Draft: DZ6808 v2.5

Public Comment Draft

Acoustics – Wind farm noise

Draft	SPEX #	Date
V2.0		17/01/09
V2.3		23/01/09
V2.4		02/02/09
V2.5		09/02/09

DRAFT

New Zealand Standard

Committee: P 6808

DO NOT USE THIS DRAFT AS A STANDARD – IT MAY BE ALTERED BEFORE FINAL PUBLICATION

Standards New Zealand

Private Bag, Wellington. Fax: 04 498 5994

EXPLANATORY NOTES FOR REVIEWERS

Credentials

This document is a proposed New Zealand Standard in terms of the Standards Act 1988. Issue as a draft in this form provides the required statutory opportunity for consideration and comment by the bodies and persons having an interest in the Standard.

Commenting

(a) Comments are invited, preferably in electronic format, on the technical content, wording and general arrangement of this draft. Please use the comments pages, provided behind this notice, for your comments.
(b) Editorial matters (i.e. spelling, punctuation, grammar, numbering, references etc) will be corrected before final publication.
(c) Electronic comments should be sent by e-mail to craig.watkin@standards.co.nz or on a disc. Other formats - Comments should preferably be typewritten. Please do not return marked-up drafts as comments.
(d) When completing the comments page ensure that the number of this draft, your name and organisation (if applicable) is recorded. Please place relevant clause numbers beside each comment.
(e) Please provide supporting reasons and suggested wording, for each comment. Where you consider that specific content is too simplistic, too complex or too detailed, provide an alternative.
(f) If the draft is acceptable without change, an acknowledgement to this effect would be appreciated.
(g) Normally no acknowledgement of comment is sent. All comments received by the due date will be put before the relevant drafting committee. Where appropriate, changes will be incorporated before the Standard is formally approved.

	Postal address:	Physical address:
	Standards New Zealand	Level 10
	Private Bag 2439	Radio New Zealand House
	WELLINGTON 6140	155 The Terrace
		WELLINGTON 6011
Telephone:	+64 4 498 5904	
Fax:	+64 4 498 5994	
Enquiries:	Craig Watkin	
Email	craig.watkin@standards.co.nz	
Web site:		www.standards.co.nz

RECOMMENDED CHANGES TO DRAFT STANDARD

<table>
<tr><td rowspan="2">To: Craig Watkin
Standards New Zealand
Private Bag 2439
WELLINGTON

Fax: +64 4 498 5994
Email: craig.watkin@standards.co.nz</td><td colspan="2">From: (Your Name and Address)</td></tr>
<tr><td>Closing date for comment

30 April 2009</td><td>Date of your comments</td></tr>
<tr><td colspan="3">DZ6808/v2.4   Committee: 6808
Title: Acoustics – Wind farm noise</td></tr>
</table>

Comment is preferred in electronic format using Microsoft Word 97 or above, following the layout below. Electronic drafts are available from Standards New Zealand web site at http://www.standards.co.nz.

The following form is for comments to be submitted electronically. Please email your comments to craig.watkin@standards.co.nz

GENERAL COMMENT

Type your general comments in the box. The comment box will automatically expand to accommodate comments of any length.

SPECIFIC COMMENT

Insert the number of the clause, paragraph or figure. Do not preface the number with words (i.e. 1 not clause 1). If there is no clause number, use the section heading (e.g. Preface). Insert the page, paragraph and line number as appropriate. Use a new row for each comment.

The rows will automatically expand to accommodate comments of any length. Remove unused rows, or insert additional rows as required. To insert extra rows at the end of the table, go to the last cell and press the TAB key.

Clause/ Para/ Figure/ Table No	**Page No**		**Recommended Changes and Reason** *Exact wording of recommended changes should be given*

New Zealand Standard

Acoustics – Wind farm noise

Superseding NZS 6808:1998

COMMITTEE REPRESENTATION

This draft Standard was prepared under the supervision of the P6808 Committee the Standards Council established under the Standards Act 1988.

The committee consisted of representatives of the following nominating organisations:

Energy Efficiency and Conservation Authority
Executive of Community Boards
Local Government New Zealand
Massey University
Ministry for the Environment
Ministry of Health
New Zealand Acoustical Society
New Zealand Institute of Environmental Health Inc.
New Zealand Wind Energy Association
Resource Management Law Association
University of Auckland

ACKNOWLEDGEMENT

Standards New Zealand gratefully acknowledges the contribution of time and expertise from all those involved in developing this Standard.

COPYRIGHT

Published by Standards New Zealand, the trading arm of the Standards Council, Private Bag 2439, Wellington 6140. Telephone; (04) 498 5990, Fax; (04) 498 5994, Website; http://www.standards.co.nz.

Contents

Section

Appendices

Tables

Figures

OUTCOME STATEMENT

This Standard provides suitable methods for the prediction, measurement, and assessment of sound from wind turbines. It identifies suitable noise limits for the protection of health and amenity for the purposes of the Resource Management Act 1991.

REFERENCED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS

NZS 6801:2008 Acoustics – Measurement of environmental sound
NZS 6802:2008 Acoustics – Environmental noise
NZS 6803:1999 Acoustics – Construction noise
NZS 6805:1992 Airport noise management and land use planning
NZS 6807:1994 Noise management and land use planning for helicopter landing areas
NZS 6809:1999 Acoustics – Port noise management and land use planning

PREVIOUS EDITIONS OF NEW ZEALAND STANDARDS

NZS 6808:1998 Acoustics – The assessment and measurement of sound from wind turbine generators

INTERNATIONAL STANDARDS

IEC STANDARD

IEC 61260 (1995) Electroacoustics – Octave-band and fractional-octave-band filters
IEC 61400:- - - - Wind turbines
Part 2:2006 Design requirements for small wind turbines
Part 11:2006 Acoustic noise measurement techniques

ISO STANDARDS

ISO 9613:- - - - Acoustics – Attenuation of sound during propagation outdoors
Part 1:1993 Calculation of the absorption of sound by the atmosphere
Part 2:1996 General method of calculation
ISO 1996:- - - - Acoustics – Description, measurement and assessment of environmental noise
Part 1:2003 Basic quantities and assessment procedures
Part 2:2007 Determination of environmental noise levels

GERMAN STANDARD

DIN 45681:2005-03 Acoustics – Determination of tonal components of noise and determination of a tone adjustment for the assessment of noise immissions, with Corrigenda.

NEW ZEALAND LEGISLATION

Building Act 2004
Building Regulations 1992 (Schedule 1 New Zealand Building Code)

Education (Early Childhood Centres) Regulations 1998
Resource Management Act 1991 1991
Standards Act 1988

OTHER PUBLICATIONS

Berglund, B., Lindvall, T. and Schwela, D. (Eds). 2000. *Guidelines for community noise*. World Health Organization. http://whqlibdoc.who.int/hq/1999/a68672.pdf 7 April 1999

Craven, N.J. and Kerry, G. 2001. *A good practice guide on the sources and magnitude of uncertainty arising in the practical measurement of environmental noise*. University of Salford. ISBN 0-9541649-0-3.

LATEST REVISIONS

The users of this Standard should ensure that their copies of the above-mentioned referenced documents are the latest revisions. Amendments to referenced New Zealand Standards can be found on www.standards.co.nz.

The Standards Act 1988 states that a reference made to a Standard in any Act, regulation or bylaw refers to the latest edition of that Standard. However section 23 of the Act also makes an exception where the context otherwise requires. The Environment Court has held that where a New Zealand Standard has been incorporated by reference or cited in a district plan or a condition of consent, its version (and that of any included documents, for example another New Zealand, ISO or foreign Standard), is the version current at the date of publication of the plan or condition.

Commentary
If this were not the case, a district plan or resource consent condition could be altered, not by the appropriate planning authority and processes provided by the Resource Management Act 1991, but by the Standards Council and its processes under the Standards Act.

Where a Standard is not incorporated by reference in consent conditions, a rule or national environmental standard, but is being referred to for guidance, then references to other Standards without identification of the version can be taken to refer to the latest versions of those other Standards as provided by s.23 of the Standards Act.

FOREWORD

The purpose of this Standard is to provide suitable methods for the prediction, measurement and assessment of sound from wind turbines for use in both wind farm development and local authority planning procedures. This Standard also provides guidance on the limits of acceptability for sound received at noise sensitive locations emitted from wind farms containing one or more wind turbines. This Standard may be applied during the processes of planning and developing a wind farm, then for confirming compliance with resource consent conditions covering sound levels, and also for the investigation and assessment of noise complaints from completed wind farms.

