Town and Country Planning Act 1990

Appeal by Broadview Energy Developments Limited
Site at Spring Farm Ridge between Greatworth and Helmdon

Planning Inspectorate Reference: APP/Z2830/A/11/2165035

South Northamptonshire Council Ref: S/2010/1437/MAF

FIGURES and APPENDICES
to

PROOF OF EVIDENCE
of

Robert A Davis BSc(Eng) MIOA

on

Noise Issues

On behalf of the Helmdon, Stuchbury and Greatworth Windfarm Action Group (HSGWAG)

August 2013

Robert Davis Associates
consultants in acoustics and noise control

The Holt Upper Timsbury Romsey Hants SO51 0NU
Tel 01794 367637 email rd@rd-associates.co.uk

Figures 1 and 2

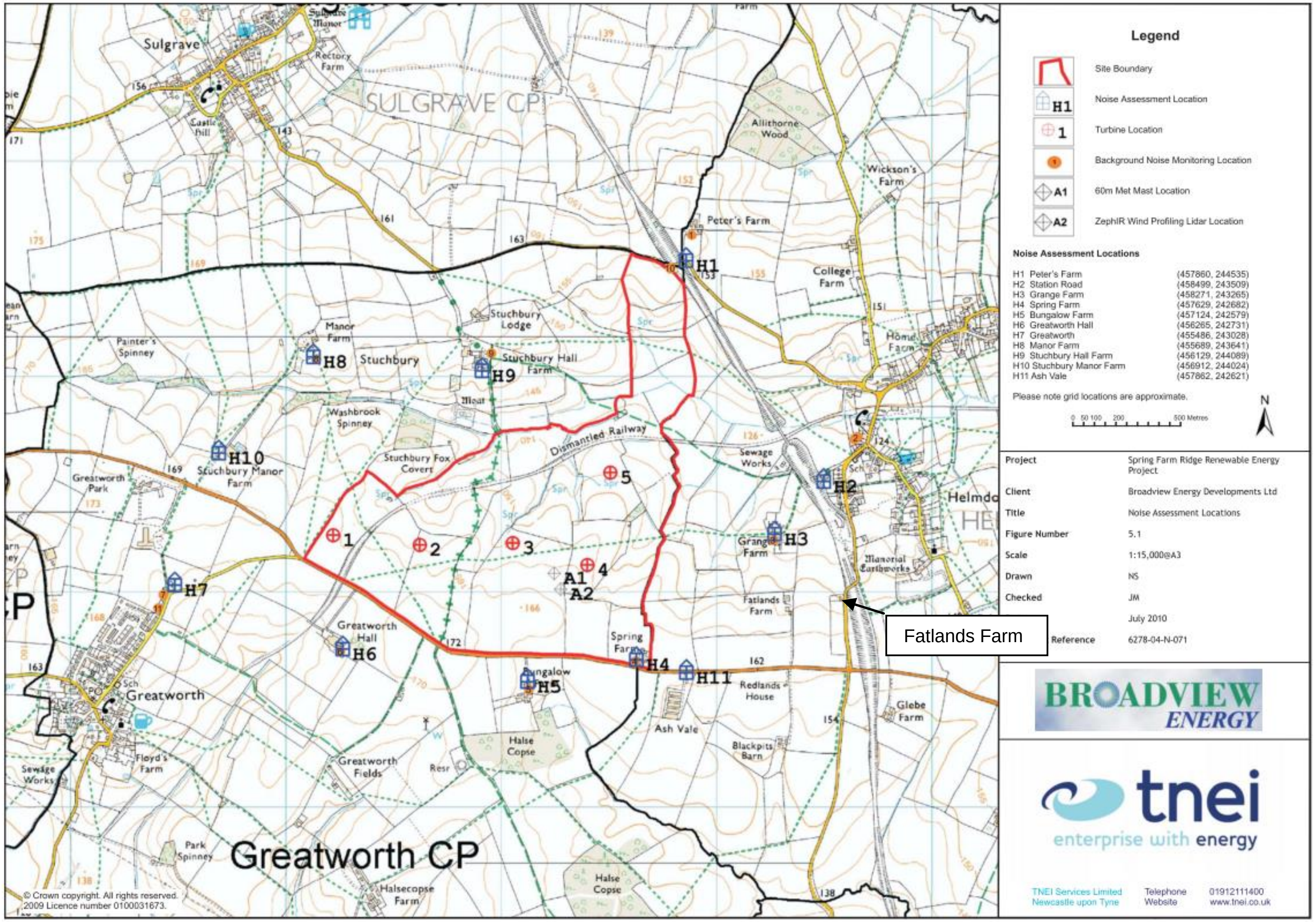


Figure 1 - Site Layout showing identified dwellings H1 – H9 *(Note: Turbine locations 1,2,3 and 5 slightly revised as FEI Table 5.1)*

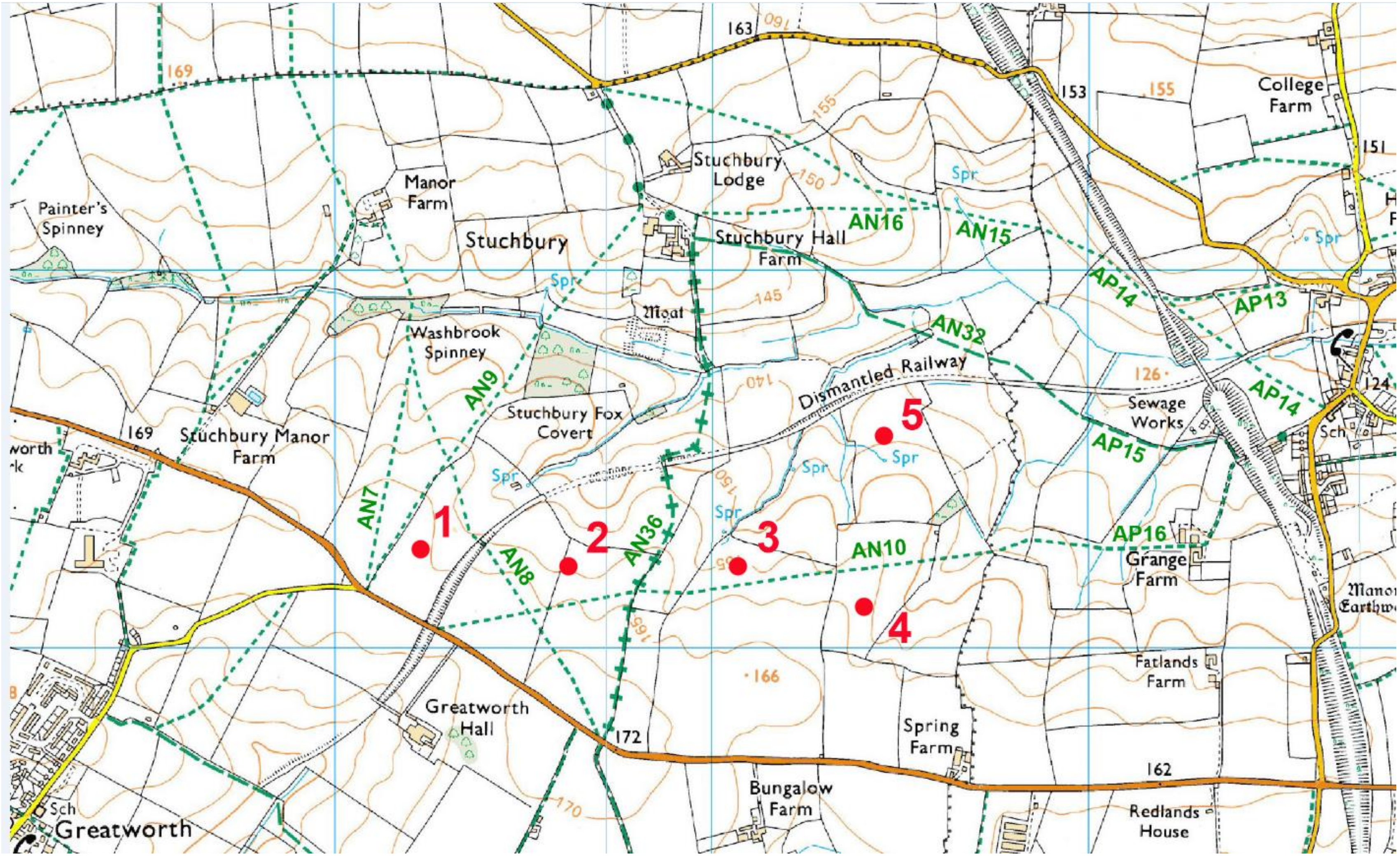


Figure 2 - Identification of Public Rights of Way

Appendix 1 – Acoustic Terminology

(2 pages)

Explanation of Terminology

Description and measurement of noise

Noise (or sound) as perceived by a listener has three principal characteristics:

Level or intensity – measured in decibels (dB). The decibel scale is logarithmic, each 10dB increase in level representing a ten-fold increase in sound intensity. The response of the human ear is not linear, so a 10dB change in noise level is often quoted as representing a halving or doubling of perceived noise level, not a ten-fold change. A change in noise level of 1dB is barely detectable. A change of 3dB is generally taken to be the smallest change that can be reliably detected.

Frequency or pitch – measured in Hertz (Hz) or cycles per second. The healthy (and young) human ear can detect sounds in the range between about 20 and 20,000 Hz, although it is most sensitive in the frequencies between about 500Hz and 10,000 Hz, the frequencies carrying most information in speech. Most environmental noise includes sounds over a wide range of frequencies. The 'mix' of frequencies making up a particular sound is one factor in determining the perceived 'character' of the sound.

Temporal variation – regular or irregular variation in level (or frequency) with time. The way in which noise varies with time (either randomly or regularly) is another factor which determines the characteristics of a sound and enables it to be identified or distinguished from other sounds.

In my proof I refer to noise levels measured in A-weighted decibels or dB(A). A-weighted sound (or noise) levels are measured using an instrument which incorporates an electronic filter which represents the response of the human ear to sound at different frequencies. The dB(A) level of a sound is therefore a measure of the perceived loudness of a sound. Most standards and guidelines concerning community response to noise refer to noise levels in dB(A). Most 'everyday' sounds are in the range between 20 and 70 dB(A).

Sound Power Level

Sound Power Level (L_w or PWL) is a measure of the overall sound energy radiated by a machine. The units are dB re 10 picowatts W (or 10^{-12}W). In this report I express sound power levels in the form PWL in dB(A). For a wind turbine, the Sound Power Level varies with wind speed. It is measured using a standard test procedure (IEC 61400-11) which determines the Sound Power Level in different frequency bands. These values, with corrections for measurement uncertainty, are used as inputs to calculation procedures to predict the dB(A) noise levels at receptor locations around a proposed wind farm.

Sound Pressure Level (Noise Level)

The sound pressure level or noise level is a measure of the intensity of sound at a specific position. Because environmental noise is rarely steady and continuous, its level usually cannot be defined by a single numerical value. In this proof I refer to the following quantities:

$L_{eq,T}$ – the equivalent-continuous noise level over a time period T. It is a measure of the average level of a noise which varies with time, defined as that steady level which would contain the same amount of sound energy over the period in question as the actual time-varying sound being measured.

$L_{90,T}$ – the sound level exceeded for 90% of a given time period T. It is effectively the level which is perceived during the quiet periods between transient noise events. The L_{90} level of the ambient noise (in the absence of specific sounds such as (in this case) a wind farm is generally termed the *background noise level*.

For the purposes of predicting noise impact, and for setting noise limits in planning conditions (and measuring noise levels to monitor compliance with such Conditions) it is standard practice to state wind farm noise levels as L_{90} levels.

