HOARE LEA

Oatfield Wind Farm.
Environmental noise assessment.

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1. Introduction

1.1 This report presents an assessment of the potential construction and operational noise impacts of the Oatfield Wind Farm (the Proposed Development) on the residents of nearby dwellings. The assessment considers both the construction and operation of the Proposed Development and also the likely impacts of its decommissioning. Other wind farms nearby, such as the consented Carrownagowan Wind Farm (approximately 4 km to the north-east) or the proposed Fahybeg Wind Farm (approximately 5 km to the east) were also considered for their potential cumulative operational noise. The Knockshanvo Wind Farm (adjacent to the Proposed Development) is currently not at planning stage so limited details are available; however, a preliminary cumulative operational noise assessment was nevertheless undertaken. Other, more distant wind farms were not considered because their potential noise contribution was considered negligible.

1.1.1 Noise and vibration which arises from the construction of a wind farm is a factor which should be taken into account when considering the total effect of the proposed development. However, in assessing the effects of construction noise, it is accepted that the associated works are of a temporary nature. The main work locations for construction of the turbines are distant from the nearest noise sensitive residences and are unlikely to cause significant effects. The construction and use of access tracks may, however, occur closer to some receptors, but with works generally occurring for shorter periods. Assessment of the temporary effects of construction noise is primarily aimed at understanding the need for dedicated management measures and, if so, the types of measures that are required. Further details of relevant working practices, traffic routes, and proposed working hours are described in the construction and traffic chapters of the Environmental Impact Assessment Report (EIAR).

1.1.2 Once constructed and operating, wind turbines may emit two types of noise. Firstly, aerodynamic noise is a 'broad band' noise, sometimes described as having a characteristic modulation, or 'swish', which is produced by the movement of the rotating blades through the air. Secondly, mechanical noise may emanate from components within the nacelle of a wind turbine. This is a less natural sounding noise which is generally characterised by its tonal content. Traditional sources of mechanical noise comprise gearboxes or generators. Due to the acknowledged lower acceptability of tonal noise in otherwise 'natural' noise settings such as rural areas, modern turbine designs have evolved to minimise mechanical noise radiation from wind turbines. Aerodynamic noise tends to be perceived when the wind speeds are low, although at very low wind speeds the blades do not rotate or rotate very slowly and so, at these wind speeds, negligible aerodynamic noise is generated. In higher winds, aerodynamic noise is generally masked by the normal sound of wind blowing through trees and around buildings. The level of this natural 'masking' noise relative to the level of wind turbine noise determines the subjective audibility of the wind farm. The relationship between wind turbine noise and the naturally occurring masking noise at residential dwellings lying around the proposed development will therefore generally form the basis of the assessment of the levels of noise against accepted standards.

1.1.3 The main noise sources associated with the substation are likely to be power transformers and cooling fans.

1.2 An overview of environmental noise assessment and a glossary of noise terms are provided in Annex A.

2. Policy and Guidance Documents

2.1 Planning Policy and Advice Relating to Noise – Ireland

2.1.1 The 2006 Wind Energy Development Guidelines (WEDG)[1] from the Department of the Environment, Heritage and Local Government (DoEHLG) include some recommendations on noise. They require that an appropriate balance is achieved between power generation and noise impacts.

2.1.2 The guidance essentially proposes limits of 45 dB(A) or 5 dB above the background, subject to lower limits of 35-40 dB(A) for day-time periods or 43 dB(A) at night, which may apply in low noise environments. Whilst subject to a degree of interpretation, these guidelines seem based on the ETSU-R-97 recommendations which apply in the UK and which are described in further detail below. These more detailed UK guidelines, and related good practice measures, will therefore be referenced when applying the (still extant) 2006 WEDG guidelines in the assessment of the proposed development.

2.1.3 The Department for Housing Local Government and Heritage (DHLGH) has been preparing a review of the 2006 WEDG, with draft guidelines submitted for consultation in December 2013. A "Preferred Draft Approach" was published in June 2017 by the DHPCLG. On noise, the preferred draft approach is described as:

The "preferred draft approach" proposes noise restriction limits consistent with World Health Organisation standards, proposing a relative rated noise limit of 5dB(A) above existing background noise within the range of 35 to 43dB(A), with 43dB(A) being the maximum noise limit permitted, day or night.

2.1.4 In December 2019, revised Wind Energy Development Guidelines have been published in draft form only at this stage.

2.2 Wind Farm Noise Guidance - UK

2.2.1 ETSU-R-97 represents current government policy in the UK for the assessment of wind farm noise. The basic aim of the ETSU Report, ETSU-R-97 'The Assessment and Rating of Noise from Wind Farms'[2], is to provide:

> *'Indicative noise levels thought to offer a reasonable degree of protection to wind farm neighbours, without placing unreasonable restrictions on wind farm development or adding unduly to the costs and administrative burdens on wind farm developers or local authorities'.*

2.2.2 The report ETSU-R-97 makes it clear from the outset that any noise restrictions placed on a wind farm must balance the environmental effects of the wind farm against the national and global benefits which would arise through the development of renewable energy sources, stating:

> *'The planning system must therefore seek to control the environmental impacts from a wind farm whilst at the same time recognising the national and global benefits that would arise through the development of renewable energy sources and not be so severe that wind farm development is unduly stifled.'*

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1 Wind Energy Development Guidelines (WEDG) from the Department of the Environment, Heritage and Local Government (DoEHLG), 2006.

2 ETSU-R-97, the Assessment and Rating of Noise from Wind Farms, Final Report for the Department of Trade & Industry, September 1996. The Working Group on Noise from Wind Turbines.

2.2.3 Guidance on good practice on the application of ETSU-R-97 has been provided by the Institute of Acoustics (IOA Good Practice Guide or GPG)[3]. This was subsequently endorsed by the UK Government[4] as current industry good practice and will therefore be referenced in the present assessment.

2.2.4 The ETSU-R-97 assessment procedure specifies that noise limits should be set relative to existing background noise levels at the nearest properties and that these limits should reflect the variation in both turbine source noise and background noise with wind speed. The wind speed range which should be considered is between the cut-in speed (the speed at which the turbines begin to operate) for the turbines and 12 m/s (43.2 km/h), where all wind speeds are referenced to a ten metre measurement height (refer to Annex F for a discussion of how wind speeds are referenced to a ten metre height).

2.2.5 Separate noise limits apply for the day-time and night-time. Day-time limits are chosen to protect a property's external amenity whilst outside their dwellings in garden areas and night-time limits are chosen to prevent sleep disturbance indoors. Absolute lower limits, different for day-time and night-time, are applied where the line of best-fit representation of the measured background noise levels equates to very low levels (< 30 dB(A) to 35 dB(A) for day-time, and < 38 dB(A) during the night).

2.2.6 The day-time noise limit is derived from background noise data measured during the 'quiet periods of the day': these comprise weekday evenings (18:00 to 23:00), Saturday afternoons and evenings (13:00 to 23:00) and all day and evening on Sundays (07:00 to 23:00). Multiple samples of ten-minute background noise levels using the $L_{A90,10min}$ measurement index are measured contiguously over a wide range of wind speed conditions (a definition of the $L_{A90,10min}$ index is given in Annex A). The measured noise levels are then plotted against the simultaneously measured wind speed data and a 'best-fit' curve is fitted to the data to establish the background noise level as a function of wind speed. The ETSU-R-97 day-time noise limit is then set to the greater of either: a level 5 dB(A) above the best-fit curve to the background noise data over a 0-12 m/s wind speed range <u>or</u> a fixed level in the range 35 dB(A) to 40 dB(A).

2.2.7 The precise choice of the fixed lower limit within the range 35 dB(A) to 40 dB(A) under ETSU-R-97 depends on a number of site-specific factors: the number of noise-affected properties, the likely duration and level of exposure and the consequences of the choice on the potential power generating capability of the wind farm. This range will be considered in the assessment below.

2.2.8 The night-time noise limit is derived from background noise data measured during the night-time periods (23:00 to 07:00) with no differentiation being made between weekdays and weekends. The ten-minute $L_{A90,10min}$ noise levels measured over these night-time periods are again plotted against the concurrent wind speed data and a 'best-fit' correlation is established. As with the day-time limit, the ETSU-R-97 night-time noise limit is also set as the greater of: a level 5 dB(A) above the best-fit background curve <u>or</u> a fixed level of 43 dB(A). This fixed lower night-time limit of 43 dB(A) was set on the basis of World Health Organization (WHO) guidance[5] for the noise inside a bedroom and an assumed difference between outdoor and indoor noise levels with windows open. WHO guidelines were revised to suggest a lower internal noise level, but conversely, a higher assumed difference between outdoor and indoor noise levels.

2.2.9 The exception to the setting of both of these day-time and night-time lower fixed limits occurs in instances where a property occupier has a financial involvement in the wind farm development. Where this is the case then the lower fixed portion of the noise limit at that property may be increased to 45 dB(A) during both the day-time and the night-time periods alike.

3 A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.
4 Letter from Secretary of State for the Department of Energy and Climate change, 20 May 2013
5 Environmental Health Criteria 12 – Noise. World Health Organisation, 1980.

2.2.10 The noise limits defined in ETSU-R-97 relate to the total noise occurring at a dwelling due to the combined noise of all operational wind turbines. It is therefore necessary to consider the combined operational noise of the proposed development with other wind farms in the area to be satisfied that the combined cumulative noise levels are within the relevant criteria. ETSU-R-97 also requires that the baseline levels on which the noise limits are based do not include a contribution from any existing turbine noise, to prevent unreasonable cumulative increases.

2.2.11 It can therefore be concluded that the methodology and guidance within ETSU-R-97 is compatible with the 2006 WEDG but provides more detailed recommendations.

2.3 Construction noise guidance

2.3.1 There are no general statutory guidelines in Ireland on construction noise and its control, although some guidance is provided in the context of national road schemes in Ireland in the National Roads Authority guidelines[6] (NRA, 2004). It is therefore general practice in Ireland to reference the UK guidance set out in the relevant British Standard: BS 5228-1.

2.3.2 BS 5228-1:2009 (amended 2014)[7] 'Code of practice for noise and vibration control on construction and open sites – Part 1: noise' (BS 5228-1) provides guidance on a range of considerations relating to construction noise including the legislative framework, general control measures, example methods for estimating construction noise levels and example criteria which may be considered when assessing the magnitude of the impacts.

2.3.3 Similarly, BS 5228-2:2009 (amended 2014)[8] 'Code of practice for noise and vibration control on construction and open sites – Part 2: vibration' BS 5228-2 provides general guidance on legislation, prediction, control and assessment criteria for construction vibration. These standards have been adopted as the relevant method to predict and assess the impacts of construction noise and vibration.

3. Scope and Methodology

3.1 Methodology for Assessing Construction Noise

3.1.1 Construction works include both moving sources and static sources. The moving sources normally comprise mobile construction plant and Heavy Goods Vehicles (HGVs). The static sources include construction plant temporarily placed at fixed locations and in some instances noise arising from blasting activities where rock is to be worked through. Consideration will also be given to the works required along the grid connection route, including potential Horizontal Directional Drilling (HDD).

3.1.2 The analysis of construction noise has been undertaken in accordance with BS 5228-1 which provides methods for predicting construction noise levels on the basis of reference data for the emissions of typical construction plant and activities. These methods include for the calculation of construction traffic along access tracks and haul routes and also for construction activities at fixed locations such as the bases of turbines, site compounds or sub stations.

3.1.3 The BS 5228 calculated levels are then compared with absolute noise limits for temporary construction activities which are commonly regarded as providing an acceptable level of protection from the short-term noise levels associated with construction activities.

6 National Roads Authority (NRA, 2004), Guidelines for the Treatment of Noise and Vibration in National Road Schemes Revision 1, 25th October 2004.

7 BS 5228-1:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 1: Noise'.

8 BS 5228-2:2009-A:2014 'Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration'.

3.1.4 Separate consideration is also given to the possible noise impacts of construction related traffic passing to and from the site along local surrounding roads. In considering potential noise levels associated with construction traffic movement on public roads, reference is made to the accepted UK prediction methodology provided by 'Calculation of Road Traffic Noise'[9] (CRTN), which is referenced in the NRA guidelines.

3.1.5 The nature of works and distances involved in the construction of a wind farm are such that the risk of non-negligible impacts relating to ground borne vibration are very low. Occasional momentary vibration can arise when heavy vehicles pass dwellings at very short separation distances, but again this is not sufficient to constitute a risk of moderate/major impacts in this instance. Accordingly, vibration impacts do not warrant detailed assessment and are therefore not discussed further in this assessment.

3.2 Methodology for Assessing Wind Farm Operational Noise

3.2.1 To undertake the assessment of operational noise in accordance with the foregoing methodology the following steps are required:

- specify the number and locations of the wind turbines on all wind farms;
- identify the locations of the nearest, or most noise sensitive, neighbours;
- measure the background noise levels as a function of site wind speed at the nearest neighbours, or at least at a representative sample of the nearest neighbours;
- determine the day-time and night-time noise limits from the measured background noise levels at the nearest neighbours;
- specify the type and noise emission characteristics of the wind turbines;
- calculate the noise immission levels due to the operation of the wind turbines as a function of site wind speed at the nearest neighbours; and
- compare the calculated wind farm noise immission levels with the derived noise limits and assess in the light of planning requirements.

3.2.2 The foregoing steps, as applied to the Proposed Development, are set out subsequently in this assessment.

3.2.3 Note that in the above, and subsequently in this assessment, the term 'noise emission' relates to the sound power level actually radiated from each wind turbine, whereas the term 'noise immission' relates to the sound pressure level (the perceived noise) at any receptor location due to the combined operation of all wind turbines on the Proposed Development.

3.3 Methodology for Assessing Substation Operational Noise

3.3.1 The likely noise emissions from the proposed substation and energy storage will also be considered in relation to existing baseline noise levels and related guidance such as the Guidance Note for Noise: License Applications, Surveys and Assessments in Relation to Scheduled Activities (NG4)[10]. These guidelines in particular set out a series of stringent noise limit for commercial/industrial type noise of between 35 to 45 dB L_{Ar}[11] (for night and day-time periods respectively) in areas of low background noise.

9 Calculation of Road Traffic Noise, HMSO Department of Transport, 1988.
10 Guidance Note for Noise: License Applications, Surveys and Assessments in Relation to Scheduled Activities (NG4), Environmental Protection Agency, Office of Environmental Enforcement, Ireland (2016).
11 Rated noise level, based on the L_{Aeq} level with a correction to account for the character of the noise in some cases.

3.4 Construction Noise Criteria

3.4.1 BS 5228-1 indicates a number of factors are likely to affect the acceptability of construction noise including site location, existing ambient noise levels, duration of site operations, hours of work, attitude of the site operator and noise characteristics of the work being undertaken.

3.4.2 BS 5228-1 informative Annex E provides example criteria that may be used to consider the magnitude of any construction noise impacts. The criteria do not represent mandatory limits but rather a set of example approaches intended to reflect the type of methods commonly applied to construction noise. The example methods are presented as a range of possible approaches (both facade and free field noise levels, hourly and day-time averaged noise levels) according to the ambient noise characteristics of the area in question, the type of development under consideration, and the expected hours of construction activity. In broad terms, the example criteria are based on a set of fixed limit values which, if exceeded, may result in a large impact unless ambient noise levels (i.e. regularly occurring levels without construction) are sufficiently high to provide a degree of masking of construction noise.

3.4.3 Based on the range of guidance values set out in BS 5228 Annex E, and other reference criteria provided by the World Health Organization (WHO), the following impact assessment scale has been derived. The values have been chosen in recognition of the relatively low ambient noise typically observed in rural environments. The presented criteria have been normalised to free-field day-time noise levels occurring over a time period, T, equal to the duration of a working day on-site. BS 5228-1 Annex E provides varied definitions for the range of day-time working hours which can be grouped for equal consideration. The values presented in Table 1 have been chosen to relate to day-time hours from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays.

Table 1 - Construction Noise Impact Assessment

Impact	Noise Level dB $L_{Aeq,T}$		Description
	4 weeks or more	1 to 4 weeks	
Major	> 75	> 85	Trigger level for noise insulation works, or costs thereof, as set out in E.4 of BS 5228-1.
Moderate	> 65 ≤ 75	> 75 ≤ 85	Most stringent threshold values for potential significant effects given in Annex E of BS 5228-1 for example methods relevant to proposed development is exceeded.
Minor	> 55 ≤ 65	> 65 ≤ 75	Noise is likely to be audible, but unlikely to change behaviour. of BS 5228-1 thresholds not exceeded.
Negligible	≤ 55	≤ 65	At least 10 dB below the most stringent criteria provided in of BS 5228-1.
The values presented above relate to noise impacts that occur during working hours from 07:00 to 19:00 on weekdays, and 07:00 to 13:00 on Saturdays. Alternate criteria would apply to noise impacts outside of these hours. For noise impacts 13:00 to 19:00 on Saturdays and 07:00 to 19:00 on Sundays the above thresholds would reduce by 10 dB(A) in each category. For noise impacts 19:00 to 07:00 on any day the above thresholds would reduce by 20 dB(A) in each category.			

3.4.4 When considering the impact of short-term changes in traffic, associated with the construction activities, on existing roads in the vicinity of the Project, reference can be made to the criteria set out in the UK Design Manual for Roads and Bridges (DMRB[12]) which is referenced in the NRA guidelines discussed above. A classification of magnitudes of changes in the predicted traffic noise level calculated using the CRTN methodology is set out: for short-term changes such as those associated with construction activities, changes of less than 1 dB(A) are considered negligible, 1 to 3 dB(A) is minor, 3

12 The Highways Agency, Transport Scotland, Transport Wales and The Department for Regional Development (Northern Ireland) (2020). 'Design Manual for Roads and Bridges, LA 111 Noise and vibration', revision 2.

to 5 dB(A) moderate and changes of more than 5 dB(A) constitute a major impact. This classification can be considered in addition to the criteria of Table 1.

3.5 Operational Noise Criteria

3.5.1 The acceptable limits for wind turbine operational noise are defined in the 2006 WEDG guideline document referenced above and these limits should not be breached. The relevant limits for the Proposed Development are set out below in Tables 4 and 5. Consequently, the test applied to operational noise is whether or not the calculated wind farm noise immission levels at nearby noise sensitive properties lie below these noise limits. Depending on the levels of background noise, the satisfaction of the derived noise limits can lead to a situation whereby, at some locations under some wind conditions and for a certain proportion of the time, the wind farm noise may be audible. However, noise levels at the properties in the vicinity of the proposed development must still be within levels considered acceptable under the applicable 2006 WEDG guidelines.

3.6 Consultation

3.6.1 The proposed assessment approach and relevant guidance for the assessment of noise and vibration were outlined in the scoping report for the proposed development. No comments were received in response regarding the proposed approach from the consultees, including the Clare County Council Environment section.

4. Baseline

4.1 General Description

4.1.1 The Proposed Development is located in a rural area distant from villages and main settlements. The noise environment in the surrounding area is generally characterised by 'natural' sources, such as wind disturbed vegetation, birds, farm animals. Other sources of noise include intermittent local road and agricultural vehicle movements in the area.

4.2 Details of the Baseline Background Noise Survey

4.2.1 A total of six noise monitoring locations were selected with RSK[13] as being representative of the background noise environment for the nearest residences to the proposed wind farm site. The six locations are shown on the plan in Annex B and listed in Table 2. Location 5 was installed in a field west of property H11 as access to this property (and other neighbouring residential properties) was refused.

Table 2 - Background Noise Monitoring Locations (approximate Easting / Northing, Irish Transverse Mercator)

Location No.	Property	Easting	Northing
Location 1	H2	552740	668075
Location 2	H38	554211	667353
Location 3	H12	555728	668753
Location 4	H39	552422	670212
Location 5	West of H11	557378	671520

13 Background noise surveys were completed by RSK with technical input from Hoare Lea.

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Location No.	Property	Easting	Northing
Location 6	H4	557739	670631

4.2.2 The assessment has considered operational noise from the Proposed Development at the monitoring locations noted above, as well as other residential properties: these assessment locations are listed in Table 3. The list of receptor locations is considered representative of noise levels typical of those receptors closest to the Proposed Development.

4.2.3 The results obtained from the six survey positions have been used to represent the background environment expected to occur at other nearby assessment locations. The use of the data in this way is justified by consideration of the terrain and the sources of background noise levels throughout the area (particularly at increased wind speeds). This approach is consistent with the guidance provided by ETSU-R-97 and current good practice as set out in the IOA GPG. Locations where such representations have been made, and the source of the representations, are represented in Table 3. It is noted that where such representations have been made, the distance between the assessment location and nearest turbine is comparable to, if not greater than, the distance between the reference monitoring location and the nearest turbine. The receptors identified are represented on Figure 13.1 in Chapter 13.

4.2.4 Table 3 highlights several properties which are currently unoccupied, generally because they are dilapidated; however, these properties were included in the assessment as a precautionary measure, as they may become occupied at a later date. Several consented residential developments were also included in the assessment although they may not currently be constructed/inhabited.

Table 3 - Assessment properties in the vicinity of the proposed development - Irish Transverse Mercator (ITM) coordinates.

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Survey Location (survey property in **bold**)
H1*	554169	667923	760	T4	Location 1
H2	552749	668070	730	T2	**Location 1**
H3*	554208	667844	830	T4	Location 1
H4*	557732	670603	740	T9	**Location 6**
H5	553776	667484	810	T4	Location 2
H6	554795	668325	740	T6	Location 3
H7	554827	668346	740	T6	Location 3
H8	555588	668690	740	T7	Location 3
H9	551894	668265	770	T2	Location 1
H10	553818	667464	850	T4	Location 2
H11	557531	671464	760	T10	**Location 5**
H12	555710	668771	810	T7	**Location 3**
H13	557621	669424	1380	T9	Location 3
H14	555657	668598	850	T7	Location 3

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Survey Location (survey property in **bold**)
H15	557856	670675	860	T9	Location 6
H16	554062	667440	990	T4	Location 2
H17	555731	671678	880	T11	Location 5
H18	557648	671527	890	T10	Location 5
H19	552888	667608	870	T4	Location 2
H20	552627	667777	980	T4	Location 1
H21	557919	670762	930	T9	Location 6
H22	557217	671968	930	T10	Location 5
H23	557799	671131	930	T9	Location 5
H24	554106	667368	1070	T4	Location 2
H25	555733	668529	960	T7	Location 3
H26	554134	667372	1090	T4	Location 2
H27	552739	667765	890	T4	Location 1
H28	557726	671503	950	T10	Location 6
H29	552557	667730	1020	T2	Location 1
H30	554082	667332	1090	T4	Location 2
H31	557781	671371	960	T10	Location 6
H32	557705	671606	980	T10	Location 6
H33	557677	671655	980	T10	Location 6
H34	557666	671690	990	T10	Location 6
H35	552898	667446	990	T4	Location 2
H37	557602	671857	1050	T10	Location 6
H38*	554259	667336	1190	T4	Location 2
H39	552448	670194	1060	T1	Location 4
H40	557653	671856	1090	T10	Location 6
H41	557589	671922	1090	T10	Location 6
H42	558047	671085	1130	T9	Location 6
H43	555393	668052	1150	T7	Location 3
H44	554384	667319	1290	T4	Location 2
H45	557962	671443	1150	T10	Location 6
H46	558203	670680	1200	T9	Location 6

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Survey Location (survey property in **bold**)
H47	555873	668359	1170	T7	Location 3
H48	558174	670858	1190	T9	Location 6
H50	552318	667509	1250	T2	Location 2
H51	552597	667502	1160	T4	Location 2
H52	552552	667484	1200	T4	Location 2
H53	552526	667477	1230	T4	Location 2
H57	552403	667443	1310	T2	Location 2
H60	555961	668283	1290	T7	Location 3
H72	555146	667678	1460	T7	Location 3
H514	552379	667690	1070	T2	Location 1
H518**	552685	667822	910	T4	Location 1
H520**	553528	667636	610	T4	Location 1
H528**	554845	668340	760	T6	Location 3
H530**	554845	668364	740	T6	Location 3
H547**	555871	668390	1150	T7	Location 3
H606*	554241	668059	780	T4	Location 1
H612***	557733	671431	930	T10	Location 6
H616***	554198	667497	1030	T4	Location 2

** Dwelling financially involved with the proposed development.*

*** Dwelling currently uninhabited or dilapidated.*

**** Site with planning permission for a residential property.*

4.2.5 The background noise monitoring exercise was conducted over the period 13/09/2023 to 19/10/2023. The equipment used for the survey comprised four 01dB CUBE logging sound level meters and two Larson Davis SoundExpert LxT sound level meters. Outdoor enhanced windshield systems were used to reduce wind induced noise on the microphones and provide protection from rain, in line with IOA GPG guidance. The microphones were installed at a height of approximately 1.2 to 1.5 metres above ground level, consistent with the requirements of ETSU-R-97.

4.2.6 The sound level meters were located on the wind farm side of the property in question where possible, never closer than 3.5 metres from the façade of the property and as far away as was practical from obvious atypical localised sources of noise such as running water, trees or boiler flues. Details and photographs of the measurement locations are presented in Annex C.

4.2.7 Most locations were deployed on 13/14 September 2023, with the exception of Location 5 which was installed on 21 September due to access difficulties. All measurement systems were calibrated on their deployment on their deployment and upon collection of the equipment on the 19 October 2023. No

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acoustically important (>0.5 dB(A)) drifts in calibration were found to have occurred on any of the systems. This equates to a total ETSU-R-97 analysis period of at least 30 days for each location, except at Location 5, where the survey duration was 27 days. In all cases, the measurement duration was in excess of the minimum of one week suggested by ETSU-R-97 and is compliant with the IOA GPG requirements.

4.2.8 All measurement systems were generally set to log the $L_{A90,10min}$ and $L_{Aeq,10min}$ noise levels continuously over the deployment period. The internal clocks on the sound level meters were all synchronized with Greenwich Mean Time (GMT) by the use of a Global Positioning System (GPS) receiver. The exception was for systems 1 and 5 where a measurement duration of 5 minutes was used, and therefore the lowest measured value each 10 minute was retained as a precautionary measure. The clock on the LIDAR wind sensor from which wind data was subsequently collected for the analysis of the measured background noise as function of wind speed was also set to GMT.

4.3 Measured Background Noise Levels

4.3.1 The ETSU-R-97 assessment method requires noise data to be related to wind speed data at a standardised height of ten metres, with wind speeds either directly measured at a height of ten metres or by calculation from measurement at other heights, the appropriate choice being determined by practitioner judgement and the available data sources. Since the publication of ETSU-R-97, the change in wind speed with increasing height above ground level has been identified as a potential source of variability when carrying out wind farm noise assessments. The effect of site specific wind shear can be appropriately addressed by implementing the ETSU-R-97 option of deriving ten metre height reference data from measurements made at taller heights. It is this method that has been used in the noise assessment for the Proposed Development to account for the potential effect of site-specific wind shear. This method is consistent with the preferred method described in the IOA GPG. Wind speeds were measured on a LIDAR remote wind sensor located within the boundary of the development site (approximate easting and northing 552955 / 669006). Values of wind speed at a standardised height of ten metres were calculated from those measured on the LIDAR ("standardised wind speed"). Full details of the calculation method are given in Annex F.

4.3.2 Figures D1 to D4 reproduced at Annex D show the range of wind conditions experienced during the noise survey period. During the quiet day-time and night-time periods wind speeds were typically of up to 14 m/s. The wind was observed to be directed from the south-west for the majority of the survey period, consistent with the typical prevailing wind direction in Ireland, with some periods of south-easterly winds. The range of conditions and amount of data obtained were in line with IOA GPG requirements.

4.3.3 Figures E1 to E12 of Annex E show the results of the background noise measurements at each of the six noise monitoring locations. The background noise data are presented in terms of $L_{A90,10min}$ background noise levels plotted as a function of standardised ten metre height wind speed. Two plots are shown for each location, one for quiet day-time periods and the other for night-time periods, both derived in accordance with ETSU-R-97.

4.3.4 Data from all survey locations were inspected to identify periods which may have been influenced by extraneous noise sources, giving rise to atypical and elevated levels. ETSU-R-97 requires that any data affected by rainfall be excluded from the analysis. Rain gauges were installed during the noise survey period at locations 2 and 3; data from these gauges were therefore combined and used at all measurement positions to exclude periods where rain was indicated in either of the gauges.

