Department of Transport and Planning

EPA VICTORIA

Wind Energy Facility Turbine Noise

Technical Guideline

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1.Glossary

Term/ Acronym	Definition
A-Frequency Weighting	Frequency weighting representing the human response to sound and its variation with frequency, in the typical range of magnitude for environmental noise levels, as specified in Australian Standard AS/NZS IEC 61672.1:2019 Electroacoustics—Sound level meters, Part 1: Specifications.
AGL	Above Ground Level
Ambient sound environment	Has the same meaning as in the Environment Reference Standard
Amplitude Modulation (AM)	Amplitude modulation of wind turbine noise relates to the change in amplitude (loudness) occurring at the blade passing frequency, which is often described as swish, whoomp, thump, or whoosh
Authorised Officer	A person appointed as an authorised officer under section 242 of the Environment Protection Act 2017
Background sound level	Sound level associated with the mix of background sounds that characterises the baseline sound environment, in the absence of the noise under investigation. For wind farm sound, the background noise is characterised by the background sound level, measured by the regression curve of the measured statistical levels $L_{A90,10min}$ (NZS6808:2010) or $L_{A95,10min}$ (NZS6808:1998).
'Blade swish'	The modulation of broadband noise at the wind turbine blade passing frequency
CIT premises	Commercial, industrial and trade premises
Cumulative sound level	The combined accumulation of operational noise generated by all proposed and existing constructed wind farms
Cut-in Wind Speed	The wind speed in m/s at which a wind turbine starts generating electricity
Cut-out Wind Speed	The maximum wind speed in m/s at which a wind turbine stops generating electricity in order to protect itself from damage
Decibel, dB	The logarithmic unit used to measure sound and vibration. It is commonly used in acoustics to express the magnitude of sound levels or the amplitude of sound waves. The decibel scale is designed to represent a wide range of sound intensities, from the faintest sounds that can be heard by the human ear to extremely loud sounds that can cause damage to hearing.
dB(A)	The noise level determined in accordance with A-frequency weighting
DTP	Department of Transport and Planning
EPA	Environment Protection Authority Victoria

Term/ Acronym	Definition
EP Act	*Environment Protection Act 2017*
ERS	*Environmental Reference Standard*, Victoria Government Gazette No. S 245 Wednesday 26 May 2021 as amended by Environment Reference Standard No. S158 Gazette 29 March 2022.
Extraneous Noise	Extraneous noise refers to any noise that is not part of the noise emissions from the WEF. Extraneous noise includes noise caused by events including precipitation, insects, fauna, local traffic or activities, and the effect of wind on the microphone diaphragm
Equivalent Noise Level, L_{eq}, L_{Aeq}	The equivalent continuous sound pressure level obtained using the fast time weighting over the measurement time interval. Expressed as $L_{eq,T}$, where T refers to the measurement time interval in minutes.
Fast time weighting	125 m/s time weighting characteristic of a sound level meter as specified in Australian/New Zealand Standard AS IEC 61672.1:2019 Electroacoustics—Sound level meters, Part 1: Specifications
Hertz (Hz)	Measurement unit for the frequency of the sound measured as cycles per second
Hub-height	The height in metres above ground level of the central point of the wind turbine rotor
IEC Standard	A Standard published by the International Electrotechnical Commission
Impulsive sound	Sound containing impulse components as part of its characteristics, comprising a single pressure peak, or sequence of such peaks, or a single burst with multiple pressure peaks, whose amplitude decays with time, or a sequence of such bursts
ISO Standard	A Standard published by the International Organisation for Standardisation
Low frequency sound	Sound below about 200 Hz
NMP	Noise Management Plan
Noise sensitive area	Has the same meaning as the Regulations
Noise sensitive location	Has the same meaning as NZS 6808:2010 clause 2.4. Where the authorising document is other than NZS 6808:2010, the noise sensitive location must be consistent with the authorising document.
NZS 6808:1998	New Zealand Standard 6808:1998 Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators
NZS 6808:2010	New Zealand Standard 6808:2010 Acoustics – Wind Farm Noise
Octave Band	Division of the frequency range used for the purposes of acoustic design and noise assessment, allowing for a more targeted control of sound as it varies with frequency. Noise is measured in octave bands using frequency filters as specified in Australian standard AS IEC 61260.1:2019, Electroacoustics - Octave-band and Fractional-octave-band Filters.

Term/ Acronym	Definition
One-third octave band	A division of the frequency range that can be used when octave bands do not provide a sufficient detail. Each octave band comprises three one-third octave bands. Noise is measured in one-third octave bands using frequency filters as specified in Australian standard AS IEC 61260.1:2019, Electroacoustics - Octave-band and Fractional-octave-band Filters.
Penalty	An additional adjustment applied to the measured sound level to account for the increased subjective annoyance due to particular characteristics of the sound such as tonality, impulsiveness or amplitude modulation
PE Act	*Planning and Environment Act 1987*
Post installation sound level	The A-frequency-weighted sound level measured according to NZS 6808 after installation of the wind turbines, when the wind farm is operational
Predicted wind farm sound level	The wind farm sound level at a receiver predicted in accordance with NZS 6808:2010
Regulations	*Environment Protection Regulations 2021 as in force*
Relevant Noise Standard	As defined in Regulation 131B
Responsible Authority	The responsible authority who is responsible for the administration and enforcement of a planning scheme or a provision of a planning scheme as described in section 13 of the Planning and Environment Act 1987.
Spectrum	The frequency spectrum, the distribution of the energy or the magnitude of a sound across each frequency component
SAC	Special Audible Characteristic
Tonal noise	noise with perceptible and definite pitch or tone
VPP	Victoria Planning Provisions
WEF	Wind Energy Facility. Land used to generate electricity by wind force. It includes land used for: a) any turbine, building, or other structure or thing used in or in connection with the generation, of electricity by wind force; b) an anemometer. It does not include turbines principally used to supply electricity for domestic or rural use of the land. Consistent with VPP clause 73.03.
Wind farm	A group of wind turbines installed in the same region, and all operated by the same operator
Wind farm site	The land on which the WEF is located, including turbines, buildings or other structures or things as defined in the planning permission for the WEF
Wind speed	A measurement of the speed of the prevailing wind (m/s) over a discrete time period, usually measured at the hub-height
Wind turbine	A machine that converts the kinetic energy of wind into electrical power

Term/ Acronym	Definition
WTG	Wind turbine generator
Zone	an area of land delineated as a zone within the VPP, that is subject to a set of land use rules under the VPP, for example identifying if a planning permit is required and the matters that must be considered before deciding to grant a permit.

2. Purpose of this guideline

2.1. Introduction

In 2021, the *Environment Protection Act 2017* (EP Act) and *Environment Protection Regulations 2021* (the Regulations) established a new regulatory framework for wind turbine noise in Victoria. Prior to this, wind farms were regulated solely under the *Planning and Environment Act* 1987 (PE Act). Noise from wind turbines was regulated through conditions of planning approval. Planning and construction phases are still regulated by planning permits, or other approvals, but turbine noise during the operational phase is regulated by EPA Victoria using the EP Act and Regulations.

This guideline supports the technical measurement and assessment of wind turbine noise emissions under the Regulations made under the EP Act. It is intended to assist wind energy facility (WEF) operators to meet their obligations.

This guideline provides information about the general environmental duty (GED) relating to noise pollution from WEFs. It is not a substitute for legal advice about the effect of the Regulations. WEF operators should obtain legal and acoustic advice about their specific circumstances.

This guideline may also be used when preparing a pre-construction (predictive) noise assessment report for a planning permit application to establish or expand a WEF.

The Regulations require wind turbine noise limits to be determined and noise levels to be assessed in accordance with either NZS 6808:1998 or NZS 6808:2010 depending on the timing of the authorising document, such as a planning permit. Therefore, this guideline refers to either the specific version of the New Zealand Standard that is being referenced, as shown above, or to NZS 6808 where the specific reference applies generally to both versions of the Standard.

EPA may also provide specific guidance to environmental auditors, as requested, to clarify any provisions in this guideline.

This guideline may be replaced, amended, or updated periodically. EPA will endeavour to ensure that any update of this guideline is provided to EPA appointed environmental auditors. Reference should also be made to EPA's website (https://www.epa.vic.gov.au/) or DTP's website (https://www.planning.vic.gov.au/) for the most recent version of this guideline and more information on the environmental audit system.

2.2. Background and scope

WEFs create sound due to the wind turbine blades interacting with the wind and from the mechanical equipment used to generate electricity in the turbines. The predicted noise output from a proposed wind energy facility is assessed as part of the planning application process for WEF developments.

A WEF operator must manage, monitor, review, and report on wind turbine noise in accordance the Regulations.

Part 5.3 of the Regulations sets out the requirements that apply to noise from wind turbines (Division 5), unreasonable and aggravated noise from commercial, industrial and trade (CIT) premises (Division 3), music entertainment venues (Division 4) and residential premises (Division 2). The Regulations define a WEF as a CIT premises and therefore, the CIT premises assessment method in Division 3 of Part 5.3 of the Regulations and the *Noise limit and assessment protocol for the control of noise from commercial, industrial and trade premises and entertainment venues* (publication 1826) applies to a WEF site.

However, regulation 117(1)(c)(xiv) specifies that when assessing the level of noise emitted from CIT premises, the noise from the wind turbines at WEFs (used to generate electricity by wind force) must not be taken into account. This is because sound produced from wind turbines is measured and assessed differently than other sound sources commonly found at typical CIT premises. The noise needs to be measured during times when wind is present which typically differs from other CIT noise assessments.

Wind turbine noise from a WEF is therefore subject to specific regulations under Division 5 of Part 5.3 of the Regulations. The EPA *Wind Energy Facility Turbine Noise Regulation Guidelines*[1] (publication 2061) supports understanding those regulations.

In addition, this Technical Guideline has been prepared to support consultants, acousticians and WEF developers and operators to assess their noise emissions and meet their obligations during the development and operation of WEF projects, by:

- providing clarity on EPA's approach to interpreting and applying NZS 6808:1998 and NZS 6808:2010 which generally establish the relevant noise standards for the measurement and assessment of wind turbine noise in Victoria
- where necessary, clarifying the approach EPA considers should be adopted in respect of matters that are not discussed in NZS 6808, or where NZS 6808 presents different options or is ambiguous
- improving the consistency of the approach taken to assessing wind turbine noise across all stages of a wind farm development, and
- providing additional certainty in the way WEF projects will be assessed and monitored.

