

# **Compliance Protocol for Wind Turbine Noise**

Guideline for Acoustic Assessment and Measurement

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## Guideline for Acoustic Assessment and Measurement

The MOE is committed to ensuring that its policies and protocols regarding wind farms continue to reflect current science. Should new information come to light, we will review and amend our policies and protocols as required.

All requirements relating to Renewable Energy Approval (REA) applications and renewable energy projects are contained in Part V.0.1 of the *Environmental Protection Act* and O. Reg. 359/09 which can be found at Ontario's e-laws website at [www.e-laws.gov.on.ca](http://www.e-laws.gov.on.ca) or the official volumes printed by Publications Ontario for the authoritative text. Specific references to the Noise Guidelines for Wind Farms (2008) are made throughout this protocol and readers are recommended to have access to a copy of the guideline itself to refer to the exact language when reading.

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PIBS# 8540e

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## **PART A: GENERAL**

### **A1 Purpose**

The purpose of this document is to provide guidance for ministry staff to perform assessments in the event of a complaint concerning noise due to the operation of a wind turbine generator or a wind farm. The intent is to provide ministry staff the essential technical tools to address noise complaints. These technical tools may be used in an integrated approach for noise complaint assessment and resolution. It is important that the assessment and resolution be consistent and clear to the complainant, to the wind farm operator, and to the ministry.

The focus of this guideline is to outline an assessment procedure for noise complaints by determining compliance with the applicable sound level limits.

### **A2 Scope**

The scope of the document aims to encompass the pertinent aspects of noise complaints resulting from the operation of wind turbines. This involves a range of issues including turbine locations and distances, compliance with conditions of MOE approvals, screening of complaints and detailed measurements of the wind turbine noise.

The procedures included in this document address primarily large modern commercial/industrial wind turbines with rated electrical power in the MW range, i.e. Class 4 turbines, and the focus is mainly on receptors in rural areas. However, some of the information may also be used to address smaller wind turbines, Class 2 and 3 wind turbines, and installations in urban areas.

Complaints about wind turbine noise in the infrasound or ultrasound ranges (i.e. outside the normal audio range), transformer substation noise, and other issues such as shadow flicker or health effects are beyond the scope of this document.

#### **A2.1 Qualitative Screening Process**

The initial screening is a qualitative assessment to focus on compliance issues related to conditions and parameters used in the approval process.

Based on the results from the qualitative screening, a decision can be made whether to perform quantitative screening or carry out detailed acoustic measurements at the site of the complainant. In some cases, based on any screening result in this protocol, the wind farm operator may decide to voluntarily undertake actions to reduce the noise impact.

## **A2.2 Quantitative Screening Process**

The quantitative screening involves short-term attended acoustic measurements and/or acoustic recording at the complaint receptor to determine if detailed acoustic measurement is needed to assess compliance with noise limits.

## **A2.3 Detailed Acoustic Measurements**

The detailed acoustic measurement procedure is intended to determine the sound levels produced by the operation of wind turbines at all applicable wind speeds to assess compliance with the MOE sound level limits.

## **A3 Background**

Unlike most industrial or commercial noise sources, the sound immissions from wind turbines occur during wind conditions that typically induce significant levels of background noise due to the wind itself.

The background sound levels during conditions when the wind turbines are in operation near its rated generating capacity are comparable to the sound levels emitted by the wind turbines themselves. Consequently, determination of compliance is challenging and it is necessary to have an accurate account of the contribution from each source. An additional challenge is that conventional acoustic instrumentation, normally used for the measurement of industrial noise sources, is prone to produce erroneous signals due to the interaction of wind blowing over the microphone (including a windscreen), particularly at winds speeds at 4 m/s and higher. Consequently, in order to accurately measure the sound levels due to wind turbines alone, a specialized technique is necessary.

The ministry's sound level limits are based on the lowest background sound level at receptor location outdoors subject to a lowest limit at nighttime (in rural areas) of 40 dBA. The limits represent an hourly "average" value based on the total acoustic energy from the source during the one hour period.

It is important to note that although wind turbine sound levels may be audible it does not necessarily mean that it is out of compliance.

## **A4 References**

The current version of each referenced publication is listed below. All the referenced publications may be replaced with updated or amended versions from time to time. Consult the MOE website for the latest versions of the reference documents and other applicable guidelines issued by the MOE.

- [1] CAN/CSA-C61400-11-07, "Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement techniques".



- [2] ISO 1996-2, "Acoustics - Description, assessment and measurement of environmental noise - Part 2: Determination of environmental noise levels"
- [3] ISO 9613-2, Acoustics – Attenuation of Sound During Propagation Outdoors, Part 2: General Method of Calculation.
- [4] Model Municipal Noise Control By-Law - Final Report. August 1978. Ontario Ministry of the Environment.
- [5] Noise Guidelines for Wind Farms – Interpretation for Applying MOE NPC Publications to Wind Power Generating Facilities - October 2008. PIBS 4709e.
- [6] Publication NPC-101 - Technical Definitions (part of Reference [4]).
- [7] Publication NPC-102 - Instrumentation (part of Reference [4]).
- [8] Publication NPC-103 - Procedures (part of Reference [4]).
- [9] Publication NPC-104 - Sound Level Adjustments (part of Reference [4]).

## **A5 Definitions**

The following definitions apply to this guideline:

“Ambient sound level”  
means background sound level.

“Approval”  
means a Certificate of Approval issued under section 9 of the Environmental Protection Act, a Renewable Energy Approval issued under section 47.3 of the Environmental Protection Act, an Environmental Compliance Approval which would be issued under Part II.1 of the Environmental Protection Act, or an approval or decision made under the Environmental Assessment Act.

“A-weighting”  
means the frequency weighting characteristic as specified in the International Electrotechnical Commission (IEC) Standard 61672, and intended to approximate the relative sensitivity of the normal human ear to different frequencies (pitches) of sound . It is denoted as “A”.

“A-weighted sound pressure level”  
means the Sound Pressure Level modified by application of an A-weighting network. It is measured in decibels, A-weighted, and denoted “dBA”.

“Background sound level”  
means the sound level that is present in the environment, produced by noise sources other than the source under impact assessment. The background sound level is typically caused by sounds from nature for receptors removed from urban areas, or by road traffic for receptors in urban/suburban areas. Highly intrusive short duration noise caused by a source such as an aircraft fly-over or a train pass-by (including light rail

transit, subways and streetcars) is normally excluded from the determination of the background sound level.

“Binning”

means the processing of measured sound level data by arranging the accumulated data in “bins” representing integer wind speeds,  $\pm 0.5$  m/s. Each “bin” is centered on the integer speed and spans 1 m/s.

