State code 23: Wind farm development

Planning guideline
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Queensland Government

Contents

Part 1 Overview

1.1 Introduction

State code 23: Wind farm development (the code) contained in the State Development Assessment Provisions (SDAP) applies to a material change of use for a new or expanding wind farm. It is intended to protect individuals, communities and the environment from adverse impacts as a result of the construction, operation and decommissioning of wind farm development.

In achieving this purpose, wind farms should be appropriately located, sited, designed, constructed and operated to ensure:

- the safety, operational integrity and efficiency of air services and aircraft operations
- risks to human health, wellbeing and quality of life are minimised by ensuring acceptable levels of amenity and acoustic emissions at sensitive land uses
- development avoids, or minimises and mitigates, adverse impacts on the natural environment (fauna and flora) and associated ecological processes
- development does not unreasonably impact on the character, scenic amenity and landscape values of the locality
- the safe and efficient operation of local transport networks and road infrastructure.

Wind farms will need to be decommissioned at the end of their operational life, and to a reasonable extent, the site should be returned to its former state.

The State code 23: Wind farm development – Planning guideline (the guideline) provides additional supporting information and actions to assist applicants in demonstrating compliance with the performance outcomes or acceptable outcomes of the code. The content of the code and guideline is based on expert technical advice, and national and international best practice. They include technical material that has been adapted from a variety of assessment frameworks and standards for wind farms, including:

- the Commonwealth Government's (2010), Draft National Wind Farm Development Guidelines
- the South Australian Government's (2009), Wind farms environmental noise guidelines
- the Victorian Government's (2016), Policy and Planning Guidelines for Development of Wind Energy Facilities in Victoria
- the New South Wales Government's (2011), Draft NSW Planning Guidelines – Windfarms
- the Standards New Zealand's (2010), NZS 6808:2010 Acoustics – Wind farm noise
- the Commonwealth Government's (2014), National Airports Safeguarding Framework – Guideline D: Managing the Risk to Aviation Safety of Wind Turbine Installations (Wind Farms)/Wind Monitoring Towers.

The contents of the code and guideline are consistent with the State Planning Policy July 2017 and the Environmental Protection (Noise) Policy 2008.

1.2 Purpose

The purpose of this guideline is to assist applicants in preparing development applications for new or expanding wind farms and to provide assistance in responding to performance outcomes and acceptable outcomes of the code. It also includes detailed methodologies for the following technical assessments:

- Electromagnetic impact assessment
- Shadow flicker assessment
- Ecological assessment
- Noise impact assessment and Noise monitoring methodology.

This guideline will be periodically reviewed and updated as guidance and technology for wind farm development advances.

1.3 Using the guideline

This guideline consists of the following parts:

- Part 1 – provides an introduction to the code and guideline
- Part 2 – provides an overview of the development assessment process for wind farms; an explanation of the types of development to which the code and guideline apply; and, advice about pre-lodgement processes
- Part 3 – provides context and advice on supporting actions and methodologies intended to assist the applicant in demonstrating compliance with the performance outcomes and acceptable outcomes of the code
- Appendices – provides additional technical guidance and material for the preparation of technical assessments.

The use of this guideline alone does not guarantee compliance with all planning and environmental management requirements for a wind farm development. This guideline should be interpreted as advice that only applies to a development application for a material change of use for wind farm development, applied for under the *Planning Act 2016* (the Planning Act).

Part 2 Assessment framework

2.1 Development assessment process

2.1.1 State Assessment and Referral Agency (SARA)

The SARA is responsible for delivering a co-ordinated, whole-of-government approach to the state's assessment of development applications by providing a single agency lodgement and assessment point for development applications where the state has a jurisdiction.

Section 48(2) of the Planning Act outlines that, generally, a regulation prescribes who the applicable assessment manager is for each type of development application.

Schedule 10, Part 21, Division 1, item 35 of the Planning Regulation 2017 (the Planning Regulation) prescribes that a material change of use for a wind farm is assessable development requiring either code or impact assessment by the chief executive administering the Planning Act.

A development application for a wind farm will be subject to code assessment if:

a) all wind turbines for the wind farm are at least 1500 metres from a sensitive land use on a non-host lot; or

b) 1 or more wind turbines for the wind farm are less than 1500 metres from a sensitive land use on a non-host lot and the owner of the non-host lot has, by deed, agreed to the turbines being less than 1500 metres from the sensitive land use.

Note for paragraph (b)—See the *Property Law Act 1974*, section 45 for the formal requirements for deeds executed by individuals.

If a development application is not subject to code assessment as above, it will be subject to impact assessment.

Section 53 of the Planning Act prescribes that when a development application for a wind farm is subject to impact assessment, the applicant must give notice of the application in accordance with the Development Assessment Rules. A properly made submission will allow the submitter the right to appeal the assessment manager's decision in the Planning and Environment Court.

The chief executive as assessment manager must decide a wind farm development application in accordance with the requirements of section 60 of the Planning Act; to the extent they are relevant.

For further and more detailed information on the development assessment framework, please visit the SARA website.

2.1.2 State Development Assessment Provisions (SDAP)

Schedule 10, Part 21, Division 2, Table 1, item 2 of the Planning Regulation prescribes that the applicable assessment benchmarks are the SDAP. A material change of use development application for a wind farm is required to be assessed against the code and any other applicable state code(s) within the SDAP.

2.1.3 Application of State code 23: Wind farm development

The code applies to all wind farm development. A wind farm:

a) means the use of premises for generating electricity by wind force, other than electricity that is to be used mainly on the premises for a domestic or rural use; and

b) includes the use of premises for any of the following, if the use relates or is ancillary to the use stated in paragraph (a)—
   i. a wind turbine, wind monitoring tower or anemometer;
   ii. a building or structure;
   iii. a storage area or maintenance facility;
   iv. infrastructure or works, including, for example, site access, foundations, electrical works or landscaping.

Development involving wind turbines that is not a material change of use for a wind farm may otherwise be assessable development under a local categorising instrument.

A wind turbine means a machine or generator that uses wind force to generate electricity, and includes the blades of the machine or generator.

2.1.4 Other approvals

In addition to requiring assessment for a material change of use for a wind farm development, an applicant may be required to meet additional statutory requirements under the Planning Act, the Planning Regulation or other applicable legislation for further aspects of the development. Subsequent development applications (for example, operational works or building works) may be required by a local government, SARA or another entity as prescribed under the Planning Regulation. This guideline does not cover such additional statutory requirements.

Further approvals or permits may also be required from a range of entities, including the Commonwealth Government, the state-owned network service provider and air services stakeholders.

2.1.5 Pre-lodgement

It is highly recommended that a pre-lodgement meeting with SARA be held prior to lodging the development application. This meeting will assist an applicant in understanding the requirements of the code and any required technical assessments based on the individual circumstances of the proposed development and site specific constraints/characteristics.

It is strongly recommended that prior to holding a pre-lodgement meeting with SARA, the applicant undertakes pre-lodgement consultation with:

- the state-owned network service provider (Ergon Energy and ENERGEX, and transmission provider Powerlink Queensland) to ensure appropriate connection of the proposed wind farm to the existing electricity grid. Please refer to the Australian Energy Market Commission's (2014) National Electricity Rules Chapter 5: Network Connection, Planning and Expansion
- air services stakeholders (including Civil Aviation Safety Authority, Airservices Australia, Department of Defence, and all nearby air services aerodrome operators) to ensure that

risks to air services associated with the proposed wind farm are appropriately considered (refer to section 3.1 of this guideline for further information)

- local government to determine any additional approvals (e.g. operational works, building works, reconfiguration of a lot, road access/driveway permits etc.) that may be required to support the material change of use, and to ensure any locally significant air services, owned and controlled by local governments, are appropriately considered.

In addition to formal pre-lodgement process, it is strongly encouraged that the applicant undertakes comprehensive consultation with the local community. The Clean Energy Council's Community Engagement Guidelines for the Australian Wind Industry provides detailed guidance on conducting community engagement activities.

Part 3 Assessment criteria

This part of the guideline provides additional information to assist applicants in demonstrating compliance with the performance outcomes or acceptable outcomes of the code. Each section is written according to the relevant provision in the code and outlines supporting information and actions that may be required to demonstrate compliance with the code, including the relevant methodology for technical assessments.

Applicants are reminded that the supporting actions contained in this part cover the minimum effort required to respond to the code. Additional assessments may be required dependent on individual project and site circumstances.

3.1 Meeting acceptable outcomes and performance outcomes: Aviation safety, integrity and efficiency

3.1.1 PO1 Location, siting and design and PO2 Lighting and marking

Context

The development or expansion of a wind farm in the vicinity of air services must not adversely impact on the safety, operational integrity and efficiency of air services. Wind farms inherently involve the construction of tall structures that can be considered a potential safety risk to low-flying commercial, private and defence aircraft. Other structures (including permanent wind monitoring towers) can be erected in association with wind farms and may also be hazardous to air services given their low visibility and intrusion into airspace.

Wind farm applicants are required to determine if proposed wind turbines and wind monitoring towers will be located near areas where low-flying activities are likely to be conducted. Activities may include:

- military and civilian airfields, airports and aerodromes
- military training
- aerial agricultural spraying
- aerial mustering
- aerial fire-fighting
- power line inspection
- helicopter operations (including search and rescue)
- recreational aviation (such as gliding, paragliding and hang-gliding).

If a wind farm is proposed to be located in the vicinity of air services, there may also be a potential for adverse impacts on defence radar, communication and navigation facilities. The movement, material and size of wind turbines and blades, as well as the marking and lighting, have the potential to interfere with radio communications equipment including for other aircraft and meteorological radar.

Supporting actions

Acceptable outcome AO1.1

The following action will demonstrate compliance with this acceptable outcome of the code:

- provide evidence (such as detailed survey and construction drawings) that all wind turbines and wind monitoring towers will be less than 150 metres above ground level and do not infringe on the obstacle limitation surfaces (OLS), procedures for air navigation services – aircraft operations (PANS-OPS) surface, restricted airspace and low flying areas of a certified, registered or military aerodrome.

Acceptable outcome AO1.2

The following actions will demonstrate compliance with this acceptable outcome of the code:

- identify potential risks to the safety, operational integrity and efficiency of air services and aircraft operations
- provide written evidence that the following entities, where relevant, have been consulted with, and have no objection to, the proposed development:
  - Airservices Australia
  - Civil Aviation Safety Authority
  - Department of Defence
  - the district aerodrome supervisor.

Note: Consultation should be undertaken according to items 27-29, 32 and 34 of the Commonwealth Government's (2014) National Airports Safeguarding Framework – Guideline D - Managing the Risk to Aviation Safety of Wind Turbine Installations (Wind Farms)/Wind Monitoring Towers.

Acceptable outcomes AO2.1, AO2.2, AO2.3, AO2.4 and AO2.5

The following action will demonstrate compliance with these acceptable outcomes of the code:

- demonstrate that all marking and lighting of wind turbines and wind monitoring towers is provided in accordance with items 30–42 of the Commonwealth Government's (2014) National Airports Safeguarding Framework – Guideline D - Managing the Risk to Aviation Safety of Wind Turbine Installations (Wind Farms)/Wind Monitoring Towers.

Performance outcomes PO1 and PO2

If compliance with acceptable outcome AO1.1, AO1.2, AO2.1, AO2.3, AO2.4 or AO2.5 of the code is unachievable, demonstrating compliance with these performance outcomes of the code may include, but is not limited to, the following actions:

- provide written evidence that the following entities where relevant have been consulted on the proposed development:
  - CASA
  - Airservices Australia
  - Department of Defence
  - the district aerodrome supervisor.

Note: Consultation should be undertaken according to items 27-29, 32 and 34 of the Commonwealth Government's (2014) National Airports Safeguarding Framework – Guideline D - Managing the Risk to Aviation Safety of Wind Turbine Installations (Wind Farms)/Wind Monitoring Towers.

Following consultation, if it is determined by one of the relevant entities that a risk assessment is required, the applicant should submit a detailed **aviation risk assessment** prepared by a suitably qualified aerodrome consultant/specialist that demonstrates the following matters have been addressed:

- the impacts of wind turbines and wind monitoring masts on flight procedures and aviation communications, navigation and surveillance (CNS) facilities, and radar operations
- departure and approach procedures for airfields
- the requirements for obstacle lights and markings on wind turbines and wind monitoring masts
- CASA's Manual of Standards Part 139 Chapter 7 and Section 9.4
- PANS-OPS and OLS, and the ability to evaluate proposals with respect to these surfaces
- published air routes and way points
- EUROCONTROL guidelines on how to assess the potential impact of wind turbines on surveillance sensors.

Methodology for a risk assessment

The methodology for preparing an aviation risk assessment is contained in the Commonwealth Government's (2014) National Airports Safeguarding Framework – Guideline D - Managing the Risk to Aviation Safety of Wind Turbine Installations (Wind Farms)/Wind Monitoring Towers.

Confirmation should be sought from CASA regarding aerodrome consultants/specialists, suitably qualified to undertake the aviation risk assessment.

The risk assessment should have regard to all potential aviation activities within the vicinity of the proposed wind farm including recreation, commercial, civil (including for agricultural purposes) and military operations. A database that contains all certified and registered aerodromes, for which the operators have been granted a certificate by CASA under CASR 139.050 and registered by CASA under CASR 139.265, is available through the CASA website at https://www.casa.gov.au/.

Additional requirements

Where a wind farm proposal is within the limits of Defence (Areas Control) Regulation (D(AC)R) height restrictions for a military airfield, the applicant is required by Federal legislation to obtain Defence approval for the proposal. The Defence approval required in these areas is separate and in addition to assessment under the Planning Act.

For wind farm development located in areas not subject to a D(AC)R, it is normal industry practice for applicants to seek Defence comments on the proposal as part of the risk assessment process prior to lodging a development application.

Whilst there is no requirement to notify CASA of proposed wind turbines or wind monitoring towers less than 150 metres in height and not infringing the OLS of an aerodrome, such structures should be reported to Airservices Australia for inclusion in the national database of tall structures.