4.3.5 In addition to the impact noise on surrounding vegetation and the sound level meter itself, in some environments rainfall can result in appreciable changes in background sound levels, for example as a result of wet roads which increase tyre noise emissions or dissipating flow noise in water courses and drainage systems. Observations whilst on-site indicated traffic noise to be a generally low or negligible influence on background sound levels, and thus the possible effect of increased tyre noise from wet roads is not considered relevant to this site. In terms of water flow noise, there were no water courses noted in the immediate vicinity of the monitoring locations that were considered likely to strongly influence background noise levels. The monitoring locations were also positioned as far as practically possible from any residential drainage systems to minimise any associated noise influence. Based on the above, rainfall is considered to have a limited effect on background sound levels. Inspection of the data generally tends to support this, given the absence of any identifiable clear data trends that are normally characteristic of a site affected by rain related background sound levels (such as flat clusters of data on the noise versus wind plot, or sharp increases in noise followed by a progressive decrease with time). Periods affected by rainfall were excluded as indicated in Annex C.

4.3.6 The measured background noise data may also have been increased by other extraneous sources or atypical events. Time-histories of the noise levels at each survey location were therefore inspected to look for any atypical relationships when compared to the wind speeds present during that time. Any elevated levels found in this way were excluded. The trend of the data when plotted against wind speed was also inspected to look for atypical relationships or outliers within the data-set (particularly at low wind speeds) which were excluded. Any data removed from the analysis in this way is indicated on the charts as red circles and detailed as 'Data Exclusions' in Annex C for each location. The analysis and filtering of the data was therefore undertaken in accordance with current good practice as set out in the IOA GPG.

4.3.7 Following removal of those data points, best-fit lines were generated using a polynomial fit of a maximum of 3rd order. These lines of best-fit were then used to derive the noise limits required by ETSU-R-97 that apply during the day-time and night-time periods up to 12 m/s. The corresponding ETSU-R-97 noise limits are summarised in Table 4 and Table 5. The noise limits have been set either at the prevailing measured background level plus 5 dB, or at the relevant fixed lower limit, whichever is the greater. The derivation of the relevant fixed lower limit value used for day-time periods (40 dB(A)) is described in a subsequent section. For financially involved locations, the noise limit was increased to a minimum of 45 dB(A).

Table 4 - Day time L_{A90} (dB) noise limits derived from the baseline noise survey - based on a 40 dB(A) lower limit

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
H1	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	48.0	51.3
H2	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H3	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	48.0	51.3
H4	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.1
H5	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H6	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H7	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H8	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H9	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H10	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H11	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.5	45.6	47.8
H12	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H13	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H14	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H15	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H16	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H17	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.5	45.6	47.8
H18	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.5	45.6	47.8

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
H19	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H20	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H21	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H22	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.5	45.6	47.8
H23	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.5	45.6	47.8
H24	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H25	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H26	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H27	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H28	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H29	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H30	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H31	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H32	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H33	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H34	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H35	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H37	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H38	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.0	48.5	51.2
H39	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.5	42.7	44.8	46.9	48.7
H40	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H41	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H42	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H43	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H44	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H45	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H46	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H47	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H48	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H50	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H51	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H52	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H53	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H57	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2
H60	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H72	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H514	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H518	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H520	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.3	44.6	48.0	51.3
H528	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H530	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H547	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.9	45.7	48.6
H606	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	48.0	51.3

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
H612	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.1	42.9	46.1
H616	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.6	43.7	46.0	48.5	51.2

Table 5 - Night time L_{A90} (dB) noise limits derived from the baseline noise survey

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
H1	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.9	49.8
H2	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H3	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.9	49.8
H4	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
H5	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H6	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H7	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H8	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H9	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H10	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H11	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H12	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H13	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H14	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H15	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H16	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H17	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H18	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H19	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H20	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H21	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H22	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H23	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H24	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H25	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H26	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H27	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H28	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H29	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H30	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H31	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H32	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H33	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H34	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H35	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4

INTERNA

Property	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
H37	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H38	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.4
H39	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	45.0
H40	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H41	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H42	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H43	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H44	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H45	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H46	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H47	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H48	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H50	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H51	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H52	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H53	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H57	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4
H60	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H72	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H514	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H518	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H520	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.4	46.9	49.8
H528	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H530	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H547	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.1	46.4
H606	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.9	49.8
H612	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
H616	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.2	46.4

5. Noise Impact Assessment

5.1 Predicted Construction Noise Levels

5.1.1 The level of construction noise that occurs at the surrounding properties will be highly dependent on a number of factors such as the final site programme, equipment types used for each process, and the operating conditions that prevail during construction. It is not practically feasible to specify each and every element of the factors that may affect noise levels, therefore it is necessary to make reasonable allowance for the level of noise emissions that may be associated with key phases of the construction.

5.1.2 In order to determine representative emission levels for this study, reference has been made to the scheduled sound power data provided by BS 5228. Based on experience of the types and number of equipment usually associated with the key phases of constructing a wind farm, the scheduled sound power data has been used to deduce the upper sound emission level over the course of a working day. In determining the rating applicable to the working day, it has generally been assumed that the plant will operate for between 75% and 100% of the working day. In many instances, the plant would actually be expected to operate for a reduced percentage, thus resulting in noise levels lower than predicted in this assessment.

5.1.3 To relate the sound power emissions to predicted noise levels at surrounding properties, the prediction methodology outlined in BS 5228 has been adopted. The prediction method accounts for factors including screening and soft ground attenuation. The size of the site and resulting separation distances to surrounding properties allows the calculations to be reliably based on positioning all the equipment at a single point within a particular working area (for example, in the case of turbine erection, it is reasonable to assume all associated construction plant is positioned at the base of the turbine under consideration). In applying the BS 5228 methodology, it has been conservatively assumed that there are no screening effects, and that the ground cover is characterised as 50% hard / 50% soft.

5.1.4 Table 6 lists the key construction activities, the associated types of plant normally involved, the expected worst-case sound power level over a working day for each activity, the (non-involved) property which would be closest to the activity for a portion of construction, and the predicted noise level. It must be emphasised that these predictions only relate the noise level occurring during the time when the activity is closest to the referenced property. The impacts at properties involved with the projects will be lower in practice so these have not been considered further in this assessment. In many cases such as access track construction and turbine erection, the separating distances will be considerably greater for the majority of the construction period and the predictions are therefore the worst-case periods of the construction phase.

Table 6 - Predicted construction noise levels

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day-Time L_{Aeq}
Upgrade Access Track	excavator / dump trucks / tippers / dozers / vibrating rollers	120	H26	35	81
Construct temporary site compounds	excavator / dump truck / tippers / rollers/ delivery trucks	120	H2	800	51
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	120	H15	50	77
Construct Sub-Station	excavator / concrete truck / delivery truck	110	H6	580	44
Construct crane hardstandings	excavators / dump trucks	120	H2	730	52

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day-Time L_{Aeq}
Construct turbine foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes / water pumps / pneumatic hammers / compressors / vibratory pokers	120	H2	730	52
Excavate and lay site cables	excavators / dump trucks / tractors & cable drum trailers / wacker plates	110	H6	770	41
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	120	H2	730	52
Reinstate crane bases	excavator / dump truck	115	H2	730	47
Reinstate road verges	excavator / dump truck	115	H26	35	76
Forestry felling around turbines and access tracks	Harvesters and forwarders, characterised by saw noise diesel engine noise emissions commonly associated with tractors and excavation noise	115	H6	420	52
Lay grid connection cable to sub-stations	excavators / dump trucks / tractors & cable drum trailers / wacker plates	110	Various	10-100	61-82
Joint Bay / Temporary Pulling Pits	Tracked Excavator / Wheeled Backhoe / Mini Tracked Excavator	105	Various	10-100	56-77

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day $L_{WA,T}$ dB(A)	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day-Time L_{Aeq}
Horizontal Directional Drilling (HDD) works	HDD power unit and drill / HDD generator / Bentonite pump / Bentonite mixer / Generator for Site Offices	115	H49 (554248 / 667171)	70	69

5.1.5 Comparing the above predicted noise levels to the range of background noise levels measured around the Proposed Development suggests that the noisier construction activities would be audible at various times throughout the construction phase. However, comparing the levels of no more than L_{Aeq} 52 dB in the majority of cases) to the significance criteria of Table 1 indicates that the majority of construction activities will have impacts of negligible magnitude.

5.1.6 For activities such as upgrade of an existing track (Western Proposed Development Area) or construction of a new site track (for the Eastern Proposed Development Area), the predicted noise levels are likely to represent those for a very short-term period when activity is closest to the receptor. Noise levels will quickly diminish as track construction/upgrade progresses, moving the activity further from the property. The short-term nature of this activity consequently categorises the impact to be of minor magnitude.

5.1.7 Similarly, other construction activities such as road widening works for turbine component delivery, as well as grid connection works along the existing road network, including construction of joint bays, will involve some localised works of short duration, which will be similar in nature to road maintenance or services connection works. Noise levels will quickly diminish as construction progresses, moving the activity further from the nearest properties. Therefore, this is considered to result in minor impacts at most.

5.1.8 HDD works is likely to be required to cross watercourses in two points, with worst-case predicted levels around 69 dB L_{Aeq}. As this specific activity is likely have a duration of less than 4 weeks for each HDD location, this would correspond to a minor impact based on the criteria of Table 1 based on standard working hours (see below).

5.1.9 In addition to on-site activities, construction traffic passing to and from the site will also represent a potential source of noise to surrounding properties. The traffic assessment for the Proposed Development has identified that the most intensive traffic would likely occur in month 8 of the construction programme. Table 7 presents the projected traffic flows for scenarios with and without the Proposed Development, on the worst-case assumption that there is no HGV in the former scenario and all construction flow are HGV. On this basis, the methodology set out in CRTN has been used to determine the associated maximum total change in the average day-time traffic noise level at any given location due to construction of the Proposed Development: see Table 8.

Table 7 - Projected traffic flows

Road	Without Development		With Development	
	Annual Average Daily Traffic Flow	Heavy Goods Vehicles	Annual Average Daily Traffic Flow	Heavy Goods Vehicles
Site 1	3292	0	3332	25
Site 2	3131	0	3171	25
Site 3	10100	0	10140	25

Road	Without Development		With Development	
	Annual Average Daily Traffic Flow	Heavy Goods Vehicles	Annual Average Daily Traffic Flow	Heavy Goods Vehicles
Site 4	7068	0	7147	7
Site 5	1305	0	1404	7
Site 6	5873	0	5955	21
Site 7	9257	0	9339	14
Site 8	6309	0	6312	49
Site 9	5525	0	5528	65
Site 10	8955	0	8958	55
Site 11 & 12	2298	0	2377	55
Site 13	11736	0	11815	2
Site 14	14049	0	14128	2
Site 15	66018	0	66097	2
Site 15*	37095	0	37174	53

Table 8 - CRTN predicted increase in day time average traffic noise levels ($L_{A10,18hour}$)

Road	Maximum Change in Traffic Noise Level, dB(A)
Site 1	0.1
Site 2	0.1
Site 3	0.1
Site 4	0.1
Site 5	1.3
Site 6	0.3
Site 7	0.2
Site 8	0.3
Site 9	0.0
Site 10	0.0
Site 11 & 12	0.0
Site 13	0.1
Site 14	0.1
Site 15	0.0
Site 15*	0.0

5.1.10 Table 8 indicates a maximum potential increase of 1.3 dB(A) in the day-time average noise level during particular phases of the construction programme at locations adjoining traffic site assessment point 5. At all other locations the predicted increase is less than 0.3 dB(A). Based on the criteria set out in the DMRB (see 3.4.4), the predicted short-term change in traffic noise level would correspond to a negligible to minor impact.

5.1.11 The construction traffic assessment considers that there is a potential for cumulative traffic increases during the construction phase associated with the Fahybeg Onshore Wind Farm, which may result in a doubling of traffic. This would however not change the outcome of the above traffic noise assessment as it would still result in negligible to minor impacts.

5.1.12 In conclusion, noise from most construction activities has been assessed and is predicted to result in a temporary minor impact. This conclusion is based on construction activities generally being limited to the following working hours: from 07:00 to 19:00 on weekdays, and 08:00 to 13:00 on Saturdays.

5.1.13 However, activities that are unlikely to give rise to noise audible at the site boundary may continue outside of the stated hours. Furthermore, turbine deliveries or concrete pours may take place outside these times with the prior consent of the relevant authorities. In addition, good practice measures recommended in BS 5228-1 should be used to minimise construction noise levels.

5.1.14 The potential exception would be HDD drilling: once a bore has been started, it may not be possible to stop until it is completed, due to safety/operational reasons, hence the potential need for some night-time working. Even if this drilling activity is of very short duration (i.e. less than 10 days), this could represent a major impact in the absence of any mitigation measures. The following measures are therefore recommended:

- HDD drilling works to be undertaken during standard day-time hours where possible and completed in the shortest practical timescale.
- Use of Best Practical Means to minimise noise generation at nearest residents, including use of quiet drilling/pumping equipment and/or temporary noise barriers installed around trenchless compounds in order to provide screening for sources located at low heights.
- The closest local residents (within 200m of the HDD works) will be kept informed of the likely period during which the work will take place, the times and durations of planned works, measures that are being taken to avoid unnecessary noise and following completion of the works.

5.1.15 The implementation of these measures is considered likely to reduce the associated impacts to a minor magnitude, considering the likely short duration of the drilling (across a relatively narrow obstacle) and the effect of the control measures proposed.

5.2 Decommissioning Noise

5.2.1 Decommissioning is likely to result in less noise than during construction of the Proposed Development, due to the reduced amount of activity and traffic likely to be involved. Decommissioning will also not involve HDD drilling out of hours. The construction phase has been considered to have minor noise impacts, therefore de-commissioning will, in the worst case, also have minor noise impacts.

5.3 Operational Wind Turbine Emissions Data

5.3.1 Three potential wind turbine models would be suitable for the wind farm with the worst-case noise arising from the Vestas V150-6MW model. The latter was determined to be marginally noisier than the other candidate turbine models considered for the Proposed Development (Nordex N133 and N149 turbines): see 5.3.6 below. The operational noise assessment is therefore based upon the noise specification of the Vestas V150-6 MW wind turbine.

5.3.2 11 turbines have been modelled using the layout as indicated on the map at Annex B. The Vestas V150 wind turbine is a variable speed, pitch-regulated machine with a rotor diameter of 150 metres and a hub height of 105 metres. Due to its variable speed operation the sound power output of the turbine varies considerably with wind speed, being quieter at the lower wind speeds when the blades are rotating more slowly. The Vestas V150 also incorporates the use of Serrated Trailing Edges (or STE), which reduce noise emissions, as standard.

5.3.3 In addition to this general low noise characteristic at lower wind speeds the candidate turbine also incorporates noise control technology. This allows the sound power output of the turbine to be reduced across a range of operational wind speeds, albeit with some loss of electrical power generation, to enable the best compromise to be achieved in any given situation between emitted noise and electrical power generation. Noise control of the candidate turbine is provided in a number of noise control modes with various noise/power output combinations. Similar noise reduction management systems are also offered by other wind turbine manufacturers. These systems are generally similar in that they rely on the turbine's computer based controller adjusting either the pitch of the blades or holding back the rotational speed of the blades to reduce emitted noise under selected wind conditions (direction, speed or some combination of the two). In this manner noise management only comes into play (and therefore potential power generation capacity is only lost) for those conditions under which it is required.

5.3.4 For the purposes of the present assessment the wind turbines on the Proposed Development have been modelled assuming selective use of the Sound Optimised 2 (SO2) noise control mode for turbines 2 and 4: this was determined to result in compliance with the predicted noise levels.

5.3.5 Vestas have supplied specified noise emission data for the V150 turbine. In the absence of specific information about uncertainty allowances in the data, a further correction factor of +2 dB was added to the specification data in line with advice in the IOA GPG. The sound power data has been made available for standardised reference wind speeds of 3 m/s to 12 m/s inclusive[14]. In addition to the overall sound power data, reference has been made to manufacturer information for the unit to derive a representative sound spectrum for the turbine, based on an energetic average of the available information at each octave band. The overall sound power and spectral data are presented in Table B3 and B4 in Annex B.

5.3.6 Tables B5 and B6 in Annex B set out noise emission levels for the Nordex N133 and N149 turbine models. Both models also have STE as standard. Although the overall A-weighted emission levels for the Nordex N133 and N149 appear to be approximately 1 dB noisier than the Vestas V150, once propagation and the spectral characteristics of the turbines are taken into account, the predicted levels from the Vestas V150 are noisier at all wind speeds, as shown in table B7 in Annex B.

5.4 Choice of Wind Farm Operational Noise Propagation Model

5.4.1 The ISO 9613-2 model[15] has been used to calculate the noise immission levels at the selected nearest residential neighbours as advised in the IOA GPG. The model accounts for the attenuation due to geometric spreading, atmospheric absorption, and barrier and ground effects. All attenuation calculations have been made on an octave band basis and therefore account for the sound frequency characteristics of the turbines.

14 ETSU-R-97 guidance considers that wind speeds of 12 m/s and above do not require further consideration.
15 ISO 9613-2:1996 'Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation', International Standards Organisation, 1996.

5.4.2 For the purposes of the present assessment, all noise level predictions have been undertaken using a receiver height of four metres above local ground level, mixed ground (G=0.5) and an air absorption based on a temperature of 10°C and 70% relative humidity. A receiver height of four metres will be typical of first floor windows and result in slightly higher predicted noise levels than if a 1.2 to 1.5 metre receiver height were chosen in the ISO 9613 algorithm. The attenuation due to terrain screening accounted for in the calculations has been limited to a maximum of 2 dB(A). In situations of propagation above concave ground, a correction of +3 dB was added. These propagation factors are shown in Annex B.

5.4.3 This method is consistent with the recommendations of the above-referenced Institute of Acoustics Good Practice Guide which provides recommendations on the appropriate approach when predicting wind turbine noise levels. The IOA GPG also allows for directional effects to be taken into account within the noise modelling: under upwind propagation conditions between a given receiver and the wind farm the noise immission level at that receiver can be as much as 10 dB(A) to 15 dB(A) lower than the level predicted using the ISO 9613-2 model. However, predictions have been made assuming downwind propagation from every turbine to every receptor at the same time as a worst-case.

5.5 Cumulative considerations

5.5.1 The consented Carrownagowan Wind Farm is located approximately 4 km to the north-east from the nearest noise-sensitive locations of Table 3, and therefore it is considered likely that noise levels from that wind farm would be below 25 dB L_{A90} at these properties. Furthermore, these locations would be unlikely to be downwind of all wind turbines at the same time, and therefore would be at least 10 dB lower in the conditions when the receptors in question are downwind from the Proposed Development. On this basis, it can be concluded that the contribution of the Carrownagowan Wind Farm is not acoustically relevant[16]. Similarly, the effect of the Proposed Development at locations closest to the Carrownagowan Wind Farm will be negligible in a similar way. Accordingly, cumulative operational effects from the Carrownagowan Wind Farm will not be considered further within this assessment.

5.5.2 Similarly, the proposed Fahybeg Wind Farm is located approximately 5 km to the east and its contribution at relevant receptors would be negligible and is not considered any further.

5.5.3 Although the application for the Knockshanvo Wind Farm has currently not been submitted (pre-planning stage), a preliminary cumulative noise assessment is presented separately below in section 5.10.

5.6 Predicted Wind Farm Operational Noise Immission Levels

5.6.1 Table 9 shows predicted noise immission levels at each of the selected assessment locations for each wind speed over the range of wind speeds where source noise emission level data are available. All wind farm noise immission levels in this report are presented in terms of the $L_{A90,T}$ noise indicator in accordance with the recommendations of the ETSU-R-97 report, obtained by subtracting 2 dB(A) from the calculated $L_{Aeq,T}$ noise levels based on the turbine sound power levels presented in Annex B.

16 The IOA GPG suggests that cumulative noise effects need not be considered where differences between existing and proposed wind farm noise levels are 10 dB or more. The addition of a noise source 10 dB(A) below that of another theoretically adds 0.4 dB to the total but is not considered to require assessment according to the IOA GPG. Therefore any increase of cumulative total noise levels by 0.4 dB or less is not considered acoustically relevant.

Table 9 - Predicted L_{A90} (dB) wind farm noise immission levels at each of the noise assessment locations as a function of standardised wind speed for the Proposed Development.

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H1	27.6	31.2	35.4	38.3	38.9	39.0	39.0	39.0	39.0	39.0
H2	28.6	32.3	36.5	39.1	39.5	39.6	39.6	39.6	39.6	39.6
H3	26.8	30.4	34.6	37.5	38.1	38.2	38.2	38.2	38.2	38.2
H4	26.3	29.7	34.0	37.5	38.3	38.4	38.4	38.4	38.4	38.4
H5	25.6	29.3	33.4	36.2	36.6	36.7	36.7	36.7	36.7	36.7
H6	27.7	31.2	35.4	38.8	39.5	39.6	39.6	39.6	39.6	39.6
H7	27.7	31.2	35.5	38.8	39.6	39.7	39.7	39.7	39.7	39.7
H8	25.9	29.4	33.6	37.1	37.9	37.9	37.9	37.9	37.9	37.9
H9	25.8	29.5	33.6	36.2	36.6	36.7	36.7	36.7	36.7	36.7
H10	25.3	29.0	33.1	35.9	36.4	36.4	36.4	36.4	36.4	36.4
H11	25.7	29.2	33.5	36.9	37.7	37.8	37.8	37.8	37.8	37.8
H12	25.4	28.8	33.1	36.5	37.3	37.4	37.4	37.4	37.4	37.4
H13	21.4	24.9	29.1	32.6	33.4	33.5	33.5	33.5	33.5	33.5
H14	24.9	28.4	32.6	36.1	36.8	36.9	36.9	36.9	36.9	36.9
H15	25.1	28.5	32.8	36.3	37.1	37.2	37.2	37.2	37.2	37.2
H16	24.5	28.1	32.3	35.1	35.7	35.7	35.7	35.7	35.7	35.7
H17	25.0	28.4	32.7	36.2	36.9	37.0	37.0	37.0	37.0	37.0
H18	24.3	27.7	32.0	35.5	36.3	36.4	36.4	36.4	36.4	36.4
H19	25.7	29.4	33.5	36.2	36.6	36.7	36.7	36.7	36.7	36.7
H20	25.9	29.6	33.7	36.4	36.9	36.9	36.9	36.9	36.9	36.9
H21	24.5	27.9	32.2	35.7	36.5	36.6	36.6	36.6	36.6	36.6
H22	23.9	27.3	31.6	35.1	35.9	36.0	36.0	36.0	36.0	36.0
H23	24.9	28.3	32.6	36.1	36.9	37.0	37.0	37.0	37.0	37.0
H24	23.8	27.4	31.6	34.5	35.0	35.1	35.1	35.1	35.1	35.1
H25	24.1	27.6	31.8	35.2	36.0	36.1	36.1	36.1	36.1	36.1
H26	23.8	27.4	31.6	34.4	35.0	35.1	35.1	35.1	35.1	35.1
H27	26.3	29.9	34.1	36.7	37.2	37.2	37.2	37.2	37.2	37.2
H28	23.8	27.2	31.5	35.0	35.8	35.9	35.9	35.9	35.9	35.9
H29	25.3	29.0	33.1	35.8	36.3	36.3	36.3	36.3	36.3	36.3
H30	23.7	27.3	31.4	34.3	34.9	34.9	34.9	34.9	34.9	34.9
H31	24.0	27.4	31.7	35.2	36.0	36.1	36.1	36.1	36.1	36.1
H32	23.6	27.0	31.3	34.8	35.6	35.7	35.7	35.7	35.7	35.7
H33	23.5	26.9	31.2	34.7	35.5	35.6	35.6	35.6	35.6	35.6
H34	23.4	26.8	31.1	34.6	35.4	35.5	35.5	35.5	35.5	35.5
H35	24.5	28.2	32.3	35.0	35.5	35.6	35.6	35.6	35.6	35.6
H37	22.9	26.3	30.6	34.1	34.9	35.0	35.0	35.0	35.0	35.0
H38	23.2	26.8	30.9	33.9	34.5	34.5	34.5	34.5	34.5	34.5
H39	23.2	26.7	31.0	34.1	34.8	34.9	34.9	34.9	34.9	34.9
H40	22.6	26.0	30.3	33.8	34.6	34.7	34.7	34.7	34.7	34.7
H41	22.6	26.0	30.3	33.8	34.6	34.7	34.7	34.7	34.7	34.7
H42	23.0	26.4	30.7	34.2	35.0	35.1	35.1	35.1	35.1	35.1
H43	23.4	26.8	31.1	34.4	35.2	35.2	35.2	35.2	35.2	35.2
H44	22.8	26.4	30.6	33.6	34.2	34.3	34.3	34.3	34.3	34.3

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H45	22.6	26.0	30.3	33.8	34.6	34.7	34.7	34.7	34.7	34.7
H46	22.1	25.5	29.8	33.3	34.1	34.2	34.2	34.2	34.2	34.2
H47	22.7	26.1	30.4	33.8	34.5	34.6	34.6	34.6	34.6	34.6
H48	22.3	25.7	30.0	33.5	34.3	34.4	34.4	34.4	34.4	34.4
H50	23.0	26.7	30.8	33.6	34.1	34.1	34.1	34.1	34.1	34.1
H51	24.0	27.6	31.8	34.5	35.0	35.0	35.0	35.0	35.0	35.0
H52	23.7	27.4	31.5	34.2	34.7	34.8	34.8	34.8	34.8	34.8
H53	23.6	27.2	31.4	34.1	34.6	34.7	34.7	34.7	34.7	34.7
H57	23.0	26.6	30.8	33.5	34.0	34.1	34.1	34.1	34.1	34.1
H60	21.9	25.3	29.6	33.0	33.8	33.9	33.9	33.9	33.9	33.9
H72	22.4	25.8	30.1	33.3	34.0	34.1	34.1	34.1	34.1	34.1
H514	24.4	28.1	32.2	34.9	35.4	35.4	35.4	35.4	35.4	35.4
H518	26.5	30.1	34.3	36.9	37.4	37.5	37.5	37.5	37.5	37.5
H520	27.7	31.4	35.5	38.0	38.4	38.5	38.5	38.5	38.5	38.5
H528	27.6	31.1	35.3	38.7	39.4	39.5	39.5	39.5	39.5	39.5
H530	27.8	31.2	35.5	38.9	39.6	39.7	39.7	39.7	39.7	39.7
H547	22.8	26.2	30.5	33.9	34.7	34.8	34.8	34.8	34.8	34.8
H606	28.2	31.8	36.0	39.0	39.6	39.7	39.7	39.7	39.7	39.7
H612	24.1	27.5	31.8	35.3	36.1	36.2	36.2	36.2	36.2	36.2
H616	24.5	28.1	32.2	35.2	35.7	35.8	35.8	35.8	35.8	35.8

5.7 Operational noise assessment

5.7.1 Figures E1 to E12 (Annex E) show, for each monitoring location, the calculated wind farm noise immission levels at most relevant noise assessment location, which correspond to those already presented in Table 9 plotted as a function of standardised wind speed.

5.7.2 The calculated noise immission levels are shown overlaid on the day-time and night-time noise limit curves of Table 4 and 5. These limits curves have been derived by calculating best-fit regression lines through the measured background noise data to give the prevailing background noise curve required by ETSU-R-97. The noise limits have then been set either at the prevailing measured background level plus 5 dB or at the relevant fixed lower limit whichever is the greater.

5.7.3 The noise limits assume that the wind turbine noise contains no audible tones. Where tones are present a correction is added to the measured or predicted noise level before comparison with the recommended limits. The audibility of any tones can be assessed by comparing the narrow band level of such tones with the masking level contained in a band of frequencies around the tone called the critical band. The criteria recommendations suggest a tone correction which depends on the amount by which the tone exceeds the audibility threshold and should be included as part of the consent conditions. The turbines to be used for this site, from the three proposed turbine models, will be chosen to ensure that the noise emitted will comply with the relevant noise limits including any tonality corrections.

5.7.4 The assessment (shown in tabular form Table 10 and Table 11) shows that the predicted windfarm noise immission levels meet the noise limits of Tables 4 and 5 under all wind speeds and at all locations. This was based on lower limits of 40 dB and 43 dB for day-time and night-time respectively, with the exception of financially involved properties where a lower noise limit of 45 dB was applied. These predicted noise immission levels have been made assuming worst-case downwind propagation.

