Drumlins Park Wind Farm

Chapter 11:
Noise & Vibration

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11.1 Introduction

11.1.1 Background and Objectives

This chapter describes the assessment undertaken of the likely noise and vibration effects arising from the proposed development comprising 8 no. wind turbines with a maximum overall ground level to blade tip height of 180 metres, 3 no. grid connection options including accompanying substations, construction compound and all associated ancillary infrastructure. A full description of the proposed development is provided in **Chapter 3** of this EIAR.

As discussed in **Chapter 3**, there are 123 no. noise sensitive locations identified within 1.8km (10-times tip height) of the proposed turbine locations. The nearest noise sensitive location (NSL) is located approximately 570m to the nearest proposed turbine location (i.e. Location H122 from proposed turbine T5).

According to the Wind Energy Development Guidelines for Planning Authorities 2006, in general, noise is unlikely to be a significant problem where the distance from the nearest turbine to any NSL is more than 500 metres. However, within this chapter, noise and vibration impact assessments have been prepared for construction and operational phase activities of the proposed development on all NSLs located within 1.8km of a wind turbine. To inform this assessment, background noise levels have been measured at representative noise sensitive locations in order to assess the potential impacts associated with the operation of the proposed development. The background noise survey was carried out by Galetech Energy Services (GES).

11.1.2 Statement of Authority

This chapter has been prepared by Mike Simms BE MEngSc MIOA MIET, Senior Acoustic Consultant at AWN Consulting Ltd. Mike has worked in the field of acoustics for over 19 years. He has extensive experience in all aspects of environmental surveying, noise modelling and impact assessment for various sectors including, wind energy, industrial, commercial and residential.

The baseline noise monitoring was undertaken by Cormac McPhillips, Project Technician at GES. Cormac has extensive experience of undertaking noise monitoring programmes in accordance with relevant standards and best practice methods.

11.1.3 Candidate Wind Turbine

The General Electric GE 5.5-158, which a hub height of 101m and rotor diameter of 158m (Option TU1), has been selected as the candidate turbine for the basis of this noise and vibration impact assessment.

This turbine was selected due to the likely greater requirement for construction activities (generation of construction noise and extended construction duration) and the likelihood for greater levels of wind turbine aerodynamic noise during the operational phase due to longer blades compared to the General Electric GE 4.0-130 (Option TU2).

11.2 Methodology

A sound wave travelling through the air is a regular disturbance of the atmospheric pressure. These pressure fluctuations are detected by the human ear, producing the sensation of hearing. To take account of the vast range of pressure levels that can be detected by the ear, it is convenient to measure sound in terms of a logarithmic ratio of sound pressures. These values are expressed as Sound Pressure Levels (SPL) in decibels (dB).

The audible range of sounds expressed in terms of Sound Pressure Levels is 0dB (for the threshold of hearing) to 120dB (for the threshold of pain). In general, a subjective impression of doubling of loudness corresponds to a tenfold increase in sound energy which conveniently equates to a 10dB increase in SPL. It should be noted that a doubling in sound energy (such as may be caused by a doubling of traffic flows) increases the SPL by 3 dB.

The frequency of sound, which is the rate at which a sound wave oscillates, is expressed in Hertz (Hz). The sensitivity of the human ear to different frequencies in the audible range is not uniform. For example, hearing sensitivity decreases markedly as frequency falls below 250Hz. In order to rank the SPL of various noise sources, the measured level has to be adjusted to give comparatively more weight to the frequencies that are readily detected by the human ear. The 'A-weighting' system defined in the international standard, BS ISO 226:2003 Acoustics - Normal Equal-loudness Level Contours has been found to provide the best correlations with human response to perceived loudness. SPLs measured using 'A-weighting' are expressed in terms of dB(A).

An indication of the level of some common sounds on the dB(A) scale is presented in **Figure 11.1**, which shows a quiet bedroom at around 35 dB(A), a nearby noisy HGV at 90 dB(A) and a pneumatic drill at about 100 dB(A).

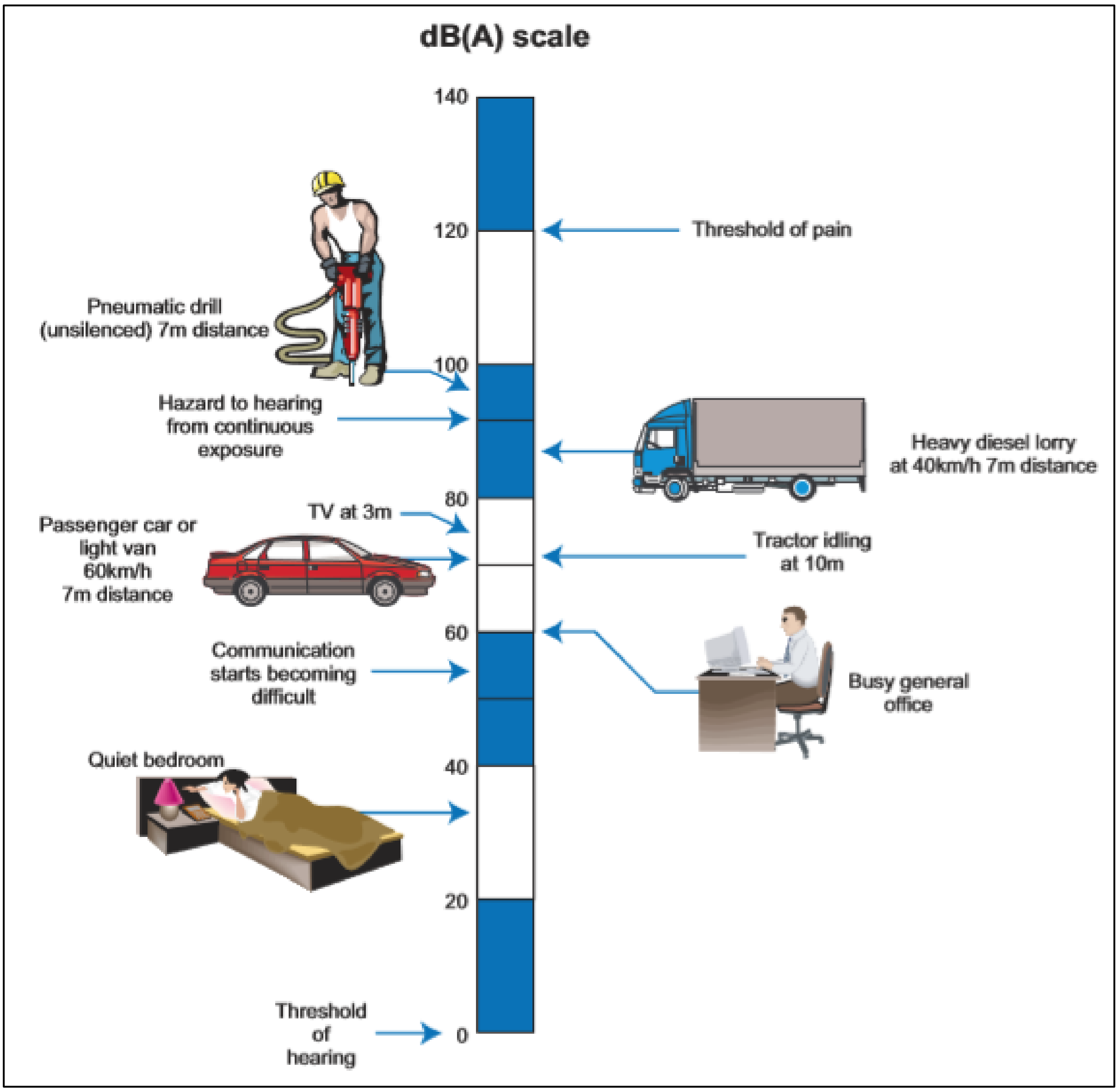

Figure 11.1: The level of typical common sounds on the dB(A) scale (NRA Guidelines for the Treatment of Noise and Vibration in National Road Schemes, 2004)

11.2.1 Noise Model

A series of computer-based prediction models have been prepared to quantify the cumulative noise level associated with the operation of the proposed development. This section discusses the methodology of the noise modelling.

11.2.1.1 Noise Modelling Software

Proprietary noise calculation software was used for the purposes of this impact assessment. The selected software, DGMR iNoise Enterprise, calculates noise levels in accordance with ISO 9613: Acoustics – Attenuation of sound outdoors, Part 2: General method of calculation, (ISO, 1996).

iNoise is a proprietary noise calculation software package for computing noise levels and propagation of noise sources. iNoise calculates noise levels in different ways depending on the selected prediction standard. In general, however, the resultant noise level is calculated considering a range of factors affecting the propagation of sound, including:-

- the magnitude of the noise source in terms of A weighted sound power levels

(L_{WA});
- the distance between the source and receiver;
- the presence of obstacles such as screens or barriers in the propagation path;
- the presence of reflecting surfaces;
- the hardness of the ground between the source and receiver;
- Attenuation due to atmospheric absorption; and
- Meteorological effects such as wind gradient, temperature gradient and humidity (these have significant impact at distances greater than approximately 400m).

The input data and assumptions made are described in the following sections.

11.2.1.2 Turbine Details

Table 11.1 details the co-ordinates of the 8 no. proposed candidate turbines that were included in this assessment.

Location	Coordinates - (ITM)	
	Easting	Northing
T1	653,742	821,348
T2	653,741	820,777
T3	653,221	820,353
T4	653,594	820,169
T5	654,169	821,144
T6	654,394	820,617
T7	655,103	820,429
T8	653,864	819,861

Table 11.1: Turbine Coordinates

Sound power levels (L_{WA}) for the selected candidate wind turbine have been supplied by General Electric.

Table 11.2 details the noise spectra used for noise modelling purposes for the proposed development. As outlined in **Section 11.3**, appropriate guidance is couched in terms of a L_{A90} criterion. The provided turbine noise is referenced in terms of the L_{Aeq} parameter. Best practice guidance contained within the IoA GPG states that "*L_{A90} levels should be determined from calculated L_{Aeq} levels by subtraction of 2 dB*". Therefore, in accordance with best practice guidance, a 2dB reduction has been applied to the predicted results in this assessment.

For the purposes of all predictions presented in this chapter, and to account for various uncertainties in the measurement of turbine source levels, a +2dB uncertainty factor has been added to the all noise emission values in line with guidance for wind turbine noise assessment contained in the IoA GPG.

Wind Speed m/s	Octave-band Centre Frequencies, Hz								Overall, dB(A)
	63	125	250	500	1k	2k	4k	8k	
4	78.4	86.3	91.0	90.9	89.8	87.9	83.2	68.8	96.8
5	82.5	89.5	94.6	96.0	95.6	92.9	87.1	72.9	101.5
6	86.4	91.8	96.4	98.9	100.5	98.3	90.9	75.2	105.2

≥7	87.2	92.6	97.2	99.7	101.3	99.1	91.7	76.0	106.0

Table 11.2: Sound Power Level of the General Electric GE 5.5-158 with a Hub Height of 101m, referenced to wind speeds at standardised 10m above ground. Values in this table do not include the uncertainty allowance, which is instead taken into account in the calculation process.

11.2.1.3 Modelling Parameters

Prediction calculations for turbine noise have been conducted in accordance with ISO 9613: Acoustics – Attenuation of sound outdoors, Part 2: General method of calculation, 1996.

In terms of calculation settings, the ground attenuation factor (general method) was set to 0.5, no metrological correction was used, and the atmospheric attenuation outlined in **Table 11.3** was used for all turbine noise calculations in accordance with guidance outlined in the IOA GPG.

Temp °C	% Humidity	Octave-band Centre Frequencies, Hz							
		63	125	250	500	1k	2k	4k	8k
10	70	0.12	0.41	1.04	1.93	3.66	9.66	32.77	116.88

Table 11.3: Atmospheric Attenuation Assumed for Noise Calculations (dB per km)

See **Annex 11.2** for further discussion of calculation parameters and settings.

11.2.1.4 Additional Information

NSL locations, ground topography and geographical features have been taken from survey information supplied by GES. **Annex 11.4** details the locations assessed as identified in a house survey conducted of all properties within 1.8km (10-times tip height) of the proposed turbines. It is standard practice for all dwellings within 10-times rotor diameter to be assessed for likely noise effects; however, as set out at **Chapter 3**, it is not currently possible to confirm the rotor diameter of the wind turbines which will be installed at the proposed development site. Therefore, and in accordance with the precautionary principle and an abundance of caution, all dwellings within 10-times overall tip height have been assessed in this chapter. Noise predictions have been prepared for a range of wind speeds at these locations.

11.3 Guidance Documents and Assessment Criteria

The following sections review best practice guidance that is commonly adopted in relation to developments such as that under consideration here.

11.3.1 Construction Phase

11.3.1.1 Noise

There is no published statutory Irish guidance relating to the maximum permissible noise level that may be generated during the construction phase of a project. Local authorities normally control construction activities by imposing limits on the hours of operation and may consider noise limits at their discretion.

In the absence of specific noise limits, appropriate criteria relating to permissible construction noise levels for a development of this scale may be found in the British Standard *BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – Noise*.

The approach adopted here calls for the designation of a noise sensitive location into a specific category (A, B or C) based on existing ambient noise levels in the absence of construction noise. This then sets a threshold noise value that, if exceeded (construction noise only), indicates a potential significant noise impact is associated with the construction activities.

Table 11.4 sets out the values which, when exceeded, potentially signify a significant effect at the facades of residential receptors as recommended by BS 5228 – 1. These levels relate to construction noise only.