The 1998 version of this standard was written prior to significant wind farm development in New Zealand. The basic methodology proved robust, but experience and research over the following decade brought to light numerous refinements and enhancements which are now addressed in this revised version of the Standard. The terminology and format of the Standard have been updated in line with the 2008 editions of NZS 6801 and NZS 6802. This includes adopting L90 in place of L95 as a measure of sound levels. The original recommended noise limits are retained, but are added to by provision for a more stringent secondary noise limit where justified by particular local circumstances. The simple prediction method in the 1998 version has been removed, and replaced by methods using octave-band calculations and which account for a wider range of factors influencing sound propagation. Measurement procedures have been clarified and wind speeds are now referenced to the wind turbine hub-height.

REVIEW OF STANDARDS

Suggestions for improvement of this Standard will be welcomed. They should be sent to the Chief Executive, Standards New Zealand, Private Bag 2439, Wellington 6140.

1 SCOPE

1.1 General

This Standard covers the prediction, measurement and assessment of the received sound from wind farms. It recommends noise limits that balance the need to avoid disturbance to people living in the vicinity with the need to provide for development of a source of renewable energy.

C1.1
This Standard is intended to avoid adverse noise effects on people caused by the operation of wind farms while enabling sustainable development or management of natural wind resources. This can be achieved through resource planning measures which address the management of effects of wind farm noise on noise sensitive activities. This approach is consistent with other acoustical Standards, for example those relating to airports, heliports, and ports (NZS 6805, NZS 6807, and NZS 6809).

This Standard incorporates guidelines for best practice assessment of projects. Application of this Standard will enable assessment of potential noise effects on people and communities and identify appropriate mitigation measures and suitable noise limits for the purposes of the Resource Management Act 1991.

1.2 Offshore wind farms

The Standard may be applied to offshore wind farms if there are on-shore effects on people and communities. Potential offshore effects including noise and vibration upon marine flora and fauna are outside the scope of this Standard.

C1.2
Offshore wind farms are likely to have limited noise effects within the immediate coastal marine area and may be close enough to shore to have some noise effects upon people and communities on land. In this Standard special consideration is not given to offshore wind farms, but the same prediction, measurement, and assessment methods, with appropriate modification, can be used for planning and management of wind farm noise received onshore. District and regional Councils may need to address jurisdictional matters.

1.3 Wind turbine types

This Standard covers both horizontal and vertical axis wind turbines used for any purpose. For wind turbines generating electricity the Standard is applicable to sound emissions from all the components comprising the wind turbine (such as blades, gearbox, and generator) and ancillary equipment in the immediate vicinity. The Standard does not address the sound from mechanical or electrical systems connected to wind turbines used for other purposes (such as pumping or milling). Sound from sources at a wind farm other than wind turbines (such as substation equipment or machinery used for construction, servicing and maintenance) should be measured and assessed according to other Standards, such as NZS 6801, NZS 6802, and NZS 6803.

C1.3
Sources of sound from wind turbines may comprise aerodynamic noise from the blades, and to a lesser extent mechanical noise from the gearbox, generator, and hydraulic systems. For wind turbines generating electricity the associated transformer is considered part of the wind turbine.

1.4 Small wind turbines

This Standard generally applies to wind farms consisting of wind turbines with a swept rotor area greater than 200 m^2 (for example, individual blade lengths greater than approximately 8 m). Small wind turbines less than this size are generally covered by the provisions of NZS 6801 and NZS 6802, although require special measurement procedures. Where it is necessary to establish that small wind turbines comply with a noise limit in the presence of wind (which then would be outside the scope of NZS 6801) some of the measurement methods presented in this Standard may be appropriate (see 7.7). A territorial authority is not precluded from applying this Standard, in whole or in part, to small wind turbines.

C1.4
For domestic scale roof-top wind turbines not connected to the electricity grid it would normally be appropriate for noise to comply with the ordinary District Plan noise limits applicable to general mechanical and electrical equipment, rather than the specific wind farm noise limits recommended in this Standard. For example, domestic scale wind turbines should generally be subject to the same noise limits as a roof-top air handling unit or the outdoor unit of an air cooled heat pump system.

1.5 Measurement procedure

This Standard deals specifically with the measurement of sound from wind farms in the presence of wind. The measurement procedure involves capturing changes in the level of wind farm sound and background sound as wind conditions change over an extensive period of time. This goes beyond the procedures described in more general measurement Standards (such as NZS 6801). However many of the provisions and recommendations in NZS 6801 are still applicable (see section 7).

1.6 Protected premises

The provisions of this Standard are intended to protect noise sensitive locations which existed, or for which a building consent or resource consent application has been filed, at the time the application for resource consent or a notice of requirement for a designation for a new or altered wind farm is filed with a consent authority. Every noise limit and provision of this Standard shall apply only during the normal operating hours of each noise sensitive activity. For example, noise limits would generally not apply at a school building at night.

C1.6
Determining the locations where sound levels from a source are to be predicted or measured will depend on many factors. See 8.4 of NZS 6802 for further guidance

1.7 Exclusions

The following sounds associated with a wind farm are outside the scope of this Standard:

a) Sound produced during the construction and commissioning of the wind farm (to be addressed in accordance with NZS 6803); and

b) Sound from all on-site sources other than the wind turbines (to be assessed in accordance with NZS 6802).

2 INTERPRETATION

2.1 Terminology

For the purposes of this Standard, the word ‘shall’ refers to requirements that are mandatory for compliance with this Standard, while the word ‘should’ refers to practices that are advised or recommended.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘Informative’ Appendix is only for information and guidance. Informative provisions do not form part of the mandatory requirements of the Standard.

Clauses prefixed by *‘C’* are comments on the corresponding clauses and are intended only as helpful guidance. The Standard can be complied with if the comment is ignored.

2.2 Noise

Noise may be considered as sound which serves little or no purpose for the exposed persons and is commonly described as ‘unwanted sound’. If a person’s attention is unwillingly attracted to the noise it can become distracting and annoying and if this persists it will provoke a negative reaction. However, low or controlled levels of noise are not necessarily unreasonable.

2.3 Time interval

For consistency with New Zealand and international Standards, the term ‘time interval’ in this Standard has a specific meaning as the period between the start and finish of a measurement. In this Standard ‘interval’ does not refer to the gap between two separate measurements.

2.4 Definitions

In this Standard the following definitions shall apply:

AGL Above ground level

Arithmetic averaging The process of finding the mean of a data set, by summing the data and dividing by the number in the data set

Background sound level The A-frequency-weighted L90 centile level measured prior to the installation of any wind turbines in an area

Centile level, ($L_{n(t)}$) The sound level which is equalled or exceeded for n% of the measurement time interval, t. For example, $L_{90(10\ min)}$ is the level exceeded for 90% of the measurement time of 10 minutes. Where a frequency weighting has been used this should be indicated in the symbol e.g. $L_{A90(10\ min)}$. For simplicity it is acceptable to write this as L90

Condition In relation to plans and resource consents or designations, includes terms, restrictions, and prohibitions imposed by a consent authority or other requiring authority or any national environmental standard, as defined in the Resource Management Act 1991 1991

Cut-in wind speed The wind speed at which the turbine starts power production (typically in the order of 4 m/s)

decibel (dB) The term (unit) used to identify 10 times the logarithm to the base 10 of the ratio of two like quantities proportional to intensity, power or energy

District plan and district rule As defined in the Resource Management Act 1991

Emission Sound emitted from a source or sources at a defined location

Energy addition The process of summing the energy of a set of sound levels, using equation 1

$$L = 10 \lg\left[\left(10^{0.1L_1} + 10^{0.1L_2} + \ldots + 10^{0.1L_N}\right)\right] \quad \text{Equation 1}$$

where:

N is the number of samples

$L_1, L_2, \ldots, L_N$ are the sample levels

L is the level resulting from the energy addition of the set of levels

Energy subtraction The process of subtracting the energy of one sound level from another sound level, using equation 2

$$L = 10 \lg\left[\left(10^{0.1L_1} - 10^{0.1L_2}\right)\right] \quad \text{Equation 2}$$

where:

L_1 is the level to be subtracted from

L_2 is the level to be subtracted

L is the resulting level

Hertz (Hz) The unit for the frequency of a sound in cycles per second

Hub-height The height in metres AGL of the central point of the wind turbine rotor

IEC Standard A Standard published by the International Electrotechnical Commission

Impulsive sound Transient sound having a peak level of short duration, typically less than 100 milliseconds

Infrasound Sound below the normal human audible frequency range, that is below about 20 Hz

ISO Standard A Standard published by the International Organization for Standardization.

