CHAPTER 10: NOISE

INTRODUCTION

10.1 This report presents an assessment of the potential construction and operational noise impact of the Heckington Fen Wind Park on the residents of nearby dwellings. The assessment considers both the wind farm's construction and its operation and also the likely impact of its de-commissioning.

10.2 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 a proposed wind farm development. However, in assessing the impact of construction noise, it is accepted that the associated works are of a temporary nature. The main works locations for construction of the turbines are distant from nearest noise sensitive residences and are unlikely to cause a significant impact. The construction and use of access tracks may, however, occur at lesser separation distances. Assessment of the temporary impacts of construction noise is primarily aimed at understanding the need for dedicated management measures and, if so, the types of measures that are required.

10.3 Once constructed and operating, wind farms may emit two types of noise. Firstly, aerodynamic noise is a more natural sounding 'broad band' noise, albeit sometimes with 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 a tonal character. 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 ensure that mechanical noise radiation from wind turbines is negligible.

10.4 Aerodynamic noise is usually only perceived when the wind speeds are fairly 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 primary objective of this noise impact assessment is therefore to establish the relationship between wind turbine noise and the naturally occurring masking noise at residential dwellings lying around the proposed wind farm and to assess these levels of noise against accepted standards.

10.5 An overview of environmental noise impact assessment and a glossary of noise terms are provided in Appendix 10.A.

SCOPE AND METHODOLOGY

General Planning Policy and Advice Relating to Noise

10.6 General guidance and policy concerning noise associated with new developments in England is presented in Planning Policy Guidance PPG24: Planning and Noise[1].

10.7 The introduction to PPG24 sets out the importance of appropriately considering noise in planning applications. The ultimate aim of the guidance is to:

'provide advice on how the planning system can be used to minimise the adverse impact of noise without placing unreasonable restrictions on development or adding unduly to the costs and administrative burdens of business.'

10.8 This need to balance essential development against potential adverse noise impact is reiterated in Section 10 of PPG24 where the issue of development control is discussed:

'Much of the development which is necessary for the… improvement of essential infrastructure will generate noise. The planning system should not place unjustifiable obstacles in the way of such development. Nevertheless, local planning authorities must ensure that development does not cause an unacceptable degree of disturbance.'

10.9 Whilst PPG24 presents general considerations relating to planning and noise issues it contains no specific references to noise from wind farms.

Specific Planning Policy and Advice Relating to Construction

10.10 In England and Wales there are two legislative instruments which address the effects of environmental noise with regard to construction noise and vibration, and nuisance. The Environmental Protection Act 1990[2] (EPA) and the Control of Pollution Act 1974[3] (CoPA). The CoPA provides two means of controlling construction noise and vibration. Section 60 provides the Local Authority with the power to impose at any time operating conditions on the development site. Section 61 allows the developer to negotiate a set of operating procedures with the Local Authority prior to commencement of site works.

10.11 To assess construction noise and vibration, PPG24 refers to BS 5228[4] 'Noise control on construction and open sites', Parts 1 to 4, as the appropriate source of guidance. This standard has been updated since PPG24 was published. The most recent update was published in January 2009 and consolidates all previous parts of the standard into BS 5228-1:2009[5] (BS 5228-1) for airborne noise and BS 5228-2:2009[6] (BS 5228-2) for ground borne vibration. These updated standards supersede all previous versions, and have therefore been adopted as the relevant versions upon which to base this assessment.

10.12 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 impact significance. Similarly, BS 5228-2 provides general guidance on legislation, prediction, control and assessment criteria for construction vibration.

Specific Planning Policy and Advice Relating to Operational Wind Farm Noise

10.13 Advice specific to noise emanating from wind energy developments may be found in Planning Policy Statement PPS22 'Renewable Energy'[7].

10.14 The relevant paragraph 22 of PPS22 states:

10.15 'Renewable technologies may generate small increases in noise levels (whether from machinery or from associated sources – for example, traffic). Local planning authorities should ensure that renewable energy developments have been located and designed in such a way as to minimise increases in ambient noise levels. Plans may include criteria that set out the minimum separation distances between different types of renewable energy projects and existing developments. The 1997 report by ETSU for the Department of Trade and Industry should be used to assess and rate noise from wind energy development.'

10.16 The basic aim of the ETSU Report, ETSU-R-97 'The Assessment and Rating of Noise from Wind Farms'8, is to provide:

10.17 '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'.

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

10.19 '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.'

10.20 The recommendations contained in ETSU-R-97 provide a robust basis for assessing the noise implications of a wind farm. ETSU-R-97 has become the accepted standard for such developments within the UK and is commended in PPS22 at paragraph 22. This methodology has therefore been adopted for the present assessment and is described in greater detail below.

Methodology for Assessing Construction Noise Impact

10.21 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.

10.22 The analysis of construction noise impact 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.

10.23 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.

10.24 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).

10.25 The nature of works and distances involved in the construction of a wind farm are such that the risk of significant 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 significant impacts in this instance. Accordingly vibration impacts do not warrant detailed assessment and are therefore not discussed further in this assessment.

Methodology for Assessing Wind Farm Operational Noise Impact

10.26 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 10 metre measurement height.

10.27 Separate noise limits apply for the daytime and night-time. Daytime limits are chosen to protect a property's external amenity and night-time limits are chosen to prevent sleep disturbance indoors. Absolute lower limits, different for daytime and night-time, are applied where the line of best fit representation of the measured background noise levels equates to very low levels (<30 to 35 dB(A) for daytime, and < 38 dB(A) during the night).

10.28 The daytime noise limit is derived from background noise data measured during so-called 'quiet periods of the day', comprising 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 10 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 Appendix 10.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 daytime noise limit, or 'criterion curve', is then set at a level 5 dB(A) above the best fit curve to the background noise data over a 0-12 m/s wind speed range. For wind speeds where the best fit curve to the background noise data lies below a level of 30 dB(A) to 35 dB(A) the criterion curve is set at a fixed level in the range 35 dB(A) to 40 dB(A). The precise choice of criterion curve level within the range 35 dB(A) to 40 dB(A) depends on a number of factors: the number of noise affected properties, the likely duration and level of exposure and the potential impact on the power output of the wind farm. The daytime limits have been set in ETSU-R-97 on the basis of protecting the amenity of residents whilst outside their dwellings in garden areas.

10.29 ETSU-R-97 clearly indicates that the daytime limit is intended to lie within the range from 35 dB(A) to 40 dB(A). Therefore one can conclude that there must be projects where 35 dB(A) is appropriate and conversely, projects where 40 dB(A) is appropriate. Within ETSU-R-97 there is a specific example: "A single wind turbine causing noise levels of 40 dB(A) at several nearby residences would have less planning merit (...) than 30 wind turbines also causing the same amount of noise at several nearby residences". Therefore, where a project offers relatively low power generating potential, the daytime limit should naturally tend towards the lower end of the range, unless the number of noise affected properties and the extent to which those properties would be affected by the higher noise levels is sufficiently low to justify noise limits tending towards the upper end of the range. Conversely, sites with relatively large power generating capacity should naturally justify limits towards the upper end of the range. Given the relatively large energy generating potential of the proposed Heckington Fen Wind Park (particularly when compared to the range of wind farm generating capacities considered at the time ETSU-R-97 was prepared) and the relatively low number of surrounding properties in the immediate vicinity of the scheme (particularly downwind of the scheme under the south westerly conditions that prevail in the UK), the limit should tend towards the upper end of the 35 dB(A) to 40 dB(A) range. The appropriate choice of value is considered subsequently in this chapter.

10.30 The night-time noise criterion curve 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 10 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 night-time noise limit is also based on a level 5 dB(A) above the best fit curve over the 0-12 m/s wind speed range. Where the night-time criterion curve is found to be below 43 dB(A) it is fixed at 43 dB(A). This night time limit in ETSU-R-97 was set on the basis of World Health Organization (WHO) guidance[1] for the noise inside a bedroom and an assumed difference between outdoor and indoor noise levels with windows open. In the time since ETSU-R-97 was released, the WHO guidelines were revised to suggest a lower internal noise level, but conversely, a higher assumed difference between outdoor and indoor noise levels. Notwithstanding the WHO guideline revisions, the ETSU-R-97 limit remains consistent with current national planning policy guidance with respect to night-time noise levels. In addition, following revision of the night-time WHO criteria, ETSU-R-97 has been incorporated into planning guidance for Wales, England and Scotland and at no point during this process was it felt necessary to revise the guidance within ETSU-R-97 to reflect the change in the WHO guideline internal levels. The advice contained within ETSU-R-97 remains a valid reference on which to continue to base the fixed limit at night.

10.31 The exception to the setting of both the daytime and night-time lower limits on the criterion curves occurs where a property occupier has a financial involvement in the wind farm development. Where this is the case then, if the derived criterion curve based on 5 dB(A) above the measured background noise level falls below 45 dB(A), the lower noise limit at that property may be set to 45 dB(A) during both the daytime and the night-time periods alike.

[1] **Environment Criteria 12 : World Health Organisation, 1980**

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

- specify the number and locations of the wind turbines;
- 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 daytime and night-time criterion curves 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;
- compare the calculated wind farm noise immission levels with the derived criterion curves and assess in the light of planning requirements.

10.33 The foregoing steps, as applied to Heckington Fen Wind Park, are set out subsequently in this assessment.

10.34 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 wind farm.

Construction Noise Impact Criteria

10.35 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.

10.36 BS 5228-1 informative Annex E provides example criteria that may be used to consider the impact significance of construction noise. 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 daytime 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, will result in a significant impact unless ambient noise levels (i.e. regularly occurring levels without construction) are sufficiently high to provide a degree of masking of construction noise.

10.37 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) and Minerals Policy Statement 2, Annex 2: Noise, the following impact significance criteria have 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 10.1 have been chosen to relate to daytime hours from 08:00 to 18:00 on weekdays, and 08:00 to 13:00 on Saturdays.

Table 10.1: Free-field Noise Criteria against which Construction Noise Impacts are Assessed

Significance	Condition
Major	Construction noise is greater than 72 dB $L_{Aeq,T}$ for any part of the construction works or exceeds 67 dB $L_{Aeq,T}$ for more than 4 weeks in any 12 month period
Moderate	Construction noise is less than or equal to 67 dB LAeq,T throughout the construction period.
Minor	Construction noise is generally less than or equal to 60 dB LAeq,T, with periods of up to 67 dB LAeq,T lasting not more than 4 weeks in any 12 month period
Negligible	Construction noise is generally less than or equal to 55 dB LAeq,T, with periods of up to 60 dB LAeq,T lasting not more than 4 weeks in any 12 month period

Operational Noise Impact Criteria

10.38 The acceptable limits for wind turbine operational noise are clearly defined in the ETSU-R-97 document and these limits should not be breached. 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 the noise limits derived in accordance with ETSU-R-97. Depending on the levels of background noise the satisfaction of the ETSU-R-97 derived 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 wind farm will still be within levels considered acceptable under the ETSU assessment method.

Consultation

10.39 Prior to undertaking the background surveys, a summary of the proposed monitoring locations was forwarded to the Environmental Health Departments of both North Kesteven District Council and Boston Borough Council for comment and were subsequently agreed to be representative for the purpose of an ETSU-R-97 assessment. This consultation was based on a preliminary project layout which was of a similar form to the layout currently proposed. The agreed noise monitoring locations are shown on Figure 10.1. Further information about the equipment used and pictures of the locations are presented in Appendix 10.C.

BASELINE

General Description

10.40 Heckington Fen Wind Park will cover an area extending approximately 1500 m north to south and 1900 m west to east. The proposed wind farm is located in an area of relatively low population density. The noise environment in the surrounding area is generally characterised by ‘natural’ sources, such as wind disturbed vegetation, birds and farm animals. Occasional military aircraft were also noted and, to the south of the site, road traffic on the A17 and A1121 is a significant source of noise. Intermittent local road and agricultural vehicle movements were also noted in the vicinity of the site.

Details of the Baseline Background Noise Survey

10.41 A total of six noise monitoring locations were agreed with the Local Authorities as being representative of the background noise environment around the wind farm site. These locations were selected as being representative of the noise environment for the nearest residences to the proposal. The six locations are shown on the plan in Appendix 10.B and listed in Table 10.2 below.

Table 10.2: Background Noise Monitoring Locations (approximate Easting / Northing)

No.	Property	Easting	Northing
1	The Old Church	521866	347304
2	College Farm	521865	344434
3	2 Council House	520168	343956
4	Side Bar Lane	518653	344925
5	Glebe Farm	518409	346134
6	Nr Mill Green Farm	520775	346569

10.42 The assessment has considered the impact of the wind farm at the monitoring locations noted above as well as other residential properties located further away from the proposal. The range of assessment locations are listed in Table 10.3. In some instances the results obtained from the six survey positions have been used to represent the background environment expected to occur at other nearby assessment locations. This approach is consistent with the guidance provided by ETSU-R-97. Locations where such representations have been made, and the source of the representations, are represented in Table 10.3 and shown on the plan in Appendix 10.B. 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.

Table 10.3: Assessment Properties in the Vicinity of the Wind Farm

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Survey Location (Table 10.2)
1 - 4 New Cottage, Side Bar Lane	518616	345176	1090	T3	4
2 Council House, East Heckington	520190	343985	1101	T15	3
Catlins Farm	521762	344327	1033	T20	2
College Farm	521901	344438	1100	T20	2
Derwent Cottage, Side Bar Lane	518666	344950	1162	T3	4

Property	Easting	Northing	Approximate Distance to Closest Turbine (m)	Closest Turbine (ID)	Survey Location (Table 10.2)
Elm Grange Farm, East Heckington	519065	344484	1167	T6	3
First Cottage, Side Bar Lane	518697	344809	1229	T3	4
Five Willow Wath Farm, Side Bar Lane	518592	346871	1100	T1	5
Glebe Farm, Side Bar Lane	518472	346187	1115	T1	5
Home Farm, East Heckington	519347	344435	998	T6	3
Mill Green Farm	519952	347320	1023	T1	6
Rakes Farm, East Heckington	520807	343779	1124	T20	3
Rectory Farm House, East Heckington	519660	344208	1048	T6	3
Six Hundreds Drove, East Heckington	520605	343705	1230	T20	3
Spinney Farm	522812	346067	1407	T21	1
Swineshead House	521150	343583	1340	T20	3
The Chapel House, Side Bar Lane	518378	345871	1221	T2	4
The Old Church	521899	347226	1241	T16	1
Unnamed Property (B1395)	518468	345518	1139	T3	4

10.43 The background noise monitoring exercise was conducted over a period of between four and six weeks. The difference in monitoring periods between measurement locations was due to equipment / battery failures that reduced the amount of data collected. As such, the overall monitoring period was extended to gain sufficient data to carry out this assessment. The equipment used for the survey comprised three Rion NL-31 logging sound level meters, two Svantek Svan 945A sound level meters and one Svantek 949 sound level meter. All meters were enclosed in environmental cases with battery power to enable 14 days continuous logging at the required 10 minute averaging periods. Outdoor windshield systems were used to reduce wind induced noise on the microphones and provide protection from rain. These windshield systems were supplied by the sound level meter manufacturer and maintain the required performance of the whole measurement system when fitted. The environmental enclosures provided an installed microphone height of approximately 1.2 m above ground level.

10.44 The sound level meters were generally located on the wind farm side of the property in question where possible, never closer than 3 m 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. The only exception to this was the monitoring location at 2 Council House. Due to the very small amenity area associated with this property and the need to avoid placing the meter in a position that obstructed the driveway, the meter was located closer than 3m from the building façade. The meter was, however, located in the amenity area on the wind farm side of the property. In addition, this location was considered likely to result in a lower background noise level than alternative locations as the building partially screened the monitoring location from road traffic noise on the A17. Details and photographs of the measurement locations are presented in Appendix 10.C.

10.45 All measurement systems were calibrated on their deployment (14th / 15th March 2011 for measurement positions 1 to 4, 29th March 2011 for measurement positions 5 and 6) and upon collection of the equipment on the 12 April 2011. No significant (>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 26 days for each location.

10.46 All measurement systems were 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 clock on the met mast 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.

Measured Background Noise Levels

10.47 Figures D.1 and D.2 reproduced in Appendix 10.D show the range of wind conditions experienced during the noise survey period. The ETSU-R-97 method requires correlation with 10 m height wind speed data which can either be derived from measured 10 m wind speeds or by calculation from measurements at other heights. Wind speeds were measured on a 70 m height meteorological mast located within the boundary of the development site (approximate easting and northing 520858, 345788). The wind shear between the 60 m and 70 m anemometers was determined for each 10 minute period in order to calculate the 80 m height wind speed (corresponding to hub height), which is then corrected to 10 m height using a standardised roughness length of 0.05 m (for further details please refer to Appendix 10.F). During the quiet daytime and night-time periods, standardised wind speeds were typically less than 10 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 for the UK.

10.48 The ETSU-R-97 method requires correlation of the noise data with wind speed data at a 10 m height which can either be derived from measured 10 m wind speeds or by calculation from measurements 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, and subsequently influences the choice of method used to derive 10 m height wind speed data.

10.49 The effect of wind shear can be addressed by implementing the ETSU-R-97 option of deriving 10 m height reference data from measurements made at taller heights. It is this method that has been used in the noise assessment for the Heckington Fen Wind Park to account for the potential effect of site specific wind shear by correlating measured baseline noise data with taller height wind speed data that enables hub height wind speed estimates to be made. This method is consistent with the provisions of ETSU-R-97 and a recent article in a UK Institute of Acoustics Bulletin[10] which provided recommendations on a range of subjects relating to wind farm noise assessment, including wind shear.

10.50 Figures E.1 to E.38 of Appendix 10.E show the results of the background noise measurements at each of the six monitoring locations. The background noise data are presented in terms of $L_{A90,10min}$ background noise levels plotted as a function of 10 m height wind speed. Two plots are shown for each location, one for quiet daytime periods and the other for night-time periods, both derived in accordance with ETSU-R-97.

10.51 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 suggests that any data that may have been affected by rainfall be excluded from the analysis. The meteorological monitoring system had a rain gauge installed during the noise survey period; data from this gauge was therefore used to exclude those periods where rain was indicated.

10.52 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 negligible influence on background sound levels, and thus the possible effect of increased tyre nose from wet roads is not considered relevant to this site. In terms of water flow noise, the site is generally flat and there were no significant water courses in the near vicinity of the monitoring locations. 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 affect 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). Notwithstanding this, the possibility exists that some of the measured background noise data at low wind speeds may have been increased by extraneous or rain related influences. Time-histories of the noise levels at each survey location were 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 which were again excluded.

10.53 Analysis of the background data measured on Side Bar Lane and at 2 Council House indicated that, at these properties, background noise levels were typically lower when wind speeds were generally from the North. This is likely to be because of the influence of road traffic noise from the A17, which runs to the South of the site. As such, when winds are from the North, the A17 is downwind of 2 Council House and the properties on Sidebar Lane and therefore these locations experience less noise from the road. For this reason, the data for these two locations has also been filtered to remove all data points when winds were from the South. This results in reducing the derived background noise curve at these receptors. Any data removed from the analysis has been indicated on the charts as red circles.

10.54 Following removal of these data points, the best-fit lines were generated using a polynomial fit of a maximum of 3rd order. These lines of 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 Tables 10.4 and 10.5. 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 is described in paragraph 10.27. For financially involved properties the lower absolute limit becomes 45 dB(A).

Table 10.4 Daytime $L_{A90,T}$ Noise Limits Derived from the Baseline Noise Survey According to ETSU-R-97

Property	Wind Speed at 10 m Height, m/s									
	3	4	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	40.0	40.4	40.9	41.6	42.3	43.0	43.8	43.8	43.8	43.8
2 Council House, East Heckington	46.9	47.6	48.3	49.0	49.7	50.2	50.2	50.2	50.2	50.2
Catlins Farm	40.0	40.0	40.0	40.9	42.5	44.2	46.0	47.7	47.7	47.7
College Farm	40.0	40.0	40.0	40.9	42.5	44.2	46.0	47.7	47.7	47.7
Derwent Cottage, Side Bar Lane	40.0	40.4	40.9	41.6	42.3	43.0	43.8	43.8	43.8	43.8
Elm Grange Farm, East Heckington	46.9	47.6	48.3	49.0	49.7	50.2	50.2	50.2	50.2	50.2
First Cottage, Side Bar Lane	40.0	40.4	40.9	41.6	42.3	43.0	43.8	43.8	43.8	43.8
Five Willow Wath Farm, Side Bar Lane	40.0	40.0	40.0	40.0	41.2	43.0	44.8	46.8	46.8	46.8
Glebe Farm, Side Bar Lane	40.0	40.0	40.0	40.0	41.2	43.0	44.8	46.8	46.8	46.8
Home Farm, East Heckington	46.9	47.6	48.3	49.0	49.7	50.2	50.2	50.2	50.2	50.2
Mill Green Farm	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.7	40.7	40.7
Rakes Farm, East Heckington	46.9	47.6	48.3	49.0	49.7	50.2	50.2	50.2	50.2	50.2
Rectory Farm House, East Heckington	46.9	47.6	48.3	49.0	49.7	50.2	50.2	50.2	50.2	50.2
Six Hundreds Drove, East Heckington	46.9	47.6	48.3	49.0	49.7	50.2	50.2	50.2	50.2	50.2
Spinney Farm	40.0	40.0	40.0	40.0	40.0	40.4	44.5	49.1	49.1	49.1
Swineshead House	46.9	47.6	48.3	49.0	49.7	50.2	50.2	50.2	50.2	50.2
The Chapel House, Side Bar Lane	40.0	40.4	40.9	41.6	42.3	43.0	43.8	43.8	43.8	43.8
The Old Church	40.0	40.0	40.0	40.0	40.0	40.4	44.5	49.1	49.1	49.1
Unnamed Property (B1395)	40.0	40.4	40.9	41.6	42.3	43.0	43.8	43.8	43.8	43.8

Table 10.5 Night-time $L_{A90,T}$ Noise Limits Derived from the Baseline Noise Survey According to ETSU-R-97

Property	Wind Speed at 10 m Height, m/s									
	3	4	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

2 Council House, East Heckington	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Catlins Farm	43.0	43.0	43.0	43.0	43.0	43.0	45.1	49.1	51.3	51.3
College Farm	43.0	43.0	43.0	43.0	43.0	43.0	45.1	49.1	51.3	51.3
Derwent Cottage, Side Bar Lane	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Elm Grange Farm, East Heckington	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
First Cottage, Side Bar Lane	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Five Willow Wath Farm, Side Bar Lane	43.0	43.0	43.0	43.0	43.0	43.0	44.3	48.9	51.5	51.5
Glebe Farm, Side Bar Lane	43.0	43.0	43.0	43.0	43.0	43.0	44.3	48.9	51.5	51.5
Home Farm, East Heckington	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Mill Green Farm	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	44.3	44.3
Rakes Farm, East Heckington	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Rectory Farm House, East Heckington	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Six Hundreds Drove, East Heckington	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Spinney Farm	43.0	43.0	43.0	43.0	43.0	43.0	43.0	48.1	48.1	48.1
Swineshead House	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
The Chapel House, Side Bar Lane	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
The Old Church	43.0	43.0	43.0	43.0	43.0	43.0	43.0	48.1	48.1	48.1
Unnamed Property (B1395)	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0

ASSESSMENT OF EFFECTS

Predicted Construction Noise Levels

10.55 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 plant, equipment etc 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.

10.56 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.

10.57 In order 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/soft.

10.58 Table 10.6 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 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 to the noise level occurring during the time when the activity is closest to the referenced property. In many cases such as access track construction and turbine erection, the separating distances will be significantly greater and therefore the predictions are the worst case for the majority of the construction period.

Table 10.6 Predicted Construction Noise Levels

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day LWA,T	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day Time Noise Levels LAeq,T
Upgrade Access Track	excavator / dump trucks / tippers / dozers / vibrating rollers	120	Rectory Cottages	260	61
Construct site tracks	excavators / dump trucks / tippers / dozers / vibrating rollers	120	Rectory Cottages	70	74
Construct Sub-Station	excavator / concrete truck / delivery truck	110	1 Council House	1350	36
Construct crane hardstandings	excavators / dump trucks	120	Catlins Farm	960	49
Construct turbine foundations	Piling Rigs / excavators / tippers / concrete trucks / mobile cranes / water pumps / pneumatic hammers / compressors / vibratory pokers	120	Catlins Farm	960	49
Excavate and lay site cables	excavators / dump trucks / tractors & cable drum trailers / wacker plates	110	Catlins Farm	960	39
Erect turbines	cranes / turbine delivery vehicles / artics for crane movement / generators / torque guns	120	Catlins Farm	960	49
Reinstate crane bases	excavator / dump truck	115	Catlins Farm	960	44

Task Name	Plant/Equipment	Upper Collective Sound Emission Over Working Day LWA,T	Nearest Receiver	Minimum Distance to Nearest Receiver	Predicted Upper Day Time Noise Levels LAeq,T
Reinstate road verges	excavator / dump truck	115	Rectory Cottages	70	69
Lay cable to sub-stations	JCB / saws / hydraulic breaker / dump truck/ tipper / wacker plate / tandem roller / tractor & cable drum trailer / delivery truck	115	Catlins Farm	960	44

10.59 Comparing the above predicted noise levels to the range of background noise levels measured around the site suggests that the noisier construction activities would be audible at various times throughout the construction phase. However, comparing the level to the impact significance criteria presented previously indicates that the majority of receptors will experience a noise impact that would be considered negligible and therefore not significant.

10.60 The exceptions to this are Rectory Cottages, which are predicted to experience a noise impact that would be considered moderate to major during construction of the new access track, upgrading of the nearest access tracks to these properties and during the reinstatement of road verges. It should, however, be noted that these predictions are based on the minimum likely working distance from these properties. Work would only take place at these distances for a very limited time during the overall construction period, with noise levels experienced at Rectory Cottages being significantly lower as the site works progress further from these properties. Given the high noise levels that are predicted at these properties, however, it is recommended that temporary site hoardings / noise barriers are positioned close to the works during the relevant phases of construction to reduce noise levels experienced at Rectory Cottages.

10.61 A solid barrier that blocks the line of site from construction works to a receptor would be anticipated to reduce noise levels by approximately 10 dB. As such, the worst case noise levels experienced at Rectory Cottages would be of the order of 64 dB. Since construction works on access tracks would be expected to be at the minimum distance from Rectory Cottages for significantly less than 4 weeks, reference to the significance criteria in Table 10.1 would indicate that, with the effect of reasonable screening from temporary hoardings, noise impacts at Rectory Cottages would be reduced to minor and therefore not significant.

10.62 In addition to on-site activities, construction traffic passing to and from the site will also represent a potential source of noise impact to surrounding properties. The traffic statement for the proposal presented in **Chapter 11** has identified that the most intensive traffic will occur in during the construction of the hard standing, access tracks and turbine foundations. Specifically the highest volume of traffic generated by construction is expected to occur in the 15th week of construction in which an average of 31 total vehicle movements is predicted per day. These predicted movements include a high portion of HGVs as well as other lighter vehicles such as vans. This flow value is well below the minimum flow volume of 1000 vehicles per day that is required by the CRTN methodology to enable reliable predictions. However, given that these vehicles will access the site from the A17, which currently experiences high existing traffic flows, (circa 10,000 vehicle movements per 12 hour day on average in 2001, based on available Highways Agency the available information). As such, the small predicted increases in road traffic would result in less than a 1 dB increase in noise levels.

Wind Turbine Emission Data

10.63 The exact model of turbine to be used at the site will be the result of a future tendering process and therefore an indicative turbine model has been assumed for this noise assessment. This operational noise assessment is based upon the noise specification of the Enercon E82-E2 2.3MW wind turbine. 22 turbines have been modelled using the layout as indicated on the map in Appendix 10.B. The candidate turbine is a variable speed, pitch regulated machine with a rotor diameter of 82 m and a hub height of 79 m. Due to its variable speed operation the sound power output of the Enercon E82 turbine varies with wind speed, being considerably quieter at the lower wind speeds when the blades are rotating more slowly.

