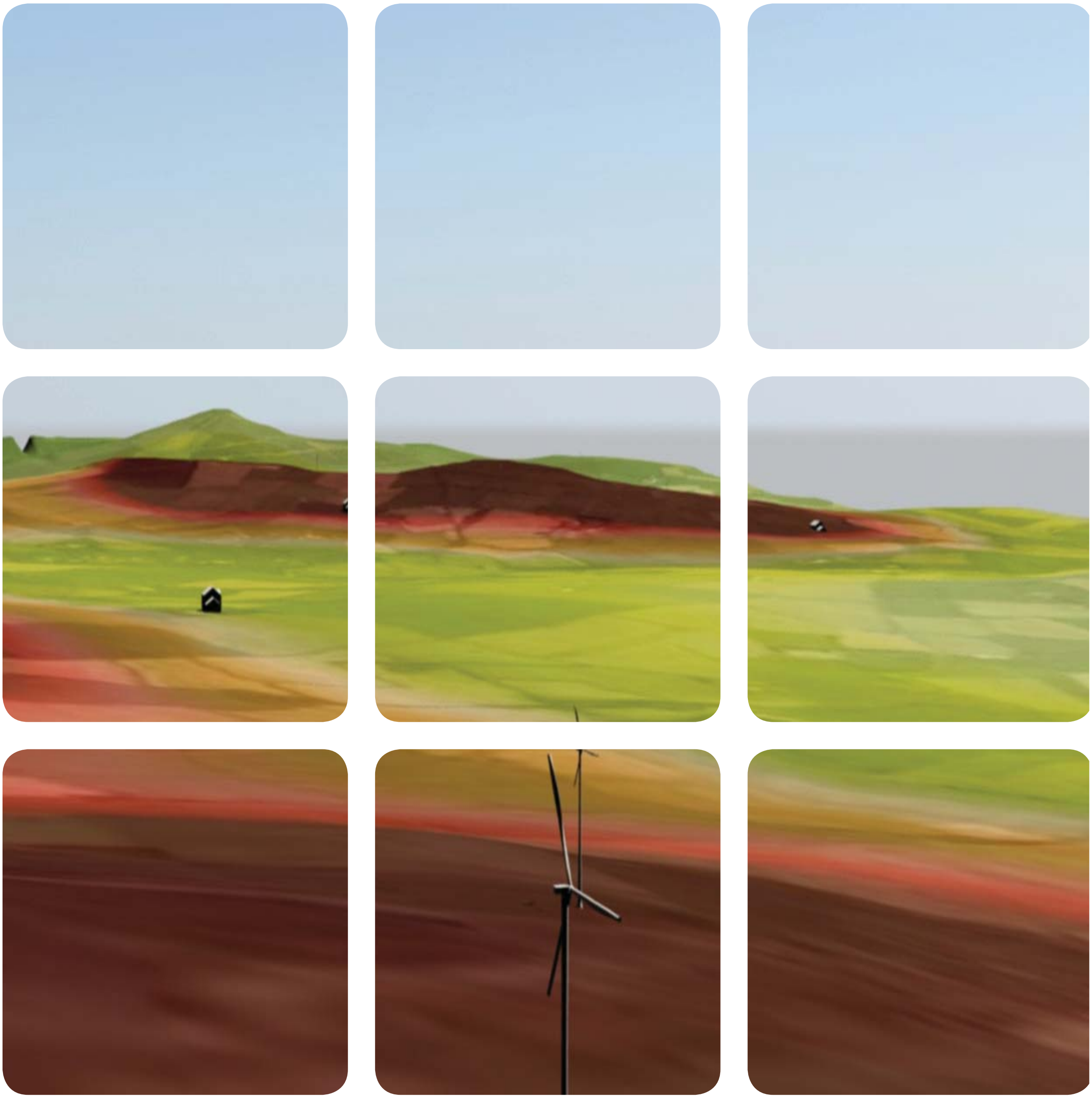
Noise Monitoring Services (Wexford Wind Farms) – Lot 1

Gibbet Hill Wind Farm Noise Monitoring Report



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Noise Monitoring Services

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Gibbet Hill Wind Farm Noise Monitoring Report

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REPORT TERMINOLOGY

A-weighting	Filtering sound levels to match human hearing sensitivity
Amplitude Modulation (AM)	Low frequency periodic fluctuations in the level of audible noise from a wind turbine (or wind turbines), the frequency of the fluctuations being related to the blade passing frequency of the turbine rotor(s)
BG noise	Background noise level
Blade passing frequency	(Rotor revolutions/minute) x (No. of blades) / 60, in Hertz
Broadband sound	The broadband sound pressure level measured by a sound level meter over a wide frequency band, usually 20 – 20,000 Hertz
BST	British Summer Time
EIS	The Environmental Impact Statement submitted at planning stage.
Fast Fourier Transform (FFT)	Fourier analysis converts a signal from its original to a representation in the frequency domain. An FFT rapidly computes such transformations and is used to identify narrow band tones in a signal.
GMT	Greenwich Mean Time
Hub height wind speed	Hub height wind speed is measured using a wind mast at turbine hub height or at the turbine hubs. If measured at the turbine hubs the values are corrected for turbulence
Infrasonic Noise	Noise in the frequency range below 20 Hertz
IoA	Institute of Acoustics
L_{A90}	The A-weighted noise level exceeded for 90% of the time during a measurement period. It L_{90} is often used for the measurement of background or ambient noise. L_{A90} excludes many transient events such as individual vehicles passing and animal sounds. It is expressed in decibels (dB). Measurement interval for metrics in this report refers to 10 minute measurement periods unless otherwise advised
L_{Aeq}	The A-weighted equivalent continuous sound pressure level represents a theoretical continuous sound, over a stated time period, T, which contains the same amount of energy as a number of sound events occurring within that time, or a source that fluctuates in level. It is expressed in decibels (dB). Measurement interval for metrics in this report refers to 10 minute measurement periods unless otherwise advised
$L_{night, outside}$	Refers to the World Health Organisation night time noise metric, i.e. the night time L_{Aeq} level averaged over the full year
Low Frequency Noise (LFN)	Noise in the frequency range 10 Hz to 160 Hertz
Narrow Band	Narrowband analysis is carried out with fine, high-resolution frequency analysis over a narrow bandwidth
Night Time	The term night time refers to the period 22:00hrs to 04:00hrs unless otherwise advised. This period was chosen as a period when wind

	turbine noise sources are likely to dominate
Noise Floor	The noise floor is the measure of the signal created from the sum of all the noise sources and unwanted signals within a noise meter, where noise is defined as any signal other than the one being monitored
NSL	Noise Sensitive Locations
Strict Compliance	All measured levels are below the threshold
Standardised Wind Speed	Turbine sound power levels determined in accordance with IEC 61400-11 are usually reported with reference to 'standardised' wind speeds at 10m height which are calculated from the hub height wind speeds using a standard equation (rather than actually measured at 10m height). This is the key reference wind speed for wind turbine noise
Substantial Compliance	Some measured levels are above the threshold but the levels are generally compliant
Time of day	Time is reported in Greenwich Mean Time (GMT)
Third Octave	Standardised constant percentage frequency bands used to evaluate acoustic signatures in more detail. Sound spectrums can be represented in octave or one-third octave frequency bands as well as in narrow frequency bands
Tone	A sound resulting from periodic or regular vibrations, composed of a simple sinusoidal waveform (pure tone) or a narrow band of frequencies
WAV Files	Waveform Audio File Format (WAVE, or more commonly known as WAV due to its filename extension) is a Microsoft and IBM audio file format standard for storing an audio bitstream on PCs
WCDCSWF	Wexford County Development Control Standards for Wind Farms
WEDG (2006)	Wind Energy Development Guidelines 2006
Wind Shear	Wind shear is the variation in horizontal wind speed with height above ground level. Under most conditions, wind speeds increase with height above ground and various equations can be used to describe this. It can be associated with weather features such as weather fronts, radiation inversions occur due to clear skies and calm winds. It can have a significant effect on sound propagation
Wind speed	Refers to 'standardised' wind speed at 10m using a roughness length of 0.05m
Wind Turbine Noise	Noise emanating from wind turbines in the frequency range 10Hz to 800Hertz

1 INTRODUCTION

RPS was commissioned by Wexford County Council to carry out noise monitoring surveys to investigate the impact of noise emanating from four wind farms near Bunclody, County Wexford. The four wind farms are:

- Gibbet Hill
- Knockalour
- Ballycadden
- Ballynancoran

This report relates to the Gibbet Hill wind farm. Detailed monitoring results are provided and are assessed in the report.

1.1 PROJECT SCOPE

Noise monitoring was carried out at 14 locations in the vicinity of the four wind farms over a period of 24 weeks. Monitoring consisted of both long-term unattended and short-term attended measurements. A number of noise parameters were measured during the survey and subsequent data analysis was carried out to assess noise levels attributable to the wind farms.

The data collected was analysed and reports prepared for each wind farm addressing compliance regarding noise emissions under the following headings:

1. Compliance with Planning Conditions on the wind farms being tested and/or predicted sound levels at noise sensitive locations, as per the planning submitted Environmental Impact Statement (EIS);

2. Compliance with the Department of Environment, Community and Local Government (DECLG), Wind Energy Development Guidelines 2006, in so far as they relate to noise standards;

3. Comment on the sound levels with regard to noise standards in each of the following:
    a) UK and other countries with well-developed wind energy infrastructure and regulations.
    b) WHO noise guidelines for night-time noise.
    c) Presence of tones, low frequencies, amplitude modulation.
    d) On the likelihood of noise nuisance as per Section 108 of the EPA Act No. 7 of 1992.

In this report data is presented based on the measurements taken and these are compared to the criteria outlined above.

2 NOISE CRITERIA

2.1 THRESHOLDS FOR COMPLIANCE & NUISANCE

2.1.1 Compliance with Planning Permission

Planning permission compliance is a matter which is determined by a planning authority and RPS has been engaged to provide an opinion in this regard.

The terms 'strict' compliance and 'substantial' compliance are used in different contexts in making such a determination.

'Strict' compliance is normally applied where matters are fully in the control of the developer, for example, the maximum height of the wind turbines.

For weather dependent planning conditions, which is the case when considering wind turbine noise, 'substantial' compliance may be more appropriate.

There is currently no statutory guidance on the threshold for compliance with planning conditions for wind farm development. In particular there is no guidance on whether or not a single exceedance for weather dependent noise is a non-compliance. Where other environmental guidelines and regulations are in force, such as the Guidelines for Planning Authorities for Quarries and Ancillary Activities, the Surface Water Regulations and the Air Quality Standards Regulations, the principle of 'substantial' compliance has been applied. Substantial compliance is based on percentiles and average levels rather than individual (single exceedance) results. No equivalent guidance on wind farm noise has been provided to planning authorities to date.

RPS has taken the view that substantial compliance is the appropriate basis for determining compliance in the case of wind farm noise.

2.1.2 Nuisance Threshold

There is no internationally accepted threshold to define nuisance from wind farm noise.

Noise nuisance is a function of the level/intensity of the noise and characteristics which give reasonable cause for annoyance.

Wind turbine noise can include tonal, low frequency and amplitude modulation (AM) components. Recent research indicates that many of the issues relating to tonal and low frequency noise complaints may be attributable to the AM noise component. Variability in weather conditions cause difficulty in assessing potential noise nuisance because noise from wind farms with these characteristics can be infrequent.

RPS has used reasonable skill, care and diligence in determining the extent of tonal, low frequency noise and AM noise. The results from the measurements taken have been compared to best international practice.

2.2 GIBBET HILL WIND FARM PLANNING PERMISSION

Planning permission (reference 20090266) for this wind farm was granted on 16th November 2009.

Condition 1 states:

'The proposed development shall be carried out strictly in accordance with:

(i) the plans and particulars lodged with the planning application; and,
(ii) the further information date stamped 20th October 2009 except as otherwise required by the conditions of this permission.

REASON:

To ensure the proposed development accords with the permission and that effective control is maintained.'

Condition 11 states:

'Within 12 months of the first operation of the wind turbines the operator shall provide a detailed independent report on the first years operations which shall include:-

a) A summary of bird collisions with the turbines;
b) A report on the noise levels experienced on dwellings adjacent to the site;
c) A report on the shadow flicker experienced on the dwellings adjacent to the site.

If abnormal results are identified above those predicted in the Environmental Impact Statement for the development, the operator shall submit proposals to reduce the impact such as limiting the use of turbines at sensitive periods. The report and any mitigation measures, including further monitoring if necessary shall be agreed in writing by the Planning Authority and the development shall operate in accordance with the agreed measures.

Reason:

To ensure that the development complies with the standards as set out in the Environmental Impact Statement and in the interests of the proper planning and sustainable development of the area.'

There are no expressed noise limits in the planning conditions set by Wexford County Council. The noise level limits are set by reference to the 'plans and particulars lodged with the planning application', as stated in Condition 1 and Condition 11 refers to the noise levels 'predicted in the Environmental Impact Statement'.

2.3 EIS NOISE IMPACT ASSESSMENT

The Environmental Impact Statement (EIS), dated September 2008, submitted with the Gibbet Hill planning application states in Section 9.1.2:

> *'The assessment has been carried out according to the County Development Plan 2007-2013, Annex 3, Wind Energy Strategy for County Wexford, issued by Wexford County Council in 2007, Department of the Environment, Heritage and Local Government Wind Farm Planning Guidelines (2006) and with reference to the recommendations of the UK Department of Trade and Industry's ETSU-R-97, The Assessment and rating of Noise from Wind Farms (DTI, 1996).'*

Section 9.1.4 of the EIS further states that the predicted noise levels are based on Nordex N90 HS wind turbines with 80m hub height, which are the turbines used on the site rather than any 'candidate' turbines at design stage.

Section 9.7 of the EIS sets out that the noise predictions presented in the EIS are worst case predictions and are presented in Figure 9.6 as L_{Aeq} noise contours. Figure 9.6 is titled '*Figure 9.6 – Noise Contours for Wind Speed of 10 m/s at 10m Height*'. It is important to note that the predictions presented in the EIS are based on a L_{Aeq} metric.

Section 9.9 and Figures 9.7-9.16 of the EIS show the measured background noise data (presented as L_{A90}) prior to the construction of the wind farm and the predicted noise levels (presented as L_{Aeq}) at five locations in the area. These locations and the corresponding (nearest but not identical location) monitoring areas used in this study are shown in **Table 2-1**:

Table 2-1: Location codes from the EIS and corresponding site number in the current report

EIS Location	Corresponding RPS Monitoring Area (Figure 3-1)
H14	Site 02
H12	Site 04
H9	Site 05
H7	Site 13
H3	Site 01

The concluding section of the EIS (at Section 9.10.3) states:

> '*The assessment shows that the total predicted wind turbine noise level of the whole wind farm meets the fixed night noise limit of 43 dB L_{Aeq} at all residential locations, under all conditions. It also shows that the total predicted turbine noise level is below the day-time noise limit of 45 dB L_{Aeq} at all residential properties, under all conditions. It has been demonstrated in this assessment that both day and night-time noise limits can be satisfied at all properties across all wind speeds*'.

It is unclear whether the ultimate commitment relating to noise emissions in the EIS is the predicted levels set out in Section 9.7 and Section 9.9 or compliance with the Wind Energy Development Guidelines as stated in Section 9.10.3. A comparison with both parameters is provided in **Section 6** of this report.

2.4 WEXFORD COUNTY DEVELOPMENT CONTROL STANDARDS FOR WIND FARMS (2007)

Section 6.9 of the Wexford County Development Control Standards for Wind Farms states:

> ***6.9 Noise***
>
> *Permitted maximum noise levels at noise sensitive residences shall be:*
>
> *45 dB L_{eq}(A) from the nearest machine between the hours of 0800 and 2000, Monday to Sunday and 43 dB L_{eq}(A) at all other times.*
>
> *To allow for reliable measurements L_{eq} levels can be converted to L_{A90} levels (for wind farm noise) with the relationship $L_{A90} = L_{eq} - 3$.*

It is important to note that the Development Control Standards are based on a L_{Aeq} metric with a conversion factor from a L_{A90} measurement. The conversion factor of 3 dB is more conservative than a 2 dB conversion referenced in ETSU_R-97 and the Institute of Acoustics Good Practice Guide at Section 4.2.5 of that document. This means that the permitted noise level on an L_{A90} basis using the Wexford County Development Control Standards for Wind Farms is 42 dB L_{90}(A) from the nearest machine between the hours of 08:00 hrs and 20:00 hrs, Monday to Sunday and 40 dB L_{90}(A) at all other times.

2.5 WIND ENERGY DEVELOPMENT GUIDELINES, 2006

The DECLG Wind Energy Development Guidelines (WEDG, 2006) provide guidance on the noise levels that should be met at the nearest Noise Sensitive Locations (NSL). The guidance cites the two main sources of noise from wind turbines as that from the mechanical elements, created during the operation of the turbine, and the aerodynamic noise generated as a result of the rotation of the turbine blade.

The Guidelines state:

> *'Noise impact should be assessed by reference to the nature and character of noise sensitive locations. In the case of wind energy development, a noise sensitive location includes any occupied dwelling house, hostel, health building or place of worship and may include areas of particular scenic quality or special recreational amenity importance. Noise limits should apply only to those areas frequently used for relaxation or activities for which a quiet environment is highly desirable. Noise limits should be applied to external locations, and should reflect the variation in both turbine source noise and background noise with wind speed. The descriptor[9], which allows reliable measurements to be made without corruption from relatively loud transitory noise events from other sources, should be used for assessing*

both the wind energy development noise and background noise. Any existing turbines should not be considered as part of the prevailing background noise.

A footnote refers to: [9] *L_{A90}, 10mm* - (should read *L_{A90}, 10 min*).

In general, a lower fixed limit of 45 dB(A)[10] or a maximum increase of 5dB(A) above background noise at nearby noise sensitive locations is considered appropriate to provide protection to wind energy development neighbours. However, in very quiet areas, the use of a margin of 5dB(A) above background noise at nearby noise sensitive properties is not necessary to offer a reasonable degree of protection and may unduly restrict wind energy developments which should be recognised as having wider national and global benefits. Instead, in low noise environments where background noise is less than 30 dB(A), it is recommended that the daytime level of the L_{A90}, 10min of the wind energy development noise be limited to an absolute level within the range of 35-40 dB(A).

A footnote refers to:

[10] *An 'A-weighted decibel' – a measure of the overall noise level across the audible frequency range (20Hz – 20kHz) with A-frequency weighting to compensate for the varying sensitivity of the human ear to sound at different frequencies. The decibel scale is logarithmic. A 10dB(A) increase in sound level represents a doubling of loudness. A change of 3dB(A) is the minimum perceptible under normal circumstances.'*

Separate noise limits should apply for day-time and for night-time. During the night the protection of external amenity becomes less important and the emphasis should be on preventing sleep disturbance. A fixed limit of 43dB(A) will protect sleep inside properties during the night.

The 2006 Guidelines were generally interpreted to impose a limit of 43 dB(A) at night at NSL, based on a L_{A90} metric. While the WEDG (2006) state that mechanical noise from a wind turbine is tonal in nature and turbines can display a 'character' (swish), no provision is made in the Guidelines for addressing Tonal, low frequency or Amplitude Modulation elements in the noise level.

2.6 INTERNATIONAL GUIDANCE AND REGULATIONS

Very few countries have regulations that are specific to wind turbine noise. Many countries, such as Germany, have general noise guidelines that apply to all noise sources, including wind turbines. The UK, Australia, Canada and Denmark all have a large operational wind turbine capacity. These countries have conducted independent research into wind turbine noise and published wind turbine noise guidelines.

2.6.1 UK Guidelines

2.6.1.1 ETSU-R-97 Guidance

The UK Department of Trade and Industry set up a Working Group on Noise from Wind Turbines in 1996. This group published guidance the following year which has become known as ETSU-R-97.

ETSU-R-97 sets out a fixed day-time limit at NSLs during quiet periods of 35-40 dB L_{A90} and a night-time limit of 43 dB L_{A90}. However the guidance states that

> '*Where the local authority and the developer are in agreement that the background noise levels do not vary significantly between the amenity periods and the night-time, then a single lower fixed limit of 35 – 40 dB(A) can be imposed based upon background noise levels taken during the amenity periods and the night analysed together*'.

Noise level limits can also be set for different wind speeds up to 12 m/s and the methodology for doing this is given in ETSU-R-97.

The limits proposed in ETSU-R-97 are set out as follows:

> *'Noise from the wind farm should be limited to 5dB(A) above background for both day and night-time (with the exception of the lower limits and simplified method described below), remembering that the background level of each period may be different.*
>
> *In low noise environments the day-time level of the $L_{A90,\ 10min}$ of the wind farm noise should be limited to an absolute level within the range of 35-40dB(A). The actual value chosen within this range should depend upon a number of factors:*
>
> - *the number of dwellings in the neighbourhood of the wind farm*
> - *the effect of noise limits on the number of kWh generated*
> - *the duration and level of exposure.'*

Guidance is also given on the measurement parameters that should be used for wind farm noise. The guidance states:

> *'The Noise Working Group is agreed that the $L_{A90,10min}$ descriptor should be used for both the background noise and the wind farm noise, and that when setting limits it should be borne in mind that the $L_{A90,10min}$ of the wind farm is likely to be about 1.5-2.5dB(A) less than the L_{Aeq} measured over the same period. The use of the $L_{A90,10min}$ descriptor for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.'*
>
> *The Noise Working Group recommends that the fixed limit for night-time is 43dB(A). This limit is derived from the 35dB(A) sleep disturbance criteria referred to in Planning Policy Guidance Note 24 (PPG 24). An allowance of 10dB(A) has been made for attenuation through an open window (free-field to internal) and 2dB subtracted to account for the use of $L_{A90,10min}$ rather than $L_{Aeq,10min}$.'*

The UK guidance is based on a L_{A90} metric. Note that the night time limit can be higher than the daytime limit in areas of low background noise under ETSU-R-96.

2.6.1.2 Institute of Acoustics Good Practice Guide

The Institute of Acoustics (IoA) published a *Good Practice Guide to the Application of ETSU-R-97 for the assessment and rating of Wind Turbine Noise* (GPG) in May 2013. A number of supplementary guidance documents including data collection and post completion measurements have been subsequently published by the IoA.

The IoA Guidance provides the most comprehensive guidance to measuring and analysing wind farm noise and therefore this study used the IoA GPG as the basis for measuring the (post completion) wind farm noise. The IoA GPG does not set limits for noise so the current guidance on limits is determined by the ETSU-R-97 guidance.

2.6.2 Recent Developments in UK Guidance

The UK Department for Communities and Local Government provided planning practice guidance for renewable and low carbon energy in July of 2013. UK guidance states:

> *'The report, 'The assessment and rating of noise from wind farms' (ETSU-R-97) should be used by local planning authorities when assessing and rating noise from wind energy developments. Good Practice Guidance on noise assessments of wind farms has been prepared by the Institute Of Acoustics. The Department of Energy and Climate Change accept that it represents current industry good practice and endorses it as a supplement to ETSU-R-97'.*

The Noise Policy Statement for England sets out noise policy for England in terms of No, Low and Significant Observed Adverse Effect Levels (NOAEL, LOAEL and SOAEL respectively). The current guidance does not provide numerical values. Research is ongoing to determine appropriate OAEL levels for different noise sources (traffic, wind turbines, industrial noise etc.).

The UK Department for Business, Energy & Industrial Strategy published a review of the evidence on the response to amplitude modulation (AM) from wind turbines with recommendations on control through the use of a Planning Condition in October 2016. This review has proposed a penalty scheme for AM based on the Institute of Acoustics metric.

The UK guidelines on AM were introduced while monitoring was underway for this report. While the new guidelines are designed for new wind farm development, the criteria proposed have been used in this assessment.

2.6.3 South Australia

South Australia is the largest producer of wind energy in Australia. The South Australian Environmental Protection Authority has published Wind farms environmental noise guidelines (ISBN

978-1-876562-43-9). In these guidelines the noise criteria for new wind farm development is set out as follows:

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

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

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

A 'rural living' zone is defined as a rural−residential 'lifestyle' area intended to have a relatively quiet amenity. The guidelines state:

'The area should not be used for primary production other than to produce food, crops or keep animals for the occupiers' own use, consumption and/or enjoyment. The noise amenity should be quieter than in an urban−residential area.'

This indicates that land used for agricultural purposes (such as the area surrounding the wind farms) falls into the higher 40 dB(A) category. The determination of whether the area should be designated in the lower limit category is made by the SA EPA in consultation with the local authority for the area concerned.

The South Australian guidance is based on a L_{Aeq} metric.

2.6.4 Denmark

The Danish Ministry of Environment and Food issued a Statutory Order on Noise from Wind Turbines in December 2011. This order sets (inter alia) the noise impact dwellings at two wind speeds only, 8m/s and 6 m/s. The limits specified at dwellings are as follows:

The total noise impact from wind turbines may not exceed the following limit values:

1. *At the most noise-exposed point in outdoor living area no more than 15 metres from dwellings in open countryside:*
   a) 44 dB(A) at a wind speed of 8 m/s.
   b) 42 dB(A) at a wind speed of 6 m/s.

2. *At the most noise-exposed point in areas with noise-sensitive land use:*
   a) 39 dB(A) at a wind speed of 8 m/s.
   b) 37 dB(A) at a wind speed of 6 m/s.

Noise-sensitive land use is defined as:

> *Areas that are actually used for or designated in district plans or town planning regulations for residential, institutional, holiday home, camping or allotment purposes or areas designated in district plans or town planning regulations for noise-sensitive recreational activities.*

The Danish Statutory Oder is based on a L_{Aeq} metric.

The Statutory Order goes on to provide a limit on low frequency Noise (LFN). LFN is defined as being in the frequency range from 10 to 160 Hz and is characterised using the A-weighted level of noise in one-third octave bands from 10 up to and including 160 Hz, calculated indoors using the method set out in Annex 1.

Annex 1 of the Statutory Order sets out a noise prediction method for use at planning stage. The Danish Statutory Order first calculates the external LFN and then applies a correction for indoor values. The total LFN from wind turbines may not exceed 20 dB at a wind speed of 8 and 6 m/s indoors in dwellings in open countryside or indoors in areas with noisesensitive land use respectively. The method for calculating the total is set out in the Annex.

For this study all measurements were taken outdoors. The Danish method is easily adapted for outdoor measurements as all that is necessary is to review the outdoor to indoor conversion factor in the calculation.

2.6.5 Canada

Wind Turbine noise in Canada is governed by the Provinces rather than at State level. The Provinces operate limits based on a L_{Aeq} metric with significant variation between them. The limits are further complicated by an additional 5 dB allowance for properties close to roads or subject to frequent aircraft overflights.

At a wind speed of 6 m/s the Canadian levels are lower [40 dB(A)] than those permitted in Denmark [42 dB(A)]. The Canadian levels are also higher [45 dB(A)] than those permitted at a wind speed of 8 m/s [44 dB(A)] in Denmark. The Canadian Provinces of Manitoba, New Brunswick and Ontario permit levels of 51 dB(A) at wind speeds of 10m/s.

2.7 WORLD HEALTH ORGANISATION NOISE GUIDELINES FOR NIGHT TIME NOISE

The World Health Organisation (WHO) examined ‘community’ noise comprising road, rail, air traffic, construction and public work, and issued guidelines in 1999 recommending a daytime limit based on annoyance of 55 dB(A) and a night time limit 10 dB(A) lower than this, i.e. 45 dB(A), outside at the noise sensitive location.

A more recent (2009) WHO document dealing with transportation noise and addressing noise sources regulated under the European Environmental Noise Directive, referred to as Noise Guidelines for Europe, refers to more recent research and sets a lower threshold of 40 dB(A) ($L_{night,outside}$). The report states:

> *'……no effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to night noise. There is no sufficient evidence that the biological effects observed at the level below 40 dB $L_{night,\ outside}$ are harmful to health. However, adverse health effects are observed at the level above 40 dB $L_{night,\ outside}$ such as self-reported sleep disturbance, environmental insomnia, and increased use of somnifacient drugs and sedatives. Therefore, 40 dB $L_{night,\ outside}$ is equivalent to the lowest observed adverse effect level (LOAEL) for night noise.'*

The 40 dB $_{Lnight,\ outside}$ criteria is based on the Directive 2002/49/EC of the European Parliament and Council of 25 June 2002 relating to the assessment and management of environmental noise, referred to as the Environmental Noise Directive (END). L_{night} is defined in the Directive as the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all the night periods of a year.

The WHO and END metric is based on an annualised measurement (L_{Aeq}) whereas all the previously outlined measurements are based on 10 minute periods.

2.8 INTERNATIONAL PRACTICE - NOISE MEASUREMENT LOCATIONS

Noise measurements for this survey were taken externally. International practice for the regulation of environmental noise is based on outdoor measurements. The World Health Organisation Guidelines and the Environmental Noise Directive are based on external noise levels. Internal measurement of low frequency noise levels at noise sensitive locations has been proposed but has not been adopted internationally for wind farm noise compliance for the following reasons:

- Permission from the property owner and access is required on each occasion to take measurements.
- Measurements may need to be taken internally over an extended period (months) which causes inconvenience to the property owner.
- Audio recordings may be required to provide verifiable evidence that the noise emanates from the wind farm, raising privacy concerns.
- Internal measurements may be contaminated by internal sources such as domestic appliances (e.g. fridges, ventilation equipment, pumps, etc.) and other domestic noise.
- Structure borne sound and room modes (standing waves) result in significant differences in measured levels between rooms or in adjacent properties.
- Measurement location(s) within a room have not been standardised and small variations (centimetres) can result in significant differences in measured levels.

Internal noise levels from wind farms are always related to external noise levels which can be measured using standardised procedures.

Environmental noise standards provide guidance on procedures and instrumentation for measuring environmental noise. Environmental noise standards such as ISO 1996-1:2016, ANSI S12.9-4(2005) as well as AS 4959-2010, NZS 6808:2010 and ETSU-R-97, which deal with wind turbine noise specifically, all rely on outdoor noise measurement locations.

The uncertainty associated with relying on internal noise measurements of wind farm noise can make enforcement difficult.

2.9 INTERPRETATION OF COMPLIANCE THRESHOLDS

Based on Sections 2.1.1 to 2.8 above the compliance guidelines for the wind farms can be summarised as set out in **Table 2-2**.

Table 2-2: Noise Thresholds

	Criteria	Limit
Planning Conditions (a) Based on the site-specific noise predictions in the EIS Section 9.7	L_{Aeq} Day-time L_{Aeq} Night-time	Site specific limits Site specific limits
Planning Conditions (b) Based on the EIS conclusion, Section 9.10.3	L_{Aeq} Day-time L_{Aeq} Night-time	45 dB(A) 43 dB(A)
Wexford County Development Control Standards for Wind Farms	L_{Aeq} Day-time L_{Aeq} Night-time	45 dB(A) 43 dB(A)
DECLG Wind Energy Development Guidelines	L_{A90} Day-time L_{A90} Night-time	45 dB(A) 43 dB(A)
ETSU-R-97 Guidance	L_{A90} Day-time L_{A90} Night-time	Greater of 35 dB(A) or Background + 5dB 43 dB(A) at night
South Australia	L_{Aeq}	40dB(A) at relevant receivers in localities in other zones, or the background noise ($L_{A90,10}$) by more than 5dB(A),
Denmark	L_{Aeq}	44 dB(A) at a wind speed of 8 m/s. 42 dB(A) at a wind speed of 6 m/s.
Canada	L_{Aeq}	45 dB(A) at a wind speed of 8 m/s. 40 dB(A) at a wind speed of 6 m/s.
WHO Guidelines for Night-time	$L_{night,outside}(L_{Aeq})$	40 dB(A)

2.10 PRESENCE OF TONES, LOW FREQUENCIES, AMPLITUDE MODULATION

2.10.1 Tones

Standard guidance can be applied when assessing the presence of a tone from wind turbines. The following methods are used to determine if a tone is present. These are, in order:

1. The subjective method
2. The objective method for tonality
3. The reference method

The subjective method uses a subjective assessment of the noise characteristics to assess the need to apply a correction factor. This requires the presence of an experienced acoustician on site to evaluate the noise emission and report on the situation.

The objective method to assess the presence of a tone uses one-third octave band analysis. This examines the level differences between adjacent one-third octave bands at different frequencies. A significant change in noise levels between adjacent bands indicates the presence of a tone. The methodology is set out in Annex C of BS4142:2014 and Annex C of ISO 1996-2:2007.

BS4142:1997 '*Method for rating industrial noise affecting mixed residential and industrial areas*' was revised in 2014; the most significant changes being the introduction of a different penalty system and a broader application of the standard. The revised standard is BS4142:2014 '*Method for rating and assessing industrial and commercial* sound'. As the revision took place after the wind farm received planning permission and were constructed the appropriate penalty is possibly the standard that was in effect at that time.

