APPENDIX 9

Environmental Noise Guidelines: Wind Farms

Environmental Protection Agency, South Australia, 2009

Wind farms environmental noise guidelines

EPA South Australia

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Disclaimer

This publication is a guide only and does not necessarily provide adequate information in relation to every situation. This publication seeks to explain your possible obligations in a helpful and accessible way. In doing so, however, some detail may not be captured. It is important, therefore, that you seek information from the EPA itself regarding your possible obligations and, where appropriate, that you seek your own legal advice.

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1 Introduction

This document aims to help developers, planning and enforcement authorities, government agencies, acoustic engineers and the broader community assess environmental noise impacts from wind farms.

Wind farms need specific guidelines because wind turbines have unique noise generating characteristics and the environments surrounding wind farms usually have low ambient noise.

The core objective of the guidelines is to balance the advantage of developing wind energy projects in South Australia with protecting the amenity of the surrounding community from adverse noise impacts.

These guidelines offer advice to assist with compliance with the general environmental duty (see box) and specific environmental policies. They are subject to amendment and persons relying on the information should check with the EPA to ensure that it is current at any given time.

Several workshops have been held to help develop these guidelines. A technical subgroup, formed from the workshop group, provided specific technical consultation during development. An earlier draft of these guidelines was distributed to the original workshop participants and their submissions were used to prepare the earlier document.

In addition, the Environment Protection Authority (EPA) has taken into consideration the documents listed in the bibliography.

During 2005−09, a review of the 2003 guidelines was carried out. This involved a three-stage stakeholders' consultation process. Comments, suggestions and proposals have been collated and appropriately included into the guidelines.

Shaded boxes throughout this document contain explanatory comments.

Guidelines

The *Environment Protection Act 1993* (EP Act) requires a duty of care for the environment. This is specified under section 25 of the Act and states:

> A person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measures to prevent or minimise any resulting environmental harm.

Guidelines published by the EPA indicate the standard of care that is likely to be required to secure compliance with the general environmental duty. They have the advantage of flexibility and can be adapted to a range of circumstances.

2 Noise criteria

The general approach in setting noise criteria for new developments is to require compliance with a base noise level.

This base noise level is typically 5dB(A) lower than the level considered to reflect the amenity of the receiving environment. Designing new developments at a lower level accounts for the cumulative effect of noise from other similar development and for the increased sensitivity of receivers to a new noise source.

A unique characteristic of wind farms is that the noise level from each wind turbine generator (WTG) rises as the wind speed at the site increases. As an offset, the background noise also generally increases under these conditions and can mask the WTG noise.

Comparison with a base noise level alone will therefore not be sufficient to indicate the potential impact of a wind farm: a farm could comply with this base level at lower wind speeds but exceed it when the wind speed rises.

Most international and interstate jurisdictions (see examples in the box) set a base noise level for low wind speeds. Many regulations also ensure that the wind farm noise does not exceed the background noise by more than 5dB(A) as the wind speed increases.

This general approach recognises the unique noise generating characteristics of wind turbines and the particular ambient noise environments of most sites and is the one used by these guidelines.

The New Zealand Standard NZS 6808 sets the predicted base noise level (L_{Aeq}) at 40dB(A). This is consistent with the approach of these guidelines, but the specified propagation model to be used in accordance with that standard does not account for factors such as ground absorption and topography effects that can substantially reduce the noise level in practice. In addition, the New Zealand Standard requires the criteria to be met at all receivers, regardless of their relative amenity or relationship with the wind farm development.

A comprehensive publication developed by the wind farm industry for the UK Department of Trade and Industry (1996) sets the base noise level (L_{A90}) at 35−40dB(A). The actual value chosen within this range depends on the number of dwellings affected, the effect on the capacity of the wind farm of meeting the standard, and the duration and level of exposure.

Wind turbines and wind farms have been operating in Denmark for over 25 years. Denmark has set a base noise level only (and does not consider the influence of background noise). The L_{Aeq} is set at 40dB(A) for a wind speed of V_{10m} = 8 m/s.

Most wind farm sites are within or next to areas where low ambient noise levels are a significant component of that area's amenity. These might include rural living zones or zones that are not intended to be subject to any other significant ambient noise sources from adjacent premises.

Equally, some rural zones are intended for rural industry or primary production/general farming, where the amenity of the area may include noise from industrial sources.

The criteria in these guidelines have been established to address these scenarios and developed in accordance with the objects of the EP Act.

Where the wind farm sites are within or next to areas where more intensive activity is expected, the base noise level may also be increased to be commensurate with the amenity of that area. It is recommended that the developer discuss such a situation with the EPA and the relevant planning authority.

2.1 Determining wind farm operating criteria

Part 7 of the *Environment Protection (Noise) Policy 2007* refers to guidelines to establish noise limits from a range of noise sources including wind farms. The general approach for new development is to subtract 5dB(A) from the policy levels to obtain the base for criteria for development.

To prevent adverse impacts from the WTG noise, the noise source level must also be compared to the corresponding background noise at the relevant receiver.

2.2 Noise criteria—new wind farm development

The predicted equivalent noise level ($L_{Aeq,10}$), adjusted for tonality in accordance with these guidelines, should not exceed:

- 35dB(A) at relevant receivers in localities[1] which are primarily intended for rural living*,or
- 40dB(A) at relevant receivers in localities[1] in other zones,or
- the background noise ($L_{A90,10}$) by more than 5dB(A),

whichever is the greater, at all relevant receivers for wind speed from cut-in to rated power of the WTG and each integer wind speed in between.

The background noise should be as determined by the data collection and regression analysis procedure recommended under these guidelines (Section 3). It should be read from the resultant graph at the relevant integer wind speed.

Compliance with the noise criteria should also be demonstrated for the approved developments in the zone adjacent to the wind farm.