L90 and L95 See centile level

Land As defined in the Resource Management Act 1991

LEQ ($L_{Aeq(t)}$) See time-average sound level

Level	The term used to indicate that a quantity is being expressed as a decibel value
Low frequency sound	Sound below about 200 Hz
Measurement time interval	The duration of a single measurement. (For the purposes of this Standard the measurement time interval shall be 10 minutes measured to an accuracy of ±1%)
Noise floor (or self-generated noise)	The lower limit of the dynamic range of a sound level meter – usually determined by either the thermal noise of the microphone or the electrical noise of the preamplifier or both
Noise limit	A sound level as stated in a rule, plan or consent condition which is not to be exceeded
Noise sensitive activity	Activities not on the wind farm site occurring within: a) Residential buildings, including boarding establishments, homes for elderly persons, retirement villages, in-house aged care facilities, and marae. However, this excludes residential accommodation in buildings which have other predominant uses such as commercial or industrial premises and ancillary buildings such as garages b) Spaces used for overnight patient medical care c) Teaching areas and sleeping rooms in educational facilities including tertiary institutions and schools, premises licensed under the Education (Early Childhood Centres) Regulations 1998 d) Temporary accommodation facilities in residentially zoned areas, including hotels and motels
Noise sensitive location or receiver	Building accommodating a noise sensitive activity
Notional boundary	A line 20 m from any side of a noise sensitive location or the legal boundary where this is closer to the noise sensitive location
Octave-band and fractional-octave-band	Frequency bands in accordance with IEC 61260
Plan	As defined in the Resource Management Act 1991
Post-installation sound level	The A-frequency-weighted L90 centile level measured after installation when a wind farm is operating (that is, the level of the background sound and the wind farm sound together)
Prescribed time frame	'Daytime', 'night-time', 'evening', or any other relevant period specified in a rule, national environmental standard or 8.3.2 of NZS 6802
Resource consent	A land use consent or a coastal permit as defined in the Resource Management Act 1991

Small wind turbine	A wind turbine with a swept rotor area less than 200 m^2, as defined in accordance with IEC 61400-2
Sound level meter	An instrument for the measurement of sound pressure level, with frequency and time weightings that comply with the provisions of the relevant IEC Standard

Sound power level, L_W Ten times the logarithm to the base 10 of the ratio of a sound power to 1 picowatt (10^{-12} watts)

$$L_W = 10 \lg \left(W / W_0 \right) \qquad \text{Equation 3}$$

where:

W_o 10^{-12} watts

W is the sound power in watts

Sound pressure (p) The root-mean-square of the difference between the instantaneous total pressure when a sound wave is present, and the static pressure in the absence of any sound wave. Measured using a stated time-weighting and frequency-weighting or frequency band. Expressed in pascals (Pa)

Sound pressure level or sound level, L_p Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference value (20 µPa)

$$L_p = 10 \lg \left(p^2 / p_0^{\,2} \right) \qquad \text{Equation 4}$$

where:

p is the sound pressure in pascals

p_o is the reference value, 20 µPa

Spectrum The distribution by frequency of the energy content in a sound

Time-average sound level ($L_{Aeq(t)}$) 10 times the logarithm, to the base 10, of the ratio of the average of the square of the A-frequency-weighted sound pressure over a specified period of time, to the square of the reference value (20 µPa). The time interval for every LEQ measurement shall be stated

$$L_{Aeq(t_3)} = 10 \lg \left(\frac{1}{t_3} \int_{t1}^{t2} p_A^{\,2}(t)\, \mathrm{dt} \Big/ p_0^{\,2} \right) \qquad \text{Equation 5}$$

where:

t_3 is the measurement time interval between start and finish times t_1 and t_2

$L_{Aeq(t3)}$ is the LEQ over time period t_3

$p_A^2(t)$ is the square of the A-frequency-weighted sound pressure as a function of time

p_o is the reference value, 20 µPa

Ultrasound High frequency sound above the normal human audible frequency range that is, above about 20 kHz

Weighting The introduction of an electronic circuit to modify the response of a sound level meter in accordance with relevant IEC Standards, for example F-time-weighting or A-frequency-weighting

Wind farm One wind turbine or a group of wind turbines installed in close proximity to one another and electrically interconnected to a common grid

Wind farm sound level — The A-frequency-weighted L90 centile level of the wind farm sound. This quantity is not measurable directly because the contribution of background sound must be accounted for. See 7.5

Wind speed — A measurement of the speed of the prevailing wind over a discrete time period. Measured in m/s with a tolerance of 0.5 m/s

Wind turbine — A device used for extracting kinetic energy from the wind

2.5 Quantities

The quantities and symbols used in this Standard are listed in table 1.

Table 1 – Symbols for sound quantities

Quantity	**Symbol**	**Acceptable typed expression**
Background sound level	$L_{A90(10\ min)}$	L90
Post-installation sound level	$L_{A90(10\ min)}$	L90
Wind farm sound level	$L_{A90(10\ min)}$	L90
Sound power level	L_w	Lw
Time-average level	$L_{Aeq(t)}$	LEQ (Leq)

C2.5
The 1998 version of this Standard used the L95 descriptor. Since 1999 this has been updated in New Zealand Standards to the L90 descriptor. There is no significant difference between the L90 and L95 values of typical environmental sound so this change does not affect the recommended noise limits in this Standard.

2.6 Notation

In accordance with international conventions, where a sound level is A-frequency-weighted this shall be denoted by an 'A' subscript in the descriptor, for example, $L_{\mathbf{A}90(10\ min)}$. Previous conventions of adding an 'A' to the units (for example dB**A**) shall not be used when reporting sound levels in accordance with this Standard. Sound levels shall be reported in the format 'value unit symbol', for example, 38 dB $L_{A90(10\ min)}$.

3 METHODOLOGY

3.1 General

3.1.1

It has been necessary to develop specific guidelines for the prediction, measurement, and assessment of sound from wind farms because the requirements of other acoustics Standards are unsuitable.

C3.1.1
The method normally applied for the measurement of sound (set out in NZS 6801) is designed for measurements in wind speeds below 5 m/s. This is not suitable for measuring sound from wind farms because wind turbines operate in wind speeds typically from 4 m/s to 25 m/s and their sound power levels change as a function of wind speed.

The normal way of specifying environmental noise limits (set out in NZ 6802), uses methods to quantify sound that rely on a measurement of the time-average level (LEQ). It is not appropriate to measure wind farm sound using the LEQ because in a windy environment it is not possible to exclude the energy of higher wind speeds at the microphone contaminating measurements, especially when measuring relatively low level wind farm sound.

3.1.2

For the purposes of this Standard, the sound of a wind farm in the presence of wind is considered to be fairly represented by the sound levels exceeded for most (90%) of the time. This avoids the result being dominated by sound levels only present for a small part of the time and reduces contamination by the sound of wind on the microphone when levels are being measured.

3.1.3

The A-frequency-weighted L90 centile level is the metric used in this Standard for wind farm sound.

C3.1.3
The L90 sound level is that level equalled or exceeded for 90% of any time interval. It approximates the mean minimum sound level and is unaffected by higher sound levels of short-term influence caused by the energy in wind gusts which would for example determine the LEQ level and not represent the sound level due to wind farm operation alone.

The L90 is used to describe the background sound level, the post-installation sound level and the wind farm sound level. See Table 1.

3.2 Process

For a proposed new wind farm, the prediction, measurement and assessment procedure in this Standard is summarised in the flow chart set out in figure 1.

