Evaluating Noise Criteria for Wind Farms: A Comparison of Background Noise Curve Fitting and Wind Speed Bin Data Post-Processing

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Abstract - In the realm of renewable energy development, the assessment of noise impact from wind farms is a critical aspect of both planning approval and compliance checking. The noise criteria applicable are based on baseline levels or a 'background + 5 dB(A)' rule. Historically, the background noise level referenced to a specific hub height wind speed has been derived using a curve fitting. This process involves the analysis of a large dataset. The curve fitting method provides a statistical model of the background noise, which is then used to establish the noise criteria for the wind farm. This paper examines the impact of amendments to the South Australian wind farm noise guidelines on the assessment of noise impact from wind farms. The 2021 amendment introduced an alternative method for post-processing background noise data in wind speed bins, aligning with the IEC 64100-11 standard. A comparative study between the superseded guidelines and the updated procedure is presented. Case studies reveal that the estimates of background noise in the wind speed range used for wind farm noise assessment, show minor variation between the two methods. Consequently, the resultant noise criteria derived from these estimates are also similar, irrespective of the post-processing procedure employed.

1 INTRODUCTION

The assessment of noise impact from various sources is a critical component of regulatory frameworks and guidelines. As knowledge advances and case studies and monitoring data are analysed, there is a recurring need to review and update noise assessment methods and procedures. This necessity is particularly relevant to wind farm developments. In 2021, the South Australian Environment Protection Authority released an updated version of the Wind Farms Environmental Noise Guidelines 2009 (SA EPA, 2021) after completion of a comprehensive review of pertinent information. The 2009 version of these guidelines provided a foundation for predicting noise impact and ensuring compliance for wind farms in South Australia and other states (SA EPA, 2009). Over the years, this document has referenced numerous relevant sources that have been updated. The 2021 guidelines were introduced to align noise assessment recommendations for wind farms with contemporary standards, such as the international standard IEC 64100-11: 2012 Ed.3.1 Wind turbines - Part 11: Acoustic noise measurement techniques (IEC 64100-11, 2018). International Electrotechnical Commission also recently released technical specification for measurements of wind farm noise at a distant receiver, which also recommends similar data post-processing technique (IEC TS 64100-11-2, 2024). After few years of implementing the updated guidelines, it is now possible to suggest some insight on the differences between current and previous regulatory practices and determine if significant changes have occurred.

2 SETTING CRITERIA FOR WIND FARMS

Typically, noise criteria for wind farms are among the strictest established under environmental regulations. These criteria are designed to preserve the amenity of rural areas and reduce the likelihood of adverse reactions from communities previously unaffected by wind farm noise. Noise criteria for wind farms are set as follows:

- A baseline criterion of 35 or 40 dB(A) in South Australia, depending on the classification of the planning zone for the sensitive receiver, or

- The “background + 5 dB(A)” rule, whichever is greater.

The noise criteria are derived for integer wind speeds of turbines, from cut-in speed to the speed at which rated power is achieved, measured at hub height. The principles for establishing noise criteria remain consistent across both versions of the guidelines. However, the procedure for deriving background noise levels for sensitive receivers has been amended in the new version of the guidelines, potentially leading to discrepancies in established noise criteria. Given that even a 1 dB difference can be significant for obtaining regulatory approvals and finalising the wind farm layout, further details are provided in this paper.

3 BACKGROUND DATA ACQUISITION AND POST- PROCESS PROCEDURES

The calculation of background noise levels is based on the collection of 10-minute L_{A90} data points, correlated with hub height wind speed, in accordance with both current and superseded versions of the Wind Farms Environmental Noise Guidelines. The L_{A90} statistical descriptor represents the noise level that is equalled to or exceeded for 90% of the measured period (A-weighted sound pressure level). Data rectification procedures to exclude extraneous noises and data affected by adverse environmental conditions are consistent across both documents. The guidelines also include recommendation on collecting not less than 500 data points for downwind conditions, which is different from requirements of other similar guidelines in Australia.

The superseded version of the guidelines calculates background noise levels using curve fitting of the valid dataset, where:

- Data is processed between cut-in wind speed and the speed of rated power.
- The trend curve is represented by a polynomial of up to the third order.
- The curve for calculating background levels is chosen based on the greatest coefficient of determination during the curve fitting process and the trend, which is expected to increase with greater wind speeds.