The current convention in noise measurement standards and other documents is to express noise levels in the following forms:

The A-weighted time-averaged (L_{eq}) noise level over a period of time T is written '*xx dB* $L_{Aeq,T}$'. For example, a noise level stated as '*60dB* $L_{Aeq,12h}$' means an A-weighted time-average noise level of 60dB over a 12 hour period. Similarly, a noise level stated a '*40 dB* $L_{A90,10m}$' means an A-weighted L_{90} level of 40 dB measured over 10 minutes. The time indicator 'T' is sometimes omitted.

Some documents may express noise levels in different forms. For example:
40 dB(A) L_{90} 10 minutes) has the same meaning as 40 dB $L_{A90,10m}$.

Amplitude Modulation ('AM')

In this context, amplitude modulation means the regular variation in level of the noise from a wind turbine or wind farm. All wind turbines exhibit AM to some extent, usually most noticeable close to the turbine where the noise has an audible 'swish' characteristic, with the noise rising and falling regularly as each blade passes an imaginary fixed point (the 'blade-passing frequency' – this would be once every half second (0.5 Hz) for a 3-bladed rotor spinning at 10 revolutions per minute, for example).

In a few instances, 'enhanced' amplitude modulation has been observed, where turbine noise exhibits a distinctive 'swish, 'whoosh' or 'thump' character at distances of 500 metres or more. Noise with this 'rhythmic' character can be more annoying than steady noise of the same measured L_{90} noise level.

The causes of enhanced amplitude modulation are not fully understood. Research is in progress.

Appendix 2 – Letter to Mr K Jones (HSGWAG) dated 5 December 2010

(5 pages)

ROBERT DAVIS ASSOCIATES
consultants in acoustics and noise control

The Holt Upper Timsbury Romsey Hampshire SO51 0NU
tel /fax 01794 367637 email noise@rd-associates.co.uk

Mr Keith Jones
Stone Gables
17, Station Road
Helmdon
Brackley
Northamptonshire
NN13 5QT

5 December 2010

Dear Mr Jones

Proposed Spring Farm Ridge Wind Farm – Noise Issues

You have asked (via Fiona Davies) for my preliminary comments on the noise assessment submitted by Broadview Energy to support their planning application. These are as follows:

Overall, the noise assessment (by TNEI) appears to be thorough and competent, and the supporting measurements and calculations appear to have been carried out in accordance with the methodologies the consultants have adopted. Baseline noise surveys were carried out in March-May 2010 at 11 locations, which appear to be representative of properties surrounding the site. Most wind farm noise assessments rely on many fewer baseline survey locations: 11 must be considered to be more-than-adequate. The results indicate that wind farm noise can be restricted to levels that would be judged ‘acceptable’, in that they are within the limits set out in ETSU-R-97. The use of ETSU-R-97 for the rating and assessment of noise from wind farms is endorsed in government planning guidance (PPS22).

However, I have some qualifications and concerns:

1 Compliance with ETSU-R-7 noise limits

1.1 Compliance with the ETSU-R-97 noise limits does not imply that there will be no adverse noise impact, merely that noise would be restricted to levels that the UK government consider are ‘acceptable’ in terms of achieving a balance between residential amenity and the requirement for alternative sources of energy. Therefore the effect of noise on residential amenity should not be discounted: I would expect wind farm noise to be audible at a number of dwellings, including the village of Helmdon, in some wind conditions. In some cases, wind farm noise would exceed existing background noise levels by up to 10 dB(A), the greatest exceedance occurring at Bungalow Farm (which I believe ids the closest property where the occupant has no financial involvement on the project).

1.2 The view that noise can significantly affect residential amenity even where the ETSU-R-97 limits can be complied with has been accepted by Inspectors at a number of recent planning appeals, including the appeal at Gorsedd Bran (APP/R6830/A/08/2074921). The Inspector’s decision to dismiss the Appeal in that case was challenged successfully by the Appellant, but this judgement was then subject to further appeal. The Court of Appeal found that:

"……whilst the ETSU-R-97 limits were a matter to which the Inspector was required to have regard, he was not bound by them. In particular, the ETSU-R-97 limits represented only one view as to the appropriate balance to be struck between the adverse effects of noise disturbance and the wider beneficial effects of windfarms, and it was for the Inspector to form his own planning judgment as to whether the noise generated by a particular proposal would be unacceptable, taking into account the evidence of local residents and his own experiences on site visits."

2 Lower 'fixed' daytime noise limits

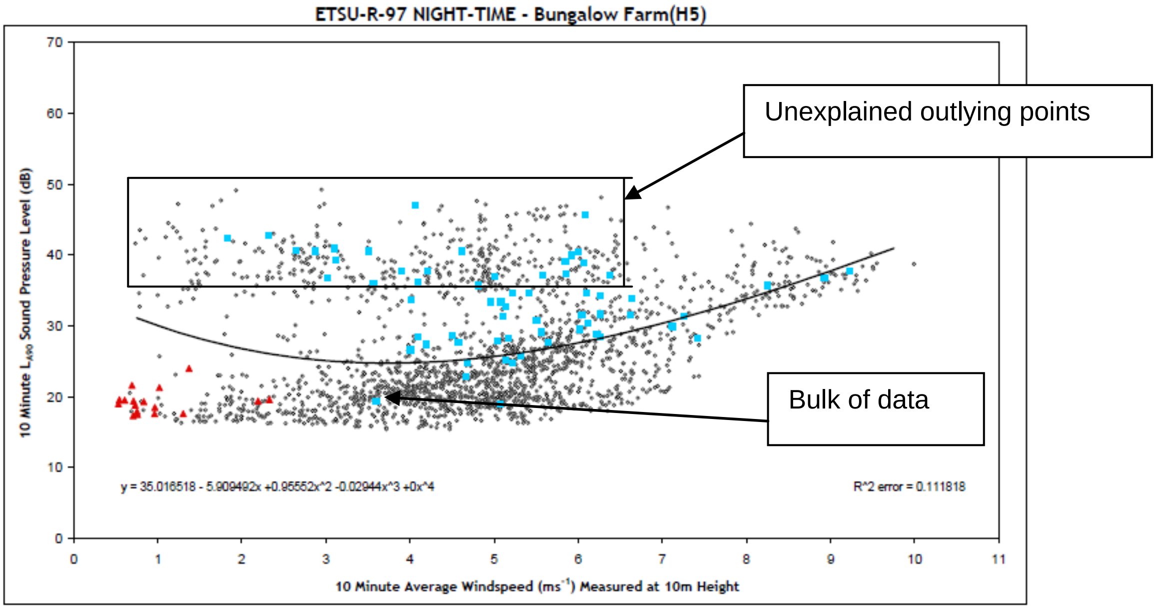
The ETSU noise limits are set at a level 5dB above the existing mean background noise levels (which vary with wind speed), subject to a fixed lower limit of 35-40 dB during the day and 43 dB at night. The value assigned to the daytime lower limit is dependent (according to ETSU-R-97) on three factors: the number of properties affected by noise, the duration and level of noise exposure, and the effect of the noise limits on the power generated by the wind farm. In this case a lower limit of 40 dB (the highest permissible) has been adopted without clear justification. From the data presented, this would not appear to be a critical factor in this case: Table 6.4 in the ES shows that the predicted noise levels would comply with the ETSU daytime limits even if the lower fixed limit were set at 35dB. However, this outcome relies on the background noise levels being representative, since the ETSU limits are based on them. I make further comments on the background noise data below in (4).

3 Margin below limits

The daytime levels at H4, H5 and H6 (Spring Farm, Bungalow Farm and Greatworth Hall) are fairly close to the limits (1-2dB) and could therefore be considered marginal in the light of the prediction uncertainty. I understand that Spring Farm and Greatworth Hall are 'financially involved' properties: if this is the case then less-restrictive noise limits (a fixed lower noise limits 45 dB for day and night) would be applied and the levels at these properties would no longer be considered 'marginal', leaving Bungalow Farm as the property most-affected. It could be argued that these houses are only 'at risk' in northerly winds, and only in a narrow range of wind speeds, but these conditions will occur from time to time.

4 Reliability of Background noise levels (and noise limits)

4.1 For these 'marginal' houses the reliability of the background noise data becomes important – if the background noise levels are set too high, so will be the ETSU noise limits. Looking at the **night-time** noise data for H5 (The Bungalow – Figure 5.11 – copy below) it is seen that the noise levels fall into two groups at low wind speeds – between 20-25 dB and 35–45 dB, with few intermediate data points. This is an unusual distribution of noise levels and the reason should be investigated.



4.2 It is clear that the 'best fit' line, representing the mean background noise level at each wind speed, is strongly influenced by the higher outlying points at wind speeds up to about 6m/s. If these outlying points are non-typical, the noise limits (derived from the background noise levels) are likely to be over-stated and therefore the noise impact under-stated.

The most likely explanations are:

- The higher levels are the result of the dawn chorus: noise levels are often significantly raised by birdsong during the period 0300 – 0500, which 'artificially' raises the average (2300 – 0700) night time noise level. I6t is obvious from the above figure that discounting the 'outlying' data points would significantly change the shape and level of the 'best fit' curve which represents the mean level. Since dawn chorus noise is generally seasonal it is usual practice to exclude data which is obviously influenced by birdsong.

- The background noise levels are dependent on wind direction. Although this may not be immediately apparent, I think it is likely that noise from the M40 (and possibly the A43) is contributing to the background levels when the wind is generally from the west or the south. This distant traffic noise is likely to have most effect at night, when noise from other local sources is likely to be greatly reduced compared with the daytime levels.

4.3 The wind direction effect can be important: for example, the wind farm noise levels would be highest at Bungalow Farm (H5) when the winds are northerly, whereas noise from the M40 and A43 will be reduced. In such cases it is common practice to 'filter' the background noise data on wind direction, so that the noise limits for a particular property are defined for the situation when the wind farm noise would be highest (the 'downwind' situation). Then the comparisons between wind farm noise and background noise are made on a 'like for like' basis. In this case it is clear that even if the night time background noise levels at Bungalow Farm were reduced at low wind speeds this would not change the noise assessment (in terms of wind farm noise meeting the ETSU limits), since the 43 dB lower limit would apply in either case.

However, if the ‘quiet daytime’ background noise levels are shown to be lower in northerly winds this could make the daytime noise assessment even more marginal at Bungalow Farm.

4.4 It might therefore be useful to analyse the raw data in more detail to see if wind direction or ‘dawn chorus’ noise are factors.

5 Exclusion of rain-affected data

Another point I notice is that TNEI did not use a rain gauge to detect rainfall on site. ETSU-R-97 requires that rain-affected noise data is excluded. It is standard practice to install a recording rain gauge on the site, or at one or more of the monitoring locations. TNEI appear to rely on Met. Office data, although the measurement location is not stated. There is no certainty that the Met. Office data accurately represents the rainfall in the vicinity of the site itself. This is perhaps a minor point, in that for most surveys the overall results are little-changed whether rain-affected data is included or excluded, but it doers introduce some uncertainty into the analysis, which can be critical in marginal cases.

6 Possibility of enhanced amplitude modulation

6.1 There is a possibility that noise from the wind farm would exhibit enhanced amplitude modulation or ‘AM’ (audible blade ‘swish’ or ‘thump’. If this occurs – it has caused complaints at a small number of UK wind farms – noise would be more intrusive than if the noise is steady and continuous. TNEI suggest that the possibility of AM occurring can be neglected because:

- Government advice, following the Salford University Report of 2007, is that the occurrence of AM is so infrequent that it can be ignored (ES para. 3.3)
- Although the causes of AM are not understood, a number of contributory factors have been identified (ES para.3.4). TNEI suggest that none of the five factors listed are present at Spring Ridge.

