combination of these. In the case of wind farm background noise assessments, the purpose of the measurements is to quantify the increase of wind induced background noise and a wind speed limit of 5 m/s at the microphone is typically adopted, with the sole aim of ensuring that wind induced microphone noise does not adversely affect the measurements by way of artificially increasing background noise. This paper examines the rationale for limiting wind speeds at the microphone to 5 m/s, and shows through field measurements that this limit does not guard against adverse effects of wind induced microphone noise. An alternative approach for preventing adverse effects of wind induced microphone noise is proposed.

1. Introduction

There are a range of Standards and guidelines used in Australia to assess wind farm noise, and all of these provide noise criteria as a base noise limit (typically 35 or 40 dB(A)) or background noise + 5 dB, whichever is the greater.

The level of the existing background noise is determined by logging noise levels at the nearest residences adjacent to the proposed wind farm, over the range of wind speeds that the wind farm will be operating.

Noise measurements for other types of environmental noise assessments are normally conducted at times of low wind speeds (less than 5 m/s) to reduce the influence of wind generated noise on the measurements. It is not possible to avoid times of high wind speeds during wind farm background noise measurements, as it is necessary to determine the noise criteria over the range of speeds in which the wind farm normally operates. Therefore the Standards and guidelines used to assess wind farm noise typically require the consideration of wind induced microphone noise. Some suggest the assessment of the actual level of wind induced background noise, but many note that the level of wind induced microphone noise will be acceptable provided the wind speed at the microphone is less than 5 m/s. It has become relatively common for consultants to monitor wind speed at the microphone, exclude all data where wind speed exceeded 5 m/s at the microphone and keep all data at less than 5 m/s, on the basis that wind induced microphone noise will be adequately addressed.

This paper reviews the requirements of the various Standards and guidelines, and investigates the level of wind induced microphone noise through field measurements to determine the suitability of the 5 m/s wind speed limit.

2. Requirements of Standards and Guidelines

A number of different Standards are used to assess wind farm noise in Australia. The requirements of the various Standards and guidelines with regards to the assessment of microphone wind generated noise are outlined below. Also included is a summary of the requirements for controlling wind induced noise in the UK Institute of Acoustics *Good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* [1], which is a document sometimes used to provide additional guidance for wind farm assessments conducted in Australia.

2.1 South Australian EPA wind farms environmental noise guidelines

Under the South Australian Wind Farm Guidelines it is necessary to *"confirm that the reported noise levels are not influenced by high wind speed across the microphone, particularly where wind speeds at the noise measurement position are expected to exceed 5 m/s"*[2]. The South Australian Guidelines state that the influence of wind induced microphone noise should be identified using the wind speed at the microphone that is exceeded for 90% of the time. However, in the case that the wind speed monitor does not report the statistical wind speed it is acceptable to use the average wind speed instead.

The recommended approach included in the South Australian Guidelines is for the wind speed measured at the microphone to be used with data from the manufacturer to determine the wind induced microphone noise. The South Australian Guidelines then note that:

- *Where manufacturers' specifications indicate that wind induced noise on the microphone is 10dB(A) or more below the background noise, the data is acceptable.*

- *Where manufacturers' specifications indicate that wind induced noise on the microphone is 10dB(A) to 4dB(A) below the background noise, the affected data may be retained with the wind induced noise subtracted from the measured background.*

- *Where manufacturers' specifications indicate that wind-induced noise on the microphone is within 4dB(A) of the affected data, the affected data should be discarded and the data should be re-analysed. If the procedure causes the regression curve to change significantly, then additional data will need to be collected within an improved wind screen.*

The South Australian Guidelines also include the statement that *"If it is not possible to obtain manufacturers' data for the windshield used, then data above 5 m/s should be discarded"*. We note that actual manufacturer data is rarely available, it is not unusual for consultants to exclude data based on this 5 m/s limit rather than predicting the level of wind induced noise and correcting for this. Additionally, it is common for the data above 5 m/s to be discarded based on the average wind speed rather than wind speed exceeded for 90% of the measurement period.

2.2 Queensland draft wind farm state code

The Draft Wind Farm State Code [3] was released in April 2014. It follows the guidance of the SA Guidelines and the approach to wind speed during background measurements is the same.