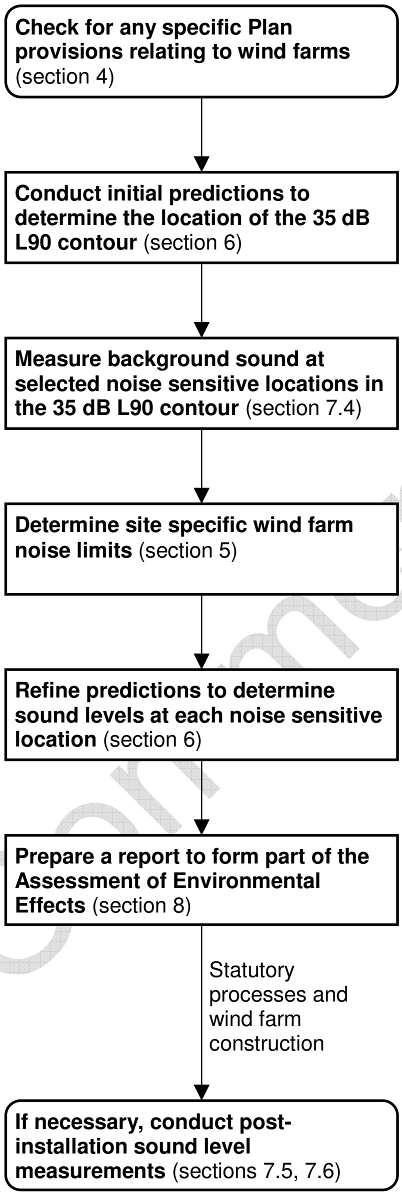

Figure 1 – Assessment process

4 LAND USE PLANNING

4.1 General

4.1.1

Wind farm sound is typically experienced at relatively low levels over wide areas and has the potential to affect nearby noise sensitive activities. However, individual's reactions to wind farm sound depend on more factors than sound level. Audibility is not an appropriate basis for setting noise limits as it is difficult to define, and could unreasonably restrict any activity that generates sound.

4.1.2

Land use planning controls relating to environmental sound attempt to provide a reasonable level of protection for the community's health, well-being and amenity, and avoid significant adverse noise effects.

4.1.3

Where provision is to be made in a district plan for wind farms, any noise limits should be based on those recommended in section 5 of this Standard.

4.2 Reverse sensitivity

People who move into an area unaware that it could be affected by wind farm noise may, understandably, experience distress and disappointment if they find themselves affected by the noise. If operation of the wind farm is subsequently affected by complaints or restraints resulting from these new residents this is known as 'reverse sensitivity'. In order to avoid this it is recommended that territorial authorities provide information that alerts prospective residents to potential noise issues for existing and future noise sensitive locations. This should apply for locations within the 40 dB wind farm sound level contour, or within the 35 dB wind farm sound level contour if a secondary noise limit has been applied. This should not include specific noise sensitive locations where it is shown in the Assessment of Environmental Effects that wind farm sound levels will be in compliance with the recommended noise limits in section 5. Wind farm developers should provide the territorial authority with the required wind farm sound level contours.

C4.2
People may commit to purchasing property without realising it will be subject to wind farm noise. An installed wind farm is usually obvious visually, but it might not be operating when prospective purchasers visit sites. There may also be a significant time lag between consent or designation and turbines being installed.

New Zealand Standards NZS 6805, NZS 6807, and NZS 6809 for airport, heliport and port noise respectively, recommend that noise contours should be included in territorial authority planning maps.

5 NOISE LIMITS

5.1 General

5.1.1

Limits for wind farm noise are required to provide protection against sleep disturbance and maintain reasonable residential amenity.

5.1.2

In order to provide a satisfactory level of protection against sleep disturbance, this Standard recommends an upper limit of wind turbine sound levels outdoors at residential locations of 40 dB L90 (see 5.2).

C5.1.2
This is based on an internationally accepted indoor sound level of 30 dB LEQ to protect against sleep disturbance (refer to Berglund, Lindvall and Schwela). This assumes a reduction from outdoors to indoors of typically 15 dB with windows partially open for ventilation. The typical reduction of 15 dB would reduce an external level of 40 dB L90 to 25 dB L90. Given that the internal target is 30 dB LEQ this allows for the difference between LEQ and L90, and for uncertainty in the outside to inside relationship.

5.1.3

The wind farm noise limit of 40 dB L90 recommended for protection of sleep is also appropriate for protecting the health of residents and maintaining reasonable amenity for most noise sensitive locations.

C5.1.3
In certain situations (see 5.3), consideration of a noise limit more stringent than 40 dB may be appropriate to further protect amenity for particular noise sensitive locations.

5.1.4

The noise limit in 5.1.2 and 5.1.3 is recommended on the basis of background sound levels at residential locations without significant wind. However, in order to determine the acceptability of predicted wind farm sound levels when there is wind driving the turbines it is necessary to compare these levels with background sound levels when there is wind (see section 7). It would not provide an acoustic benefit to restrict the wind farm sound levels to a fixed value on the occasions when an environment experiences background sound levels (caused by wind) which are higher than this value. It is therefore appropriate to combine a fixed limit with a relative noise limit for when background noise is higher. A relative noise limit of the 'background sound level +5 dB', as recommended in the previous version of this Standard for providing a reasonable level of protection for noise sensitive activities while acknowledging the variable effects of wind, has been retained.

5.1.5

Plan rules and consent conditions shall specify noise limits and the time periods during which these limits apply (see Appendix A for model consent conditions), rather than simply reference the section of this Standard where recommendations concerning appropriate limits are given.

5.2 Primary noise limit

As a guide to the limits of acceptability, at any wind speed wind farm sound levels ($L_{A90(10\ min)}$) should not exceed the background sound level by more than 5 dB, or a level of 40 dB $L_{A90(10\ min)}$, whichever is the greater. The noise limit applies at every point within the notional boundary of any noise sensitive location.

5.3 Secondary noise limit

5.3.1

In most circumstances the primary noise limit will be adequate to protect health and some degree of amenity. However, at some locations a secondary noise limit may be desirable to afford a greater degree of protection during evening and night-time. A secondary noise limit should only be considered where:

a) Background sound levels (assessed in accordance with section 7) during evening or night-time are commonly less than 25 dB when the wind farm sound levels are predicted (in accordance with section 6) to exceed the background sound level by 10 dB or more; or

b) Objectives or policies in a district plan promote a higher degree of protection of amenity, related to the sound environment of a particular locality, than generally applies in a district; or

c) District plan rules require a higher degree of protection of amenity related to the sound environment of a particular locality.

C5.3.1

The following steps provide guidance on whether a secondary noise limit can be justified:

a) Only locations where background sound levels have been assessed within the predicted 35 dB wind farm sound level contour should be considered;

b) Using predicted wind farm sound levels and measured background sound levels relating to any particular noise sensitive location under investigation, calculate for each 10-minute time interval in the evening or night-time prescribed time frames the arithmetic difference between the estimated post-installation sound level and the background sound level. The post-installation sound level should be estimated by an energy addition of the background sound level and predicted wind farm sound level. The background and wind farm sound levels should be for a range of wind conditions representative of long-term wind sampling at the wind farm;

c) The differences calculated in (b) for all 10-minute time intervals in the prescribed time frame should be arithmetically averaged (there will typically be in excess of 540 data points at night – see 7.2.2);

d) If the average difference in an evening or night-time prescribed time frame is less than 8 dB then a secondary noise limit is unlikely to be justified;

e) If the average difference in an evening or night-time prescribed time frame is greater than 8 dB then a secondary noise limit is likely to be justified.

5.3.2

Where a secondary noise limit is applicable, wind farm sound levels ($L_{A90(10\ min)}$) should not exceed the background sound level by more than 5 dB, or a level of 35 dB $L_{A90(10\ min)}$, whichever is the greater. The noise limit applies at every point within the notional boundary of an existing noise sensitive location where a secondary noise limit is shown to be justified in accordance with 5.3.1. The secondary limit only applies when the wind speed at the hub-height of the nearest wind turbine is less than 6 m/s, during evening and night-time. During daytime and for higher wind speeds the noise limit in 5.2 should always apply. It is recommended that wind farm noise limits should not be set lower than 35 dB L90 at any time.

C5.3.2

It has been found that the most sensitive time for wind farm noise is when wind speeds (and background sound levels) at noise sensitive locations are low, but wind speeds at the wind farm are above the cut-in wind speed. The exact circumstances of sensitive times vary substantially between sites and vary for the same site with different wind directions. No practical method has been identified that can accurately define all of the most sensitive times. Even with elaborate sound and wind monitoring at individual noise sensitive locations only a moderate proportion of sensitive times can be automatically identified.

The control recommended in this Standard, based on the wind speed at the turbine, will provide enhanced protection for all neighbours for a significant percentage of operational conditions. In some cases there will *still be low wind speeds at noise sensitive locations while wind farm wind speeds are above 6 m/s. However, this will only be a small proportion of potentially sensitive times.*

5.3.3

The noise limits in 5.2 and 5.3 are summarised in table 2, and their relationship to background sound levels is illustrated in figure 2.

