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Information Note

10 April 2012

A Critique of the IoA Treatment of Background Noise for Wind Farm Noise Assessments

Summary

This information note examines the revision to the ETSU-R-97 method of deriving noise conditions for wind farm planning permissions from background noise measurements, as proposed in an article in the *Acoustics Bulletin* of the Institute of Acoustics (IoA).[1] We have used actual wind speed data to model the impact of the revision on noise conditions and likelihood of noise complaints from neighbours.

The revision is designed to correct for site-specific wind shear that was erroneously assumed to be constant between two heights in the ETSU-R-97 guidance. The impact of this assumption is shown graphically in Appendix 1. However, in this note we show that the *Acoustics Bulletin* revision increases the uncertainty of the background noise curves and reduces confidence in the reliability of noise conditions based on them.

We show that the revised methodology can produce different noise conditions depending on the dates chosen for the baseline background noise survey, thus yielding differences in permitted wind farm noise levels of as much as 5dB for the same site. Consequently, use of the methodology can lead to the situation where predicted noise levels from turbines at a given proximity to dwellings are deemed acceptable, whereas measurements taken two weeks later would give the opposite result.

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[1] Prediction and Assessment of Wind Turbine Noise Dick Bowdler, Andrew Bullmore, Bob Davis, Malcolm Hayes, Mark Jiggins, Geoff Leventhall, Andrew McKenzie. Institute of Acoustics Bulletin, p35-37 March/April 2009. See http://www.ioa.org.uk/uploads/publication-documents/Acoustics%20Bulletin%20Mar-Apr%20009.pdf

Use of the new methodology can even result in site layouts where the wind farm noise would breach the old-style ETSU conditions, which are sometimes mistakenly believed to be the less benign of the two methodologies.

We also show how the wind speed data accumulated from an on-site anemometer can be used to predict the likelihood and frequency of noise complaints from neighbours for a hypothetical site layout, taking into account the bearing and proximity of the turbines to dwellings. The results demonstrate that separation distances that could be judged acceptable under the new methodology, would nevertheless be likely to trigger significant numbers of noise complaints from neighbouring dwellings. Unsurprisingly, the modeling shows that increasing the separation distance between dwellings and turbines reduces the likelihood of noise complaints.

We suggest that this analysis of likelihood of complaints provides a straightforward means of quantifying loss of amenity, and should be carried out for all proposed wind farms.

Introduction

Wind turbine noise is a problem of considerable concern to prospective and actual neighbours of wind farms, to wind power developers, and to decision makers in the planning system. The current guidance used in the United Kingdom for setting wind farm noise limits at neighbouring properties is the sixteen year old document *The Assessment and Rating of Noise from Wind Farms*, commonly known by its reference number, ETSU-R-97, a convention we adopt in this article. Unfortunately, ETSU-R-97 contains errors and omissions which limit its utility for noise assessment.

A fundamental requirement for the accurate prediction and assessment of turbine noise at neighbouring dwellings is an understanding of wind shear (the variation of wind speeds at different altitudes) and how this varies with time of day, wind speed, topography, and other variables. The authors of ETSU-R-97 were not meteorologists, and failed to understand that wind shear varies, and quite substantially, according to time of day. For example, after sunset when the solar heating of the ground and the near ground atmosphere ceases, wind shear tends to increase, with the result that wind speeds at turbine blade heights are considerably greater than wind speeds at or near ground level. This leads to high turbine speeds and thus high turbine noise levels at times when wind-induced masking noise nearer the ground is minimal. It is not surprising therefore, that many of the complaints about turbine noise arise in relation to evening and night time disturbance.

The ETSU-R-97 approach to wind shear leads to noise assessments that considerably understate the noise impact of wind farm developments, and also to noise conditions that are breached at times of high wind shear. In an attempt to rectify this situation, a group of acousticians published alternative guidance in the *Acoustics Bulletin* in 2009 (hereinafter referred to as the *Bulletin* or the *Bulletin* method).[2] However, that paper made no attempt to validate the suggested modification to existing guidance or to determine if it was an effective methodology for dealing with the issue of wind shear in turbine noise assessments. This information note seeks to fill that gap.

Testing the *Acoustics Bulletin* Methodology

The ETSU-R-97 wind farm noise assessment, and the *Bulletin* method variant, both rely on an initial baseline survey in the absence of wind turbines of the pre-existing background noise levels at the amenity areas of neighbouring dwellings.[3] These noise level measurements, which are usually accumulated for two weeks, were originally plotted with respect to the wind speeds measured at a height of 10 metres above ground level at the wind farm site. Two different charts for different times of the day are produced in order to determine an appropriate night time noise condition, and another, amenity-hours, condition for all other times.[4] A robust noise condition is vital to ensure protection of the amenity of wind farm neighbours.

The noise conditions are usually derived from least-squares, best-fit, polynomial curves for the two sets of data. ETSU-R-97 states that:

> […] *the criterion curve for acceptable levels of wind farm noise during day-time, i.e 07:00–23:00 each day, is usually equal to the day-time curve plus 5dB(A) at every wind speed. Where this criterion curve falls below the lower limit (35-40dB(A)..), the criterion curve should be amended so that it equals the lower limit.*[5]

Similarly, the guidance deems levels of wind farm noise at night time acceptable if they are no more than 5dB above the night-time curve or a fixed limit of 43dB, whichever is the greater.

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[2] Prediction and Assessment of Wind Turbine Noise Dick Bowdler, Andrew Bullmore, Bob Davis, Malcolm Hayes, Mark Jiggins, Geoff Leventhall, Andrew McKenzie. Institute of Acoustics Bulletin, p35-37 March/April 2009. See http://www.ioa.org.uk/uploads/publication-documents/Acoustics%20Bulletin%20Mar-Apr%20009.pdf

[3] For a description of the ETSU-R-97 methodology see pages 99 – 102 of the guidance.
[ETSU-R-97 Guidance Document - PDF,16MB]

[4] Night time refers to 11 pm to 7 am. The noise condition for all other times is based on data collected at quiet amenity times which are defined as 6 pm to 11 pm plus 1 pm to 6 pm on Saturday plus 7 am to 6 pm on Sunday.

[5] ETSU-R-97, p. 101.

