European Offshore Wind Deployment Centre

Environmental Statement

Appendix 24.1: In Air Noise Baseline Technical Report

A project part-funded by the European Union under the European Economic Plan for Recovery in the field of Energy

1 IN – AIR NOISE BASELINE TECHNICAL REPORT

1 This baseline technical report describes the measurement of the background noise and derivation of noise limits at various locations along the shoreline near the proposed European Offshore Wind Deployment Centre (EOWDC) to the north of Aberdeen.

1.1 Information for the Non-Technical Summary

2 A baseline noise survey has been carried out in order to establish the existing background noise at the four closest residential properties to the proposed offshore wind farm and at a further two locations representative of properties further inland where the influence of noise from the sea will be lower. The measurement locations were agreed with the Environmental Health Departments at Aberdeen City and Aberdeenshire Council. This document summarises the findings.

3 The measured background noise levels are influenced by sea noise and by traffic noise, especially that from the A90. Noise levels also show a correlation with increasing wind speed.

4 The results are used to derive the noise limits for the proposed EOWDC according to the UK Department of Trade & Industry's ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms* (DTI, 1996).

1.2 Introduction

5 An assessment has been carried out of the existing noise environment at locations along the shoreline closest to the proposed development to the north of Aberdeen.

6 The baseline survey has been carried out to derive noise limits for the proposed development according to guidance normally used for onshore wind farms. This guidance has been used as there is currently a lack of Planning Policy Guidance for offshore wind farms with respect to noise impact on onshore residential properties.

7 This approach has been agreed with the Environmental Health Officers from Aberdeen City and Aberdeenshire Councils.

1.2.1 Methodology Consultation

8 Aberdeen Offshore Wind Farm Limited (AOWFL) submitted a Request for an Environmental Impact Assessment (EIA) Scoping Opinion in August 2010. Chapter 6.9 deals with in-air noise assessment. None of the responses received identified specific requirements for in-air noise assessment for residential properties onshore.

9 The Environmental Health Officers of Aberdeen City Council and Aberdeenshire Council have been consulted regarding the assessment methodology and the choice of measurement locations for the baseline noise survey:

- Andrew Gilchrist, Aberdeen City Council (110106)
- John Dawson, Aberdeenshire Council (110106)

1.2.2 Key Guidance Documents

10 The following key documents have been used in the assessment:

- Scottish Executive (2011). Planning Advice Note PAN 1/2011: Planning and Noise
- Scottish Executive (2010). Web based 'renewables advice'
- DTI Working Group on Noise from Wind Turbines (1996). The Assessment and Rating of Noise from Wind Farms ETSU-R-97
- Aberdeenshire Council (2005). Use of Wind Energy in Aberdeenshire: Guidance for Developers – Supplementary Planning Guidance Part 1
- Bowdler et al (2009). Institute of Acoustics (IOA) Bulletin Vol 34 no 2, March/April 2009 Prediction and Assessment of Wind Turbine Noise

11 The documents listed above have all been written for the purpose of assessing onshore wind farm developments but have been adopted for this project as providing suitable guidance on assessing background noise and deriving noise limits for the onshore residential properties.

1.2.3 Data Information and Sources

12 Background noise data was measured at 6 locations for three weeks. Wind speed was simultaneously measured with a SoDAR (Sound Detection and Ranging) remote sensing device on a field at Easter Hatton. This onshore wind data has been translated to the offshore wind farm location as described in (Oldbaum 2011).

- Oldbaum Services Limited (2011a). Wind speed data spatial translation – Method Statement for Aberdeen Offshore Windfarm Limited (Appendix 3).
- Hayes McKenzie Partnership Ltd. (2011). Measurement of background noise data and rainfall.
- Oldbaum Services Limited (2011b). Wind speed data spatial translation – Wind data analysis for Aberdeen Offshore Windfarm Limited (Appendix 4).

1.3 Baseline Description

1.3.1 Legislative and Planning Context

Planning Advice Note PAN1/2011, Planning and Noise

PAN1/2011 indentifies two sources of noise from wind turbines; mechanical noise and aerodynamic noise. It states that '*Good acoustical design and siting of turbines is essential to minimise the potential to generate noise*'. It refers to the '*web based planning advice*' on renewables technologies for onshore wind turbines.

Scottish Executive Web Based Planning Advice, Onshore Wind Turbines

13 The web based Planning Advice, Onshore Wind Turbines refers to ETSU-R-97, *Assessment and Rating of Noise from Wind Farms* (DTI, 1996a), as the document that *'should be followed by applicants and consultees and used by planning authorities to assess and rate noise from wind energy developments*'. There is no equivalent guidance for offshore wind farms, but there is no reason why the ETSU-R-97 guidance should not apply. ETSU-R-97 contains noise limits designed to protect external amenity during the day and sleep disturbance at night. These limits are derived from baseline noise measurements carried out at potentially affected properties around the proposed development site.

ETSU-R-97, The Assessment and Rating of Noise from Wind Farms

14 ETSU-R-97, *The Assessment and Rating of Noise from Wind Farms* (DTI 1996a), presents the recommendations of the Working Group on Noise from Wind Turbines, set up in 1993 by the DTI as a result of difficulties experienced in applying the noise guidelines existing at the time to wind farm noise assessments. The group comprised independent experts on wind turbine noise, wind farm developers, DTI personnel and local authority Environmental Health Officers. In September 1996 the Working Group published its findings by way of report ETSU-R-97. This document describes a framework for the measurement of wind farm noise and contains suggested noise limits, which were derived with reference to existing standards and guidance relating to noise emission from various sources.

15 The form of the noise limits proposed in ETSU-R-97 is that noise should be limited to X dB L_{A90} or 5 dB above the ‘prevailing background noise level’, whichever is the greater.

16 For night-time (2300-0700) the value of ‘X’ is given as 43, to protect against sleep disturbance indoors with a window open. The prevailing background noise is that acquired during the same night-time hours.

17 For day-time hours (evenings and week-ends) ‘X’ is given as 35-40 with the actual value in the range dependant on:

- The number of dwellings in the neighbourhood of the wind farm.
- The effect of noise limits on the number of kWh generated.
- The duration and level of exposure.

The prevailing background noise is that acquired during the quiet day-time hours, as defined in ETSU-R-97.

18 A simplified limit of 35 dB L_{A90} for 10 m height wind speeds up to 10 m/s is specified for smaller or more remote schemes obviating the need for background noise measurements in such cases. This also provides a useful tool for determining the extent of baseline monitoring required for any proposal.

19 It is stated that the $L_{A90,10min}$ noise descriptor should be adopted for both background and wind farm noise levels and that, for the wind farm noise, this is likely to be between 1.5 and 2.5 dB less than the L_{Aeq} measured over the same period. The $L_{Aeq,t}$ is the equivalent continuous 'A' weighted sound pressure level occurring over the measurement period t. It is often used as a description of the average noise level. Use of the L_{A90} descriptor for wind farm

noise allows reliable measurements to be made without corruption from relatively loud, transitory noise events from other sources.

20 ETSU-R-97 also specifies that a penalty should be added to the predicted noise levels, where any tonal component is present. The level of this penalty is described and is related to the level by which any tonal components exceed audibility.

Lord Hunt's Response to Environmental Protection UK

21 In October 2009, The Rt Hon Lord Hunt of Kings Heath OBE (Minister of State, DECC) wrote to Environmental Protection UK in response to their claim that a review of ETSU was due. He states:

'You're quite right that modern turbines are generally larger than those on which the ETSU-R-97 guidance was based. Noise outputs from these larger turbines have also, however, reduced in that time. Since the ETSU-R-97 derived noise limits are a function of background noise, there is currently no evidence to suggest that the larger turbines are any more likely to cause a noise impact than earlier and smaller designs. Similarly, there is currently no evidence to suggest that the small incidence of Amplitude Modulation (AM) that is reported to occur at a few sites is as a result of turbine size'.
'In essence, therefore, we continue to support the approach set out in Planning Policy Statement (PPS) 22 - Renewable Energy, including the use of ETSU-R-97 to "ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels".

Use of Wind Energy in Aberdeenshire: Supplementary Planning Guidance Part 1

22 A variation to the lower fixed noise limits described by ETSU-R-97, (see above). Aberdeenshire Council specify lower noise limits at 38 dB $L_{A90,10min}$ during night-time and 35 dB $L_{A90,10min}$ during day-time for very quiet locations. Theses lower fixed noise limits are valid for measurements carried out externally and have been applied to this study.

Institute of Acoustics Bulletin Article, Prediction and Assessment of Wind Turbine Noise, March/April 2009

23 Institute of Acoustics Bulletin Vol 34 no. 2 (Bowdler et al., 2009) contains an agreement, jointly authored by a number of consultants working in the wind turbine sector for both developers, local authorities and third parties, on an agreed methodology for addressing issues not covered by ETSU-R-97. This includes a methodology for dealing with vertical wind shear (which is the difference of the wind speed at different heights).

24 It should be noted that this article is written in the context of onshore wind farms, but the recommendation for dealing with wind shear is also applicable for offshore wind farms.

1.3.2 Baseline Conditions

Measurement Positions

25 Noise measurements were agreed to be carried out at six measurement locations, representing the four closest dwellings to the proposed

development site and two locations further inland, as indicated on Figure 1, Appendix 1 and as described below.

Four Winds (E395191, N814956)

26 Four Winds is a property to the west of the proposed development roughly 1,530 m from the shore and 470 m to the west of the A90. The equipment was located in the eastern corner of the garden, closest to the proposed wind farm site and near to the amenity area, as shown in Photographs 1. The principal source of noise at this location was road traffic during installation, and road traffic and wind in the trees during collection of the equipment.

Photographs 1 Four Winds Baseline Noise Measurement Position

16 Chapelwell Wynd, Balmedie (E396968, N817138)

27 16 Chapelwell Wynd is a property to the west of the proposed development roughly 575 m from the shore and 645 m to the east of the A90. The equipment was located in the rear garden, by a pond so that the house was shielded from sea noise and in the amenity area, as shown in Photographs 2. The principal sources of noise at this location were road traffic, the sea, helicopters and the trickling of the pond (which was being drained by the owner to prevent future noise) during installation, and the sea, helicopters and wind in the trees during collection of the equipment.

Photographs 2 16 Chapelwell Wynd Baseline Noise Measurement Position

Easter Hatton (E396245, N816102)

28 Easter Hatton is a property to the west of the proposed development roughly 915 m from the shore and 65 m to the east of the A90. The equipment was located in the side garden, in the middle of the lawn amenity area, as shown in Photographs 3. The principal sources of noise at this location were road traffic and the sea during installation, and road traffic, the distant sea, aeroplanes and wind in the trees during collection of the equipment.

Photographs 3 Easter Hatton Baseline Noise Measurement Position

Hareburn House (E396294, N813979)

29 Hareburn House is a property to the west of the proposed development roughly 180 m from the shore and 780 m to the east of the A90. The equipment was located in the rear garden, between the house and the bushes in the amenity area, as shown in Photographs 4. The principal sources of noise at this location were the sea and distant road traffic during installation, and the sea, helicopters and wind in the bushes during collection of the equipment.

Photographs 4 Hareburn House Baseline Noise Measurement Position

3 Tarbothill Farm Cottages (E395696, N813430)

30 3 Tarbothill Farm Cottages is a property to the west of the proposed development roughly 680 m from the shore and 330 m to the east of the A90. The equipment was located in the side garden, in the amenity area, as shown in Photographs 5. The principal sources of noise at this location were the sea and distant road traffic during installation, and road traffic, the distant sea, distant farm machinery and wind in the bushes during collection of the equipment.

Photographs 5 3 Tarbothill Farm Cottages Baseline Noise Measurement Position

16 Dubford Gardens, Bridge of Don (E393913, N812140)

31 16 Dubford Gardens is a property to the west of the proposed development roughly 2,070 m from the shore and 720 m to the west of the A90. The equipment was located in the middle of the rear garden, in the amenity area, as shown in Photographs 6. The principal sources of noise at this location were road traffic and rain noise during installation, and road traffic and wind in the trees during collection of the equipment.

Photographs 6 16 Dubford Gardens Baseline Noise Measurement Position

Measurement Procedure

Instrumentation

32 The baseline noise measurements were made with four Larson Davis model LD-820 Precision Integrating Sound Level Meters fitted with 1/2" microphones, one Larson Davis model LD-831 and one Larson Davis model LD-824, which comply with the type 1 standard in IEC 651-1:1979. The microphones were fitted with 45 mm radius foam ball windshields surrounded by secondary windshields of 40 mm thickness, in line with recommendations in ETSU W/13/00386/REP, Noise Measurements in Windy Conditions (DTI, 1996b), and were mounted on tripods at a height of 1.2 m. Pre-calibration was carried out using a Bruel & Kjaer model 4231 acoustic calibrator (s/n 2218188). The calibration of each meter was checked at the end of the monitoring period using the same acoustic calibrator.

33 Noise monitoring equipment was left at the measurement positions for a period of 21 days from 15th February to 8th March 2011. The meters were programmed to measure a number of statistical noise indices, including the L_{A90}, together with the maximum and minimum levels and the L_{Aeq} (the Equivalent Continuous A-Weighted Sound Pressure Level) over consecutive 10-minute periods. Results were automatically stored at 10-minute intervals, synchronised to wind speed measurements from the on-site SoDAR to allow for later correlation between the two.

34 Calibration of the noise measurement equipment was carried out before the monitoring period commenced and was checked at the end. A drift of no more than 1.2 dB was noted at any location.

35 Wind speed and direction measurements were made with the AQ500 SoDAR unit installed at East Hatton, Balmedie (NGR E396714, N815608) at various heights up to 200 m agl (above ground level) during the course of the noise measurement. This data has been translated to the proposed EOWDC location as described in (Oldbaum 2011a and 2011b).

36 Rain data for the site has been obtained from the Met Office Central Climate Unit for the background noise survey. Periods with recorded rainfall from the Met Office data have been excluded from any further assessment.

Wind Shear

37 It is now well established that wind speed experienced by a wind turbine cannot be correctly predicted from 10 m height wind speed measurements and ground roughness conditions alone. Hub height wind speed, and hence the wind speed experienced by the wind turbine, may be under-predicted under these conditions and hence the output noise level may be under-predicted. To correctly account for this in the assessment methodology, background noise is referenced to hub height wind speed, as described in the agreement published in the Institute of Acoustics Bulletin (Bowdler et al., 2009).

38 Wind speed and direction was measured with an AQ500 SoDAR remote sensing device at Easter Hatton, Balmedie, an onshore location near the coastline. The data was recorded in 5 m steps from 50 m to 200 m. This data has been translated to the location of the offshore wind farm as described in (Oldbaum 2011b). For the assessment, the measured data correlating to hub height wind speed is used.

39 This translated hub height wind speed has then been corrected to 'standardised' 10 m height wind speed, as required by the method described in the IoA Bulletin using the same methodology as is used by the manufacturers to produce noise data for 'standardised' 10 m height wind speed, i.e.:

$$V_{10} = V_h \cdot \frac{\ln\left(\frac{h_{10}}{z_0}\right)}{\ln\left(\frac{h_h}{z_0}\right)}$$

40 Where V_{10} and V_h are the 'standardised' 10 m height (h_{10}) and hub height (h_h) wind speeds respectively, and z_0 is the standardised ground roughness length (= 0.05 m).

41 This standardisation is not intended to reflect actual 10 m height wind speed conditions and does not affect the relationship between turbine noise, background noise, and the derived noise limits.

Results of Noise Measurements

42 Raw data results of the noise measurements are not included in this chapter due to the relatively large amount of information gathered. Figures are, however, available on request which show the $L_{A90,10min}$ and $L_{Aeq,10min}$ in periods of 24 hours from midday to midday, at the measurement location, together with wind speed.

43 The noise limits are derived in accordance with ETSU-R-97 and the Aberdeenshire Supplementary Planning Guidance, as agreed with Aberdeen City Council and Aberdeenshire Council Environmental Health Officers.