10.64 Enercon have supplied their guaranteed noise emission data for the E82 turbine which has been derived from various sound power tests, and represent the values that the manufacturer warrant will not be exceeded in practice. This includes an allowance for measurement uncertainty. The sound power data has been made available for 10 m height reference wind speeds of 5 to 12 m/s inclusive. In addition to the overall sound power data, reference has been made to a test report 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 10.7 and Table 10.8.

Table 10.7 Wind Turbine Sound Power Levels for an 80 m hub height Enercon E82-E2 2.3MW Turbine

Wind Speed at 10 m Height (m/s)	Sound Power Level (dB LAeq)
5	98.3
6	102.7
7	105.3
8	105.5
9	105.5
10	105.5
11	105.5
12	105.5

Table 10.8 Octave Band Sound Power Spectrum (dB L_{Aeq}) for the Enercon E82-E2 2.3MW Operating in Reference Wind Speed Conditions (v_{10} = 8 m/s)

Octave Band Centre Frequency, Hz	A-Weighted Sound Power Level, dB(A)
63	86.7
125	94.7
250	94.4
500	97.0
1000	98.8
2000	93.9

4000	81.6
8000	73.5

Choice of Wind Farm Operational Noise Propagation Model

10.65 Whilst there are several noise propagation models available, here the ISO 9613-2 model[11] has been used to calculate the noise immission levels at the selected nearest residential neighbours. This model has been identified as most appropriate for use in predicting far-field noise radiation from wind turbines in such rural sites.

10.66 The model accounts for the attenuation due to geometric spreading, atmospheric absorption, and ground effects. The model offers the ability to account for barrier effects however this has not been included for in this assessment. All attenuation calculations have been made on an octave band basis and therefore account for the sound frequency characteristics of the turbines. The ISO 9613-2 algorithm has been chosen as being the most robust prediction method based on the findings of a joint European Commission research project into wind farm noise propagation over large distances. The title of the research project was 'Development of a wind farm Noise Prediction Model'[12].

10.67 Whilst it is impossible to specify exact error bands on noise predictions, the ISO 9613-2 model was found to be the best available both in flat and complex terrain. This model, like all the others, tends to over-estimate the noise at nearby dwellings rather than under-estimate it. The only exception to this finding was the general tendency for the ISO 9613-2 model to over predict the excess attenuation due to screening by ground features. For this reason the attenuation due to screening accounted for in the calculations has been limited to a maximum of 2 dB(A). With this limitation applied to the ISO 9613-2 model the over-riding conclusion of the work undertaken as part of the EC research study was that the ISO 9613-2 model tended to predict noise levels which would generally occur under downwind propagation conditions. The probability of non-exceedence of the levels predicted by the ISO 9613-2 model was around 85%. The other important outcome of the research was to clearly demonstrate that under upwind propagation conditions between a given receiver and the wind farm the noise immission level at that receiver will be as much as 10 dB(A) to 15 dB(A) lower than the level predicted using the ISO 9613-2 model.

10.68 For the purposes of the present assessment, all noise level predictions have been undertaken using a receiver height of 4 m above local ground level, mixed ground (g=0.5) and an air absorption based on a temperature of 10℃ and 70% relative humi dity. A receiver height of 4 m will be typical of first floor windows and result in slightly higher predicted noise levels than if a 1.2 m to 1.5 m receiver height were chosen in the ISO 9613 algorithm. There are no screening effects found at the site and therefore this element was excluded from the model.

Predicted Wind Farm Operational Noise Immission Levels

10.69 Table 10.9 shows predicted noise immission levels, L_p, at each of the selected assessment locations for each 10 m height wind speed from 4 m/s to 12 m/s inclusive. 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 warranted turbine sound power levels presented in Table 10.7 and Table 10.8.

Table 10.9 Predicted $L_{A90,T}$ Wind Farm Noise Immission Levels at 4 m Height at Each of the Noise Assessment Locations as a Function of 10 m Height Wind Speed – 22 Enercon E82 Turbines

Property	Wind Speed at 10 m Height, m/s							
	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	30.9	35.3	37.9	38.1	38.1	38.1	38.1	38.1
2 Council House, East Heckington	31.7	36.1	38.7	38.9	38.9	38.9	38.9	38.9
Catlins Farm	31.1	35.5	38.1	38.3	38.3	38.3	38.3	38.3
College Farm	31.0	35.4	38.0	38.2	38.2	38.2	38.2	38.2
Derwent Cottage, Side Bar Lane	30.5	34.9	37.5	37.7	37.7	37.7	37.7	37.7
Elm Grange Farm, East Heckington	30.9	35.3	37.9	38.1	38.1	38.1	38.1	38.1
First Cottage, Side Bar Lane	30.3	34.7	37.3	37.5	37.5	37.5	37.5	37.5
Five Willow Wath Farm, Side Bar Lane	29.8	34.2	36.8	37.0	37.0	37.0	37.0	37.0
Glebe Farm, Side Bar Lane	30.7	35.1	37.7	37.9	37.9	37.9	37.9	37.9
Home Farm, East Heckington	32.0	36.4	39.0	39.2	39.2	39.2	39.2	39.2
Mill Green Farm	32.5	36.9	39.5	39.7	39.7	39.7	39.7	39.7
Rakes Farm, East Heckington	30.4	34.8	37.4	37.6	37.6	37.6	37.6	37.6
Rectory Farm House, East Heckington	31.9	36.3	38.9	39.1	39.1	39.1	39.1	39.1
Six Hundreds Drove, East Heckington	30.0	34.4	37.0	37.2	37.2	37.2	37.2	37.2
Spinney Farm	28.3	32.7	35.3	35.5	35.5	35.5	35.5	35.5
Swineshead House	28.7	33.1	35.7	35.9	35.9	35.9	35.9	35.9
The Chapel House, Side Bar Lane	30.2	34.6	37.2	37.4	37.4	37.4	37.4	37.4
The Old Church	29.9	34.3	36.9	37.1	37.1	37.1	37.1	37.1
Unnamed Property (B1395)	30.6	35.0	37.6	37.8	37.8	37.8	37.8	37.8

Residual Wind Farm Operational Noise Impacts

10.70 **Figures E.1 to E.38 (Appendix 10.E)** show the calculated wind farm noise immission levels at the 19 noise impact assessment locations and correspond to those already presented in Table 10.9, plotted as a function of 10 m height wind speed. The calculated noise immission levels are shown overlaid on the daytime and night-time noise limit criterion curves. These criterion 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.

10.71 The ETSU-R-97 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 ETSU-R-97 recommendations suggest a tone correction which depends on the amount by which the tone exceeds the audibility threshold. The turbines to be used for this site will emit noise which contains no tones that would incur a penalty when assessed by the method specified in ETSU-R-97; this will be included in the tender and warranty agreements for the site and should be included in any noise conditions. No corrections for tones have therefore been included in this assessment.

10.72 The assessment (shown in tabular form in Table 10.10 & Table 10.11) shows that the predicted wind farm noise immission levels meet the ETSU-R-97 derived noise limits under all wind speeds and at all locations, based on a lower day-time limit of 40 dB(A).

Table 10.10 Exceedances of the ETSU-R-97 Derived Day-time Criterion Curves by the Predicted LA90,T Wind Farm Noise Immission Levels at Each Noise Assessment Location. Exceedances based on 40 dB(A) lower daytime limit and negative values indicate the immission level is below the limit.

Property	Wind Speed at 10 m Height, m/s							
	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	-10.1	-6.3	-4.4	-4.9	-5.8	-5.7	-5.7	-5.7
2 Council House, East Heckington	-16.6	-12.9	-11.0	-11.3	-11.3	-11.3	-11.3	-11.3
Catlins Farm	-8.9	-5.4	-4.4	-5.9	-7.6	-9.4	-9.4	-9.4
College Farm	-9.0	-5.5	-4.6	-6.1	-7.8	-9.5	-9.5	-9.5
Derwent Cottage, Side Bar Lane	-10.4	-6.6	-4.7	-5.3	-6.1	-6.1	-6.1	-6.1
Elm Grange Farm, East Heckington	-17.4	-13.7	-11.8	-12.1	-12.1	-12.1	-12.1	-12.1
First Cottage, Side Bar Lane	-10.7	-6.9	-5.0	-5.6	-6.4	-6.3	-6.3	-6.3
Five Willow Wath Farm, Side Bar Lane	-10.2	-5.8	-4.5	-6.0	-7.9	-9.9	-9.8	-9.8
Glebe Farm, Side Bar Lane	-9.3	-4.9	-3.6	-5.1	-6.9	-9.0	-8.9	-8.9
Home Farm, East Heckington	-16.3	-12.6	-10.7	-11.0	-11.0	-11.0	-11.0	-11.0
Mill Green Farm	-7.5	-3.1	-0.5	-0.3	-0.3	-1.0	-1.0	-1.0
Rakes Farm, East Heckington	-17.9	-14.2	-12.3	-12.6	-12.6	-12.6	-12.6	-12.6
Rectory Farm House, East Heckington	-16.4	-12.7	-10.8	-11.1	-11.1	-11.1	-11.1	-11.1
Six Hundreds Drove, East Heckington	-18.3	-14.6	-12.7	-13.0	-13.0	-13.0	-13.0	-13.0
Spinney Farm	-11.7	-7.3	-4.7	-5.0	-9.0	-13.7	-13.6	-13.6
Swineshead House	-19.6	-15.9	-14.0	-14.3	-14.3	-14.3	-14.3	-14.3
The Chapel House, Side Bar Lane	-10.8	-7.0	-5.1	-5.6	-6.5	-6.4	-6.4	-6.4
The Old Church	-10.1	-5.7	-3.1	-3.4	-7.5	-12.1	-12.0	-12.0
Unnamed Property (B1395)	-10.4	-6.6	-4.7	-5.3	-6.1	-6.0	-6.0	-6.0

Table 10.11 Exceedances of the ETSU-R-97 Derived Night-time Criterion Curves by the Predicted $L_{A90,T}$ Wind Farm Noise Immission Levels at Each Noise Assessment Location. Exceedances with negative values indicate the immission level is below the limit

Property	Wind Speed at 10 m Height, m/s							
	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	-12.1	-7.7	-5.1	-4.9	-4.9	-4.9	-4.9	-4.9
2 Council House, East Heckington	-11.3	-6.9	-4.3	-4.1	-4.1	-4.1	-4.1	-4.1
Catlins Farm	-11.9	-7.5	-4.9	-4.7	-6.8	-10.8	-13.0	-13.0
College Farm	-12.0	-7.6	-5.0	-4.8	-6.9	-10.9	-13.1	-13.1
Derwent Cottage, Side Bar Lane	-12.5	-8.1	-5.5	-5.3	-5.3	-5.3	-5.3	-5.3
Elm Grange Farm, East Heckington	-12.1	-7.7	-5.1	-4.9	-4.9	-4.9	-4.9	-4.9
First Cottage, Side Bar Lane	-12.8	-8.4	-5.8	-5.6	-5.6	-5.6	-5.6	-5.6
Five Willow Wath Farm, Side Bar Lane	-13.2	-8.8	-6.2	-6.0	-7.4	-12.0	-14.5	-14.5
Glebe Farm, Side Bar Lane	-12.3	-7.9	-5.3	-5.1	-6.4	-11.0	-13.6	-13.6
Home Farm, East Heckington	-11.0	-6.6	-4.0	-3.8	-3.8	-3.8	-3.8	-3.8
Mill Green Farm	-10.5	-6.1	-3.5	-3.3	-3.3	-3.3	-4.6	-4.6
Rakes Farm, East Heckington	-12.6	-8.2	-5.6	-5.4	-5.4	-5.4	-5.4	-5.4
Rectory Farm House, East Heckington	-11.1	-6.7	-4.1	-3.9	-3.9	-3.9	-3.9	-3.9
Six Hundreds Drove, East Heckington	-13.0	-8.6	-6.0	-5.8	-5.8	-5.8	-5.8	-5.8
Spinney Farm	-14.7	-10.3	-7.7	-7.5	-7.5	-12.6	-12.6	-12.6
Swineshead House	-14.3	-9.9	-7.3	-7.1	-7.1	-7.1	-7.1	-7.1
The Chapel House, Side Bar Lane	-12.8	-8.4	-5.8	-5.6	-5.6	-5.6	-5.6	-5.6
The Old Church	-13.1	-8.7	-6.1	-5.9	-5.9	-11.0	-11.0	-11.0
Unnamed Property (B1395)	-12.4	-8.0	-5.4	-5.2	-5.2	-5.2	-5.2	-5.2

10.73 The ETSU-R-97 fixed part of the limit during the daytime should lie within the range from 35 dB(A) to 40 dB(A). The factors to be used to determine where in this range have been discussed above. Given the scale of this scheme, coupled with the effect that having a limit at the lower end of this range would have on the number of turbines installed, it is considered wholly appropriate to set the limit toward the upper end of the range. To support this, it must be recognised that the power generating capacity of modern wind turbines has dramatically increased over that which was typical at the time the ETSU-R-97 guidelines were produced. For example at the time the guide was produced, a wind farm site comprising around 85 turbines would have been required to achieve a similar generating capacity to that which is proposed at Heckington Fen with 22 turbines, thus highlighting the significance of the scheme.

10.74 In determining the choice of limit within the 35 dB(A) to 40 dB(A) range, it is worth considering the stringency of these values in the context of the general day-time noise climate in the UK as well as the types of absolute daytime limit values referenced in other noise assessments. Table 10.12 provides a summary of such references in terms of the L_{Aeq} value (an energy average of the noise over a given period). The lower limit range of 35 dB(A) to 40 dB(A) for wind farms is expressed in terms of the L_{A90} value; the equivalent range in terms of the L_{Aeq} values (for comparison with the values in the table) is 37 dB(A) to 42 dB(A).

Table 10.12 Example UK references for noise statistics in addition to noise polices which reference absolute limit values to assess different types of noise sources

Reference	Description	Reference Day Time Noise Levels. All levels are free-field LAeq values for 16 hour period between 07:00 and 23:00 unless otherwise stated.
PPG24: Planning and Noise	PPG24 provides a Noise Exposure Category scheme for rating the suitability of noise conditions for new residential development. It specifically states that the NEC procedure is not applicable to assessing the introduction of new sources to an existing residential area. The values do however provide a reference when considering the possibility of future residential development near existing dwellings.	At day time noise levels less than 55 dB(A), PPG24 states that noise is not a consideration when proposing new residential development. The exception to this is when industrial noise dominates the day time levels, however according to PPG24 definitions an ETSU-R-97 compliant wind farm would not be considered a dominant source.
MPS2: Controlling and Mitigating the Environmental Effects of Mineral Extraction in England, Annex 2: Noise	MPS2 modify states that "minerals are essential for development and through that for our quality of life. Minerals planning ensures that the need for minerals by society and the economy is carefully balanced against the impacts of extraction and processing on people and the environment". Annex 2 provides guidance on recommended planning condition limits for day, evening and night noise levels.	Planning should attempt to achieve day time (07:00 to 19:00) noise levels less than 10dB(A) above the background, but states this is likely to impose unreasonable burdens in many instances, and thus permits a limit up to 55 dB LAeq, 1 hour. It further states that allowances need to be made for brief periods where noise levels will be higher, and suggests an increased limit of up to 70 dB LAeq, 1 hour for up to 8 weeks in one year. Absolute limits are not provided for the evening hours (19:00 23:00), however an absolute limit of 42 dB LAeq,1 hour is stated for the night time (23:00 to 07:00)
Noise Insulation (Road) Regulations 1975	Prescribes a daytime trigger value for the noise level impact at properties affected by new roads. Above this trigger value, affected residents may be eligible for compensation / remedial insulation measures for their properties.	Daytime noise level of 63 dB(A) (converted value as described in Annex 2 of PPG24)
National Noise Incidence Survey 2000/2001 (United Kingdom): Volume 1 - Noise Levels	Prepared by the Building Research Establishment, and supported by the Department for the Environment Food and Rural Affairs. The report presented the findings of a nation wide noise survey of 1020 locations in England and Wales used to estimate population statistics for noise exposure.	The study indicates the following day time external façade exposures (includes the influence of noise reflected from the building): ▪ 90% of the population live in dwellings with exposure above 50 dB(A) ▪ 55% of the population live in dwellings with exposure above 55 dB(A) ▪ 10% of the population live in dwellings with exposure above 65 dB(A)
WHO Guidelines for Community Noise	Presents health-based guideline noise values for different environments	Day time noise levels between 50 dB(A) and 55 dB(A) are sufficient to invoke moderate annoyance. Levels greater than 55 dB(A) are sufficient to invoke serious annoyance.

10.75 It can be seen from Table 10.12 that the absolute limit range for wind farms is substantially below the absolute limit values used for assessing road transportation and mining industry developments, both of which could represent significant and dominant sources in otherwise quiet areas. The absolute limit range for wind farms is well below the 50 dB(A) value defined by WHO guidelines as the onset for moderate annoyance. The range is also well below the façade value of 50 dB(A) that the National Noise Incidence survey defined as the minimum level that the dwellings of 90% of the English and Welsh population are already exposed to. In addition to these external noise standards, it is worth considering that the ETSU-R-97 absolute outdoor limit range is of a similar magnitude to the levels defined in other UK guidance documents for acceptable resting and listening conditions inside of residential accommodation and education spaces.

10.76 These comparisons, in conjunction with the UK governments increased formal commitment to renewable energy development since ETSU-R-97 was formulated, highlights that even the maximum absolute limit of 40 dB(A) represents a very stringent criterion that places considerable burdens and constraints on the expansion of renewable energy from wind farms.

Low Frequency Noise and Vibration

10.77 Low frequency noise and vibration resulting from the operation of wind farms, together with the often associated subject of blade swish, are all issues that have been attracting an increasing amount of attention over recent years. Consequently Appendix 10.A includes a detailed discussion of these topics. In summary of the information provided therein, the current recommendation is that ETSU-R-97 should continue to be used in its present form for the assessment and rating of operational noise from wind farms.

ALTERNATIVE SCHEME OPTIONS

10.78 Whilst the assessment presented above demonstrates that the site can be operated within the requirements of ETSU-R-97 with 22 Enercon E82-E2 2.3MW turbines, there are alternative turbines available that, whilst slightly larger than the Enercon machine, can provide a higher potential generating capacity per turbine. Consequently, it would be potentially feasible to increase the overall generating capacity of the site whilst at the same time reducing the total number of turbines used. Since this may be seen as beneficial for various reasons, the differences in noise levels that would result in changing to alternative turbines has been considered here for two different candidate turbines.

10.79 The alternative candidate turbines that have been considered in this assessment are the Nordex N90 (low speed) 2.5 MW turbine and the Vestas V90 3.0MW turbine. If the Nordex N90 option is used, the number of turbines on the site could be reduced to 21, with a slight increase in overall site generating capacity from the 22 turbine Enercon E82 base case (50.6MW). If the Vestas V90 turbine is used, the number of turbines could be reduced to 18, again with a higher overall generating capacity than in the base case. Both of these candidate turbines can be installed with an 80m hub height, however the rotor diameters of both the Nordex N90 and Vestas V90 are 90m as compared to the 82m rotor diameter of the Enercon E82 machine.

10.80 It should be noted that any reduction in turbine numbers would not result in the proposed turbine positions changing. Turbines would be excluded from the proposed layout without any associated change in turbine locations.

10.81 As for the Enercon turbines that have been considered in the assessment above, Nordex and Vestas have provided noise data for the alternative turbine options. The following tables summarise the turbine source noise data provided by the relevant manufacturers. The sound power levels presented below relate to measured levels, plus an allowance for measurement uncertainty. This is consistent with the data used above for the Enercon turbines.

Table 10.13 Wind Turbine Sound Power Levels for an 80 m hub height Nordex N90LS 2.5MW Wind Turbine

Wind Speed at 10 m Height (m/s)	Sound Power Level (dB L_{Aeq})
3	94.5
4	98.5
5	101.5
6	103.5
7	104.5
8	105.0
9	105.3
10	105.5
11	105.5
12	105.5

Table 10.14 Octave Band Sound Power Spectrum (dB L_{Aeq}) for the Nordex N90LS 2.5MW Turbine Operating in Reference Wind Speed Conditions (v_{10} = 8 m/s)

Octave Band Centre Frequency, Hz	A-Weighted Sound Power Level, dB(A)
63	88.0
125	93.3
250	97.9
500	97.0
1000	94.3
2000	95.5
4000	90.3
8000	77.2

Table 10.15 Wind Turbine Sound Power Levels for an 80 m hub height Vestas V90 3.0MW Turbine

Wind Speed at 10 m Height (m/s)	Sound Power Level (dB L_{Aeq})
4	97.9
5	100.9
6	104.2
7	106.1
8	107.0
9	106.9
10	105.9
11	105.2
12	105.3

Table 10.16 Octave Band Sound Power Spectrum (dB L_{Aeq}) for the Vestas V90 3.0MW Turbine Operating in Reference Wind Speed Conditions (v_{10} = 8 m/s)

Octave Band Centre Frequency, Hz	A-Weighted Sound Power Level, dB(A)
63	91.1
125	93.1
250	95.8
500	98.1
1000	100.6
2000	99.8
4000	95.9
8000	85.6

10.82 If the Nordex N90 option is progressed, the scheme will consist of turbines located as per the plan shown in Appendix 10.B, but with Turbine 1 excluded. Given this layout, the following exceedances of the noise limits presented in Table 10.4 and Table 10.5 would be predicted. Numbers in brackets in the following tables indicate the predicted increase in noise level for each receptor from the 22 turbine Enercon E82 base case.

Table 10.17 Exceedances of the ETSU-R-97 Derived Day-time Criterion Curves by the Predicted $L_{A90,T}$ Wind Farm Noise Immission Levels at Each Noise Assessment Location with 21 x Nordex N90 Turbines. Exceedances based on 40 dB(A) lower daytime limit and negative values indicate the immission level is below the limit. Figures in brackets show the increase or decrease in relation to the 22 turbine Enercon E82 base case.

Property	Wind Speed at 10 m Height, m/s									
	3	4	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	-13.0 (-)	-9.3 (-)	-6.9 (3.1)	-5.6 (0.7)	-5.3 (-0.9)	-5.5 (-0.6)	-6.0 (-0.3)	-5.8 (-0.1)	-5.8 (-0.1)	-5.8 (-0.1)
2 Council House, East Heckington	-18.9 (-)	-15.6 (-)	-13.3 (3.3)	-12.0 (0.9)	-11.7 (-0.7)	-11.7 (-0.4)	-11.4 (-0.1)	-11.2 (0.1)	-11.2 (0.1)	-11.2 (0.1)
Catlins Farm	-12.5 (-)	-8.5 (-)	-5.5 (3.4)	-4.4 (1.0)	-5.1 (-0.6)	-6.3 (-0.4)	-7.7 (-0.1)	-9.2 (0.1)	-9.2 (0.1)	-9.2 (0.1)
College Farm	-12.7 (-)	-8.7 (-)	-5.7 (3.4)	-4.6 (1.0)	-5.2 (-0.6)	-6.4 (-0.3)	-7.8 (0.0)	-9.4 (0.2)	-9.4 (0.2)	-9.4 (0.2)
Derwent Cottage, Side Bar Lane	-13.3 (-)	-9.6 (-)	-7.2 (3.2)	-5.8 (0.8)	-5.5 (-0.8)	-5.8 (-0.5)	-6.3 (-0.2)	-6.1 (0.0)	-6.1 (0.0)	-6.1 (0.0)
Elm Grange Farm, East Heckington	-19.8 (-)	-16.5 (-)	-14.2 (3.3)	-12.9 (0.9)	-12.6 (-0.7)	-12.6 (-0.4)	-12.3 (-0.1)	-12.1 (0.1)	-12.1 (0.1)	-12.1 (0.1)
First Cottage, Side Bar Lane	-13.5 (-)	-9.9 (-)	-7.5 (3.2)	-6.1 (0.8)	-5.8 (-0.8)	-6.0 (-0.5)	-6.6 (-0.2)	-6.3 (0.0)	-6.3 (0.0)	-6.3 (0.0)
Five Willow Wath Farm, Side Bar Lane	-14.7 (-)	-10.7 (-)	-7.7 (2.6)	-5.7 (0.2)	-5.9 (-1.4)	-7.1 (-1.1)	-8.7 (-0.8)	-10.5 (-0.6)	-10.5 (-0.6)	-10.5 (-0.6)
Glebe Farm, Side Bar Lane	-13.6 (-)	-9.6 (-)	-6.6 (2.7)	-4.6 (0.3)	-4.8 (-1.3)	-6.0 (-1.0)	-7.6 (-0.7)	-9.4 (-0.5)	-9.4 (-0.5)	-9.4 (-0.5)
Home Farm, East Heckington	-18.7 (-)	-15.4 (-)	-13.1 (3.2)	-11.8 (0.8)	-11.5 (-0.8)	-11.5 (-0.5)	-11.2 (-0.2)	-11.0 (0.0)	-11.0 (0.0)	-11.0 (0.0)
Mill Green Farm	-11.7 (-)	-7.7 (-)	-4.7 (2.8)	-2.7 (0.4)	-1.7 (-1.2)	-1.2 (-0.9)	-0.9 (-0.6)	-1.4 (-0.4)	-1.4 (-0.4)	-1.4 (-0.4)
Rakes Farm, East Heckington	-20.1 (-)	-16.8 (-)	-14.5 (3.4)	-13.2 (1.0)	-12.9 (-0.6)	-12.9 (-0.3)	-12.6 (0.0)	-12.4 (0.2)	-12.4 (0.2)	-12.4 (0.2)
Rectory Farm House, East Heckington	-18.8 (-)	-15.5 (-)	-13.1 (3.3)	-11.8 (0.9)	-11.5 (-0.7)	-11.6 (-0.4)	-11.3 (-0.1)	-11.1 (0.1)	-11.1 (0.1)	-11.1 (0.1)
Six Hundreds Drove, East Heckington	-20.5 (-)	-17.2 (-)	-14.9 (3.4)	-13.6 (1.0)	-13.3 (-0.6)	-13.3 (-0.3)	-13.0 (0.0)	-12.8 (0.2)	-12.8 (0.2)	-12.8 (0.2)
Spinney Farm	-15.2 (-)	-11.2 (-)	-8.2 (3.5)	-6.2 (1.1)	-5.2 (-0.5)	-5.2 (-0.2)	-8.9 (0.1)	-13.4 (0.3)	-13.3 (0.3)	-13.3 (0.3)
Swineshead House	-21.7 (-)	-18.4 (-)	-16.1 (3.5)	-14.8 (1.1)	-14.5 (-0.5)	-14.5 (-0.2)	-14.2 (0.1)	-14.0 (0.3)	-14.0 (0.3)	-14.0 (0.3)
The Chapel House, Side Bar Lane	-13.9 (-)	-10.2 (-)	-7.8 (2.9)	-6.5 (0.5)	-6.2 (-1.1)	-6.4 (-0.8)	-6.9 (-0.5)	-6.7 (-0.3)	-6.7 (-0.3)	-6.7 (-0.3)
The Old Church	-13.8 (-)	-9.8 (-)	-6.8 (3.4)	-4.8 (1.0)	-3.8 (-0.6)	-3.7 (-0.3)	-7.5 (0.0)	-11.9 (0.2)	-11.9 (0.2)	-11.9 (0.2)
Unnamed Property (B1395)	-13.4 (-)	-9.8 (-)	-7.3 (3.0)	-6.0 (0.6)	-5.7 (-1.0)	-5.9 (-0.7)	-6.4 (-0.4)	-6.2 (-0.2)	-6.2 (-0.2)	-6.2 (-0.2)

Table 10.18 Exceedances of the ETSU-R-97 Derived Night-time Criterion Curves by the Predicted $L_{A90,T}$ Wind Farm Noise Immission Levels at Each Noise Assessment Location with 21 x Nordex N90 Turbines. Exceedances with negative values indicate the immission level is below the limit. Figures in show the increase or decrease in relation to the 22 turbine Enercon E82 base case.