***Rural living**

A 'rural living' zone is a rural−residential 'lifestyle' area intended to have a relatively quiet amenity. The area should not be used for primary production other than to produce food, crops or keep animals for the occupiers' own use, consumption and/or enjoyment. The noise amenity should be quieter than in an urban−residential area.

If there is uncertainty about the zone and whether the rural living criteria should be applied, the question is to be determined, for the purposes of these Guidelines, by the EPA in consultation with the council for the area concerned.

2.3 Agreements with wind farm developers

Wind farm developers commonly enter into agreements with the owners of private land suitable for a wind farm site. The agreement provides the wind farm developers with the appropriate siting and generally offers the landowner a level of compensation and diversity in their income stream.

The criteria have been developed to minimise the impact on the amenity of premises that do not have an agreement with wind farm developers.

Notwithstanding this, the EPA cannot ignore noise impacts on the basis that an agreement has been made between the developer and the landowner. Developers cannot absolve themselves of their obligations under the EP Act by entering into an agreement with a landowner.

If it is shown that a development is having an 'adverse effect on an amenity value of an area that … unreasonably interferes with the enjoyment of the area', then appropriate action can be taken under the EP Act.

[1] Refer to Glossary for definition of 'locality'.

However, the existence of an agreement will affect the consideration of whether the interference is unreasonable in a given situation. It is unlikely that there will be unreasonable interference if:

- a formal agreement is documented between the parties,
- the agreement clearly outlines to the landowner the expected impact of the noise from the wind farm and its effect upon the landowner's amenity, and
- the likely impact of exposure will not result in adverse health impacts (eg the level does not result in sleep disturbance).

A risk associated with relying on such agreements still remains where the criteria in these guidelines are exceeded. This is because an interpretation of 'unreasonable' is required in any future assessment of the impact of wind farm noise initiated by a complaint from the landowner (or future landowners).

World Health Organization Guidelines for Community Noise recommend 30dB(A) indoor limit to prevent negative effects on sleep. The Working Group on Noise from Wind Turbines (Final Report, ETSU for DTI, 1996) recommends the outdoor noise limit of 45dB(A) (after any adjustment for tonality) for landowners having financial involvement in the wind farm. If the wind farm noise does not exceed 30dB(A) indoors and 45dB(A) outdoors at the localities belonging to the financial stakeholders it is considered acceptable. In particular situations the expected noise impact can be above the recommended limits. In this case the landowner has to agree in writing with the higher level of exposure and the developer should discuss the issue with the EPA.

2.4 Staged development

The procedure and criteria presented in these guidelines are for greenfield sites, but a wind farm may be developed over a number of separate stages.

A previous stage of the wind farm that is installed and operating may raise the background noise level at the relevant receivers by up to 5dB(A).

Any subsequent stage in the development of the wind farm site should meet the criteria using the background noise levels as they existed prior to the wind farm. Therefore, the noise generated by existing WTGs from a previous stage should not be considered as part of the background noise in determining criteria for subsequent stages.

2.5 Cumulative development

Separate wind farm developments in close proximity to each other may impact on the same relevant receiver.

Therefore, as for staged development, any additional wind farm that may impact on the same relevant receiver as an existing wind farm should meet the criteria using the background noise levels as they existed before the original wind farm site development. The noise generated by existing WTGs from another wind farm should not be considered as part of the background noise in determining criteria for subsequent development.

On occasion it will not be possible to determine the background noise levels as they existed before the original wind farm development.

This may result in subsequent developers of new wind farm sites needing to provide sufficient distance from a relevant receiver (which is common to an existing site) such that the alternative baseline criteria is met at that receiver for all operating wind speeds of the WTGs up to the speed of the rated power.

3 Meeting the criteria

This section describes the steps to be taken for assessing whether wind farm noise reaching receivers at relevant locations will comply with the criteria of these guidelines.

Background noise is measured at relevant receiver locations at continuous 10-minute intervals and particularly over the range of wind speeds at which the WTGs operate. The data must adequately represent conditions at the site and cover approximately 2,000 intervals.

Wind speed is measured in intervals that correlate with the background noise measurements at relevant receiver locations. The wind speed data, together with the manufacturer's noise data for the WTG and using a suitable model, is then used to predict noise levels at each integer wind speed from cut-in to rated power.

The correlated wind speed and background noise data are plotted to give a standard graph for background noise at each relevant receiver. This graph is then used in conjunction with the predicted noise levels to assess whether the wind farm will meet the criteria of these guidelines.

3.1 Background noise

What is background noise?

Background noise is the lull in the ambient noise environment.

Intermittent noise events such as from aircraft , dogs barking, mobile farm machinery and the occasional vehicle travelling along a nearby road are all part of the ambient noise environment but would not be considered part of the background noise unless they were present for at least 90% of the time.

Why is background noise important?

Background noise can mask the noise effects of new development such as a wind farm and the level of masking is a critical factor in assessing the impact of a wind farm.

Wind generated noise can provide a masking effect, particularly as it has similar characteristics to wind farm generated noise.

Background noise measurement locations

Background noise measurements should be carried out at locations that are relevant for assessing the impact of WTG noise on nearby premises (relevant receivers).

Relevant receiver locations are premises:

- where someone resides or has development approval to build a residential dwelling;
- where the predicted noise level exceeds the base noise level for the area [35 or 40dB(A)] for wind speeds up to the speed of the rated power
- that are representative of the worst-case situation when considering the range of premises, eg a house located among a group of nearby houses within a residential zone.

1 A proposed wind farm site with a zone in its vicinity that is primarily for residential land-use and is yet to be fully developed should be discussed with the relevant planning authority and the EPA.

   These locations will probably also be considered relevant receivers and background noise levels will be required at the zone boundary.