44 Due to a technical error, the sound level meter at Hareburn House only recorded data for 3 days. During that period background noise levels were between 40 and 58 dB L_{A90} at 3 m/s and 52 and 59 dB L_{A90} at higher wind speeds during amenity hours and 42 and 55 dB L_{A90} at 3 m/s and 52 and 55 dB L_{A90} at higher wind speeds during night hours. Comparing the measured noise level of Hareburn House with the noise levels obtained at 3 Tarbothill Farm and 16 Chapelwell Wynd leads to the conclusion that background noise levels are generally higher at Hareburn House due to the proximity of the sea. The approach taken to use the noise limits derived from the measurement at Chapelwell Wynd as a substitute for Hareburn House is considered conservative as lower noise levels were recorded at this property compared to Tarbothill Farm. It is also assumed that using those noise limits is more representative for the houses in Blackdog which are further back from the shoreline as Hareburn House and would therefore receive less sea noise than Hareburn House.

45 Although the measured background noise data show a strong influence from the sea and the traffic noise of the A90 at all locations except Dubford Gardens, it also shows a correlation with increasing wind speed.

Noise Limits

46 Plots have been produced of the measured L_{A90} background noise levels against wind speed at six locations representing the four closest residential properties to the wind farm site and two more distant properties representative of properties further inland where the influence of noise from

the sea will be lower. The derived noise limits are based on the lower ETSU-R-97 day time limit and the night time limit of 38 dB L_{A90} or background noise level plus 5 dB, whichever is the greater. The plots for these locations also show the upper ETSU-R-97 day time limit for completeness.

47 The measured background noise correlated with equivalent offshore wind speed and subsequently derived noise limits according to ETSU-R-97 are shown in Chart X.1 to X.10 in Appendix 2 for the night hours and quiet day-time hours periods for the representative residential locations.

Other Residential Properties

48 The assessments carried out for the background noise measurement locations are generally representative of the properties most likely to be affected in each area. This has been determined by considering distance from the sea, distance from the A90, and the type of residential area.

49 Generally all other properties in the area being represented receive a lower predicted noise level and, assuming background noise is similar, will receive a lower impact than the assessed location.

50 The only area to which this doesn’t apply is 16 Dubford Gardens. This is due to the measurement being chosen for being both further from the A90, and on the edge of the Aberdeen suburb of Bridge of Don. Although there are properties closer to the wind farm site, which will therefore have a higher predicted noise level from the wind farm, these properties will equally have a higher background noise than that of 16 Dubford Gardens, due to their proximity to the A90, sea and being in a more built-up region. 16 Dubford Gardens was therefore chosen to represent this area due to its location balancing these factors.

1.4 Summary

51 An assessment of the existing background noise at properties near the proposed EOWDC has been performed. The guidance contained within ETSU-R-97 has been used to derive noise limits at these properties.

52 Background noise measurements were made at six locations representative of those likely to be most affected by noise from the proposed development. These locations were agreed with the Environmental Health Officers for the Local Planning Authorities from the Aberdeen City and Aberdeenshire Councils.

53 Analysis of the measured data has been performed in accordance with ETSU-R-97 to determine the existing background noise environment at these six locations.

1.5 Appendices

- Appendix 1: Map showing measurement locations
- Appendix 2: Assessment charts from background noise survey
- Appendix 3: Oldbaum Services Limited (2011a). Wind speed data spatial translation – Method Statement for Aberdeen Offshore Windfarm Limited
- Appendix 4: Oldbaum Services Limited (2011b). Wind speed data spatial translation – Wind data analysis for Aberdeen Offshore Windfarm Limited.

1.6 References

Aberdeenshire Council: Use of Wind Energy in Aberdeenshire: Guidance for Developers – Supplementary Planning Guidance Part 1, August 2005

Acoustics Bulletin: Prediction and Assessment of Wind Turbine Noise, Institute of Acoustics, Vol 34 No.2, March/April 2009

Department of Trade and Industry: W/45/00656/00/00, The Measurement of Low Frequency Noise at Three UK Windfarms, 2006

ETSU for the Department of Trade and Industry: ETSU W/13/00385/REP, A Critical Appraisal of Wind Farm Noise Propagation, 2000

ETSU for the Department of Trade and Industry: ETSU-R-97, The Assessment and Rating of Noise from Wind Farms, 1996

ETSU for the Department of Trade and Industry: W/13/00386/REP, Noise Measurements in Windy Conditions, 1996

Lord Hunt's Response to Environmental Protection UK: http://www.environmental-protection.org.uk/news/detail/?id=2300

Moorhouse et al., University of Salford: DEFRA NANR233, Research into amplitude modulation of wind turbine noise, July 2007

Moorhouse et al., University of Salford: DEFRA NANR45, Proposed criteria for assessment of low frequency noise disturbance, February 2005

Office of the Deputy Prime Minister: Planning Policy Statement PPS22, Renewable Energy, 2004

Office of the Deputy Prime Minister: Planning for Renewable Energy, A Companion Guide to PPS22, 2004

Scottish Executive: Web Based Planning Advice, Onshore Wind Turbines, (2010).

Scottish Executive: Planning Advice Note PAN1/2011, Planning and Noise Scottish Executive Development Department, 2011.

Appendix 1

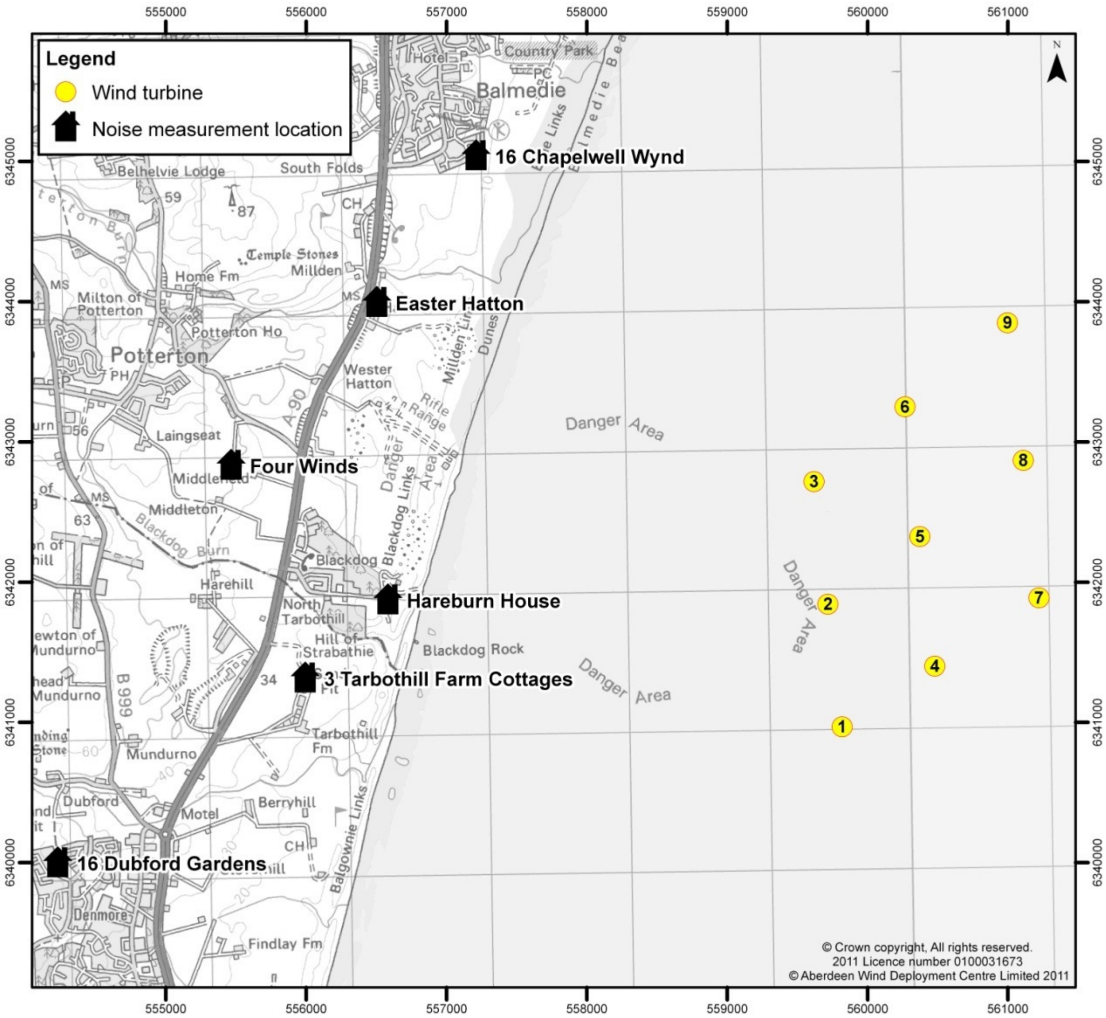


Figure 1 - Noise measurement locations

Appendix 2

Four Winds

Chart 1

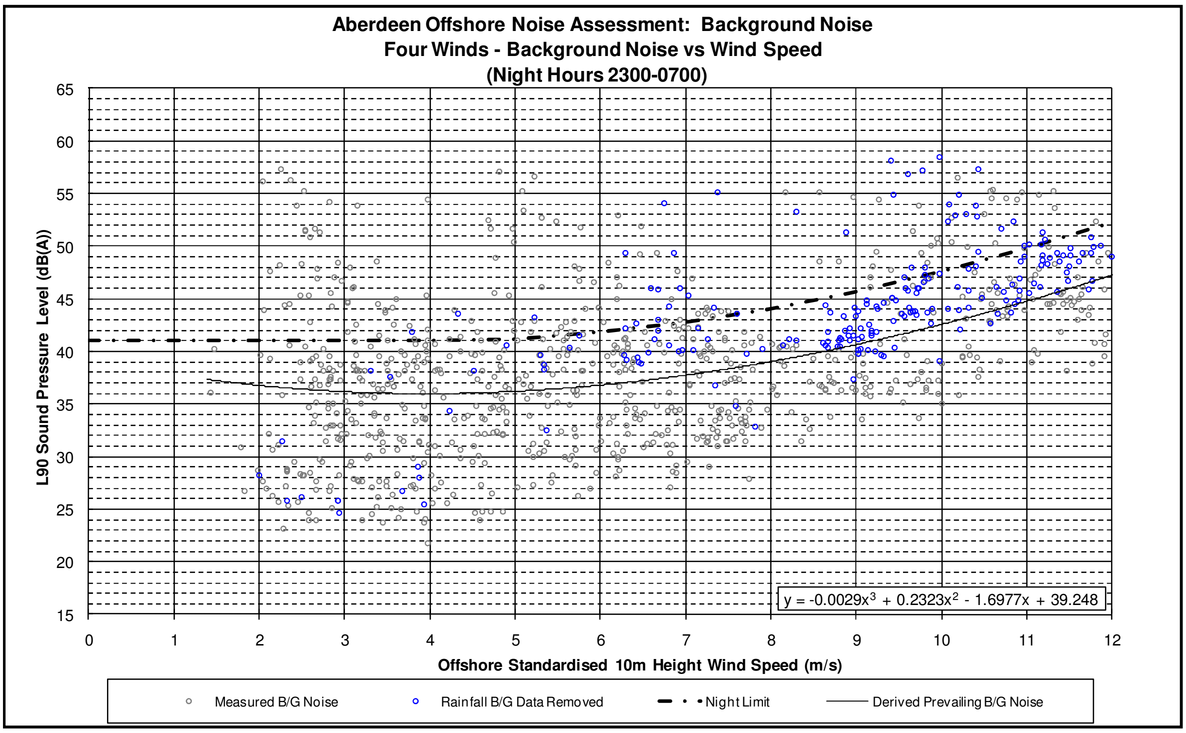
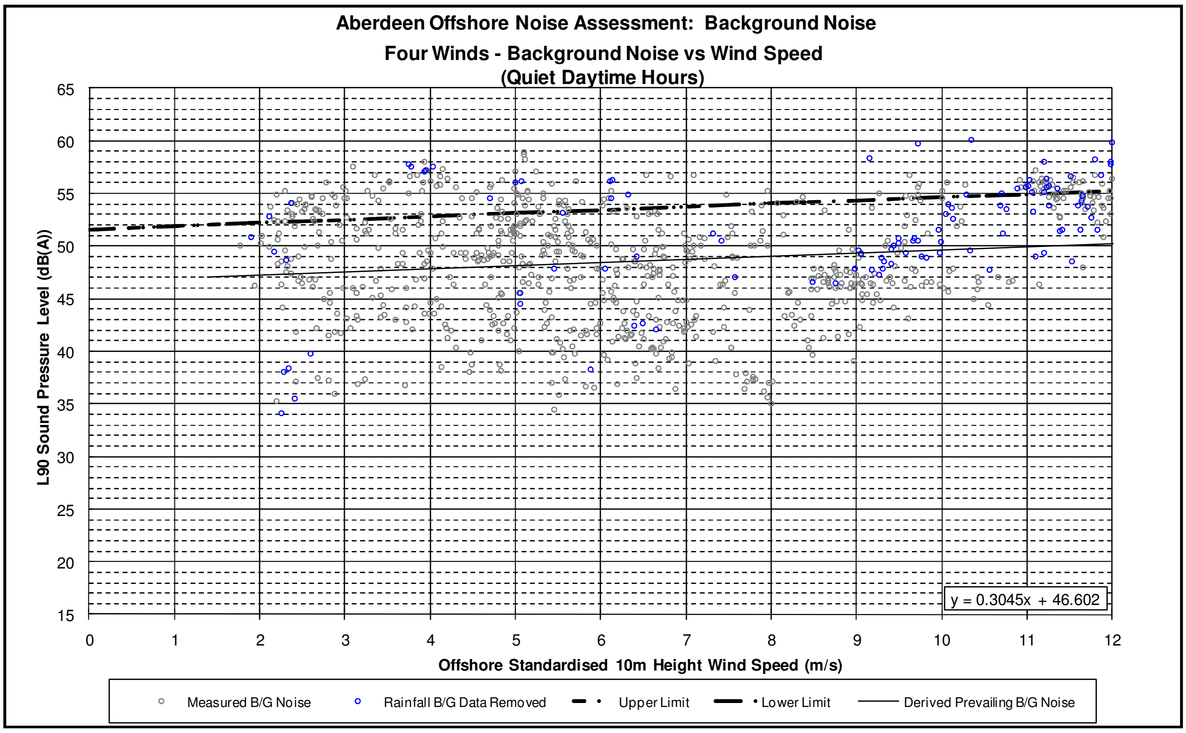


