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PROPOSED WIND TURBINE AT SHOREHAM PORT

ADUR AND WORTHING

NOISE IMPACT ASSESSMENT

Technical Report: R4997-1 Rev 0

Date: 19th May 2014

For: Fine Energy Ltd
212 Zellig Building
The Custard Factory
Birmingham
B9 4AU

24 Acoustics Document Control Sheet

Project Title: Proposed Wind Turbine at Shoreham Port, Shoreham-by-Sea
Noise Impact Assessment

Report Ref: R4997-1 Rev 0

Date: 19th May 2014

	Name	Position	Signature	Date
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For and on behalf of 24 Acoustics Ltd				

Document Status and Approval Schedule

Revision	Description	Prepared By	Approved By
0	Approved for Issue	David Coles	Reuben Peckham

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This report was completed by 24 Acoustics Ltd on the basis of a defined programme of work and terms and conditions agreed with the Client. The report has been prepared with all reasonable skill, care and diligence within the terms of the Contract with the Client and taking into account the project objectives, the agreed scope of works, prevailing site conditions and the degree of manpower and resources allocated to the project.

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It should be noted that the assessment presented within this report is valid at the time that it was undertaken. Compliance with ETSU-R-97 is not indicative that complaints from some residents will not occur. Any party considering developing a wind turbine on the site at a later date should undertake their own due diligence to ensure that the site remains suitable (on noise grounds) for development.

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EXECUTIVE SUMMARY

24 Acoustics Ltd has been instructed by Fine Energy Ltd to undertake an assessment of the likely noise impact of the operation of two 100 kW wind turbines to be installed on land at Shoreham Port in Shoreham-by-Sea.

The assessment has been undertaken following detailed background noise surveys at noise-sensitive receptors near to the proposed turbines and acoustic modelling of the noise emission from the turbines to predict operational noise levels at the receptor locations under a range of wind speeds.

A comparison of the predicted noise levels has been made with the background noise levels in accordance with the guidance described in ETSU-R-97 (Assessment and Rating of Noise from Wind Farms).

The assessment indicates that the noise level from the proposed turbines will be lower than the ETSU-R-97 derived noise limits for both the quiet daytime and night time periods at all receptors.

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1.0 INTRODUCTION

1.1 24 Acoustics Ltd has been instructed by Fine Energy Ltd to undertake an assessment of the likely noise impact of the operation of two Norvento nED100 100 kW wind turbines operating at Shoreham Port in Shoreham-by-Sea.

1.2 The assessment has been undertaken following detailed background noise surveys at noise-sensitive receptors near to the proposed turbines and acoustic modelling of the noise emission from the turbines to predict operational noise levels at the receptor locations under a range of wind speeds.

1.3 All sound pressure levels quoted in this report are in dB relative to 20 µPa. All sound power levels are quoted in dB relative to 10e-12 Watts. A glossary of the acoustic terminology used in this report is provided in Appendix A.

2.0 SITE DESCRIPTION AND PROPOSED WIND TURBINE

2.1 Shoreham Port is located in Shoreham-by-Sea, approximately 9 km east of Worthing in West Sussex.

2.2 It is proposed to install two Norvento nED100 100 kW wind turbines on land at Shoreham Port, at OS coordinates TQ 24043 04688 and TQ 24131 04694.

2.3 The turbines will have a hub height of 25 m and blade diameter of 22 m, giving a total tip height of approximately 35.5 m.

2.4 The nearest residential properties to the site are detailed as follows:

No	Name/ Address	OSGB36 Grid Reference	Distance from Turbine
1	Locks Court	TQ 24123 05028	332 m
2	Coates Court	TQ 24183 05042	348 m
3	27 Albion Street	TQ 23789 04990	390 m
4	29 Victoria Road	TQ 23915 05154	480 m
5	5 Colebrook Road	TQ 24533 05108	575 m

Table 1: Receptor Locations (distances are to closest turbine)

2.5 Given the urban location of the turbines and the density of residential housing nearby, predicted noise levels were only calculated to a small number of residential properties. The noise levels predicted to these properties can be considered representative of the noise levels experienced at surrounding properties.

2.6 Figure 1 provides an aerial image of the site, turbine and receptor locations.

3.0 ASSESSMENT CRITERIA AND CONSULTATION

3.1 For assessment of noise from turbines/wind farms in the UK, ETSU-R-97 'The Assessment and Rating of Noise from Wind Farms' [Reference 1] is used. This document defines a framework for the measurement of noise from wind turbines and suggests noise limits for use in assessing the noise impact from wind turbines at the planning application stage of a project.