Should a development approval under the Planning Act be issued, the applicant will be required (as a condition of approval) to submit Registered Professional Engineer of Queensland (RPEQ) certified as-constructed plans to the Aeronautical Information Service of the Royal Australian Air Force (RAAF AIS) for any structures that are at a height of:

- 30 metres or more above ground level for structures within 30 km of an aerodrome; or

- 45 metres or more above ground level for structures located elsewhere.

Suggested further information

- The Commonwealth Government's (2014) National Airports Safeguarding Framework – Guideline D - Managing the Risk to Aviation Safety of Wind Turbine Installations (Wind Farms)/Wind Monitoring Towers.
- Aviation Assessments for Wind Farm Developments. This document can be requested by emailing airport.developments@airservicesaustralia.com.
- Further information on the reporting of tall structures may be found in the CASA Advisory Circular (2005) AC 139-08(0) – Reporting of Tall Structures.

3.2 Meeting acceptable outcomes and performance outcomes: Electromagnetic interference and shadow flicker

3.2.1 PO3 Electromagnetic interference

Context

Microwave, television, radar or radio transmissions and reception may be affected by the presence of wind turbines in the form of Electromagnetic Interference (EMI). This occurs as wind turbines can block, reflect or refract electromagnetic waves emitted from a source. In addition, they can also on-transmit or scatter radio communication signals.

Supporting actions

No acceptable outcome has been provided. Therefore, the application must demonstrate compliance with the performance outcome.

Performance outcome PO3

Demonstrating compliance with this performance outcome of the code may include, but is not limited to, the following actions:

- Undertake an assessment of potential EMI (**electromagnetic interference impact assessment**), prepared by a suitably qualified person. This may include undertaking surveys of pre-existing communications signals, as well as an assessment review of potential impacts and how they will be mitigated or managed.
- Assess the level of electromagnetic emissions generated by the wind turbines and their associated transmission infrastructure, and the potential to cause interference to nearby radio communications systems.

Methodology for an electromagnetic interference impact assessment

An EMI impact assessment should be prepared to demonstrate that the wind farm development is designed and sited to minimise EMI to pre-existing television, radar and radio transmission and reception. The assessment should detail the potential EMI impacts, a preliminary impact assessment and any required mitigation measures.

Further detail on how to prepare this technical assessment report is contained in **Appendix 1 – Electromagnetic interference impact assessment methodology.**

Suggested further information

- The Australian Communications and Media Authority database can also assist to identify any communication services in a relevant area.
- A search of the Australian Mobile Telecommunications Association's Radio Frequency National Site Archive database (RFNSA) provides information on Australian base stations, including electromagnetic energy reports, site locations and carrier contact details for existing sites.

3.2.2 PO4 Shadow flicker

Context

The rotating blades of wind turbines can cast intermittent shadows that appear to flicker to an observer at a fixed ground position. Since wind turbines are tall structures, shadow flicker can be observed at considerable distances, but usually only occurs for brief times at any given location. The most common problem associated with shadow flicker is annoyance for those in affected locations. This is most closely associated with the duration of shadow flicker experienced above a certain level of intensity.

Shadow flicker may occur under certain conditions of geographical position and time of day, when the sun passes behind rotating blades of a wind turbine and casts a moving shadow over neighbouring areas. Shadow flicker from wind turbines can potentially impact on the amenity of urban and rural development by creating a ‘strobing’ shadow effect.

The duration of shadow flicker, its intensity and the locations it affects are most strongly determined by the relative position of the sun, the turbine and the receptor. The relative position of the sun varies with latitude, time of day and time of year. Other influential factors include:

- the size of the wind turbine blades and the height of the tower
- surface topography
- intervening vegetation
- direction of the wind (and hence the rotor plane of the wind turbine)
- weather (particularly cloud cover)
- general visibility (including presence of mist, smoke and other particulates).

Supporting actions

Acceptable outcome AO4.1

The following action will demonstrate compliance with this acceptable outcome of the code:

- Undertake a **shadow flicker assessment** that identifies the potential impacts and how these may be mitigated or managed. This assessment should consider the potential impacts on existing or approved sensitive land uses, and ensure that any modelled blade shadow flicker impacts affecting a sensitive land use do not exceed 30 hours per annum and 30 minutes per day.

Acceptable Outcome AO4.2

The following action will demonstrate compliance with this acceptable outcome of the code:

- Provide information which demonstrates that the wind turbine blades have a low reflectivity surface treatment/finish.

Methodology for a shadow flicker assessment

Further guidance on assessing the impacts of shadow flicker on existing or approved sensitive land uses is contained in **Appendix 2 – Shadow flicker assessment methodology.**

Suggested further information

No further reference material is suggested.

3.3 Meeting acceptable outcomes and performance outcomes: Flora and fauna

3.3.1 PO5 Flora and fauna

Context

Wind farm development has the potential to impact on flora, fauna and associated ecological processes within and surrounding a development site, including bird and bat strike and barotrauma, along with potential impacts on the migratory routes of certain bird species.

As state regulated vegetation clearing requirements are addressed under separate approvals and permits under the Planning Act, the guidance material for wind farm developments predominately focuses on the local ecological impacts unique to wind farms – namely birds and bats. The assessment of birds and bats will form a major part of ecological impact assessments for a wind farm project, because of the potential for collisions with wind turbines. The location and migratory paths of bird and bat populations or species may influence the turbine footprint and layout of a wind farm development.

Supporting actions

No acceptable outcome has been provided. Therefore, the application must demonstrate compliance with the performance outcome.

Performance outcome PO5

Demonstrating compliance with this performance outcome of the code may include, but is not limited to, the following actions:

- Undertake an **ecological assessment** that identifies and assesses any risk to flora, fauna and associated ecological processes and how this risk may be mitigated or managed through the siting and design of the wind farm. An ecological assessment should accompany the application and include a review of:
  - bird and bat flight paths
  - fauna habitat and corridors
  - on-site vegetation and corridors including worst case scenario impacts to regulated vegetation and locally significant vegetation (for example, where a project layout includes a level of flexibility to allow for final micro-siting)
- Where the ecological assessment identifies potential risks to flora, fauna and associated ecological processes, evaluate and consider alternative locations for wind turbine locations or demonstrate appropriate mitigation measures.
- Preparation of a preliminary vegetation management plan, a preliminary fauna management plan and a preliminary bird and bat management plan.

Note: Where clearing of vegetation is unavoidable, it is the applicant's responsibility to ensure all relevant approvals and permits are obtained, including under the Planning Act, the *Vegetation Management Act 1999*, the *Nature Conservation Act 1992* and the *Environment Protection and Biodiversity Conservation Act 1999*.

Methodology for undertaking an ecological assessment

A detailed methodology for how to prepare an ecological assessment is contained in **Appendix 3 – Ecological assessment methodology.**

Supporting information

No further reference material is suggested.

3.4 Meeting acceptable outcomes and performance outcomes: Traffic and access

3.4.1 PO6 Access, manoeuvring areas and parking

Context

The maintenance and operation of wind farm development requires access and parking for operational staff and for large and heavy service vehicles. As such, the development must demonstrate:

- safe, efficient and sustainable access to the site for all vehicle types and sizes anticipated throughout the operation and maintenance of the wind farm
- sufficient parking for the forecasted staff, maintenance and heavy service vehicles throughout the operation and maintenance of the wind farm
- safe and efficient manoeuvring areas on site to enable all vehicle types and sizes to exit the site in a forward direction.

Supporting actions

No acceptable outcome has been provided. Therefore, the application must demonstrate compliance with the performance outcome.

Performance outcome PO6

Demonstrating compliance with this performance outcome of the code may include, but is not limited to, the following action:

- Submit as part of the development application, a planning report and design drawings demonstrating compliance with the relevant access, manoeuvring and parking codes and/or policies of the applicable Australian Standard or local government planning scheme.

Suggested further information

Further guidance on the relevant access, manoeuvring and parking codes or policies can be found in the applicable local government planning scheme, Australian Standard or can be provided at the pre-lodgement meeting with SARA.

3.5 Meeting acceptable outcomes and performance outcomes: Stormwater management

3.5.1 PO7 Stormwater management and PO8 Watercourses and drainage features

Context

The development and operation of a wind farm and ancillary structures (such as internal access roads, hardstand areas, car parks, etc.) has the potential to change the natural drainage features on a site.

An applicant should outline measures to control soil erosion, stormwater and impacts on existing natural drainage patterns as part of the development application process. A stormwater management plan should address the impacts of the development and demonstrate that the quantity and quality of all stormwater, wastewater, discharges and overflows leaving the site is managed and treated to the quality and quantity of receiving waters prior to discharge.

Supporting actions

No acceptable outcome has been provided. Therefore, the application must demonstrate compliance with the performance outcome.

Performance outcome PO7

Demonstrating compliance with this performance outcome of the code may include, but is not limited to, the following actions:

- Provide a **statement prepared and certified by an RPEQ** that the quantity and quality of all stormwater, wastewater, discharges and overland flows leaving the site are of the same quality and quantity of receiving waters prior to development; or
- Provide a **stormwater management plan** prepared and certified by an RPEQ in accordance with section 2.3 of the Queensland Urban Drainage Manual, demonstrating all stormwater, wastewater, discharges and overland flows leaving the site are of the same quality and quantity of receiving waters prior to development.

Performance outcome PO8

Demonstrating compliance with this performance outcome of the code may include, but is not limited to, the following actions:

- Provide a **site plan** demonstrating that the clearing of vegetation is not proposed within any watercourse or drainage feature; or
- Where clearing is proposed in these areas provide a **stormwater management plan** prepared and certified by an RPEQ in accordance with section 2.3 of the Queensland Urban Drainage Manual demonstrating that the clearing has been minimised and appropriate measures have been included to ensure the protection of bank stability, water quality and habitat.

Methodology for preparing a stormwater management plan

The methodology for preparing a stormwater management plan is contained in the following documents:

- Queensland Urban Drainage Manual, Department of Energy and Water Supply, 2013
- IECA Best practice erosion and sediment control – for construction and building sites, 2008.

The stormwater management methodologies for quality and quantity outlined in these resources should be followed by an RPEQ when responding to the performance outcomes, in order to demonstrate best practice environmental management objectives.

Suggested further information

The Department of Infrastructure, Local Government and Planning State Planning Policy—state interest guideline, Water quality supports the implementation of the SPP.

3.6 Meeting acceptable outcomes and performance outcomes: Character, scenic amenity and landscape values

3.6.1 PO9 Character, scenic amenity and landscape values

Context

In order to access a suitable wind resource, wind farm developments may be located in areas of high scenic amenity or landscape value. The height and potential scale of wind farms and wind turbines creates an unavoidable level of visibility, and may impact on local perceptions of scenic amenity or landscape value. A visual assessment should be undertaken to understand and minimise the impact of a wind farm project on landscape significant to the local community. The visual assessment should not only include the turbines structures themselves, but also include the ancillary structures including wind farm monitoring towers and electrical infrastructure connecting wind turbines and substation(s).

Supporting actions

No acceptable outcome has been provided. Therefore, the application must demonstrate compliance with the performance outcome.

Performance outcome PO9

Demonstrating compliance with this performance outcome of the code may include, but is not limited to, the following actions:

- Undertake a **visual impact assessment report** that identifies and proposes measures to avoid or minimise adverse impacts from the development on significant landscape values and scenic amenity, including view corridors and viewpoints. The relevant local government planning scheme or regional plan may assist in identifying scenic amenity and/or landscape values to be addressed.
- Provide a **written statement and/or services plan** that demonstrates the location of electrical infrastructure associated with the wind turbines are where practical, located underground, and where possible, within internal access roads and co-located with other services.

Methodology for undertaking a visual impact assessment

In order to address the impacts on scenic amenity or landscape values, a visual assessment should take into consideration the Queensland Government's (2007) Identifying and protecting scenic amenity values.

The visual assessment report should include the following content:

- a description of the potential impacts on scenic amenity or landscape values
- visual simulations or photomontages demonstrating the anticipated visual impact of the development in the context of the surrounding area, and from key public view points
- a landscaping plan that details any proposed measures such as materials, finish or colour which are intended to minimise visual impacts of associated wind farm structures.

Suggested further information

The Commonwealth Government's Draft National Wind Farm Development Guidelines outline best practice for industry and planning authorities.

3.7 Meeting acceptable outcomes and performance outcomes: Separation distances

3.7.1 PO10 Separation distances

Context

The height and potential scale of wind farms and wind turbines creates an unavoidable level of visibility, and may impact on local perceptions of scenic amenity or landscape value, particularly when located within proximity to sensitive land uses.

Separate to the acoustic criteria, the code seeks to achieve adequate separation between wind turbines and existing or approved sensitive land uses on non-hosts lots. Non-host lots are premises that do not accommodate any part of a wind farm development and will either adjoin, or be in close proximity to, the host lots making up the wind farm site.

By comparison, host lots will either be owned by the proponent or will be subject to a formal agreement, between the landowner and the proponent, to host the wind farm on the land. Such agreements will specify agreed setbacks. Non-host lot owners may not be afforded the opportunity to enter into such an agreement (i.e. deed of release). Accordingly, it is necessary that sensitive land uses on non-host lots are appropriately setback from wind turbines in the absence of any agreement with the proponent.

Supporting actions

Acceptable outcome AO10.1

The following action will demonstrate compliance with this acceptable outcome of the code:

- A **site plan** demonstrating that all wind turbines are setback at least 1,500m from all existing or approved sensitive land uses on non-host lots. It is important that the site plan includes: all proposed wind turbine locations; all existing or approved sensitive land uses; dimensions from wind turbines to sensitive land uses; and, supporting aerial photography.

Acceptable Outcome AO10.2

The following action will demonstrate compliance with this acceptable outcome of the code:

- A **site plan** demonstrating all proposed setbacks from wind turbines to existing or approved sensitive land uses on non-host lots. It is important that the site plan includes: all proposed wind turbine locations; all existing or approved sensitive land uses; dimensions from wind turbines to sensitive land uses; and supporting aerial photography.
- Provide **deed of releases** from all non-host lot owners where wind turbines are proposed within 1,500m of their respective existing or approved sensitive land uses. The deed of release will need to state the agreed reduced setback.