“Class 1 Area”

means an area with an acoustical environment typical of a major population centre, where the background sound level is dominated by the activities of people, usually road traffic, often referred to as “urban hum”.

“Class 2 Area”

means an area with an acoustical environment that has qualities representative of both Class 1 and Class 3 Areas:

- (a) sound levels characteristic of Class 1 during daytime (07:00 to 19:00 or to 23:00 hours);
- (b) low evening and night background sound level defined by natural environment and infrequent human activity starting as early as 19:00 hours (19:00 or 23:00 to 07:00 hours).

“Class 3 Area”

means a rural area with an acoustical environment that is dominated by natural sounds having little or no road traffic, such as the following:

- (a) a small community with less than 1000 population;
- (b) agricultural area;
- (c) a rural recreational area such as a cottage or a resort area; or
- (d) a wilderness area.

“dBA”

means the A-weighted sound pressure level.

“Decibel”

means a dimensionless measure of Sound Level or Sound Pressure Level, denoted as dB.

“Exclusion limit”

means the lowest value of the sound level limit at a specific point of reception for the stationary source, i.e., the sound level limit when the background sound level is below this exclusion limit.

“Equivalent sound level,  $L_{eq}(T)$ ”

means the A-weighted sound pressure level of a steady sound carrying the same total energy in the time period T as the observed fluctuating sound. The time period T is given in hours.  $L_{eq}$  without a specific time period means one hour  $L_{eq}$  (1).

“Ministry”

means the Ontario Ministry of the Environment.

“MOE”

means the Ontario Ministry of the Environment.

“Noise”

means unwanted sound.

“Point of reception”

has the same meaning as in the Noise Guidelines for Wind Farms and is subject to the same qualifications described in that document.

“Practitioner”

has the same meaning as the qualified acoustical practitioner.

“Qualified acoustical practitioner”

means a person trained and currently active in the field of environmental acoustics and noise/vibration control who is familiar with Ministry noise guidelines and procedures and has a combination of formal university education, training and experience necessary to perform the wind turbine noise measurements. The qualified acoustical professional should preferably be a Professional Engineer.

“Receptor”

means a Point of Reception or a Participating Receptor.

“Setback”

means the horizontal distance (plan-view) in metres separating the wind turbine coordinates and the coordinates of a noise receptor.

“Sound level”

means the A-weighted Sound Pressure Level.

“Sound level limit”

means the limiting value described in terms of the one hour Equivalent Sound Level,  $L_{eq}$ .

“Sound pressure”

means the instantaneous difference between the actual pressure and the average or barometric pressure at a given location. The unit of measurement is the micro Pascal ( $\mu\text{Pa}$ ).

“Sound power level”

means the rating that,

- (a) is given to a wind turbine by the manufacturer of the wind turbine, calculated in accordance with standard CAN/CSA-C61400-11-07, “Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques”, dated October 2007, rounded to the nearest whole number, and
- (b) applies in respect of the wind turbine when the wind turbine is operating at 95 per cent of its name plate capacity;

“Sound pressure level”

means twenty times the logarithm to the base 10 of the ratio of the effective pressure ( $\mu\text{Pa}$ ) of a sound to the reference pressure of  $20 \mu\text{Pa}$ .

“Tonality”

means a pronounced audible tonal quality of the sound such as a whine, screech, buzz or hum.

“Urban hum”

means aggregate sound of many unidentifiable noise sources due to the activities of people and primarily composed of road traffic related sound sources.

Other technical terms are defined in References [5] and [6].

## **PART B: COMPLAINT ASSESSMENT – QUALITATIVE SCREENING**

### **B1 Purpose**

The qualitative screening is the initial step in the assessment of a wind turbine noise complaint. It does not require detailed calculations or sophisticated measurements and uses conservative assumptions regarding the noise impact of wind turbines.

The qualitative screening assists in evaluating the complaint with respect to specific parameters used in the approval. Following this initial screening, and if required, further qualitative screening may be performed.

### **B2 Qualitative Screening**

The following steps are recommended to be performed in sequence but can also be performed in parallel.

#### **B2.1 Step 1 - Initial Screening**

Determine the current setback from the receptor to the closest wind turbine. A receptor located within 1,500 m of a Class 4 wind turbine may be considered to be potentially in a noise area ranging from about 30 dBA and up depending on the distance and number of turbines (within about 3 km of the receptor). Outside this 1,500 m distance any detectable sound levels from land based wind turbines will not exceed the ministry's sound level limits.

Therefore, further noise assessment would not be practical or necessary and this fact should be communicated to the complainant.

Alternatively, if the closest wind turbine is within the 1,500 m zone then proceed with Step 2.

#### **B2.2 Step 2 – Site Visit and Interview**

If the closest wind turbine is within the 1,500 m zone, then obtain a full description of the nature of complaint including specific details about the noise from the complainant. The purpose is to identify from the complainant specific details about the problem that would assist in determining further action. A set of open questions are in the sample form in Appendix A.

Take note from site observations of any other noise sources within the complainant's property and in the immediate vicinity (i.e. dryers, coolers, fans, generators, etc). Also take note of any unusual features such as trees, shrubbery, water features, hills, ancillary buildings, etc. The purpose is to identify noise sources and features that will

have an impact on the background noise and possibly on acoustic measurements if needed.

Determine on-site the actual setback distance to the closest wind turbine and proceed to Step 3.

### **B2.3 Step 3 - Check for Setback Reductions**

Verify the locations of all wind turbines up to 1,500 metres surrounding the property of the complaint site in order to determine if there has been a significant change in the layout of the wind farm as compared to the layout that was submitted in the application for approval.

Note: Any significant discrepancies with respect to the ministry's approval (CofA or REA) will require the owner/operator to apply for an amendment to the ministry's approval.

If it is found that the discrepancy in some wind turbine locations (within the 1,500 m radius) resulted in setbacks from the complaint receptor reduced by more than 4 % from the approved layout then the change will be considered as significant.

Note: Technically, a reduction in setback due to the closest wind turbine of 4% can result in an increase in sound level at the receptor of 0.35 dB. Although such increase is not perceptible, it may result in excess over the sound level limit at that location.

In this case, the noise assessment needs to be verified using the as-built layout affecting the complainant's location and using the prediction model according to the Noise Guidelines for Wind Farms (2008), Reference [5]. Specifically the parameters to be used must reflect the worst-case noise impact by assuming the maximum acoustic immissions from the turbines and lowest sound level limit (i.e. high wind shear conditions).