Assessment category and threshold value period (T)	Threshold values, $L_{Aeq,T}$ dB		
	Category A Note A	Category B Note B	Category C Note C
Night-time (23:00 to 07:00hrs)	45	50	55
Evenings and weekends Note D	55	60	65
Daytime (07:00 – 19:00hrs) and Saturdays (07:00 – 13:00hrs)	65	70	75

Table 11.4: Example Threshold of Potential Significant Effect at Dwellings

Note A Category A: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are less than these values.
Note B Category B: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are the same as category A values.
Note C Category C: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are higher than category A values.
Note D 19:00 – 23:00 weekdays, 13:00 – 23:00 Saturdays and 07:00 – 23:00 Sundays.

The following assessment method is only valid for residential properties.

For the appropriate period (e.g. daytime) the ambient noise level is determined and rounded to the nearest 5 dB. In this instance, with the rural nature of the site, properties near the proposed development have daytime ambient noise levels that typically range from 45 to 55 dB $L_{Aeq,1hr}$. Therefore, all properties will be afforded a Category A designation.

If the specific construction noise level exceeds the appropriate category value (e.g. 65 dB $L_{Aeq,T}$ during daytime periods) then a significant effect is deemed likely to have occurred.

11.3.1.2 Additional Vehicular Traffic Activity on Public Roads

Once operational, the wind farm would be visited periodically for maintenance purposes, with a total of 1-2 trips per week. The vehicle used will typically be a light goods vehicle (LGV)/van. The number of vehicles trips is not such that any likely significant additional noise would be generated.

11.3.1.3 Vibration

Vibration standards come in two varieties: those dealing with human comfort and those dealing with cosmetic or structural damage to buildings. With respect to this development, the range of relevant criteria used for building protection is expressed in terms of Peak Particle Velocity (PPV) in mm/s.

Guidance relevant to acceptable vibration within buildings is contained in the following documents:-

- BS 7385 – *Evaluation and measurement for vibration in buildings – Part 2: Guide to damage levels from groundborne vibration* (1993); and
- BS 5228 – *Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration* (2009+A1:2014).

BS 7385 states that there should typically be no cosmetic damage if transient vibration does not exceed 15 mm/s at low frequencies rising to 20 mm/s at 15 Hz and 50 mm/s at 40 Hz and above. These guidelines relate to relatively modern buildings and should be reduced to 50% or less for more critical or sensitive buildings.

BS 5228 recommends that, for soundly constructed residential property and similar structures that are generally in good repair, a threshold for minor or cosmetic (i.e. non-structural) damage should be taken as a peak particle velocity of 15 mm/s for transient vibration at frequencies below 15 Hz and 20 mm/s at frequencies greater than 15 Hz.

Transport Infrastructure Ireland (TII) (formerly National Roads Authority (NRA)) document Guidelines for the Treatment of Noise and Vibration in National Road Schemes (NRA, 2004) also contains information on the permissible construction vibration levels during the construction phase as shown in **Table 11.5**.

Allowable vibration (in terms of peak particle velocity) at the closest part of sensitive property to the source of vibration, at a frequency of		
Less than 10Hz	**10 to 50Hz**	**50 to 100Hz (and above)**
8 mm/s	12.5 mm/s	20 mm/s

Table 11.5: Allowable Transient Vibration at Properties

11.3.2 Operational Phase

11.3.2.1 Noise

The noise assessment has been undertaken in accordance with guidance in relation to acceptable levels of noise from wind farms as contained in the document *Wind Energy Development Guidelines for Planning Authorities* published by the Department of the Environment, Heritage and Local Government in 2006. These guidelines are in turn based on detailed recommendations set out in the Department of Trade & Industry (UK) Energy Technology Support Unit (ETSU) publication *The Assessment and Rating of Noise from Wind Farms (1996)*. The ETSU document has been used to supplement the guidance contained within the 2006 Guidelines where necessary.

Wind Energy Development Guidelines for Planning Authorities 2006

Section 5.6 of the *Wind Energy Development Guidelines for Planning Authorities* published by the Department of the Environment, Heritage and Local Government (2006) addresses noise and outlines the appropriate noise criteria in relation to wind farm developments.

The following extracts from this document should be considered.

> *"An appropriate balance must be achieved between power generation and noise impact."*
>
> *"In the case of wind energy development, a noise sensitive location includes any occupied house, hostel, health building or place of worship and may include areas of particular scenic quality or special recreational importance. Noise limits should apply only to those areas frequently used for relaxation of 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."*
>
> *"In general, a lower fixed limit of 45dB(A) 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."

This represents the commonly adopted daytime noise criterion curve in relation to wind farm developments. However, an important caveat should be noted as detailed in the following extract:-

"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 30dB(A), it is recommended that the daytime level of the LA90, 10min of the wind energy development be limited to an absolute level within the range of 35 – 40dB(A)."

In relation to night-time periods the following guidance is given:-

"A fixed limit of 43dB(A) will protect sleep inside properties during the night."

This limit is defined in terms of the $L_{A90,10min}$ parameter. This represents the commonly adopted night-time lower limit noise criterion curve in relation to wind farm developments.

In summary, the *Wind Energy Development Guidelines for Planning Authorities 2006* outline the following guidance to identify appropriate wind turbine noise criteria curves at noise sensitive locations:-

- Identify an appropriate absolute limit level between 35 – 40 dB $L_{A90,10min}$ for quiet daytime environments with background noise levels less than 30 dB $L_{A90,10min}$;
- 45 dB $L_{A90,10min}$ for daytime environments greater than 30 dB $L_{A90,10min}$ or a maximum increase of 5 dB above background noise (whichever is higher), and;
- 43 dB $L_{A90,10min}$ or a maximum increase of 5 dB above background noise (whichever is higher) for night-time periods.
- Note that while the caveat of an increase of 5dB(A) above background for night-time operation is not explicit within the current guidance it is commonly applied in noise assessments prepared and is detailed in numerous examples of planning conditions issued by local authorities and An Bórd Pleanála.

The proposed operational noise criteria curves for wind turbine noise at various noise sensitive locations are presented in **Section 11.5.3**.

The Assessment and Rating of Noise from Wind Farms – ETSU-R-97

As stated previously, the core of the noise guidance contained within the *Wind Energy Development Guidelines for Planning Authorities 2006* is based on the 1996 ETSU publication *The Assessment and Rating of Noise from Wind Farms* (ETSU-R-97).

ETSU-R-97 calls for the control of wind turbine noise through the application of noise limits at the nearest noise sensitive properties. ETSU-R-97 considers that absolute noise limits applied at all wind speeds are not suited to wind turbine developments and recommends that noise limits should be set relative to the existing background noise levels at noise sensitive locations. A critical aspect of the noise assessment of wind energy proposals relates to the identification of baseline noise levels through on-site noise surveys.

ETSU-R-97 states on page 58, "…*absolute noise limits and margins above* *background should relate to the cumulative effect of all wind turbines in the area which contribute to the noise received at the properties in question…"*. Therefore, the noise contribution from all wind turbine developments in the area should be included in the assessment.

Institute of Acoustics Good Practice Guide

The guidance contained within 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* (2013) (IoA GPG) and Supplementary Guidance Notes are considered to represent best practice and have been adopted for this assessment. The IoA GPG states that, at a minimum, continuous baseline noise monitoring should be carried out at the nearest noise sensitive locations for typically a two-week period and should capture a representative sample of wind speeds in the area (i.e. cut in speeds to wind speed of rated sound power of the proposed turbine). Background noise measurements (i.e. $L_{A90,10min}$) should be related to wind speed measurements that are collated at the site of the wind turbine development. Regression analysis is then conducted on the data sets to derive background noise levels at various wind speeds to establish the appropriate day and night-time noise criterion curves.

Noise emissions associated with the wind turbine can be predicted in accordance with ISO 9613: *Acoustics – Attenuation of sound outdoors, Part 2: General method of calculation* (1996). This is a noise prediction standard that considers noise attenuation offered, amongst others, by distance, ground absorption, directivity and atmospheric absorption. Noise predictions and contours are typically prepared for various wind speeds and the predicted levels are compared against the relevant noise criterion curve to demonstrate compliance with the appropriate noise criteria.

Where noise predictions indicate that reductions in noise emissions are required in order to satisfy any adopted criteria, consideration can be given to detailed downwind analysis and operating turbines in low noise mode, which is typically offered by modern wind turbine units.

Reference has been made to the IoA GPG for guidance on the methodology for the background noise survey and operational phase impact assessment for wind turbine noise

Future Potential Guidance Changes

Proposed changes to the assessment of noise impacts associated with onshore wind energy developments are outlined in the Department of Environment, Community & Local Government (DECLG) document *Review of the Wind Energy Guidelines 2006 "Preferred Draft Approach"*, published in June 2017. Updated draft guidelines are yet to be published and therefore, in line with best practice, the assessment presented in the EIAR is based on the current guidance outlined in Section 5.6 of the *Wind Energy Development Guidelines for Planning Authorities 2006*.

World Health Organization (WHO) Noise Guidelines for the European Region

The WHO *Environmental Noise Guidelines for the European Region* (2018) provide guidance on protecting human health from exposure to environmental noise. They set health-based recommendations based on average environmental noise exposure of several sources of environmental noise, including wind turbine noise. Recommendations are rated as either 'strong' or 'conditional'. A strong recommendation, "*can be adopted as policy in most situations*" whereas a conditional recommendation, "*requires a policy-making process with substantial debate and involvement of various stakeholders. There is less certainty of its efficacy owing to lower quality of evidence of a net benefit, opposing values and* *preferences of individuals and populations affected or the high resource implications of the recommendation, meaning there may be circumstances or settings in which it will not apply*".

The objective of the WHO *Environmental Noise Guidelines for the European Region* is to provide recommendations for protecting human health from exposure to environmental noise from transportation, wind farm and leisure sources of noise. The guidelines present recommendations for each noise source type in terms of L_{den} and L_{night} levels above which there is risk of adverse health risks.

In relation to wind turbine noise, the WHO Guideline Development Group (GDG) state the following:-

> *"For average noise exposure, the GDG conditionally recommends reducing noise levels produced by wind turbines below 45 dB L_{den}, as wind turbine noise above this level is associated with adverse health effects.*
>
> *No recommendation is made for average night noise exposure L_{night} of wind turbines. The quality of evidence of night-time exposure to wind turbine noise is too low to allow a recommendation.*
>
> *To reduce health effects, the GDG conditionally recommends that policy-makers implement suitable measures to reduce noise exposure from wind turbines in the population exposed to levels above the guideline values for average noise exposure. No evidence is available, however, to facilitate the recommendation of one particular type of intervention over another."*

The quality of evidence used for the WHO research is stated as being 'Low' and, as a result, the recommendations are therefore conditional.

The WHO *Environmental Noise Guidelines for the European Region* aim to support the legislation and policy-making process at a local, national and international level, and thus may be considered by Irish policy makers for any future revisions of Irish national guidelines.

There is potential for increased uncertainty due to the parameter used by the WHO for assessment of exposure (i.e. L_{den}) which, it is acknowledged, may be a poor characterisation of wind turbine noise and may limit the ability to observe associations between wind turbine noise and health outcomes, as stated below.

> *"Even though correlations between noise indicators tend to be high (especially between L_{Aeq} - like indicators) and conversions between indicators do not normally influence the correlations between the noise indicator and a particular health effect, important assumptions remain when exposure to wind turbine noise in L_{den} is converted from original sound pressure level values. The conversion requires, as variable, the statistical distribution of annual wind speed at a particular height, which depends on the type of wind turbine and meteorological conditions at a particular geographical location. Such input variables may not be directly applicable for use in other sites. They are sometimes used without specific validation for a particular area, however, because of practical limitations or lack of data and resources. This can lead to increased uncertainty in the assessment of the relationship between wind turbine noise exposure and health outcomes. Based on all these factors, it may be concluded that the acoustical description of wind turbine noise by means of L_{den} or L_{night} may be a poor characterization of wind turbine noise and may limit the ability to observe associations between wind turbine noise and health outcomes…*
>
> *…Further work is required to assess fully the benefits and harms of exposure to*

> *environmental noise from wind turbines and to clarify whether the potential benefits associated with reducing exposure to environmental noise for individuals living in the vicinity of wind turbines outweigh the impact on the development of renewable energy policies in the WHO European Region."*

Based upon the review set out above, it is concluded that the conditional WHO recommended average noise exposure level (i.e. 45dB L_{den}) should not currently be applied as target noise criteria for the proposed development.