However, it is now understood that wind farm layouts which apparently comply with these ETSU-R-97 criteria based on 10 metre wind speeds often breach the resulting noise conditions during times of higher wind shear. The ETSU-R-97 error in calculating the impact of wind shear is demonstrated in Appendix 1.

The *Bulletin* method acknowledges that the 10 metre wind speed is not a reliable indicator of the actual wind speeds at hub height. Instead, it recommends plotting the background noise levels against a synthesized 10 metre wind speed which is derived from the estimated hub height wind speed based on actual wind shear measurements and scaled down to what would have been the 10 metre wind speed had the wind shear been a single, constant value for the duration of the baseline noise survey. This is referred to as the 'standardised' 10 metre wind speed.

The rationale for this complicated manipulation of the background noise charts is to attempt to adjust for site specific wind shear and to permit easy comparison with turbine noise predictions provided by the manufacturers, who use a similar practice.

It is possible to demonstrate the effect of the *Bulletin* method's recommended manipulation of background noise plots using real wind speed data. Among REF's datasets we have a year's worth of wind speed measurements taken every 10 minutes at four heights (30, 40, 50, and 60 metres) from a wind speed mast at a site in the east of England. Using this data it is possible to derive a hub height wind speed assuming a wind turbine model with hub height of 80 metres. The formula used for this is the standard power law formula:

$$V_1 = V_2 * (h_1/h_2)^m$$

where

V_1 = wind speed in meters per second at a height of h_1 metres above ground level and

V_2 = wind speed in meters per second at a height of h_2 metres above ground level, and

m is the wind shear exponent

By performing a least squares fit to each ten minute set of wind speeds at the 4 heights it is possible to determine each 10 minute value of m, from which it is possible to derive the value of wind speeds at both turbine hub height (80 metres) and the ETSU-R-97 assessment height (10 metres).

As a starting point we have adopted two, theoretical, smooth background-versus-10-metre-wind-speed profiles (one for night time, 11pm – 7am, and one for amenity hours), which are shown below. These are typical of the average background noise graphs obtained in baseline surveys of amenity and night time periods in the quiet regions of countryside in the United Kingdom. Measured background-*vs*-wind-speed graphs are obviously not free of scatter as these are, but the reason for choosing clean average starting data is to isolate and illustrate the specific effects of the *Bulletin* method's recommended data transformation.

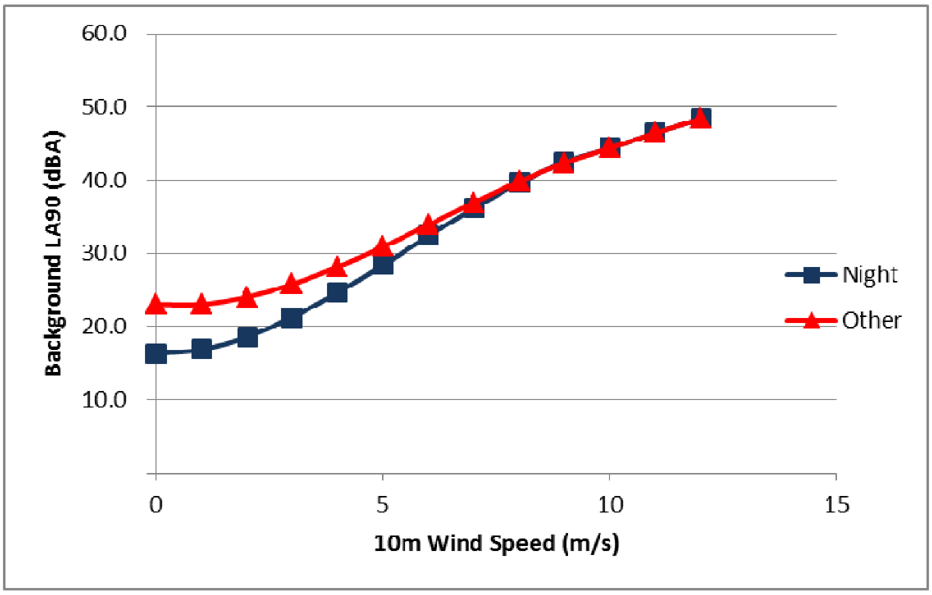

Figure 1: The two selected profiles chosen to represent average background noise vs 10 metre wind speeds for Night times (11 pm to 7 am) and all other times.

We can use the average background profiles above, and the set of anemometry data, to derive, by interpolation, background noise data points and the 10 metre wind speed for every 10 minutes of a year. We can also derive from the anemometry data the 'standardised' 10 metre wind speed defined by the *Bulletin* methodology.

The *Bulletin* method introduces scatter, reducing noise condition accuracy

The following graph shows the effect of the *Bulletin* method transformation. The blue points are the derived average background noise data points for a two week period of night times (11pm to 7am). The red points are the same average background noise points but now plotted against the *Bulletin* method's 'standardised' wind speed. The substantial increase in scatter is a direct result of the *Bulletin* methodology.