Suggested further information

No further reference material is suggested.

3.8 Meeting performance outcomes: Acoustic amenity

3.8.1 PO11 and PO12 Audible acoustic emissions

Context

Wind farm developments are typically sited in areas with low ambient acoustic levels, and have unique noise generating characteristics, including output that varies with wind speed and turbine location. The noise characteristics associated with wind farms are generally described within two categories:

- **Mechanical noise** which is produced from the gearbox and generator, bearings, yawing mechanism and blade pitch control mechanism in the nacelle and hub. Mechanical noise from modern wind turbines is not generally a dominant source of emitted noise.
- **Aerodynamic noise** which is noise produced by air passing over the blades of the wind turbine. Aerodynamic noise can be divided into four generation mechanisms: inflow turbulence, tip noise, trailing edge noise and blade tower interaction. Trailing edge noise is generally the most significant wind turbine blade noise source.

Noise generation associated with wind farm developments is complex. Audible acoustic emissions must be considered and modelled during the development assessment process. To ensure clear and consistent noise assessment of wind farm development(s), this guideline presents best practice noise criteria, as well as the methodology for assessment of wind farm noise during the development assessment process. The applicable acoustic criteria has been established based on national and international best practice, including a detailed review of the various standards, guidelines and frameworks in place throughout Australia, New Zealand and abroad.

Acoustic criteria

The code provides separate acoustic criteria for host and non-host lots. Where reference to ‘existing or approved sensitive land uses’ is included, this is taken to be at the time of lodgement of the application.

Host lots

A host lot (also commonly referred to as host property) means a parcel of land that accommodates any part of a wind farm development. Host lots will either be owned by the proponent or will be subject to a formal agreement, between the landowner and the proponent, to host the wind farm on the land. Such agreements will generally provide a financial benefit to the landowner. Owners of host lots will need to provide owner’s consent in order for the development application to be properly made and lodged with the department for assessment.

The acoustic criteria for the predicted acoustic level at sensitive land uses on host lots is listed in Table 1.

Table 1 Acoustic criteria for host lots

Noise characteristic	Time of day	Acoustic level does not exceed
Predicted[1] outdoor (free-field) A-Weighted equivalent acoustic level (L_{Aeq}), assessed at all noise affected existing or approved sensitive land use(s)	Night (10 pm – 6 am)	1) 45 dB(A), or 2) the background noise (L_{A90}) by more than 5 dB(A), whichever is the greater, for wind speed from cut-in to rated power of the wind turbine and each integer wind speed in between referenced to hub height.

The 45 dB(A) or 5 dB(A) above the background noise level described in Table 1 has been established to ensure the health and safety of individuals and the community, regardless of whether the landowner is receiving a financial benefit. The approach is consistent with that taken in other states and the recommendations of the World Health Organisation's (1999) Guidelines for Community Noise, which specifies 45 dB(A) outside bedrooms with windows open, to protect against sleep disturbance.

Despite the above, agreements with landowners to host turbines must be an informed consent and should specify the predicted acoustic levels at all sensitive land uses on the property, and the setbacks from turbines to sensitive land uses.

In order to allow the wind farm to operate for the entirety of its projected lifespan, agreements with landowners must be maintained if the host lot is sold or leased.

Non-host lots

A non-host lot (also commonly referred to as non-host property) means a parcel of land that does not accommodate any part of a wind farm development. Non-host lots will either adjoin, or be in close proximity to, the host lots making up the wind farm site. Sensitive land uses on non-host lots are subject to more stringent acoustic criteria, unless a deed of release is agreed between the owner of the non-host lot and the proponent, with the owner of the non-host lot accepting increased acoustic levels and/or reduced setbacks from turbines at their respective sensitive land uses.

The acoustic criteria for the predicted acoustic level at sensitive land uses on non-host lots is listed in Table 2.

[1] Predicted by noise modelling carried out using the sound power levels of the proposed turbines in accordance with the methodology contained in Appendix 4 – Noise impact assessment methodology.

Table 2 Acoustic criteria for non-host lots

Noise characteristic	Time of day	Acoustic level does not exceed
Predicted[2] outdoor (free-field) A-Weighted equivalent acoustic level (L_{Aeq}), assessed at all noise affected existing or approved sensitive land use(s)	Night (10 pm – 6 am)	1) 35 dB(A), or 2) the background noise (L_{A90}) by more than 5 dB(A), whichever is the greater, for wind speed from cut-in to rated power of the wind turbine and each integer wind speed in between referenced to hub height.
	Day (6 am – 10 pm)	1) 37 dB(A), or 2) the background noise (L_{A90}) by more than 5 dB(A), whichever is the greater, for wind speed from cut-in to rated power of the wind turbine and each integer wind speed in between referenced to hub height.

The prescribed acoustic criteria described in Table 2 have been developed to minimise the impact on the amenity of noise affected existing or approved sensitive land use(s) that do not have an agreement with the wind farm proponent. The criteria must be achieved at the sensitive land uses of non-host lots unless a deed of release is negotiated and agreed between the owner of the non-host lot and the proponent.

A deed of release allows non-host lot owners to accept a reduced setback (relating to the applicable level of assessment) and/or agreed acoustic levels at their sensitive land uses. To ensure it is an informed consent, the deed of release must clearly articulate the agreement between parties, including the following information where applicable:

- the agreed setback distance, where less than 1,500m, between turbines and sensitive land uses
- the agreed predicted day and night acoustic levels at sensitive land uses
- explanation of the proposed variation to acoustic levels (departure from the criteria stated in Table 2) and any expected or potential impacts to amenity at the non-host lot owner's sensitive land use(s).

Despite the above, and as previously outlined, an outdoor night time acoustic level of more than 45 dB(A) or 5 dB(A) above the background noise level at a sensitive land uses is not considered suitable and will unlikely be accepted by the department due to the potential for sleep disturbance (World Health Organisation, 1999). Achieving this minimum level of protection is vital in protecting the health and safety of individuals and the community.

In order to allow the wind farm to operate for the entirety of its projected lifespan, agreements with landowners with respect to acoustic levels and setbacks must be maintained if the non-host lot is sold or leased.

[2] Predicted by noise modelling carried out using the sound power levels of the proposed turbines in accordance with the methodology contained in Appendix 4 – Noise impact assessment methodology.

Supporting actions

Performance outcome PO11

The following action will demonstrate compliance with this performance outcome of the code:

- A **noise impact assessment** undertaken by a suitably qualified acoustic consultant with suitable acoustic experience demonstrating compliance with the prescribed acoustic level in Table 1 of the code.

Performance outcome PO12

The following actions will demonstrate compliance with this performance outcome of the code:

- A **noise impact assessment** undertaken by a suitably qualified acoustic consultant with suitable acoustic experience demonstrating compliance with the prescribed acoustic level in Table 2 of the code.
- Where necessary, provide **deed of releases** from all non-host lot owners where the acoustic level stated in Table 2 of the code cannot be achieved at their respective sensitive land use(s).

Methodology for undertaking a noise impact assessment

The methodology for undertaking a noise impact assessment for a wind farm development is detailed, along with modelling and assessment parameters and assumptions, in Part 1 of **Appendix 4 – Noise methodologies.** Actions to note when undertaking the noise impact assessment report are as follows:

- the noise impact assessment must consider impacts on existing or approved sensitive land uses (at the time of lodgement)
- noise modelling is to include predictions of free-field acoustic levels at all existing or approved sensitive receivers
- all technical reports are to be prepared by a suitably qualified acoustic consultant who is eligible for membership of the Australian Acoustical Society or whose firm is a member of the AAAC or is an RPEQ with suitable acoustic experience.

Methodology for undertaking operational noise monitoring

The methodology for undertaking operational noise monitoring and the associated reporting for a wind farm development are detailed in Part 2 of **Appendix 4 – Noise methodologies.**

Should a wind farm development be approved, the department will apply conditions of approval in relation to the noise criteria of the code. The conditions of approval will require that the proponent undertake operational noise monitoring within the first 12 months of the wind farm being fully operational and will also require the submission of a range of associated reporting, including a noise monitoring plan, noise monitoring reports and an operational regime/strategy. The results of operational noise monitoring will be used for determining compliance with the noise criteria in the code and any conditions of approval.

Although operational noise monitoring does not form part of the assessment of a wind farm development application, it is important for an applicant to understand the noise monitoring methodology to be used for operating wind farms in Queensland. This methodology is used by the department when preparing and applying conditions of approval.

Suggested further information

No further reference material is suggested.

3.9 Meeting acceptable outcomes and performance outcomes: Construction

3.9.1 PO13 Construction management

Context

The construction of a wind farm, including its ancillary structures and associated infrastructure, can have an adverse impact on environmental values, water quality objectives, local amenity, traffic and road infrastructure if not managed and carried out appropriately. It is important that construction activities are undertaken in accordance with a range of measures that minimise and mitigate against all potential adverse impacts.

Supporting actions

No acceptable outcome has been provided. Therefore, the application must demonstrate compliance with the performance outcome.

Performance outcome PO13

Demonstrating compliance with this performance outcome of the code may include, but is not limited to, the following actions:

- A **construction management plan** prepared by a suitably qualified person, identifying all potential construction impacts and the proposed measures to be undertaken to avoid, manage and mitigate the identified impacts. This should include:
  - description of the proposed construction work associated with the development
  - description of the proposed hours of work and what work will be undertaken during those hours
  - description and location of sensitive uses that may be affected by noise, vibration and dust emissions from the construction work
  - description of the activities and equipment likely to generate noise, vibration and dust emissions
  - description of the noise, vibration and dust impact control measures to be implemented to minimise noise, vibration and dust impacts at sensitive uses
  - description of the methods to be used to monitor performance and receive, record and respond to complaints.
- A **traffic management plan** prepared by a RPEQ, identifying all potential construction traffic impacts on road network function (including intersection levels of service) and safety, proposed routes, and the proposed measures to be undertaken to avoid, manage and mitigate the identified impacts.
- An **erosion and sediment control plan** prepared and certified by a RPEQ in accordance with the best practice principles contained in the IECA Best Practice erosion and sediment control document, demonstrating stormwater and erosion sediment control measures and practices will be implemented to ensure the quantity and quality of all stormwater, wastewater, discharges and overland flows leaving the site are of the same quality and quantity of receiving waters prior to development. Alternatively, the applicant may provide an **RPEQ certified statement** that stormwater and erosion sediment control measures and practices will be implemented to ensure the quantity and quality of all stormwater, wastewater, discharges and overland flows leaving the site are of the same quality and quantity of receiving waters prior to development.

Methodology for preparing a construction erosion and sediment control plan

The methodology for preparing a construction erosion and sediment control plan is contained in the following resources:

- Queensland Urban Drainage Manual, Department of Energy and Water Supply, 2013.
- IECA Best practice erosion and sediment control – for construction and building sites, 2008.

The erosion and sediment control methodologies outlined in these resources should be followed by an RPEQ when responding to the performance outcome, in order to demonstrate best practice environmental management objectives during the construction phase of a wind farm.

Methodology for preparing a construction traffic management plan

The methodology for preparing a construction traffic management plan is contained in the following resources:

- Department of Transport and Main Roads (2006) Guidelines for assessment of road impacts of development (GARID).
- Best practice guidelines prepared by Austroads.

The construction traffic management plan should include consideration of the potential construction impacts on the local and regional road network. The construction traffic management plan should include a preliminary road impact assessment, a preliminary pavement impact assessment, a preliminary road use management plan and a preliminary traffic management. The reporting should address:

- details of construction traffic volumes (identified by vehicle type) and proposed transport routes (including site access)
- an assessment of the potential construction traffic impacts on road network function (including intersection levels of service) and safety
- an assessment of the capacity of the existing road network to accommodate the type and volume of construction traffic (including over-dimensional traffic, considering gradient, base construction of road, angle of entry/exit, volume of traffic) during construction and operation
- details of any potential upgrades, any special traffic control management requirements for construction, and any special provisions for site access
- details of measures to mitigate or manage potential construction traffic impacts, including traffic control during construction, and measures to control impacts on existing natural drainage patterns and dust generated by construction traffic.

Suggested further information

- Austroads

Appendices

Appendix 1 - Electromagnetic impact assessment methodology

Methodology – assessment of potential EMI impacts

An EMI assessment should be prepared to demonstrate that the wind farm development is designed and sited to ensure minimal EMI to pre-existing television, radar and radio reception or transmission. The assessment should detail all potential EMI impacts, a preliminary impact assessment and any required mitigation measures.

Review of licensed radio communication services

The applicant should conduct a search of the Australian Communications and Media Authority (ACMA) Register of Radiocommunications Licences to obtain a list of all licensed radio communications services that adjoin the wind farm. A radial distance of 50–60 kilometres from the centre of the wind farm would normally capture all of the potentially affected services. This search will not determine whether users of radio communications devices operating under a class licence (typically low-interference, private operators) exist in the area. Early engagement could occur with such users to identify impacts up front. It is also suggested that applicants review the Australian Mobile Telecommunications Association's Radio Frequency National Site Archive (RFNSA) database.

Identify potentially affected radio communication services

The applicant can determine which radio communication services may be affected by the wind farm development by calculating the distance between line-of-sight radio paths and the proposed wind farm. This may be specific to individual wind turbines, as any turbine (including blades) within a line-of-sight radio path or within close proximity to a broadcast site may impact on the performance of a radar facility.

To calculate the distance between line-of-sight radio paths and the proposed wind farm, the Fresnel zone must first be calculated. The Fresnel zone is a volume of space between transmitting and receiving stations, through which radio waves will, if uninterrupted, travel in a straight line from the transmitter to the receiver.

Separation distances for the following categories are recommended to ensure a wind turbine will not interfere with a radio communications service:

- obstruction to radio line-of-sight path
- obstruction to radar line-of-sight
- near-field effects
- reflection/scattering.