BS4142 provides guidance on assessing the presence of a tone from industrial noise sources. While not explicitly required the methods are usually followed in order, i.e. if a tone is detected subjectively, the objective method is used to determine an appropriate penalty. If this does not result in a penalty the reference method may be referred to.

The ETSU-R-97 tonal assessment methodology is constructed around the use of 2 minute audio samples in every 10 minutes of measurement.

The reference method assesses the prominence of tones using critical band Fast Fourier Transform (FFT) analysis and penalties are calculated in accordance with BS4142. This method is set out in Annex C of ISO 1996-2:2007 and also referred to as the Joint Nordic Method. Where it is deemed necessary from results using the subjective or objective methods, the reference method has been applied.

Where a tone is considered to be present, a rating or correction factor is applied to the noise level measured. This rating will only be applied to the ETSU-R-97, South Australian and Danish criteria. Neither the planning permission conditions nor the Wexford County Development Control Standards for Wind Farms make any reference to a rated noise level.

2.10.2 Low Frequency Noise

In Denmark a Statutory Order on Noise from Wind Turbines (SO 1284, 2011) deals specifically with low frequency noise from wind turbines at planning stage. The methodology is based on predicting low frequency noise levels external to a property and then applying a standard sound insulation difference to determine levels indoors. It is important to note that the method is based on a predicted rather than measured level and the indoor to outdoor correction is based on a 'standard' sound insulation level.

For this study all measurements were taken externally. The level internally is directly related to the noise level externally. In terms of enforcement the wind farm operators cannot easily be held responsible for building specific characteristics that may in some cases increase the relative loudness of low frequency noise due to selective filtering and modal resonances of the receiving structure.

In the UK a study by the University of Salford proposed criteria for internal low frequency noise levels at one-third octave bands from 10Hz to 160Hz. The study was commissioned to provide guidance for Environmental Health Officers investigating low frequency noise complaints. In many cases the noise in these complaints emanates from adjoining domestic properties. This study also outlines the difficulties associated with taking internal noise measurements.

To determine appropriate external low frequency noise levels a correction for sound insulation must be made. The sound insulation level difference provided in the Danish Statutory Order is greater than 20 dB at frequencies as low as 100 Hz (**Table 5-2**). In the absence of hard data for low frequency sound insulation levels in Ireland a more conservative approach may be warranted. RPS has adopted a spectrum of corrections taken from Beranek (1998). The RPS corrections are applied at a more conservative sliding scale, which has a 15 dB correction at 160 Hz and zero below 25 Hz. The RPS corrections were applied to the DEFRA guidelines for internal noise.

A data matrix of unweighted sound level at each one-third octave band against date and time was created where each record represents a 10 minute interval. Intervals that are considered daytime are removed leaving night only (22:00 – 04:00). The value of each interval at each one-third octave band is checked against the University of Salford internal guidelines adjusted for external measurements by RPS as set out in **Table 5-2** and exceedances recorded.

It is important to note that low frequency noise in the context of this report refers to emission frequencies from the turbine. Low frequency 'whump' type noise is related to amplitude modulation and is measured and accounted for separately in this report. Amplitude modulation is a low frequency noise but the mechanism for measuring and reporting it has now been clarified by the Institute of Acoustics.

2.10.3 Amplitude Modulation

A guidance document on rating Amplitude Modulation (AM) noise has been published by the Institute of Acoustics (IOA, 2016). This guidance is the culmination of several years work following on from the publication of the Good Practice Guide on Wind Turbine Noise in 2013. The process included wide consultation among acousticians working in industry, regulatory bodies and academic research on the topic.

During the consultation process the issue of taking noise measurements indoors or outdoors was discussed at length. The decision was made to take amplitude modulation measurements outdoors, primarily because of the practical difficulties associated with making repeatable noise measurements indoors. As part of the consultation on this topic the working group stated:

> *'The working group's objective is to define a metric that can be used reliably within the planning system, and external measurements are the only practicable option. For specific complaint or nuisance measurements, Investigators are of course free to make internal measurements and assessments in connection with the specific issues. Indoor measurements are problematic for a variety of reasons including, access difficulties, corruption by other sources, and room modes which could result in different responses in different positions in the room. These factors can cause a large variation in noise levels which can affect reproducibility.*
>
> *It is considered unnecessary to account for all of these factors when wind turbine AM can be measured reliably outdoors. Furthermore the noise data input to the recommended metric is band-limited to reduce the influence of high- and low-frequency background noise. To some (although indeterminate) extent, this reflects the sound attenuation characteristics of building facades and windows in preferentially reducing higher frequencies rather than low, which may mean that the outdoor metric better reflects the perception of AM indoors, compared with a metric based on broadband A-weighted noise data where other sources may mask the AM. This is a possible incidental benefit of band-limiting which is incorporated into the recommended method for other reasons.'*

While not ruling out internal measurements the guidance does point out the factors that would cloud the issue in the event of a planning authority taking enforcement action for excessive amplitude modulation. The IoA Guidance on AM is however limited to the standardisation of a methodology for measuring and rating AM. The working group preparing the guidance did not provide a limit for AM, only a method for rating it.

In 2013, Renewable UK published a report on Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect along with a Template Planning Condition on Amplitude Modulation: Noise Guidance Notes. This provided an initial industry led response to the issue of AM and defined the concept of 'enhanced' or 'Other Amplitude Modulation' levels. A threshold of 3 dB excess AM was proposed as an appropriate limit.

The UK Department of Environment and Climate Change (DECC) commissioned research on appropriate guidelines on AM. The result of this research the DECC published two reports, the latest of which, *Wind Turbine AM Review – Phase 2 Report*, published in August 2016 recommends using the IoA metric for quantifying AM and proposes testing and review of an additional penalty of 3 to 5 dB on a sliding scale for unacceptable or excessive levels of AM as shown on **Figure 2-1**. The report concludes:

> *'Based on the evidence found, a recommendation has been made on the elements required to construct a planning condition to control AM. <u>It is noted that the AM control has only been designed for use with new planning applications, and applicability for use in Statutory</u>*

Nuisance investigations on existing wind turbine sites, where the regime is different and outside the project scope,[1] *has not been considered as part of this review.*

Any condition developed using the elements proposed in this study should be subject to a period of testing and review. The period should cover a number of sites where the condition has been implemented, and would be typically in the order of 2-5 years from planning approval being granted.'

In the context of this report, the UK methodology for assessing AM was only finalised while monitoring was in progress. Further research will be required before a definitive penalty scheme for AM will be imposed in the UK. Nonetheless analysis for the presence of AM was carried out using this methodology on WAV files in which AM was likely to be present.

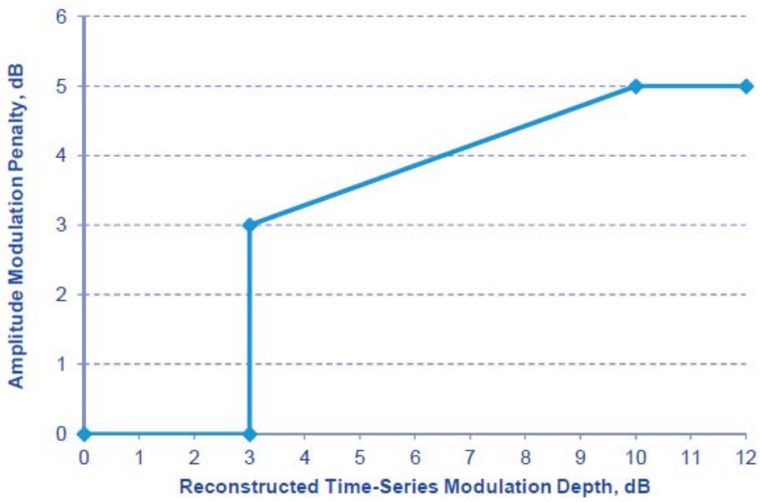


Figure 2-1: UK DECC Proposed AM Level Penalty Scheme

2.11 THE LIKELIHOOD OF NOISE NUISANCE

Section 108 of the EPA Act No.7 of 1992 states that a complaint may be made to the District Court for '*any noise which is so loud, so continuous, so repeated, of such duration or pitch or occurring at such times as to give reasonable cause for annoyance to a person in any premises in the neighbourhood or to a person lawfully using any public place*'.

The noise data was analysed to assess whether the noise from the wind farms could potentially constitute a nuisance.

[1] RPS emphasis

3 MONITORING METHODOLOGY AND DATA COLLECTION

3.1 SITE LOCATION

Gibbet Hill wind farm is located in the townlands of Graigue More and Kiltilly approximately 3.5km north east of Bunclody, County Wexford. The development comprises six wind turbines and the wind farm was commissioned in 2013.

3.2 PREVIOUS NOISE MONITORING DATA

Background noise monitoring for the Gibbet Hill wind farm was carried out in 2008 and included in the Environmental Impact Assessment (September 2008). This was prior to the commissioning of any wind farms in the area and provides baseline noise measurements from that period.

Planning permission for Gibbet Hill wind farm was granted on 16th November 2009 (Planning Reference No. 20090266).

3.3 MONITORING METHODOLOGY

Noise monitoring was carried out in accordance with the Institute of Acoustics (IoA) document ''*A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise'' and* Supplementary Guidance Notes. The IoA document provides guidance on the assessment methodology for all wind farm developments in accordance with the ETSU-R-97 method. The assessment methodology provides procedures for predicting the noise levels from both existing and proposed wind farm developments at NSLs. The guidance also establishes the link between wind speed and noise levels from wind turbines and gives a procedure for carrying out noise surveys.

Wind turbine noise differs from other sources of noise as most noise measurement standards and equipment are designed around low wind conditions. In addition wind turbine noise is acoustically similar to background wind noise and can be difficult to isolate. Another factor in this regard is that wind turbine noise guidelines and wind turbine noise levels generally are in the same intensity range as the background noise.

In order to determine compliance with wind farm noise limits particular measures are internationally recognised as providing the most relevant data, i.e. isolating wind turbine noise from other sources. During this study the following measures were adopted:

1. Isolating night time (10pm to 4am) data so that wind turbine noise was prominent.
2. The use of a double windshield on the microphone.
3. Screening out data with non-wind turbine noise content.

3.4 INSTRUMENTATION

Instrumentation used during the survey were Bruel & Kjaer model 2250 noise level meters with the following capabilities:

- Measurements set for Fast time weighting;
- 1/3 Octave measurements from 6 Hz to 20kHZ;
- L(Z) Peak;
- LAeq, LAmax, LAmin, LApeak, L(C)eq, L(C)min, L(C)max, L(Z)eq, L(Z)min, L(Z)max;
- LN Statistical Noise Levels of L1, L5, L10, L90, L95 and L99;
- Fast Fourier Transform (FFT) analysis from 0 Hz to 200 Hz; and
- Audio recording (24 bit rate) of a sample of measurements.

A weather protection system was used on all microphones in accordance with IoA Good Practice Guidance. This consisted of an enhanced double wind screen placed around the microphone of the meter. This served to both reduce the effect of wind induced noise on the measurement and to protect the microphone from rain droplets. All microphones were positioned at a height of 1.2-1.5m above ground, as specified in ETSU-R-97.

3.5 NOISE MONITORING LOCATIONS FOR THIS REPORT

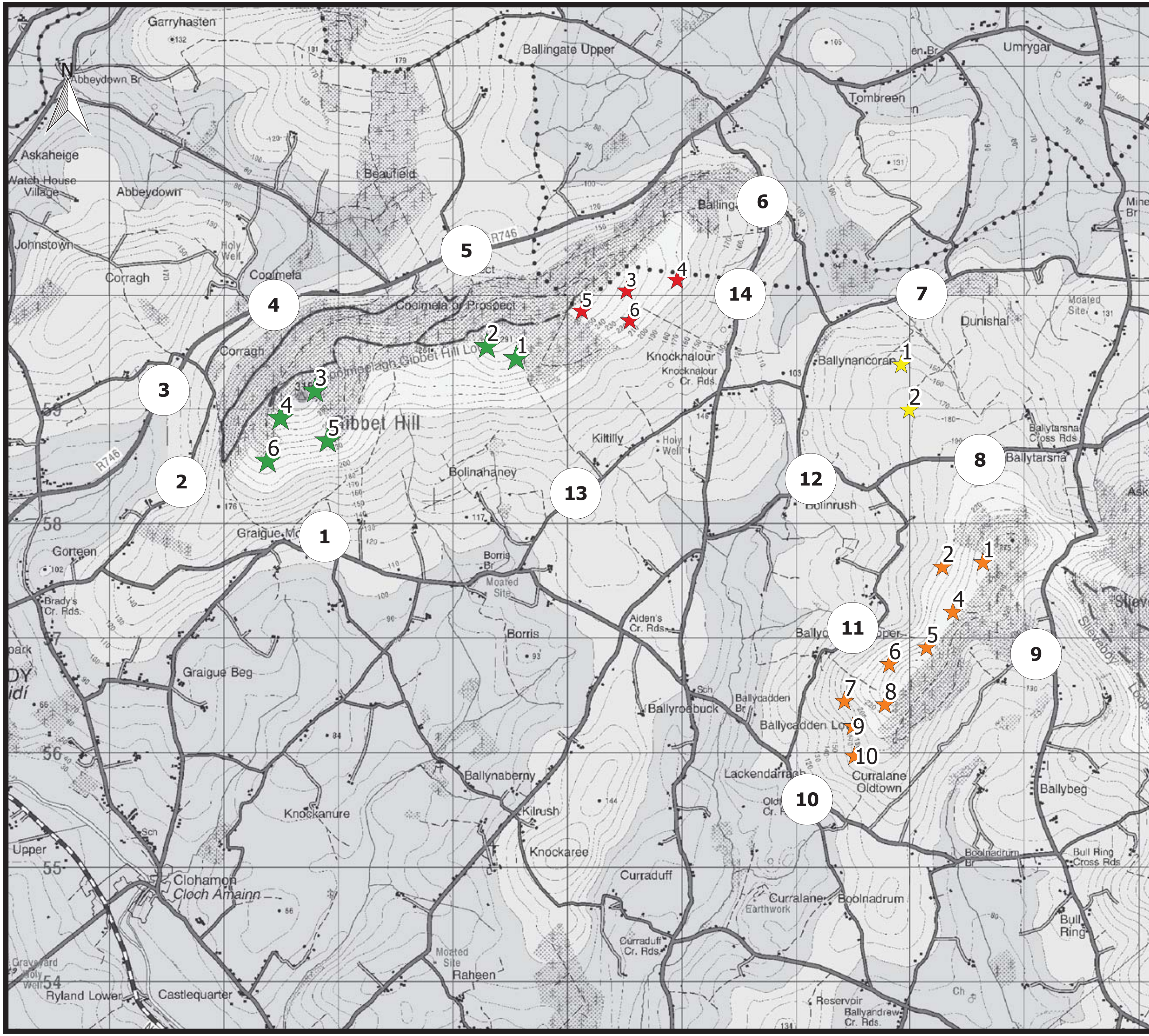
The noise monitoring locations are shown in **Figure 3-1** along with the turbine locations for the four wind farm sites. The monitoring locations were chosen on the basis of providing a representative sample of properties surrounding the wind farms and to provide comparable locations to those used in the original EIS studies. The locations were identified by RPS from a desk study of the area and a map indicating 500 metre diameter circles was provided to Wexford County Council. Wexford County Council then approached landowners in each of the circled areas to request their cooperation with the study. Following discussions with the landowners thirteen sites were identified by Wexford County Council. One site was later relocated so fourteen sites were monitored in total. The majority of the landowners were willing to cooperate on the basis of confidentiality, i.e. they did not wish to be identified by either text or images published in the report. For this reason the monitoring locations are only identified as Site 01 to Site 14 with no personally identifable information included in the report. Each monitoring location is shown as a 500m diameter area to protect the confidentiality of the host location.

3.5.1 Site 06 and Site 14

Shortly after the start of monitoring, the instrumentation at Site 06 was interfered with (attempted theft suspected). It was decided to relocate the monitoring equipment to a less visible site but due to logistics it was necessary to move outside the 500m radius of Site 06. Therefore Site 14 came into existance for the remainder of the monitoring. As the two sites are not inside the original 500m radius criteria, the results are reported separately.

3.5.2 Gibbet Hill Specific Locations

Wexford County Council requested that a separate report be prepared for each wind farm. The locations that are most impacted by the Gibbet Hill wind farm are Site 01, Site 02, Site 03, Site 04, Site 05 and Site 13. Detailed analysis for each of these locations is included in this report.



Legend

- Monitored Locations
- ★ Knocknalour
- ★ Ballynancoran
- ★ Ballycadden
- ★ Gibbett Hill

Client Wexford County Council — wexford Co. Co.

Project *Wexford Wind Farms*

Title Noise Monitoring Areas

Figure 3.1

RPS®

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E ireland@rpsgroup.com

Drawn by:	CMcC	**Project No.**	MGE0552
Checked by:	EMK	**File Ref.**	MGE0552QG001F01
Approved by:	EMK		
Scale:	nts	**Drawing No.** QG001	**Rev.** F01
Date:	20/04/2017		

3.6 WEATHER DATA

RPS installed two weather stations, at Sites 03 and 13, which recorded wind speed wind direction (using an anemometer mounted on a meteorological mast at 10m height) and rainfall in ten-minute logging periods for the full monitoring period. The wind masts were located outside the turbulent wake of the wind farms but subject to local site conditions.

Wind speed data at the measurement sites was used to determine periods under which significant wind shear may be present, i.e. relatively high wind speeds at turbine hub height but low wind speeds at the measurement location. Rainfall of <0.1mm in a 10min period was not recorded. Measurements related to high wind shear conditions may provide the worst case noise levels, in particular AM is recognised as being prevalent under high wind shear conditions.

3.7 WIND FARM OPERATIONAL DATA

Consideration was given to requesting switch-offs at the wind farms. From early monitoring results it was clear that switch-offs would have limited value and would have to be arranged for specific conditions in order to be effective. This would require coordination with the national grid and have operational consequences for the wind farm operators. The wind farm operators did indicate a willingness to facilitate switch-offs but the likelihood of achieving the desired weather and operating conditions at short notice was not considered practicable.

Measuring the noise over an extended period provided a better mix of conditions and facilitated full cooperation from the operators.

3.8 CONFIRMATION OF SPECIFIC EVENTS

In addition to being provided with data from the wind farm operators, RPS was provided access to the wind farm control centres and data acquisition systems. This allowed RPS to examine specific turbine operating conditions and verify the data provided by the operators.

Events highlighted in the noise logs or identified from preliminary data analysis were examined in detail during this access. This facilitated a focus on specific operating or weather conditions that may give rise to noise issues.

3.9 NOISE LOGS

Noise logs were collected by a number of residents in the vicinity of the assessment area throughout the monitoring period (June – December). In the logs residents recorded characteristics of the noise they could hear, rated it on a scale from 1 to 10 (where 10 is worst) and noted the time and date. Within the monitoring period approximately 300 individual records were collected.

3.10 LONG-TERM NOISE MONITORING

Long-term monitoring comprised 14 unattended monitoring stations which allowed noise to be measured simultaneously at all sites in the area.

Measurements of turbine noise were carried out continuously in 10-minute intervals in accordance with ETSU-97-R and synchronised with wind speed, direction and other operational data from the site.

Noise was initially recorded continuously to provide data that could be analysed at any future stage in the project. All measurements were time stamped to allow for correlation with other noise, meteorological and other relevant data. Noise measurements were referenced to Greenwich Mean Time to allow synchronisation with wind turbine data.

Continuous monitoring was carried out for a period of five weeks. Due to logistical problems with some of the noise meters monitoring was carried out for an additional week to ensure five weeks of data were available for analysis. At the end of the five week period an additional three weeks monitoring was carried out during ‘Winter’ conditions following representations critical of the monitoring being carried out during the ‘Summer’ season only.

In order to provide continuity of data at representative sites, three sites were chosen for monitoring during the interim period i.e. the time between the five week and three week monitoring periods. Sites on the west, centre and east of the wind farms were chosen, Sites 03, 09 and 13. Due to the volume of data being generated noise monitoring/measurement was continued on a 24 hour basis but recording of sound was reduced to night time hours only.

Due to the rural nature of the monitoring locations, the dawn chorus was a particular problem particularly during the summer months. This was the dominant noise source from 4am (BST) during the summer period. From around 6am traffic began to dominate the sound field and later in the day agricultural and domestic activity became the dominant sources. From an examination of the initial data it was clear that to isolate wind turbine noise the only period of interest would be 10pm to 4am.

3.11 ATTENDED MONITORING

Attended monitoring was carried out to assess the presence of tones, low frequency noise and amplitude modulation. Site visits were carried out on 15th/16th June, 13th July, 15th/16th August and 12th/13th/14th October 2016. Subjective monitoring for tonal and AM components in the wind turbine noise was carried out on each occasion. A five point subjective scale was used to evaluate the intensity of tonal and AM components. The scale is presented in **Table 3-1** and given the nature of wind turbine noise does not have a zero point on the scale.

Table 3-1: Subjective Scale for Tonal and AM Components

1	2	3	4	5
Not Significant	Noted	Evident	Clearly Audible	Dominant

The site visits were carried out to coincide with weather conditions that were expected to lead to significant AM and/or tonal components. This was based on weather forecasts and information coming in from the log sheets described in **Section 3.9**. Tonal and AM components were noted as outlined in **Table 6-2**.

4 NOISE MODEL

4.1 MODEL PARAMETERS

A noise model was generated for the area which incorporated the turbines from each of the four wind farms as well as each monitoring location. This was carried out to assess the impact of each wind farm on the individual monitoring locations, in particular where more than one wind farm may be having an effect on noise levels at the monitoring location. The noise model was carried out in accordance with the Institute of Acoustics (IoA) Good Practice Guidance document ''*A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*''. The model is referred to as the IoA model.

The model was calculated using ISO9613-2:1996 Acoustics – Attenuation of sound during propagation outdoors – Part 2: General Method of Calculation. This method of calculation is based on conditions favourable to propagation, i.e. moderate downwind conditions or under temperature inversions. In the case of four separate wind farms it is unlikely that the receiver will be downwind of all the turbines in the area so the calculation is relatively conservative.

The IoA GPG has recognised ISO 9613 as the most appropriate modelling method for wind farm noise provided certain parameters are included in the model calculations. The ground attenuation factor has a significant impact on the predicted noise levels at receiving locations due to differing absorption rates. A ground attenuation factor of 0.0 applies to hard ground (such as paving, water or concrete surfaces) and a ground attenuation factor of 1.0 applies to porous or soft ground (grassland, trees, vegetation). In accordance with the guidance a ground attenuation factor of 0.5 was applied to the model.

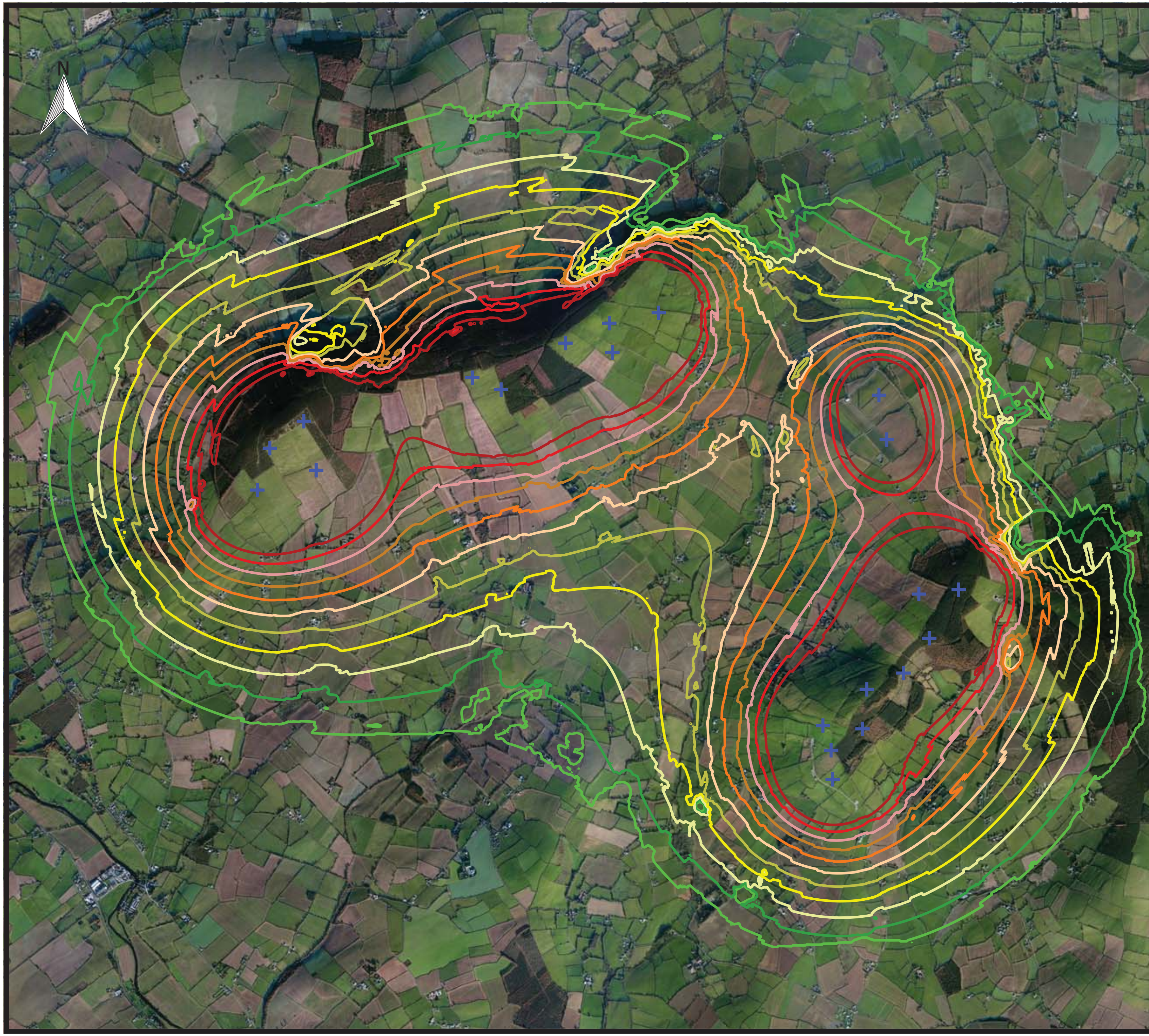
The guidance also recommends a receiver height of 4.0m and atmospheric conditions of 10˚C and 70% humidity, all of which were adopted in the noise model. The noise model predicted noise levels from the wind turbines at a wind speed of 10m/s in order to represent a worst case scenario for the propagation of noise from the wind turbines to the receiver points.

4.2 MODEL DATA

Terrain data for the noise model was obtained from Wexford County Council in the form of OSI Mapping. The terrain for an area of approximately 94km^2 was mapped using a 5m x 5m grid (approximately 9,000,000 grid points). A site survey was carried out by Wexford County Council to obtain the locations of the turbines for each of the four wind farms. The location data was subsequently provided to RPS and was incorporated in to the noise model.

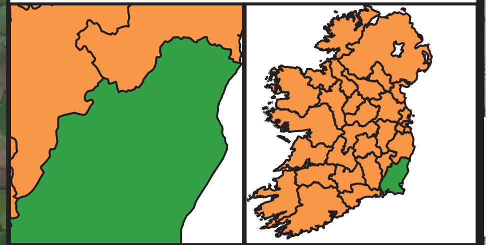
Sound power level data for the turbines for Gibbet Hill wind farm was obtained from the EIS report for the wind farm. As the turbines installed in the other three wind farms differed from what was quoted in the EIS reports the sound power level data for the turbines in the remaining wind farms was obtained from data provided to RPS by the turbine manufacturer.

Noise levels were calculated for each of the monitoring locations and the locations used for the EIS. The model prepared for this report using the IoA methodology is referred to as the IoA model.



Legend

- Turbine Locations
- Noise Prediction Contours
  - <35
  - 35-36
  - 36-37
  - 37-38
  - 38-39
  - 39-40
  - 40-41
  - 41-42
  - 42-43
  - 43-44
  - 44-45
  - >45



Client *Wexford County Council*

Project *Noise Monitoring Services (Wexford Wind Farms) - Lot 1*

Title **Noise Prediction Plot at 10m/s Wind Speed**

Figure **4.1**

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Drawn by: RMcK		**Project No.** MGE0552	
Checked by: EMcK		**File Ref.** MGE0552QG0009F01	
Approved by: GMcE			
Scale: nts		**Drawing No.** QG0009	**Rev.** F01
Date: 20/06/2017			

4.3 MODEL RESULTS

The results for Sites 01, 02, 03, 04, 05 and 13 are detailed in the sections below. The results show the contribution of each turbine (referred to as T1 – T6) at the Gibbet Hill wind farm towards the overall noise level at the site. The model results are shown on **Figure 4-1.** The predicted levels are compared to the levels predicted in the original EIS (referred to as the EIS model) submitted with the planning application for Gibbet Hill.

4.3.1 Site 01

The overall noise level result and contribution of each turbine at the Gibbet Hill wind farm to this noise level is shown in **Table 4-1**.

Table 4-1: Noise Level Results – Site 01, Gibbet Hill Turbines

Gibbet Hill T1 (dB L_{Aeq})	Gibbet Hill T2 (dB L_{Aeq})	Gibbet Hill T3 (dB L_{Aeq})	Gibbet Hill T4 (dB L_{Aeq})	Gibbet Hill T5 (dB L_{Aeq})	Gibbet Hill T6 (dB L_{Aeq})	Total Gibbet Hill (dB L_{Aeq})
28.5	29.1	35.2	36.5	40.1	39.3	44.5

The predicted noise level at a standardised wind speed of 10m/s at night time for this site in the EIS model is 43 dB(A). This is lower than the IoA model predicted level of 44.6 dB(A), as shown in **Figure 6-4**. The EIS model used a ground factor of G = 1.0, the RPS model uses the IoA recommended ground factor of G = 0.5 (intermediate ground).

Turbines T5 and T6 are shown to have the greatest impact on noise levels from the wind farm at Site 01.

The impact on noise levels at the site from all four wind farms are shown in **Table 4-2**. The trendline L_{Aeq} level at 10m/s was ~45.6 dB(A), based on measured L_{A90} less background noise + 3dB, as shown on **Figure 6-4**. The model predicted level was lower than the corrected measured level.

Table 4-2: Noise Levels from each wind farm – Site 01, All Wind Farms

Gibbet Hill (dB L_{Aeq})	Knocknalour (dB L_{Aeq})	Ballynancoran (dB L_{Aeq})	Ballycadden (dB L_{Aeq})	Total Noise Level at Site 01(dB L_{Aeq})
44.5	22.8	10.0	24.3	44.6

Noise levels at Site 01 are dominated by the turbines from Gibbet Hill wind farm. The difference in the noise level contribution between Knocknalour and Gibbet Hill wind farms is greater than 10 dB and therefore Knocknalour wind farm is having no impact on noise levels at Site 01. Ballynancoran and Ballycadden wind farms are also not having any impact on noise levels at Site 01.

4.3.2 Site 02

The overall noise level result and contribution of each turbine at the Gibbet Hill wind farm to this noise level is shown in **Table 4-3**.

Table 4-3: Noise Level Results – Site 02, Gibbet Hill Turbines

Gibbet Hill T1 (dB L_{Aeq})	Gibbet Hill T2 (dB L_{Aeq})	Gibbet Hill T3 (dB L_{Aeq})	Gibbet Hill T4 (dB L_{Aeq})	Gibbet Hill T5 (dB L_{Aeq})	Gibbet Hill T6 (dB L_{Aeq})	Total Gibbet Hill (dB L_{Aeq})
18.3	19.1	33.4	36.7	27.9	39.2	42.0

The predicted noise level at a standardised wind speed of 10m/s at night time for this site in the EIS model is 41 dB(A). This is lower than the IoA model predicted level of 42.1 dB(A).

Turbine T6 is shown to have the greatest impact on noise levels from the wind farm at Site 02.

The impact on noise levels at the site from all four wind farms are shown in **Table 4-4**. The trendline measured L_{Aeq} level at 10m/s was ~40.9 dB(A) based on L_{A90} less background noise + 3dB, as shown in **Figure 6-6**. The predicted level was higher than the corrected measured level.

Table 4-4: Noise Levels from each wind farm – Site 02, All Wind Farms

Gibbet Hill (dB L_{Aeq})	Knocknalour (dB L_{Aeq})	Ballynancoran (dB L_{Aeq})	Ballycadden (dB L_{Aeq})	Total Noise Level at Site 02 (dB L_{Aeq})
42.0	19.7	12.9	14.0	42.1

Noise levels at Site 02 are dominated by the turbines from Gibbet Hill wind farm. The difference in the noise level contribution between Knocknalour and Gibbet Hill wind farm is greater than 10 dB and therefore Knocknalour wind farm is having no impact on noise levels at Site 02. Ballynancoran and Ballycadden wind farms are also not having any impact on noise levels at Site 02.