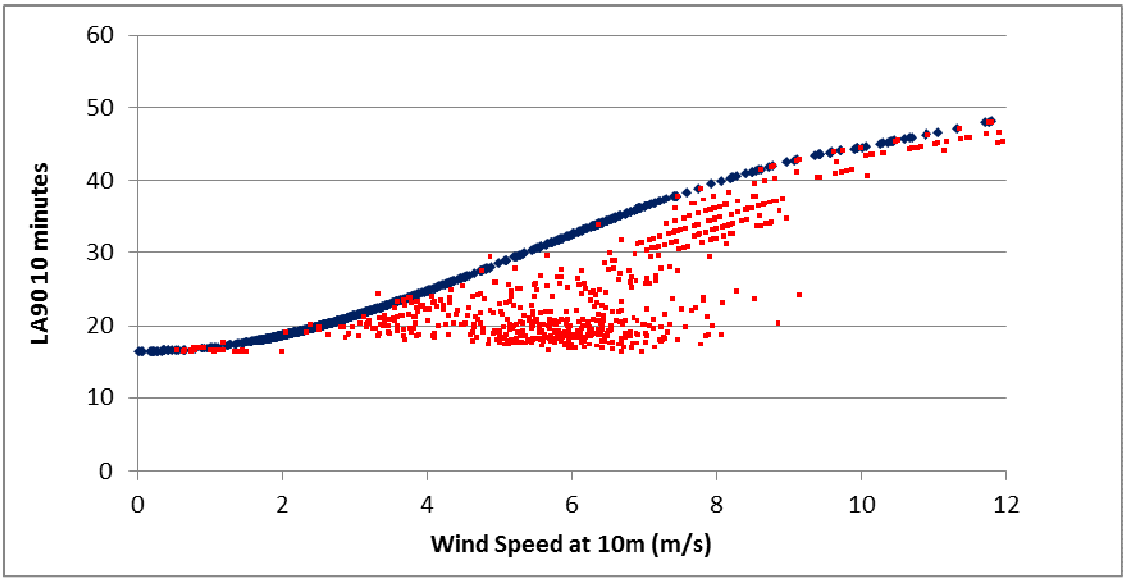

Figure 2: The blue points above show two weeks of an ETSU-R-97-type plot of average noise vs 10 metre wind speed. The red points are the same average noise data points vs the *Bulletin* method's transformed 10 metre wind speed (the so-called 'standardised' wind speed). The horizontal axis indicates the 10 metre wind speed for the blue points and a 'standardised' 10 metre wind speed for the red points.

What is immediately obvious is that the *Bulletin* method's transformation moves most of the background noise points under the original blue line; the degree to which the points drop depends on the wind shear at the time. This data covers a two week period that includes some periods of relatively high wind shear, so there are many points significantly lower than the simple ETSU line of background noise versus actual 10 metre wind speed. It may be noted that at higher wind speeds the shift of the red points from the blue points is much smaller, because wind shear tends to decrease at higher wind speeds.

The next step in deriving a background noise condition according to the *Bulletin* methodology requires fitting a smooth polynomial to the transformed data. However, what is also clear from the above data is that whereas the blue dots fall on a smooth line, the *Bulletin* method's transformation results in an asymmetrical distribution of red points which a polynomial is unlikely to fit well. The following chart demonstrates this problem.

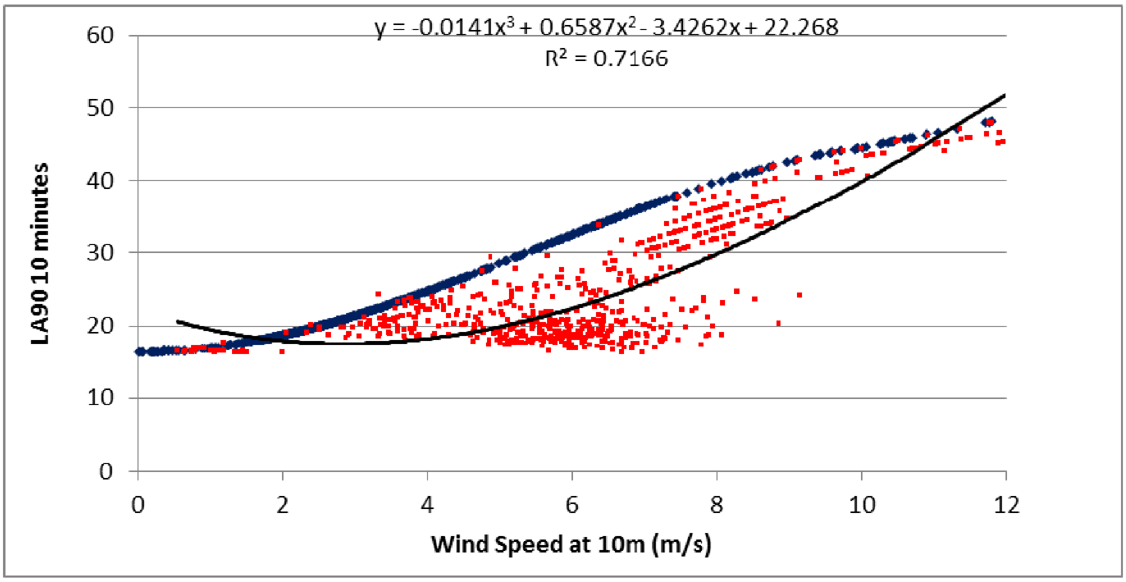

Figure 3: The data in Figure 2 with a best-fit third order polynomial (black line) fitted to the red Bulletin-methodology data.

The critical wind speed range of 5 to 8 m/s is particularly poorly represented by the polynomial with a third of the background noise data points being 4 dB or more beneath the line.

Furthermore, at the lowest and highest wind speeds, the polynomial fits the data particularly poorly.

It is clear that the mathematical transformation proposed by the *Bulletin* authors to account for wind shear results in a poorer fit with more scatter. The figures show what is intuitively understandable; namely that background noise at a neighbouring dwelling is not closely related to, or dependent on, hub height wind speeds – particularly in the wind speed range of 0-8 m/s. Crucially, it follows that any noise condition based on this fit will be less reliable.

The *Bulletin* method's noise conditions vary depending on the date of the baseline noise survey

Another major problem with using the *Bulletin* methodology is that the resulting noise condition limits vary significantly depending on the particular wind shear that occurred during the background noise baseline survey, leading to a high risk of sampling error. This is demonstrated in the following pair of figures, which show that if monitoring was carried out over two different fortnights two weeks apart in 2008, the *Bulletin* method's transformation shifts the average background noise data in a significantly different manner.

The first graph is for the amenity hours in the two weeks commencing 17 February 2008. Over this period, wind shear tended to be low, so the displacement of the red points from the average background (blue points) is reduced, as is the scatter. This plot can be contrasted with that obtained using the *Bulletin* method for the fortnight commencing 3 February 2008. In this case, wind shear tended to be higher, so the displacement of the red points - the *Bulletin* method's transformed points - from the average background line, is greater and the scatter is greater.