2.3 Australian Standard 4959- 2010

Australian Standard 4959:2010 [4] indicates that data that may be adversely affected by microphone wind effects should not be included in the analysis. As additional guidance it states that:

"There is a potential for significant regenerated noise to be created by wind effects on a microphone and wind shield (if not used in accordance with the manufacturer's instructions), which can affect the accuracy of measurements of background noise. For this reason noise level measurements are not typically conducted in wind speeds in excess of 5 m/s at the microphone and specially built wind shields are required for microphones used in higher wind speeds. As wind is one of the defining features of a wind farm site, the Regulatory Authority may request documentary evidence showing the use of a suitable windscreen if wind speeds at the noise measurement position may reasonably be expected to exceed 5 m/s"

The above statements could easily be interpreted as indicating that data below 5 m/s will not be affected by wind induced noise, while data above 5 m/s is likely to be affected and so should potentially be excluded from the analysis.

2.4 New Zealand Standard 6808:2010

New Zealand Standard 6808:2010 [5] is used to assess wind farm noise in Victoria. New Zealand Standard 6808:2010 contains no requirements for the microphone wind generated noise to be assessed.

2.5 Draft NSW wind farm noise guidelines

The Draft NSW wind farm noise guidelines were released for public consultation in December 2011 [6]. The draft guidelines provide the following guidance with respect to wind induced noise:

"Data affected by wind across the microphone inducing 'instrumentation noise' that affects the measured noise level by more than 1dB(A) should be excluded from the data set (also refer to Section 5)."

We note that Section 5 does not exist in the Draft guideline, and no further guidance on specific procedures on assessing wind induced noise is provided. A 1 dB(A) change in noise level would occur when the predicted wind induced microphone noise level is within 6 dB of the measured L_{A90}.

2.6 Institute of Acoustics Good Practice Guide

The Supplementary Guidance Note 2 of the Institute of Acoustics GPG provides a detailed discussion the issue of wind induced noise. In summary the GPG identifies that not all wind screens are suitable for the control of wind induced noise at wind speeds above 4-5 m/s in low noise environments. The GPG does not favour the correction of measured noise levels for wind induced noise, on the basis that there is a lack of a standardised method for measuring the performance of wind shields, and that the use of an average wind speed at the microphone could not reasonably be expected to allow prediction of the wind induced L_{A90}. Instead, the GPG recommends a wind shield that provides *"significantly greater reduction in wind-generated noise than a standard windscreen"*. Additionally, the GPG notes that with regards to standard (90 mm - 100 mm) wind screens that:

"Measurements using standard wind screens can only be considered reliable where the measurement location is sheltered and there is evidence that the local wind speeds at the microphone height did not exceed 5 m/s during the survey period."

2.7 Summary

There is a large degree of variation between requirements of the various standards and guidelines, but the wind speed of 5 m/s is commonly identified as a limit or point at which wind induced noise may start to adversely affect results. The authors note that the 5 m/s threshold has been widely adopted in the industry as the wind speed below which no adverse effects are able to occur.

Data below 5 m/s is typically used in assessments with data above excluded, even in South Australia where the assessment of the actual level of wind induced noise is recommended by the

Guidelines. The only Standards or guidelines not including a 5 m/s limit are the Draft New South Wales guidelines which require the assessment of the actual level of wind induced noise, and New Zealand Standard 6808:2010 which does not address wind induced microphone noise.

The 5 m/s wind speed limit at the microphone appears to have been adopted from general environmental noise assessment procedures. A wind speed of 5 m/s is used as a limit or guideline level in the industrial noise policies of Queensland [7], South Australia [8], Australian Capital Territory [9], New South Wales [10] and Tasmania [11]. The original source of this 5 m/s limit is not known to the authors, but it is reasonable to believe that it is intended to limit both wind induced noise on the microphone, and wind induced noise in vegetation. In the case of wind farms the primary purpose of the background noise measurements is to measure the wind induced noise in vegetation, so the only possible purpose of the 5 m/s limit is to prevent wind induced noise on the microphone.

3. Assessment Methodology

To assess wind induced microphone noise during background noise measurements the wind speed is normally logged using an anemometer adjacent to the microphone. It is typical practice for the wind speed to only be logged at the most wind exposed location during a round of background noise monitoring at receivers. Our previous assessments of calculating wind induced noise based on measured wind speed during background noise measurements at residences had identified only two 10-minute periods when wind induced noise was within 10 dB of the measured noise level. However, those monitoring locations had all been either relatively well sheltered from the wind or near significant vegetation and it is possible there may be increased influence at more exposed sites.

To investigate the relationship between wind speed at the microphone and wind induced noise, measurements have been undertaken at relatively exposed locations. The method used to determine the influence of wind induced microphone noise, equipment used, and the four monitoring locations used for this investigation are described below.