3.2 ETSU-R-97 requires the assessment of wind turbine noise to be assessed at night (between 23:00 and 07:00 hours) and during the 'quiet daytime hours' (evenings from 18:00- 23:00, Saturday afternoons between 13:00 and 18:00 and Sundays from 07:00 until 18:00). For the day-time period a noise limit of 35- 40 dBA or 5 dBA above the prevailing background noise level is set (whichever is the greater). The distinction between the use of the absolute noise limit of 35 or 40 dBA is not explicitly stated, however, it relates to the number of receptor properties, the effect of the noise limit on the amount of electrical power generated and the duration of the level of exposure. At night the noise limit is 43 dBA or 5 dBA above the prevailing background noise level, whichever is greater.

3.3 Where the occupier of a property has some financial involvement with the wind turbine/ wind farm, the day and night-time lower noise limits are increased to 45 dB(A).

3.4 The noise limits apply across the turbine operational wind speeds (usually between 4 and 10 m/s) and it is necessary to quantify both the background noise level and the noise level emitted by the turbine(s) as a function of wind speed. The background noise level is measured simultaneously with wind speed (determined at a height of 10 m) and noise level is set by calculation of a best fit curve through values of background noise plotted against wind speed for both the quiet daytime and night time operational periods.

3.5 Both the noise emitted from the turbine and the background noise levels are determined in terms of the overall A-weighted $L_{90,10\ min}$ sound pressure level. This is 2 dBA less than the $L_{Aeq,\ 10\ min}$ sound pressure level recorded over the same period.

3.6 ETSU-R-97 provides a simplified methodology for smaller or more remote schemes when the predicted noise level from the turbine does not exceed 35 dB L_{A90} at all wind speeds of up to 10 m/s. The can avoid the need to undertake background noise surveys when this scenario arises.

3.7 ETSU-R-97 also states 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.

3.8 The noise limits in ETSU-R-97 take into account the fact that all wind turbines exhibit specific noise characteristics described as blade swish to a certain extent. Severe cases of blade swish can exhibit themselves as amplitude modulation. Current studies indicate, however, that cases of amplitude modulation are rare. Some parties also have concern about infrasound and low frequency noise from wind farms. Again studies indicate that any such noise is very unlikely to be prejudicial to the health of a wind farm neighbour.

3.9 In the past decade there have been many planning appeals and public inquiries relating to proposed wind farm/ wind turbine sites. There have been a number of technical disputes between acoustic consultants working on behalf of the different parties. To minimise these disputes an agreement between these groups was published by the Institute of Acoustics in April 2009 [Reference 2] (known as the IoA Agreement).

3.10 In summary the IoA Agreement provides clarification of the following issues:

- The acquisition of baseline noise data at receptor locations and analysis of this data to take into account site- specific wind shear. Specifically this states that to account for the effects of local wind shear wind speeds should preferably be measured at two heights and then derived to a 10 m height (rather than measured, as stipulated in ETSU-R-97). When background noise surveys are carried out for sites where wind speeds can only be measured at 10 m height, then the noise assessment should take account of the wind shear variations using a method that should be explained. Where noise assessments are based solely on measured 10 m height wind speeds the noise limits in planning conditions should also refer to measured 10 m height wind speeds;

- The prediction of wind turbine noise at receptor locations- stating that the propagation methodology of ISO 9613 [Reference 3] be used with a ground effects condition of G=0.5 used with a 4 m receptor height and the turbine vendor's warranted sound power level data, together with the effect of acoustic barriers, ensuring that no account should be taken of barrier attenuation caused by a landform unless there is no line-of-sight between the receptor and the highest point of the turbine rotor (in which case a barrier correction of 2 dB(A) can be justified;

- Vibration and low frequency noise. It is concluded that there is no robust evidence that low frequency noise (including noise and ground-borne vibration) from wind farms, generally has adverse effects on wind farm neighbours.

IoA Good Practice Guide

3.11 The Institute of Acoustics has recently (May 2013) published a '*Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*' [Reference 4]. This provides some useful guidance on best practice for the modelling of wind turbine noise and measurement of background noise levels. Where practicable, the guidance contained in the best practice guide has been followed in this assessment, namely:

- Use of polynomial regression for background noise data (unless a specific noise source requires consideration through linear regression analysis);

- Removal of samples immediately before and after rainfall;

- Removal of elevated background noise levels due to the dawn chorus;

- Correction of wind speed measured at hub height to a standardized height of 10 m.

Consultation

3.12 As part of the assessment an Environmental Health Officer (Mr Michael Lavender) at Adur and Worthing Council has been consulted to agree the scope of the assessment and the background noise survey locations. He agreed that two background noise survey locations would be acceptable and stated that he would like to attend site to witness the siting of the noise monitoring equipment. Mr Lavender also agreed that it would be acceptable to measure wind speed at hub height, at a location representative of the proposed turbine location.

4.0 BACKGROUND NOISE AND WIND SPEED SURVEYS

4.1 Background noise surveys were carried out between 30th April and 14th May 2014 in accordance with the requirements of ETSU-R-97 at the receptor locations representative of residential properties most likely to be affected by noise from the proposed wind turbines, as shown in Figure 1 and described below:

- 5 Colebrook Road (at OS coordinates TQ 24538 05104);
- 29 Victoria Road (at OS coordinates TQ 23912 05176).