Property	Wind Speed at 10 m Height, m/s									
	3	4	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	-16.0 (-)	-12.0 (-)	-9.0 (3.1)	-7.0 (0.7)	-6.0 (-0.9)	-5.5 (-0.6)	-5.2 (-0.3)	-5.0 (-0.1)	-5.0 (-0.1)	-5.0 (-0.1)

Property	Wind Speed at 10 m Height, m/s									
	3	4	5	6	7	8	9	10	11	12
2 Council House, East Heckington	-15.0 (-)	-11.0 (-)	-8.0 (3.3)	-6.0 (0.9)	-5.0 (-0.7)	-4.5 (-0.4)	-4.2 (-0.1)	-4.0 (0.1)	-4.0 (0.1)	-4.0 (0.1)
Catlins Farm	-15.5 (-)	-11.5 (-)	-8.5 (3.4)	-6.5 (1.0)	-5.5 (-0.6)	-5.0 (-0.4)	-6.8 (-0.1)	-10.6 (0.1)	-12.8 (0.1)	-12.8 (0.1)
College Farm	-15.7 (-)	-11.7 (-)	-8.7 (3.4)	-6.7 (1.0)	-5.7 (-0.6)	-5.2 (-0.3)	-7.0 (0.0)	-10.8 (0.2)	-13.0 (0.2)	-13.0 (0.2)
Derwent Cottage, Side Bar Lane	-16.3 (-)	-12.3 (-)	-9.3 (3.2)	-7.3 (0.8)	-6.3 (-0.8)	-5.8 (-0.5)	-5.5 (-0.2)	-5.3 (0.0)	-5.3 (0.0)	-5.3 (0.0)
Elm Grange Farm, East Heckington	-15.9 (-)	-11.9 (-)	-8.9 (3.3)	-6.9 (0.9)	-5.9 (-0.7)	-5.4 (-0.4)	-5.1 (-0.1)	-4.9 (0.1)	-4.9 (0.1)	-4.9 (0.1)
First Cottage, Side Bar Lane	-16.5 (-)	-12.5 (-)	-9.5 (3.2)	-7.5 (0.8)	-6.5 (-0.8)	-6.0 (-0.5)	-5.7 (-0.2)	-5.5 (0.0)	-5.5 (0.0)	-5.5 (0.0)
Five Willow Wath Farm, Side Bar Lane	-17.7 (-)	-13.7 (-)	-10.7 (2.6)	-8.7 (0.2)	-7.7 (-1.4)	-7.2 (-1.1)	-8.2 (-0.8)	-12.6 (-0.6)	-15.2 (-0.6)	-15.2 (-0.6)
Glebe Farm, Side Bar Lane	-16.6 (-)	-12.6 (-)	-9.6 (2.7)	-7.6 (0.3)	-6.6 (-1.3)	-6.1 (-1.0)	-7.1 (-0.7)	-11.5 (-0.5)	-14.1 (-0.5)	-14.1 (-0.5)
Home Farm, East Heckington	-14.8 (-)	-10.8 (-)	-7.8 (3.2)	-5.8 (0.8)	-4.8 (-0.8)	-4.3 (-0.5)	-4.0 (-0.2)	-3.8 (0.0)	-3.8 (0.0)	-3.8 (0.0)
Mill Green Farm	-14.7 (-)	-10.7 (-)	-7.7 (2.8)	-5.7 (0.4)	-4.7 (-1.2)	-4.2 (-0.9)	-3.9 (-0.6)	-3.7 (-0.4)	-5.0 (-0.4)	-5.0 (-0.4)
Rakes Farm, East Heckington	-16.2 (-)	-12.2 (-)	-9.2 (3.4)	-7.2 (1.0)	-6.2 (-0.6)	-5.7 (-0.3)	-5.4 (0.0)	-5.2 (0.2)	-5.2 (0.2)	-5.2 (0.2)
Rectory Farm House, East Heckington	-14.9 (-)	-10.9 (-)	-7.9 (3.3)	-5.9 (0.9)	-4.9 (-0.7)	-4.4 (-0.4)	-4.1 (-0.1)	-3.9 (0.1)	-3.9 (0.1)	-3.9 (0.1)
Six Hundreds Drove, East Heckington	-16.6 (-)	-12.6 (-)	-9.6 (3.4)	-7.6 (1.0)	-6.6 (-0.6)	-6.1 (-0.3)	-5.8 (0.0)	-5.6 (0.2)	-5.6 (0.2)	-5.6 (0.2)
Spinney Farm	-18.2 (-)	-14.2 (-)	-11.2 (3.5)	-9.2 (1.1)	-8.2 (-0.5)	-7.7 (-0.2)	-7.4 (0.1)	-12.3 (0.3)	-12.3 (0.3)	-12.3 (0.3)
Swineshead House	-17.8 (-)	-13.8 (-)	-10.8 (3.5)	-8.8 (1.1)	-7.8 (-0.5)	-7.3 (-0.2)	-7.0 (0.1)	-6.8 (0.3)	-6.8 (0.3)	-6.8 (0.3)
The Chapel House, Side Bar Lane	-16.9 (-)	-12.9 (-)	-9.9 (2.9)	-7.9 (0.5)	-6.9 (-1.1)	-6.4 (-0.8)	-6.1 (-0.5)	-5.9 (-0.3)	-5.9 (-0.3)	-5.9 (-0.3)
The Old Church	-16.8 (-)	-12.8 (-)	-9.8 (3.4)	-7.8 (1.0)	-6.8 (-0.6)	-6.3 (-0.3)	-6.0 (0.0)	-10.8 (0.2)	-10.9 (0.2)	-10.9 (0.2)
Unnamed Property (B1395)	-16.4 (-)	-12.4 (-)	-9.4 (3.0)	-7.4 (0.6)	-6.4 (-1.0)	-5.9 (-0.7)	-5.6 (-0.4)	-5.4 (-0.2)	-5.4 (-0.2)	-5.4 (-0.2)

10.83 As can be seen from the above tables, whilst the predicted noise levels are different if the Nordex turbine is used as compared to the Enercon machine (with predicted noise levels higher at some wind speeds and lower at others), the ETSU-R-97 derived noise are still predicted to be achieved at all receptors for all wind speeds considered here.

10.84 The following tables show the same information as Tables 10.17 and 10.18, but for the alternative option consisting of 18 Vestas V90 3.0MW machines. This assessment relates to the layout shown on the figure in Appendix 10.B with turbines 1, 7, 11 and 16 removed.

Table 10.17 Exceedances of the ETSU-R-97 Derived Day-time Criterion Curves by the Predicted $L_{A90,T}$ Wind Farm Noise Immission Levels at Each Noise Assessment Location with 18 x Vestas V90 Turbines. Exceedances based on 40 dB(A) lower daytime limit and negative values indicate the immission level is below the limit. Figures in brackets show the increase or decrease in relation to the 22 turbine Enercon E82 base case.

Property	Wind Speed at 10 m Height, m/s								
	4	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	-11.7 (-)	-9.3 (0.8)	-6.6 (-0.3)	-5.4 (-1.0)	-5.2 (-0.3)	-6.2 (-0.4)	-7.1 (-1.4)	-7.8 (-2.1)	-7.7 (-2.0)
2 Council House, East Heckington	-17.8 (-)	-15.5 (1.2)	-12.9 (0.1)	-11.7 (-0.6)	-11.3 (0.1)	-11.4 (0.0)	-12.4 (-1.0)	-13.1 (-1.7)	-13.0 (-1.6)
Catlins Farm	-10.8 (-)	-7.8 (1.1)	-5.3 (0.0)	-5.1 (-0.7)	-5.9 (0.0)	-7.7 (-0.1)	-10.5 (-1.1)	-11.2 (-1.8)	-11.1 (-1.7)
College Farm	-10.9 (-)	-7.9 (1.1)	-5.5 (0.0)	-5.3 (-0.7)	-6.1 (0.0)	-7.9 (-0.1)	-10.6 (-1.1)	-11.3 (-1.8)	-11.2 (-1.7)
Derwent Cottage, Side Bar Lane	-12.0 (-)	-9.6 (0.9)	-6.9 (-0.3)	-5.7 (-0.9)	-5.5 (-0.3)	-6.5 (-0.4)	-7.4 (-1.4)	-8.1 (-2.1)	-8.0 (-2.0)
Elm Grange Farm, East Heckington	-18.7 (-)	-16.4 (1.0)	-13.8 (-0.1)	-12.6 (-0.8)	-12.2 (-0.1)	-12.3 (-0.2)	-13.3 (-1.2)	-14.0 (-1.9)	-13.9 (-1.8)
First Cottage, Side Bar Lane	-12.2 (-)	-9.8 (0.9)	-7.2 (-0.2)	-6.0 (-0.9)	-5.8 (-0.2)	-6.7 (-0.3)	-7.7 (-1.3)	-8.4 (-2.0)	-8.3 (-1.9)
Five Willow Wath Farm, Side Bar Lane	-13.6 (-)	-10.6 (-0.3)	-7.3 (-1.4)	-6.6 (-2.1)	-7.4 (-1.4)	-9.4 (-1.5)	-12.4 (-2.5)	-13.1 (-3.2)	-13.0 (-3.1)
Glebe Farm, Side Bar Lane	-12.1 (-)	-9.1 (0.2)	-5.8 (-0.9)	-5.2 (-1.6)	-6.0 (-0.9)	-8.0 (-1.0)	-11.0 (-2.0)	-11.6 (-2.7)	-11.5 (-2.6)

Property	Wind Speed at 10 m Height, m/s								
	4	5	6	7	8	9	10	11	12
Home Farm, East Heckington	-17.5 (-)	-15.2 (1.1)	-12.6 (0.0)	-11.4 (-0.7)	-11.0 (0.0)	-11.1 (-0.1)	-12.1 (-1.1)	-12.8 (-1.8)	-12.7 (-1.7)
Mill Green Farm	-11.5 (-)	-8.5 (-1.0)	-5.2 (-2.1)	-3.3 (-2.8)	-2.4 (-2.1)	-2.5 (-2.2)	-4.2 (-3.2)	-4.9 (-3.9)	-4.8 (-3.8)
Rakes Farm, East Heckington	-19.1 (-)	-16.8 (1.1)	-14.2 (0.0)	-13.0 (-0.7)	-12.6 (0.0)	-12.7 (-0.1)	-13.7 (-1.1)	-14.4 (-1.8)	-14.3 (-1.7)
Rectory Farm House, East Heckington	-17.6 (-)	-15.3 (1.1)	-12.7 (0.0)	-11.5 (-0.7)	-11.1 (0.0)	-11.2 (-0.1)	-12.2 (-1.1)	-12.9 (-1.8)	-12.8 (-1.7)
Six Hundreds Drove, East Heckington	-19.5 (-)	-17.2 (1.1)	-14.6 (0.0)	-13.4 (-0.7)	-13.0 (0.0)	-13.1 (-0.1)	-14.1 (-1.1)	-14.8 (-1.8)	-14.7 (-1.7)
Spinney Farm	-14.1 (-)	-11.1 (0.6)	-7.8 (-0.5)	-5.9 (-1.2)	-5.4 (-0.5)	-9.6 (-0.6)	-15.2 (-1.6)	-15.9 (-2.3)	-15.8 (-2.2)
Swineshead House	-20.9 (-)	-18.6 (1.0)	-16.0 (-0.1)	-14.8 (-0.8)	-14.4 (-0.1)	-14.5 (-0.2)	-15.5 (-1.2)	-16.2 (-1.9)	-16.1 (-1.8)
The Chapel House, Side Bar Lane	-12.8 (-)	-10.3 (0.4)	-7.7 (-0.7)	-6.5 (-1.4)	-6.3 (-0.7)	-7.2 (-0.8)	-8.2 (-1.8)	-8.9 (-2.5)	-8.8 (-2.4)
The Old Church	-13.4 (-)	-10.4 (-0.2)	-7.1 (-1.3)	-5.2 (-2.0)	-4.7 (-1.3)	-8.9 (-1.4)	-14.5 (-2.4)	-15.2 (-3.1)	-15.1 (-3.0)
Unnamed Property (B1395)	-12.2 (-)	-9.8 (0.6)	-7.1 (-0.5)	-5.9 (-1.2)	-5.7 (-0.5)	-6.7 (-0.6)	-7.6 (-1.6)	-8.3 (-2.3)	-8.2 (-2.2)

Table 10.18 Exceedances of the ETSU-R-97 Derived Night-time Criterion Curves by the Predicted $L_{A90,T}$ Wind Farm Noise Immission Levels at Each Noise Assessment Location with 18 x Vestas V90 Turbines. Exceedances with negative values indicate the immission level is below the limit. Figures in brackets show the increase or decrease in relation to the 22 turbine Enercon E82 base case.

Property	4	5	6	7	8	9	10	11	12
1 - 4 New Cottage, Side Bar Lane	-14.3 (-)	-11.3 (0.8)	-8.0 (-0.3)	-6.1 (-1.0)	-5.2 (-0.3)	-5.3 (-0.4)	-6.3 (-1.4)	-7.0 (-2.1)	-6.9 (-2.0)
2 Council House, East Heckington	-13.2 (-)	-10.2 (1.2)	-6.9 (0.1)	-5.0 (-0.6)	-4.1 (0.1)	-4.2 (0.0)	-5.2 (-1.0)	-5.9 (-1.7)	-5.8 (-1.6)
Catlins Farm	-13.8 (-)	-10.8 (1.1)	-7.5 (0.0)	-5.6 (-0.7)	-4.7 (0.0)	-6.9 (-0.1)	-11.8 (-1.1)	-14.8 (-1.8)	-14.7 (-1.7)
College Farm	-13.9 (-)	-10.9 (1.1)	-7.6 (0.0)	-5.7 (-0.7)	-4.8 (0.0)	-7.0 (-0.1)	-12.0 (-1.1)	-14.9 (-1.8)	-14.8 (-1.7)
Derwent Cottage, Side Bar Lane	-14.6 (-)	-11.6 (0.9)	-8.3 (-0.3)	-6.4 (-0.9)	-5.5 (-0.3)	-5.6 (-0.4)	-6.6 (-1.4)	-7.3 (-2.1)	-7.2 (-2.0)
Elm Grange Farm, East Heckington	-14.1 (-)	-11.1 (1.0)	-7.8 (-0.1)	-5.9 (-0.8)	-5.0 (-0.1)	-5.1 (-0.2)	-6.1 (-1.2)	-6.8 (-1.9)	-6.7 (-1.8)
First Cottage, Side Bar Lane	-14.9 (-)	-11.9 (0.9)	-8.6 (-0.2)	-6.7 (-0.9)	-5.8 (-0.2)	-5.9 (-0.3)	-6.9 (-1.3)	-7.6 (-2.0)	-7.5 (-1.9)
Five Willow Wath Farm, Side Bar Lane	-16.6 (-)	-13.6 (-0.3)	-10.3 (-1.4)	-8.4 (-2.1)	-7.5 (-1.4)	-8.9 (-1.5)	-14.5 (-2.5)	-17.8 (-3.2)	-17.7 (-3.1)
Glebe Farm, Side Bar Lane	-15.1 (-)	-12.1 (0.2)	-8.8 (-0.9)	-6.9 (-1.6)	-6.0 (-0.9)	-7.5 (-1.0)	-13.1 (-2.0)	-16.3 (-2.7)	-16.2 (-2.6)
Home Farm, East Heckington	-12.9 (-)	-9.9 (1.1)	-6.6 (0.0)	-4.7 (-0.7)	-3.8 (0.0)	-3.9 (-0.1)	-4.9 (-1.1)	-5.6 (-1.8)	-5.5 (-1.7)
Mill Green Farm	-14.5 (-)	-11.5 (-1.0)	-8.2 (-2.1)	-6.3 (-2.8)	-5.4 (-2.1)	-5.5 (-2.2)	-6.5 (-3.2)	-8.5 (-3.9)	-8.4 (-3.8)
Rakes Farm, East Heckington	-14.5 (-)	-11.5 (1.1)	-8.2 (0.0)	-6.3 (-0.7)	-5.4 (0.0)	-5.5 (-0.1)	-6.5 (-1.1)	-7.2 (-1.8)	-7.1 (-1.7)
Rectory Farm House, East Heckington	-13.0 (-)	-10.0 (1.1)	-6.7 (0.0)	-4.8 (-0.7)	-3.9 (0.0)	-4.0 (-0.1)	-5.0 (-1.1)	-5.7 (-1.8)	-5.6 (-1.7)
Six Hundreds Drove, East Heckington	-14.9 (-)	-11.9 (1.1)	-8.6 (0.0)	-6.7 (-0.7)	-5.8 (0.0)	-5.9 (-0.1)	-6.9 (-1.1)	-7.6 (-1.8)	-7.5 (-1.7)
Spinney Farm	-17.1 (-)	-14.1 (0.6)	-10.8 (-0.5)	-8.9 (-1.2)	-8.0 (-0.5)	-8.1 (-0.6)	-14.2 (-1.6)	-14.9 (-2.3)	-14.8 (-2.2)
Swineshead House	-16.3 (-)	-13.3 (1.0)	-10.0 (-0.1)	-8.1 (-0.8)	-7.2 (-0.1)	-7.3 (-0.2)	-8.3 (-1.2)	-9.0 (-1.9)	-8.9 (-1.8)
The Chapel House, Side Bar Lane	-15.4 (-)	-12.4 (0.4)	-9.1 (-0.7)	-7.2 (-1.4)	-6.3 (-0.7)	-6.4 (-0.8)	-7.4 (-1.8)	-8.1 (-2.5)	-8.0 (-2.4)
The Old Church	-16.4 (-)	-13.4 (-0.2)	-10.1 (-1.3)	-8.2 (-2.0)	-7.3 (-1.3)	-7.4 (-1.4)	-13.4 (-2.4)	-14.2 (-3.1)	-14.1 (-3.0)
Unnamed Property (B1395)	-14.8 (-)	-11.8 (0.6)	-8.5 (-0.5)	-6.6 (-1.2)	-5.7 (-0.5)	-5.8 (-0.6)	-6.8 (-1.6)	-7.5 (-2.3)	-7.4 (-2.2)

10.85 Again, whilst the above table demonstrates that predicted noise levels for the Vestas V90 scheme are different to those predicted for the Enercon E82 base scheme (with higher noise levels predicted at some wind speeds and lower noise levels at other wind speeds), the ETSU-R-97 derived noise limits are again predicted to be met at all receptors and for all wind speeds.

MITIGATION, OFFSETTING AND ENHANCEMENT MEASURES

Proposed Construction Noise Mitigation Measures

10.86 To reduce the potential noise impact of construction noise, the following types of mitigation measures are proposed:

10.87 Those activities that may give rise to audible noise at the surrounding properties and heavy goods vehicle deliveries to the site would be limited to the hours 08:00 to 18:00 Monday to Friday and 08:00 to 12:00 on Saturdays. Turbine deliveries would only take place outside these times with the prior consent of the Council and the Police. Those activities that are unlikely to give rise to noise audible at the site boundary will continue outside of the stated hours.

10.88 All construction activities shall adhere to good practice as set out in BS 5228.

10.89 All equipment will be maintained in good working order and any associated noise attenuation such as engine casing and exhaust silencers shall remain fitted at all times.

10.90 Where flexibility exists, activities will be separated from residential neighbours by the maximum possible distances.

10.91 A site management regime will be developed to control the movement of vehicles to and from the proposed development site.

10.92 Construction plant capable of generating significant noise and vibration levels will be operated in a manner to restrict the duration of the higher magnitude levels.

10.93 During construction of new site access, temporary screens will be used to reduce the impact of noise on residents at Rectory Cottages. These screens will be constructed from solid sheet material with no gaps and will be positioned such that the line of site from construction works to Rectory Cottages is completely obscured.

Proposed Operational Noise Mitigation Measures

10.94 The selection of the final turbine to be installed at the site would be made on the basis of enabling the relevant ETSU-R-97 noise limits to be achieved at the surrounding properties.

STATEMENT OF RESIDUAL SIGNIFICANCE

Table 10.19 Summary Table of Effects

Potential Effect	Evaluation of Effect
Construction Noise	Noise levels have been predicted using the methodology set out in BS 5228. Based on impact assessment criteria derived and supported by a range of noise policy and guidance, the overall impact of construction noise is considered to represent a negligible impact at the majority of receptors. The construction of new access tracks is predicted to result in a minor impact at Rectory Cottages. These predicted impacts would be considered not significant in EIA terms.
Operational Noise	Noise criteria have been established in accordance with ETSU-R-97. It has also been shown that these criteria are achievable with a commercially available turbine suitable for the site. The basis of the ETSU-R-97 method is to define acceptable noise limits thought to offer reasonable protection to residents in areas around wind farm developments. Operational noise immission levels are acceptable in terms of the guidance commended by planning policy for the assessment of wind farm noise, and therefore considered not significant in EIA terms.

MONITORING

10.95 It is proposed that if planning consent is granted for the proposed development, conditions attached to the planning consent should include the requirement that, in the event of a noise complaint, noise levels resulting from the operation of the wind farm are measured in order to demonstrate compliance with the conditioned noise limits. Such monitoring should be done in full accordance with ETSU-R-97 and include penalties for any tonal characteristics of the noise.

SUMMARY OF KEY FINDINGS AND CONCLUSIONS

10.96 This report has presented an assessment of the impact of construction and operational noise from the proposed Heckington Fen Wind Farm on the residents of nearby dwellings.

10.97 A number of residential properties lying around the wind farm have been selected as being representative of the closest located properties to the wind farm. The minimum separation distance between the nearest turbine and the closest residential property is approximately 960 m. Noise impact assessments have been undertaken at these properties by comparing predicted construction and operational noise levels with relevant impact assessment criteria. In the case of construction noise, relevant impact assessment criteria is 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 four to six weeks at each location.

10.98 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 negligible.

10.99 Operational noise from the wind farm has been assessed in accordance with the methodology set out in the 1996 DTI Report ETSU-R-97, 'The Assessment and Rating of Noise from Wind farms'. This document provides a robust basis for assessing the operational noise impact of a wind farm as recommended by PPS22.

10.100 To undertake the assessment of noise impact in accordance with the foregoing methodology the following steps have been undertaken:

- measure the existing background noise levels at the nearest neighbours as a function of site wind speed;
- determine the day-time and night-time criterion curves from the measured background noise levels at the nearest neighbours;

- specify the type and noise emission (the sound power actually emitted by the turbines) characteristics of the wind turbines;
- specify the number and locations of the wind turbines;
- identify the locations of the nearest, or most noise sensitive, neighbours;
- calculate the noise immission levels (the noise levels resulting at a particular location some distance away from the source of noise) due to the operation of the wind turbines as a function of site wind speed at the nearest neighbours;
- compare the calculated wind farm noise immission levels with the derived criterion curves.

10.101 The above steps have been applied to the Heckington Fen Wind Farm with the noise impact assessment being undertaken at a total of 19 locations comprising residential properties lying in the vicinity of the background noise monitoring locations.

10.102 Applying the ETSU-R-97 derived noise limits at the assessment locations it has been demonstrated that both the daytime and night-time noise criterion limits can be satisfied at all properties across all wind speeds. Specifically, this assessment has determined that the most stringent noise limits of ETSU-R-97 are predicted to be achieved. This assessment has been based on the use of the manufacturer's warranted sound power data for the Enercon E82 2.3MW wind turbine which is typical of the type and size of turbine which may be considered for this site, and assuming worst case downwind propagation. Further predictions have been carried out for alternative schemes using the Nordex N90 2.5MW turbine and the Vestas V90 3.0MW turbine. The ETSU-R-97 derived noise limits are also predicted to be achieved with these alternative turbine options.

10.103 In summary, the overall impact of construction noise is considered to represent a negligible impact at the majority of receptors, with a minor impact predicted at Rectory Cottages. The overall impact of construction noise is therefore not considered significant in EIA terms. Operational noise immission levels are acceptable in terms of the guidance commended by planning policy for the assessment of wind farm noise, and therefore considered not significant in EIA terms.

REFERENCES

1 Planning Policy Guidance Note 24: Planning and Noise, HMSO 2001.

2 Environmental Protection Act, Part III, HMSO, 1990.

3 Control of Pollution Act, Part III, HMSO, 1974.

4 BS 5228 Noise and Vibration Control on Construction and Open Sites

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

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

7 Planning Policy Statement 22 (PPS 22) Renewable Energy, ODPM 2004.

8 ETSU-R-97, the Assessment and Rating of Noise from Wind Farms, Final ETSU-R-97 Report for the Department of Trade & Industry. UK Noise Working Group, 1997.

9 Calculation of Road Traffic Noise, HMSO Department of Transport, 1988.

10 Prediction and assessment of wind turbine noise – agreement about relevant factors for noise assessment from wind energy projects. D Bowdler, AJ Bullmore, RA Davis, MD Hayes, M Jiggins, G Leventhall, AR McKenzie. Institute of Acoustics, Acoustics Bulletin, Vol 34, No 2 March/April 2009.

11 ISO 9613-2 'Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation', International Standards Organisation, ISO 9613-2, 1996.

12 JOR3-CT95-0091 'Development of a Wind farm Noise Propagation Prediction Model', Bass J H, Bullmore A J, Sloth E, Final Report for EU Contract JOR3-CT95-0051, 1998.

APPENDIX 10.A: GENERAL APPROACH TO NOISE IMPACT ASSESSMENT AND 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 impact 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 impact of sound relies on a basic appreciation of both these components. This Appendix provides an overview of these topics. A glossary of acoustic terminology is included at the end of this Appendix.

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 impact of environmental sound is therefore limited to its effects on people or animals.

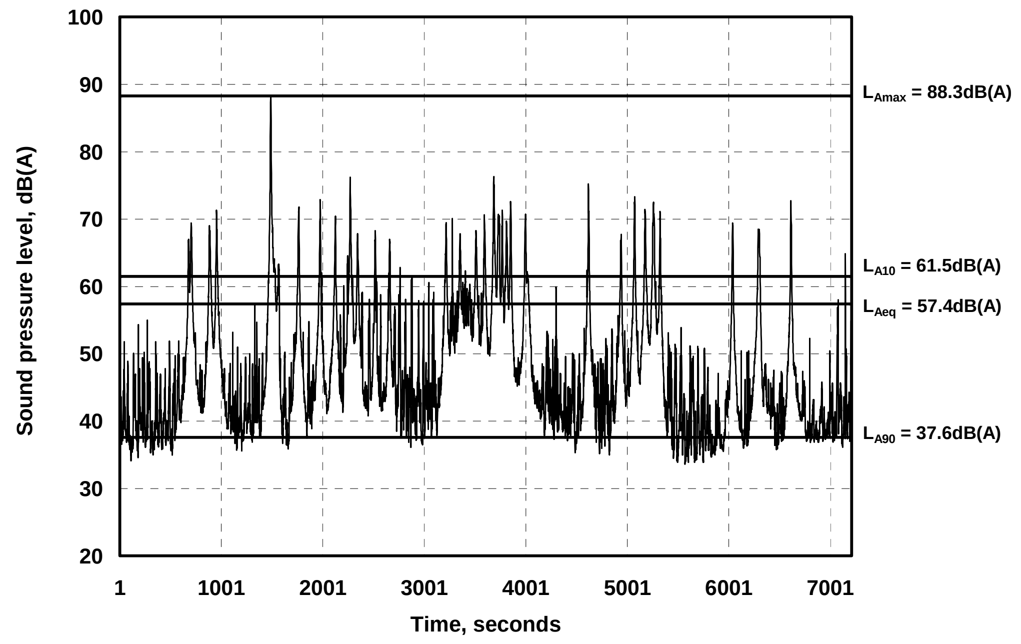
A.5 Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

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 m 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 impact 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 L_A, 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 $L_{Aeq,1hour}$ 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 impact 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 daytime ($L_{Aeq,16hr}$, 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 impact.

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 U.K.

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.

A.29 Temporal variations outside the noise index averaging periods, 'T'

A.30 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.31 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.32 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.33 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 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;
- social and economic effects;

SPEECH INTERFERENCE

A.34 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.35 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.36 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.37 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.38 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.39 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.40 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.41 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.42 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.

A.43 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 impact assessment, so an appropriate methodology must be adopted for assessing the effectiveness of any noise mitigation measures adopted for the proposed development.

A.44 When assessing the potential impact 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 are at least considered in all cases.