Chart 2



16 Chapelwell Wynd

Chart 3

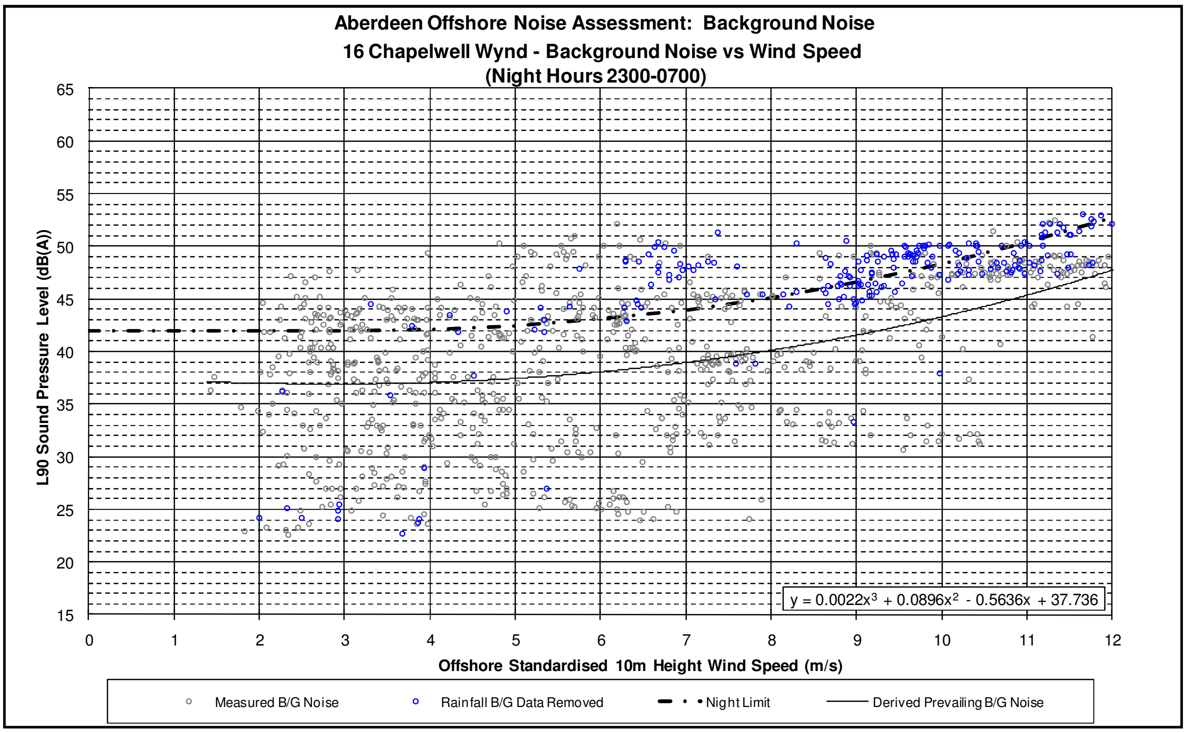
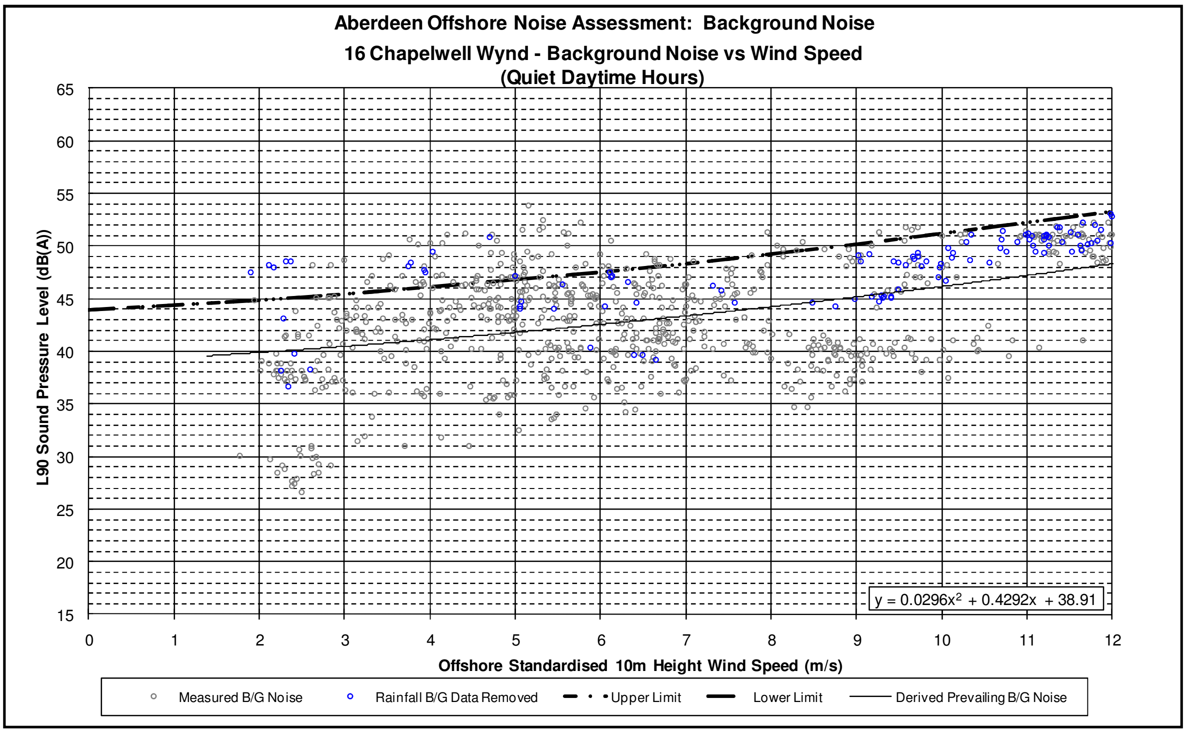


Chart 4



Easter Hatton

Chart 5

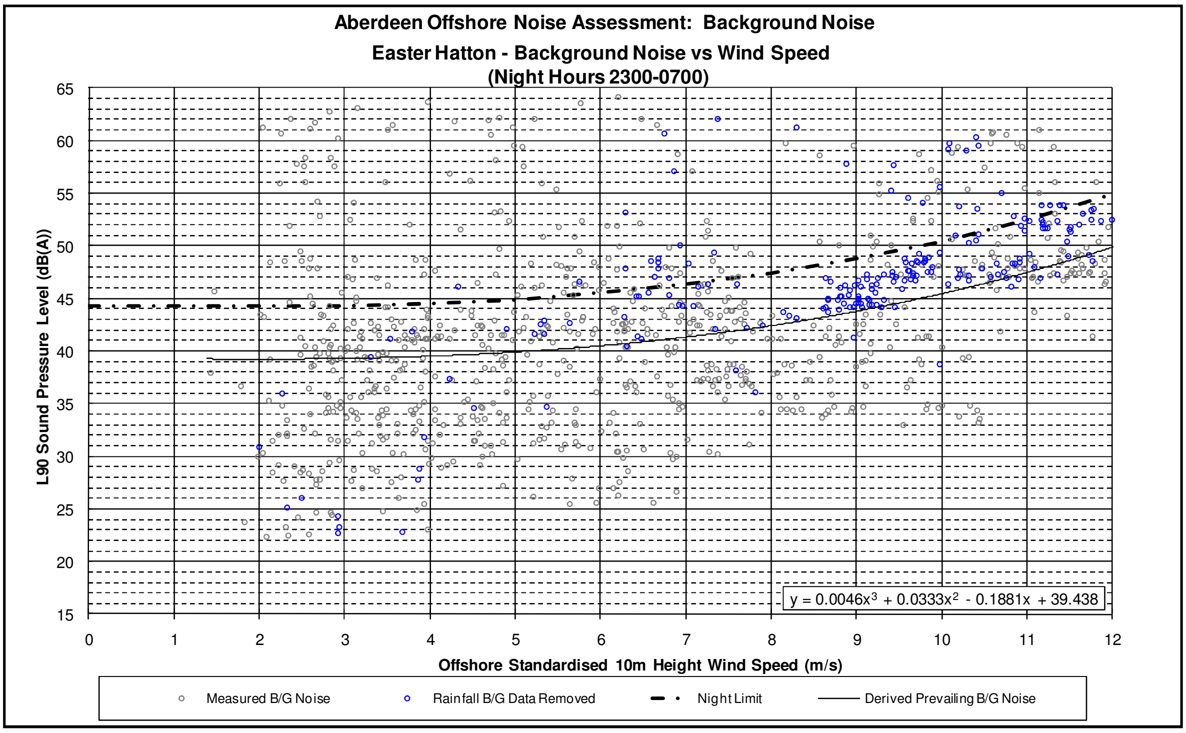
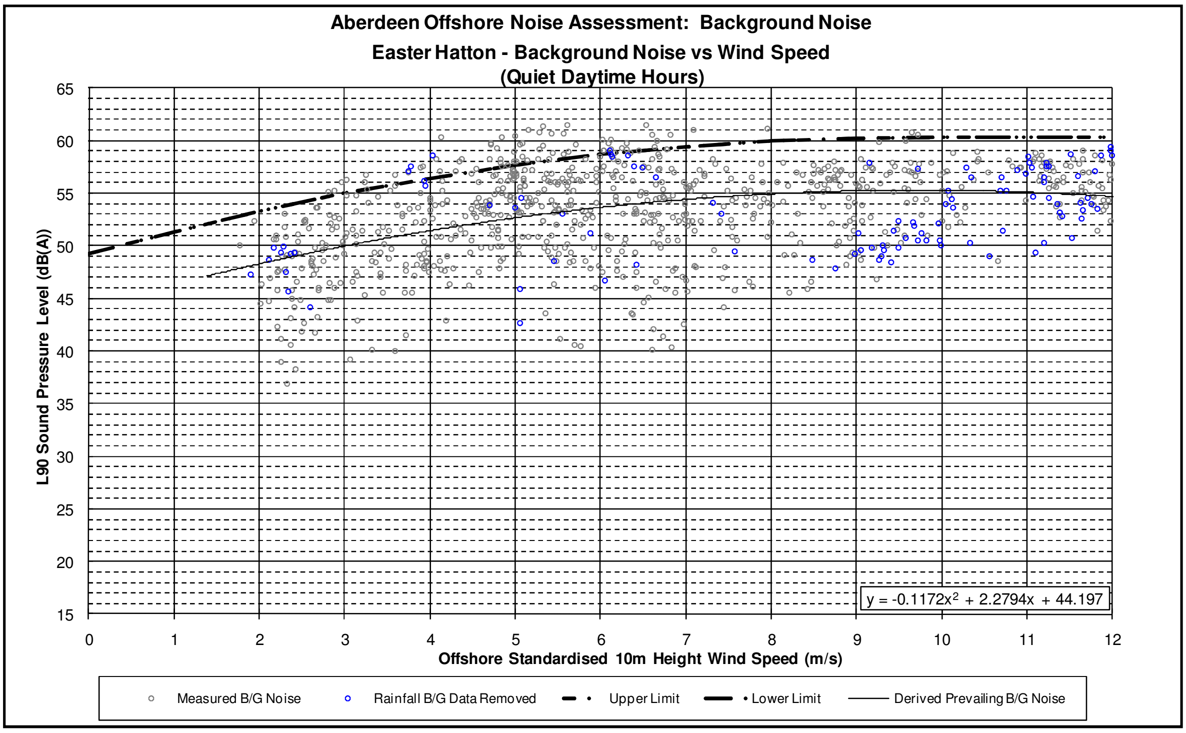


Chart 6



3 Tarbothill Farm Cottages

Chart 7

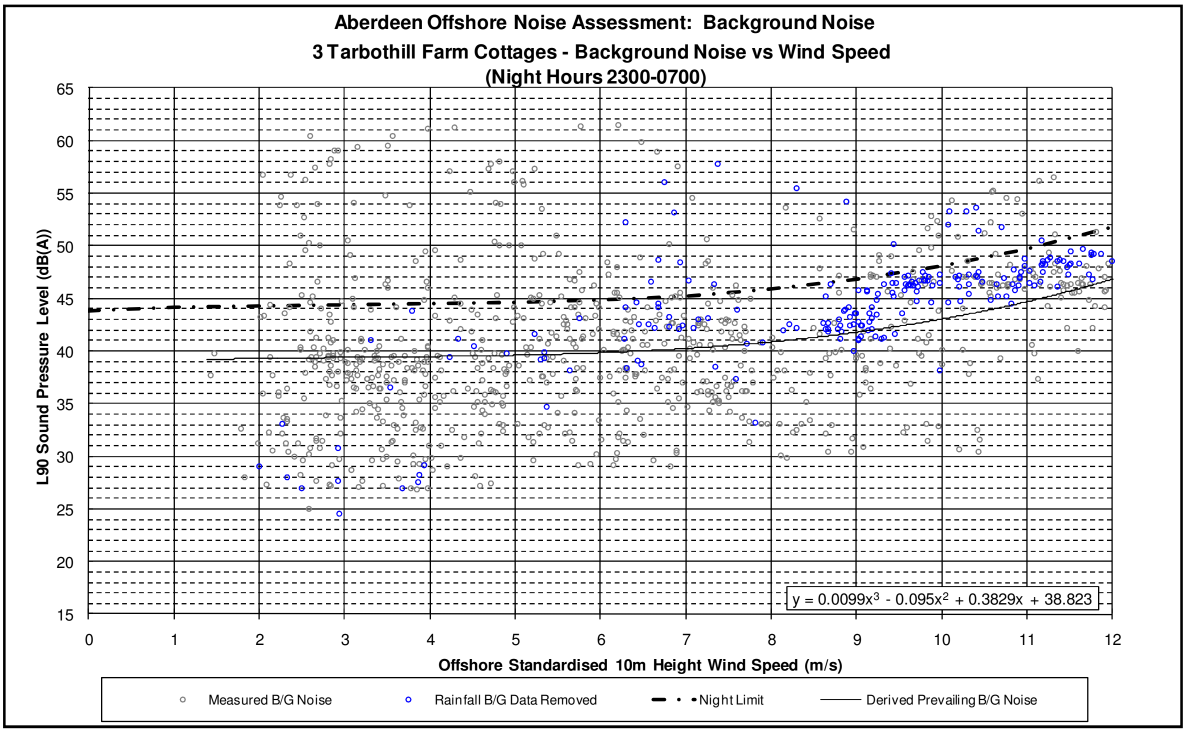
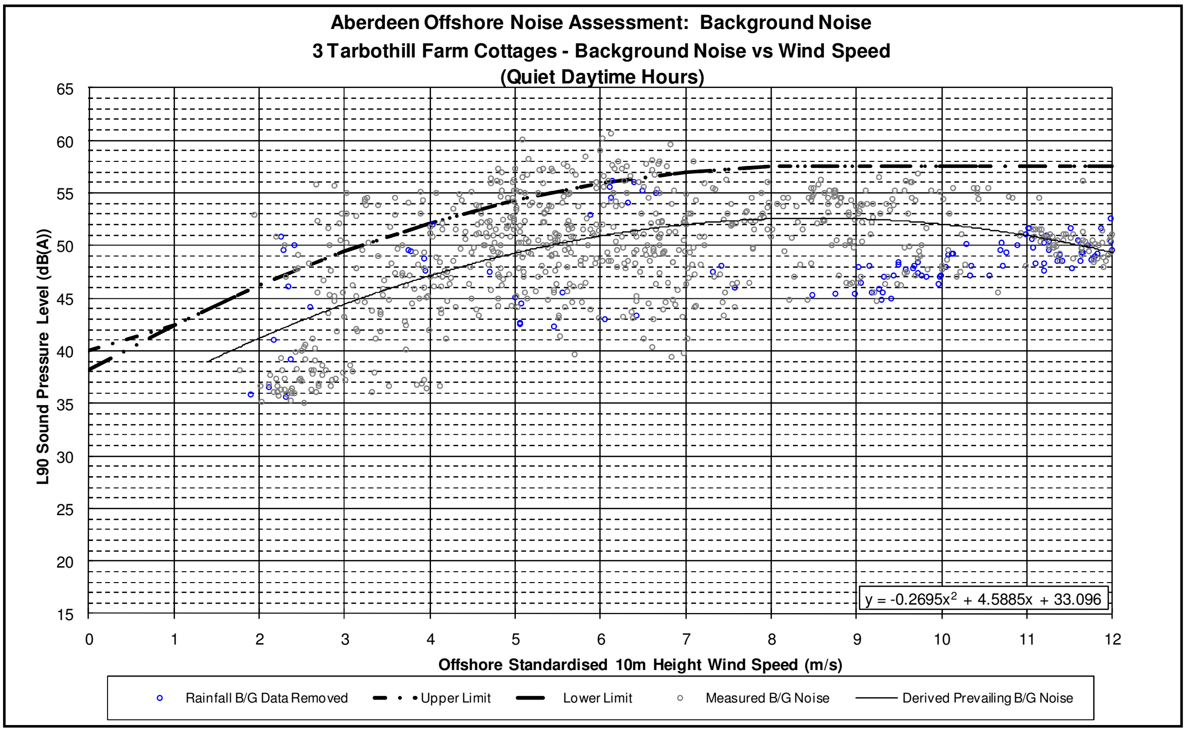