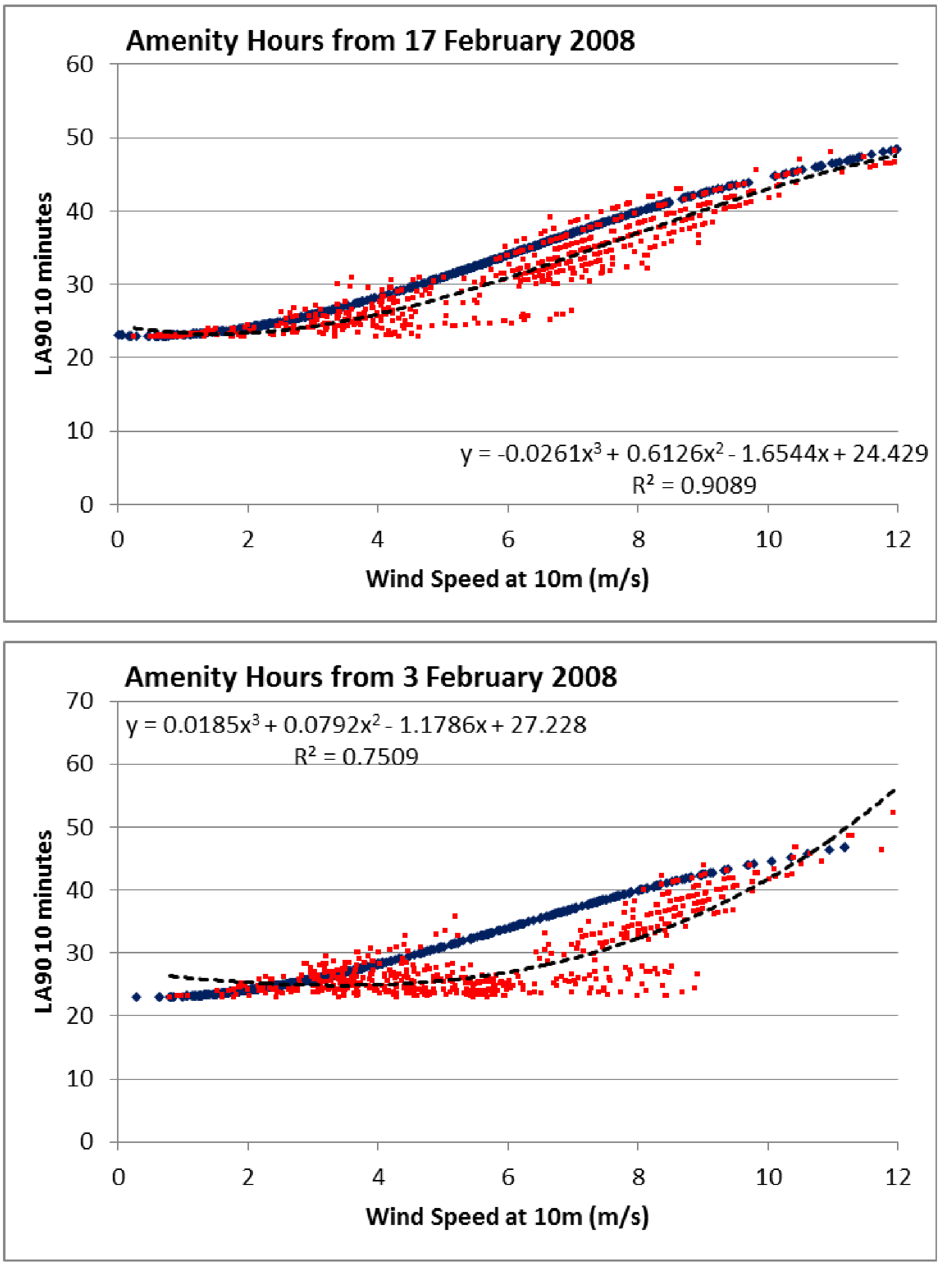

Figure 4: Two plots showing how the *Bulletin* method's transformation produces different results for the same input background noise data depending on the dates of the wind speed measurements.

If one uses these two separate fortnight periods to derive amenity hour noise conditions from a least squares 3rd order polynomial fit to the red points in Figure 4, one obtains two different noise conditions as shown in the following table.

Table 1: Amenity-hours noise conditions A and B resulting from the *Bulletin* methodology when derived from two different fortnights in a year. Condition A is from the fortnight commencing 17 February 2008. Condition B is from the fortnight commencing 3 February 2008. This demonstrates how choice of baseline survey period results in different levels of noise condition protection for neighbours.

Wind Speed 'Standardised' to 10 metre	Amenity Condition A (dBA)	Amenity Condition B (dBA)	Difference (dBA)
0	35	35	-
1	35	35	-
2	35	35	-
3	35	35	-
4	35	35	-
5	35	35	-
6	36	35	1
7	39	35	4
8	42	37	5
9	45	42	4
10	48	47	1
11	51	54	-3
12	53	62	-9

The difference of 4–5 dB(A) over the 'standardised' 10 metre wind speed range of 7 – 9 m/s is a very significant difference in terms of protected amenity for neighbours. The impacts of this are quantified and demonstrated in the following section.

The *Bulletin* method's noise condition is potentially less protective than the ETSU-R-97 condition

It is often the case that developers treat the derived amenity-hours noise condition as a target and locate as many turbines on a site as will meet this noise limit with minimal head room. A typical example of the ensuing turbine noise profile is shown in the following graph, which plots the two conditions from Table 1 and shows the profile for a turbine noise level that only just meets the higher noise condition at a 'standardised' wind speed of 6 m/s but has more headroom at all other wind speeds.

It is clear from Figure 5 that the turbine noise level exceeds the lower of the two conditions which would have been obtained had the baseline survey measurements, from which the condition is derived, been taken two weeks earlier.

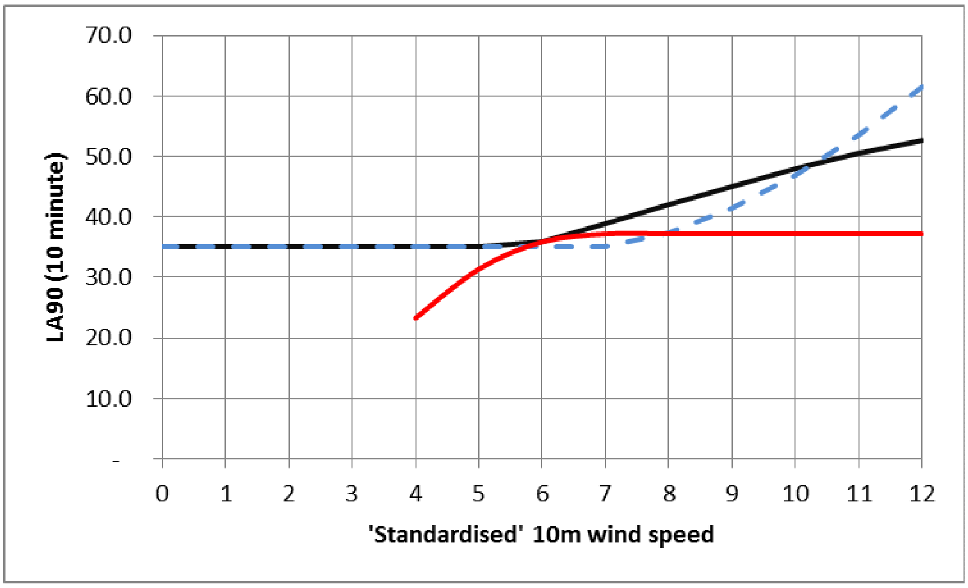

Figure 5: Red line gives turbine noise profile. The two amenity-hours noise condition profiles are obtained from the two different periods shown in Figure 4. The black line is amenity condition A, and the dashed blue line is amenity condition B.