11.3.2.2 Special Characteristics of Turbine Noise

Infrasound/Low Frequency Noise

Low Frequency Noise is noise that is dominated by frequency components less than approximately 200Hz whereas Infrasound is typically described as sound at frequencies below 20Hz. In relation to Infrasound, the following extract from the Environmental Protection Agency (EPA) document *Guidance Note for Noise Assessment of Wind Turbine Operations at EPA Licensed Sites (NG3)* (EPA, 2011) is noted here:-

> *"There is similarly no significant infrasound from wind turbines. Infrasound is high level sound at frequencies below 20 Hz. This was a prominent feature of passive yaw "downwind" turbines where the blades were positioned downwind of the tower which resulted in a characteristic "thump" as each blade passed through the wake caused by the turbine tower. With modern active yaw turbines (i.e. the blades are upwind of the tower and the turbine is turned to face into the wind by a wind direction sensor on the nacelle activating a yaw motor) this is no longer a significant feature."*

With respect to infrasonic noise levels below the hearing threshold, the World Health Organisation (WHO) document *Community Noise* (WHO, 1995) has stated that:-

> *"There is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects."*

In 2010, the UK Health Protection Agency published a report entitled *Health Effects of Exposure to Ultrasound and Infrasound, Report of the independent Advisory Group on Non-ionising Radiation*. The exposures considered in the report related to medical applications and general environmental exposure. The report notes:-

> *"Infrasound is widespread in modern society, being generated by cars, trains and aircraft, and by industrial machinery, pumps, compressors and low speed fans. Under these circumstances, infrasound is usually accompanied by the generation of audible, low frequency noise. Natural sources of infrasound include thunderstorms and fluctuations in atmospheric pressure, wind and waves, and volcanoes; running and swimming also generate changes in air pressure at infrasonic frequencies.*
>
> *For infrasound, aural pain and damage can occur at exposures above about 140 dB, the threshold depending on the frequency. The best-established responses occur following acute exposures at intensities great enough to be heard and may possibly lead to a decrease in wakefulness. The available evidence is inadequate to draw firm conclusions about potential health effects associated with exposure at the levels normally experienced in the environment, especially the effects of long-term exposures. The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects."*

The UK Institute of Acoustics Bulletin in March 2009 included a statement of agreement between acoustic consultants regularly employed on behalf of wind farm developers, and conversely acoustic consultants regularly employed on behalf of community groups campaigning against wind farm developments (IAO JS2009). The intent of the article was to promote consistent assessment practices, and to assist in restricting wind farm noise disputes to legitimate matters of concern. In relation to the issue of infrasound, the article states the following:-

> *"Infrasound is the term generally used to describe sound at frequencies below 20 Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles.*
>
> *Sounds at frequencies from about 20 Hz to 200 Hz are conventionally referred to as low-frequency sounds. A report for the DTI in 2006 by Hayes McKenzie concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view."*

The article concludes that:-

> *"from examination of reports of the studies referred to above, and other reports widely available on internet sites, we conclude that there is no robust evidence that low frequency noise (including 'infrasound') or ground-borne vibration from wind farms, generally has adverse effects on wind farm neighbours".*

A report released in January 2013 by the South Australian Environment Protection Authority namely, *Infrasound levels near windfarms and in other environments* (EPA, 2013[1]) found that the level of infrasound from wind turbines is insignificant and no different to any other source of noise, and that the worst contributors to household infrasound are air-conditioners, traffic and noise generated by people.

The study included several houses in rural and urban areas, both adjacent to and away from a wind farm, and measured the levels of infrasound with the wind farms operating and switched off.

There were no noticeable differences in the levels of infrasound under these different conditions. In fact, the lowest levels of infrasound were recorded at one of the houses closest to a wind farm, whereas the highest levels were found in an urban office building.

The South Australian EPA's study concluded that the level of infrasound at houses near wind turbines was no greater than in other urban and rural environments, and stated that:-

> *"The contribution of wind turbines to the measured infrasound levels is insignificant in comparison with the background level of infrasound in the environment."*

A German report, titled *Low Frequency Noise incl. Infrasound from Wind Turbines and Other Sources* presents the details of a measurement project which ran from 2013. The report was published by the State Office for the Environment, Measurement and Nature Conservation of the Federal State of Baden-Württemberg in 2016 and

[1] EPA South Australia, 2013, Wind farms https://www.epa.sa.gov.au/files/477912_infrasound.pdf

concluded the following in relation to infrasound from wind turbines:-

> *"The measured infrasound levels (G levels) at a distance of approx. 150 m from the turbine were between 55 and 80 dB(G) with the turbine running. With the turbine switched off, they were between 50 and 75 dB(G). At distances of 650 to 700 m, the G levels were between 55 and 75 dB(G) with the turbine switched on as well as off."*
>
> *"For the measurements carried out even at close range, the infrasound levels in the vicinity of wind turbines – at distances between 150 and 300 m – were well below the threshold of what humans can perceive in accordance with DIN 45680 (2013 Draft) "*
>
> *"The results of this measurement project comply with the results of similar investigations on a national and international level."*

Amplitude Modulation

In the context of this assessment, amplitude modulation (AM) is defined in the IOA Noise Working Group (Wind Turbine Noise) Amplitude Modulation Working Group (AMWG) document *A Method for Rating Amplitude Modulation in Wind Turbine Noise* (IOA, 2016) as:-

> *"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 (BPF) of the turbine rotor(s)."*

It is now generally accepted that there are two mechanisms which can cause AM:-

- 'Normal' AM, and;
- 'Other' AM (sometimes referred to 'Excessive' AM).

In both cases, the result is a regular fluctuation in amplitude at the Blade Passing Frequency (BPF) of the wind turbine blades (the rate at which the blades of the turbine pass a fixed point). For a three-bladed turbine rotating at 20 rpm, this equates to a modulation frequency of 1 Hz.

'Normal' AM — An observer at ground level close to a wind turbine will experience 'blade swish' because of the directional characteristics of the noise radiated from the trailing edge of the blades as it rotates towards and then away from the observer.

This effect is reduced for an observer on, or close to, the turbine axis, and therefore would not generally be expected to be significant at typical separation distances, at least on relatively level sites.

The RenewableUK AM project (RenewableUK, 2013) has coined the term 'normal' AM (NAM) for this inherent characteristic of wind turbine noise, which has long been recognised and was discussed in ETSU-R-97 in 1996.

'Other' AM — In some cases AM is observed at large distances from a wind turbine (or turbines). The sound is generally heard as a periodic 'thumping' or 'whoomphing' at relatively low frequencies.

On wind farm sites where it has been reported, occurrences appear to be occasional, although they can persist for several hours under some conditions, dependent on atmospheric factors, including wind speed and direction.

It was proposed in the RenewableUK 2013 study that the fundamental cause of this type of AM is transient stall conditions occurring as the blades rotate, giving rise to the periodic thumping at the blade passing frequency.

Transient stall represents a fundamentally different mechanism from blade swish and can be heard at relatively large distances, primarily downwind of the rotor blade.

The RenewableUK AM project report adopted the term 'Other AM' (OAM) for this characteristic. The terms 'enhanced' or 'excess' AM (EAM) have been used by others, although such definitions do not distinguish between the source mechanisms and presuppose a 'normal' level of AM, presumably relating back to blade swish as described in ETSU-R-97.

Frequency of Occurrence of AM

Research by Salford University commissioned by the United Kingdom Department of Environment Food and Rural Affairs (DEFRA), the Department of Business, Enterprise and Regulatory Reform (BERR) and the Department of Communities and Local Government (CLG) investigated the issue of AM associated with wind turbine noise. The results were reviewed and published in the report Research into Aerodynamic Modulation of Wind Turbine Noise (2007). The broad conclusions of this report were that aerodynamic modulation was only considered to be an issue at 4 no., and a possible issue at a further 8 no., of 133 no. sites in the UK that were operational at the time of the study and considered within the review. At the 4 no. sites where AM was confirmed as an issue, it was considered that conditions associated with AM might occur between about 7% and 15% of the time. It also emerged that for three out of the four sites the complaints have subsided, in one case due to the introduction of a turbine control system. The research has shown that AM is a rare and unlikely occurrence at operational wind farms.

It should be noted that AM is associated with wind turbine operation and it is not possible to predict an occurrence of AM at the planning stage. It should also be noted that it is a rare event associated with a limited number of wind farms. While it can occur, it is the exception rather than the rule.

RenewableUK Research Document states the following in relation to matter:-

Page 68 Module F "*even on those limited sites where it has been reported, its frequency of occurrence appears to be at best infrequent and intermittent*."

Page 6 Module F "*It has also been the experience of the project team that, even at those wind farm sites where AM has been reported or identified to be an issue, its occurrence may be relatively infrequent. Thus, the capture of time periods when subjectively significant AM occurs may involve elapsed periods of several weeks or even months*."

Page 61 Module F "*There is nothing at the planning stage that can presently be used to indicate a positive likelihood of OAM occurring at any given proposed wind farm site, based either on the site's general characteristics or on the known characteristics of the wind turbines to be installed*."

Assessment of AM

Research and Guidance in the area is ongoing with recent publications being issued by the Institute of Acoustics (IoA) Noise working Group (Wind Turbine Noise)

Amplitude Modulation Working Group (AMWG) namely, *A Method for Rating Amplitude Modulation in Wind Turbine Noise* (August 2016) (The Reference Method). The document proposes an objective method for measuring and rating AM. The AMWG does not propose what level of AM is likely to result in adverse community response or propose any limits for AM. The purpose of the group is simply to use existing research to develop a Reference Methodology for the measurement and rating of amplitude modulation.

The definition of any limits of acceptability for AM, or consideration of how such limits might be incorporated into a wind farm planning condition, is outside the scope of the AMWG's work and is currently the subject of a separate UK Government funded study. In the absence of published guidance, it is considered best practice to adopt the penalty rating and assessment scheme contained in an article published in the Institute of Acoustics publication *Acoustics Bulletin* (Vol. 42 No. 2 March/April 2017) titled, Perception and Control of Amplitude Modulation in Wind Turbines Noise.

Where it occurs, AM is typically an intermittent occurrence, therefore assessment may involve long-term measurements. The measurement method outlined in the IoA AMWG document, known as the 'Reference Method', will provide a robust and reliable indicator of AM and yield important information on the frequency and duration of occurrence, which can be used to evaluate different operational conditions including mitigation.

11.3.2.3 Comments on Human Health Impacts

The National Health & Medical Research Council

The Australian authority on health issues, the National Health and Medical Research Council (NHMRC), conducted a comprehensive independent assessment of the scientific evidence on wind farms and human health, the findings are contained in the NHMRC *Information Paper: Evidence on Wind Farms and Human Health 2015*, which concluded:-

> *"After careful consideration and deliberation, NHMRC concluded that there is no consistent evidence that wind farms cause adverse health effects in humans. This finding reflects the results and limitations of the direct evidence and also takes into account the relevant available parallel evidence on whether or not similar noise exposure from sources other than wind farms causes health effects"*

Health Canada

Health Canada, Canada's national health organisation, released preliminary results of a study into the effect of wind farms on human health in 2014[2]. The study was initiated in 2012 specifically to gather new data on wind farms and health. The study considered physical health measures that assessed stress levels using hair cortisol, blood pressure and resting heart rate, as well as measures of sleep quality. More than 4,000 hours of wind turbine noise measurements were collected and a total of 1,238 households participated.

No evidence was found to support a link between exposure to wind turbine noise and any of the self-reported illnesses. Additionally, the study's results did not support a link between wind turbine noise and stress, or sleep quality (self-reported or measured). However, an association was found between increased levels of wind

[2] Health Canada 2014, Wind Turbine Noise and Health Study: Summary of Results. Available at https://www.canada.ca/en/health-canada/services/environmental-workplace-health/noise/wind-turbine-noise/wind-turbine-noise-health-study-summary-results.html

turbine noise and individuals reporting of being annoyed.

New South Wales Health Department

In 2012, the New South Wales (NSW) Health Department provided written advice to the NSW Government that stated existing studies on wind farms and health issues had been examined and no known causal link could be established.

NSW Health officials stated that fears that wind turbines make people sick are 'not scientifically valid'. The officials wrote that there was no evidence for 'wind turbine syndrome', a collection of ailments including sleeplessness, headaches and high blood pressure that some people believe are caused by the noise of spinning blades.

The Australian Medical Association

The Australian Medical Association put out a position statement, Wind Farms and Health 2014[3]. The statement said:-

> *"The available Australian and international evidence does not support the view that the infrasound or low frequency sound generated by wind farms, as they are currently regulated in Australia, causes adverse health effects on populations residing in their vicinity. The infrasound and low frequency sound generated by modern wind farms in Australia is well below the level where known health effects occur, and there is no accepted physiological mechanism where sub-audible infrasound could cause health effects."*

Journal of Occupational and Environmental Medicine

The review titled, *Wind Turbines and Health: A Critical Review of the Scientific Literature* was published in the Journal of *Occupational and Environmental Medicine, 2014*. An independent review of the literature was undertaken by the Department of Biological Engineering of the Massachusetts Institute of Technology (MIT). The review took into consideration health effects such as stress, annoyance and sleep disturbance, as well as other effects that have been raised in association with living close to wind turbines. The study found that:

> *"No clear or consistent association is seen between noise from wind turbines and any reported disease or other indicator of harm to human health."*

The report concluded that living near wind farms does not result in the worsening of the quality of life in that region.

11.3.2.4 Vibration

A recent report published in Germany by the State Office for the Environment, Measurement and Nature Conservation of the Federal State of Baden-Württemberg in 2016 titled *Low Frequency Noise incl. Infrasound from Wind Turbines and Other Sources*, conducted a vibration measurement study for an operational Nordex N117 – 2.4 MW wind turbine. The report concluded that at distances of less than 300m from the turbine vibration levels had dropped so far that they could no longer be differentiated from the background vibration levels.

Considering the distances from the nearest NSL's to any of the proposed turbines (the nearest NSL being c. 570m from the nearest turbine), the level of vibration will be significantly below any thresholds for perceptibility. Therefore, vibration criteria have not been specified for the operational phase of the proposed development.

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3 Australian Medical Association, 2014, Wind farms and health. Available at https://ama.com.au/position-statement/wind-farms-and-health-2014

11.3.2.5 EPA Description of Effects

The significance of effects of the proposed development shall be described in accordance with the EPA guidance document *Draft Guidelines on the information to be contained in Environmental Impact Assessment Reports Draft, August 2017*. Details of the methodology for describing the significant of the effects are provided in **Chapter 1**.

The effects associated with the proposed development are described with respect to the EPA guidance in the relevant sections of this chapter.

