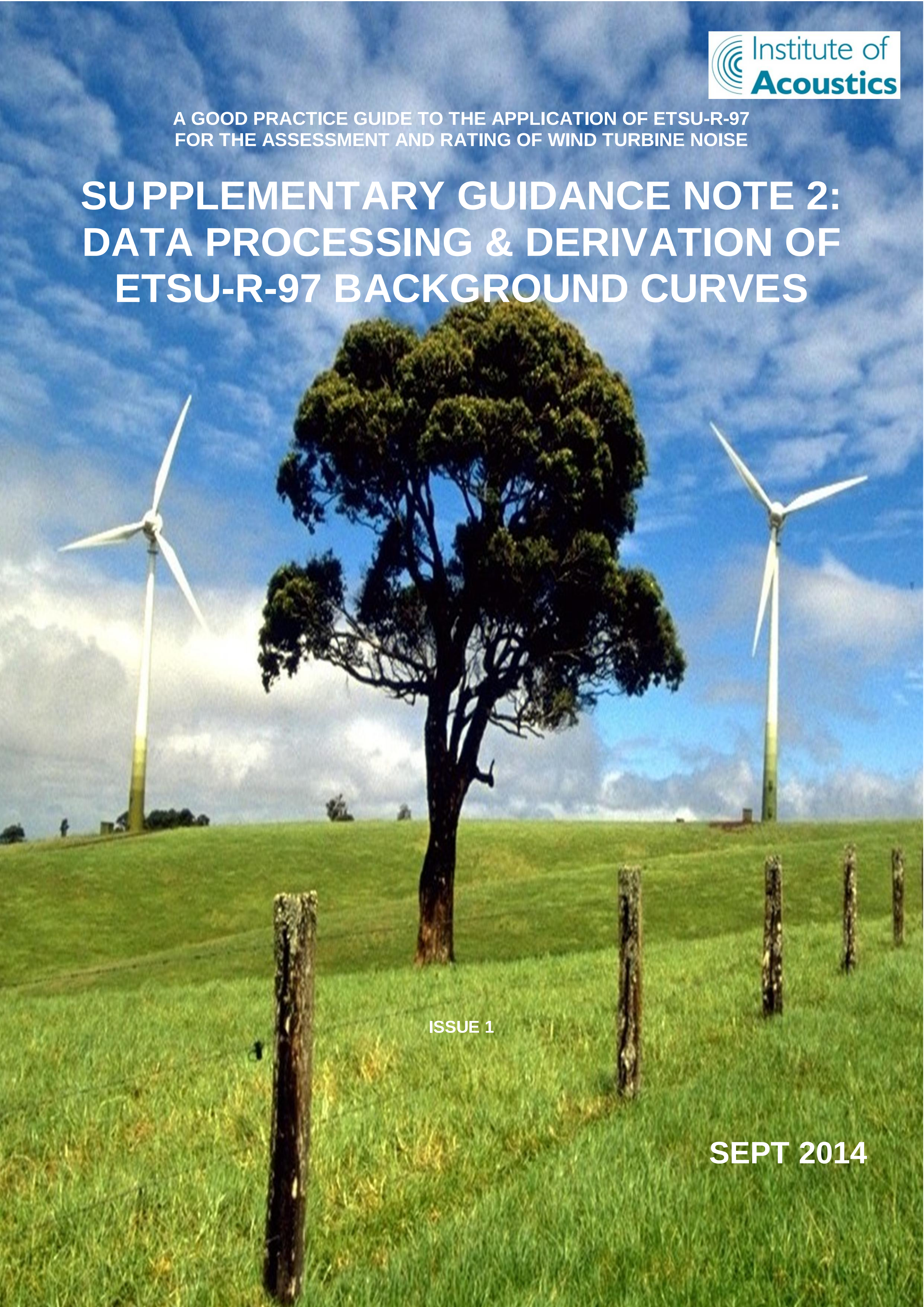
Institute of Acoustics

A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE

SUPPLEMENTARY GUIDANCE NOTE 2: DATA PROCESSING & DERIVATION OF ETSU-R-97 BACKGROUND CURVES



ISSUE 1

SEPT 2014

PREFACE

This document has been produced by a working group on behalf of the Institute of Acoustics consisting of the following members:

Matthew Cand	Hoare Lea Acoustics
Robert Davis	RD Associates
Chris Jordan	Northern Group Systems (Environmental Health)
Malcolm Hayes	Hayes McKenzie Partnership Ltd.
Richard Perkins	Parsons Brinckerhoff Ltd.

The working group gratefully acknowledges the assistance provided by James Mackay from TNEI Services in the drafting of this note.

This supplementary guidance note has been produced to supplement the IOA document 'A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE' which is available on the IOA website at the following link: http://www.ioa.org.uk/publications/good-practice-guide (checked 06.09.14).

Prior to publication of this note, a peer review was undertaken by a separate group.

Any comments on this document should be sent to ETSUCONSULT@IOA.ORG.UK. The IOA will keep the document under review, and consider updating when significant changes to current good practice have occurred.

Richard Perkins
Working Group Chairman & Editor.

Institute of Acoustics

3rd Floor St Peter's House
45-49 Victoria Street
St. Albans
Hertfordshire
AL1 3WZ
United Kingdom
www.ioa.org.uk

Supplementary Guidance Notes

Number	Title	Information
1	**Data Collection**	Equipment specifications; measurement surveys: Practical considerations and set-up guidance and examples.
2	**Data Processing & Derivation of ETSU-R-97 background curves**	Data filtering, processing and regression analysis for different types of noise environments.
3	**Sound Power Level Data**	Manufacturer's data and warranties analysis.
4	**Wind Shear**	Wind speed references and long-term data analysis.
5	**Post Completion measurements**	Examples, considerations and strategies.
6	**Noise Propagation over water for on-shore wind turbines**	Noise propagation for on – shore turbines, or those close to the shore over large bodies of water.

CONTENTS

1 Context

1.1 Background

1.1.1 The Institute of Acoustics (IOA) published 'A GOOD PRACTICE GUIDE TO THE APPLICATION OF ETSU-R-97 FOR THE ASSESSMENT AND RATING OF WIND TURBINE NOISE' (GPG) in May 2013 to provide technical assistance for the undertaking of wind turbine noise assessments using the ETSU-R-97 document. In order to keep the GPG to a reasonable length, but not to lose clarifications and case studies, it was decided to produce a number of supplementary guidance notes which would support the GPG.

1.1.2 This guidance note will be of relevance to:

i. Acoustics consultants;
ii. Local Planning Authority (LPA) Environmental Health and Planning departments;
iii. Developers;
iv. The Planning Inspectorate or equivalent regulating authority;
v. The general public.

1.2 Scope of the Document

1.2.1 A series of six Supplementary Guidance Notes have been produced. This Supplementary Guidance Note 2 supports Section 3 of the GPG. It provides examples of data processing which can be used to ensure that the influence of atypical noise sources on the measurement of background noise levels is minimised and to ensure that a typical representation of the existing noise environment is obtained. The derivation of ETSU-R-97 background noise curves is also discussed.

1.3 Statutory Context

1.3.1 This Supplementary Guidance Note has been approved by the IOA Council for use by IOA Members and others involved in the assessment and rating of wind turbine noise using ETSU-R-97. It covers technical matters of an acoustic nature which the IOA-NWG believes represent current good practice.