There are many possible configurations of turbines and dwellings which could result in a noise profile as illustrated in Figure 5 but for the purposes of this discussion the diagram below describes a single potential site layout for a hypothetical two turbine wind farm with four dwellings situated NW, NE, SW and SE of the turbines.

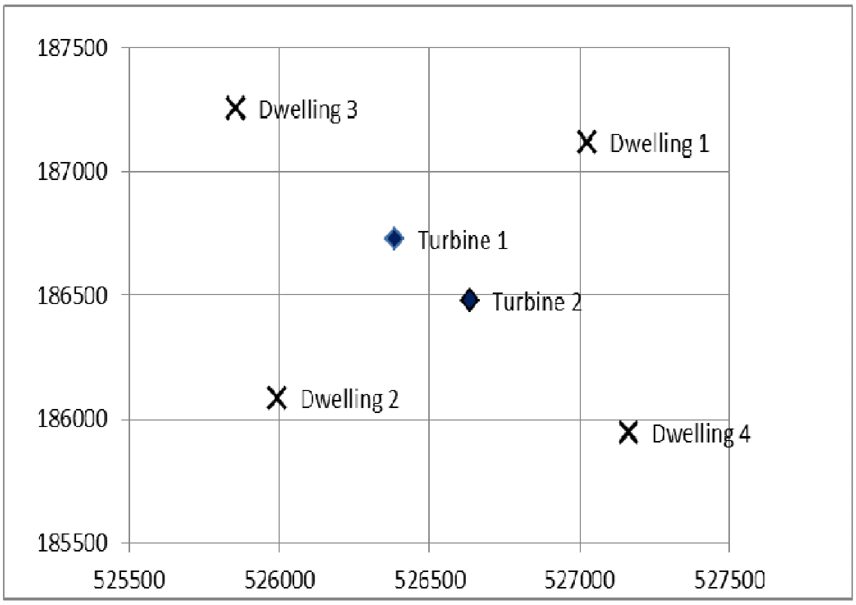

Figure 6: Hypothetical turbine and dwelling layout resulting in potential maximum turbine noise level assessed as 37.2 dB at dwellings 1 and 2, and 35.7 dB at dwellings 3 and 4.

Dwellings 1 and 2 are 750 metres from both turbines and the maximum predicted turbine noise level at these dwellings is 37.2 dBA.[6] Dwellings 3 and 4 are 750 metres from one turbine, and the maximum predicted turbine noise level at these dwellings is 35.7 dBA. The red line in Figure 5 is the predicted turbine noise level at dwellings 1 and 2. The predicted turbine noise level at the pinch-point of 6 m/s 'standardised' wind speed is 35.9dBA for dwellings 1 and 2 (34.4dBA for dwellings 3 and 4).

We have chosen the layout of the four hypothetical dwellings so that the impact of wind direction can also be taken into account. The prevailing wind direction in the United Kingdom is south westerly, so it is to be expected that dwelling 1 would face the worst noise impact.

It is generally stated by wind farm acousticians in the United Kingdom that predicted turbine noise levels are 10dB lower when a dwelling is upwind of a turbine compared to the maximum downwind level, and 2dB less when a dwelling is at 90 degrees to downwind. A formula to quantify this effect has been proposed by these acousticians as follows:

$$\text{Angle Attenuation} = 10 - \left(10^{5/3} - (A/18)^{5/3}\right)^{3/5}$$

where A is the angle in degrees between the wind direction at the turbine and the direction of turbine to dwelling. We are not aware of published data that confirms these assumptions, but nonetheless we have used the formula above as a convenient means to factor in the wind direction effects on turbine noise level predictions at the four dwellings for each of the ten minute periods in the year for which we have anemometry data.

With our wind speed dataset and the data derived from it as described in the previous sections, it is possible to investigate compliance with the different noise conditions. We have concentrated on compliance in the evening hours (i.e. between 7pm and 11pm) because this is when the fixed part of the noise condition is lower (35-40dB instead of the night-time 43dB), the background noise levels also tend to be low and wind shear tends to be increasing. The combination of these factors leads to the increased likelihood of noise problems for neighbours.

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[6] We have used the ISO 9613 methodology to calculate turbine noise levels using octave band levels for a typical 80m high turbine. The choice of parameters used in ISO 9613 calculations are contentious but in this case are not critical to the arguments discussed here which are concerned with the relative noise impacts arising from use of different methodologies for accounting for wind shear.

The following table lists the percentage of evening hours (7pm to 11pm) when there would be breaches of conditions based on condition A and condition B from Table 1. Also, shown is the percentage of time, a standard ETSU-R-97 type condition based on the measured 10 metre wind speed would be exceeded.

Table 2. The frequency of evening hours in a year which would be in breach of noise conditions derived using the *Bulletin* methodology and ETSU-R-97 for the same turbine and dwelling layout. Condition A is derived using the fortnight commencing 17 February 2008. Condition B is from the fortnight commencing 3 February 2008.

	Condition A breaches	**Condition B breaches**	**ETSU condition breaches**
Dwelling 1	0%	13%	6%
Dwelling 2	0%	4%	2%
Dwelling 3	0%	1%	0%
Dwelling 4	0%	2%	0%
Any Dwelling	0%	18%	8%

What we can see from the above table is that a *Bulletin* type condition based on 'standardised' 10 metre wind speeds for a baseline survey carried out in a relatively low shear fortnight would not be breached. Thus our hypothetical wind farm layout would be deemed on the basis of this baseline survey period to produce acceptable noise levels.