Obstruction to radio line-of-sight path

An obstruction to radio line-of-sight path occurs when the location of a wind turbine causes radio communications signals to be partially or fully obstructed, resulting in a reduction or loss of signal. It is generally accepted that effects from obstruction by wind turbines can be avoided by placing the turbines, including blades, outside the second Fresnel zone of the line of sight path of a point to point radio link. This is considered a conservative approach.

The second Fresnel zone at any point can be calculated and is dependent upon the frequency of the signal, the length of the radio communications path, and the distance of the particular point in question along the radio communications path.

The maximum second Fresnel zone distance of a link occurs at the mid-point along the path. The formula for calculating the second Fresnel zone distance at any given point is shown in **Figure 1**.

$$F_2 = \sqrt{\frac{2\lambda d_1 d_2}{d_1 + d_2}}$$

where

F_2 = Second Fresnel zone radius

λ = Wavelength in metres

d_1, d_2 are distances from each end of radio path to the point under consideration

Figure 1 The formula for calculating the second Fresnel zone distance

Source: EPHC, 2010

Obstruction to radar line-of-sight

Radar services may be affected by wind turbines hundreds of kilometres away if they are located within the radar operating range and line-of-sight. As a guide, long range 23 centimetres (1300MHz) radars, such as those used for aircraft en-route surveillance, can have an operating range in the order of 200 nautical miles (radius of search volume in nautical miles), a 10 centimetres (3000MHz) aircraft approach radar 60 nautical miles, and a 3 centimetres (9000MHz) aircraft final approach radar 15 nautical miles. Individual radar operators will be able to advise whether a wind farm development may impact on their services.

Near-field effects

This occurs when a wind turbine is located in such close proximity to an antenna that it changes the characteristics of that antenna. Transmitting and receiving antennas have a 'near-field' zone, which requires freedom from any object that can conduct or absorb radio waves.

The near-field zone can be calculated based upon the frequency of the signal, the gain, and the orientation of the antenna. Typical calculations give the near-field zone for:

- high band Ultra High Frequency (UHF) signals, such as cellular telephones (800MHz to 1900MHz) as approximately 20 metres
- point-to-point microwave links as approximately 720 metres
- low band VHF paging systems approximately 4 metres.

As can be seen from the above examples, the near-field zone varies widely depending upon the service type. It is recommended that a wind farm applicant consider any telecommunications site within one kilometre of the proposed wind turbines as a potentially affected party with respect to near-field effects.

Reflection/scattering

Reflection/scattering occurs when radio signals are reflected (scattered) by the wind turbine blades, interfering with a radiocommunications signal.

A ratio of the scattered signal to the received signal can be used to determine the full effect of this form of interference. This can be calculated and is dependent upon the distance of the receiver and transmitter to the wind turbine tower. Some methods use worst-case Radar Cross Section (RCS) (which is conservative), or a variant on the second Fresnel zone calculation for users close to a wind turbine. RCS is relevant to all radiocommunications services, not just radar services. Required Signal-to-Noise Ratio (SNR) for different services is variable, but can be of the order of 30 decibels (dB).

An exclusion zone to meet the SNR requirement can be calculated and is dependent upon the gain and radiation pattern of the antenna, the worst case RCS and the distances between user, transmission tower and wind turbine. Higher frequency signals generally utilise antenna patterns with higher gain.

There is no single criterion for potential impact on radiocommunications services due to scattering. It is recommended that potential impact due to reflections/scattering should be discussed with a potentially affected party if the wind farm applicant intends to locate a wind turbine within two kilometres of any telecommunications site.

It should also be noted that the accuracy of radiocommunications site coordinates in the ACMA database is variable, and it relies upon the accuracy of individuals providing the correct data when applying for a new service. It also does not guarantee that a particular service is operating, or operating in accordance with ACMA regulations. Should there be an indication that any individual services may be impacted, or are within, for instance, five kilometres of causing an impact, then it is recommended that independent verification of the radiocommunications site co-ordinates is carried out to confirm the existence of any issues.

Methodology – preliminary impact assessment

Having determined which radiocommunications services may be potentially affected by the wind farm, a preliminary impact assessment should be conducted to determine the level of risk for each of the potential impacts that are expected for each identified service. This will assist in a preliminary determination of the mitigation methods to be considered at the next stage.

If there is a low risk of impact, or the impact cannot be easily quantified, then mitigation methods may be proposed for implementation after construction, when the actual effects can be measured. There may also be the opportunity to reduce any general exclusion zones due to the specific circumstances of the development. For example, some exclusion zones are based on methods using worst-case RCS to determine signal loss due to scattering. However, while RCS can be minimised, the actual RCS is difficult to determine accurately. Using the worst-case RCS can result in overly conservative exclusion zones.

This information will inform any required mitigation strategies to ensure minimal impacts on electromagnetic interference.

Methodology – mitigation strategy

Best practice to reduce the effects of EMI involves designing the wind turbines to minimise their Radar Cross Section (RCS). This reduces the extent to which the turbines will reflect or scatter radio energy. This can be achieved by:

- careful choice of tower and nacelle shape and construction materials
- the use of absorbing (or non-reflective) materials for blade construction
- consideration of the spacing of wind turbines in relation to any affected services.

As mentioned above, RCS is relevant to all radio communications services, not just radar services.

Mitigation options may be different for each individual service affected, depending on the type of service and the level of interference expected.

Appendix 2 - Shadow flicker assessment methodology

The suggested method for assessment for potential shadow flicker impacts is as follows:

- determine the extent of shadows from turbines, based on a distance of 265 m x maximum blade chord (no assessment is required for residences beyond this distance)
- identify all existing or approved sensitive land uses within the extent of shadows from proposed turbine positions
- use modelling software with relevant modelling assumptions (as identified in tables below) to calculate the theoretical annual shadow flicker duration at each existing or approved sensitive land use, accounting for topography
- consider possible impacts of shadow flicker; identifying those impacts with negligible or significant risks
- demonstrate how the wind farm turbine location is designed to minimise the impact of shadow flicker on existing or approved sensitive land uses.

Sensitivity

Shadow flicker duration can be very sensitive to location, varying by up to approximately 0.8 hours per metre of horizontal displacement (per annum). Thus, in an extreme case, one end of a sensitive land use may experience no shadow flicker while the other end may exceed the limit. For this reason, the assessment method requires reporting of the maximum value of shadow flicker duration within 50 m of the centre of a sensitive land use. This addresses a range of other sensitivity considerations such as the offset between rotor and towers, and some minor inaccuracies in the modelling equations, as well as annual variation in shadow flicker. Topographical variations will also need to be considered.

Recommended modelling assumptions

The assumptions or settings recommended for use in modelling shadow flicker are as follows:

Model Parameter	Setting
Zone of influence of shadows	265 m x maximum blade chord
Minimum angle to the sun	3 degrees
Shape of the sun	Disk
Time and duration of modelling	One full year representing a non-leap year 12 to 15 years after the date of DA submission
Orientation of the rotor	Sphere or disk facing the sun
Offset between rotor and tower	Not required
Time step	Ten (10) minutes or less
Effects of topography	Include
Receptor height	1.5 m – 2 m and window / balcony height where dwellings have more than one storey
Receptor location	A map should be provided and the highest level of annual shadow flicker within 50 m of the centre of a dwelling reported.

Grid size for mapping and assessment of shadow flicker at a receptor	Not more than 25 m

Means of mitigating modelled estimates

The table below contains some potential mitigation measures that may be used to reduce the modelled exposure on an existing or approved sensitive land use to shadow flicker.

Mitigation	Constraints
Cloud cover assessment	Annual limit reduced to 10 hours/year (recommended method of assessment described below)
Vegetation blocking shadows	Where it can be shown that the view of a source turbine is completely blocked, the contribution of that turbine may be ignored.
Scheduling turbine operation	Annual limit reduced to 10 hours/year

The recommended method for assessment of cloud cover is to:

- obtain *Bureau of Meteorology* data on cloud cover from the closest site (reporting at least 9am and 3pm cloud cover) with at least three years of data
- determine monthly averages separately for the 9 am and 3 pm proportion of cloudy days
- reduce shadow flicker occurring in a given month by the proportion of cloudy days (evening shadow flicker should be reduced using the proportion from 3 pm and morning shadow flicker using the proportion from 9 am)
- sum the reduced monthly totals to determine the revised annual exposure.

Appendix 3 - Ecological assessment methodology

In accordance with the code, this section details the suggested methodology for undertaking the ecological assessment of vegetation communities, flora, terrestrial fauna and their habitats and birds and bats.

Ecological assessments are necessary where wind farms have the potential to impact on ecological values through:

- bird and bat collisions with wind turbines
- habitat destruction and other impacts resulting from clearing of native vegetation for the construction of roads and turbine hardstands
- indirect effects (such as potential alienation at a site), where wind farms change the use of habitats by birds and bats on or near a wind farm.

The results of the ecological assessments are used to describe the existing environment and to assess the potential impacts that the development may have on flora and fauna. This information will support the development assessment process, but may also be used for various approvals and permits under other legislation that may be required (e.g. offset agreements established under the *Environmental Offsets Act 2014*).

The results of an ecological assessment may also inform a separate approval process and referral to the Federal Minister of the Environment for consideration under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) if the proposal is likely to impact on Matters of National Environmental Significance. This will be facilitated through other approvals and permits, not the material change of use application.

Content of the ecological assessment for wind farms

The ecological assessment should include:

- a desktop review of available information to identify any birds and bat species which may be impacted by the project, including obstruction of and proximity to flight paths
- field surveys to map the vegetation and identify flora and fauna species, including corridors
- a review of vegetation and corridors including worst case scenario impacts to regulated vegetation and locally significant vegetation (for example, where a project layout includes a level of flexibility to allow for final micro-siting)
- species-specific studies to obtain more information about flora and fauna (particularly birds and bats) that may be at risk from the development
- avoidance, mitigation and offset strategies to minimise or mitigate impacts on species if required
- implementation processes for monitoring programs associated with the construction and operation of the wind farm development
- a preliminary vegetation management plan, a preliminary fauna management plan and a preliminary bird and bat management plan.

Methodology for assessing impacts on birds and bats

Desktop assessment

A desktop assessment can be undertaken to identify whether the proposed wind farm has the potential for adverse impacts on any bird or bat species. These impacts include the risk of collision with wind turbines, and where the construction of a wind farm may affect the way species use the site.

A desktop assessment uses existing information in published reports or online databases to identify if there are known to be any bird and bat species on or adjacent to the proposed wind farm site.

The desktop assessment should encompass particular habitats that may support significant bird and bat communities, such as Ramsar wetlands which will provide habitat for waterbirds, and caves which may provide roosting and breeding sites for bats (e.g. may suggest that given the proximity to a wind farm, there may be a potential to impact seasonal migration of protected birds).

Examples of bird and bat issues that may constrain a wind farm development include the use of the site by bird species which are at higher risk of collision with turbines, or the presence of large concentrations of bat species (e.g. cave dwelling bats) which may be at risk of collision with wind turbines. These issues may restrict the location of turbines at a wind farm site.

Field studies

Outputs from the desktop review will inform the type of field studies that may be required to verify the bird and bat species at the proposed wind farm site and to explore how they use the site. At a minimum, field surveys should aim to:

- identify bird and bat habitats and habitat components, and validate the results of the desktop review
- undertake bird utilisation surveys and modelling to identify species at risk of collision or displacement (particularly listed threatened species)
- undertake bat surveys to identify any species in the area.

Field surveys should aim to cover all planned areas of disturbance, including grid infrastructure, and may require a number of visits depending on the species being surveyed and any changes in the size and layout of wind farm.

They should provide sufficient information to determine whether any additional development applications or permits are required under other legislation.

Bird surveys

Studies in Australia and overseas have shown that some species of birds are at a higher risk of collision with wind turbines than others. Bird utilisation surveys aim to identify the avian species on site, the numbers present, the height that birds fly, and the utilisation across the site. Utilisation studies often include a description of bird behaviour, which usually refers to activities such as feeding, resting or moving, as these can aid the understanding of potential impacts of a wind farm development.

The survey design may need to include reference (or control) points and treatment points to allow for a ‘Before and After Control Impact’ (BACI) design if the site supports significant bird species. A BACI design includes reference sites placed at a sufficient distance from the proposed turbine locations to obtain data outside the zone of influence of the turbines. Data is quantitative and is collected at pre-determined fixed points. The surveys are conducted during relevant seasons with regards to the species being studied and the location of the site, and would normally involve sampling of different relevant habitats on the site. Data is usually recorded in a way that allows a collision risk model to be formulated to estimate the potential collision risk of a species.

Monitoring of the impacts of a wind farm should occur in the operational phase of the development where there has been a specific need identified by the approving authority (i.e. through conditions on a development approval). Monitoring regimes will be aided by the earlier survey and modelling work.

Bat surveys

Similar to birds, studies in Australia and overseas have shown that some bat species are at a higher risk of collision with wind turbines or barotrauma (caused by rapid air pressure reduction near moving turbine blades, resulting in lung damage). Field surveys can be carried out to determine which bat species use the site, including for breeding, roosting, foraging or movement. Methods that can be used to identify the bat species on the site and give an indication of their use of the site include:

- mist nets or harp traps placed across presumed flight paths of bats
- using bat detection systems to record and analyse the echolocation calls of bats.

Note that mist nets and harp traps will require permits to catch and handle bats from state wildlife regulatory authorities and will also require Animal Ethics Clearance. Non-intrusive methods such as bat call detecting will generally not require a permit because they do not involve the catching or handling of bats. Whichever methods are used, these should only be employed by appropriately qualified and experienced ecologists.

It should be noted that bat utilisation data cannot be obtained by using the above techniques, which are only useful for species identification and to gain an appreciation of populations). Currently the only possible means of quantifying the density of bats on a site is using techniques such as radar, but even these systems have their limitations.