2 Data Processing

2.1 Introduction

2.1.1 Scatter graphs and time history plots should be analysed to identify atypical data as required by ETSU-R-97. This can be supplemented by information provided by residents as discussed in paragraph 2.5.9 of the main GPG. The graphs in this SGN include rain data (blue squares) and manually excluded data (red triangles). Inclusion of these data on scatter plots ensures transparency and demonstrates that the dataset has been appropriately analysed (explanations for manually excluded data should always be provided). There are a number of factors which may need to be considered when analysing background noise data, this note expands on each of the key points raised in Section 3 of the main GPG document.

2.2 Adequate dataset

2.2.1 A minimum of 200 valid data points should be recorded during both amenity hours and night time periods (100 where data has been filtered for wind direction). Care should be taken to ensure that the data set is representative of typical levels, e.g. 200 data points collected when the wind is blowing from a direction which rarely occurs according to a historical wind rose may not provide a robust dataset. At the same time, a wind direction that results in a lower background noise level being derived would result in a conservative assessment.

2.2.2 The range of data collected should enable a suitable representation of typical background, considering site-specific factors based on the individual characteristics of the noise environment at each location. In the example illustrated below in Figure 13, the scatter in the data is associated with different wind directions due to the presence of a distant road source: sufficient data was obtained to characterise the variation of background with wind speed over the relevant range of wind speeds for the relevant wind direction. In other cases, a review of the time history of the measurements can show that outliers in the scatter of the data can be attributed to individual atypical events or a period of increased rainfall, and the adequacy of the remaining data can then be considered in line with the GPG requirements.

2.3 Data filtering

2.3.1 The soundscape at any given location will typically be made up of number of different elements including: wind-induced noise from vegetation, road traffic noise, noise from local agricultural activities and noise from animals including birds and livestock. Any data affected by noise which is not considered to be typical for a location should be identified and removed; atypical conditions can include roadworks, boiler flues, seasonal agricultural activities (such as harvesting or grain drying) noisy DIY activities or an annual event such as a music festival.

2.3.2 It should however be noted that the background noise assessment is an objective assessment and assessors should not have any preconceptions about the likely spread of the data set or the correlation with wind speed. Any data exclusions should be clearly identified and explained.

2.3.3 Identification of unrepresentative data can be difficult but atypical noise sources are often not influenced by wind speed and can therefore result in 'banding' in the noise data which can be apparent in scatter graphs of background noise level against wind speed. Figures 1 and 2 illustrate data that was influenced by a fixed level noise source, in this case a boiler flue and other anomalous noise data removed from the analysis (shown in red).

Figure 1 Scatter Graph Showing Dataset Affected by Boiler Flue

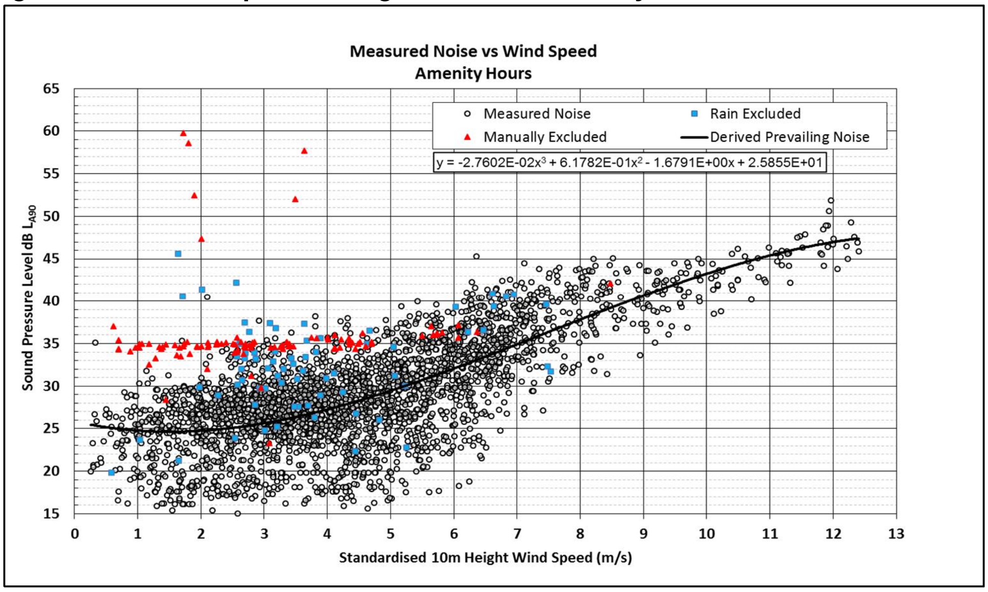
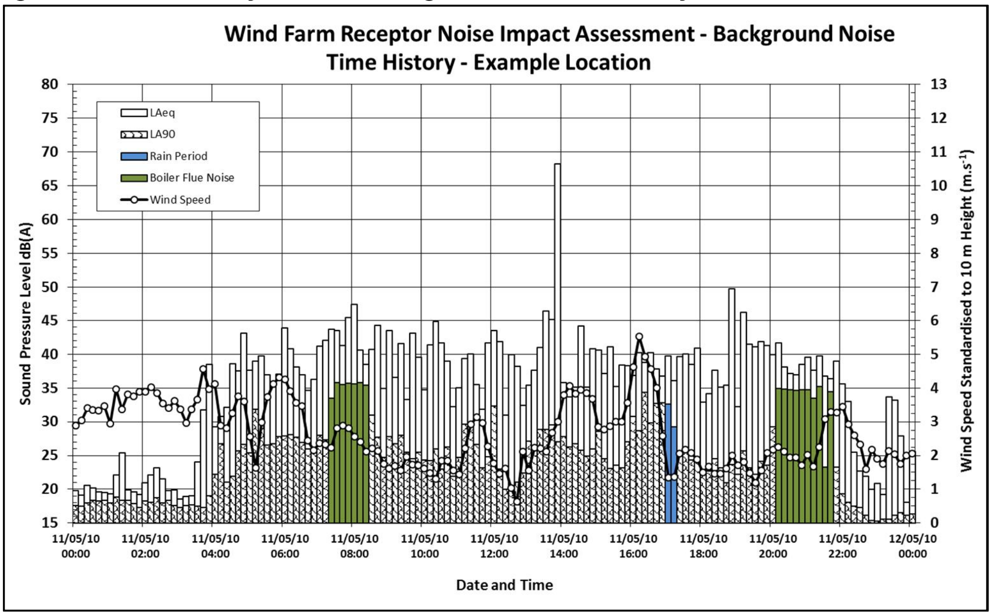