However, if the *Bulletin* method condition had been set based on data collected a fortnight earlier, that condition would be breached 13% of all evening hours at dwelling 1, and 4% of all evening hours at dwelling 2. (The difference reflects the frequency with which the wind direction is from the south west as opposed to a north easterly direction.) If the impact on all four dwellings is taken into account, the *Bulletin* method type condition would be breached at one or other of the dwellings 18% of all evening hours. Thus, if the baseline survey had been carried out 2 weeks earlier, our hypothetical wind farm layout would be judged unacceptable.

It is interesting to note that the traditional ETSU-R-97 style condition, which is based on the actual wind speed at 10 metre height rather than a shear-adjusted wind speed, would also be breached at dwellings 1 and 2 and up to 8% of all evening hours. This exercise shows that, as has been demonstrated by others,[7] the *Bulletin* methodology can produce noise conditions

[7] In *The Effect of a Common Wind Shear Adjustment Methodology on the Assessment of Wind Farms when applying ETSU-R-97,* 2011, Mike Stigwood of MAS Environmental describes the results of using actual site-specific baseline background noise surveys to compare wind farm noise conditions derived from ETSU-R-97 and the

that are less benign for neighbourhood amenity than ETSU-R-97 style conditions in spite of the claim of the authors that it overcomes the problem of site specific wind shear which was not accounted for by ETSU-R-97.

Because the *Bulletin* methodology is sensitive to sampling error and results in different noise conditions depending on the dates chosen for the baseline noise survey, it would be a matter of chance whether the site layout given in Figure 6 would be judged to be acceptable or not acceptable. This is not an adequate or fair basis for assessing the merit of a wind farm application.

Quantifying Noise Impact on Neighbouring Dwellings

For the forgoing reasons, it is our opinion that the *Bulletin* methodology is unsound and incapable of providing a proper assessment of whether a turbine layout is likely to cause noise problems. We believe that a more robust and straightforward methodology is to use a year's worth of on-site anemometry data to calculate the likelihood of complaints from neighbouring dwellings based on the BS4142 metric for assessing the impacts of industrial noise on neighbouring dwellings; namely that if the turbine noise is 8dB or more greater than the background noise level then that noise is likely to trigger a complaint.[8] If the turbine noise is between 3 and 8dB above the background, this is classed as 'marginal significance' and complaints are possible.

This approach continues to favour wind farm development as the locality of wind farms is rarely one of a mixed industrial and residential setting where greater noise from industry is

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Bulletin method. The study demonstrates that the Bulletin method of accounting for wind shear results in less protection from wind farm noise for neighbours. See http://www.masenv.co.uk/publications

[8] BS4142 classifies the likelihood of noise complaints as follows. If the LAeq of an industrial noise source that is without acoustic character sufficient to attract attention is 10dB higher than the LA90 of the existing background noise then complaints are likely. If the industrial noise (LAeq) is around 10dB lower than the existing background noise (LA90) then complaints are unlikely. A difference of +5dB is described as of marginal significance. Following ETSU practices, wind farm noise assessments use the LA90 convention for both background and turbine noise and usually adopts a fixed difference of 2dB between LAeq and LA90 noise levels for turbines. Consequently, the BS4142 complaints differences, when expressed following the ETSU convention of LA90 noise index for both turbine noise and background is as follows: If the wind farm noise (LA90) is around 8dB higher than the existing background noise (LA90) then complaints are likely. If the wind farm noise is around 12dB lower than the existing background noise then complaints are unlikely. A difference of +3dB is described as of marginal significance and complaints are possible. Where the noise contains character such as a drone or intermittency then a 5db penalty is applied to the source of noise.

expected. A rural setting would normally attract stricter criteria. Further when BS4142 is used as a planning control it is usual to set limits at least 5dB below the complaint trigger.

The following table shows the outcome of this exercise for the turbine and dwelling layout given in Figure 6. The *Evening* column gives the percentages of evenings (6pm to 11pm) in the year when there is an hour or more of consecutive periods of turbine noise levels of 33dB[9] or greater and which exceed background noise to the point where complaints are likely. It can be seen that one or other dwelling is **likely** to complain on 7% of evenings in a year and there is a **possibility** that they will complain on a further 16% of evenings in a year giving a total of 23% of the year. This amounts to more than two months of evenings.

Table 3: The frequency of evenings in a year when noise complaints are likely or possible given a minimum separation distance from dwellings to turbines of 750 metres and a layout as in Figure 6. 'Complaints likely' are the evenings of the year when turbine noise is predicted to be 8dB or more above background for an hour or more. 'Complaints possible' are the *additional* evenings of the year when turbine noise is predicted to be 3dB or more above background for an hour or more.

Location	**Complaints Likely**	**Complaints Marginal**
Dwelling 1	5%	12%
Dwelling 2	2%	5%
Dwelling 3	2%	2%
Dwelling 4	1%	8%
Any dwelling	7%	16%

We have also carried out a similar assessment of night times (11pm to 7am). In the case of night hours, BS4142 measures noise over 5 minute periods in recognition of the increased sensitivity to noise at night. Table 4 shows the frequency of nights when complaints are likely and when there is a marginal chance of complaints. In view of the fact that background noise drops through the night hours and wind shear tends to be greatest, the night time impact is even more significant. For this turbine layout, there is likely to be turbine noise sufficient to trigger complaints at one or other dwelling on 78% of all nights.

[9] An LA90 of 33dB is selected as the lower noise level to be considered in this note because BS4142 concerns itself with industrial noise levels of 35dB LAeq and higher. A wind turbine LA90 noise level of 33dB is considered equivalent to an LAeq level of 35dB .

Table 4: The frequency of nights in a year when noise complaints are likely or possible given a minimum separation distance from dwellings to turbines of 750 metres and a layout as in Figure 6. 'Complaints likely' are the nights of the year when turbine noise is predicted to be 8dB or more above background for ten minutes or more. 'Complaints marginal' are the *additional* nights of the year when turbine noise is predicted to be 3dB or more above background for ten minutes or more.