3.1 Equipment

A Rion NL-22 noise logger was used for these measurements, with the wind speed logged in corresponding 10-minute intervals using a NRG #40 cup anemometer and Nomad 2 wind data logger. The anemometer was positioned approximately 2 m from the microphone, at the same height as the microphone but far enough away that it was not audible at the microphone. The Nomad 2 data logger provides both the average wind speed and standard deviation of the wind speed during each 10 minute period. The microphone of the noise logger was protected using a standard 90 mm wind shield.

3.2 Relationship to convert wind speed to wind induced noise

The wind speeds measured at the microphone can be used to predict the resulting level of wind induced microphone noise. A number of studies have been undertaken to determine the relationship between the two. This study uses the relationship provided by Cooper, Leclercq and Stead in 2010 [12], which used measurements in atmosphere and provides a method to determine the wind induced L_{A90}. The equation used the convert wind speed to the level of wind induced microphone noise for a 90 mm wind shield is provided as Equation 1, where μ is the mean wind speed during the 10 minute period and σ is the standard deviation of the wind speed during the 10 minute period.

$$L_{A90} = 10 \times \log((\mu - 1.28 \times \sigma)^{6.14}) - 7.6 \quad (1)$$

The mean minus 1.28 times the standard deviation provides the 10th percentile wind speed (wind speed exceeded for 90 percent of the measurement period), which was previously shown to provide a far better estimate of the wind induced L_{A90} than the average wind speed.

3.3 Measurement sites

On the basis of the lack of significant influence of wind induced noise on previous measurements at residential locations, the four sites used for this investigation were selected in relatively wind exposed locations and/or away from significant sources of wind induced noise. Far more sheltered sites near to vegetation, that would have been more representative of background noise at the actual residence around which the locations were based, were avoided.

Aerial images showing the locations selected for the measurements are provided in Figure 1. Images showing the equipment at each of the four locations and view towards the nearest trees are included in Figure 2. A description of each of the locations is also included below.

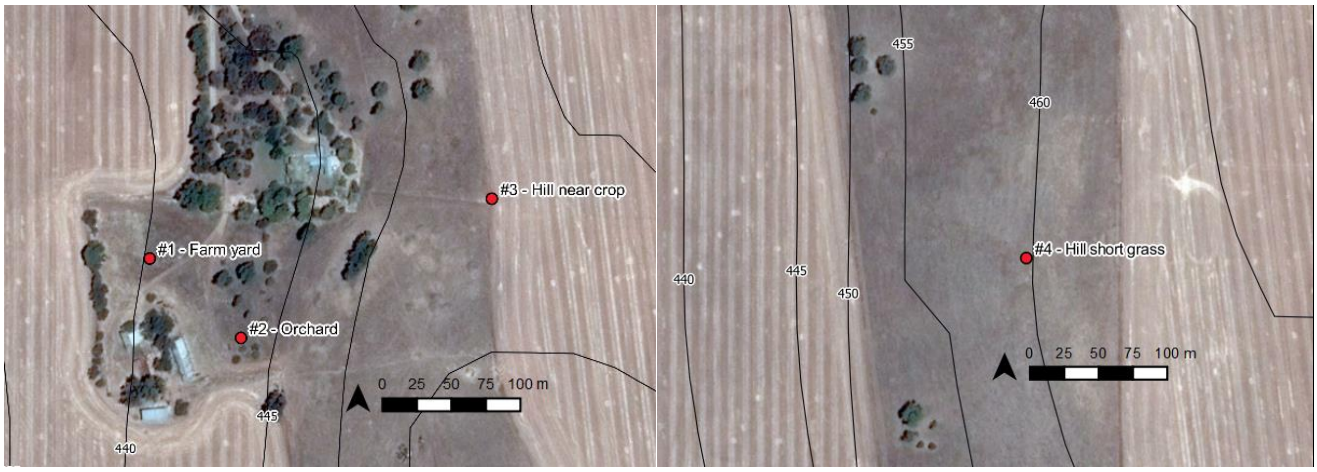

Figure 1. Aerial images showing the four monitoring locations and the surrounding vegetation and topography

3.3.1 Site 1 – Centre of farm yard

The first site was located in the centre of the farm yard, and is the most sheltered of the four locations. The nearest trees to this site are located between 35 m and 50 m on most sides of the monitoring location, with heights ranging from typically 5 m to the west, up to 9 m to the north east. The grass was closely grazed, with height of 20 – 150 mm.