A.45 Table 4.1 of the WHO Guidelines 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	LAeq, dB	Time base, hours	LAmax, dB
Outdoor living area	Serious annoyance, daytime and evening	55	16	-
	Moderate annoyance, daytime and evening	50	16	-
Dwelling, indoors	Speech intelligibility and moderate annoyance, daytime 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)	Speech intelligibility, disturbance of information extraction, message communication	35	-	-

A.46 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.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 impact 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 impact of a noise over and above the impact 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 impact. 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.

EFFECTS OF NOISE ON WILDLIFE

A.51 There are large numbers of papers in the literature which describe the effects of noise on birds and animals, both wild and livestock.

A.52 Just as noise impact assessment on humans is made difficult by the variability of responses between different people and between different situations, noise impact assessment on wildlife is even more problematical, not least due to the problem of monitoring the response of wildlife to noise.

A.53 For larger species it may be possible to install telemetry on the body of the animal to relay information about its body systems (e.g. heart rate, temperature etc.). However, the minimum physical sizes of telemetry systems means this is not an option for smaller species. Also, even where it is possible, the fact that the animals must first be captured to have a system installed disturbs them, and the results of the subsequent study may be biased. In the absence of such telemetric data, researchers must rely on observations such as flight from nests, short term departure from usually populated areas and deviations from expected line of travel. However, flock and pack instincts often mean that just one animal changing course or taking flight can result in all the others doing the same.

A.54 The only truly robust determinant to the impact of noise on wildlife is the long term desertion of traditionally inhabited areas, or a reduction in breeding numbers. However, even these factors can be brought into question when the noise is a result of some other local activity, such as the passage of vehicles. In these cases it is often difficult to establish whether the observed effect is a consequence of the visual disturbance or the noise.

A.55 Direct comparisons of results between species, or even between different research findings into the same species, are therefore often unclear, and it is difficult to draw firm conclusions as to the impact of noise on wildlife, other than in a highly generalised manner.

A.56 General features apparent from the literature are that the most sensitive time for animals is during nesting or breeding seasons. Those that take flight whilst sitting on their eggs or tending their young can leave them open to predators, even if they return fairly quickly. However, many species have been shown to habituate to noise of all types, including road traffic noise, aircraft noise or even the decreasing effectiveness with time of impulsive type bird scarers, such as those used around airports.

LOW FREQUENCY NOISE AND VIBRATION – WIND FARMS

A.57 One issue that has increasingly been raised concerning potential noise impact 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.58 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.59 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.60 The fact that low frequency sound and infrasound from wind farms has only relatively recently 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.61 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.62 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.63 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 impact 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.

C-WEIGHTING

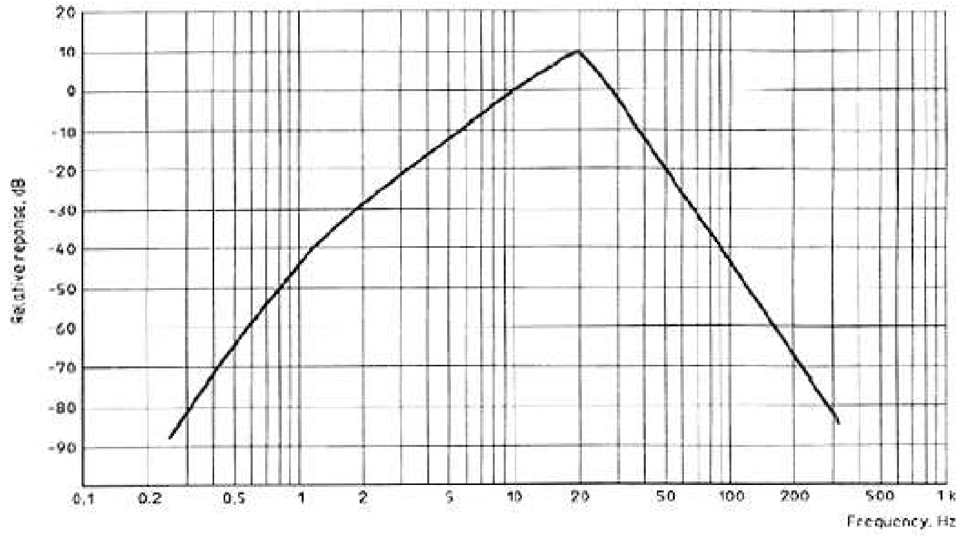
A.64 One such curve is denoted C-weighting, as also described in the Noise Appendix to the full ES. Unlike the A-weighting curve, which gradually reduces the significance of frequencies below 1000 Hz until at 10 Hz the attenuation is 70 dB, the C-weighting curve is flat to within 1 dB down to about 50 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 impact than at lower overall noise levels.

A.65 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.

G-WEIGHTING

A.66 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. A graphical representation of the G-weighting curve is shown below.

Figure A2: The G-weighting curve used for the assessment of infrasound



A.67 In terms of the threshold of audibility for low frequency sound, different countries generally adopt their own criteria. The following table is reproduced from Table 9 of the DEFRA report by Leventhall [1] and shows typical examples of audibility thresholds from two different standards, showing significant similarity between the two standards.

Table A2: Comparison of two different thresholds quoted in reference as being used for the assessment of low frequency sound

Third Octave Band Frequency (Hz)	Hearing Threshold (dB)	ISO 226 Threshold (dB)
(8)	(103)	-
10	95	-
12.5	87	-
16	79	-
20	71	74.3
25	63	65.0

31.5	55.5	56.3
40	48	48.4
50	40.5	41.7
63	33.5	35.5
80	28	29.8
(100)	(23.5)	25.1

A.68 As mentioned previously, one of the problems of determining the threshold of audibility to low frequency sound when compared with higher frequency sounds is that the variability between individual subjects tends to be higher. Because of this spread of data, it is sometimes considered prudent to determine the lowest level of audibility as perceived by someone who is extremely sensitive to low frequency sound. There are some people who are more sensitive, and some who are less sensitive, to low frequency sound. Measurements on groups of subjects indicate that the standard deviation of the threshold is around 6 dB. Therefore, allowing two standard deviations for variations about the mean sensitivity leaves the potential for only 2.5% of the population being more sensitive than 12 dB below the average threshold.

A.69 It is against these typical threshold criteria, accounting for potential variability in sensitivity between different subjects, that assessments of the potential impact of low frequency sound and infrasound are undertaken.

INFRASOUND

A.70 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 to cause health problems. It has, however, been the case that dedicated research investigations have shown this not to be the case.

A.71 As early as 1997 a report by Snow [2] 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 km. During the experiments a wide range of wind speeds and directions were recorded. It was found that the vibration levels at 100 m 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 m from the turbines.

A.72 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 km, 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.

A.73 More recently, 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 [1]. 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.74 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. 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.75 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 have frequently been 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 have subsequently explained that [3]:

> *'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.76 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.77 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.'*

A.78 Even more recently, in 2006, the results of a study specifically commissioned by the 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 [4].

A.79 The DTI LFN Report is a comprehensive study containing many pages of detailed results of measurements of both infrasound and low frequency sound around the three wind farms included in the study. These measurements were undertaken using measurement systems capable of detecting noise down to frequencies of 1 Hz, with results being reported up to a frequency of 500 Hz, thus extending beyond the full spectrum of what is normally considered to cover both infrasound (<20 Hz) and low frequency sound (20 Hz to 200 Hz).

A.80 The measurement locations at the three wind farms were selected to be at residential properties where occupants had raised concerns relating to low frequency sound disturbance. Noise immission measurements are reported both externally to and internally to the properties in question. In addition to these noise immission measurements, the results of noise emission measurements undertaken on a number of wind turbines are also reported with the aim of quantifying the level of infrasound actually emitted from individual wind turbines and wind farms.

A.81 Before summarising the findings of the DTI LFN Report, it is noted that the prevalence of the perceived problem of infrasound and/or low frequency sound is not a widespread one. Quoting from the Executive Summary to the DTI LFN Report:

> *'of the 126 wind farms operating in the UK, 5 have reports of low frequency sound problems which attract adverse comment concerning the noise. Therefore, such complaints are the exception rather than a general problem which exists for all wind farms'.*

A.82 The DTI LFN Report was actually commissioned primarily to investigate the effects of infrasound. This investigation was commissioned as a direct result of the claims made in the press concerning health problems arising from noise of such a low frequency 'that it is beyond the audible range, such that you can't hear it but you can feel it as a resonance'. For this reason the results pertaining to infrasound are reported separately from those pertaining to audible low frequency sound above 20 Hz.

A.83 In respect of infrasound, the DTI LFN 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.84 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.

A.85 Indeed, in the face of the apparent misunderstanding of the conclusions reached in the various reports on infrasound, and how these conclusions should be applied to consideration of the radiation of such noise from wind farms, the British Wind Energy Association have issued a fact sheet relating to the subject [5]. This fact sheet concludes:

> *'With regard to effects of noise from wind turbines, the main effect depends on the listener's reaction to what they may hear. There are no direct health effects from noise at the level of noise generated by wind turbines. It has been repeatedly shown by measurements of wind turbine noise undertaken in the UK, Denmark, Germany and the USA over the past decade, and accepted by experienced noise professionals, that the levels of infrasonic noise and vibration radiated from modern, upwind configuration wind turbines are at a very low level; so low that they lie below the threshold of perception, even for those people who are particularly sensitive to such noise, and even on an actual wind turbine site.*

LOW FREQUENCY SOUND

A.86 A report prepared for DEFRA by Casella Stanger [6] 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.87 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 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.88 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 impact 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.89 In November 2006 the Government released a statement [7] 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.90 The Government statement concluded the position regarding low frequency sound from wind farms with the definitive advice to all 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.91 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. Whilst it was therefore acknowledged that this effect of enhanced amplitude modulation of blade aerodynamic noise may occur, it was also concluded that there were a number of factors that should be borne in mind when considering the importance to be placed on the issue when considering present and proposed wind farm installations:

- it appeared that the effect had only been reported as a problem at a very limited number of sites (the DTI report looked at the 3 out of 5 U.K. sites where it has been reported to be an issue out of the 126 onshore wind farms reported to be operational at the time);
- the effect occurred only under certain conditions at these sites (the DTI LFN Report was significantly delayed while those involved in taking the measurements waited for the situation to occur at each location);
- at one of the sites concerned it had been demonstrated that the effect can be reduced to an acceptable level by the introduction of a Noise Reduction Management System (NRMS) which controls the operation of the necessary turbines under the relevant wind conditions (this NRMS had to be switched off in order to gain the data necessary to inform the DTI LFN Report);
- whilst still under review, it appeared that the most likely cause of the increased amplitude modulation was related to an increase in the stability of the atmosphere during evening and night time periods, hence the increased occurrence of such an effect at these times, but this effect had been shown by measurement of wind speed profiles to be extremely site specific;
- internal noise levels were below all accepted night-time criteria limits and insufficient to wake residents, it was only when woken by other sources of a higher level (such as local road traffic) that there were self-reported difficulties in returning to sleep.

A.92 With regard to amplitude modulation and how it should be accounted for when assessing proposals to develop new wind farms, the Government adopted as robust a stance on this issue as it did on the Low Frequency Noise issue discussed above. In this respect the advice note issued in November 2006 also considered the 'isolated circumstances' in which the effect has been observed and again offered the definitive advice to all 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.

A.93 Following publication of the findings of the DTI LFN report and their provisional advice on how the findings of the report should not be allowed to influence the adoption of ETSU-R-97 as the appropriate methodology, the Government commissioned an independent research project to further investigate the findings of the report. The scope of this research project included a more detailed investigation into the prevalence of the impact of enhanced levels of amplitude modulation across UK wind farms. This research work was awarded to the University of Salford who reported on their findings in July 2007 [8].

A.94 Wholly in line with the suggestions of the DTI LFN Report, the Salford Report concluded that that the occurrence of increased levels of 'blade swish' is infrequent and therefore need not be accounted for in addition to the noise assessment methodology presented in ETSU-R-97, whose suggested noise limits already account for typically encountered levels of blade swish.

A.95 As a direct consequence of the findings of the report by the University of Salford, BERR (formerly the DTI) issued a statement in August 2007 [9] which concluded:

> *'A comprehensive study by Salford University has concluded that the noise phenomenon known as aerodynamic modulation (AM) is not an issue for the UK's wind farm fleet.*
>
> *AM indicates aerodynamic noise from wind turbines that is greater than the normal degree of regular fluctuation of blade swoosh. It is sometimes described as sounding like a distant train or distant piling operation.*
>
> *The Government commissioned work assessed 133 operational wind projects across Britain and found that although the occurrence of AM cannot be fully predicted, the incidence of it from operational turbines is low.'*

A.96 Commentating on wind farm worries, Energy Minister Malcolm Wicks said:

> *'Where there are legitimate problems we will address them. But it is essential that we produce more wind power if we are to meet our climate change and security of supply aims."*
>
> *Out of all the working wind farms at the time of the study, there were four cases where AM appeared to be a factor. Complaints have subsided for three out of these four sites, in one case as a result of remedial treatment in the form of a wind turbine control system. In the remaining case, which is a recent installation, investigations are ongoing.*
>
> *Based on these findings, Government does not consider there to be a compelling case for more work into AM and will not carry out any further research at this time; however it will continue to keep the issue under review.'*

A.97 The statement then concludes with the advice:

> *'Government continues to support the approach set out in Planning Policy Statement (PPS) 22 – Renewable Energy. This approach is for local planning authorities to "ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels", through the use of the 1997 report by ETSU to assess and rate noise from wind energy developments.'*

REFERENCES FOR LFN AND AM SECTION

[1] 'A review of published research on low frequency noise and its effects', G. Leventhall, report for DEFRA, 2003

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

[3] 'Wind farm noise', P. Styles, letter by Prof P Styles and S Toon printed in The Scotsman, August 2005.

[4] 'The measurement of low frequency noise at three UK wind farms', M. Hayes, DTI Report W/45/00656/00, 2006

[5] 'Low frequency noise and wind turbines', BWEA Briefing Sheet, 2005

[6] 'Low frequency noise', Report by Casella Stanger for DEFRA, 2001

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

[8] 'Research into Aerodynamic Modulation of Wind Turbine Noise', Report by University of Salford, URN 07/1235 (July 2007)

[9] 'Government statement regarding the findings of the Salford University report into Aerodynamic Modulation of Wind Turbine Noise', BERR, Ref: 2007/033 (1st August 2007)

GLOSSARY OF ACOUSTIC 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 impact 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 impact 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.
Audible sound	a sound that can be heard above all other ambient sounds
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 daytime, 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 LAeq,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 it's 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

TERMINOLOGY	DESCRIPTION
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
Masking	the effect whereby an otherwise audible sound is made inaudible by the presence of other sounds
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 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 it's 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 impact is 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
Third-octave band frequency analysis	a frequency analysis using frequency bands one third of an octave wide
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

APPENDIX 10.B: LOCATIONS MAP

Figure B1 Map showing the layout of the turbines (green dots), the noise monitoring locations (blue dots within red circles), the additional noise assessment locations (orange dots within red circles).

APPENDIX 10.C: NOISE MONITORING INFORMATION SHEETS

Noise Monitoring Information Sheet	
Location	
Name	The Old Church, Amber Hill
Description	The meter was located on the patio area at a distance of approximately 20m from the property, on the side of the property nearest to the proposed site. The microphone was mounted at a height of 1.5m and at a distance of more than 3.5m from all acoustically hard surfaces other than the ground. Sources of noise that were audible at this location included farm activities and farm animals, very occasional road traffic on Claydike Bank, bird song, occasional distant bird scarers and occasional military aircraft. This location was selected as this property is the closest residential receptor to the North East of the proposed scheme. SLM Location: 521866, 347304.

Equipment	**Type**	**Serial Number**	**Last Calibrated**
Sound Level Meter	SVANTEK SVAN 945A	11944	08/06/2010
Pre-amplifier	SVANTEK SV-11	14035	08/06/2010
Microphone	GRAS 40AN	80023	08/06/2010
Calibrator	Rion NC-74	34551669	18/02/2011
SLM Range	130 dB		

Data Collected						
File	**Time Start [GMT]**	**Time End [GMT]**	**Cal Start**	**Cal End**	**Drift**	**Notes**
@HEC	28/02/11 14:40	09/03/11 02:30	0.6	0.6	0.0	No significant drift
@HEC2	15/03/11 12:00	26/03/11 09:50	0.6	0.5	-0.1	No significant drift
@HEC2	29/03/11 09:50	07/04/11 19:10	0.5	0.5	0.0	No significant drift

Data Exclusions
Data has been excluded from the assessment at this location during periods when the rain gauge registered rain and during periods when the sound level meter registered an overload. In addition, the data was inspected to identify those periods when noise levels were atypical. These periods have also been excluded from the assessment.

Table C1 Information on the equipment, measurement location, and noise data at The Old Church.

Figure C1 View of the monitoring location at The Old Church looking North East.

Figure C2 View of the monitoring location at The Old Church looking North West.

Figure C3 **View of the monitoring location at The Old Church looking South.**

Figure C4 **View of the monitoring location at The Old Church looking East.**

Noise Monitoring Information Sheet	
Location	
Name	College Farm
Description	The meter was located in the garden area of the property. The microphone was mounted at a height of 1.5m above ground level and was more than 3.5m from any acoustically reflective surfaces other than the ground. Sources of noise that were audible at this location included farm machinery in use on neighbouring fields and at the farm buildings approximately 50m to the North East of the monitoring location, livestock at the farm buildings to the North East, distant road traffic, birdsong, distant bird scarers and occasional military aircraft movements. The monitoring location was selected as it was the nearest residential property to the South East of the proposed site for which access permissions could be obtained. SLM Location: 521865, 344434.

Equipment	**Type**	**Serial Number**	**Last Calibrated**
Sound Level Meter	SVANTEK SVAN 945A	6494	29/04/2010
Pre-amplifier	SVANTEK SV-11	5890	29/04/2010
Microphone	GRAS 40AN	42889	29/04/2010
Calibrator	Rion NC-74	34551669	18/02/2011
SLM Range	130 dB		

Data Collected

File	**Time Start [GMT]**	**Time End [GMT]**	**Cal Start**	**Cal End**	**Drift**	**Notes**
@HEC	01/03/11 09:10	09/03/11 12:00	-0.1	0.0	0.1	No significant drift
@HEC2	15/03/11 12:50	24/03/11 14:30	0.0	0.3	0.3	No significant drift
@HEC2	29/03/11 12:00	07/04/11 21:20	0.3	0.3	0.0	No significant drift

Data Exclusions

Data has been excluded from the assessment at this location during periods when the rain gauge registered rain and during periods when the sound level meter registered an overload. In addition, the data was inspected to identify those periods when noise levels were atypical. These periods have also been excluded from the assessment.

Table C2 **Information on the equipment, measurement location, and noise data at College Farm.**

Figure C5 View of the monitoring location at College Farm looking North East.

Figure C7 View of the monitoring location at College Farm looking South West.

Figure C6 View of the monitoring location at College Farm looking East.

Figure C8 View of the monitoring location at College Farm looking South.

Noise Monitoring Information Sheet							
Location							
Name	2 Council House						
Description	The meter was located in the rear patio area of the property, on the side of the property closest to the proposed site. The microphone was positioned at a height of 1.5m above local ground level, however due to the small external amenity area at the rear of the property and the need to keep the meter off the driveway to allow access for vehicles, the meter was positioned at approximately 2m from the building façade. IT was decided to leave the meter at the rear of the property, as this location was more screened from noise generated by road traffic on the A17 than the front of the property. Sources of noise that were noted as being audible at this location included road traffic on the A17, birdsong and occasional military aircraft movements. This location was selected as being representative of the properties along the A17, to the South of the proposed site. SLM Location: 520168, 343956.						
Equipment	**Type**	**Serial Number**	**Last Calibrated**				
Sound Level Meter	Rion NL-31	00531145	21/02/2011				
Pre-amplifier	Rion NH-21	07743	21/02/2011				
Microphone	Rion UC53A	304546	21/02/2011				
Calibrator	Rion NC-74	34551669	18/02/2011				
SLM Range	20-100 dB						
Data Collected							
File	**Time Start [GMT]**	**Time End [GMT]**	**Cal Start**	**Cal End**	**Drift**	**Notes**	
AU2_1300	01/03/11 10:50	15/03/11 12:50	93.8	93.8	0.0	No significant drift	
AU2_1301	15/03/11 13:30	29/03/11 10:00	93.8	93.8	0.0	No significant drift	
AU2_1302	29/03/11 10:30	12/04/11 10:30	93.8	93.7	-0.1	No significant drift	
Data Exclusions							
Data has been excluded from the assessment at this location during periods when the rain gauge registered rain and during periods when the sound level meter registered an overload. In addition, the data was inspected to identify those periods when noise levels were atypical. These periods have also been excluded from the assessment. In addition, data which was recorded with wind directions between 90 and 270 degrees (i.e. wind directions with a component from the South) have also been excluded to minimise the influence of road traffic noise from the A17 on the derived background noise.							

Table C3 **Information on the equipment, measurement location, and noise data at 2 Council House.**

Figure C9 **View of the monitoring location at 2 Council House looking South West.**

Figure C10 **View of the monitoring location at 2 Council House looking South East.**

Figure C11 View of the monitoring location at 2 Council House looking North West.

Figure C12 View of the monitoring location at 2 Council House looking North East.

Noise Monitoring Information Sheet	
Location	
Name	Side Bar Lane
Description	The meter was located in the agricultural land immediately to the rear of Derwent House on Side Bar Lane, on the same side of the property as the proposed site. The microphone was positioned at a height of approximately 1.5m above local ground level and at a distance of more than 3.5m from any acoustically reflective surfaces other than the ground. Sources of noise that were audible at this location included road traffic noise on the A17 (approximately 450m to the South East of the meter position), occasional road traffic on Side Bar Lane, birdsong and occasional military aircraft movements. This monitoring location was selected to provide representative background noise levels from the properties towards the South end of Side Bar Lane. The meter was not located in the amenity space of a residential property as access permissions could not be agreed. SLM Location: 518653, 344925.

Equipment	**Type**	**Serial Number**	**Last Calibrated**
Sound Level Meter	Rion NL-31	00110060	04/01/2010
Pre-amplifier	Rion NH-21	07772	04/01/2010
Microphone	Rion UC-53A	304789	04/01/2010
Calibrator	Rion NC-74	34551669	18/02/2011
SLM Range	20-110 dB		

Data Collected

File	**Time Start [GMT]**	**Time End [GMT]**	**Cal Start**	**Cal End**	**Drift**	**Notes**
AU2_1501	15/03/11 15:00	29/03/11 12:40	94.0	94.0	0.0	No significant drift
AU2_1502	29/03/11 13:10	12/04/11 11:50	94.0	93.8	-0.2	No significant drift

Data Exclusions

Data has been excluded from the assessment at this location during periods when the rain gauge registered rain and during periods when the sound level meter registered an overload. In addition, the data was inspected to identify those periods when noise levels were atypical. These periods have also been excluded from the assessment.

In addition, data which was recorded with wind directions between 90 and 270 degrees (i.e. wind directions with a component from the South) have also been excluded to minimise the influence of road traffic noise from the A17 on the derived background noise.

Table C4 Information on the equipment, measurement location, and noise data at Side Bar Lane.

Figure C13 **View of the monitoring location at Side Bar Lane looking South.**

Figure C15 **View of the monitoring location at Side Bar Lane looking North.**

Figure C14 **View of the monitoring location at Side Bar Lane looking South East.**

Figure C16 **View of the monitoring location at Side Bar Lane looking North East.**

Noise Monitoring Information Sheet						
Location						
Name	Glebe Farm					
Description	The meter was located in a paddock immediately adjacent to the rear garden of the property. The microphone was positioned at a height of 1.5m above local ground level and more than 3.5m from any acoustically reflective surfaces other than the ground. Audible sources of noise at this location included cockerels and dogs at Glebe Farm, occasional road traffic on Side Bar Lane, birdsong and occasional military aircraft. This monitoring location was selected to provide background noise levels that are representative for the properties at the North end of Side Bar Lane, further from the influence of the A17. SLM Location: 518409, 346134.					
Equipment	**Type**	**Serial Number**	**Last Calibrated**			
Sound Level Meter	SVANTEK SVAN 949	6749	15/09/2009			
Pre-amplifier	SVANTEK SV-12	5916	15/09/2009			
Microphone	GRAS 40AE	49372	15/09/2009			
Calibrator	Rion NC-74	34551669	18/02/2011			
SLM Range	130 dB					
Data Collected						
File	**Time Start [GMT]**	**Time End [GMT]**	**Cal Start**	**Cal End**	**Drift**	**Notes**
HEC	01/03/11 10:10	10/03/11 20:00	-0.4	-0.6	-0.2	No significant drift
HEC2	15/03/11 14:10	29/03/11 12:20	-0.6	-0.3	0.3	No significant drift
HEC2	29/03/11 12:40	07/04/11 22:50	-0.3	-0.3	0.0	No significant drift
Data Exclusions						
Data has been excluded from the assessment at this location during periods when the rain gauge registered rain and during periods when the sound level meter registered an overload. In addition, the data was inspected to identify those periods when noise levels were atypical. These periods have also been excluded from the assessment.						

Table C5 **Information on the equipment, measurement location, and noise data at Glebe Farm.**

Figure C17 **View of the monitoring location at Glebe Farm looking West.**

Figure C18 **View of the monitoring location at Glebe Farm looking South East.**

Figure C19 View of the monitoring location at Glebe Farm looking North East.

Figure C20 View of the monitoring location at Glebe Farm looking North West.

Noise Monitoring Information Sheet	
Location	
Name	Mill Green Farm (proxy)
Description	The meter was located on agricultural land at the northern end of the proposed wind farm site. The meter location was at a distance of approximately 1.1km from the property known as Mill Green Farm. The microphone was positioned at 1.5m above local ground level and more than 3.5m from any acoustically reflective surface other than the ground. Sources of noise that were audible at this location included distant noise from farm plant and machinery, sheep in the adjoining field approximately 200m from the monitoring location and occasional military aircraft movements. This monitoring location was selected to provide a proxy for Mill Green Farm, which is the closest property to the North of the proposed site. Access permission for monitoring at Mill Green Farm was not granted and there are no alternative nearby residential properties. The selected monitoring position was considered likely to experience lower levels of background noise than Mill Green Farm as there are several mature trees in the near vicinity of the property that are not evident near the monitoring location. SLM Location: 518409, 346134.

Equipment	**Type**	**Serial Number**	**Last Calibrated**
Sound Level Meter	Rion NL-32	01030553	21/02/2011
Pre-amplifier	Rion NH-21	08179	21/02/2011
Microphone	Rion UC-53A	304789	21/02/2011
Calibrator	Rion NC-74	34551669	18/02/2011
SLM Range	20-110 dB		

Data Collected

File	**Time Start [GMT]**	**Time End [GMT]**	**Cal Start**	**Cal End**	**Drift**	**Notes**
AU2_2601	15/03/11 16:00	29/03/11 13:30	94.2	93.9	-0.3	No significant drift
AU2_2602	29/03/11 14:00	12/04/11 12:20	93.9	94.0	0.1	No significant drift

Data Exclusions

Data has been excluded from the assessment at this location during periods when the rain gauge registered rain and during periods when the sound level meter registered an overload. In addition, the data was inspected to identify those periods when noise levels were atypical. These periods have also been excluded from the assessment.

Table C6 **Information on the equipment, measurement location, and noise data at Mill Green Farm Proxy Location.**

Figure C21 View of the monitoring location at Mill Green Farm (proxy) looking North.

Figure C22 View of the monitoring location at Mill Green Farm (proxy) looking East.

Figure C23 View of the monitoring location at Mill Green Farm (proxy) looking South.

Figure C24 View of the monitoring location at Mill Green Farm (proxy) looking West.