Species-specific studies

The results of the field surveys may lead to additional species-specific surveys being required to assess the potential impacts of a wind farm development on significant species such as listed threatened species, or species at particular risk (e.g. birds of prey, wetland birds or bats at risk of collision with wind turbines). A species-specific study may be required to demonstrate that the wind farm is not going to have a significant impact on a bird or bat species that has been identified as at risk from the field surveys.

Bird studies

Collision risk for birds and bats at wind farm sites is dependent on several factors, some of which are not yet well understood. Some of these factors include species type, population densities, utilisation of the area, and the height at which a particular species flies. Risks can be reduced by gaining an understanding of how the site is used by birds and bats through the implementation of utilisation studies for particular species.

Collision risk modelling

The data from either general bird utilisation studies or specific species utilisation studies can be input into Collision Risk Models (CRMs) which aim to estimate the number of birds at risk of colliding with wind turbines on a site. They are generally used for testing potential impacts on significant species. CRMs generally use bird observational data from the site and bird size, flight speed, population sizes, and avoidance rates, along with inputs about the technical specification of wind turbines (e.g. turbine height, blade length, blade dimensions) and wind direction. CRMs can provide an indication of the magnitude of the collision risk by particular bird species at a site. In the absence of observed data, scenario modelling can be done, where a series of assumptions about bird use at a site are input into the model to assess collision risk. The inputs can be varied to test a range of scenarios.

Bat studies

Bat studies that are particularly designed to measure whether the site is used by species of concern can also be implemented. These may include studies to assess the use of a site by concentrations of threatened species, such as bats which may use a maternity cave within the vicinity of a proposed wind farm, thereby placing greater numbers of individuals at risk of collision with wind turbines. These studies may involve the design and implementation of a study that uses the deployment of bat call detectors at a number of strategically located sites over the period when bats are breeding and are most active, in the spring and summer months.

Population viability analysis

Population Viability Analysis (PVA) was developed as a modelling tool for determining the viability (extinction probability) of populations of threatened species, where information was available on a range of population variables. It provides a means of organising and analysing information about the population of a threatened species. PVA is a useful modelling approach to explore a range of scenarios that may arise from the impacts of a wind farm (particularly collision risk) on bird populations.

It is a well-researched, formalised approach and its information requirements are well-documented. However, for most threatened species there is an absence of measured population and demographic variables that are required as inputs into a PVA and the results of the PVA need to be interpreted with consideration of the limitations of the data that have been used.

Appendix 4 - Noise methodologies

This guidance material has been prepared for wind farm applicants, proponents, planners, assessment managers, and acoustic consultants to provide practical information on how to address the assessment criteria for noise impacts associated with wind farm developments. The code and guideline is based on current knowledge and research, and represents best practice noise assessment for wind farm developments.

Part 1 of this appendix details the methodology that should be adopted for Noise impact assessments, prepared when modelling the acoustic impacts of a proposed wind farm.

Part 2 of this appendix details the methodology that should be adopted for operational noise monitoring, being the measurement of noise resulting from operating wind turbines.

This guidance material assumes that all acoustical assessments and monitoring relating to wind farm developments are conducted by a suitably qualified acoustic consultant with suitable acoustic experience. This guideline material will be periodically reviewed as new information regarding wind turbine noise becomes available from manufacturers, researchers and consultants in Australia and overseas.

Part 1 – Noise impact assessment methodology

Wind farm developments are typically sited in areas with low ambient noise levels and have unique noise generating characteristics, including output that varies with wind speed and turbine location. The assessment and modelling of noise impacts during the development assessment phase is a crucial factor in determining the potential impacts on existing or approved sensitive land use(s) in proximity to a wind farm proposal.

General

A unique characteristic of wind farms is that there is an increase in noise level emitted from each turbine as the hub height wind speed at the site increases. The increase in hub height wind speed is typically accompanied by a slightly lesser increase in ground level wind speeds which may increase the background noise level at sensitive land use receptor locations, particularly at higher wind speeds. Wind turbines typically start generating electricity at hub wind speeds around 3-4ms^{-1} (11 km/h) and reach maximum or ‘rated’ capacity at wind speeds of around 11ms^{-1} (40 km/h) at the turbine hub height.

Types of noise wind turbines produce can be classified into the following categories:

- Mechanical noise which is produced from the gearbox and generator, bearings, yawing mechanism and blade pitch control mechanism in the nacelle and hub. Mechanical noise from modern wind turbines is not generally a dominant source of emitted noise.
- Aerodynamic noise is noise produced by air passing over the blades of the wind turbine. Aerodynamic noise can be divided into four generation mechanisms: inflow turbulence, tip noise, trailing edge noise and blade tower interaction. Trailing edge noise is generally the most significant wind turbine blade noise source.

This guideline provides a framework for the assessment of noise impacts associated with wind farm developments.

Sensitive land use receptors

The code’s noise criteria apply to all existing or approved sensitive land uses for which sensitive receptors may be identified. Sensitive land uses mean any of the following as defined in the code:

1. caretakers accommodation

2. child care centre
3. community care centre
4. community residence
5. detention facility
6. dual occupancy
7. dwelling house
8. dwelling unit
9. educational establishment
10. health care services
11. hospital
12. hotel
13. multiple dwelling
14. non-resident workforce accommodation
15. relocatable home park
16. residential care facility
17. resort complex
18. retirement facility
19. rooming accommodation
20. rural workers' accommodation
21. short-term accommodation
22. tourist park.

A sensitive land use receptor does not include a temporary or mobile habitable building structure sited on the land (i.e. a caravan on private property).

Wind turbine noise characteristics

The wind turbine noise criteria contained within the code take into account the fundamental characteristics of wind farm noise, including aerodynamic noise from the rotating blades, amplitude modulation, the mechanical noise of the gearbox and other hub and nacelle components, as well as other less frequent and short term noises that may occur, such as braking or start-up procedures. Specifically, the following characteristics have been taken into account in determining the criteria:

- Amplitude Modulation (AM) is an expected characteristic of wind turbine noise (commonly described as a 'swish'). Enhanced amplitude modulation (EAM) has been reported from a limited number of wind farms on limited occasions. Considerable research has been conducted and is ongoing to determine and fully understand the sources of amplitude modulation generation and the conditions which may enhance amplitude modulation to a level which is considered by receptors to be an adverse noise characteristic. Current international research is aimed at defining and measuring EAM further so that suitable assessment standards can be developed, if necessary.
- Modern turbines produce broadband noise across the frequency spectrum. With large separation distances, higher frequency noise is attenuated at a greater rate, resulting in a higher concentration of lower frequency noise at residences. It is noted that the normal acoustic environment contains many other sources of low frequency sound which are commonly experienced, such as the sound of diesel engines, aircraft fly-overs, blasting, mechanical plant (including pumps, compressors, air-conditioners and gas turbines), surf waves breaking on a beach, waterfalls, thunder, wind blowing the foliage of trees and shrubs, etc.

Tonality

A correctly operating wind turbine may exhibit sound with tonal characteristics. These characteristics can be minimised or avoided by careful design and/or mitigation measures. Wind farm developers should seek to avoid the installation of wind turbines that exhibit sound with tonal characteristics by specifying the supply of wind turbines from a manufacturer which guarantees that the supplied wind turbines will not exhibit tonal characteristics at residences.

Impulsivity

Impulsive sound is a transient sound which is not a normal characteristic of wind turbine noise but which may occur infrequently as a result of mechanical or aerodynamic problems with the wind turbine. Impulsive sound is best addressed during the operational phase by maintenance, if and when it occurs.

Noise criteria

The noise criteria applies to aspects of normal wind farm operations which can be readily predicted at the planning stage of the development. Noise modelling predictions are to be free-field near existing or approved sensitive land uses. Measurements of background noise levels and operational noise levels are to be conducted at the same, or similar, locations, normally between 5 metres and 20 metres from the sensitive land use.

Wind turbine noise levels

The predicted A-weighted equivalent noise level for wind farm development, assessed as free-field noise levels at all existing or approved sensitive land use receptors, at a normal height of 1.5m AGL, should not exceed:

On host lots:

1) Outdoors night time (10 pm to 6 am) L_{Aeq} 45 dB(A) or the background noise (L_{A90}) by more than 5 dB(A), whichever is the greater, for wind speed from cut-in to rated power of the wind turbine and each integer wind speed in between referenced to hub height.

On non-host lots:

1) Outdoors day time (6 am to 10 pm) L_{Aeq} 37 dB(A) or the background noise (L_{A90}) by more than 5 dB(A), whichever is the greater, for wind speed from cut-in to rated power of the wind turbine and each integer wind speed in between referenced to hub height.
2) Outdoors night time (10 pm to 6 am) L_{Aeq} 35 dB(A) or the background noise (L_{A90}) by more than 5 dB(A), whichever is the greater, for wind speed from cut-in to rated power of the wind turbine and each integer wind speed in between referenced to hub height.

OR

3) If a deed of release is negotiated between landowner and proponent, the agreed level and not exceeding outdoors night time (10 pm to 6 am) L_{Aeq} 45 dB(A) or the background noise (L_{A90}) by more than 5dB(A), whichever is the greater, for wind speed from cut-in to rated power of the wind turbine and each integer wind speed in between referenced to hub height.

L_{Aeq} is the equivalent noise level emitted by wind turbines. L_{A90} is determined by the data collection and regression analysis procedure of this guideline (refer to Background noise and wind speed data).

The night time period of 10 pm to 6 am has been selected for separate analysis to provide more emphasis to the value of prevention of sleep disturbance in the generally rural areas that surround wind farm sites. The limitation of the night period to 6 am provides consistency with the assessment times used by Queensland Transport and Main Roads for State-controlled roads and also the commonly approved commencement time of 6 am for rural based industries, such as quarries. Restriction of the night period to 10 pm to 6 am will avoid the shoulder period between 6 am and 7 am which typically contains an increased level of road traffic noise, rural activities and natural extraneous noise (i.e. increased ambient noise levels) compared to the pre-6 am period.

The noise criteria should be applied only during the normal operating hours of each sensitive land use.

For example, day-time noise limits would generally apply to a school, commercial office or childcare centre, whilst a residential dwelling, aged-care facility or relocatable home park would be subject to both daytime and night-time noise limits.

Staged wind farm development

The methodology in this guideline is intended to apply to greenfield sites where no wind turbines are installed. A single wind farm may be developed over a number of stages. Where a wind farm is proposed to be developed over a number of stages, the noise criteria that are applied to the initial stage of development approval will be applied to the cumulative noise level of all subsequent stages of the development.

Background noise from nearby wind farms

The wind turbine noise criteria that are applied to the new or expanded wind farm development will be based upon the same background noise scatter plot and regression analysis as used for the existing wind farm for the sensitive land uses (i.e. criteria should be based on the background noise level without the contribution of noise from existing wind farms).

Wind environment

Hub height

All wind data related to the wind environment at the site and the operating performance of the wind turbines shall be expressed in terms of the proposed hub height of the turbines.

Wind mast and monitoring instrumentation

Wind masts should be constructed to a height of not less than 60 per cent of the proposed hub height with wind measuring instrumentation installed at a minimum of two heights near the top of the mast separated by an appropriate distance (ideally greater than 20m).

Wind data must be sampled so that 10 minute samples can be measured, or post-processed from the measured data, to allow correlation/synchronisation with noise monitoring 10 minute sampling periods.

Wind data

Wind data that is not measured at hub height shall be extrapolated to the hub height using the following equations:

Wind shear factor, $\propto = \dfrac{\log {}^{V_1}/_{V_2}}{\log {}^{H_1}/_{H_2}}$

Extrapolated wind speed, $V_{FHH} = \frac{\boldsymbol{V_1}}{\left(\boldsymbol{H_1}/H_{FHH}\right)^{\propto}}$

Where:

α = wind shear factor

V_1 = wind velocity at measurement height 1 in m/s

V_2 = wind velocity at measurement height 2 in m/s

H_1 = measurement height of V1 in m

H_2 = measurement height of V2 in m/s (H_1 or H_2 to be at least 60% of final hub height)

H_{FHH} = final hub height in m

V_{FHH} = wind velocity at final hub height in m/s.

Wind farm design

All sensitive land use receptors should be identified for a minimum distance of 3 kilometres from the nearest potential wind turbine location in the area surrounding the proposed wind farm.

As a general guide, the minimum spacing between wind turbines should be three times blade diameter in the cross-wind direction(s) and five times blade diameter for the downwind direction(s) for the dominant wind directions. If the wind farm developer proposes to use alternate spacing distances, justification for the spacing distances should be provided.

The wind farm developer should select a representative wind turbine manufacturer(s) and model(s) to be considered for the wind farm and obtain the spectral sound power level data for the selected turbines from the respective manufacturer(s). The provided sound power level data shall be related to the hub height wind speeds.

Preliminary estimates of wind turbine noise levels should be calculated using a computer noise prediction model (refer to Noise modelling).

The outcomes of the wind farm design preliminary noise modelling will be:

1. identification of sensitive land use receptors that may be potentially impacted by wind turbine noise exceeding the noise criteria in the code
2. identification of suitable representative sensitive land use receptors to be used for background noise monitoring to determine the applicable wind turbine noise criteria
3. confirmation of the wind farm design, including the number of wind turbines, the type of wind turbines (i.e. standard or low noise trailing edge blade designs), the hub height, and the proposed wind turbine locations on the wind farm site.

Existing noise environment

Noise monitoring locations

The purpose of monitoring the existing noise environment is to:

1. describe the ambient noise environment of the area surrounding the wind farm during the day and night period
2. determine the background noise levels ($L_{A90,\ 10min}$) correlated for a range of hub height wind speeds for the day and night periods to determine the relevant outdoor wind turbine noise criteria at the selected representative noise monitoring locations.

Noise monitoring locations shall be representative of the nearest sensitive land use receptors to the proposed wind farm site and shall preferably include receptors in all direction(s) from the wind farm. Noise monitoring may be undertaken at a representative location for groups of sensitive land use receptors. The applicant shall justify the number and locations selected for noise monitoring given the:

- dimensions and scale of the proposed wind farm site
- number and location of the potentially affected sensitive land use receptors
- the topography and description of the physical environment between the wind farm and the sensitive land use receptor locations.