6.2 The current position is that the causes of AM are not understood, and there is no up-to-date evidence on how prevalent the problem may be, given that turbine design is evolving and turbines are becoming larger. Therefore there is no certainty that enhanced AM will not occur at Spring Ridge. RenewableUK (previously the British Wind Energy Association) have recently awarded a research contract to study the causes of AM and to devise a method of objective measurement, to enable a planning condition to be developed to address AM should it occur (there is currently no robust technical basis on which to found such a condition). This initiative, taken by the organisation representing wind farm developers and operators, confirms that AM is a ‘live issue' and remains a matter of concern.

7 Reliability of noise predictions

7.1 I also draw attention to the limitations of the noise propagation ‘model’ used to predict wind farm noise. The model used in ISO 9613-2, which has been shown to generally provide a realistic estimate of wind farm noise levels at local receptors. However, the predictions depend on the model inputs: in this case the inputs include an assumption about ground conditions (Section 4 in the ES) which could result in noise levels being under-predicted by about 2 dB in situations where the surroundings of a receptor location (perhaps a patio or courtyard) are predominantly hard-surfaced.

7.2 The propagation model assumes that the ground is substantially flat, and therefore does not take account of enhanced propagation effects that can occur in some terrain in some weather conditions. In this case, it appears that the village of Helmdon is in a ‘bowl’ to the ENE of the wind farm site, which is elevated. I understand that in some weather conditions residents report unusual sound propagation effects. These effects, if they occurred when the wind turbines were operating, could increase the level of noise perceived in Helmdon, although it is very unlikely that the ETSU noise limits would be breached, given the distances involved. However, it is a factor worthy of consideration, given the number of dwellings in Helmdon, where background noise levels (particularly at night) are generally conspicuously low, as can be seen from Figure 5.5 in the ES (if the unexplained ‘outlying’ data points are discarded).

8 Concluding Comments

8.1 Overall, the noise assessment presented in the ES appears to be thorough and competent. As it stands, it demonstrates that the wind farm can be operated within limits derived using the ETSU-R-97 procedure (and if planning permission is given, a condition could be applied which would constrain noise levels to appropriate limits).

8.2 However noise is still, in my view, a factor to be taken into account for the following reasons:

- Compliance with the ETSU limits does not infer that there would be no effect of residential amenity by reason of noise.

- There are unexplained anomalies in the baseline noise data, which should be investigated, since the noise limits are founded on this baseline data.

- Wind turbine noise will be audible in Helmdon for a significant percentage of the time. Noise propagation towards Helmdon may be enhanced by the local topography. The prediction methodology used takes no account of topographical factors. Neither does it incorporate a ‘safety margin’ to take account of extensive sound-reflective surfaces at receptor locations.

- There is a possibility that wind turbine noise would exhibit enhanced amplitude modulation (‘swish’ or ‘thump’) which would make the noise more intrusive. The likelihood of AM occurring cannot be predicted and it is not possible to devise an effective condition to address AM should it occur.

I hope that these comments are helpful and constructive. Please let me know if I can advise you further or if you have any queries.

Yours sincerely

R A Davis

Appendix 3 – Extracts from Proof of S Arnott to the previous inquiry

(3 pages)

BED/SA/2: Proof of evidence

PINS Ref: APP/Z2830/A/11/2165035

TOWN AND COUNTRY PLANNING ACT 1990

An appeal by Broadview Energy Developments Limited concerning Land at Spring Farm Ridge Lane to the North of Welsh Lane, between Greatworth and Helmdon

PROOF OF STEPHEN ARNOTT BSc(Hons) MSc MIOA
on behalf of Broadview Energy Developments Limited

5.6 At para 8.46 the EPO discusses the change in World Health Organisation (WHO) limits and suggests therefore that ETSU-R-97 severely underestimates the night time noise impact. This aspect has been considered at inquiry, e.g. at Goveton (APP/K1128/A/08/2072150) [CD 6.34 para 43] where Inspector Woolcock observed that very low background levels had been considered by the authors of ETSU-R-97, and that lower fixed limits were not considered necessary to provide a reasonable degree of protection of amenity. Irrespective of changes to WHO guidance, Government evidently continue to support the original standard. In my experience, this locality is not an especially quiet rural setting, as noted in para. 3.2. The concept of 'Quiet areas in open country' is defined in the Environmental Noise Directive[10] as an area undisturbed by noise from traffic, industry or recreational activities and this is clearly not such an area.

5.7 At para 8.48 the EPO confirmed the TNEI assessment had been undertaken in accordance with ETSU-R-97, but then raised three areas of concern which I will address in turn.

5.8 **Some data plots exhibit a scatter of data that appears to split and this was not explained.** A time series analysis suggests the split is due to the dawn chorus, which is often a very striking feature with significant increases of around 20 dBA observed. This phenomenon occurs from perhaps an hour before sunrise and progresses throughout the night, until the affect is overridden by the progressive increase in noise that is often seen towards morning. The recent report for DECC[11] by Hayes McKenzie discussed the topic of data exclusions and noted that ETSU-R-97 [CD 9.1 page 86] treats animal activity during the night as part of the background noise, but that it is sometimes excluded. It can be argued that this is seasonal and therefore misrepresents the background noise levels in the locality. Although it is possible to manually exclude such data every day, the resulting shift will produce a background noise curve that is not representative of any period, or season. This topic has been considered at inquiry[12] (para 11.55 p 94), where Inspector Baird felt that any distortions due to birdsong were not significant, particularly in view of the fixed minimum limits and I consider that the same situation is applicable here.

5.9 **The higher 40dB day time limit has been adopted without explanation.** This is simply untrue and potentially misleading to members of the Development Control Committee, as reference to the TNEI assessment [Table 6.4 page 34] clearly shows. The 35dB limit was used and in fact this was only relevant at Peters Farm at one wind speed of 3ms^{-1}, as all other wind speed and locations relied upon background + 5dB. The EPO then suggests that noise data gathered 16 years ago, at unspecified locations and with no relationship to wind speed, warrants a lower noise limit being adopted. In my opinion the background noise survey was comprehensive and robust and provides a fair reflection of the noise climate at the nearest sensitive receptors.

5.10 **The TNEI reports notes an uncertainty of +/- 3dB in modelling and good practice suggests a correction should be applied** i.e. adding another 3dB.

---

[10] DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 relating to the assessment and management of environmental noise, Article 3

[11] Report HM:2293/R1, 'How noise impacts are considered" Hayes McKenzie Partnership Ltd, 6/4/11

[12] APP/H0928/A/09/2093576 , Grise Wind Farm, Calthwaite, Penrith, Secretary of State for Communities and Local Government, February 2010.

5.13 At para 8.49 1) the EPO returns again to the WHO limits and suggests an alternative assessment, although I consider that his assessment is based on some misconception of the changes that actually took place in WHO guidance. At night, consideration of amenity impacts is not aimed at

[13] Bass, J.H, Bullmore, A.J, Sloth,E ,Development of a windfarm noise propagation prediction model, May 1998, Contract JOR3-CT95-0051, European Commission , Brussels
[14] Bullmore et al, Wind farm Noise Prediction and comparison with Maeasurements, Proc 3rd International meeting on Wind Turbine Noise, 17-19 June 2009, Aalborg, Denmark
[15] Cooper, J, Evans, T. Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms, Proc Acoustics 2011, 2-4 November, Gold Coast, Australia

someone enjoying their garden, but focussed instead upon potential sleep disturbance. There has been much discussion and confusion at inquires about the relevant changes in guidance since ETSU-R-97 was introduced. I have detailed the changes in Appendix 2. In the context of the ETSU-R-97, adopting the current assumption of 21dB typical façade attenuation, together with the existing external limit of L_{90}, 10min 43 dB(A) would equate to an L_{eq} 24dB(A) in the bedroom. Under those circumstances the incidence of sleep disturbance should be minimal and adoption of the ETSU-R-97 guidance should not result in a loss of amenity at night.

Appendix 4 - Extract from 1999 WHO Document (Reference 5)

(4 pages)

GUIDELINES FOR COMMUNITY NOISE

Edited by

Birgitta Berglund
Thomas Lindvall
Dietrich H Schwela

This WHO document on the *Guidelines for Community Noise* is the outcome of the WHO-expert task force meeting held in London, United Kingdom, in April 1999. It bases on the document entitled "Community Noise" that was prepared for the World Health Organization and published in 1995 by the Stockholm University and Karolinska Institute.

World Health Organization, Geneva
Cluster of Sustainable Development and Healthy Environment (SDE)
Department for Protection of the Human Environment (PHE)
Occupational and Environmental Health (OEH)

d. The risk for noise-induced hearing impairment increases when noise exposure is combined with vibrations, ototoxic drugs or chemicals (Fechter 1999). In these circumstances, long-term exposure to LAeq,24h of 70 dB may induce small hearing impairments.

e. It is uncertain whether the relationships in ISO Standard 1999 (ISO 1990) are applicable to environmental sounds having a short rise time. For example, in the case of military low-altitude flying areas (75–300 m above ground) LAmax values of 110–130 dB occur within seconds after onset of the sound.

In conclusion, dose-response data are lacking for the general population. However, judging from the limited data for study groups (teenagers, young adults and women), and on the assumption that time of exposure can be equated with sound energy, the risk for hearing impairment would be negligible for LAeq,24h values of 70 dB over a lifetime. To avoid hearing impairment, impulse noise exposures should never exceed a peak sound pressure of 140 dB peak in adults, and 120 dB in children.

4.2.3. Sleep disturbance effects

Electrophysiological and behavioral methods have demonstrated that both continuous and intermittent noise indoors lead to sleep disturbance. The more intense the background noise, the more disturbing is its effect on sleep. Measurable effects on sleep start at background noise levels of about 30 dB LAeq. Physiological effects include changes in the pattern of sleep stages, especially a reduction in the proportion of REM sleep. Subjective effects have also been identified, such as difficulty in falling asleep, perceived sleep quality, and adverse after-effects such as headache and tiredness. Sensitive groups mainly include elderly persons, shift workers and persons with physical or mental disorders.
Where noise is continuous, the equivalent sound pressure level should not exceed 30 dBA indoors, if negative effects on sleep are to be avoided. When the noise is composed of a large proportion of low-frequency sounds a still lower guideline value is recommended, because low-frequency noise (e.g. from ventilation systems) can disturb rest and sleep even at low sound pressure levels. It should be noted that the adverse effect of noise partly depends on the nature of the source. A special situation is for newborns in incubators, for which the noise can cause sleep disturbance and other health effects.

If the noise is not continuous, LAmax or SEL are used to indicate the probability of noise-induced awakenings. Effects have been observed at individual LAmax exposures of 45 dB or less. Consequently, it is important to limit the number of noise events with a LAmax exceeding 45 dB. Therefore, the guidelines should be based on a combination of values of 30 dB LAeq,8h and 45 dB LAmax. To protect sensitive persons, a still lower guideline value would be preferred when the background level is low. Sleep disturbance from intermittent noise events increases with the maximum noise level. Even if the total equivalent noise level is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep.

Therefore, to avoid sleep disturbance, guidelines for community noise should be expressed in terms of equivalent sound pressure levels, as well as LAmax/SEL and the number of noise events. Measures reducing disturbance during the first part of the night are believed to be the most effective for reducing problems in falling asleep.

4.2.4. *Cardiovascular and psychophysiological effects*

Epidemiologial studies show that cardiovascular effects occur after long-term exposure to noise (aircraft and road traffic) with LAeq,24h values of 65–70 dB. However, the associations are weak. The association is somewhat stronger for ischaemic heart disease than for hypertension. Such small risks are important, however, because a large number of persons are currently exposed to these noise levels, or are likely to be exposed in the future. Other possible effects, such as changes in stress hormone levels and blood magnesium levels, and changes in the immune system and gastro-intestinal tract, are too inconsistent to draw conclusions. Thus, more research is required to estimate the long-term cardiovascular and psychophysiological risks due to noise. In view of the equivocal findings, no guideline values can be given.