Chart 8



16 Dubford Gardens

Chart 9

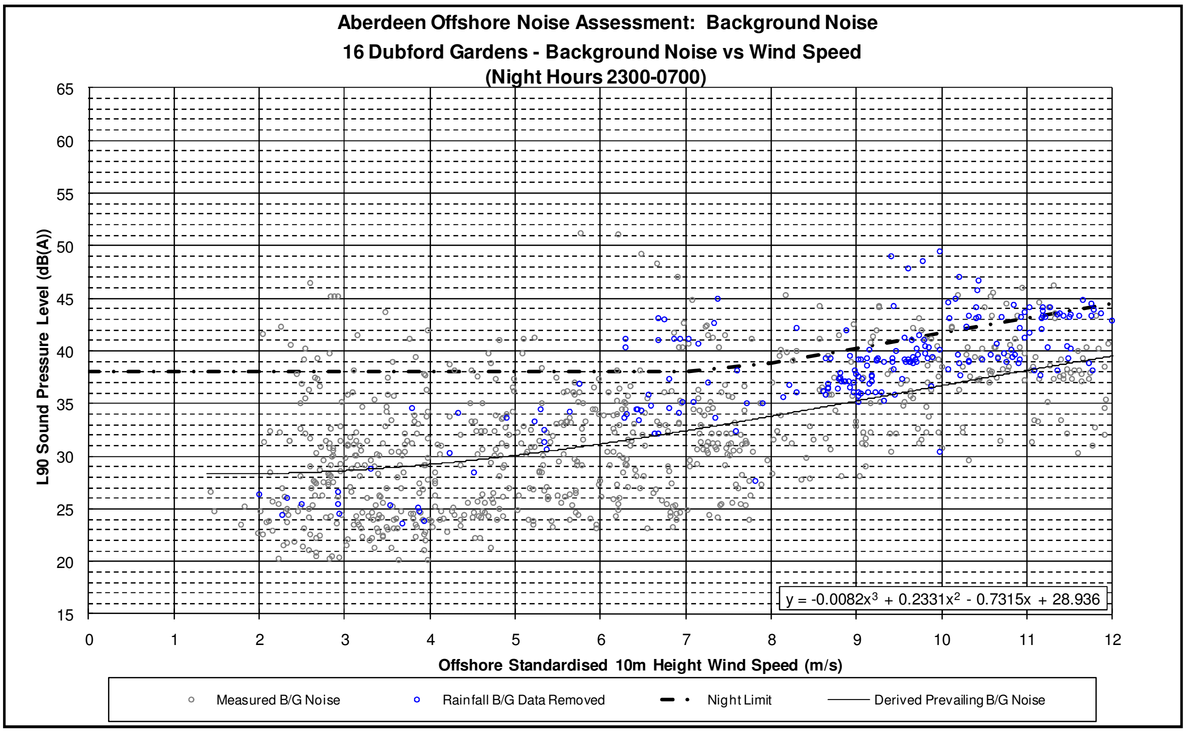
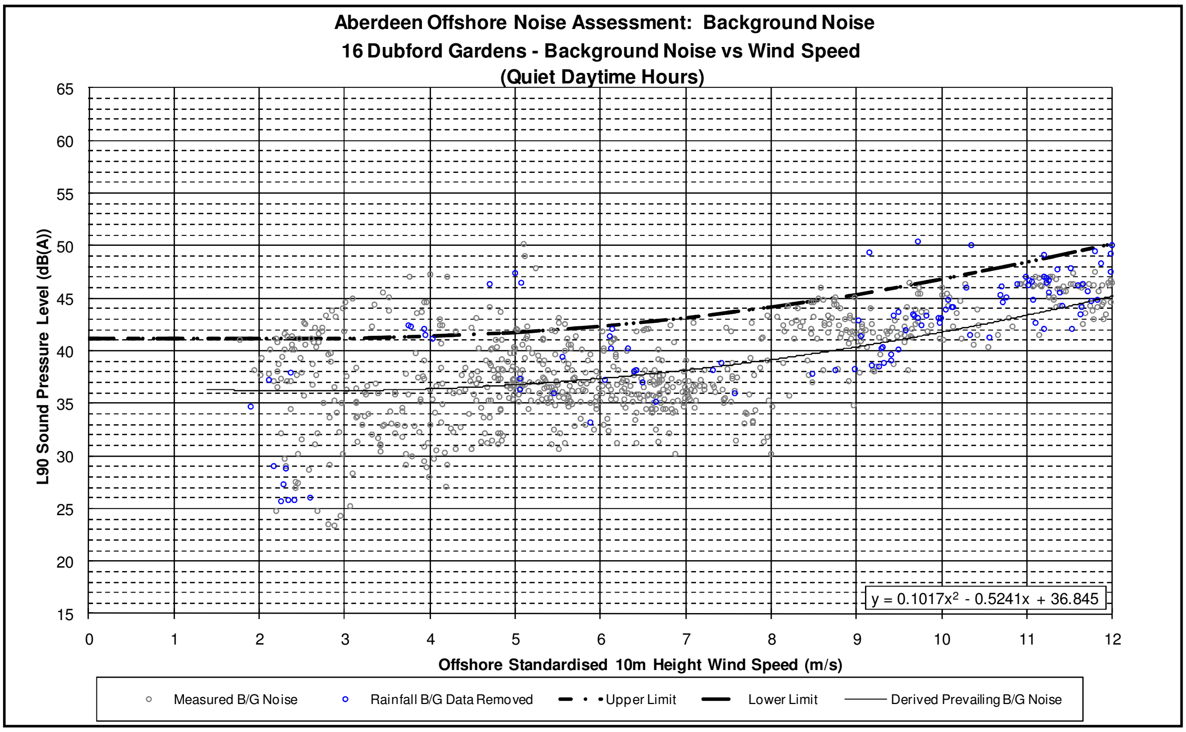


Chart 10



OLDBAUM SERVICES LIMITED

Wind speed data spatial translation – Method Statement

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2/27/2011

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Overview:

Method statement for the translation of wind speed data for noise assessment from onshore to offshore.

Report No.:	RAOWFL001
Document type:	Method Statement
Site:	Aberdeen Offshore Windfarm
Analysis Period:	-
Client:	Aberdeen Offshore Windfarm Limited - -
Client Contact	Anthony Hunt & Gavin Scarf
Contractor:	Oldbaum Services Limited Unit 13a; The Alpha centre Stirling University Innovation park Stirling; Scotland FK9 4NF
Order No.:	-
Order date:	-
Document date:	27th February 2011
Author:	A Oldroyd (andy@oldbaumservices.co.uk)
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Revision Status	Final (Revision 2)

A Oldroyd M Griesbaum

The report consists of 14 pages including all annexes

Contents

1.0 Scope

The following method statement details the process to be undertaken to translate data from the AQ500 SoDAR deployment at Easter Hatton to the position of the proposed Aberdeen Offshore Windfarm.

The installation at Easter Hatton is detailed in the following reports, which are available upon request:

Method Statement: MSVFALL002-151210

Risk Assessment: RAVFALL002-261110

Install Report: IFVFLL002-120111

The coastal location represents a good compromise to onsite data acquisition for offshore wind farms.

Given the flat terrain nature of the installation, the SoDAR (Sound Detecting And Ranging) location should experience similar flow conditions to that of the offshore wind farm.

From the primary wind direction, the wind will approach the wind farm and SoDAR location from onshore (South West – Westerly being the predominant direction). As the wind translates from onshore to offshore, a new internal boundary layer will form, and develop until new free stream flow conditions are developed. Typically this can be in the order of 15km – 20km from the coastline, depending on local conditions. Therefore it can be expected that the offshore wind farm location will feel the effect of the onshore constraints.

From offshore, easterly winds, the flow can be thought of as open sea conditions. Again a coastal location is a good compromise for these conditions, as the close proximity of the installations to the coast line means that local roughness effects have had very little time and space to modify the flow such that the SoDAR will experience significantly different conditions from that seen offshore.

Section 2 introduces the AQ500 SoDAR system in general terms, with typical validation results, acquired in Scottish conditions, shown in Annex 1.

Section 3 states the methodology used to translate the data series spatially from the install location to the proposed wind farm installation. The technique shown can be thought of as standard industry practice, minimising any increase in uncertainty in wind speed.

2.0 Instrumentation

The following section introduces the technology used to capture wind speed data. The AQ500 SoDAR system is a well respected reliable unit which has been in use since 2002 in the wind industry. There are now over 200 units in operation, providing accurate wind speed data for a variety of roles within the wind industry sector.

2.1 AQ500 SoDAR system

Figure 2.1 shows the AQ500 system on site in Sweden, housed within its own trailer unit.

The system is designed to be primarily powered by PV input, but has the energy security of a small generator back-up system which is intelligently controlled to help maintain the voltage level in the 600Ah of battery storage.

The system is flexible, relatively easy to deploy, and has a good track record in the wind industry. As a first look system the AQ500 has an unprecedented track record in terms of data quality, system reliability, and customer base within the wind industry.

Figure 2.1: In deployment in Sweden with Thnadners attachment

Table 2.1 summarises the specification of the SoDAR system. Figure 2.2 shows the actual AQ500 antenna housed within the trailer unit. The whole setup is designed to minimise side-lobe sound propagation, i.e noise pollution, and to minimise broadband loud noise interference with the return signal.

Item	Specification	Range
1	Height Range	20-200m
2	Height Resolution	5m
3	Accuracy Wind Speed	0.1m/s
4	Antenna Arrangement	3-beam
5	Antenna Height	1.2m
6	Antenna Width	1m
7	Antenna Weight	70kg
8	Data Transfer	GSM
9	Data Format	ASCII via SODWIN Software

10	Operating Frequency	3144Hz
11	Temperature Range	-40 °C to +60 °C
12	Humidity Range	10 to 100% RH

Table 2.1: AQ500 system specification

The AQ500 is unique on the market in that it is a three beam arrangement rather than the more common phased array type approach. The main benefit of this technique is that the system has generally better data availability statistics throughout the height range (typically greater than 95% at 90m), is less prone to background noise issues, and is less prone to error in rain conditions. Rain intensifies the scatter of the output sound signal, meaning the return signal is generally at a lower level. As the AQ500 is capable of emitting 300W peak pulses, the system is capable of returning values even in rain periods. Annex 1 gives some indicative values of an AQ500 in comparison with a Met mast station.

Figure 2.2: AQ500 antenna in standalone setup – most systems now deployed in trailer unit

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Table 2.2 specifies the AQ500 trailer and power supply solution.

Item	Specification	Range
1	Solar Input	480W
2	Generator	5kW
3	Battery Storage	600Ah
4	SMS notification	Via GSM
5	Trailer Height	2m
6	Trailer Width	1.4m
7	Trailer weight (incl. SoDAR)	1100kg
8	Fuel Tank Size	200 l
9	Power Consumption	30-50W
10	Pulse Power (max)	300W (user set or adaptive according to SNR)
11	Acoustic Power	17W (Max)
12	Electrical heating	240V AC user defined thermostat

Table 2.2 Power Supply specification

2.1.2 Health and Safety and System Security

The AQ500 is a self contained unit with little or no user intervention required in the setup of the system.

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The system is fully self contained with no potential for environmental impact. All systems can be fully isolated with a central kill on/off switch available. All systems are provided with fire extinguishers as required.

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In order to translate the data form onshore to offshore conditions, numerical modelling techniques will be employed which are standard within the wind industry.

For this project, the most appropriate software is the WAsP (Wind Atlas analysis and application Programme) software developed by the Danish Technical University at RISOE, Roskilde. WAsP 10.0 will be used for this analysis, which has been specifically updated to help with coastal boundaries in the numerical domain, and the transition from onshore to offshore conditions.

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Therefore a speedup value will be calculated for each sector bin, and this will be applied to each wind speed value within the bin. This will have no negative impact on the wind shear profile derived from this process.

The procedural methodology for the Aberdeen Offshore Windfarm is:

1. AQ500 data received and quality checked using Oldbaum standard practice for SoDAR data;
2. Data analysed and summarised to show mean wind speed, profile by sector, turbulence by sector and both wind speed and wind direction distributions;
3. Data summarised and collated into 30 degree sector bins;
4. Definition of numerical run within WAsP, including importing of local terrain maps;
5. Import of data series and summary of data acquisition point within WAsP;
6. Plausibility check of WAsP values with initial analysis values reported in 2;
7. Data summary of wind speed coefficients at the Aberdeen Offshore Wind development area;
8. Modification of SoDAR time series using WAsP calculated coefficients.

The output will be a wind speed timeseries consistent with industry best practice and suitable for use within the noise measurement campaign.

5.0 About Oldbaum

Oldbaum Services is a wind energy consultancy, with roots tracing back to 2003. In 2003 Technical Director Andy Oldroyd won a Green Energy Award whilst working for Chillwind for introducing a new measurement technique (Sound Detecting and Ranging or SoDAR) to the wind industry sector.

Andy, and his fellow Director Monica Griesbaum have continued to bring innovation and rigour to the wind industry, pioneering quality control and wind sensor use with such novel techniques as LiDAR and SoDAR.

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Oldbaum Services are part of the Leosphere Wind Experts programme, and have been working with all forms of LiDAR since 2005. Oldbaum have designed acceptance tests and measurement campaigns for all forms of LiDAR (Continuous wave or pulse) and have therefore a unique perspective and experience in the unique challenges posed by each system type.

Annex 1.0: AQ500 validation results

The following is an extract of a test undertaken at Myers Hill in Scotland. The data IS FORM a well instrumented 80m met mast as reference, with the AQ500 being located 300m to the South West of the system. No filters have been applied apart form directional filters to exclude the influence of the 1MW NEG MICON WTG's located to the North East and South East of the met mast.

Full test results can be downloaded here: http://www.aqs.se/wordpress/wp-content/uploads/2009/12/AQSMH001_221209.pdf (large file)

Annex 1.0: Data Availability

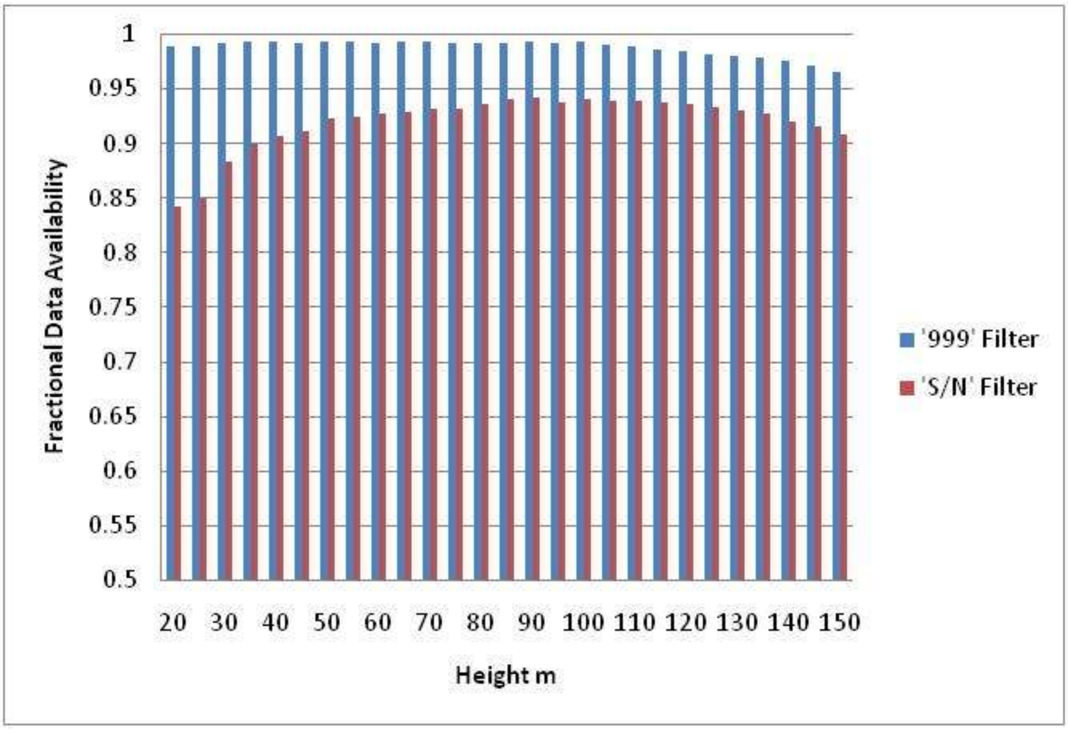

Figure A1.1: Data Availability of AQ500 System

Annex 1.0: Correlation Results

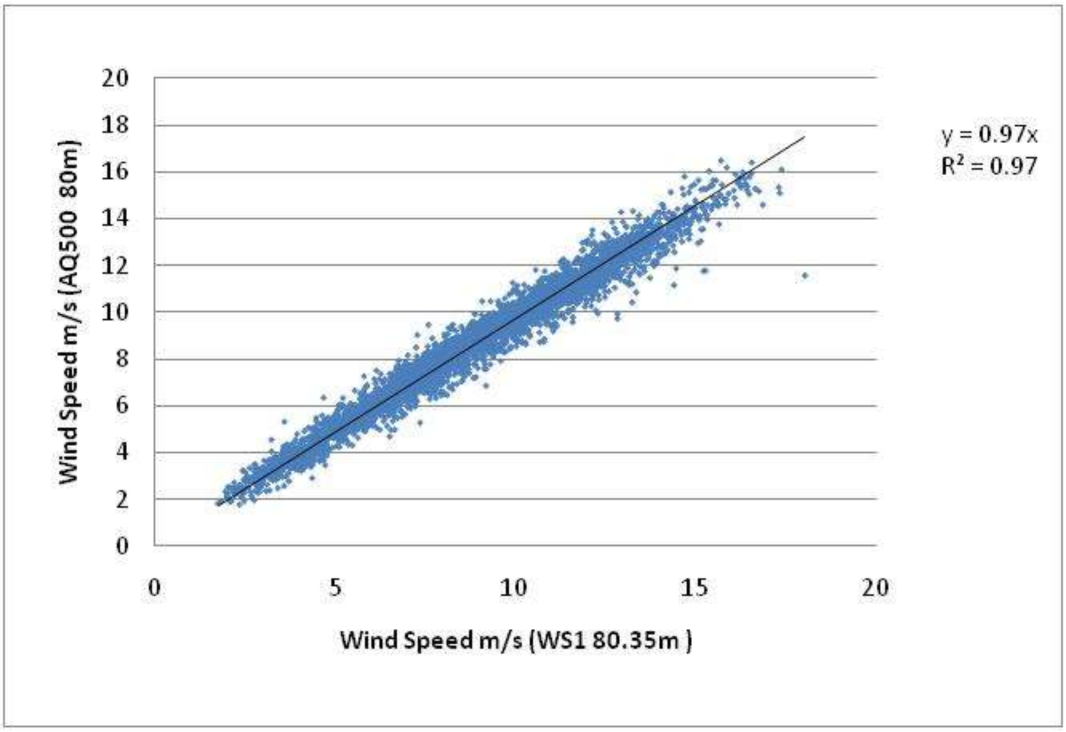

Figure A1.2: Overall correlation with 80m mast @ 80m, 300m Separation. Direction filter applied