Table 10 - Difference between the derived day time noise limits (Table 4) and the predicted L_{A90} (dB) wind farm noise immission levels (Table 9) at each noise assessment location. Negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H1	-17.4	-13.8	-9.6	-6.7	-6.1	-6.0	-6.0	-6.0	-9.0	-12.3
H2	-11.4	-7.7	-3.6	-0.9	-0.5	-0.4	-1.7	-5.0	-8.4	-11.7
H3	-18.2	-14.6	-10.4	-7.5	-6.9	-6.8	-6.8	-6.8	-9.8	-13.1
H4	-18.7	-15.3	-11.0	-7.5	-6.7	-6.6	-6.6	-6.6	-6.6	-7.7
H5	-14.4	-10.7	-6.6	-3.9	-3.4	-4.9	-7.0	-9.3	-11.8	-14.5
H6	-12.3	-8.8	-4.6	-1.2	-0.5	-0.4	-0.6	-3.3	-6.1	-9.0
H7	-12.3	-8.8	-4.5	-1.2	-0.4	-0.3	-0.6	-3.2	-6.0	-8.9
H8	-14.1	-10.7	-6.4	-2.9	-2.2	-2.1	-2.3	-4.9	-7.7	-10.7
H9	-14.2	-10.5	-6.4	-3.8	-3.4	-3.3	-4.6	-7.9	-11.3	-14.6
H10	-14.7	-11.0	-6.9	-4.1	-3.6	-5.2	-7.2	-9.5	-12.0	-14.8
H11	-14.3	-10.9	-6.6	-3.1	-2.3	-2.2	-3.7	-5.7	-7.7	-9.9
H12	-14.7	-11.2	-6.9	-3.5	-2.7	-2.6	-2.9	-5.5	-8.3	-11.2
H13	-18.6	-15.2	-10.9	-7.4	-6.6	-6.5	-6.8	-9.4	-12.2	-15.1
H14	-15.1	-11.6	-7.4	-3.9	-3.2	-3.1	-3.3	-5.9	-8.7	-11.7
H15	-15.0	-11.5	-7.3	-3.8	-3.0	-2.9	-2.9	-2.9	-5.7	-8.9
H16	-15.5	-11.9	-7.7	-4.9	-4.3	-5.9	-7.9	-10.2	-12.8	-15.5
H17	-15.0	-11.6	-7.3	-3.9	-3.1	-3.0	-4.5	-6.5	-8.5	-10.7
H18	-15.7	-12.3	-8.0	-4.5	-3.7	-3.6	-5.2	-7.1	-9.2	-11.4
H19	-14.3	-10.6	-6.5	-3.8	-3.4	-5.0	-7.0	-9.3	-11.8	-14.6
H20	-14.1	-10.4	-6.3	-3.6	-3.1	-3.1	-4.4	-7.7	-11.1	-14.3
H21	-15.5	-12.1	-7.8	-4.3	-3.5	-3.4	-3.4	-3.5	-6.3	-9.5
H22	-16.1	-12.7	-8.4	-4.9	-4.1	-4.0	-5.6	-7.5	-9.6	-11.8
H23	-15.1	-11.7	-7.4	-3.9	-3.1	-3.0	-4.6	-6.5	-8.6	-10.8
H24	-16.2	-12.6	-8.4	-5.5	-5.0	-6.5	-8.6	-10.9	-13.4	-16.1
H25	-15.9	-12.5	-8.2	-4.8	-4.0	-3.9	-4.2	-6.8	-9.6	-12.5
H26	-16.2	-12.6	-8.5	-5.6	-5.0	-6.6	-8.6	-10.9	-13.4	-16.2
H27	-13.8	-10.1	-5.9	-3.3	-2.8	-2.8	-4.1	-7.4	-10.7	-14.0
H28	-16.2	-12.8	-8.5	-5.0	-4.2	-4.1	-4.1	-4.2	-6.9	-10.2
H29	-14.7	-11.0	-6.9	-4.2	-3.7	-3.7	-5.0	-8.3	-11.7	-14.9
H30	-16.4	-12.7	-8.6	-5.7	-5.1	-6.7	-8.7	-11.0	-13.5	-16.3
H31	-16.0	-12.6	-8.3	-4.8	-4.0	-3.9	-3.9	-4.0	-6.8	-10.0
H32	-16.4	-13.0	-8.7	-5.2	-4.4	-4.3	-4.3	-4.4	-7.2	-10.4
H33	-16.5	-13.1	-8.8	-5.3	-4.5	-4.4	-4.4	-4.5	-7.3	-10.5
H34	-16.6	-13.2	-8.9	-5.4	-4.6	-4.5	-4.5	-4.6	-7.4	-10.6
H35	-15.5	-11.8	-7.7	-5.0	-4.5	-6.1	-8.1	-10.4	-12.9	-15.7
H37	-17.1	-13.7	-9.4	-5.9	-5.1	-5.0	-5.0	-5.1	-7.8	-11.1
H38	-21.8	-18.3	-14.1	-11.1	-10.5	-10.5	-10.5	-11.4	-13.9	-16.7
H39	-16.8	-13.3	-9.0	-5.9	-5.2	-5.6	-7.8	-9.9	-12.0	-13.8
H40	-17.4	-14.0	-9.7	-6.2	-5.4	-5.3	-5.3	-5.4	-8.1	-11.4

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H41	-17.4	-14.0	-9.7	-6.2	-5.4	-5.3	-5.3	-5.4	-8.2	-11.4
H42	-17.0	-13.6	-9.3	-5.8	-5.0	-4.9	-4.9	-5.0	-7.8	-11.0
H43	-16.7	-13.2	-8.9	-5.6	-4.9	-4.8	-5.0	-7.6	-10.4	-13.4
H44	-17.2	-13.6	-9.4	-6.4	-5.8	-7.4	-9.4	-11.7	-14.2	-17.0
H45	-17.4	-14.0	-9.7	-6.2	-5.4	-5.3	-5.3	-5.4	-8.1	-11.4
H46	-17.9	-14.5	-10.2	-6.7	-5.9	-5.8	-5.8	-5.9	-8.7	-11.9
H47	-17.4	-13.9	-9.6	-6.3	-5.5	-5.4	-5.6	-8.3	-11.1	-14.0
H48	-17.7	-14.3	-10.0	-6.5	-5.7	-5.6	-5.6	-5.7	-8.5	-11.7
H50	-17.0	-13.3	-9.2	-6.4	-5.9	-7.5	-9.5	-11.8	-14.4	-17.1
H51	-16.0	-12.4	-8.2	-5.5	-5.0	-6.6	-8.6	-10.9	-13.5	-16.2
H52	-16.3	-12.7	-8.5	-5.8	-5.3	-6.9	-8.9	-11.2	-13.7	-16.5
H53	-16.4	-12.8	-8.6	-5.9	-5.4	-7.0	-9.0	-11.3	-13.8	-16.6
H57	-17.0	-13.4	-9.2	-6.5	-6.0	-7.6	-9.6	-11.9	-14.4	-17.2
H60	-18.1	-14.7	-10.4	-7.0	-6.3	-6.2	-6.4	-9.0	-11.8	-14.7
H72	-17.7	-14.2	-9.9	-6.7	-6.0	-5.9	-6.1	-8.8	-11.6	-14.5
H514	-15.6	-12.0	-7.8	-5.1	-4.6	-4.6	-5.9	-9.2	-12.6	-15.8
H518	-13.5	-9.9	-5.7	-3.1	-2.6	-2.6	-3.8	-7.2	-10.5	-13.8
H520	-12.3	-8.6	-4.5	-2.0	-1.6	-1.5	-2.8	-6.1	-9.5	-12.8
H528	-12.4	-9.0	-4.7	-1.3	-0.6	-0.5	-0.7	-3.4	-6.2	-9.1
H530	-12.2	-8.8	-4.5	-1.1	-0.4	-0.3	-0.6	-3.2	-6.0	-8.9
H547	-17.2	-13.8	-9.5	-6.1	-5.3	-5.3	-5.5	-8.1	-10.9	-13.8
H606	-16.8	-13.2	-9.0	-6.0	-5.4	-5.3	-5.3	-5.3	-8.3	-11.6
H612	-15.9	-12.5	-8.2	-4.7	-3.9	-3.8	-3.8	-3.9	-6.6	-9.9
H616	-15.5	-11.9	-7.8	-4.8	-4.3	-5.8	-7.9	-10.1	-12.7	-15.4

Table 11 - Difference between the derived night-time noise limits (table 5) and the predicted L_{A90} (dB) wind farm noise immission levels (Table 9) at each noise assessment location. Negative values indicate the immission level is below the limit

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H1	-17.4	-13.8	-9.6	-6.7	-6.1	-6.0	-6.0	-6.0	-7.9	-10.9
H2	-14.4	-10.7	-6.6	-3.9	-3.5	-3.4	-3.4	-3.8	-7.3	-10.2
H3	-18.2	-14.6	-10.4	-7.5	-6.9	-6.8	-6.8	-6.8	-8.7	-11.6
H4	-18.7	-15.3	-11.0	-7.5	-6.7	-6.6	-6.6	-6.6	-6.6	-6.6
H5	-17.4	-13.7	-9.6	-6.9	-6.4	-6.3	-6.3	-6.3	-7.5	-9.7
H6	-15.3	-11.8	-7.6	-4.2	-3.5	-3.4	-3.4	-3.4	-4.5	-6.8
H7	-15.3	-11.8	-7.5	-4.2	-3.4	-3.3	-3.3	-3.3	-4.5	-6.8
H8	-17.1	-13.7	-9.4	-5.9	-5.2	-5.1	-5.1	-5.1	-6.2	-8.5
H9	-17.2	-13.5	-9.4	-6.8	-6.4	-6.3	-6.3	-6.7	-10.2	-13.1
H10	-17.7	-14.0	-9.9	-7.1	-6.6	-6.6	-6.6	-6.6	-7.8	-10.0
H11	-17.3	-13.9	-9.6	-6.1	-5.3	-5.2	-5.2	-5.2	-5.2	-5.2
H12	-17.7	-14.2	-9.9	-6.5	-5.7	-5.6	-5.6	-5.6	-6.8	-9.1
H13	-21.6	-18.2	-13.9	-10.4	-9.6	-9.5	-9.5	-9.5	-10.6	-12.9

INTERNA

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H14	-18.1	-14.6	-10.4	-6.9	-6.2	-6.1	-6.1	-6.1	-7.2	-9.5
H15	-18.0	-14.5	-10.3	-6.8	-6.0	-5.9	-5.9	-5.9	-5.9	-5.9
H16	-18.5	-14.9	-10.7	-7.9	-7.3	-7.3	-7.3	-7.3	-8.5	-10.7
H17	-18.0	-14.6	-10.3	-6.9	-6.1	-6.0	-6.0	-6.0	-6.0	-6.0
H18	-18.7	-15.3	-11.0	-7.5	-6.7	-6.6	-6.6	-6.6	-6.6	-6.6
H19	-17.3	-13.6	-9.5	-6.8	-6.4	-6.3	-6.3	-6.3	-7.5	-9.7
H20	-17.1	-13.4	-9.3	-6.6	-6.1	-6.1	-6.1	-6.5	-9.9	-12.9
H21	-18.5	-15.1	-10.8	-7.3	-6.5	-6.4	-6.4	-6.4	-6.4	-6.4
H22	-19.1	-15.7	-11.4	-7.9	-7.1	-7.0	-7.0	-7.0	-7.0	-7.0
H23	-18.1	-14.7	-10.4	-6.9	-6.1	-6.0	-6.0	-6.0	-6.0	-6.0
H24	-19.2	-15.6	-11.4	-8.5	-8.0	-7.9	-7.9	-7.9	-9.1	-11.3
H25	-18.9	-15.5	-11.2	-7.8	-7.0	-6.9	-6.9	-6.9	-8.0	-10.3
H26	-19.2	-15.6	-11.5	-8.6	-8.0	-7.9	-7.9	-7.9	-9.1	-11.3
H27	-16.8	-13.1	-8.9	-6.3	-5.8	-5.8	-5.8	-6.2	-9.6	-12.6
H28	-19.2	-15.8	-11.5	-8.0	-7.2	-7.1	-7.1	-7.1	-7.1	-7.1
H29	-17.7	-14.0	-9.9	-7.2	-6.7	-6.7	-6.7	-7.1	-10.5	-13.5
H30	-19.4	-15.7	-11.6	-8.7	-8.1	-8.1	-8.1	-8.1	-9.3	-11.5
H31	-19.0	-15.6	-11.3	-7.8	-7.0	-6.9	-6.9	-6.9	-6.9	-6.9
H32	-19.4	-16.0	-11.7	-8.2	-7.4	-7.3	-7.3	-7.3	-7.3	-7.3
H33	-19.5	-16.1	-11.8	-8.3	-7.5	-7.4	-7.4	-7.4	-7.4	-7.4
H34	-19.6	-16.2	-11.9	-8.4	-7.6	-7.5	-7.5	-7.5	-7.5	-7.5
H35	-18.5	-14.8	-10.7	-8.0	-7.5	-7.5	-7.5	-7.5	-8.7	-10.9
H37	-20.1	-16.7	-12.4	-8.9	-8.1	-8.0	-8.0	-8.0	-8.0	-8.0
H38	-21.8	-18.3	-14.1	-11.1	-10.5	-10.5	-10.5	-10.5	-10.5	-11.9
H39	-19.8	-16.3	-12.0	-8.9	-8.2	-8.1	-8.1	-8.1	-9.2	-10.1
H40	-20.4	-17.0	-12.7	-9.2	-8.4	-8.3	-8.3	-8.3	-8.3	-8.3
H41	-20.4	-17.0	-12.7	-9.2	-8.4	-8.3	-8.3	-8.3	-8.3	-8.3
H42	-20.0	-16.6	-12.3	-8.8	-8.0	-7.9	-7.9	-7.9	-7.9	-7.9
H43	-19.7	-16.2	-11.9	-8.6	-7.9	-7.8	-7.8	-7.8	-8.9	-11.2
H44	-20.2	-16.6	-12.4	-9.4	-8.8	-8.8	-8.8	-8.8	-10.0	-12.2
H45	-20.4	-17.0	-12.7	-9.2	-8.4	-8.3	-8.3	-8.3	-8.3	-8.3
H46	-20.9	-17.5	-13.2	-9.7	-8.9	-8.8	-8.8	-8.8	-8.8	-8.8
H47	-20.4	-16.9	-12.6	-9.3	-8.5	-8.4	-8.4	-8.4	-9.5	-11.8
H48	-20.7	-17.3	-13.0	-9.5	-8.7	-8.6	-8.6	-8.6	-8.6	-8.6
H50	-20.0	-16.3	-12.2	-9.4	-8.9	-8.9	-8.9	-8.9	-10.1	-12.3
H51	-19.0	-15.4	-11.2	-8.5	-8.0	-8.0	-8.0	-8.0	-9.2	-11.4
H52	-19.3	-15.7	-11.5	-8.8	-8.3	-8.2	-8.2	-8.2	-9.4	-11.6
H53	-19.4	-15.8	-11.6	-8.9	-8.4	-8.4	-8.4	-8.4	-9.6	-11.8
H57	-20.0	-16.4	-12.2	-9.5	-9.0	-8.9	-8.9	-8.9	-10.2	-12.4
H60	-21.1	-17.7	-13.4	-10.0	-9.3	-9.2	-9.2	-9.2	-10.3	-12.6
H72	-20.7	-17.2	-12.9	-9.7	-9.0	-8.9	-8.9	-8.9	-10.0	-12.3
H514	-18.6	-15.0	-10.8	-8.1	-7.6	-7.6	-7.6	-8.0	-11.4	-14.4
H518	-16.5	-12.9	-8.7	-6.1	-5.6	-5.6	-5.6	-6.0	-9.4	-12.4
H520	-15.3	-11.6	-7.5	-5.0	-4.6	-4.5	-4.5	-4.9	-8.4	-11.3

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H528	-15.4	-12.0	-7.7	-4.3	-3.6	-3.5	-3.5	-3.5	-4.6	-6.9
H530	-15.2	-11.8	-7.5	-4.1	-3.4	-3.3	-3.3	-3.3	-4.4	-6.7
H547	-20.2	-16.8	-12.5	-9.1	-8.3	-8.3	-8.3	-8.3	-9.4	-11.7
H606	-16.8	-13.2	-9.0	-6.0	-5.4	-5.3	-5.3	-5.3	-7.1	-10.1
H612	-18.9	-15.5	-11.2	-7.7	-6.9	-6.8	-6.8	-6.8	-6.8	-6.8
H616	-18.5	-14.9	-10.8	-7.8	-7.3	-7.2	-7.2	-7.2	-8.4	-10.6

5.7.5 According ETSU-R-97, the lower fixed part of the limit during the day-time should lie within the range from 35 dB(A) to 40 dB(A). The factors to be used to determine where in this range are considered below:

- Number of affected properties: The area immediately north and north-west of the Proposed Development is of very low population density. Whilst there are several properties to the south of the Proposed Development, these would generally be upwind of the proposed turbines under prevailing south-westerly wind conditions.
- Duration and level of exposure: As noted above, many of the properties considered are located south and therefore upwind of the Proposed Development for the majority of the time. Properties located east of the Proposed Development would be exposed to the predicted levels for a larger proportion of the time; however, non-involved properties in this area are predicted to be exposed to levels of 38 dB and less.
- Generation capacity: With a potential generation capacity of more than 50 MW, the proposed development alone represents a large-scale development. In addition, reducing the lower limit applicable during day-time periods would have a substantial impact on the potential generation capacity of the scheme.

5.7.6 Based on the above considerations, and in the context of noise policy in Ireland, it is considered wholly appropriate to set the day-time limit at the upper end of the range, at 40 dB(A).

5.7.7 The selection of the final turbine model to be installed at the site will be made on the basis of enabling the relevant noise limits of Tables 4 and 5 to be achieved at the surrounding properties.

5.8 Low Frequency Noise, Vibration and Amplitude Modulation

5.8.1 Low frequency noise and vibration resulting from the operation of wind farms are issues that have been attracting a certain amount of attention over recent years. Consequently, Annex A includes a detailed discussion of these topics. In summary of the information provided therein, modern turbines do not emit perceptible levels of infrasound and vibration at typical separation distances and therefore this does not require further specific assessment.

5.8.2 Annex A also discusses the subject of wind turbine blade swish Amplitude Modulation (or AM). There is however no definitive planning guidance as to the appropriate assessment of this aspect of wind farm noise in current Irish planning guidelines.

5.9 Substation

5.9.1 The main noise sources associated with the substation are likely to be the power transformers and their cooling fans. The transformer noise is generally fairly constant once energised, whereas the cooling fans operate as needed, depending on load and ambient temperature. The noise from the transformers is usually tonal in nature with most energy contained within discrete frequency components at 100 Hz and harmonics thereof. The cooling fans are likely to be broad-band in nature but switch on and off.

5.9.2 The proposed substation is located approximately 580 m from the nearest non-involved noise-sensitive locations (H6/H7). Based on experience of similar installations, the associated noise levels at these properties is unlikely to be more than 30 dB L_{Aeq} due to separation distances involved. This would be clearly below the most stringent noise limit of 35 dB L_{Aeq} recommended in the NG4 guidance for classified installations, even when accounting for the potential character of the noise source[17]. Therefore, no specific mitigation measures are considered to be required in this instance.

5.10 Preliminary cumulative noise assessment – Knockshanvo Wind Farm

5.10.1 Although not submitted for planning, publicly available information for the Knockshanvo Wind Farm suggests a likely final layout for the turbines: Table B8 in Annex B. This was therefore used as the basis for a preliminary cumulative operational assessment. Although cumulative construction noise was not considered due to the lack of required information about the proposal, it is considered unlikely that additional high magnitude impacts would arise.

5.10.2 Potential noise emissions from the Knockshanvo Wind Farm were therefore modelled on the basis of a Vestas V162 6.8MW candidate turbine, with a hub height of 104 m and tip heights of 185 m as this was considered representative of this cumulative development. Tables B9 and B10 in Annex B set out the noise emission levels for the Vestas V162 6.8MW, determined from manufacturer information in the same way as for the Proposed Development (section 5.3).

5.10.3 Based on the location of the turbines, the schedule of assessment locations in Table 3 is still considered representative of the properties closest to both Developments and potentially most likely to be affected by cumulative noise levels. Table 12 below presents, for at all these locations, the predicted cumulative noise levels including the Knockshanvo Wind Farm and the Proposed Development, based on the assumption described above. These predictions assume that all receptors are downwind of all wind turbines at the same time: therefore, these cumulative noise levels are unlikely to occur in practice.

Table 12 - Predicted cumulative L_{A90} (dB) wind farm noise immission levels at each of the noise assessment locations as a function of standardised wind speed – the Proposed Development and the Knockshanvo Wind Farm.

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H1	28.4	31.7	36.0	38.9	39.4	39.5	39.6	39.6	39.6	39.6
H2	29.2	32.7	36.9	39.6	40.0	40.1	40.1	40.2	40.2	40.2
H3	27.7	30.9	35.2	38.2	38.7	38.8	38.9	38.9	38.9	38.9
H4	29.3	31.8	36.4	39.6	40.2	40.4	40.6	40.7	40.7	40.7
H5	26.4	29.8	34.0	36.7	37.2	37.3	37.4	37.4	37.4	37.4
H6	28.8	31.9	36.2	39.5	40.2	40.3	40.4	40.4	40.4	40.4
H7	28.8	31.9	36.3	39.6	40.2	40.4	40.4	40.5	40.5	40.5
H8	28.9	31.5	36.0	39.2	39.8	40.0	40.2	40.3	40.3	40.3

17 Expected to have a L_{Ar} of 35 dB(A) or lower when accounting for potential characteristics of the source.

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H9	26.5	29.9	34.1	36.7	37.1	37.2	37.3	37.3	37.3	37.3
H10	26.2	29.5	33.7	36.5	36.9	37.1	37.1	37.2	37.2	37.2
H11	26.8	29.9	34.3	37.7	38.4	38.5	38.6	38.6	38.6	38.6
H12	29.3	31.6	36.3	39.4	39.9	40.2	40.4	40.5	40.5	40.5
H13	30.0	31.7	36.6	39.6	39.9	40.3	40.6	40.7	40.7	40.7
H14	28.4	30.8	35.4	38.6	39.1	39.4	39.5	39.6	39.6	39.6
H15	28.5	30.9	35.5	38.7	39.2	39.5	39.7	39.8	39.8	39.8
H16	25.4	28.7	33.0	35.8	36.3	36.4	36.5	36.5	36.5	36.5
H17	26.1	29.1	33.5	36.9	37.6	37.8	37.8	37.9	37.9	37.9
H18	25.7	28.6	33.1	36.4	37.1	37.3	37.4	37.4	37.4	37.4
H19	26.4	29.8	34.0	36.7	37.2	37.3	37.3	37.3	37.3	37.3
H20	26.7	30.0	34.3	37.0	37.4	37.5	37.6	37.6	37.6	37.6
H21	27.9	30.4	35.0	38.2	38.7	39.0	39.1	39.2	39.2	39.2
H22	25.0	28.0	32.4	35.8	36.5	36.7	36.7	36.8	36.8	36.8
H23	26.7	29.5	34.0	37.4	38.0	38.2	38.3	38.3	38.3	38.3
H24	24.8	28.0	32.3	35.2	35.7	35.8	35.9	35.9	35.9	35.9
H25	28.0	30.3	35.0	38.1	38.6	38.9	39.1	39.2	39.2	39.2
H26	24.7	28.0	32.3	35.2	35.7	35.8	35.9	35.9	35.9	35.9
H27	26.9	30.3	34.6	37.3	37.7	37.8	37.8	37.9	37.9	37.9
H28	25.4	28.3	32.7	36.1	36.7	36.9	37.0	37.0	37.0	37.0
H29	26.1	29.4	33.7	36.4	36.8	36.9	37.0	37.0	37.0	37.0
H30	24.6	27.9	32.1	35.0	35.5	35.7	35.7	35.7	35.7	35.7
H31	25.7	28.6	33.0	36.4	37.0	37.2	37.3	37.3	37.3	37.3
H32	25.1	28.0	32.4	35.8	36.5	36.6	36.7	36.7	36.7	36.7
H33	24.9	27.9	32.3	35.7	36.3	36.5	36.6	36.6	36.6	36.6
H34	24.8	27.7	32.2	35.5	36.2	36.4	36.5	36.5	36.5	36.5
H35	25.3	28.7	32.9	35.6	36.1	36.2	36.2	36.3	36.3	36.3
H37	24.2	27.2	31.6	35.0	35.7	35.9	35.9	36.0	36.0	36.0
H38	24.3	27.5	31.8	34.7	35.2	35.4	35.4	35.5	35.5	35.5
H39	27.4	29.7	34.4	37.4	37.8	38.1	38.3	38.4	38.4	38.4
H40	24.0	27.0	31.4	34.8	35.5	35.6	35.7	35.7	35.7	35.7

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H41	23.9	26.9	31.3	34.7	35.4	35.5	35.6	35.6	35.6	35.6
H42	25.9	28.5	33.0	36.3	36.8	37.1	37.2	37.3	37.3	37.3
H43	25.8	28.5	33.0	36.2	36.7	36.9	37.0	37.1	37.1	37.1
H44	24.1	27.2	31.5	34.5	35.0	35.2	35.3	35.3	35.3	35.3
H45	24.8	27.5	32.1	35.4	36.0	36.2	36.3	36.3	36.3	36.3
H46	27.7	29.8	34.5	37.6	38.0	38.4	38.6	38.7	38.7	38.7
H47	27.2	29.4	34.1	37.2	37.6	37.9	38.1	38.2	38.2	38.2
H48	26.8	29.0	33.7	36.8	37.3	37.6	37.8	37.9	37.9	37.9
H50	24.0	27.3	31.5	34.3	34.7	34.8	34.9	34.9	34.9	34.9
H51	24.8	28.1	32.4	35.1	35.6	35.7	35.8	35.8	35.8	35.8
H52	24.6	27.9	32.1	34.9	35.3	35.5	35.5	35.5	35.5	35.5
H53	24.5	27.8	32.0	34.8	35.2	35.3	35.4	35.4	35.4	35.4
H57	23.9	27.2	31.4	34.2	34.6	34.8	34.8	34.9	34.9	34.9
H60	26.8	29.0	33.7	36.8	37.2	37.5	37.7	37.8	37.8	37.8
H72	24.4	27.2	31.6	34.8	35.3	35.5	35.6	35.7	35.7	35.7
H514	25.2	28.5	32.8	35.5	35.9	36.0	36.1	36.1	36.1	36.1
H518	27.2	30.6	34.8	37.5	37.9	38.0	38.0	38.1	38.1	38.1
H520	28.2	31.7	35.9	38.5	38.9	39.0	39.0	39.0	39.0	39.0
H528	28.7	31.8	36.2	39.4	40.1	40.2	40.3	40.3	40.3	40.3
H530	28.9	31.9	36.3	39.6	40.3	40.4	40.5	40.5	40.5	40.5
H547	27.3	29.6	34.2	37.4	37.8	38.1	38.3	38.4	38.4	38.4
H606	29.0	32.2	36.5	39.6	40.1	40.3	40.3	40.3	40.3	40.3
H612	25.7	28.6	33.0	36.4	37.0	37.2	37.3	37.4	37.4	37.4
H616	25.5	28.7	33.0	35.9	36.4	36.6	36.6	36.7	36.7	36.7

5.10.4 Tables 13 and 14 below sets out a comparison between the noise limits derived above (Tables 4 and 5) and the predicted cumulative noise levels of Table 12. The assessment set out in these tables shows that the predicted cumulative windfarm noise immission levels meet the derived noise limits under all wind speeds and at all locations during the night-time. During the day-time, the limits are also generally met at all properties with some limited exceptions at some properties (numbered 2, 6, 7, 8, 12, 13, 528, 530) where there is a predicted excess above the noise limit of a maximum of 0.4 dB(A). An excess of 0.4 dB(A) is not acoustically important and is unlikely to be perceptible and would generally be considered negligible. Furthermore, the predictions assume downwind propagation from all turbines which would be unlikely to occur in this manner in reality, given the location of the properties and the turbines considered. On this basis, the cumulative noise levels are likely to be acceptable in practice.

Table 13 - Difference between the derived day time noise limits (Table 4) and the predicted cumulative L_{A90} (dB) wind farm noise immission levels (Table 12) at each noise assessment location. Negative values indicate the noise immission level is below the limit.