   The relevant planning authority can then be informed about the potential impacts on any future residential development.

   Nearby areas for which the zoning intent is not clear should also be discussed with the relevant planning authority and the EPA.

2 Background noise generally increases at a greater rate than noise from WTGs at high wind speeds. If the wind farm is predicted to achieve the base noise level at the very high wind speed of 10 m/s, 10 metres above the ground (V_{10m}; see Section 3.4) the wind farm noise at even higher wind speeds is expected to be masked by the increasing background noise. Therefore the impact will not be adverse and further investigation is not required.

   The only exception is a receiver within 1,500 metres of the wind farm site that is in an area unlikely to be exposed to a windy environment. This specific circumstance should be discussed with the EPA.

3 The worst-case situation may not always be the closest receiver to the wind farm site. The closest receiver should always be a measurement position but other locations where the background noise environment may differ due to prevailing weather patterns and/or local topography should also be included as relevant receivers.

   Background noise environments likely to differ at receivers around a wind farm site should also be discussed with the EPA.

Background noise measurement position

All measurements should be made outdoors. 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).

The property boundary of the receiving premises is generally not considered a valid measuring position for large rural properties unless a house is located near the boundary or the development plan clearly envisages noise sensitive development at such a location.

In general, any area within 30 metres of a house and in the direction of the wind farm would be a valid measuring position. Care should be taken to ensure that the area is not screened from the wind farm by house, shelter or other elements.

Background noise levels can be significantly affected by local conditions, such as the presence of trees nearby. Photographs from multiple directions are to be taken showing the noise measurement position and associated surroundings, such as buildings, trees and topography. This will ensure that no significant physical changes have been made to the locations since the time of the initial background noise measurements.

Care must be taken when using a measurement position to represent other receivers in the locality. Trees, grass and shrubs should be representative of the local area that is being assessed. Background noise measurements should represent the natural background in the immediate vicinity of the relevant receiver; extraneous noise sources (water pumps, air conditioning units, electrical transformers, etc) should not influence the data. In case selection of the representative point is not straightforward a conservative approach should be taken by placing the microphone in the quieter location.

Data collection

Equipment

Background noise levels should be collected for continuous 10-minute intervals using sound level meters or loggers of at least Class 2 certification in accordance with Standard AS IEC−61672. The lower limit of the instrument measurement range must be chosen to provide accurate measurements which might be limited by the noise floor of the data acquisition device.

The meters or loggers must be calibrated on site immediately before and after any measurement period using a calibrator which is suitable for the class of the instrument and complies with AS IEC−60942.

Class 2 certified monitoring equipment provides a sufficient level of accuracy for assessing the impact of wind farms under these guidelines.

Wind

Microphones should be protected with windshields in accordance with the microphone manufacturer's instructions, and the protection should be sufficient to ensure the noise level threshold of the monitoring equipment does not adversely affect the data used in the analysis. If microphones cannot be appropriately protected then affected data should not be collected.

As part of the development application, developers should 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 (a high wind speed for the purposes of noise level measurement conditions). It is permitted to report noise measurement data at higher wind speeds if they have been taken with special windshields. The windshield performance should be confirmed by sufficient technical information proving accuracy of such measurements.

Affected data should be identified by monitoring statistical wind speed (ie equalled or exceeded for 90% of the measurement time) at the noise measurement position (1.2−1.5 metres above ground level at the relevant receiver) over 10-minute intervals that correspond with the noise level measurement intervals. Not all wind monitoring instruments can provide the wind speed statistical parameters. In this case reporting the average wind speed to identify validity of the noise measurements is permissible. Accuracy of the wind speed measurements should be ±0.5m/s or better.

If wind data from the single wind speed monitor are not representative for all of the noise monitoring locations, the wind speed should be measured separately at each of the locations.

This information would then be compared with both the collected data for that interval and the manufacturer's specifications for the windshield performance under those conditions:

- 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.

If it is not possible to obtain manufacturers' data for the windshield used, then data above 5 m/s should be discarded.

Rain

Rain periods during monitoring may also adversely affect the collected data. If rain was recorded in the vicinity during the collection period the developer must supply evidence that the affected data has not been used in the analysis.

The nearest weather station might not provide a sufficient indication of localised conditions in remote areas. A simple method might record rain using a local gauge or collection method that is regularly checked, and discard all data in periods where rain was detected.

Data

Data not adversely affected by the effects of wind or rain should be collected for a sufficient period to cover the range of wind speeds and directions generally expected at the wind farm site.

Particular emphasis should be placed on collecting background noise data corresponding to the operating wind speed range of the WTGs.

Sufficient data is considered to be approximately 2,000 measurement intervals (or the equivalent of two weeks' worth of data) where at least 500 points are collected for the worst- case wind direction (refer to Section 4.1). If it appears to be impractical to collect 500 valid data points under the worst-case wind direction conditions, the situation should be discussed with the EPA.

Compliance checking will require the similar noise data collection process to be repeated when the wind farm is operational (see Section 4).

Background noise varies naturally throughout the year, with different prevailing wind directions, foliage on trees, atmospheric conditions and the like. It is advised to use the collected wind statistics and weather forecast to perform the background monitoring during periods when the percentage of the worst-case wind direction data is sufficiently high to collect the required number of data. If collection of the noise statistics under the worst-case wind direction requires an unreasonably long monitoring time, less data that still provides a robust correlation between the background noise and wind speed may be acceptable (generally a few hundred points).

A community concern is that the developer may measure during a limited (minimum two weeks) period that is not representative of the whole year.

This guideline recommends that compliance checking be repeated at different periods of the year where valid concerns exist.

The developer must collect representative background noise data. Non-compliance may result in one or a number of WTGs being stopped or de-rated under certain conditions.