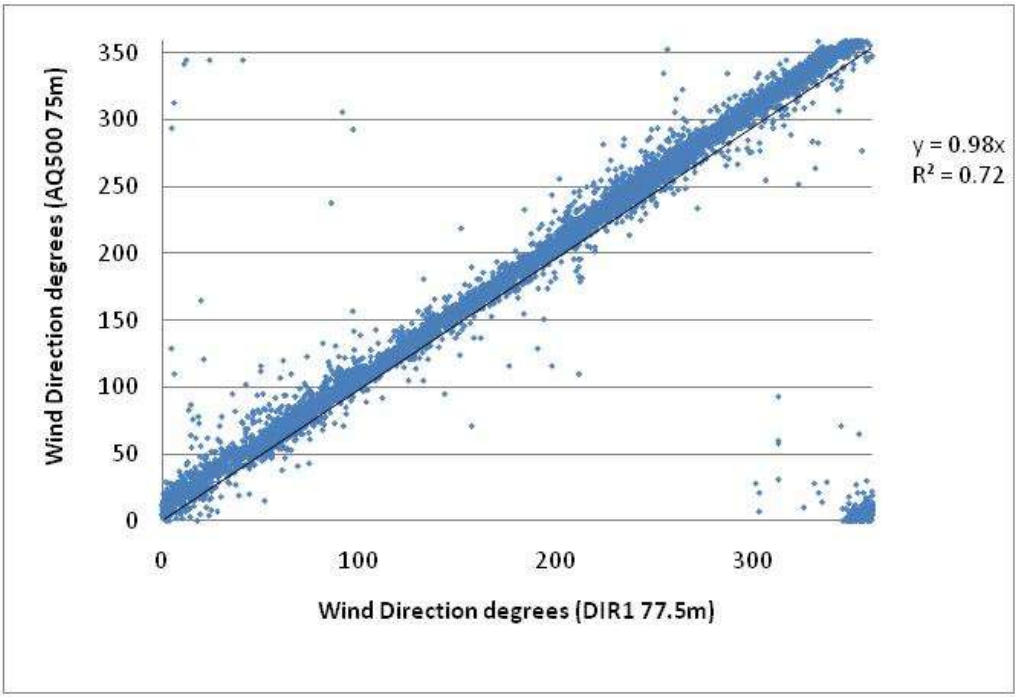

Figure A1.3: Direction Correlation – No applied filter

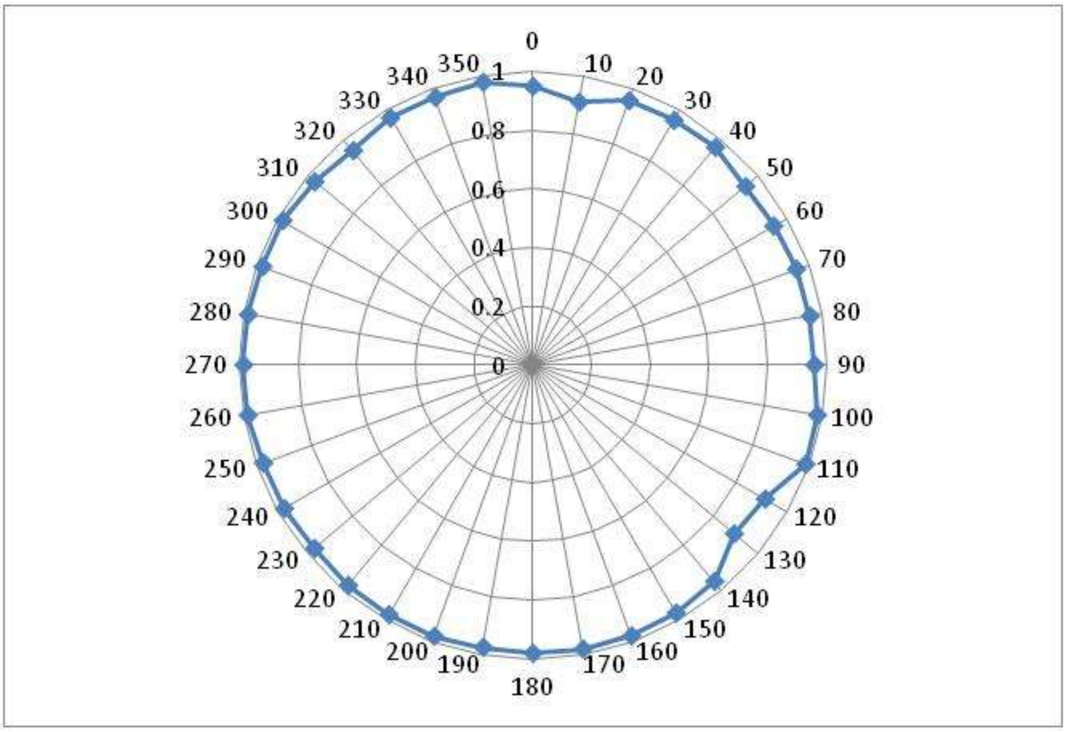

Figure A1.4: Correlation by Direction. Kinks show location of NEG Micon systems

Annex 1.0: Shear Profile Results

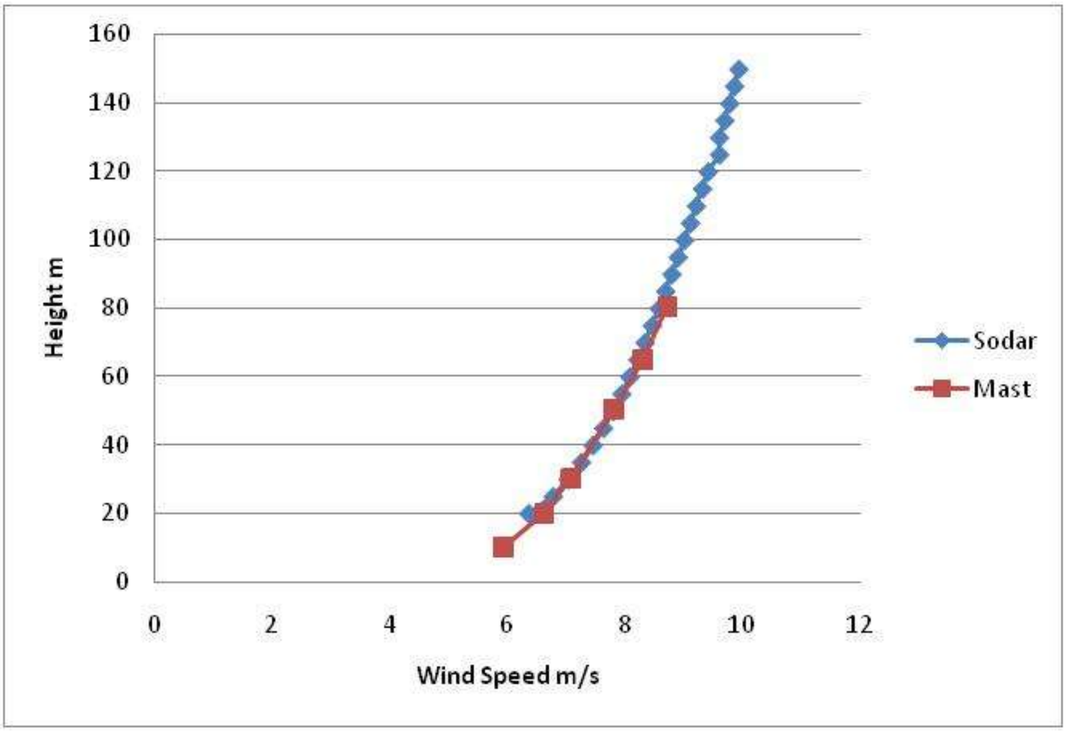

Figure A1.5: Shear profile Direction filter applied

	Mast	Sodar
c	0.0017	0.0026
b	4.9921	4.8059
α	0.2003	0.2081
R^2	0.9944	0.9979

Table A1.1: Regression analysis output equation of form cx^b .

Annex 1.0: turbulence Intensity

All RS systems have issue with turbulence through spatial and temporal averaging, or in some cases systematic filtering of the turbulence spectrum. IN this case we advocate the use of bin averaged values. Time series turbulence should be treated with caution, however Bin averaging shows the ability of the system for site classification.

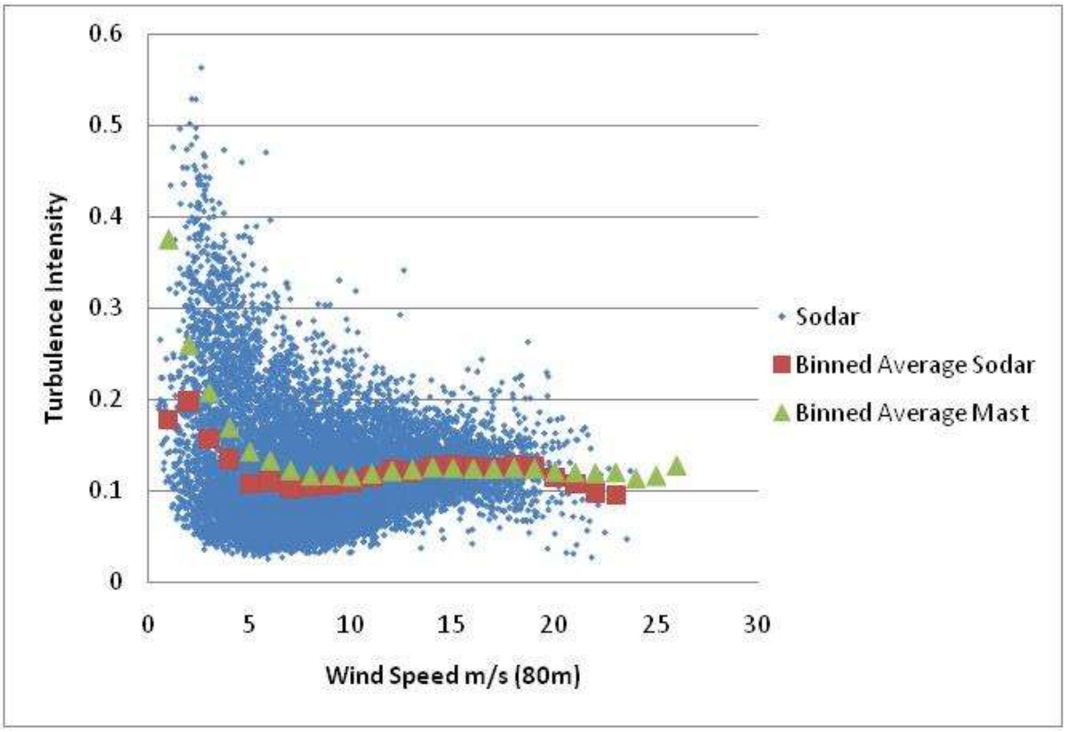

Figure A1.6: Turbulence Bin averaged values

Annex 1.0: Rain performance

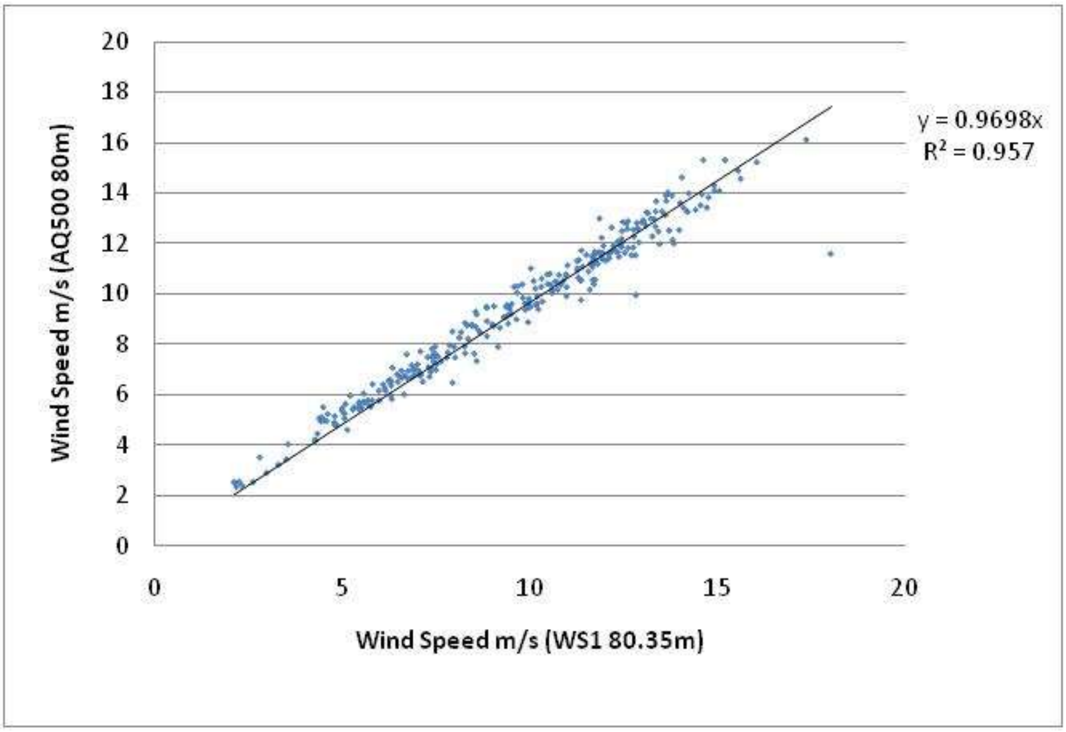

Figure A1.7: Rain period data

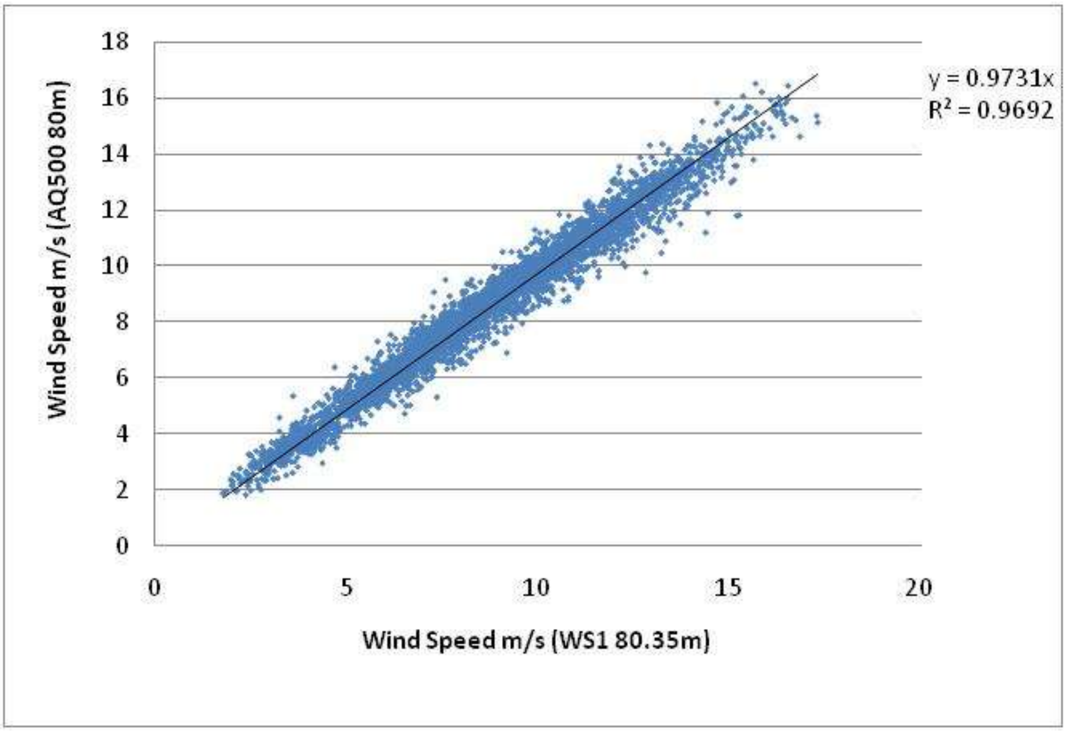

Figure A1.8: Non rain affected,

: End of Document

Wind speed data spatial translation

Aberdeen Offshore Windfarm Limited

Andy Oldroyd

3/18/2011

Oldbaum Services Limited
Unit 13a; the Alpha Centre; Stirling University Innovation Park
Stirling; Scotland
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Overview:

Wind data analysis for Aberdeen offshore wind farm limited

Report No.:	RAOWFL002 - 180310
Document type:	Report
Site:	Easter Hatton
Analysis Period:	-
Client:	Aberdeen Offshore Windfarm Limited - -
Client Contact	Anthony Hunt; Gavin Scarf
Contractor:	Oldbaum Services Limited Unit 13a; The Alpha centre Stirling University Innovation park Stirling; Scotland FK9 4NF
Order No.:	-
Order date:	-
Document date:	18th March 201
Author:	A Oldroyd (andy@oldbaumservices.co.uk) P Maji (p.maji@oldbaumservices.co.uk)
Verified by:	M Griesbaum (monica@oldbaumservices.co.uk)
Revision Status	Final

A Oldroyd M Griesbaum

The report consists of 23 pages including all annexes

Contents

1.0 Scope

The following report details the process undertaken to translate data from the AQ500 SoDAR deployment Easter Hatton to the position of the proposed Aberdeen Offshore Windfarm.

The installation at Easter Hatton is detailed in the following reports, which are available upon request:

Method Statement: MSVFALL002-151210

Risk Assessment: RAVFALL002-261110

Install Report: IFVFLL002-120111

The coastal location represents a good compromise to onsite data acquisition for offshore wind farms.

The location to be used as the wind farm site is: **400533, 814777.**

Given the flat terrain nature of the installation, the SoDAR (Sound Detecting And Ranging) the assumption is that the wind farm location should experience similar flow conditions to that of the offshore wind farm.

From the primary wind direction, the wind will approach the wind farm and SoDAR location from onshore (South West – Westerly being the predominant direction). As the wind translates from onshore to offshore, a new internal boundary layer will form, and develop until new free stream flow conditions are developed. Typically this can be in the order of 15km – 20km from the coastline, depending on local conditions. Therefore it can be expected that the offshore wind farm location will feel the effect of the onshore roughness.

From offshore, easterly winds, the flow can be thought of as open sea conditions. Again a coastal location is a good compromise for these conditions, as the close proximity of the installations to the coast line means that local roughness effects have had very little time and space to modify the flow such that the SoDAR will experience significantly different conditions from that seen offshore.

Section 2 introduces the AQ500 SoDAR system in general terms, with typical validation results, acquired in Scottish conditions, shown in Annex 1.

Section 3 states the methodology used to translate the data series spatially from the install location to the proposed wind farm installation. The technique shown can be thought of as standard industry practice, minimising any increase in uncertainty in wind speed.

Section 4 summarises the results of the analysis.

.0 Instrumentation

The following section introduces the technology used to capture wind speed data. The AQ500 SoDAR system is a well respected reliable unit which has been in use since 2002 in the wind industry. There are now over 200 units in operation, providing accurate wind speed data for a variety of roles within the wind industry sector.

2.1 AQ500 SoDAR system

Figure 2.1 shows the AQ500 system on site in Sweden, housed within its own trailer unit.

The system is designed to be primarily powered by PV input, but has the energy security of a small generator back-up system which is intelligently controlled to help maintain the voltage level in the 600Ah of battery storage.

The system is flexible, relatively easy to deploy, and has a good track record in the wind industry. As a first look system the AQ500 has an unprecedented track record in terms of data quality, system reliability, and customer base within the wind industry.

Figure 2.1: In deployment at Easter Hatton with Thnadners attachment

Table 2.1 summarises the specification of the SoDAR system. Figure 2.2 shows the actual AQ500 antenna housed within the trailer unit. The whole setup is designed to minimise side-lobe sound propagation, i.e noise pollution, and to minimise broadband loud noise interference with the return signal.

Item	Specification	Range
1	Height Range	20-200m
2	Height Resolution	5m
3	Accuracy Wind Speed	0.1m/s
4	Antenna Arrangement	3-beam
5	Antenna Height	1.2m
6	Antenna Width	1m
7	Antenna Weight	70kg
8	Data Transfer	GSM
9	Data Format	ASCII via SODWIN Software
10	Operating Frequency	3144Hz
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12	Humidity Range	10 to 100% RH

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4.0 Analysis results

Section 4 summarises the data analysis as used to generate the final output time series. The terrain file used to generate the wind analysis in WAsP is shown in Figure 4.1:

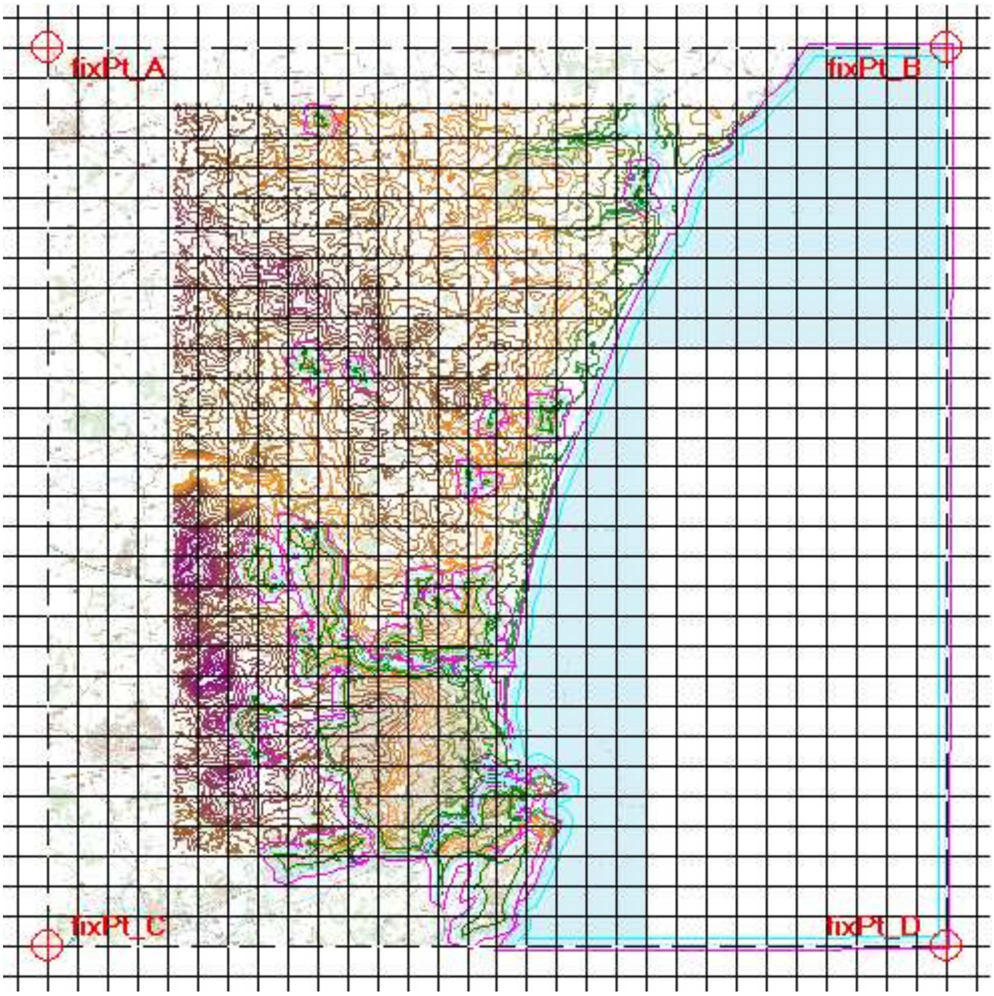

Figure 4.1: Contour map showing 10m height contours with roughness used for calculation.

4.1 Data filtering

SoDAR data can be prone to some errors in measurement which can be eliminated through careful filtering. These errors can include:

- Fixed echo;
- Low signal to noise ratio;
- Data loss through high background noise levels.

In this case the following data filters were used to clean the dataset prior to analysis:

- Data screened for null values (e.g. “9999”)

- Data with low signal to noise ratio (S:N < 50) removed.

The data period covered is from the 17th December 2010 (00:00) till 10th March 2011 (23:50).

4.2 Easter Hatton Summary

Figure 4.2 shows the wind speed data analysis output from WAsP.

A reference height of 120m was chosen by the client as being the hub height reference for this project, and is therefore used to summarise the data analysis.

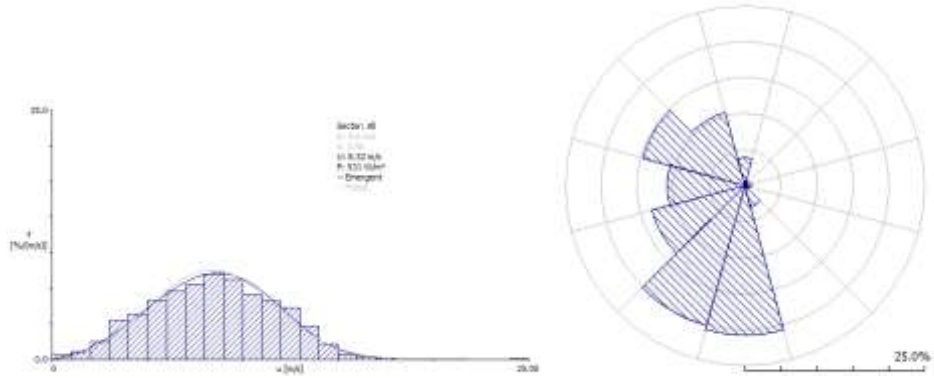

Figure 4.2: WAsP summary of SoDAR output at 120m (A=9.6, k=3.06, U=8.57m/s)

Figure 4.2 clearly shows the wind speed within the analysis period rarely came from easterly sectors, with the predominant direction being southerly during this period.

Figure 4.3 shows the site characteristic turbulence as a function of wind speed

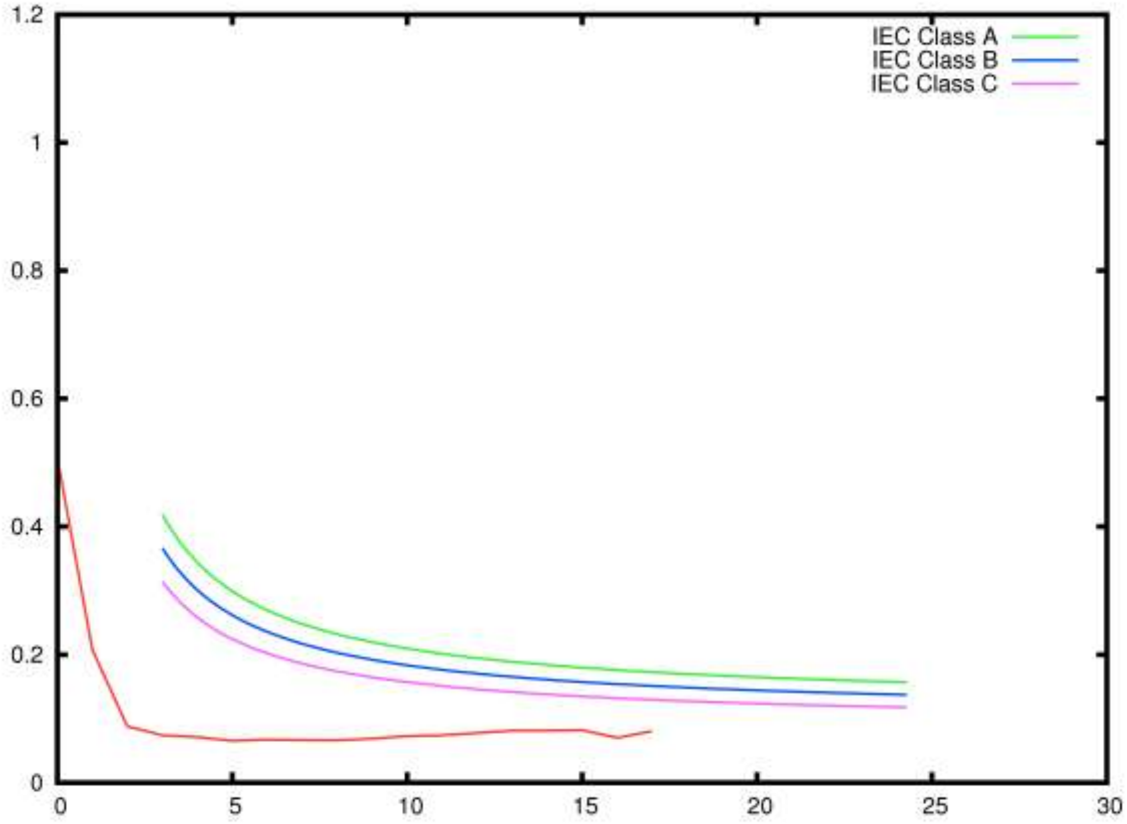

Figure 4.3: Site characteristic wind speed on data submitted.

Figure 4.4 shows the turbulence by sector with Table 4.1 showing the shear profile by sector.

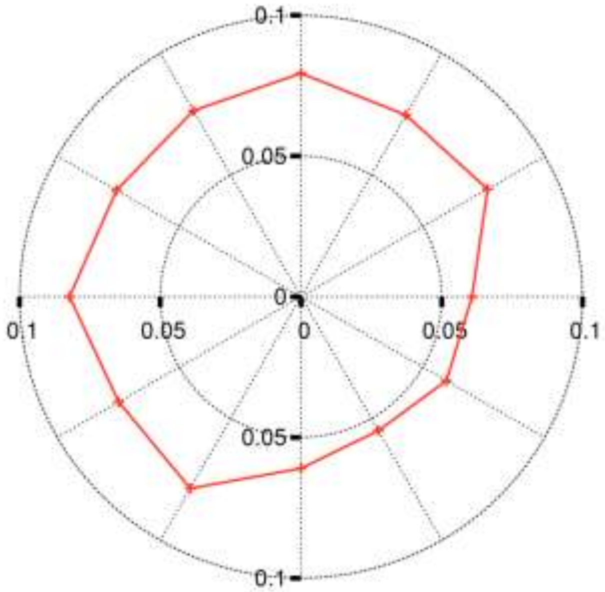

Figure 4.4: Turbulence intensity Rose

	Direction Sector	Mean Exponent
1	345-15	0.438
2	15-45	0.753
3	45-75	--
4	75-105	--
5	105-135	--
6	135-165	--
7	165-195	0.140
8	195-225	0.295
9	225-255	0.248
10	255-285	0.282
11	285-315	0.337
12	315-345	0.295

Table 4.1: Shear mean exponent by sector

The Turbulence rose shows a consistent level of turbulence by sector, supporting the little effect of local features on the SoDAR site. There is however high shear from Sector 2, which is most likely, a function of very few data points in these sectors as opposed to being physical.

The mean shear profile is 0.205, with a reported turbulence intensity of 8.02% at 15m/s. This is a typical value for offshore supporting the suitability of the location for providing data for the offshore project.