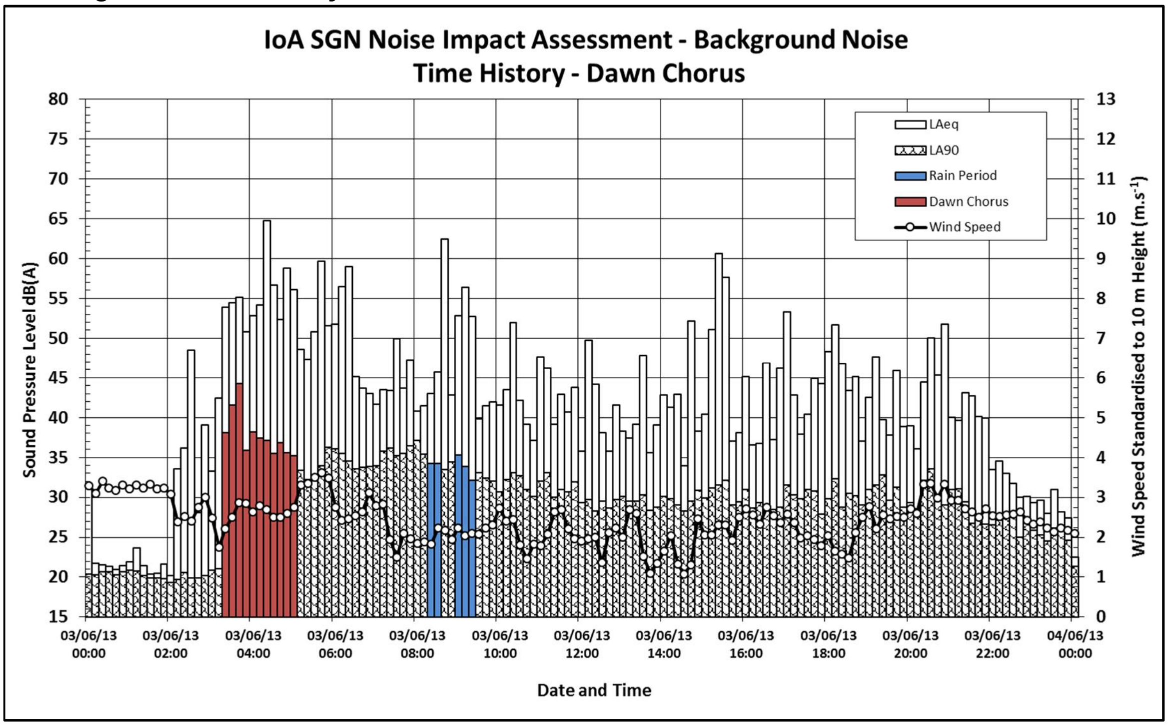
Figure 2 Time History Plot Showing Dataset Affected by Boiler Flue



2.3.4 For some situations (for example a farm with milking sheds which operate all year round), the full dataset may be representative of the environment at the measurement location. However, the affected data should be excluded if the dataset is to be used as a proxy data set for other locations which are not subject to the specific noise source identified.

2.3.5 The influence of the early morning dawn chorus on the overall dataset should also be investigated. The dawn chorus can lead to elevated levels of background noise approximately one hour before and half an hour after sun rise. The impact of the dawn chorus varies significantly throughout the year (being at its most noticeable in the spring) whilst some locations are affected more than others. Figure 3 provides an example of a dataset with clear dawn chorus effects; where clear dawn chorus effects are present the affected data should be removed.

Figure 3 Time History with Clear Dawn Chorus Events

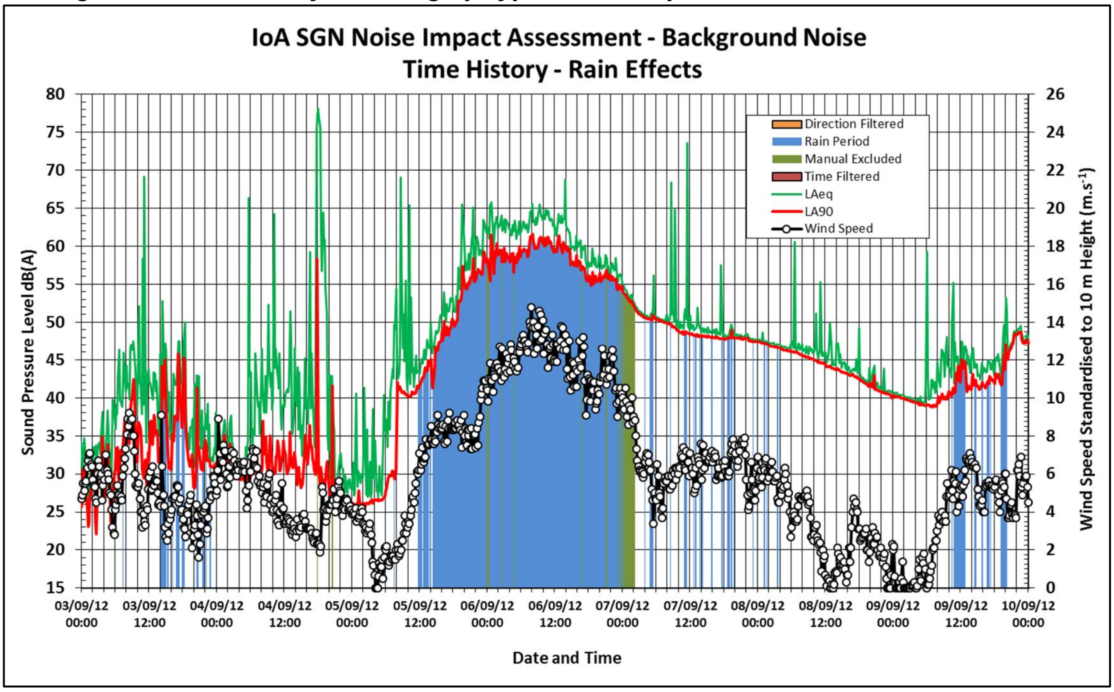


2.3.6 Removal of clear dawn chorus effects will affect the average background noise levels most notably during the ETSU-R-97 night-time hours. Depending on the range of noise levels and wind speeds recorded, the removal of clear dawn chorus may also affect the noise limits although the impact can be very small due to the reliance on the ETSU-R-97 night time fixed minimum limit of 43dB (rather than the background noise level plus 5dB) at most quiet rural locations. In the event that a lower night-time noise limit is agreed then such effects may become more important to eliminate.

2.4 Rain Data

2.4.1 Rain can affect background noise measurements at some locations much more than others. Levels can be increased due to the direct effects of the rain (as noise is generated by rain hitting buildings and vegetation) but, at some locations, it is the indirect effects which can have the biggest influence on measured levels. Indirect effects can include increased noise resulting from traffic passing along wet roads and increased noise from watercourses as flow rates increase following rain. In some areas of the UK, particularly quiet, hilly, regions, the impact of increased river flows can be very significant. In some locations, where a river has a large catchment area, rainfall falling in the wider area can affect background noise levels at properties several kilometres away, which are located next to an affected river, for an extended period after the rain has fallen. Figure 4 shows data collected at a property affected by increased river flow. Initially the noise data illustrates a fairly typical diurnal variation but after a period of heavy rainfall it can be seen that levels remain high for several days. If rainfall and the resulting watercourse flow rates during that period are atypical it may be appropriate to remove the affected period. It may also be seen from Figure 4 that prior to rainfall, an increase in background noise level occurs that may be the result of increased water flow due to rainfall elsewhere in the river catchment.