4.2 Background noise levels measured at 5 Colebrook Road are considered representative of noise levels that would be experienced at properties close to the port and associated works. Background noise levels measured at 29 Victoria Road are considered representative of noise levels that would be experienced at properties located away from the port.

4.3 Mr Michael Lavender from Adur and Worthing Council met 24 Acoustics' engineer on site at the start of the surveys on 30th April 2014 to agree the precise siting of the instrumentation. Photographs showing the survey locations are displayed in Figure 2.

4.4 The noise surveys were undertaken using the following instrumentation:

- 2 x Rion NL-52 precision grade class 1 accuracy sound level meter;
- Brüel and Kjær 4231 acoustic calibrator.

4.5 The instrumentation was calibrated before and after the surveys in accordance with the manufacturers' instructions. No drift in calibration was recorded. The calibration certificates of the instrumentation used are provided in Appendix B.

4.6 The sound level meters were installed at a height of approximately 1.5 m above local grade level. Dual-layer environmental windshields were fitted to the microphones. Measurements were undertaken in samples of ten minutes in terms of the $L_{A90,\ 10\ min}$ sound pressure level.

4.7 A NRG #40C calibrated anemometer and #200P wind vane were installed at hub height (25 m) on a lighting tower close to the proposed turbine locations (at OS coordinates TQ 24055 04750). The meteorological instruments were used to log wind speed, wind direction, temperature and precipitation (all time-synchronised with noise measurements) throughout the survey period.

5.0 WIND TURBINE NOISE PREDICTIONS

5.1 Source noise data for the Norvento nED100 wind turbine are provided by the manufacturer in an IEC 61400-11 test report by Aresse Engineering S.L. [Reference 5], extracts of which can be found in Appendix D. Wind turbine sound power levels and frequency dependence are described below in Tables 2 and 3. The report states that tonal penalties do not apply. It should be noted that this wind turbine is capable of operating in a 'low noise' mode, with a reduced power output. The assessment here assumes the turbine is operating at full power, with maximum noise output.

	Standardised 10 m Wind Speed, m/s & L_{Aeq} Sound Power Levels, dB				
	6	**7**	**8**	**9**	**10**
Apparent Sound Power Level, $L_{WA,k}$ (dB)	96.4	99.0	100.0	100.7	100.3
IEC 61400-11 Uncertainty (dBA)	0.95	0.80	0.75	0.70	1.00
Uncertainty x 1.645 (dBA)	1.6	1.3	1.2	1.2	1.6
ETSU Tonal Penalty (dBA)	0.0	0.0	0.0	0.0	0.0
Effective Sound Power Level (dBA)	**98.0**	**100.3**	**101.2**	**101.8**	**101.9**

Table 2: Norvento nED100 L_{Aeq} Sound Power Levels

Octave Band Sound Power Level, dB Octave Band Centre Frequency								
31.5	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
75.9	82.3	86.5	92.2	96.2	96.6	96.2	85.2	69.3

Table 3: Sound Power Level Frequency Spectrum for 10 m Wind Speed of 10 m/s

5.2 Uncertainty has been calculated by multiplying the IEC 61400-11 test uncertainty by 1.645 in accordance with the IoA Good Practice Guide (Paragraph 4.3.6).

5.3 Predictions of the noise emission from the proposed wind turbines have been carried out using IMMI 2011-1 noise mapping software. The propagation methodology of ISO 9613 has been used which takes into account the effects of geometric divergence, acoustic screening and atmospheric and ground absorption.

5.4 The calculations have assumed an ambient temperature of 10 °C and relative humidity of 70%. Downwind propagation conditions have been assumed throughout. The calculations have determined the noise level from the turbines at a receptor height of 4 m above local grade level and have assumed a ground absorption factor of G=0 (which complies with current agreed understanding).

5.5 At this site no account has been taken of any acoustic shielding that may be provided by the natural topography of the land or buildings. The calculations therefore represent a worst-case assessment.

5.6 The results of the acoustic model are provided graphically in Figure 3 as a noise contour map and are described below (both assuming the maximum noise output that is experienced at 10 m wind speeds of 10 m/s). The turbine noise levels have been corrected from L_{Aeq} sound pressure levels to L_{A90} sound pressure levels by subtracting 2 dBA in accordance with the ETSU-R-97 methodology.