This guideline focusses on the sound from the wind turbines and does not provide detailed guidance on noise from:

- the construction of a WEF or transmission line
- operation of on-site sources other than wind turbines, such as substation or battery equipment

[1] https://www.epa.vic.gov.au/for-business/find-a-topic/noise-guidance-for-businesses/wind-energy-facility-turbine-noise-regulation-guidelines

- servicing, and maintenance activities at the WEF.

Risks from noise from construction of WEFs must be managed consistent with both the general environmental duty (GED) and the obligation to not emit and not permit to emit *unreasonable noise* under section 166 of the EP Act (see EPA Publication 1820.1: *Construction – guide to preventing harm to people and the environment*). In addition, the *Civil Construction, Building and Demolition Guide* (publication 1834) supports the civil construction, building and demolition industries to eliminate or reduce the risk of harm to human health and the environment and prevent unreasonable noise during the construction of projects through good environmental practice.

The GED also applies to noise from electrical substations and other infrastructure at a WEF, including maintenance and servicing activities. Noise from this type of equipment and activities may also be assessed under Division 3 (CIT) of the Regulations. In addition to not exceeding the noise limits set under the Regulations, noise must not be *unreasonable* having regard to the factors of unreasonable noise, including frequency spectrum (r.120) in the low frequencies (refer to *Noise guidelines: Assessing low frequency noise* (EPA Publication 1996). See also *Commerce, industry and trade noise guidelines*[2] and *Unreasonable noise guidelines*[3].

2.4. Intended audience

This technical guideline has been prepared by EPA for proponents and operators of wind farms, planners, consultants and acousticians. However, it may also be useful for other parties involved in the process, such as:

- planning or responsible authorities and other statutory authorities
- environmental auditors
- people concerned about noise from wind turbines.

3. Regulatory Framework

3.1. Roles and responsibilities

Various government entities are responsible for the planning approval of WEF or regulation of WEF noise.

The Minister for Planning is the Responsible Authority for assessing and determining new planning permit applications of all energy generation facilities with an output of 1 megawatt or greater, including wind energy facilities.

Local council will be the Responsible Authority for a planning permit application for development of a noise sensitive location, for example a new residence near a wind farm for which a planning permit is required.

EPA is an independent statutory authority that operates under the EP Act . EPA's role is to protect human health and the environment by reducing the harmful effects of pollution and waste, including noise pollution.

[2] https://www.epa.vic.gov.au/for-business/find-a-topic/noise-guidance-for-businesses/commerce-industry-and-trade-noise-guidelines
[3] https://www.epa.vic.gov.au/for-business/find-a-topic/noise-guidance-for-businesses/unreasonable-noise-guidelines

EPA regulates noise from ongoing operations once a WEF begins operating. It may also investigate complaints related to wind turbine noise and take enforcement actions for failures to meet the compliance requirements set out in the EP Act and Regulations. For more information on the compliance requirements for WEF operators under the Act and Regulations, see *Wind Energy Facility Turbine Noise Regulation Guidelines*.

3.2. Victoria Planning Provisions

The Victoria Planning Provisions (VPP) outline planning requirements for planning permit applications. The planning policy for WEFs in Victoria is set out in clause 52.32 of the VPPs. Clause 52.32 outlines the planning requirements related to the establishment of wind energy facilities in Victoria.

In particular, VPP clause 52.32-4 requires the proponent to provide a pre-construction (predictive) noise assessment report prepared by a suitably qualified and experienced acoustician that:

- Reports on a pre-construction (predictive) noise assessment conducted in accordance with *New Zealand Standard NZS6808:2010, Acoustics - Wind Farm Noise*.
- Provides an assessment of whether the proposed wind energy facility will comply with the noise limit for that facility under Division 5 Part 5.3 of the *Environment Protection Regulations 2021*.
- Where the proposed wind energy facility will be the subject of a wind turbine noise agreement under Division 5 of Part 5.3 of the *Environment Protection Regulations 2021,* specifies the premises of the relevant landowner (including any particular buildings) to which the agreement relates and provides an assessment of whether the proposed wind energy facility will comply with the modified noise limit for that facility specified in the agreement.
- Is prepared on the basis that the relevant noise standard under Division 5 of Part 5.3 of the *Environment Protection Regulations 2021* will be *New Zealand Standard NZS6808:2010, Acoustics - Wind Farm Noise* and includes an assessment of whether a high amenity noise limit is applicable under Section 5.3 of the standard.

The planning provisions also include an application requirement that proponents include a report prepared by an environmental auditor appointed under Part 8.3 of the EP Act that verifies whether or not the pre-construction (predictive) noise assessment was conducted in accordance with New Zealand Standard NZS6808:2010, Acoustics - Wind Farm Noise.

For information about the planning approval process refer to https://www.planning.vic.gov.au/guides-and-resources/guides/all-guides/renewable-energy-facilities/wind-energy-facilities, clause 52.32 of the VPP and the *Planning Guidelines for Development of Wind Energy Facilities* (Department of Transport and Planning, September 2023).

3.3. The general environmental duty and unreasonable noise

The GED (section 25 of the EP Act) requires people who are engaging in any activity that may give rise to risks of harm to human health or the environment from pollution or waste to minimise those risks, so far as reasonably practicable. This requires those risks be eliminated so far as reasonably practicable, or if that is not possible, to be reduced so far as reasonably practicable.

The EP Act also prohibits the emission of *unreasonable noise*. Section 166 of the EP Act imposes an obligation on any individual not to emit unreasonable noise and not to permit the emission of an unreasonable noise. This applies to the emission of noise from any place or premises that is not a residential premises.

Unreasonable noise is defined in section 3(1) of the EP Act, which includes prescribed unreasonable noise. In addition to prescribed unreasonable noise, noise may be unreasonable based on its characteristics and the circumstances in which it is emitted as set out in sections 3(1)(a)(i)-(v) of the EP Act.

The obligations to comply with the GED and prevent unreasonable noise emissions apply to WEFs. To provide greater certainty to the industry, Division 5 of Part 5.3 of the Regulations was introduced to set out what WEF operators must do to demonstrate compliance with noise emission duties under the EP Act. Regulation 131H prescribes wind turbine noise as *unreasonable noise* if it exceeds the noise limit for the WEF or, if the noise is assessed at an alternative monitoring point, the applicable alternative monitoring point criterion.

For greater clarity on how to comply with the GED, an Act compliance note[4] was included in regulations 131C and 131CA(1). These regulations set out how operators of WEFs must comply with the GED under Section 25(1) of the EP Act with respect to wind turbine noise. Specifically, to comply with the GED, operators of WEFs must ensure that wind turbine noise complies with the noise limits for that facility and must take all applicable actions set out in Division 5 of Part 5.3 of the Regulations to manage and review the wind turbine noise.

Noise management plans (NMPs) are a specific requirement for operational WEFs under Regulation 131E. NMPs are used to demonstrate an understanding of the risks of noise-related harm associated with the operation of the WEF, and to document procedures to control those risks and rectify any noncompliance. As the initial design of a WEF will have lasting implications for how risks can be prevented or minimised, it is good practice to develop a NMP during the design, approval and construction phases. Then, when the NMP becomes a statutory requirement under the Regulations, it will be available for further refinement and provision to EPA upon request.

3.4. Compliance and Enforcement

If EPA determines that the noise from a WEF is *unreasonable*, EPA will then take enforcement action in accordance with the Compliance and Enforcement Policy[5]. In determining the appropriate enforcement response, EPA takes an escalating approach and considers:

- the nature and seriousness of the non-compliance
- the risk of harm that has arisen from the non-compliance
- the characteristics of the person engaging in the activity, and
- other relevant criteria and factors (for example, public interest).

[4] Regulation 6 of the Regulations states that if a note at the foot of a provision of the Regulations states 'Act compliance' followed by a reference to a section number, the regulation provision sets out the way in which a person's duty or obligation under that section of the Act is to be performed in relation to the matters and to the extent set out in the regulation provision.

[5] https://www.epa.vic.gov.au/about-epa/publications/1798-2

Find out more about EPA's regulatory approach[6] and Compliance and Enforcement Policy. and Compliance and Enforcement Policy.

3.5. Environment Reference Standard

The NZS 6808:1998 or NZS 6808:2010 and the Regulations only apply to noise sensitive locations defined in the relevant New Zealand Standard (NSZ6808). The environmental values set out in the *Environment Reference Standard* (ERS) may apply to other areas that are not noise sensitive locations.

The ERS is a legislative instrument made under the EP Act which:

- identifies environmental values that the Victorian community want to achieve and maintain
- provides a way to assess those environmental values in locations across Victoria

The EP Act and other Victorian legislation require EPA and other decision makers to consider the ERS when making environment protection approval decisions where relevant. For more information, refer to the *Guide to the Environment Reference Standard* (publication 1992).

In regard to the application of the ERS to WEFs, the ambient sound indicators and objectives in the ERS will not be relevant when considering the impact of wind turbine noise on noise sensitive areas under the environment protection framework because wind turbine noise is subject to direct regulation under Division 5 Part 5.3 of the Regulations (see Figure 1).

Under the PE Act, a responsible authority may consider any relevant ERS before deciding on an application for a planning permit[7]. For example, the environmental value of *human tranquillity and enjoyment outdoors in natural areas*, its indicators and objectives within the ERS may be considered during the planning process in relation to 'natural areas'.

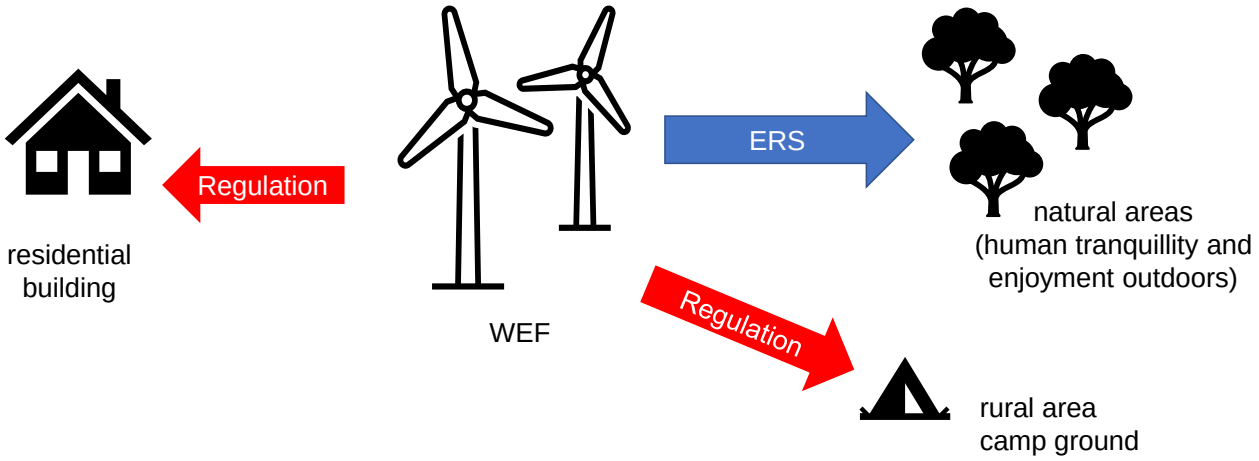

Figure 1 Application of the Regulations to noise sensitive areas and ERS to other areas, as considered during the planning process.