3.3.2 Site 2 - Orchard

At Site 2 the noise logger was located in an orchard, with several deciduous trees nearby (not in leaf) and situated in approximately 200 mm of grass. The deciduous trees did not appear to contribute to noise levels at this location, with the background noise controlled by 8 m eucalyptus trees located 45 m to the north and south east.

3.3.3 Site 3 – Hill near crop

This was a very wind exposed site, on the top of a ridgeline which runs north-south. The logger was 90 m from eucalyptus trees of approximately 10 m height located to the north west and south west. There was closely grazed grass to one side of the noise logger and a cereal crop of 250 mm height to the other.

3.3.4 Site 4 – Hill with short grass

Site 4 was a very wind exposed site, located near the crest of a hill and away from significant vegetation. The logger was located 150 m from a group of four 7 m eucalyptus trees, and 115 m from another 7 m eucalyptus tree. The grass was grazed to a height of 20 – 50 mm.

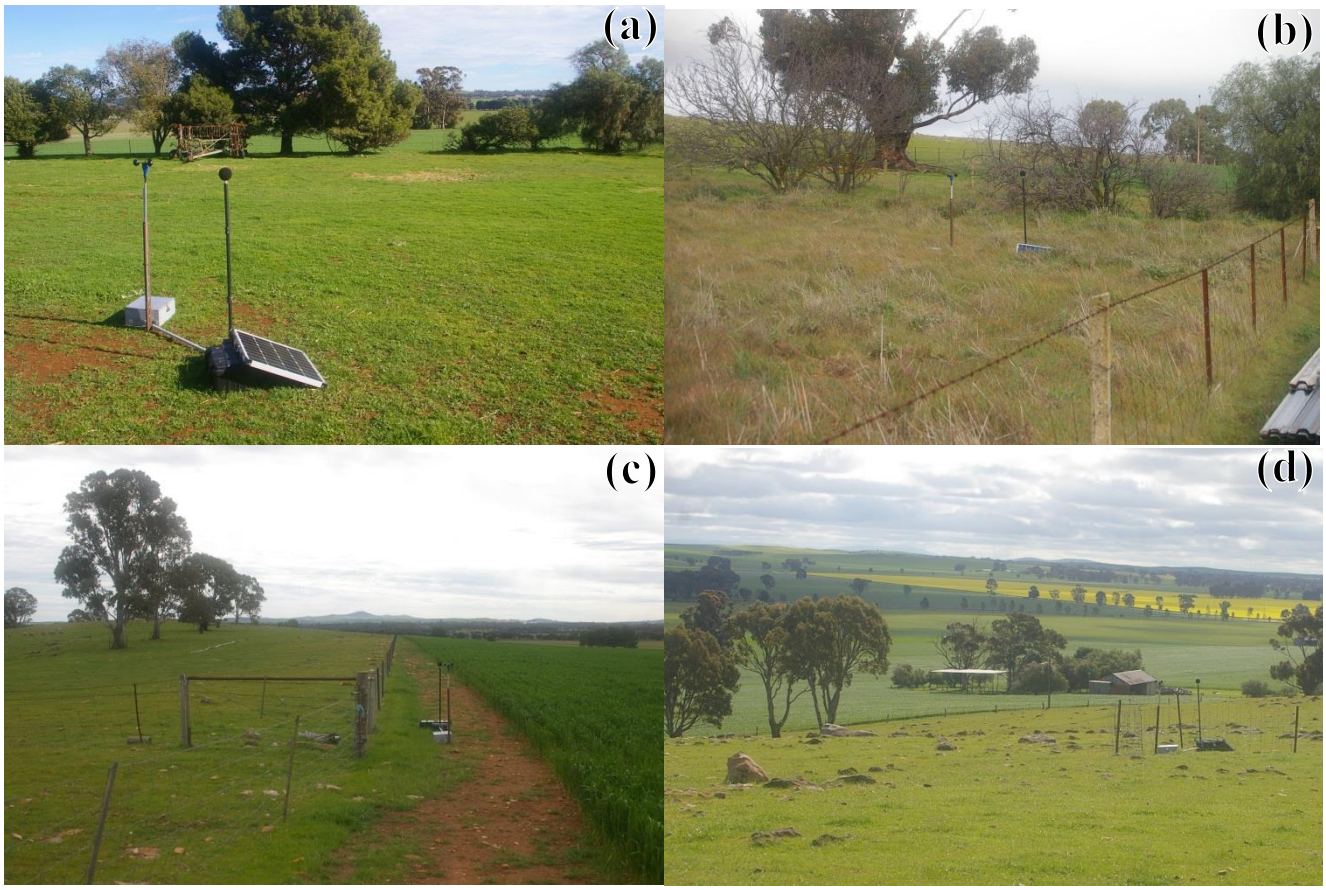

Figure 2. Photographs of monitoring locations; (a) location #1 in farm yard looking west, (b) location #2 in orchard looking south east, (c) location #2 on hill near crop looking north, (d) location #4 on hill looking north west