11.4 Description of the Existing Environment

As outlined above, prior to undertaking noise prediction modelling, it is crucial to understand the typical background noise levels at the nearest NSLs to the development site. The background noise survey was conducted by installing unattended sound level meters at four representative locations in the surrounding area.

The installation, retrieval and management of all measurement instrumentation detailed in this section has been carried out by GES. GES has confirmed that all measurement data collected during the baseline noise surveys has been carried out in accordance with the Institute of Acoustic (IoA) Guidance Document, *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* (2013) and accompanying, Supplementary Guidance Note 1: *Data Collection* (2014).

The analysis and assessment of all survey data has been carried out by AWN Consulting.

11.4.1 Choice of Measurement Locations

The noise measurement locations used were selected by GES. Noise monitoring locations were identified by preparing a preliminary noise model contour at an early stage of project development. Any locations that fell inside the predicted 35 dB L_{A90} noise contour were considered for noise monitoring in line with current best practice guidance outlined in the IoA GPG. The selection of the noise monitoring locations was informed by a site visit and supplemented by reviewing aerial images of the study area and other online sources of information (e.g. Google Earth).

The locations selected for baseline noise monitoring are outlined in the following sections. Coordinates for the noise monitoring locations are detailed in **Table 11.6**.

Location	Coordinates - (ITM)	
	Easting	Northing
A (H001)	653,648	822,032
B (H007)	655,190	821,065
C (H015)	654,692	819,726
D (H021)	653,055	820,960

Table 11.6: Measurement Location Coordinates

Significant noise sources in this area were noted to be distant traffic movements, activity in and around the residences and wind generated noise from local foliage and other typical anthropogenic sources typically found in such rural settings.

There was no perceptible source of vibration noted at any survey location.

Figures 11.2 - **11.5** illustrate the installed noise monitoring kits. The locations of the unattended noise monitors are shown in **Figure 11.6**

Figure 11.2: Location A (H001) – yellow ellipse shows location of sound level meter

Figure 11.3: Location B (H007)

Figure 11.4: Location C (H015)

Figure 11.5: Location D (H021)

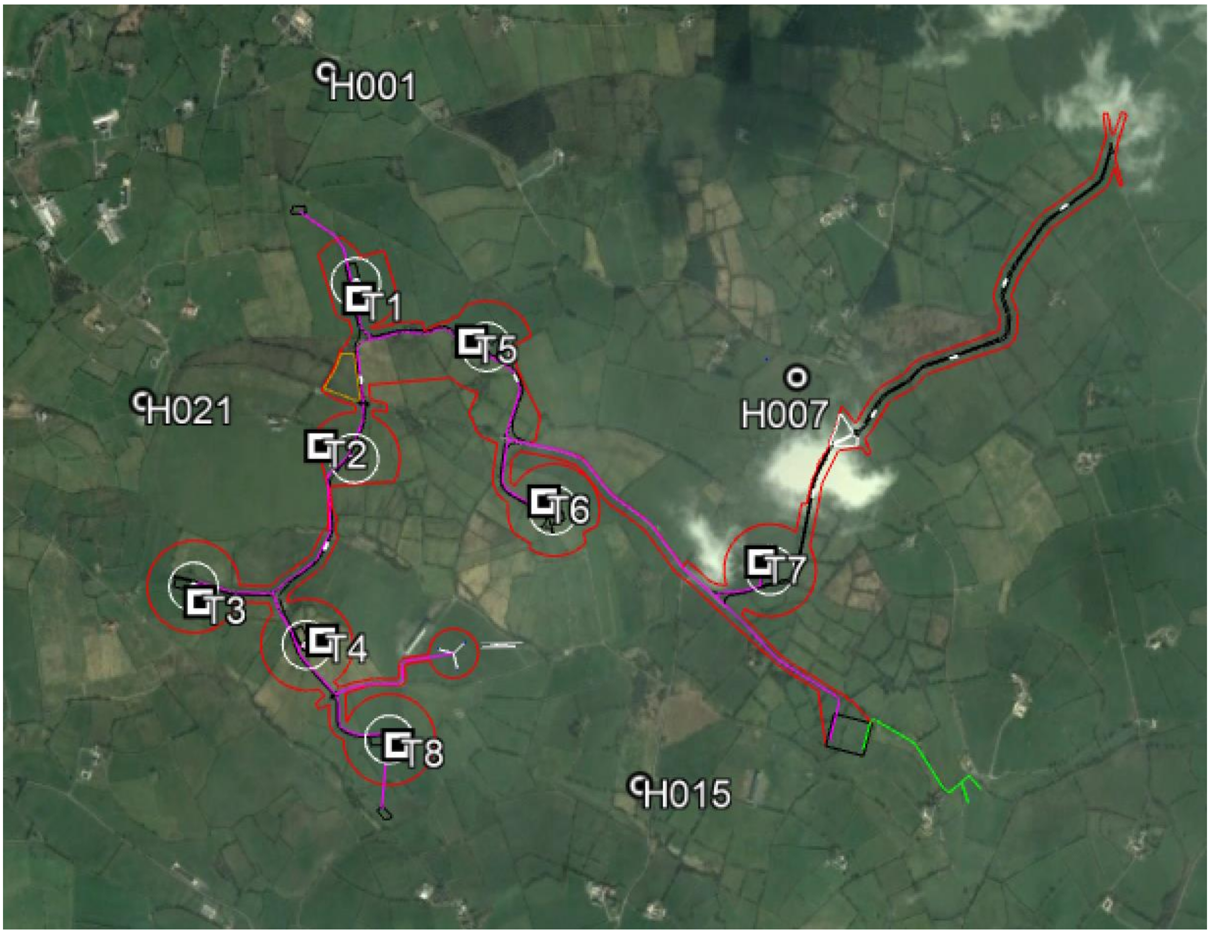

Figure 11.6: Noise Survey Locations

11.4.2 Measurement Periods

Noise measurements were conducted at each of the monitoring locations over the periods outlined in **Table 11.7**

Location	Start Date	End Date
A (H001)	19:20hrs on 5 June 2019	21:10hrs on 26 June 2019
B (H007)	16:20hrs on 5 June 2019	16:10hrs on 15 July 2019
C (H015)	17:50hrs on 5 June 2019	07:50hrs on 1 July 2019
D (H021)	17:30hrs on 5 June 2019	06:30hrs on 23 June 2019

Table 11.7: Measurement Periods

A variety of wind speed and weather conditions, which were identified from data gathered at the proposed development's temporary meteorological mast, were encountered over the survey periods in question. **Figure 11.7** illustrates the distributions of wind speed and wind direction standardised to 10 metre height over the survey period detailed in **Table 11.7**.

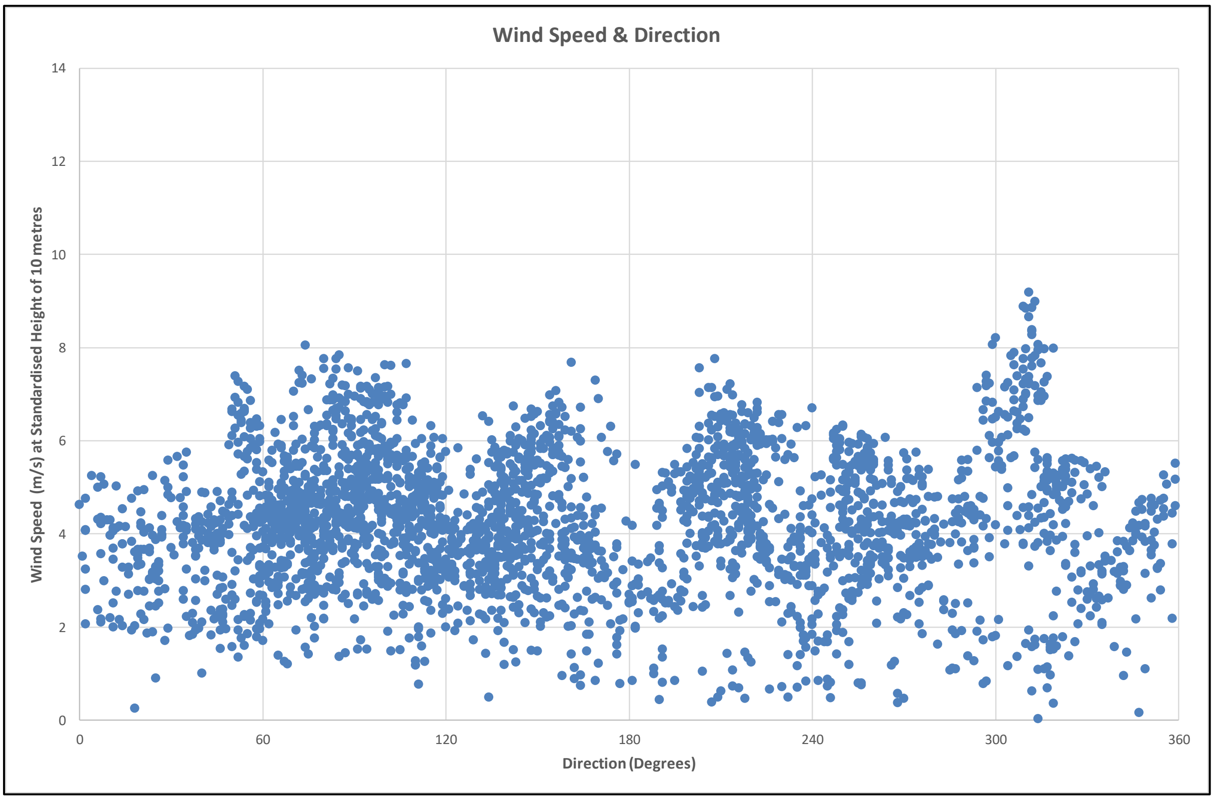

Figure 11.7: Distribution of Wind Speed & Direction over the survey period

11.4.3 Personnel and Instrumentation

GES installed and removed the noise monitors at all locations, with the following instrumentation being used:

Location	Equipment	Serial Number
A (H001)	Svantek 955	15276
B (H007)	Larson Davis Sound Expert LxT	5123
C (H015)	Svantek 955	15277
D (H021)	Larson Davis Sound Expert LxT	4808

Table 11.8: Instrumentation Details

Before and after the survey, the measurement apparatus was check and calibrated using a sound level calibrator where appropriate. Relevant calibration certificates are presented in **Annex 11.3**.

Rainfall was monitored and logged using a 'Theodor Friedrichs 7041.00' tipping bucket rain gauge which was installed on the on-site meteorological mast. This allows for the identification of periods of rain fall to allow for the removal of affected sample periods from the noise monitoring data sets. This approach complies with best practice when calculating the prevailing background noise levels.

Wind data was measured at the meteorological mast with anemometers at 64.6m and 80m above ground level. This data was supplied by GES to AWN for analysis.

11.4.4 Procedure

Measurements were conducted at the four locations over the survey periods outlined in **Table 11.7**. Data samples for all measurements (noise, rainfall and wind) were logged continuously at 10-minute interval periods for the duration of the survey.

Where survey personnel noted potential primary noise sources contributing to noise build-up during the installation and removal of the sound level meters from site (e.g. identified significant noise sources in the area such as local traffic or farming activities), $L_{Aeq,10min}$ and $L_{A90,10min}$ parameters were measured in this instance.

11.4.5 Consideration of Wind Shear

Wind shear is defined as the increase of wind speed with height above ground. As part of a robust wind farm noise assessment, due consideration should be given to the issue of wind shear. In this assessment, relevant guidance has been followed as described in the IoA GPG. It is standard procedure to reference noise data to standardised 10 metre height wind speed.

Wind speed measurements at 80m and 64.6m heights have been corrected to a height of 101m (i.e. the assumed hub height for this assessment) in accordance with Method B of the IOA GPG. The calculated hub height wind speeds were then corrected to standardised 10 metre height wind speed.

The IoA GPG presents the following equations in relation to the derivation of a standardised wind speed at 10m above ground level:

Shear Exponent Profile:	$U = U_{ref} \times [(H \div H_{ref})]^m$ Where: U Calculated wind speed Uref Measured HH wind speed. H Height at which the wind speed will be calculated. Href Height at which the wind speed was measured. m shear exponent = log(U/Uref)/log(H/Href)

The calculated hub height wind speeds have been standardised to 10 m height using the following equation:

Roughness Length Shear Profile:	$U_1 = U_2 \times [(\ln(H_1 \div z))/ (\ln(H_2 \div z))]$ Where: H1 The height of the wind speed to be calculated (10m) H2 The height of the measured or calculated HH wind speed. U1 The wind speed to be calculated. U2 The measured or calculated HH wind speed. z The roughness length. Note: A roughness length of 0.05m is used to standardise hub height wind speeds to 10m height in the IEC 61400-11:2003 standard, regardless of what the actual roughness length seen on a site may have been. This 'normalisation' procedure was adopted for comparability between test results for different turbines.

It is important to reiterate that any reference to wind speed in the following sections of this chapter should be understood to be the 10m height standardised wind speed reference unless explicitly stated otherwise.

11.4.6 Analysis of Background Noise Data

The results of the background noise monitoring programme are extensive in nature.

The following sections present an overview and statistical analysis of the noise monitoring data obtained from the survey programme at each location for both daytime and night-time periods.

The data sets have been filtered to remove issues such as the dawn chorus and the influence of other atypical noise sources. An example of atypical sources would be short isolated periods of raised noise levels attributable to local sources, agricultural activity, boiler flues and the operation of gardening or farm equipment.

Sample periods affected by rainfall or when rainfall resulted in prolonged periods of atypical noise levels have also been screened form the data sets. The assessment methods outlined above are in line with the guidance contained in the IoA GPG.