4.2.5. *Mental health effects*

Studies that have examined the effects of noise on mental health are inconclusive and no guideline values can be given. However, in noisy areas, it has been observed that there is an increased use of prescription drugs such as tranquilizers and sleeping pills, and an increased frequency of psychiatric symptoms and mental hospital admissions. This strongly suggests that adverse mental health effects are associated with community noise.

4.2.6. *Effects on performance*

The effects of noise on task performance have mainly been studied in the laboratory and to some extent in work situations. But there have been few, if any, detailed studies on the effects of noise on human productivity in community situations. It is evident that when a task involves auditory signals of any kind, noise at an intensity sufficient to mask or interfere with the perception of these signals will also interfere with the performance of the task. A novel event, such as the start of an unfamiliar noise, will also cause distraction and interfere with many kinds of tasks. For example, impulsive noises such as sonic booms can produce disruptive effects as the result of startle responses; and these types of responses are more resistant to habituation.

Mental activities involving high load in working memory, such as sustained attention to multiple cues or complex analysis, are all directly sensitive to noise and performance suffers as a result. Some accidents may also be indicators of noise-related effects on performance. In addition to the direct effects on performance, noise also has consistent after-effects on cognitive performance with tasks such as proof-reading, and on persistence with challenging puzzles. In contrast, the performance of tasks involving either motor or monotonous activities is not always degraded by noise.

Table 4.1: Guideline values for community noise in specific environments.

Specific environment	Critical health effect(s)	LAeq [dB]	Time base [hours]	LAmax fast [dB]
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	- -
Dwelling, indoors Inside bedrooms	Speech intelligibility and moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30	16 8	 45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	during class	-
Pre-school bedrooms, indoors	Sleep disturbance	30	sleeping -time	45
School, playground outdoor	Annoyance (external source)	55	during play	-
Hospital, ward rooms, indoors	Sleep disturbance, night-time Sleep disturbance, daytime and evenings	30 30	8 16	40 -
Hospitals, treatment rooms, indoors	Interference with rest and recovery	#1		
Industrial, commercial shopping and traffic areas, indoors and outdoors	Hearing impairment	70	24	110
Ceremonies, festivals and entertainment events	Hearing impairment (patrons:<5 times/year)	100	4	110
Public addresses, indoors and outdoors	Hearing impairment	85	1	110
Music through headphones/ earphones	Hearing impairment (free-field value)	85 #4	1	110
Impulse sounds from toys, fireworks and firearms	Hearing impairment (adults) Hearing impairment (children)	- -	- -	140 #2 120 #2
Outdoors in parkland and conservation areas	Disruption of tranquillity	#3		

#1: as low as possible;
#2: peak sound pressure (not LAmax, fast), measured 100 mm from the ear;
#3: existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low;
#4: under headphones, adapted to free-field values

47

Appendix 5 - Extract from Reference BS8233:1999 (Reference 7)

(3 pages)

BRITISH STANDARD

BS 8233:1999

Sound insulation and noise reduction for buildings — Code of practice

ICS 91.120.20

7.3 Limits for noise levels

For each design criterion a range of levels exist that are considered to meet it. The designer should use judgement to select a level appropriate for the particular circumstances. In noisy workshops etc., the activity noise will be dominant and so the indoor ambient noise level will not be critical. In most other situations indoor ambient noise will be important.

NOTE Guidance on limits is given in Table 5 for various types of room having different functions.

Limits for good conditions and reasonable conditions are given. Normally, only the upper noise limit will need to be decided (see Table 5). In some cases, such as open-plan offices and restaurants, a moderate noise level is required to ensure adequate privacy while not causing disturbance, so upper and lower limits should be considered (Table 6).

Unless otherwise stated, the noise should be assumed to be steady, such as that due to road traffic, mechanical services, or continuously running plant, and should be the noise level in the space during normal hours of occupation but excluding any noise produced by the occupants and their activities. The time period T should be appropriate for the activity involved (e.g. 23.00–07.00 for bedrooms). As the noise will be fairly steady, a short measuring period will usually be sufficient to establish the typical outdoor level.

7.4 Noise indices

Noise levels which may be due to traffic or ventilation systems are described in Table 5 using dBA. The noise rating (NR) system, a graphical method described in annex B, is also in common use for rating noise from ventilation systems. Although there is no direct relationship between dBA and NR, the following approximate relation applies in the absence of strong low frequency noise:

NR ≈ dBA − 6.

Although the NR system is currently the preferred method for rating noise from mechanical ventilation systems in the UK, other methods are also available which are more sensitive to noise at low frequencies [20]. Low frequency noise can be disturbing or fatiguing to occupants, but may not have much effect on the dBA or NR value.

7.5 Limits for reverberation time

As well as indoor ambient noise level, the reverberation time, T, measured in seconds (s), should also be considered because it affects the noise level in the space, and also affects the clarity of speech and the warmth of music. Even where good speech conditions are not paramount, an excessively long reverberation time will accentuate the background noise and reduce the clarity of public address announcements.

Although the acoustic design of auditoria is a specialized subject and is beyond the scope of this code of practice, general guidance on designing rooms for speech (e.g. meeting rooms) is given in **7.6.7**.

7.6 Guidance for specific types of building

7.6.1 ***Dwellings***

7.6.1.1 *Mandatory requirements*

The sound insulation between adjoining dwellings is controlled by the Building Regulations [2], [3], [4], which require reasonable standards for certain walls, floors, and stairs. As there are differences between the requirements for England and Wales, Scotland, and Northern Ireland, the appropriate national regulations should be consulted. These are supported by the following technical documents:

— England and Wales, Approved Document for Part E [21];

— Scotland, Part H of the Technical Standards [22];

— Northern Ireland, Technical Booklets G and G1 [23].

The appropriate document should be consulted at an early stage of design.

7.6.1.2 *Design criteria and limits for intrusive external noise*

For dwellings, the main criteria are reasonable resting/sleeping conditions in bedrooms and good listening conditions in other rooms. Occupants will usually tolerate higher levels of anonymous noise, such as that from road traffic, than noise from neighbours which may trigger complex emotional reactions that are disproportionate to the noise level. For simplicity, only anonymous noise is considered in Tables 5 and 6.

As well as protection for the building, barriers or bunds should be considered to protect the gardens. In gardens and balconies etc. it is desirable that the steady noise level does not exceed 50 $L_{Aeq,T}$ dB and 55 $L_{Aeq,T}$ dB should be regarded as the upper limit.

7.6.1.3 *Internal planning*

In order to minimize disturbance from internally generated noise the following points should be considered.

— In houses and flats, services should be kept away from bedrooms.

— As footfall noise can be particularly disturbing, care should be taken to avoid locating stairs next to noise sensitive rooms, such as bedrooms, in adjacent dwellings. It should be noted that footfalls on concrete stairs produce less low frequency noise than on timber stairs.

— In flats, avoid locating bedrooms near the lift and circulation areas; less sensitive rooms may be used as buffers. Compatibility between rooms of adjacent dwellings can be ensured by handing and stacking identical dwelling plans.

Table 5 — Indoor ambient noise levels in spaces when they are unoccupied

Criterion	Typical situations	Design range $L_{Aeq,T}$ dB	
		Good	Reasonable
Reasonable industrial working conditions	Heavy engineering	70	80
	Light engineering	65	75
	Garages, warehouses	65	75
Reasonable speech or telephone communications	Department store	50	55
	Cafeteria, canteen, kitchen	50	55
	Wash-room, toilet	45	55
	Corridor	45	55
Reasonable conditions for study and work requiring concentration	Library, cellular office, museum	40	50
	Staff room	35	45
	Meeting room, executive office	35	40
Reasonable listening conditions	Classroom	35	40
	Church, lecture theatre, cinema	30	35
	Concert hall, theatre	25	30
	Recording studio	20	25
Reasonable resting/sleeping conditions	Living rooms	30	40
	Bedrooms[a]	30	35

[a] For a reasonable standard in bedrooms at night, individual noise events (measured with F time-weighting) should not normally exceed 45 dB L_{Amax}.

Table 6 — Indoor ambient noise levels in spaces when they are unoccupied and privacy is also important

Criterion	Typical situations	Design range $L_{Aeq,T}$ dB
Reasonable acoustic privacy in shared spaces	Restaurant	40–55
	Open plan office	45–50
	Night club, public house	40–45
	Ball room, banquet hall	35–40
	Reception room	35–40

7.6.1.4 *Other precautions*

It is recommended that any partition separating a WC from a noise sensitive room should have a weighted standardized level difference ($D_{nT,w}$) of at least 38 dB.

In flats, sound absorbent materials should be applied to the ceiling surfaces of internal corridors and stairwells to reduce propagation of noise through the building.

NOTE Carpets can also provide useful absorption.

Resilient floor coverings, such as carpet with underlay, can be used to minimize noise from footsteps on stair treads, corridors and landings. Noise will be reduced at the same floor level and to rooms below the floor or stair. The quietest types of sanitary, heating and plumbing equipment (e.g. WCs, ball valves, refuse chutes etc.) should be used; however their location is more important than their detailed design.

It is good practice to isolate vibration in the heating pipework from the building structure, at least near the pump. This may be achieved by using resilient fixings on pipe runs. Where pipes penetrate walls and floors, air gaps should be sealed to reduce airborne noise transmission in such a way that structure-borne noise is not transmitted: this may be achieved by packing the gap with mineral wool, and sealing the faces with non-hardening mastic. Building Regulations guidance for fire safety should be taken into account [24], [25], [26]. Ventilation fans and similar equipment should have resilient mountings where structure-borne noise could be a problem.

Care should be taken to position lifts to minimize noise disturbance from the operation of the control gear. Lift doors should operate quietly, and acoustic signals to herald lift arrival should not be audible within dwellings.

NOTE For additional guidance see [10].

Appendix 6 – Extract from *'Burnett-Hall on Environmental Law'*

(3 pages)

Burnett-Hall on Environmental Law

Third Edition

GENERAL EDITORS

Richard Burnett-Hall, M.A. (Cantab.)
Solicitor and Chartered Patent Agent
Consultant, Bristows

Brian Jones, M.A. (Cantab.)
Consultant, Herbert Smith LLP
Honorary Professor, University of Wales (Aberystwyth)

SWEET & MAXWELL

THOMSON REUTERS

achieve similar benefits with a lesser degree of harm.[149]Applications have been rejected in part at least because developers have not demonstrated that effects have been minimised.[150]

7–089 Part of the exercise in assessing the planning balance in any wind farm case is assessing the weight to be given to the benefits arising from the particular development. It is generally accepted that, at the time of the determination of an application, the greater the shortfall against a regional target for the provision of renewable energy generating capacity, the greater the weight which should be attached to the benefits of the scheme then under consideration.[151] This is perhaps why national planning policy in PPS22 previously required developers to "demonstrate" the benefits of their scheme.[152]

7–090 Noise from wind turbines has been a particularly controversial issue. PPS22 provided at para.22 that the document known as ETSU-R-97 "should be used to assess and rate noise from wind energy development". It had been argued that this means that it was not necessary for a planning decision-maker to look beyond compliance with noise limits derived from ETSU-R-97. However, the need to look beyond ETSU compliance and consider the noise effects of wind turbine developments in amenity terms was explained by the Court of Appeal in the case of *Tegni Cymru Cyf v Welsh Ministers*.[153] The Court of Appeal noted that ETSU seeks to strike a balance between interests and was based on compromise, and that ETSU did not mean that people would not be adversely affected by noise levels which fall below the guideline levels.[154] It was held that, when considering the effect of noise levels on residential amenity, compliance with ETSU was not a complete answer. Pitchford L.J. noted that it was decided by the inspector[155] that "ETSU indicative levels in relation to the proposal which he was considering were not the last word on "acceptable" noise levels", and that the Judge at first instance had acknowledged that ETSU "did not represent an absolute standard against which the proposal was to be judged".[156] The Court rejected a submission that a decision-maker was not entitled to look beyond ETSU compliance.[157] As a result of this case it is apparent that compliance with ETSU-derived noise limits is not the only relevant consideration and that it is necessary for decision-makers to consider the acceptability of noise effects more generally.