4. Results

4.1 Speed at which wind induced noise becomes important

To examine the influence of wind induced microphone noise the measured noise levels at each of the locations are plotted against the wind speed at the microphone. Also included on the graphs is the noise level that would be measured if the measurement was controlled by wind induced microphone noise, and a line 10 dB above the predicted wind induced level. At a level more than 10 dB above the wind induced microphone level the influence of wind induced noise is 0.4 dB(A) or less, and considered by the South Australian and Queensland guidelines to be insignificant.

Any data points at the line of predicted wind induced microphone noise are controlled by wind induced microphone noise, while data points 4 - 10 dB above this line are noise affected under the South Australian and Queensland guidelines would be corrected for this influence. In the case of the Draft New South Wales Guidelines the data point is excluded when the measure level is within 6 dB of the wind induced level (resulting in 1 dB(A) change in measured level). Figures 3 to 6 present the measurement results at locations 1 to 4 respectively.

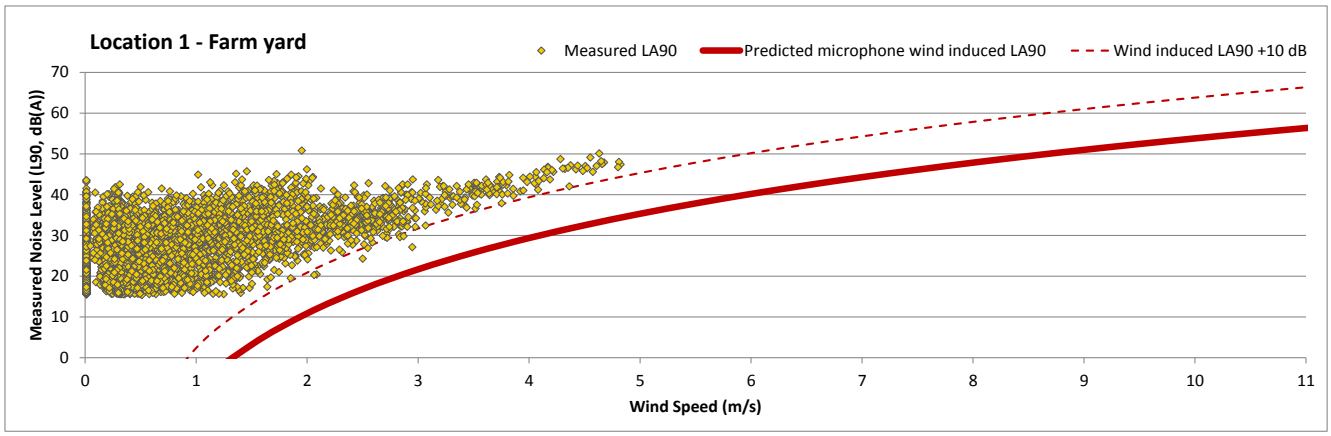

Figure 3. Noise levels at Location 1 plotted against microphone wind speed

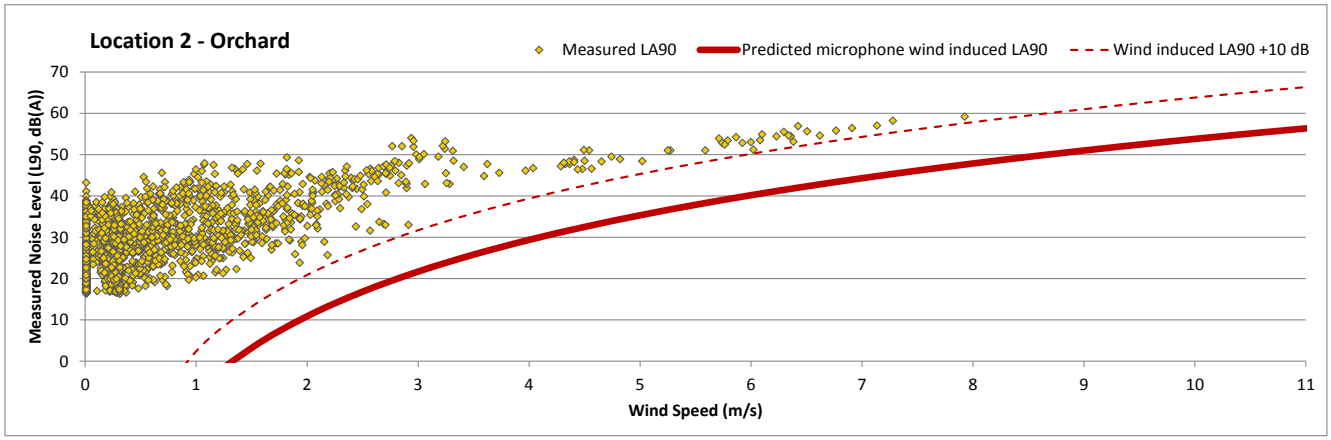

Figure 4. Noise levels at Location 2 plotted against microphone wind speed

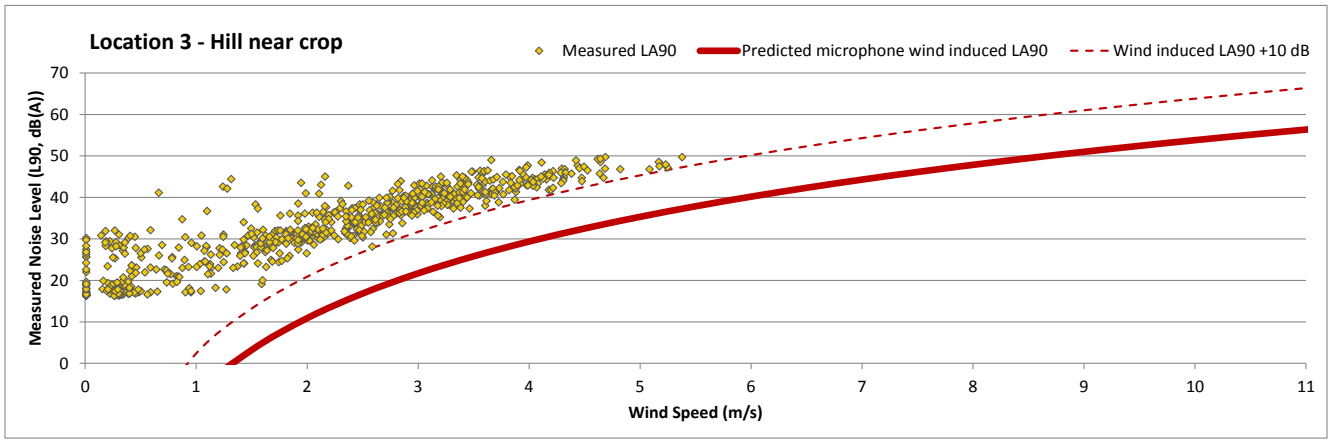

Figure 5. Noise levels at Location 3 plotted against microphone wind speed

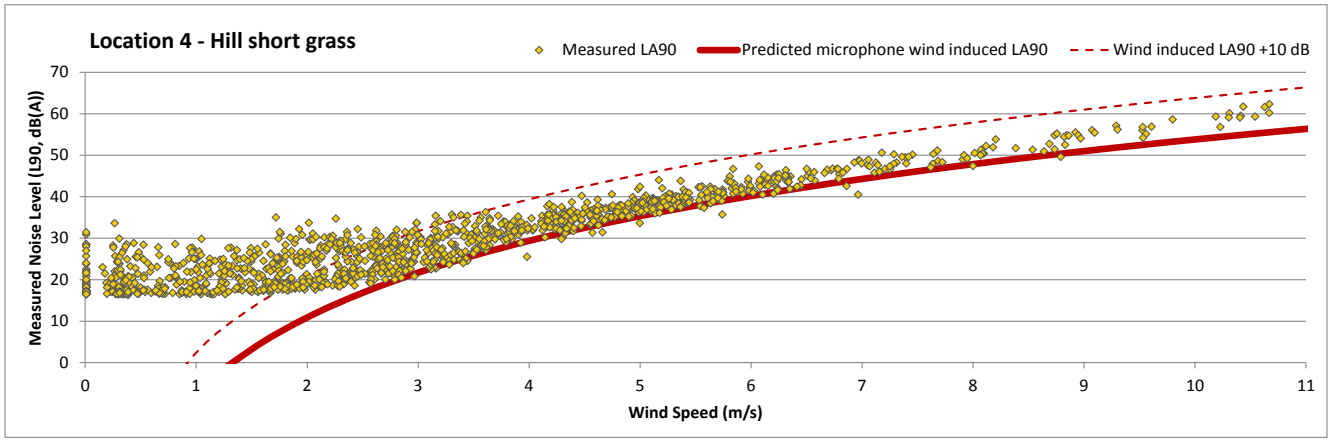

Figure 6. Noise levels at Location 4 plotted against microphone wind speed