If the modelling calculations determine a level greater than the sound level limit, the owner/operator of the wind facility should be required to implement appropriate noise abatement measures to achieve compliance with the limits. However, further noise assessment may not be required if the owner of the wind turbine is prepared to voluntarily reduce the sound levels.

If there are no reductions of setback greater than 4% then proceed to Step 4.

### **B2.4 Step 4 - Check Predicted Noise Impact**

Check the calculated sound level in the Summary Noise Impact Assessment Table corresponding to the receptor in the approved noise assessment report for the wind farm. If the results indicate compliance with a margin of at least 5 dB below the limit

(i.e. 35 dBA or lower), further noise assessment at the site would be at the discretion of ministry staff.

Note: Since the prediction model uses conservative parameters to estimate the noise impact at receptors, it is very unlikely that the sound level limits would be exceeded. Also, in this low range acoustic measurements of wind turbine noise are difficult to make. This fact may be reported to the complainant as part of the complaint resolution.

However, if the predicted level is less than 5 dB from the limit (i.e. above 35 dBA) then further assessment at the complaint location would be warranted. – proceed to Section C, Complaint Assessment - Quantitative Screening or, alternatively, Section D, Complaint Assessment –Detailed Acoustic Measurements.

## **PART C: COMPLAINT ASSESSMENT – QUANTITATIVE SCREENING**

### **C1 Purpose**

The quantitative screening process has been designed to provide additional information to that obtained in the initial qualitative screening process. The quantitative screening involves noise measurements and use of instrumentation.

The purpose of the quantitative screening process is to determine the need for further action in evaluating the complaint resulting from wind turbine noise. Detailed long-term acoustic measurements at the site of the complaint may be appropriate as a result of the quantitative screening.

### **C2 Attended Screening Measurements**

The measurement of sound levels at points of reception located at significant distances from the turbines require special instrumentation, specific testing conditions, and careful analysis of the data.

The objective is to determine the wind turbine equivalent sound level at a point of reception. It is recommended that the attended screening measurements be carried out at times when the background sound level is very low. To the extent possible, the measurements should be performed at times when wind turbines operate near maximum output capacity while wind speeds at ground elevation (height of 4.5 m or less) are low, optimally not exceeding 3 m/s with a 4 m/s maximum.

#### **C2.1 Sound Level Measuring Instrumentation**

The sound level measuring instrumentation consists of the following:

- Integrating sound level meter
- Acoustic calibrator
- Wind screen, tripod, etc

The sound level measuring instrumentation needs to meet the following requirements:

- Sound level meter specifications according to the IEC standard 61672-1 Sound Level Meters, Part 1: Specifications.
- Class 1 or Class 2 microphone systems – see the note below for explanation.
- The instrumentation having a constant frequency response over at the 20 Hz to 20000 Hz frequency range.



Note: Should Class 2 rather than Class 1 microphone systems be used, it is recommended that the noise floor of the microphone be below 25 dB.

## **C2.2 Acoustic Calibrator**

The complete sound measurement system, including any recording, data logging or computing systems, shall be calibrated immediately before and after the measurement session at one or more frequencies using an acoustic calibrator on the microphone.

The acoustic calibrator shall have an accuracy equal to or better than  $\pm 0.3$  dB and fulfill the requirements of Class 1 according to IEC 60942 in the temperature range where it is used.

## **C2.3 Measurement Procedure**

### **C2.3.1 Receptor location**

Measurements for the purposes of complaint assessment should be performed at a point of reception.

### **C2.3.2 Time of measurements**

The noise measurements associated with the complaint assessment should be mindful of the complaint character. In addition, the measurements should consider predictable worst case parameters such as high wind shear and wind direction toward the receptor. It is recommended that the measurements be performed during lowest background noise conditions. This period of time is normally in the late evening or night time.

### **C2.3.3 Microphone height**

The measurement position at a given receptor is outside the identified receptor dwelling and at a height of 1.5 metres for single storey dwellings or 4.5 metres for two-storey dwellings. Preferably, the measurement height should be consistent with the receptor height modelled for approval purposes.

### **C2.3.4 Microphone position**

Appropriate judgement is expected to be used when positioning the microphone. Some general guidance is given below:

- The microphone position shall be sufficiently away from any large reflecting surfaces (5 metres recommended). This requirement does not apply if using a small vertical reflecting board attached to the building façade.
- The microphone should be located at a point near the receptor dwelling that is not shielded from the wind turbine noise.

- Wherever possible, the microphone should not be located near deciduous trees or foliage that may affect the noise.

### **C2.3.5 Wind speed measurement location**

The wind speed measurement position should be in the vicinity of the noise measurement position, at a height of 10 metres above ground. The measurement position should represent an open area where the wind is not shielded by nearby buildings or objects.

The wind speed measurement should also be performed at the microphone height to comply with the maximum wind speed requirement specified below.

Wind speed measurements should be carried out at the same time as the noise measurements.

### **C2.3.6 Acoustic measurements**

The objective of the measurements is to determine the overall equivalent sound level  $L_{eq}$  when the turbines are operational under the following conditions:

- The optimum range of wind speeds at the microphone location is up to 3 m/s.
- The maximum wind speed at the microphone location does not exceed 4 m/s.
- The background sound level does not affect the measurement of the overall equivalent sound level  $L_{eq}$ .

### **C2.3.7 Extraneous noise sources**

Measurement needs to be inhibited when the sound level is affected by noise from extraneous sources such as vehicle noise, dogs barking and wind gusts, i.e. other than wind turbines.

### **C2.3.8 Duration of measurement**

Noise measurements need to be performed over a minimum period of one hour. The actual accumulated time period of the measured  $L_{eq}$  needs to be at least 20 minutes. This should represent the worst case equivalent sound level  $L_{eq}$  during the one hour period, following the inhibition of the measurements due to extraneous sources.

### **C2.3.9 Tonality (tonal assessment)**

Should a tone be clearly audible, a 5 dB tonal adjustment (addition) should be to the measured  $L_{eq}$  in accordance with Publication NPC-104, Sound Level Adjustments.

Should a quantitative determination of tonality be required, a 1/3 octave band frequency analysis of the turbine noise needs to be performed. Tonality adjustment

should be made in accordance with the procedure described in the international standard ISO 1996-2.

### **C2.3.10 Background sound level**

This procedure is based on the measurement of the overall equivalent sound level  $L_{eq}$  and does not in principle require a separate measurement of the background sound level. Nevertheless, knowledge of the background sound level would be useful. If possible and if conditions allow, the background sound level should be determined. Note that the background sound level does not include the contribution from the wind turbine noise.

Where appropriate, the background sound level should be measured using the same instrumentation and for the same duration as the overall sound level described in this section. The background sound level is subtracted from the overall level to determine the equivalent sound level of the wind turbines.