[6] https://www.epa.vic.gov.au/about-epa/what-we-do/epa-regulatory-approach
[7] PE Act 1987 section 60(1A)(f)

3.7. Applicable standard for wind farm noise in the Victoria planning provisions

Since 2011, the VPPs have adopted the New Zealand Standard (NZS) 6808:2010 *Acoustics - Wind farm noise* to address noise impacts during the planning, assessment, and commissioning of proposed wind energy facilities in Victoria.

VPP Clause 52.32 requires assessment of the predicted noise output of a wind energy facility against the 2010 version of the Standard.

Wind farm projects with approvals in place prior to Amendment VC78 coming into operation (on 15 March 2011) remain subject to the requirements of the 1998 version of the Standard (with any variations set out in the approval), unless subsequent amendment to their approval included updating to require adherence to the 2010 version of the Standard (with any variations set out in the approval).

3.6. Applicable standard for wind farm noise in the Regulations

The Regulations require wind turbine noise limits to be determined and noise levels to be assessed in accordance with either NZS 6808:1998, NZS 6808:2010 depending on the timing of the authorising document, such as a planning permit. These Standards provide specific requirements for the prediction, measurement and assessment of sound from wind turbines. A planning permit for an individual WEF may also modify the assessment methods within NZS 6808:1998 or NZS 6808:2010 for that WEF.

Standards New Zealand originally published NZS 6808 *Acoustics - The Assessment and Measurement of Sound from Wind Turbine Generators* in 1998. The Standard was subsequently revised and re-published in 2010 as NZS 6808:2010 *Acoustics – Wind farm noise* (the 2010 Standard), incorporating several modifications and other additional guidance, including, for example, the adoption of $L_{A90,10minute}$ noise levels instead of $L_{A95,10minute}$.

3.8. Environment Protection Regulations 2021

Regulation 131B of the Regulations sets out the *relevant noise standard* for a WEF. That is:

- NZS 6808:2010 for WEFs with an authorising document issued on or after 1 January 2011 or an authorising document amended to require compliance with NZS 6808:2010
- NZS 6808:1998 for WEFs authorised before 1 January 2011 that have not had approvals amended to require compliance with NZS 6808:2010
- As modified or replaced, with a reference to NZS 6808:2010 or NZS 6808:1998, by an authorising document which originally referred to either the 2010 Standard or the 1998 Standard[8].

3.9. Application of the 1998 and 2010 standards

As set out above, the applicable noise limits for a WEF will be established under either NZS 6808:1998 or NZS 6808:2010 in accordance with regulation 131B of the Regulations.

If a WEF's planning approval / authorising document specifies that NZS 6808:1998 applies, this is the primary method by which EPA will assess that WEF's compliance with noise limits.

However, this guideline recommends that, in the interests of best practice, WEF operators may apply NZS 6808:2010 to inform ongoing operational assessment of projects with existing approvals that were

[8] Where the authoring document does not refer to NZS 6808:1998 or NZS 6808:2010, or where it is amended or modified to remove any reference to the relevant standard, the relevant noise standard will be as set out in item 1 or 2 of the table in regulation 131B of the regulations.

assessed in accordance with NZS 6808:1998, in respect to aspects of assessment for which NZS 6808:1998 is silent.

In particular, in accordance with Regulation 131BA(3), the recommended process for undertaking regression analysis and excluding extraneous noise as described in the NZS 6808:2010 may assist WEF operators to demonstrate reliability and consistency in assessing sound measurement data to assess compliance with the applicable noise limits. Note that some historic planning conditions have modified some aspects of the Standard.

NZS 6808:2010 and NZS 6808:1998 do not apply to the associated electrical substations and transmission lines, co-located batteries and solar farms, to construction of the wind farm or to small wind turbines with a swept rotor area of less than or equal to 200 m^2. Instead, these noise sources will be required to comply with Division 3 of Part 5.3 of the Regulations (Unreasonable and aggravated noise from commercial, industrial and trade premises) once operational.

3.10. Requirements for verification or review by Environmental Auditors

Both the VPP and the Regulations require independent verification of the project documentation related to wind turbine noise to be undertaken by an EPA appointed environmental auditor during the planning permit application, and post-construction (operational) phases of the project respectively, including:

- Pre-construction (predictive) noise assessment (VPP 52.32-4)
- Post Construction Noise Assessment (Regulation 131D (3)(b))
- Noise Management Plan (Regulation 131E (3))

Under the clause 52.32-04 of the VPP, a pre-construction (predictive) noise assessment report, prepared by a suitably qualified and experienced acoustician, is required to be submitted as part of the planning permit application for a WEF. Clause 52.32-04 also requires the submission of an environmental auditor report which verifies whether or not the pre-construction (predictive) noise assessment was conducted in accordance with NZS6808:2010.

Once the WEF becomes operational, under regulations 164(ca)(i) and 164(ca)(ii), the function of the environmental auditors in assessing WEF noise are:

(i) to independently verify whether or not any post-construction noise assessment conducted for a wind energy facility was conducted in accordance with the NZS 6808:2010; and

(ii) to review any noise management plan prepared for a wind energy facility and any periodic monitoring undertaken under regulation 131G for the facility.

These have therefore been called 'verification reports' and 'review reports' for the post-construction noise assessment and noise management plan respectively.

Further guidance is provided in the Environmental Auditor Guidelines – Verification and review for wind energy facilities.

3.11. Other Guidelines and Standards

There are a range of other Guidelines and Standards in relation to noise from wind turbines.

NZS 6808:2010 currently refers to IEC standard IEC 61400 Part 11[9], which relates to the determination of the source sound power output of wind turbines through measurement close to the turbine. While it does not apply to the measurement and assessment of wind farm noise in the community which is measured at large distances from the WEF, the sound power measured using this IEC standard can be used as an input to WEF noise modelling and predictions in Victoria.

There are other guidelines referred to by NZS 6808:2010 which may assist, for example, the UK Institute of Acoustics (UK IoA) has published their *Good Practice Guide to the Application of ETSU-R-97 For the Assessment and Rating of Wind Turbine Noise*[10] (2013) which provides additional guidance for the application of ETSU-R-97 in the UK, but is also generally relevant for the application of NZS 6808 in the Victorian context.

Additionally new standards, such as IEC 61400-11-2[11] *Wind Energy Systems – Part 11-2 Measurement of wind turbine noise characteristics in receptor position,* may also be relevant to inform the measurement where NZS 6808 has indicated a new standard may be able to be applied. Any new standards must be consistent with an assessment performed using NZS6808 and must not be used outside its scope of application.

4. Overview of Methodology for Assessment

The process for prediction, measurement and assessment of wind turbine noise required for the operational phase of a WEF project is shown in Figure 2. Further details on key steps in this process are outlined in subsequent sections.

[9] IEC 61400-11 *Wind turbine generator systems – Part 11: Acoustic noise measurement techniques.* International Electrotechnical Commission, 2006.
[10] *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*, UK Institute of Acoustics, 1 May 2013.
[11] IEC 61400-11-2 *Wind energy generation systems – Part 11-2: Measurement of wind turbine noise characteristics in receptor position*. International Electrotechnical Commission, 2021 (Draft).