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H1	-13.3	-9.1	-6.1	-5.6	-5.5	-5.4	-5.4	-8.4	-11.7	-13.3
H2	-7.3	-3.1	-0.4	0.0	0.1	-1.2	-4.5	-7.8	-11.1	-7.3
H3	-14.1	-9.8	-6.8	-6.3	-6.2	-6.1	-6.1	-9.1	-12.4	-14.1
H4	-13.2	-8.6	-5.4	-4.8	-4.6	-4.4	-4.4	-4.4	-5.4	-13.2
H5	-10.2	-6.0	-3.3	-2.8	-4.3	-6.3	-8.6	-11.1	-13.9	-10.2
H6	-8.2	-3.8	-0.5	0.2	0.3	0.1	-2.5	-5.3	-8.2	-8.2
H7	-8.1	-3.7	-0.5	0.2	0.4	0.2	-2.4	-5.2	-8.1	-8.1
H8	-8.6	-4.0	-0.8	-0.2	0.0	-0.1	-2.6	-5.4	-8.3	-8.6
H9	-10.1	-5.9	-3.3	-2.9	-2.8	-4.0	-7.3	-10.7	-14.0	-10.1
H10	-10.5	-6.3	-3.5	-3.1	-4.6	-6.6	-8.8	-11.3	-14.1	-10.5
H11	-10.1	-5.7	-2.3	-1.6	-1.5	-3.0	-4.9	-7.0	-9.2	-10.1
H12	-8.4	-3.7	-0.6	-0.1	0.2	0.1	-2.4	-5.2	-8.1	-8.4
H13	-8.3	-3.4	-0.4	-0.1	0.3	0.3	-2.1	-4.9	-7.9	-8.3
H14	-9.2	-4.6	-1.4	-0.9	-0.6	-0.7	-3.3	-6.1	-9.0	-9.2
H15	-9.1	-4.5	-1.3	-0.8	-0.5	-0.3	-0.3	-3.1	-6.3	-9.1
H16	-11.3	-7.0	-4.2	-3.7	-5.2	-7.2	-9.4	-11.9	-14.7	-11.3
H17	-10.9	-6.5	-3.1	-2.4	-2.2	-3.7	-5.6	-7.7	-9.9	-10.9
H18	-11.4	-6.9	-3.6	-2.9	-2.7	-4.2	-6.1	-8.2	-10.4	-11.4
H19	-10.2	-6.0	-3.3	-2.9	-4.4	-6.4	-8.6	-11.1	-13.9	-10.2
H20	-10.0	-5.7	-3.0	-2.6	-2.5	-3.7	-7.0	-10.4	-13.7	-10.0
H21	-9.7	-5.0	-1.8	-1.3	-1.1	-0.9	-0.9	-3.6	-6.9	-9.7
H22	-12.0	-7.6	-4.2	-3.5	-3.3	-4.8	-6.7	-8.8	-11.0	-12.0
H23	-10.5	-6.0	-2.6	-2.0	-1.8	-3.3	-5.2	-7.2	-9.4	-10.5
H24	-12.0	-7.7	-4.8	-4.3	-5.8	-7.8	-10.1	-12.6	-15.3	-12.0
H25	-9.7	-5.0	-1.9	-1.4	-1.1	-1.2	-3.7	-6.5	-9.4	-9.7
H26	-12.0	-7.7	-4.8	-4.4	-5.8	-7.8	-10.1	-12.6	-15.4	-12.0
H27	-9.7	-5.4	-2.8	-2.3	-2.2	-3.5	-6.8	-10.1	-13.4	-9.7

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H28	-11.8	-7.3	-3.9	-3.3	-3.1	-3.0	-3.0	-5.8	-9.0	-11.8
H29	-10.6	-6.3	-3.6	-3.2	-3.1	-4.3	-7.6	-11.0	-14.3	-10.6
H30	-12.2	-7.9	-5.0	-4.5	-6.0	-8.0	-10.2	-12.7	-15.5	-12.2
H31	-11.5	-7.0	-3.6	-3.0	-2.8	-2.7	-2.7	-5.5	-8.7	-11.5
H32	-12.0	-7.6	-4.2	-3.6	-3.4	-3.3	-3.3	-6.1	-9.3	-12.0
H33	-12.1	-7.7	-4.3	-3.7	-3.5	-3.4	-3.4	-6.2	-9.4	-12.1
H34	-12.3	-7.8	-4.5	-3.8	-3.6	-3.6	-3.6	-6.4	-9.6	-12.3
H35	-11.3	-7.1	-4.4	-3.9	-5.5	-7.4	-9.7	-12.2	-15.0	-11.3
H37	-12.8	-8.4	-5.0	-4.3	-4.2	-4.1	-4.1	-6.9	-10.1	-12.8
H38	-17.6	-13.2	-10.3	-9.8	-9.7	-9.6	-10.5	-13.0	-15.8	-17.6
H39	-10.3	-5.6	-2.6	-2.2	-2.4	-4.4	-6.4	-8.5	-10.3	-10.3
H40	-13.0	-8.6	-5.2	-4.6	-4.4	-4.3	-4.3	-7.1	-10.3	-13.0
H41	-13.1	-8.7	-5.3	-4.7	-4.5	-4.4	-4.4	-7.2	-10.4	-13.1
H42	-11.6	-7.0	-3.7	-3.2	-2.9	-2.8	-2.8	-5.6	-8.8	-11.6
H43	-11.6	-7.0	-3.9	-3.3	-3.1	-3.2	-5.8	-8.6	-11.5	-11.6
H44	-12.8	-8.5	-5.5	-5.0	-6.5	-8.4	-10.7	-13.2	-15.9	-12.8
H45	-12.5	-8.0	-4.6	-4.0	-3.8	-3.7	-3.7	-6.5	-9.7	-12.5
H46	-10.2	-5.5	-2.4	-2.0	-1.7	-1.4	-1.3	-4.1	-7.3	-10.2
H47	-10.6	-5.9	-2.8	-2.4	-2.1	-2.1	-4.6	-7.4	-10.4	-10.6
H48	-11.0	-6.3	-3.2	-2.7	-2.4	-2.2	-2.2	-5.0	-8.2	-11.0
H50	-12.7	-8.5	-5.7	-5.3	-6.8	-8.8	-11.0	-13.6	-16.3	-12.7
H51	-11.9	-7.6	-4.9	-4.4	-5.9	-7.9	-10.2	-12.7	-15.5	-11.9
H52	-12.1	-7.9	-5.1	-4.7	-6.2	-8.2	-10.4	-12.9	-15.7	-12.1
H53	-12.2	-8.0	-5.2	-4.8	-6.3	-8.3	-10.5	-13.1	-15.8	-12.2
H57	-12.8	-8.6	-5.8	-5.4	-6.9	-8.8	-11.1	-13.6	-16.4	-12.8
H60	-11.0	-6.3	-3.2	-2.9	-2.5	-2.6	-5.1	-7.9	-10.8	-11.0
H72	-12.8	-8.4	-5.2	-4.7	-4.5	-4.6	-7.2	-10.0	-12.9	-12.8
H514	-11.5	-7.2	-4.5	-4.1	-4.0	-5.2	-8.5	-11.9	-15.2	-11.5
H518	-9.5	-5.2	-2.5	-2.1	-2.0	-3.3	-6.6	-9.9	-13.2	-9.5
H520	-8.3	-4.1	-1.5	-1.2	-1.1	-2.3	-5.6	-9.0	-12.3	-8.3
H528	-8.2	-3.9	-0.6	0.1	0.2	0.0	-2.5	-5.3	-8.3	-8.2

INTERNA

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H530	-8.1	-3.7	-0.4	0.3	0.4	0.2	-2.4	-5.2	-8.1	-8.1
H547	-10.5	-5.8	-2.7	-2.2	-1.9	-2.0	-4.5	-7.3	-10.2	-10.5
H606	-12.8	-8.5	-5.4	-4.9	-4.8	-4.7	-4.7	-7.7	-10.9	-12.8
H612	-11.4	-7.0	-3.6	-3.0	-2.8	-2.7	-2.7	-5.5	-8.7	-11.4
H616	-11.3	-7.0	-4.1	-3.6	-5.1	-7.0	-9.3	-11.8	-14.6	-11.3

Table 14 - Difference between the derived night-time noise limits (table 5) and the predicted cumulative L_{A90} (dB) wind farm noise immission levels (Table 12) at each noise assessment location. Negative values indicate the immission level is below the limit

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H1	-13.3	-9.1	-6.1	-5.6	-5.5	-5.4	-5.4	-7.3	-10.2	-13.3
H2	-10.3	-6.1	-3.4	-3.0	-2.9	-2.9	-3.3	-6.7	-9.7	-10.3
H3	-14.1	-9.8	-6.8	-6.3	-6.2	-6.1	-6.1	-8.0	-10.9	-14.1
H4	-13.2	-8.6	-5.4	-4.8	-4.6	-4.4	-4.4	-4.4	-4.4	-13.2
H5	-13.2	-9.0	-6.3	-5.8	-5.7	-5.7	-5.6	-6.8	-9.0	-13.2
H6	-11.2	-6.8	-3.5	-2.8	-2.7	-2.6	-2.6	-3.7	-6.0	-11.2
H7	-11.1	-6.7	-3.5	-2.8	-2.7	-2.6	-2.6	-3.7	-6.0	-11.1
H8	-11.6	-7.0	-3.8	-3.2	-3.0	-2.8	-2.8	-3.9	-6.2	-11.6
H9	-13.1	-8.9	-6.3	-5.9	-5.8	-5.7	-6.1	-9.5	-12.5	-13.1
H10	-13.5	-9.3	-6.5	-6.1	-5.9	-5.9	-5.9	-7.1	-9.3	-13.5
H11	-13.1	-8.7	-5.3	-4.6	-4.5	-4.4	-4.4	-4.4	-4.4	-13.1
H12	-11.4	-6.7	-3.6	-3.1	-2.8	-2.6	-2.5	-3.7	-6.0	-11.4
H13	-11.3	-6.4	-3.4	-3.2	-2.7	-2.4	-2.3	-3.4	-5.7	-11.3
H14	-12.2	-7.6	-4.4	-3.9	-3.7	-3.5	-3.4	-4.5	-6.8	-12.2
H15	-12.1	-7.5	-4.3	-3.8	-3.5	-3.3	-3.2	-3.2	-3.2	-12.1
H16	-14.3	-10.0	-7.2	-6.7	-6.6	-6.5	-6.5	-7.7	-9.9	-14.3
H17	-13.9	-9.5	-6.1	-5.4	-5.2	-5.2	-5.1	-5.1	-5.1	-13.9
H18	-14.4	-9.9	-6.6	-5.9	-5.7	-5.6	-5.6	-5.6	-5.6	-14.4
H19	-13.2	-9.0	-6.3	-5.9	-5.7	-5.7	-5.7	-6.9	-9.1	-13.2
H20	-13.0	-8.7	-6.0	-5.6	-5.5	-5.5	-5.9	-9.3	-12.3	-13.0
H21	-12.7	-8.0	-4.8	-4.3	-4.1	-3.9	-3.8	-3.8	-3.8	-12.7
H22	-15.0	-10.6	-7.2	-6.5	-6.3	-6.3	-6.2	-6.2	-6.2	-15.0
H23	-13.5	-9.0	-5.6	-5.0	-4.8	-4.7	-4.7	-4.7	-4.7	-13.5
H24	-15.0	-10.7	-7.8	-7.3	-7.2	-7.1	-7.1	-8.3	-10.5	-15.0
H25	-12.7	-8.0	-4.9	-4.4	-4.1	-4.0	-3.9	-5.0	-7.3	-12.7
H26	-15.0	-10.7	-7.8	-7.4	-7.2	-7.2	-7.1	-8.3	-10.5	-15.0
H27	-12.7	-8.4	-5.8	-5.3	-5.2	-5.2	-5.6	-9.0	-12.0	-12.7
H28	-14.8	-10.3	-6.9	-6.3	-6.1	-6.0	-6.0	-6.0	-6.0	-14.8
H29	-13.6	-9.3	-6.6	-6.2	-6.1	-6.0	-6.4	-9.9	-12.8	-13.6
H30	-15.2	-10.9	-8.0	-7.5	-7.4	-7.3	-7.3	-8.5	-10.7	-15.2

Property	Standardised 10 m Wind Speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
H31	-14.5	-10.0	-6.6	-6.0	-5.8	-5.7	-5.7	-5.7	-5.7	-14.5
H32	-15.0	-10.6	-7.2	-6.6	-6.4	-6.3	-6.3	-6.3	-6.3	-15.0
H33	-15.1	-10.7	-7.3	-6.7	-6.5	-6.4	-6.4	-6.4	-6.4	-15.1
H34	-15.3	-10.8	-7.5	-6.8	-6.6	-6.6	-6.5	-6.5	-6.5	-15.3
H35	-14.3	-10.1	-7.4	-6.9	-6.8	-6.8	-6.7	-8.0	-10.2	-14.3
H37	-15.8	-11.4	-8.0	-7.3	-7.2	-7.1	-7.0	-7.0	-7.0	-15.8
H38	-17.6	-13.2	-10.3	-9.8	-9.7	-9.6	-9.5	-9.5	-11.0	-17.6
H39	-13.3	-8.6	-5.6	-5.2	-4.9	-4.7	-4.6	-5.7	-6.6	-13.3
H40	-16.0	-11.6	-8.2	-7.6	-7.4	-7.3	-7.3	-7.3	-7.3	-16.0
H41	-16.1	-11.7	-8.3	-7.7	-7.5	-7.4	-7.4	-7.4	-7.4	-16.1
H42	-14.6	-10.0	-6.7	-6.2	-5.9	-5.8	-5.7	-5.7	-5.7	-14.6
H43	-14.6	-10.0	-6.9	-6.3	-6.1	-6.0	-5.9	-7.0	-9.3	-14.6
H44	-15.8	-11.5	-8.5	-8.0	-7.8	-7.8	-7.7	-8.9	-11.1	-15.8
H45	-15.5	-11.0	-7.6	-7.0	-6.8	-6.7	-6.7	-6.7	-6.7	-15.5
H46	-13.2	-8.5	-5.4	-5.0	-4.7	-4.4	-4.3	-4.3	-4.3	-13.2
H47	-13.6	-8.9	-5.8	-5.4	-5.1	-4.9	-4.8	-5.9	-8.2	-13.6
H48	-14.0	-9.3	-6.2	-5.7	-5.4	-5.2	-5.1	-5.1	-5.1	-14.0
H50	-15.7	-11.5	-8.7	-8.3	-8.2	-8.1	-8.1	-9.3	-11.5	-15.7
H51	-14.9	-10.6	-7.9	-7.4	-7.3	-7.3	-7.2	-8.4	-10.6	-14.9
H52	-15.1	-10.9	-8.1	-7.7	-7.6	-7.5	-7.5	-8.7	-10.9	-15.1
H53	-15.2	-11.0	-8.2	-7.8	-7.7	-7.6	-7.6	-8.8	-11.0	-15.2
H57	-15.8	-11.6	-8.8	-8.4	-8.2	-8.2	-8.1	-9.4	-11.6	-15.8
H60	-14.0	-9.3	-6.2	-5.9	-5.5	-5.3	-5.2	-6.3	-8.6	-14.0
H72	-15.8	-11.4	-8.2	-7.7	-7.5	-7.4	-7.3	-8.4	-10.7	-15.8
H514	-14.5	-10.2	-7.5	-7.1	-7.0	-6.9	-7.3	-10.7	-13.7	-14.5
H518	-12.5	-8.2	-5.5	-5.1	-5.0	-5.0	-5.4	-8.8	-11.8	-12.5
H520	-11.3	-7.1	-4.5	-4.2	-4.1	-4.0	-4.4	-7.8	-10.8	-11.3
H528	-11.2	-6.9	-3.6	-2.9	-2.8	-2.7	-2.7	-3.8	-6.1	-11.2
H530	-11.1	-6.7	-3.4	-2.8	-2.6	-2.5	-2.5	-3.6	-5.9	-11.1
H547	-13.5	-8.8	-5.7	-5.2	-4.9	-4.7	-4.6	-5.7	-8.0	-13.5
H606	-12.8	-8.5	-5.4	-4.9	-4.8	-4.7	-4.7	-6.5	-9.5	-12.8
H612	-14.4	-10.0	-6.6	-6.0	-5.8	-5.7	-5.7	-5.7	-5.7	-14.4
H616	-14.3	-10.0	-7.1	-6.6	-6.4	-6.4	-6.3	-7.6	-9.8	-14.3

5.10.5 Satisfactory control of cumulative noise immission levels would be achieved through enforcement of individual consent limits for each of the individual wind farms. These specific limits would be determined by splitting the total noise limit (tables 4 and 5 above) into individual parts such that each wind farm could operate within their respective noise limits. These specific limits would need to be determined following submission of the planning application for the Knockshanvo Wind Farm. The resulting partial noise limits would be such that compliance of the Proposed Development and the Knockshanvo Wind Farm with their respective noise limits would maintain the conclusion of the cumulative assessment and result in cumulative levels which do not exceed the derived cumulative noise criteria.

6. Summary of Key Findings and Conclusions

6.1.1 This report has presented an assessment of the impacts of construction and operational noise from the Proposed Development on the residents of nearby dwellings.

6.1.2 Several residential properties lying around the wind farm have been selected as being representative of the closest located properties to the wind farm. Noise assessments have been undertaken at these properties by comparing predicted construction and operational noise levels with relevant assessment criteria. In the case of construction noise, relevant assessment criteria are in the form of absolute limit values derived from a range of environmental noise guidance. In relation to operational noise, the limits have been derived from the existing background noise levels at six surrounding properties, as derived from measurements made over approximately 4 to 5 weeks at each location.

6.1.3 The construction noise assessment has determined that associated levels are expected to be audible at various times throughout the construction programme, but remain with acceptable limits such that their temporary impacts are considered of minor magnitude.

6.1.4 Decommissioning is likely to result in less noise than during construction of the Proposed Development. The construction phase has been considered to have minor noise impacts, therefore decommissioning will, in the worst case, also have minor noise impacts.

6.1.5 Operational noise from the wind farm has been assessed in accordance with the criteria set out in the 2006 Irish Wind Energy Development Guidelines (WEDG), supplemented by more detailed UK guidelines. This provides a robust basis for assessing the operational noise of a wind farm.

6.1.6 Applying the derived noise limits at the assessment locations it has been demonstrated that both the day-time and night-time noise criterion limits can be satisfied at all properties across all wind speeds. This outcome may be achieved through use of turbine constraints applied to some of the proposed development turbines. Specifically, this assessment has determined that a day-time lower 40 dB(A) noise limit is achievable for the proposed development, considering cumulative noise effects. This assessment has been based on the use of the manufacturer's warranted sound power data for the Vestas V150-6 MW wind turbine, which is typical of the upper end of the noise emission levels for the range of turbine models which may be installed. In addition, worst-case downwind propagation was assumed.

6.1.7 Operational noise from the substation complies with the requirements of the relevant NG4 guidelines.

6.1.8 In summary, the overall levels of construction and decommission noise are considered to represent a minor impact. At some locations under some wind conditions and for a certain proportion of the time, the wind farm operational noise may be audible; however, operational noise immission levels comply with the criteria of the guidance commended by planning policy for the assessment of wind farm noise.

Annex A - General Approach to Noise Assessment & Glossary

A.1. Some sound, such as speech or music, is desirable. However, desirable sound can turn into unwanted noise when it interferes with a desired activity or when it is perceived as inappropriate in a particular environment.

A.2. When assessing the effects of sound on humans there are two equally important components that must both be considered: the physical sound itself, and the psychological response of people to that sound. It is this psychological component which results in those exposed differentiating between desirable sound and unwanted noise. Any assessment of the effects of sound relies on a basic appreciation of both these components. This Annex provides an overview of these topics. A glossary of acoustic terminology is included at the end of this Annex.

A.3. The assessment of environmental noise can be best understood by considering physical sound levels separately from the likely effects that these physical sound levels have on people, and on the environment in general.

A.4. Physical sound is a vibration of air molecules that propagates away from the source. As acoustic energy (carried by the vibration back and forth of the air molecules) travels away from the source of the acoustic disturbance it creates fluctuating positive and negative acoustic pressures in the atmosphere above and below the standing atmospheric pressure. For most types of sound normally encountered in the environment these acoustic pressures are extremely small compared to the atmospheric pressure. When acoustic pressure acts on any solid object it causes microscopic deflections in the surface. For most types of sound normally encountered in the environment these deflections are so small they cannot physically damage the material. It is only for the very highest energy sounds, such as those experienced close to a jet engine for example, that any risk of physical damage exists. For these reasons, most sound is essentially neutral and has no cumulative damaging physical effect on the environment. The effects of environmental sound are therefore limited to its effects on people or animals.

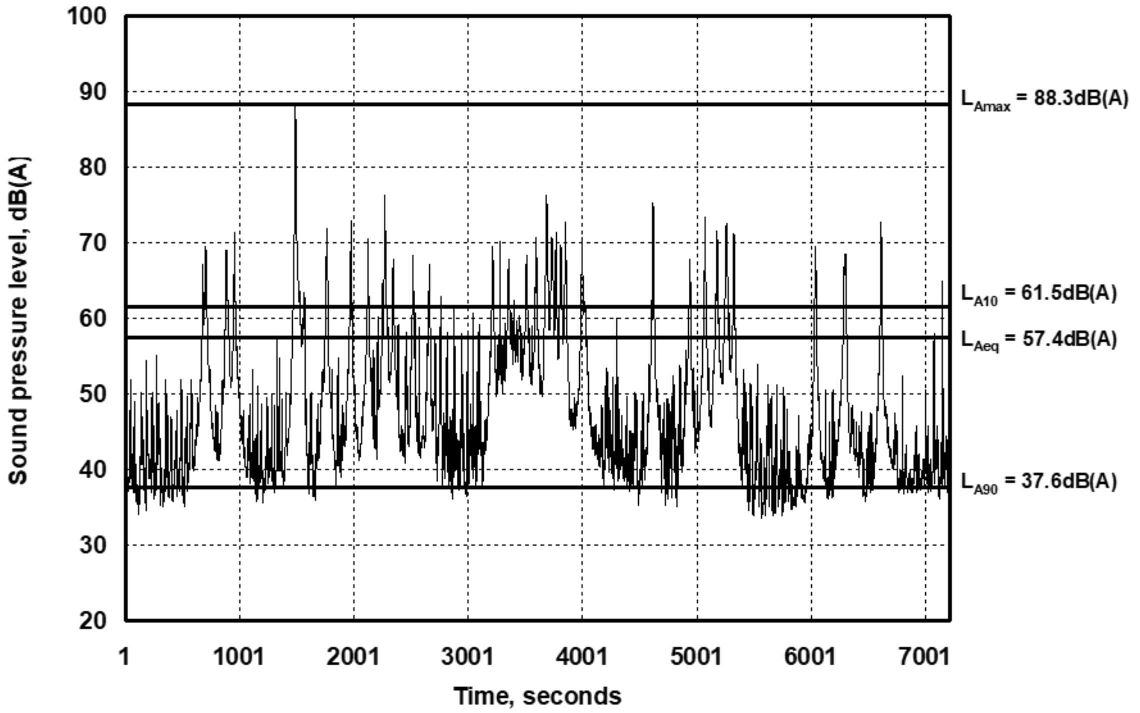
A.5. Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

Indicators of physical sound levels

A.6. Physical sound is measured using a sound level meter. A sound level meter comprises two basic elements: a microphone which responds in sympathy with the acoustic pressure fluctuations and produces an electrical signal that is directly related to the incident pressure fluctuations, and a meter which converts the electrical signal generated by the microphone into a decibel reading. Figure A1 shows an example of the time history of the decibel readout from a sound level meter located approximately 50 metres from a road. The plot covers a total time period of approximately 2 hours. The peaks in the sound pressure level trace correspond to the passage of individual vehicles past the measurement location.

A.7. Assigning a single value to the time varying sound pressure level presented in Figure A1 is clearly not straightforward, as the sound pressure level varies by over 50 dB with time. To overcome this, the measurement characteristics of sound level meters can be varied to emphasise different features of the sound that are thought to be most relevant to the effect under consideration.

Figure A1 Sample plot of the sound pressure level measured close to a road over a period of approximately two hours.



Objective measures of noise

A.8. The primary purpose of measuring environmental noise is to assess its effects on people. Consequently, any sound measuring device employed for the task should provide a simple readout that relates the objectively measured sound to human subjective response. To achieve this, the instrument must, as a minimum, be capable of measuring sound over the full range detectable by the human ear.

A.9. Perceived sound arises from the response of the ear to sound waves travelling through the air. Sound waves comprise air molecules oscillating in a regular and ordered manner about their equilibrium position. The speed of the oscillations determines the frequency, or pitch, of the sound, whilst the amplitude of oscillations governs the loudness of the sound. A healthy human ear is capable of detecting sounds at all frequencies from around 20 Hz to 20 kHz over an amplitude range of approximately 1,000,000 to 1. Even relatively modest sound level meters are capable of detecting sounds over this range of amplitudes and frequencies, although the accuracy limits of sound level meters vary depending on the quality of the unit. When undertaking measurements of wind turbine noise, as with all other noise measurements, it is important to select a measurement system that possesses the relevant accuracy tolerances and is calibrated to a matching standard.

A.10. Whilst measurement systems exist that are capable of detecting the range of sounds detected by the human ear, the complexities of human response to sound make the derivation of a likely subjective response from a simple objective measure a non-trivial problem. Not only does human response to sound vary from person to person, but it can also depend as much on the activity and state of mind of an individual at the time of the assessment, and on the 'character' of the sound, as it can on the actual level of the sound. In practice, a complete range of responses to any given sound may be observed. Thus, any objective measure of noise can, at best, be used to infer the average subjective response over a sample population.

Sound levels and decibels

A.11. Because of the broad amplitude range covered by the human ear, it is usual to quantify the magnitude of sound using the decibel scale. When the amplitude of sound pressure is expressed using decibels (dB) the resultant quantity is termed the sound pressure level. Sound pressure levels are denoted by a capital 'L', as in L dB. The conversion of sound pressure from the physical quantity of Newton per square metre, or Nm-2, to sound pressure level in dB reduces the range from 0 dB at the threshold of hearing to 120 dB at the onset of pain. Both of these values are derived with respect to the hearing of the average healthy young person.

A.12. Being represented on a logarithmic amplitude scale, the addition and subtraction of decibel quantities does not follow the normal rules of linear arithmetic. For example, two equal sources acting together produce a sound level 3 dB higher than either source acting individually, so 40 dB + 40 dB = 43 dB and 50 dB + 50 dB = 53 dB. Ten equal sound sources acting together will be 10 dB louder than each source operating in isolation. Also, if one of a pair of sources is at least 10 dB quieter than the other, then it will contribute negligibly to the combined noise level. So, for example, 40 dB + 50 dB = 50 dB.

A.13. An increase in sound pressure level of 3 dB is commonly accepted as the smallest change of any subjective significance. An increase of 10 dB is often claimed to result in a perceived doubling in loudness, although the basis for this claim is not well founded. An increase of 3 dB is equivalent to a doubling in sound energy, which is the same as doubling the number of similar sources. An increase of 10 dB is equivalent to increasing the number of similar sources tenfold, whilst an increase of 20 dB requires a hundredfold increase in the number of similar sources and an increase of 30 dB requires a thousand times increase in the number of sources.

Frequency selectivity of human hearing and A-weighting

A.14. Whilst the hearing of a healthy young individual may detect sounds over a frequency range extending from less than 20 Hz to greater than 20 kHz, the ear is not equally sensitive at all frequencies. Human hearing is most sensitive to sounds containing frequency components lying within the range of predominant speech frequencies from around 500 Hz to 4000 Hz. Therefore, when relating an objectively measured sound pressure level to subjective loudness, the frequency content of the sound must be accounted for.

A.15. When measuring sound with the aim of assessing subjective response, the frequency selectivity of human hearing is accounted for by down-weighting the contributions of lower and higher frequency sounds to reduce their influence on the overall reading. This is achieved by using an 'A'-weighting filter. Over the years, the A-weighting has become internationally standardised and is now incorporated into the majority of environmental noise standards and regulations in use around the world to best replicate the subjective response of the human ear. A-weighting filters are also implemented as standard on virtually all sound measurement systems.

A.16. Sound pressure levels measured with the A-weighting filter applied are referred to as 'A weighted' sound pressure levels. Results from such measurements are denoted with a subscripted capital A after the 'L' level designation, as in 45 dB LA, or alternatively using a bracketed 'A' after the 'dB' decibel designation, as in 45 dB(A).

Temporal variation of noise and noise indices

A.17. The simple A-weighted sound pressure level provides a snapshot of the sound environment at any given moment in time. However, as is adequately demonstrated by Figure A1, this instantaneous sound level can vary significantly over even short periods of time. A single number indicator is therefore required that best quantifies subjective response to time varying environmental noise, such as that shown in Figure A1. The question thus arises as to how temporal variations in level should be accounted for. This is most often achieved in practice by selecting a representative time period and calculating either the average noise level over that time period or, alternatively, the noise level exceeded for a stated proportion of that time period, as discussed below.