## **C2.4 Documentation**

The following information should be reported:

1. Conditions during the measurement, including but is not limited to:
  - time and dates of the measurement
  - temperature and humidity
  - weather conditions
  - range of wind speeds encountered
  - wind direction
  - confirmation that the wind turbines were operating
2. Statement about of whether tonality was observed.
3. Results of measurements in terms of the equivalent sound level  $L_{eq}$ .
4. Diagram/drawing showing the location of instrumentation, location of buildings and other local features, and location of turbines.

## C2.5 Compliance with Limits

The  $L_{eq}$  results of the attended measurements obtained during this screening process should be compared with the applicable limits contained in Reference [5] and given in the table below:

<b>Standardized Wind Speed at 10 m Height, m/s</b>	<b>Sound Level Limit dBA</b>
<5	40.0
6	40.0
7	43.0
8	45.0
9	49.0
10	51.0

## **C3 Acoustic Recording by Resident/Complainant**

### **C3.1 Scope**

The method of measurement described in this section provides information on instrumentation requirement, measurement procedure, data analysis and documentation related to the measurement and recording of the wind turbine noise performed by the resident.

The measurement and analysis procedure applies to sound in the audible frequency range (20 Hz to 20 kHz) and can include the measurement of the A-weighted equivalent sound level,  $L_{eq}$ , at a receptor. The application of this procedure is recommended for receptors located at a distance up to 1,000 metres from the nearest turbine.

### **C3.2 Overview**

This acoustic screening measurement is initiated by a resident via a remotely operated tamper proof recording device. The approach may be utilized when it is not possible for ministry staff to make attended observations or measurements at a resident's home during periods when a resident deems wind turbine noise disturbing.

The procedure involves installing a special sound recording system/device at a resident's home to collect between three to nine, 10 minute sound recordings, of the offending noise at the exact time of the occurrence.

The recording equipment must have the capability of being activated by a resident at any time from inside the resident's home. It must automatically perform a recording of set duration (10 minutes), and stores the audio recording along with the date and time of the recording, for off site analysis.

The off site analysis will also require operational information of the wind farm. In addition, it will require details of atmospheric conditions at the resident's home and at the hub height at the closest or relevant wind turbines. If the analysis indicates that wind turbine noise is audible and that the majority of the 10 minute  $L_{eq}$  exceed the applicable limits additional assessment would be warranted. This additional work may consist of:

- More acoustic recordings at the resident's location.
- Attended screening measurements in accordance with section C2.
- Detailed acoustic measurements in accordance with section D.

### **C3.3 Instrumentation**

#### **C3.3.1 Acoustic Instrumentation**

The instrumentation is intended for short term attended noise measurements. The recording device can be composed of either a digital recorder or a sound level meter capable of recording sound files and  $L_{eq}$  simultaneously. The minimum requirements of both devices and the peripheral equipment are noted below:

##### **Device 1: Digital Recorder**

1. Class 1 or Class 2 microphone systems – see the Note 2 below for explanation.
2. Ability to be triggered from indoors by a resident
3. The instrumentation having a constant frequency response over at the 20 Hz to 20000 Hz frequency range.
4. The filters meeting the requirements of IEC 61260 for Class 1 filters.
5. Ability to record a 10 minute digital audio waveform file (wav file) at a sampling rate of at least 44 kHz;

Note 1: A .wav file is a Microsoft and IBM audio file format standard for storing an audio bit stream on a personal computer.

6. In addition to the requirements above, appropriate software is also required to:
  - determine the 10 minute  $L_{eq}$  from the 10 minute sample,
  - analyse the files in 1/3 rd octaves, or
  - obtain a Fast Fourier Transforms (FFTs) from the measurements.

Note 2: Given the long term and outdoor nature of the measurements, along with special wind screen requirements (outlined below), and with the understanding that Class 1 microphone systems are designed for indoor lab settings, some Class 2 microphone systems may be used. It is noted that the Class 2 microphone may not strictly meet the requirements outlined, but appropriateness of Class 2 microphones was demonstrated during the field-testing. If Class 2 microphone systems are used, caution is advised to ensure that:

- Noise floor of the microphones is below 30 dB
- Frequency range is suitable between at least 20 Hz to 8000 Hz, where microphone response is effectively flat.

## **Device 2: Sound level meter**

The sound level meter needs to meet the following requirements:

1. Type 1 sound level meter according to the IEC standard 61672-1 Sound Level Meters, Part 1: Specifications.
2. Class 1 or Class 2 microphone systems – see the note 2 above for explanation.
3. The instrumentation having a constant frequency response over at the 20 Hz to 20000 Hz frequency range.
4. The filters meeting the requirements of IEC 61260 for Class 1 filters.
5. The instrumentation being capable of measuring audio recordings continuously during the measurement campaign, at sampling rate of at least 44 kHz.

### **C3.3.2 Narrowband spectra determination (Both Devices)**

This equipment shall fulfill the relevant requirements for IEC 61672 over the frequency range of 20 Hz to 20000 Hz.

### **C3.3.3 Acoustic calibrator**

The complete sound measurement system, including any recording, data logging or computing systems, shall be calibrated immediately before and after the measurement session at one or more frequencies using an acoustic calibrator on the microphone.

The acoustic calibrator shall have an accuracy equal to or better than  $\pm 0.3$  dB and fulfill the requirements of Class 1 according to IEC 60942 in the temperature range where it is used.

### **C3.3.4 Wind screens**

For the measurement of wind turbine sound immission, a primary wind screen shall be used which consists of open cell foam with a diameter of approximately 90mm centred on the diaphragm of the microphone. A larger diameter secondary wind screen (approximately 450 mm) is recommended to be used to reduce the noise from wind blowing over the microphone.

The specifications of the secondary wind screen are indicated in IEC 61400-11 as follows:

*“...could, consist of a wire frame of approximate spherical shape, at least 450 mm in diameter, covered with a 13 mm to 25 mm layer of open cell foam with a porosity of 4 to 8 pores per 10mm. This secondary spherical windscreen shall be placed symmetrically over the smaller primary windscreen.”*

### **C3.3.5 Anemometer**

The anemometer and its signal processing equipment shall have a maximum deviation from the calibration value of  $\pm 0.2$  m/s in the wind speed range from 4 m/s to 12 m/s. The anemometer itself shall have accuracy equal to or better than  $\pm 0.5$  m/s at 10m/s and an output resolution of  $\pm 0.2$  m/s or less. Wind direction should be measured within 5 degrees. The data should be averaged over at least a 5 minute period.