APPENDIX 10.D: WIND SPEEDS AND DIRECTIONS

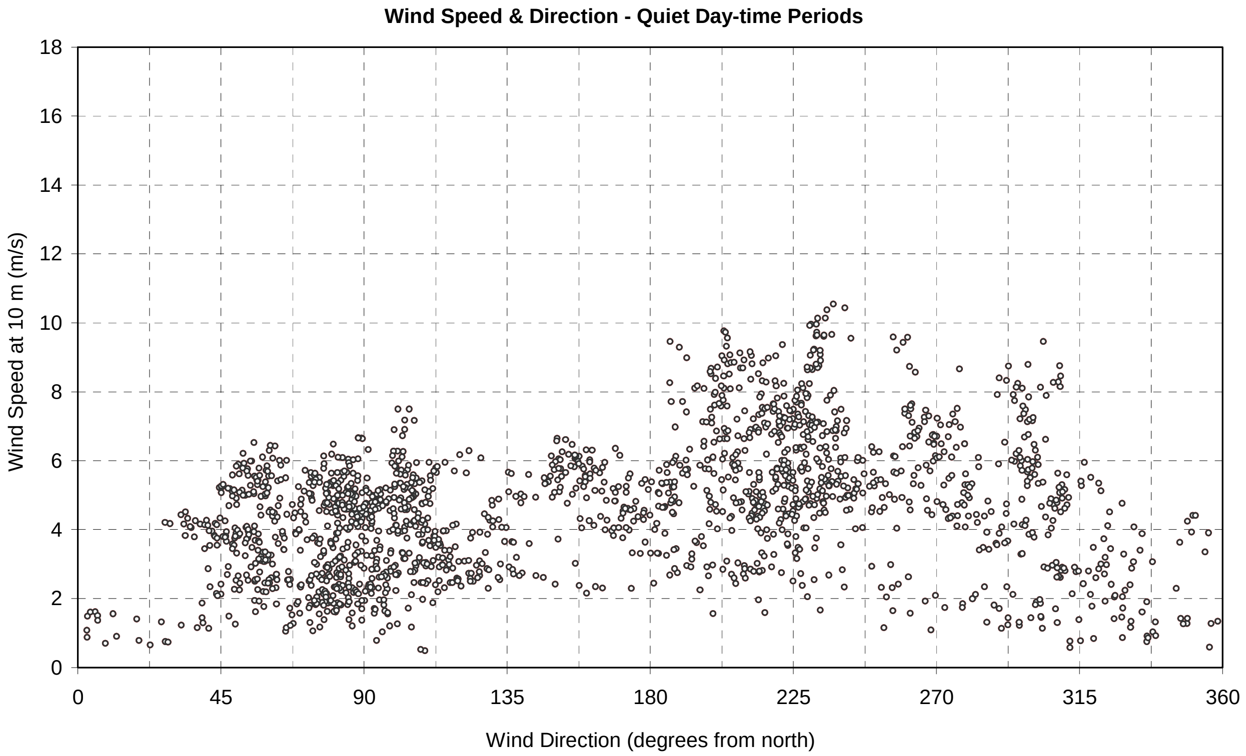


Figure D1 **Wind speed and direction range during all quiet day-time periods (all data shown – data exclusions vary for different measurement locations).**

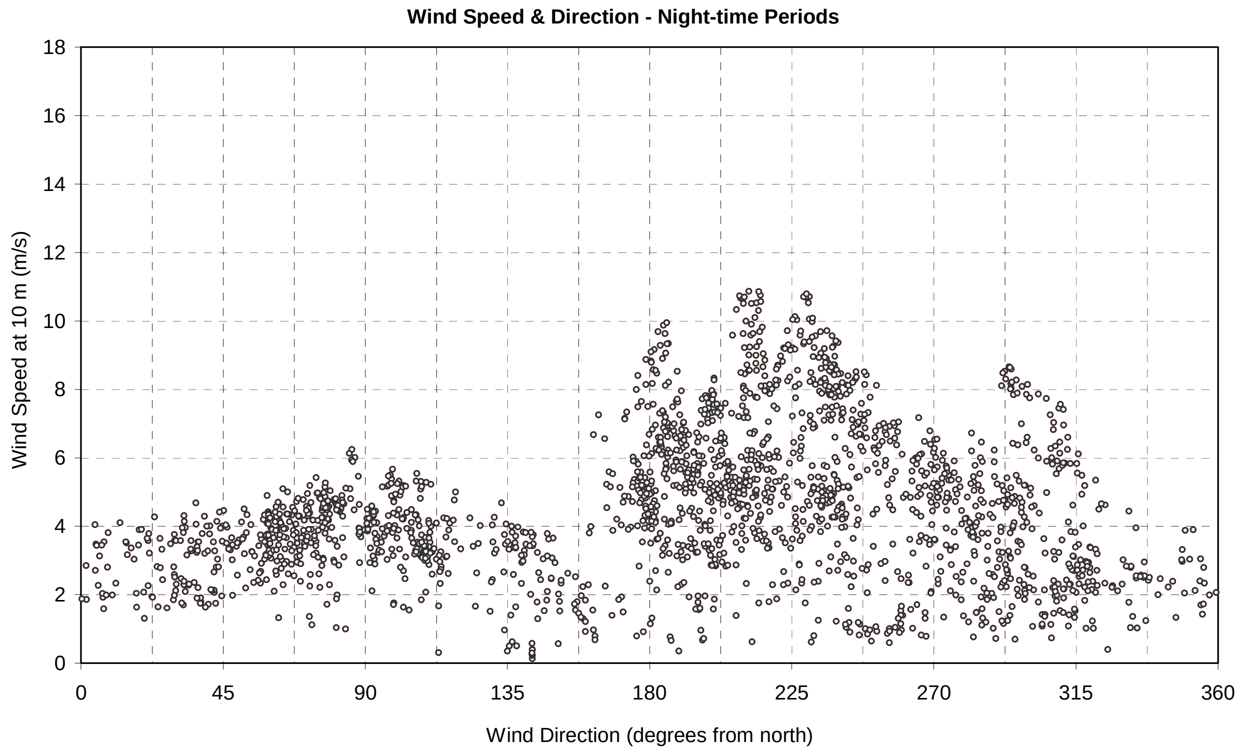


Figure D2 **Wind speed and direction range during all night-time periods (data all data shown – data exclusions vary for different locations).**

APPENDIX 10.E: BACKGROUND NOISE AND NOISE LIMITS

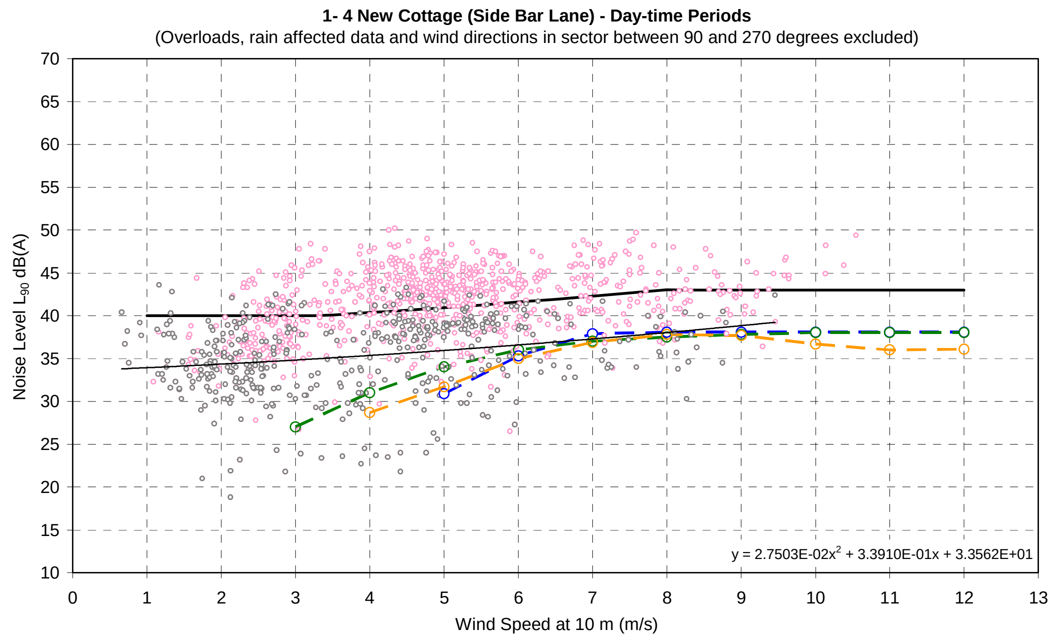


Figure E1 Chart of background noise levels measured at Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for 1-4 New Cottage during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue curve with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

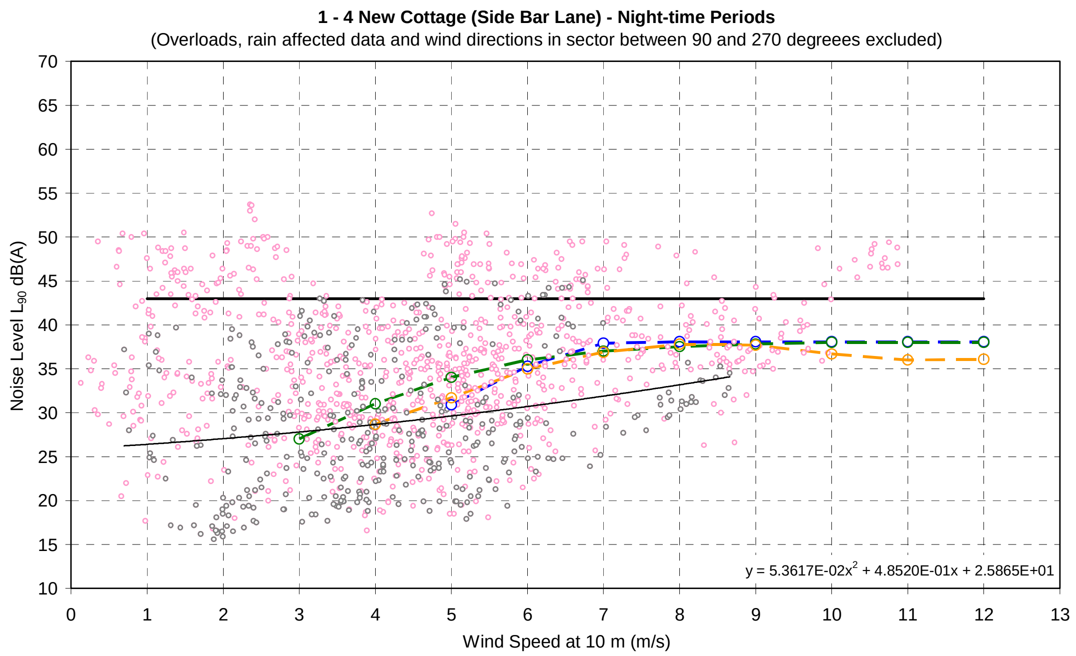


Figure E2 Chart of background noise levels measured at Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for 1-4 New Cottage during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue curve with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

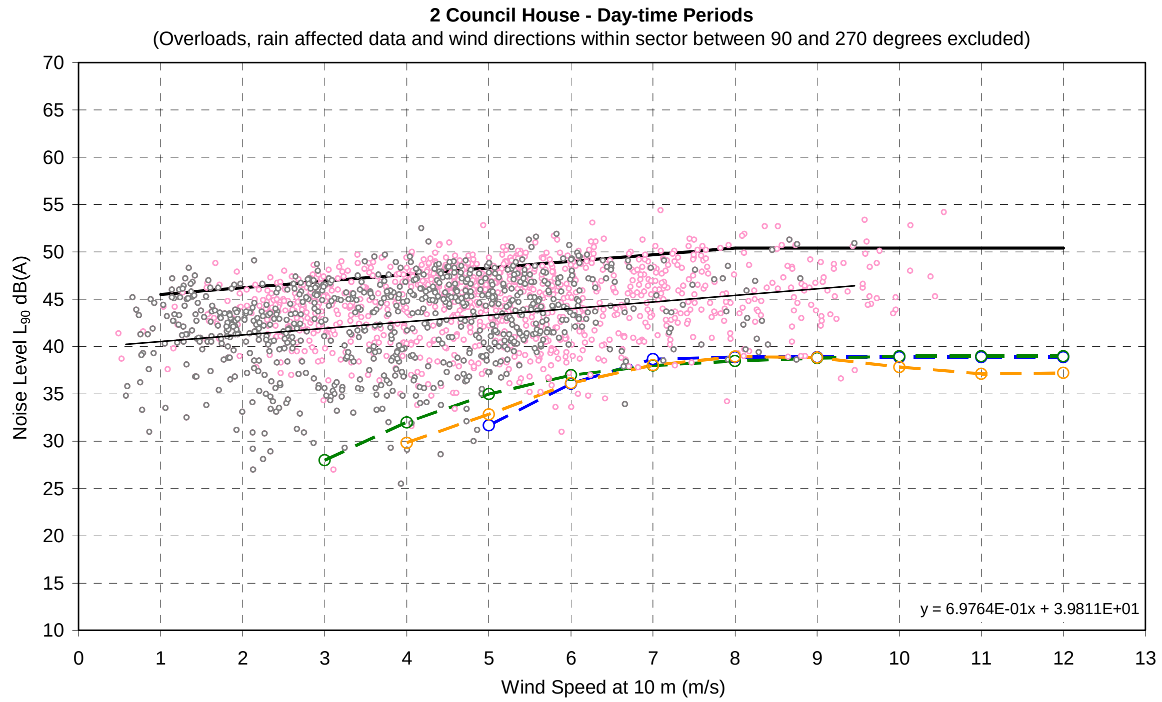


Figure E3 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for 2 Council House during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

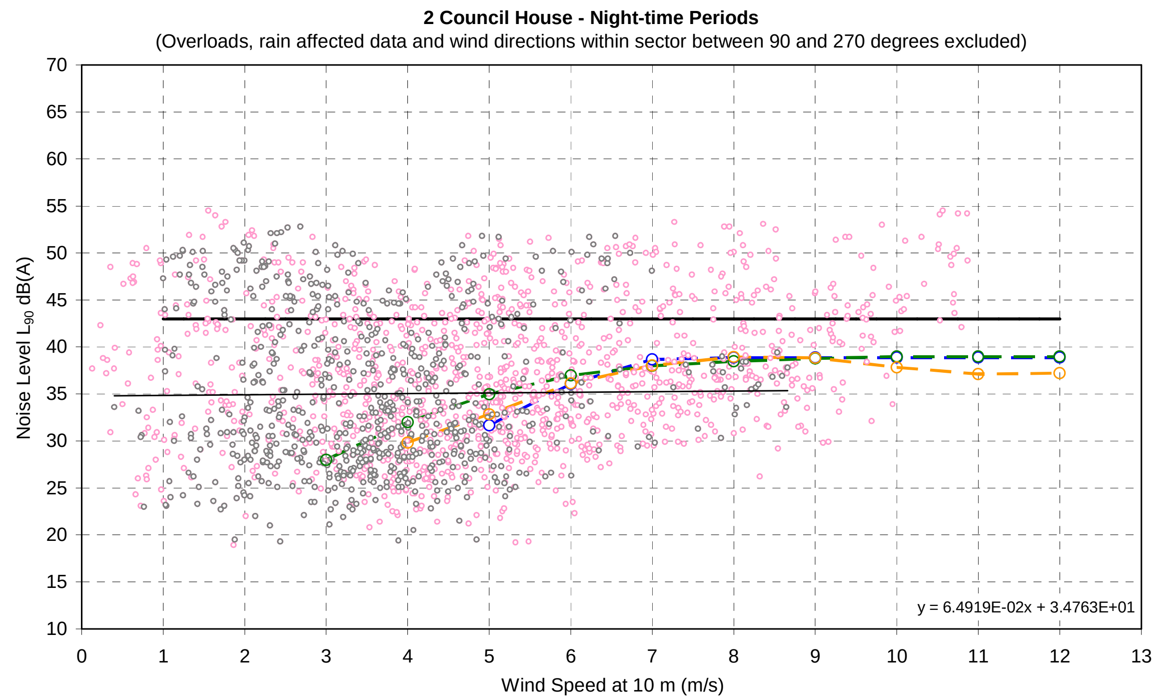


Figure E4 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for 2 Council House during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

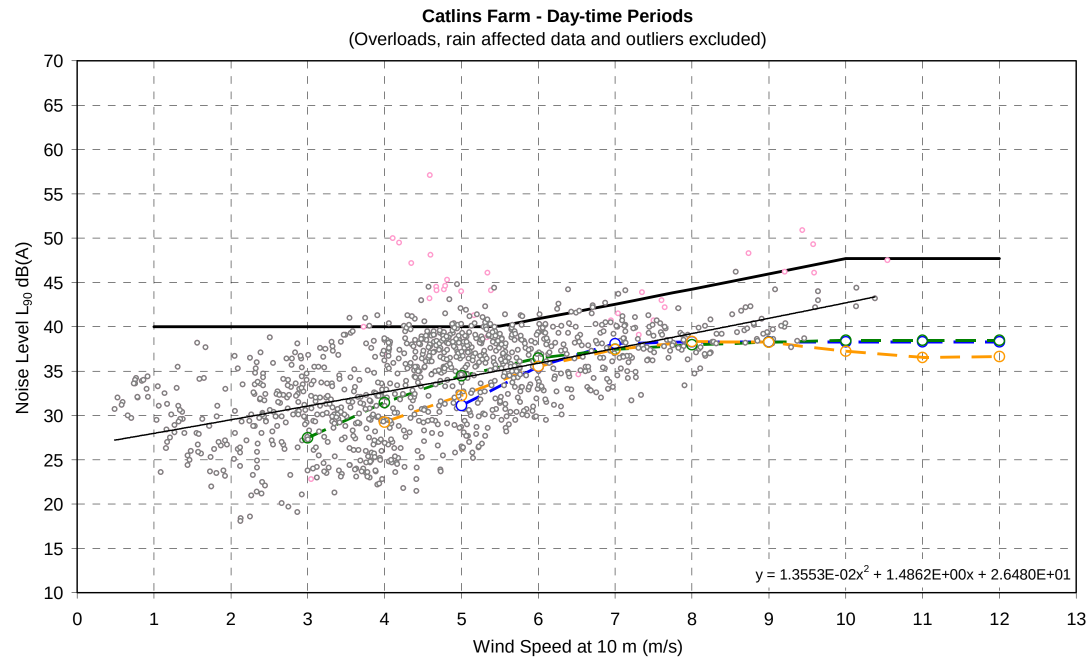


Figure E5 Chart of background noise levels measured at College Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Catlins Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

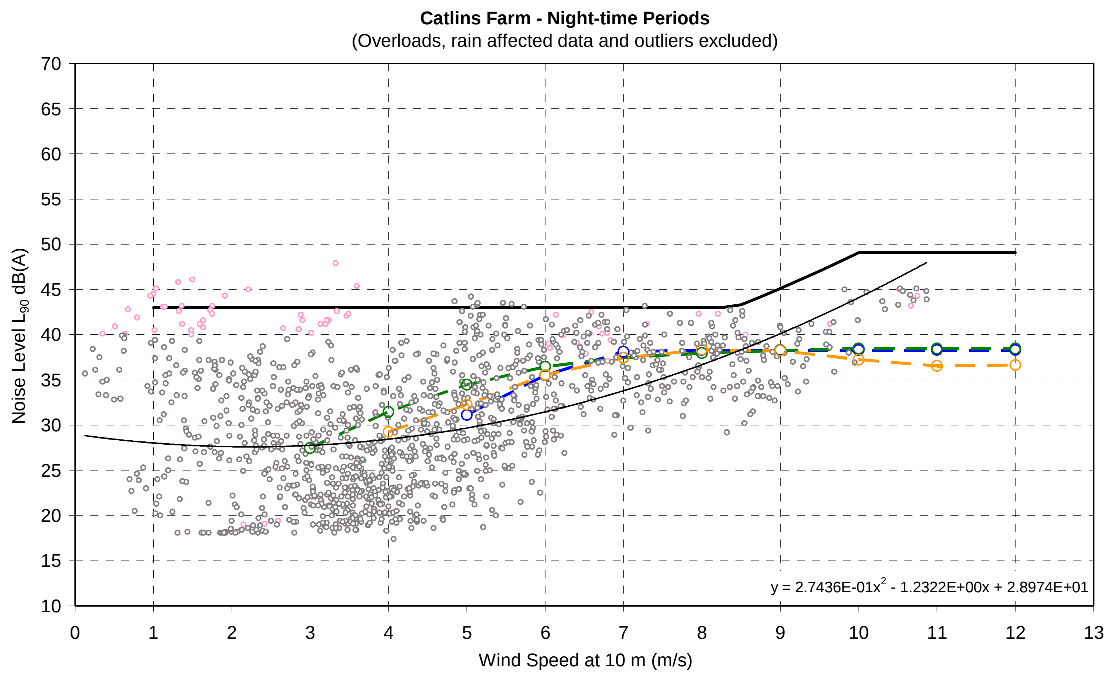


Figure E6 Chart of background noise levels measured at College Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Catlins Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

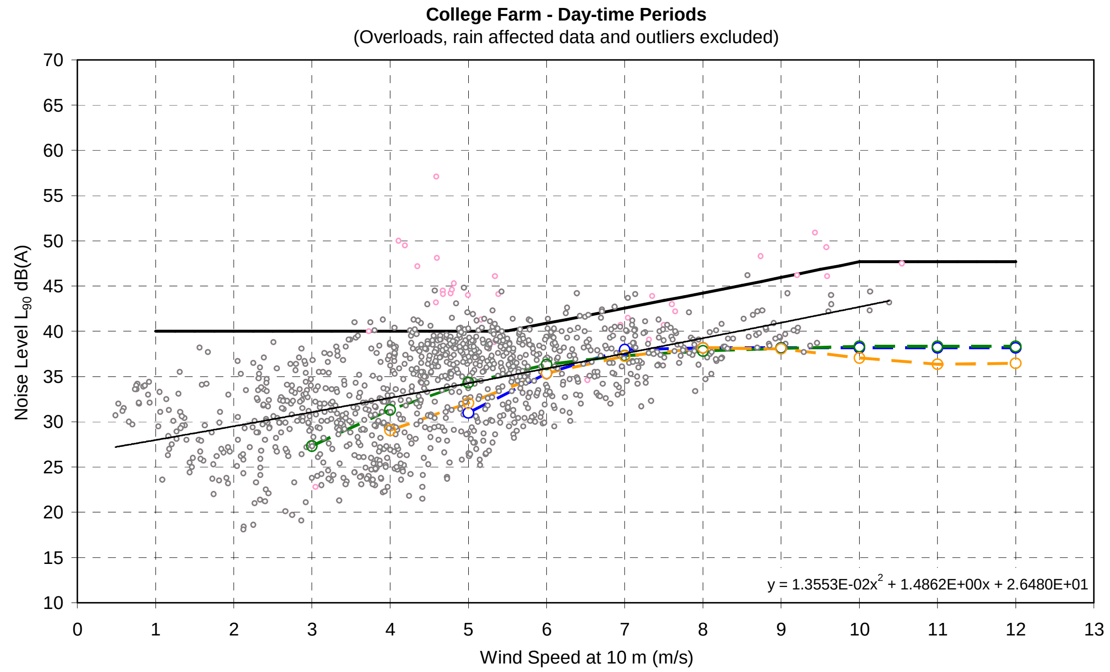


Figure E7 Chart of background noise levels measured at College Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for College Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

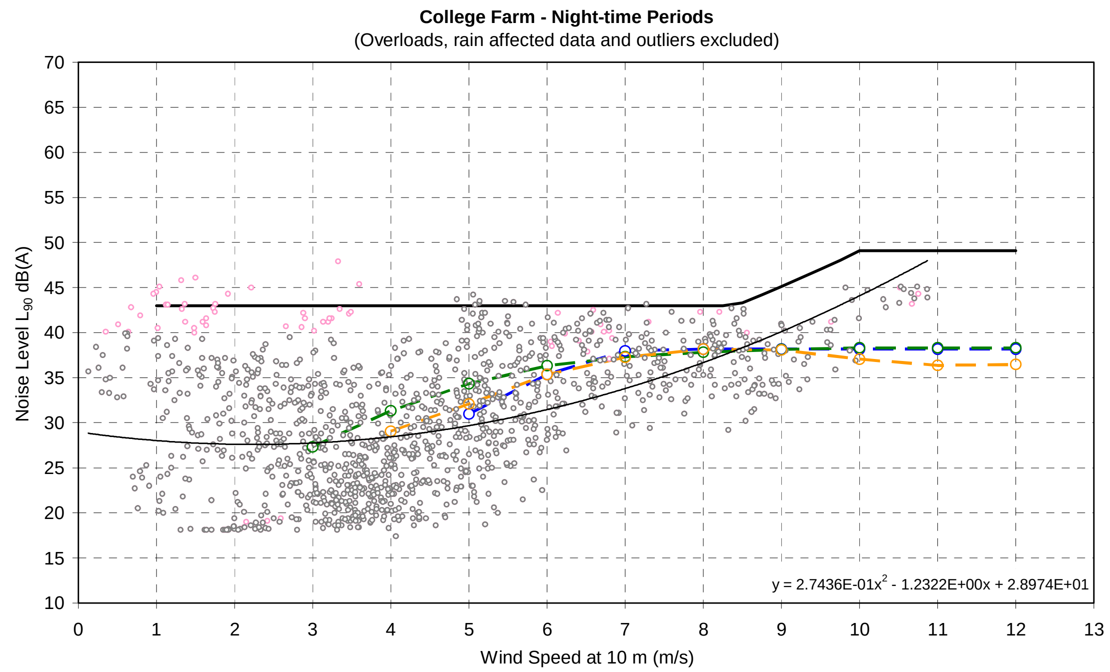


Figure E8 Chart of background noise levels measured at College Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for College Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

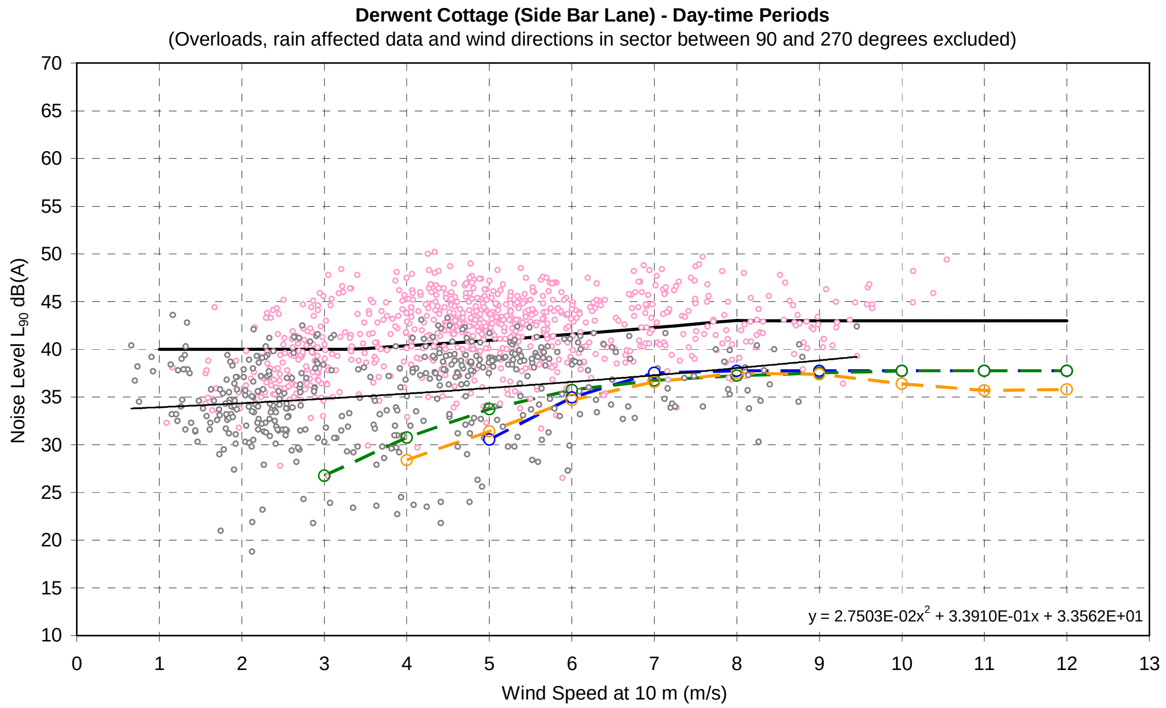


Figure E9 Chart of background noise levels measured on Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Derwent Cottage during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