The results presented in the following sections refer to the noise data collated during 'quiet periods' of the day and night as defined in the IoA GPG. These periods are defined as follows:

- Daytime amenity hours are:-
  - All evening from 18:00 to 23:00hrs;
  - Saturday afternoons from 13:00 to 18:00hrs; and,
  - Sunday from 07:00 to 18:00hrs.
- Night-time hours are 23:00 to 07:00hrs.

11.4.7 Background Noise Levels

The following sections present the results of the noise monitoring data obtained from the background noise survey in accordance with the methodology discussed above.

11.4.7.1 Location A (H001)

Daytime:-

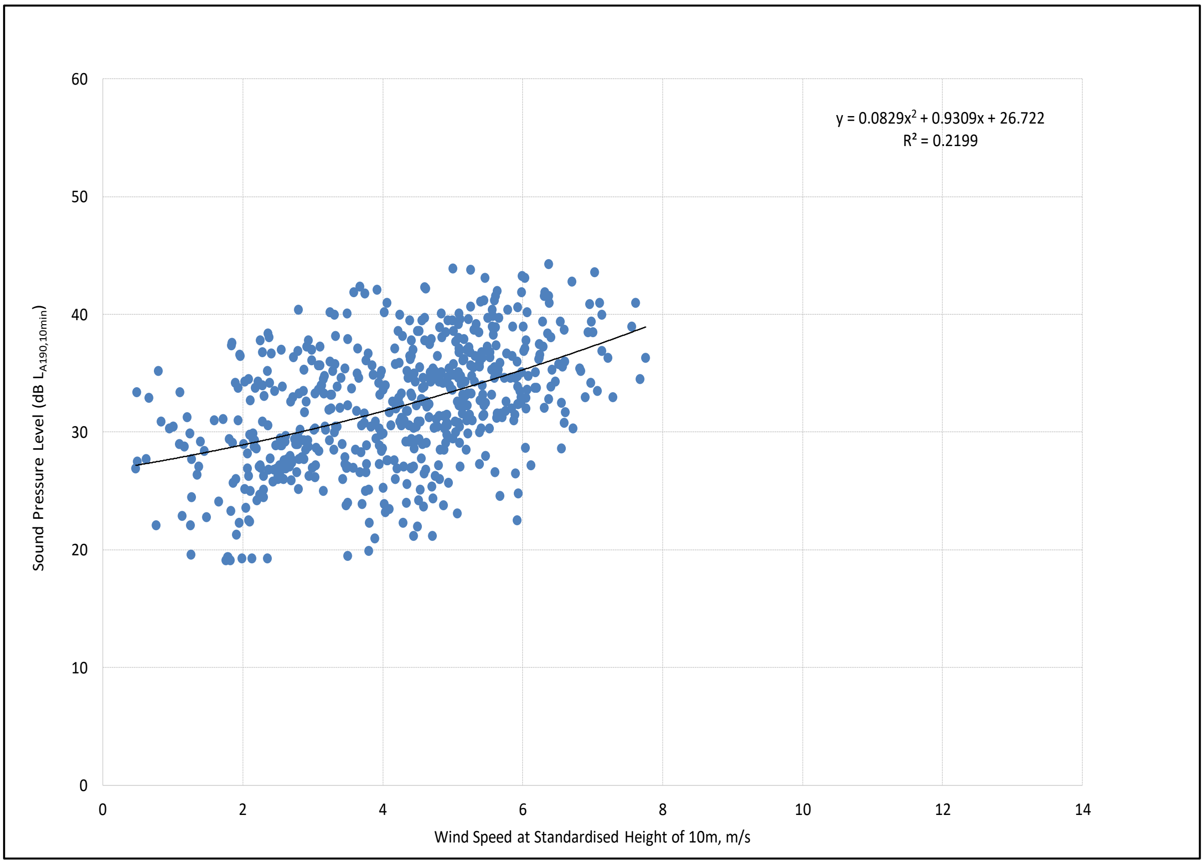

Figure 11.8: Background Noise Levels $L_{A90,10\ min}$ dB – Location A (H001) – Daytime

Night-time:-

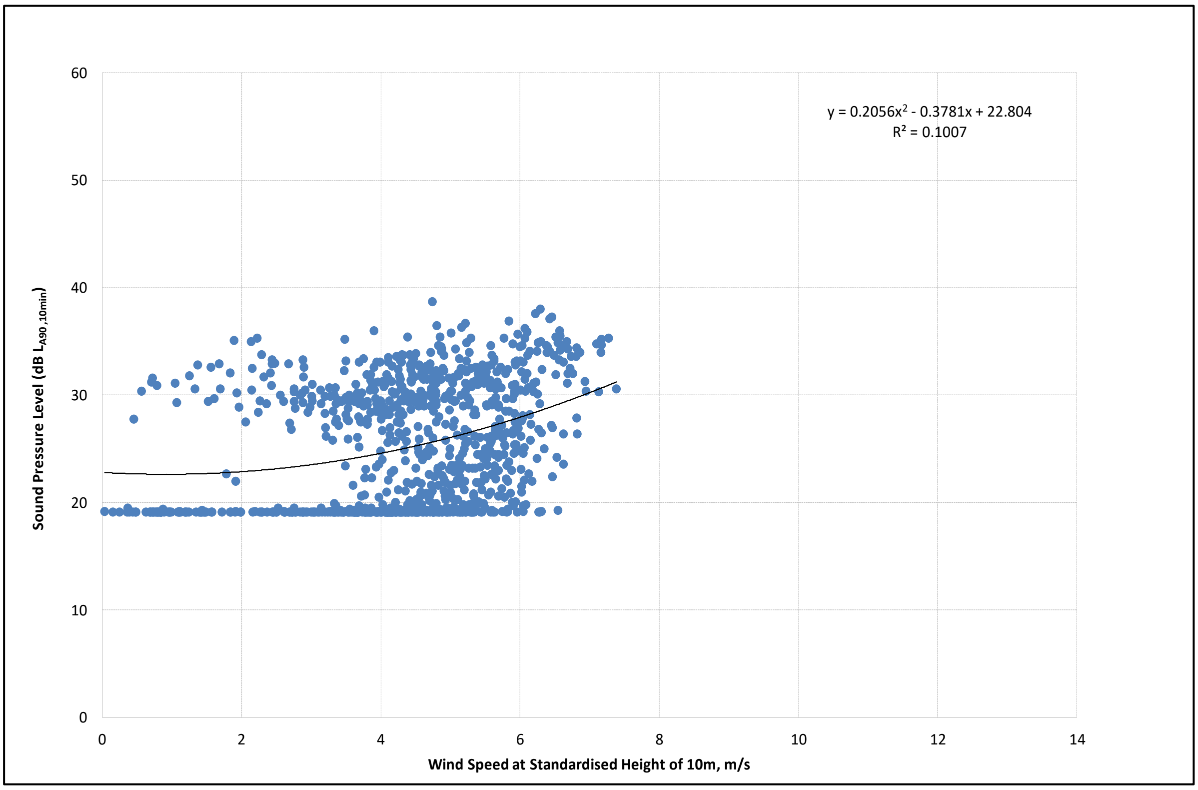

Figure 11.9: Background Noise Levels $L_{A90,10\ min}$ dB – Location A (H001) – Night-time

11.4.7.2 Location B (H007)

Daytime:-

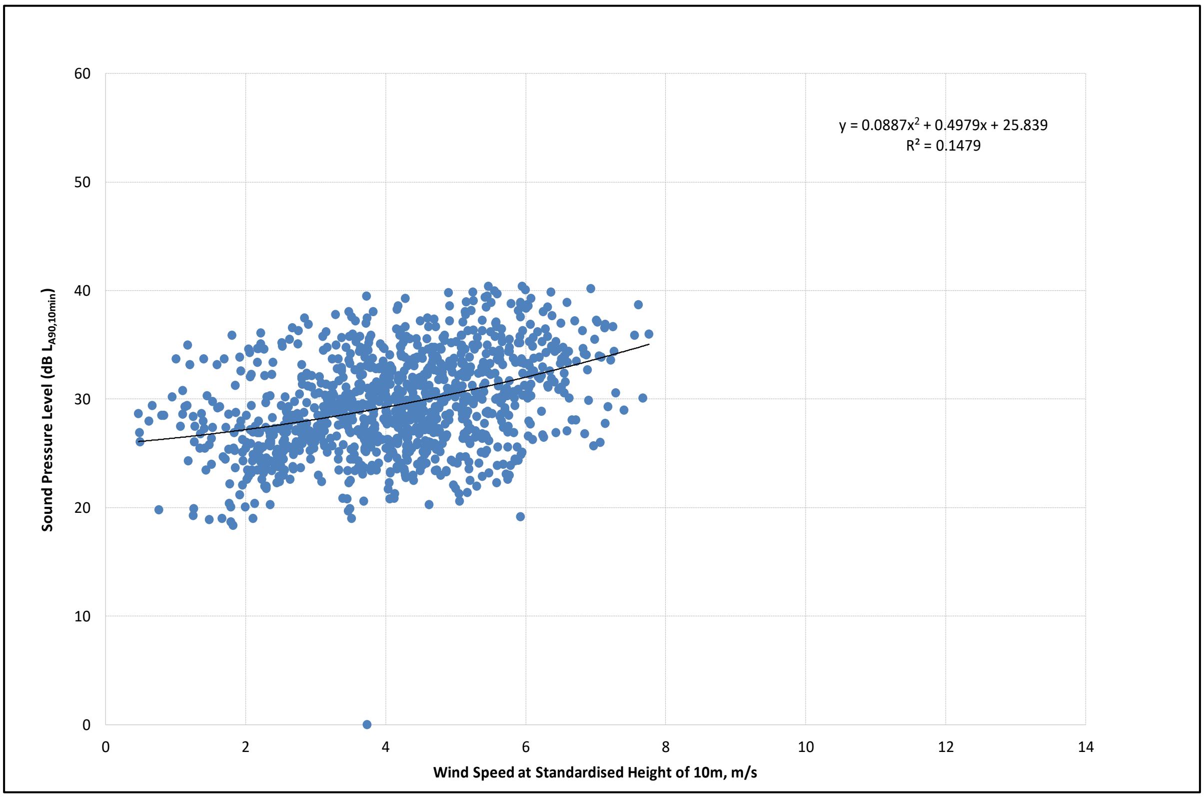

Figure 11.10: Background Noise Levels $L_{A90,10\ min}$ dB – Location B (H007) – Daytime

Night-time:-

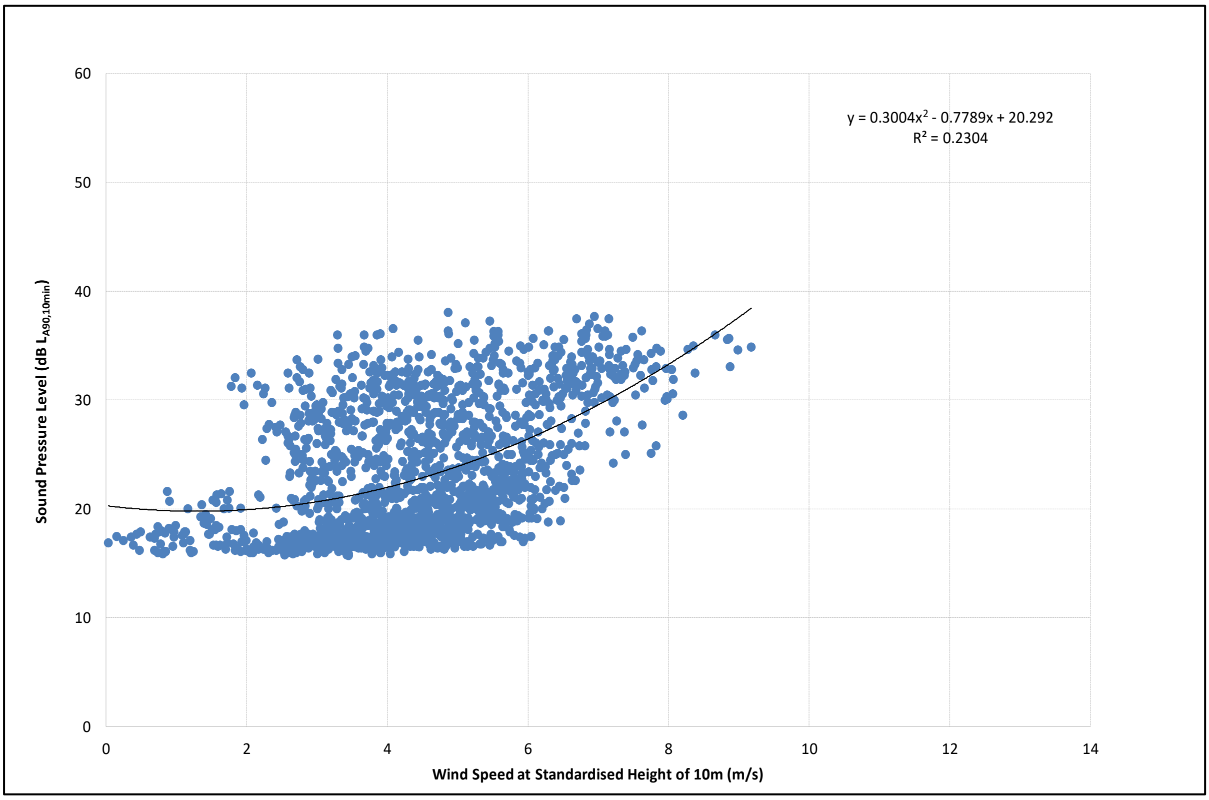

Figure 11.11: Background Noise Levels $L_{A90,10\ min}$ dB – Location B (H007) – Night-time