7–091 A similar approach has been adopted by the High Court in considering ETSU. In *Lee v Secretary of State for Communities and Local Government*,[158] the Court recognised that the critical issue was whether there would be noise disturbance to an unacceptable degree, noted that the inspector in that case had acknowledged that there would be some noise impact even where the ETSU levels were

---

[149] *Lee v Secretary of State for Communities and Local Government* [2011] EWHC 807 (Admin) at [52]–[54].
[150] See, for example, *Enertrag v East Lindsey DC*[2011] PAD 27 and *RWE Npower Renewables v Northumberland CC* [2012] PAD 9.
[151] See, for example, *RWE Npower Renewables v Milton Keynes Council* [2012] PAD 10.
[152] PPS22 para.1(viii).
[153] [2010] EWCA Civ 1635.
[154] At [12]–[13], [34].
[155] The inspector's decision is reported as *Tegni Cymru Cyf v Denbighshire CC* [2010] PAD 9.
[156] At [24].
[157] See [28].
[158] [2011] EWHC 807 (Admin).

achieved and upheld an approach of taking amenity concerns into account.[159] In *Hulme v Secretary of State for Communities and Local Government*,[160] the High Court at first instance upheld an inspector's decision which departed from the ETSU methodology.[161] Discussions about ETSU-R-97 have featured also in a number of planning appeal decisions.[162]

Consideration of actual noise effects, as they would be perceived in the real world, is likely to be a relevant consideration pursuant to s.38(6) of the Planning and Compulsory Purchase Act 2004 and the provisions of the relevant statutory development plan, as most such plans have policies on noise or amenity. If not, it is likely that actual noise levels, and what they mean in terms of the actual effect on the living conditions of nearby occupiers and the amenity of the area, would be relevant considerations in terms of environmental impact assessment and as material planning considerations under s.70(2) of the TCPA. It is also notable that a failure to provide noise-related data has led to the quashing of planning permission.[163] **7–092**

Pollution control

PPS23 (*Planning and Pollution Control*) previously provided guidance on how systems for pollution control and the management of contaminated land should be taken into account when considering proposals for development.[164] The key policy aims of PPS23 were to facilitate planning for good quality, sustainable development that takes appropriate account of pollution control and contamination issues. **7–093**

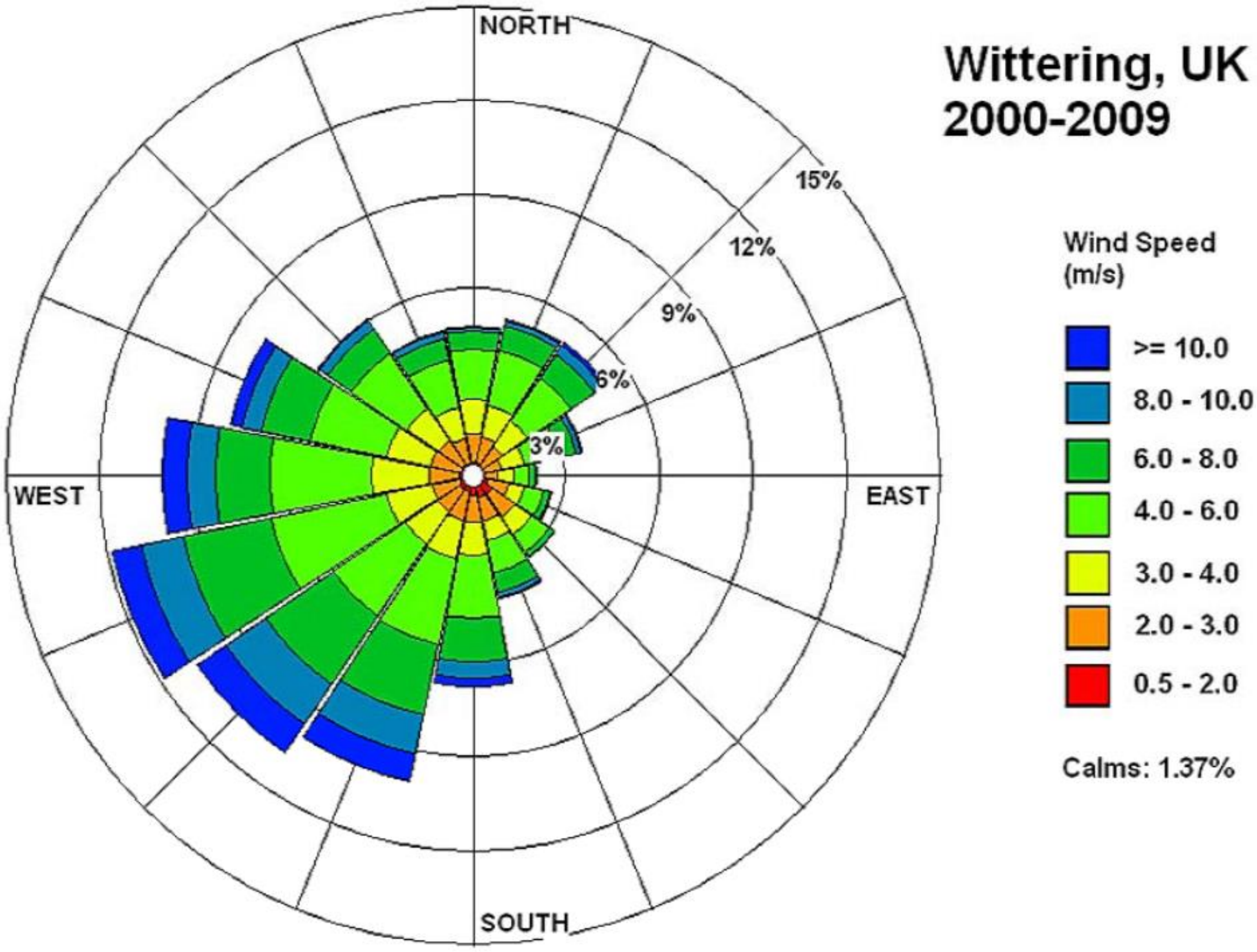
PPS23 advised that: **7–094**

- any consideration of the quality of land, air or water and potential impacts arising from development, possibly leading to impacts on health, was capable of being a material planning consideration, in so far as it arises or may arise from or may affect any land use;
- the planning system plays a key role in determining the location of development which may give rise to pollution, either directly or indirectly, and in ensuring that other uses and developments are not, as far as possible, affected by major existing or potential sources of pollution; and

[159] At [43]-[47].
[160] [2010] EWHC 2386 (Admin).
[161] At [51]–[52]. The inspector's decision is reported as *RES Developments Ltd v West Devon BC* [2010] PAD 14.
[162] See for example: *Pennant Wind Energy v Blaenau Gwent CBC* [2010] PAD 39; *Derbyshire Wind Energy v North East Derbyshire DC & Derbyshire Dales DC* [2010] PAD 32; *Morgan v South Hams DC* [2009] PAD 46; *Ecotricity v Breckland DC* [2009] PAD 39.
[163] See the consent order dated August 4, 2008 agreed in the Court of Appeal in *Hulme v Secretary of State for Communities and Local Government*, C1/2008/0793, following the High Court decision in that case ([2008] EWHC 637 (Admin)).
[164] There was also a letter sent to Chief Planning Officers on May 30, 2008 to circulate a new set of model planning conditions intended for use during the development on land affected by contamination. They replace Appendix 2B of Annex 2 of PPS23 and paras 56–59 of Appendix A of Circular 11/95: *Use of conditions in planning permission*.

Appendix 7 – Wind Rose for RAF Wittering

(1 page)


NORTH
WEST
EAST
SOUTH
3%
6%
9%
12%
15%
Wittering, UK
2000-2009
Wind Speed
(m/s)
>= 10.0
8.0 - 10.0
6.0 - 8.0
4.0 - 6.0
3.0 - 4.0
2.0 - 3.0
0.5 - 2.0
Calms: 1.37%

Appendix 8 – Extract from DTI ‘Low-Frequency Noise Report’ (Reference 9)

(2 pages)

dti

THE MEASUREMENT OF LOW FREQUENCY NOISE AT THREE UK WIND FARMS

CONTRACT NUMBER: W/45/00656/00/00

URN NUMBER: 06/1412

GRAS Preamplifier Type 26AK-S1 (A-Weighted noise floor < 2.5μV) giving an estimated noise floor of 14.8 dB(A). During periods of no wind and with windows closed and the dwelling empty, noise levels as low as 12 dB(A) were measured within Site 2: Location 1.

The averaged measured noise reduction from free-field A-Weighted to internal "free-field" A-Weighted sound pressure levels was found to be as follows:

Site	Location	Window Closed		Window Open	
		Level Difference	Std Dev.	Level Difference	Std Dev.
1	1	15.5	0.6		
2	1	14.5	0.4	10.1	1.1

Table 6: detailing measured A-weighted level difference

These calculated level differences may be compared with the suggested insertion losses within PPG24[45] and PAN 56[46](10 – 15 dB for an open window) and the assumed 15 dB reduction within WHO Guidelines for Community Noise.

The levels measured at Site 1: Location 1 indicate that, even with windows closed, that this level of performance is just achieved. Measurements at Site 2: Location 1 indicate that with windows wide open, a level reduction of 10 dB(A) is achieved and 14.5 dB(A) with windows closed.

An assessment of the low frequency performance of the two structures was undertaken which indicates that Site 1: Location 1 increases at a relatively constant insertion loss with increasing frequency, with an average insertion loss of 2.8 dB at 20 Hz rising to 18.8 dB at 500 Hz. Whereas the performance at Site 2: Location 1 indicates a rapid increase in the insertion loss from 20 Hz

---

[45] Planning Policy Guidance 24: Planning and Noise: PPG24: ODPM

[46] Planning Advice Note: PAN 56 Planning and Noise: April 1999: The Scottish Office

Appendix 9 – Abstract from Conference Paper relating to Research into Amplitude Modulation

(14 pages)

Fourth International Meeting on Wind Turbine Noise

Rome Italy 12-14 April 2011

Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause & Effect

Andrew Bullmore, Mark Jiggins, Matthew Cand: Hoare Lea Acoustics[1]
Malcolm Smith: Institute of Sound & Vibration Research[2], University of Southampton, UK
Sabine Von-Hunerbein[3]: Acoustics Research Centre, University of Salford, UK
Robert Davis: Robert Davis Associates[4], UK

Abstract

The issue of amplitude modulated noise (often referred to as 'blade swish' or 'AM') arising from the operation of wind turbines is presently receiving a high focus of attention. Whilst the acceptability of audible noise from wind turbines continues to be the subject of considerable debate, the specific issue of AM has come to the fore following the publication of a number of studies claiming that the existence of such noise may result in an enhanced possibility of adverse effects, both in terms of subjective response and in terms of direct adverse health effects.

The issue of AM is not a new one, having been the subject of a previous study undertaken on behalf of DEFRA in the UK by the University of Salford in 2007. That study was initiated following complaints of what was believed to be problematic levels of low frequency noise arising from a limited number of operational wind farms.

A research project is underway which aims to improve understanding of the phenomenon, and develop an objective method for quantifying levels of AM and provide a well-defined dose-response relationship. This paper will discuss preliminary results and invite contributions from the wind turbine noise research community on the subject. The project is 100 % funded by RenewableUK.