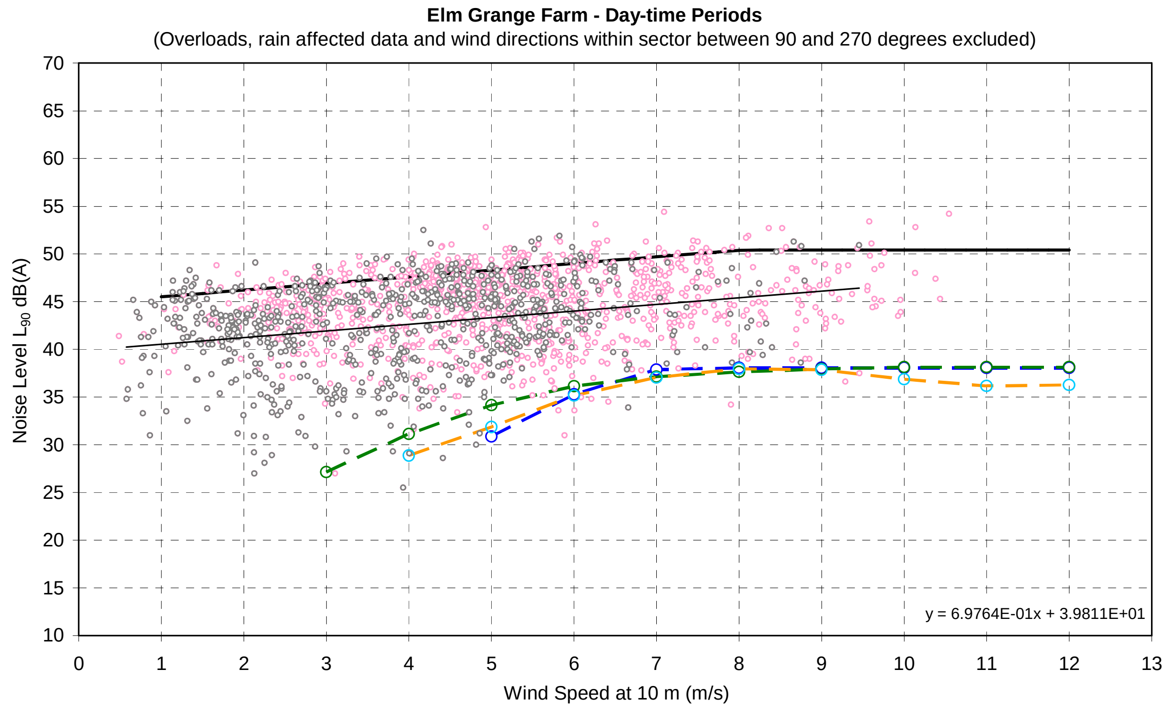


Figure E11 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Elm Grange Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

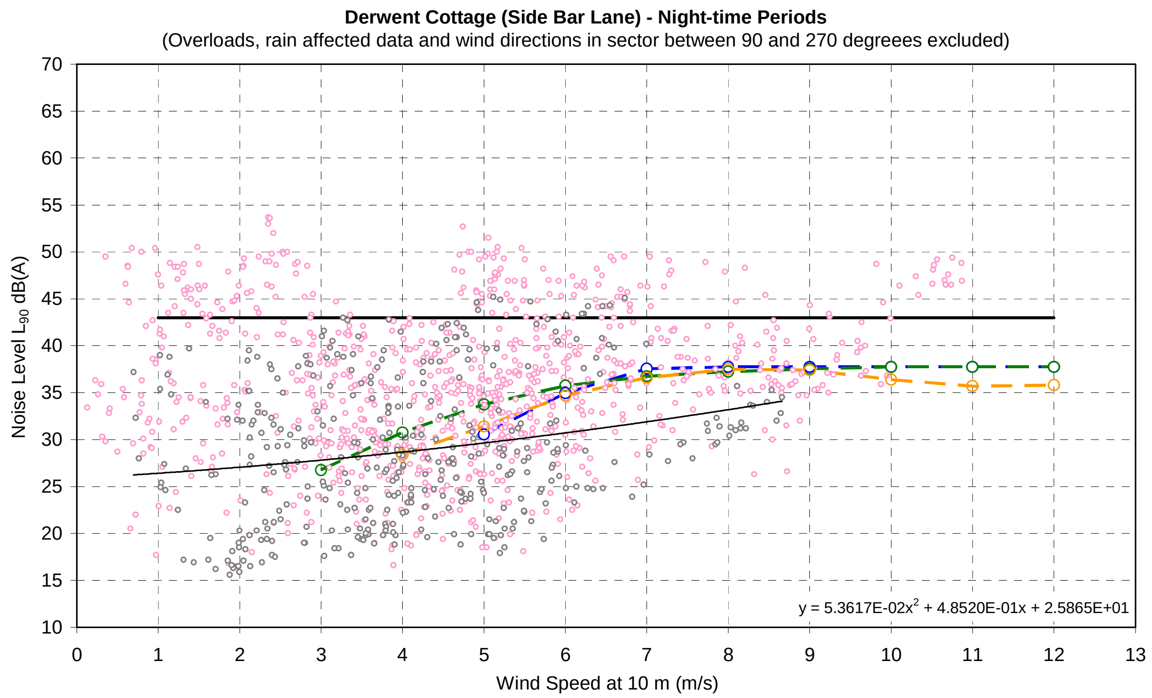


Figure E10 Chart of background noise levels measured on Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Derwent Cottage during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

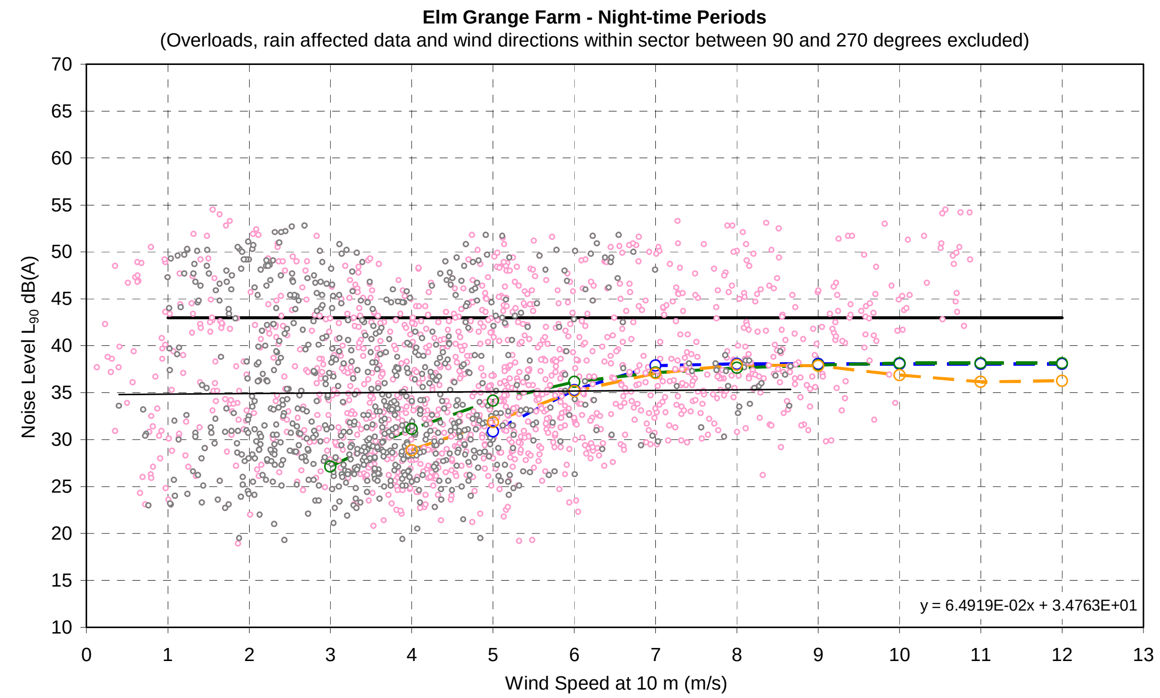


Figure E12 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Elm Grange Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

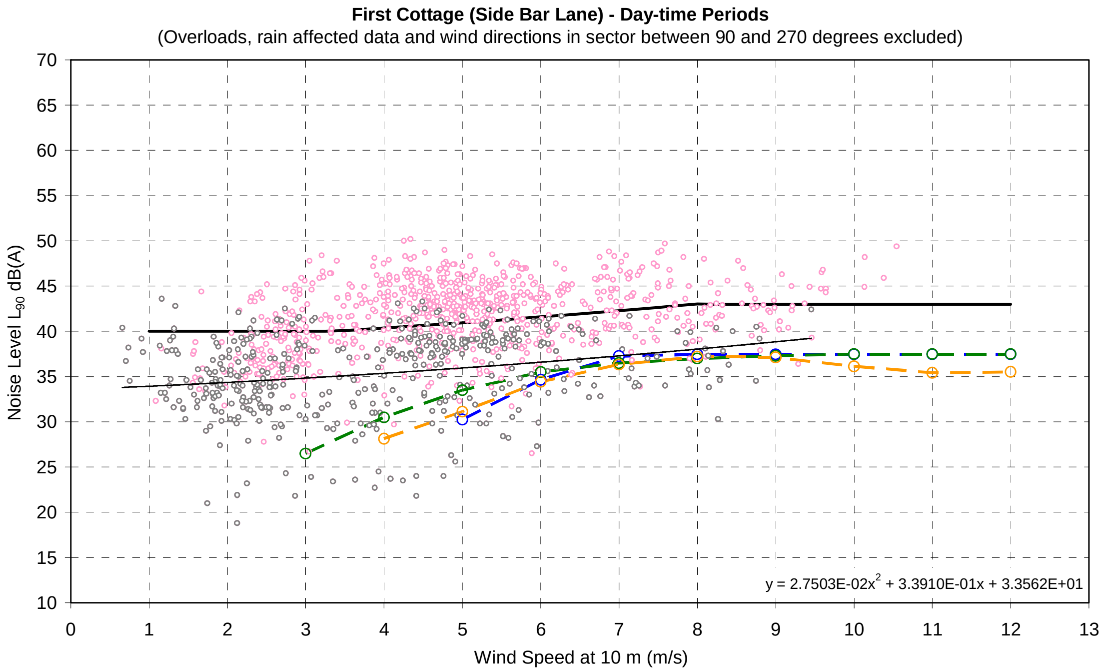


Figure E13 Chart of background noise levels measured on Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for First Cottage during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

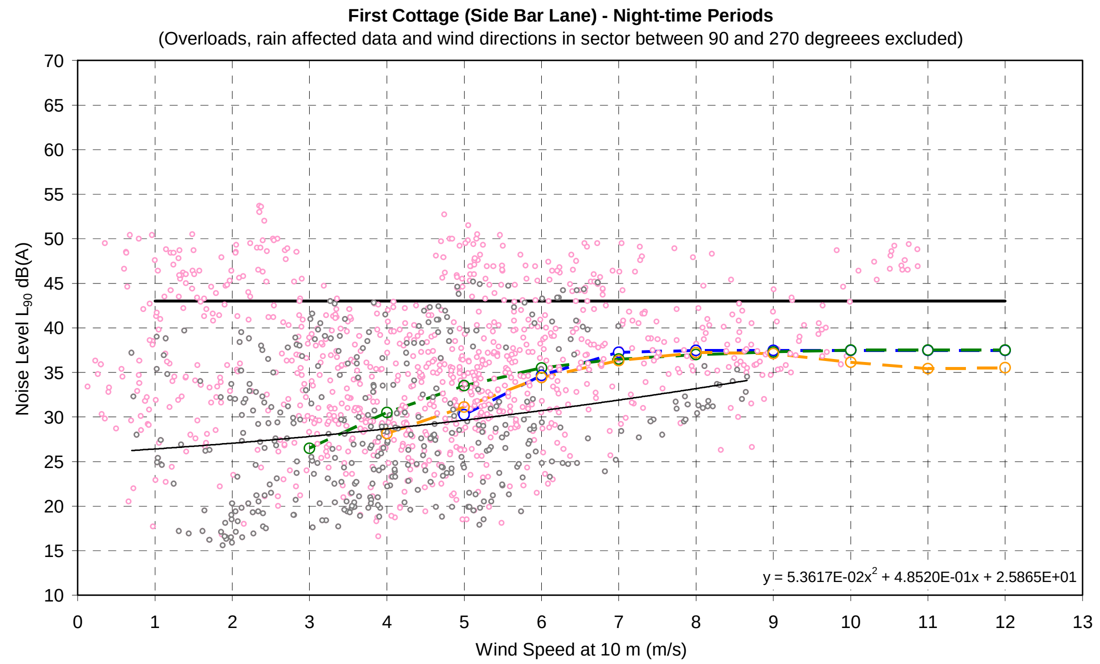


Figure E14 Chart of background noise levels measured on Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for First Cottage during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed dark curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

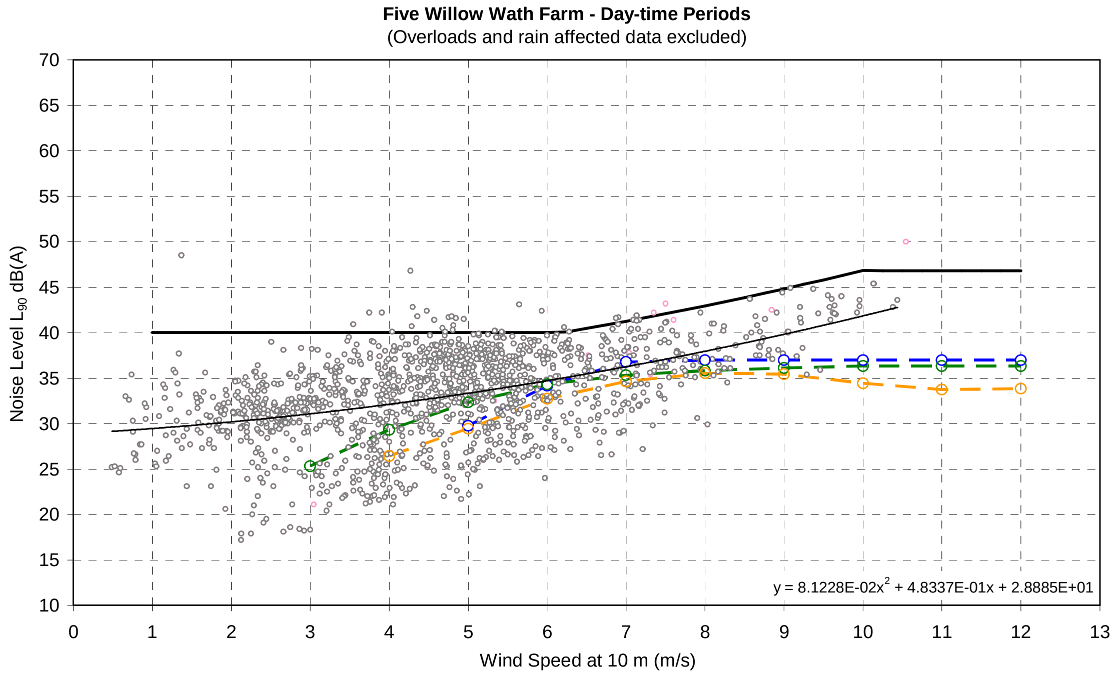


Figure E15 Chart of background noise levels measured at Glebe Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Five Willow Wath Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

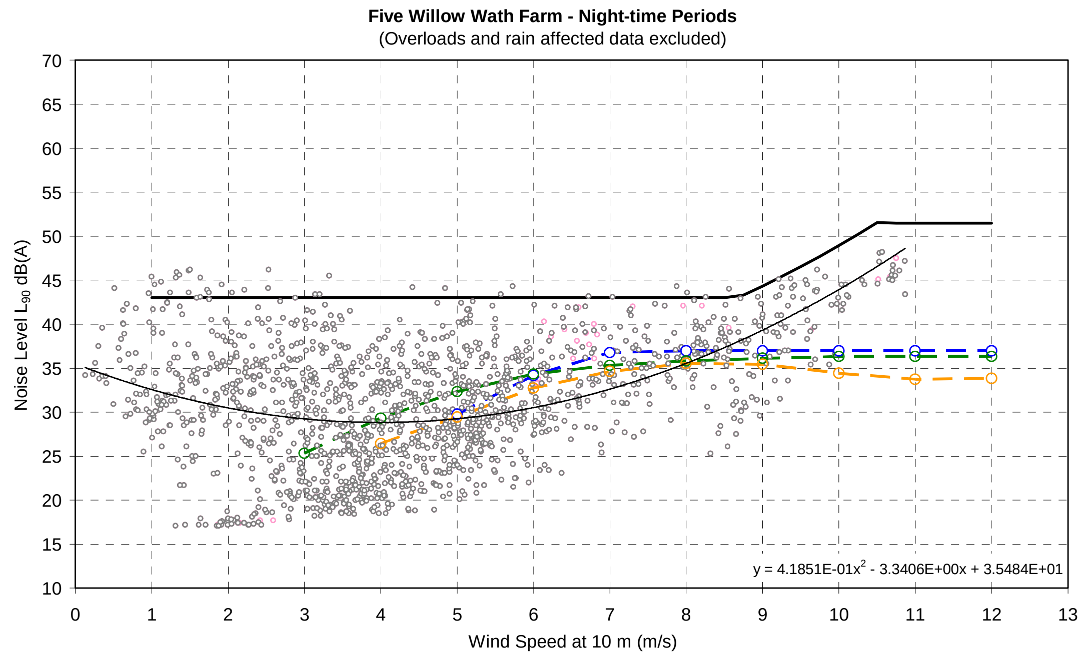


Figure E16 Chart of background noise levels measured at Glebe Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Five Willow Wath Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

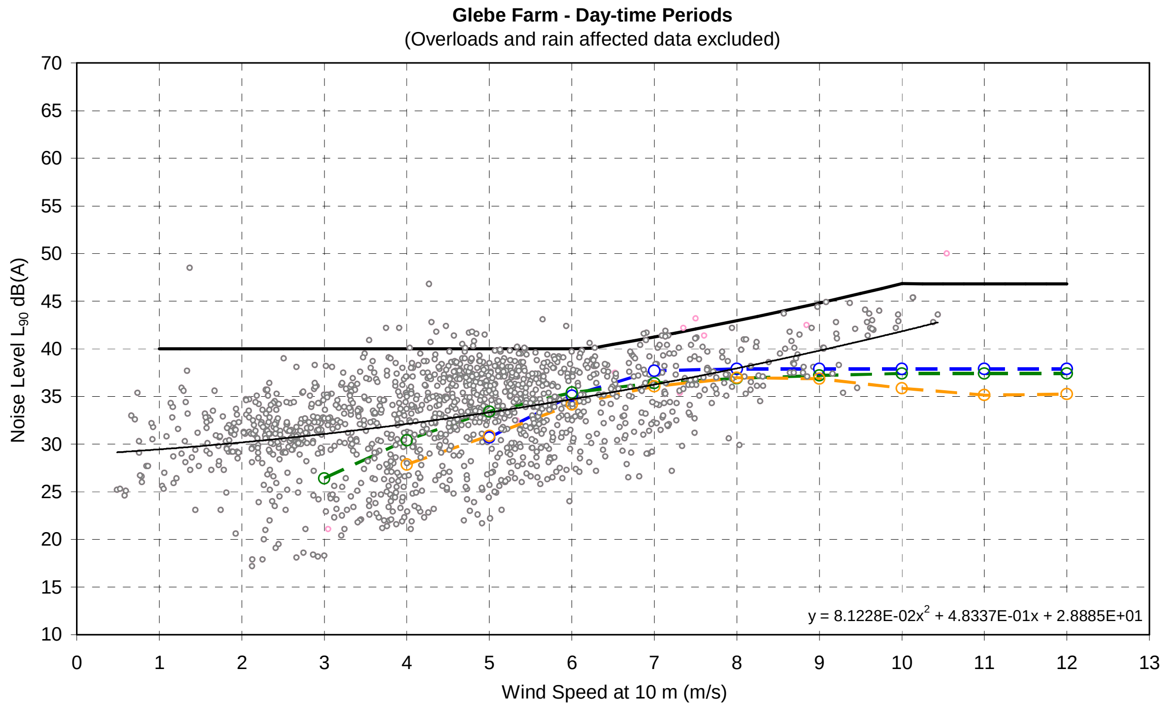


Figure E17 Chart of background noise levels measured at Glebe Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Glebe Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

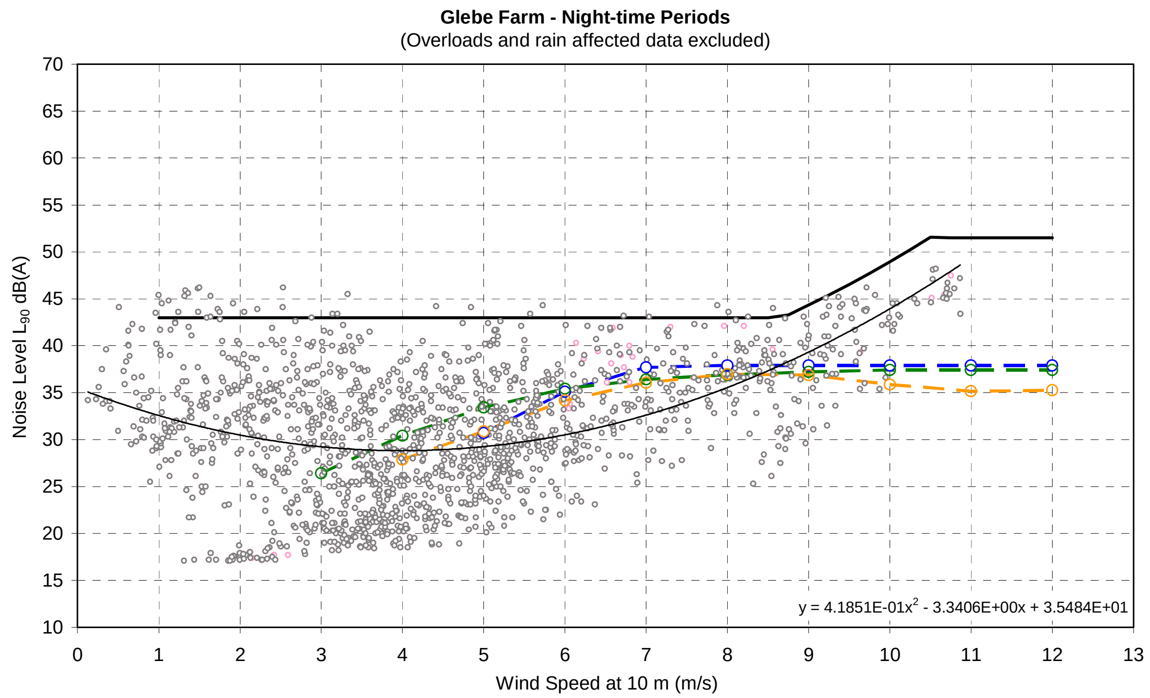


Figure E18 Chart of background noise levels measured at Glebe Farm against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Glebe Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

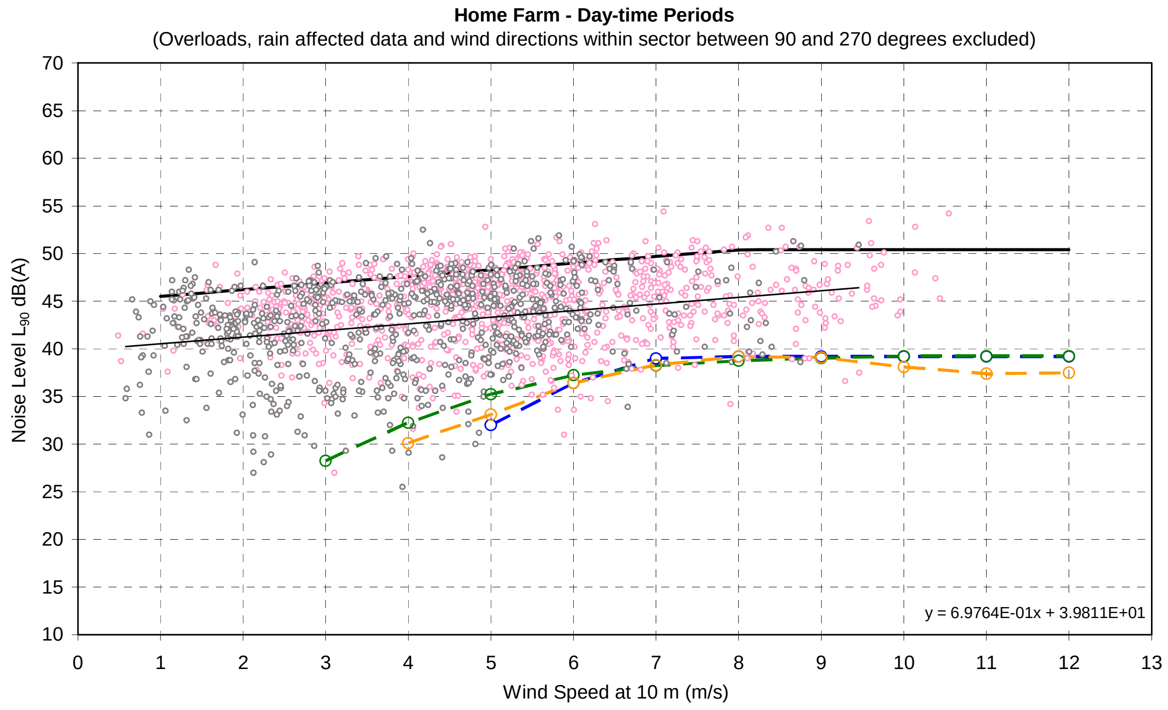


Figure E19 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Home Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

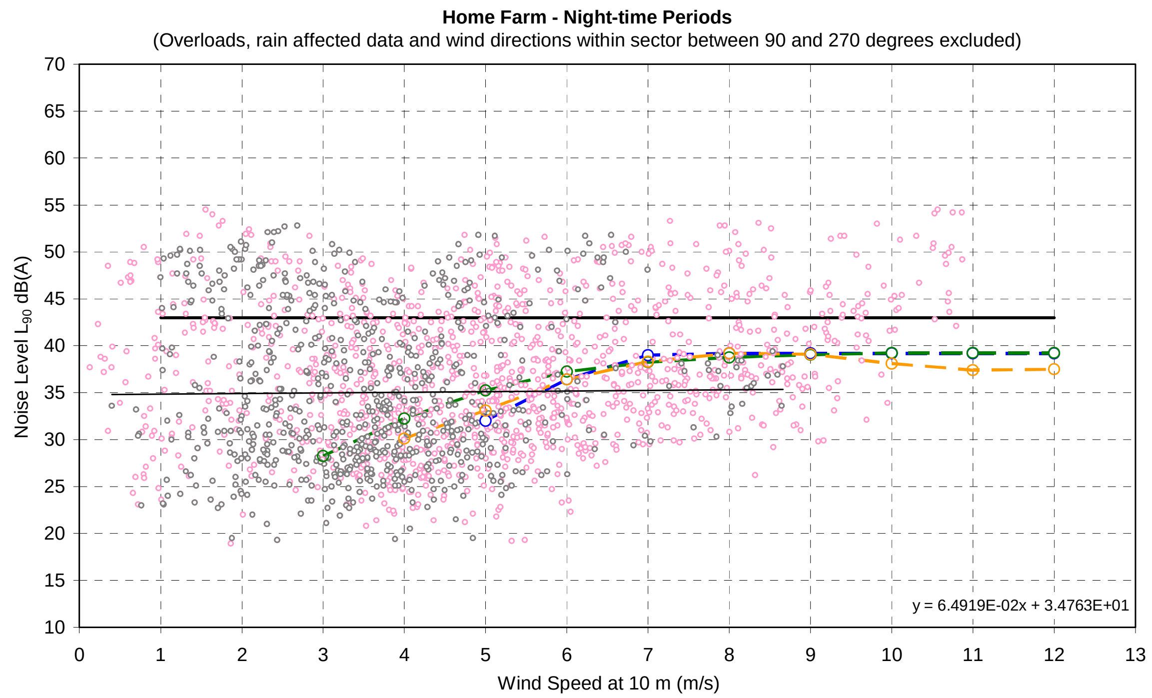


Figure E20 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Home Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