4.3.3 Site 03

The overall noise level result and contribution of each turbine at the Gibbet Hill wind farm to this noise level is shown in **Table 4-5**.

Table 4-5: Noise Level Results – Site 03, Gibbet Hill Turbines

Gibbet Hill T1 (dB L_{Aeq})	Gibbet Hill T2 (dB L_{Aeq})	Gibbet Hill T3 (dB L_{Aeq})	Gibbet Hill T4 (dB L_{Aeq})	Gibbet Hill T5 (dB L_{Aeq})	Gibbet Hill T6 (dB L_{Aeq})	Total Gibbet Hill (dB L_{Aeq})
18.4	19.4	33.6	35.6	26.1	34.8	39.8

The predicted noise level at a standardised wind speed of 10m/s at night time for this site in the EIS model is 39 dB(A). This is lower than the model predicted level of 39.8 dB(A).

Turbines T3, T4 and T6 are shown to have the greatest impact on noise levels from the wind farm at Site 03.

The impact on noise levels at the site from all four wind farms are shown in **Table 4-6**. The trendline L_{Aeq} level at 10m/s was ~45.4 dB(A), based on measured L_{A90} less background noise + 3dB, as shown on **Figure 6-8**. The predicted level was considerably lower than the corrected measured level trendline. An analysis of the contours in this area indicated that a +3dB correction should be applied to the predicted level. There is still a significant difference between the modelled and measured levels at this location. While significant effort was made to exclude non-wind farm noise from the measurements Site 03 is close to a regional road and this influences the L_{Aeq} level significantly at this location.

Table 4-6: Noise Levels from each wind farm – Site 03, All Wind Farms

Gibbet Hill (dB L_{Aeq})	Knocknalour (dB L_{Aeq})	Ballynancoran (dB L_{Aeq})	Ballycadden (dB L_{Aeq})	Total Noise Level at Site 03 (dB L_{Aeq})
39.8	19.9	12.5	14.1	39.8

Noise levels at Site 03 are dominated by the turbines from Gibbet Hill wind farm. The difference in the noise level contribution between Knocknalour and Gibbet Hill wind farm is greater than 10 dB and therefore Knocknalour wind farm is having no impact on noise levels at Site 03. Ballynancoran and Ballycadden wind farms are also not having any impact on noise levels at Site 03.

4.3.4 Site 04

The overall noise level result and contribution of each turbine at the Gibbet Hill wind farm to this noise level is shown in **Table 4-7**.

Table 4-7: Noise Level Results – Site 04, Gibbet Hill Turbines

Gibbet Hill T1 (dB L_{Aeq})	Gibbet Hill T2 (dB L_{Aeq})	Gibbet Hill T3 (dB L_{Aeq})	Gibbet Hill T4 (dB L_{Aeq})	Gibbet Hill T5 (dB L_{Aeq})	Gibbet Hill T6 (dB L_{Aeq})	Total Gibber Hill (dB L_{Aeq})
21.6	22.9	37.6	36.8	21.2	27.8	40.7

The predicted noise level at a standardised wind speed of 10m/s at night time for this site in the EIS model is 42 dB(A). This is higher than the IoA model predicted level of 40.8 dB(A).

Turbines T3 and T4 are shown to have the greatest impact on noise levels from the wind farm at Site 04.

The impact on noise levels at the site from all four wind farms are shown in **Table 4-8**. The trendline L_{Aeq} level at 10m/s was ~39.3 dB(A), based on measured L_{A90} less background noise + 3dB, as shown on **Figure 6-10**.

Table 4-8: Noise Levels from each wind farm – Site 04, All Wind Farms

Gibbet Hill (dB L_{Aeq})	Knocknalour (dB L_{Aeq})	Ballynancoran (dB L_{Aeq})	Ballycadden (dB L_{Aeq})	Total Noise Level at Site 04 (dB L_{Aeq})
40.7	25.7	12.4	14.8	40.8

Noise levels at Site 04 are dominated by the turbines from Gibbet Hill wind farm. The difference in the noise level contribution between Knocknalour and Gibbet Hill wind farm is greater than 10 dB and therefore Knocknalour wind farm is having no impact on noise levels at Site 04. Ballynancoran and Ballycadden wind farms are also not having any impact on noise levels at Site 04.

4.3.5 Site 05

The overall noise level result and contribution of each turbine at the Gibbet Hill wind farm to this noise level is shown in **Table 4-9**.

Table 4-9: Noise Level Results – Site 05, Gibbet Hill Turbines

Gibbet Hill T1 (dB L_{Aeq})	Gibbet Hill T2 (dB L_{Aeq})	Gibbet Hill T3 (dB L_{Aeq})	Gibbet Hill T4 (dB L_{Aeq})	Gibbet Hill T5 (dB L_{Aeq})	Gibbet Hill T6 (dB L_{Aeq})	Total Gibbet Hill (dB L_{Aeq})
29.3	37.3	31.3	23.6	23.7	21.3	39.1

The predicted noise level at a standardised wind speed of 10m/s at night time for this site in the EIS model is 40 dB(A). This in good agreement with the IoA method model predicted level of 40.4 dB(A).

Turbine T2 is shown to have the greatest impact on noise levels from the wind farm at Site 05.

The impact on noise levels at the site from all four wind farms are shown in **Table 4-10**. The trendline L_{Aeq} level at 10m/s was 40.4 dB(A), based on measured L_{A90} less background noise + 3dB, as shown on **Figure 6-12.** The predicted level was in agreement with the corrected measured level at this site.

Table 4-10: Noise Levels from each wind farm – Site 05, All Wind Farms

Gibbet Hill (dB L_{Aeq})	Knocknalour (dB L_{Aeq})	Ballynancoran (dB L_{Aeq})	Ballycadden (dB L_{Aeq})	Total Noise Level at Site 05 (dB L_{Aeq})
39.1	34.2	14.9	17.2	40.4

Noise levels at Site 05 are dominated by the turbines from Gibbet Hill wind farm. The difference in the noise level contribution between Knocknalour and Gibbet Hill wind farm is 5 dB and therefore Knocknalour wind farm is having some impact on noise levels at Site 05. At Site 05 it is possible that Knocknalour wind farm dominates the noise level in certain wind conditions. The difference in the noise level contribution between Ballynancoran and Gibbet Hill wind farm is greater than 10 dB and therefore Ballynancoran wind farm is having no impact on noise levels at Site 05. Ballycadden wind farm is not having any impact on noise levels at Site 05.

4.3.6 Site 13

The overall noise level result and contribution of each turbine at the Gibbet Hill wind farm to this noise level is shown in **Table 4-11**.

Table 4-11: Noise Level Results – Site 13, Gibbet Hill Turbines

Gibbet Hill T1 (dB L_{Aeq})	Gibbet Hill T2 (dB L_{Aeq})	Gibbet Hill T3 (dB L_{Aeq})	Gibbet Hill T4 (dB L_{Aeq})	Gibbet Hill T5 (dB L_{Aeq})	Gibbet Hill T6 (dB L_{Aeq})	Total Gibbet Hill (dB L_{Aeq})
34	32.4	27.2	26.3	28.4	26.2	38.0

The predicted noise level at a standardised wind speed of 10m/s at night time for this site in the EIS model is 37 dB(A). This is lower than the RPS predicted level of 40.2 dB(A). Turbines T1 and T2 are shown to have the greatest impact on noise levels from the wind farm at Site 13.

The impact on noise levels at the site from all four wind farms are shown in **Table 4-12**.

Table 4-12: Noise Levels from each wind farm – Site 13, All Wind Farms

Gibbet Hill (dB L_{Aeq})	Knocknalour (dB L_{Aeq})	Ballynancoran (dB L_{Aeq})	Ballycadden (dB L_{Aeq})	Total Noise Level at Site 13 (dB L_{Aeq})
38.0	34.6	23.7	30.0	40.2

This total noise level is greater than the prediction in the EIS as the Gibbet Hill EIS noise model did not include the Knocknalour wind turbines. If the Knocknalour turbines were considered the LAeq prediction would be closer to 40.2 dB(A), the value as the RPS model.

The corresponding L_{Aeq} level at 10m/s was 39.3 dB(A), based on measured L_{A90} less background noise + 3dB, as shown on **Figure 6-14**. The predicted level was higher than the corrected measured level.

Noise levels at Site 13 are dominated by the turbines from Gibbet Hill wind farm; however the difference in the noise level contribution between Knocknalour and Gibbet Hill wind farm is 3 dB and therefore Knocknalour wind farm is having a potentially noticeable impact on noise levels at Site 13. In northerly winds Site 13 is downwind of both Gibbet Hill and Knocknalour wind farms. As the wind swings to the West Gibbet Hill may become more dominant whereas when the wind has a more Easterly component Knocknalour may become dominant. In the event of either wind farm having some or all turbines out of service the other will dominate the noise levels when operating.

Ballycadden wind farm is also having some impact on noise levels at Site 13 due a difference in noise levels between it and Gibbet Hill of 7dB. The difference in the noise level contribution between Ballynancoran and Gibbet Hill wind farm is greater than 10 dB and therefore Ballynancoran wind farm is having no impact on noise levels at Site 13.

4.3.7 Overall Modelling Results

In general the EIS and RPS models are in good agreement. The main difference is that the RPS model, which was based on the latest IoA guidance, predicted slightly higher noise levels south and west of

Gibbet Hill and for Sites 04 and 05 the EIS prediction was higher. Some of the difference can be explained by the fact that the RPS model is a cumulative model of all four wind farms, whereas the EIS model only considered Gibbet Hill turbines. The noise impact at specific locations due to specific wind turbines can be assessed from the model. In most cases a limited number of turbines dominate the impact. In the case of Site 13, which has the lowest cumulative impact, the impact could arise from either the Gibbet Hill or Knocknalour wind farms.

5 DATA ANALYSIS

5.1 CALIBRATION

All equipment used for the noise monitoring surveys were checked by RPS to ensure that they were fit for purpose, in adequate working order and were calibrated to an accredited standard. All the sound level meters used are Class 1 Sound Level Meters which are calibrated in accordance with the requirements as specified in:

- BS 7580: Part 1: 1997; or
- ICE 60651 and 60804 Type 1; or
- BS EN IEC 61672-1:2003.

All meters and the acoustic calibrators were externally calibrated through an Accredited Calibration process. The Accredited Calibration process provides calibration that is approved by independent audit by national accreditation authorities.

The RPS Calibration Procedure (Procedure No: RPS – 104) was complied with to ensure that an adequate system of calibration traceability was maintained for RPS owned instrumentation/equipment.

All calibration certificate details are provided in **Appendix A**. All noise meters were field checked in advance of the survey and all meters were calibrated before and after the survey using a calibrator to an accuracy of ± 0.3dB.

No instances of a significant variation in calibration levels before or after a measurement period was noted.

Noise levels for compliance purposes are generally in excess of 35 dB(A) so no corrections for instrument self-noise were necessary.

5.2 DATA QUALITY CONTROL

Survey data from the measurements was downloaded from the Secure Digital card used in the noise meter and a backup copy was made of the raw data. The raw data was stored in Bruel & Kjaer Measurement Partner Suite file format.

Measuring 14 sites continuously led to some technical issues with the equipment. This did not impact on the accuracy of the data but did mean that data for some periods could not be recovered. A running list of data collected from site and backed up onto hard disc was maintained throughout the measurement period. At the end of the initial five week period it emerged that due to technical difficulties (batteries running flat, Secure Digital card faults, etc.) some data could not be recovered. Additional monitoring was carried out for a sixth week to ensure sufficient data was collected during this phase.

As outlined in **Section 3.10** monitoring was carried out for an initial five week period, then for an interim period of fifteen weeks on three sites and finally for a three week period in November/December 2016. Due to the constrained nature of the interim period some data was not recovered and it was not possible to extend the interim period prior to the final three week monitoring period. Data was collected with an average contracted recovery rate of 97% over the separate 5, 15, and 3 week periods.

5.3 DATA VALIDATION

As outlined in **Section 5.3.1**, measuring wind turbine noise requires the specific sound of the wind turbines to be isolated from the ambient sound, which includes all sound at the measurement location including distant sounds such as traffic and nearby sounds from human activity.

Wind farm operators are only responsible for noise caused by the wind turbines. In order to isolate noise emanating from the wind farm, data filtering was carried out to exclude data that was not considered to be relevant. Filtering of data was carried out in accordance with the Institute of Acoustics Supplementary Guidance (SGN) Note 5: Post Completion Measurements. The guidance states that the following can be carried out during data analysis:

- ‘Filter out any periods when rainfall may have affected the results’ (see SGN2)
- Unless there is any particular requirement to measure day-time noise levels (i.e. complaint during these periods) it may be useful to filter out all data except that measured between 2300 and 0400 when competing noise (including early morning birdsong and traffic) would be at a minimum. Evening measurements may also be sufficiently affected by spurious sources, depending on the background noise character of the locality.’’

As the measurements were carried out at night some data was measured close to the noise floor of the instrumentation. In order to avoid this data having an impact on data trend lines it was also filtered out.

5.3.1 Filtering non-Wind Farm Noise

Weather stations were established at Sites 03 and 13 recording local wind speed and direction along with rainfall events. The data for the rainfall was aggregated so that if rain was recorded on either Site 03 or Site 13 all data was excluded for that period.

From a preliminary noise analysis of the data it was found that data for the period 22:00 hrs to 04:00 hrs provided sufficiently clear wind turbine noise for preliminary analysis. Earlier than 22:00 hrs resulted in significant anthropogenic sound and after 04:00 hrs birdsong tended to dominate the soundscape During the period 06:00 hrs to 20:00 hrs there was a generally high level of sound unrelated to the wind farms that tended to mask the wind farm noise. **Figure 5-1** shows an aggregated measurement over a 10 day period indicating the average number of seconds in a 10 minute period in which tones were detected using the one third octave band method, i.e. if a tone were detected for a 1 second period it is reflected in the plot at the time of day it occurred. As illustrated in **Figure 5-1** the vast majority of tones occur during the day time. From an examination of the frequency profiles these tones are not attributable to wind farm noise.

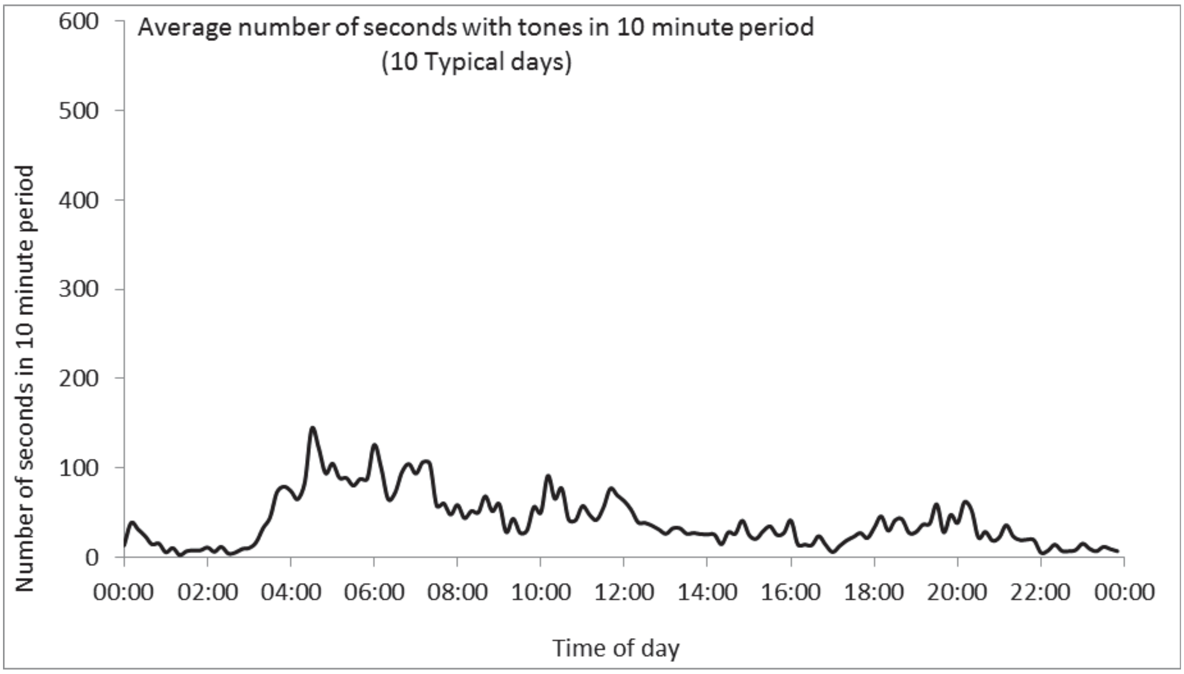

Figure 5-1: Occurrence of tones as defined in Section 2.9.1

Similarly an analysis of the aggregated presence of low frequency noise is plotted against the time of day in which it occurred in **Figure 5-2**. This illustrates that low frequency noise is present throughout the day and is significantly lower at night when wind turbine noise is the dominant noise source. This is in agreement with the fact that natural and other human activities (e.g. traffic, agriculture, industy, etc.) are sources of low frequency noise that are greater than those arising from wind farms.

As outlined in **Section 3.3** a filter of night time (22:00hrs to 04:00hrs) was applied to all data in order to isolate wind farm noise only. The data collected during this period was then examined for both tonal and low frequency content.

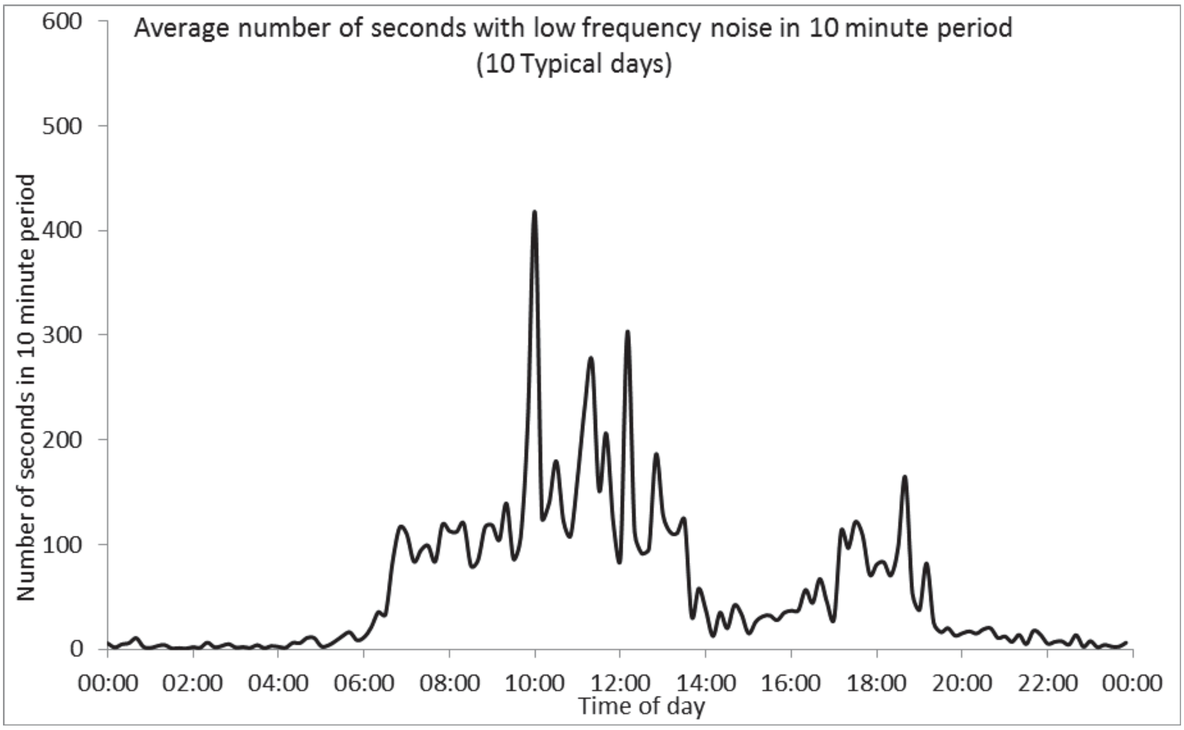

Figure 5-2: Average number of seconds within a 10 minute period with low frequency noise

5.4 FUNDAMENTAL PARAMETERS

Following the data download and subsequent processing steps, analysis of the data was carried out for the parameters stated in **Section 1.1**. Metrics such as L_{Aeq} and L_{A90} were examined for validity and consistency with wind turbine noise. Where unusual levels were recorded a range of techniques were used, as far as practicable, to isolate noise being examined as wind farm noise only.

Wind speed analysis was carried out in accordance with the Institute of Acoustics Supplementary Guidance Note 4: Wind Shear for the document ''*A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*''. The roughness length used was the one provided in the EIS, i.e. 0.05m. All wind speeds presented in this report are corrected for wind shear unless otherwise stated.

5.4.1 L_{Aeq} or L_{A90}

Wind turbine noise is different from other noise sources. With most noise sources measurements are taken under fair weather conditions, i.e. light winds. In the case of wind turbine noise measurements must of necessity be taken in windy conditions and the noise level varies with those wind conditions. At lower wind speeds the difference between L_{Aeq} and L_{A90} can be significant, particularly if noise unrelated to wind turbine operation is included in the data.

L_{Aeq} tends to be sensitive to peaks in the noise signal, such as the passing of an individual vehicle or a single loud call from an animal. It thus tends to include a significant proportion of non-wind farm noise. L_{A90} is reflective of noise levels that are relatively steady, such as wind farm noise. IoA Working Group, IoA(2016), states:

> '*The Noise Working Group is agreed that the $L_{A90,10min}$ descriptor should be used for both the background noise and the wind farm noise, and that when setting limits it should be borne in mind that the $L_{A90,10min}$ of the wind farm is likely to be about 1.5-2.5dB(A) less than the L_{Aeq} measured over the same period. The use of the $L_{A90,10min}$ descriptor for wind farm noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources*'.

This reinforces the original research finding from ETSU (1997) which arrived at the same conclusion.

Wind turbine noise, excluding AM, is relatively steady in nature. Variation in the noise level due to AM is treated separately in this report. In order to isolate wind turbine noise only measurements should be carried out using the L_{A90} metric. For the purpose of this report a 3 dB correction to the L_{A90} level, based on the Wexford County Development Control Standards for Wind Farms, was applied.

5.4.1.1 Statistical comparisons of L_{Aeq} and L_{A90} at Sites 03 and 13

Long duration datasets were collected at Site 03 and Site 13 and these were analysed to compare L_{Aeq} measurements to L_{A90} measurements. **Figure 5-3** and **Figure 5-4** illustrate the relationship between L_{Aeq} and L_{A90}. Both are plotted for the night-time period along with a normalised wind turbine noise curve for illustration purposes. The characteristic shape of a noise curve for a large pitch controlled wind turbine is that it rises to a plateau at a wind speed of 8 to 10 metres per second. Measured wind turbine noise would be expected to follow this characteristic shape.

In the figures it is notable that the L_{A90} data clusters about this type of curve whereas the L_{Aeq} levels do not follow the pattern and appear to be more randomly distributed. This confirms the IoA Working Group position regarding the use of a L_{A90} measurement for wind turbine noise. In seeking to attribute noise levels specific to wind turbine noise the case is readily made using the L_{A90} metric, whereas it is not so clear using the L_{Aeq} metric.

Note in both cases however that at wind speeds greater than 10m/s the L_{Aeq} levels continue to rise and are unrelated to wind turbine noise.

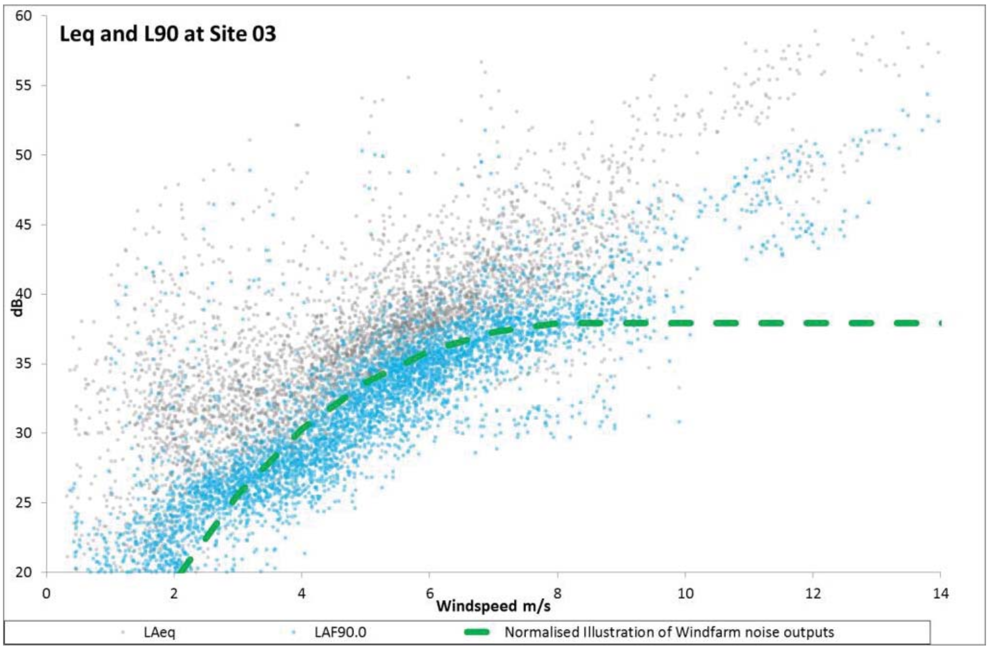

Figure 5-3: Statistical comparison of L_{Aeq} and L_{A90} at Site 03

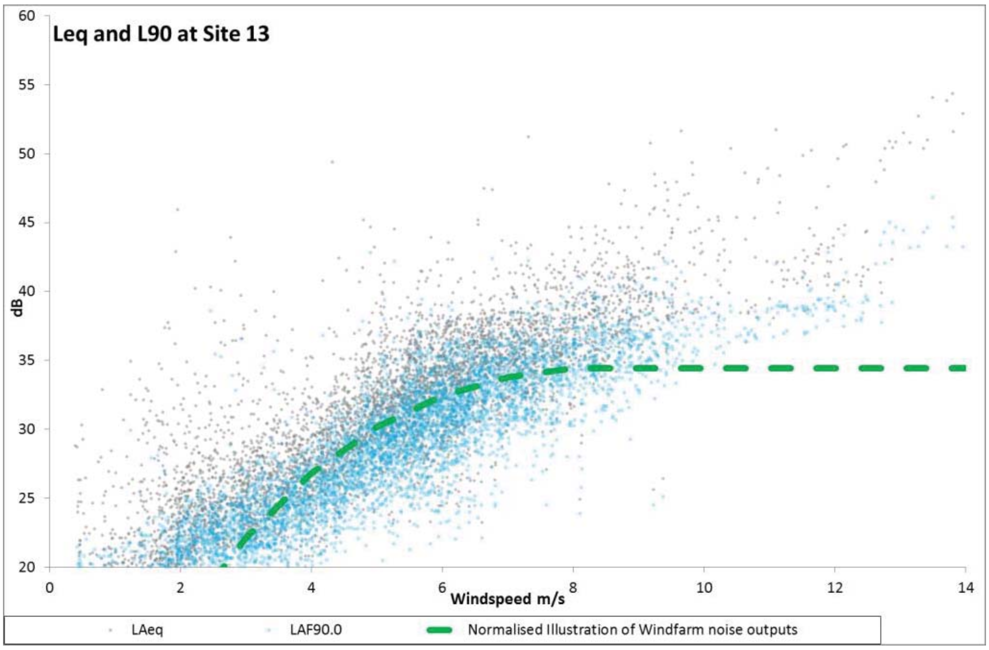

Figure 5-4: Statistical comparison of L_{Aeq} and L_{A90} at Site 13

5.5 TONAL ANALYSIS

The assessment of the presence of tones was carried out using the methodology described in **Section 2.10.1**. The primary method of analysis used was the objective one third octave method.

A data matrix of sound pressure levels at each one third octave band against date time was created where each record represents a 10 minute interval. Intervals that are considered day-time are removed leaving night only (22:00hrs – 04:00 hrs).

In each 10 minute interval the level of each one third octave band is compared to the band above and below it. A tone is detected if the amplitude of a third octave band is sufficiently greater than both the third octave band above and below it.

The objective method set out in ISO 1996-2:2007 sets out the difference between adjacent bands required. The difference in the amplitude must be 15 dB at lower frequencies 8 dB at mid-frequencies and 5 dB at higher frequencies as shown in **Table 5-1.**

Table 5-1: One Third Octave Band differences indicating the presence of a tone

Frequency Band Hz	Delta dB
Below 160 Hz	15
160 – 400 Hz	8
Over 400 Hz	5

The reference method using Fast Fourier Transform (FFT) analysis was carried out on selected data. The reference method is the objective method set out in Annex C of ISO1996-2:2007.

5.6 LOW FREQUENCY NOISE

As outlined in **Section 2.10.2** low frequency noise levels indoors from external sources depend on the external noise level from those sources, the noise insulation of the structure of the building and the internal room dimensions. It is difficult to measure low frequency noise indoors over long periods and the measurement methodology has a significant bearing on the result. As a consequence there is no agreement other than several internal measurement locations may be required simultaneously to determine the low frequency noise level in a room.

For this study low frequency noise content was assessed using one-third octave band (10-160Hz) spectra using the thresholds and sound insulation values set out in **Table 5-2**.

Table 5-2: Low Frequency Noise levels

Frequency	Danish correction	RPS correction	DEFRA (internal)	RPS limits (external)
LZeq 10Hz	4.9	0	92	92
LZeq 12.5Hz	5.9	0	87	87
LZeq 16Hz	4.6	0	83	83
LZeq 20Hz	6.6	0	74	74
LZeq 25Hz	8.4	0	64	64
LZeq 31.5Hz	10.8	1	56	57
LZeq 40Hz	11.4	3	49	52
LZeq 50Hz	13	5	43	48
LZeq 63Hz	16.6	7	42	49
LZeq 80Hz	19.7	9	40	49
LZeq 100Hz	21.2	11	38	49
LZeq 125Hz	20.2	13	36	49
LZeq 160Hz	21.2	15	34	49

A data matrix of unweighted sound level at each one third octave band against date and time was created where each record represents a 10 minute interval. Intervals that are considered day-time are removed leaving night only (22:00 – 04:00 hrs). The value of each interval at each one third octave band is checked against the University of Salford internal guidelines adjusted for external measurements by RPS as set out in **Table 5-2** and exceedances recorded.

5.7 AMPLITUDE MODULATION

As outlined in **Section 2.10.3** the UK Institute of Acoustics (IoA) Amplitude Modulation Working Group (AMWG) has developed a method for analysing and rating AM (IoA AMWG, 2016). RPS developed Matlab code to process WAV files and calculate a rated AM level in accordance with the IoA method. As this methodology was released during the measurement period, it was necessary to develop a mechanism for evaluating AM noise during the course of the project.

The AMWG has also produced an example of an implementation of the routine described in the IoA AMWG report. This was used to benchmark an implementation developed by RPS using Matlab.

5.7.1 Benchmarking RPS Matlab Implementation of IoA Method for Rating AM

In order to validate the RPS implementation a series of validation tests were carried out on sample waveforms. Three sample waveforms were collected from three different turbine types; Enercon E82 2.3 MW, Vestas V52 0.85MW and a Seimens SWT3.0-101 3 MW at three wind farms unrelated to this project. Data was collected in the form of 100ms third octave band data and WAV recordings. Measurements were carried out using a Bruel & Kjaer model 2250 noise meter with sound recording capability.

The data was analysed in two ways and the results were compared as follows:

- Path A: One third octave values measured using a Bruel & Kjaer 2250 noise level meter were analysed using the IoA method for rating AM (vers. 1.3); and
- Path B: WAV recordings were made simultaneously by the noise level meter were analysed using the RPS implementation.

5.7.2 AM Signal Processing

Three test signals are considered, referred to as 'Enercon', 'Vestas' and 'Siemens'. The test signals are each of 10 minutes duration.

'Path A' consists of the following steps:

1. The 1/3-octave unweighted L_{Aeq} values produced by Bruel & Kjaer software are A-weighted.
2. The 1/3-octave values are aggregated into the three gross frequency bands used in the IoA methodology, i.e. 50-200 Hz, 100-400 Hz and 200-800 Hz to produce L_{Aeq} values.
3. The L_{Aeq} values in each gross frequency band are processed by the IoA AM rating method to produce an overall AM value for each file.

The RPS implementation ('Path B') takes a recorded noise measurement (WAV file) and carries out the entire processing chain in the Matlab environment.

5.7.3 AM Code Validation Results

Table 5-3 to **Table 5-5** summarise the results for the three files. Overall AM ratings are given for both signal processing Paths, for each of the three gross frequency bands, for each of the three test files.