Location	**Complaints Likely**	**Complaints Marginal**
Dwelling 1	60%	13%
Dwelling 2	50%	11%
Dwelling 3	25%	5%
Dwelling 4	47%	14%
Any dwelling	78%	8%

It is helpful to see a noise level plot for a day when complaints are likely. The following figure shows a 24 hour period of turbine noise and background noise. The period of the day when the difference between turbine noise and background is least is 11am to 5pm, but for most of the remainder of the hours of the day, it is clear that the turbine noise is 8dB and more higher than background noise levels.

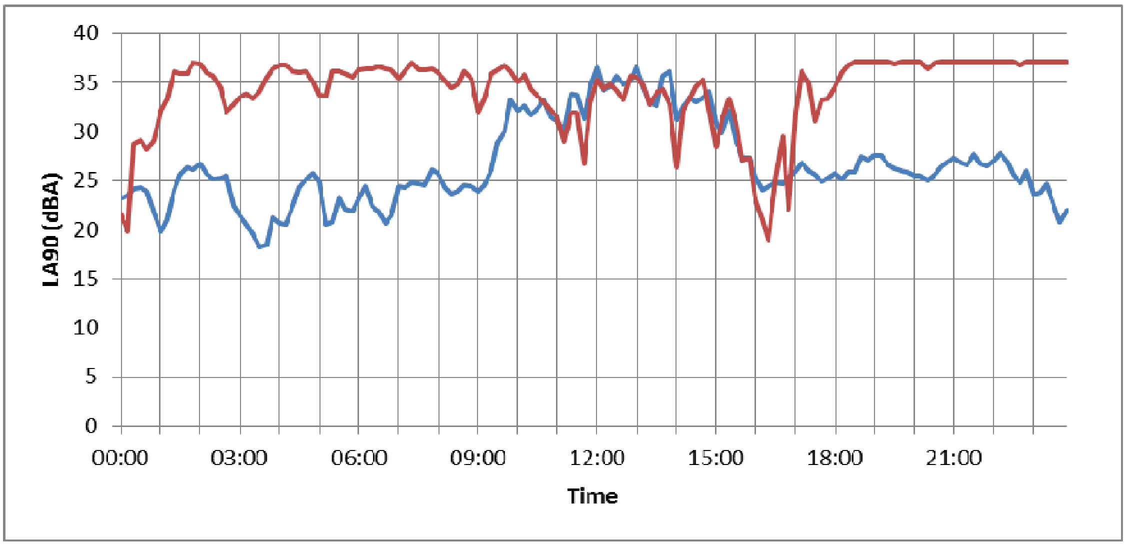

Figure 7: Average background noise (blue line) and turbine noise (red line) at Dwelling over all 24 hours of the 8th of February 2008). The periods of high wind shear during the evening and night result in an increased difference between the two noise levels, resulting in an increased probability of complaints.

We have repeated the exercise assuming that our hypothetical site in Figure 6 is revised so that all dwellings are moved away from the turbines until a minimum separation distance of 1,000 metres between each house and the nearest turbine(s) is achieved. The following table shows a reduction in potential complaint frequency, though the night time levels of complaint are still unacceptably high at 27% of all nights.

Table 5: The frequency **of** evenings and nights when noise complaints are likely given a minimum separation distance from dwellings to turbines of 1000m.

Location	**Evenings**		**Nights**	
	Complaints Likely	**Complaints Marginal**	**Complaints Likely**	**Complaints Marginal**
Dwelling 1	0%	2%	19%	13%
Dwelling 2	0%	1%	7%	6%
Dwelling 3	0%	0%	1%	1%
Dwelling 4	0%	0%	0%	4%
Any Dwelling	0%	3%	27%	21%

It is not until a separation distance of 1,150 metres is achieved that complaints according to this metric would fall to zero because the predicted turbine noise level drops below 33dB. However, it should not be assumed these results confirm that a separation distance of 1,150 metres would prevent noise complaints. The BS4142 guidance indicates that the wind turbine noise would need to be 12 dB lower than background before complaints are *unlikely* to occur. Furthermore, we have not taken into account the possibility that the turbine noise may contain 'acoustic features' such as beats or hums or thumps that increase the likelihood of complaints.

The levels of Amplitude Modulation (AM) that we discussed in a previous note[10] would reasonably be considered to constitute such an acoustic feature. The BS4142 guidance would require a 5dB penalty to be applied to the turbine noise if AM was a feature. This effectively means that noise differences between background and turbine of 3dB or more would be likely to result in complaints.

Audibility is also an issue for determining the significance of loss of amenity. It needs to be appreciated that a zero difference between background and turbine noise levels does *not* indicate that the turbine noise will be inaudible. The turbine noise would need to be *lower* than the background for it to be likely to be masked by ambient noise and thus inaudible.

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[10] See http://www.ref.org.uk/publications/242-the-den-brook-amplitude-modulation-noise-condition

Inaudibility depends on how effectively the background noise masks the turbine noise. Some noise can be audible 12dB below the background noise but generally only if its characteristics are very different to the existing masking noise environment.

What our exercise does show is that the minimum separation distances between turbines and dwellings indicated by the *Bulletin* methodology as sufficient will nevertheless result in noise complaints and unreasonable loss of neighbours' amenity. Whereas one of the variable *Bulletin* noise conditions suggests that a 750 metre separation distance for our hypothetical site would be acceptable, our calculations show that the distance would need to be nearer 1,150 metres, and without any acoustic feature to avoid noise complaints. Our method also usefully demonstrates that the impacts for each dwelling vary depending on its bearing with respect to the turbines.

We recommend our method of quantifying the potential frequency of noise complaints in a year as a means of revealing the actual impacts of noise from a proposed wind farm in a much more accessible way than the material routinely produced in noise assessments.

Independent Verification

One of the difficulties inherent in assessing the merits of current wind farm noise methodologies is that the requisite data needed to test them is not provided by the authors. Effective, indeed proper, scientific process requires that sufficient data is produced such that assertions, calculations and conclusions can be independently verified. We would very much like to see a greater openness with wind turbine noise data, and with this in mind will undertake to provide the data used in this study on request so that others can test our calculations and conclusions.[11]

Dr Lee Moroney
Dr John Constable
10 April 2012

[11] All requests can be directed to planning@ref.org.uk, or by post to 21 John Adam Street, London, WC2N 6JG.

Appendix 1.