### **C3.3.6 Calibration**

All the relevant equipment must have calibration traceable to an accredited acoustic laboratory. The maximum time from the last calibration shall be as stated for each item of equipment. The calibration schedule shall adhere to the requirements set out in NPC-202.

### **C3.3.7 Tamper Proof Case**

The device shall be secured within a tamper proof case within the resident's dwelling. With the exception of the device's external triggering component, the resident should not have access to the controls of the recording device. It is noted that the 10 m long microphone extension cable, microphone and external power supply may all protrude out of the tamper proof case.

### **C3.3.8 External Trigger**

The external triggering device should be capable of starting a 10-minute digital recording when activated.

## **C3.4 Measurement Procedure**

### **C3.4.1 Time of Measurements**

Measurements are to taken at the discretion of the resident.

### **C3.4.2 Microphone height**

The measurement position at a given receptor is outside the identified receptor dwelling and at a height of 1.5 metres for single storey dwellings or 4.5 metres for two-storey dwellings. Preferably, the measurement height should be consistent with the receptor height modelled for approval purposes.

### **C3.4.3 Microphone position**

Appropriate judgement is expected to be used when positioning the microphone. Some general guidance is given below:



- The microphone position shall be sufficiently away from any large reflecting surfaces (5 metres recommended). The microphone should be located at a point near the receptor dwelling that is not shielded from the wind turbine noise.
- Wherever possible the microphone should not be located near trees or foliage which may dominate the noise environment. This guideline may not always be satisfied depending on the receptor location, but every effort to select an appropriate location should be made.

#### **C3.4.4 Anemometer Location**

The wind measurement position should be in the vicinity (within 5 m) of the noise measurement position, at the same height as the microphone. The wind measurement position should represent an open area where the wind is not shielded by nearby buildings or objects.

#### **C3.4.5 Anemometer Measurements**

Wind speed and direction measurements are carried out simultaneously and synchronously with the noise measurements. For each five minute interval, the average wind speed, and wind direction should be recorded.

#### **C3.4.6 Acoustic measurements**

Sound recordings are initiated with the device's external triggering component at the discretion of the resident. The audio sample is recommended to be recorded with a sampling rate of 44 kHz (not compressed).

#### **C3.4.7 Supplementary Measurements**

For the time frame of assessment, (days when recordings were activated by a resident), the wind farm operator must provide a detailed summary of the wind plant's operation. This information will include as a minimum:

1. identification of the closest wind turbine,
2. output production of relevant turbines ( predicted sound immissions greater than 30 dBA at the resident's home),
3. relevant rotor RPMs,
4. the total number of turbines operating
5. wind speed and direction data at hub-height of the closest wind turbine.
6. The analysis of these recordings will consist of aural listening for identification of wind turbine noise relative to other background sources. Results are to identify segments of audible wind turbine sounds useful for possible data

analysis of sound level (A-weighted  $L_{eq}$  and  $L_{90}$  of segments), frequency analysis (for tonality) or temporal variations (amplitude modulation).

(For reference if Part D of this Protocol is used.)

#### **C3.4.8 Number of Measurement Intervals**

No less than three and no more than nine 10-minute recordings are required to be recorded by the resident.

#### **C3.4.9 Tonality (tonal assessment)**

Should a tone be clearly audible, a 5 dB tonal adjustment (addition) should be to the measured  $L_{eq}$  in accordance with Publication NPC-104, Sound Level Adjustments.

Should a quantitative determination of tonality be required, a 1/3 octave band frequency analysis of the turbine noise needs to be performed. Tonality adjustment should be made in accordance with the procedure described in the international standard ISO 1996-2.

#### **C3.5 Documentation**

The following information should be reported:

1. Conditions during the measurement, including but not limited to:
  - time and dates of the measurement
  - temperature and humidity range
  - general weather conditions
  - range of wind speeds
  - range of wind directions
2. Confirmation that the wind turbines were operating
3. Statement about of whether tonality was observed during acoustic recordings.
4. Results of measurements in terms of the equivalent sound level  $L_{eq}$ .
5. If applicable (turbines are audible in recordings) comparison of the measured/calculated 10 minute  $L_{eq}$  values to the applicable Sound Level Limit, and a statement of whether the recordings are in compliance with those limits.
6. Diagram/drawing showing the location of instrumentation, location of buildings and other local features, and location of turbines.

### C3.6 Compliance

- A: If the wind turbine(s) are not audible in any of the recordings then additional analysis is not required. The recordings have indicated that wind turbine noise is in compliance with the limits noted in 2008 Noise Guidelines.
- B: If the wind turbine(s) are audible in a recording (does not include extraneous noise sources) then the following additional analysis is required for the subject recording.
1. determine the value of the 10 minute  $L_{eq}$  via software or obtain it directly from the recording device; (The transmission loss of the secondary wind screen in octave band if applicable, should also be accounted for in the calculation of the 10 minute  $L_{eq}$ .)
  2. determine if the wind turbine noise is tonal.
  3. obtain the average wind speed at the microphone height (1.5 or 4.5 metres) over the 10 minute recording session.

Results of the 10 minute  $L_{eq}$  (including tonal penalty if applicable) are to be compared against the applicable sound level limits contained in the 2008 Noise Guidelines and shown in the following Table.

<b>Standardized Wind Speed at 10 m Height, m/s</b>	<b>Sound Level Limit dBA</b>
<5	40.0
6	40.0
7	43.0
8	45.0
9	49.0
10	51.0

## **PART D: COMPLAINT ASSESSMENT – DETAILED ACOUSTIC MEASUREMENTS**

### **D1 General**

Detailed acoustic measurements are normally carried out subsequent to a screening that suggests that the turbine(s) may be out of compliance with ministry sound level limits.

#### **D1.1 Purpose**

This section establishes a detailed measurement procedure for long term acoustic measurements of wind turbine noise. The objective of the detailed measurements is to determine the sound level produced by the operation of wind turbines at all applicable wind speeds for comparison with the MOE sound level limits.

This measurement procedure also applies to acoustic audit measurements that may be required as a condition of an MOE approval or any other instrument under ministry legislation. The ministry may also require, at its own discretion, that specific measurements or assessment additional to those described herein be carried out.

The measurements and analysis in this section should only be carried out by a qualified acoustical practitioner or someone under the supervision of a qualified acoustical practitioner.

#### **D1.2 Scope**

The method of measurement described in this section provides information on instrumentation requirement, measurement procedure, data analysis and documentation.

The method applies to a single turbine, or a group of turbines. It has been developed primarily for large modern commercial/industrial wind turbines with rated electrical power in the MW range; however, it may also be applicable to smaller turbines. It should be noted that typical sound power levels of large modern commercial/industrial wind turbines are in the range of 100 – 107 dBA.