Table 2 – Noise limits summary

Background sound level	Primary noise limit (L90)	Secondary noise limit* (L90)
> 35 dB	background + 5 dB	background + 5 dB
30 – 35 dB	40 dB	
< 30 dB		35 dB

* Introduction of a secondary noise limit is subject to conditions in 5.3.1 being met.

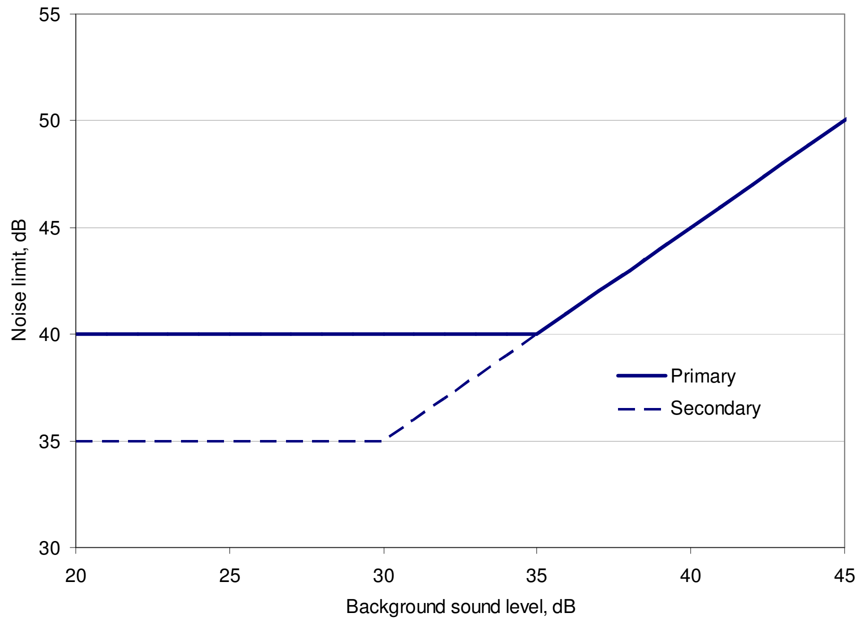

Figure 2 – Relationship between background sound level and noise limits

5.4 Special audible characteristics

5.4.1

This standard presents a method for the assessment of sound from wind turbines in the far-field, that is, at distances where the cyclic variations in sound due to blade rotation are no longer discernible. However, consideration shall be given to whether there are any special audible characteristics of the wind farm sound when comparing measured levels with noise limits.

5.4.2

The noise limits in 5.2 and 5.3 are specified without any adjustment applied for special audible characteristics (that is, tonality, impulsiveness, and audible modulation). Predicted or measured wind turbine sound levels with special audible characteristics shall be adjusted by adding up to +6 dB to the level. This adjustment is a penalty to account for the adverse subjective response likely to be aroused by sounds containing those characteristics.

5.4.3

Assessment of tonality and impulsiveness shall be conducted in accordance with Appendix B. The adjustment k_2 determined in accordance with Appendix B shall be applied to measured or predicted wind farm sound levels.

5.4.4

No appropriate objective test for audible modulation has been standardised. If a wind farm is deemed subjectively to create sound with a clearly audible modulation an adjustment of +5 dB shall be applied to the wind farm sound level for the wind conditions under which the modulation occurs.

C5.4.4
Modulation special audible characteristics occur when there is significant amplitude modulation of the aerodynamic sound from a wind turbine such that there is a greater than normal degree of fluctuation at about once per second.

It is envisaged that appropriate objective tests for modulation special audible characteristics will be developed in future.

Older styles of wind turbine used 'stall regulation', which can give rise to amplitude modulation noise effects under certain wind conditions. This effect is characterised by a 'beating' or 'thumping' sound and is significantly lower in modern 'pitch regulated' wind turbines.

5.4.5

The cumulative adjustment resulting from 5.4.3 and 5.4.4 shall not exceed 6 dB.

5.5 Other factors

5.5.1

Although wind turbines may produce some sound at (ultrasound and infrasound) frequencies considered to be outside the normal range of human hearing these components will be well below the threshold of human perception.

5.5.2

Claims have been made that low frequency noise and vibration from wind turbines have caused illness and other adverse physiological effects among a very few people worldwide living near wind farms. The paucity of evidence does not justify at this stage, any attempt to set a precautionary limit more stringent than those recommended in 5.2 and 5.3.

C5.5.2
Research claiming to show a causative link between wind turbine sound and vibro-acoustic disease has been reviewed during the preparation of this Standard. The research published at the time of this review does not show that a causative link exists.

5.5.3

No recommendations for assessing the potential impact of groundborne vibration are made because such vibration is not perceptible beyond the boundary of the wind farm. However, building vibrations induced by incident airborne sound (so-called 'secondary vibration') can act as a new source of airborne sound as well as possibly causing rattling in building elements or of loose items such as ornaments. Such rattling is known to exacerbate annoyance. Secondary vibration will occur when other sounds are also present in the environment, so a careful investigation of the source of any rattling or vibration should be made before attributing the rattling or vibration to the operation of the wind turbines.

5.6 Cumulative effects

5.6.1

Where a wind farm has been, or is proposed to be, developed over a number of separate stages, the wind farm in its final form should meet the noise limits using the background sound levels as they existed prior to the existence of any previous stage of the wind farm. This means that the wind farm sound level from a previous stage shall not be considered as part of the background sound level in determining noise limits for subsequent stages.

5.6.2

Where a new wind farm will impact on the same noise sensitive locations as an existing wind farm, it should meet the noise limits using the background sound levels as they existed before the original wind farm development. This means that the wind farm sound from another wind farm shall not be considered as part of the background sound level in determining noise limits for subsequent development. However, where noise sensitive locations are outside the 35 dB wind farm sound level contour of the original wind farm development, its contribution to the background sound level may be ignored.

5.7 Uncertainty

Prediction and measurement of sound levels from wind farms involve values of a range of parameters which can be known or predicted only within a certain tolerance. The sizes of such uncertainties determine the level of confidence in the overall results. Information on uncertainties is provided in Appendix C.

6 PREDICTIONS

6.1 Methods

6.1.1

Predictions of sound levels from wind farms are used to determine their environmental noise impact before installation takes place. This includes initial predictions to identify noise sensitive locations which might be exposed to a wind farm sound level greater than 35 dB $L_{A90(10\ min)}$ at 95% rated power, and then predictions to establish the likely wind farm sound levels at each of these locations.

6.1.2

Predictions of wind farm sound levels shall take into account:

(a) Sound power levels and positions of wind turbines;

(b) Directivity of propagation;

(c) Meteorological conditions;

(d) Attenuation due to geometric spreading;

(e) Attenuation due to atmospheric absorption;

(f) Attenuation due to absorption by the ground;

(g) Miscellaneous attenuation, for example, through foliage and buildings; and

(h) Barrier and terrain screening.

6.1.3

There is not a standardised sound propagation calculation method directly applicable to wind turbines. However, an example of a prediction method (from ISO 9613-2) which has been shown to correlate well with measured data for wind farms is detailed in Appendix D. This method provides a good balance between accuracy and completeness on one hand, and the effort of obtaining data to enter into the model on the other. Other prediction methods which can be shown to be appropriate for a given situation may be used, provided the details, assumptions, and limitations of the model are stated.

C6.1.3
The ISO 9613-2 prediction method gives results for light downwind conditions in all directions simultaneously. While this is not physically possible, it provides a conservative assessment.

6.1.4

Whatever the prediction method used, the wind farm sound levels at a given noise sensitive location shall be determined by calculating the individual contributions of each wind turbine in octave-bands from at least 63 Hz to 4 kHz, and then A-weighting and energy adding these results to determine an overall predicted level.

6.1.5

A set of overall levels shall be predicted covering the wind speed range for which sound power level data are available from the manufacturer, and calculated at hub-height wind speed.

6.1.6

The levels predicted for the wind speed corresponding to 95% rated power of the turbines should be used for determining the positions of the 35 dB and 40 dB sound level contours around the wind farm.

6.2 Sound power levels

6.2.1

The sound power levels of a wind turbine used for predicting sound levels should be obtained from the wind turbine manufacturer. For the purposes of this Standard it is recommended 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 sound power level shall be adjusted for tonality (if any). The resultant predicted time average (LEQ) wind farm sound levels occurring at receiver locations shall be taken as the predicted L90 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 shall be reported together with the technical reasons for using the differing values. If a Standard other than IEC 61400-11 has been used by the manufacturer to specify the sound power levels the Standard adopted shall be stated in reports.