The noise prediction section of the guidelines specifies the sound power of the turbines as a major input for predicting noise impact. The sound power of turbines for relevant hub height wind speeds should be determined in accordance with the measurement procedure in the international standard IEC 61400-11: 2012 (IEC 61400-11, 2018). This standard involves processing and reporting data in wind speed bins. The current version of the guidelines aligns with the methodology in the IEC standard. However, it causes some discrepancies in data post-processing compared to the older guidelines because:

- It generally involves more data for post-processing due to the inclusion of extra data at the ends of the wind speed range. The wind speed bins have a width of ±0.5 m/s and are centred on the integers, thus capturing additional data points at the cut-in wind speed and the speed of rated power, as shown in Figure 1 (additional data is shown in orange).
- The calculation of background noise levels in wind speed bins does not require a curve fitting process and is based on simple arithmetic averaging of the data in the bin. Therefore, the calculated background depends only on the noise data in the bin and is not influenced by noise levels acquired at other wind speeds.

While the current computational procedure is simpler and eliminates subjectivity in background computation, it does not control the expected trend of background noise versus wind speed, which may differ significantly from the curve fitting method. The degree of this difference is explored based on case studies where pre-construction background noise was monitored to set relevant noise criteria, and data was processed according to both current and superseded procedures.

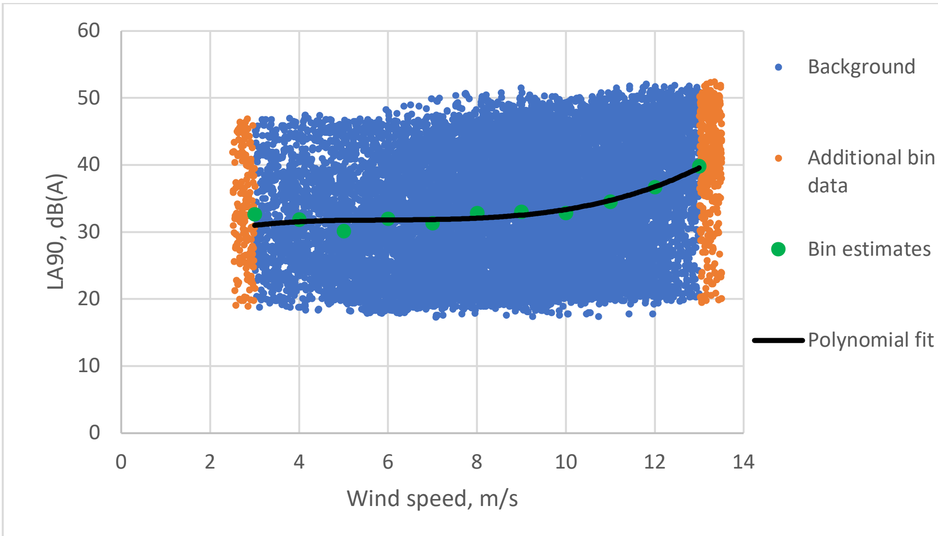

Figure 1 – Background noise data and background noise estimates

4 BACKGROUND NOISE ASSESSMENT- CASE STUDIES

4.1 Background magnitudes

Some Australian states still lack clarity on the application of regulatory practices for assessing compliance or resolving complaints. In some cases, noise criteria were derived using outdated guidelines, and applying the amended guidelines may require revising these criteria. Difference between the guidelines is explored in this paper for monitoring locations in the vicinity of two proposed wind farm sites, where background noise data was collected for purpose of establishing the noise criteria.

Noise monitoring was conducted at five locations at one wind farm and four locations at another. All locations were in quiet rural areas. Data was collected using Class 1 instruments, and standard data rectification procedures were applied to rectify data collected during adverse environmental conditions and extraneous noise events. L_{A90} levels were correlated with a hub height of 150 m and processed for wind speeds of 3-13 m/s. Although the intended hub height for both sites was not exactly the same, the same reference height was used to provide a consistent basis for wind speeds for both wind farm sites. A third-order polynomial fit, which provided the greatest coefficient of determination, was used to compute background noise estimates in accordance with the superseded guidelines.