The measurement and analysis procedure applies to sound in the audible frequency range (20 Hz to 20 kHz) and is based on the measurement of the A-weighted equivalent sound level,  $L_{eq}$ , at a receptor. The application of this procedure is recommended for receptors located at a distance up to approximately 1,000 metres from the nearest turbine. This distance recommendation is only approximate; for example, it may be further limited by the local ambient sound levels. In general, however, it is expected that beyond 1,000 metres from the turbine, it would not be possible to differentiate between the ambient noise and noise produced by turbine operations.

## **D1.3 Overview**

The principle of the procedure is to measure the overall equivalent sound level at a point of reception at times when the turbines are operational and when they are not operational (parked). In both cases, the measurements are made by logging the equivalent sound level  $L_{eq}$  in one-minute intervals along with 1/3rd Octave band spectra within the 20 Hz to 20,000 Hz frequency range. Additionally, audio recordings of each interval are recorded for the purposes of post measurement listening and source verification. It is recommended that a minimum of 120 one-minute intervals when the turbines are operational be measured for each integer wind speed.

The ambient noise measurements are carried out with turbines in the vicinity of the point of reception parked. The parked turbines are those that, if operating, would contribute or would likely to contribute to the ambient equivalent sound level. In general, every effort should be made to park all the turbines that would cause the cumulative predicted contribution at the receptor to rise above 30 dBA. It is recommended that a minimum of 60 one-minute intervals be measured for each integer wind speed when the turbines are not operational.

Following the determination of the overall  $L_{eq}$  and the ambient  $L_{eq}$  at all applicable wind speeds and conditions, the ambient  $L_{eq}$  is logarithmically subtracted from the overall  $L_{eq}$  to determine the  $L_{eq}$  produced by the wind turbines.

Wind speed and direction measurements are carried out simultaneously and synchronously with the noise measurements for each one-minute interval.

## **D2 Instrumentation**

### **D2.1 Acoustic Instrumentation**

The instrumentation is intended for long term, outdoor, unattended noise measurements.

#### **D2.1.1 Sound level measurement**

The sound level measuring instrumentation needs to meet the following requirements:

- Type 1 sound level meter according to the IEC standard 61672-1 Sound Level Meters, Part 1: Specifications.
- Class 1 or Class 2 microphone systems – see the note below for explanation.
- The instrumentation having a constant frequency response over at the 20 Hz to 20000 Hz frequency range.
- The filters meeting the requirements of IEC 61260 for Class 1 filters.

- The instrumentation being capable of measuring audio recordings continuously during the measurement campaign, at sampling rate of at least 8000Hz.

Note: Given the long term and outdoor nature of the measurements, along with special wind screen requirements (outlined below), and with the understanding that Class 1 microphone systems are designed for indoor lab settings, some Class 2 microphone systems may be used. It is noted that the Class 2 microphone may not strictly meet the requirements outlined, but appropriateness of Class 2 microphones was demonstrated during the field-testing. If Class 2 microphone systems are used, practitioners are urged to use caution to ensure that:

- Noise floor of the microphones is below 25dB
- Frequency range is suitable between at least 20Hz to 8000Hz, where microphone response is effectively flat.

It is expected that should the sound levels outside the range of such microphones be a concern, that more sensitive microphones be employed in those circumstances.

#### **D2.1.2 Narrowband spectra determination**

This equipment shall fulfill the relevant requirements for IEC 61672 over the frequency range of 20 Hz to 20000 Hz.

#### **D2.1.3 Acoustic calibrator**

The complete sound measurement system, including any recording, data logging or computing systems, shall be calibrated immediately before and after the measurement session at one or more frequencies using an acoustic calibrator on the microphone.

The acoustic calibrator shall have an accuracy equal to or better than  $\pm 0.3$ dB and fulfill the requirements of Class 1 according to IEC 60942 in the temperature range where it is used.

#### **D2.1.4 Wind screens**

For the measurement of wind turbine sound immission, a primary wind screen shall be used which consists of open cell foam with a diameter of approximately 90mm centred on the diaphragm of the microphone. A larger diameter secondary wind screen (approximately 450 mm) is recommended to be used to reduce the noise from wind blowing over the microphone.

The specification of the secondary wind screen are indicated in IEC 61400-11 as follows:

*“...could, for example, consist of a wire frame of approximate spherical shape, at least 450 mm in diameter, covered with a 13 mm to 25 mm layer of open cell foam with a*

*porosity of 4 to 8 pores per 10mm. This secondary spherical windscreen shall be placed symmetrically over the smaller primary windscreen.”*

### **D2.1.5 Additional measures**

Although the use of the secondary windscreen is preferred, in an effort to increase the signal to noise ratio between the turbine noise and the ambient environment, practitioners may use additional techniques such as more detailed analysis techniques making use of correlation, or vertical reflecting boards. The use of these boards shall adhere to the recommendations of the IEA Recommended practices for wind turbine noise immission testing. If any of these additional measures are to be used, this should be disclosed and discussed with the ministry staff prior to conducting the measurements.

## **D2.2 Non-acoustic Instrumentation**

Non-acoustic instrumentation comprises of anemometers.

The anemometer and its signal processing equipment shall have a maximum deviation from the calibration value of  $\pm 0.2$  m/s in the wind speed range from 4 m/s to 12 m/s. The anemometer itself shall have accuracy equal to or better than  $\pm 0.2$  m/s at 10m/s and an output resolution of  $\pm 0.1$  m/s or less. Wind direction should be measured within 5 degrees.

## **D2.3 Calibration**

All the relevant equipment must have calibration traceable to an accredited acoustic laboratory. The maximum time from the last calibration shall be as stated for each item of equipment.

## **D3 Measurement Procedure**

### **D3.1 Receptor Location**

Measurements for the purposes of complaint assessment should be performed at a point of reception. Note that acoustic audit measurements should be performed at varying locations, including points of reception. The number of measurement locations for an acoustic audit are expected to vary from site to site. Some general recommendations to establish a minimum number of locations are given in the Acoustic Audit section.

### **D3.2 Time of Measurements**

The MOE sound level limits, contained in Reference [5], and associated modelling parameters were developed in the context of predictable worst case scenario. Consequently, the complaint assessment should be mindful of the predictable worst case parameters such as high wind shear and wind direction toward the receptor.

Naturally, the complaint assessment needs to consider issues such as timeliness of the assessment and input of the complainant.

### **D3.3 Noise Measurement Location**

#### **D3.3.1 Microphone height**

The measurement position at a given receptor is outside the identified receptor dwelling and at a height of 1.5 metres for single storey dwellings or 4.5 metres for two-storey dwellings. Preferably, the measurement height should be consistent with the receptor height modelled for approval purposes.