Table 5-3: Summary results for AM rating evaluations Test case 1 Enercon Turbines

Site	AM rating for each gross frequency band		
Enercon	**50-200 Hz**	**100-400 Hz**	**200-800 Hz**
Path A	5.03 dB	5.04 dB	5.59 dB
Path B	5.09 dB	5.04 dB	5.47 dB

Table 5-4: Summary results for AM rating evaluations Test case 2 Vestas Turbines

Site	AM rating for each gross frequency band		
Vestas	**50-200 Hz**	**100-400 Hz**	**200-800 Hz**
Path A	-1	-1	-1
Path B	-1	-1	-1

Table 5-5: Summary results for AM rating evaluations Test case 3 Seimens Turbines

Site	AM rating for each gross frequency band		
Siemens	**50-200 Hz**	**100-400 Hz**	**200-800 Hz**
Path A	6.32	3.97	2.92
Path B	6.23	3.81	2.93

The maximum value for each file across the gross frequency bands is highlighted in red in the tables. Note: a figure of '-1' indicates that AM was not declared, because there were insufficient 10-second blocks containing prominent AM in the signal.

As can be seen from **Table 5-3** to **Table 5-5**, the maximum difference between Paths A and B is 0.16 dB across all measurements. Among the maximum values across the three gross frequency bands, the maximum difference is 0.12 dB. Based on these results the RPS implementation is suitable for use directly on WAV recorded files.

5.7.4 Additional filtering on Amplitude Modulation Data

WAV files were analysed in accordance with the (IoA AMWG, 2016), using the RPS implementation. Audio recordings were pre-filtered using the criteria outlined in **Section 5.3.1**, i.e. taken in the period 22:00 hrs to 04:00 hrs period and excluding rain events.

When measuring wind farm noise for compliance purposes it is necessary to isolate wind farm noise from other sources. Even though sound recordings were pre-screened significant numbers of files recorded traffic events, animal noises such as dogs barking and other unrelated sounds. Additional screening to remove files containing sounds unrelated to wind farm operation were screened out using the following criteria:

1. If $L_{Aeq} > L_{A10}$

   Wind Farm noise tends to be relatively steady state. Even with significant AM components, the L_{Aeq} for a 10 minute WAV file should be lower than the L_{A10} for the same period.
2. If the L_{Aeq}-$L_{A90} > 6$

   WAV files with a significant difference between the L_{Aeq} and the L_{A90} contain short duration, high energy noise events, such as a vehicle passing quickly through the area.
3. Amplitude at 800 Hz < 1000 Hz or higher

   Wind turbine noise and AM in particular tend to occur at frequencies below 800 Hz. Where birdsong (which can be measured as AM) is contained in the recordings a filter was used to remove any recordings where the high frequency content was greater than the frequencies of interest.

An additional filtration criteria where $L_{A10} > L_{A90} + 10$ dB was found to have no effect on the data so was not used. These filtration mechanisms facilitated the isolation of non-wind farm noise from the files of interest and are effective in removing non-wind farm related noise events.

6 RESULTS

The following is a summary of the data for the Gibbet Hill wind farm. Results are based on and compared to night-time thresholds. From a preliminary analysis of the data it was clear that using day-time data would be problematic as it was difficult to isolate wind turbine noise only. In all cases if the night-time thresholds are met, day-time levels will also be in compliance.

6.1 PERIODS EXAMINED

As outlined in **Section 5.3.1** night refers to 22:00 hrs to 04:00 hrs. This truncated night period was chosen following preliminary analysis of the optimum period in which to isolate wind farm noise. Note that considerably more data is available for Site 03 and Site 13 than the other four sites. This is due to the fact that monitoring continued at these sites throughout the full monitoring period. At Sites 01, 02, 04 and 05 monitoring was undertaken for five weeks in the summer and was carried out for three weeks in the winter period.

Table 6-1: Aggregate periods of data per site

SITE	Site 01	Site 02	Site 03	Site 04	Site 05	Site 13
Number of 10 minute intervals Monitored	9197	9121	19244	9303	8214	21420
Number of 10 minute intervals during the night period	2286	2268	4813	2340	2059	5322

As can be seen from **Table 6-1** the number of periods for which data is available is very large and even when rainfall and other non-relevant events are excluded, sufficient data remains to draw statistically robust conclusions. Percentage figures presented in the tables below are calculated based on the total night-time period monitored.

6.2 WEATHER DATA

Wexford County Council sought assistance from the four wind farm operators in the area. The following wind farm data was made available to RPS:

1. Wind speed measured at the nacelle and corrected for ‘free field’ conditions.
2. Wind direction measured at the nacelle and corrected for ‘free field’ conditions.
3. Turbine output data.
4. Turbine interruption data (due to faults or grid output limits).

This data is commercially sensitive and was provided on a strictly confidential basis. RPS has used the data to prepare this report and no longer has access to raw data as provided by the wind farm operators in accordance with the terms under which it was provided to us.

Wind speed and direction is highly variable and this is one of the reasons the monitoring period was extended. The windrose for Rosslare meteorological station, the closest to the site for which long term average data is available, is shown in **Figure 6-1.** Wind is predominantly from the southwest with lower occurrences of northerly or southeasterly winds.

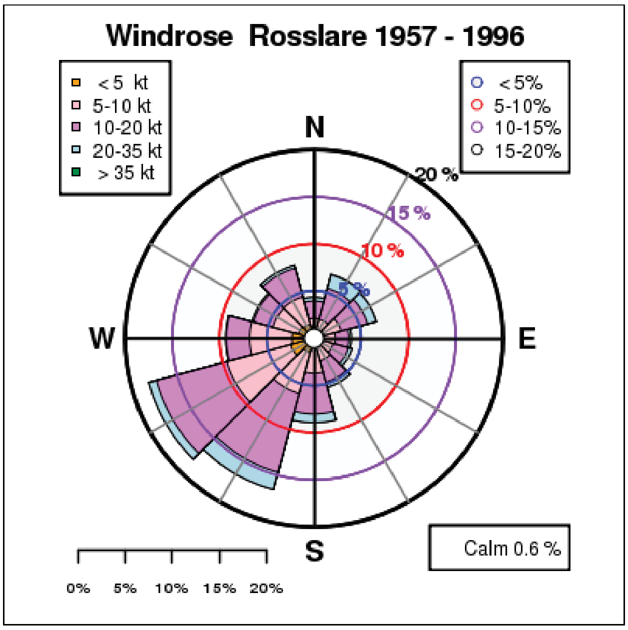

Figure 6-1: Met Eireann windrose for Rosslare station 1957-1996

When determining the wind speed and direction at any particular time, the average wind speed from all turbines in the relevant wind farm were averaged. This was used to create a windrose of wind speed and direction (**Figure 6-2**). There was little variation between turbines in any particular 10 minute intervals with a median standard deviation across turbines is small and thus a gross mean is appropriate.

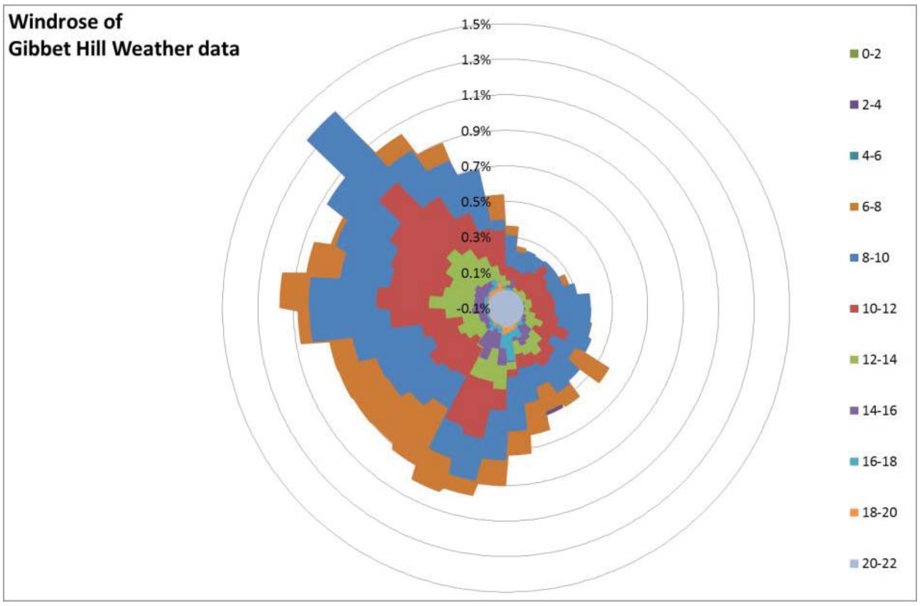

Figure 6-2: Windrose of Gibbet Hill weather data (all turbines all time)

6.2.1 Wind speed and direction

Data from Sites 03 and 13 rarely included localised wind from the north, whereas the wind farm data and long term Rosslare data indicated a more frequent occurrence. This is probably due to localised topographical sheltering effects even at 10m above ground. Using the turbine hub height wind direction also provided reliable wind direction data for all 14 sites.

Due to these site specific issues with the wind direction data it was decided to use the wind direction data from the wind farms to correlate with noise levels. This provides a more representative picture of 'downwind' conditions. Based on a comparison of the hub height wind direction and the localised wind direction on Sites 03 and 13 localised measurements could not provide a reliable indication of when the turbines were upwind of the measurement location.

Wind speed and direction for the Gibbet Hill wind farm was averaged and plotted as a wind rose in **Figure 6-2**. This indicates that a range of wind speeds from calm to 22m/s was measured over the survey period. Wind direction was predominantly from the southwest as would be expected but data was collected for all directions.

Wind speeds were standardised to 10m in accordance with IoA Guidance. Wind shear values were converted using roughness length utilised in the EIS, i.e. 0.05m. The use of a 'standardised' wind speed measurement height is necessary to correlate with the international standard used for the measurement and analysis of acoustic emissions from wind turbines.

6.3 NOISE LOGS

The noise logs provided were analysed for correlations between specific wind conditions and noise 'events'. There was little correlation between the wind direction and reported noise at the monitored location. There did appear to be an important correlation in reported annoyance and large difference in the wind speed at the turbines and the local wind speed. This would correlate with periods of high wind shear.

The average wind speed from all turbines in the relevant wind farm was compared to the average wind speed of the nearest one or two turbines. There was no significant difference in the average windspeed recorded for the wind farm in total and the average wind speed recorded for the nearest turbine(s). Therefore the average wind speed for the entire windfarm was used.

From an analysis of the noise logs that noise events are more closely related to periods of high wind shear rather than wind speed or direction. The noise logs also referred to low frequency noise 'whump' and other terms that relate to AM type noise rather than low frequency noise in isolation.

6.4 ATTENDED MONITORING

In order to provide first hand information on noise levels arising on the measurement sites an experienced acoustician attend at the sites on dates between June and October to listen to the noise sources audible at each location.

Table 6-2: Attended Site Notes

Date	Time (BST)	Location	Note
16th June	03:29	Site 01	AM evident
16th June	04:24	Site 03	AM evident, tonal noted
16th June	04:45	Site 13	AM noted no tonal
13th July	20:48	Site 13	AM noted, possible tonal
15th August	23:40	Site 03	AM noted, possible tonal
16th August	04:25	Site 03	Tonal noted, no significant AM
16th August	15:54	Site 04	Very faint tonal
12th October	22:17	Site 03	Tonal and AM noted
12th October	23:06	Site 05	Tonal and AM Evident
13th October	02:39	Site 13	No significant tone or AM
13th October	03:27	Site 04	Tonal evident
14th October	01:45	Site 13	No significant AM or tonal
14th October	01:58	Site 01	AM noted
14th October	02:38	Site 02	AM noted
14th October	03:20	Site 03	AM clearly audible

Measurements were taken during weather conditions that were thought likely to give rise to adverse noise components such as tonal noise, low frequency noise and/or AM. In order to adequately assess the noise arising from the wind farms the noise monitoring surveys were carried out during night hours (23:00 hrs - 07:00 hrs) when noise levels from other sources (birdsong, traffic etc.) were at a minimum. This allowed for the isolation of wind farm noise. Other non-wind farm noise sources during the survey were excluded during data analysis.

6.5 LIMITS BASED ON EIS STATEMENTS

As outlined in **Section 2** there are no expressed noise limits in the Planning Conditions imposed by Wexford County Council. The noise level limits are set by reference to the 'plans and particulars lodged with the planning application'. Condition 1 states this and Condition 11 refers to the noise levels predicted in the EIS.

RPS has examined the planning documents provided by Wexford County Council and is of the opinion that the relevant site specific noise level limit for Gibbet Hill wind farm based on Figure 9.6 of the EIS for each of the measurement sites is presented in **Table 6-3**:

Table 6-3: Site specific L_{Aeq} level limit for Gibbet Hill wind farm based on Figure 9.6 of the EIS

SITE	Site 01	Site 02	Site 03	Site 04	Site 05	Site 13
Noise level at 10m/s	43	41	39	42	40	37

Because some of the measured noise levels are close to background noise levels it is necessary to correct for background noise. A noisemeter detects the cumulative noise level of wind turbine noise and background noise. In order to isolate wind turbine noise only, background noise levels must be subtracted logarithmically from the overal noise level.

In addition it is necessary to ask whether these limits are to be measured as L_{Aeq} or L_{A90} and whether 'strict' compliance is required, i.e. if a single noise measurement exceeds these levels is the wind farm non-compliant? The EIS makes reference to L_{Aeq} levels, therefore it must be taken that L_{Aeq} levels are appropriate. As outlined in **Section 5.4.1** it is difficult to isolate wind farm noise from other sources so the L_{A90} metric with a conversion to L_{Aeq} is also reported. RPS present the data as measured and provide an opinion as to whether 'substantial compliance' or 'strict compliance' is achieved.

6.5.1 Compliance

In determining compliance the evaluation has been made using the L_{A90} measurement adjusted for background noise levels with 3 dB added to obtain a L_{Aeq} noise level, (L_{A90} – background noise) + 3dB. The basis for using this metric is set out in **Section 5.4.1** where the case for using a L_{A90} measurement in order to isolate wind turbine noise from other frequently occurring sources. This is referred to as 'corrected L_{Aeq}' in the following sections.

Background noise levels at the sites were taken from the nearest equivalent measurement location set out in the EIS. These are set out in **Table 2-1**. In some cases the adjustment is trivial but nonetheless it is carried out.

The reason for using a +3 dB conversion from L_{A90} to L_{Aeq} is because the EIS for Gibbet Hill makes reference (at Section 9.1.2) to the Wexford County Development Control Standards for Wind Farms, which sets out a 3 dB conversion factor. As outlined previously this is more conservative than 'standard' industry practice. 3 dB is appropriate as there is no specific consideration in the Planning Conditions of special audible characteristics, such as tonal noise, of the wind turbine noise. In the circumstances it is not unreasonable to adopt a conservative factor.

Condition 1 and Condition 11 refer to the noise levels predicted in the Gibbet Hill EIS. RPS has examined Figure 9.6 of the EIS and RPS is of the opinion that the appropriate site specific noise limit for the measurement sites adjacent to the Gibbet Hill wind farm are those set out in **Table 6-3**.

In order to evaluate compliance with these levels consideration was only given to night-time noise levels which were pre-filtered for rain events. It is important to bear in mind that a direct comparison with L_{Aeq} measurements, while stated in the table, is not appropriate as it is not possible to attribute the L_{Aeq} noise level to the wind farms with any certainty.

The L_{A90} levels adjusted for background noise and L_{A90} levels adjusted for background noise and converted to L_{Aeq} levels using the Wexford County Development Control Standards for Wind Farms conversion factor are also provided in **Table 6-4**.

Table 6-4: Exceedance of the levels stated in Figure 9.6 of the EIS

SITE	Site 01	Site 02	Site 03	Site 04	Site 05	Site 13
EIS Limit (site specific L_{Aeq}) dB	***43***	***41***	***39***	***42***	***40***	***37***
Number of intervals where L_{Aeq} exceeded Site Specific level (night period)	158	60	750	75	65	595
Number of intervals where (L_{A90}-BG*) +3dB was over Site Specific level (night period)	184 (8.0%)	46 (2.0%)	677 (14.1%)	25 (1.1%)	20 (1.0%)	518 (9.7%)

*Background noise

6.5.2 Compliance with Figures 9.7 to 9.16 of the EIS

Figures 9.7 to 9.16 of the EIS set out an ETSU-R-97 type curve for compliance. For the purpose of this report comparison is only made with the night-time levels. In the EIS the predicted noise level at particular sites was set out as a curve on a plot against background noise. In five cases the EIS sites were close enough to the sites for this study to make direct comparisons. The curves for these sites are reproduced in the figures below (red line) and compared against the L_{Aeq} measured level as this is the metric presented in the EIS.

The solid red line represents the site specific predicted level in the EIS and the dashed red line represents the level indicated in the conclusion of the EIS. Site 03 is too far removed from any of the EIS sites to use one of the the ETSU-R-97 type curves. In the case of Site 03 a reference level was taken from Figure 9.6 of the EIS so the threshold is limited to a 10m/s wind speed.

As can be seen in the plots L_{Aeq} data is significantly scattered. The black line is a trendline fit to the measured data. In all cases this trendline continues to increase with increasing wind speed. This is not consistent with wind turbine noise and reflects the fact that L_{Aeq} includes noise from multiple sources unrelated to the wind farm.

It is therefore not possible to state with any degree of confidence whether the wind farm is compliant or not with the data presented in Figures 9.7 to 9.16 in the EIS using the L_{Aeq} metric. In determinining compliance it is necessary to demonstrate that the noise levels being reported are attributable to the wind farm only.

The background noise level data was reported in the EIS as L_{A90} levels. This facilitates correcting the measured noise levels for background noise level when using the L_{A90} metric. Results based on the L_{Aeq} measurement cannot be corrected for background noise level.

6.5.3 Site 01

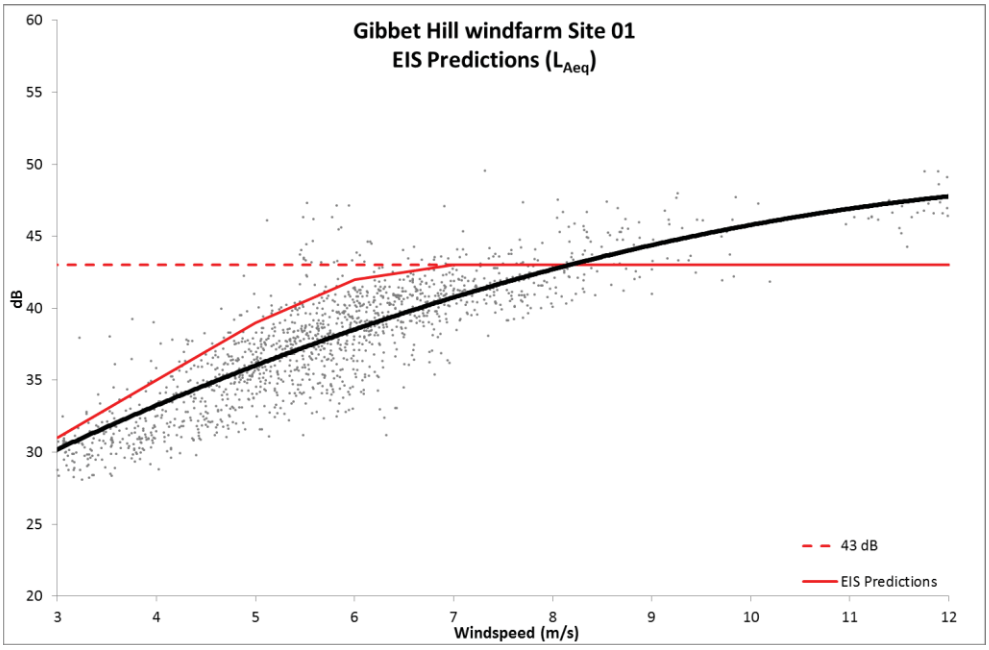

Figure 6-3: Site 01 L_{Aeq} data compared to EIS Figure 9.7 (Location H3)

Figure 6-4: Site 01 Corrected L_{Aeq} compared to EIS Figure 9.7 (Location H3)

The L_{A90} minus BG Noise + 3 dB data (Corrected L_{Aeq}) and the trendline both exceed the levels predicted in Figure 9.7 of the EIS at wind speeds in excess of 8m/s. They also exceed background noise + 5 dB at higher wind speeds. From this data the measured and corrected noise levels exceed those predicted in the EIS at Site 01 at corrected wind speeds in excess of 8m/s.

6.5.4 Site 02

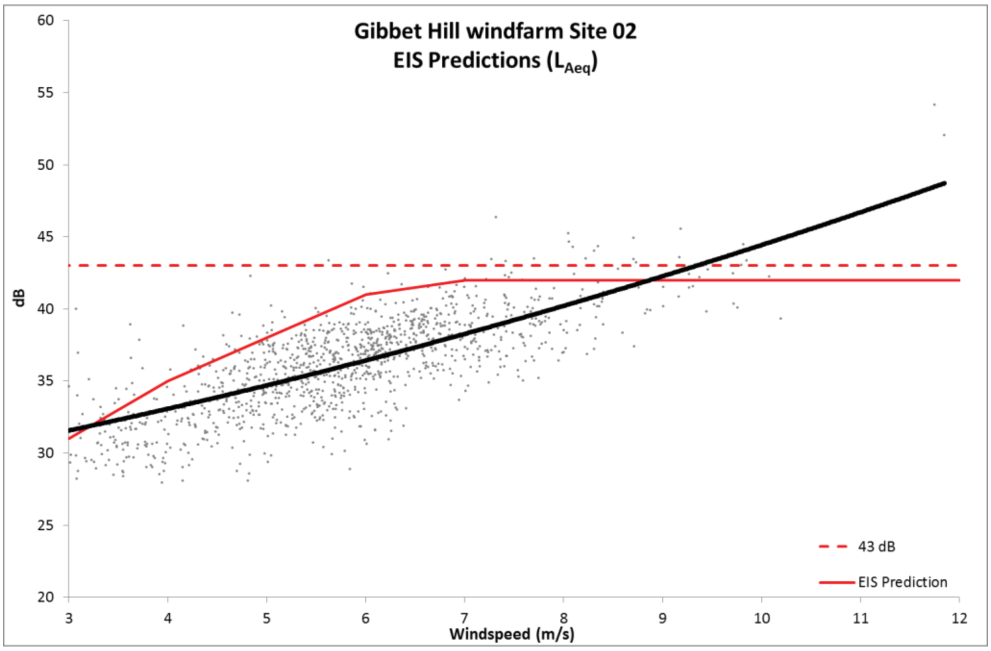

Figure 6-5: Site 02 L_{Aeq} data compared to EIS Figure 9.15 (Location H14)

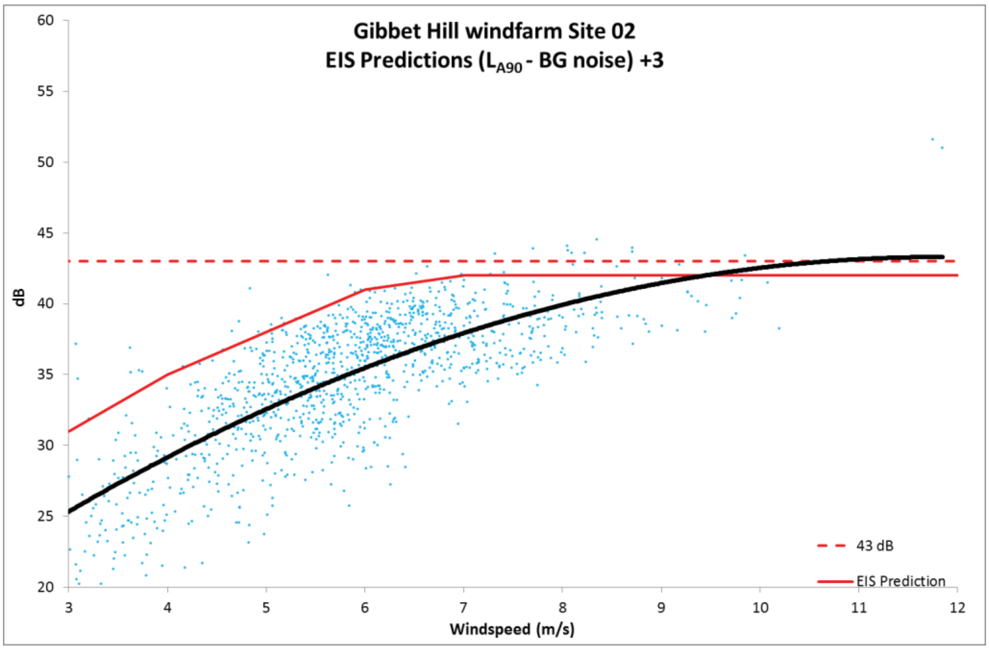

Figure 6-6: Site 02 Corrected L_{Aeq} compared to EIS Figure 9.15 (Location H14)

The L_{Aeq} data and the trendline exceed the levels predicted in Figure 9.15 of the EIS at wind speeds in excess of 9m/s. As stated above, it is not possible to state with any degree of confidence whether the wind farm is compliant or not with the data presented in Figure 9.9 in the EIS using the L_{Aeq} metric.

However the L_{A90} corrected for background noise level plus 3dB to convert to L_{Aeq} is substantially below the level predicted in the EIS. From this data the noise levels are 'substantially' compliant with those predicted in the EIS at Site 02.

6.5.5 Site 03

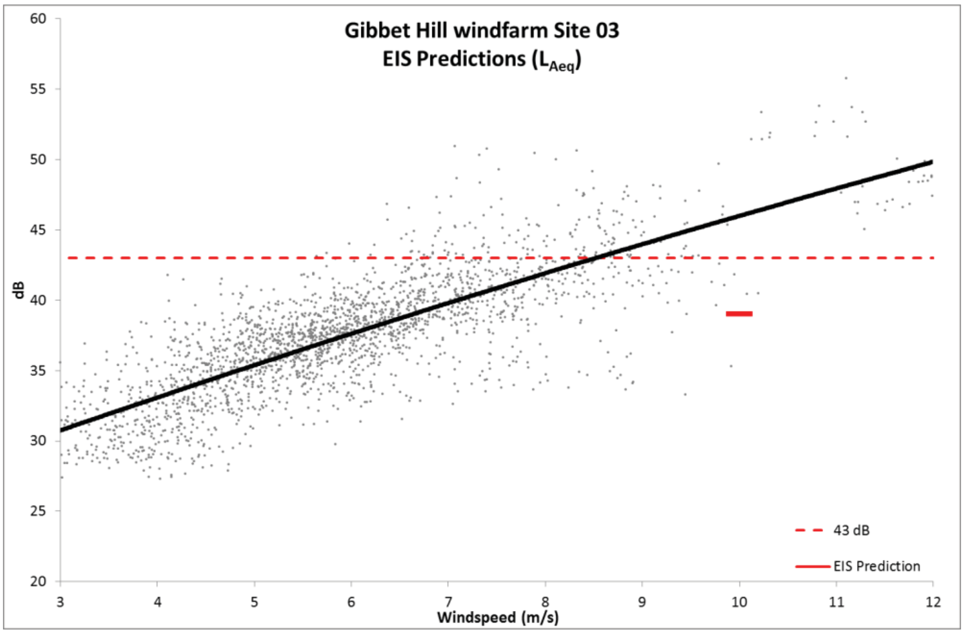

Figure 6-7: Site 03 L_{Aeq} data compared to EIS Figure 9.6

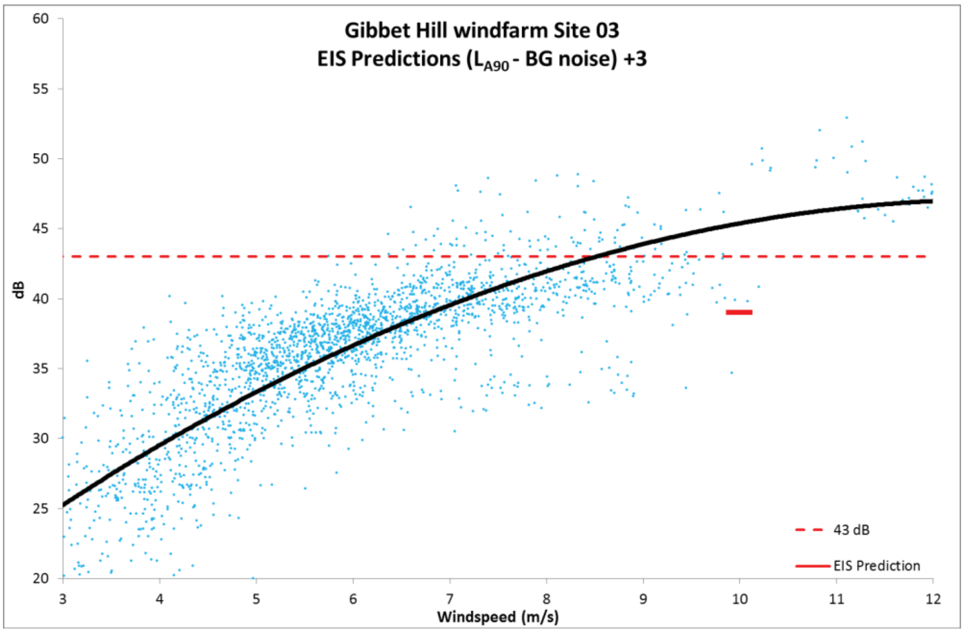

Figure 6-8: Site 03 Corrected L_{Aeq} compared to EIS Figure 9.6

There is no directly corresponding location for Site 03 in Section 9.8 of the EIS. For this site a single wind speed noise level is extracted from Figure 9.6 of the EIS. The data and the trendlines for both L_{Aeq} and L_{A90} exceed the levels predicted in Figure 9.6 of the EIS at wind speeds above 9 m/s. They also exceed background noise + 5 dB at higher wind speeds. From this data some of the measured and corrected noise levels exceed those predicted in the EIS at Site 03 at wind speeds above 9 m/s. While some of the data at higher wind speeds may not be directly attributable to the wind farm the trendline of the Corrected L_{Aeq} data exceeds the noise level predicted in the EIS conclusion at wind speeds above 9 m/s. The trendline also exceeds the level predicted in Figure 9.8 of the Gibbet Hill EIS.

6.5.6 Site 04

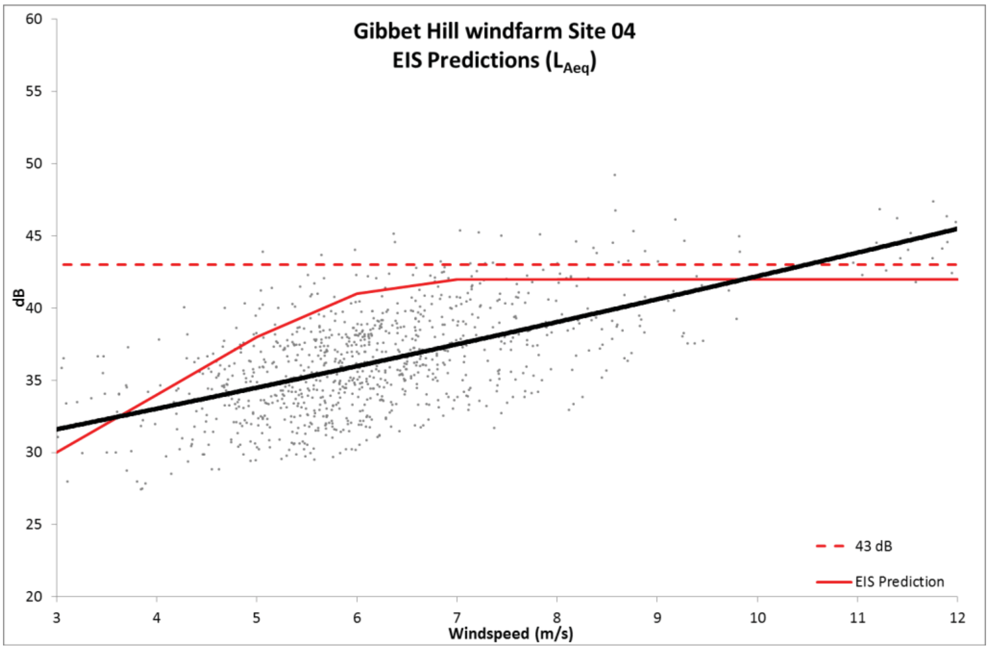

Figure 6-9: Site 04 L_{Aeq} data compared to EIS Figure 9.13 (Location H12)

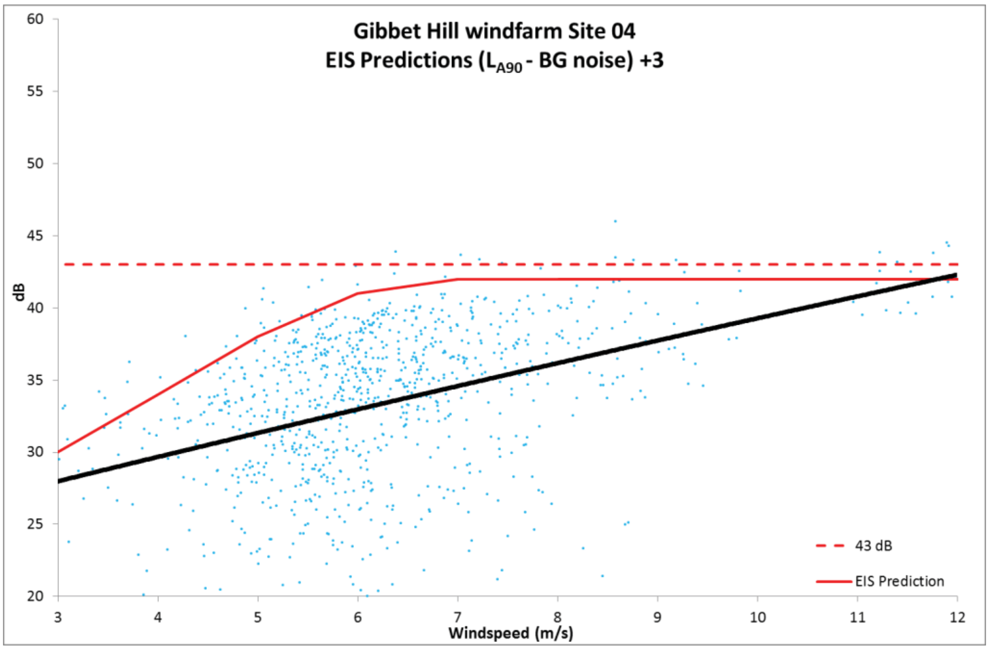

Figure 6-10: Site 04 Corrected L_{Aeq} compared to EIS Figure 9.13 (Location H12)

The L_{Aeq} data and the trendline exceed the levels predicted in Figure 9.13 of the EIS at wind speeds in excess of 10m/s, but as noted previously it is not possible to state with any degree of confidence whether the wind farm is compliant or not with the data presented in Figures 9.11 in the EIS using the L_{Aeq} metric.