Table 1 and Table 2 summarise the background noise level calculations for the monitoring locations. The estimates show that the difference in calculated background levels is small for most of the estimates, with the relative difference typically not exceeding 10% in the worst case. However, sometimes the relative difference may be substantial like for monitoring location B2, where it exceeds 20% at 3 m/s. The difference is often greater at the lower end of the wind speed range.

Table 1 - Background noise estimates L_{A90} (dB(A)), Site 1

Wind speed, m/s	**Location**									
	A1		A2		A3		A4		A5	
	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin
3	27.3	29.8	31.0	32.6	29.0	30.3	25.3	26.6	24.0	25.7
4	30.2	33.0	31.5	31.8	30.4	31.3	27.1	28.0	26.0	26.1
5	32.0	28.0	31.7	30.1	31.3	30.4	28.3	30.0	27.2	26.0
6	33.1	32.8	31.8	31.9	31.7	31.6	29.0	28.8	27.9	27.6
7	33.6	33.7	31.9	31.3	31.9	31.8	29.4	29.5	28.4	28.6
8	33.9	34.5	32.1	32.8	32.0	32.3	29.6	30.0	28.7	29.3
9	34.2	34.7	32.5	33.0	32.1	32.4	29.9	30.1	29.2	29.5
10	34.8	34.4	33.4	32.8	32.4	32.2	30.4	30.2	30.0	29.6
11	35.9	35.6	34.7	34.5	33.2	32.8	31.2	31.1	31.3	31.2
12	37.7	37.8	36.8	36.7	34.5	34.4	32.5	32.4	33.4	33.4
13	40.6	40.7	39.6	39.8	36.5	36.4	34.5	34.6	36.5	36.5

Table 2 - Background noise estimates L_{A90} (dB(A)), Site 2

Wind speed, m/s	**Location**							
	B1		B2		B3		B4	
	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin
3	23.9	26.8	13.5	17.0	21.4	21.8	23.5	24.2
4	25.8	26.3	17.7	18.1	22.1	22.1	24.4	24.9
5	27.6	27.4	21.3	20.0	23.5	23.7	25.5	24.9
6	29.2	28.8	24.4	23.6	25.5	25.1	26.7	27.2
7	30.8	30.4	27.0	27.8	27.9	28.0	28.1	28.3
8	32.2	32.0	29.1	30.0	30.4	30.4	29.5	29.3
9	33.4	33.8	30.8	31.1	32.8	33.3	30.8	31.0
10	34.5	35.0	32.0	31.4	35.0	34.9	32.0	32.4
11	35.5	36.0	32.7	32.5	36.7	36.8	33.1	33.3
12	36.4	35.9	33.1	32.5	37.7	37.2	34.0	33.7
13	37.1	36.9	33.1	35.1	37.7	39.0	34.6	35.4

4.2 Applicable noise criteria

Differences in background noise estimates do not necessarily imply that the applicable noise criteria are also different. Section 2 explains the procedure for setting noise criteria at affected sensitive receivers, which remains the same for both current and superseded guidelines. At low background noise levels, the noise criteria are equivalent to the baseline limit (35 or 40 dB(A)). Therefore, a fraction of a dB or even few dB difference in background noise estimates may not change the applicable noise criteria.

Differences in background noise estimates may influence applicable noise criteria where the “background + 5 dB(A)” rule is applied. The guidelines do not mention rounding results for the purpose of establishing noise criteria. Table 3 and Table 4 illustrate the peculiarities of this process and show criterion estimates with one digit after the decimal point to highlight differences in the resultant criteria. Resultant noise criteria in the tables are based on 35 dB(A) baseline criterion where it is applicable.

Unlike background noise estimates, in most of the cases there is no discrepancy in the lower wind speed criteria since they are equivalent to the baseline limits. More noticeable differences are detected at higher wind speeds, especially at the speed of rated power. Despite noticeable differences in noise criteria at higher wind speeds, this may not critically affect the choice of turbines or site layout. Many modern wind turbines reach maximum sound power at wind speeds lower than the speed of rated power. For example, the wind turbine intended for the first site reaches maximum sound power at 10 m/s, which, combined with a lower applicable criterion, makes this wind speed more important for demonstrating expected noise compliance. Table 3 shows that the difference in derived criteria at this wind speed is subtle, and changes in post-processing techniques have little influence on the outcome.