C6.2.1

This Standard places priority on received sound levels at locations remote from turbines rather than emission at the turbines. For the purposes of prediction based on emission values determined in accordance with IEC 61400-11, this Standard recommends a prediction process which requires sound power LEQ emission values be converted to received L90 sound pressure level as part of the prediction process. For the purposes of this Standard, the predicted wind farm LEQ at any receiver location is deemed to be equivalent to the L90 value.

6.2.2

IEC 61400-11 requires wind turbine sound power levels to be reported against a wind speed measured at 10 m AGL. However, this Standard uses hub-height wind speeds in the analysis of the background and post-installation sound levels. This approach takes into account variations in atmospheric stability and wind shear on the wind farm site. In order to undertake predictions of sound at given hub-height wind speeds, the 10 m AGL wind speeds (V_z) reported under IEC 61400-11 shall be converted to their hub-height equivalents (V_s) using Equation 6 (Equation 7 from IEC 61400-11).

$$V_s = V_z \left[\frac{\ln\left(\frac{z_{ref}}{z_{0ref}}\right) \ln\left(\frac{H}{z_0}\right)}{\ln\left(\frac{H}{z_{0ref}}\right) \ln\left(\frac{z}{z_0}\right)} \right] \quad \text{.......... Equation 6}$$

where:

z_{0ref} is the reference roughness length of 0.05 m

z_0 is the roughness length (see table 1 of IEC 61400-11)

H is the rotor centre height (hub-height)

z_{ref} is the reference height, 10 m

z is the anemometer height

C6.2.2

Manufacturers' quoted sound power levels relate to a range of hub-height wind speeds, usually between 6 m/s (at 10 m AGL) and a wind speed producing up to 95% of the rated power of the wind turbine.

7 MEASUREMENTS

7.1 Locations

7.1.1

Sound level measurements are used:

a) to define the noise limits (see 5.2 and 5.3);
b) to verify the predicted wind farm sound levels; and
c) to confirm compliance with noise limits.

7.1.2

Every sound level measurement shall be made at clearly identified noise sensitive locations.

7.1.3

Background sound measurements and subsequent analysis to define the relative noise limits should be carried out where wind farm sound levels of 35 dB $L_{A90(10\ min)}$ or higher are predicted for noise sensitive locations, when the wind turbines are at 95% rated power.

7.1.4

When considering a group of noise sensitive locations it is acceptable to conduct background sound measurements at a representative location. These measurements shall then be used to define noise limits that apply to every noise sensitive locations in that group. The sound generating features at the representative location shall be similar in proximity and character to those at other noise sensitive locations represented by this location.

7.1.5

Sound level measurement positions shall be within the notional boundary of noise sensitive locations and where practical should be on the wind farm side of the noise sensitive locations. Measurement positions should be more than 3.5 m from any significant reflecting surfaces other than the ground (see 6.1.2 of NZS 6801), and from other structures or objects, for example, trees or power lines.

7.2 Sound data

7.2.1

Sound level measurements should be made during the whole range of wind speeds and directions generally expected at the wind farm, and include the normal operating range of the turbines, that is, from cut-in to rated power. For dual-speed wind turbines the measurements should include the cut-in wind speed for the higher generating capacity. The number of measurements made shall be sufficient to allow dependable correlations to be obtained between the sound levels and the wind speeds (see 7.4 and 7.5).

7.2.2

It is expected that a minimum of 10 days of continuous monitoring will be required to give a suitable range of data. Typically, this will give in excess of 1440 data points, which should be plotted against the appropriate corresponding wind data. It may be necessary to take further measurements if the results show:

a) An unexplainable wide scatter, or

b) 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 at a certain time of year, or for extended periods of time.

7.2.3

The instrumentation used for the sound measurements shall meet the requirements of section 5 of NZS 6801. The microphone shall be protected from extraneous wind sound by using a manufacturer's purpose designed wind shield in accordance with 7.2.3 of NZS 6801. In addition, cables, supporting tripods and any other equipment associated with the measurement system shall be secured so as to avoid extraneous wind sound generated in close proximity to the microphone. In some cases a sound level meter with a low noise floor may be necessary so that sound levels at low wind speeds can be accurately measured.

7.2.4

Sound levels shall be measured in accordance with NZS 6801 except for the greater than 5 m/s wind speed limit, and the greater than 3 m/s downwind limit, under 7.2.4 of NZS 6801. Measurement time intervals of 10 minutes shall be used.

7.2.5

Extraneous sound levels caused by events, including high local wind speeds exceeding the microphone wind shield rating, precipitation, insects, fauna, and so on, should, as far as is practical for an unattended monitoring exercise, be identified and removed from the data set.

C7.2.5

If a particular noise sensitive location is, for example, permanently surrounded by trees, the tree induced background sound may be considered as part of the general overall background sound at that location. For locations influenced by factors such as traffic sound, the background sound level measurements should include times in the early morning when traffic sound reduces to a minimum. Care should be taken to obtain background levels representative of quiet times of the year.

Methods for identifying extraneous sound events include octave-band spectrum measurements and asking residents to keep an activity log during measurements.

7.3 Wind data

7.3.1

As it is necessary to correlate sound level measurements with wind speed and direction, concurrent measurement of wind speed and direction shall be taken within the wind farm site at a known height AGL, preferably at the height of the wind turbine hub. To allow for a meaningful correlation with the sound level measurements, wind speed and direction should be monitored over 10-minute time intervals synchronised with the sound level measurement intervals, and average values found for every interval. Wind speed measurements are usually not required at the locations where the sound measurements are made.

7.3.2

If measurements have not been conducted at hub-height then the hub-height wind speeds should be predicted from wind-shear relationships. These are found by monitoring wind speeds over a range of heights (see 6.2.2). Typically, monitoring at just two heights will be sufficient.

7.3.3

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 this is not certain another position (unaffected by the turbines) should be selected for the post-installation measurements and, prior to installation of the wind farm, simultaneous wind speed measurements should be made at the two locations. The relationship between the wind speeds at the two positions will allow the post-installation measurements to be referenced to the same wind speeds as background measurements.

7.4 Background measurements

7.4.1

Plot the background sound level measurements against the wind speeds existing at the time of each measurement to obtain a scatter plot. Examine this plot to determine whether a singular regression relationship is evident. If there are markedly different groups within the scatter plot then separate scatter plots may be required for different conditions, including wind directions, wind speeds, and of times-of-day.

7.4.2

Find the regression curve which gives the best correlation coefficient possible between sound level and wind speed for each scatter plot. Use this to describe the average background sound level at different wind speeds. Sparseness of data or obvious outliers should not be allowed to unreasonably influence the regression curve. This may require removal of outliers in the data, for example, caused by periods of lawn mowing.

7.4.3

A poor correlation between wind speed and sound level does not necessarily indicate an incorrect analysis, as under some circumstances the wind conditions at the wind farm site may be different from those at the noise sensitive location. In this case it is possible that the wind turbine sound is not masked by local wind effects (that is, the background sound level is too low). However this conclusion should only be formed after the wind conditions are well understood, which might necessitate local wind monitoring.

7.4.4

Where multiple regressions are indicated (see 7.4.1) and, therefore, several regression curves have been obtained, noise limits should be set on the basis of the most stringent regression curve derived, that is, the curve showing the lowest sound levels, unless it is possible to accommodate different wind conditions in the wind farm programming. In cases where the lowest background sound levels are experienced when the wind is blowing from the noise sensitive location towards the wind farm, it is reasonable to consider additional attenuation that may occur due to upwind propagation from the wind turbines towards the noise sensitive location.

7.5 Post-installation measurements

7.5.1

Post-installation sound levels shall, where practicable, be measured at the same locations where the background sound levels were determined.

7.5.2

Post-installation measurements will capture both the wind farm sound and the background sound. In order to assess wind farm sound level alone, the contribution of the background sound shall be removed.

C7.5.2
While a simple energy subtraction of pre- and post-installation levels is not strictly mathematically correct for L90 centile levels, the difference may be taken as the L90 wind farm sound levels

7.5.3

After adjusting the post-installation measurements for background sound (see 7.5.2) draw a scatter plot of the levels against wind speed and obtain a regression curve in the same manner as described in 7.4.

7.5.4

An assessment for any special audible characteristics shall be undertaken (see 5.4) covering the range of operational wind speeds.