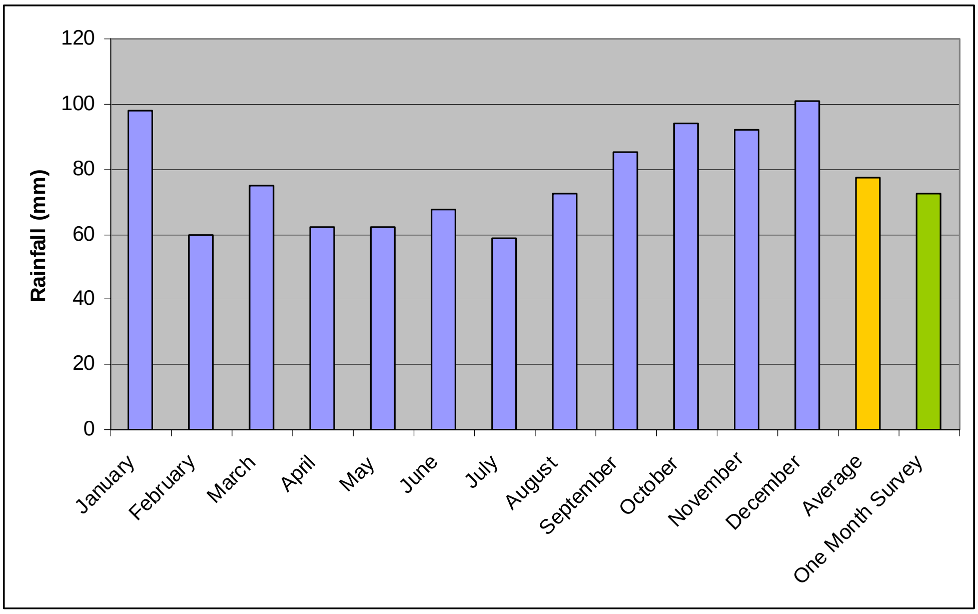
Figure 4 Time History Showing a) Typical, then b) Rain Affected Data



a) Typical Data 04/09/12 and Rain Affected Data 07/09/12

2.4.2 It should be noted that, at some locations, the background noise environment will be dominated by noise from watercourses and the data may therefore show little correlation with wind speed. In such circumstances data filtering may not be necessary, this can sometimes be supported by using long term rain data for the area to show that rain fall during the survey period was not unusually high as illustrated in Figure 5. Rainfall data obtained at nearby weather stations may be used as long term rain data collected at the wind farm site may not be available.

Figure 5 Comparison of Long Term Rain Data and Data Collected During Background Noise Survey

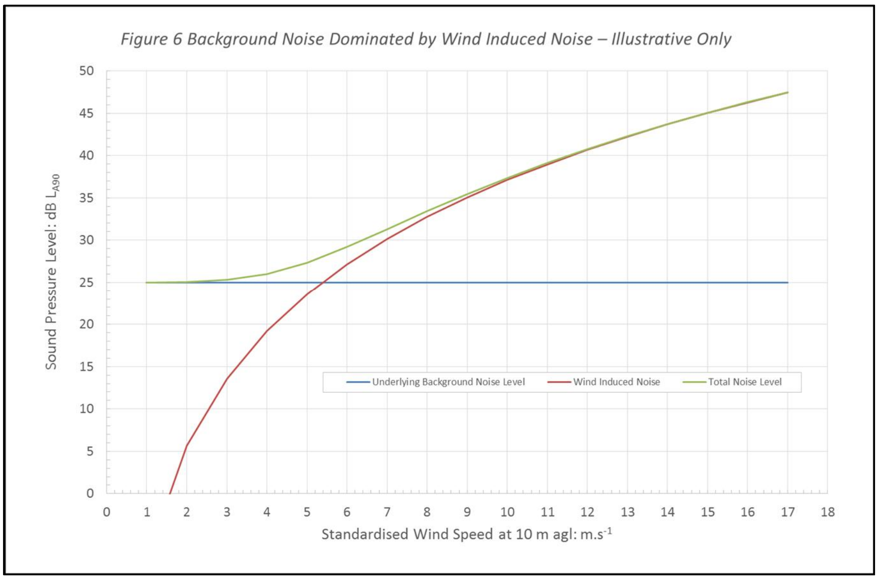


2.5 Traffic Noise

2.5.1 Background noise data collected at locations which are dominated by traffic noise may show very little correlation with wind speed. Whilst this is not consistent with many of the example datasets in ETSU-R-97 this does not invalidate such datasets.

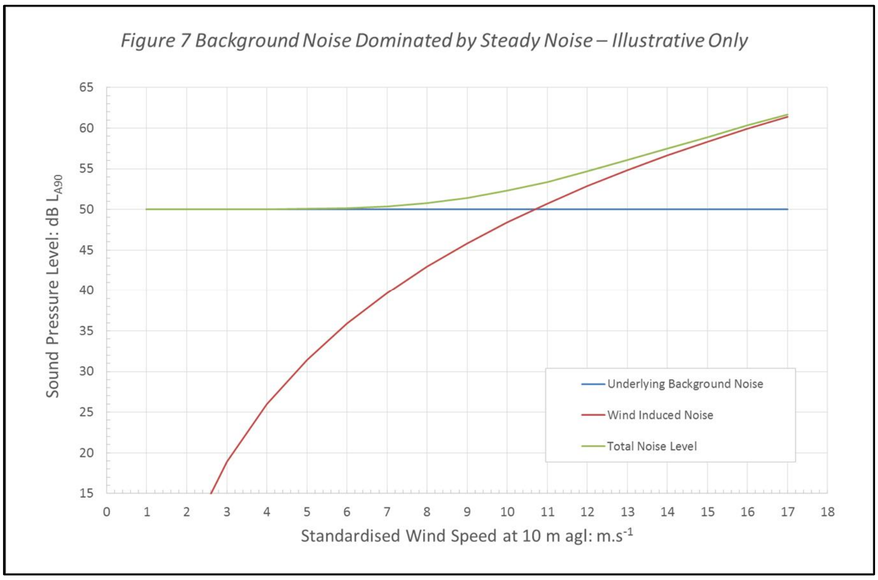
2.5.2 As Figure 6 illustrates, in typical quiet rural locations background noise is composed of the underlying 'steady' noise together with an element that reflects the 'wind induced noise'; this might be interaction of the wind with trees, foliage or buildings for example. As wind speed increases, the wind induced component becomes increasingly dominant.

Figure 6 Background Noise Dominated by Wind Induced Noise – Illustrative Only



2.5.3 Figure 7 shows a different scenario. In situations of higher background noise, more typically found in urban locations but also in rural areas influenced by a very loud noise source e.g. a motorway or a large river with constantly high flow rates, the impact of the wind component is quite different. Wind induced noise increases in just the same way, but since the underlying noise is at a significantly higher level the resultant overall background noise level does not change until higher wind speeds are experienced.

Figure 7 Background Noise Dominated by Steady Noise – Illustrative Only

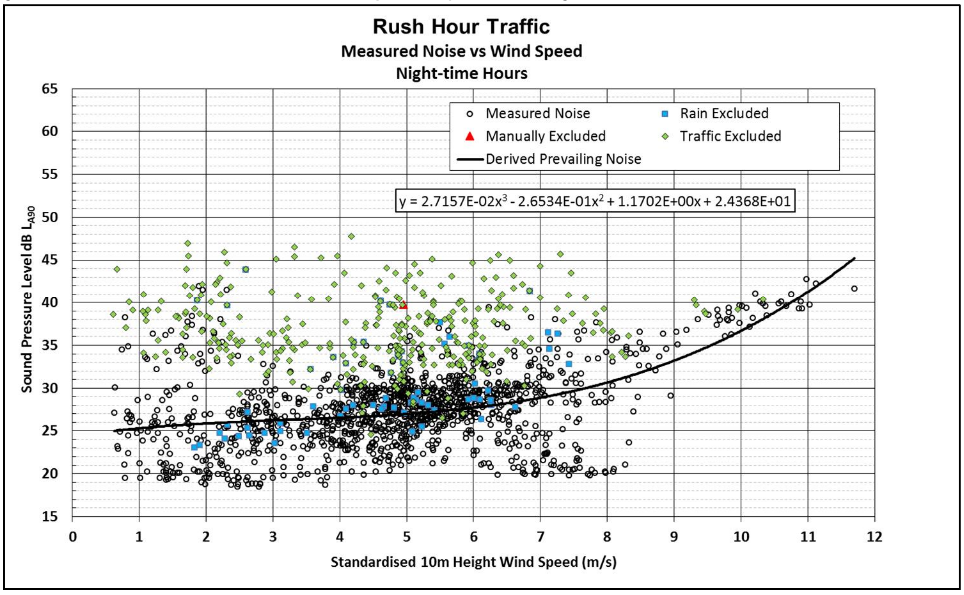


2.5.4 At some locations adoption of a noise limit which does not vary significantly with wind speed may be appropriate as long as the levels of 'steady' noise is representative of typical conditions at the property in question.