Equivalent continuous sound level, $L_{Aeq,T}$

A.18. The equivalent continuous sound level, or $L_{Aeq,T}$ averages out any fluctuations in level over time. It is formally defined as the level of a steady sound which, in a stated time period 'T' and at a given location, has the same sound energy as the time varying sound. The $L_{Aeq,T}$ is a useful 'general' noise index that has been found to correlate well with subjective response to most types of environmental noise.

A.19. The equivalent continuous sound level is expressed $L_{Aeq,T}$ in dB, where the A–weighting is denoted by the subscripted 'A', the use of the equivalent continuous index is denoted by the subscripted 'eq', and the subscripted 'T' refers to the time period over which the averaging is performed. So, for example, 45 dB $L_{Aeq,1hr}$ indicates that A-weighted equivalent continuous noise level measured over a one hour period was 45 dB.

A.20. The disadvantage of the equivalent continuous sound level is that it provides no information as to the temporal variation of the sound. For example, an $L_{Aeq,1hr}$ of 60 dB could result from a sound pressure level of 60 dB(A) continuously present over the whole hour's measurement period, or it could arise from a single event of 96 dB(A) lasting for just 1 second superimposed on a continuous level of 30 dB(A) which exists for the remaining 59 minutes and 59 seconds of the hour long period. Clearly, the subjective effect of these two apparently identical situations (if one were to rely solely on the L_{Aeq} index) could be quite different.

A.21. The aforementioned feature can produce problems where the general ambient noise level is relatively low. In such cases the $L_{Aeq,T}$ can be easily 'corrupted' by individual noisy events. Examples of noisy events that often corrupt $L_{Aeq,T}$ noise measurements in situations of low ambient noise levels include birdsong or a dog bark local to a noise monitoring point, or an occasional overflying aircraft or a sudden gust of wind. This potential downside to the use of $L_{Aeq,T}$ as a general measurement index is of particular relevance to the assessment of ambient noise in quiet environments, such as those typically found in rural areas where wind farms are developed.

A.22. Despite these shortcomings in low noise environments, the $L_{Aeq,T}$ index is increasingly becoming adopted as the unit of choice for both UK and European guidance and legislation, although this choice is often as much for reasons of commonality between standards as it is for overriding technical arguments. In the Government's current planning policy guidance notes the $L_{Aeq,T}$ noise level is the index of choice for the general assessment of environmental noise. This assessment is undertaken separately for day time ($L_{Aeq,16hr}$ 07:00 to 23:00) and night time ($L_{Aeq,8hr}$ 23:00 to 07:00) periods. However, it is often the case for quiet environments, or for non-steady noise environments, that more information than can be gleaned from the $L_{Aeq,T}$ index may be required to fully assess potential noise effects.

Maximum, L_{Amax}, and percentile exceeded sound level, $L_{An,T}$

A.23. Figure A1 shows, superimposed on the time varying sound pressure level trace and in addition to the $L_{Aeq,T}$ noise level, examples of three well established measurement indices that are commonly used in the assessment of environmental noise impacts. These are the maximum sound pressure level, L_{Amax}, the 90 percentile sound pressure level, $L_{A90,T}$ and the ten percentile sound pressure level, $L_{A10,T}$.

A.24. The $L_{Amax,F}$ readings is suited to indicating the physical magnitude of the single individual sound event that reaches the maximum level over the measurement period, but it gives no indication of the number of individual events of a similar level that may have occurred over the time period.

A.25. Unlike the $L_{Aeq,T}$ index and the $L_{Amax,F}$ indices, percentile exceeded sound levels, percentage exceeded sound levels provide some insight into the temporal distribution of sound level throughout the averaging period. Percentage exceeded sound levels are defined as the sound level exceeded by a fluctuating sound level for n% of the time over a specified time period, T. They are denoted by $L_{An,T}$ in dB, where 'n' can take any value between 0% and 100%.

A.26. The $L_{A10,T}$ and $L_{A90,T}$ indices are the most commonly encountered percentile noise indices used in the UK.

A.27. The 10%'ile index, or $L_{A10,T}$ provides a measure of the sound pressure level that is exceeded for 10% of the total measurement period. It therefore represents the typical upper level of sound associated with specific events, such as the passage of vehicles past the measurement point. It is the traditional index adopted for road traffic noise. This index is useful because traffic noise is not usually constant, but rather it fluctuates with time as vehicles drive past the receptor location. The $L_{A10,T}$ therefore characterises the typical level of peaks in the noise as vehicles drive past, rather than the lulls in noise between the vehicles.

A.28. The $L_{A90,T}$ noise index is the noise level exceeded for 90% of the time period, T. It provides an estimate of the level of continuous background noise, in effect performing the inverse task of the $L_{A10,T}$ index by detecting the lulls between peaks in the noise. It is for this reason that the $L_{A90,T}$ noise index is the favoured unit of measurement for wind farm noise where, for the reasons discussed above, the generally low $L_{Aeq,T}$ noise levels are easily corrupted by intermittent sounds such as those produced by livestock, agricultural vehicles or the occasional passing vehicle on local roads. The $L_{A90,T}$ noise level represents the typical lower level of sound that may be reasonably expected to be present for the majority (90%) of the time in any given environment. This is usually referred to as the 'background' noise level.

Temporal variations outside the noise index averaging periods, 'T'

A.29. Averaging noise levels over the time period 'T' of the $L_{Aeq,T}$ and $L_{An,T}$ noise indices can successfully account for variations in noise over the time period, T. Some variations, however, exhibit trends over longer periods. At larger distances from noise sources meteorological factors can significantly affect received noise levels. At a few hundred metres from a constant level source of noise the potential variation in noise levels may be greater than 15 dB(A). To account for this variability consideration must be taken of meteorological conditions, particularly wind direction, when measurements and predictions are undertaken. As a general rule, when compared with the received noise level under neutral wind conditions, wind blowing from the source to the receiver can slightly enhance the noise level at the receiver (typically by no more than 3 dB(A)), but wind blowing from the receiver to the source can very significantly reduce the noise level at the receiver (typically by 15 dB(A) or more).

A.30. A similar effect occurs under conditions of temperature inversion, such as may exist after sunset when radiative cooling from the ground lowers the temperature of the air lying at low level more quickly than the air at higher levels, by loss of temperature through convective effects. This results in the air temperature increasing with increasing height above the ground. Depending on the source to receiver distance relative to the heights of the source and receiver, this situation can lead to sound waves becoming 'trapped' in the layer of air lying closest to the ground. The consequence is that noise levels at receptor locations can increase relative to those experienced under conditions of a neutral temperature gradient or a temperature lapse. The maximum increases compared to neutral conditions are similar to those experienced under downwind conditions of no more than around 3 dB(A). It is also worth noting that temperature lapse conditions, which is the more usual situation where temperature decreases with increasing height, can result in reductions in noise level at receptor locations by 15 dB(A) or more compared with the neutral conditions. The similarity between the magnitude of potential variations in noise levels for wind induced and temperature induced effects is not surprising, as the physical mechanisms behind the variations in level are the same for both situations: both variations result from changes in the speed of sound as a function of height above local ground level.

A.31. Temperature inversions on very still days can also affect noise propagation over much larger distances of several kilometres. These effects can produce higher than expected noise levels even at these very large distances from the source. A classic example that many people have experienced is the distant, usually inaudible, railway train that suddenly sounds like it is passing within a few hundred metres of a dwelling. However, these situations must generally be considered as rare exceptions to the usually encountered range of noise propagation conditions, especially in the case of wind farm noise as they rely on calm wind conditions under which wind turbines do not operate.

Effects of sound on people

A.32. Except at very high peak acoustic pressures, the energy levels in most environmental sounds are too low to cause any physical disruption in any part of the body, just as they are too low to cause any direct physical damage to the environment. The main effects of environmental sound on people are therefore limited to possible interference with specific activities or to some kind of annoyance response. Some researchers have claimed statistical associations between environmental noise and various long term health effects such as clinical hypertension or mental health problems, although there is no consensus on possible causative mechanisms. Evidence in support of health effects other than annoyance and some indicators of sleep disturbance is weak. However, the theory that psychological stress caused by annoyance might contribute to adverse health effects in otherwise susceptible individuals seems plausible. Health effects in the 'more usual' definition of physiological health therefore remain as a theoretical possibility which has neither been proved nor disproved. However, the World Health Organisation (WHO) defines health in the wider context of:

> *'a state of complete physical, mental and social well-being and not merely the absence of infirmity'.*

And within this wider context potential health effects of environmental noise are summarised by the World Health Organisation as:

- interference with speech communications;
- sleep disturbance;
- disturbance of concentration;
- annoyance; and
- social and economic effects.

Speech interference

A.33. The instantaneous masking effects of unwanted noise on speech communication can be predicted with some accuracy by using specialist methods of calculation, but the overall effect of a small amount of speech interference on everyday life is harder to judge. The significance of speech masking depends on the context in which it occurs. For example, isolated noise events could interfere with telephone conversations by masking out particular words or parts of words but, because of the high redundancy in normal speech, the masking of individual words can often have no significant effect on the intelligibility of the overall message. Notwithstanding the above, noise levels from wind farms at even the closest located dwellings in otherwise quiet environments are usually no more than around 30 dB(A) indoors, even with windows open. This internal noise level is 5 dB(A) below the 35 dB(A) suggested by the World Health Organisation as the lowest potential cut-on level for issues relating to speech intelligibility.

Sleep disturbance

A.34. Although sleep seems to be a fundamental requirement for humans, the most significant effect of sleep loss seems to be increased sleepiness the next day. Sleep normally follows a regular cyclic pattern from awake through light sleep to deep sleep and back, this cycle repeating several times during the night at around 90 minute intervals. Most people wake for short periods several times every night as part of the normal sleep cycle without necessarily being aware of this the next day. REM, or rapid eye movement, sleep is associated with dreaming and occurs several times each night during the lighter sleep stages.

A.35. Electroencephalography (EEG) and similar techniques can be used to detect transient physiological responses to noise at night. Transient responses can be detected by short bursts of activity in the recorded waveforms which often settle back down to the same pattern as immediately before the event. Sometimes a transient response will be the precursor of a definite lightening of sleep, or even of an awakening, but often no discernible physical event happens at all.

A.36. These results suggest that at least parts of the auditory system remain fully operational even while the listener is asleep. The main purpose of this seems to be to arouse the listener in case of danger or in case some particular action is required which cannot easily be accomplished whilst remaining asleep. On the other hand, the system appears to be designed to filter out familiar sounds which experience suggests do not require any action. A very loud sound is likely to overcome the filtering mechanism and wake the listener, while intermediate and quieter sounds might only wake a listener who has a particular focus on those specific sounds. There is no evidence that the transient physiological responses to noise whilst asleep are anything other than normal. There is also considerable anecdotal evidence that people habituate to familiar noise at night, although some of the research evidence on this point is contradictory.

A.37. There is no consensus on how much sleep disturbance is significant. Some authorities take a precautionary approach, under which any kind of physiological response to noise is considered important, irrespective of whether there are any next day effects or not. Other studies suggest that transient physiological responses to unfamiliar stimuli at night are merely an indication of normal function and do not need to be considered as adverse effects unless they contribute to significant next-day effects. Recent World Health Organisation guidelines based mainly on laboratory studies suggest indoor limit values of 30 dB L_{Aeq} and 45 dB L_{Afmax} to avoid sleep disturbance, while other studies carried out in-situ, where habituation to the noise in question may have occurred, have found that much higher levels can be tolerated without any noticeable ill-effects.

Noise annoyance

A.38. Noise annoyance describes the degree of ‘unwantedness’ of a particular sound in a particular situation. People’s subjective response to noise can vary from not being bothered at all, through a state of becoming aware of the noise, right through to the point of becoming annoyed by the noise when it reaches a sufficiently high level. There is no statutory definition of noise annoyance.

A.39. Numerous noise annoyance surveys carried out over the last three decades have attempted to establish engineering relationships between the amount of noise measured objectively using sound level meters and the amount of community annoyance determined from questionnaires. The chief outcome of ‘reported annoyance’ has been measured using a very large range of different ideas. Both the wording of any questionnaire used and the context in which the question is put, and the manner in which it is therefore interpreted by respondents, can be very important. Some researchers are developing standardised questionnaire formats to encourage greater comparability between different studies, but this does not address the possibility of different contextual effects.

A.40. Notwithstanding these problems, there is a general consensus that average reported annoyance increases with aggregate noise level in long term static situations. However, there has been comparatively little research and consequently no real agreement on the effects of change. Some studies have found that even small changes in noise level can have unexpectedly large consequences on reported annoyance, while others have found the opposite. The most likely explanation for these apparent discrepancies is that underlying or true annoyance depends on many non-acoustic factors in addition to noise level alone, and that the extent to which reported annoyance actually represents underlying annoyance can be highly dependent on context. As a consequence, attempts to find a common relationship across all noise sources and listening situations have generally floundered. This task has been complicated by the great range of individual sensitivities to noise observed in the surveys, often affected as much by attitude as by noise level.

A.41. Whether or not an exposed individual has a personal interest in a given sound often has a significant bearing on their acceptance of it. For example, if recipients gain benefit from an association with the sound producer, or if they accept that the sound is necessary and largely unavoidable, then they are likely to be more tolerant of it. This is often the case even if they don’t necessarily consider it desirable. A good example of this is road traffic noise which is the dominant noise heard by over 90% of the population but results in relatively few complaints.

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A.42. Notwithstanding the fact that attitudes may be as important as overall levels in determining the acceptance of a particular noise, there still remains a need to objectively quantify any changes in noise level. Whilst it may not be possible to attribute a particular degree of annoyance to a given noise level, an objective measure of noise that bears some relationship to annoyance is still useful. This objective measure enables an assessment of the effect of changes to be assessed on the basis that any reduction in overall noise level must be beneficial. Possible noise mitigation measures form a central consideration of any noise assessment, so an appropriate methodology must be adopted for assessing the effectiveness of any noise mitigation measures adopted.

A.43. When assessing the potential effects of any new source of noise, it is common practice to compare the A-weighted 'specific' noise level produced by the new source (usually measured using the $L_{Aeq,T}$ index) against the existing A-weighted 'background' noise level measured using the $L_{A90,T}$ index, as this is the typical level of noise that can be reasonably expected to be present the majority of the time to potentially 'mask' the new 'specific' noise. The assessment is therefore undertaken within the context of the existing noise environment. In some circumstances, it may prove equally instructive to compare the absolute level of a new specific noise against accepted absolute levels defined in standards or other relevant documents. The assessment is therefore undertaken against benchmark values, rather than against the context of the existing noise environment. Whatever approach is actually adopted for final assessment purposes, and often a combination of the two approaches is appropriate, it is important that the relevance of both contextual and benchmark assessments is at least considered in all cases.

A.44. Table 4.1 of the 2000 WHO Guidelines for Community Noise presents guideline benchmark values for environmental noise levels in specific environments. The noise levels relevant to residential dwellings are listed here in Table A1.

Table A1 Relevant extracts from 'Table 4.1 - Guideline Values for Community Noise in Specific Environments'

Specific Environment	Critical Health Effects	$L_{Aeq,T}$	Time base (hrs)	L_{Amax} (dB)
Outdoor living area	Serious annoyance, day time and evening	55	16	-
	Moderate annoyance, day time and evening	50	16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, day time and evening	35*	16	-
	Sleep disturbance, night time	30*	8	45*
Outside bedrooms	Sleep disturbance, window open (outdoors)	45	8	60
School class rooms (included for potential effects on concentration) indoors	Speech intelligibility, disturbance of information extraction, message communication	35*	-	-

** N.B. the highlighted guideline values relate to internal noise levels within the relevant rooms, and corresponding external noise levels, even with windows open, would be at least 10 to 15dB (A) higher.*

A.45. The text accompanying the Table in the WHO Guidelines explains that the levels given in the Table are set at the lowest levels at which the onset of any adverse health due to exposure to noise has been identified. The text continues:

> *'These are essentially values for the onset of health effects from noise exposure. It would have been preferred to establish guidelines for exposure-response relationships. Such relationships would indicate the effects to be expected if standards were set above the WHO guideline values and would facilitate the setting of standards for sound pressure levels (noise immission standards)'.*

A.46. More recently, Environmental Noise Guidelines for the European Region (2018) were published and include general recommendations for wind turbine noise. However, they are designed to inform policy on noise, at the population and strategic level. They are based on the Lden noise indicator, which requires knowledge of the noise levels experienced over the course of a full year. This type of noise index is more suitable for general strategic studies and not appropriate for assessing the acceptability of noise produced by any specific development. Furthermore, these guidelines do not provide recommendations for indoor noise levels and the 2000 WHO Guidelines for Community Noise remain applicable in this regard. For these reasons, the 2018 guidelines will not be referenced any further.

A.47. In addition to consideration of the absolute A-weighted level of a new specific source of noise, other properties of the noise can heighten its potential effects when introduced into an existing background noise environment. Such properties of noise are commonly referred to as 'acoustic features' or the 'acoustic character'. These acoustic features can set apart the new source of noise from naturally occurring sounds. Commonly encountered acoustic features associated with transport and machinery sources, for example, can include whistles, whines, thumps, impulses, regular or irregular modulations, high levels of low frequency sound, rumbling, etc.

A.48. Due to the potential of acoustic features to increase the effects of a noise over and above the effects that would result from an otherwise 'bland' broad band noise of the same A-weighted noise level, it is common practice to add a 'character correction' to the specific noise level before assessing its potential effects. The resulting character corrected specific noise level is often referred to as the 'rated' noise level. Such character corrections usually take the form of adding a number of decibels to the physically measured or calculated noise level of the specific source. Typical character corrections are around +5 dB(A), although the actual correction depends on the subjective significance of the particular feature being accounted for.

A.49. The objective identification and rating of acoustic features can introduce a requirement to analyse sound in greater detail than has thus far been discussed. To this point all discussion has focussed on the use of the overall A-weighted noise level. This single figure value is derived by summing together all the acoustic energy present in the signal across the entire audible spectrum from around 20 Hz to 20,000 Hz, albeit with the lower and higher frequency contributions down-weighted in accordance with the A-weighting filter characteristics to account for the reduced sensitivity of the human ear at these frequencies.

A.50. However, in order to identify the presence of tones (which are concentrations of acoustic energy over relatively small bands of frequency), or in order to identify excessive levels of low frequency noise, it may be necessary to determine the acoustic energy present in the noise signal across much smaller frequency bands. This is where the concept of octave band analysis, fractional (e.g. 1/3, 1/12, 1/24) octave band analysis, or even narrow band Fast Fourier Transform (FFT) analysis is introduced. The latter enables signals to be resolved in frequency bandwidths of down to 1 Hz or even less, thereby enabling tonal content to be more easily identified and measured. As standard, noise emission data for wind turbines is supplied as octave band data, with narrow band tests also being undertaken to establish the presence of any tones in the radiated noise spectrum.

Low frequency noise and vibration – wind farms

A.51. One issue that has increasingly been raised concerning potential noise effects of operational wind farms relates not to the overall noise levels, but to the specific issue of low frequency sound. However, confusion sometimes arises from the use of the generalised term 'low frequency sound' to describe specific effects that may, or sometimes may not, actually relate the low frequency character of the sound itself.

A.52. In this respect, there are three distinct characteristics of sound that should be clearly differentiated between:

- Low frequency sound in the range from around 20 Hz to 200 Hz, which therefore lies within the commonly referenced range of human hearing of around 20 Hz to 20,000 Hz;
- Very low frequency sound, or infrasound, below 20 Hz, which therefore lies below the commonly referenced lower frequency limit of human hearing;

- Amplitude modulated sound that characterises the 'swish, swish' sound sometimes heard from rotating wind turbine blades.

A.53. Looking at the first two of the three types of sound referred to in the preceding bullet points, a distinction is usually made between low frequency sound and very low frequency sound, otherwise termed infrasound. This distinction is based on the fact that the frequency range of audible noise is generally taken to be from 20 Hz to 20,000 Hz. Therefore, the range of frequencies from about 20 Hz to 200 Hz is usually taken to cover audible low frequency sound, whereas frequencies below 20 Hz are usually described as infrasound. The implication here is that low frequency sound is audible and infrasound is inaudible. However, this relatively arbitrary distinction between low frequency sound and infrasound can introduce some confusion in that frequencies below 20 Hz can still be heard provided they produce a sound pressure level at the ear of the listener that lies above the threshold of audibility of that listener to sound at that particular frequency.

A.54. The fact that low frequency sound and infrasound from wind farms has been highlighted as a potential problem by some groups does not mean that that the wind energy industry had not previously considered the issue. In fact, the issue of low frequency sound was one of the predominant technical hurdles associated with the some of the earliest larger scale wind turbines installed in the USA. These turbines were of the 'downwind' type, 'downwind' referring here to the fact that the rotor blades were located downwind of the turbine tower rather than upwind of it, as is the case for current machines. It was found that the interruption of wind flow past the tower resulted in a region of lower than average wind speed immediately in the wake of the tower. The passage of the blades into this region of lower wind speed in the wake of the tower, then back into the higher wind speed as they emerged from the wake of the tower back into the main wind stream, resulted in the generation of low frequency sound, often in the subjective form of a distinctive impulse, often referred to as a 'thump' or 'tower thump'. It was for this reason that modern day turbine configurations now have the blades upwind of the tower, as research and measurements demonstrated that low frequency sound radiation is reduced to sub-audible levels once the interaction of downwind tower wake effects with the rotating blades are removed from the design.

A.55. One of the problems inherent in the assessment of both low frequency sound and infrasound is the variability of hearing sensitivity across human subjects with otherwise healthy hearing. This threshold for sound below 200 Hz varies significantly more between different subjects than does the hearing threshold at higher frequencies. However, what is always true is that the perception threshold to lower frequency noise is much higher than the perception threshold for speech frequencies between around 250 Hz to 4,000 Hz. For example, the average person with healthy hearing is some 70 dB less sensitive to sounds at 20 Hz than to sounds that fall within the range of speech frequencies. An additional factor relevant to the perception of infrasound is that, although audibility remains below 20 Hz, tonality is lost below 16 Hz to 18 Hz, thus losing a key element of perception.

A.56. Both low frequency sound and infrasound are generally present all around us in modern life. They may be generated by many natural sources, such as thunder, earthquakes, waves and wind. They may also be produced by machinery including household appliances such as washing machines and air conditioning units, all forms of transport and by turbulence. The presence of low frequency sound and infrasound in our everyday lives is heightened by the fact that the attenuation of sound in air is significantly lower at low frequencies than at the mid to high frequencies. As a result, noise which has travelled over long distances is normally biased towards the low frequencies. However, the fact that human hearing naturally down-weights, or filters out, sounds of such low frequencies means we are generally not aware of its presence. It is only under circumstances when it reaches a sufficiently high level, for example in the 'rumble' of distant thunder or the sound of large waves crashing on a shore, that we become aware of its presence.

A-weighting

A.57. It is because the human ear increasingly filters out sounds of lower frequencies that environmental noise measurements are undertaken as standard using sound level meters that apply the A-weighting curve, as it filters out lower frequency sounds to the same degree as the hearing of a healthy person with unimpaired hearing. The A-weighted sound level is used as a measure of subjective perception of sound unless there exists such a predominance of low frequency sound or infrasound relative to the level of sound at higher frequencies that the use of the A-weighting curve would down-weight the actual source of the problem to such a degree that the resultant objective noise levels do not truly reflect the potential subjective effects of the noise. It is for this reason that a number of alternative weighting curves have been developed, specifically aimed at better accounting for the assessment of low frequency sound and infrasound.

Alternative frequency weightings

A.58. One such curve is denoted C-weighting. Unlike the A weighting curve, which gradually reduces the significance of frequencies below 1000 Hz until at 10 Hz the attenuation is 70 dB, the C-weighting curve is flat to within 1 dB down to about 50 Hz and then drops by 3 dB at 31.5 Hz and 14 dB at 10 Hz. The C weighting curve was originally developed to reflect the fact that, at higher overall noise levels, low frequencies can have a greater subjective effect than at lower overall noise levels.

A.59. One relatively simple measure of undertaking a first-pass assessment as to whether low frequency sound is likely to be an issue is to determine the difference between the overall C weighted noise level and the overall A weighted noise level. The C weighted level includes contributions from low frequency sound, whereas the A weighted level filters it out. It has been suggested in that a level difference of more than 20 dB indicates that low frequency sound may be subjectively significant, but more detailed investigations are in practice required to determine whether or not this is actually the case.

A.60. Another curve, termed the G weighting curve, has been specifically derived to provide a measure of the audibility of infrasound when considered separately from higher frequency noise. The G weighting curve falls off rapidly above 20 Hz and below 20 Hz it follows assumed hearing contours with a slope of 12 dB per octave down to 2 Hz.

Wind-farm infrasound and vibration

A.61. Over the past few years there has been considerable attention paid to the possibility that operational wind farms may radiate sufficiently high levels of infrasound or vibration to cause health problems. Dedicated research investigations have however repeatedly shown this not to be the case.

A.62. As early as 1997 a report by Snow[18] gave details of a comprehensive study of infrasound and low frequency sound (up to around 100 Hz) and vibration measurements made in the vicinity of a wind farm. Measurements were made both on the wind farm site, and at distances of up to 1 kilometre. During the experiments a wide range of wind speeds and directions were recorded. It was found that the vibration levels at 100 metres from the nearest turbine itself were a factor of 10 lower than those recommended for human exposure in the most critical buildings (i.e. laboratories for precision measurements), and lower again than the limits specified for residential premises. A similar comparison with recognised limits for assessing structural damage showed that the measured vibrations were a factor of 100 below the recommended guidelines at 100 metres from the turbines.

A.63. Noise and vibration levels were found to comply with recommended residential criteria even on the wind turbine site itself. Although low level infrasonic (i.e. below 20 Hz) periodic noise from the wind farm was detected by instrumentation at distances up to 1 kilometre, the measuring instruments used were much more sensitive than human hearing. Based on his measurements Snow concluded that subjective detection of the wind turbines may be apparent at this distance, but if this is the case it will be due to higher frequency components (which are more readily masked by general ambient environmental noise) and not the low frequency components which lie below the threshold of audibility.

18 'Low frequency noise and vibration measurements at a modern wind farm', D. Snow, ETSU Report ETSU W/13/00392/REP, 1997

A.64. In 2003, findings on both low frequency sound and infrasound have been compiled into the previously referenced extensive review report commissioned by DEFRA and prepared by Dr G Leventhall[19]. Dr Leventhall notes that despite the numerous published studies there is little or no agreement about the biological effects of infrasound or low frequency sound on human health. Leventhall notes that direct evidence of adverse effects of exposure to low-intensity levels of infrasound (less than 90 dB) is lacking. He goes on to describe the low frequency hearing threshold i.e. the lowest levels which are audible to an average person with normal hearing. He notes the threshold at 4 Hz is about 107 dB, at 10 Hz it is about 97 dB and at 20 Hz it is 79 dB. As such, high levels of infrasound are required to exceed the hearing thresholds at such low frequencies. Leventhall therefore concluded that most people can be reassured that there will be no serious consequences to peoples' health from infrasound exposure.

A.65. Indeed, specifically in relation to wind farms and infrasound, Leventhall went further still with his statement of reassurance. This additional reassurance followed the voicing of concerns by some interested parties that, because infrasound and very low frequency vibrations could be measured from wind farms, then it must follow that these were a potential hazard and source of annoyance. In fact what those concerned observers failed to account for is that highly sensitive electronic measuring equipment designed solely to detect such infrasonic sounds and vibrations is orders of magnitude more sensitive than even the most sensitive human. Thus, whilst such measurement systems may be able to detect such low-level phenomena, the same stimuli can have no effect on humans. Typical levels of infrasound produced by a wind turbine at representative separation distances would not exceed 70 dB, and clearly below the perception thresholds discussed above. In the light of this, Leventhall issued an open statement:

> *'I can state quite categorically that there is no significant infrasound from current designs of wind turbines. To say that there is an infrasound problem is one of the hares which objectors to wind farms like to run. There will not be any effects from infrasound from the turbines'.*

A.66. In 2004/2005 researchers from Keele University investigated the effects of the extremely low levels of vibration resulting from wind farms on the operation of a seismic array installed at Eskdalemuir in Scotland. This is one of the most sensitive ground-borne vibration detection stations in the world. The results of this study were initially misinterpreted, as just discussed for the DEFRA/Leventhall report, in that if infrasonic vibrations from wind farms can be measured, then they must consequentially have some potential effect on humans. In order to clarify their position, the authors subsequently explained[20] that:

> *'The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect'.*

A.67. They then continue:

> *'Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise – they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health'.*

A.68. In relation to airborne infrasound as opposed to ground-borne vibrations, the researchers are equally robust in their conclusions, stating:

> *'The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect low frequency sound. There is no scientific evidence to suggest that infrasound [at such an extremely low level] has an impact on human health'.*

19 'A review of published research on low frequency noise and its effects', G. Leventhall, report for DEFRA, 2003
20 'Wind farm noise', P. Styles, letter by Prof P Styles and S Toon printed in The Scotsman, August 2005.