7.6 Compliance assessment

7.6.1

Prior to construction, the probability of the wind farm meeting the limits set out in 5.2 and 5.3, is assessed by comparing predicted wind farm sound levels with the corresponding average background sound levels as indicated by the regression curve of the background sound levels. If the predictions are less than 35 dB L90 it can be determined immediately that the wind farm will comply, otherwise comparison with background sound levels may be required to determine compliance.

7.6.2

Post-installation, to determine conformance with the limits set out in 5.2 and 5.3, a comparison shall be made between the best fit regression line of the background sound levels and the regression curve of the wind farm sound levels (that is, the measured post-installation levels adjusted for background sound) corrected for any special audible characteristics. Any correction for special audible characteristics should apply at the wind speeds at which it is assessed. Any correction should be applied to the assessed wind farm sound level before the resulting value is compared to the applicable noise limit to determine compliance.

7.6.3

If the background levels were not measured prior to installation (7.4), it may be necessary to obtain background sound level measurements for limited periods at critical wind speeds to satisfy 5.2 and 5.3 (for example, if post-installation sound levels exceed 40 dBA L90). These measurements may be for a limited range of wind speeds and directions, while the wind turbine(s) are not operating. This is commonly referred to as 'on/off' testing.

C7.6.3
Where on/off testing is to be used to show compliance, it is not necessary to turn the complete wind farm off. The contribution from individual turbines to the sound at a measurement location can be determined and those turbines which collectively are 10 dB lower than the highest contributor may remain on for the purposes of on/off testing. The duration of the off time needs only to be sufficient to get a number of representative 10-minute samples. Generally two or three samples should be sufficient.

7.6.4

When sound levels from wind turbines have been established as complying with the noise limits in 5.2 and 5.3 of this Standard, nothing in this Standard shall prevent further monitoring at any later date as a check on compliance. Testing may, for example, be conducted at a later date when investigating noise complaints.

7.7 Small wind turbines

7.7.1

As discussed in 1.4, small wind turbines may be subject to either general noise limits set down in an applicable plan, or the wind farm noise limits in section 5 of this Standard.

7.7.2

On/off testing (see 7.6.3) is often an appropriate method for measuring small wind turbine sound levels.

C7.7.2
Significant background or post-installation sound surveys are generally not warranted for small wind turbines.

7.7.3

The following procedure should be used for compliance measurements of small wind turbines:

a) Measurements shall generally be conducted in accordance with NZS 6801, although measurements can be conducted in the presence of wind;

b) Every measurement shall be expressed as the L90 sound level;

c) If the small wind turbine sound is steady then a measurement time interval of 2 minutes may be appropriate (see A2 of NZS 6802);

d) Measurements shall be conducted with the turbine operational and then repeated immediately to measure the 'background' sound level with the turbine shut off (on/off testing);

e) The background sound level with the turbine off shall be energy subtracted from the 'post-installation' sound level with the turbine operating;

f) No wind speed measurements are required as the background sound levels will be measured for wind conditions similar to those that occurred while the turbine was operating;

g) The power or rotational speed of the turbine should be recorded during testing as appropriate to define the operating characteristics; and

h) On/off measurements should be repeated on different occasions under different wind conditions as required to obtain results representing the whole operational range defined in terms of power or rotational speed.

7.7.4

If the simplified method in 7.7.3 is not sufficient to obtain representative sound levels for a small wind turbine, the full measurement procedures in section 7 of this Standard should be used.

8 DOCUMENTATION

8.1 Predictions

Any report of wind farm sound level predictions in accordance with this Standard shall refer to this Standard and provide the following:

(a) A map showing the topography (contour lines) in the vicinity of the wind farm, the position of the wind turbines, and noise sensitive locations;

(b) Noise sensitive locations for which wind farm sound levels are calculated;

(c) Wind turbine sound power levels;

(d) The make and model of the wind turbines;

(e) The hub-height of the wind turbines;

(f) Distance of noise sensitive locations from the wind turbines;

(g) Calculation procedure used;

(h) Meteorological conditions assumed;

(i) Air absorption parameters used;

(j) Ground absorption parameters used;

(k) Topography/screening assumed; and

(l) Predicted far-field wind farm sound levels.

8.2 Background sound levels

Any report of background sound level measurements and assessment in accordance with this Standard shall refer to this Standard and provide the following:

(a) Description of the sound monitoring equipment including ancillary equipment;

(b) The location of sound monitoring positions;

(c) Description of the anemometry equipment including the height AGL of the anemometer;

(d) Position of wind speed measurements;

(e) Time and duration of the monitoring period;

(f) Averaging period for both sound and wind speed measurements;

(g) Atmospheric conditions: the wind speed, direction, and rainfall at the wind farm position shall be recorded;

(h) Number of data pairs measured (wind speed in m/s, background sound in L90);

(i) Description of the regression analysis; and

(j) Graphical plot showing the data scatter and the regression curve.

8.3 Compliance assessment

Any report of wind farm post-installation sound level measurements and compliance assessment made in accordance with this Standard shall refer to this Standard and provide the following:

(a) Description of the sound monitoring equipment including any ancillary equipment;

(b) A statement confirming the use of A-frequency-weighting;

(c) The monitoring positions;

(d) Description of the anemometry equipment including the height AGL of the anemometer;

(e) Position of wind speed measurements;

(f) Make and model of the wind turbines;

(g) Number of operational wind turbines;

(h) Time and duration of monitoring period;

(i) Averaging period for both sound and wind speed measurements;

(j) Atmospheric conditions: the wind speed, direction, and rainfall at the wind farm position shall be recorded;

(k) Number of data pairs measured (wind speed in m/s, sound in L90);

(l) Description of the regression analysis;

(m) Graphical plot showing the data scatter and the regression line;

(n) Graphical plot showing the data scatter and the regression lines for both the background and the wind farm in operation;

(o) Assessment of special audible characteristics; and

(p) A statement that the wind farm complies with relevant limits – or not – as determined from the results of the measurements.

APPENDIX A
MODEL CONSENT CONDITIONS

(Informative)

The following are model consent conditions for noise from a new wind farm. Resource consent conditions for many wind farms using the previous version of this Standard were substantially longer and more complex than these model conditions. Such extensive conditions are no longer necessary as the technical details have now been incorporated into this version of the Standard and can be referenced by the following conditions:

1. The consent holder shall ensure that, at any wind speed, wind farm sound levels measured and assessed in accordance with NZS 6808:2009 *Acoustics – Wind farm noise* do not exceed the background sound level by more than 5 dB, or a level of 40 dB $L_{A90(10\ min)}$, whichever is the greater. The assessment position shall be at any point within the notional boundary of any noise sensitive locations existing or for which a building or resource consent had been filed at [date the wind farm application was filed].

2. Within three months of the wind farm becoming operational, the consent holder shall appoint a suitably qualified acoustic engineer to conduct post-installation sound level measurements and a compliance assessment in accordance with NZS 6808:2009 *Acoustics – Wind farm noise* to demonstrate compliance with condition [1]. Within one month of the post-installation measurements the compliance assessment report shall be submitted to the [regulatory, planning or environmental manager], [Council name]. These post-installation measurements and compliance assessment shall be repeated and resubmitted following any subsequent changes to the wind farm.

3. The consent holder shall ensure that noise from the substation and noise from activity and equipment on the site other than wind turbines, measured in accordance with the provisions of NZS 6801:2008 *Acoustics – Measurement of environmental sound*, and assessed in accordance with the provisions of NZS 6802:2008 *Acoustics – Environmental noise*, does not exceed the following noise limits during the stated time frames. The assessment position shall be the same as for condition [1].

Daytime 7am to 10pm	55 dB $L_{Aeq\ (15\ min)}$
Night-time 10pm to 7am the following day	40 dB $L_{Aeq\ (15\ min)}$
Night-time 10pm to 7am the following day	75 dB L_{AFmax}

4. Noise from all construction, maintenance and decommissioning work shall be measured, assessed and controlled in accordance with NZS 6803:1999 *Acoustics – Construction noise*. The consent holder shall ensure that construction noise does not exceed the limits set out in Tables 2 and 3 of NZS 6803.

5. The consent holder shall prepare and adopt a Construction Noise Management Plan documenting how compliance with condition [4] will be achieved and maintained. Prior to any construction works the Construction Noise Management Plan shall be submitted to the [regulatory, planning or environmental manager], [Council name].

If an Assessment of Environmental Effects only defines a 'consenting envelope' or gives different turbine options then the following additional condition should be included.