[1] Hoare Lea Acoustics, 140 Aztec West Business Park, Almondsbury, Bristol BS32 4TX. andrewbullmore@hoarelea.com

[2] Institute of Sound and Vibration Research, University Road, SOUTHAMPTON S017 1B, UK. mgs@isvr.soton.ac.uk

[3] University of Salford, Salford, Greater Manchester M5 4WT, UK. S.VonHunerbein@salford.ac.uk

[4] Robert Davis Associates, The Holt, Upper Timsbury, Romsey Hants, SO51 0NU UK. noise@rd-associates.co.uk

Introduction

The issue of amplitude modulated noise (often referred to as 'blade swish' or 'AM') arising from the operation of wind turbines is presently receiving a high focus of attention. Whilst the acceptability of audible noise from wind turbines continues to be the subject of considerable debate, the specific issue of AM has come to the fore following the publication of a number of studies claiming that the existence of such noise may result in an enhanced possibility of adverse effects, both in terms of subjective response and in terms of direct adverse health effects.

Residual confusion is still often encountered as to what aspect of wind farm noise people are actually complaining of, particularly as the term 'low frequency sound' is often used to refer to broadband amplitude modulated aerodynamic sound. With specific regard to low frequency sound and infrasound, repeated studies have confirmed the lack of sufficient energy in these low frequency and/or infrasonic frequency bands to result in the claimed direct adverse health or even subjective effects from operational wind farms. Hence the possible existence of enhanced levels of AM provided a possible causal link between a physically measurable and subjectively perceptible effect and reported adverse responses. It should be noted here that what constitutes 'normal' and 'enhanced' levels of AM is still the subject of some debate. In this respect it is noted here that aerodynamic noise from wind turbines is always amplitude-modulated at the blade-passing frequency. Work by Oerlemans described below confirms that the dominant noise source for typical wind turbine operating conditions is the outer section of blade, near the tip. The directivity of noise radiated from this area of blade, which varies in time for rotor position, explains the generally-observed 'normal' level of amplitude modulation (swish) at locations close to the turbine. This directivity-related effect diminishes as distance from the turbine increases as the 'angle of view' to the extremes of the rotor disk becomes small. However, the reported AM problems concern 'enhanced' levels of AM, where AM is distinctly audible at distances in excess of 500 metres, is sometimes impulsive in nature (described as 'thump') and is observed to occur intermittently rather than being an inherent feature of the radiated noise.

The authors are part of a consortium which was commissioned by the RenewableUK association to undertake further research to improve the understanding of wind turbine Amplitude Modulation (AM). Specifically, the aim of this study is to obtain a better understanding of the causes of AM (and therefore its likelihood of occurrence), develop a reproducible means of objectively quantifying AM, and obtain an associated dose-response relationship based on this objective metric.

As this research is currently on-going, the present paper presents a brief review of current knowledge and experience of AM: relevant and available studies in the scientific and technical literature, as well as relevant reports of disturbance or complaints from wind turbines, mainly in the UK. Further developments may be referred to in the presentation, and contributions from the wind turbine noise research community on the subject will be invited.

In the UK

ETSU-R-97

The ETSU-R-97 report [1] noted that blade swish, defined as a rhythmic modulation of the aerodynamic noise of the turbines, can be audible in some circumstances by wind farm neighbours at typical separation distances. It suggested that it might be due to directivity of trailing edge noise, dependent on blade profile and tip speed, and it was described as being dominated by high frequencies: 800 – 1000 Hz and above. It will be more apparent closer to the turbines, with typical variations of 2-3 dB(A) in A-weighted levels, but with stronger variations in some frequency bands. But with increasing observer distance, because of atmospheric absorption and the reduced impact of directivity effects, this modulation becomes less pronounced. As the relative contribution of background noise will also generally increase, this would reduce the prominence of the "swish". The document reports variations in swish levels between different turbines, as well as site-specific variations for the same turbine type.

ETSU-R-97 on page 68 contains further descriptions of AM:

"This modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3dB(A) (peak to trough) when measured close to a wind turbine. As distance from the wind farm increases, this depth of modulation would be expected to decrease because of atmospheric absorption […]. However, it has been found that positions close to reflective surfaces may result in an increase in the modulation depth […]. If there are more than two hard, reflective surfaces, then the increase in modulation depth may be as much as +/- 6dB(A) (peak to trough)." Due to standing wave effects from reflection from building structures, the modulation in specific frequency bands can increase significantly.

The noise limits defined within ETSU-R-97 were established on the basis that they took account of the noise from wind turbines containing a certain level of AM, but the report also suggested that it would be useful to undertake further work to understand and assess this feature of wind turbine noise.

Additional UK research

A report for ETSU in the UK in 1999 [2] monitored turbine noise at close range of what would currently be considered a relatively small turbine (32 m to the hub). It concluded that *"the experimentally observed modulation* [measured close to the turbine] *is due to a combination of tower shadow effects as the blades pass the tower plus the preferential radiation of noise into some directions in preference to others."* It should be noted that that this "shadow effect" was a predominantly a shielding mechanism rather than a blade-tower interaction effect, the test turbine being of the upwind type.

The modulation observed above 1 kHz, which was more marked than at 500 Hz and below, was found to be strongly correlated to yaw error, but not with wind shear or turbulence intensity, and only weakly correlated with wind speed.

Jiggins [3] measured turbine swish from several wind farm sites in some detail, both at close range and further away from several wind turbine sites. The turbines studied were also relatively small in size compared to more recent machines.

He noted variations in the time between peaks, which may have been due to the contributions of different turbines. Variations in time in the depth of the modulation (observed in a limited frequency range), similar to "beating", suggested a possible interaction of noise between two or more turbines. The modulation in the high-frequency bands was observed to be reduced further away from the turbines. The document also reported an experimental study of loudness perception of simulated broad-band sounds of increasing modulation depth.

Government-funded studies

In 2006, the results of a study specifically commissioned by the DTI to look at the effects of infrasound and low frequency sound arising from the operation of wind farms were published [4]: referred to as the "DTI LFN Report". This report was actually commissioned primarily to investigate the effects of "infrasound", 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. 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. Whilst it is known that infrasound can have an adverse effect on people, these effects can only come into play when the infrasound reaches a sufficiently high level.

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, audible, levels of low frequency sound were below permitted night time low frequency sound criteria.

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 level of amplitude modulation of the blade passing noise, making the 'swish, swish, swish' sound (often referred to as 'blade swish') more prominent than normal. This was referred to in the report as "audible modulation of the aerodynamic noise" or 'AM'. 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

Jiggins [3] measured turbine swish from several wind farm sites in some detail, both at close range and further away from several wind turbine sites. The turbines studied were also relatively small in size compared to more recent machines.

He noted variations in the time between peaks, which may have been due to the contributions of different turbines. Variations in time in the depth of the modulation (observed in a limited frequency range), similar to "beating", suggested a possible interaction of noise between two or more turbines. The modulation in the high-frequency bands was observed to be reduced further away from the turbines. The document also reported an experimental study of loudness perception of simulated broad-band sounds of increasing modulation depth.

Government-funded studies

In 2006, the results of a study specifically commissioned by the DTI to look at the effects of infrasound and low frequency sound arising from the operation of wind farms were published [4]: referred to as the "DTI LFN Report". This report was actually commissioned primarily to investigate the effects of "infrasound", 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. 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. Whilst it is known that infrasound can have an adverse effect on people, these effects can only come into play when the infrasound reaches a sufficiently high level.

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, audible, levels of low frequency sound were below permitted night time low frequency sound criteria.

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 level of amplitude modulation of the blade passing noise, making the 'swish, swish, swish' sound (often referred to as 'blade swish') more prominent than normal. This was referred to in the report as "audible modulation of the aerodynamic noise" or 'AM'. 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

UK wind farms. This research work was awarded to the University of Salford who reported on their findings in July 2007 [5].

In the questionnaire sent out by the University of Salford, AM was defined as "*Wind turbine blade noise which is modulated at blade passing frequency (typically once per second) with a sharper attack and a more clearly defined character than usual blade swoosh. It is sometimes described as being like a distant train or distant piling operation.*" This description derives from the observations made in the DTI LFN study.

A total of 133 windfarm sites were operational across the UK at the time of the survey. Based on responses from local authorities with wind-farms in their areas, the report concluded that: "*AM was considered to be a factor in four of the sites, and a possible factor in another eight. Regarding the four sites, analysis of meteorological data suggests that the conditions for AM would prevail between about 7% and 15% of the time. AM would not therefore be present most days, although it could occur for several days running over some periods. 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.*"

The reported noted that "*the causes of AM are not fully understood and that AM cannot be fully predicted at current state of the art*". But it does suggest that "*[a]erodynamic noise generation depends primarily on the rotor tip speed, but there is also some dependence on wind speed. Therefore, if wind speed is not even across the rotor plane then some fluctuation in level can be expected as the blade turns.*"

The report goes on to finally conclude:-

"*Considering the need for further research, the incidence of AM and the number of people affected is probably too small at present to make a compelling case for further research funding in preference to other types of noise which affect many more people. On the other hand, since AM cannot be fully predicted at present, and its causes are not understood we consider that it might be prudent to carry out further research to improve understanding in this area.*"

Following receipt of the report, the UK Government [6] stated that it "*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.*" The statement then concludes with the advice of the continued support of the ETSU-R-97 methodology.

Following a freedom of information request, the full data used to support the conclusions of the Salford University report was published on the internet [7]. The four sites with noise complaints identified by the local authorities as arising from turbine AM were: Bears Down (designated 'First Site' in Sections 4.1 to 4.4 of the University of Salford report), Askam ('Second site'), Deeping St Nicholas ('Third site') and Llyn Alaw ('Fourth site'). The report notes that AM may have been "*a possible factor in another eight sites*".

1) Bears Down

Several complaints were received from 4 locations: "*Loud/noisy*", "*rhythmic*" "*thumping*", "*sometimes overlapping*", "*like a washing machine*". No complaints were recorded following remedial works in 2004. The Salford analysis suggests that the weather conditions in which the AM was found to occur would be present on average around 15% of the time.

2) Askam (Far Old Park Farm, Ireleth, Askam-In-Furness)

In the report by the local authority, AM was described as being "like train in next field" and "percussive" with what was termed the "Van Den Berg effect (i.e. AM) apparent occasionally". This is thought to refer to the results published by Van Den Berg which are described below. "*The characteristics of the noise -chopping, whoomphing etc- are very noticeable even at levels below 35dB(A). An example: LA90 34dB, noise judged to be a nuisance at 600m UPWIND of turbines.*" "*A consultant considered the nature of the topography i.e. landform sloping downwards from the turbines contributed to the characteristics of the noise*". Measurements "*have indicated that third octave band levels when complaints were received before the implementation of wind turbine control features, indicated level changes of 12–15dB.*" The available information suggests that this corresponds to "site 1" in the DTI LFN report.

A "library" of conditions leading to nuisance was arduously built up and noise management system put in place. Complaints have reduced dramatically since this system was put in place. It was found that "*AM occurred specifically for Easterly winds and for speeds from the cut-in speed, of around 5m/s, up to 10 m/s measured at a height of 10m above ground level*". Specifically, "*AM on this site was associated with three specific wind turbines. To alleviate the problem, a turbine control system was programmed to shut down these three machines for wind directions between 55° and 130°.*"

Wind shear effects associated with atmospheric stability effects can be dismissed as a cause there, as they were found to be very limited at the site, based on anemometry measurements. But the Salford report noted that "*topographical effects result in some wind turbines being 'unsure' as to the wind direction. This is caused by the wind turbine wind vane being influenced by the wind direction at the hub height of the rotor but the wind direction at the lower arc of the rotor may be from a different direction.*" This would result in the turbine blades, at some points in their rotation, not being fully pointed into the wind.

3) Deeping St Nicholas

One complainant describes periods of operation when amplitude modulation of the aerodynamic noise (AM) is clearly audible inside and outside the building. The Salford report notes that this occurred when the wind direction was in a narrow sector, and the wind speed in a given range (neither very high or very low). Analysis of long-term anemometry data led the authors to conclude that the range of conditions associated with AM would be expected to occur for 7% of the year on average.