11.4.7.3 Location C (H015)

Daytime:-

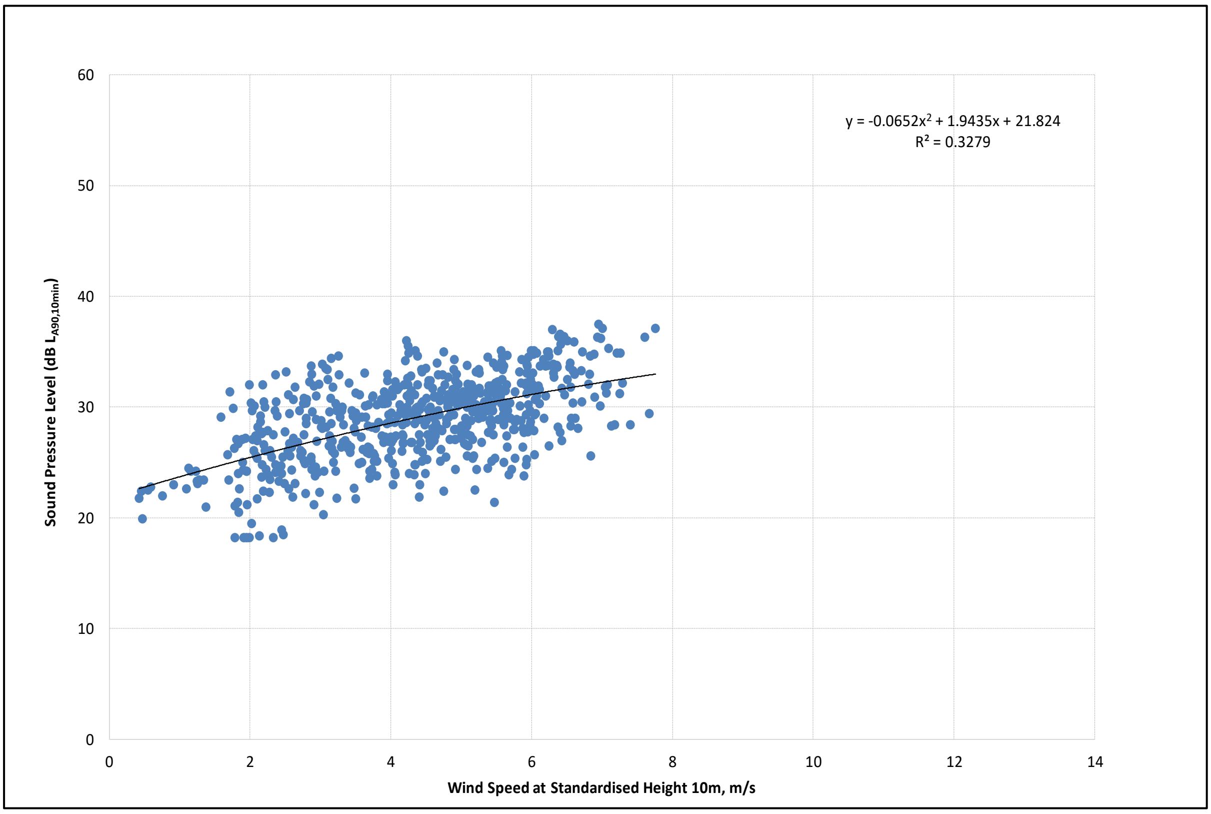

Figure 11.12: Background Noise Levels $L_{A90,10\ min}$ dB – Location C (H015) – Daytime

Night-time:-

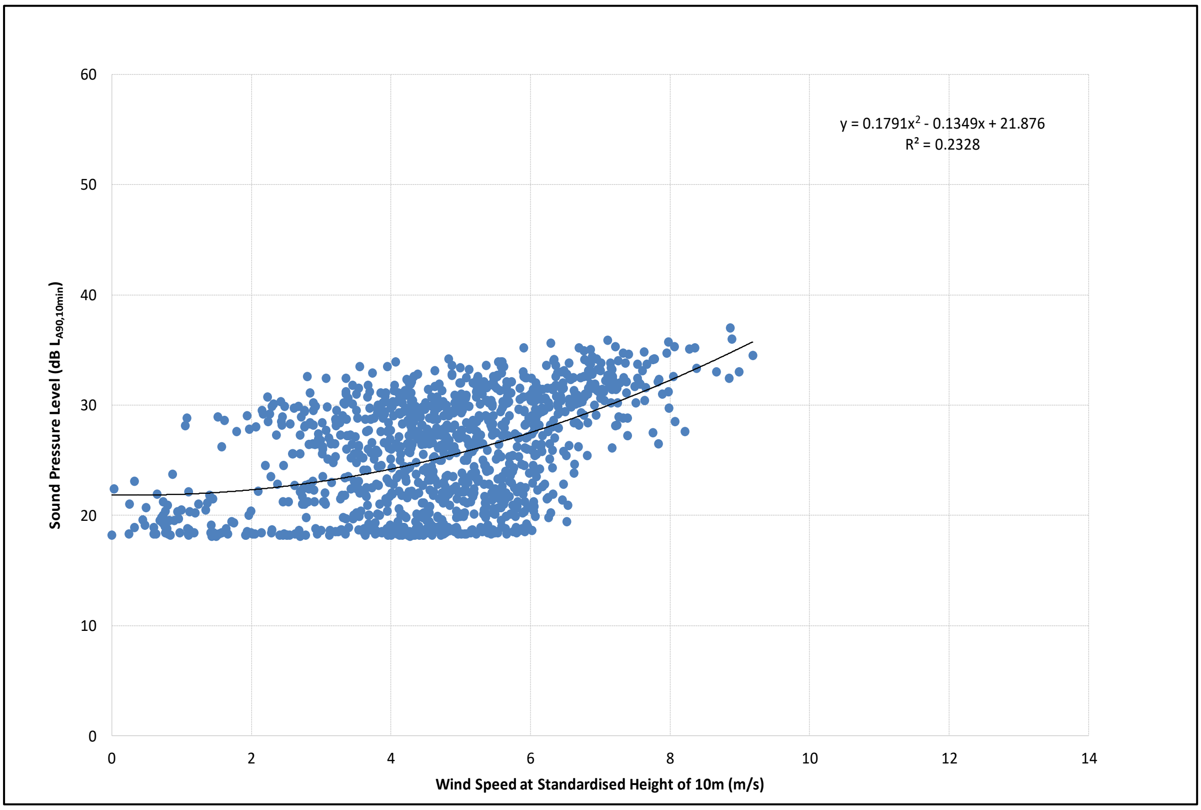

Figure 11.13: Background Noise Levels $L_{A90,10\ min}$ dB – Location C (H015) – Night-time

11.4.7.4 Location D (H021)

Daytime:-

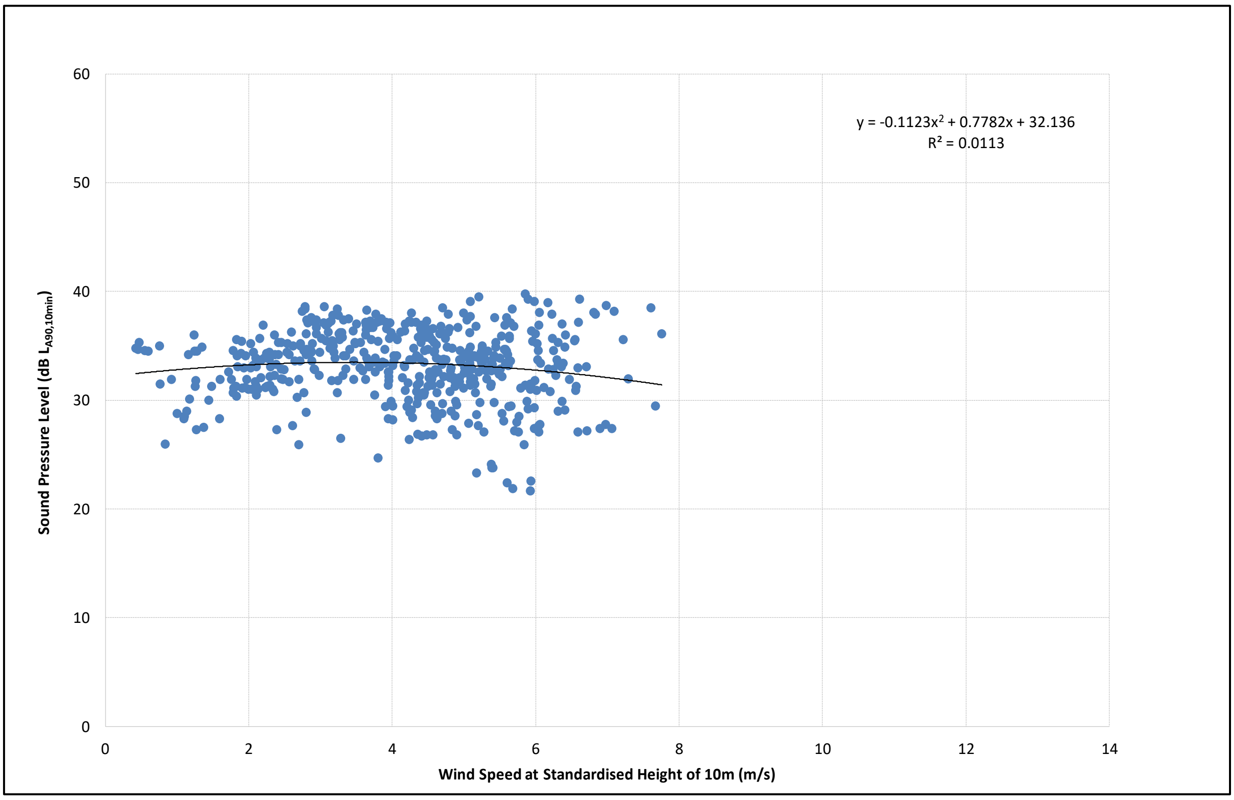

Figure 11.14: Background Noise Levels $L_{A90,10\ min}$ dB – Location D (H021) – Daytime

Night-time:-

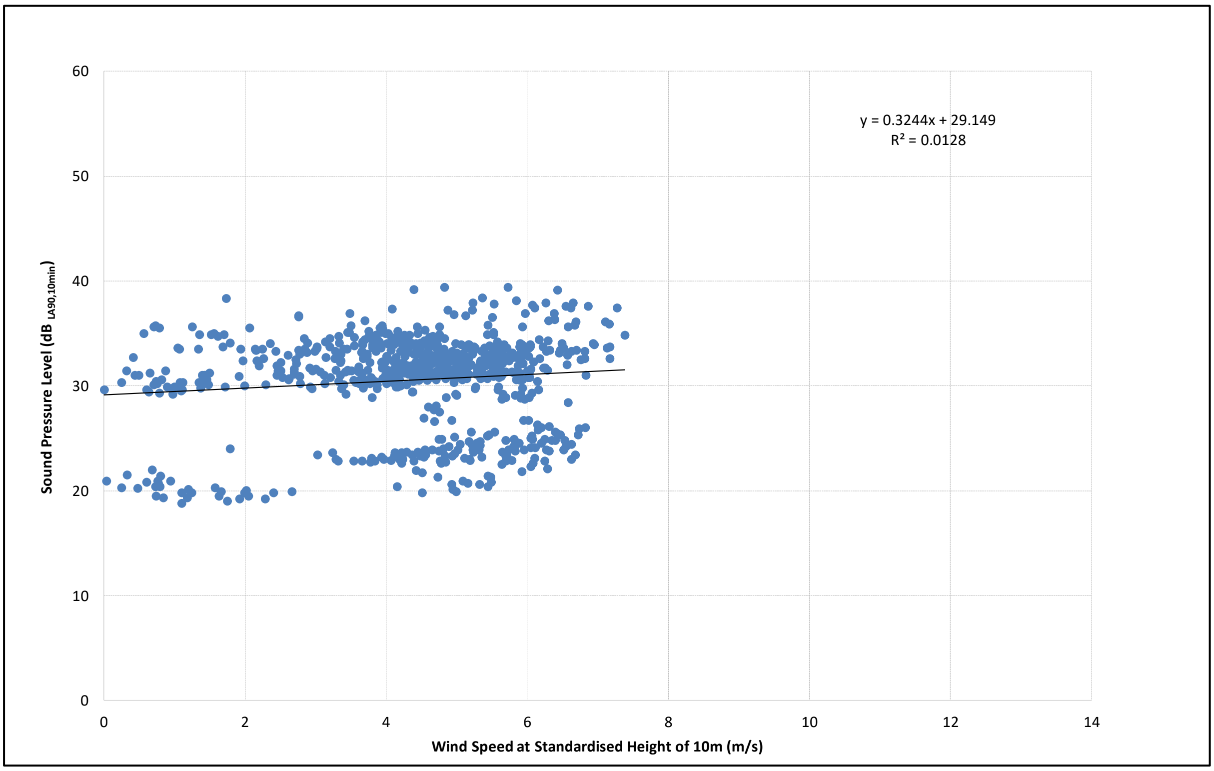

Figure 11.15: Background Noise Levels $L_{A90,10\ min}$ dB – Location D (H021) – Night-time

Table 11.9 presents the various derived $L_{A90,10min}$ noise levels for each of the monitoring locations for daytime quiet periods and night-time periods. These levels have been derived using regression analysis carried out on the data sets in line with guidance contained the IoA GPG and its SGN No. 2 Data Collection.