4.4 Wind Farm data Summary

Figure 4.5 shows the WAsP wind speed predicted output at the Wind Farm location.

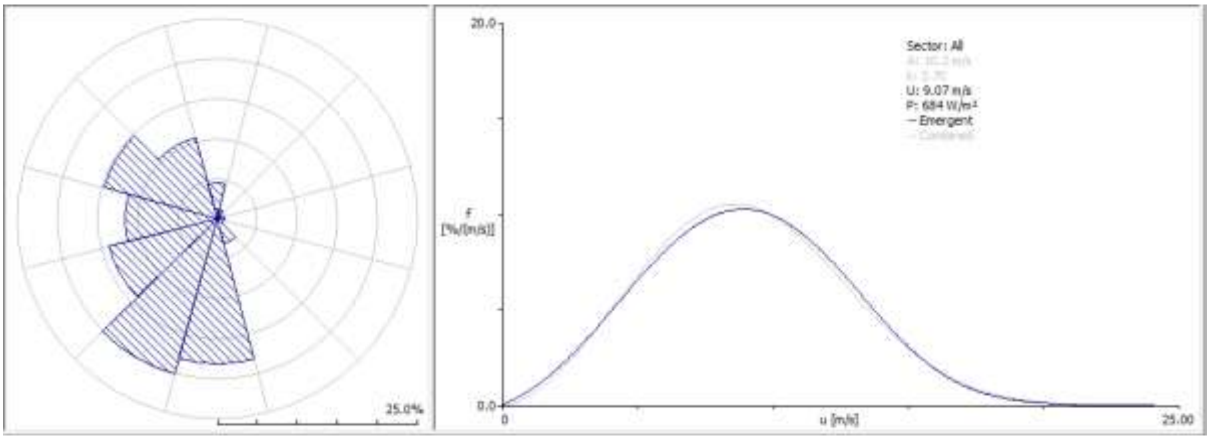

Figure 4.5: WAsP output at 120m (A=10.2m/s, k=2.7; U=9.07m/s)

Figure s 4.6 and 4.7 shows the shear output for the onshore SoDAR and offshore location respectively where the shear has reduced as the flow has migrated from onshore to offshore. This is to be expected, and supports the method used.

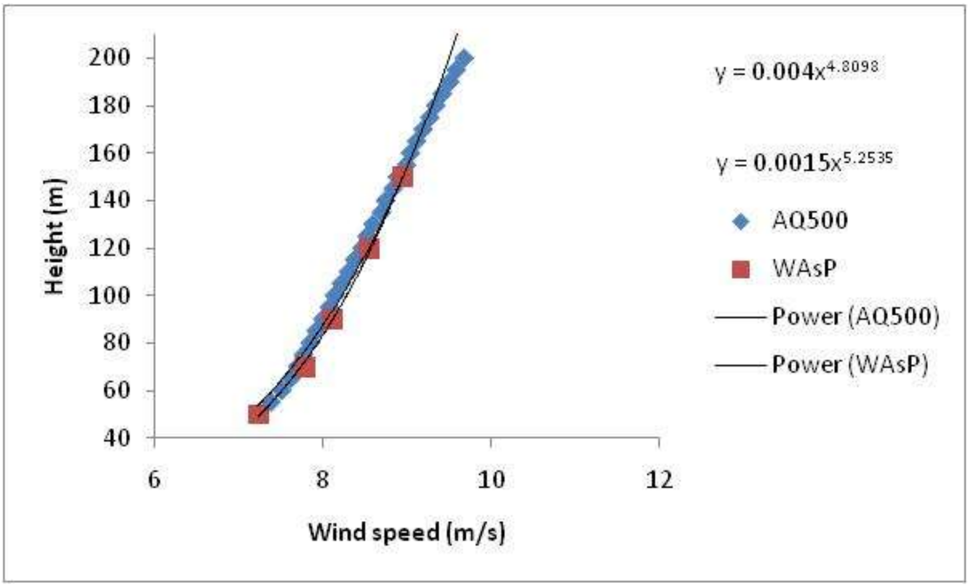

Figure 4.6: SoDAR and WAsP derived Shear Profile for Easter Hatton

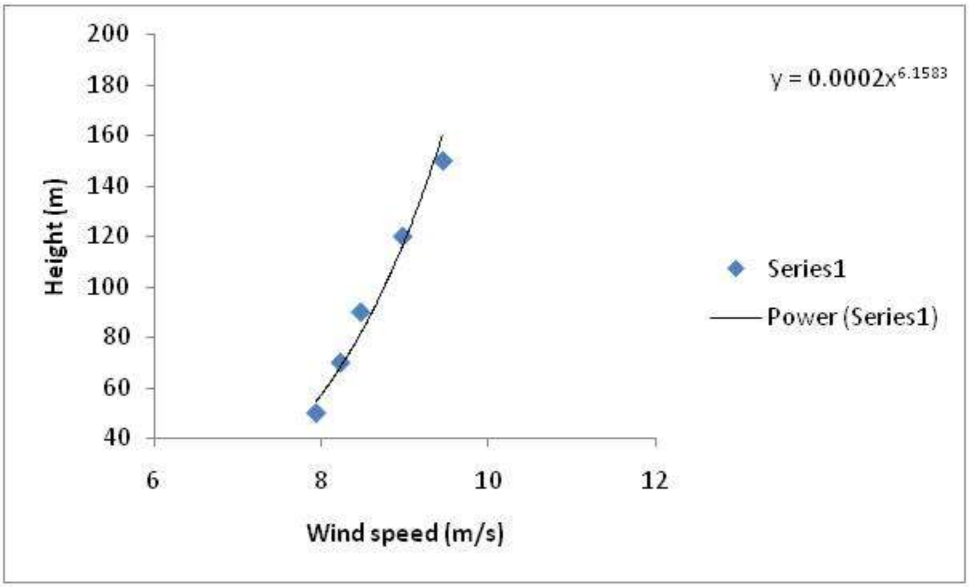

Figure 4.7: WAsP Predicted hear profile (0.16)

The wind speed predicted has increased slightly from 8.57m/s to 9.07m/s at 120m

The predicted WAsP climate was calculated at 5 heights (50m, 70m, 90m, 120m, and 150m), and the resultant wind speed ratio between the WAsP predicted output and the actual SoDAR recorded value was used to calculate a coefficient.

The WAsP values are also used to generate the predicted shear profile, which in turn is used to give a flow modification coefficient for each height level recorded by the SoDAR.

Table 4.3 summarises the 5 calculated coefficients, and table 4.4 the coefficients used to modify the time series.

Height	OWC wind speed from WAsP	Wind climate at reference site from WAsP	Scaling factor
50	7.23	7.95	1.099585
70	7.78	8.33	1.070694
90	8.11	8.6	1.060419
120	8.55	9.07	1.060819
150	8.94	9.51	1.063758

Table 4.3: Scaling Factors from WAsP onshore and Predicted

Mean Speed M/s	Height (m)
7.86806	50
7.990778	55
8.104483	60
8.210508	65
8.309909	70
8.40353	75
8.492062	80
8.576074	85
8.656043	90
8.732374	95
8.805411	100
8.875451	105
8.94275	110
9.007534	115
9.07	120
9.130323	125
9.188657	130
9.245141	135
9.2999	140
9.353044	145
9.404675	150
9.454883	155
9.503753	160
9.55136	165
9.597774	170
9.643058	175
9.68727	180
9.730466	185
9.772695	190
9.814003	195
9.854433	200

Table 4.4: Modified SoDAR shear profile for all heights

The coefficients are then used to modify the SoDAR time series at all heights and the resultant time series generated is the output of this report.

Figure 4.8 shows the final shear profile generated from the modified SoDAR time series.

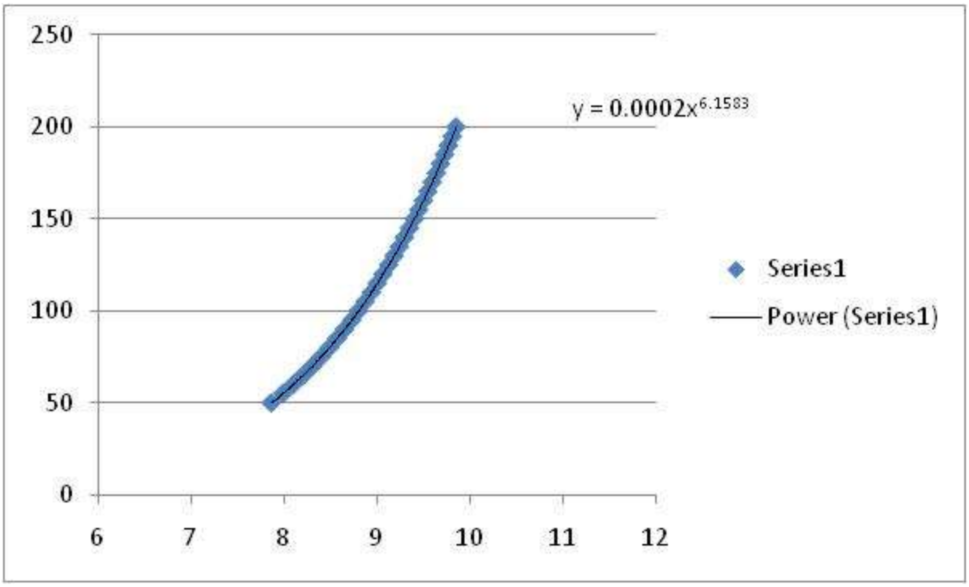

Figure 4.8: modified SoDAR data now representing the offshore wind farm climate (Shear =0.16)

5.0 Summary

An analysis has been performed to translate locally acquired onshore SoDAR data form an AQ500 system to a location offshore.

The onshore dataset has been characterised into a climate file suitable for WAsP and used to generate a predicted wind speed value at the wind farm location. This was done for 5 heights.

The resultant predicted wind shear and speed up effect was then used to calculate the speed up coefficients for all heights, ranging from 50m – 200m in 5m increments.

The output is a modified time series which is sent in accompaniment to this report.

The reference height was 120m, and the resultant wind speed increased from 8.57m/s to 9.07m/s.

6.0 About Oldbaum

Oldbaum Services is a wind energy consultancy, with roots tracing back to 2003. In 2003 Technical Director Andy Oldroyd won a Green Energy Award whilst working for Chillwind for introducing a new measurement technique (Sound Detecting and Ranging or SoDAR) to the wind industry sector.

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Oldbaum Services are part of the Leosphere Wind Experts programme, and have been working with all forms of LiDAR since 2005. Oldbaum have designed acceptance tests and measurement campaigns for all forms of LiDAR (Continuous wave or pulse) and have therefore a unique perspective and experience in the unique challenges posed by each system type.

Annex 1.0: AQ500 validation results

The following is an extract of a test undertaken at Myers Hill in Scotland. The data IS FORM a well instrumented 80m met mast as reference, with the AQ500 being located 300m to the South West of the system. No filters have been applied apart from directional filters to exclude the influence of the 1MW NEG MICON WTG's located to the North East and South East of the met mast.

Full test results can be downloaded here: http://www.aqs.se/wordpress/wp-content/uploads/2009/12/AQSMH001_221209.pdf (large file)

Annex 1.0: Data Availability

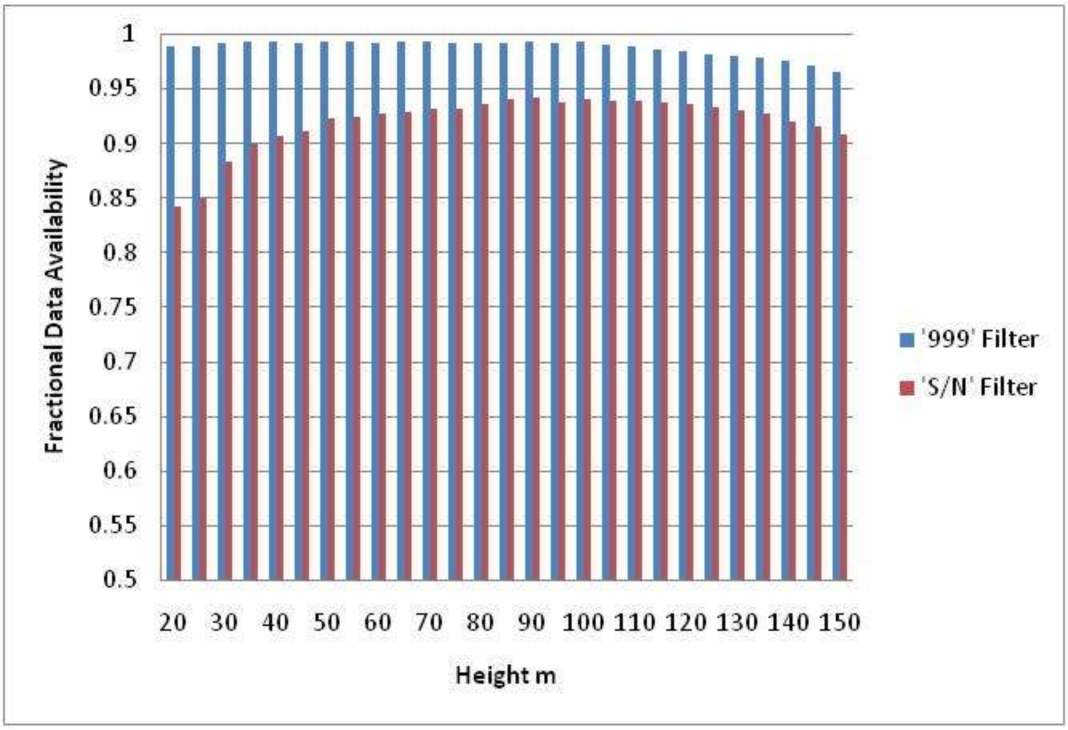

Figure A1.1: Data Availability of AQ500 System

Annex 1.0: Correlation Results

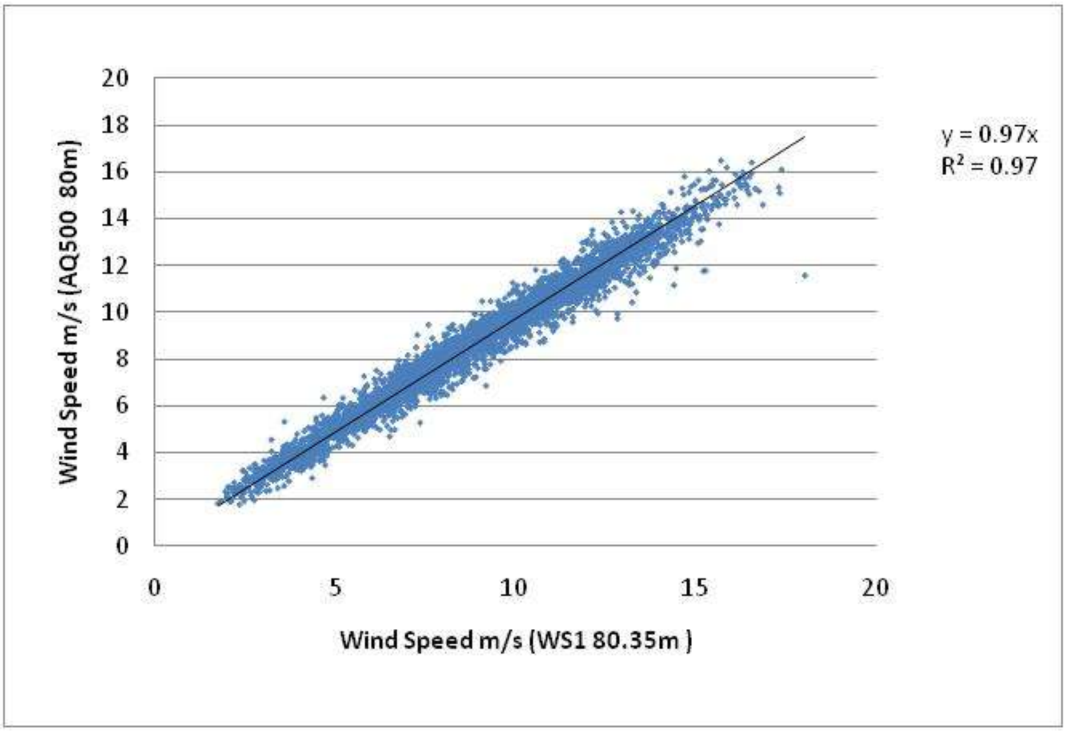

Figure A1.2: Overall correlation with 80m mast @ 80m, 300m Separation. Direction filter applied