3.2 Wind speed measurements

Manufacturers of wind turbines publish noise level data for their machines derived through a comprehensive international measurement standard.

Generally the noise level generated by a wind turbine increases as the wind speed increases. Data should be provided for at least each integer wind speed from cut-in speed up to the speed of the rated power.

Wind speeds (in m/s) should be measured at the WTG hub height. For the purpose of the guidelines it is permitted to report wind speeds at other heights where wind speed at the hub height can be accurately calculated (refer to the text below). The noise level data for each WTG is used as the basis for predicting the total noise level from a wind farm.

Wind speed at the wind farm site and background noise at the relevant receiver must be correlated so that background noise and wind farm noise can be compared. Therefore, wind speed measurements must be made in 10-minute intervals that correlate/synchronise with the background noise data collection.

Measurement height

A developer will often measure wind speed at different heights to determine whether wind conditions at the site are suitable for an economically viable wind farm development. It may be acceptable to convert the results from a different measurement height (for example meteorological tower sensors) to the hub height provided the wind shear model used to do this is clearly stated and accepted by the EPA. Atmospheric stability conditions should be taken into account to assure accurate conversion of the data from the different height.

All wind speeds referred to in these guidelines and within any development application submitted to a planning authority should be expressed at the WTG hub height.

All predicted and measured noise levels should be based on noise level data derived from wind speed measurements referring to the WTG hub height.

Measurement location

The same location should be used for measuring wind speed and direction for all of the following procedures:

- background noise measurements,
- noise predictions,
- compliance checking.

Therefore the wind speed measurement location at the wind farm site should not:

- be significantly affected by the operation of the WTGs in their final location,
- provide lower wind speed results than other locations on the wind farm site, where those locations will house WTGs that affect the noise level at a relevant receiver.

For large or topographically diverse wind farm sites, the suitability of the wind speed measurement location may need to be confirmed as part of the development assessment process.

Wind measurements at the WTG nearest to the relevant receiver should be used for compliance/complaints checking if it is not possible to perform measurements at the same location as it was used for the background noise data acquisition. Evidence that the wind speed and direction sensor is certified for the accurate determination of wind parameters is to be supplied as a part of the report. Accuracy of the wind speed measurements should be ±0.5m/s and wind direction measurements ±3º or better.

3.3 Noise level prediction

The noise level associated with the wind farm should be predicted at all locations identified as relevant receivers under these guidelines, for wind speeds from cut-in speed to the speed of the rated power and each integer speed in between. All noise sources associated with the wind farm operation (eg substations, switch yards) should be taken into account and results of the prediction compared with the noise criteria (Section 2.2).

WTG manufacturers generally do not test or extrapolate tested results above wind speeds of rated power.

The measurement of noise levels under high wind speeds (used to determine the sound power level of a turbine model) is difficult.

Where wind farms comply with the noise level criteria in these guidelines up to rated power, it is unlikely that adverse impacts will occur at higher wind speeds.

Propagation model

A suitable model must be selected (or developed) to predict the worst-case noise level at all relevant receivers. There is no standard procedure directly applicable to sound propagation from wind farms. It is recommended to use noise prediction methods in accordance with ISO9613−2 or CONCAWE[2].

The noise level at the relevant receiver locations should be predicted, allowing for the propagating effect of wind (the noise sounds louder downwind than upwind) in the direction from the wind farm to the receiver at each reportable wind speed. This represents a worst- case situation. In most situations there will be different wind directions and speeds between each WTG on a wind farm site and the relevant receiver. These effects will reduce the actual noise level when compared to that predicted under worst-case conditions.

A conservative approach should be used for predicting wind farm noise by calculating noise levels in octave bands from at least 63 to 4,000Hz to determine an overall predicted level and using the following inputs:

- atmospheric conditions at 10ºC and 80% humidity,
- weather category 6 (if CONCAWE method is utilised),
- hard ground (zero ground factor).

If another prediction method and modelling inputs are employed to carrying out the noise level prediction, the details of the model should be clearly stated and the approach discussed with the Authority.

The following information should be provided as part of the development application:

- the propagation model, and any variation of the model, used for the prediction,
- an estimate of the model accuracy in dB(A),
- the assumptions used as input to the model, including allowances for noise absorption due to air, ground, topographical and wind effects.

Noise levels should be predicted by an acoustic engineer defined for the purposes of these guidelines as an engineer who is eligible for membership of both the Australian Acoustical Society and the Institution of Engineers Australia.

Sound power data

The sound power level can be thought of as the noise signature for the WTG model proposed for the wind farm.

The sound power level data at wind speeds from cut-in speed to the speed of rated power and each integer speed in between should be specified in the development application as determined in accordance with International Electrotechnical Standard IEC 61400−11. The sound power level determined in accordance with other relevant standard or procedure might be acceptable for the purpose of the guidelines.

At the time of development application, the contractual arrangements for a particular WTG model may not have been finalised between the developer and WTG supplier. If the WTG model to be installed differs from that indicated at the time of development application, the developer should assess and discuss the effect on the propagation model with the EPA.

The wind farm developer must also discuss changes to the type, location or operation of the WTGs with the relevant planning authority.

[2] Refer to Bibliography.

Tonality

Tonality is a characteristic that can increase the adverse impact of a given noise source and it can be determined by breaking the noise signature down into discrete frequency bands.

If tonality is a characteristic of the WTG noise, 5dB(A) should be added to the predicted or measured noise level from the wind farm.

To help determine whether there is tonality, the method and results of testing (such as in accordance with IEC 61400−11) carried out on the proposed WTG model to determine the presence of tonality should also be specified in the development application.

3.4 Data analysis

Background noise and wind speed data

At the completion of the data collection period there should be a minimum of 2,000 pairs of synchronised background noise and wind speed measurements where at least 500 points are collected for the worst-case wind direction (refer to Section 4.1). The data should be collected at wind speeds between the cut-in speed and the speed of rated power.