2.5.5 Notwithstanding the above, it may sometimes be necessary to filter out traffic noise if it is considered atypical, for example, if measurements were affected by increased traffic movements occurring during an annual music festival or the measurements were undertaken during a rare wind direction that increased the prevailing background noise.

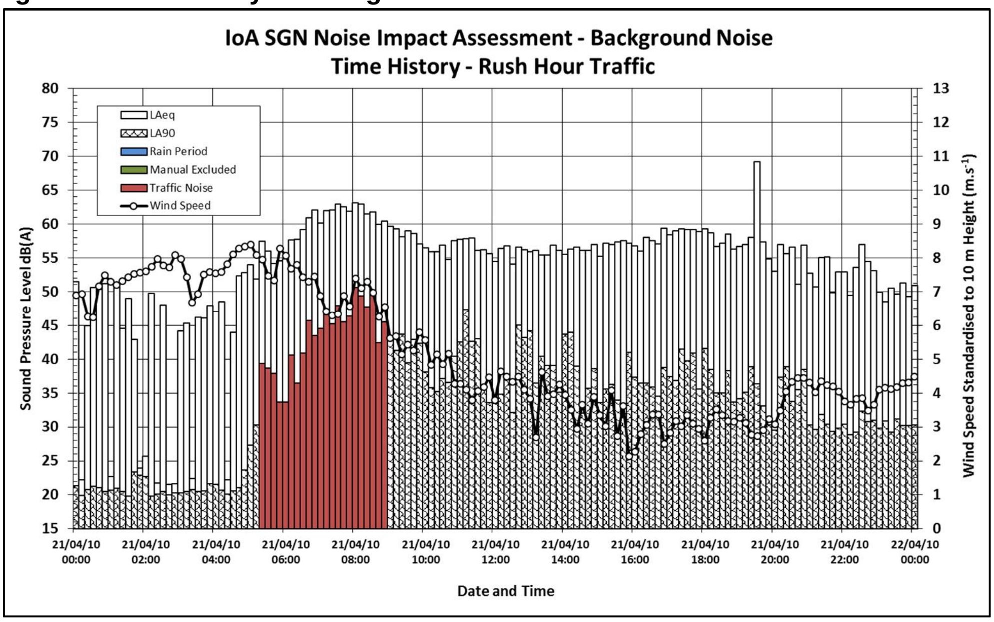
2.5.6 Rush hour traffic can influence measured background noise levels as this may be evident for some sites where a split or a large range in the data can occur as shown in Figure 8.

Figure 8 Scatter Plot Affected by Early Morning Rush Hour Traffic



2.5.7 Examination of a time history graph can prove useful where such splits are evident in the data, periods of low background noise can occur during the early hours of the morning whilst rush hour traffic can begin to dominate towards the end of the ETSU-R-97 night time period. Figure 9 provides a time history graph where background noise data is affected by a morning rush hour. Where rush hour traffic is considered typical it should not be removed from the dataset.

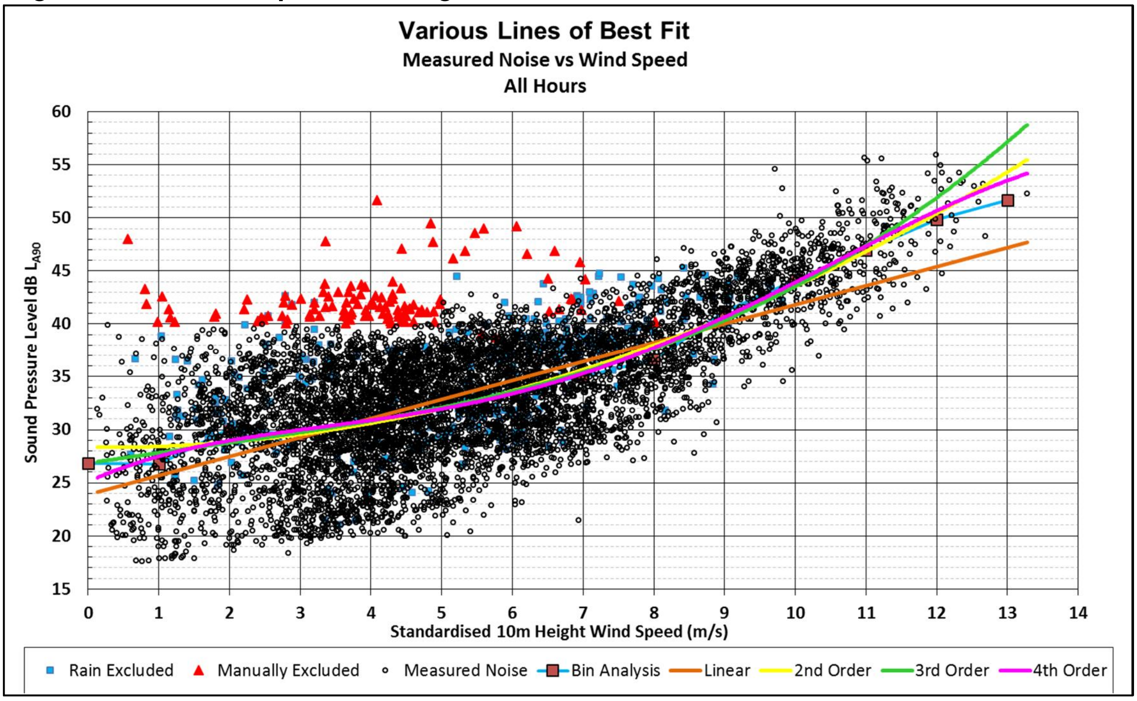
Figure 9 Time History Showing Increase in Noise Levels due to Traffic Noise



2.6 Derivation of Wind Speed & Background Noise Plots

2.6.1 For a given dataset a number of methods can be adopted to derive the average prevailing background noise level. Figure 10 illustrates linear, 2nd, 3rd and 4th order polynomials for the same dataset.

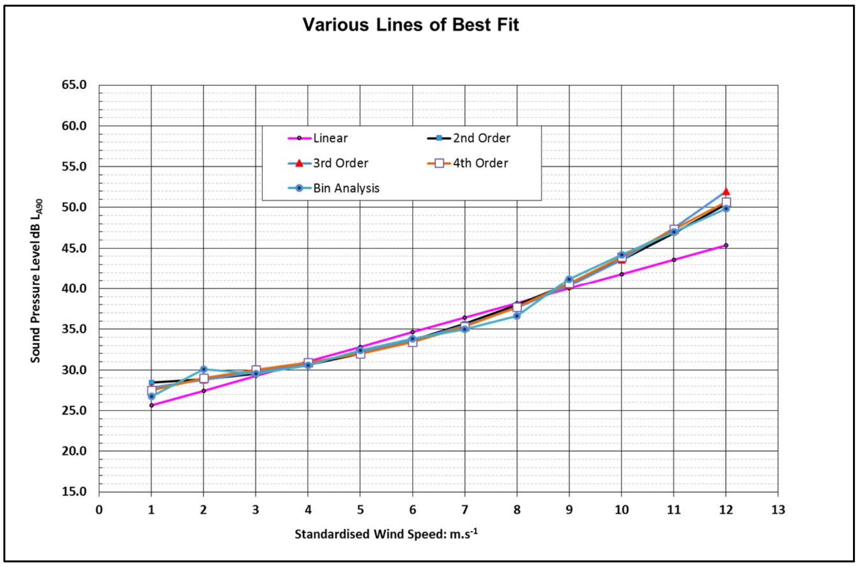
Figure 10 Scatter Graph Illustrating Various Lines of Best Fit



2.6.2 The choice of line of best fit requires a degree of professional judgement but the chosen curve should be representative of the entire dataset whilst being mindful of the values of the limits being derived at the key wind speeds. In the example above it would not be appropriate to use a linear line of best fit as it underestimates background noise at lower and upper wind speeds whilst over estimating background noise for mid-range wind speeds; the third or fourth order polynomial provides a better all-round fit.