Generally, noise monitoring should be conducted at all sensitive land use receptors where the predicted noise level is greater than 35 dB(A).

Ambient and background noise levels shall be measured at outdoor locations with the microphone at a height of 1.2−1.5 metres above ground level, within 20 metres of the receptor dwelling and at least 5 metres from any significant vertical reflecting surfaces. The monitoring locations should be on the wind farm side of a dwelling and as far as practicable from potential sources of domestic noise (e.g. air conditioners, water pumps, etc) and a similar distance from vegetation noise sources (trees) as the façade is from those sources. The monitoring location should not be screened from the proposed wind farm site by existing or potential future building structures on the sensitive land use site, such as sheds, tanks, or other potential barrier structures.

Monitoring locations shall be described by:

1. location co-ordinates (GPS Latitude/Longitude)
2. photographic images of the location and the surroundings in multiple directions.

Ground level meteorological monitoring

Meteorological monitoring at ground level shall be conducted simultaneously with the noise monitoring at selected locations near to the noise monitoring locations.

The purpose of the meteorological monitoring at ground level is to determine whether there was any rainfall or high wind speeds recorded during the noise monitoring period that might affect the measured noise levels. Wind or rain affected noise samples shall be discarded from the noise data set to be used for determining the noise criteria.

The number of meteorological stations deployed during the noise monitoring will be dependent upon the dimension and scale of the proposed wind farm, and the number and spread of the proposed noise monitoring locations. The applicant shall justify the number and locations selected for simultaneous meteorological noise monitoring during the noise monitoring studies. If the meteorological mast on the wind farm site (or in the vicinity) has the capability to measure rainfall during the noise monitoring period, separate rainfall sensors at ground level may not be required.

Monitoring synchronisation and duration

The noise monitoring instrumentation, the ground level meteorological monitoring station(s) and the wind mast anemometers shall be time synchronised for the duration of the noise monitoring so that 10 minute synchronised noise and meteorological data samples may be measured for compilation and analysis. The monitoring duration should be at least six weeks to provide sufficient noise data for day and night periods. Any shorter duration should be justified.

Instrumentation

Sound

Background and ambient noise levels should be collected for continuous 10 minute intervals using sound level meters or noise loggers having Class 1 or Class 2 certification, in accordance with AS IEC−61672.1-2004 Electroacoustics – Sound level meters.

All noise monitoring equipment must have an inherent noise floor no greater than 20 dB(A). The meters or loggers must be suitably calibrated before and after measurements and if the difference is greater than 1dB, then the data should be discarded.

Windshields

Microphones should be protected with windshields which reduce wind induced noise on the microphone. Suitable windshields include those with a minimum diameter of 100mm and/or those including a double wind shield arrangement. In addition, noise samples recorded with microphone level wind speeds above 5 ms^{-1} for more than 90% of any 10 minute period should be discarded from the regression analysis.

Meteorology

Instrumentation to measure the required meteorological data can take many forms, but must include transducers able to quantify the wind speed to an accuracy of ±1m/s or better, and any occurrence of precipitation greater than 0.2mm. Statistical wind speed (i.e. equalled or exceeded for 90% of the measurement time to match the noise measurement parameter used) is the preferred wind speed measurement parameter. However, if wind monitoring instruments do not output the wind speed statistical parameters then reporting of average wind speed is permissible.

If rotating cup anemometers or wind vanes are used, they should beare appropriately maintained and in good condition. If cup anemometers are used, noise emissions from the equipment should not significantly contribute to the measured noise levels, particularly at higher wind speeds. If the instrumentation includes cooling fans, it must be ensured that the cooling fan noise level at the noise measurement location is at least 10 dB less than the ambient noise level.

Anemometers which use ultrasonic detection methods are possible. Ultrasonic anemometers have no moving parts and can measure wind speed, wind direction and the vertical vector of wind direction.

Data compilation and correlation

Rain

Noise monitoring conducted during rain periods may be adversely affected by the rainfall.

Noise monitoring samples measured in the presence of any rain (0.2mm or more) in any 10 minute monitoring interval shall be discarded from analysis. The rainfall shall be detected by the local ground level meteorological station installed as part of the noise monitoring studies.

Extraneous noise

Extraneous noise is defined as noise that is not typical of the long term noise environment at monitoring or receptor locations. Extraneous noise may include noise of insects (if seasonal), birds (if seasonal), frogs (if seasonal), farm animal noise, local vehicle traffic, emergency services sirens, etc. For example, insect noise can be considered extraneous noise in some circumstances if it is not typical of the long term noise environment.

Where dominant extraneous noise contributions are identified in the noise data set then the extraneous contribution should be removed. One method of achieving this would be by use of the frequency spectrum to provide a noise data set that is more representative of periods when the extraneous noise is not present. Removal of any dominant extraneous noise contribution is to be conducted prior to the affected noise data being included in the scatter plot for determination of the background noise level. The applicant shall clearly identify whether extraneous noise was present during the monitoring samples used for the data analysis. If the extraneous noise contributions are dominant in the noise samples, then the extraneous noise contribution shall be excluded or filtered. The methodology used for adjustment or exclusion due to extraneous noise should be documented and justified in the reporting documentation.

Once the dominant extraneous noise contribution has been removed for the noise samples, the modified samples may be included in the scatter plot for determining the background noise levels.

Background noise and wind speed data

Monitored noise samples shall be correlated with the corresponding hub height wind speed (between approximate wind turbine cut-in speed and the approximate speed of rated power) and plotted to form a scatter plot of the data for each of the day and night periods.

A best fit third order regression analysis shall be carried out separately on the day and night background noise hub height wind speed data. Any alternative analysis proposed (i.e. a bin analysis) should be justified by the applicant.

The graph for each relevant receiver showing the plotted points, the fitted regression line, the polynomial describing that line and the correlation coefficient shall be included in the development application.

Figure 1 shows a typical scatter graph and regression line.

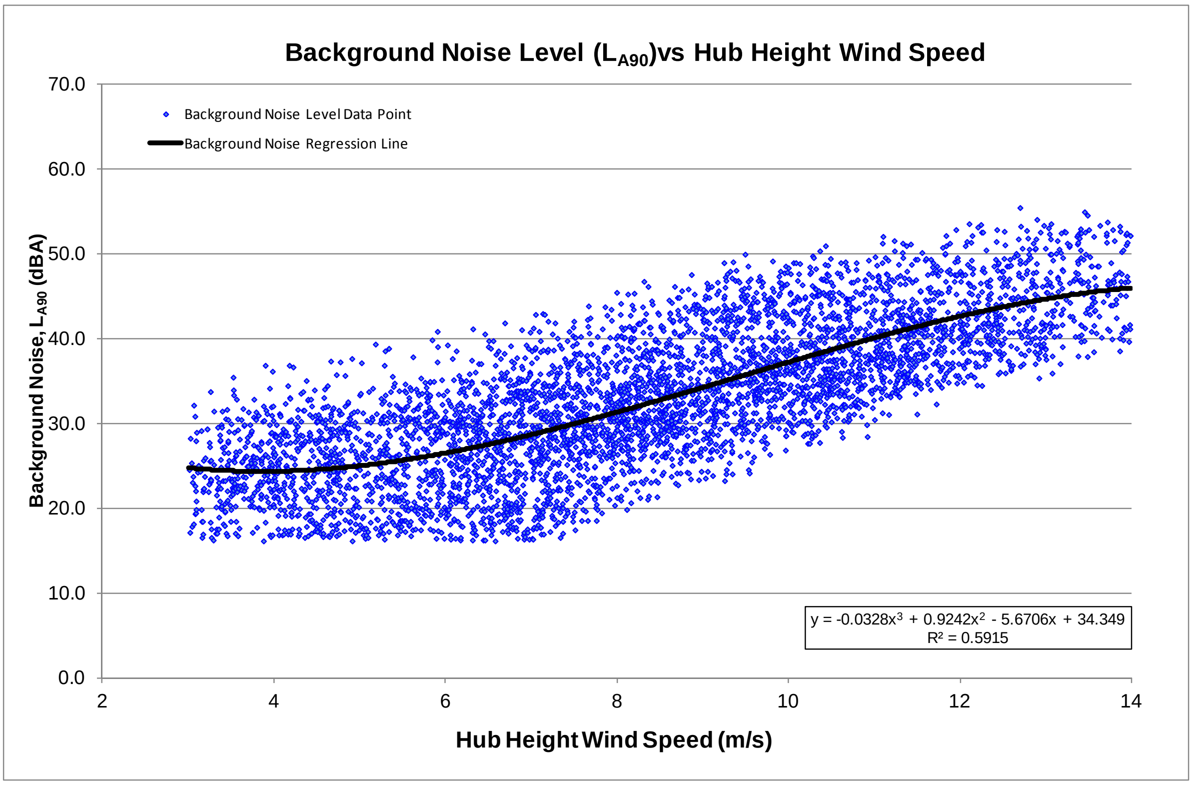

Figure 1 **Background noise level at the sensitive land use receptor vs. hub height wind speed**

Wind turbine noise criteria

The base criterion should be overlaid on the scatter graph along with a line representing the background noise level regression line plus 5 dB(A) for each of the day and night periods. The line formed by the combination of the minimum level and the background level plus 5 dB(A) line shall be the wind turbine noise criteria for the respective day or night period. Figure 2 and Figure 3 show typical wind turbine noise criteria plots for each daily period.

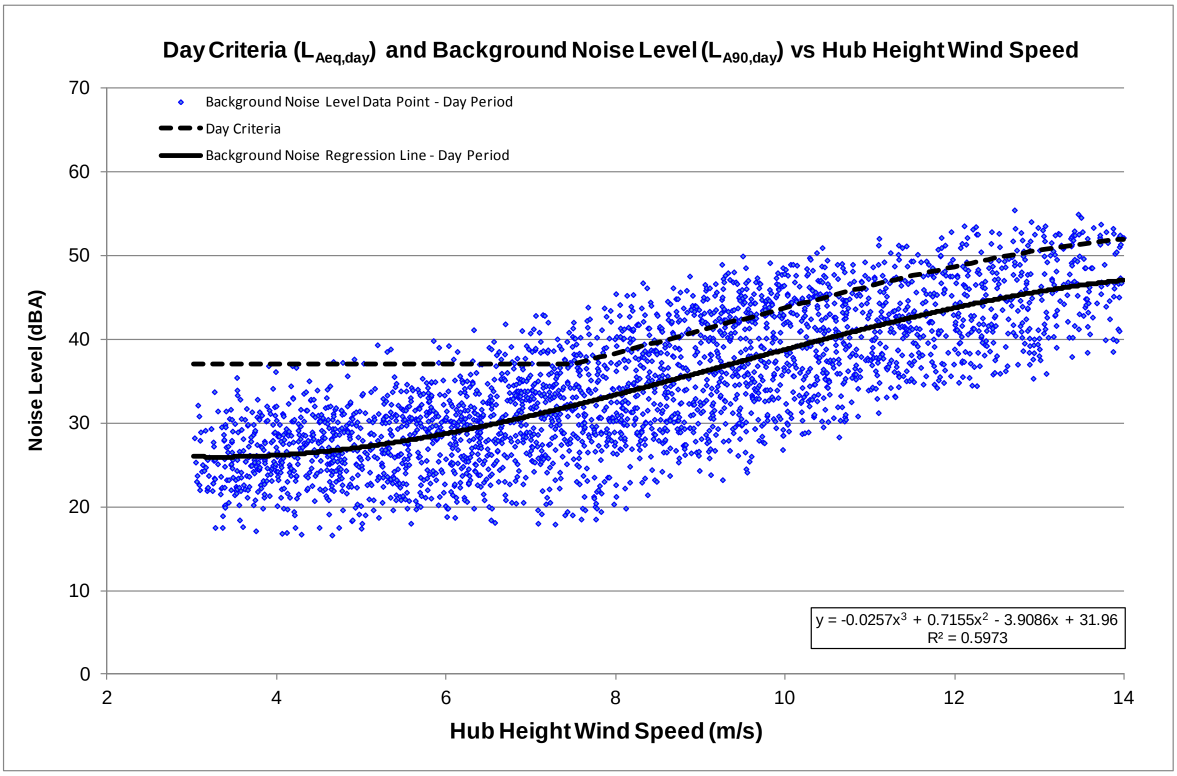

Figure 2 Wind turbine noise criteria plot for day period

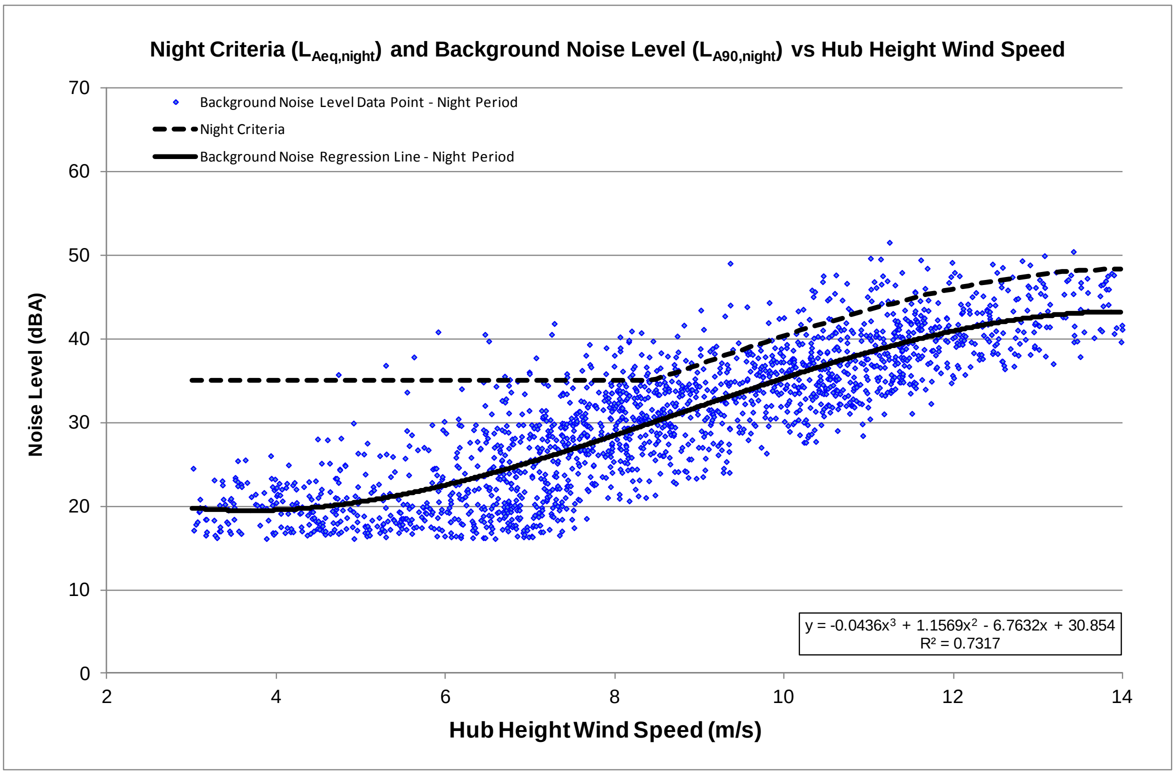

Figure 3 Wind turbine noise criteria plot for night period

Predicted noise levels

Wind turbine noise levels shall be predicted at all identified sensitive land use receptors near the proposed wind farm for integer wind speeds from wind turbine cut-in speed to the speed of the rated power, with the wind speed referenced to hub height of the wind turbines.