A best fit regression analysis should be carried out on the data. The polynomial order (from linear up to third order) providing the best correlation coefficient should be used to present the fitted regression line to calculate background level L_b. The correlation coefficient should be specified for each polynomial order. If a higher order of polynomial is used, a justification for its utilisation should be provided. Generally background noise demonstrates an incremental trend if the wind speed increases.

The graph for each relevant receiver showing the plotted points, the fitted regression line, the polynomial describing that line and the correlation coefficient should be included in the development application. A typical graph is shown for information.

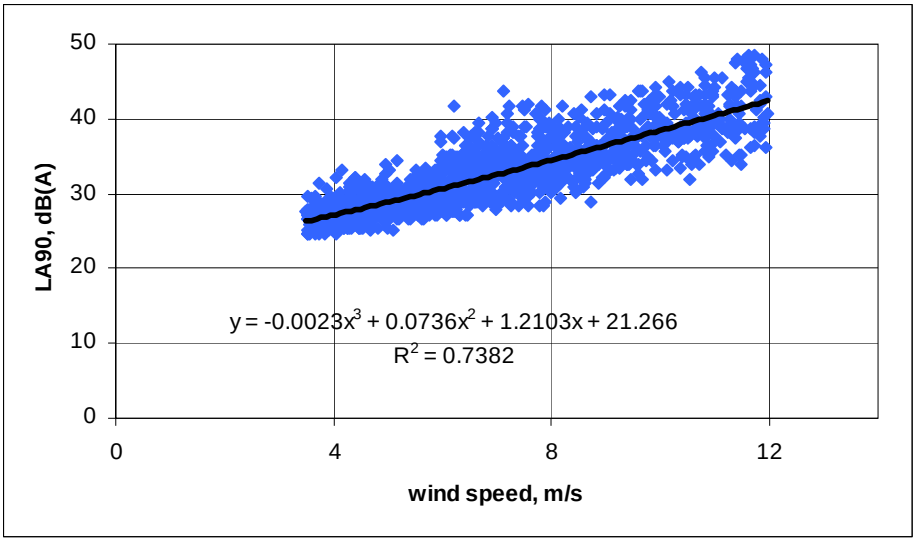

Figure 1 Background noise at the receiver vs wind speed at wind farm

The predicted noise level should be overlaid on such a graph to determine compliance with the criteria.

4 Compliance checking

It is unlikely that the worst-case noise propagation conditions of the prediction procedure of these guidelines will often be repeated during operation of the wind farm. The actual impacts are therefore likely to be less than the predicted impacts.

Notwithstanding this, the prediction process relies on assumptions about a range of inputs, and the procedure given in this section for measuring the actual noise impact is a means of confirming compliance or otherwise with the predicted impact.

The measurement of wind farm noise is expected to be difficult due to the masking effect of the ambient noise and its influence on the base noise level descriptor (L_{Aeq}). The background noise descriptor (L_{A90}) is used to remove this effect.

Data analysis or further measurement should be chosen depending on results of the noise screening procedure. The flow chart below provides guidance on compliance checking noise measurements and data reporting.