However the L_{A90} corrected for background noise level plus 3dB to convert to L_{Aeq} is below the level predicted in the EIS. From this data the noise levels are substantially compliant with those predicted in the EIS at Site 04.

6.5.7 Site 05

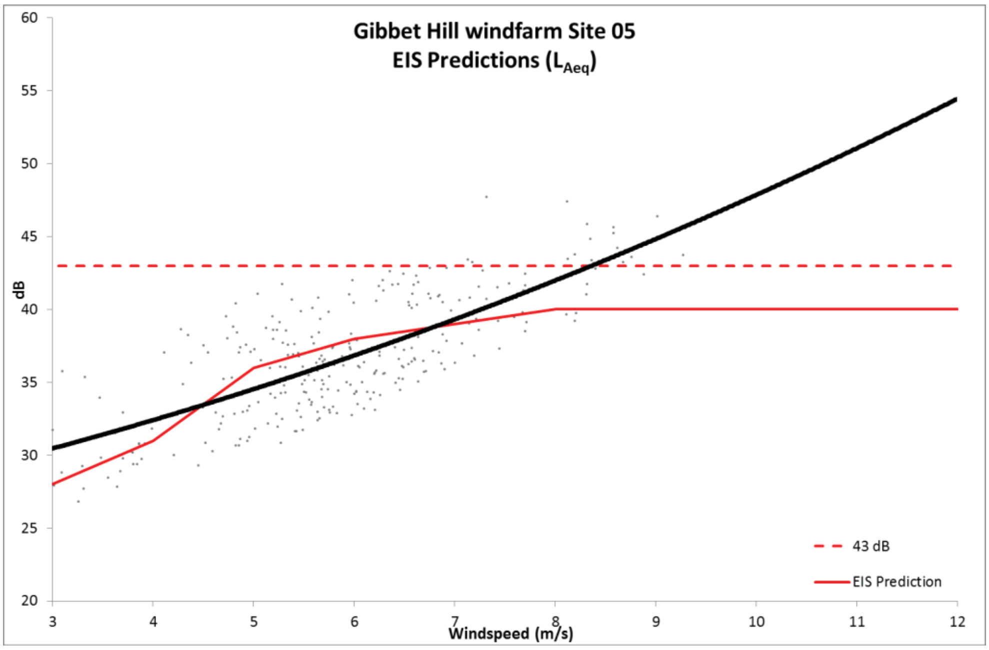

Figure 6-11: Site 05 L_{Aeq} data compared to EIS Figure 9.11 (Location H9)

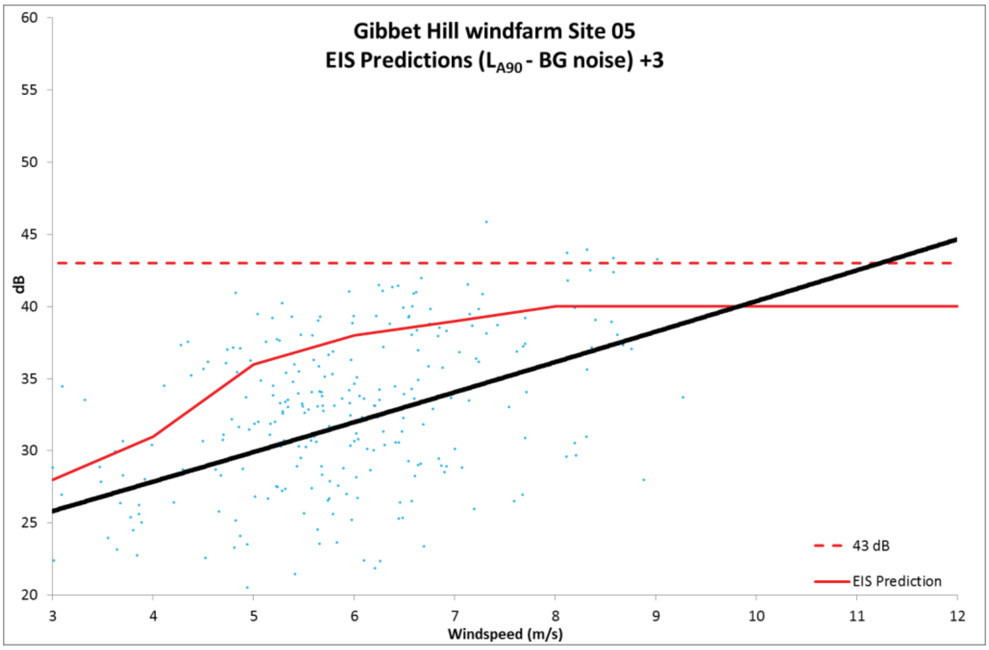

Figure 6-12: Site 05 Corrected L_{Aeq} compared to EIS Figure 9.11 (Location H9)

The L_{Aeq} data and the trendline exceed the levels predicted in Figure 9.11 of the EIS at wind speeds in excess of 10m/s. As noted previously it is not possible to state with any degree of confidence whether the wind farm is compliant or not with the data presented in Figures 9.13 in the EIS using the L_{Aeq} metric.

However the L_{A90} corrected for background noise level plus 3dB to convert to L_{Aeq} is below the level predicted in the EIS. From this data the measured and corrected noise levels are substantially compliant with those predicted in the EIS at Site 05.

6.5.8 Site 13

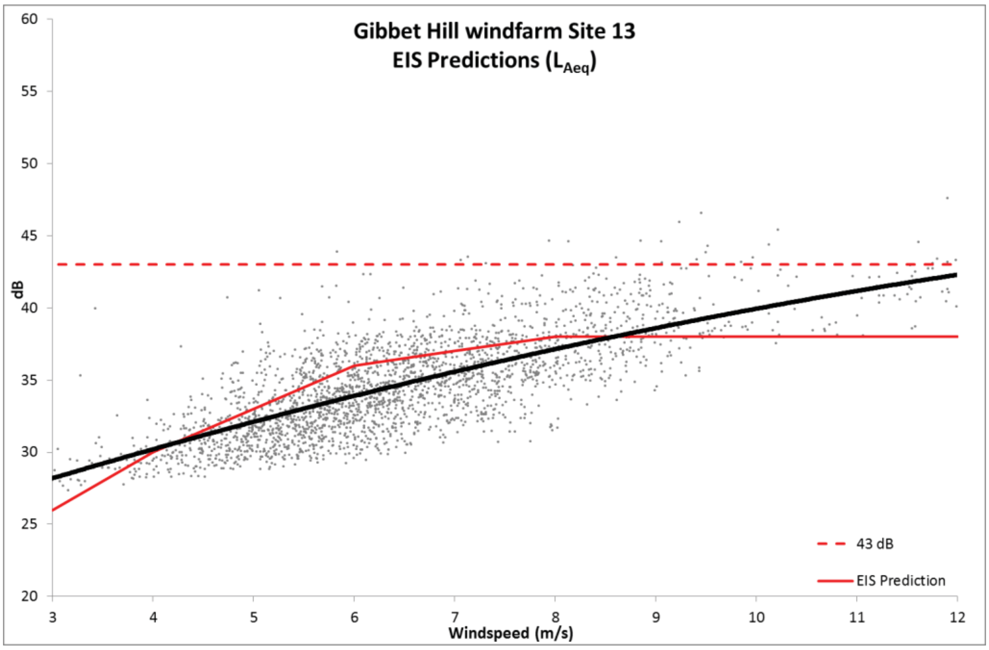

Figure 6-13 Site 13 L_{Aeq} data compared to EIS Figure 9.9 (Location H7)

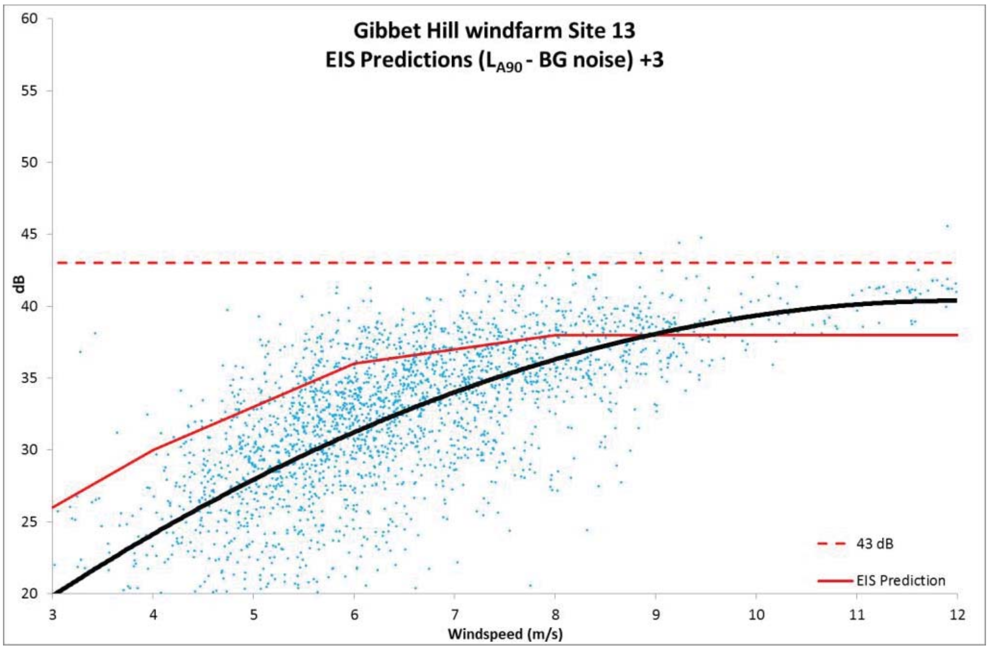

Figure 6-14 Site 13 Corrected L_{Aeq} compared to EIS Figure 9.9 (Location H7)

The L_{Aeq} data and the L_{A90} corrected for background noise level plus 3dB to convert to L_{Aeq} trendlines are substantially below the level predicted in the EIS at corrected wind speeds of less than 8.5m/s and 9m/s respectively. While a significant number of data points are above the EIS trendline, not all this data can be attributed directly to wind farm noise. From this data the noise level trendline is below that predicted in the EIS at Site 13 at corrected wind speeds up to 9m/s.

6.5.9 Compliance with the EIS Conclusion

The conclusion to the EIS is set out in Section 3.1.3 and states:

> *'The assessment shows that the total predicted wind turbine noise level of the whole wind farm meets the fixed night noise limit of 43 dB L_{Aeq} at all residential locations, under all conditions. It also shows that the total predicted turbine noise level is below the day-time noise limit of 45 dB L_{Aeq} at all residential properties, under all conditions. It has been demonstrated in this assessment that both day and night-time noise limits can be satisfied at all properties across all wind speeds'*.

For the purpose of compliance the night time level of 43 dB L_{Aeq} at all residential locations is taken as the threshold. As stated in **Section 5.3.1** it is necessary to evaluate this against L_{A90} levels adjusted for background noise and converted to L_{Aeq} levels. Data was filtered according to the methods outlined in **Section 5.3.1** and **5.7.4** before counting.

Table 6-5: Count of 10 minute intervals exceeding 43 dB

SITE	Site 01	Site 02	Site 03	Site 04	Site 05	Site 13
EIS Conclusion dB L_{Aeq}	***43***	***43***	***43***	***43***	***43***	***43***
Number of intervals where L_{Aeq} exceeded 43 dB (night)	165	22	225	51	39	26
Number of intervals where L_{A90} exceeded 43 dB (night)	50	2	77	2	1	0
Number of intervals where (L_{A90}-BG)+3 exceeded 43 dB (night)	186 (8.1%)	12 (0.5%)	136 (2.8%)	16 (0.7%)	5 (0.2%)	8 (0.2%)

As can be seen from **Table 6-5** there are a number of exceedances of the night-time limit. In order to determine if these exceedances were related to wind turbine noise a sample of the files was examined for 'other' noise sources. The results of this sampling indicated that a significant number of the events reported in the table were due to factors other than wind turbine noise, e.g. cars passing during the measurement period, animal noises, etc.

Sites 02, 04, 05 and 13 are substantially compliant with the levels set out in the conclusion of the EIS. Site 01 and Site 03 are not compliant depending on the threshold set for 'substantial' compliance.

6.6 DECLG WIND ENERGY DEVELOPMENT GUIDELINES

The Department of Environment, Community and Local Government (DECLG) 'Wind Energy Development Guidelines', [WEDG(2006)] sets a night-time limit of 43 dB based on a L_{A90} metric. The L_{A90} levels were filtered to night-time levels only and excluded rain events. The number of exceedances of this level is reported in **Table 6-6.**

Table 6-6: Comparison with WEDG (2006) night time limit

SITE	Site 01	Site 02	Site 03	Site 04	Site 05	Site 13
DECLG WEDG(2006), Night-time dB(A) Based on L_{A90}	***43***	***43***	***43***	***43***	***43***	***43***
Number of intervals where L_{A90} exceeded 43 dB (night)	50 (2.2%)	2 (0.1%)	77 (1.6%)	2 (0.1%)	1 (0.0%)	0 (0.0%)

As can be seen from the table there are a relatively small number of exceedances of the night-time limit when using the L_{A90} metric as advised in the guidelines. In order to determine if these exceedances were related to wind turbine noise only a sample of the files was examined for 'other' noise sources. The results of this sampling indicated that a number of the events reported in the table were due to factors other than wind turbine noise.

All sites can be considered in substantial compliance with the WEDG (2006) night-time limit when measured using a L_{A90} metric.

6.7 INTERNATIONAL GUIDANCE AND OTHER STANDARDS

Comparisons are made with guidance and standards from four other countries, the UK, South Australia, Canada and Denmark in the following section.

6.7.1 UK

The UK standard as outlined in **Section 2.6.1** is based on ETSU-R-97. Such curves were provided in the EIS and have been compared with measured data in **Section 6.5.2**. In this case however the comparison is made against L_{A90} levels as set out in ETSU-R-97.

The pre-construction background noise measurements at lower wind speeds were less than 30 dB(A). On that basis that the most conservative interpretation of ETSU-R-97 was taken, the lower limit of 35 dB(A) would apply until the background noise level exceeded 30 dB(A) at which point the limit becomes background noise plus 5 dB(A) during quiet periods. A fixed limit of 43 dB(A) at night applies separately.

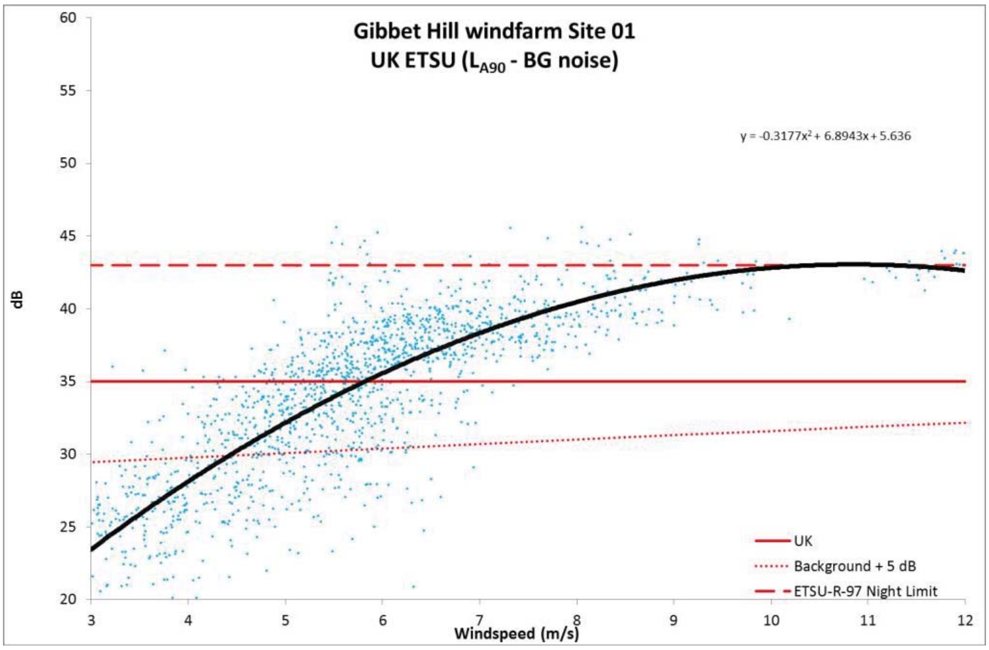

Figure 6-15: Site 01 Corrected L_{A90} against UK ETSU guidelines

On the basis of a conservative interpretation of ETSU-R-97, Site 01 does not comply with UK guidance levels at corrected wind speeds greater than 6 m/s based on the pre-construction background noise levels during quiet periods. The wind farm meets ETSU-R-97 criteria at night.

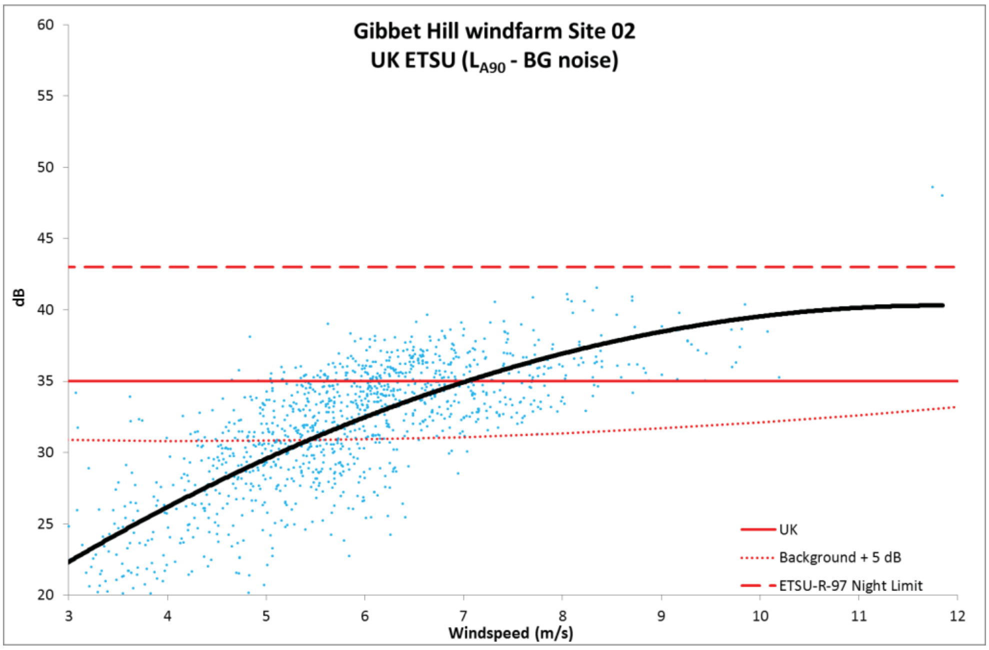

Figure 6-16: Site 02 Corrected L_{A90} against UK ETSU guidelines

On the basis of a conservative interpretation of ETSU-R-97, Site 02 does not comply with UK guidance levels at corrected wind speeds greater than 7 m/s based on the pre-construction background noise levels during quiet periods. The wind farm meets ETSU-R-97 criteria at night.

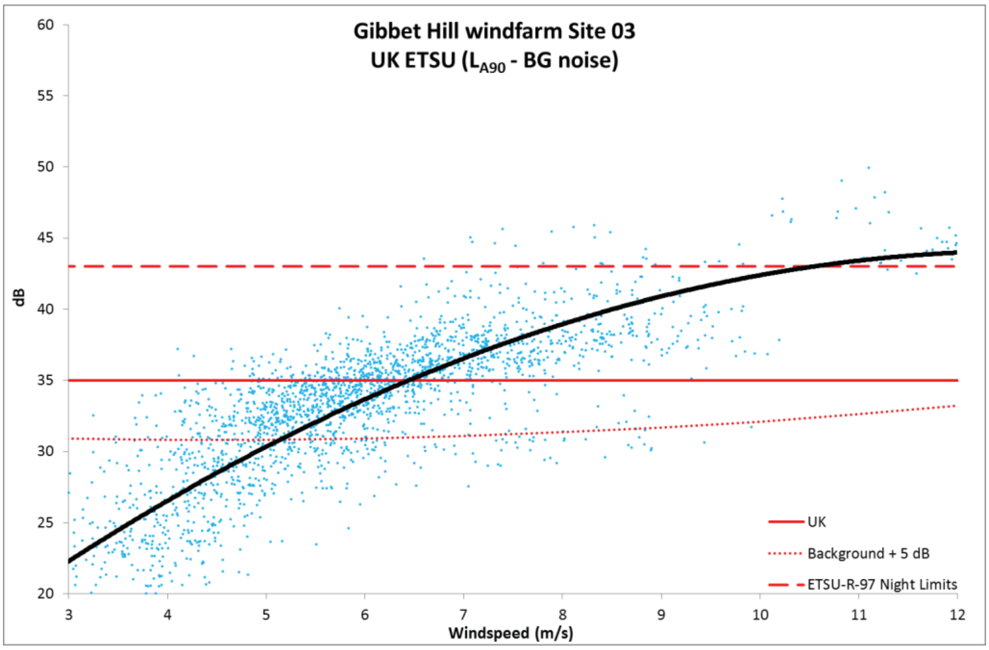

Figure 6-17: Site 03 Corrected L_{A90} against UK ETSU guidelines

On the basis of a conservative interpretation of ETSU-R-97, Site 03 does not comply with UK guidance levels at corrected wind speeds greater than 6.5 m/s based on the pre-construction background noise levels during quiet periods. The wind farm meets ETSU-R-97 criteria at night.

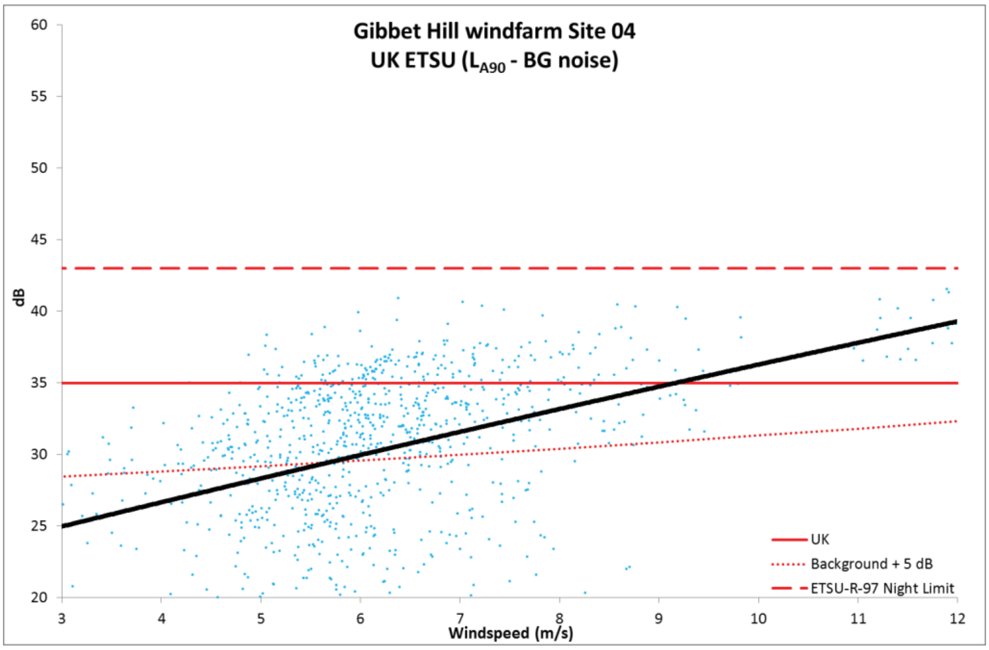

Figure 6-18: Site 04 Corrected L_{A90} against UK ETSU guidelines

On the basis of a conservative interpretation of ETSU-R-97, Site 04 does not comply with UK guidance levels at corrected wind speeds greater than 9 m/s based on the pre-construction background noise levels during quiet periods. The wind farm meets ETSU-R-97 criteria at night.

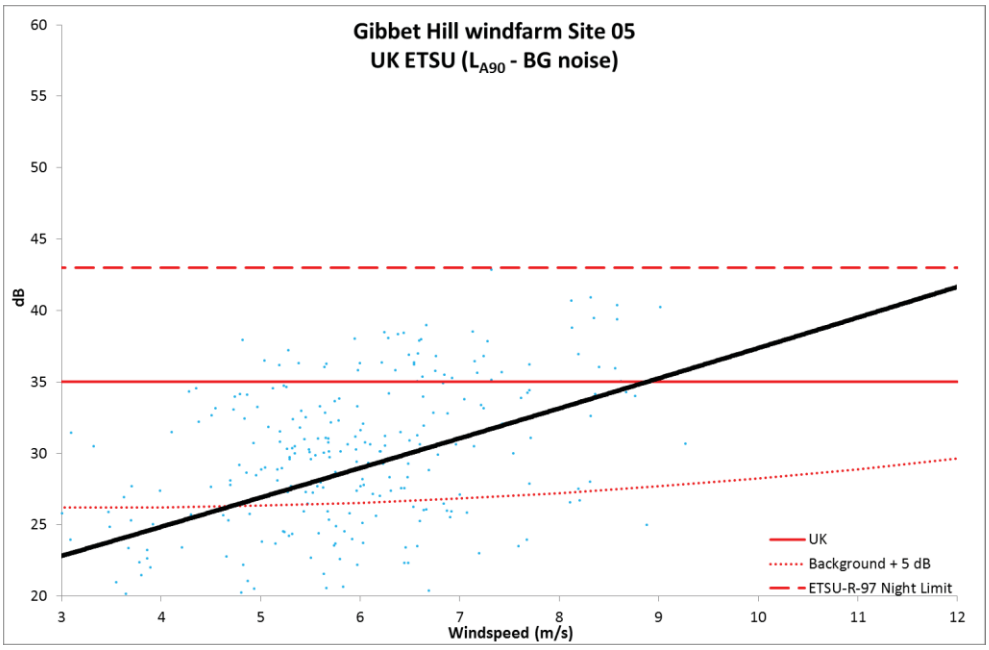

Figure 6-19: Site 05 Corrected L_{A90} against UK ETSU guidelines

On the basis of a conservative interpretation of ETSU-R-97, Site 05 does not comply with UK guidance levels at corrected wind speeds greater than 9 m/s based on the pre-construction background noise levels during quiet periods. The wind farm meets ETSU-R-97 criteria at night.

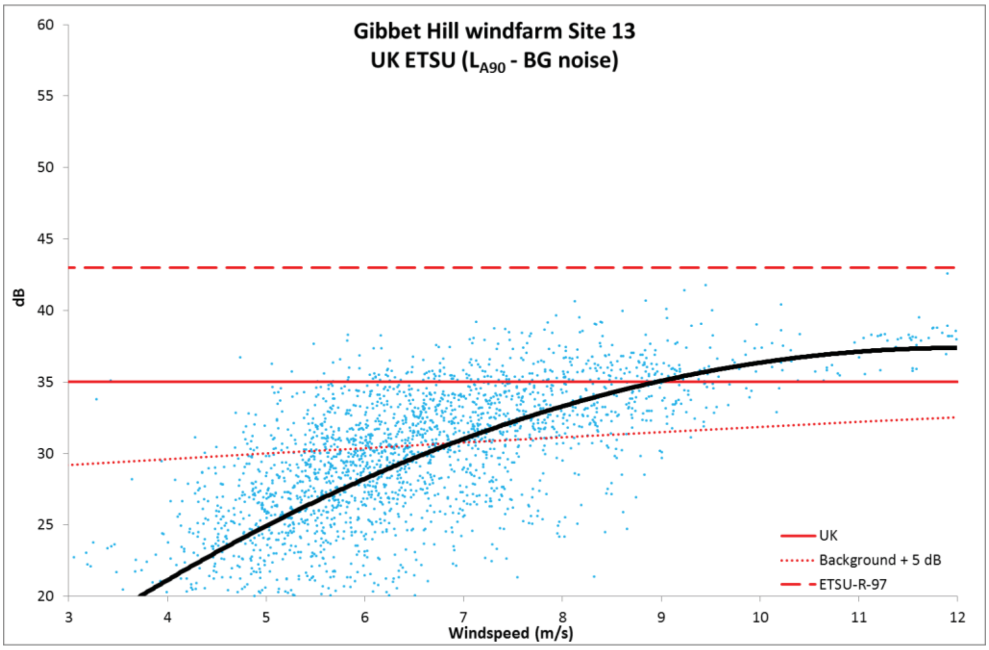

Figure 6-20: Site 13 Corrected L_{A90} against UK ETSU guidelines

On the basis of a conservative interpretation of ETSU-R-97, Site 13 does not comply with UK guidance levels at corrected wind speeds greater than 9 m/s based on the pre-construction background noise levels during quiet periods. The wind farm meets ETSU-R-97 criteria at night.

In the case of Sites 01, 02, 03 and 13 the trendline through the data conforms to the expected curve for wind turbine noise. In the case of Site 03 there are measurements over the 43 dB(A) threshold but these would appear to be outliers. In the case of Sites 04 and 05. The trendline does not conform to the expected wind farm noise curve. Noise unrelated to the wind farm is likely to distort the noise measurements in those cases. In all cases the noise levels attributable to the wind farm at night time are below 43 dB(A).

6.7.2 South Australia

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

- *40dB(A) at relevant receivers in localities in other zones, or*
- *the background noise (L_{A90},10) by more than 5dB(A),*

whichever is the greater, at all relevant receivers'.

Due to the low background noise levels measured in the area the threshold for all sites is set at 40 dB(A) for the purpose of the South Australia Noise Standards.