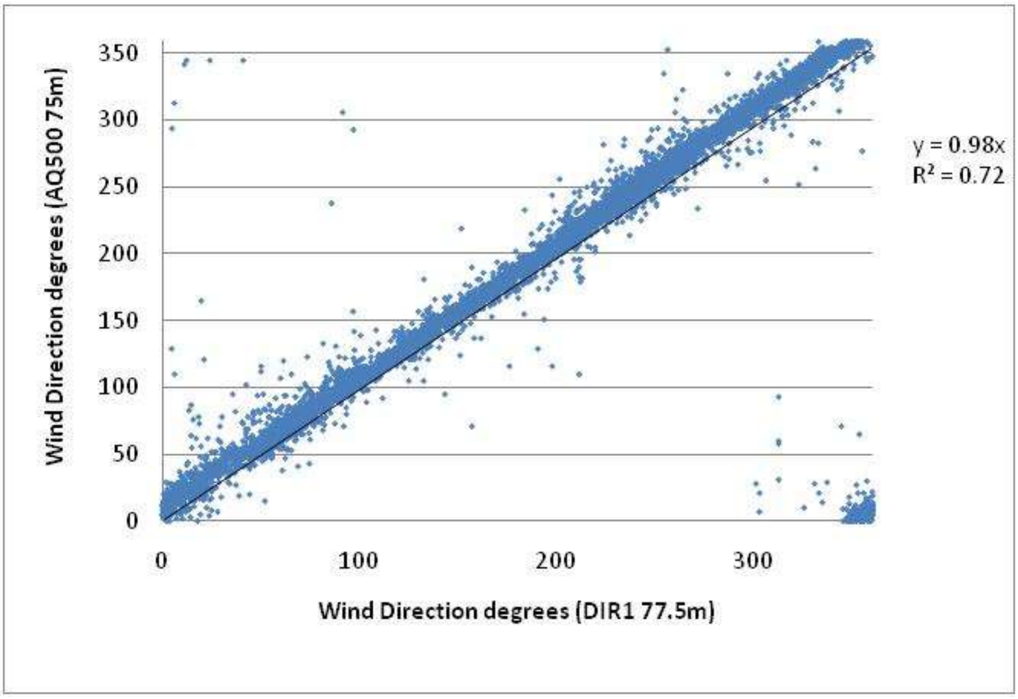

Figure A1.3: Direction Correlation – No applied filter

Wind speed data spatial translation

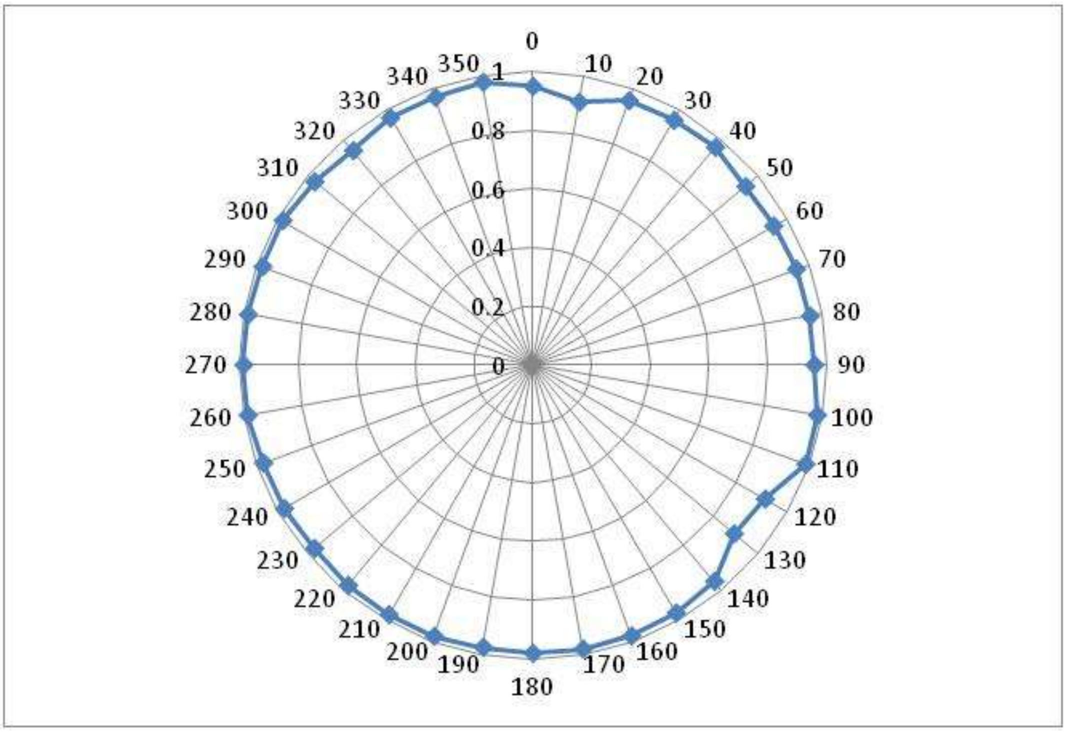

Figure A1.4: Correlation by Direction. Kinks show location of NEG Micon systems

Annex 1.0: Shear Profile Results

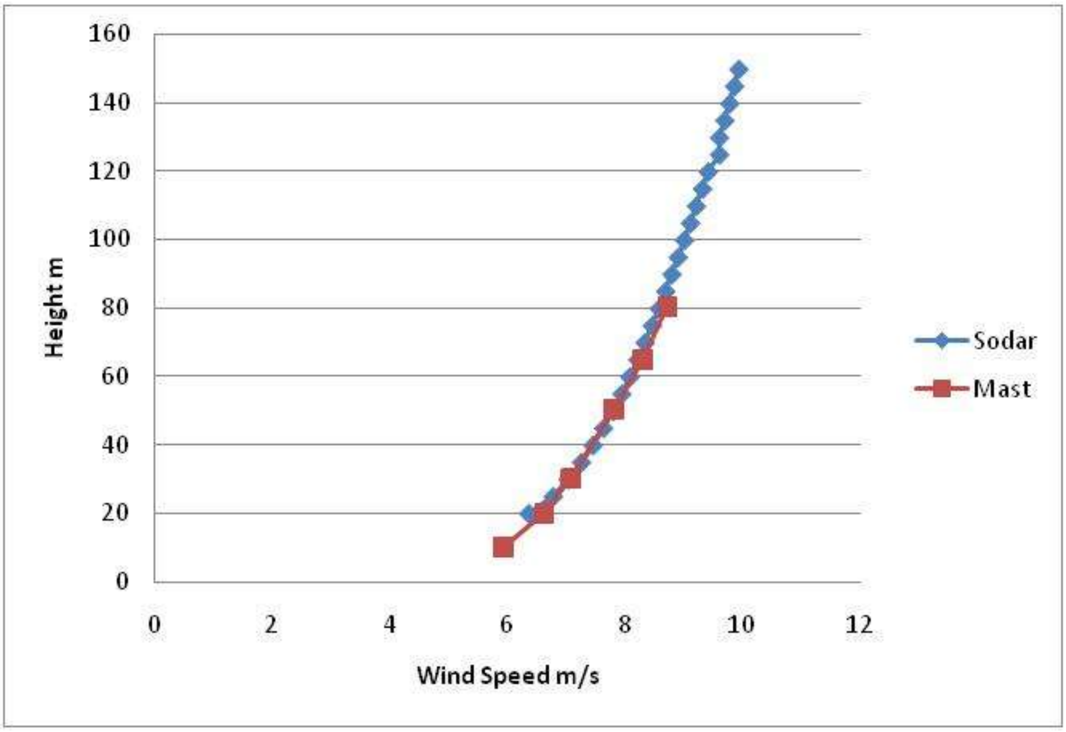

Figure A1.5: Shear profile Direction filter applied

Wind speed data spatial translation

	Mast	SoDAR
c	0.0017	0.0026
b	4.9921	4.8059
α	0.2003	0.2081
R^2	0.9944	0.9979

Table A1.1: Regression analysis output equation of form cx^b .

Annex 1.0: turbulence Intensity

All RS systems have issue with turbulence through spatial and temporal averaging, or in some cases systematic filtering of the turbulence spectrum. IN this case we advocate the use of bin averaged values. Time series turbulence should be treated with caution; however Bin averaging shows the ability of the system for site classification.

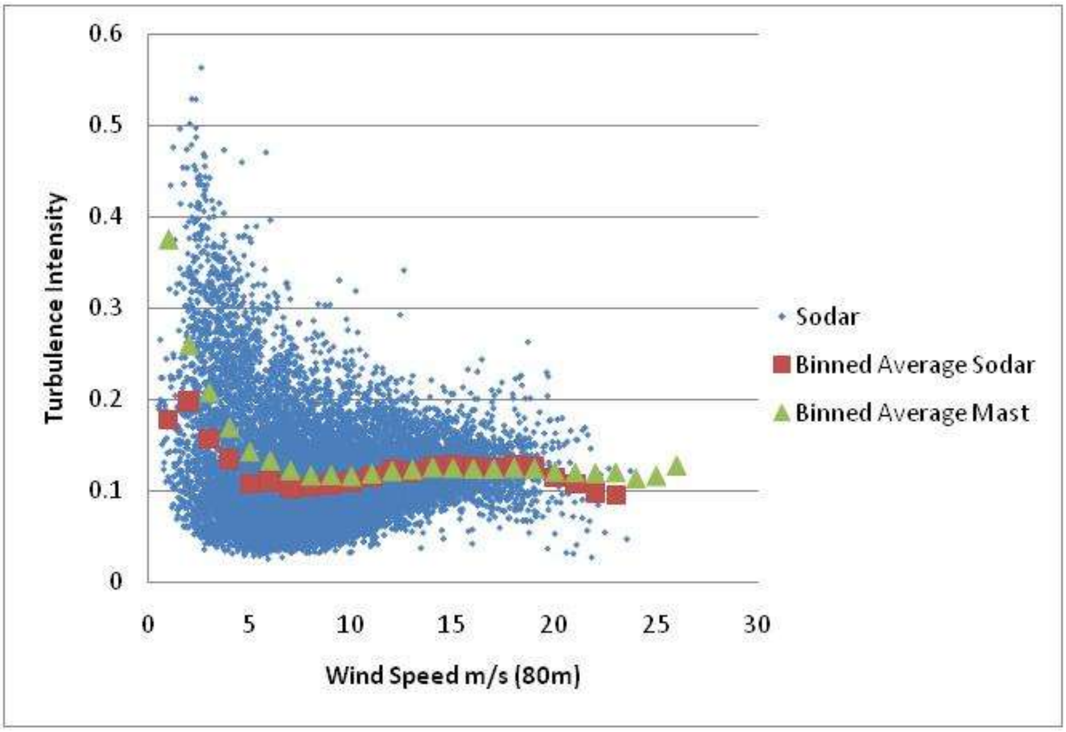

Figure A1.6: Turbulence Bin averaged values

Annex 1.0: Rain performance

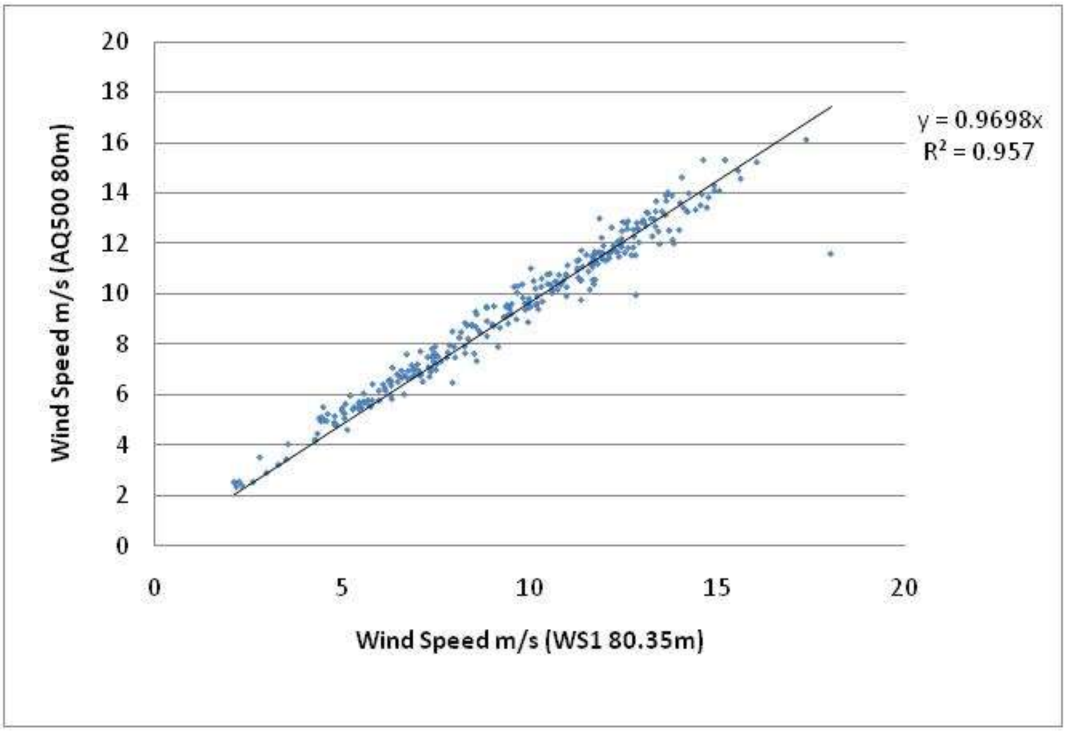

Figure A1.7: Rain period data

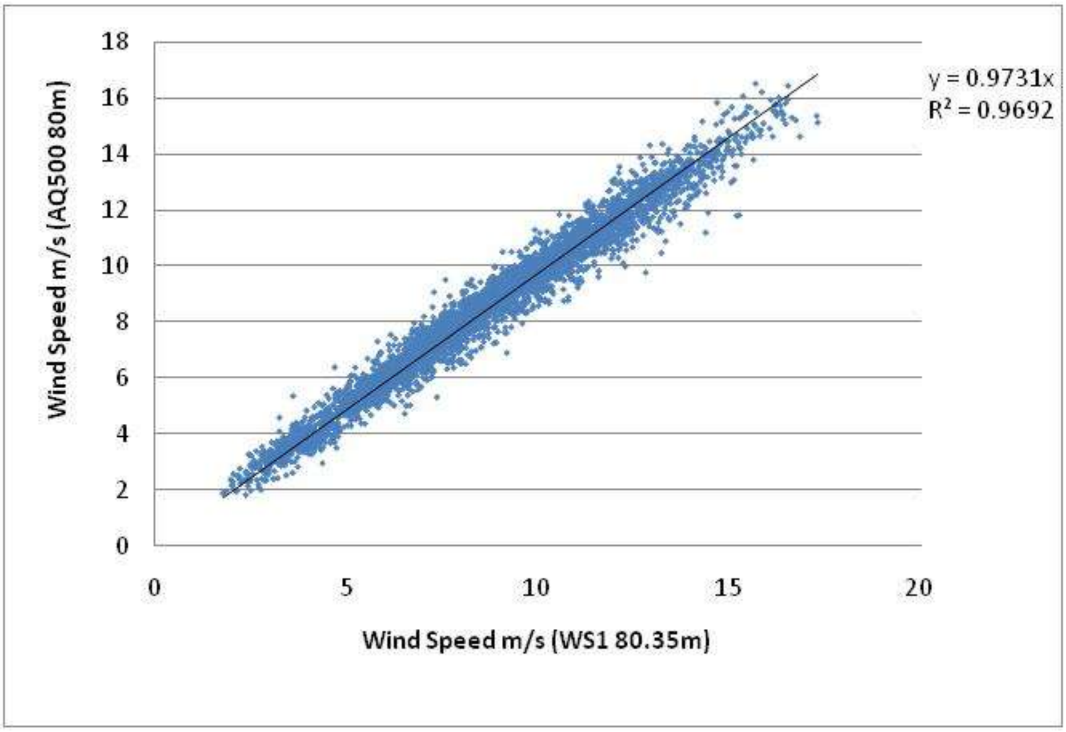

Figure A1.8: Non rain affected,

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