The results at the first three sites are relatively similar in that measured L_{A90} levels were almost always more than 10 dB above the level that would have been expected from wind induced noise. At these three locations, the only data points within 10 dB of the wind induced microphone noise level were at speeds of 2 – 3 m/s at Location 1. A review of results at these locations does not indicate that 5 m/s is a suitable threshold speed above which results may be adversely affected. There are measurement results a similar distance above the wind induced noise level for wind speeds of between 2 and 8 m/s. There is no indication that measured noise levels are approaching the wind induced microphone noise level at higher wind speeds, as measured levels are increasing at the same rate as the wind induced microphone noise level.

Measurement results at the fourth site were regularly dominated by wind induced microphone noise. At this location, once again a limit of 5 m/s at the microphone did not provide any protection against adverse effects of wind induced microphone noise. At this site the results were adversely affected once the measured level raised above the noise floor of the sound level meter at about 1.7 m/s. If anything, rather than a trend towards increased microphone noise at high speeds, a trend towards measured levels climbing above the wind induced noise level was observed from 5 m/s onwards.

It is important to recognise that at three of the four sites there was negligible influence from wind induced microphone noise, despite these measurement locations being selected on the basis that they were relatively wind exposed and away from significant sources of wind generated noise. In practice it is therefore likely to be relatively rare for wind induced noise to be an issue at a measurement site as residences are normally surrounded by more vegetation. However, it is possible that a receiver near a wind farm will be similarly situated as the fourth measurement location, surrounded by no trees with very little grass. There is therefore the possibility that measurements could be undertaken at a site where wind induced microphone noise might adversely affect results.

4.2 Use of average rather than 10th percentile wind speed

The use of the average wind speed rather than 10th percentile (exceeded for 90% of the measurement period) wind speed results in an overestimate of the level of wind induced microphone noise. This in turn results in overcorrection of measured levels for wind induced microphone noise and a slight lowering of measured noise level. However, an overestimate of the wind induced microphone noise level may also result in unnecessary exclusion of data points which are unaffected by wind induced microphone noise. Taking Location 3 as an example, when 10th percentile wind speeds are used in the analysis (Figure 5) no data points are judged to be adversely affected. However, as shown in Figure 7, a large number of data points would be excluded under both the SA and draft NSW Guidelines if average wind speeds were used for the assessment.

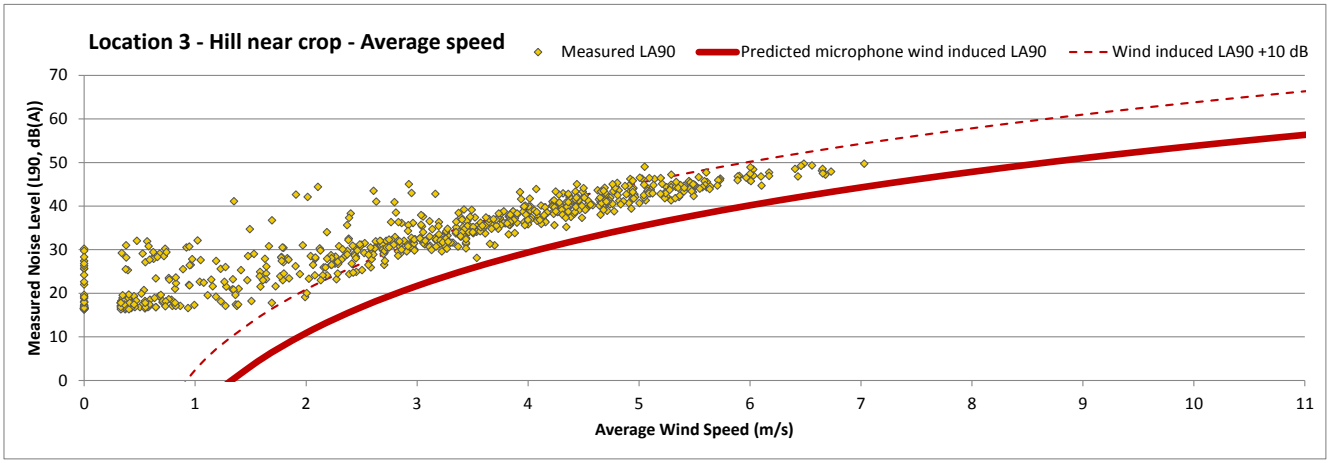

Figure 7. Noise levels at Location 3 plotted against average microphone wind speed rather than wind speed exceeded for 90 % of the measurement interval