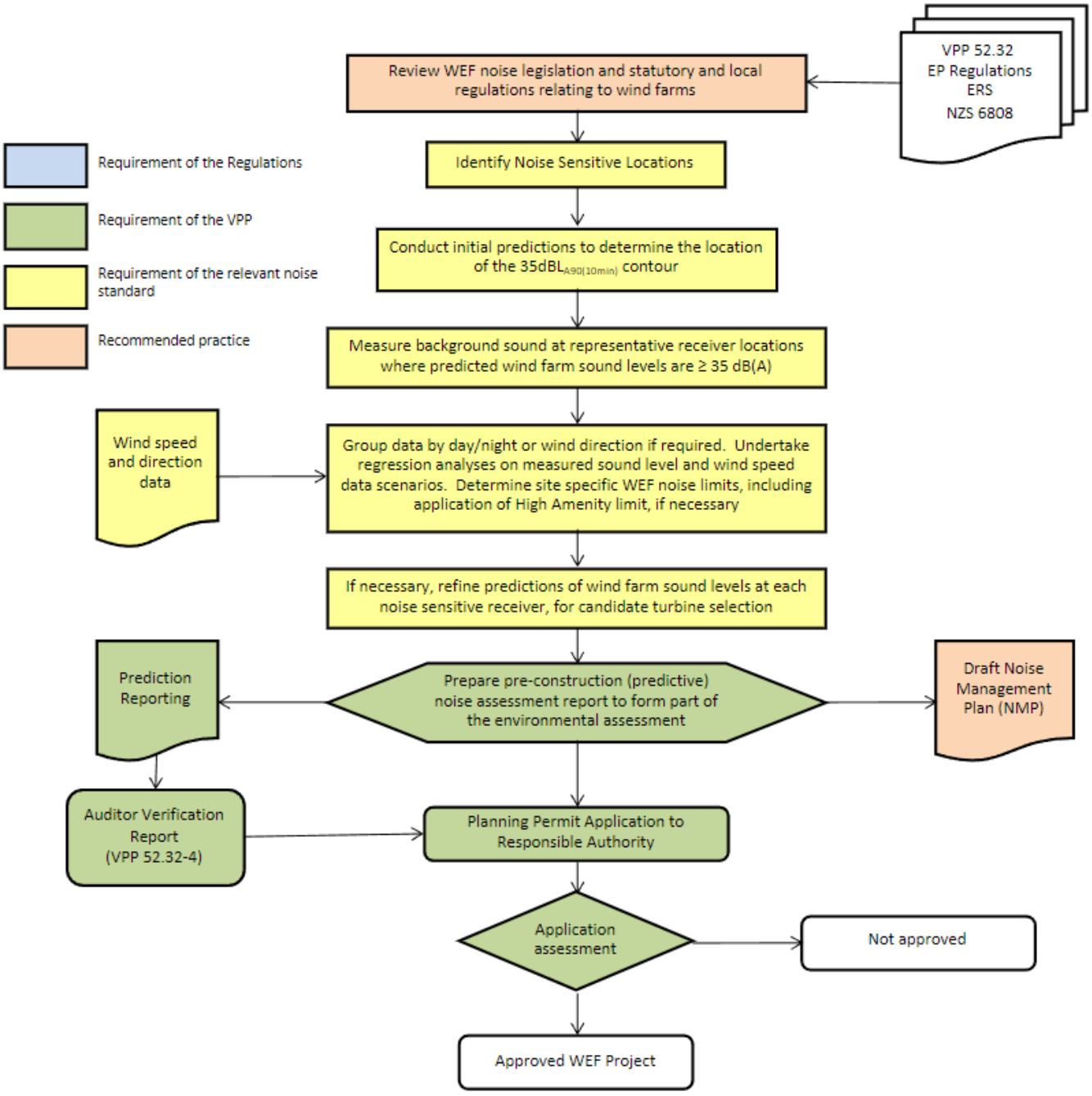

Figure 2: Planning phase process

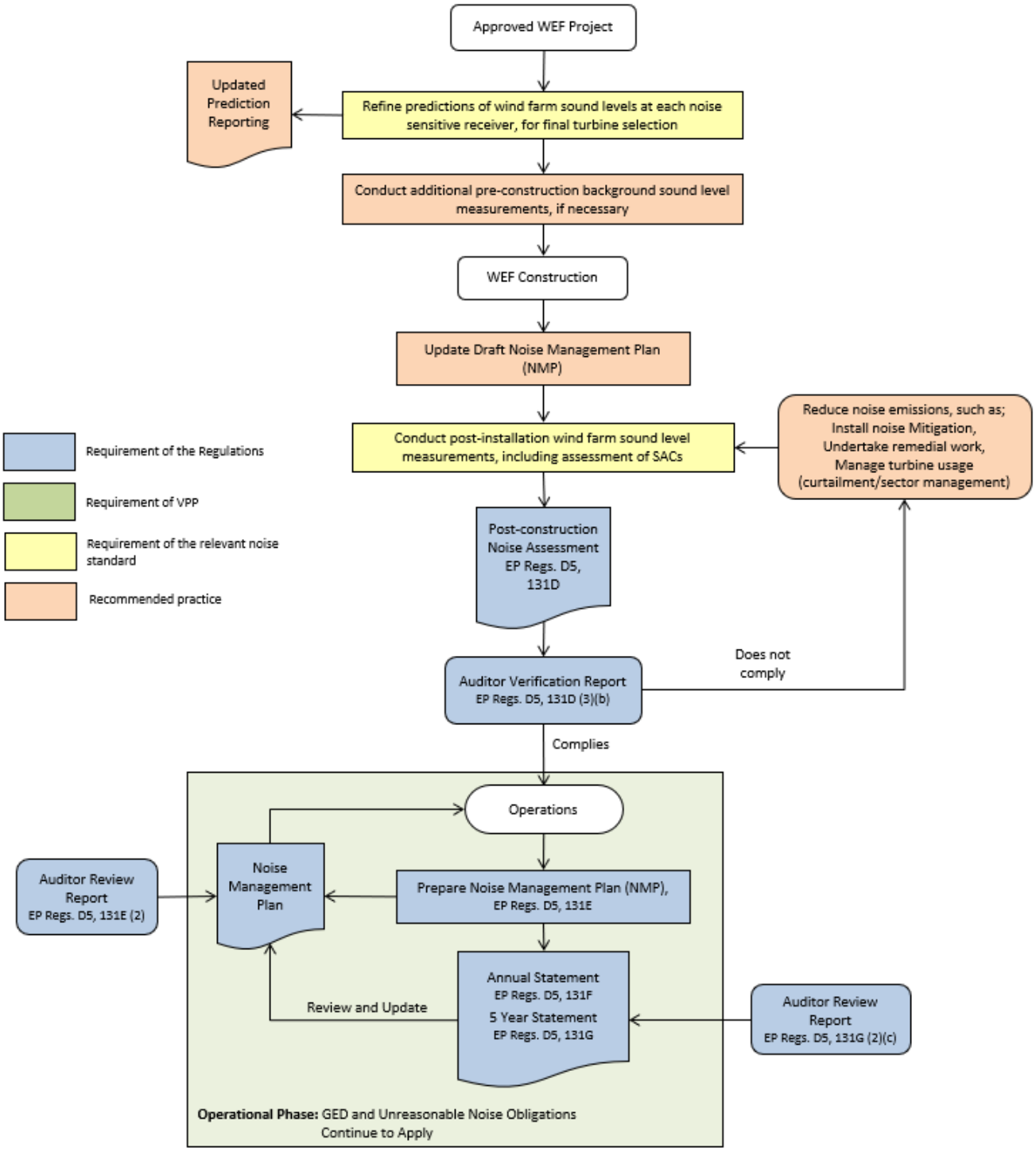

Figure 3: Construction and operational phase process.

4.1. Noise Sensitive Locations

The Regulations define noise sensitive *areas* in Part 1.2 (regulation 4). However, NZS 6808:2010 refers to 'noise sensitive locations'. For wind turbine noise, you must use the noise sensitive location definition. For other noise, such as noise from ancillary infrastructure at the WEF, use the noise sensitive area definition. NZS 6808:1998 does not define noise sensitive locations, instead noise limits apply at any

residential site. This technical guideline generally refers to *noise sensitive locations*, following the convention of NZS 6808:2010, however, assessment locations for WEFs should be consistent with the authorising document.

In accordance with NZS 6808:2010, wind turbine noise should only be assessed at *noise sensitive locations* (for example, residential and educational buildings) as defined in section 2.4 of the Standard. Examples of noise sensitive locations are:

- buildings that are already used for a noise sensitive use, regardless of the land use zone
- land that is in a residential or township zone, regardless of whether there are any buildings on the land
- campgrounds, caravan parks and tourist establishments, in some circumstances

The definition of a noise sensitive location excludes buildings *on the wind farm site* (generally referred to as 'hosts'). This means host locations are not noise sensitive locations. For example, if the wind farm landowners' house(s) is on the same title as any of the wind turbines or ancillary equipment in the immediate vicinity, then those buildings are excluded from the assessment and are not protected by the Standard, unless there is a specific agreement under the regulations. Nevertheless, EPA considers it is good practice to set a limit of 45 dB $L_{A90(10\ min)}$ or background + 5 dB, whichever is greater at these host locations, which is consistent with noise limits for agreements under reg 131BA(2)(b) Noise agreements (subject to regulation 131A) may be established with individual landowners.

Outside the wind farm site, all noise sensitive locations are subject to noise limits in accordance with the Regulations. This includes existing dwellings within one kilometre of a wind farm turbine where owners have provided written consent to the application being lodged, in accordance with clause 52.32-2 of the VPPs, or subject to a wind turbine noise agreement in accordance with Regulation 131BA(2). Refer to section 5 of this guide for information on noise limits.

4.2. Intermediate, derived and 'alternative monitoring points'

The Regulations contain the concept of demonstrating compliance at an 'alternative monitoring point' (Regulation 131BB). An alternative monitoring point is a location other than a location determined in accordance with the relevant noise standard, for the assessment of wind turbine noise. (This approach is commonly adopted in environmental noise assessment of industrial facilities, particularly where it is awkward, inconvenient, impractical or impossible to undertake compliance measurements at the noise sensitive receiver itself.)

In some cases, operators may be unable to access identified noise sensitive locations because landowners refuse or are unable to provide access. For post-construction wind farm sound measurements undertaken as part of the Annual Statement (reg 131F) and 5-yearly wind turbine noise monitoring (reg 131G), wind farm sound measurements can be undertaken at alternative monitoring points (reg 131BB) which should generally be defined and justified in the NMP (reg 131E(2)(b)).

However, regulation 131BB(1) does not allow alternative measuring points to be used for post-construction wind farm sound measurements undertaken to demonstrate compliance in the post-construction noise assessment (to satisfy regulation 131D). Therefore, if operators are unable to access noise sensitive locations to undertake the measurements for the post-construction noise assessment, they should contact the EPA to discuss how to proceed. It would usually be necessary to undertake measurements at a location that is representative of the noise exposure at the relevant noise sensitive location.

Therefore, undertaking wind turbine noise measurements *directly at the noise sensitive location* is to be adopted, where practical, for the post-construction noise assessment, acknowledging that the regression methodology developed in ETSU-R-97 and adopted in NZS 6808 is specifically designed to enable measurement and assessment of wind turbine noise in the background sound environment at the receiver.

Where alternative monitoring points are proposed to be used to support the annual or 5-yearly wind turbine noise monitoring, a well-established theoretical or empirical relationship between the noise levels at the alternative monitoring point and the noise sensitive location is required. This relationship and how it was derived needs to be justified, supported by documented evidence.

Note that, simultaneous noise level measurements at intermediate locations (that is, between the wind farm and specific noise sensitive locations) should not be used to justify the rejection of concurrent data points at the noise sensitive location based on their tonality or noise level.

The regression analysis approach is designed to reasonably accommodate variation in noise levels and SACs without resorting to more complex analysis such as 'near field' operational noise level measurements to exclude extraneous noise at the receiver.

4.3. The 35 dB L_{A90} sound level contour

In accordance with NZS 6808:2010, initial calculations of wind farm noise are made to determine noise sensitive locations exposed to predicted wind farm sound levels greater than or equal to 35 dB $L_{A90(10\ min)}$. Further prediction, assessment and measurement of wind farm sound is required for these noise sensitive locations, and not for locations exposed to a predicted wind farm sound level less than 35 dB $L_{A90(10\ min)}$.

The initial predictions of wind farm sound levels used to determine which noise sensitive locations are exposed to 35 dB $L_{A90(10\ min)}$ or more should be made using ISO 9613-2:1996 *Acoustics — Attenuation of sound during propagation outdoors — Part 2: General method of calculation* prediction method prescribed in appendix D1 of NZS 6808:2010, taking into account the topography and atmospheric absorption. Uncertainties within the modelling need to be clearly outlined with sufficient allowances made during the determination of the 35 dB $L_{A90(10min)}$ predicted contour so that its extent would not omit any noise sensitive locations that would require further assessment.