6. The consent holder shall appoint a suitably qualified acoustic engineer to conduct wind farm sound level predictions for the final selected wind turbine type and layout in accordance with NZS 6808:2009 *Acoustics – Wind farm noise* to demonstrate predicted compliance with condition [1]. The prediction report shall be submitted to the [regulatory, planning or environmental manager], [Council name] prior to the wind farm construction.

APPENDIX B
SPECIAL AUDIBLE CHARACTERISTICS

(based on Appendix B4 of NZS 6802:2008)

(Normative)

B1 Introduction

Sound that has special audible characteristics, such as tonality or impulsiveness, is likely to cause adverse community response at lower sound levels, than sound without such characteristics. Subjective assessment can be sufficient in some circumstances to assess special audible characteristics.

CB1

Special audible characteristics may be:

a) Tonal, for example, a hum or a whine. Examples include transformers, gear box whine;
b) Impulsive sound, for example, bangs or thumps.

Users should note that direct measurement and calculation by the reference method is a feature now available in some instrumentation systems, enabling instant results to be available in the field without complex post-measurement processing.

B2 Objective test methods

If there is doubt about the presence of tonality, the following two methods provide an objective measure for tonality. The simplified test method may be carried out using 1/3 octave-band measurement equipment. The reference test method requires the use of narrow band analysis. If the simplified method does not indicate tonality, it may still be necessary to use the reference method to confirm the presence or absence of tonality. In addition, the reference method can properly assess modulated tones where the tone is varying or complex tones with many closely-spaced tone components.

B3 Simplified test method for tonality

A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one-third octave-bands in the sound spectrum. An adjustment for tonality shall be applied if the L90 in a one-third octave-band exceeds the arithmetic mean of the L90 in both adjacent bands by more than the values given in table B1.

Table B1 – One-third octave-band level differences

One-third octave-band	Level difference
25 - 125 Hz	15 dB
160 - 400 Hz	8 dB
500 - 10000 Hz	5 dB

NOTE – At frequencies below 500 Hz the criterion could be too severe and tones might be identified when none is actually audible. For complex spectra the method is often inadequate and the reference method should be used.

B4 Reference test method for tonality

The reference method is that prescribed as Annex C to ISO 1996-2:2007 or an equivalent method.

CB4

An example of an alternative method is the DIN 45681 method.

B5 Adjustment k_2

Where special audible characteristics are confirmed, the value of the adjustment (k_2) shall be 5 dB for that sample, provided that where the reference method is used, the value of the adjustment (k_2) may be 6 dB where justified. The adjustment k_2 shall only be applied to measurement time intervals in which special audible characteristics are present. Only one adjustment value (k_2) shall be applied to each measurement, even if more than one type of special audible characteristic is present.

APPENDIX C
UNCERTAINTY

(reproduced from Appendix A of NZS 6801:2008)

(Informative)

The uncertainty of sound levels as determined in this Standard depends on the sound source, the measurement time interval, the weather conditions, the distance from the source, the measurement method and instrumentation.

It is good practice to state the uncertainty and confidence level for all sound levels determined in accordance with this Standard. Uncertainty should be determined in accordance with the procedures in Craven and Kerr (2001). These procedures involve determining the standard uncertainty for every source of uncertainty in the measurement/assessment process, and summing these standard uncertainties in quadrature (root sum of squares) to obtain the combined uncertainty. If a source of uncertainty is assumed to have a normal distribution, standard uncertainty is related to standard deviation, but this is not always the case and rectangular distributions are also common.

When comparing a sound level with an applicable noise limit, the sound level should be deemed to comply if the sound level is equal to or less than the noise limit. It should be deemed not to comply if the sound level is greater than the noise limit, regardless of the uncertainty. Where compliance or non-compliance is marginal and contested, steps should be taken to reduce the uncertainty, where possible.

APPENDIX D
PREDICTION METHOD EXAMPLE

(Informative)

D1 Example method

An appropriate prediction method for the purposes of this Standard is detailed in ISO 9613-2 and is outlined in the following steps:

Step 1. Determine octave-band downwind sound levels from a single turbine to be used in the wind farm according to Equation 7 for each wind speed and for each octave-band over a range which at least includes 63 Hz to 4 kHz.

$L_f = L_{Wf} + D_{Cf} – A_f$ ....Equation 7

where:

L_f is the predicted sound pressure level downwind of a single wind turbine for the octave-band with centre frequency f;

L_{Wf} is the octave-band sound power level in decibels, produced by the point sound source, which is assumed to be the rotor hub of the wind turbine;

D_{Cf} is the directivity correction for the source; and

A_f is the octave-band attenuation, in decibels, that occurs during propagation from the point sound source to the receiver.

The total attenuation A_f is the arithmetic sum of the following types of attenuation:

A_{div} the attenuation due to geometrical divergence, defined as:

$$A_{div} = 20\lg(d) + 11$$ ....Equation 8

where:

d is the distance in metres from the source to the receiver

A_{atm} the attenuation due to atmospheric absorption, defined as:

$$A_{atm} = \alpha \frac{d}{1000}$$ ....Equation 9

where:

d is the distance in metres from the source to the receiver, and

α is the atmospheric attenuation coefficient for each octave-band as given in table D1 or as otherwise defined in ISO 9613-1.

Table D1 – Atmospheric attenuation coefficient for octave-bands

Temperature, °C	Relative humidity, %	Atmospheric attenuation coefficient α, dB/km							
		Octave-band centre frequency, Hz							
		63	125	250	500	1000	2000	4000	8000
10	70	0.1	0.4	1.0	1.9	3.7	9.7	32.8	117.0
20	70	0.1	0.3	1.1	2.8	5.0	9.0	22.9	76.6
30	70	0.1	0.3	1.0	3.1	7.4	12.7	23.1	59.3
15	20	0.3	0.6	1.2	2.7	8.2	28.2	88.8	202.0
15	50	0.1	0.5	1.2	2.2	4.2	10.8	36.2	129.0
15	80	0.1	0.3	1.1	2.4	4.1	8.3	23.7	82.8

A_{gr} the attenuation due to ground attenuation, as described in 7.3 of ISO 9613-2;

A_{bar} the attenuation due to screening of obstacles or barriers including terrain features, as described in 7.4 of ISO 9613-2; and

A_{misc} the attenuation due to miscellaneous effects including propagation through foliage or buildings, as described in Annex A of ISO 9613-2.

Step 2. Apply the A-weightings appropriate to each octave-band (values as given in table D2)

Table D2 – A-weighting values for octave-bands

	Octave-band centre frequency, Hz							
	63	125	250	500	1000	2000	4000	8000
Values to be added, dB	-26.2	-16.1	-8.6	-3.2	0	+1.2	+1.0	-1.1

Step 3. Combine the resulting A-weighted octave-band levels into an overall A-weighted value, for each wind speed, by means of Equation 1 (that is, the band values are 'energy added').

D2 Simplified method

Under certain circumstances, a number of simplifications may be made to the ISO 9613 model to allow a simple prediction of wind farm sound levels. These conditions are as follows:

(a) The ground between the wind farm and the receiving point of interest is generally flat or of steady incline, and no barriers to line-of-sight exist;

(b) There is no significant build-up of buildings or foliage between wind turbines and the receiving location which screens line-of-sight;

(c) The ground near the turbines and the receiving location is generally porous and uncompacted;

(d) The turbine spectrum is not dominated by tones.

Under these circumstances an approximation to the value calculated by the ISO 9613 model may be made by following the steps in D1 but at Step 1 make the following simplifications:

(e) Ignore A_{bar} and A_{misc}

(f) Approximate A_{gr} by the following equation:

$$A_{gr} = 4.8 - (2h_m / d)[17 + (300 / d)]$$ ....Equation 10

where:

h_m is the average height of propagation between source and receiver and

d is the distance between source and receiver.

Where equation 9 results in a number less than zero, a value of zero shall be assumed for A_{gr}.

When using the above approximation for A_{gr} the directivity correction D_{Cf} shall be 3.0 dB to account for the ground reflection near the source. This is equivalent to the assumption of hemispherical spreading used in previous version of this standard.

CD2

This method is similar to the process used in Equation 1 in NZS 6808:1998, except that it is necessary to calculate the result separately for each octave-band, which avoids the errors due to the simplification of air absorption, and a nominal calculation of ground absorption is included.

No allowance is made for shielding of sources, and in a situation where shielding is present, this method will over-predict the sound level. In such situations, the full ISO 9613 method should be used, as it properly addresses shielding and the interaction with ground absorption.