A.69. In 2006, the results of a study specifically commissioned by the UK Department of Trade and industry (DTI) to look at the effects of infrasound and low frequency noise (LFN) arising from the operation of wind farms have been published in what is commonly referred to as the DTI LFN Report[21]. This Report is quite categorical in its findings: infrasound is not the perceived health threat suggested by some observers, nor should it even be considered a potential source of disturbance. Quoting from the Executive Summary to the DTI LFN Report:

> *'Infrasound noise emissions from wind turbines are significantly below the recognised threshold of perception for acoustic energy within this frequency range. Even assuming that the most sensitive members of the population have a hearing threshold which is 12 dB lower than the median hearing threshold, measured infrasound levels are well below this criterion.*
>
> *The document "Community Noise" prepared for the World Health Organisation, states that "there is no reliable evidence that infrasound below the hearing threshold produce physiological or psychological effects". Other detection mechanisms of infrasound only occur at levels well above the threshold of audibility.*
>
> *It may therefore be concluded that infrasound associated with modern wind turbines is not a source which will result in noise levels which may be injurious to the health of a wind farm neighbour'.*

A.70. This has been subsequently confirmed by many international studies and reviews. For example, a study for the National Institute for Public Health and the Environment (RIVM) in the Netherlands[22] published in 2020 concluded in this regard that:

> *'Although low frequency sound and infrasound might have other effects than 'normal' sound has, these effects are highly unlikely at sound levels typical for wind turbines. Brain studies show that low frequency and infrasound are processed in the same parts of the brain as 'normal' sound and there is no evidence that infrasound elicits any reaction at sub-audible levels.'*

A.71. In conclusion, whilst is known that infrasound can have an adverse effect on people (potential adverse health impacts are listed by the World Health Organisation as stress, irritation, unease, fatigue, headache, possible nausea and disturbed sleep), these effects can only come into play when the infrasound reaches a sufficiently high level. This is a level above the threshold of audibility. However, all available information from measurements on current wind turbines reveals that the level of infrasound emitted by these wind turbines lies below the threshold of human perception.

Low frequency sound

A.72. A report prepared for DEFRA by Casella Stanger[23] lists wind farms as a possible source of audible low frequency sound (20 Hz to 200 Hz). However, this is one possible source in a list of many commonly encountered sources such as pumps, boilers, fans, road, sea and rail traffic, the wind, thunder, the sea, etc. The report only considers the general issues associated with low frequency sound and makes no attempt to quantify the potential problem associated with each of these sources. This is in contrast to other reports which have considered the specific situation associated with wind farms.

A.73. In respect of low frequency sound as opposed to infrasound, the DTI LFN Report identified that wind farm noise levels at the studied properties were, under certain conditions, measured at a level just above the threshold of audibility. The report therefore concluded that 'for a low frequency sensitive person, this may mean that low frequency sound associated with the operation of the three wind farms could be audible within a dwelling'. This conclusion was, however, placed into some context with the qualifying statement that 'at all measurement sites, low frequency sound associated with traffic

21 'The measurement of low frequency noise at three UK wind farms', M. Hayes, DTI Report W/45/00656/00, 2006
22 Health effects related to wind turbine sound: an update, I. van Kamp, G.P. van den Berg, National Institute for Public Health and the Environment (RIVM), RIVM report 2020-0150, October 2020.
23 'Low frequency noise', Report by Casella Stanger for DEFRA, 2001.

movements along local roads has been found to be greater than that from the neighbouring wind farm'. In particular, it was concluded that, although measurable and under some conditions may be audible, levels of low frequency sound were below permitted night time low frequency sound criteria, including the latest UK criteria resulting from the 2003 DEFRA study into the effects of low frequency sound.

A.74. Based on the findings of the DTI LFN Report, low frequency sound in the greater than 20 Hz frequency range may, under some circumstances, be measured to be of a comparable or higher level than the threshold of audibility. On such occasions this low frequency sound may become audible to low frequency sensitive persons who may already be awake inside nearby properties, but not to the degree that it will cause awakenings. However, such noise should still be assessed for its potential subjective effects in the conventional manner in which environmental noise is generally assessed. In particular, the subjective effects of this audible low frequency sound should not be confused with the claimed adverse health effect arguments concerning infrasound which, in any event, have now been shown from the results of the DTI LFN Report to be wholly unsubstantiated.

A.75. In November 2006, the UK Government released a statement[24] concerning low frequency sound, reiterating the conclusion of the DTI LFN report that:

> *'there is no evidence of health effects arising from infrasound or low frequency sound generated by wind turbines'.*

A.76. The Government statement concluded the position regarding low frequency sound from wind farms with the definitive advice to all English Local Planning Authorities and the Planning Inspectorate that PPS22 and ETSU-R-97 should continue to be followed for the assessment of noise from wind farms.

Blade swish (amplitude modulation)

A.77. The noise assessment methodology presented in ETSU-R-97, sets out noise limits which already account for typically encountered levels of blade swish. Notwithstanding the conclusions and advice presented in the preceding paragraphs concerning both infrasound and low frequency sound, the DTI LFN Report went on to suggest that, where complaints of noise at night had occurred, these had most likely resulted from an increased amplitude modulation of the blade passing noise, making the 'swish, swish, swish' sound (often referred to as 'blade swish') more prominent than normal.

A.78. Since then, this aspect of wind turbine noise has become the subject of several research projects in the UK and abroad in the past years and the state of knowledge on the subject is still evolving. In Ireland, however, there is currently no fixed guidelines on the assessment of AM from wind farms.

24 'Advice on Findings of the Hayes McKenzie Report on Noise Arising from Wind Farms', URN 06/2162 (November 2006).

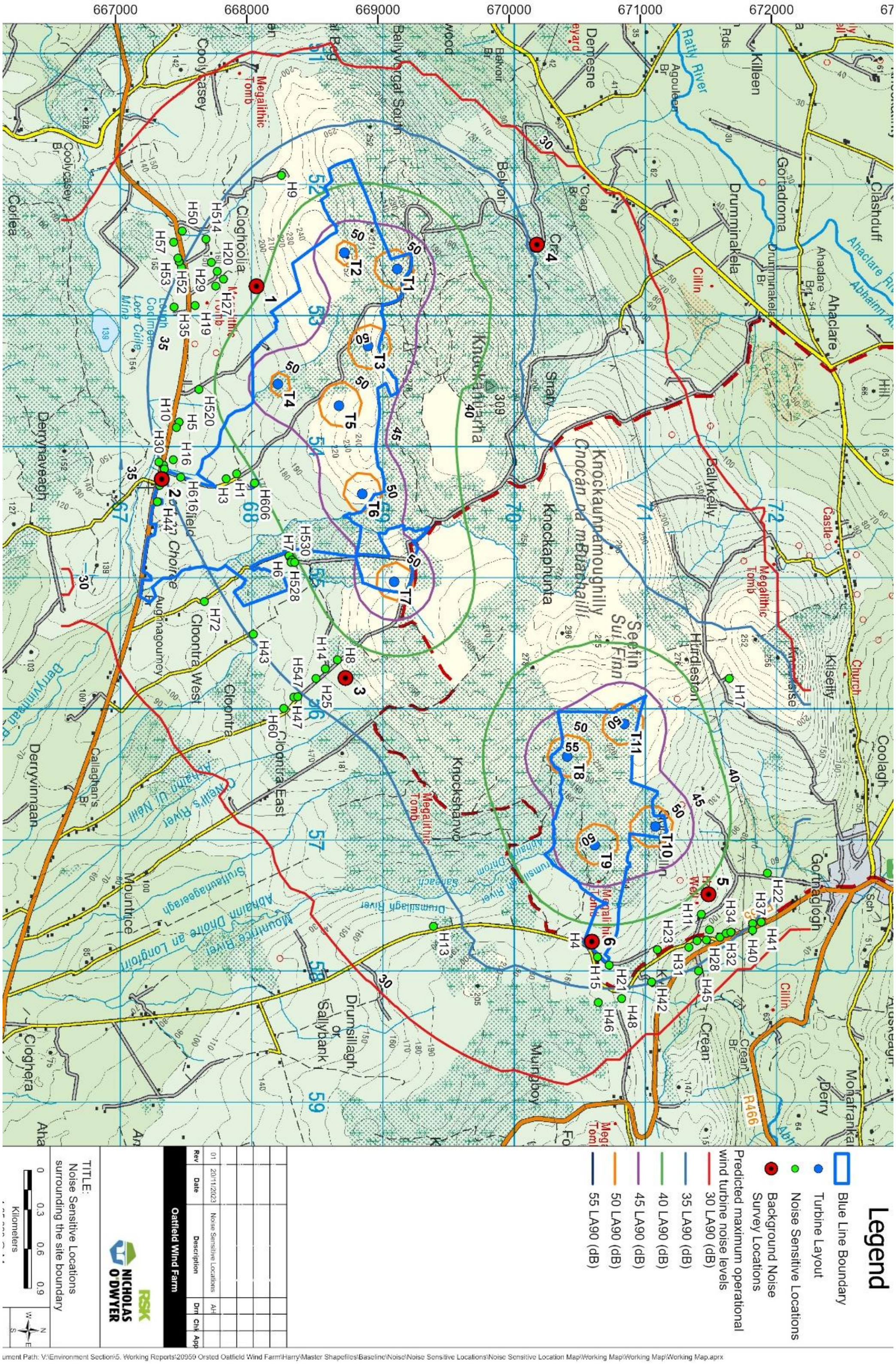
Glossary of Acoustics Terminology

Terminology	Description
A-weighting	A filter that down-weights low frequency and high frequency sound to better represent the frequency response of the human ear when assessing the likely effects of noise on humans
Acoustic character	One or more distinctive features of a sound (e.g. Tones, whines, whistles, impulses) that set it apart from the background noise against which it is being judged, possibly leading to a greater subjective effect than the level of the sound alone might suggest
Acoustic screening	The presence of a solid barrier (natural landform or manmade) between a source of sound and a receiver that interrupts the direct line of sight between the two, thus reducing the sound level at the receiver compared to that in the absence of the barrier
Ambient noise	All-encompassing noise associated with a given environment, usually a composite of sounds from many sources both far and near, often with no particular sound being dominant
Annoyance	A feeling of displeasure in this case evoked by noise
Attenuation	The reduction in level of a sound between the source and a receiver due to any combination of effects including: distance, atmospheric absorption, acoustic screening, the presence of a building façade, etc.
Audio frequency	Any frequency of a sound wave that lies within the frequency limits of audibility of a healthy human ear, generally accepted as being from 20 Hz To 20,000 Hz
Background noise	The noise level rarely fallen below in any given location over any given time period, often classed according to day time, evening or night time periods (for the majority of the population of the UK the lower limiting noise level is usually controlled by noise emanating from distant road, rail or air traffic)
Db	Abbreviation for 'decibel'
Db(a)	Abbreviation for the decibel level of a sound that has been a-weighted
Decibel	The unit normally employed to measure the magnitude of sound
Directivity	The property of a sound source that causes more sound to be radiated in one direction than another
Equivalent continuous sound pressure level	The steady sound level which has the same energy as a time varying sound signal when averaged over the same time interval, t, denoted by $L_{Aeq,t}$
External noise level	The noise level, in decibels, measured outside a building
Filter	A device for separating components of an acoustic signal on the basis of their frequencies
Frequency	The number of acoustic pressure fluctuations per second occurring about the atmospheric mean pressure (also known as the 'pitch' of a sound)
Frequency analysis	The analysis of a sound into its frequency components
Ground effects	The modification of sound at a receiver location due to the interaction of the sound wave with the ground along its propagation path from source to receiver
Hertz	The unit normally employed to measure the frequency of a sound, equal to cycles per second of acoustic pressure fluctuations about the atmospheric mean pressure
Impulsive sound	A sound having all its energy concentrated in a very short time period
Instantaneous sound pressure	At a given point in space and at a given instant in time, the difference between the instantaneous pressure and the mean atmospheric pressure
Internal noise level	The noise level, in decibels, measured inside a building
L_{Aeq}	The abbreviation of the a-weighted equivalent continuous sound pressure level
L_{A10}	The abbreviation of the 10 percentile noise indicator, often used for the measurement of road traffic noise
L_{A90}	The abbreviation of the 90 percentile noise indicator, often used for the measurement of background noise
Level	The general term used to describe a sound once it has been converted into decibels
Loudness	The attribute of human auditory response in which sound may be ordered on a subjective scale that typically extends from barely audible to painfully loud
Noise	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure.

Terminology	Description
	Subjectively: sound that evokes a feeling of displeasure in the environment in which it is heard, and is therefore unwelcomed by the receiver
Noise emission	The noise emitted by a source of sound
Noise immission	The noise to which a receiver is exposed
Noise nuisance	An unlawful interference with a person's use or enjoyment of land, or of some right over, or in connection with it
Octave band frequency analysis	A frequency analysis using a filter that is an octave wide (the upper limit of the filter's frequency band is exactly twice that of its lower frequency limit)
Percentile exceeded sound level	The noise level exceeded for n% of the time over a given time period, t, denoted by $L_{An,t}$
Receiver	A person or property exposed to the noise being considered
Residual noise	The ambient noise that remains in the absence of the specific noise whose effects are being assessed
Sound	Physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure
	Subjectively: the sensation of hearing excited by the acoustic oscillations described above (see also 'noise')
Sound level meter	An instrument for measuring sound pressure level
Sound pressure amplitude	The root mean square of the amplitude of the acoustic pressure fluctuations in a sound wave around the atmospheric mean pressure, usually measured in pascals (Pa)
Sound pressure level	A measure of the sound pressure at a point, in decibels
Sound power level	The total sound power radiated by a source, in decibels
Spectrum	A description of the amplitude of a sound as a function of frequency
Standardised wind speed	Values of wind speed at hub height corrected to a standardised height of ten metres using the same procedure as used in wind turbine emission testing
Threshold of hearing	The lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa)
Tone	The concentration of acoustic energy into a very narrow frequency range

Annex B – Location Maps and Turbine Coordinates

Figure B1 Map showing the layout of the turbines (green circles), the noise monitoring locations (red dots), the noise assessment locations (green dots) and calculated maximum noise level contours (L_{A90}, dB). Ordnance Survey Ireland license AR 0017023.



Turbine & Propagation Details

Table B1 – Turbine coordinates (Irish Transverse Mercator) – Proposed Development

Turbine	Easting	Northing	Turbine	Easting	Northing
T1	552609	669147	T7	554992	669124
T2	552483	668745	T8	556327	670443
T3	553196	668926	T9	557004	670652
T4	553486	668237	T10	556861	671116
T5	553650	668703	T11	556080	670879
T6	554325	668881			
All turbines modelled using the hub height of 105 m and operating in standard PO6000 mode, except for T2 and T4 operating in mode SO2.					

Table B2-Propagation attenuation effects due to terrain (dB) – Proposed Development – Positive numbers are due to terrain shielding barrier effects (e.g. 2), representing a decrease in noise levels, and negative numbers (e.g. -3) represent an increase in predicted noise levels due to concave ground effects. Where there is a zero shown, neither terrain shielding nor concave ground were found.

Property	Turbine										
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
H1	0	0	0	0	0	0	0	0	0	2	0
H2	0	0	0	0	0	0	0	0	0	2	0
H3	0	0	0	0	0	0	0	0	0	2	0
H4	2	2	0	2	0	0	0	0	0	0	0
H5	0	0	0	0	0	0	0	0	0	0	0
H6	0	0	0	0	0	0	0	0	2	2	0
H7	0	0	0	0	0	0	0	0	2	2	0
H8	0	0	0	0	0	0	0	0	0	0	0
H9	0	0	0	0	0	0	0	2	2	2	2
H10	0	0	0	0	0	0	0	0	0	2	0
H11	2	2	2	2	2	2	2	2	0	0	2
H12	0	0	0	0	0	0	0	0	0	0	0
H13	0	0	0	0	0	0	0	0	0	0	0
H14	0	0	0	0	0	0	0	0	0	0	0
H15	2	2	2	2	2	2	0	0	0	0	0
H16	0	0	0	0	0	0	0	0	0	2	0
H17	2	2	2	2	2	2	2	0	0	0	0
H18	2	2	2	2	2	2	2	2	0	0	2
H19	0	0	0	0	0	0	0	0	0	0	0
H20	0	0	0	0	0	0	0	0	2	2	0
H21	2	2	2	2	2	2	0	0	0	0	0
H22	2	2	2	2	2	2	2	0	0	0	0
H23	2	2	2	2	2	2	2	2	0	0	0
H24	0	0	0	0	0	0	0	2	2	2	0
H25	0	0	0	0	0	0	0	0	0	0	0
H26	0	0	0	0	0	0	0	2	2	2	0
H27	0	0	0	0	0	0	0	2	2	2	2

Property	Turbine										
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
H28	2	2	2	2	2	2	2	2	0	0	2
H29	0	0	0	0	0	0	0	2	2	2	2
H30	0	0	0	0	0	0	0	0	2	2	0
H31	2	2	2	2	2	2	2	2	0	0	2
H32	2	2	2	2	2	2	2	2	0	0	0
H33	2	2	2	2	2	2	2	2	0	0	0
H34	2	2	2	2	2	2	2	2	0	0	0
H35	0	0	0	0	0	0	0	0	0	0	0
H37	2	2	2	2	2	2	2	0	0	0	0
H38	0	0	0	0	0	0	0	2	2	2	2
H39	0	0	0	2	2	2	2	2	2	2	2
H40	2	2	2	2	2	2	2	0	0	0	0
H41	2	2	2	2	2	2	2	0	0	0	0
H42	2	2	2	2	2	2	2	0	0	0	0
H43	0	0	0	0	0	0	0	0	0	0	0
H44	0	0	0	0	0	0	0	0	0	0	0
H45	2	2	2	2	2	2	2	0	0	0	0
H46	0	0	0	0	0	0	0	0	0	0	0
H47	0	0	0	0	0	0	0	0	0	0	0
H48	2	2	2	2	2	0	0	0	0	0	0
H50	0	0	0	0	0	0	0	2	2	2	0
H51	0	0	0	0	0	0	0	0	0	2	0
H52	0	0	0	0	0	0	0	0	0	2	0
H53	0	0	0	0	0	0	0	0	0	2	0
H57	0	0	0	0	0	0	0	0	0	2	0
H60	0	0	0	0	0	0	0	0	0	2	0
H72	0	0	0	0	0	0	0	0	0	0	0
H514	0	0	0	0	0	0	0	0	2	2	2
H518	0	0	0	0	0	0	0	2	2	2	0
H520	0	0	0	0	0	0	0	0	0	0	0
H528	0	0	0	0	0	0	0	0	2	2	0
H530	0	0	0	0	0	0	0	2	2	2	0
H547	0	0	0	0	0	0	0	0	0	0	0
H606	0	0	0	0	0	0	0	0	0	2	0
H612	2	2	2	2	2	2	2	2	0	0	2
H616	0	0	0	0	0	0	0	0	0	0	0

Table B3 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – Vestas V150-6 MW

Turbine operational mode	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
PO6000	-	-	94.8	98.2	102.5	106	106.8	106.9	106.9	106.9	106.9	106.9
SO2	-	-	94.3	98.2	102.2	104.0	104.0	104.0	104.0	104.0	104.0	104.0
Derived from: Vestas 'Performance Specification V150-6.0 MW', document 0098-0749.V01, 13/10/2020. +2 dB margin added to account for uncertainties.												

INTERNA

Table B4 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) – normalised to 100 dB(A) - Vestas V150-6 MW

Octave Band Centre Frequency (Hz)								
63	125	250	500	1000	2000	4000	8000	A
81.1	88.7	93.4	95.1	94	89.9	82.9	72.9	100
Derived from: Vestas document V150-6.0 MW Third Octaves, 0095-3747.V01, 03/11/2020								

Table B5 - Wind turbine sound power levels (dB L_{Aeq}) used in the noise assessment – alternative turbine models

Turbine type	Standardised 10 m Wind Speed (m/s)										
	1	2	3	4	5	6	7	8	9	10	11	12
Nordex N133 4.8 MW	-	-	95.5	97.0	102.5	106.7	108.0	108.0	108.0	108.0	108.0	108.0
Nordex N149 5.7MW	-	-	96.0	97.2	101.8	106.2	107.6	107.6	107.6	107.6	107.6	107.6
Based on Nordex document reference F008_272_A13_EN, 01/03/2018 (N133) and F008_275_A13_EN, 14/02/2020 (N149). With +2 dB margin added to account for uncertainties.												

Table B6 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) – alternative turbine models (Nordex N133/N149) – normalised to 100 dB(A).

Octave Band Centre Frequency (Hz)								
63	125	250	500	1000	2000	4000	8000	A
83.0	88.7	91.0	91.8	93.6	94.1	91.8	81.2	100.0
Based on Nordex document 'Octave sound power levels', reference F008_272_A14_EN, 01/03/2018								

Table B7 – Predicted noise levels at location H8 - L_{A90} (dB) – for the three turbine models considered above.

Turbine type	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Vestas V150 6 MW			25.9	29.4	33.6	37.1	37.9	37.9	37.9	37.9	37.9	37.9
Nordex N133 4.8 MW	-	-	25.1	26.6	32.1	36.3	37.6	37.6	37.6	37.6	37.6	37.6
Nordex N149 5.7MW	-	-	25.6	26.8	31.4	35.8	37.2	37.2	37.2	37.2	37.2	37.2

Table B8 – Turbine coordinates (Irish Transverse Mercator) – Knockshanvo Wind Farm

Turbine	Easting	Northing	Turbine	Easting	Northing
K1	553298	669432	K6	558465	669920
K2	556662	670008	K7	553369	670112
K3	556895	669603	K8	556727	669047
K4	553810	669899	K9	558870	669562
K5	556211	669447			
All turbines modelled with a hub height of 104 m.					

Table B9 - Wind turbine sound power levels (dB L_{Aeq}) – Knockshanvo Wind Farm – Vestas V162-6.8 MW

Turbine operational mode	Standardised 10 m Wind Speed (m/s)											
	1	2	3	4	5	6	7	8	9	10	11	12
Mode PO6800	-	-	96.0	96.9	101.4	104.9	105.3	105.7	106.1	106.4	106.4	106.5
Derived from: 'Performance Specification, EnVentus V162-6.8 MW 50/60 Hz' Vestas document ref. 0114-3788 V01, 18/01/2022. +2 dB margin added to account for uncertainties.												

Table B10 - Octave band sound power spectrum (dB L_{Aeq}) for reference wind speed conditions (v_{10} = 8 m/s) – normalised to 100 dB(A) - Knockshanvo Wind Farm - Vestas V162-6.8 MW

Octave Band Centre Frequency (Hz)								
63	125	250	500	1000	2000	4000	8000	A
81.3	88.8	93.3	95.1	94.0	90.0	83.3	73.6	100.0
Derived from: Vestas document: V162-6.2MV Third Octaves, document ref. 0105-5200_00, 21/04/2022.								

Annex C – Noise Monitoring Information Sheets

Table C1 – Information on the measurement location, equipment and noise data at Location 1.

Measurement Location Name	Location 1 (BN1)
Measurement Location Description	The microphone was placed at the rear of a detached house (H2) near Cloghoolia, Co. Clare, which was relatively elevated and distant from the R471 road. The location was chosen to avoid interference from animals on the other side of the property. Nearby noise sources: occasional local road traffic, birdsong, vegetation, occasional dogs barking and farm animal noise such as geese and goats. SLM Location: 52.7616598 / -8.7002006 (lat/lon), ITM 552740 / 668075

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Larson Davis Sound Expert	LXT 0005977	1 June 2022
Pre-amplifier	PRMLxT1L	055817	1 June 2022
Microphone	377B02	SN31620	1 June 2022
Calibrator	RION NC - 75	34613228	25 July 2023
SLM Range	17 – 118 dB(A)		

Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
14/09/2023 13:10	19/10/2023 11:20	94.0	94.3	0.3	No significant drift

Data Exclusions
Periods 10 minutes before, during and after rainfall was detected were removed (based on both rain gauges installed). The following atypical periods were also excluded: • Quiet day-time with L_{A90} > 40 dB(A) below 7.5 m/s • Night-time with L_{A90} > 40 dB(A) below 7.5 m/s

Figure C1 View of the monitoring location at Location 1 looking East

Figure C2 View of the monitoring location at Location 1 looking West

INTERNA

Figure C3 View of the monitoring location at Location 1 looking north

Table C2– Information on the measurement location, equipment and noise data at Location 2.

Measurement Location Name	Location 2 (BN2)
Measurement Location Description	The microphone was placed to the west side of a house (H38) in a farmyard. This property was chosen as representative of other properties to the west where access was refused. The chosen location was chosen at a similar distance to the R471 road as the other neighbouring properties and was located to provide sufficient distance between the farmyard and the monitoring location to minimise the influence of farm activities on the noise monitoring data. Nearby noise sources included local road traffic, birdsong, vegetation and occasional dogs barking. A rain logger was also installed at this location. SLM Location: 52.7552975 / -8.6783138 (lat/lon), ITM 554211 / 667353

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	01dB Metravib Cube	10695	
Pre-amplifier	PRE22N	10862	
Microphone	40CD	224214	
Calibrator	RION	34613228	25/07/23
SLM Range	21 – 138 dB(A)		

Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
14/09/2023 12:10	19/10/2023 11:00	94.0	94.1	0.1	No significant drift

Data Exclusions
Periods 10 minutes before, during and after rainfall was detected were removed (based on both rain gauges installed). The following atypical periods were also excluded: • Quiet day-time with L_{A90} > 40.5 dB(A) below 5 m/s or > 45 dB(A) below 9 m/s • Night-time with L_{A90} > 35 dB(A) below 3 m/s or > 45 dB(A) below 8 m/s

INTERNA

Figure C4 - View of the monitoring location at Location 2 looking East

Figure C5 - View of the monitoring location at Location 2 looking south

Table C3 – Information on the measurement location, equipment and noise data at Location 3.

Measurement Location Name	Location 3 (BN3)
Measurement Location Description	The property (H12) is a detached two storey dwelling near Glenmore Upper, Oatfield Co. Clare. The microphone was positioned in a small field in front of the property at 1.5 m height. Background noise sources included occasional road traffic, vegetation and birdsong. Rain logger also installed at this location. SLM Location: 52.7680000 / -8.6560278 (lat/lon), ITM 555728 / 668753

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	01dB Metravib Cube	11111	
Pre-amplifier	PRE22N	10129	
Microphone	40CD	287790	
Calibrator	RION	34613228	25/07/23
SLM Range	21 – 138 dB(A)		

Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
14/09/2023 10:00	19/10/2023 09:50	94.0	94.3	0.3	No significant drift

Data Exclusions
Periods 10 minutes before, during and after rainfall was detected were removed (based on both rain gauges installed). The following atypical periods were also excluded: • Quiet day-time with L_{A90} > 40 dB(A) below 8 m/s • Night-time with L_{A90} > 30 dB(A) below 4 m/s

Figure C7 View of the monitoring location at Location 3 - looking South

Figure C8 View of the monitoring location at Location 3 - looking east

INTERNA

Figure C9 View of the monitoring location at Location 3 - looking Southwest

Table C4 – Information on the measurement location, equipment and noise data at Location 4

Measurement Location Name	Location 4 (BN4)
Measurement Location Description	The property is a detached two storey dwelling (H39) near the 12 O' Clock Hills, Oatfield Co. Clare. The microphone was positioned to the west of the property at 1.5 m height, following discussion with the resident at a suitably representative location which would not be obtrusive. Background noise sources included occasional road traffic, vegetation and birdsong. SLM Location: 52.7808369 -8.7052321 (lat/lon), ITM 552422 / 670212

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	01dB Metrvib Cube	10696	
Pre-amplifier	PRE22N	1610507	
Microphone	40CD	224320	
Calibrator	RION	34613228	25/07/23
SLM Range	21 – 138 dB(A)		

Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
13/09/2023 10:00	19/10/2023 09:50	94.0	94.5	0.5	No significant drift

Data Exclusions
Periods 10 minutes before, during and after rainfall was detected were removed (based on both rain gauges installed). The following atypical periods were also excluded: • Quiet day-time with L_{A90} > 50 dB(A) below 9 m/s • Night-time with L_{A90} > 40 dB(A) below 5 m/s or > 45 dB(A) below 9 m/s

Figure C10 View of the monitoring location at Location 4 looking West

Figure C11 View of the monitoring location at Location 4 looking east

Figure C12 View of the monitoring location at Location 4 looking South

Table C5 – Information on the measurement location, equipment and noise data at Location 5.