Receptor		Predicted Sound Pressure Level, dB L_{A90}
No.	**Name/ Address**	
1	Locks Court	42.9
2	Coates Court	42.2
3	27 Albion Street	40.8
4	29 Victoria Road	39.1
5	5 Colebrook Road	36.9

Table 4: Results of Noise Propagation Calculations, 10 m/s Wind Speed at 10 m Height

5.7 A full detailed summary of all results at each receptor can be found in Appendix C.

6.0 NOISE IMPACT ASSESSMENT

6.1 The measured $L_{A90,10min}$ background noise levels have been plotted against corresponding wind speeds (corrected from 25 m height to 10 m reference height in accordance with best practice) at the background noise measurement locations for both the quiet daytime and for the night-time periods. Periods which were exposed to rainfall have been removed from the analysis (together with the measured samples acquired immediately before and after rainfall ceased). A period after daylight has been removed from the analysis to account for the elevated background noise level that can occur as a result of the dawn chorus (all in accordance with the recommendations of the IoA Good Practice Guide). Atypical data points have also been removed from the analysis. Noise level and wind speed time histories showing the data that have been omitted from the assessment are provided in Appendix E. Polynomial regression lines have been calculated through the background noise data to give the prevailing background noise data as required for the derivation of the ETSU-R-97 noise limits.

6.2 Figures 4 to 7 show the background noise levels, the derived ETSU-R-97 noise limits and the noise level predicted from the turbines across the range of operational wind speeds for both the quiet daytime and night-time periods.

6.3 Where it is considered that too few data points have been measured at a specific wind speed, that wind speed has been considered to be outside the range of measured wind speeds. In this case, the noise limit derived for the maximum wind speed within the measured range has been adopted for that wind speed. This is shown as a flat line at the top end of Figures 4 to 7 and is in line with guidance in the IoA Good Practice Guide.

6.4 The analysis indicates that the predicted noise level from the turbines will be lower than ETSU-R-97 noise limits for both the daytime and night-time periods at all receptor locations.

Cumulative Assessment

6.5 A review of the Adur and Worthing Councils' planning website has been undertaken to identify any existing or planned wind turbines close to the proposed turbines at Shoreham Port. No relevant wind turbines were identified.

7.0 CONCLUSIONS

7.1 24 Acoustics Ltd has been instructed by Fine Energy Ltd to undertake an assessment of the likely noise impact of the operation of two 100 kW wind turbines to be installed on land at Shoreham Port in Shoreham-by-Sea.

7.2 The assessment has been undertaken following detailed background noise surveys at the nearest noise-sensitive receptors to the proposed turbines and acoustic modelling of the noise emission from the turbines to predict operational noise levels at the receptor locations under a range of wind speeds.

7.3 A comparison of the predicted noise levels has been made with the background noise levels in accordance with the guidance described in ETSU-R-97 (Assessment and Rating of Noise from Wind Farms).

7.4 The assessment indicates that the noise level from the proposed turbines will be lower than the ETSU-R-97 derived noise limits for both the quiet daytime and night time periods at all receptors.

REFERENCES

1. ETSU-R-97, Assessment and Rating of Noise from Wind Farms, Department of Trade and Industry, 1997.

2. Prediction and Assessment of Wind Turbine Noise, Institute of Acoustics, Acoustics Bulletin March, April 2009.

3. ISO 9613, Acoustics- Attenuation of Sound During Propagation Outdoors, International Standards Organisation, 1993.

4. 'A Good Practice Guide to the Application of ETSU-R-97 For The Assessment And Rating Of Wind Turbine Noise', Institute of Acoustics, May 2013.

5. Technical Report - DEWI SP - NORVENTO NED100 ED3.0, TR-13-035c, Aresse Engineering S.L., 2013.



Project: Shoreham Port, Shoreham-by-Sea	**Description:** Proposed Turbine, Receptor and Background Noise Survey Locations	
DWG No: Figure 1	**Scale:** N.T.S.	**Rev:** A
Date: May 2014	**Drawn By:** DC	**Job No:** 4997-1

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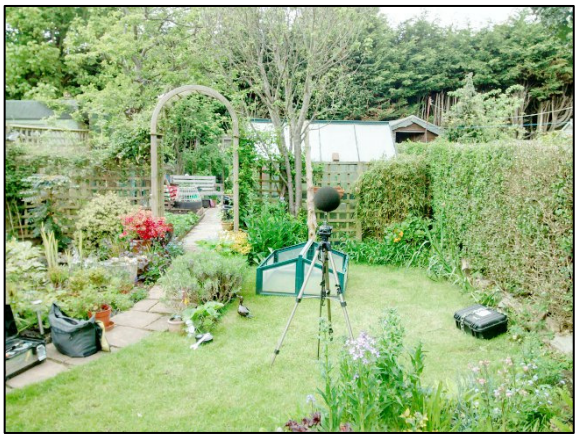
5 Colebrook Road





29 Victoria Road

Project: Shoreham Port, Shoreham-by-Sea	**Title:** Photographs of survey locations	
DWG No: Figure 2	**Scale:** N.T.S.	**Rev:** A
Date: May 2014	**Drawn By:** DC	**Job No:** 4997-1



Project: Shoreham Port, Shoreham-by-Sea	**Description:** Turbine Noise Contour Map, 10 m/s wind speed, L_{A90}		24Acoustics www.24acoustics.co.uk
DWG No: Figure 3	**Scale:** N.T.S.	**Rev:** A	
Date: May 2014	**Drawn By:** DC	**Job No:** 4997-1	