11.4.7.5 Summary

Location	Period	Derived $L_{A90,\ 10\ min}$ Levels (dB) at various Standaridsed 10m Height Wind Speeds (m/s)								
		4	5	6	7	8	9	10	11	12
A (H001)	Day	31.8	33.4	35.3	37.3	37.3	37.3	37.3	37.3	37.3
	Night	24.6	26.1	27.9	30.2	30.2	30.2	30.2	30.2	30.2
B (H007)	Day	29.2	30.5	32.0	33.7	33.7	33.7	33.7	33.7	33.7
	Night	22.0	23.9	26.4	29.6	29.6	29.6	29.6	29.6	29.6
C (H015)	Day	28.6	29.9	31.1	32.2	32.2	32.2	32.2	32.2	32.2
	Night	24.2	25.7	27.5	29.7	29.7	29.7	29.7	29.7	29.7
D (H021)	Day	33.5	33.2	32.8	32.1	32.1	32.1	32.1	32.1	32.1
	Night	30.4	30.8	31.1	31.4	31.4	31.4	31.4	31.4	31.4

Table 11.9: Derived Levels of $L_{A90,\ 10\ min}$ for Various Wind Speeds.

Note that values at 8 m/s and upwards take the values from 7 m/s in accordance with the wind speed coverage found during the survey period.

It is noted that the survey period did not capture wind speeds over the full range between 4 and 12 m/s; however the candidate wind turbine reaches its rated power at 7m/s (at standardised 10m above ground) and therefore, in accordance with IoA GPG section 2.9.3, the range of wind speeds covered is sufficient.

The background noise data is used to derive appropriate noise limits for each of the noise survey locations. Following review of the data collated at Location D (H021), it appeared that the data was affected by a local noise source, relatively loud in nature, which was present only through part of the survey period, therefore it was not possible to yield any usable baseline results from the data obtained at this location. However, given that a baseline envelope assessment was being derived for the purposes of setting appropriate noise criteria for the proposed development site, it is considered that the baseline noise data from the three other locations was more than sufficient for this purpose.

11.5 Description of Likely Effects

11.5.1 Do Nothing Scenario

If the proposed development is not progressed, the existing noise environment in the vicinity of the subject site and noise sensitive receptors will remain largely unchanged.

11.5.2 Construction Phase

A variety of items of plant and machinery will be in use for the purposes of site preparation and construction of turbines, access tracks, grid connection and other site works. There will be vehicular movements to and from the site that will make use of existing roads. Due to the nature of these activities, there is potential for the generation of significant levels of noise. These are discussed in the following sections.

The predicted noise levels referred to in this section are indicative only and are intended to demonstrate that it will be possible for the contractor to comply with current best practice guidance. It should also be noted that the predicted 'worst-case' levels are expected to occur for only short periods of time at a very limited number of properties. Construction noise levels will be lower than these levels for most of the time at most properties in the vicinity of the proposed development.

11.5.2.1 Construction of Turbines, Substation and Access Tracks

As the construction programme has been established in outline form only and will be subject to post-consent refinement, as is the normal course, it is difficult to calculate the precise magnitude of noise emissions to the local environment. However, it is possible to predict typical noise levels using guidance set out in BS 5228-1:2009+A1:2014 *Code of practice for noise and vibration control on construction and open sites – Noise*. In this instance, the noise-sensitive locations surround the site at distances varying with the nearest currently inhabited dwelling to any proposed work area being the order of 230m (i.e. approximate distance between H008 and the proposed arterial access track). Several indicative noise sources that would be expected on a site of this nature have been identified and noise predictions of their potential impacts prepared to nearby houses. The assessment is representative of a 'worst-case', with construction noise levels being slightly lower at properties located further than 230m from the works.

Table 11.10 outlines the noise levels associated with typical construction noise sources assessed in this instance along with typical sound pressure levels and spectra from BS 5228 – 1: 2009. Calculations have assumed an 'on-time' of 66% for each item of plant i.e. 8-hours over a 12-hour assessment period.

In all instances, the total construction noise levels are predicted to be below the appropriate Category A value (i.e. 65dB $L_{Aeq,T}$) and therefore a significant effect is not predicted in relation to the nearest noise sensitive locations in terms of construction noise.

There are no items of plant or machinery that would be expected to give rise to noise levels that would be considered out of the ordinary or in exceedance of acceptable levels.

Item (BS5228 ref)	Activity	Plant Noise Level at 10m Distance (dB $L_{Aeq,T}$) [1]	Plant Noise Level at 230m Distance (dB $L_{Aeq,T}$)
HGV Movement	Removing spoil and transporting fill and other materials.	79	52
Tracked Excavator	Removing soil and rubble in preparation for foundation.	77	40
Piling Operations	Standard pile driving.	88	61
General Construction	All general activities plus deliveries of materials and plant.	84	57
Dewatering Pumps	If required.	80	53
JCB	For services, drainage and landscaping.	82	55
Vibrating Rollers	Road surfacing.	77	50
Total Construction Noise (cumulative for all activities)			64

Table 11.10: Typical Construction Noise Emission Levels

Due to the distance of the proposed works from noise sensitive locations, significant vibration impacts are not likely. Considering the distances between these construction activities and nearby noise sensitive locations, vibration from these activities would not be perceptible and would be orders of magnitude below levels where cosmetic or structural damage would be expected.

11.5.2.2 Construction of arterial access track

A new arterial access track will be constructed to facilitate access to the site, for construction as well as maintenance.

There are several noise-sensitive locations to the north and south of the access track; the three nearest NSLs and the distance from the proposed track are listed in **Table 11.11**.

Location Ref.	Coordinates (ITM)		Approximate Distance to Access Track (m)
	Easting	Northing	
H094	656023	821359	140
H008	655311	821134	230
H007	655190	821065	235

Table 11.11: Nearest NSLs to Arterial Access Track

Several items of plant and machinery will be required during the construction of this section of access track with the potential to cause noise and vibration impacts at the nearest NSLs.

Table 11.12 outlines the noise levels associated with typical construction noise sources. The typical sound pressure levels and spectra used in this assessment have been taken from BS 5228–1: 2009+A1:2014. Calculations have assumed an on-time 66% for each item of plant i.e. 8-hours over a 12 hours assessment period.

Item (BS 5228 Ref.)	Stage	Plant Noise Level at 10m Distance (dB $L_{Aeq,T}$)
Bull Dozer (C5.15)	Site Clearing / Excavating	83
Articulated Lorry (C5.17)		81
Tracked Excavator (C5.18)		80
Vibratory Road Roller (C5.20)	Road Construction	75
Tracked Excavator (C5.35)		74

Table 11.12: Typical Road Construction Plant

Based on the assumptions outlined above the 'worst-case' predicted noise levels at each location are presented in **Table 11.13**.

Item (BS 5228 Ref.)	Stage	Predicted Noise Level (dB $L_{Aeq,T}$)
H094	Site Clearing / Excavating	63
	Road Construction	54
H008	Site Clearing / Excavating	60
	Road Construction	52
H007	Site Clearing / Excavating	60
	Road Construction	52

Table 11.13: Predicted Road Construction Noise Imission Levels

The construction noise levels are predicted to be within the potential significant noise impact values (i.e. 65 dB $L_{Aeq,T}$) as outlined in **Table 11.6** for daytime periods and weekdays. At greater distances noise from the works, the construction noise levels will be lower.

11.5.2.3 Substation & Grid Connection

The construction of the wind farm's grid connection (of the 3 no. options presented at **Chapter 3**), including associated substation, will result in works similar to those outlined above in relation to site clearing, excavating and general construction works. It is highly unlikely that piling or other loud/high impact operations will be required for the construction of any of the grid connection options. While such works, particularly in relation to the installation of underground and overhead electricity lines will occur within c. 100m of various residential dwellings and notably along the respective 38kV overhead line options, the short-term and transient nature of such works will ensure that any noise and vibration effects which may be experienced will not likely be significant.

11.5.2.4 Haul Route Upgrade Works

The proposed upgrade works along the turbine component haul route will be similar in nature to construction activities and will involve similar plant and machinery as those outlined above. While works at some of these locations are in close proximity to residential dwellings (i.e. <50m); given the temporary nature of the construction activities and their presence along public roads with existing traffic noise, significant effects are not assessed as likely. Similarly, significant levels of vibration are not assessed as likely.

In all instances, the total predicted construction noise levels are anticipated to be below the appropriate Category A value (i.e. 65dB LAeq,1hr) and therefore a significant effect is not likely in relation to the nearest noise sensitive locations in terms of construction noise.

11.5.3 Operational Phase

11.5.3.1 Wind Turbine Noise Criteria Curves

With respect to the relevant guidance documents outlined in **Section 11.2,** the following noise criteria curves have been identified for the proposed development. The criteria curves have been derived following a detailed review of the background noise data conducted at the nearest noise sensitive locations.

It is proposed to adopt a lower daytime threshold of 40dB $L_{A90,10\text{-}min}$ for low noise environments, i.e. where the background noise is less than 30 dB(A). This follows a review of the prevailing background noise levels and is considered appropriate in light of the following:-

- The EPA document '*Guidance Note for Noise: Licence Applications, Surveys and Assessments in Relation to Scheduled Activities (NG4)*' proposes a daytime noise criterion of 45 dB(A) in 'areas of low background noise'. The proposed lower threshold here is 5 dB more stringent than this level.
- It is reiterated that the *Wind Energy Development Guidelines for Planning Authorities 2006* states that "*An appropriate balance must be achieved between power generation and noise impact*." Based on a review of other national guidance issued by the EPA in relation to acceptable noise levels in areas of low background noise, it is considered that the criteria adopted as part of this assessment are robust.

Following comparison of the previously presented guidance, the proposed operational limits in $L_{A90,10min}$ for the proposed development are:

- 40dB $L_{A90,10min}$ for quiet daytime environments of less than 30dB $L_{A90,10min}$;
- 45dB $L_{A90,10min}$ for daytime environments greater than 30dB $L_{A90,10min}$ or a maximum increase of 5dB above background noise (whichever is higher), and;
- 43dB $L_{A90,10min}$ or a maximum increase of 5dB above background noise (whichever is higher) for night-time periods.

This set of criteria has been chosen as it accords with the intent of the relevant Irish guidance and is comparable to noise conditions applied to similar developments by An Bord Pleanála.

Table 11.14 outlines the derived noise criteria curves based on the information contained within **Table 11.9**.

Location	Period	Derived $L_{A90,\ 10\ min}$ Levels (dB) at various Standaridsed 10m Height Wind Speeds (m/s)

		4	5	6	7	8	9	10	11	12
H001 (A)	Day	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	Night	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H007 (B)	Day	40.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	Night	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H015 (C)	Day	40.0	40.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	Night	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
All Other Locations	Day	40.0	40.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
	Night	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

Table 11.14: Noise Criteria Curves

Note that, per Section 11.4.7.5 above, Location D has been omitted due to the presence of extraneous noise throughout the baseline noise monitoring programme.

11.5.3.2 Noise Assessment

The noise levels resulting from the operation of the proposed development have been calculated for all NSLs identified within 1,800m of the proposed wind turbines.

A 'worst-case' assessment has been completed assuming all noise locations are downwind of all turbines at the same time. The predicted levels have been compared against the adopted noise criteria curves as detailed in **Table 11.14**. **Annex 11.5** presents the details of the noise prediction exercise at all 123 no. NSLs. It should also be noted that, having reviewed the locations of other wind energy developments in the wider area, it is concluded that here is no potential for cumulative effects to arise. A noise contour map for standard mode operation rated power at a wind speed of 7m/s (i.e. highest noise emission) has been presented in **Annex 11.6**.

The cumulative predicted noise levels at various wind speeds have been compared against the noise criteria curves. The predicted noise levels at all locations for the various wind speeds are below the noise criteria curves adopted for this assessment

As the predicted noise levels associated with the proposed development will be within noise criteria curves recommended in the *Wind Energy Development Guidelines for Planning Authorities 2006*, it is assessed that significant noise effects will not arise as a result of the proposed wind turbines

11.5.3.3 Site Traffic

There is no significant traffic volumes expected during the operational phase, with 1-2 visits to site by a LGV per week. Therefore, and in addition to the substantial distances from on-site access tracks to the nearest NSL; there are no significant noise and vibration impacts anticipated during the operational phase.

11.5.3.4 Substation & Grid Connection

There are 3 no. possible locations of the substation, only one of which will ultimately be constructed (see **Chapter 3** for further details). The approximate locations of the substations are shown in **Table 11.15**:

Option	Locality	Easting	Northing

G1	Crossbane	653556	821578
G2	Lislongfield	653849	819616
G3	Cornawall/Drumanan	655365	819890

Table 11.15: Locations of Substation Options

During the operational phase, the selected substation will be operational on a day to day basis. The noise emission level associated with a typical wind farm substation approximately 93 dB L_{WA}.