NZ 6808:2010 requires the predicted far-field wind farm sound levels to be reported. EPA recommends that reports should be accompanied by a map showing the predicted 35 and 40 dB $L_{A90(10\ min)}$ sound level contours associated with the proposed WEF development overlayed on a cadastre or aerial photograph for future management purposes. This will support future assessment of cumulative sound level at any nearby WEF developments. The 35 and 40 dB $L_{A90(10\ min)}$ sound level contours should be based on all turbines operating at 95% of rated power, in accordance with section 6.1.6 of NZS 6808:2010. However, in practice, sound power levels for turbines are usually provided at full rated power, and using those values is also acceptable. Initially these sound level contours will be based on the candidate turbine selection and sites, and then revised to reflect the final turbine selection and locations.

Where there are no noise sensitive locations exposed to predicted wind farm sound levels greater than 35 dB $L_{A90(10\ min)}$, the assessment and measurement of wind farm sound may not be required at any location. Nevertheless, it may be beneficial for WEF developers to undertake background sound level measurements at the nearest noise sensitive locations, to document the pre-construction environment to assist with compliance assessment at a later date.

4.4. Encroachment and reverse sensitivity

Applications for development of a new noise sensitive location (e.g. a house) may be received by a Responsible Authority (usually the local council) following the lodgement of an application of a planning permit for a WEF, referral of a proposal for a WEF under the Environment Effects Act 1978, or the construction of a WEF.

VPP clause 35.07-1 requires a planning permit for a dwelling or bed and breakfast, or other accommodation in the Farming Zone where the following requirements are not met:

Must be located more than one kilometre from the nearest title boundary of land subject to:

- A permit for a wind energy facility; or
- An application for a permit for a wind energy facility; or
- An incorporated document approving a wind energy facility; or
- A proposed wind energy facility for which an action has been taken under section 8(1), 8(2), 8(3) or 8(4) of the *Environment Effects Act 1978*.

Establishment of new noise sensitive locations should be discouraged within the predicted 35 $dBL_{A90(10\ min)}$ sound level contour of a wind farm. For example, if a planning permit application for a new house in a farming zone is being considered then the decision guidelines in VPP clause 35.07-6 require the Responsible Authority to consider whether the site is suitable for the use or development and whether the proposal is compatible with adjoining and nearby land uses. Considerations include whether the use of the building(s) will be adversely affected by the existing or proposed nearby wind energy facility due to noise.

If the Responsible Authority is considering approving the proposal, appropriate noise attenuation should be incorporated into the development of the noise sensitive location as part of the permit , consistent with VPP clause 13.05. These measures could include building design responses such as architectural acoustic treatments involving enhanced sound insulation for doors, windows, roof and walls.

Section 1.3 of NZS6808:2010 states that the Standard is intended to protect noise sensitive locations that existed before a wind farm. Therefore, parties wishing to establish new sensitive locations close to WEFs should be aware that they may not be afforded the same acoustic protection as a house that existed before the wind farm.

5. Noise Limits

Noise limits applicable to WEFs in Victoria must be determined in accordance with the relevant noise standard subject to regulation 131B of the Regulations. The relevant noise standard for a WEF is:

- NZS 6808:2010 for WEFs with an authorising document issued on or after 1 January 2011 or an authorising document amended to require compliance with NZS 6808:2010
- NZS 6808:1998 for WEFs authorised before 1 January 2011 that have not had approvals amended to require compliance with NZS 6808:2010

- As modified or replaced, with a reference to NZS 6808:2010 or NZS 6808:1998, by an authorising document which originally referred to either the 2010 Standard or the 1998 Standard[12].

In general, under NZS 6808:2010 and NZS 6808:1998 a noise limit of 40 dB(A) or background sound level +5 dB (whichever is the greater) is considered an acceptable limit for noise sensitive locations(standard acceptable noise limit).

The noise limit for premises subject to an agreement, made in accordance with regulation 131A, is as specified in the agreement (for agreements before 1 November 2021), or the greater of 45 dB(A) or the background sound level + 5 dB (for agreements made on or after 1 November 2021) pursuant to regulation 131BA(2).

Background sound level is determined by regression analysis of sound level and wind speed measurements in accordance with NZS 6808:2010 or NZS 6808:1998, as applicable.

Regulation 131BA (3) also allows for noise limits for WEFs required to be measured and assessed under NZS 6808:1998 to have extraneous noise excluded from the background sound level data set in accordance with NZS 6808:2010 (by applying the procedures that relate to extraneous noise in section 7.2 of the NZS 6808:2010).

5.1. Noise limits do not apply during construction or commissioning

The requirements for WEFs in Division 5 of Part 5.3 of the Regulations and the noise limits in NZS 6808:1998 and NZS 6808:2010 do not apply during the construction or commissioning period. Nevertheless, the requirements of the general environment duty under section 25 of the EP Act and unreasonable noise under section 166 EP Act apply (see also Civil Construction, Building and Demolition Guide, publication 1834.1).

During the period between any wind turbine first generating power and the post-construction compliance assessment, the WEF operator should ensure that the wind turbine sound levels are consistent with the sound levels modelled as part of the approval process. During commissioning, to help manage risks of non-compliance where predicted wind farm sound levels are close to the noise limits, it is good practice to conduct initial wind turbine sound level measurements following the operation of the first turbines to verify the predicted levels.

5.2. Application of high amenity area noise limit

The standard acceptable noise limit is appropriate at most noise sensitive locations. NZS 6808:2010 also allows a High Amenity Area (HAA) limit to be applied when the circumstances at a noise sensitive location justify a more stringent limit to afford a greater degree of amenity protection in the evening or at night.

In Victoria the HAA limit:

- should apply to a dwelling located in the following zones predominantly intended for residential development: Low Density Residential Zone (LDRZ), Township Zone (TZ), Rural Living Zone (RLZ), and Green Wedge A Zone (GWAZ).

[12] Where the authoring document does not refer to the 1998 Standard or the 2010 Standard, or where it is amended or modified to remove any reference to the relevant standard, the relevant noise standard will be as set out in item 1 or 2 of the table in regulation 131B of the regulations.

- should not apply to dwellings in the Farming Zone (FZ)
- should not be applied in any location where background sound levels are already affected by other specific sources such as road traffic noise (based on 5.3.1 of the 2010 Standard)
- only applies for WEF wind speeds up to and including 6 m/s during evening and night-times.
- is applicable only when there is no agreement made in accordance with regulation 131A.

The Environmental Reference Standard defines natural areas where the environmental value of 'human tranquillity and enjoyment outdoors in natural areas' applies. In some circumstances, HAA limits may be applied to campgrounds, caravan parks and tourist establishment in such natural areas, where this environmental value is considered to be relevant.

Consistent with section 5.3 of the NZS 6808:2010, where a HAA noise limit applies, the base wind turbine noise limit should be 35 dB(A) for wind speeds ≤ 6 m/s at hub height during evening and night-times. Above 6 m/s the base wind turbine noise limit should be 40 dB(A) or background sound level + 5 dB (that is, the standard acceptable noise limit). Where an HAA noise limit does not apply, the standard acceptable noise limit should apply at all wind speeds. In all cases, the relative limit of 'background sound level +5 dB' applies if background sound level is higher than the base wind turbine noise limit.

NZS 6808:1998 does not include a provision for HAA limits.

5.3. Staged developments and cumulative sound level

In accordance with section 5.6.1 of the NZS 6808:2010, the noise limits (including HAA limits) apply to the cumulative sound level of all wind farms affecting any individual noise sensitive location. Sections 5.6.2–5.6.4 of NZS 6808:2010 provide guidance on how to determine and apply these noise limits.

To facilitate the assessment of potential WEF developments, or the installation of additional turbines by third parties, it is important for the WEF operator to have available:

- all background, where available, and WEF noise level measurements undertaken for the development of their project
- sound level predictions based on the final turbine layout and type
- compliance measurement reports.

This is particularly relevant for existing WEF permit holders seeking to progress developments approved based on the NZS 6808:1998, since NZS 6808:2010 explicitly addresses the cumulative effects from multiple WEFs or those developed in stages.

This is also consistent with the requirements for an NMP set out in regulation 131E(2)(a), which include procedures for the identification, assessment and control of risks of harm to human health and the environment from wind turbine noise.

6. Uncertainty

As with all sources of noise, there is uncertainty in all predictions and measurements of wind turbine noise and background sound levels. The methodology in NZS 6808:2010 has been specifically designed to manage the effects of this uncertainty.

Appendix C of NZS 6808:2010 (which is notated as 'informative' – rather than 'normative') states compliance should be determined regardless of the uncertainty.

However, the prediction method should ensure that any uncertainty generally results in conservative predictions. A margin for uncertainty (i.e. contingency) should be included in the predictions, where necessary, consistent with good industry practice.

6.1. Uncertainty in Predictions

The uncertainty in the predictions is determined primarily by the specified outdoor sound propagation algorithm (ISO 9613-2). It also depends on other factors such as the wind turbine sound power data and inputs into the propagation algorithm, such as the terrain.

Uncertainty in the predicted wind farm sound level may result in a risk that is carried by the WEF developer. It is therefore important for the WEF developer to consider and understand the extent of uncertainties in the wind turbine noise predictions and to allow appropriate margins in the calculations, so as to manage their risk of non-compliance once the WEF becomes operational.

In this context, the main purpose of the predictions is to give the developer and Responsible Authority confidence that the noise limits will be achieved once the WEF becomes operational. All model inputs and assumptions must be clearly stated, justified and referenced to verifiable sources when applying the outdoor sound propagation algorithm, since different combinations of input parameters can generate similar results. All wind farm sound level predictions are required to be reported in accordance with section 8.1 of NZS 6808:2010.

The predictions are used to identify which noise sensitive locations are exposed to ≥ 35 dB $L_{A90(10\ min)}$. If there are no such locations, compliance can be determined solely by predictions.

6.2. Uncertainty in Measurements

Consistent with NZS 6808:2010, it is good practice to state the uncertainty of the measurements. Details of the uncertainty should be included in compliance assessment reports and may follow guidance from Craven and Kerry (2001). The JCGM Guide to the expression of uncertainty in measurement (GUM) 2008 may also be used to determine the measurement uncertainty.

The data analysis techniques in NZS 6808:2010, using regression curves, are designed to manage the most significant sources of variability in the sound level measurements, by averaging across a large number of data points.