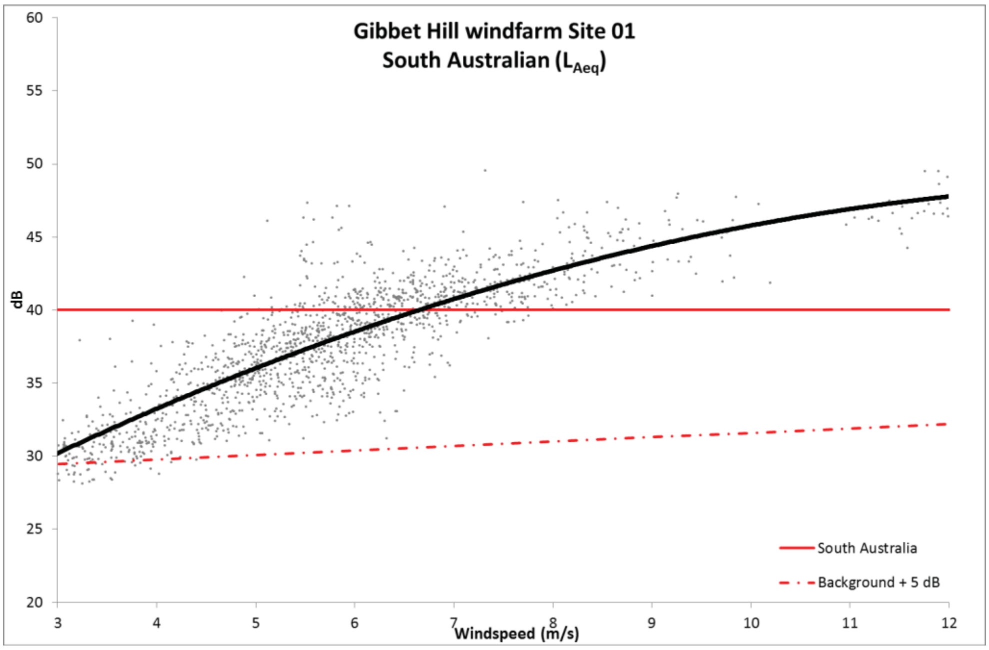

Figure 6-21: Site 01 L_{Aeq} data against background noise levels and South Australian guidelines

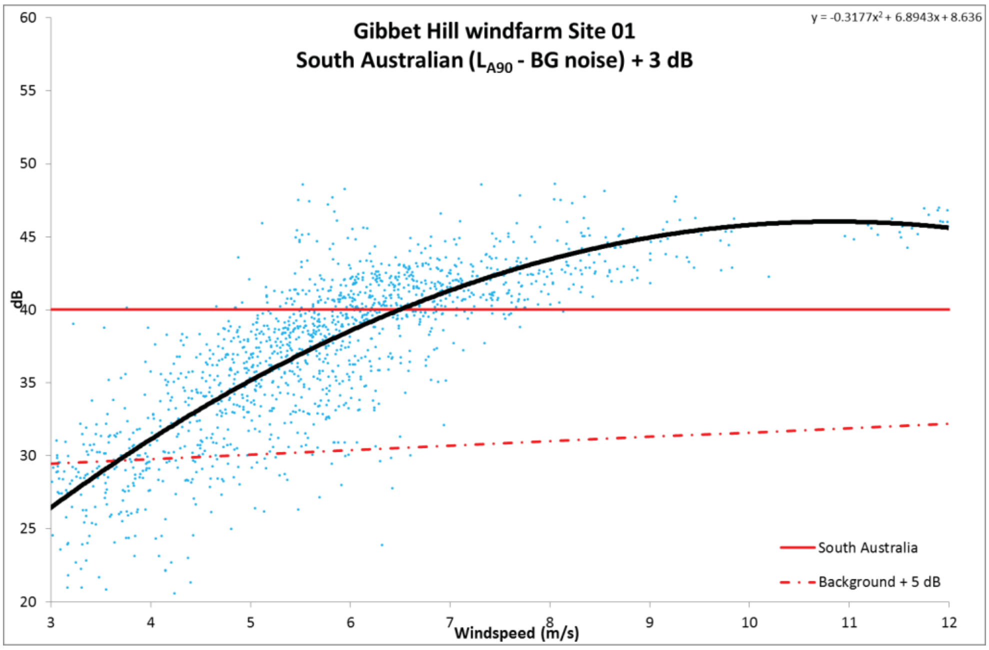

Figure 6-22: Site 01 Corrected L_{A90} against South Australian guidelines

Data plotted using both L_{Aeq} and L_{A90}, corrected for background plus 3 dB along with the trendline through the data exceed the 40 dB(A) threshold at Site 01 at corrected wind speeds in excess of 6.5 m/s.

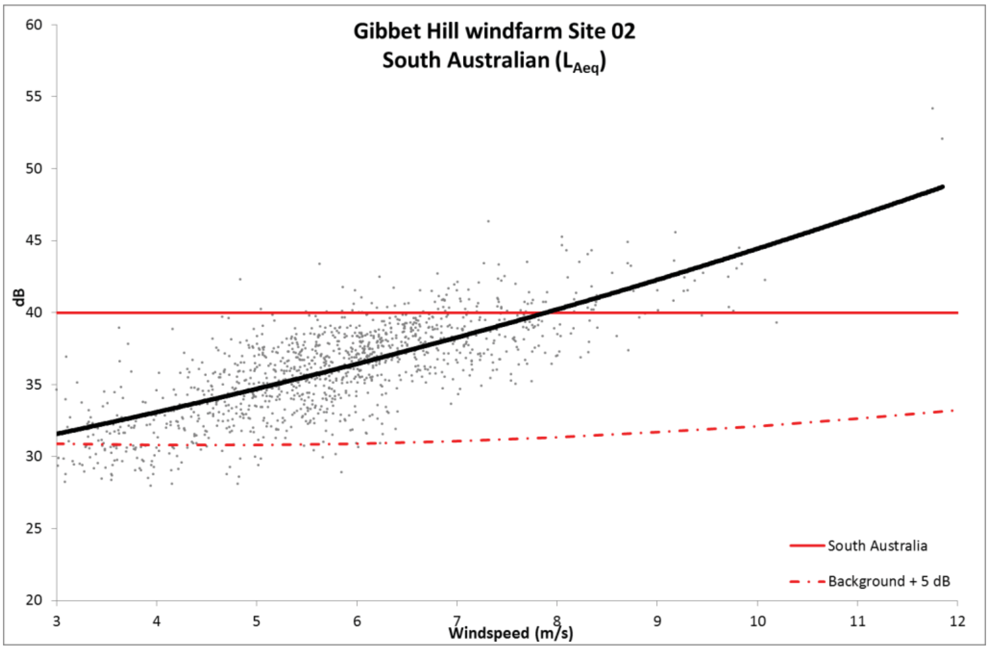

Figure 6-23: Site 02 L_{Aeq} data against background noise levels and South Australian guidelines

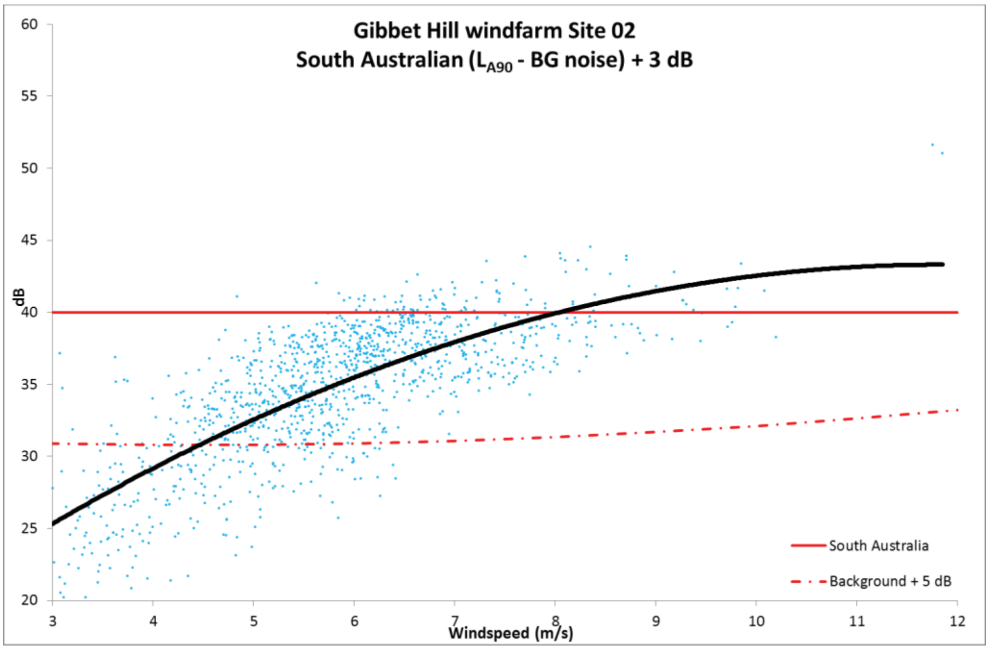

Figure 6-24: Site 02 Corrected L_{A90} against South Australian guidelines

Data plotted using both L_{Aeq} and $L_{A90,}$ corrected for background plus 3 dB along with the trendline through the data exceed the 40 dB(A) threshold at Site 02. In the case of the L_{A90} corrected for background plus 3 dB plot the exceedance is marginal as the data at higher wind speeds is likely to contain noise from sources other than the wind farm.

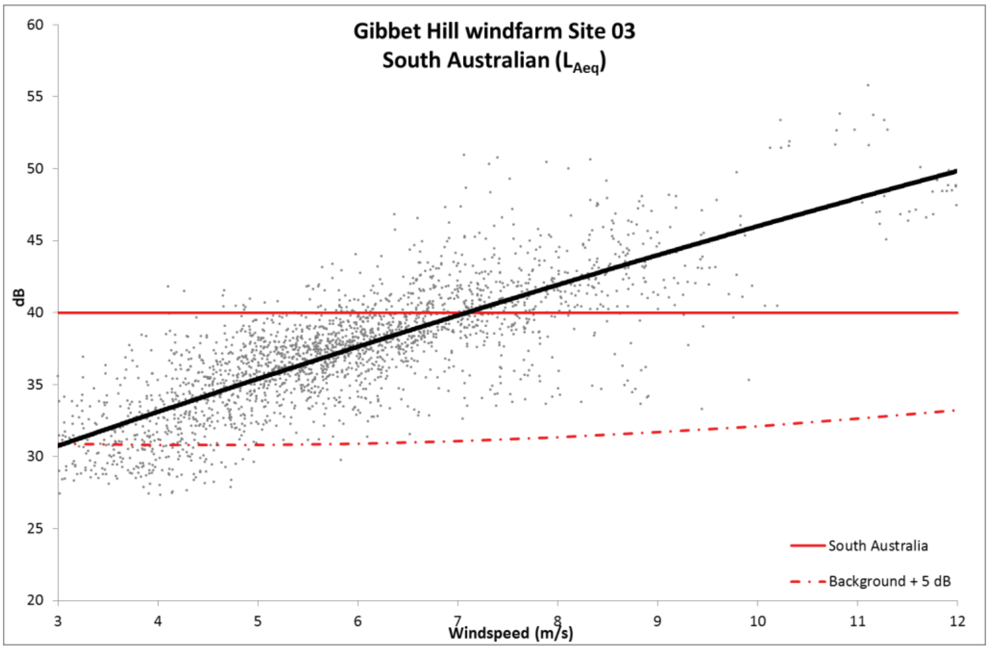

Figure 6-25: Site 03 L_{Aeq} data against background noise levels and South Australian guidelines

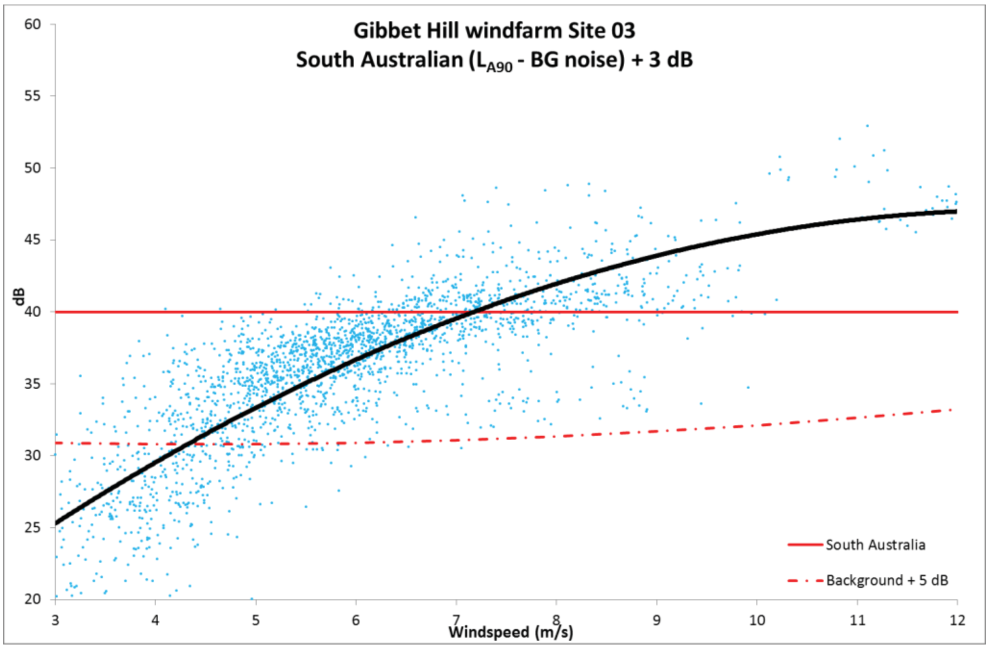

Figure 6-26: Site 03 Corrected L_{A90} against South Australian guidelines

Data plotted using both L_{Aeq} and L_{A90}, corrected for background plus 3 dB along with the trendline through the data exceed the 40 dB(A) threshold at Site 03 at corrected wind speeds in excess of 7 m/s.

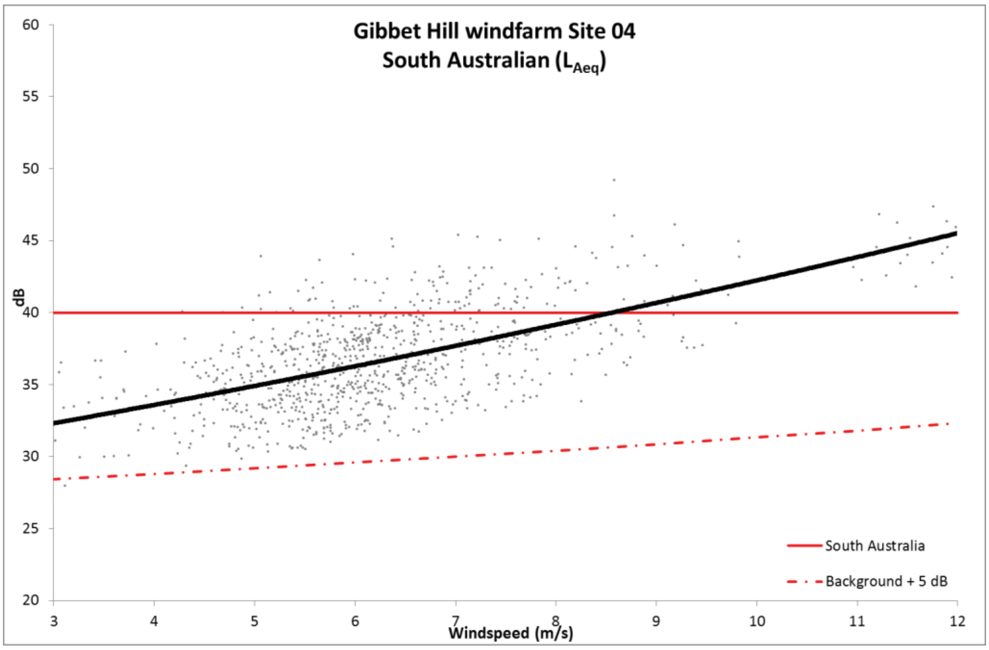

Figure 6-27: Site 04 L_{Aeq} data against background noise levels and South Australian guidelines

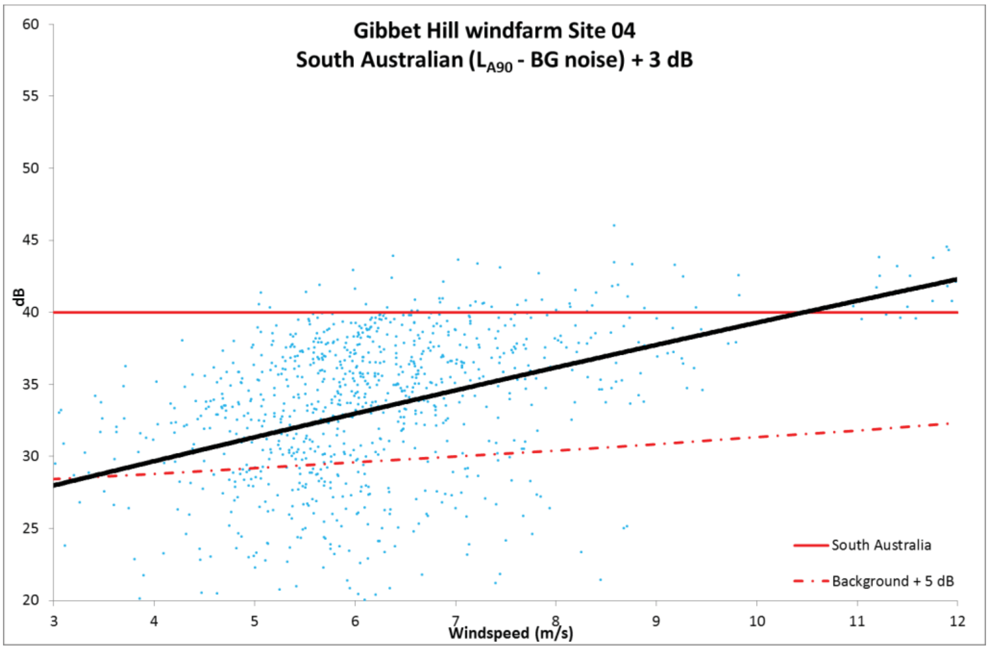

Figure 6-28: Site 04 Corrected L_{A90} against South Australian guidelines

Data plotted using both L_{Aeq} and L_{A90} corrected for background plus 3 dB along with the trendline through the data exceed the 40 dB(A) threshold at Site 04. In the case of the L_{A90} corrected for background plus 3 dB plot the exceedance is marginal as the data is unlikely to relate to wind farm noise.

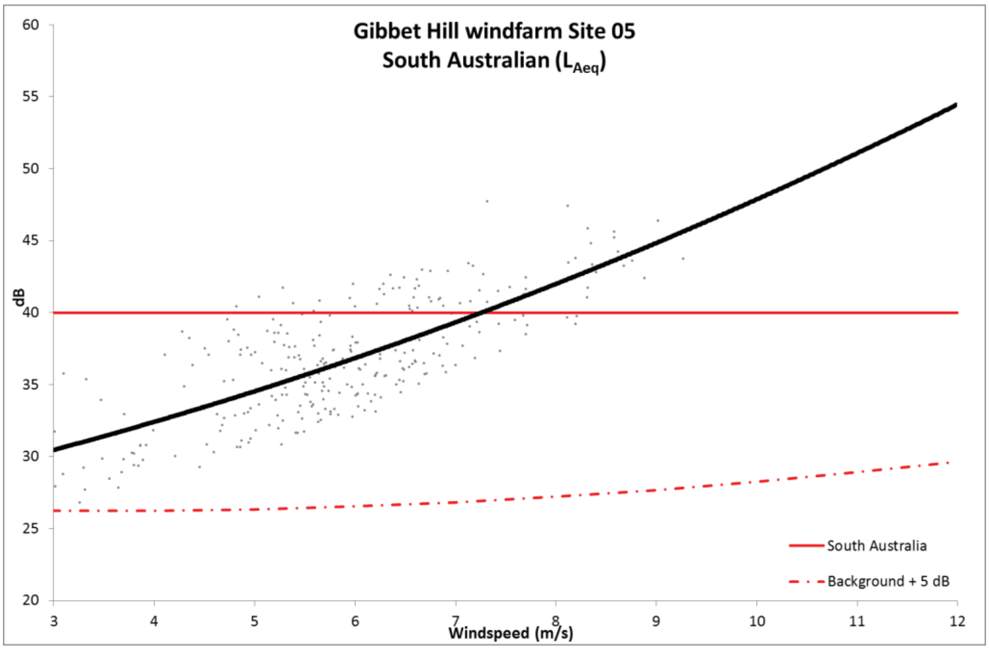

Figure 6-29: Site 05 L_{Aeq} data against background noise levels and South Australian guidelines

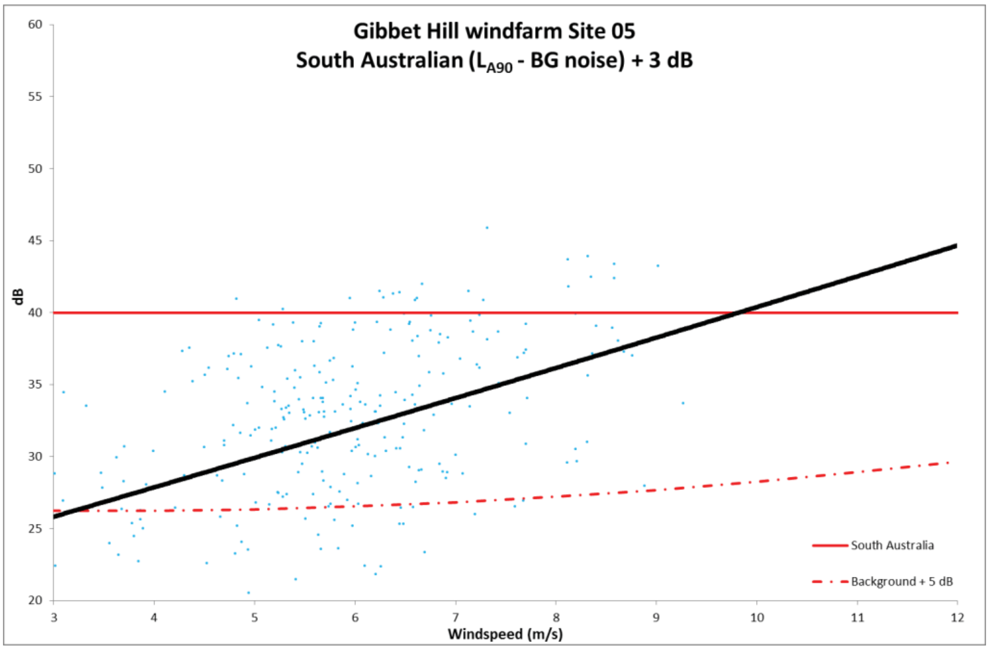

Figure 6-30: Site 05 Corrected L_{A90} against South Australian guidelines

Data plotted using both L_{Aeq} and L_{A90} corrected for background plus 3 dB along with the trendline through the data exceed the 40 dB(A) threshold at Site 05 at corrected wind speeds in excess of 7 m/s in the case of L_{Aeq} data. In the case of the L_{A90} corrected for background plus 3 dB plot the exceedance is marginal as outlined previously on Sites 02 and 04.

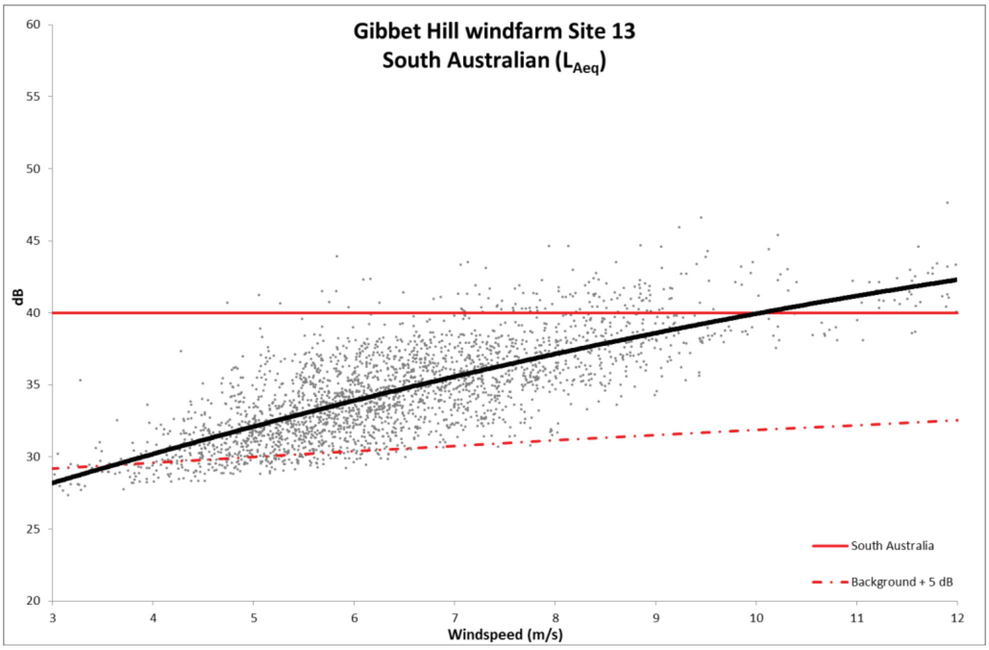

Figure 6-31: Site 13 L_{Aeq} data against background noise levels and South Australian guidelines

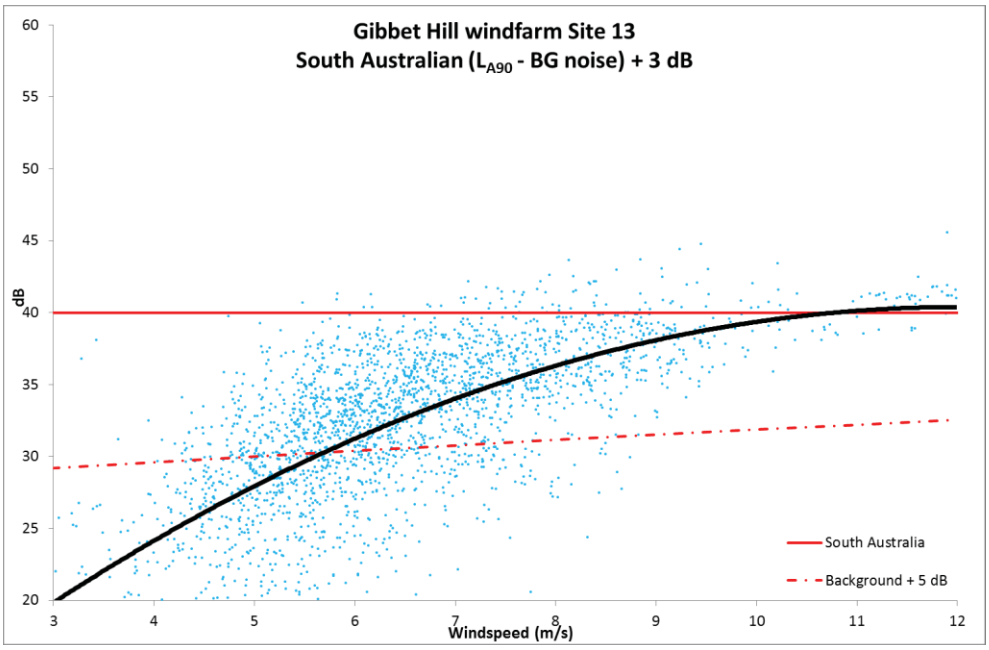

Figure 6-32: Site 13 Corrected L_{A90} against South Australian guidelines

Data plotted using L_{Aeq} the trendline through the data exceeds the 40 dB(A) threshold at Site 13 at corrected wind speeds of greater than 10 m/s. This is unlikely to be directly attributable to wind turbine noise. In the cases of the L_{A90} corrected for background plus 3 dB plot the exceedance is also marginal. It is likely that the noise level attributable to the wind farms meets the South Australian guidelines at Site 13.

6.7.3 Canada and Denmark

The Danish Regulations limit noise at the most noise-exposed point in outdoor living area no more than 15 metres from dwellings in open countryside:

A. 44 L_{eq} dB(A) at a wind speed of 8 m/s.
B. 42 L_{eq} dB(A) at a wind speed of 6 m/s.

In Canada the situation is more complex in that each province regulates noise independently. At a wind speed of 6 m/s the Canadian levels are lower [40 dB(A)] than those permitted in Denmark [42 dB(A)]. The levels are higher [45 dB(A)] than those permitted at a wind speed of 8 m/s [44 dB(A)] in Denmark. The Canadian Provinces of Manitoba, New Brunswick and Ontario permit levels of 51 dB(A) at wind speeds of 10 m/s.

The levels are illustrated on **Figure 6-33** to **Figure** 6-44, with Canada's guideline levels presented in Orange colour and Denmark in Red.

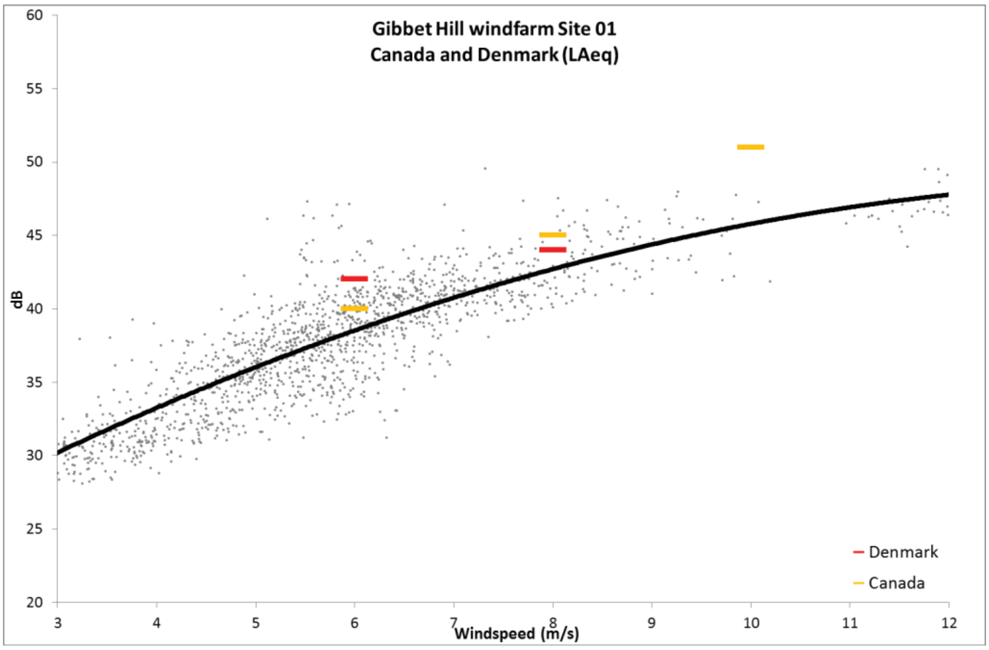

Figure 6-33: Site 01 L_{Aeq} data against Danish guidelines

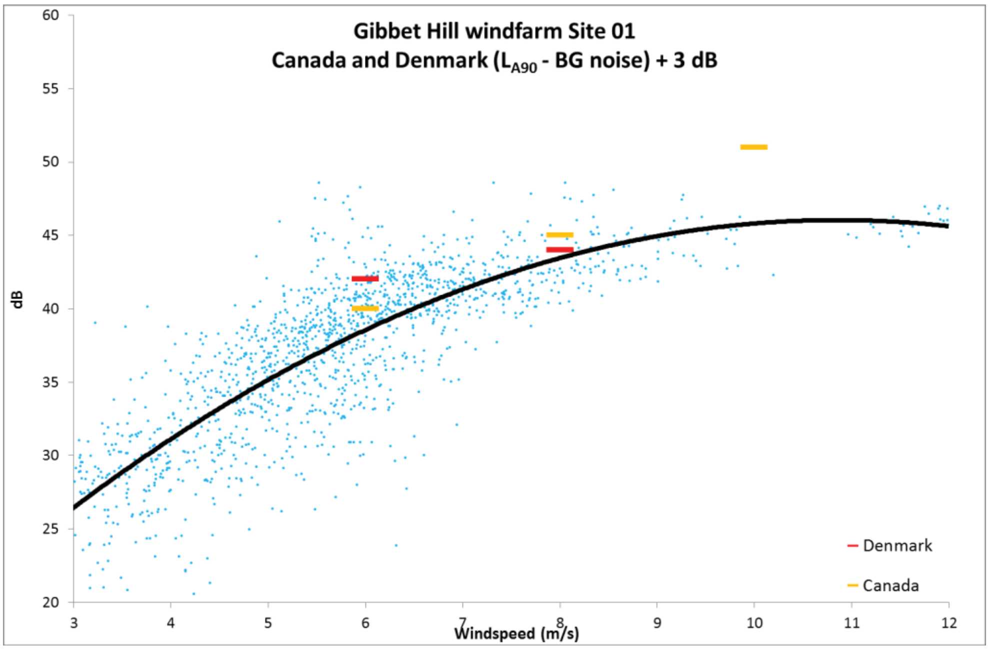

Figure 6-34: Site 01 L_{A90} minus BG noise + 3dB data against Danish guidelines

Data plotted using both L_{Aeq} and L_{A90}, corrected for background plus 3 dB along with the trendlines through the data both meet the Danish and Canadian thresholds at Site 01.