Table 3 - Derived noise criteria at wind farm Site 1, dB(A)

Wind speed, m/s	**Location**									
	A1		A2		A3		A4		A5	
	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin
3	35	35	36.0	37.6	35	35.3	35	35	35	35
4	35.2	38.0	36.5	36.8	35.4	36.3	35	35	35	35
5	37.0	35.0	36.7	35.1	36.3	35.4	35	35	35	35
6	38.1	37.8	36.8	36.9	36.7	36.6	35	35	35	35
7	38.6	38.7	36.9	36.3	36.9	36.8	35	35	35	35
8	38.9	39.5	37.1	37.8	37.0	37.3	35	35	35	35
9	39.2	39.7	37.5	38.0	37.1	37.4	35	35.1	35	35
10	39.8	39.4	38.4	37.8	37.4	37.2	35.4	35.2	35	35
11	40.9	40.6	39.7	39.5	38.2	37.8	36.2	36.1	36.3	36.2
12	42.7	42.8	41.8	41.7	39.5	39.4	37.5	37.4	38.4	38.4
13	45.6	45.7	44.6	44.8	41.5	41.4	39.5	39.6	41.5	41.5

Table 4 - Derived noise criteria at wind farm Site 2, dB(A)

Wind speed, m/s	Location							
	B1		B2		B3		B4	
	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin	Polynomial	Bin
3	35	35	35	35	35	35	35	35
4	35	35	35	35	35	35	35	35
5	35	35	35	35	35	35	35	35
6	35	35	35	35	35	35	35	35
7	35.8	35.4	35	35	35	35	35	35
8	37.2	37.0	35	35.0	35.4	35.4	35	35
9	38.4	38.8	35.8	36.1	37.8	38.3	35.8	36.0
10	39.5	40.0	37.0	36.4	40.0	39.9	37.0	37.4
11	40.5	41.0	37.7	37.5	41.7	41.8	38.1	38.3
12	41.4	40.9	38.1	37.5	42.7	42.2	39.0	38.7
13	42.1	41.9	38.1	40.1	42.7	44.0	39.6	40.4

4.3 Note on statistical properties of the data set

The data set was analysed to identify parameters that may correlate with differences in background estimates under current and previous guidelines. This analysis may indicate whether such differences are expected to be significant. Key statistics such as the number of data points, sample variance, standard deviation, and other metrics (Chung, 2001, Sokal et al., 1995) were examined within the wind speed bins for each wind speed and monitoring location. This was done to verify if there is a substantial correlation with the relative difference between background estimates computed according to the current and superseded procedures. It is challenging to identify a specific statistical descriptor that indicates if the relative difference will be substantial. However, some observations can be made based on the case studies:

- The expected difference may be small if the number of data points in the wind speed bin is also small, e.g. the correlation coefficient with number of data points is negative.

- The standard deviation and variance of data in the wind speed bin are negatively correlated with the expected relative difference, e.g. less data scattering corresponds to a greater expected relative difference.

These observations are counterintuitive, as one might expect that the difference in sound pressure level estimates would be smaller if post-processing is done with a larger number of data points and less data scattering. Overall, the relative difference shows a relatively high correlation with these parameters. The absolute magnitude of the correlation coefficient for the standard deviation is above 0.54 for all monitoring locations except one (location B3), and the correlation is above 0.59 for the number of data points, also excluding one location (location B3). As noted above, these statistic descriptors are negatively correlated with the relative difference between the background estimates.

5 SUMMARY

This paper investigates the influence of background noise data post-processing under both current and superseded South Australian Wind Farms Environmental Noise Guidelines on setting criteria for wind farm developments. The current guidelines utilise wind speed bins for data post-processing, while the superseded guidelines recommend a curve fitting method. Case studies presented in the paper indicate that there may be noticeable differences in background noise estimates, particularly at very low or high wind speeds. However, this does not necessarily imply significant differences in the applicable noise criteria at the same wind speeds, as the criteria-setting procedure depends on the choice between the baseline criterion and the background noise-based criterion. The case studies suggest that changes in the data post-processing procedure are unlikely to be critical for wind farm developments. Further analysis of additional case studies may be needed to generalise this conclusion.

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