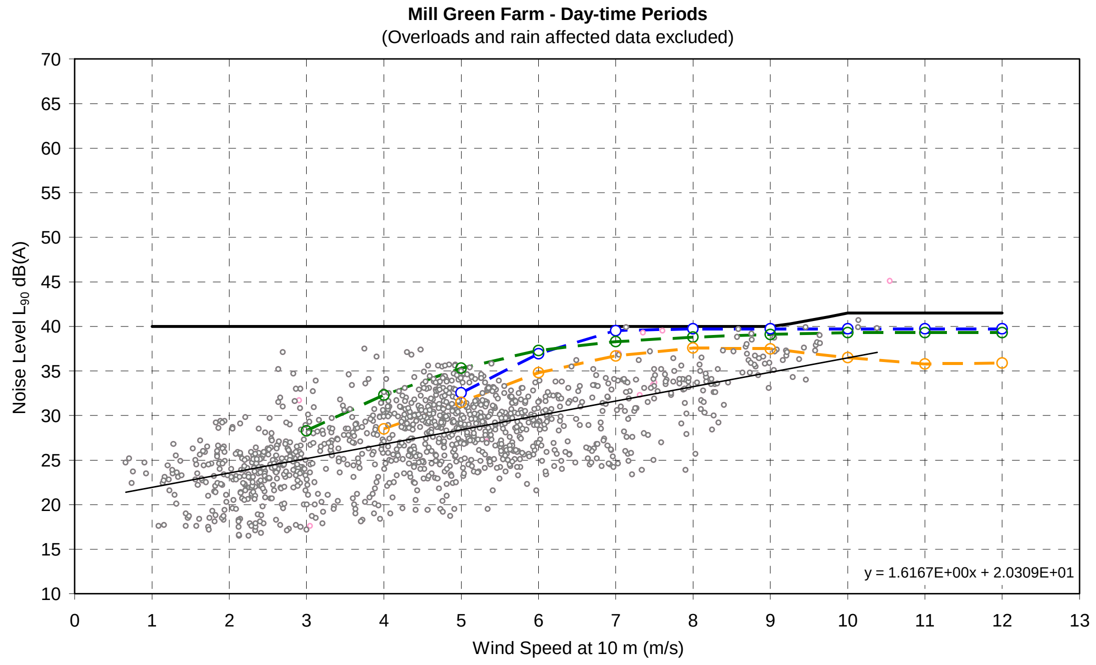


Figure E21 Chart of background noise levels measured at Mill Green Farm (proxy) against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Mill Green Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

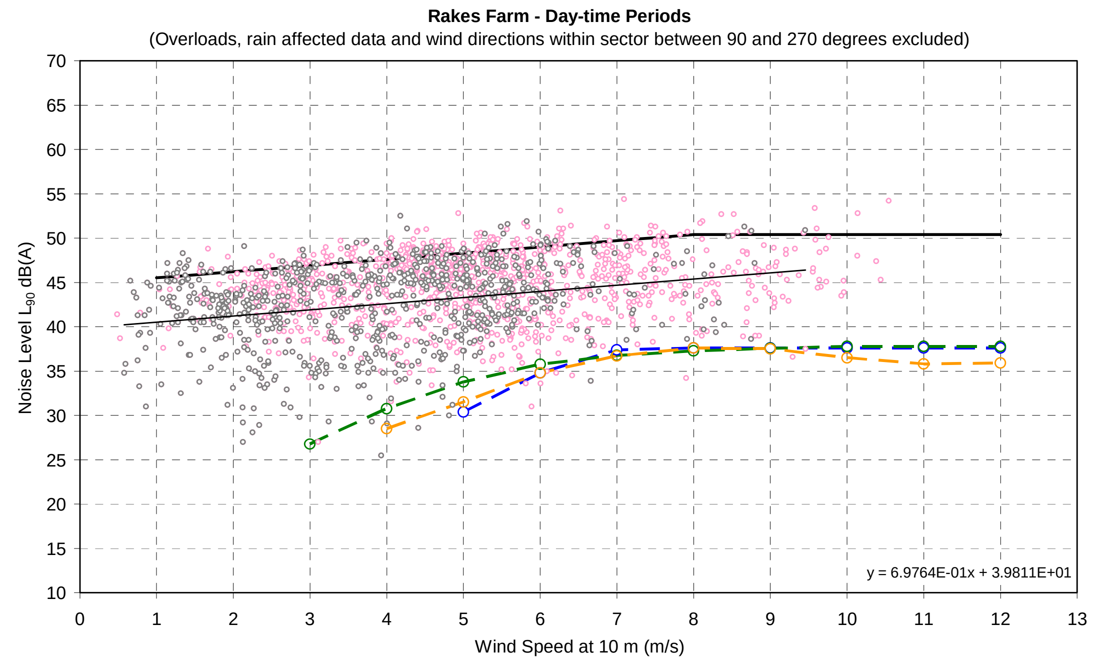


Figure E23 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Rakes Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

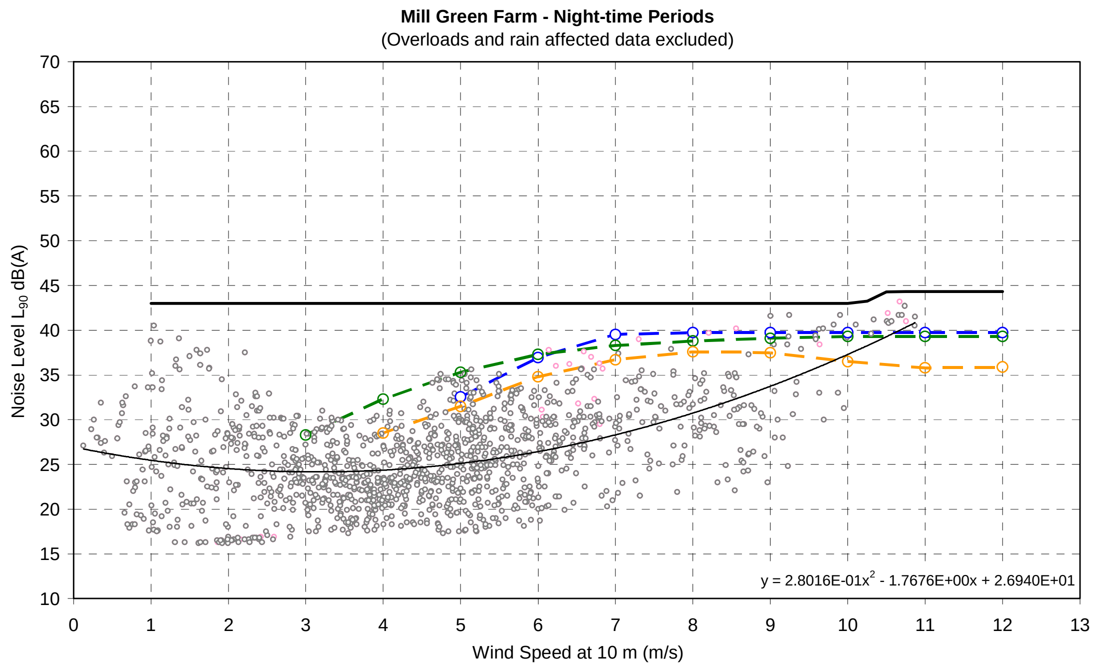


Figure E22 Chart of background noise levels measured at Mill Green Farm (proxy) against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Mill Green Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

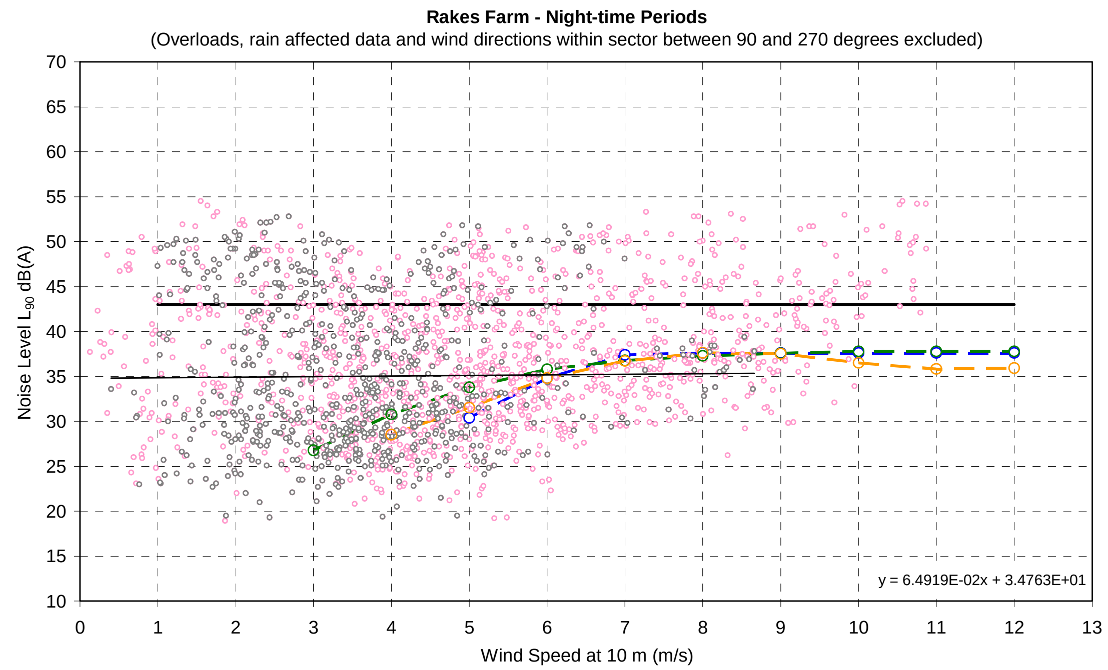


Figure E24 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Rakes Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

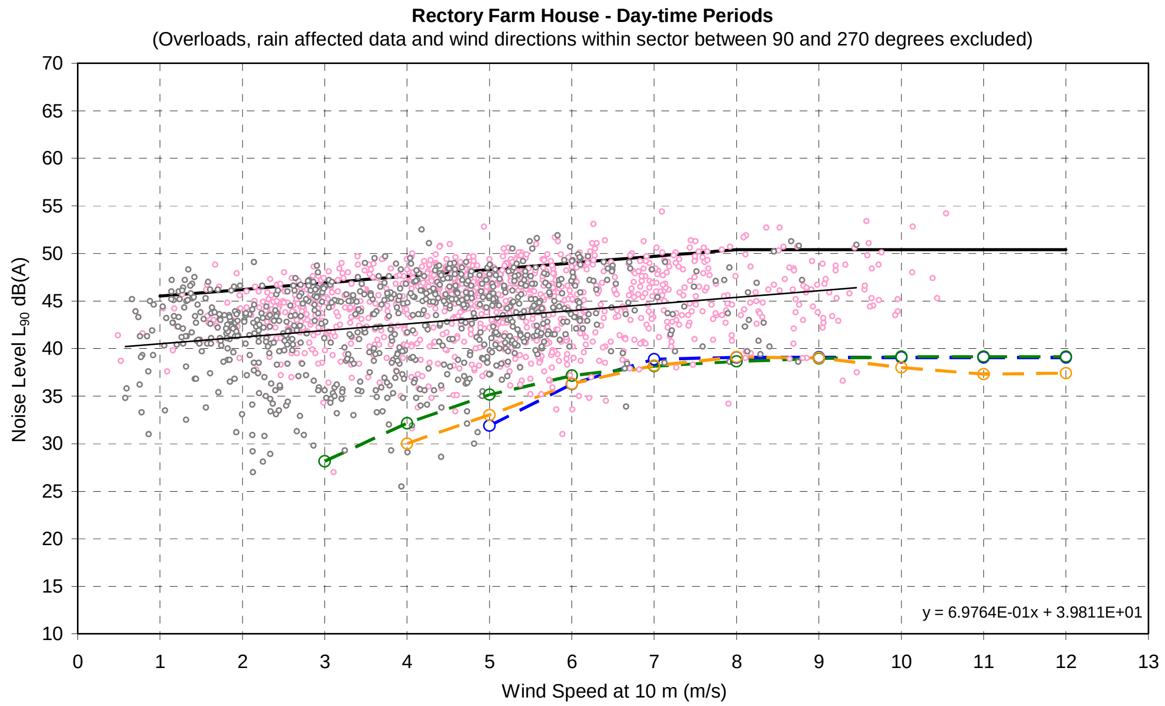


Figure E25 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Rectory Farm House during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

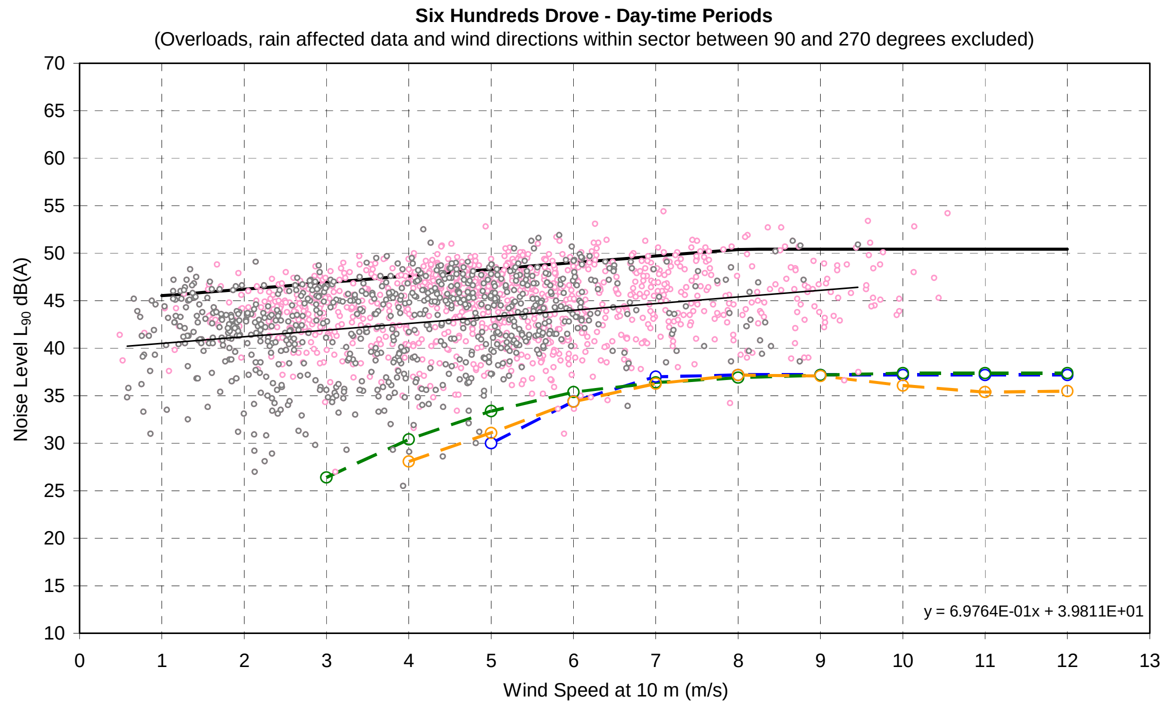


Figure E27 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Six Hundreds Drove during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

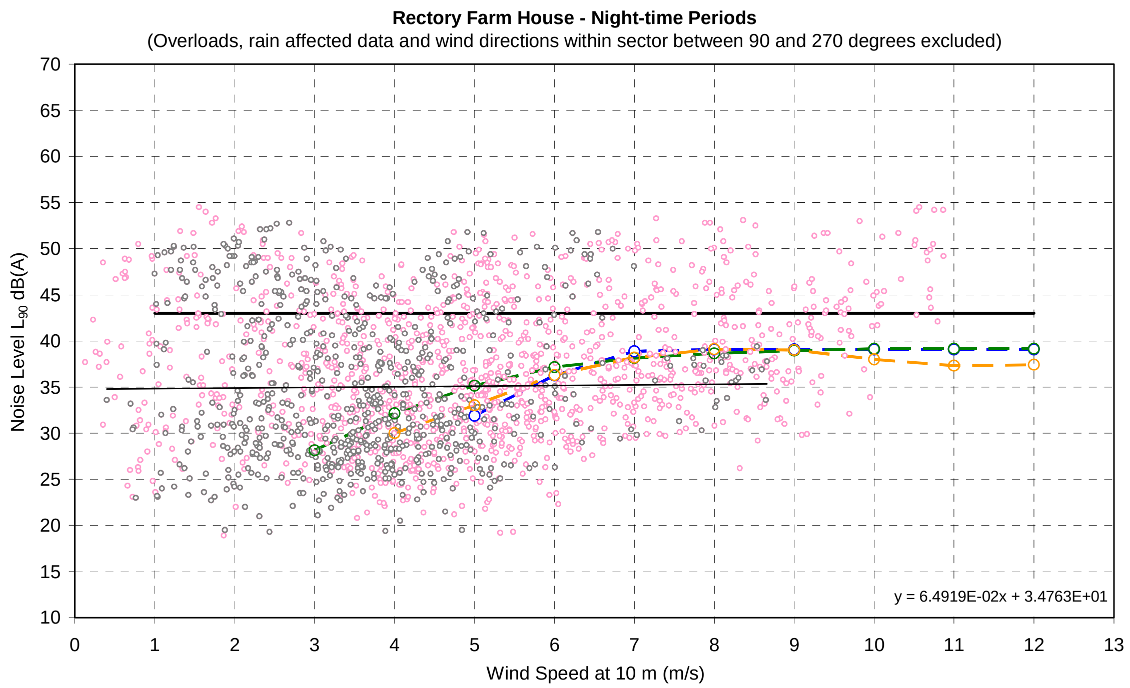


Figure E26 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Rectory Farm House during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

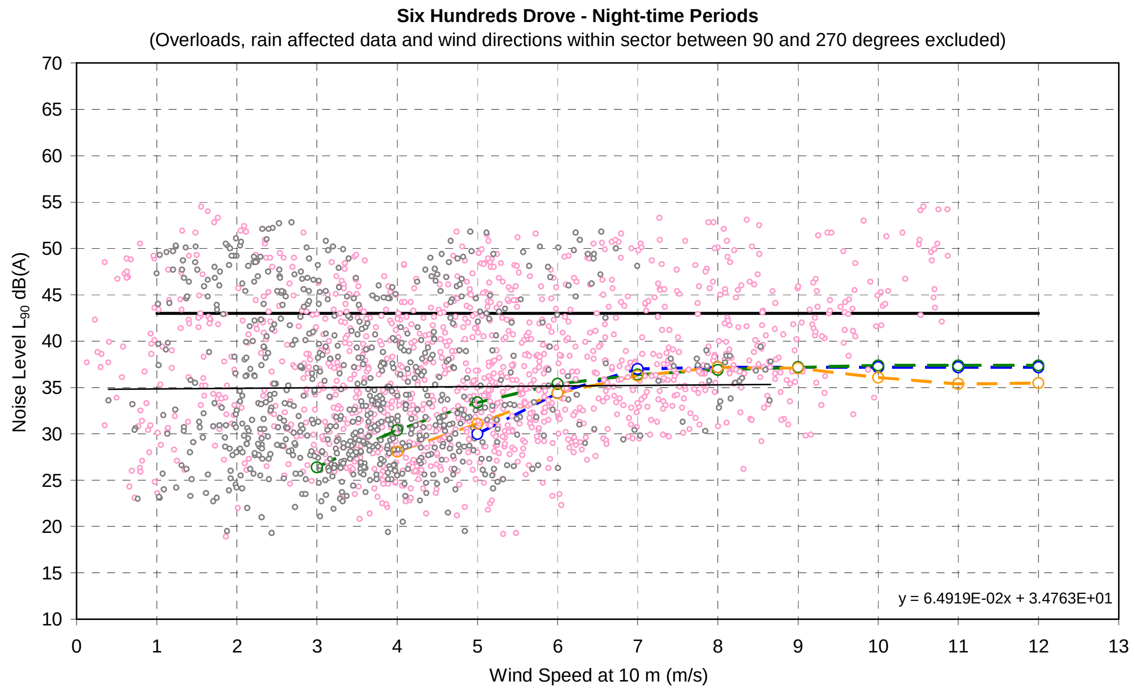


Figure E28 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Six Hundreds Drove during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

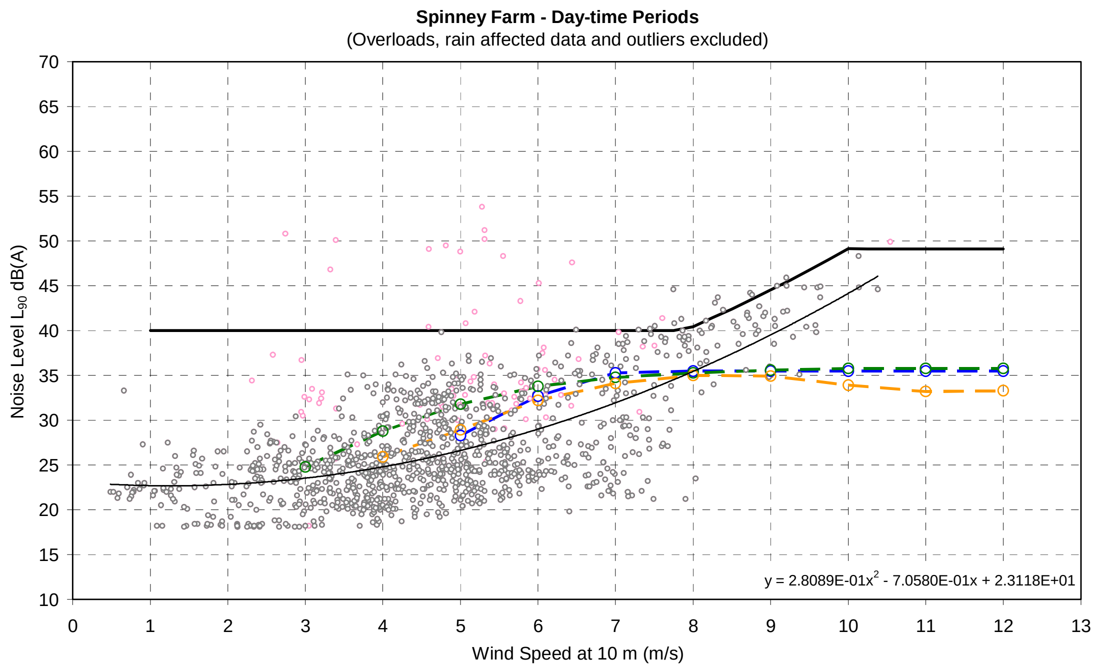


Figure E29 Chart of background noise levels measured at The Old Church against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Spinney Farm during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

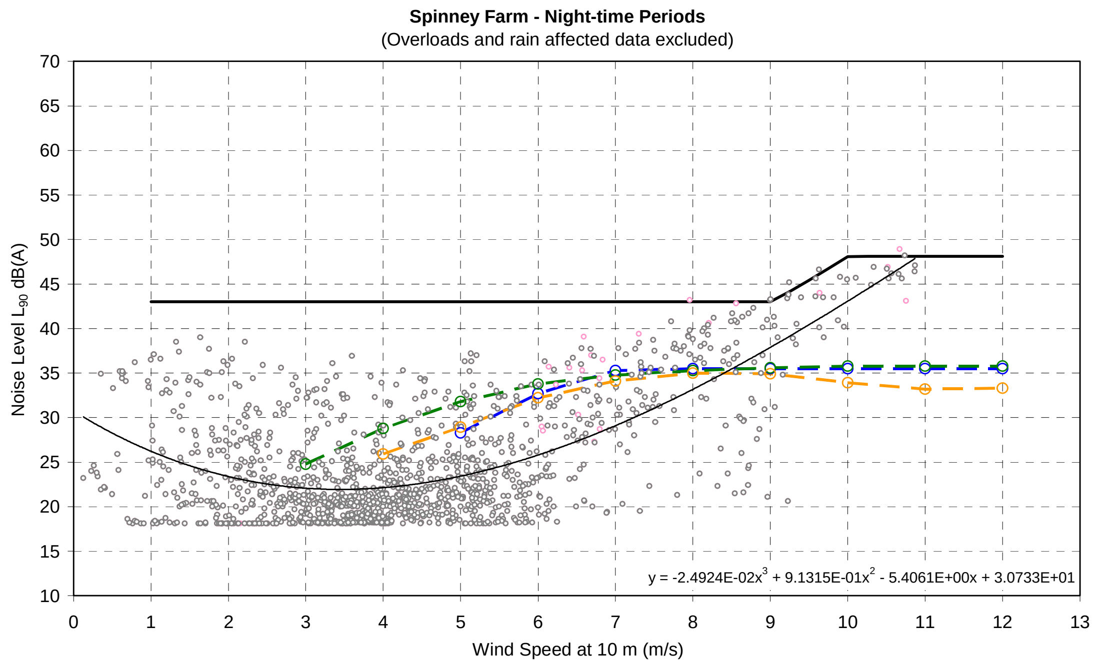


Figure E30 Chart of background noise levels measured at The Old Church against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Spinney Farm during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

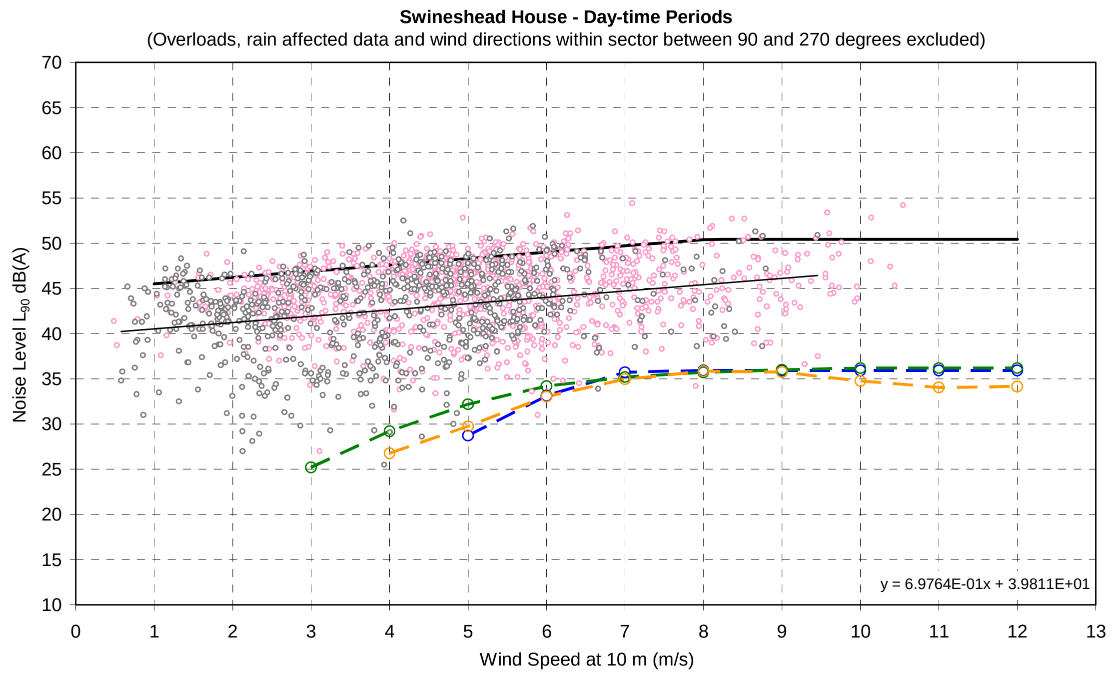


Figure E31 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Swineshead House during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