Noise emissions from substation transformers are not included in the assessment of noise in this section. Substation noise will be assessed using the standard industrial noise methodology in Queensland.

Noise modelling

A suitable noise model must be selected to predict the worst-case noise level at sensitive land use receptors in the minimum octave band frequency range from
63 Hz to 4 kHz.

There is no standard noise model specifically applicable to sound propagation from wind farms.

CONCAWE and ISO 9613-2:1996 Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation is commonly used for wind turbine noise assessments and are supported by a significant amount of research confirming that with a suitable level of safety factors and consideration of ground topography, the predicted noise levels agree well with measured noise levels during operations of the wind farm after construction.

Software programs which apply noise prediction algorithms in accordance with CONCAWE or ISO 9613-2 are recommended for noise prediction assessments under this guideline, however alternative propagation algorithms such as Nord2000 or Harmonise, may also be used, provided relevant supporting information is provided.

ISO 9613-2 specifies a method for predicting L_{Aeq} noise levels at a distance from a source under meteorological conditions favourable to noise propagation, namely downwind propagation (<5 ms^{-1}), or equivalently propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night. The method is conservative because it assumes that the favourable propagation conditions occur simultaneously in all directions. Where receptors are located upwind of the dominant wind directions then the noise levels are expected to be less than predicted using this method.

Topographical ground contours with a 1 m or 5 m resolution are preferred for preparation of the noise model. If a lesser resolution is proposed (such as 10 m topographic contours), the lesser resolution should be justified in the context of proximity of sensitive land use receptors to the wind turbines and the shape, or irregularity, of the ground topography between the wind turbines and the sensitive land use receptors.

The noise prediction models shall have the following inputs, with alternative values supported by relevant documentation:

Concawe:

- warranted sound power levels
- 10°C temperature
- 70% relative humidity
- acoustically soft ground for all surfaces other than water, asphalt or concrete
- barrier attenuation of no greater than 2 dB(A)
- weather category 6 (night with no cloud and wind from the wind farm to the dwelling under consideration).

ISO 9613-2:

- warranted sound power levels
- 10°C temperature
- 70% relative humidity
- 50% acoustically hard ground and 50% acoustically soft ground
- barrier attenuation of no greater than 2 dB(A)
- 4m receiver height
- application of a 3 dB(A) correction where a "concave" ground profile exists.

If concave topography is present between a particular wind turbine location and a particular sensitive land use receptor location (e.g. wind turbine located on an elevated ridge relative to receptor location) then experience has shown that ISO 9613 predicted noise levels underestimate the actual measured levels, due to reduced ground effect and the potential for additional reflection paths.

A correction of +3 dB should be added to the calculated component overall A-weighted noise level for propagation ‘across a valley’, i.e. a concave ground profile, or where the ground falls away significantly, between a particular turbine and the particular receiver location.

The recommended criterion for determining if the ground topography is concave is:

$$h_m \geq 1.5 \times \frac{|h_s - h_r|}{2}$$

Where h_m is the mean height above the ground level of the direct line of sight from the receiver to the source (as defined in ISO 9613-2), and h_s and h_r are the heights above local ground level of the source and receiver respectively.

The predicted L_{Aeq} noise levels at each sensitive land use receptor shall be determined for each hub height wind speed and over-plotted on the noise criteria curves graph to compare the predicted wind turbine noise level and the day and night criteria. Figure 4 shows a comparison of a predicted wind turbine noise levels per hub height wind speed with the noise criteria.

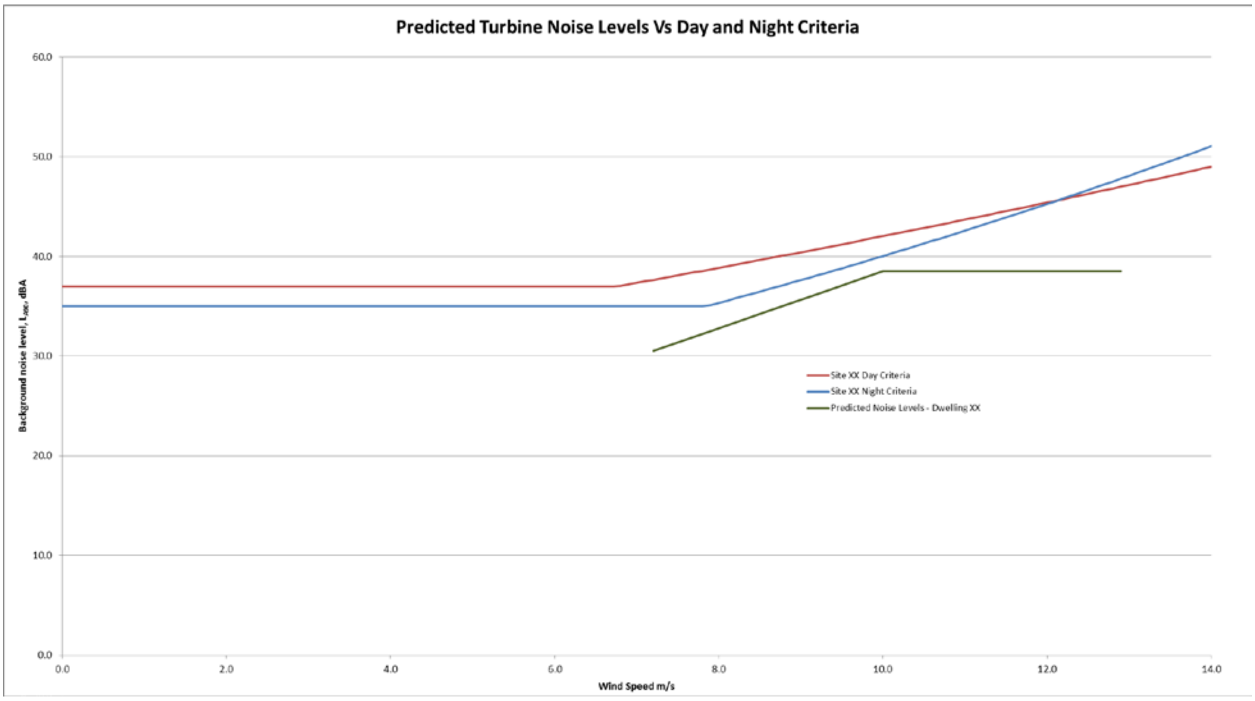

Figure 4 **Predicted wind turbine noise levels vs. day and night criteria**

Where alternative noise propagation algorithms or methods are used the input parameters must be documented in detail and supporting documentation regarding prediction uncertainties must be provided.

The following information shall be provided in the acoustic report supporting the development application:

- description of the noise propagation model and all input information. An electronic copy of the noise propagation model, including all noise prediction files and graphical output files shall be available for SARA upon request
- a tabulated list of worst-case predicted wind turbine noise levels at each identified sensitive land use receptor for each turbine integer wind speed for all wind turbines being considered for the wind farm
- noise contours (dB(A)) for the predicted wind turbine noise levels should be presented for the worst case operational wind speed for the proposed wind farm development, showing predicted levels from at least 30 dB(A) contours
- the sound power levels of the proposed turbines referenced to turbine hub height wind speed, from cut-in wind speed to rated power, including the corresponding octave band sound levels from 63 Hz to 4 kHz.

Background noise levels from nearby wind farms

The noise from each individual wind farm shall meet the code noise criteria at existing or approved sensitive land uses, determined using background noise levels that existed before wind farm site developments.

Management of potential exceedances of criteria

Predicted noise levels from the proposed wind farm operation must comply with the code noise criteria for both day and night periods at all existing or approved sensitive land use receptors.

Where potential exceedances of the criteria are indicated as a result of noise prediction modelling, then modifications to the wind farm design (e.g. wind turbine layout, number of wind turbines operating, time of day for wind turbine operations, upgrade to low noise wind turbine type, etc.) should be carried out.

The development application shall comprise a proposal where the predicted wind turbine noise levels do not exceed the criteria for any sensitive land use receptor.

The noise impact assessment prepared to support a development application for a wind farm should include all necessary documentation to fully satisfy the noise criteria within the code.

Part 2 – Noise monitoring methodology

This part defines the noise monitoring methodology to be used for operating wind farms in Queensland. It provides the method for measuring the noise from operating wind turbines; the results of which will be used for determining compliance with the noise criteria included within the code and any conditions of approval.

It is noted that noise experienced at sensitive land use receptors as a result of a wind farm will often be similar to, or lower than, the ambient noise from other sources, such as wind in the trees. This can make the separation of wind farm noise from ambient noise very difficult. Therefore, this methodology may be supplemented with additional noise measurements to assist in determining the contribution of noise from a wind farm. The additional measurements may include noise logging at an intermediate/alternative location between the wind farm and sensitive land use receptors or on/off testing. Any variation to this methodology should be discussed with the department prior and justified accordingly based on site-specific circumstances.

Preparation of a Noise monitoring plan

Should a wind farm development be approved, the conditions of approval will require that the proponent prepare and submit to the department a Noise monitoring plan, prior to the commencement of construction. The Noise monitoring plan should provide details of the proposed operational noise monitoring for the specific circumstances of the wind farm and include, at a minimum, the following information:

- the proposed residential monitoring locations (including demonstration of any necessary access arrangements/consents)
- the proposed number of noise monitoring periods and the duration of each noise monitoring period
- the proposed make and model of equipment and wind shields used for noise monitoring
- the proposed method for determining wind speed and rainfall at microphone height
- details of any additional noise measurements to assist in the determination of the contribution of noise from the wind farm
- the measured background noise levels at the proposed residential monitoring locations
- the proposed method of determining wind speed at hub height (by direct measurement or measurement and correction) and demonstration that the wind speed is equivalent to the wind speed used for background noise monitoring.

In relation to the final point, the background noise monitoring conducted for the preparation of the development application is often correlated with the wind speed measured at wind masts on the wind farm site. As the project develops, wind masts are often removed to make way for wind turbines. Therefore, wind speed measurements from another location are often required for correlation with noise monitoring.

It is critical that the wind speed used for correlation within the noise modelling is equivalent to the wind speed used for correlation within the operational noise monitoring. One method is to use an anemometer from the nacelle of a wind turbine located close to the original wind mast. When using a nacelle anemometer an adjustment should be made to the measured wind speed to account for the passing of the blades. Another method is to use a permanent wind mast. Where a permanent wind mast is used, it should be correlated against the original wind mast for a period when both masts are present. This will allow any differences in wind speed to be factored into the noise monitoring.

Noise monitoring locations

Operational noise monitoring locations should be selected from the locations where background noise measurements have occurred, be representative of the nearest sensitive land use receptors to the wind farm and include, where possible, sensitive land use receptors in all directions from the wind farm. Proposed noise monitoring locations may require demonstration of necessary access arrangements/consents (i.e. where located on private property).

The applicant should justify the locations (including the number of locations) selected for noise monitoring with regard to the site-specific circumstances of the wind farm, including:

- dimensions, scale and layout of the proposed wind farm
- number and location of the potentially affected sensitive land use receptors
- comparison of predicted noise levels to the criteria within the code and subsequent conditions of any approval
- the topography between the wind turbines and the sensitive land use receptor locations.

Where possible, the noise monitoring equipment should be placed in the same location as where background noise measurements have occurred. Noise monitoring locations should be described within the Noise monitoring plan by:

1. location co-ordinates (GPS Latitude/Longitude)
2. photographic images of the location and the surroundings in all directions.

Ground level meteorological monitoring

Meteorological monitoring at ground level should be conducted simultaneously with the operational noise monitoring at locations as near as possible to the noise monitoring locations.

The purpose of the meteorological monitoring at ground level is to determine whether there was any rainfall or high wind speeds recorded during the noise monitoring period that might affect the measured noise levels. Wind or rain affected noise samples should be discarded from the noise data set to be used for correlations.

The number of meteorological stations deployed during the noise monitoring will be dependent upon the dimension and scale of the proposed wind farm, and the number and spread of the proposed noise monitoring locations. The applicant should justify the number and locations selected for simultaneous meteorological noise monitoring based on site-specific circumstances and the selected noise monitoring locations. If a meteorological mast on the wind farm site (or in the vicinity) has the capability to measure rainfall during the noise monitoring period, separate rainfall sensors at ground level may not be required.

Instrumentation to measure the required meteorological data can take many forms, but must include transducers able to quantify the wind speed to an accuracy of ±1m/s or better, and any occurrence of precipitation greater than 0.2mm. Statistical wind speed (i.e. the calculated wind speed exceeded for 90% of the measurement time to match the noise measurement parameter used) is the required wind speed measurement parameter.