Measurement Location Name	Location 5 (BN5)
Measurement Location Description	Access to properties south of Gortnaglogh such as H11 or H18 was not possible. Therefore, the measurement location was installed in a field to the west, close to the boundary of property H11. Background noise sources mainly included vegetation and birdsong, as well as agricultural activities and occasional noise from cattle. SLM Location: 52.7930018 / –8.6319343. (lat/lon), ITM 557378 / 671520

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	Larson Davis Sound Expert	LXT 0005802	19 December 2022
Pre-amplifier	PRMLxT1L	055711	19 December 2022
Microphone	377B02	SN310135	19 December 2022
Calibrator	RION NC - 75	34613228	25 July 2023
SLM Range	17 – 118 dB(A)		

Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
21/09/2023 14:20	19/10/2023 13:00	94.0	94.3	0.3	No significant drift

Data Exclusions
Periods 10 minutes before, during and after rainfall was detected were removed (based on both rain gauges installed). The following atypical periods were also excluded: • Quiet day-time with L_{A90} > 45 dB(A) below 8 m/s • Night-time with L_{A90} > 43 dB(A) below 11 m/s

Figure C13 View of the monitoring location at Location 5 looking North

Figure C14 View of the monitoring location at Location 5 looking east

Figure C15 View of the monitoring location at Location 5 looking west

Table C6 – Information on the measurement location, equipment and noise data at Location 6.

Measurement Location Name	Location 6 (BN6)
Measurement Location Description	Located to the rear of a property (H4) near Fermoyle Co. Clare, the microphone was placed at a height of 1.5 m at a boundary fence. Background noise sources included occasional road traffic, vegetation and birdsong. SLM Location: 52.7850439, - 8.6264757 (lat/lon), ITM 557739 / 670631

Equipment	Type	Serial Number	Last Calibrated (UKAS)
Sound Level Meter	01dB Metravib Cube	10694	
Pre-amplifier	PRE22N	10862	
Microphone	40CD	224214	
Calibrator	RION		
SLM Range	20 – 100 dB(A)		

Time Start (GMT)	Time End (GMT)	Cal Start	Cal End	Drift	Notes
14/09/2023 09:50	19/10/2023 13:50	94.0	94.1	0.1	No significant drift

Data Exclusions
Periods 10 minutes before, during and after rainfall was detected were removed (based on both rain gauges installed). The following atypical periods were also excluded: • Quiet day-time with L_{A90} > 40 dB(A) below 10 m/s or > 35 dB(A) below 5.5 m/s • Night-time with L_{A90} > 40 dB(A) below 12 m/s or > 30 dB(A) below 4 m/s

INTERNA

Figure C16 View of the monitoring location at Location 6 looking Southwest

Figure C17 View of the monitoring location at Location 6 looking south

Figure C18 View of the monitoring location at Location 6 looking west

Annex D – Wind Speeds and Directions

Figure D1 Wind speed and direction range during all quiet day-time periods (Location 1 data shown; other data excluded at some of the other locations).

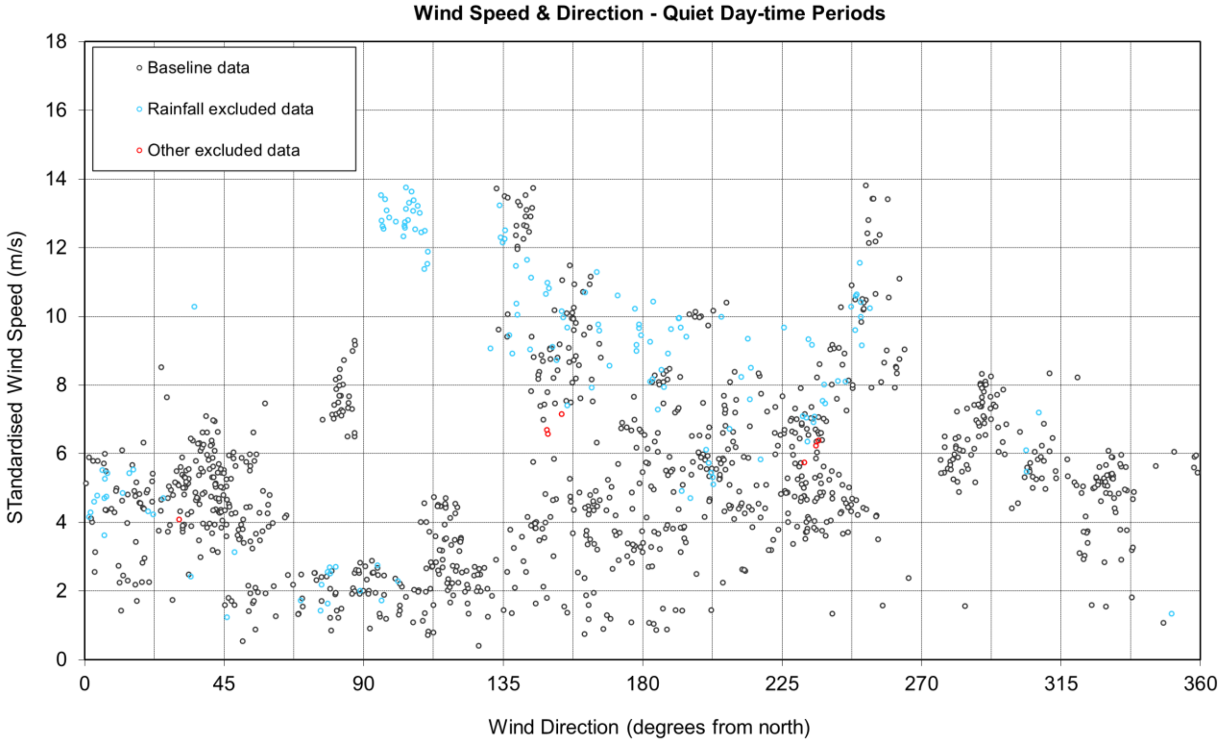


Figure D2 Wind speed and direction range during all night-time periods (Location 1 data shown; other data excluded at some of the other locations)).

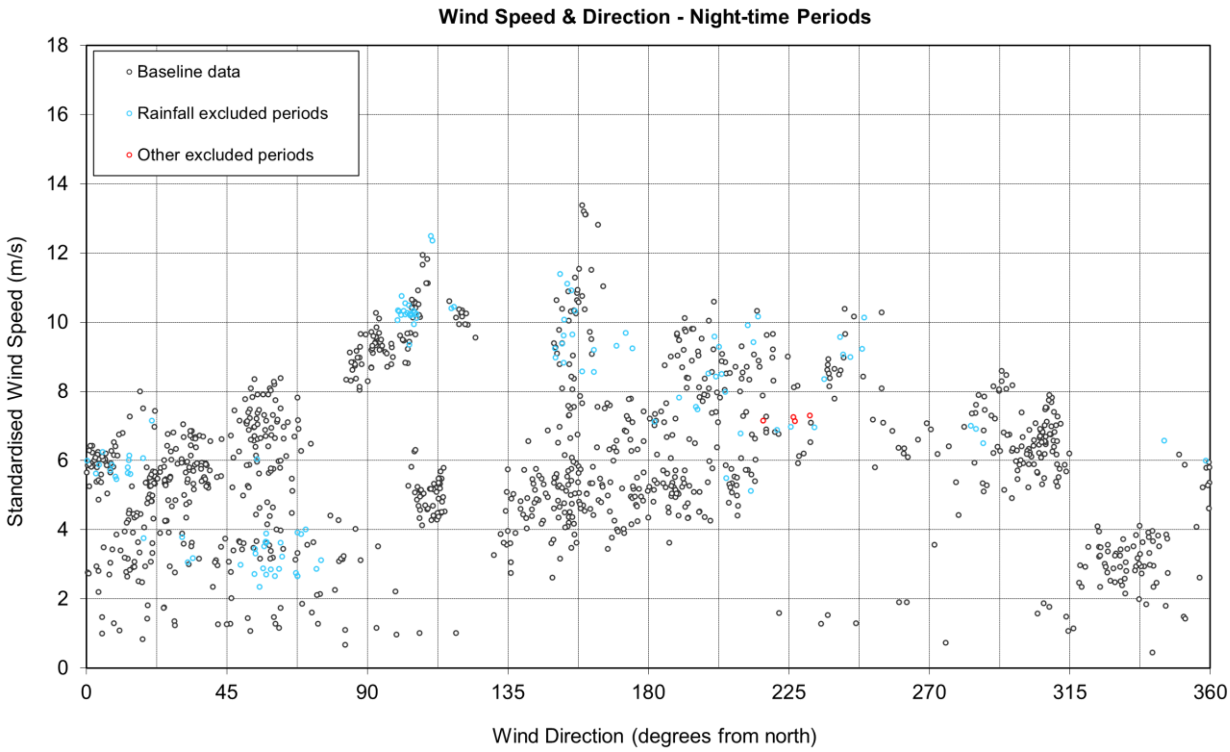


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Figure D3 Wind speed and direction range during all quiet day-time periods (Location 5 data shown; other data excluded at some of the other locations).

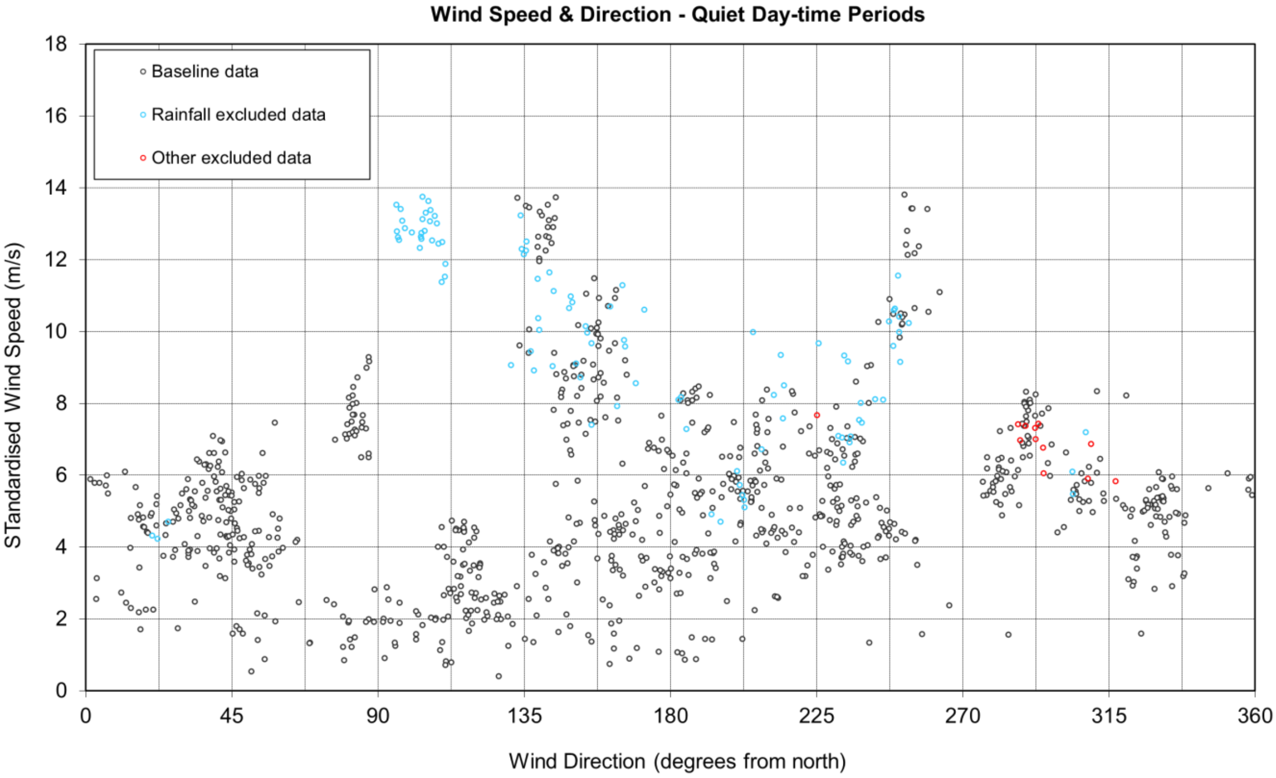
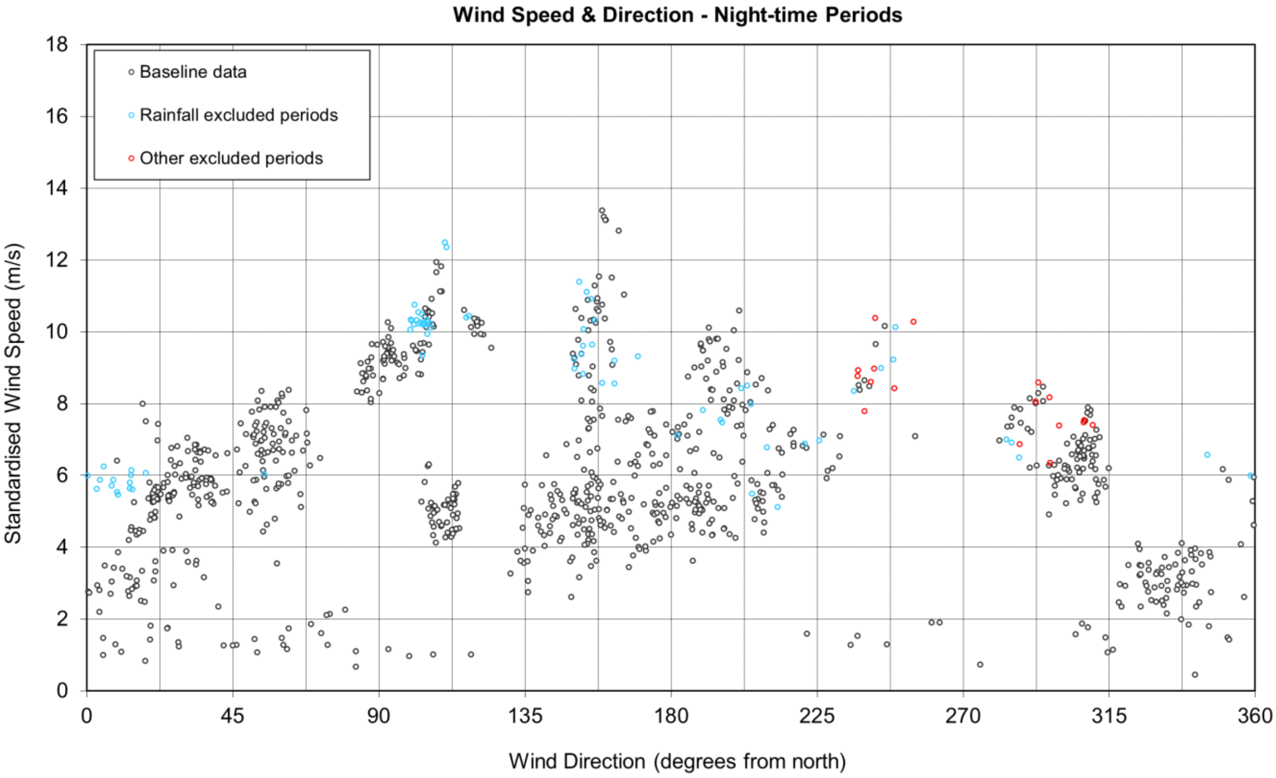


Figure D4 Wind speed and direction range during all night-time periods (Location 5 data shown; other data excluded at some of the other locations).



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Annex E – Background Noise and Noise Limits

Figure E1 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 1 during quiet day time periods. Predicted immission noise levels at location H2 are also shown for the Proposed Development.

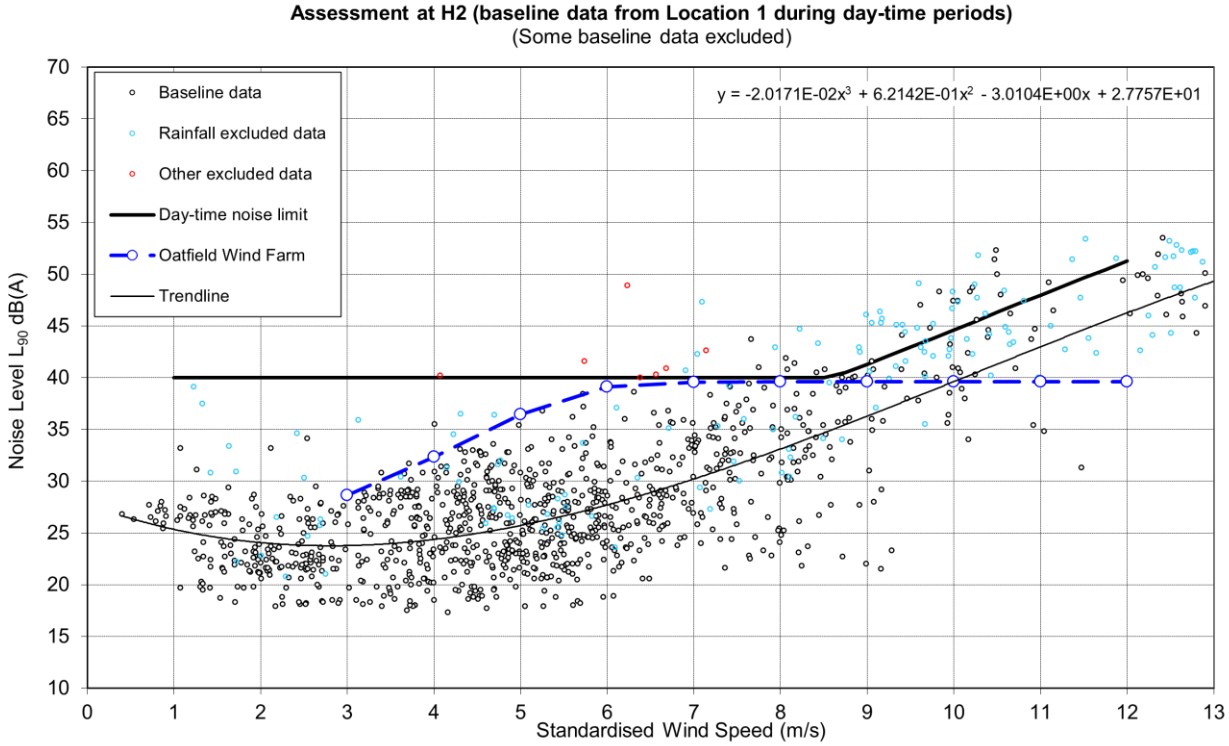

Figure E2 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 1 during night time periods. Predicted immission noise levels at location H2 are also shown for the Proposed Development.

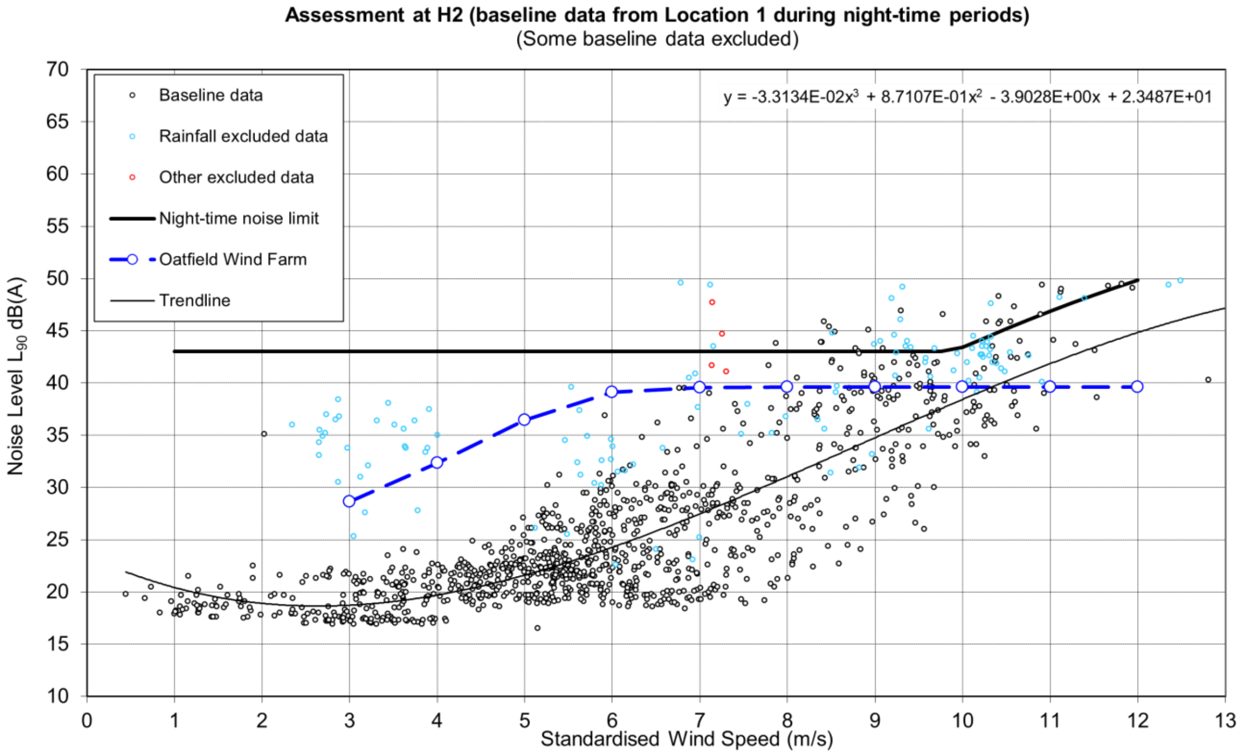

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Figure E3 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 2 during quiet day time periods. Predicted immission noise levels at location H5 are also shown for the Proposed Development.

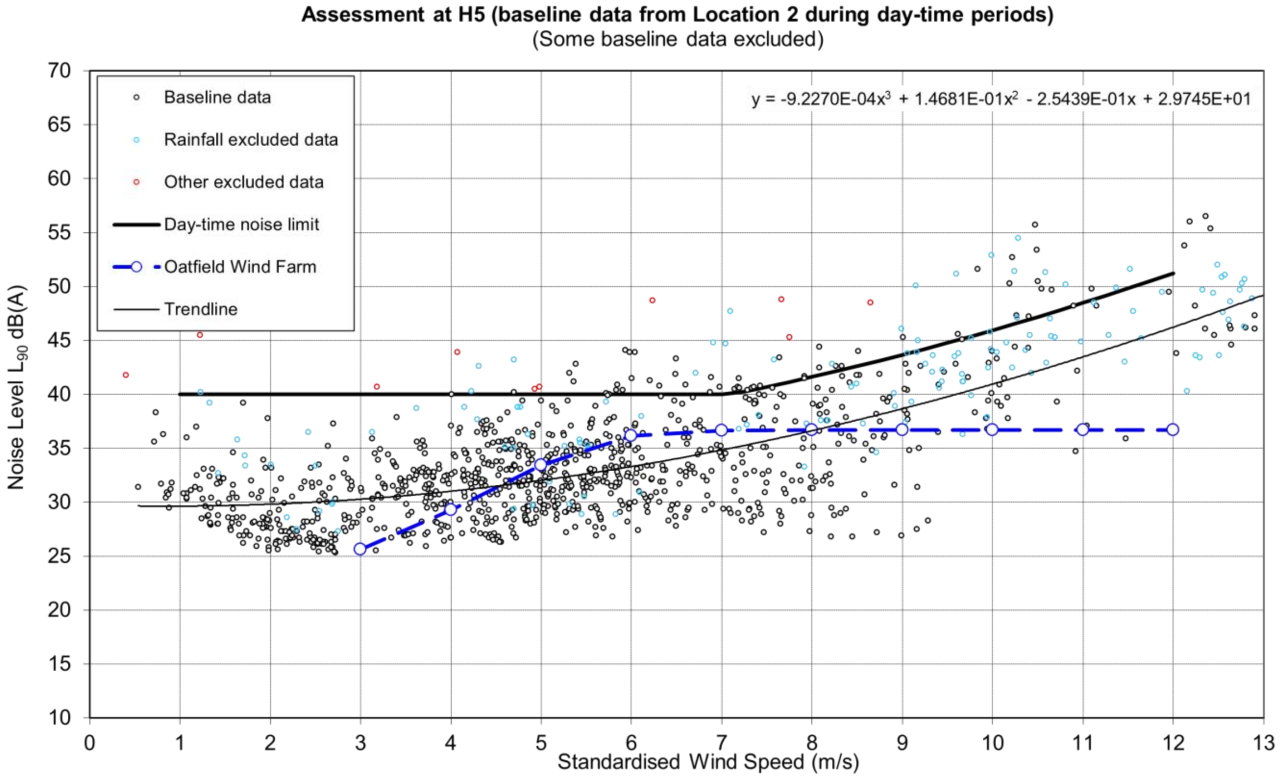

Figure E4 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 2 during night time periods. Predicted immission noise levels at location H5 are also shown for the Proposed Development.

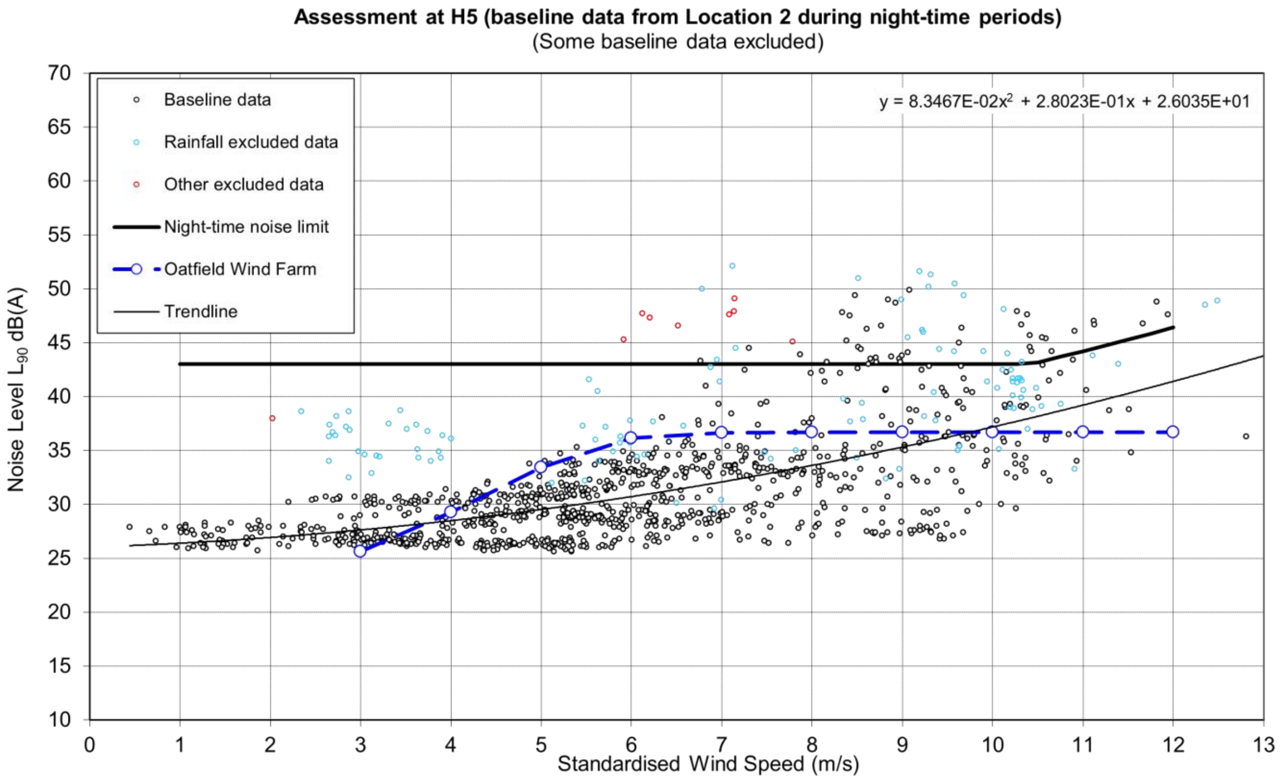

Figure E5 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 3 during quiet day time periods. Predicted immission noise levels at location H7 are also shown for the Proposed Development.