7. Prediction and Assessment of Proposals

The following guidance draws primarily from NZS 6808:2010 and as a result in many instances refers to matters that are addressed in NZS 6808:2010 but in respect of which NZS 6808:1998 is silent including filtering. EPA recommends that WEFs that are governed by NZS 6808:1998 under their authorising document may, as a matter of good practice, choose to apply the below guidance to predict and assess WEF noise, where practical. Notwithstanding this, where the methods are documented in both NZS6808:1998 and NZS6808:2010 but differ, EPA confirms that, in respect of WEFs operating pursuant to an authorising document that refers to NZS6808:1998, EPA will assess compliance with noise limits primarily by reference to NZS6808:1998.

7.1. Acoustician

The WEF noise assessment modelling and post-construction sound measurements should be undertaken by a suitably qualified and experienced acoustician, who should be eligible for full membership of the Australian Acoustical Society (AAS, www.acoustics.org.au) or be a corporate member of the Association of Australian Acoustic Consultants (AAAC, www.aaac.org.au).

7.2. Locations where predictions need to be undertaken

Wind turbine noise predictions at the permit application stage should be undertaken at all individual noise sensitive locations that intersect or are within the 35 dB $L_{A90,\,10\,min}$ predicted wind farm sound level contour for operation at 95% or full rated power. The predictions for the individual noise sensitive locations and those to determine the 35 dB $L_{A90,\,10\,min}$ contour should be undertaken using sound power levels determined in accordance with IEC 61400-11 at wind speeds up to rated power of the wind turbine for the candidate and final turbine selection.

7.3. Required prediction model and environmental parameters

The prediction of wind farm sound levels should preferably be undertaken using the ISO 9613-2 outdoor sound propagation model described in appendix D1 of NZS 6808:2010. Other propagation models, e.g. CONCAWE may also be used, where appropriate and adequately justified. NZS 6808:2010 recommends that wind farm sound level predictions be based on the apparent sound power and tonality values for the nominated wind turbine model, determined in accordance with IEC 61400-11. The resultant predicted time-average (L_{Aeq}) wind farm sound levels occurring at receiver locations shall be taken as the predicted L_{A90} wind farm sound level. If sound power values used for the prediction process differ from values determined in accordance with IEC 61400-11 for the nominated wind turbine model, the numerical differences must be reported together with the technical reasons for using the differing values. If a method other than that of IEC 61400-11 has been used by the manufacturer to specify the sound power levels the method adopted must be stated in reports.

The simplified prediction method in appendix D2 of NZS 6808:2010 is not as accurate as other standard outdoor sound propagation models and should not be used.

Calculations of predicted wind farm sound levels should state the operating conditions for the wind turbines.

Where sound level predictions at noise sensitive locations submitted with a permit application rely on turbines operating on the basis of a 'noise management mode', reduced speed, curtailment, any other sub-optimum mode or adopting directivity factors for noise emissions, this should be clearly stated in the assessment and documented in the NMP. Evidence will be required in the subsequent post-construction noise assessment (reg. 131D), annual statement (reg. 131F) and wind turbine noise monitoring (reg. 131G) that the necessary controls are being maintained during ongoing operations.

The sound level predictions should generally be based on the following environmental parameters (Bass et. al. 1998, IoA Good Practice Guide 2013):

- relative humidity, 70%
- temperature, 10°C
- ground absorption (G), G less than or equal to 0.5
- sound propagating downwind, meteorological correction C_{met} = 0

- receiver height *h* = 4.0 m

Other parameters may also be used, where they are more appropriate, and can be adequately justified.

The source should be located at the proposed hub height of the turbine, with a sensitivity analysis undertaken with the source at maximum tip height. This is particularly relevant when considering the influences of terrain screening where the top half of the turbine blade may still be visible. In addition, for any instances where there is a significant 'concave' topography between the wind turbine and noise sensitive locations, a sensitivity analysis should be conducted using a value of G = 0. In particular, the topography should be considered to be concave where the mean propagation height is greater than (or equal to) 1.5 times the equivalent propagation height over flat ground. A clear description of the topography and justification of any model assumptions or adjustments should be included in the prediction report.

It is not necessary to apply any penalty for special audible characteristics (SACs) during the prediction of wind farm sound levels because SACs are either not able to be predicted, or if there is a known tonality SAC, the type of turbine would generally be prohibited under section 5.4.1 of NZS 6808:2010. In accordance with this section of NZS 6808:2010, if the turbine source data reveals SACs (e.g. tonality) that are likely to be assessable when measured at the noise sensitive locations in accordance with ISO 1996:2017, then those turbines cannot be used for the WEF development.

7.4. Background and Operational Sound Level Measurements and Analysis

The background sound levels, and operational wind turbine noise are required to be measured to confirm compliance with the noise limits.

Full sound level measurements are not required if, in accordance with section 7.1.2 of NZS 6808:2010, the WEF developer elects to adopt a WEF noise limit of 40 $dBL_{A90(10\ min)}$ at all operating wind speeds and conducts on/off compliance tests (except if SACs are detected).

Background sound level measurements adopted for the post-construction compliance analysis should be from within approximately 5 years of the post-construction measurements. Where necessary, additional pre-construction background sound level measurements should be undertaken to provide contemporary background sound level measurements prior to construction of the WEF. It is not expected that new background sound level measurements would be required for preparation of the annual statement (Reg.131F) or Wind turbine noise monitoring undertaken under regulation Reg.131G.

Note that post-construction sound level measurements should be undertaken at the same locations as the pre-construction background sound level measurements, where possible, and should be analysed using the same filtering approach as adopted for the pre-construction analysis.

To avoid the perception of a conflict of interest, the post-construction sound level measurements may be undertaken by a different consultant led by a suitably qualified and experienced acoustician to that commissioned to undertake the initial noise level assessment.

7.5. Sound level measurements

Sound levels should be measured at representative locations of all noise sensitive locations where the predicted wind farm sound level is 35 dB $L_{A90(10\ min)}$ or higher. Where noise sensitive locations or groups of noise sensitive locations are located near to each other with similar vegetation around them and are likely to be subject to similar wind conditions and sound propagation conditions from the nearest wind turbines, a measurement at one location can be considered representative of the sound level at each of

the individual noise sensitive locations (see section 7.1.5 of NZS 6808:2010). Evidence should be provided to support the decision to adopt a location as being representative of other nearby noise sensitive locations.

Where an alternative monitoring point does not have background sound level measurements undertaken prior to the construction of the WEF, then the measured background sound levels at nearby noise sensitive locations may be adopted for the alternative monitoring point, where they can be justified as being representative.

As noted in Section 4.2, an alternative monitoring point is not to be used for the WEF post-construction noise assessment under Reg.131D.

The location of the noise level measurements should be documented on a map overlaid on a cadastre or aerial photograph, and be accompanied by a description and photographs of the monitoring location, including the typical characteristics of the ambient sound environment (see section 8 of NZS 6808:2010).

The instrumentation used for the sound measurements should, at a minimum, meet the requirements of AS 1055 and be equipped with a manufacturer's approved wind shield. AS 1055 includes broadly equivalent provisions to NZS 6801, which is referenced in NZS 6808:2010for basic measurement requirements.

Noise level measurements and analysis must be undertaken between at least 25–5,000 Hz one-third octave bands.

The noise floor of the sound level meter must be taken into account when conducting regression analysis.

It is recommended that wind shields with a minimum 90 mm diameter be used for background sound levels and wind turbine noise measurements. Wind shields less than 90 mm are unlikely to be sufficient to prevent contaminated sound measurements generated by wind at the microphone when wind speeds exceed 5 m/s.

The documentation for the wind shield should include an estimation of the self-generated windscreen noise at integer wind speeds up to 95% or full rated power of the wind turbine. Manufacturers of sound level meters may provide details of their wind shield, in the form of graph identifying wind generated sound level for different wind speeds.

Alternatively, self-generated sound may be estimated using the following relationship (Cooper, J., Leclercq, D., & Stead. M. (2010)):

$$L_{Aeq} = 10\log(v^{C_1}) + C_2$$

Where:

L_{Aeq} = the A-weighted self-generated equivalent sound level

v = wind speed at the microphone in m/s, determined by measurement or predicted based on the measured hub height wind speed and wind shear

C_1 = 6.14 (Wind shield diameter 90 mm)

C_2 = -7.6 (Wind shield diameter 90 mm)

For the purposes of detailed analysis, it is preferable to keep a continuous record of the measured sound levels using a digital acquisition device that:

- meets the Class 1 (Type 1) requirements set out in Australian Standard AS IEC 61672.1
- holds a current calibration certificate issued by a calibration laboratory accredited with the National Australian Testing Association (NATA, 2019).
- is capable of sampling at least 12 kHz, with a minimum resolution of 16 bits
- has an intrinsic electronic noise sufficiently low so it doesn't significantly influence the measurement
- has a noise floor and a dynamic range adequate for the sound measured, which is the peak sound pressure level of the noise measured. This should be at least 10 dB below saturation at any time.
- has an electrical self-check function
- has reliable data storage.

If audio recordings are conducted for the purpose of post-processing data, the recording device should have a linear frequency response consistent with the requirements of Australian Standard AS IEC 61672.1. The device should also have intrinsic noise sufficiently low to ensure analysis can be conducted without having to adjust for low signal-to-noise ratio. The recording device should also be able to disable all automatic gain controls and limiters and allow for a lossless compression recording format. The audio recordings should include a calibration tone generated using an acoustic calibrator or pistonphone compliant with and calibrated to the requirements of AS IEC 60942.

Sound level measurements should be made during a representative range of wind speeds in accordance with section 7.2.1 of the 2010 Standard, including wind speeds above the rated power of the turbine.

7.6. Wind measurements

The wind speed data should be measured at the hub height for assessments under both NZS 6808:1998and NZS 6808:2010. Notwithstanding the fact that NZS 6808:1998refers to reporting manufacturer data for operational sound levels at 8 m/s at 10 m above ground level, wind speed measurements should be taken at hub height as specified in Section 7.3.1 of NZS 6808:2010.

If hub height wind speed measurements are not available, the analysis should be based on prediction of the hub height wind speed involving measurements at a minimum of two heights, with one of the measurements not less than half the proposed hub height and taking account of the measured wind shear.

The wind speed must be determined with equipment capable of measuring wind speed with a tolerance of ± 0.5 m/s.

The post-construction sound level/wind speed regression analysis is based on the measurements of wind speed at the wind farm site. In accordance with S7.3.3 of NZS6808:2010, '*The same location and height should be used for the wind measurements before and after installation provided the wind at this position is not likely to be affected by the turbines*'.