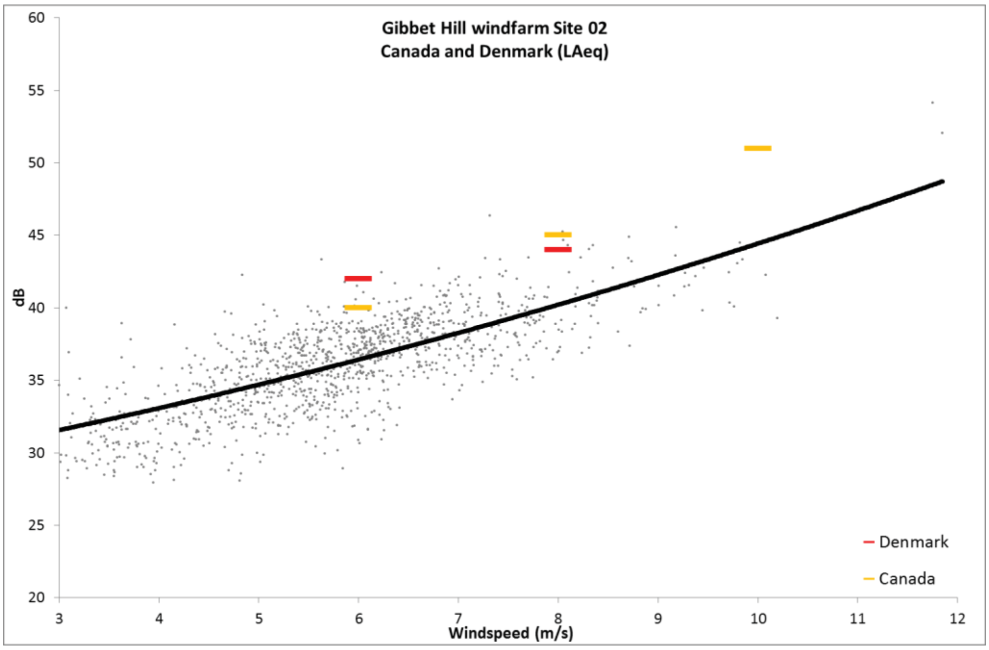

Figure 6-35: Site 02 L_{Aeq} data against Danish guidelines

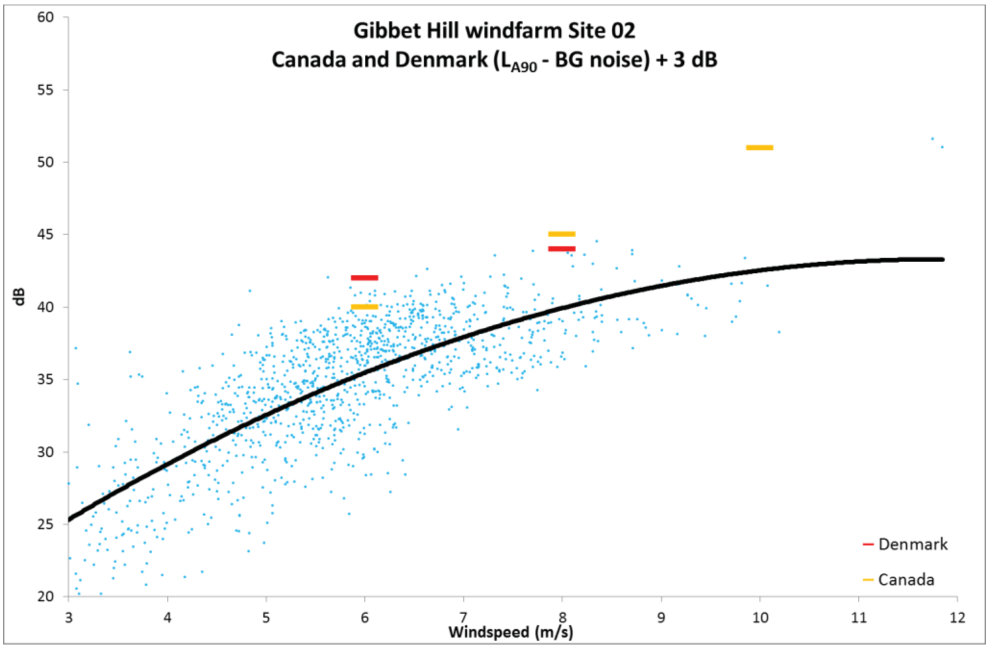

Figure 6-36: Site 02 L_{A90} minus BG noise + 3dB data against Danish guidelines

Data plotted using both L_{Aeq} and L_{A90}, corrected for background plus 3 dB along with the trendlines through the data both meet the Danish and Canadian thresholds at Site 02.

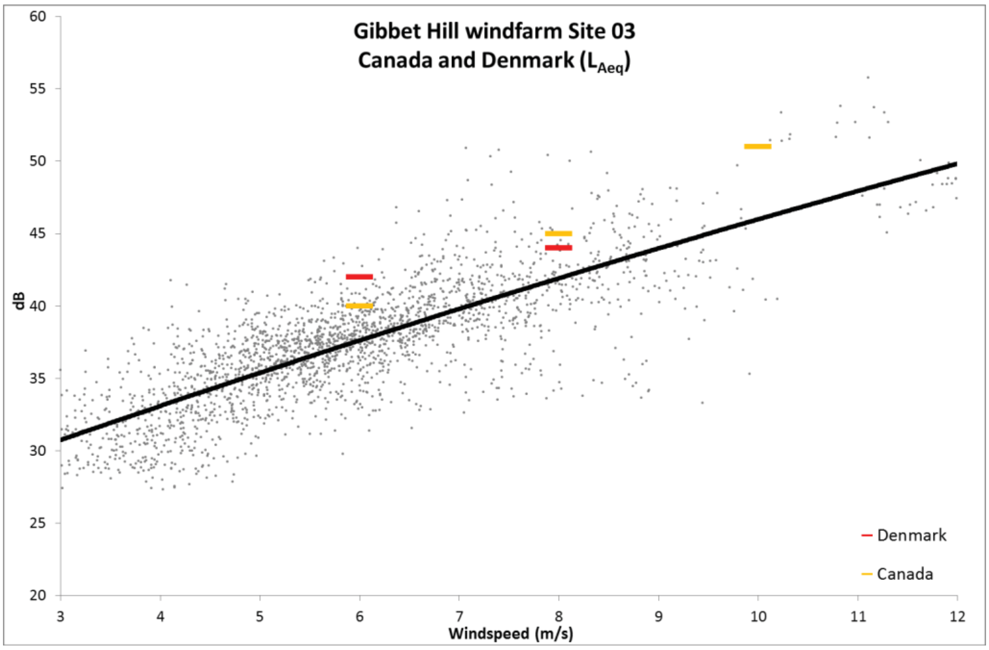

Figure 6-37: Site 03 L_{Aeq} data against Danish guidelines

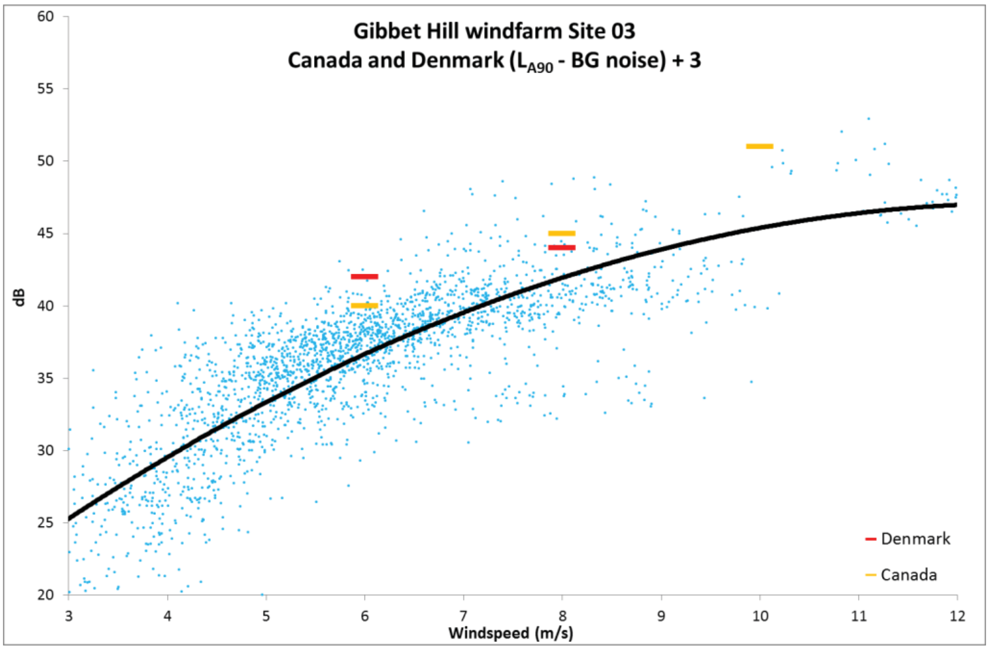

Figure 6-38: Site 03 L_{A90} minus BG noise + 3dB data against Danish guidelines

Data plotted using both L_{Aeq} and L_{A90}, corrected for background plus 3 dB along with the trendlines through the data both meet the Danish and Canadian thresholds at Site 03.

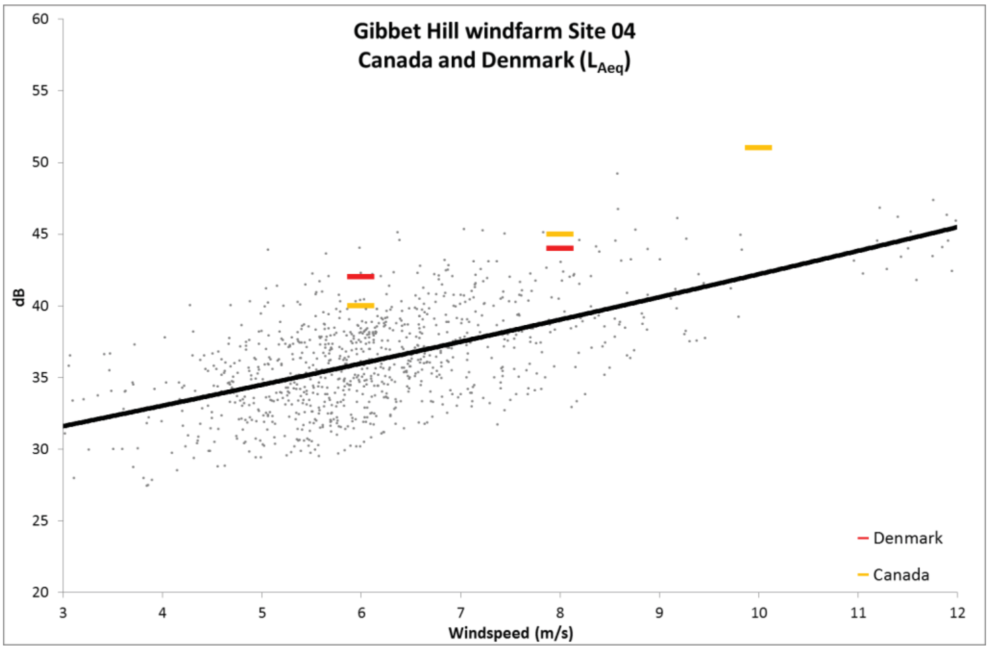

Figure 6-39: Site 04 L_{Aeq} data against Danish guidelines

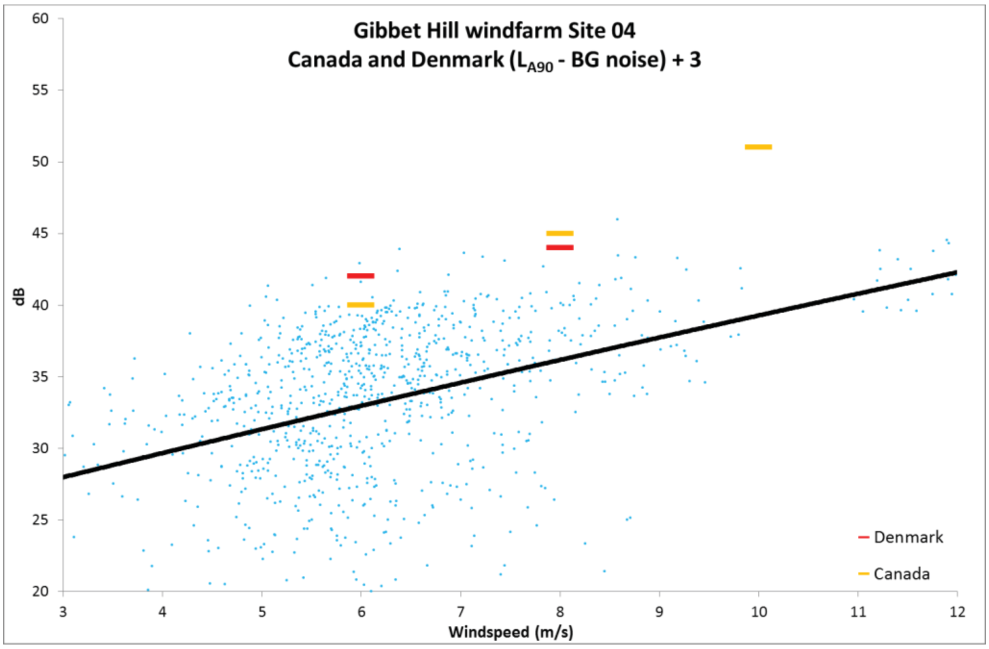

Figure 6-40: Site 04 L_{A90} minus BG noise + 3dB data against Danish guidelines

Data plotted using both L_{Aeq} and L_{A90}, corrected for background plus 3 dB along with the trendlines through the data both meet the Danish and Canadian thresholds at Site 04.

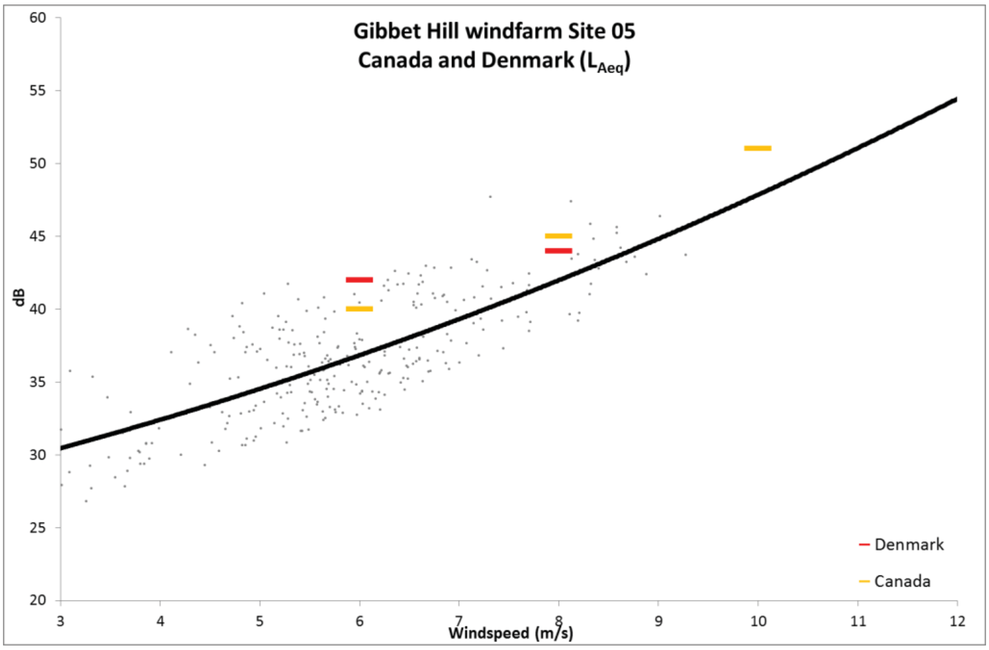

Figure 6-41: Site 05 L_{Aeq} data against Danish guidelines

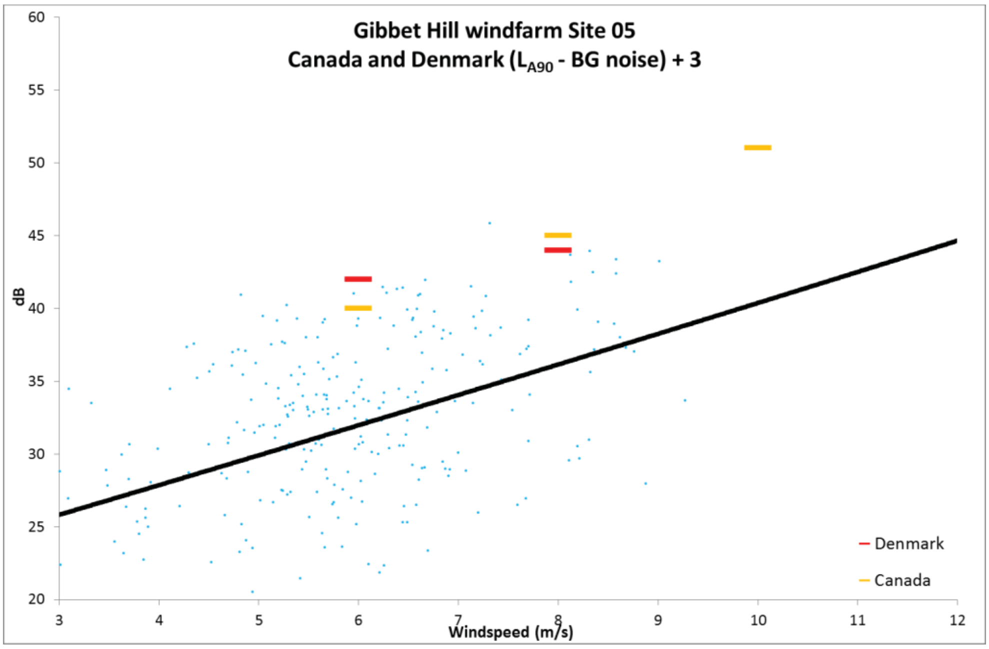

Figure 6-42: Site 05 L_{A90} minus BG noise + 3dB data against Danish guidelines

Data plotted using both L_{Aeq} and L_{A90} corrected for background plus 3 dB along with the trendlines through the data both meet the Danish and Canadian thresholds at Site 05.

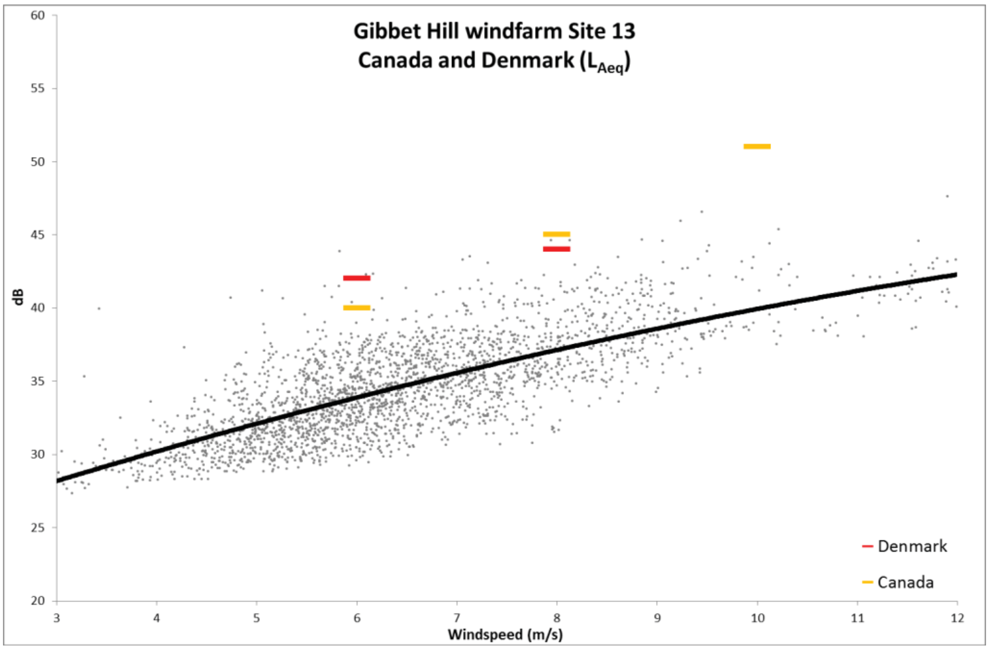

Figure 6-43: Site 13 L_{Aeq} data against Danish guidelines

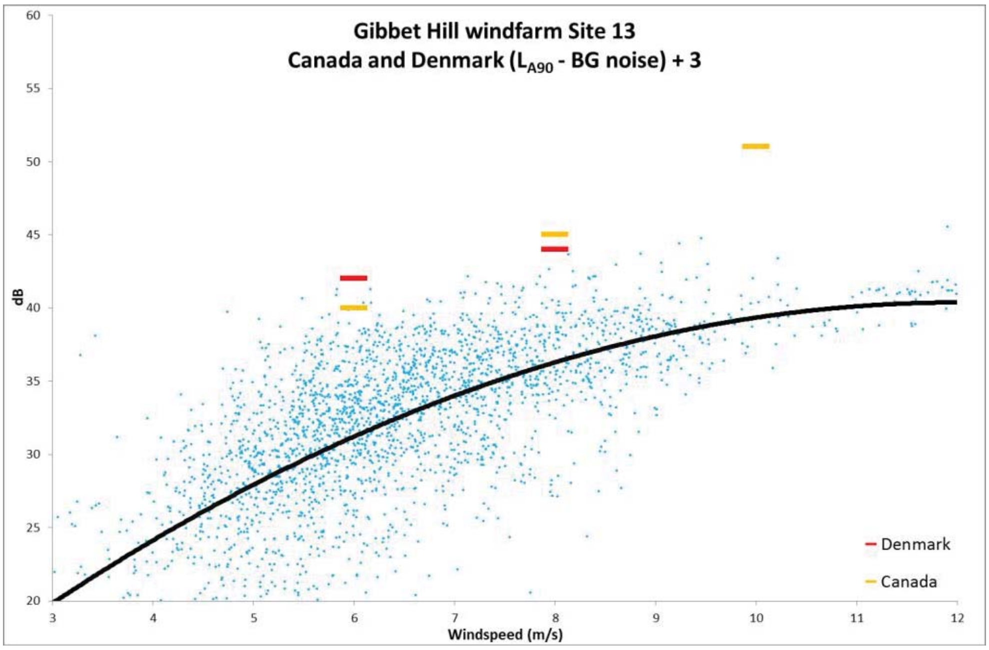

Figure 6-44: Site 13 L_{A90} minus BG noise + 3dB data against Danish guidelines

Data plotted using both L_{Aeq} and L_{A90} corrected for background plus 3 dB along with the trendlines through the data both meet the Danish and Canadian thresholds at Site 13.

It can be seen from the plots that when using the L_{Aeq} metric the trendline does not conform to the expected shape for wind turbine noise. The L_{A90} metric however does present in the expected shape. In all cases the trendlines are lower than the Danish and Canadian thresholds at 6m/s and 8m/s and 10m/s for the Canadian threshold.

6.8 WORLD HEALTH ORGANISATION NOISE GUIDELINES FOR NIGHT TIME NOISE

The WHO limit for night-time noise is 40 dB $L_{night,outside.}$ This metric as outlined in **Section 2.7** is calculated on an annual average basis. Theoretically this would require continuous monitoring for an entire year to provide a definitive answer. For this project Sites 03 and 13 were monitored for 24 weeks and the other sites for 8 weeks.

The modelling for the EIS was carried out at a worst case wind speed of 10m/s. The L_{A90}–background + 3dB at wind speed of 10 m/s (derived from trendline) along with the average night time levels over the period for which it is available was calculated and are presented in **Table 6-7**.

Table 6-7: Average night time levels over the full monitoring period

Site number	Average L_{A90} –BG + 3dB over the full measurement period	L_{A90} –BG + 3dB at wind speed of 10 m/s (derived from EIS)
Site 01	39.2	45.6
Site 02	36.2	40.9
Site 03	39.1	45.4
Site 04	35.8	39.3
Site 05	32.7	40.4
Site 13	32.8	39.3

The data indicates that the levels are consistent within the WHO thresholds and long term average noise levels are on average 5.8 dB below the predicted maximum level from the EIS.

6.9 TONAL ANALYSIS

As outlined in **Section 5.3.1** significant tonal noise, unrelated to the wind farm, was detected (using the methodology described in **Section 2.10.1** during the day period.

One third octave analysis for tonal measurements was used on data filtered to maximise the likelihood of detection. The number of 10 minute periods in which a tone was detected is reported in **Table 6-8**.

Table 6-8: Number of intervals in which a tone was detected using third octaves

SITE	Site 01	Site 02	Site 03	Site 04	Site 05	Site 13
Number of night periods examined	2286	2268	4813	2340	2059	5322
Number of intervals where a tone was detected (night)	1	27	0	140	32	0

The extent of occurrence of tonal noise using the one third octave method was not significant and many of the tones detected were at higher frequencies unrelated to wind turbine noise.

6.9.1 Attended Tonal Noise Measurements

The noise logs indicated the presence of a tone and attendance on site by an acoustician in May, June, August and October confirmed a tone in the region of 160 Hz was present on occasions. Of the different site visits the most prominent tone noted and analysed using FFT narrow band analysis occurred at Site 03 on 16th August at 03:46 hrs. The results of this FFT analysis are presented in **Figure 6-45** and **Table 6-9.**

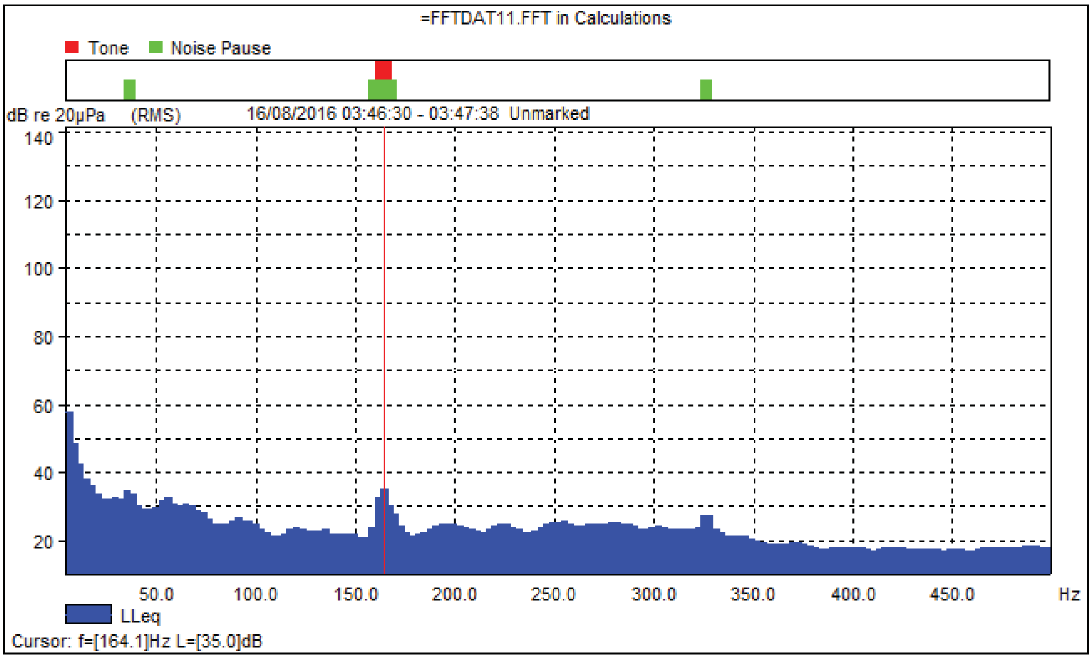

Figure 6-45 FFT Analysis Plot

As can be seen on the plot a tone is detected at 164.1 Hz. This sound is above the threshold of hearing for pure tones (~16 dB at 160 Hz). The objective method for pure tonal assessment applies a penalty based on the difference in energy between the tone and the associated masking or 'critical' band.

Table 6-9: FFT Analysis Result

SITE 03	Tone Frequency (Hz)	Critical Bandwidth (Hz)	Critical Bandwidth Start (Hz)	Tone Penalty (dB)
16/08/2016 03:46:30	164.1	100	114.1	0.0

Table 6-9 shows the tone frequency detected and the corresponding critical band. The energy in the tone is compared to the energy in the critical band using the Joint Nordic Method II. The penalty is calculated at 0.0 dB as the tone is not sufficiently prominent to warrant a penalty. This is consistent with experience while on site generally where this tone was audible but not prominent enough to warrant a penalty.

6.9.2 Unattended Tonal Noise Measurements

The noise logs made several references to the presence of tonal noise. As the objective method using third octave band measurements did not indicate the presence of tones related to wind farm noise, further analysis was carried out on selected data using the reference (FFT) method.

In order to isolate periods in which a tone related to wind farm noise was likely to arise the one third octave band results were reanalysed using a lower threshold difference between bands, i.e. the thresholds in one third octave frequency bands from 160 Hz to 400 Hz were reduced to 5 dB between bands. This is a departure from the standard methodology and likely to identify worst case conditions. This identified an additional number of time periods in which tones might arise. No time periods were identified for Site 02. A number of these periods for each site were subjected to FFT analysis and the results are set out in **Table 6-10**.

Table 6-10: Unattended FFT Tonal Detections

SITE	Date	Site 02	Prominent Tone Frequency Hz	Tone Level dB	Masking Level dB	Penalty Kt dB
01	01/07/2016	22:43	168.8	30.6	28.0	0.7
01	02/07/2016	00:16	168.8	29.3	25.8	1.5
01	27/11/2016	00:15	165.6	32.0	30.8	0.0
03	03/09/2016	00:24	165.6	31.5	24.9	4.7
03	21/11/2016	01:21	165.6	27.2	20.9	4.3
03	28/06/2016	23:51	165.6	30.8	22.3	6.0
04	01/07/2016	00:50	165.6	22.6	20.9	0.0
04	04/12/2016	03:03	168.8	30.4	27.2	1.2
04	24/11/2016	03:52	168.8	26.3	22.5	1.8
05	24/07/2016	22:30	**No tone detected**			
05	27/07/2016	23:01	150.0	22.0	8.6	6.0
05	28/07/2016	03:40	150.0	21.7	17.4	2.4
13	17/10/2016	22:13	168.8	27.1	23.2	2.0
13	27/10/2016	03:24	168.8	26.7	23.7	1.0

As can be seen from the table even when FFT analysis is applied to what is likely to be worst case conditions, the occasions on which a tonal penalty is warranted is limited. Prominent tones are audible in the 150-170 Hz region and in some cases sufficiently audible to warrant a penalty using the ISO 1996-2:2007 methodology.

Tonal noise, while noted, is only sufficient to warrant a penalty using the reference method on occasions. Tonal noise, while it does arise, cannot be considered to be a substantial issue at Sites 01, 02, 04 and 13. At Sites 03 and 05 tonal penalties of 6.0 dB were warranted on occasions and Site 03 is impacted most frequently by tonal noise.

6.10 LOW FREQUENCY NOISE

As outlined in **Section 5.6** low frequency Noise was quantified using the University of Salford criteria corrected for outdoor measurements. The results are presented in **Table 6-11**.

Table 6-11: Low frequency Noise Detections

SITE	Site 01	Site 02	Site 03	Site 04	Site 05	Site 13
Number of intervals where low frequency noise was detected (all day)	**454**	**1405**	**146**	**2133**	**91**	**161**
Number of intervals where low frequency noise was detected (night)	**62**	**93**	**1**	**174**	**0**	**3**

The incidence of low frequency noise when measured according to the University of Salford thresholds is low and generally not attributable to the wind turbines. This is not surprising given the noise spectrum of the wind turbines. Low frequency noise cannot therefore be considered a substantial issue in the overall context, however AM needs to be viewed separately.

6.11 AMPLITUDE MODULATION (AM)

AM is a distinct feature of wind turbine noise. Until recently no agreed methodology was available to measure it accurately. Some researchers have tried to measure AM directly using low frequency microphones or geophones. The results have been inconsistent and inaccurate and led to debate regarding low frequency noise emissions from wind turbines. What was being described as low frequency noise in many cases is likely to have been amplitude modulation mis-presented.AM is a low frequency phenomenon as it occurs at the 'blade passing frequency' and multiples of it. The blade passing frequency refers to the number of times per second that one of the turbine blades passes the tower. For large wind turbines this is approximately once per second or 1Hz. The wind turbines do not inherently create noise at this frequency. The noise from the wind turbine at low to mid-frequencies (from 50Hz to 800Hz) changes in amplitude/volume and creates the characteristic 'thumping' sound associated with wind turbines.

A methodology for quantifying AM is now agreed. The IoA methodology for determining AM provides a consistent and robust method of determining the extent of the phenomenon. The methodology was developed and agreed by a Working Group comprising all sides of the debate. It was finally published following extensive consultation and modification in August 2016.

RPS recorded WAV files and carried out preliminary filtration on these files as described in **Sections 5.3.1** and **5.7.4**. The IoA methodology has a further filtering step whereby if AM is not detected in a sufficiently high number of 10 second periods in the overall 10 minute period the 10 minute period is not considered as warranting a penalty.

The determination of what is an acceptable level of AM is still in development as outlined in **Section 2.10.3**. The UK DECC recommends using the IoA metric for quantifying AM and proposes testing and review of an additional penalty of 3 to 5 dB on a sliding scale for unacceptable or excessive levels of AM. It is noted that the AM control has only been designed for use with new planning applications, and applicability for use in nuisance investigations on existing wind turbine sites, was not considered by DECC. Guidance on AM control is awaited in Ireland.

The UK guidance on AM was published while this study was underway and is not applicable to existing wind turbine sites. It is nonetheless the only robust method for quantifying AM and at least provides some indication of the scale of the problem. In order to quantify the level of AM at each site twelve 10-minute periods were randomly selected from the data which was pre-filtered to isolate conditions under which AM was most likely to be detected.