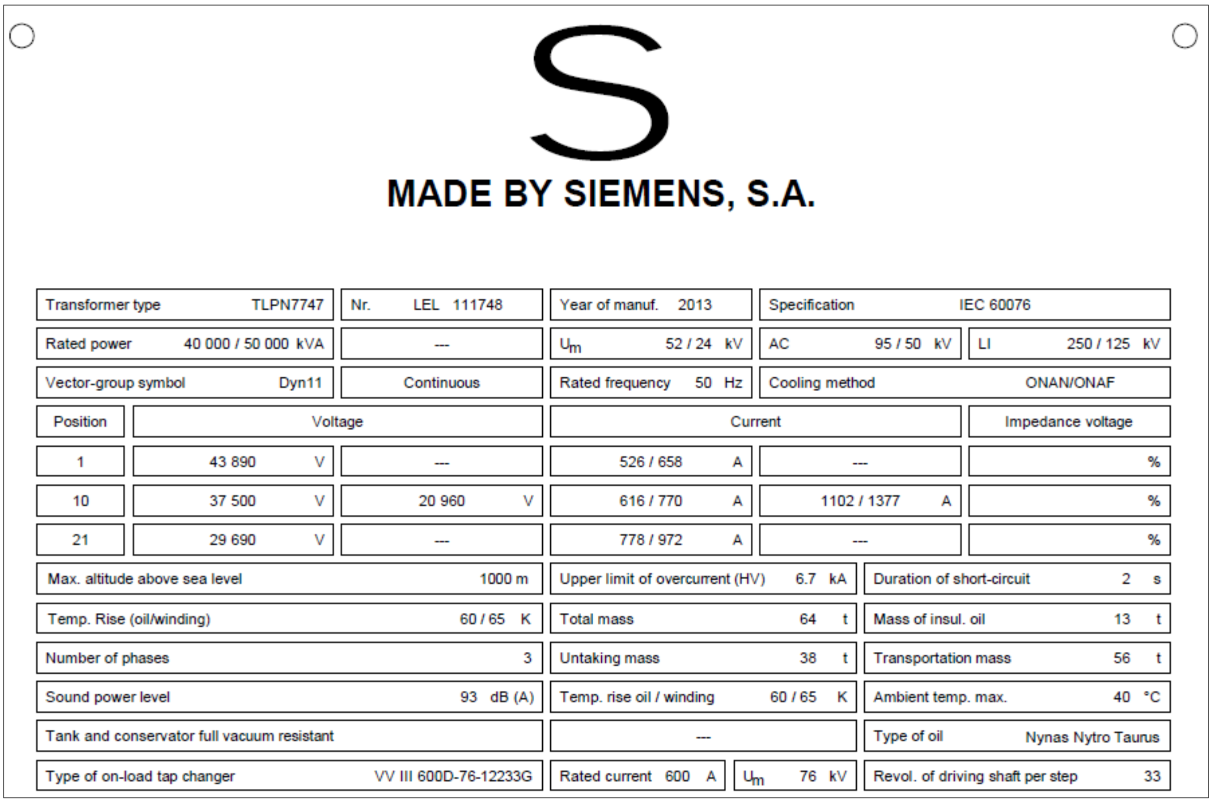

Figure 11.16: Statement of L_W for typical substation used for assessment

An iteration of the noise model has been developed to consider the expected noise level from the substations at the nearest NSLs (within 1,800m of a proposed turbine location). The predicted noise levels for each of the possible substation locations are presented in **Tables 11.16** to **11.18**.

Location	Noise Level due to Substation
H002	23.7
H001	23.6
H024	23.4
H029	23.3
H030	23.1
H028	22.7
H031	22.7
H027	22.1
H022	21.7

H023	20.9

Table 11.16: Highest 10 noise levels at NSLs due to operation of substation (Option G1 at Crossbane)

Location	Noise Level due to Substation
H061	26.4
H060	25.6
H016	22.6
H093	21.2
H071	21.0
H062	20.8
H070	20.7
H069	20.4
H068	19.6
H015	19.6

Table 11.17: Highest 10 noise levels at NSLs due to operation of substation (Option G2 at Lislongfield)

Location	Noise Level due to Substation
H013	27.9
H095	27.5
H012	26.6
H014	26.5
H011	23.4
H015	19.6
H054	17.7
H057	16.5
H056	16.4
H053	15.9

Table 11.18: Highest 10 noise levels at NSLs due to operation of substation (Option G3 Cornawall/Drumanan)

The 'worst-case' predicted levels are expected to be the order of 23 to 28dB(A). As the predicted levels are below 35dB L_{Aeq}, it is assessed that there is no potential for cumulative effects with the operational wind turbines and overall noise levels would remain compliant with the levels prescribed in the *Wind Energy Development Guidelines for Planning Authorities 2006*.

As the proposed overhead and underground electricity lines are functionally inert, it is assessed that there is no likelihood for noise and vibration impacts to occur as a result of the operation of the grid connection options.

11.5.4 Decommissioning Phase

In relation to the decommissioning phase, similar overall noise levels as those calculated for the construction phase would be expected, as similar plant, machinery and equipment will be used.

In all instances, the total predicted decommissioning noise levels are anticipated to be below the appropriate Category A value (i.e. 65dB LAeq,1hr) and therefore a significant effect is not predicted in relation to the nearest noise sensitive locations in terms of decommissioning noise.

11.6 Mitigation and Monitoring Measures

11.6.1 Construction Phase

Construction activities will be completed in accordance with the provisions, where relevant, of *BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – Noise* which offers detailed guidance on the control of noise & vibration from demolition and construction activities. The relevant practices be adopted during construction shall include:-

- Limiting the hours during which site activities likely to create high levels of noise or vibration are permitted;
- Establishing channels of communication between the contractor/developer, Local Authority and residents;
- Appointing a site representative responsible for matters relating to noise and vibration;
- Monitoring typical levels of noise and vibration during critical periods and at sensitive locations; and
- Keeping site access tracks even to mitigate the potential for vibration from HGVs.

Furthermore, a variety of practicable noise control measures will be employed. These include:-

- Selection of plant with low inherent potential for generation of noise and/or vibration;
- Placing of noisy/vibratory plant as far away from sensitive properties as permitted by site constraints, and;
- Regular maintenance and servicing of plant items.

11.6.1.1 Noise

The various contractors involved in the construction phase will be obliged, under contract, to take specific noise abatement measures and comply with the recommendations of *BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – Noise*. The following list of measures will be implemented, as relevant, to ensure compliance with the relevant construction noise criteria:

- No plant or machinery will be permitted to cause a public nuisance due to noise;
- The best means practicable, including proper maintenance of plant, will be employed to minimise the noise produced by on site operations.
- All vehicles and mechanical plant will be fitted with effective exhaust silencers and maintained in good working order for the duration of the contract;
- Compressors will be attenuated models fitted with properly lined and sealed acoustic covers which will be kept closed whenever the machines are in use and all ancillary pneumatic tools shall be fitted with suitable silencers;
- Machinery that is used intermittently will be shut down or throttled back to a minimum during periods when not in use;
- Any plant, such as generators or pumps, which may be required to operate

outside of general construction hours will be surrounded by an acoustic enclosure or portable screen;
- During the course of the construction programme, supervision of the works will include ensuring compliance with the limits detailed in **Table 11.4** using methods outlined in *BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – Noise*;
- The hours of construction activity will be limited to avoid unsociable hours where possible. Construction operations shall generally be restricted to between 07:30hrs and 20:00hrs Monday to Friday and between 07:30hrs and 18:00hrs on Saturdays, with no operations on Sundays or public holidays. However, to ensure that optimal use is made of good weather periods, at occasional critical periods within the construction programme (i.e. concrete pours, rotor/tower deliveries and turbine erection) or in the event of an emergency; activities may be necessary outside out of these hours.

Based on assessment of the geological composition of the site undertaken to date, it is concluded that significant levels of rock are not present. In the unlikely event that rock is encountered, rock breaking may be employed to utilise this rock in the construction of access tracks or hardstands. If rock breaking is required, the following measures will be implemented, where necessary, to mitigate noise emissions:-

- Fit suitably designed muffler or sound reduction equipment to the rock breaking tool to reduce noise without impairing machine efficiency;
- Ensure all air lines are sealed;
- Use a dampened bit to eliminate a 'ringing' sound;
- Erect an acoustic screen between compressors or generators and noise sensitive area. When possible, line of sight between top of machine and reception point will be obscured; and
- Enclose the breaker or rock drill in portable or fixed acoustic enclosure with suitable ventilation.

11.6.1.2 Vibration

Vibration from construction activities shall be limited to the values set out in **Table 11.5**. It should be noted that these limits are not absolute but provide guidance as to magnitudes of vibration that are very unlikely to cause cosmetic damage. Magnitudes of vibration slightly greater than those in the table are normally unlikely to cause cosmetic damage, but construction work creating such magnitudes should proceed with caution. Where there is existing damage these limits may need to be reduced by up to 50%.

Considering the large distances between locations where piling may take place (i.e. turbine locations) and the nearest NSLs, no likely significant impact will be experienced. Therefore, no mitigation measures are proposed.

11.6.2 Operational Phase

An assessment of the operation noise levels has been undertaken in accordance with best practice guidelines and procedures. The findings of the assessment confirm that predicted operational noise levels will be within the relevant best practice noise criteria curves for wind farms. Therefore, noise mitigation measures are not required for the operational phase of this development.

If alternative turbine technologies are considered for installation, an updated noise assessment will be prepared to confirm that the associated noise levels comply with the noise criteria curves and/or the relevant operational criteria associated with conditions of consent.

In the unlikely event that an issue with low frequency noise is associated with the proposed development, an appropriate detailed investigation shall be undertaken. Due consideration shall be given to guidance on conducting such an investigation which is outlined in Appendix VI of the EPA document entitled *Guidance Note for Noise: Licence Applications, Surveys and Assessments in Relation to Scheduled Activities* (NG4) (EPA, 2016). This guidance is based on the threshold values outlined in the Salford University document Procedure for the assessment of low frequency noise complaints, Revision 1, December 2011.

In the unlikely event that a complaint is received which indicates potential amplitude modulation (AM) associated with turbine operation, an independent acoustic consultant shall be employed to assess the level of AM in accordance with the methods outlined in the Institute of Acoustics (IoA) Noise working Group (Wind Turbine Noise) Amplitude Modulation Working Group (AMWG) namely, *A Method for Rating Amplitude Modulation in Wind Turbine Noise* (August 2016) or subsequent revisions (August 2016) (The Reference Method) or subsequent revisions and mitigate as necessary.

11.6.3 Decommissioning Phase

The mitigation measures to be implemented during the decommissioning of the proposed development are the same as those proposed for the construction phase of the development.

11.6.4 Monitoring

11.6.4.1 Construction Phase

No monitoring of noise levels during the construction phase is proposed.

11.6.4.2 Operational Phase

Post commissioning operational noise monitoring will be undertaken to ensure compliance with the relevant noise criteria. In relation to assessment of operational wind turbine noise, the guidance outlined in the IoA GPG and Supplementary Guidance Note 5: Post Completion Measurements (July 2014) should be followed. Should the assessment identify any exceedances of the appropriate criteria, relevant corrective actions will be taken. An Outline Noise Monitoring Programme has been prepared by GES and is enclosed at **Annex 11.7**.

11.6.4.3 Decommissioning Phase

No monitoring of noise levels during the decommissioning phase is proposed.

11.7 Residual Effects

This section outlines the likely residual noise and vibration effects associated with the proposed development taking account of the mitigation measures.

11.7.1 Do Nothing Scenario

If the proposed development were not to proceed then the existing noise environment will remain unchanged.

11.7.2 Construction Phase

During the construction phase, there will likely be some effect on nearby noise sensitive locations due to noise emissions from site traffic and other activities. However, given that the construction phase of the development is temporary in nature and the distances between the main construction works and nearby noise sensitive properties, it is assessed that the noise generated will not be excessively intrusive. Furthermore, the application of binding noise limits and construction hours, along with implementation of appropriate noise and vibration mitigation measures, will ensure that noise and vibration effect is unlikely to be significant. The residual effects are assessed to be likely negative, slight and temporary; and unlikely to be significant.

11.7.3 Operational Phase

11.7.3.1 Wind Turbine Noise

Following an appraisal of other wind farm developments, it was concluded in accordance with the guidance contained in Section 5.1. of the IOA GPG that the proposed wind turbines are a sufficient distance from other such developments that there is no potential for cumulative effects to arise.

The predicted noise levels associated with the proposed development will be within best practice noise criteria curves recommended in Irish guidance *Wind Energy Development Guidelines for Planning Authorities 2006*. It is not considered that a significant effect is associated with the operational phase of the proposed development.

While noise levels at low wind speeds will increase due to the proposed development, and specifically the operation of the turbines, the predicted levels will be low, albeit new sources of noise will be introduced into the soundscape.

For most of the locations assessed here the likely effect of the operational turbines is negative, slight and long-term, and for those that may experience slightly higher noise levels, the likely effect will be negative, moderate and long-term but unlikely to be significant.

11.7.3.2 Substation Noise

The associated effect from the day to day operation of the substation, in combination with the operational wind turbines, has been assessed and no likely significant residual effects are assessed as likely.

11.7.3.3 Vibration

There is no expected source of vibration related with the operational phase of the proposed development and therefore no residual effect is assessed as likely.

11.7.4 Cumulative & Transboundary Effects

There are no existing, permitted or proposed wind turbine developments which have the potential to result in a likely cumulative effect on the noise-sensitive locations in the study area. While there a number of single/micro-generation developments located in the wider area, particularly in Northern Ireland, these are assessed to be sufficiently distant that they will not interact with the proposed development. Similarly, there are no noise sensitive locations located within Northern Ireland which have the potential to be affected by the proposed development.

11.8 Summary

The noise environment at a set of representative noise-sensitive locations in the vicinity of the proposed development has been quantified by an appropriate survey of background noise levels. The results of the background noise survey have been used to derive noise level criteria for these and other noise-sensitive locations.

Using sound emission data specific to the turbine model, and a proven noise propagation model, the operational noise levels at 123 noise-sensitive locations have been predicted. In all cases the wind farm noise levels fall within the adopted criteria. The noise impact of the development is therefore unlikely to be significant.