Where wind speed measurements at the original met mast or remote sensing device[13] location are not possible, alternative measurement locations on the wind farm site may be adopted. The wind speed measurements at any alternative measurement location should be reasonably adjusted so that they are representative of the original measurement location based on either correlations of concurrent measurements undertaken at both locations over some period of time or theoretical modelling of the relationship.

Where the original wind speed and direction measurement locations have the potential to be downwind of operating turbines in particular meteorological conditions, then the measured wind speeds should be 'de-waked' where possible, to provide the 'wake free' equivalent wind speed at the met mast location.

Consideration may also be given to adopting the average wind speeds measured at turbine-mounted anemometers. If wind speeds from turbine-mounted anemometers are used in the analysis, the selection of the relevant turbine should be justified.

Any analysis of wind speed data for the site must be undertaken by a suitably qualified and experienced wind engineering specialist. This specialist must provide the 10-minute mean wind speed at hub height, suitable for the regression analysis. The start and end times of the 10-minute wind and noise periods must align.

7.7. Data analysis

Consistent with 7.2.1 of NZS 6808:2010, the background and operational wind turbine sound levels should be determined at all integer hub height wind speeds representative of the typical site exposure, including between cut-in of the turbines and the rated power of the turbines. The intent is to achieve a reasonable spread of wind speeds and directions which are representative of the typical conditions on the site.

The sound level and wind speed data is to be analysed using a regression analysis to find an appropriate correlation between the data for wind speeds from cut-in to the rated power of the turbines.

NZS 6808:2010 recommends that sound level measurements should be conducted over a minimum of 10 days. However, to ensure sufficient data is collected to allow meaningful regression analysis, operators should consider noise surveys of up to 6 weeks duration. The monitoring period should generally allow around 2,000 data points to be measured, including around 500 in the downwind wind direction, where this can be achieved within a 6-week period. Where the downwind direction to a particular receiver is not the predominant wind direction, fewer data points will be able to be measured. Providing a wind rose for the assessment period for comparison with the long-term average wind rose diagrams for the site can help to demonstrate that the measurements are representative of typical conditions.

Following filtering of the data to exclude extraneous noise as far as practicable (see Section 7.8), the sound levels are to be determined by undertaking a regression analysis on a minimum of 200 valid data points, with no fewer than 5 valid data points in any 1 m/s wind speed bin. Where it is necessary to filter for day and night-time periods and wind direction, a data set of no fewer than 100 data points (and 3 data points in any 1 m/s wind speed data bin) may be adequate.

The regression analysis should be undertaken using up to at least a 3rd order polynomial regression curve to demonstrate sufficient representation of prevailing sound levels.

[13] e.g. LiDAR or SoDAR devices.

Section 7.4.2 of NZS 6808:2010 suggests that in some cases a 'bin analysis' procedure based on the method outlined in IEC 61400-11 might be more appropriate. The proposed IEC 61400-11-2 standard adopts a bin-analysis method rather than regression analysis. Where the analysis is undertaken in wind-speed bins, the bin width must be 1 m/s centred on integer wind speeds between cut-in and rated power of the turbine. The bin value must be calculated as the arithmetic average of the measured sound levels within each wind-speed bin.

The data used for the analysis of background sound levels should be plotted against the hub-height wind speeds existing at the time of each measurement to obtain a scatter plot. If a singular regression relationship is not evident, different scatter plots and regression analysis may better represent the measurements, for example, where there is distinct difference across the day, evening and night times.

Where necessary, the data may also be split by wind directions corresponding to:

- the quadrant centred on the dominant wind direction recorded during the survey period, or
- downwind direction, and
- the remaining three quadrants (considered together).

A balance is required between splitting the data to improve the overall correlation, without resulting in insufficient data during other time periods.

For high amenity areas, NZS 6808:2010 provides for a more stringent limit for evening and night times. In this case, the data may be split to periods corresponding to the more sensitive evening and night times.

The regression analysis should be undertaken separately for each of the scenarios. In many cases the night data for the prevailing wind should be sufficient to assess compliance. It is essential that the analysis is tailored to address the factors that influence background sound levels in different directions. This includes the use of the same (or very similar) wind speeds and direction measurement locations for pre- and post-construction monitoring, to the extent practicable.

The data scenarios are proposed to improve the correlation of measured sound levels to wind speed, particularly during the night-time period when more stable atmospheric conditions sometimes result in higher levels of wind shear, and there are fewer anthropogenic sound sources which are uncorrelated with wind speed.

The regression curve should be determined from the full range of wind speeds, and then truncated at the cut-in wind speed of the turbines, and the highest measured wind speed, and 'flat lined' or plateaued at the minima and maxima of the regression curve in accordance with Section 2.9.1 of the IoA Supplementary Guidance Note 2[14].

Section C7.2.1 of NZS 6808:2010 states it may be necessary to take further measurements if the results show:

- The distribution of data points is not uniform between minimum and maximum for each 1 m/s wind speed interval (for example there are gaps in the distributions or there is a more densely populated area of data points)

[14] A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, Supplementary Guidance Note 2: Data Processing & Derivation of ETSU-R-97 Background Curves, UK Institute of Acoustics, 1 September 2014.

- A lack, or sparseness, for one or more wind condition which, upon examination of the sound level/wind speed relationship, may represent an important subset of data. For example, a wind condition which demonstrates a tendency towards low sound levels at high wind speeds should be adequately represented in the data set if it is significant in the annual wind 'rose'.

This may require measurements to be made for extended periods of time to ensure that data includes the representative range of wind conditions.

It is not necessary for measurements to be undertaken strictly within each of the four seasons. However, it is necessary to ensure that the meteorological conditions during the measurement period reasonably represent the typical range of meteorological conditions at the development site.

7.8. Filtering and Data Exclusion

Consistent with section 7.2.4 of NZS6808:2010, the key requirement for the post-construction wind turbine noise level measurements is that the noise measured is representative of the noise from the wind turbines and excludes other extraneous noise as far as practical.

A range of techniques may be used to 'exclude' data points, or periods during which measured noise levels are unlikely to be due to the wind farm including:

- truncation of the data based on turbine cut-in speed
- removal of 'extraneous noise', potentially based on one-third octave band frequency analysis
- excluding data at times when precipitation occurs
- when WEF or turbine generation capacity is negligible.

Data may also need to be excluded where the measurement equipment is subject to damage, malfunctions, loss of power or unreliable calibration.

Where these exclusions eliminate a substantial amount of measurement data leading to a very sparse final data, additional measurements may be required.

The analysis of the pre- and post-construction measurement data should be compared on a 'like-for-like' basis wherever possible, that is, using the same filtering and data exclusion approach for both sets of data. Wherever filtering or data exclusion has been applied, this must be identified in the report and the methods, means and justification of the exclusions must be reported.

7.9. Truncation

The post-construction measurement regression curve may be truncated at both low and high wind speeds corresponding to turbine cut-in wind speed (typically around 3 m/s), and at the highest typically measured site wind speed with sufficient data points (around 12–15 m/s) (refer section 7.2.1 of NZS 6808:2010).

However, in practice, it is wind speeds between 6–10 m/s that are critical for most WEF post-construction noise level assessments because these typically correspond to the highest emergence of WEF noise over the background sound level. This is because stable meteorological conditions (and therefore low ground-level wind speeds and background sound levels at the receivers) are less likely at higher wind speeds. On that basis, truncation of the data to the 'operating wind speeds' is likely to be unnecessary.

7.10. Extraneous Noise

Extraneous noise from insects, fauna and so on at the noise sensitive location, or alternative monitoring point may be identified using automated signal processing of the recorded sound level data and excluded from the data analysis.

A reasonable methodology (Griffin et. al, 2013) excludes 10-minute data pairs where the level is dominated by a single one-third octave band. This is defined as:

- Where the highest A-weighted one-third octave band noise level is within 5 dB of the overall broadband A-weighted noise level, and
- The noise level of the one-third octave band is greater than 20 dB L_{A90}.

It is recommended to review time history charts and listen to samples of recorded audio during periods identified as possibly affected by extraneous noise to verify that the sound is from extraneous sources and that the method is accurately identifying extraneous noise.

7.11. Precipitation

Noise measurements affected by precipitation should be excluded from the analysis. 10-minute data pairs that have any measured precipitation amount greater than or equal to 0.1 mm per 10-minute period measured at site met mast or locally to noise measurement equipment should be excluded from the analysis. Precipitation can also be identified by reviewing time history charts and listening to samples of recorded audio.

7.12. WEF or turbine generation capacity

As noted earlier, many WEFs are commissioned under restrictions to their generation capacity due to external constraints imposed by AEMO or other circumstances. Since curtailed operation due to temporary grid constraints is not considered to be 'normal operation' of the WEF, periods of 'abnormal' operation may be excluded from the analysis where the power generation from individual turbines or the WEF as a whole does not match the expected power generation outputs for the wind speeds of the wind farm site.

This may be based on relatively straightforward evaluations of the whole WEF power output, or more complex analysis of detailed SCADA data comparing the expected outputs of individual wind turbines with local wind speeds.

Similarly, during commissioning, as well as normal operations, it is commonplace for individual turbines to be shut down for remedial work and routine maintenance. Periods where not all the turbines are 'available' for generation may be excluded from the analysis.

In practice, if the effect of the curtailment of any turbines at any specific measurement location in any 10-minute period would result in a difference in overall predicted wind farm sound level of 1 dB(A) or less at the receiver, calculated using the noise model prepared in accordance with this Guideline, then the measurement data should not be excluded from the analysis.

7.13. Ground level wind speeds

Some analysis approaches exclude noise level/wind speed data pairs where the *ground-level* wind speed is greater than 5 m/s. The intention of excluding data at high ground-level wind speeds is to exclude periods where the measurement is likely to be dominated by high local background sound levels. The aim is therefore to focus the assessment on periods of lower background sound levels at the

receiver, when wind turbine noise is likely to be most evident. In this respect, this approach appears to be consistent with section 7.2.4 of NZS 6808:2010 which allows for the exclusion of extraneous sound.

However, it can lead to the exclusion of large numbers of data-pairs at higher hub-height wind speeds, particularly in low wind-shear conditions, which can result in sparse data for the regression.

As noted earlier, post-construction wind turbine noise levels do not usually exceed the compliance limits at higher wind speeds, because the turbine sound power output has plateaued around 11–13 m/s.

Since the regression approach of NZS 6808 is specifically intended to accommodate ground level wind speeds greater than 5 m/s, an exclusion for high ground level wind speeds is considered unnecessary and is not recommended.