The data was selected by isolating the conditions under which AM was likely to be measured. Each 10-minute period was allocated a random number and the periods with the largest random number were selected. Two hours of data (twelve 10-minute periods) were selected for each site. The results are presented in **Table 6-12** to **Table 6-17**.

Table 6-12: Site 01 Amplitude Modulation Detections

Date	Time	AM Level
05/12/2016	01:40	2.6
04/12/2016	01:40	3
09/07/2016	00:40	-1
06/07/2016	23:30	5.4
02/08/2016	22:10	-1
23/07/2016	23:50	3.9
26/06/2016	22:10	4.9
18/11/2016	22:30	3.2
24/06/2016	22:40	4.4
25/06/2016	01:20	4.6
31/07/2016	23:00	3.4
03/12/2016	02:30	3.4

As can be seen from **Table 6-12** AM in excess of 3 dB is a common feature in the noise at Site 01.

Table 6-13: Site 02 Amplitude Modulation Detections

Date	Time	AM Level
21/07/2016	23:00	-1
08/07/2016	00:00	5.8
22/11/2016	23:30	8.0
03/08/2016	01:50	-1
06/12/2016	01:00	-1
29/11/2016	03:00	2.8
08/07/2016	03:30	4.5
04/08/2016	01:50	6.2
26/06/2016	01:10	5.2
25/06/2016	01:50	6.7
02/07/2016	00:50	9.0
21/07/2016	23:00	-1

As can be seen from **Table 6-13** AM in excess of 3 dB is a regular feature in the noise at Site 02.

Table 6-14: Site 03 Amplitude Modulation Detections

Date	Time	AM Level
29/09/2016	22:00	5
17/09/2016	03:20	4.3
09/12/2016	01:30	3.4
14/07/2016	23:30	-1
30/09/2016	02:50	5
03/09/2016	22:00	2.9
17/09/2016	01:00	5.2
24/09/2016	01:40	-1
01/07/2016	02:50	5.5
15/09/2016	23:50	5.8
12/10/2016	03:50	4.2
01/09/2016	01:20	3.5

As can be seen from **Table 6-14** AM in excess of 3 dB is a consistant feature in the noise at Site 03.

Table 6-15: Site 04 Amplitude Modulation Detections

Date	Time	AM Level
21/11/2016	23:00	-1
26/07/2016	23:00	4.8
07/07/2016	01:20	2.1
15/07/2016	01:30	4.1
20/11/2016	23:20	7.4
23/06/2016	22:00	4.2
06/12/2016	01:50	4.6
25/11/2016	03:50	6.3
28/07/2016	22:30	4.5
03/08/2016	23:20	6.9
24/11/2016	23:40	5.4
24/06/2016	23:50	6.6

As can be seen from **Table 6-15** AM in excess of 3 dB is a consistant feature in the noise at Site 04.

Table 6-16: Site 05 Amplitude Modulation Detections

Date	Time	AM Level
28/11/2016	03:50	3.8
29/07/2016	02:40	5.1
29/07/2016	01:30	5
22/11/2016	01:00	-1
11/07/2016	01:10	-1
15/07/2016	22:30	-1
26/07/2016	23:00	-1
21/11/2016	23:20	-1

19/11/2016	03:20	-1
15/11/2016	22:30	-1
09/07/2016	02:00	2.7
07/07/2016	02:30	-1

As can be seen from **Table 6-16** AM in excess of 3 dB is an occasional feature in the noise at Site 05 and less so than at other sites.

Table 6-17: Site 13 Amplitude Modulation Detections

Date	Time	AM Level
24/09/2016	22:00	4.5
10/10/2016	01:40	2.8
12/10/2016	23:40	2.9
23/08/2016	03:00	1.9
06/08/2016	23:10	-1
31/10/2016	01:10	2.7
27/08/2016	00:30	-1
01/09/2016	02:10	4.3
04/09/2016	02:40	3
11/07/2016	02:50	3.1
25/06/2016	23:10	4.2
28/10/2016	03:10	3.3

As can be seen from **Table 6-17** AM in excess of 3 dB is a common feature in the at Site 13.

As can be seen in the tables above AM is a feature in the noise at all sites. Using the IoA methodology for quantifying AM the levels exceed 3 at all sites on an intermittant basis. The 3 dB threshold is currently a recommendation for new wind farm developments in the UK and may be revised as more information becomes available from measurements taken using the IoA methodology.

Currently there are no guidelines on AM control noise in Ireland. AM is also not regulated under the Planning Conditions imposed on Gibbet Hill wind farm.

6.12 LIKELIHOOD OF NOISE NUISANCE (UNDER S.108 OF THE EPA ACT, 1992)

An action for nuisance can be taken by issuing a notice of intent under section 108(3) of the Environmental Protection Agency Act, 1992, making a complaint to the District Court in relation to noise. To sustain a complaint noise must be such as to give ‘reasonable cause for annoyance’, which is further defined as:

> *‘so loud/so continuous/so repeated/of such duration or pitch/occurring at such times as to give reasonable cause for annoyance to the complainant or a person in any premises in the neighbourhood, or a person lawfully using a public place’.*

In RPS's opinion the overall noise levels (loudness) are in substantial compliance at most sites. Depending on the interpretation of the 'definitive' committments in the EIS, Site 01 and Site 03 may not be compliant. As shown on **Table 6-5** for Site 01 (8.1%) and Site 03 (2.8 %) the noise levels exceed 43 dB(A) for the night periods. It is not possible to attribute these exceedances to wind turbine noise alone but the likelihood is that some exceedances occur.

The 'pitch' includes such factors as low frequency and tonal noise which in RPS's opinion are generally under control. Worst case conditions at Site 03 have identified a tonal noise issue at that location. Using the internationaly recognised Joint Nordic method for tonal analysis, penalties of 4.4 to 6.0 dB were warranted on three occasions at Site 03.

AM is effectively a repetitive change in the nature of the noise. There is currently no guideline on AM control in Ireland. Analysis for this report was carried out using recently published guidelines for new wind farm development in the UK. A sample of files analysed for AM using the IoA methodology yielded results which were higher than preliminary guidelines issued in the UK for new wind farm development.

The nature of AM noise is such that it is recognised as the type of noise that is likely to give reasonable cause for annoyance. While AM may be an issue when evaluated using UK criteria for new wind farm developments, no guidance is currently available in Ireland on AM. Based on preliminary UK guidance the levels of AM reported would have the effect of increasing the measured noise levels by 3 to 5 dB with a 'rating' penalty. Consideration must also be given to the fact that the wind farm was constructed prior to any guidelines being published.

7 CONCLUSIONS

RPS collected data on 14 sites over a period of 24 weeks from 22nd June 2016 to 9th December 2016. Overall data recovery for the period was over 95% for the five week summer period and the three week winter period. Data recovery for the intervening period was 78% on three sites. It was not possible to increase the recovery for the intervening period as the winter period followed immediately, with no lag. The data comprises noise measurement data, weather data and sound recordings (WAV files) and amounts to approximately 3 TB in total.

Data was analysed under several criteria for compliance with Planning Conditions and international practice on the control of wind farm noise. A sample of WAV files were further analysed to determine compliance with the latest UK guidance on AM, which was published while the monitoring was in progress.

7.1 PLANNING COMPLIANCE

Guidance is needed on the threshold for ‘compliance’ with planning conditions, particularly on whether or not a single exceedance for weather dependent noise levels is sufficient to warrant enforcement action. Based on other environmental regulation limits such as the Guidelines for Planning Authorities for Quarries and Ancillary Activities, the Surface Water Regulations and Air Quality Standards Regulations the principle of ‘Substantial’ compliance has been applied. No equivalent guidance on wind farm noise compliance has been provided to planning authorities.

The planning conditions relating to Gibbet Hill wind farm do not specify a particular noise level limit but require that the noise attributable to the wind farm conforms to the levels set out in the planning application documents. In determining compliance it is necessary to demonstrate that the noise levels being reported are attributable to the wind farm only.

As set out in Section 2.1 RPS has taken the view that ‘substantial compliance’ is the appropriate basis for determining compliance in the case of wind farm noise.

This report outlines the methodologies used to isolate wind turbine noise from other noise at the monitoring locations and concludes that the appropriate metric for compliance is based on the L_{A90} measurement, corrected for background noise and converted to L_{Aeq} using the 3 dB factor referenced in the EIS.

Using this metric and applying a tolerance for ‘Substantial’ compliance, Sites 02, 04, 05 and 13 are substantially compliant with the noise levels predicted in the EIS.

The data and the trendline for Site 01 and Site 03 both exceed the levels predicted in Figure 9.7 of the EIS at wind speeds in excess of 8.0 and 8.5 m/s respectively.

There is no directly corresponding location for Site 03 in Section 9.9 of the EIS. For this site a single wind speed noise level is extracted from Figure 9.6 of the EIS. The data and the trendlines for both L_{Aeq} and L_{A90} exceed the levels predicted in Figure 9.6 of the EIS at wind speeds of 8m/s. The analysis indicates that some of the measured and corrected noise levels exceed those predicted in the EIS at Site 03.

Similarly Sites 02, 04, 05 and 13 are compliant with the levels set out in the conclusion of the EIS. Site 01 and Site 03 are not compliant at higher wind speeds.

7.2 COMMENTRY RELATING TO OTHER STANDARDS

7.2.1 WEDG (2006)

All sites can be considered in substantial compliance with the WEDG (2006) night-time limit when measured using a L_{A90} metric.

7.2.2 UK

Based on a conservative interpretation of the UK ETSU-R-97 Guidance document, the quiet period noise levels should be lower than 35 dB(A). It is clear from the plots in **Section 6.7.1** that the trendline exceeds the 35 dB(A) threshold at all sites. Based on the curves presented the wind turbine noise exceeds the ETSU-R-97 threshold for quiet periods at all sites.

The noise level is in compliance with the ETSU-R-97 guideline for night-time noise at all sites.

At Site 03 the trendline exceeds the 43 dB(A) guideline at high wind speeds but it cannot be determined with certainty that the noise measured at higher wind speeds is directly attributable to the wind farm.

7.2.3 South Australian

Data plotted using both L_{Aeq} and L_{A90} corrected for background plus 3 dB along with the trendline through the data exceed the South Australian 40 dB(A) threshold at all Sites. At Sites 02, 04, 05 and 13 the exceedance is marginal and if measured on a 'substantial' compliance basis these four sites comply (**Section 6.7.2**).

7.2.4 Canada and Denmark

It can be seen from the plots that when using the L_{Aeq} metric the trendline does not conform to the expected shape for wind turbine noise. The L_{A90} metric however does present in the expected shape. In all cases the trendlines are lower than the Canadian and Danish thresholds at 6m/s and 8m/s (**Section 6.7.3**) and the Canadian threshold at 10m/s.

7.2.5 World Health Organisation

The data indicates that the levels are consistently within the WHO thresholds (**Section 6.8**).

7.2.6 Tonal Analysis

From the analysis of tones over the full monitoring period and narrow band analysis carried out using attended measurements a tone in the region of 160 Hz was found. The objective assessment of this tone in accordance with BS4142:1997 and BS4142:2014 found that no tonal penalty was warranted (**Section 6.9**).

While tonal noise is audible, no significant tonal noise penalties are warranted using the objective method (ISO 1996-2:2007) of assessment. When worst case conditions were analysed using the reference method (ISO 1996-2:2007) some tonal penalties were warranted at Sites 03 and 05 in particular. Due to the limited number of periods identified in which tonal penalties are warranted, the wind farm is not considered to have a significant tonal noise issue

7.2.7 Low Frequency Noise

The incidence of low frequency noise when measured according to the University of Salford thresholds is low and generally not attributable to the wind turbines. This is not surprising given the noise spectrum of the wind turbines (**Section 6.9**).

7.2.8 Amplitude Modulation

RPS used the IoA methodology to determine AM as it provides a consistent and robust method of determining the extent of the phenomenon. Two hours of worst case data were isolated and analysed using the IoA methodology. For the data analysed the AM results were found to exceed the 3dB threshold recommended in the UK for new wind farm developments (**Section 6.11**).

7.2.9 Likelihood of noise nuisance as per Section 108 of the EPA Act No. 7 of 1992.

There is no internationally accepted threshold to define nuisance from wind farm noise. A difficulty in assessing possible nuisance is that the noise from wind farms can be infrequent with regards to tonal and low frequency noise detections. Recent research indicates that many of the issues relating to tonal and low frequency noise complaints may be attributable to AM.

The IoA methodology provides (since August 2016) a reliable method for quantifying AM. The nature of AM noise is such that it is recognised internationally as the type of noise that is likely to give reasonable cause for annoyance. Analysis of a sample of WAV files for AM found variable presence of excessive AM during night hours.

7.3 SUMMARY

Table 7-1 provides a summary of the analysis relating to planning compliance and **Table 7-2** provides a summary of commentary relating to the other criteria set out in the tender document.

Table 7-1: Compliance with Planning Conditions - Summary

Planning	Criteria	Status
Planning Conditions (a) Based on the site specific noise predictions in the EIS Section 9.7	L_{Aeq} Day-time L_{Aeq} Night-time	a) Sites 02, 04, 05 and 13 are substantially compliant with EIS Section 9.7 b) Sites 01 and 03 trendlines exceed the predicted levels at corrected wind speeds greater than 8 m/s
Planning Conditions (b) Based on the EIS conclusion, Section 9.10.3	L_{Aeq} Day-time L_{Aeq} Night-time	Sites 02, 04, 05 and 13 are substantially compliant, Site 01 and Site 03 are not compliant depending on the threshold set for substantial compliance

Table 7-2: Commentary on Other Criteria - Summary

Other Criteria	Criteria	Status
DECLG Wind Energy Development Guidelines	L_{A90} Day-time L_{A90} Night-time	All sites are substantially compliant
ETSU-R-97 Guidance	L_{A90} Day-time L_{A90} Night-time	Exceeds the quiet period criteria at higher wind speeds. Compliant with the night-time threshold
South Australia	L_{Aeq}	Sites 02, 04, 05 and 13 comply with the threshold. Sites 01 and 03 exceed the threshold at higher wind speeds
Denmark	L_{Aeq}	All sites are substantially compliant
Canada	L_{Aeq}	All sites are substantially compliant
WHO Guidelines for Night-time	$L_{night,outside}(L_{Aeq})$	All sites are substantially compliant
Tonal Noise	One Third Octave and Joint Nordic methods	Some tones detected but not consistent enough to warrant tonal penalties
Amplitude Modulation	IoA Methodology	Significant AM detected. Levels in excess of 3 dB detected on all sites to varying degree
Section 108 of the EPA Act		Noise levels generally not excessive, limited tonal and low frequency noise detected. Excessive AM detected to varying degree at all sites

8 REFERENCES

Beranek, L., Ed., (1998), Noise Reduction, Peninsula Publishing, California.

BS 4142:1997 Method for Rating industrial noise affecting mixed residential and industrial areas.

BS 4142:2014 Methods for rating and assessing industrial and commercial sound

Cand, M., Davis, R., Jordan, C., Hayes, M., & Perkins, R. (2013). *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise.* St. Albans: Institute of Acoustics. Guidance Document and Supplementary Guidance Notes.

DIN (2013) 45680:2013-09 - Entwurf: Messung und Beurteilung tieffrequenter Geräuschimmissionen, [Measurement and assessment of low-frequency noise immissions].

Environmental Noise Directive (2002), Directive 2002/49/EC.

ETSU-R-97 (1997), The assessment and rating of noise from wind farms.

Hayes Mackenzie Partnership Ltd., (2006), The measurement of low frequency noise at three UK wind farms, Contract number W/45/00656/00/00 for the Department of Trade and Industry.

Institute of Acoustics Noise Working Group (Wind Turbine Noise) Amplitude Modulation Working Group Final (I0A AMWG), 2016, A method for Rating Amplitude Modulation in Wind Turbine Noise.

ISO 226: 2004 Acoustics – Normal equal-loudness-level contours.

ISO 1996-1:2016 Acoustics — Description, measurement and assessment of environmental noise

Moorhouse, A., Waddington, D., Adams, M., (2011), Proposed criteria for the assessment of low frequency noise disturbance, Revision 1, Contract no. NANR45, DEFRA.

Denmark SO (2011), Statutory Order on noise from wind turbines, Order No. 1284 of 15th December 2011.

World Health Organisation, (1999), Guidelines for Community Noise, Geneva.

WSP- Parsons Brinckerhoff, 2016, Wind Turbine AM Review Phase 2 Report, Project no. 3514482A.

APPENDIX A

Calibration Certificates

Brüel & Kjær
The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA DANAK CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1339158

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2479724	Id: - 2479724
Microphone:	Brüel & Kjær Type 4189	No: 281993	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 17516	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 202652	
Software version:	BZ7222 Version 2.1	Pattern Approval:	PTB1.63-4046158
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2014-11-21

Date of issue: 2014-11-21

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær
The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1360944

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2506117	Id: - 2506117
Microphone:	Brüel & Kjær Type 4189	No: 2529734	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 16622	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2460008	
Software version:	BZ7222 Version 2.1	Pattern Approval:	PTB1.63-4046158
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in* ***Environmental conditions*** *sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2016-02-14

Date of issue: 2016-02-14

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær
The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA
DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1605491

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2567756	Id: -
Microphone:	Brüel & Kjær Type 4189	No: 2470482	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: -	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2626210	

Software version: BZ7222 Version 2.1 Pattern Approval: PTB1.63-4046158
Instruction manual: BE1712-18

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C
Environment conditions: *See actual values in* ***Environmental conditions*** *sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2016-07-08

Date of issue: 2016-07-08

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær
The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1359690

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2590440	Id: - 2590440
Microphone:	Brüel & Kjær Type 4189	No: 2589639	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 16110	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2626210	

Software version:	BZ7222 Version 2.1	Pattern Approval:	PTB1.63-4046158
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-12-12

Date of issue: 2015-12-12

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær

The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA

DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1605511

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2611593	Id: -
Microphone:	Brüel & Kjær Type 4189	No: 2697054	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: -	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2626210	
Software version:	BZ7222 Version 2.1	Pattern Approval:	PTB1.63-4046158
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2016-07-09

Date of issue: 2016-07-09

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær

The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

DANAK CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1310500

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2626210	Id: -
Microphone:	Brüel & Kjær Type 4189	No: 2785433	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 15085	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2022652	

Software version:	BZ7222 Version 2.1	Pattern Approval:	PTB1.63-4046158
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-07-21

Date of issue: 2015-07-21

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

CERTIFICATE OF CALIBRATION

Date of issue: 06 August 2015   Certificate Number: CDK1505903

DANAK
CAL Reg.nr. 307

Brüel & Kjær

The Calibration Laboratory
Skodsborgvej 307. DK-2850 Nærum, Denmark
Tel: +45 45 800 500   Fax: +45 45 801 405
Email: ukservice@bksv.com

Jonas Johannessen
Approved Signatory

CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2690265	Id: -
Microphone:	Brüel & Kjær Type 4189	No: 2748694	
Associated Calibrator:	Brüel & Kjær Type 4231	No: 2389038	
Calibrator Certificate:	CDK1505835	Calibrator Level:	93.99 dB SPL
SLM Software Version:	BZ7225 Version 3.4		

Date of calibration: 06 August 2015

CUSTOMER:

RPS Group Ltd.
Mervue
G1 Galway
Ireland

CALIBRATION CONDITIONS:

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: Air Temperature: 22.6 °C, Air Pressure: 101.6 kPa, Relative Humidity: 49.0 %RH

SPECIFICATIONS:

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in BS7580: Part 1: 1997.

PROCEDURE:

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 5.1 - DB: 4.60) by using procedure 2250-4189.

RESULTS:

Unless otherwise stated herein, the reported uncertainty is based upon a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with DANAK requirements. The uncertainties refer to the measured values only with no account being taken of the ability of the device under test to maintain its calibration.

Note: Calibration as received.

Brüel & Kjær
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Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA DANAK
CAL Reg nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1359578

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2818081 Id: - 2820751	
Microphone:	Brüel & Kjær Type 4189	No: 2821415	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 15083	
Supplied Calibrator:	None		
Software version:	BZ7222 Version 3.5.3	Pattern Approval:	PTB1.63-4055843 / 1.63-4055845
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House, IDA Business & Technology Park
Clonshaugh
Dublin 17
Ireland

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-12-03

Date of issue: 2015-12-03

Steen Vodstrup Andersen
Calibration Technician

Susanne Jørgensen
Approved Signatory

Certificate of Calibration

Issued by University of Salford (Acoustics Calibration Laboratory)
UKAS ACCREDITED CALIBRATION LABORATORY NO. 0801

APPROVED SIGNATORIES
Claire Lomax [x] Andy Moorhouse [ ]
Gary Phillips [ ] Danny McCaul [ ]

C. Lomax

0801

acoustic calibration laboratory
The University of Salford, Salford, Greater Manchester, M5 4WT, UK
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t 0161 295 3030/0161 295 3319 f 0161 295 4456 e c.lomax1@salford.ac.uk

Certificate Number: 02685/3 Date of Issue: 3 May 2016

PERIODIC TEST OF A SOUND LEVEL METER to IEC 61672-3:2006

FOR:	Enfonic Ltd Tecpro House IDA Business & Technology Park Clonshaugh Dublin 17
FOR THE ATTENTION OF:	Gary Duffy
PERIODIC TEST DATE:	03/05/2016
TEST PROCEDURE:	CTP12 (Laboratory Manual)

Sound Level Meter Details

Manufacturer	Bruel & Kjaer	
Model	2250	
Serial number	3001734	
Class	1	
Hardware version	4.0	Software version: BZ7222 Version 4.6.1

Associated Items	**Microphone**	**Preamplifier**	**Calibrator**
Manu	Bruel & Kjaer	Bruel & Kjaer	Bruel & Kjaer
Model	4189	ZC 0032	4231
Serial Number	3022867	24016	2465766
Calibrator Adaptor	-	-	UC0210

Test Engineer (initial): GP Name: Gary Phillips

Certificate Number: 02685/3 Date of Issue: 3 May 2016

Procedures from IEC 61672-3: 2006 and TPS 49 Edition 2 June 2009 were used to perform the periodic tests. Manufacturer's instruction manual was marked as follows: B&K 2250 BE 1712-15 April 2007 from hardware version 1.1.

Adjustment data used to adjust the sound levels indicated in response to the application of a multi-frequency sound calibrator to sound levels equivalent to those that would be indicated in response to plane, progressive sound waves were obtained from the manufacturer's instruction manual referred to in this certificate. The sound level meter calibration check frequency is 1000 Hz, the reference sound pressure level is 94 dB. As this instrument only has a single range, this range is the reference level range.

The environmental conditions in the laboratory at the start of the test were:
Static pressure 101.863 kPa ± 0.015 kPa, air temperature 22.3 °C ± 0.3 °C, relative humidity 36.7 % ± 1.7%.

The initial response of the instrument to application of the associated sound calibrator was 93.8 dB (C). The instrument was then adjusted to indicate 94.0 dB (C). This indication was obtained from the calibration certificate of the calibrator, 02685/1 and information in the manufacturer's instruction manual specified in this certificate, when the instrument is configured as follows; Input: Top Socket, Transducer: 4189, Sound Field Correction: Free-field, Windscreen Auto Detect: Off, Windscreen Correction: None. The instrument was calibrated without a windshield. Consult manufacturer's instructions if using a windshield.

With the microphone installed the level of self-generated noise was:

A: **17.2 dB***

* Under-range indicated on instrument display.

With the microphone replaced by the electrical input device specified in the manufacturer's instruction manual, the levels of self-generated noise were:

A: **13.2 dB***
B: **12.3 dB***
C: **13.4 dB***
$Z_{LF\text{-}Normal}$: **18.5 dB***
$Z_{LF\text{-}Extended}$: **23.2 dB***

* Under-range indicated on instrument display.

The environmental conditions in the laboratory at the end of the test were:
Static pressure 101.951 kPa ± 0.015 kPa, air temperature 22.8 °C ± 0.3 °C, relative humidity 37.0 % ± 1.7%.

Certificate Number: 02685/3 Date of Issue: 3 May 2016

The sound level meter submitted for testing has successfully completed the class 1 periodic tests of IEC 61672-3:2006, for the environmental conditions under which the tests were performed. As public evidence was available, from an independent testing organization responsible for approving the results of pattern evaluation tests performed in accordance with IEC 61672-2:2003, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2002, the sound level meter submitted for testing conforms to the class 1 requirements of IEC 61672-1:2002.

The microphone corrections applied as specified in 12.6 of IEC 61672-3:2006 were obtained from a frequency response measured by this Laboratory using the electrostatic actuator method. This response in isolation is not covered by our UKAS accreditation.

Instruments used in the verification procedure were traceable to *National Standards*. The multi-frequency calibrator method was employed in the acoustical tests of a frequency weighting.

The uncertainty evaluation has been carried out in accordance with UKAS requirements. All measurement results are retained at the acoustic calibration laboratory for at least four years.

Brüel & Kjær

The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK14010525

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2580156	Id: -
Microphone:	Brüel & Kjær Type 4950	No: 2698718	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 17445	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2343370	

Software version:	BZ7222 Version 2.1	Pattern Approval:	PTB1.63-4046158
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-07-21

Date of issue: 2015-07-21

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

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Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA DANAK CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK14032515

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2638881	Id: - 2638881
Microphone:	Brüel & Kjær Type 4189	No: 2846376	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: -	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: -	

Software version: BZ7222 Version 2.1 Pattern Approval: PTB1.63-4046158
Instruction manual: BE1712-18

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C
Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2016-01-21 Date of issue: 2016-01-21

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

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ilac-MRA DANAK CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1410515

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 2654662	Id: - 2654662
Microphone:	Brüel & Kjær Type 4950	No: 2737145	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 6822	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2123002	

Software version: BZ7222 Version 2.1 Pattern Approval: PTB1.63-4046158
Instruction manual: BE1712-18

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C
Environment conditions: *See actual values in* ***Environmental conditions*** *sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-07-21 Date of issue: 2015-07-21

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær

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Skodsborgvej 307, DK-2850 Nærum, Denmark

DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1359391

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 3000855	Id: - 2626210
Microphone:	Brüel & Kjær Type 4950	No: 2778445	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 16743	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2626210	

Software version: BZ7222 Version 2.1 Pattern Approval: PTB1.63-4046158
Instruction manual: BE1712-18

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C
Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-11-21

Date of issue: 2015-11-21

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær

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Skodsborgvej 307, DK-2850 Nærum, Denmark

DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1359688

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 3001350	Id: - 3001350
Microphone:	Brüel & Kjær Type 4950	No: 2778447	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 16741	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 3005345	

Software version: BZ7222 Version 2.1 Pattern Approval: PTB1.63-4046158
Instruction manual: BE1712-18

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C
Environment conditions: *See actual values in* ***Environmental conditions*** *sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-12-12 Date of issue: 2015-12-12

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

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ilac-MRA

DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1359678

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 3002365	Id: - 3002365
Microphone:	Brüel & Kjær Type 4950	No: 2807020	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 15085	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 3005345	

Software version: BZ7222 Version 2.1 Pattern Approval: PTB1.63-4046158
Instruction manual: BE1712-18

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C
Environment conditions: *See actual values in* ***Environmental conditions*** *sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-12-12

Date of issue: 2015-12-12

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær

The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

CERTIFICATE OF CALIBRATION

No: CDK1404221

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250 Light	No: 3002367 Id: -
Microphone:	Brüel & Kjær Type 4950	No: 2778447
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 17907
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2460008

Software version: BZ7133 Version 4.3.2 Pattern Approval: PTB

Instruction manual: BE1853-11

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Clonshaugh
17 Dublin
Ireland

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in **Environmental conditions** sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 Light has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 5.1 - DB: 5.10) by using procedure B&K proc 2250-L-4950 (IEC61672).

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-06-09

Date of issue: 2015-06-09

Jonas Johannessen
Calibration Technician

Morten Høngård Hansen
Approved Signatory

Brüel & Kjær
The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

DANAK
CAL Reg.nr. 307

CERTIFICATE OF CALIBRATION

No: CDK1360941

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2250	No: 3006895	Id: - 3006895
Microphone:	Brüel & Kjær Type 4952	No: 2550918	
Preamplifier:	Brüel & Kjær Type ZC-0032	No: 16530	
Supplied Calibrator:	Brüel & Kjær Type 4231	No: 2460008	
Software version:	BZ7222 Version 2.1	Pattern Approval:	PTB1.63-4046158
Instruction manual:	BE1712-18		

CUSTOMER

Enfonic Ltd
Tecpro House
IDA Business & Technology Park
Dublin

CALIBRATION CONDITIONS

Preconditioning: 4 hours at 23°C ± 3°C

Environment conditions: *See actual values in* ***Environmental conditions*** *sections.*

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2250 has been calibrated in accordance with the requirements as specified in IEC61672-1:2002 class 1. Procedures from IEC 61672-3:2006 were used to perform the periodic tests. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 4.9 - DB: 4.90) by using procedure 2250-4189.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2016-02-14

Date of issue: 2016-02-14

M. Önder
Mikail Önder
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær

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Skodsborgvej 307, DK-2850 Nærum, Denmark

ilac-MRA DANAK
CAL Reg.No. 307
Member of EA MLA

CERTIFICATE OF CALIBRATION

No: CDK1505904

CALIBRATION OF

Sound Level Meter:	Brüel & Kjær Type 2260	No: 2076252 Id: -
Microphone:	Brüel & Kjær Type 4193	No: 2812159

CUSTOMER

RPS Group Ltd.
Mervue
G1 Galway
Ireland

CALIBRATION CONDITIONS

Preconditioning:	4 hours at 23°C ± 3°C
Environment conditions:	Pressure: 101,3kPa ± 3kPa. Humidity: 25% - 70% RH. Temperature: 23°C ± 3°C.

SPECIFICATIONS

The Sound Level Meter Brüel & Kjær Type 2260 has been calibrated in accordance with the requirements as specified in IEC 60651 and 60804 type 1. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær Sound Level Meter Calibration System 3630 with application software type 7763 (version 5.1 - DB: 5.10) by using procedure B&K proc 2260-4193-BZ7210-V2.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-08-10

Date of issue: 2015-08-11

Jonas Johannessen
Calibration Technician

Susanne Jørgensen
Susanne Jørgensen
Approved Signatory

Brüel & Kjær
The Calibration Laboratory
Skodsborgvej 307, DK-2850 Nærum, Denmark

DANAK
CAL Reg.No. 307
Member of EA MLA

CERTIFICATE OF CALIBRATION

No: CDK1505835

CALIBRATION OF

Calibrator:	Brüel & Kjær Type 4231	No: 2389038 Id: -
½ Inch adaptor:	Brüel & Kjær Type UC-0210	
Pattern Approval:	PTB-1.61-4057176	

CUSTOMER

RPS Group Ltd.
Mervue
G1 Galway
Ireland

CALIBRATION CONDITIONS

Preconditioning:	4 hours at 23°C ± 3°C
Environment conditions:	Pressure: 101.29 kPa. Humidity: 47 % RH. Temperature: 23 °C.

SPECIFICATIONS

The Calibrator Brüel & Kjær Type 4231 has been calibrated in accordance with the requirements as specified in IEC60942:2003 Annex B Class 1. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær acoustic calibrator calibration application software Type 7794 (version 2.5) by using procedure P_4231_D07.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2015-08-04

Date of issue: 2015-08-04

Susanne Nygaard
Susanne Nygaard
Calibration Technician

Morten Høngård Hansen
Approved Signatory

Brüel & Kjær

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ilac-MRA

DANAK
CAL Reg.No. 307
Member of EA MLA

CERTIFICATE OF CALIBRATION

No: CDK1605829

CALIBRATION OF

Calibrator:	Brüel & Kjær Type 4231	No: 2389038 Id: -
½ Inch adaptor:	Brüel & Kjær Type UC-0210	
Pattern Approval:	PTB-1.61-4057176	

CUSTOMER

RPS Group Ltd.
Mervue
G1 Galway
Ireland

CALIBRATION CONDITIONS

Preconditioning:	4 hours at 23°C ± 3°C
Environment conditions:	Pressure: 101.79 kPa. Humidity: 50 % RH. Temperature: 22.7 °C.

SPECIFICATIONS

The Calibrator Brüel & Kjær Type 4231 has been calibrated in accordance with the requirements as specified in IEC60942:2003 Annex B Class 1. The accreditation assures the traceability to the international units system SI.

PROCEDURE

The measurements have been performed with the assistance of Brüel & Kjær acoustic calibrator calibration application software Type 7794 (version 2.5) by using procedure P_4231_D07.

RESULTS

Calibration Mode: **Calibration as received.**

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the device under calibration.

Date of calibration: 2016-08-30

Date of issue: 2016-08-30

Susanne Jørgensen
Susanne Jørgensen
Calibration Technician

Morten Høngård Hansen
Approved Signatory