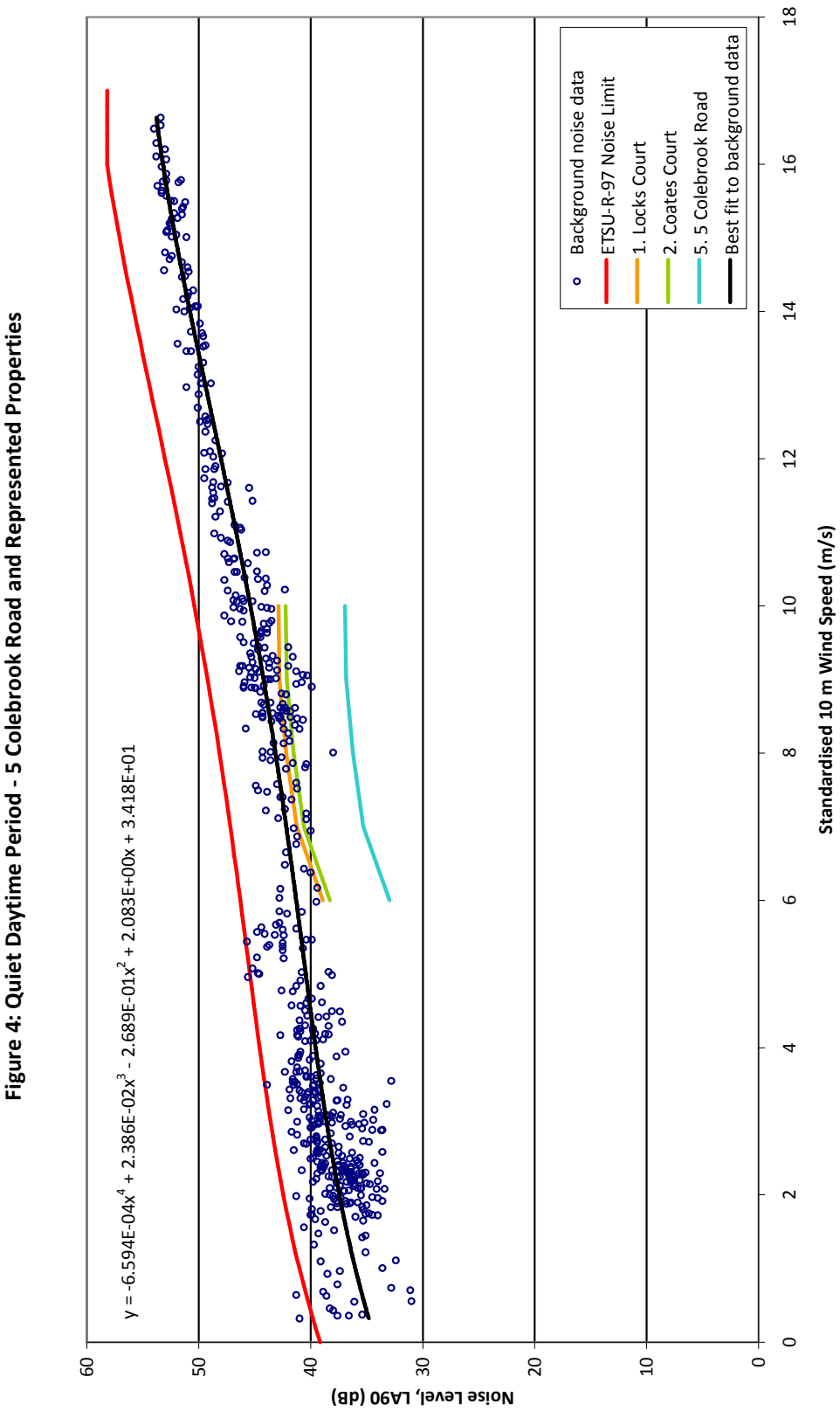


Figure 4: Quiet Daytime Period - 5 Colebrook Road and Represented Properties

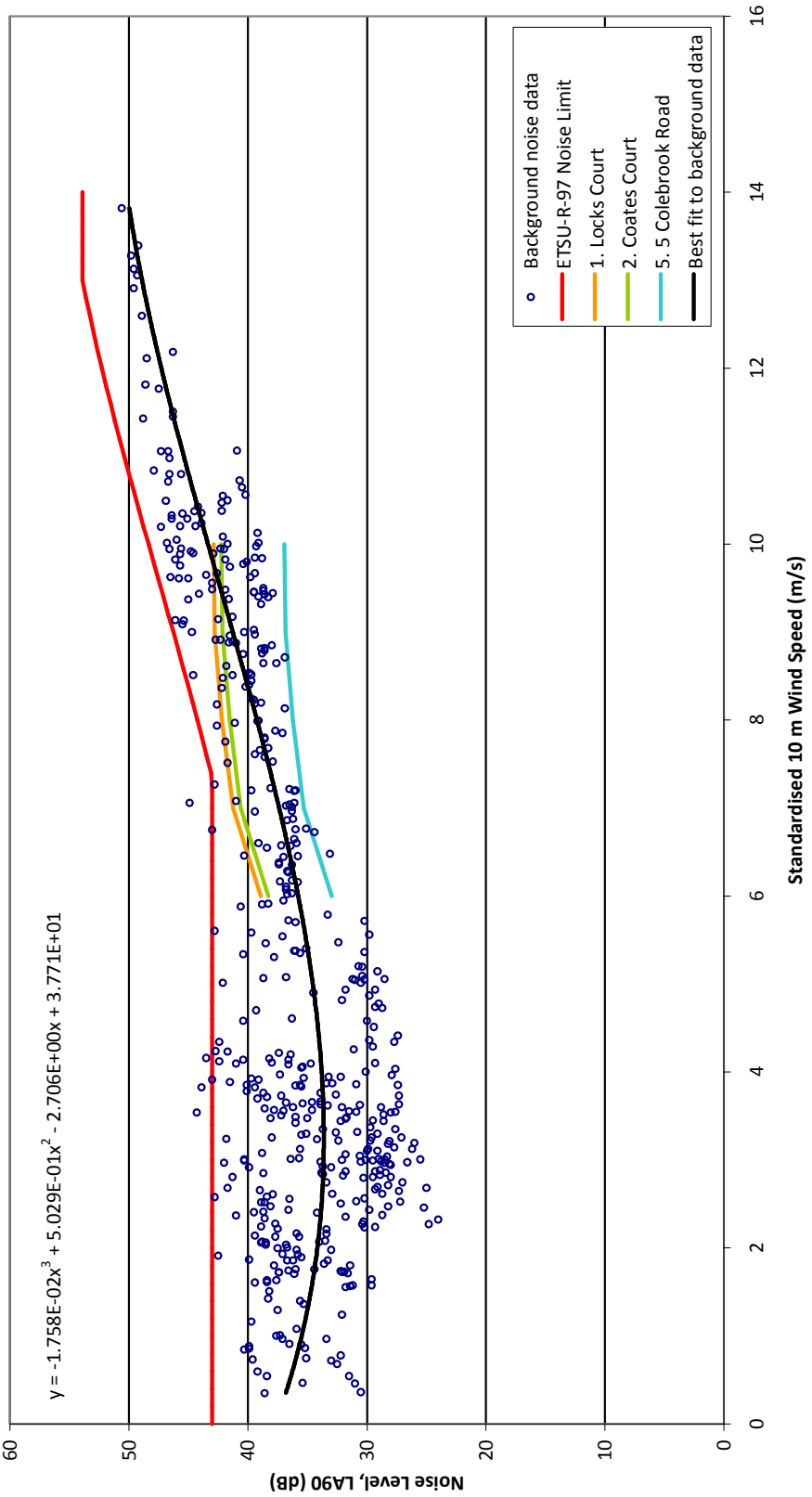


Figure 5: Night-time Period - 5 Colebrook Road and Represented Properties

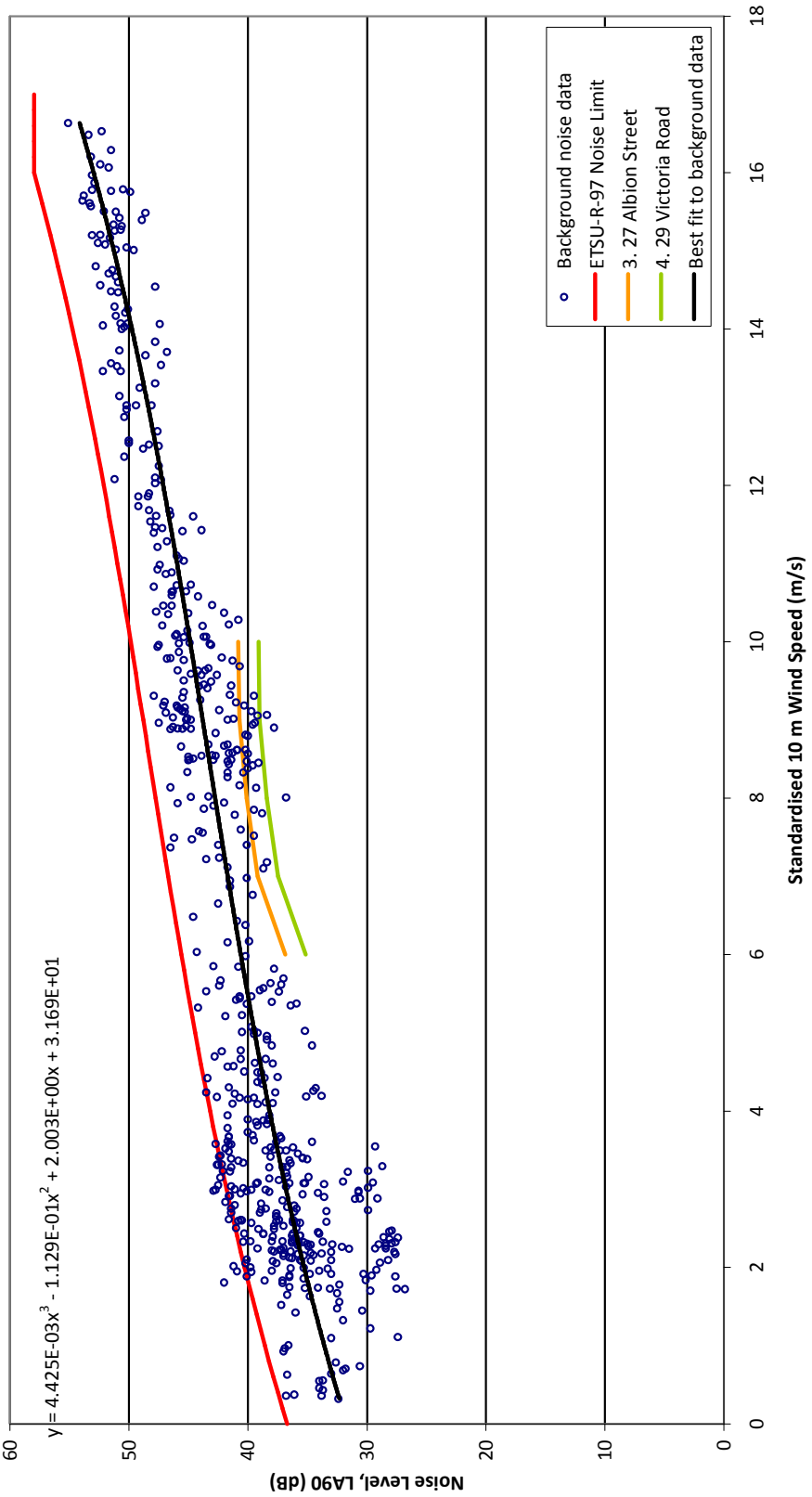


Figure 6: Quiet Daytime Period - 29 Victoria Road and Represented Properties

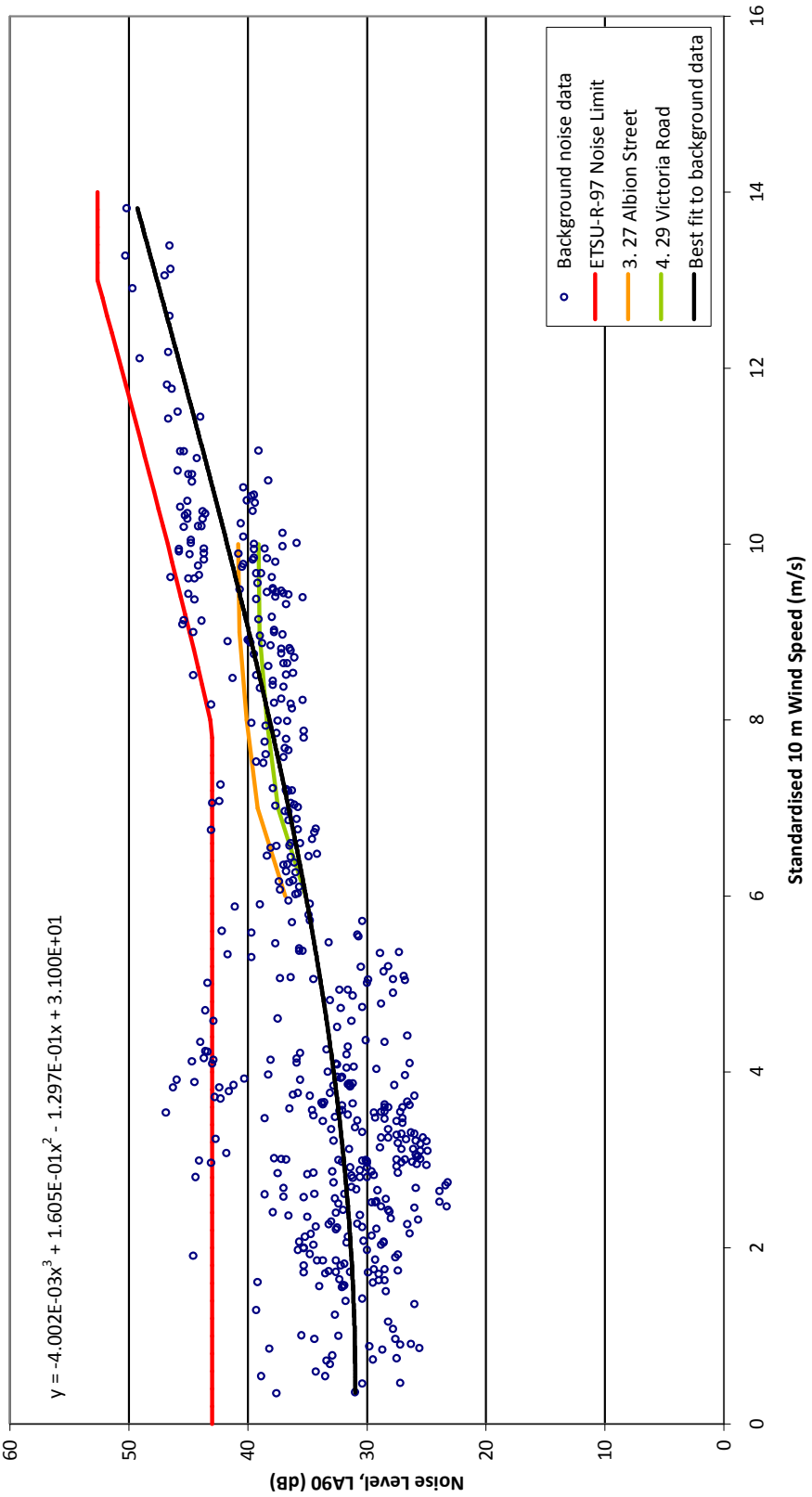


Figure 7: Night-time Period - 29 Victoria Road and Represented Properties

APPENDIX A – ACOUSTIC TERMINOLOGY

Noise is defined as unwanted sound. The range of audible sound is from 0 to 140 dB. The frequency response of the ear is usually taken to be around 18 Hz (number of oscillations per second) to 18000 Hz. The ear does not respond equally to different frequencies at the same level. It is more sensitive in the mid-frequency range than the lower and higher frequencies and because of this, the low and high frequency components of a sound are reduced in importance by applying a weighting (filtering) circuit to the noise measuring instrument. The weighting which is most widely used and which correlates best with subjective response to noise is the dBA weighting. This is an internationally accepted standard for noise measurements.