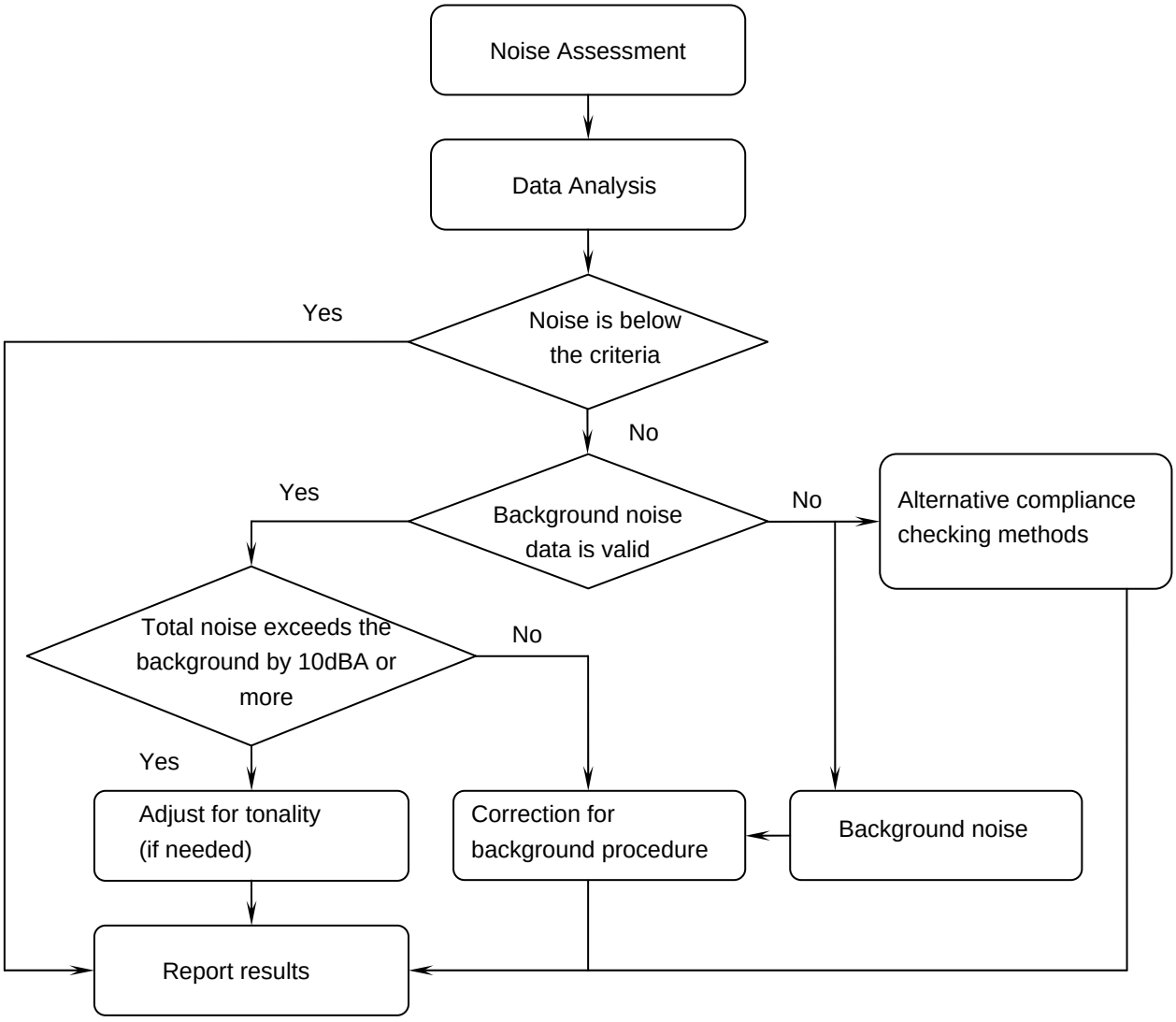

Figure 2 Compliance checking flow chart

4.1 Noise assessment procedure

Wind farm noise screening measurements follow a similar procedure to background noise monitoring (Section 3). The $L_{A90,10}$ is measured with the wind farm operating at relevant receiver locations, over continuous 10-minute intervals and over at least the range of wind speeds from the cut-in speed to the speed of the rated power of the WTGs. The data must cover not less than 2,000 intervals where at least 500 pairs of data correspond to the worst case wind direction.

Wind speed is measured in accordance with Section 3.3 in intervals that correlate with the ambient noise measurements.

Compliance checking should be based on data associated with the worst case wind direction from the wind farm to the relevant receiver. A wind direction spread of 45° either side of the direct line between the nearest WTG and the relevant receiver is considered acceptable. This will not always be practical, given prevailing wind conditions. Data measured during known extraneous noise events should not be included in the analysis.

Cases in which it appears to be impractical to collect 500 valid data points under worst case wind direction conditions should be discussed with the EPA.

Choice of the nearest WTG may be ambiguous. For example, two or more WTGs are located at the similar distances from the receiver and the worst case scenario for the noise propagation is not obvious. It is not expected that such situation is frequently encountered in practice. In this case data post- process should be carried out and reported for each of the possible worst case wind directions.

If data adjusted for tonality (if needed) is below the criteria it should be reported as such and no further data analysis or additional noise measurements are required.

4.2 Data analysis of wind farm noise measurements

Regression analysis should be repeated on the ambient noise $L_{A90,10}$ and wind speed measurement data using the same polynomial order or linear regression as for Section 3.4. If a higher order of the polynomial is used, justification for its utilisation should be provided. The correlation coefficient should be specified in the compliance checking report.

Data below the cut-in speed and above the speed of the rated power should not be included (see Section 3.4).

A graph should be prepared for each relevant receiver showing

- the plotted points,
- the fitted regression line indicating combined wind farm and background noise level L_R,
- the polynomial describing that line and the correlation coefficient in the compliance checking report.

In addition, the graph should have the criteria determined in accordance with these guidelines superimposed.

4.3 Criteria

The combined wind farm and background noise level L_R is to be determined from ($L_{A90,10}$) data measured in accordance with the compliance checking procedure by the regression analysis described in Sections 3.3 and 4.2.

The wind farm noise level L_{WF} is to be determined in accordance with one of the procedures described below (if needed). Generally it should demonstrate an incremental trend with the wind speed increase and be in compliance with the sound power characteristic of the WTG.

In accordance with these guidelines the wind farm noise level (adjusted for tonality if needed) should not exceed:

- 35dB(A) at relevant receivers in localities which are primarily intended for rural living, or
- 40dB(A) at relevant receivers in localities in other zones, or
- the background noise ($L_{A90,10}$) by more than 5dB(A),

whichever is the greater, at all relevant receivers, for wind speeds from cut-in to rated power of the WTG and each integer wind speed in between.

The compliance checking report should contain the graph with the calculated wind farm noise and the criteria determined in accordance with these guidelines superimposed. If the combined wind farm and background noise levels (adjusted for tonality in accordance with Section 4.4) are below the criteria, calculation of the wind farm noise level is not necessary.

Procedures in Sections 4.4 or 4.5 are also waived if the background noise level is at least 10dB(A) below the combined wind farm and background noise level for wind speeds from the cut-in speed to the speed of the rated power. In this case the tonality penalty (if any) should be added directly to the combined noise level L_R and compared with the criteria.

4.4 Correction for background

This is the preferable method for calculation of the wind farm noise. It should be employed when noise monitoring of the wind farm is done at commissioning and subsequent compliance checking procedures. The method is based on the logarithmic subtraction of the acquired background noise level L_b (for the worst case wind direction) from the combined noise level measurements L_R.

The wind farm noise level L_{WF} is to be adjusted for tonality in accordance with these guidelines and compared with the criteria. Results of the calculations should be reported in the supplied documentation.

The compliance checking report should contain confirmation that the background noise data based on the previous background measurements (if any) are still valid. Otherwise background data acquisition procedure in Section 3 should be repeated with WTGs parked or offline with WTG rotor revolutions below 2r/min. Otherwise alternative compliance checking methods in Section 4.5 can be discussed with the EPA.

4.5 Alternative compliance checking procedures

Recent advancement in acoustic data acquisition (such as directional noise monitors) has introduced a method to separate wind farm noise contribution from other sources. If the methods above can not be used for the compliance checking, alternative techniques may be employed.