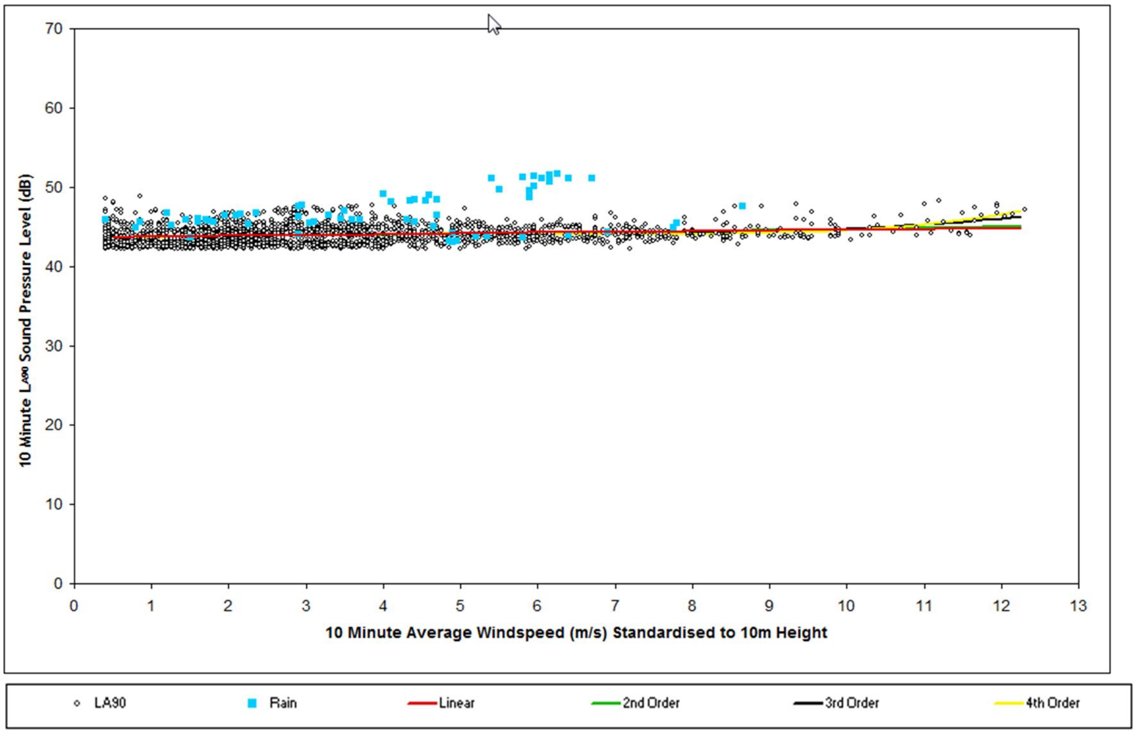
2.6.3 Figure 11 below details the best fit regression curves with bin analysis also applied to the data within Figure 10. This provides an indication as to the curve that may be appropriate for determination of the prevailing background noise level at this location.

Figure 11 detailing best fit regression curves and bin analysis results for same data set.



2.6.4 Figure 12 illustrates linear, 2nd, 3rd and 4th order polynomials for a very different dataset. Background noise at this measurement location was dominated by a nearby weir, flow rates varied very little over the seasons and the whole dataset was considered representative of the location.

Figure 12 Scatter Graph Illustrating Various Lines of Best Fit



2.6.5 Given that background noise at this measurement location was dominated by a nearby weir, flow rates varied very little with wind speed, in this instance the use of a linear polynomial would be appropriate.

2.6.6 Normally a third order polynomial is considered to be appropriate by the IOA NWG but each dataset should be carefully considered to derive a line of best fit that adequately reflects the dataset whilst also providing robust limits for the key wind speeds. For most sites where pitch regulated turbines are proposed / installed the key wind speed (where predicted turbine noise is closest to the derived noise limit) is often between 6 and 8 metres per second. The choice of the most appropriate polynomial will be subject to a degree of judgment and it should be noted that the choice should not be made based on which order results in the highest r-squared value.

2.7 Directional Analysis

2.7.1 The dataset below provides an example of where directional filtering would be appropriate. The noise sensitive property is located to the north east of a proposed wind farm and there is a motorway to the north east of the property. Under ‘typical’ conditions (when the wind is blowing from the south and or the west) motorway noise would be lower, however a large proportion of the baseline dataset was collected during periods of north easterly winds which are not very common and would result in higher average background noise levels due to an increase in the contribution from the motorway.