#### **D3.3.2 Microphone position**

As each site may have its own constraints as to where the microphone may be placed, practitioners are expected to use appropriate judgement when locating the microphone. Some general guidance is outlined as follows:

- The microphone position shall be sufficiently away from any large reflecting surfaces (5 metres recommended). This requirement does not apply if using a small vertical reflecting board attached to the building façade.
- The microphone should be located at a point near the receptor dwelling that is not shielded from the wind turbine noise.
- Wherever possible the microphone should not be located near deciduous trees or foliage that may affect the noise. Although, depending on the receptor location, the above guidance may not always be satisfied, every effort should be made to comply with the above guidance.

### **D3.4 Wind measurement location**

The wind measurement position should be in the vicinity of the noise measurement position, at a height of 10 metres above ground. The wind measurement position should represent an open area where the wind is not shielded by nearby buildings or objects.

### **D3.5 Acoustic Measurements**

The objective of the measurements is to determine the overall equivalent sound level  $L_{eq}$  when the turbines are operational and the background equivalent sound level  $L_{eq}$  when the turbines are parked. Following the determination of the overall  $L_{eq}$  and the background  $L_{eq}$  at all applicable wind speeds and conditions, the ambient  $L_{eq}$  is subtracted from the overall  $L_{eq}$  to determine the  $L_{eq}$  produced by the wind turbines.

Wind speed and direction measurements are carried out simultaneously and synchronously with the noise measurements for each one-minute interval.



### **D3.5.1 Acoustic measurements with turbines operational**

Measurements are conducted with the turbines operational by logging the equivalent sound level in one-minute intervals, one-minute Leq, along with 1/3rd Octave band spectra within the 20Hz to 20,000Hz frequency range. Additionally, audio recordings of each interval are required to be recorded for the purposes of post measurement listening and source verification. The audio sample is recommended to be recorded with a sampling rate of 8000Hz or higher (not compressed) and which can then be used in the determination of tonality. It should be noted that this limits the range of tonality analysis to below 3kHz. If analysis of tones at higher frequencies is desired, a higher sampling rate will be required.

### **D3.5.2 Acoustic measurements with turbines parked**

Ambient noise measurements shall be carried out at a point of reception with all turbines in the vicinity of the receptor point parked. The prediction model will be used to determine the number of turbines that require parking in order for the predicted noise contribution of the wind farm to fall to 30 dBA or less.

### **D3.6 Non-acoustic Measurements**

Wind speed and direction measurements are carried out simultaneously and synchronously with the noise measurements. For each one minute interval, the average wind speed along with the minimum and maximum wind speeds are recorded, along with the wind direction.

### **D3.7 Supplementary Measurements**

The following measurements, while not mandatory, are of benefit to the analysis:

1. Wind speed at turbine hub height
2. Wind speed at noise measurement height (i.e. 1.5 m, 4.5 m, etc)
3. Turbine Power output
4. Temperature and humidity
5. Statistical noise indices during each interval ( $L_n$ )

It is understood that measuring and documenting the wind shear coefficient,  $m$ , may be of value. The wind shear coefficient should also be calculated and reported using the measured hub height and measured 10 m high location using the equation below. It is not recommended to use the equation below for determining the wind speed at other heights, or obtaining the wind shear using extrapolated points.

$$m = \frac{\log\left(\frac{v_{hub}}{v_{10}}\right)}{\log\left(\frac{h_{hub}}{h_{10}}\right)}$$

Equation 1

where:

- m is the wind shear coefficient
- $v_{hub}$  is the wind speed at turbine hub height
- $v_{10}$  is the wind speed at a height of 10 metres
- $h_{hub}$  is the turbine hub height
- $h_{10}$  is the height of 10 metres.

The turbine power output is important to track as it will indicate whether the turbine is generating power. However, it should be noted that in order to correlate this to the sound levels, it may be difficult to look at the total plant output versus specific turbine output. As a guide, it is recommended that only the closest turbine power output be referenced.

## **D3.8 Number of Measurement Intervals**

### **D3.8.1 Overall equivalent sound level – turbines operational**

No less than 120 one-minute intervals are required to be measured for each integer wind speed (within  $\pm 0.5$  m/s) for the data set to be considered large enough to conduct the analysis. This total number applies to intervals which have not been omitted in the data reduction phase (see earlier section). In an audit scenario, this amount of data is required between 4 – 7 m/s integer wind speeds inclusively.

### **D3.8.2 Overall equivalent sound level – turbines parked**

Ambient noise measurements should be performed with the turbines parked and conducted within the same general measurement period. Measurements of ambient noise obtained during other periods are not recommended and should only be used with great caution to ensure that they represent the “current” ambient noise. No less than 60 one-minute intervals are required to be measured for each integer wind speed (within  $\pm 0.5$  m/s) for the ambient noise level to be determined.

Preconstruction ambient monitoring may be carried out in an audit scenario provided that the location is specified as part of the MOE Approval, and the same exact location is used post construction. The season of measurement should be sufficiently close to

that of the turbine operational case in order that the same ambient vegetation and atmospheric patterns apply to both measurement sessions. For this scenario, it is recommended that the practitioner/wind farm owner provide an audit testing plan as part of the approvals process, which identifies the locations the audits are to be taken.

### **D3.8.3 Tonality (tonal assessment)**

If there is a concern regarding the tonal nature of the turbine noise, the requirements in this section will apply. Such analysis may be triggered if there is observed tonal characteristic sound from the turbine, or if the turbine manufacturer's noise test report shows tonal audibility ( $\Delta L_{a,k}$ ) to be a positive value greater than 3, see References [1] and [2].

In the event that tonality measurements are to be carried out or analysed, for each integer wind speed, at least five one-minute intervals are required for wind turbine noise and background noise (turbines parked). These intervals shall be as close as possible to the integer wind speed.

## **D4 Acoustic audit procedure**

The acoustic audit measurement procedure is the same as the complaint measurement procedure subject to the following additions or changes:

### **D4.1 Locations**

As a general guideline, for new wind plants constructed as per the 2008 Noise guidelines, the total number of receptors which may require noise immission measurements should be the higher of:

1. Number of turbines divided by 10; or
2. Number of receptor locations with noise levels predicted above 37 dBA divided by 5; or
3. A maximum of 5 measurement locations

The locations chosen should represent worst case, non-participating receptor locations. In case of non-integer ratios, the result should be rounded to the closest integer.