Attended measurement procedures can be used for compliance measurements at a single receiver. The monitored noise is to be accurately recorded and extraneous noise should be excluded from the data analysis either during the data acquisition or post-acquisition data processing. Attended monitoring should include at least four site visits with each visit including eight hours of monitoring or more and equally including day and night time periods. Measurements should be taken when the wind direction corresponds to the worst case scenario. It might require periodical shut down of WTGs to enable a determination of the noise contribution associated with operation of the wind farm.

If an alternative technique enables reliable monitoring of the wind farm noise using L_{Aeq} descriptor, it should be measured and reported as such. Comparison of the noise criteria with the wind farm noise should also be performed using L_{Aeq} magnitudes. Details of the alternative monitoring program should be discussed with the EPA.

4.6 Tonality

Where, in the opinion of an officer authorised under the EP Act or an acoustical engineer (see definition in Glossary), the wind farm exhibits tonality as a characteristic, the developer or wind farm operator should conduct a tonality test in accordance with a procedure acceptable to the EPA.

An addition of 5dB(A) should be made to the measured noise level from a wind farm where tonality is shown to be a characteristic. It should be noted that the tonal characteristic penalty applies only if it is audible at the relevant receiver. Absence of tone in noise emission if measured close to the WTGs and/or other relevant wind farm elements is sufficient proof that the tone at the receiver is not associated with the wind farm operation.

4.7 Annoying characteristics

These guidelines have been developed with the fundamental characteristics of noise from a wind farm taken into account. These include the aerodynamic noise from the passing blades (commonly termed ‘swish’) and the infrequent and short-term braking noise.

However, annoying characteristics that are not fundamental to a typical well-maintained wind farm should be rectified. Such characteristics may include infrasound (low frequency noise below the audible frequency range that manifests as a rattle in lightweight materials such as glass) or adverse mechanical noise (perhaps generated as a failure of a component).

Infrasound was a characteristic of some wind turbine models that has been attributed to early designs in which turbine blades were downwind of the main tower. The effect was generated as the blades cut through the turbulence generated around the downwind side of the tower.

Modern designs generally have the blades upwind of the tower. Wind conditions around the blades and improved blade design minimise the generation of the effect. The EPA has consulted the working group and completed an extensive literature search but is not aware of infrasound being present at any modern wind farm site.

4.8 Excessive noise

The operation of the wind farm should comply with the criteria at all relevant receivers. The extent of relevant receivers is confined to those identified during the development assessment stage (including proposed developments near the wind farm which have approved development applications).

The EPA can require the developer to repeat the compliance checking procedure if it receives any complaint that may be valid about an unreasonable interference on those premises from noise impacts.

An Environment Protection Order as provided under Section 93 of the EP Act may be issued by the EPA to secure compliance with the criteria in these guidelines.

This may mean that the operation of certain WTGs would be restricted under certain wind speed conditions.

The EPA recognises that there will be natural variations in background noise throughout the year, with different prevailing wind directions, foliage on trees, atmospheric conditions and possibly with changes to local conditions such as buildings, trees or topography that may affect compliance with the criteria.

Where this may be the case, the onus of responsibility to prove this resides with the developer or current operator of the wind farm.

A range of alternative compliance checking procedures can remove the influence of background noise to accurately determine the wind farm noise in isolation.

Where measurements of the ambient noise indicate that excessive noise from the wind farm may exist, it is likely that the EPA will restrict operation of the wind farm subject to proof of compliance with the criteria under one of these accepted procedures such as those detailed in the Clause 6 of the International Energy Agency recommended practices (1997).

5 Documentation

Development applications for wind farms are referred to the EPA by the relevant planning authority for assessment of the environmental noise impact.

If it appears likely that the criteria under these guidelines will be approached, developers should discuss the development with the EPA at the pre-lodgement stage before submitting the application to ensure they provide all relevant information.

All relevant information on the noise impacts should be included with the application. Possible information requirements are summarised below.

5.1 Predicted noise from the wind farm

a make and model of WTGs to be used, including hub height, cut-in wind speed and speed of the rated power

b octave or one-third octave band sound power levels and associated wind speed of WTGs to be used

c positions of all WTGs shown in topographical map

d table of WTGs and relevant receivers coordinates including distances and angle directions between the receiver and nearest WTG

e description of the zone category, zone maps (if available) for all receivers in (e), as outlined in the relevant Development Plan under the *Development Act 1993*

f predicted noise levels for those premises in (e) for worst-case wind direction for wind speeds from cut-in speed to the speed of the WTG rated power

g the model used and the method for deriving the noise levels in (f)

h indication of accuracy of the wind farm noise prediction

i amount of noise reduction, if any, allowed for acoustic screening to estimate the levels in (h)

j topographical map of wind farm and affected premises showing labelled noise contour lines

k location of wind measuring position(s) used for noise assessment and compliance purposes.

5.2 Measurement and assessment of background noise

a description of noise measuring equipment used, including make, model and type and including type and model of windscreen used for the microphone, data demonstrating valid calibration for all equipment at the time of measurements

b noise measurement position including height above ground, wind speed (at the noise measurement position) and distance to nearest building structure

c description and photograph of measurement position showing nearby trees and building structures

d angle direction between the line connecting the noise measurement point and the nearest WTG and North (measured clockwise)

e atmospheric conditions at the wind farm including wind speed and direction, description of wind speed and direction measuring equipment used

f wind speed data at the noise measurement site

g time and duration of monitoring

h sampling time for wind and noise measurements.

i total number of data pairs measured (wind farm speed and background noise level) and number of data pairs measured at the worst wind conditions between the cut-in wind speed and speed of the rated power

j description of regression analysis method

k graphical plot of data in Section 3.4 and regression curve

l correlation coefficient and equation for the regression curve.