2.7.2 Figure 13 shows the full dataset and a split in the data is evident.

Figure 13 Scatter Graph Illustrating Dataset Affected by Motorway

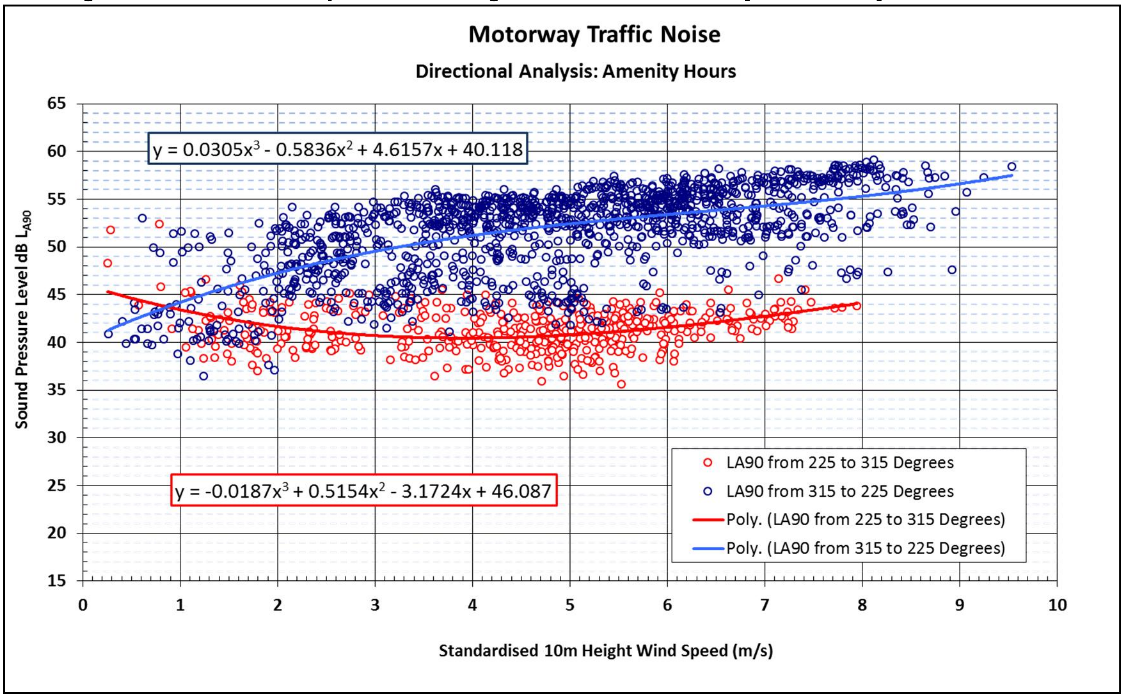
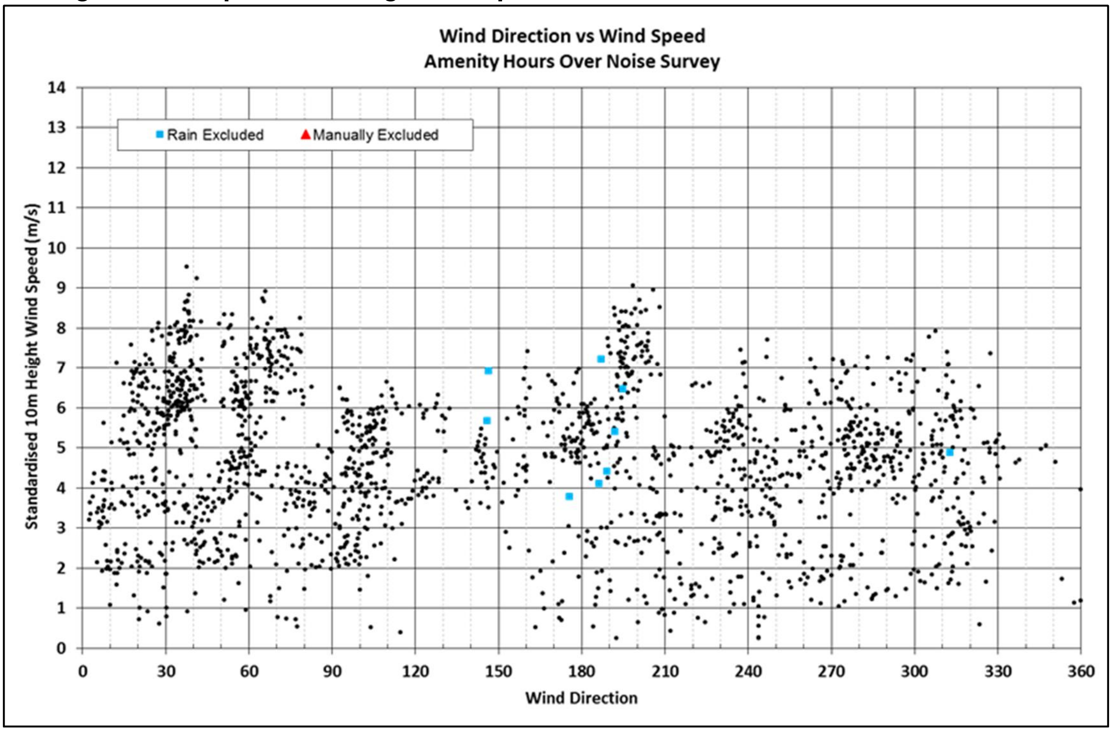


Figure 14 Graph Illustrating Wind Speed Vs Wind Direction



2.7.3 Removal of data collected when the wind was flowing from +/- 45degrees of the motorway removes the band of louder background considered in this example to be unrepresentative for this location.

2.8 Use of a Single Fixed Minimum Limit

2.8.1 At some sites background noise levels do not vary significantly during amenity hours and night time periods as is illustrated in Figures 15 and 16, for such situations it may be appropriate to derive one noise limit to be applied during all periods as described at page 63 of ETSU-R-97. A merged dataset is provided in Figure 17.