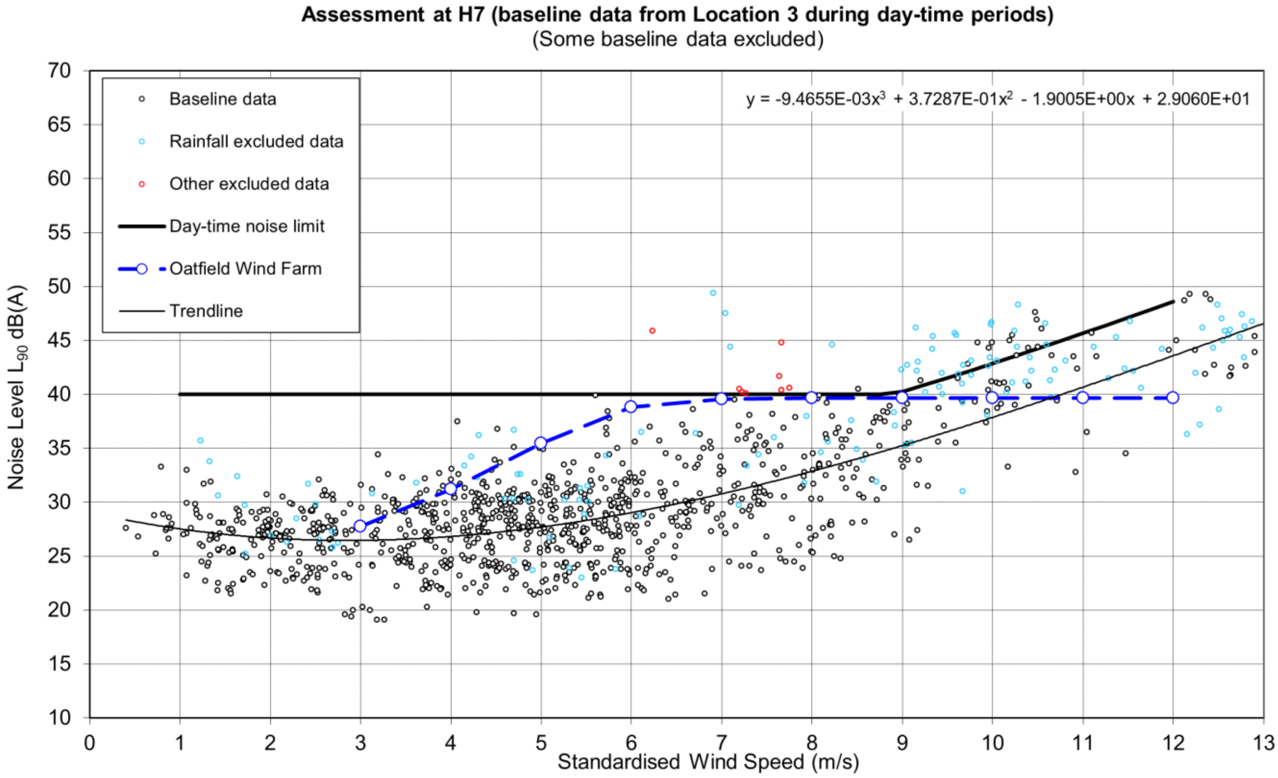

Figure E6 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 3 during night time periods. Predicted immission noise levels at location H7 are also shown for the Proposed Development.

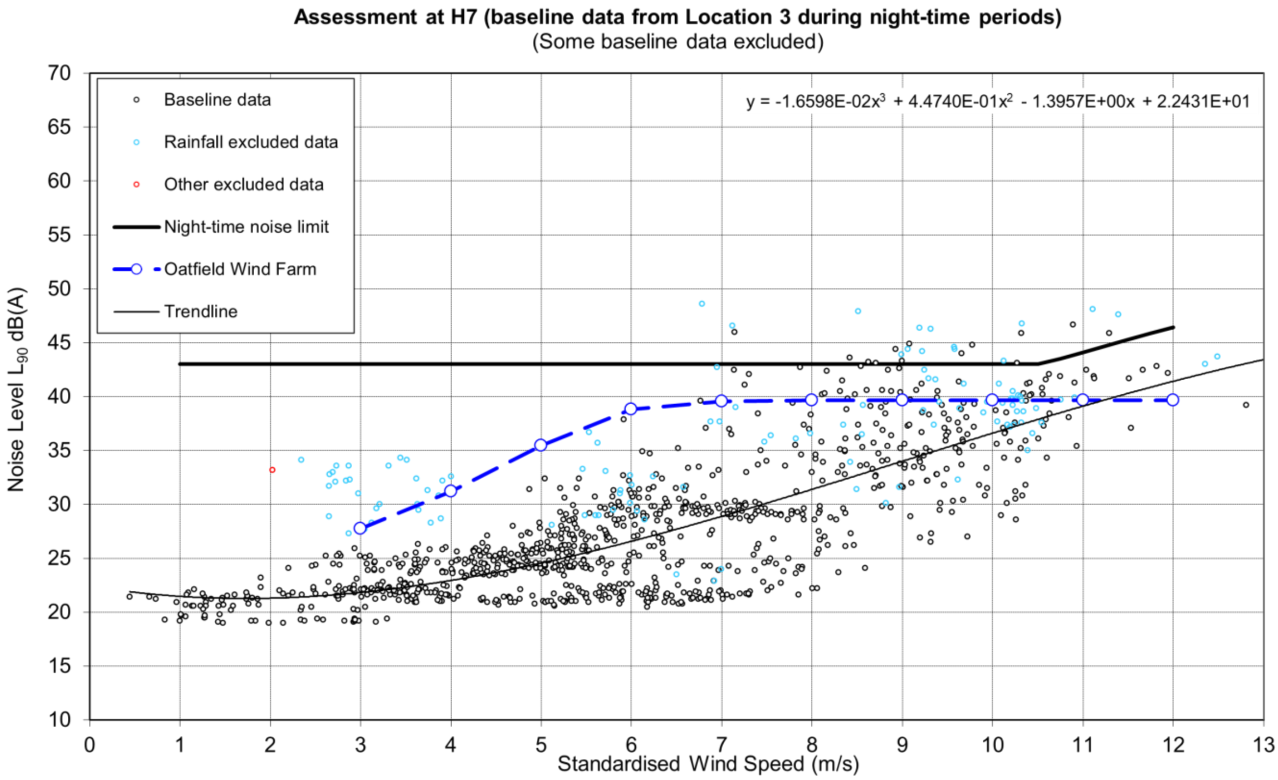

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Figure E7 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 4 during quiet day time periods. Predicted immission noise levels at location H39 are also shown for the Proposed Development.

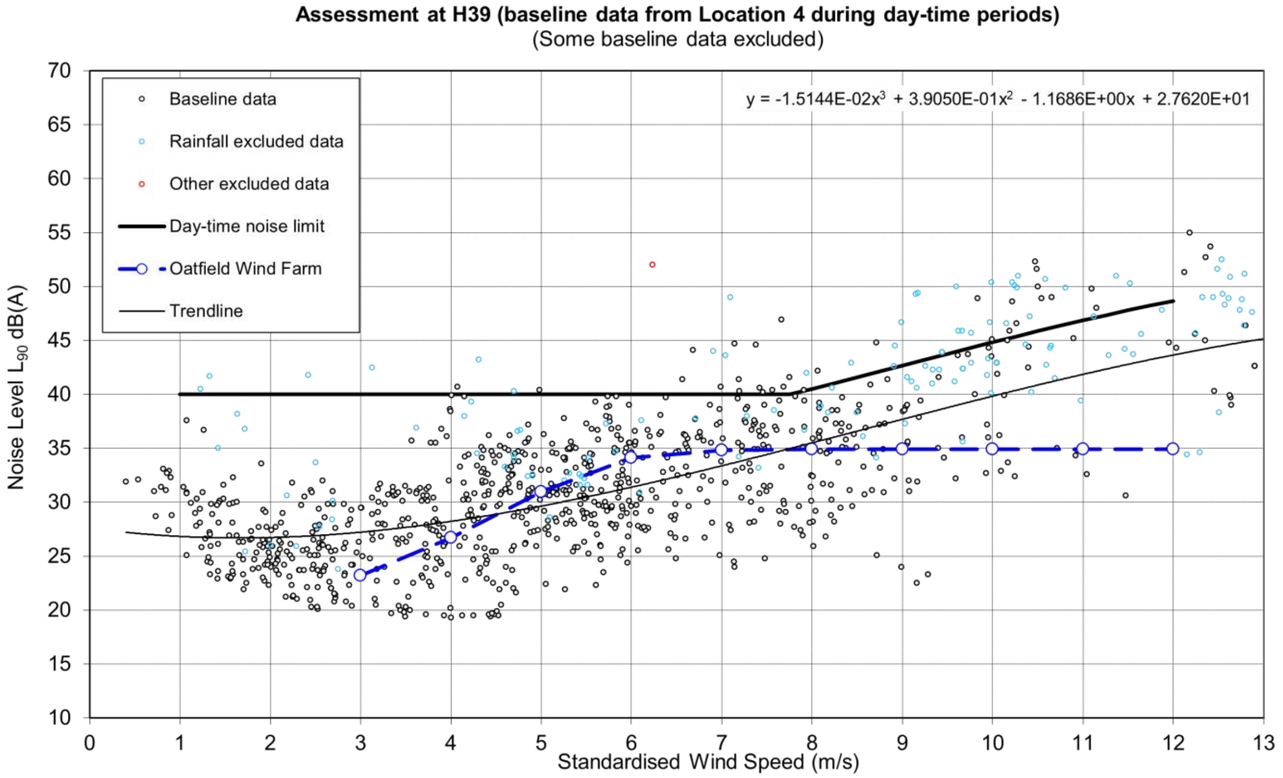

Figure E8 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 4 during night time periods. Predicted immission noise levels at location H39 are also shown for the Proposed Development.

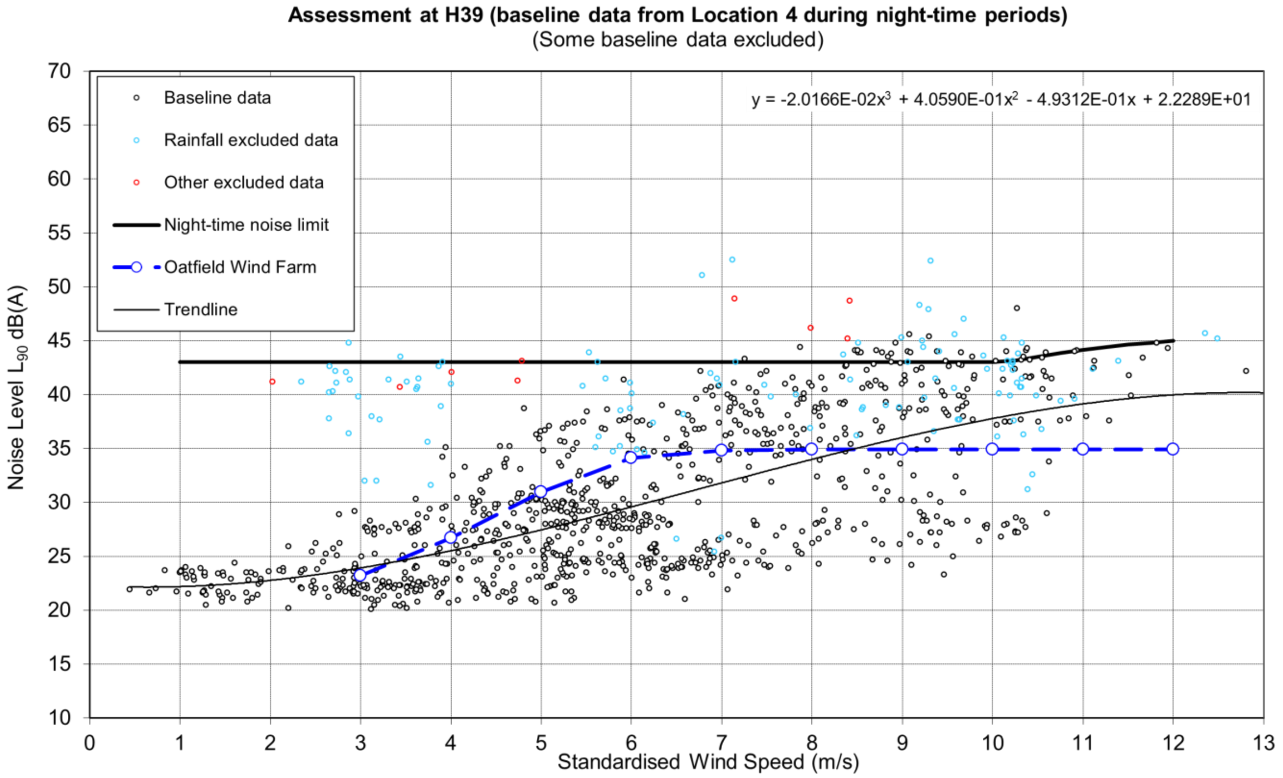

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Figure E9 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 5 during quiet day time periods. Predicted noise levels at location H11 are also shown for the Proposed Development.

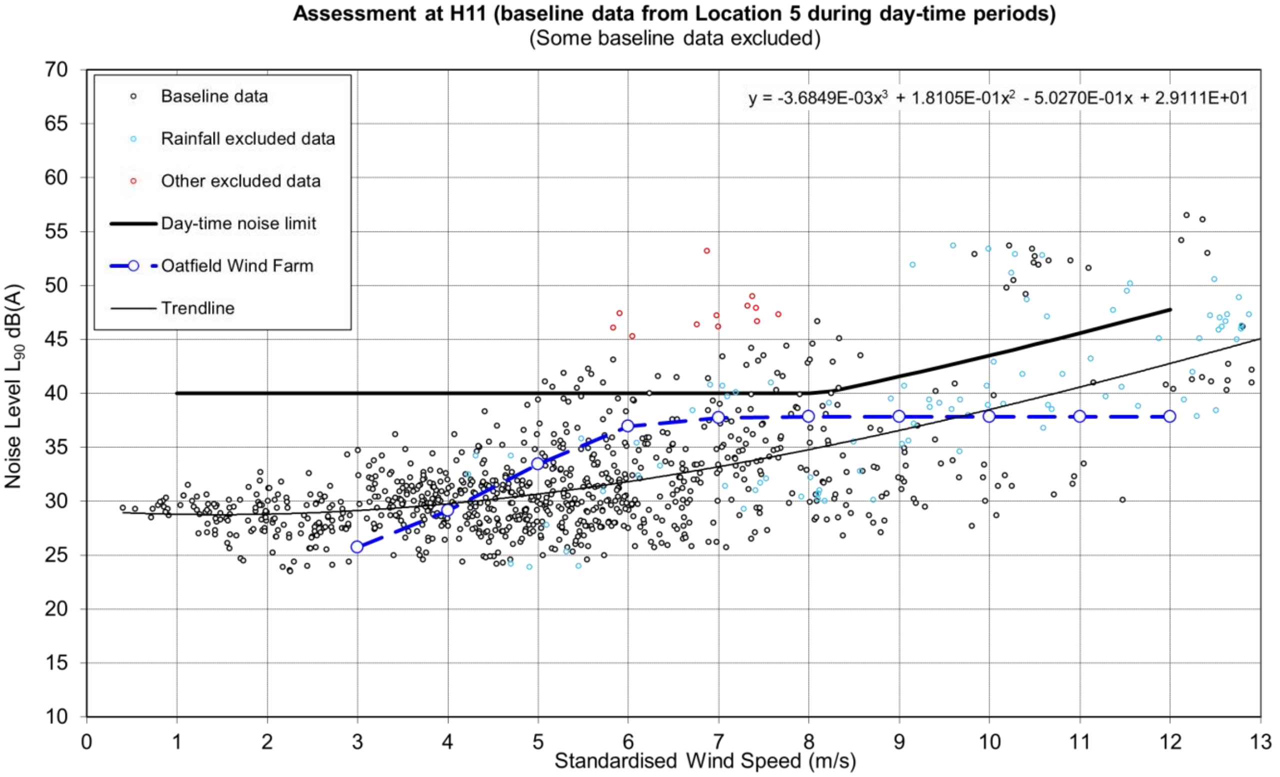


Figure E10 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 5 during night time periods. Predicted noise levels at location H11 are also shown for the Proposed Development.

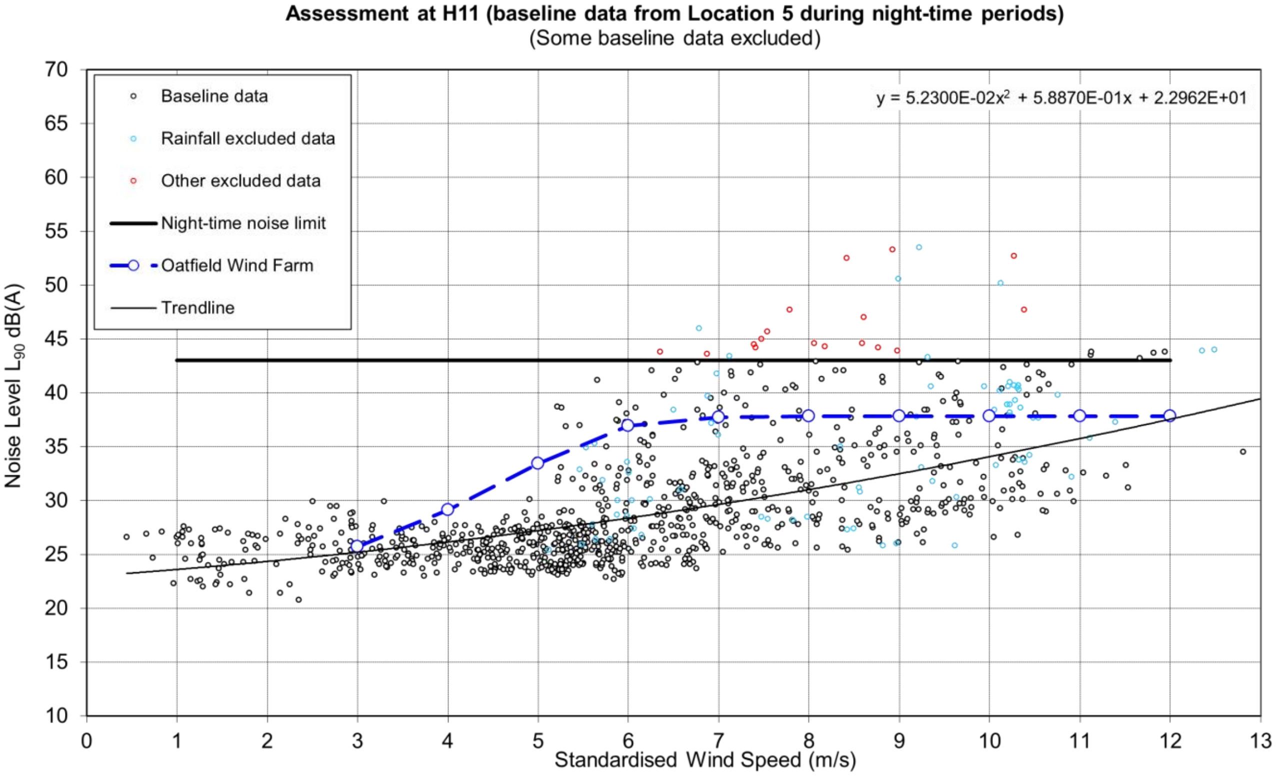


Figure E11 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 6 during quiet day time periods. Predicted immission noise levels at location H15 are also shown for the Proposed Development.

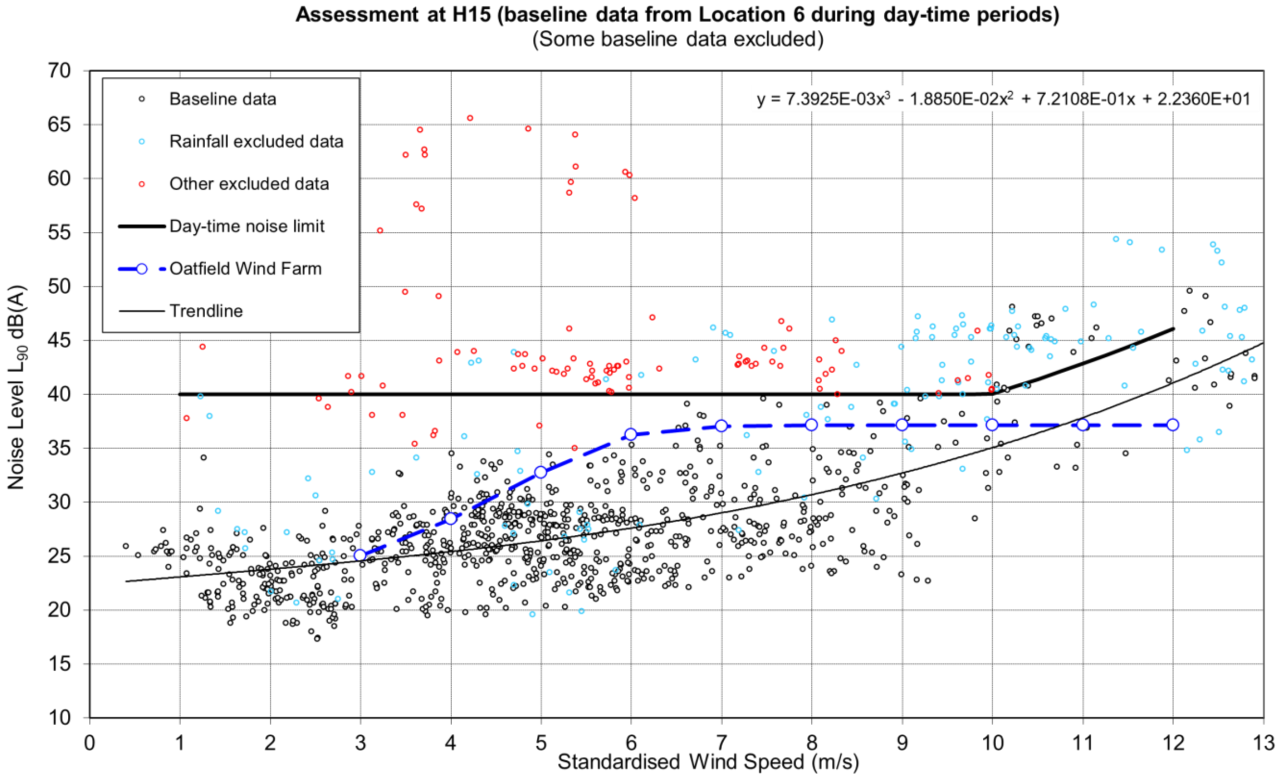
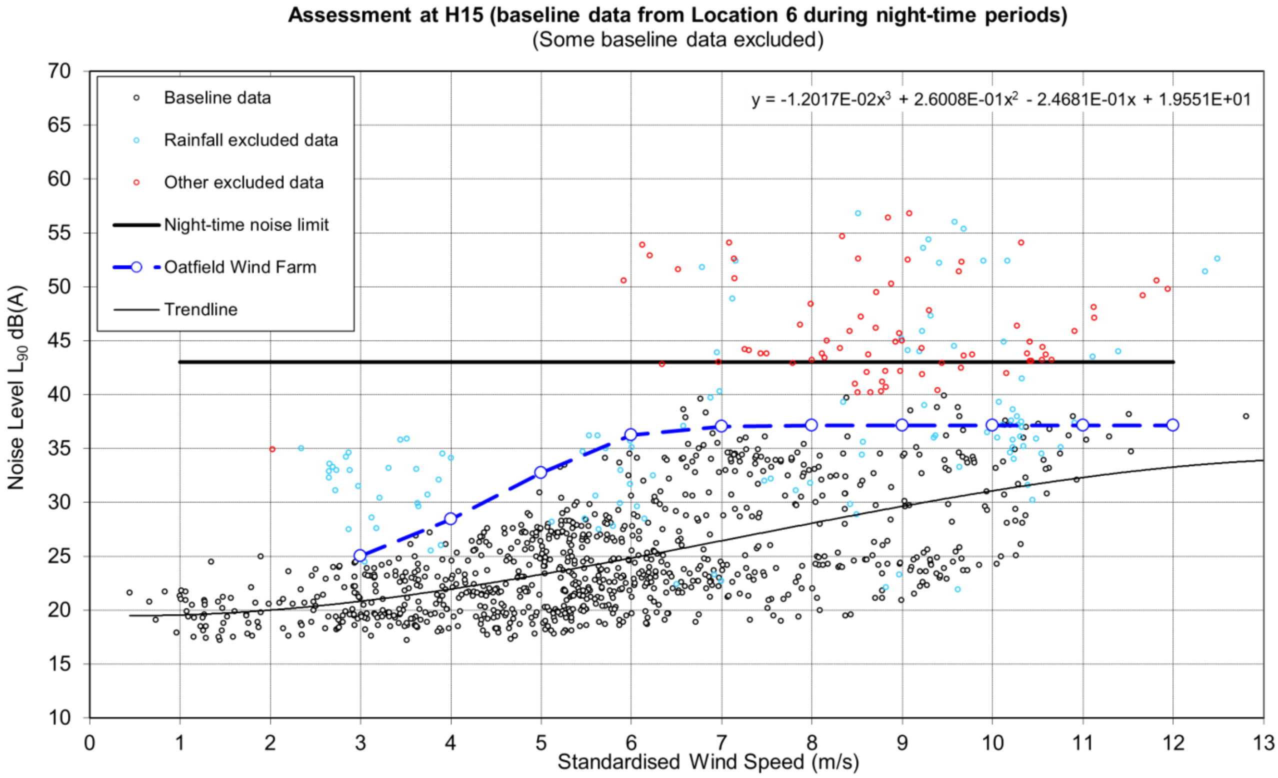


Figure E12 Chart of background noise levels against wind speeds, the best fit curve to the data, the derived noise limit curve for Location 6 during night time periods. Predicted immission noise levels at location H15 are also shown for the Proposed Development.



Annex F – Wind Speed Calculations

F.1 The IOA GPG[25] requires that noise data recorded every 10 minutes are related to standardised ten metre wind speeds experienced at the hub height of the turbines, at a location on the wind farm representative of the wind farm. These wind speeds can be either measured directly at the turbine hub height or derived by calculation from measurements at two heights, with measurements at the upper height not less than 60% of the turbine hub height and measurements at least 15 metres below that. These are referred to as 'Method A' or 'Method B' in the IOA GPG which describes these as the preferred methods to use. IOA GPG SGN4[26] provides additional guidance on these methods.

F.2 The site of the Proposed Development has a temporary LIDAR remote sensing measuring system installed which measured wind conditions at various heights including:

- 105 metre wind speed and wind direction
- 110 metre wind speed and wind direction

F.3 The 105 m measurement height is consistent with the proposed candidate hub height of 105 metres and therefore meets the requirements of the IOA GPG. The LIDAR meets the accuracy and calibration requirements of the IOA GPG. Equation 1 of SGN4 was used to calculate a standardised ten-metre height wind speed from the hub height wind speed every ten minutes assuming the reference roughness length of 0.05 metres.

F.4 Wind speeds are standardised to a height of ten metres assuming a reference ground roughness length of 0.05 metres as described in the IOA GPG. This approach is of the same form as that given in BS EN 61400-11:2003[27] for calculating ten metre wind speeds related to hub height wind speeds when providing source noise emission data for wind turbines.

F.5 By using this method, measured background noise levels were correlated to ten metre wind speeds calculated from wind speeds at hub height. Any likely difference in the shear profile during the 24 hours of the day will be accounted for within the method and be reflected in the resulting standardised ten metre wind speed data. The method used to calculate ten metre wind speeds from those at hub height is the same as that used when deriving noise emission data for the turbines. Because the same method has been used, direct comparison of background noise levels, noise limits and predicted turbine noise immission levels may be undertaken. This method is consistent with guidance published in the IOA GPG.

25 A Good Practice Guide to the Application of ETSU R 97 for the Assessment and Rating of Wind Turbine Noise, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, May 2013.

26 A Good Practice Guide to the Application of ETSU R 97 for the Assessment and Rating of Wind Turbine Noise - Supplementary Guidance Note 4: Wind Shear, M. Cand, R. Davis, C. Jordan, M. Hayes, R. Perkins, Institute of Acoustics, July 2014.

27 IEC 61400 11:2003 Wind turbine generator systems - Part 11: Acoustic noise measurement techniques.

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