4) Llyn Allaw

The noise character was described as AM, with "swoosh swish" and "beating (rhythmic)". During the site visit, council representatives experienced audible blade noise woosh.

Bowdler review

Bowdler [8] reviews the state of knowledge at the time of the article to assist with further work on the subject. He notes that the general descriptions of AM in refs [1] and [2] are consistent with the subsequent work of Oerlemans and Scheper [9], which showed that the directivity of the trailing edge noise from the blade, combined with the Doppler amplification effect of the blade movement, would explain the 'normal' swishing noise of a turbine. More recent research by these authors [10] has validated this model using measurements, and shown that "*for both cross-wind directions, the average level is lower than in the up- and downwind directions, but the variation in level is larger.*"

Bowdler describes his observation that, in a crosswind direction the swish reduces, and that the "maximum modulation" is experienced at 45 degrees from the crosswind direction. In the work of Oerlemans and Scheper, this intermediate location does not correspond to the worst-case modulation depth; however at 45 degrees from crosswind there is a combination of both high absolute noise level and deeper modulation.

These effects of radiation directivity could be expected to decrease with increased separation distance, as the directivity effects relative to the observer reduce in magnitude. However, Bowlder argues that this might not be the case in some situations, in particular 45 degrees from downwind, because of a shadowing effect form the tower in one case. He also considers that the Oerlemans model can be interpreted as describing "standard" turbine swish as opposed to the enhanced impulsive "thumping" described by others.

Bowdler also reviews the complaints related to AM at Deeping St Nicholas and proposes a likely correlation of specific "thump" occurrences to the 45-degrees-from-crosswind conditions discussed above; however this interpretation need to be taken with caution because of uncertainties as to the exact wind direction reference used. Bowdler also discusses the Wharrels Hill site but notes that "thump" was not observed there.

Europe

As noted in Reference [5], European regulations on wind turbine noise are generally stated in terms of maximum dB(A) noise levels and make no particular allowances for AM.

Van den Berg publications

Van den Berg [11] has described measurements at a 30MW, 17-turbine wind farm located on the Dutch-German border. One of the main findings of this research was that measured sound levels were higher than predicted at set 10 m height wind speeds because of wind shear effects, which are now well-recognised and incorporated in the study of wind farms in the UK according to best practice.

But another of the reported main findings is that "*wind turbines can produce sound with an impulsive character.*" The "thumping" nature of the wind turbine sound was observed in some occasions, and the author suggested that this must have contributed to the annoyance of the residents. The example illustrated in the article shows a modulation of up to +/-5 dB (peak to trough), measured at 750 m from the nearest turbine, 2 m away from a reflective surface, in the middle of the night. Because of the presence of a reflective surface, this is consistent with comments in ETSU-R-97. Pulses of depth 3-4 dB occurred for dozen of seconds with the worst cases impulses for no more than ~3s; they are also described as more "*pronounced and annoying*" at higher rotational speeds. The noise level graph shown exhibits a clear impulsive shape. The frequency and conditions of occurrence are not described.

Van den Berg distinguishes the standard "swish", which can be heard during most conditions and the more pronounced "thump" described in the paper. Van den Berg has stated (in verbal evidence at the Bald Hills Wind Farm Project hearing, as reported in Ref. [14]) that the layout (i.e. turbines in line or "randomly" laid out) was not more likely to lead to "impulsiveness".

The varying depth of modulation in the latter was attributed by the author to short periods of synchronisation in phase of the rotation of the dominant turbines (closest to the measurement location). He speculated that this surprising emission of pulses would not be apparent in measurements of single turbines, because of his proposed synchronisation effect. The author also suggests that the interaction of the blade passing the tower influences the character of the noise.

Bowdler casts some doubt on this analysis as the modulation depth would not increase if turbines become in phase. Examining this hypothesis in his review, Bowdler notes that: "*it is perhaps more correct to suggest not that, when turbine noises are in phase the level increases, but rather that when they are out of phase the modulation is reduced because they average each other out*". Bowdler also notes that in modern upwind turbine configurations, blade-tower interaction effects have been shown [9] to be marginal acoustically. Bowdler notes that in other publications, Van den Berg has attributed AM clapping or beating to wind velocity differentials across the turbine rotor associated with wind shear, and Bowdler suggests similar differentials could occur with turbulence of meteorological or topographical origin.

Finland – Di Napoli

In 2009, Di Napoli presented [12] measurements made at single, isolated 1 MW turbine (66 m hub, pitch regulated), located approximately 750 m from holiday houses in Finland. Measurement made at a point 530 m from the turbine showed some AM, with levels generally varying with wind speed but some periods of clear, apparently impulsive peaks at blade passing frequency, with a worst-case amplitude of 5 dB peak-to-peak for at least a few seconds.

The author describes this as generally occurring as wind speed decreased or stopped accelerating, and reports observing it to a certain degree during most of the recording on the day of the measurements. Some "notches" or double-pulses were apparent at times. These results indicate that whilst turbine-turbine interaction may be a contributory factor in some cases, it is not the only potential cause of AM effects.

Australia

A 2006 review of the subject [13] concluded that there were little publicly available records of complaints from large modern wind farms at the time, with the exception of the Toora Wind Farm, located in South Gippsland Shire Council, Victoria, Australia.

A report by Fowler [14] notes that residents near Toora have reportedly complained about the audible rhythmic noise, and the turbine blade rotation being "clearly audible". The author of the latter report therefore argues that a 5 dB penalty should be added for "special audible characteristics" which was specified in the New Zealand standard NZ6808:1998 [15] applicable at the time. But it is not clear however if this modulation was typical of turbines or if some enhanced modulation was experienced at this site. The author might apply this penalty to all wind turbines according to his interpretation of the NZ standard, due to the inherent character of the wind turbine noise.

Another recent review [16] suggests that, based on the available information, the general inclusion of this penalty for all wind farm schemes would not be justified. It cites the first draft of the Australian National Wind Farm Development Guidelines [17] for which excessive swish is referred to as one of the potential Special Audible Characteristics (or SACs), but recommends for example that *"[w]ith the exception of tonality, the assessment of SACs will not be carried out during the noise impact assessment phase, that is, pre-construction*".

The wind farm at Waubra (Victoria) is another site which has received some attention in the press as some residents have complaining about the health effects impacts of wind turbine noise. The descriptions from some residents include: "*when in sync, every minute or two you can hear 3-4 big wooshes that you can actually feel*". "*[You] feel that you have motion sickness*", "*I wake up 5-6 times at night*".

A report by Thorne for one of the residents [18] has described "*pulsing at low frequency*" which some residents believe is at the origin of their problems. However, the frequency of occurrence of this feature was not determined. It is not therefore known whether this modulation was a continuous feature of the site which would then potentially warrant a penalty for "special audible characteristics". The author suggests that this "*rumble/thump*" may be caused by the downstream wake from adjacent turbines or by interaction of the blade with the tower.

New Zealand

West Wind, Meridian's wind farm near Wellington, comprises 62 Turbines on elevated hills with valleys either side. It was officially opened in April 2009. Since then, the company's been dealing with complaints from people living in the adjacent Makara Valley, as reported in the media.

Ref [18] quotes one resident as saying: *"[we] get the low frequency thump/whump inside the house, is very similar to a truck driving past or boy racers sub-woofer 100m away[…] we have no line of sight [sic] turbines and the closest one is 1.35km away. […]. The sound is extremely 'penetrating' and while we have a new house with insulation and double glazing, the low frequency modulation is still very evident in the dead of night. It is actually less obvious outside as the ambient noise screens out the sound."* The rumble/thump is reportedly heard just before or after wind gusts.

The planning conditions for the West Wind project [19] require a penalty of 5 dB be added for "special audible characteristics", such as tonality or "audible modulation". The text then goes on to clarify that *"a test for modulation is if the measured peak to trough levels exceed 5 dBA on a regularly varying basis or if the spectral characteristics, third octave band levels, exhibit a peak to trough variation that exceeds 6dB on a regular basis in respect of the blade pass frequency"*. The recently revised New Zealand standard NZS6808:2010 has a test for modulation that is similar to those conditions.

A noise compliance report published by the operator [20] describes measurements undertaken at various locations around the wind farm. It showed clear levels of tonality in the measured turbine noise. Mitigation measures are described which aimed to reduce the tonal noise emissions by changing the operation of the turbines. The presence of these tones was said to explain the audibility of the wind farm even at relatively large separation distances.

The report then goes on to consider amplitude modulation. It argues that (in theory) during "high power conditions", the use of turbine blade pitch adjustment may lead to aerodynamic noise becoming more audible at receiver locations, and that this may be more easily perceived in sheltered rather than exposed locations. Following an analysis of complaint records (mentioning "*whoosh*") and a review of the measurements, the report concludes that audible modulation has only found been found to occur for very short periods, i.e. no more than 5 seconds in a 1 minute recording, and on no regular basis. Although some modulation which met the level test of the condition of the condition (>6 dB change in the 160 Hz octave band), this was for such brief intervals that it was considered inappropriate to apply a penalty for this characteristic.

A subsequent report [21] notes that following the progressive implementation of mitigation measures across the wind farm (between February and April 2010), tonality levels and the number of complaints from residents both reduced significantly.

Conclusions

On the basis of this review, it is apparent that there remains some debate on the definition of AM, let alone its causes. Some instances of 'enhanced' AM are reported as distinctly audible at distances in excess of 500 metres, sometimes impulsive in nature when they usually come to be described as 'thump'. However, the low frequency of occurrence of this feature is notable and to date has made definitive research on the subject difficult.

The mechanisms causing enhanced AM need to be understood so that the risk of its occurring on a particular site can be mimimised by design, and effective remedial action can be taken on sites where it is found to occur after installation. One possible source mechanism is cyclic variation in aerodynamic blade loading caused by non-uniform inlet flow across the rotor disc, possibly resulting from wind shear, yaw error or large-scale atmospheric turbulence. At a distant receptor, the perception of 'at source' AM may also be influenced by propagation effects resulting from atmospheric factors, changes in background noise levels or interaction between modulated noise from a number of turbines. It seems likely that the phenomenon will eventually be linked to a combination of factors, including but not necessarily limited to this list.

The current RenewableUK sponsored research project aims to improve the understanding of this phenomenon through further fundamental research into the causes of AM, using a combination of data available to date, further study of wind turbine aerodynamic design and control systems, theoretical models and additional targeted measurements on wind turbine sites where the presence of enhanced levels of AM has been reported.

A robust objective metric for the rating of AM effects is required which would relate directly to the subjective impact of AM where it occurs. Fundamental to developing a dose response relationship is the use of a metric which represents the characteristics of the stimulus (the amplitude-modulated noise) and weights these characteristics to generate (ideally) a single number value that can be shown to correlate with subjective response. It is planned to undertake carefully controlled listening tests to assess and develop this metric, which could provide a robust basis for an AM 'correction factor' or 'penalty' to be added to a measured noise level to reflect the increased subjective response to amplitude-modulated noise.

It is planned to publish and disseminate the outcome of this research. The authors would like to invite contributions from the wind turbine noise research community on the subject. Assistance in the collation of relevant audio or acoustic data would be particularly appreciated.

Acknowledgements

The financial support of RenewableUK for this research project is gratefully acknowledged.

References

[1] 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.

[2] Wind turbine measurements for Noise source identification - ETSU W/13/00391/00/REP - Dr A J Bullmore, Mr J F Lowson, Dr J H Bass, Dr P Dunbabin, 1999.

[3] Subjective Perception of Wind Turbine Blade Noise, By Mark Jiggins MIOA, MSc Thesis in Acoustics, Vibration and Noise Control, Department of Building Engineering & Surveying Heriot-Watt University, Riccarton, Edinburgh, UK, October 1997.