### **D4.2 Time of Measurements**

The MOE Sound Level Limits were developed along with modelling parameters to account for the predictable worst case scenario. As such, the requirement in the modelling stage is to account for the Average Summer night time wind velocity profile. As specific sites may exhibit worst case wind shear coefficients outside of summer months, it is recommended that the Acoustic Audit measurements be carried out during the month with the highest average night time wind shear coefficient, and an average

hub height wind speed greater than 4 m/s. This will ensure that the worst case wind velocity profile can be expected during times where, typically, the turbines will be operational and generating power. This time-frame can be determined from historical wind measurements for the site –usually carried out in wind studies prior to the construction of the wind farm.

Due to weather constraints and instrument reliability, conducting measurements between December and February is not recommended in Canada and actual equipment constraints should be verified prior to conducting any measurements.

## **D5 Data Processing and Analysis**

### **D5.1 General**

The accumulated sound level data must be processed before it can be used to determine compliance. This processing involves data reduction and filtering to allow for comparison with the sound level limits.

### **D5.2 Data Reduction and Filtering**

In order for the data to be considered for the analysis the following requirements must be met for each interval. Intervals that do not satisfy these requirements need to be omitted or removed from the data set:

1. Interval must be measured between 22:00 and 05:00. i.e. night time only.
2. Rainfall must not have happened within at least one hour of the measurement interval
3. The maximum or minimum wind speed measured during the interval should not differ from the average by more than 2 m/s.

The above requirements apply to both turbine operational and parked cases. Additional filters can be considered such as wind direction, and removing individual events. However, it is acknowledged that this may not be feasible in all cases. Additional filters may also be helpful in cases where signal-to-noise is low.

The above requirements apply to both turbine operational and parked cases. Additional filters can be considered such as wind direction, and removal of individual events may be helpful where signal-to-noise is low. This additional filtering should be discussed with the ministry staff to ensure that the data would be accepted by the ministry.

### **D5.3 Effects of Insects and Fauna**

The analysis shall identify the influence of any insects, fauna, or other extraneous but constant sources of noise and verify them through sound recordings. Noise from insects can be removed from the 1/3rd Octave spectra of each measurement. It has to

be shown, however, that the contribution of the wind turbine noise in those frequencies is minimal.

#### **D5.4 Determination of Turbine Sound Level**

The measured sound levels when the turbines are operating represent the overall sound levels, including the ambient noise. In order to determine the sound level produced by the wind turbines, the ambient sound level needs to be subtracted from the overall level.

Following the filtering and data reduction described above, the resulting equivalent levels ( $L_{eq}$ ) for all the remaining intervals should be plotted separately for both cases: turbines operating; and turbines parked. The  $L_{eq}$  levels should be plotted against the measured 10 m wind speed for those intervals.

The noise contribution of the wind turbines can be determined by logarithmically subtracting the ambient levels from the turbine operational levels. As stated previously, the ambient sound levels must be measured during the same measurement campaign.

For wind speeds where less than 120 intervals were measured, the results can still be reported, but do not constitute a data set large enough to make a compliance assessment.

#### **D5.5 Data Analysis**

It is recommended that the “binning method” be used for the analysis of the accumulated one-minute sound level data.

The accumulated sound levels, one-minute interval levels, need to be binned by integer wind speed. Binning means arranging the sound level data within a “bin” representing an integer wind speed,  $\pm 0.5$  m/s. Once binned, the mean and standard deviation of the  $L_{eq}$  is computed for each wind speed. This is carried out for both the “turbines operating” and the “turbines parked” cases. Subsequently, for each integer wind speed, the turbine noise contribution is computed by logarithmically subtracting the mean  $L_{eq}$  of the “turbines parked” case from that of the “turbines operating” case.

Should it be required, the standard deviation of the resultant turbine sound level can be determined by using appropriate statistical methods. This added information may provide insight into the variation of the turbine contribution and aid in understanding the turbine immission levels at the measurement point.

#### **D5.6 Tonal Assessment**

The tonal audibility shall be determined for all valid data records as per ISO-1996-2. If a tone is identified at any of the wind speeds, the average tonal audibility correction shall be added to the final noise contribution of the wind turbine at those wind speeds.

## D6 Assessment of Compliance

Results of measurements and analysis are to be compared against the applicable sound level limits contained in Reference [5] and shown in the following Table 3.

**Table 3 Sound Level Limits for Wind Turbines**

Wind Speed (m/s) at 10 m height (agl)	4	5	6	7	8	9	10
Wind Turbine Sound Level Limits Class 3 Area, dBA	40.0	40.0	40.0	43.0	45.0	49.0	51.0
Wind Turbine Sound Level Limits Class 1 & 2 Areas, dBA	45.0	45.0	45.0	45.0	45.0	49.0	51.0

Results shall be rounded to the nearest integer for comparison with the limit for each wind speed category.

In order to be deemed in compliance the numerical values of the results must not exceed the limit at each wind speed category.

## D7 Documentation

The following information should be reported:

1. Conditions during the measurement. This includes, but is not limited to:
  - a The dates of the measurement campaign
  - b The temperature range
  - c The general weather conditions
  - d The range of wind speeds encountered
  - e The wind rose showing the wind directions encountered
  - f A statement, signed by the operator of the wind farm, confirming that the wind turbines in question were operating as normal for the duration of the campaign (except during parked ambient noise measurements)
2. The result of the analysis outlined in section 3.4 should be presented both graphically and tabulated. They should include:
  - a The total sound curve/levels
  - b The ambient sound curve/levels

- c The turbine sound curve/levels
- d Calculated standard deviation on all 3 sets, at each integer wind speed (if applicable)

The results must cover a wind speed range of at least 4 – 7 m/s as outlined in earlier sections.

3. Acknowledgement of whether tonality was observed from the audio signals. If tonality is observed, the tonal adjustments that were applied in the analysis should be reported.
4. Comparison of the total contribution of the turbines (including tonality) to the applicable Sound Level Limit, and a statement of whether the wind farm is in compliance with those limits.

## **PART E: APPENDICES**

### **E1 Appendix A: Noise Complaint Form**

Resident's name and address

Describe the problem:

When did the noise become a problem?

Where in your property is the noise a problem? (Look for i.e. inside or outside the house).

When is the noise a problem? (Look for i.e. night-time, weekdays, season, etc)

For how long does the noise problem occur? (This will help deciding the approach for attended measurements)

Describe the ambient conditions when noise is a problem (ie wind strength, wind general direction, approximate temperature, precipitation, other)

What are the ambient conditions when the noise is not a problem? (What else is audible?)

Compared to other noise sources in your area, why is this noise a problem? (Look for i.e. louder, distinct pitch, other characteristics).

Other comments.