5.3 Compliance checking

a description of all noise monitoring equipment, including type of microphone and wind protection used, data demonstrating valid calibration when measurements were taken

b noise measurement position(s) including height above ground, wind speed (at the noise measurement position) and distance to nearest building structure and WTG

c photographs of noise monitoring position taken before the wind farm was installed (at the noise modelling stage) and at the time of compliance checking, showing the noise measurement position and associated surroundings, such as buildings, trees and topography

d angle direction between the line connecting the noise measurement point and the nearest WTG and North (measured clockwise)

e description of atmospheric conditions, wind speed and direction measuring equipment used and the location on the wind farm, including height above ground level

f make and model of WTGs monitored, including hub height, cut-in wind speed and speed of the rated power

g details of which WTGs were operating during compliance check

h time and duration of monitoring period

i list of all monitored data showing wind speed, wind direction and noise level

j presence of any audible annoying noise characteristics

k graphical plots of relevant data in accordance with Section 4

l conclusions highlighting correspondence to the criteria.

Bibliography

Australian Standard AS 1055−1997 *Acoustics—Description and measurement of environmental noise.*

Australian Standard AS IEC 61672-2004, *Electroacoustics—Sound level meters.*

Australian Standard Draft DR07153 CP (to be AS 4959−200X), *Acoustics−Measurement, prediction and assessment of noise from wind turbine generators.*

Australian Wind Energy Association 2002, *Best practice guidelines for implementation of wind energy projects in Australia*.

CONCAWE Report No.4/81: “The propagation of noise from petroleum and petrochemical complexes to neighbouring communities”, 1981

International Electrotechnical Commission 1998, *Wind turbine generator systems—Part 11: Acoustic emission measurement techniques*, IEC Wind Energy Standard 61400−11.

International Electrotechnical Commission 2002, *Electroacoustics—Sound level meters—Part 1: Specifications*, IEC Standard 61672−1.

International Electrotechnical Commission 2003, *Electroacoustics—Sound calibrators*, IEC Standard 60942.

International Energy Agency 1997, *IEA Recommended practices for wind turbine testing and evaluation—1*0, Measurement of noise emission from wind turbine at receptor locations.

International Organization for Standardization 1996, *Acoustics- Attenuiation of sound during propagation outdoors, Part2: General method of calculation*, ISO 9613-2

New Zealand Standard NZS 6808:1998, *Acoustics—The assessment and measurement of sound from wind turbine generators*.

UK Department of Trade and Industry 1996, *The assessment and rating of windfarm noise*, Noise Working Group Final Report, ETSU−R−97.

World Health Organization 1999, WHO Guidelines for Community Noise.

Acts

Development Act 1993, South Australia.

Environment Protection Act 1993, South Australia.

Glossary

A-weighted	Frequency weighted as specified in *Australian Standard AS 1259−1990 Noise level meters* or its replacement
acoustic engineer	A person eligible for membership of both the Institution of Engineers Australia and the Australian Acoustical Society
authorised officer	A person appointed to be an authorised officer under Division 1 of Part 10 of the Environment Protection Act 1993
ambient noise	The total noise in a given environment
background noise	Measured ambient noise, in the absence of the noise under investigation, measured using time weighting 'F', that is equalled or exceeded for 90% of the measurement time interval. Expressed as $L_{A90,T}$, where T refers to the measurement time interval in minutes
base noise level	Means an $L_{Aeq,10}$ of 35dB(A) or 40dB(A) depending on the receiver zoning
calculated background noise	Background noise level L_b at a receiver calculated by the regression analysis from the measured background noise data in accordance with these guidelines
combined wind farm and background noise	Total wind farm and background noise level L_R at a receiver calculated by the regression analysis from the measured data in accordance with these guidelines
dB(A)	The noise level in decibels, obtained using the 'A' weighted network of a noise level meter as specified in Australian Standard AS 1259−1990 Noise level meters or its replacement
equivalent noise level	The equivalent continuous A-weighted sound pressure level obtained using time weighting 'F', over the measurement time interval. Expressed as $L_{Aeq,T}$, where T refers to the measurement time interval in minutes
IEC	International Electrotechnical Commission
impulsive noise	Noise containing impulse components as part of its characteristics, comprising a single pressure peak, or sequence of such peaks, or a single burst with multiple pressure peaks, whose amplitude decays with time, or a sequence of such bursts

locality	Locality means an area to which a Development Plan applies (whether described in the Plan as a locality, or as a zone or a precinct or otherwise) that is— (a) made subject to a set of land use rules by provisions of the Plan; and (b) not itself further divided by the Plan into areas that are made subject to separate sets of land use rules.
low frequency noise	A noise with perceptible and definite content in the audible frequency range below 250Hz
measurement place	A place at the receiver where the noise level is to be measured
predicted noise level	The $L_{Aeq,10}$ wind farm noise level at a receiver predicted in accordance with these guidelines
premises	Any land, or the whole or part of a building or structure
receiver	Premises that may be affected by the noise source, other than premises on the same land as the noise source
T	Measurement time interval; taken to be 10 minutes unless stated otherwise
tonal noise	Noise with perceptible and definite pitch or tone
$\mathbf{V_{10m}}$	Wind speed measured in metres per second (m/s) at the wind farm site at 10 metres above the ground
WTG	Wind turbine generator
wind farm	A group of WTGs installed in the same region and all operated by the same operator. It is not necessary that all WTGs are located on the same premises
wind farm noise	The L_{WF} wind farm noise level at a receiver calculated from the measured data in accordance with these guidelines
zone	An area of land delineated as a zone, precinct or otherwise in the relevant Development Plan under the Development Act 1993, that is subject to a set of land-use rules under that Plan