[4] The Measurement of Low Frequency Noise at Three UK Wind Farms, Hayes McKenzie Partnership for the DTI, 01/07/2006.

[5] Research into aerodynamic modulation of wind turbine noise, Report by University of Salford for Department for Business, Entreprise and Regulatory Reform, URN 07/1235, July 2007, Contract NANR233.

[6] Energy Minister Malcolm Wicks, Government Statement regarding the Findings of the Salford University Report into Aerodynamic Modulation of Wind Turbine Noise, 2007.

[7] Renewable Energy Foundation website, http://www.ref.org.uk, 06 February 2009.

[8] D. Bowdler, Institute of Acoustics Bulletin, Vol 33 no 4, 08/07/2008.

[9] Stefan Oerlemans and Gerard Schepers. Prediction of Wind Turbine Noise and Comparison To Experiment. Second International Meeting on Wind Turbine Noise, Lyon, France, September 20–21, 2007.

[10] Stefan Oerlemans and Gerard Schepers, Prediction of Wind Turbine Noise Directivity and Swish, Third International Meeting on Wind Turbine Noise Aalborg Denmark 17 – 19 June 2009.

[11] Van den Berg, Effects of the Wind Profile at Night on Wind Turbine Sound", J. Sound Vib. 277 (4-5), 955-970 (2004).

[12] Carlo Di Napoli, Case Study: Wind Turbine Noise in a small and quiet community in Finland, Third International Meeting on Wind Turbine Noise Aalborg Denmark 17 – 19 June 2009.

[13] Complaints from noise of wind turbines – Australian and New Zealand experience Colin Tickell, Proceedings of Acoustics 2006, 20-22 Nov 2006, Christchurch New Zealand.

[14] "Toora Wind Farm – Review of the environmental noise monitoring program" Graeme E. Harding &Associates Pty Ltd, report 045-177/1, January 2005.

[15] NZS 6808:1998. New Zealand Standard. Acoustics – The Assessment and Measurement of Sound from. Wind Turbine Generators. April 1998.

[16] Wind Farms Technical Paper, Environmental Noise, Sonus Pty Ltd, Adelaide, Australia, November 2010.

[17] Environment Protection Heritage Council (EPHC), 2009 and 2010, "National Wind Farm Development Guidelines – Public Consultation Draft", Adelaide

[18] Dr Bob Thorne, Noise Measurement Services Pty Ltd (Brisbane) Noise Impact Assessment Report, Waubra Wind Farm Report No 1537 - Rev 1 - July 2010

[19] Wellington Environment Court Decision W59/2007, 20th July 2007

[20] M. Hayes, P. Botha, Project West Wind Wind Farm, Noise Compliance Assessment, 17th March 2010

[21] P. Botha, Project West Wind Wind Farm Noise Compliance Assessment, 14th September 2010

Appendix 10 – Extracts from Swinford Decision Letter (Conditions and Guidance Notes (5 pages)

Report to the Secretary of State for Communities and Local Government

by John Woolcock BNatRes(Hons) MURP DipLaw MPIA MRTPI
an Inspector appointed by the Secretary of State for Communities and Local Government

The Planning Inspectorate
Temple Quay House
2 The Square
Temple Quay
Bristol BS1 6PN
☎ GTN 1371 8000

Date 9 October 2009

Town and Country Planning Act 1990

Harborough District Council

appeal by

Nuon UK Ltd

Inquiry opened on 14 July 2009

Land to the north-east of Swinford

File Ref: APP/F2415/A/09/2096369

bond or other financial provision is satisfactory. The applicant, or their agent or successors in title shall ensure that the approved bond or other financial provision is maintained throughout the duration of this consent and the bond or other financial provision will be subject to a five yearly review from the commencement of the development, to be conducted by a competent independent professional approved in writing by the local planning authority who has relevant experience within the wind energy sector, and provided to the applicant, or their agent or successors in title, the landowner(s) and the local planning authority.

19. The rating level of noise emissions from the combined effects of the wind turbines (including the application of any tonal penalty) when calculated in accordance with the attached Guidance Notes 1-4 shall not exceed the noise values set out in Tables 1 & 2 within the Guidance Notes. Noise limits for properties within 2 km of a wind turbine, which lawfully exist or have planning permission for construction at the date of this planning permission, but are not listed in these tables, shall be those of the nearest location listed in Tables 1 & 2.

20. Within 28 days from the receipt of a written request from the local planning authority following a complaint to it, the wind farm operator shall, at its own expense, employ an independent consultant approved in writing by the local planning authority to assess the level of noise emissions from the wind farm at the complainants property following the procedure described in the attached Guidance Notes. Details of the assessment and its results as to whether a breach of the noise limits in Condition 19 has been established shall be reported to the local planning authority as soon as the assessment is completed.

21. Upon notification in writing from the local planning authority of an established breach of the noise limits in Condition 19 the wind farm operator shall, within 28 days propose a scheme to the local planning authority to mitigate the breach to prevent its future occurrence, including a timetable for its implementation. Following the written approval of the scheme by the local planning authority it shall be activated forthwith and thereafter retained.

22. Wind speed, wind direction and power generation data for each wind turbine shall be continuously logged and provided to the local planning authority at its request and in accordance with the attached Guidance Notes within 28 days of such a request. Such data shall be retained for a period of 5 years.

23. Prior to the commencement of development, details of a nominated representative for the development to act as a point of contact for local residents (in connection with conditions 19 - 24) together with the arrangements for notifying and approving any subsequent change in the nominated representative shall be submitted to and approved in writing by the local planning authority. The nominated representative shall have responsibility for dealing with any noise complaints made during construction, operation and decommissioning of the wind farm and liaison with the local planning authority.

24. On the written request of the local planning authority, following a complaint to it considered by the local planning authority to relate to regular fluctuation in the turbine noise level (amplitude modulation), the wind farm operator shall at its expense employ an independent consultant approved in writing by the local planning authority to undertake the additional assessment outlined in Guidance Note 5 to

ascertain whether amplitude modulation is a contributor to the noise complaint as defined in Guidance Note 5. If the said assessment confirms amplitude modulation to be a contributor as defined in Guidance Note 5, the local planning authority shall request that within 28 days of the completion of the noise recordings referred to in Guidance Note 5, the developer shall submit a scheme to mitigate such effect. Following the written approval of the scheme and the timescale for its implementation by the local planning authority the scheme shall be activated forthwith and thereafter retained.

25. No lighting, symbols, signs or logos or other lettering, other than those required for health and safety, traffic management or aviation safety, shall be displayed on any part of the turbines or any other building or structures without the prior written approval of the local planning authority.

26. All cables within the development site between turbines and from the turbines to the substation shall be set underground.

27. The number of turbines shall not exceed 11. The blade tip height of turbines shall not exceed 125 m in height. The hub height of the turbines shall not exceed 84 m and shall not be less than 76 m.

28. All turbine blades shall rotate in the same direction.

29. If any of the wind turbines hereby permitted ceases to operate for a continuous period of 6 months then, unless otherwise approved in writing by the local planning authority, a scheme for the decommissioning and removal of the wind turbine and any other ancillary equipment and structures relating solely to that turbine, shall be submitted to and approved in writing by the local planning authority within 3 months of the end of the 6 month cessation period. The scheme shall include details for the restoration of the site. The scheme shall be implemented and site restoration completed within 12 months of the date of its approval by the local planning authority.

30. No development shall commence on site until the Ministry of Defence has been provided with the following information:

(i) The date of commencement of the construction.
(ii) The height above ground level and the location of the tallest structure.
(iii) The maximum extension height of any construction equipment.
(iv) Details of site lighting.

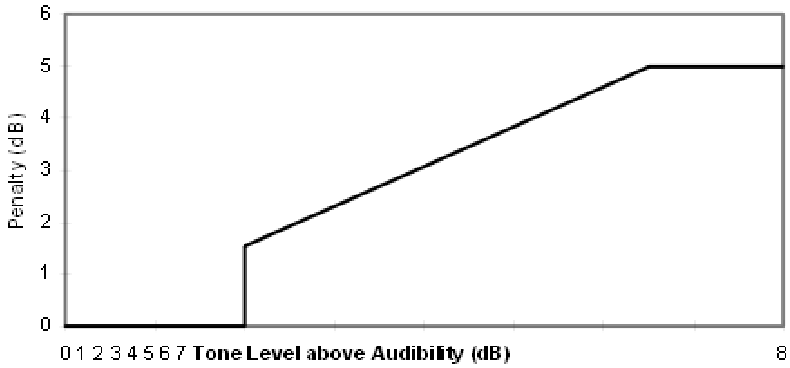
Guidance notes relating to conditions on next page -

(b) For each of the 2-minute samples the margin above or below the audibility criterion of the tone level difference, Delta L_{tm}, should be calculated by comparison with the audibility criterion given in Section 2.1 on pages 104-109 of ETSU-R-97.

(c) The margin above audibility is plotted against wind speed for each of the 2-minute samples. For samples for which the tones were below the audibility criterion or no tone was identified, substitute a value of zero audibility.

(d) A linear regression should then be performed to establish the margin above audibility at the assessed wind speed for each integer wind speed. If there is no apparent trend with wind speed then a simple arithmetic average shall be used.

(e) The tonal penalty is derived from the margin above audibility of the tone according to the figure below. The rating level at each wind speed is the arithmetic sum of the wind farm noise level, as determined from the best fit curve described in Note 2, and the penalty for tonal noise.



NOTE 4

If the rating level is above the limit set out in the conditions, measurements of the influence of background noise should be made to determine whether or not there is a breach of condition. This may be achieved by repeating the steps in Note 2, with the wind farm switched off, and determining the background noise at the assessed wind speed, L_3. The wind farm noise at this speed, L_1, is then calculated as follows where L_2 is the measured level with turbines running but without the addition of any tonal penalty:

$$L_1 = 10\log\left[10^{L_2/10} - 10^{L_3/10}\right]$$

The rating level is re-calculated by adding the tonal penalty (if any) to the derived wind farm noise L_1. If the rating level lies at or below the values set out in the conditions then no further action is necessary. If the rating level exceeds the values set out in the conditions then the development fails to comply with the conditions.

NOTE 5

Amplitude Modulation (AM) is the regular variation of the broadband aerodynamic noise caused by the passage of the blades through the air at the rate at which the blades pass the turbine tower. ETSU-R-97, "The Assessment and Rating of Noise from Wind Turbines", assumes that a certain level of AM (blade swish) is intrinsic to the noise emitted by the wind turbine and may cause regular peak to trough variation in the noise of around 3 dB and up to 6 dB in some circumstances. The noise assessment and rating framework recommended in ETSU-R-97 fully takes into account the presence of this intrinsic level of AM when setting acceptable noise limits for wind farms.

Where the local planning authority considers the level of AM may be at a level exceeding that envisaged by ETSU-R-97, they may require the operator to appoint an approved independent consultant to carry out an assessment of this feature under Condition 24. In such circumstances, the complainant(s) shall be provided with a switchable noise recording system by the independent consultant and shall initiate recordings of the turbine noise at times and locations when significant amplitude modulation is considered to occur. Such recordings shall allow for analysis of the noise in one-third octave bands from 50Hz to 10kHz at intervals of 125 milliseconds. The effects of amplitude modulation are normally associated with impacts experienced inside properties or at locations close to the property, such as patio or courtyard areas. For this reason the assessment of the effect necessarily differs from the free-field assessment methodologies applied elsewhere in these Guidance Notes.

If, over a period of 6 months, commencing at a time of the first occasion at which the local planning authority records an amplitude modulation event, the complainant fails to record 5 occurrences of significant amplitude modulation, in separate 24 hour periods, then its existence as a contributor to the noise complaint shall be excluded. If, however, the independent consultant, on analysis of the noise recordings, identifies that amplitude modulation is a significant contributor to the noise complaint then the local planning authority shall be informed in writing.