ETSU-R-97 gives a mathematical definition quantifying wind shear and examples of wind speeds at various heights at page 120. The definition is based on an assumption that the wind speed at turbine hub height is a constant multiple of the wind speed at 10 metres height which has been proved to be an error resulting in a significant understatement of turbine noise at neighbouring dwellings.[12]

The set of wind speed data used in this study can be used to illustrate the problem. We have calculated the predicted noise levels of a single turbine at a dwelling located 500 metres to the North West of the turbine given the actual range of wind directions experienced over a year and using the erroneous ETSU-R-97 wind shear assumption to derive the range of hub height wind speeds.

The results of these calculations for a year of night time wind speed data are plotted in Figure 8. The noise levels range over 10 dB for any given wind speed arising from the variation in wind directions: noise levels when the dwelling is up-wind of the turbine are expected to be 10 dB lower than when downwind. Because the dwelling in this calculation is north east of the turbines and the prevailing wind is south westerly, the noise levels tend to be more often at the higher end of the 10dB range.

It can be inferred from the graph that a noise condition fixed at 35dB at low wind speeds would not be breached. Furthermore, although the background level is exceeded for wind speeds between 4 and 7 m/s, the turbine noise levels do not reach 8 dB above background, so it might also be inferred that noise complaints would not arise. However, these inferences would be wrong as can be seen from Figure 9.

Figure 9 shows the results of the same calculation but using the actual hub height wind speeds and using the correct wind shear assumptions. What is immediately apparent is that the turbine noise at the dwelling is significantly greater than the background noise for much of the time. In fact, in this example, 75% of the time the turbine noise exceeds background and 40% of the time that exceedence is more than 8 dB indicating that noise complaints would be likely. It can also be seen that a 35dB noise limit would be breached.

Thus, these two figures show how the wind shear error in ETSU-R-97 might have led the authors into the mistake of very significantly underestimating the noise impacts for

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[12] '*Effects of the wind profile at night on wind turbine sound*', G.P. van den Berg, J. of Sound and Vibration, 2003.

neighbours and loss of amenity arising from the high fixed limit noise levels the guidance recommends.

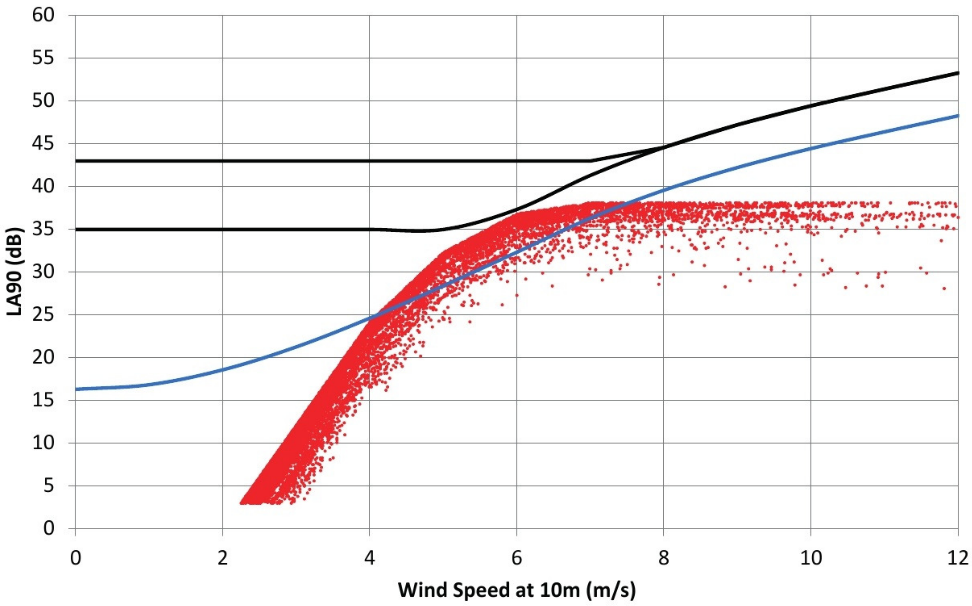

Figure 8: Predicted wind turbine noise based on the erroneous ETSU-R-97 assumption regarding wind shear. The red dots are wind turbine noise; blue line is night hours prevailing background noise curve and the two black lines are 35dB and 43 dB noise limits based on this background.

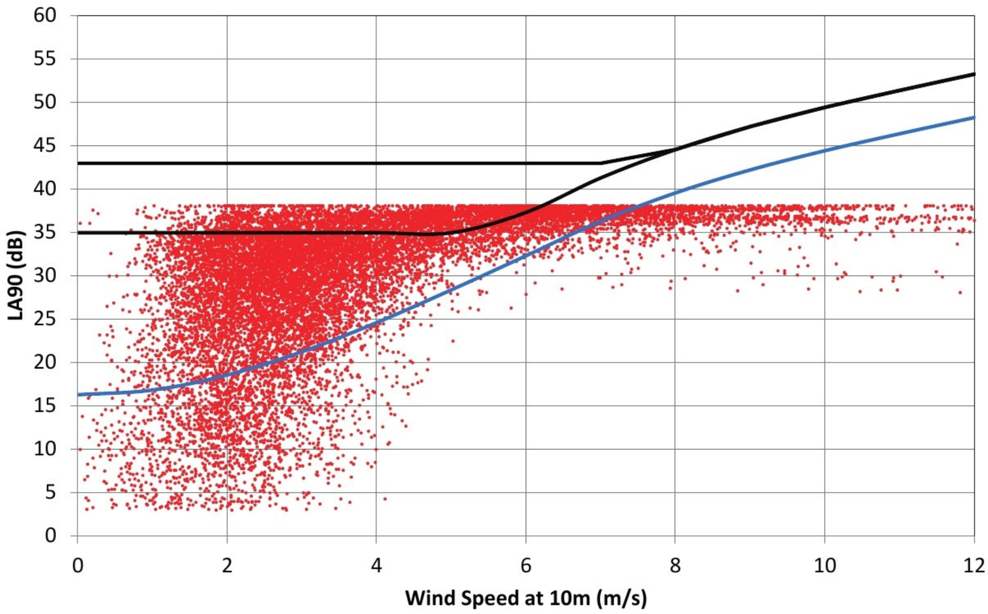

Figure 9: Predicted wind turbine noise based on actual wind shear. The red dots are wind turbine noise; blue line is night hours prevailing background noise curve and the two black lines are 35dB and 43 dB noise limits based on this background.