If rotating cup anemometers or wind vanes are used, they should be appropriately maintained and in good condition. If cup anemometers are used, noise emissions from the equipment should not significantly contribute to the measured noise levels, particularly at higher wind speeds. If the instrumentation includes cooling fans, it must be ensured that the cooling fan noise level at the noise measurement location is at least 10 dB(A) less than the ambient noise level.

Anemometers which use ultrasonic detection methods are possible. Ultrasonic anemometers have no moving parts and can measure wind speed, wind direction and the vertical vector of wind direction.

Monitoring parameters

Although the guideline requires noise modelling to be conducted using the L_{Aeq} descriptor, it is not usually practical to measure the noise from a wind farm using the L_{Aeq} descriptor because intermittent noise from sources such as wind gusts in trees, vehicles, birds and insects are included. To minimise the interference from the intermittent noise sources, the L_{A90} descriptor is used as a proxy for the L_{Aeq} for the purposes of operational noise monitoring.

Monitoring duration and synchronisation

The noise monitoring instrumentation, the ground level meteorological monitoring stations and the wind mast anemometers should be time synchronised for the duration of the noise monitoring so that 10 minute synchronised noise and meteorological data samples may be measured for compilation and analysis.

The noise monitoring duration should be a minimum of six weeks to provide sufficient noise data for day and night periods. Any shorter duration should be discussed with the department prior and justified accordingly based on site-specific circumstances.

An important aspect is to ensure that the wind speed used for the correlation within the noise modelling is equivalent to (provides the same average wind speed as) the wind speed used for the correlation with noise monitoring. It is the proponent’s responsibility to demonstrate that the wind speed used for monitoring is equivalent when taking into account location and wake effects (when the anemometer is downwind of a turbine).

Should a wind farm development be approved, the conditions of approval will require that operational noise monitoring be conducted twice within the first year of the development being fully operational (i.e. all proposed turbines operating). This will comprise the completion of noise monitoring once within three months and once following nine months of the development being fully operational. This will provide sufficient data over a twelve month period for the department to determine compliance or otherwise with the noise criteria included within the code and any conditions of approval.

Instrumentation

Sound

Noise measurements should be collected for continuous 10 minute intervals using sound level meters or noise loggers having Class 1 or Class 2 certification in the previous two years, in accordance with AS IEC−61672.1-2004 Electroacoustics – Sound level meters.

All noise monitoring equipment must have an inherent noise floor no greater than 20 dB(A). The meters or loggers must be suitably calibrated before and after measurements and if the difference is greater than 1 dB(A), then the data should be discarded.

Windshields

Microphones should be protected with windshields which reduce wind induced noise on the microphone. Suitable windshields include those with a minimum diameter of 100 mm and/or those including a double wind shield arrangement. In addition, noise samples recorded with microphone level wind speeds above 5 ms^{-1} for more than 90% of any 10 minute period should be discarded from the regression analysis.

Rain

Noise monitoring conducted during rain periods may be adversely affected by the rainfall. Noise monitoring samples measured in the presence of any rain (0.2mm or more) in any 10 minute monitoring interval should be discarded from analysis.

Extraneous noise

Extraneous noise is defined as noise that is not typical of the long term noise environment at monitoring or receptor locations. Extraneous noise may include noise of insects (if seasonal), birds (if seasonal), frogs (if seasonal), farm animal noise, local vehicle traffic, emergency services sirens, etc. For example, insect noise can be considered extraneous noise in some circumstances if it is not typical of the long term noise environment.

Where dominant extraneous noise contributions are identified in the noise data set then the extraneous contribution should be removed. One method of achieving this would be by use of the frequency spectrum to provide a noise data set that is more representative of periods when the extraneous noise is not present. Removal of any dominant extraneous noise contribution is to be conducted prior to the affected noise data being included in the scatter plot for determination of the background noise level. The applicant should clearly identify whether extraneous noise was present during the monitoring samples used for the data analysis. If the extraneous noise contributions are dominant in the noise samples, then the extraneous noise contribution should be excluded or filtered. The methodology used for adjustment or exclusion due to extraneous noise should be documented and justified in the Noise monitoring plan. The methodology used for the operational noise monitoring must be consistent with that used for the noise modelling.

Preparation of a Noise monitoring report

Should a wind farm development be approved, the conditions of approval will require that the proponent submit separate Noise monitoring reports, outlining the results of the noise monitoring, at three and twelve months following the wind farm being fully operational.

The Noise monitoring reports should outline the derived wind farm noise level at sensitive land use receptors, adjusted for any tonality. This will be used by the department when determining compliance or otherwise with the acoustic criteria within the code and the conditions of approval, for sensitive land use receptors at each integer wind speed.

The Noise monitoring reports should clearly outline the results of the noise monitoring as conducted in accordance with the Noise monitoring plan prepared in accordance with this methodology.

Correlation of noise and wind speed data

Monitored L_{A90} noise samples should be correlated with the corresponding hub height wind speed (between approximate wind turbine cut-in wind speed and the approximate wind speed at rated power) and plotted to form scatter plots of the data. As outlined, to minimise the interference from the intermittent noise sources, the L_{A90} descriptor is used as a proxy for the L_{Aeq} for the purposes of noise monitoring.

For monitoring locations, each of the day and night periods should have separate scatter plots. The data collected in all wind directions is used. A best fit third order regression analysis should be carried out for the noise and hub height wind speed data. Any alternative analysis proposed (i.e. a bin analysis) should be justified by the proponent.

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 on the plot.

The pre-construction (background noise monitoring) regression line is then subtracted from the post-construction (operational noise monitoring) regression line to determine the derived wind farm noise. It is noted that if background noise monitoring is not available, the operational noise monitoring measurement is taken as the derived wind farm noise level. Figure 5 shows a typical scatter graph and regression line analysis.

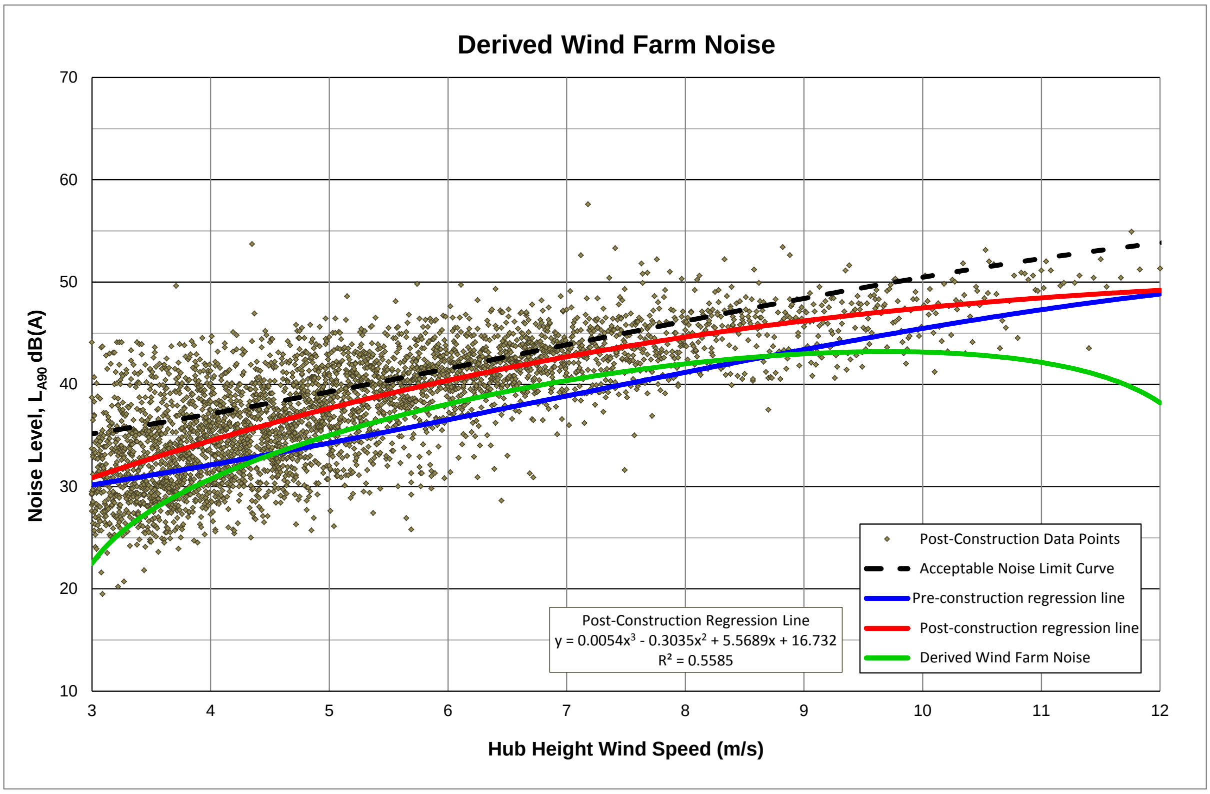

Figure 5 Example of regression line analysis to determine derived wind farm noise level

Tonality

Tonality should be determined by logging the (L_{Aeq}) noise in one third octave bands at the residential locations. All 10 minute L_{Aeq} noise data (i.e. without data exclusion) in one third octave bands are separated into groups of integer wind speeds ± 0.5m/s. For each 10 minute interval, where a one third octave band is 5 dB(A) above the level of both adjacent one third octave bands and there is no evidence that the noise is from another source, the 10 minute interval is potentially tonal.

Evidence that the noise is from another source could be by comparison with noise measured close to turbines or by listening to an audio recording of the sound at that time. The number of potentially tonal intervals in each wind speed group is added. Where the number of potentially tonal intervals is less than 10% in each wind speed group, it is concluded that the wind farm does not exhibit significant tonality. Where more than 10% of any wind speed group is potentially tonal at a residence, 5 dB(A) is to be added to the derived wind farm noise level at that wind speed.

Preparation of an Operational strategy

Should a wind farm development be approved, within the first twelve months of the wind farm being fully operational, proponents will be afforded the opportunity to rectify any non-compliance with the acoustic criteria within the code and the conditions of approval. This may include the implementation of turbine-specific operating measures/regimes or Wind Sector Management strategies.

At twelve months following the wind farm being fully operational, the conditions of approval will require that the proponent submit an Operational strategy. The Operational strategy should outline any specific operating measures/regimes or Wind Sector Management strategies required to ensure ongoing compliance with the acoustic criteria within the code and the conditions of approval. The proponent will be required to operate the wind farm in accordance with the Operational strategy until the development ceases operations.

Abbreviations

Abbreviation	Meaning
^{o}C	Degrees Celsius.
ACMA	The Australian Communications and Media Authority.
AGL	Above ground level.
AHD	Australian Height Datum.
AS	Australian Standard.
AS/NZS	Australian Standard/New Zealand Standard.
BCA	Building Code of Australia.
dB	Decibel. The unit of sound level.
dBA	A measured sound pressure level that incorporates A-weighting is denoted LpA, and has units of dB(A), often written as dBA.
EP Act	*Environmental Protection Act 1994*.
EPP (Noise)	Environmental Protection (Noise) Policy 2008.
Hz	Hertz.
IEC	International Electrotechnical Commission.
ISO	International Standards Organisation.
km	Kilometre.
km/h	Kilometre per hour.
L_{Aeq}	Time averaged A-weighted equivalent continuous sound pressure level.
L_{A90}	A-weighted sound pressure level which is exceeded for 90% of the measurement period. Often referred to as the Background noise level.
m	Metre.
ms^{-1}	Metres per second.
Qld	Queensland.
RPEQ	Registered Professional Engineer of Queensland.

Glossary

Term	Meaning
Ambient noise level	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source. Ambient noise levels would typically include a summary of all noise descriptors including L_{Aeq} and statistical parameters such as L_{A90}, L_{A10} and L_{A01}.
Amplitude modulation	Amplitude modulation special audible characteristics occur when there is significant amplitude modulation of the aerodynamic sound from one of more wind turbines such that there is a greater than normal degree of fluctuation as a function of the blade passing frequency (typically about once per second for larger turbines).
A-weighting	The A-weighting approximates the response of the human ear, particularly for sounds of moderate and low levels.
Background noise level	Minimum ambient noise level, evaluated as the level exceeded for 90 per cent of 10 minute sample periods ($LA_{90,10\ minute}$) during a defined time period of interest (e.g. daytime, evening or night-time).
Day	6 am to 10 pm.
dB	Decibel. The unit of sound level. A measurement of sound level expressed as a logarithmic ratio of sound pressure P relative to a reference pressure of P_r=20 mPa, i.e. dB = 20 x log(P/P_r).
Free-field	A region in space where sound may propagate free from any form of obstruction, usually greater than 5m from any significant vertical reflecting surface.
Frequency	Frequency is the number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz). Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals.
Impulsiveness	Transient sound having a peak level of short duration, typically less than 100 milliseconds.
Hertz (Hz)	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
L_{Aeq}	The equivalent continuous (time-averaged) A-weighted sound level.
L_{A90}	The A-weighted noise level equalled or exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.
Low frequency noise	Sound with frequencies between 20Hz and 200 Hz.
Night	10 pm to 6 am.

Term	Meaning
Octave band	Sound, which can occur over a range of frequencies, may be divided into octave bands for analysis. For environmental noise assessments, sound is commonly divided into 7 octave bands. The octave band frequencies are 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz and 4kHz.
Sound pressure level (L_P)	A logarithmic ratio of a sound pressure measured at distance, relative to the threshold of hearing (20 µPa RMS) and expressed in decibels.
Sound power level (L_W)	The level of total sound power radiated by a sound source. A logarithmic ratio of the acoustic power output of a source relative to 10^{-12} Watts and expressed in decibels.
Special audible characteristics	Distinctive characteristics of a sound which are likely to subjectively cause adverse community response at lower levels than a sound without such characteristics. Examples are tonality (e.g. a hum or a whine), enhanced amplitude modulation and impulsiveness (e.g. bangs or thumps).
Tonality	Noise containing a perceptible pitch component.

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