Figure 15 Amenity Hours Dataset

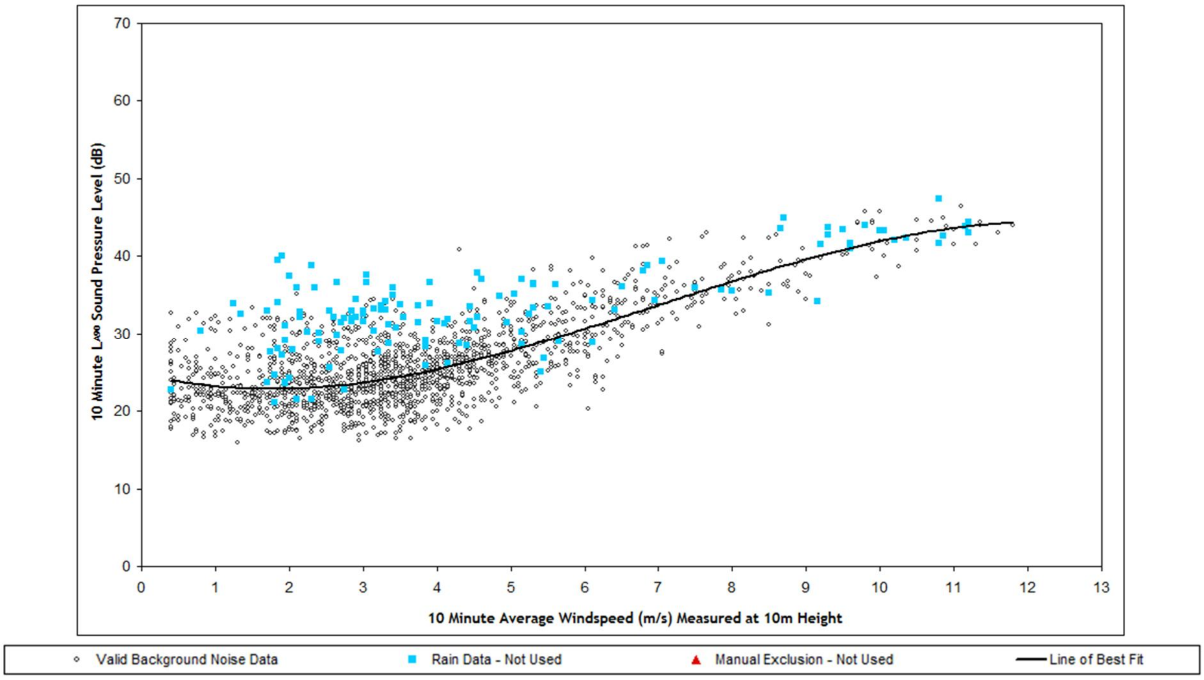


Figure 16 Night Time Dataset

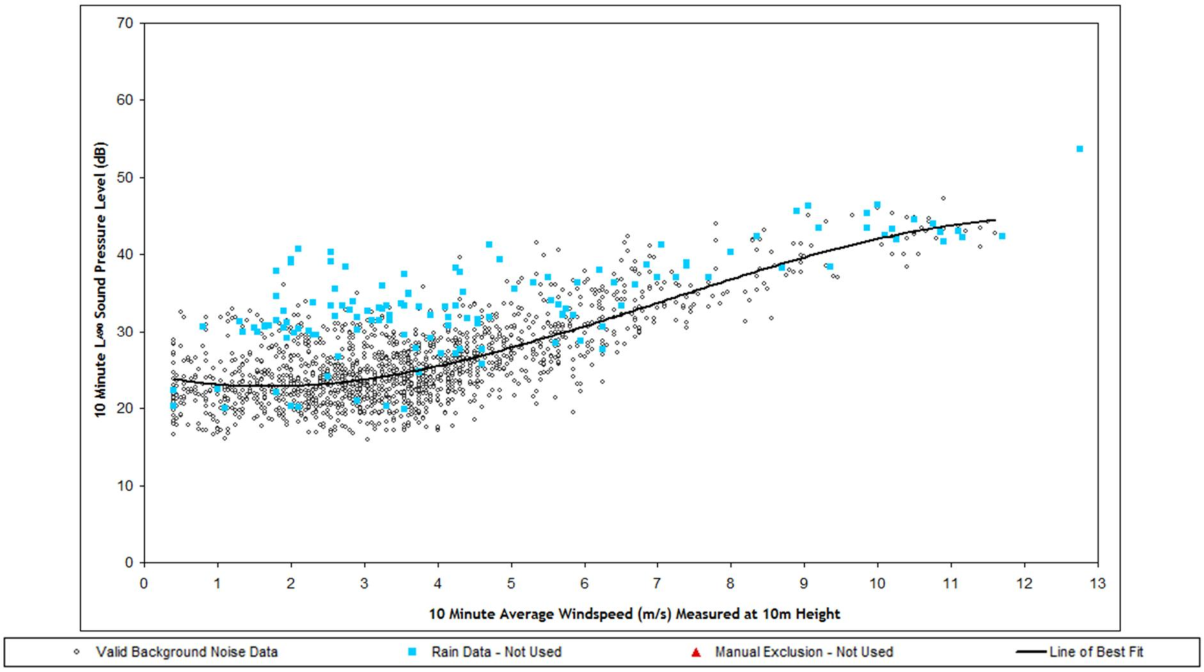
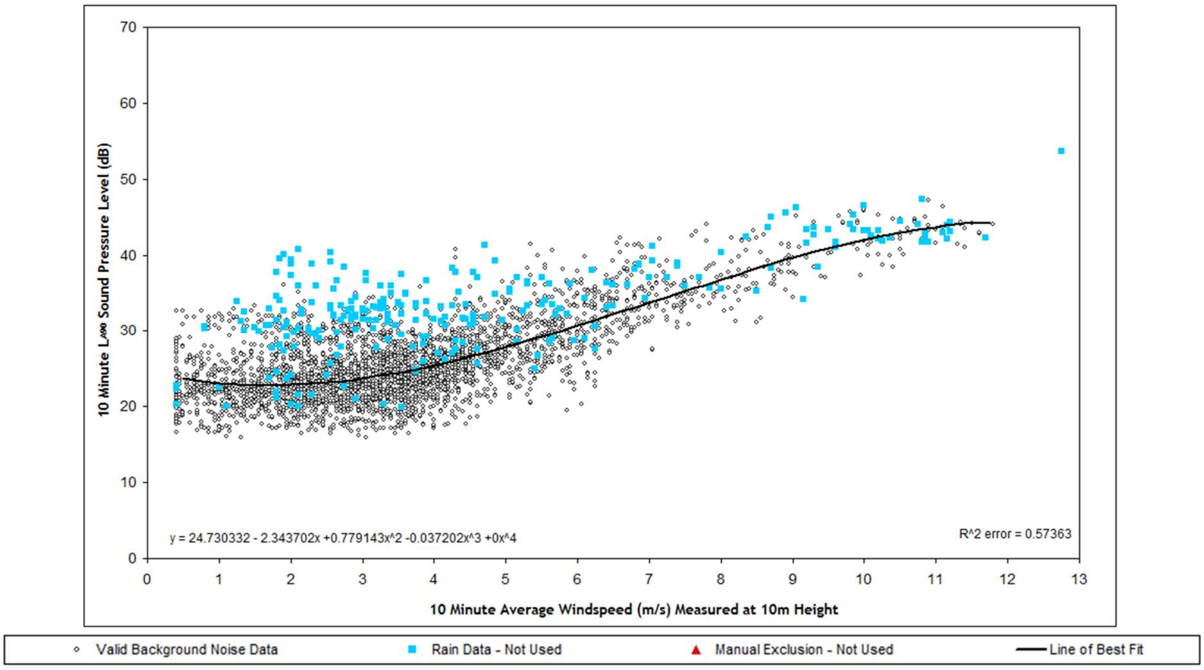


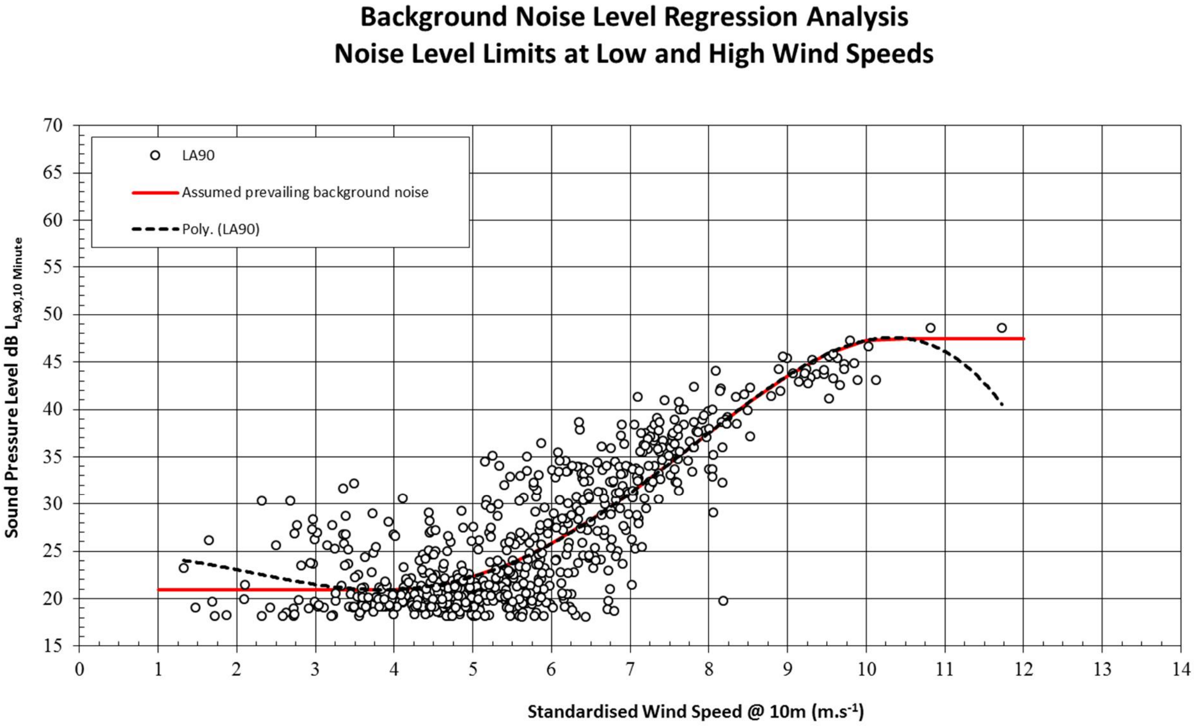
Figure 17 Combined Amenity Hours and Night Time Dataset



2.9 Limiting the Upper and Lower Background Noise Levels

2.9.1 The GPG suggests that where a noise curve increases at lower wind speeds then levels should be fixed at the minima. Where background noise data has not been collected for higher wind speeds it may be appropriate to cap the background noise curve (and therefore the associated noise limit) as illustrated in Figure 18 below. It is normal to run the regression analysis on the full dataset before applying the cap.

Figure 18 Flat Lined Background Noise Level at Lower Wind Speeds



Institute of Acoustics