7.14. Data Access & Retention

Where required, wind speed and sound level data may be provided to owners of noise sensitive locations by prior agreement with the operator. Given the large raw datasets generated, this should be limited to processed 10-minute wind speed, noise level and, where necessary, SAC penalty data. It is not appropriate or necessary to provide original proprietary sound level meter files, or digital recordings.

Processed site measurement data should be retained by the consultant or operator for at least 7-years following commissioning of the wind farm. Raw measurement data and digital audio recordings can comprise very large files, and do not need to be retained in their original form following processing. However, a clear record of any data filtering or data exclusion methods should be made in the associated reports so that subsequent assessments are comparable.

7.15. On/off testing

Where on/off testing is undertaken it should be in accordance with section 7.7 of NZS 6808:2010. This requires measurements representative of the whole operational range of the WEF. The measurements should include those in a down wind or cross wind direction at a minimum of three wind speeds as follows:

- a wind speed above and within 2 m/s of cut-in wind speed
- a wind speed within 2 m/s of that corresponding to 95% or full rated power of the turbine, and
- an intermediate wind speed.

If the noise sensitive location is in a cross-wind quadrant during on/off testing, to demonstrate compliance, the operational wind turbine noise level should be at least 2 dB below the noise limit.

Since the ancillary systems of a wind turbine make an insignificant contribution to the far-field noise levels, it is not necessary for the local turbine systems to be completely turned off in order to complete the 'off measurements'. It is considered sufficient that the turbine is not generating any significant levels of power, as demonstrated by the SCADA or other onboard monitoring systems.

7.16. Assessment of Special Audible Characteristics

NZS 6808:2010 specifies that wind farms should be designed so that their sound does not have special audible characteristics (SACs) at noise sensitive locations. SACs may include tonality, impulsiveness or significant amplitude modulation. Consistent with NZS 6808:2010 section B4 and NZS6808:1998 section 5.3.2 only one adjustment may be applied.

Under NZS 6808:2010, the measured 10-minute L_{A90} operational wind farm sound levels are required to be adjusted (or penalised) by up to 6 dB if SACs are present at noise sensitive locations. The SAC adjustment is intended to be applied where SACs are regularly observable, for example, under particular environmental conditions (e.g. wind speed and/or direction). It is not intended for this adjustment to be applied where SACs rarely occur.

Where the authorising document is NZS 6808:1998 if SACs are present the adjustment is +5 dB.

The presence or absence of SAC must be identified subjectively by an acoustician, prior to objective measurements (described below) being undertaken. The assessment should be guided by both on-site observations and preliminary screening of sound logging data supported by clear audio recordings. The assessment must be sufficient to determine the regular presence of SACs before concluding whether any further objective assessment is required. The duration of assessment should be adequate to confirm or exclude the regular presence of SACs. The period to be assessed should be specified in the WEF's NMP.

Records made during the post-construction noise assessment should document the listening tests carefully, noting the date, location, time and duration, and a description of the sound heard and its character (if any).

While the listening test is sufficient to determine whether a penalty should be applied, objective analysis across the entire monitoring period dataset should be considered. Most common acoustic measurement instrumentation do not provide sufficient functionality to identify SACs in real time. It is therefore necessary to undertake detailed post-processing and signal analysis on the sound level measurements or recordings in order to determine whether any SAC is regularly observable, and if the adjustments should be applied.

This should be undertaken by evaluating at least 1-2 minutes samples of recorded audio from each 10-minute measurement period using digital signal processing techniques to implement the objective measurement methods described further below, supplemented by further listening to samples to validate the presence of SACs in measurement periods identified by the screening method to contain SACs. Presence of SACs in the audio sample results in the determined penalty for the entire 10-minute period.

In accordance with section B4 of NZS 6808:2010, the value of the adjustment for tonality, impulsiveness or amplitude modulation should be 5 dB. However, a value of between 1–5 dB, or a between 1–6 dB should be used where the WSP/Parsons Brinkerhoff method for AM or ISO 1996-2:2007 for tonality are used respectively. The maximum value of the correction is 5 dB (or 6 dB if the ISO tonality test is used) even if more than one type of SAC is present.

If SACs are determined to be present under particular environmental conditions (e.g. for a particular wind speed or direction) then the procedure in section 8.3 of NZS 6808:2010 should be adjusted so that the quadrant(s) under which SACs occur are subject to a separate regression analysis.

As the Standard requires the wind farm to be designed so that its sound does not have SACs, adjustments for SACs are only applied to operational sound level measurements (if present), and are not required to be applied to sound level predictions undertaken during the development and assessment stages of the project.

It is accepted that objective test methods for wind farm SACs are subject to ongoing development and evaluation. Therefore, methods for the objective identification and penalisation of SACs should be

based on the state of knowledge at the time of the assessment. A reasonable starting point for the evaluation of SACs is as follows:

7.17. Tonality

Where an acoustician's listening to samples indicates that the sound from the wind farm is likely to be tonal, then an objective measurement of wind farm sound tonality should be undertaken by determining the *tonal audibility* in accordance with the method in ISO/PAS 20065, and then determining the appropriate tonal adjustment (penalty) in accordance with Table J.1 of ISO 1996-2:2017.

7.18. Impulsiveness

Experience suggests that wind farm operations are unlikely to result in significant or regularly occurring impulsive sound. Where an acoustician's listening to samples indicates that the sound from the wind farm includes regularly occurring impulsive characteristics, a 5 dB penalty should be applied. Caution should be exercised in adopting the objective measurement of impulsiveness in accordance with Appendix E of AS 1055.1:2018[15],[16], as it may mis-identify impulsive characteristics of wind farms in windy and high-background sound level situations (known as a 'false positive' identification).

7.19. Amplitude modulation

Section B3.1 of NZS 6808:2010 acknowledges that some amplitude modulation will always be present given the nature of a rotating turbine. This section of the guideline relates to situations of increased or atypical amplitude modulation, referring to cyclical modulation of audible aerodynamic sound from wind turbines related to the blade pass frequency.

Where an acoustician's listening to samples indicates that wind turbine noise appears to exhibit significant amplitude modulation, then an objective measurement of amplitude modulation should be undertaken in accordance with the UK IoA Amplitude Modulation Work Group (AMWG) method (2016). The UK IoA method provides a robust and well accepted way of identifying periods of Amplitude Modulation, while minimising the number of potential false-positive results from non-wind farm sources. The IoA method implements a hybrid of time-series and frequency domain analysis. Open-source Python software has been released to apply the method for determining an amplitude modulation (AM) rating in an accepted and consistent manner.

Once the AM rating has been determined using the IoA AMWG method, the AM penalty can be determined based on Perkins et. al (2016) - referred to as the WSP/Parsons Brinkerhoff method.

Where possible, the entire 10-minute period should be evaluated.

7.20. Low frequency sound

Low frequency sound is not specifically required to be measured or assessed under NZS 6808:2010.

While it is acknowledged that there is some low frequency sound generated by wind farms, for turbines operating in accordance with NZS 6808:1998 or NZS 6808:2010 and the manufacturer's specifications, the measured levels are generally found to be low at noise sensitive locations.

[15] *Australian Standard AS1055:2018 Acoustics - Description and measurement of environmental noise.* Standards Australia, 2018.

[16] AS1055:2018 adopts a contemporary methodology for identification of impulsive sound based on a proposal by Pedersen (2000, 2002) and adopted as NordTest Method NT ACOU 112.

The objective measurement and assessment of low frequency sound is therefore not automatically or routinely required for WEF projects in Victoria.

Frequency spectrum is a *prescribed factor* under regulation 120 that is considered when determining if noise from CIT constitutes *unreasonable noise* in accordance with section 3(1)(a)(v) of the EP Act. Whether low frequency sound is unreasonable noise would need to be determined by an EPA Authorised officer in the unusual circumstance where concerns arise about the frequency spectrum of wind farm sound, noting that *Noise guidelines: Assessing low frequency noise* (publication 1996) does not apply to noise from wind turbines.

8. Documentation, Compliance Assessment and Reporting

Section 8 of NZS 6808:2010 sets out the minimum requirements for documenting the background and operational sound level measurements and post-construction compliance assessment. These requirements are consistent with AS 1055.1 and AS 1055.2.

To support the post-construction noise assessment and NMP, and facilitate their review, the reporting and documentation should also provide the following information in addition to that required to be provided in accordance with NZS 6808:2010:

- yearly average wind roses indicating the prevailing wind direction
- measured wind roses showing the extent of the wind directions and speeds measured during the noise survey period
- specific details regarding the particular equipment used to undertake sound level measurements, and details of both NATA and field calibration checks of the equipment
- 35 and 40 $dBL_{A90(10\ min)}$ predicted wind farm sound level contours.

8.1. Compliance assessment

Compliance based on operational sound level measurements should be determined using relevant noise standard and the procedures specified in this guideline.

Measured operational sound levels above rated power of the wind turbines (typically 11~14m/s) are often strongly influenced by high background and wind-induced noise on the microphone, and may not reasonably represent the noise contribution from the wind farm itself. In these circumstances, it may be appropriate to infer compliance where it can be shown that operational sound levels comply with the necessary criteria at wind speeds up to the rated power of the wind turbines.

If the wind turbine noise is found to be non-compliant with the requirements of the planning permit or the Regulations, the developer or operator must take immediate action to bring the wind turbine noise into compliance until longer term remedial works are undertaken by either de-rating the relevant turbine(s), switching the turbine(s) into a noise management mode, or turning the turbine(s) off, in accordance with the WEFs Noise Management Plan (see the Wind Energy Facility Turbine Noise Regulation Guidelines). Wind turbines may be operated in a non-complying condition for short periods if agreed by EPA for the purposes of investigating and reducing the noise.

If operational measurements do not demonstrate compliance, measurements should be repeated as soon as possible, once remedial works have been implemented, e.g. applying alternative operating measures that achieve compliance in equivalent physical conditions to the situation where non-

compliance previously occurred. Further operational measurements should be conducted following any additional remedial works.

9. Regulatory requirements

Guidance regarding the following regulatory requirements is provided in the *Wind Turbine Noise Regulation Guidelines* (publication 2061):

- Post-construction noise assessment
- Preparation and submission of a Noise Management Plan (NMP)
- Selection and use of alternative monitoring points for measurements other than the post-construction noise assessment
- Preparation of the annual statement
- Preparation of five-yearly wind turbine noise monitoring

10. Reference documents

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