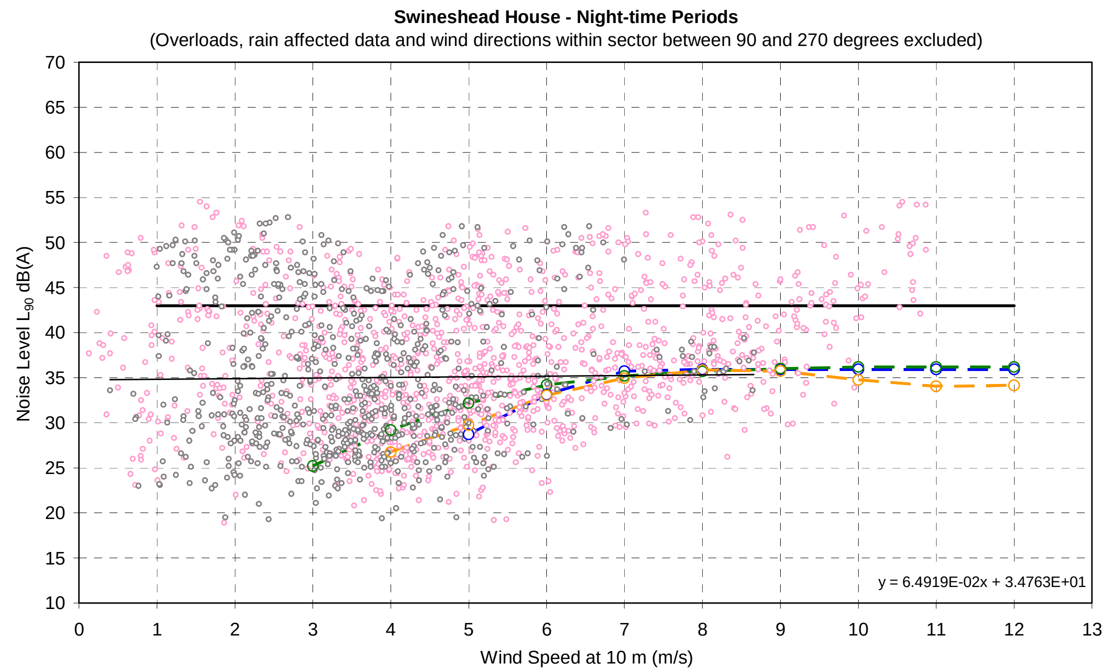


Figure E32 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Swineshead House during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

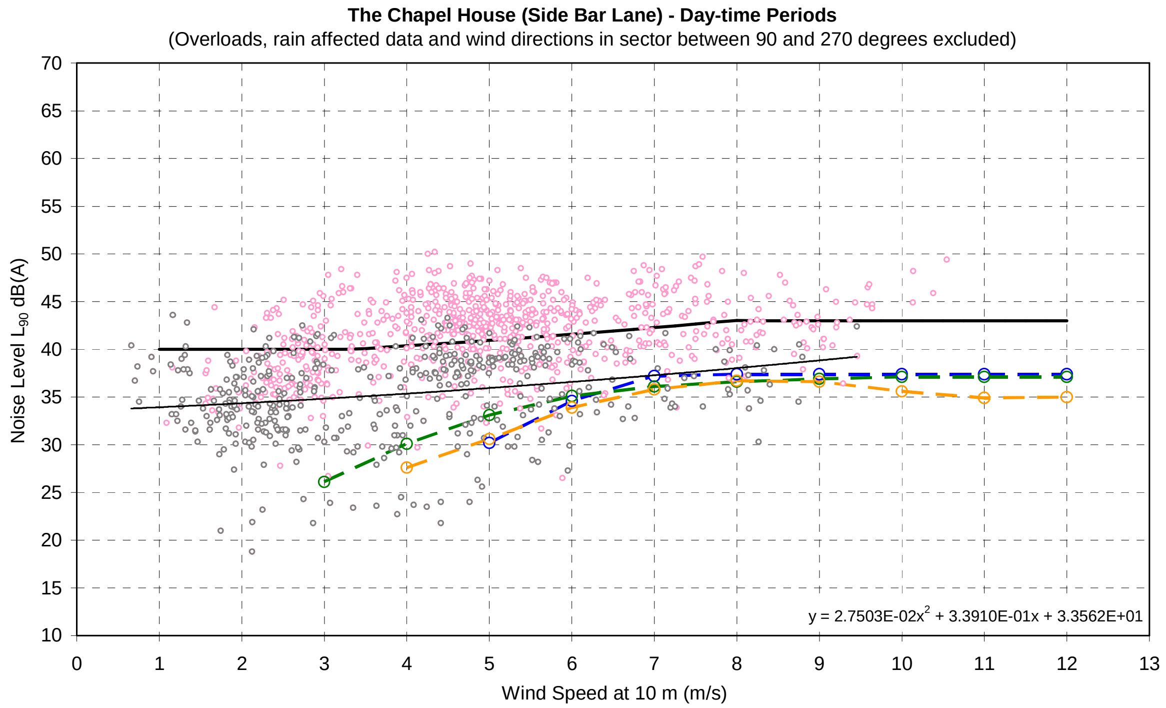


Figure E33 Chart of background noise levels measured on Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for The Chapel House during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

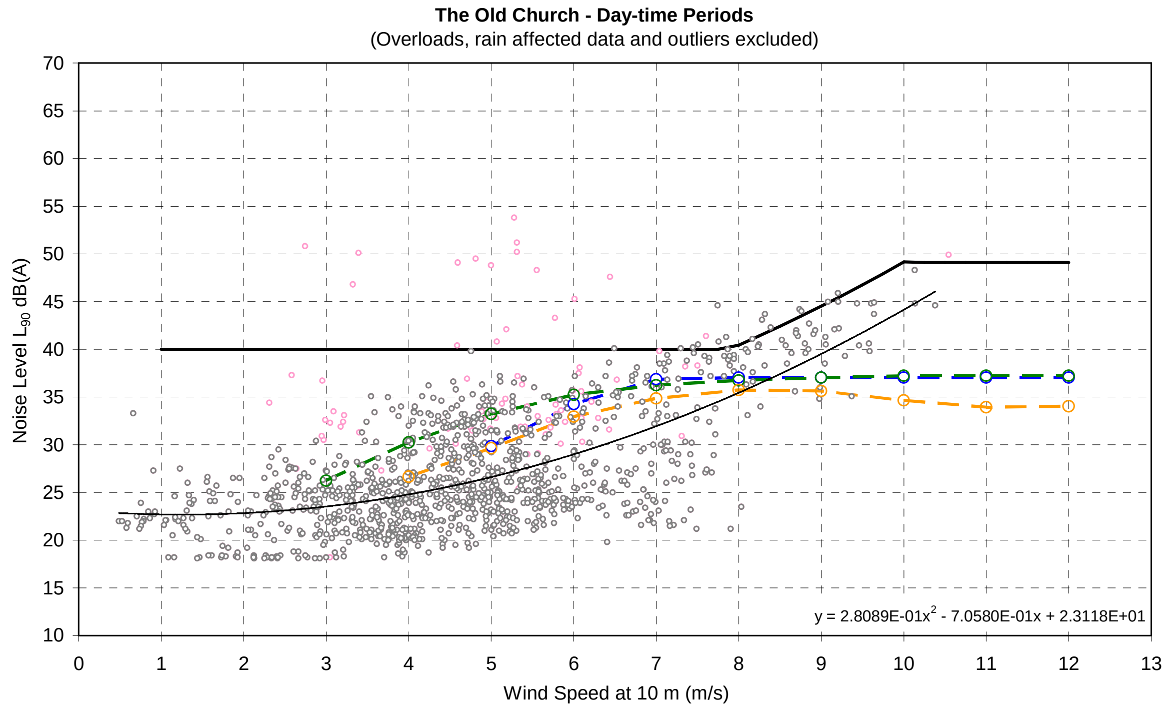


Figure E35 Chart of background noise levels measured at The Old Church against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for The Old Church during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

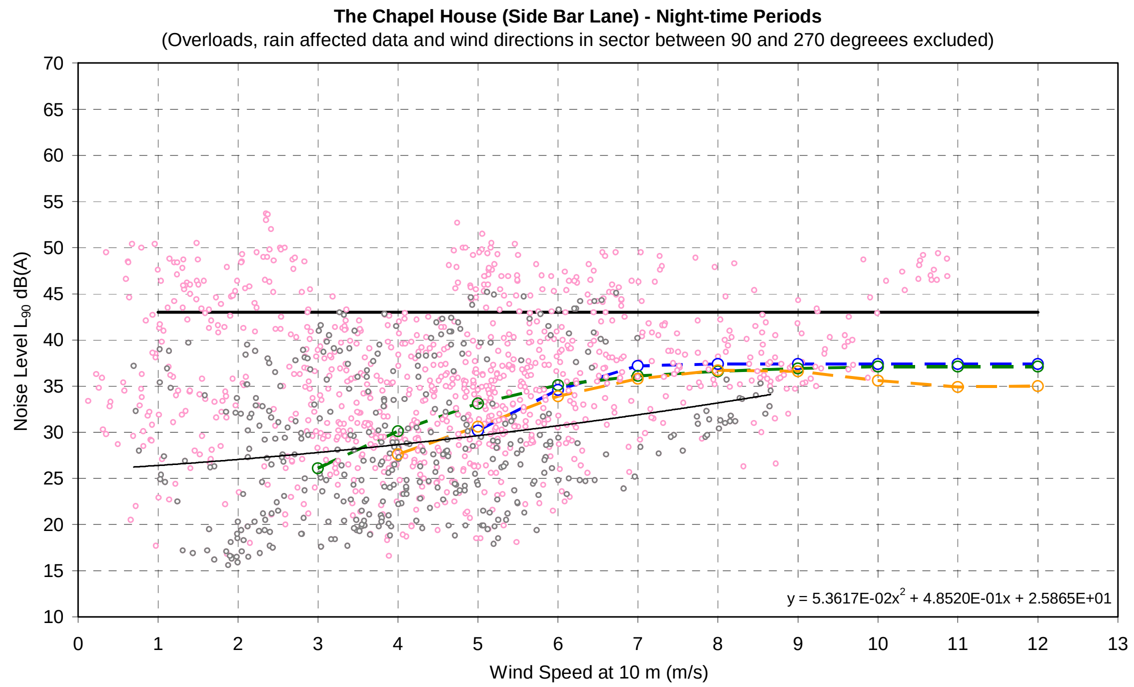


Figure E34 Chart of background noise levels measured on Side Bar Lane against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for The Chapel House during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

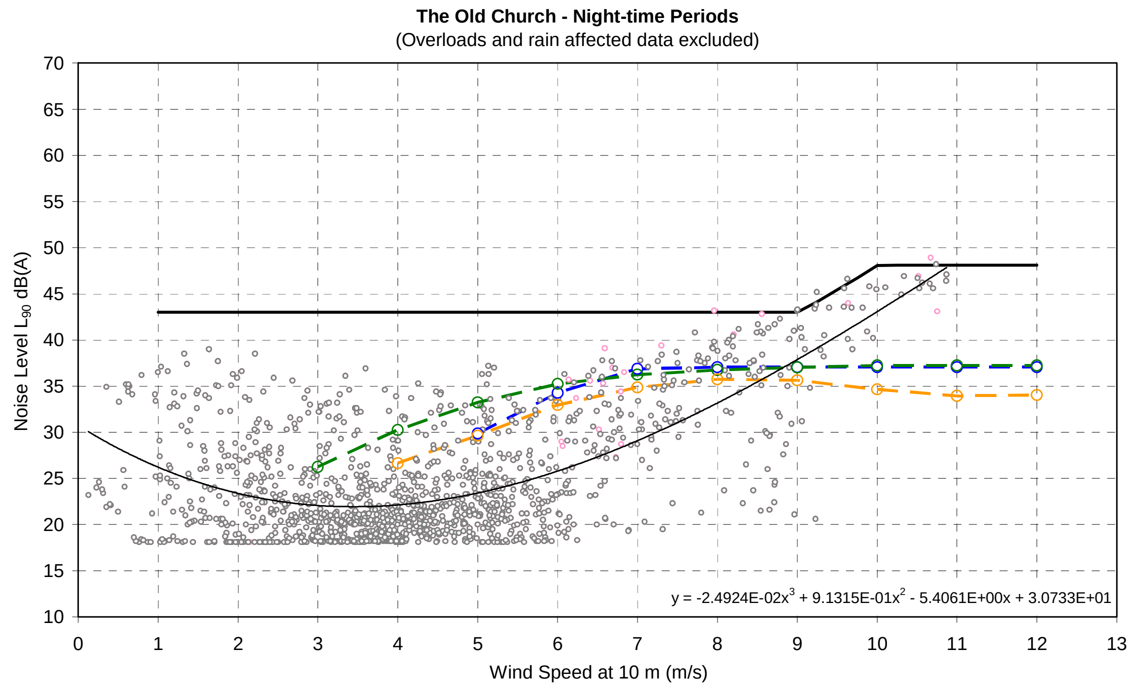


Figure E36 Chart of background noise levels against measured at The Old Church wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for The Old Church during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

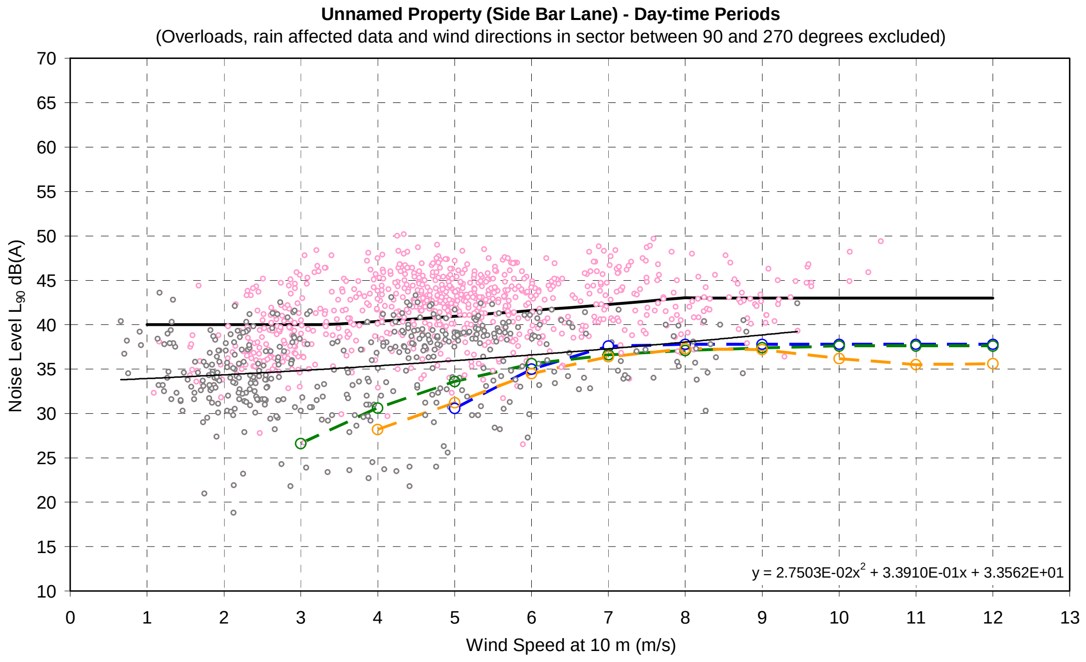


Figure E37 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Unnamed Property (Side Bar Lane) during daytime. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed blue line with open circles), the 21 x Nordex N90LS option (thick dashed green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

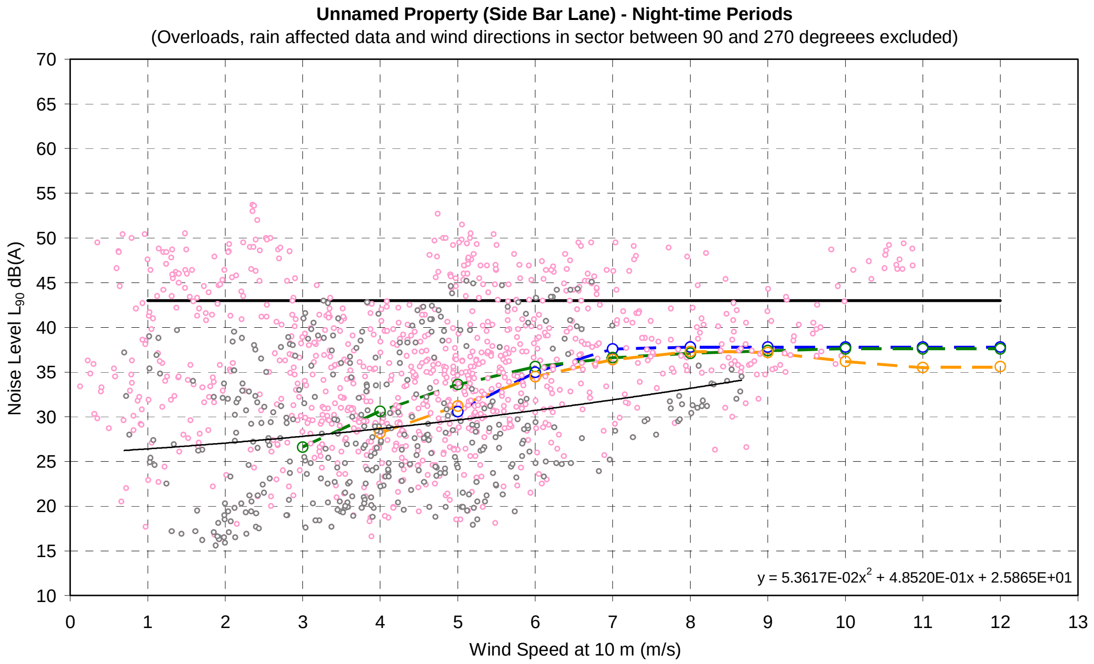


Figure E38 Chart of background noise levels measured at 2 Council House against wind speeds (open grey circles), the best fit curve to this data (thin black line), the derived noise limit curve (thick black line) for Unnamed Property (Side Bar Lane) during night-time. Predicted immission noise levels are shown for the 22 x Enercon E82 option (thick dashed dark blue line with open circles), the 21 x Nordex N90LS option (thick dashed dark green curve with open circles) and 18 x Vestas V90 option (thick dashed orange curve with open circles). Excluded data also shown (open red circles).

APPENDIX 10.F: WIND SPEED CALCULATIONS

BACKGROUND

F.1 An important consideration when specifying the sound power outputs of wind turbines is the fact that wind speed varies with height above the ground. This effect is commonly termed 'wind shear'. Therefore, if the wind speed on a site is characterised in terms of, say, the wind speed measured at 10 m above ground level, then some means must be available for converting this 10 m height wind speed to whatever the hub height of the proposed turbine will be. This is important because it is this hub height wind speed (i.e. the wind speed seen by the rotor of the wind turbine) that determines the actual sound power radiated by that turbine.

F.2 The example of a 10 m height wind speed is selected here because this height is frequently adopted as a 'reference'. For example, in ETSU-R-97 [1] the wind speed dependent background noise levels are specified as a function of 10 m height site wind speeds. Likewise, the declared sound power data measured in accordance with the internationally adopted standard for the measurement of wind turbine sound power output, IEC61400-11 [2], is also referenced to a 10 m height wind speed.

F.3 The ground roughness length, z, indicates the degree to which wind is slowed down by friction as it passes close to the ground: the rougher the ground, the more the wind is slowed down and the larger the roughness length.

F.4 Table 11 of ETSU-R-97 gives examples of roughness lengths, as repeated here in Table F1. Figure F1 shows the wind speed profiles corresponding to the four ground roughness lengths given in Table F1.

F.5 However, it has been found from measurements that the influence of the ground may not be the only factor affecting the variation of wind speed as a function of height above the ground. Another key factor can be the amount of turbulence in the atmosphere itself.

F.6 Generally speaking, under a typical daytime meteorological scenario, the atmosphere lying above the ground will exhibit what is termed 'neutral' characteristics. In such cases the atmosphere itself has little effect on the wind speed profile which is then controlled primarily by ground roughness. However, under certain conditions, typically on a summer's evening following a warm day, the radiative effects of the ground can cool the air lying close to the earth at a rate faster than the convective cooling of the air lying above. This can result in a highly stable atmosphere, one of the characteristics of which is a pronounced wind shear effect. This means that the relative difference between the wind speed at 10m height and that at hub height during affected evening / night-time periods may be significantly greater than the difference which typically exists during daytime periods or other 'neutral' conditions.

Type of terrain	Roughness length, z
Water, snow or sand surfaces	0.0001 m
Open, flat land, mown grass, bare soil	0.01 m
Farmland with some vegetation (reference)	0.05 m
Suburbs, towns, forests, many trees and bushes	0.3 m

TABLE F1: Table 11 of ETSU-R-97 showing the typical roughness lengths associated with different terrain types

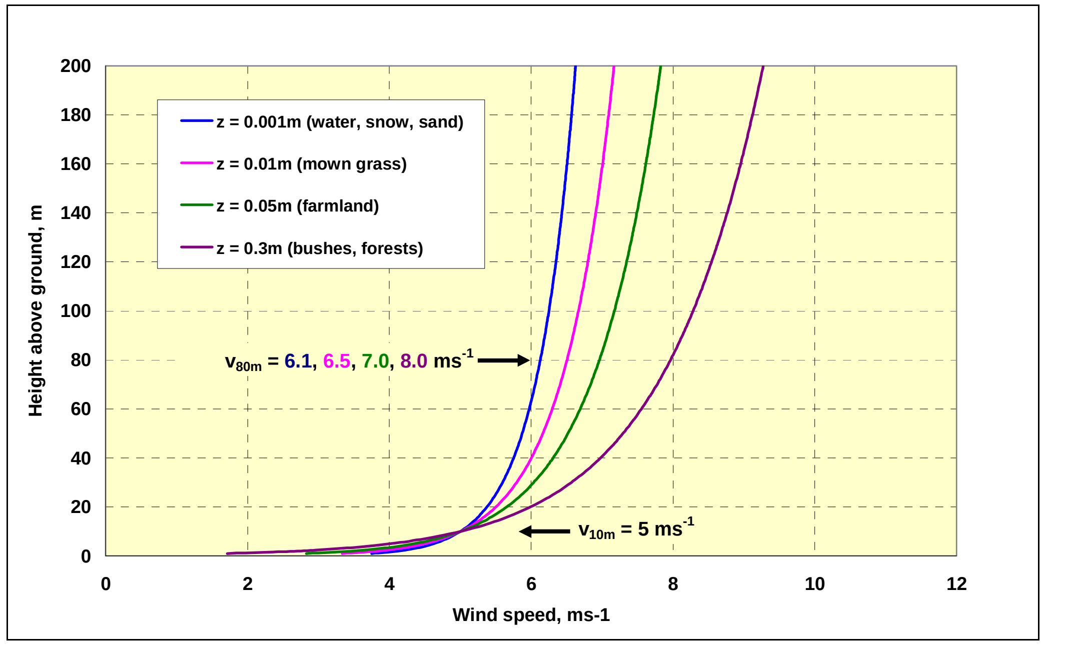


FIGURE F1: Wind speed profiles calculated for the four different ground roughness lengths listed in Table F1. The figure adopts a fixed wind speed at 10m height of v_{10}=5ms^{-1} then presents the calculated wind speeds at other heights as the curved lines. The calculated wind speeds at 80m height corresponding to the assumed U_{10}=5ms^{-1} are also presented as numerical values, ranging from U_{80}=6.1 ms^{-1} for a ground roughness length of z=0.001m to U_{80}=8.0ms^{-1} for ground roughness length of z=0.3m.

F.7 When undertaking noise certification measurements of wind turbine sound power outputs, the relevant procedure applies a standard means of converting between hub height and 10m height wind speeds. This involves using a 'standard' roughness length of 0.05 in Equation F1, regardless of what the actual roughness length seen on the test site may have been. This 'normalisation' procedure is adopted to ensure direct comparability between test results for different turbines. However, when this standardised data is subsequently used to calculate the sound power radiated from an installed turbine on an actual wind farm site, it is important to convert between 10m height wind speeds and hub height wind speeds using the actual wind speed differences experienced on the site itself. These hub height wind speeds may well be different from those calculated by assuming the standard 0.05m ground roughness length.

F.8 The relevance of this conversion between wind speeds at 10 m height and wind speeds at hub height has come under increasing scrutiny recently with the acknowledgement that, on some sites, the wind shear (i.e. the increase in wind speed with increasing height above ground level) can vary significantly between daytime and evening/night time periods. This difference occurs for the reasons discussed above concerning the radiative cooling effects of the earth on the lower levels of air. When this effect occurs, the wind speed seen by the turbine blades at night can be significantly higher than that derived using either a 'standard' assumed roughness length based on the characteristics of the general terrain, or from using on a roughness length or shear factor based on longer term averaged measurements of the difference in wind speeds measured at two different heights. This issue, and the manner in which it has been accounted for in the case of Heckington Fen Wind Park, is discussed in the following section.

APPROACH

F.9 The site of Heckington Fen Wind Park has a temporary 70 m met. mast installed with instrumentation at various heights as follows:-

- 70 m Wind speed
- 60 m Wind speed
- 35 m Wind speed
- 10 m Wind speed
- 70 m Wind direction
- 30 m Wind direction

F.10 Wind speeds are needed at a height of 10 m for correlation with measured noise data as specified in ETSU-R-97. ETSU-R-97 also requires the noise assessment be performed with a wind speed maximum of no more than 12 m/s at 10 m height. Whilst it would be possible to use the direct measurement of wind speeds at a height of 10 m, this approach has been questioned due to a possible difference in the wind shear profile during the evenings and night-times when compared to the day-time. To remove criticism of the analysis process, all 10 m wind speed data is calculated from wind speeds which will be directly experienced by the wind turbines. Wind speeds are therefore related directly to those at hub height and corrected to 10 m height assuming reference conditions. Reference conditions are those used when reporting the measured and/or warranted sound power levels of the wind turbines and assume a ground roughness length of 0.05 m. The process used to calculate the 10 m height wind speeds is therefore described below.

METHODOLOGY

F.11 ETSU-R-97 specifies that where measurements are not made using a 10 m met mast, measurements at other heights may be used to provide 10 m height wind speeds by calculation. Equation F1 is given in ETSU-R-97 for this purpose.

$$U_1 = U_2 \cdot \frac{\ln\left(H_1/z\right)}{\ln\left(H_2/z\right)} \qquad [F1]$$

F.12 Where:

H_1 The height of the wind speed to be calculated (10 m)

H_2 The height of the measured wind speed

U_1 The wind speed to be calculated

U_2 The measured wind speed

z The roughness length (0.05 m in the case of reference conditions)

F.13 Equation F1 is of the same form as that given in BS EN 61400-11:2003 [2] for calculating 10 m wind speeds related to hub height wind speeds when providing source noise emission data for wind turbines. ETSU-R-97 suggests that the roughness length may be calculated from wind speed measurements at two heights, by inverting equation F1.

F.14 Alternatively, wind shear can be described by the wind shear exponent according to equation F2 as follows:

$$U = U_{ref} \cdot \left[\frac{H}{H_{ref}}\right]^m \qquad [F2]$$

F.15 Where:

U calculated wind speed.

U_{ref} measured wind speed

H height at which the wind speed will be calculated

H_{ref} height at which the wind speed is measured

M shear exponent

F.16 Again, the wind shear exponent may be calculated from wind speed measurements at two heights, by inverting equation F2.

F.17 Data from the met. mast were available for the duration of the survey. These data were used to perform a calculation of the shear exponent found between the highest two wind speed measurements of 70 m and 60 m for every ten minute period.

F.18 Where wind speeds were the same at both heights or lower at greater height, the shear exponent was assumed to be zero. The shear exponents so calculated for every ten minute period were then used to calculate the hub height wind speed from that measured at 70 m using equation F2.

F.19 Equation F1 was then used to calculate a 10 m height wind speed from the hub height wind speed every ten minutes assuming the reference roughness length of 0.05 m.

CONCLUSIONS

F.20 By using this method, measured background noise levels were correlated to 10 m 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 10 m wind speed data.

F.21 The method used to calculate 10 m 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.

F.22 This method is consistent with recent guidance published in an Institute of Acoustic Bulletin article [3].

REFERENCES FOR OPERATIONAL CALCULATION OF WIND SPEEDS

[1] DTI Noise Working Group. (1996). The Working Group on Noise from Wind Turbines: ‘The Assessment and rating of Noise from Wind farms’, ETSU Report ETSU-R-97.

[2] IEC61400-11:2003 Wind turbine generator systems - Part 11: Acoustic noise measurement techniques.

[3] Prediction and assessment of wind turbine noise – agreement about relevant factors for noise assessment from wind energy projects. D Bowdler, AJ Bullmore, RA Davis, MD Hayes, M Jiggins, G Leventhall, AR McKenzie. Institute of Acoustics, Acoustics Bulletin, Vol 34, No 2 March/April 2009.