4.3 Impact of excluding wind induced data points

The data presented in this paper is analysed against wind speed at microphone height rather than against wind speed at hub height, such that it is not possible to determine the impact on noise criteria from the exclusion of wind induced data points.

The aim of the assessment and exclusion based on wind speed is to prevent excessively high noise criteria being recorded at a site due to artificial wind induced noise on the microphone. However, there are two possible reasons for a data point being excluded from an assessment, if other data points at similar wind speeds are not excluded. Either:

- the local wind speed was higher than typical during that measurement, and so wind induced noise was excessive and it was correct to exclude that point, or,

- the local environment was particularly quiet during that period, resulting in the background noise level falling to the wind induced noise level.

While the aim of the exclusion of data points is to control the former, it is not possible to establish that the cause of exclusion was not the latter. If the exclusion was the result of local levels being quiet then the exclusion will result in an increase in noise criteria, the opposite result to that intended from the analysis of wind speed at the microphone. We would strongly suggest that the impact of the exclusion of data points is reviewed, and that if any significant changes result then the whole data set should be discarded and another gathered with an improved wind shield.

5. Recommended Approach

It is clear from the above examples that discarding data at speeds above 5 m/s does not protect against the influence of wind induced noise. If we consider data within 10 dB of the wind induced level to affected by wind induced microphone noise, then the only data affected at location 1 was at 2 – 3 m/s, while at location 4 data was affected from 1.7 m/s, and dominated by wind induced noise from 3 m/s.

The use of average wind speeds to identify periods which are affected by wind induced microphone noise can also not be recommended on the basis that it significantly overestimates the influence, causing incorrect corrections and potentially exclusion of many valid data points. There is potential for these exclusions to result in higher noise criteria than would exist with no data exclusion, which is not the intent of the exclusion procedure.

One approach to guard against an adverse impact from exclusion of data points would be to set a maximum percentage of data points that may be excluded at any given speed. However, the approach we favor is similar to that suggested by the South Australian Guidelines; if the exclusion significantly changes the regression result then the data set should be discarded, and additional measurements undertaken using wind shields with improved performance. Our recommended approach for reviewing the influence of wind induced noise is summarised as follows:

- Only statistical wind speed should be used to identify the data points that are affected by wind induced microphone noise, measured adjacent to, and at the height of the microphone.

- Correct data points within 4 – 10 dB above the predicted wind induced microphone level for wind induced noise.

- Exclude all data points within 4 dB of the predicted wind induced microphone noise level. If the exclusion of data points results in a significant (1 dB) change in noise criteria then the data set should be excluded, and new data measured using improved wind shields.

- Where it is impractical to measure the background noise level without influence of wind induced microphone noise then the base noise limit (35 or 40 dB(A) depending on the site and the relevant Standard or Guideline) may be adopted.

While the Institute of Acoustics Good practice guide relies on the use of oversized shields to protect against adverse effects, we do not believe this approach necessarily achieves its goal. The performance of a 180mm diameter wind shield is only 2 – 5 dB better than that provided by a 90 mm wind shield for speeds of 2 – 8 m/s [12]. There is still therefore the potential for adverse effects at quiet wind exposed sites when using oversized wind shields.

6. Conclusion

The Guidelines and Standards used to assess wind farm noise in Australia generally require that it is ensured that wind induced microphone noise does not influence the background noise measurements that are undertaken to define noise criteria. The majority of the standards and guidelines attempt to achieve this aim by limiting the wind speed at the microphone to no more than 5 m/s. The measurements presented in this paper indicate that the 5 m/s limit does not achieve its goal, with wind induced noise shown at to be influencing measurement results at two sites at wind speeds as low as 2 m/s.

We believe that using statistical wind data to predict the wind induced noise level in every 10 minute monitoring period is the only method which is able to ensure that wind induced microphone noise is not adversely affecting background noise measurement results. While the use of oversized wind shields reduces the level of wind induced microphone noise, the performance of these shields is not necessarily sufficient to prevent adverse effects at particularly quiet sites.

Acknowledgements

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