For variable sources, such as traffic, a difference of 3 dBA is just distinguishable. In addition, a doubling of traffic flow will increase the overall noise by 3 dBA. The 'loudness' of a noise is a purely subjective parameter, but it is generally accepted that an increase/ decrease of 10 dBA corresponds to a doubling/ halving in perceived loudness.

External noise levels are rarely steady, but rise and fall according to activities within an area. In attempt to produce a figure that relates this variable noise level to subjective response, a number of noise indices have been developed. These include:

i) The L_{Amax} noise level

This is the maximum noise level recorded over the measurement period.

ii) The L_{Aeq} noise level

This is "equivalent continuous A-weighted sound pressure level, in decibels" and is defined in British Standard BS 7445 [1] as the "value of the A-weighted sound pressure level of a continuous, steady sound that, within a specified time internal, T, has the same mean square sound pressure as a sound under consideration whose level varies with time".

It is a unit commonly used to describe construction noise and noise from industrial premises and is the most suitable unit for the description of other forms of environmental noise. In more straightforward terms, it is a measure of energy within the varying noise.

iii) The L_{A10} noise level

This is the noise level that is exceeded for 10% of the measurement period and gives an indication of the noisier levels. It is a unit that has been used over many years for the measurement and assessment of road traffic noise.

iv) The L_{A90} noise level

This is the noise level that is exceeded for 90% of the measurement period and gives an indication of the noise level during the quieter periods. It is often referred to as the background noise level and is used in the assessment of disturbance from industrial noise.

APPENDIX B - INSTRUMENTATION CALIBRATION CERTIFICATES

MEASUREMENT SYSTEMS

CERTIFICATE OF CONFORMANCE

Date of Issue	**23 October 2012**
Customer	**24 Acoustics Limited**
Certificate Number	**CONF101219**

	Manufacturer	**Type**	**Serial Number**
Sound Level Meter	Rion	NL-52	00620968
Preamplifier	Rion	NH-25	21009
Microphone	Rion	UC-59	03889

This is to certify that the instrument was tested and calibrated at the Manufacturer's factory according to their specification and that the product satisfied all the relevant requirements of the following Standards:

IEC 61672-1:2002 Class 1.

The instrument also received a functional check by ANV Measurement Systems prior to despatch in the UK, in accordance with our standard procedures.

Signed..... Position Calibration Manager Date..23/10/2012

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ACOUSTICS NOISE AND VIBRATION LIMITED. REGISTERED IN ENGLAND NO. 3549028. REGISTERED OFFICE AS ABOVE.

MEASUREMENT SYSTEMS

CERTIFICATE OF CONFORMANCE

Date of Issue	**23 October 2012**
Customer	**24 Acoustics Limited**
Certificate Number	**CONF101220**

	Manufacturer	**Type**	**Serial Number**
Sound Level Meter	Rion	NL-52	00620965
Preamplifier	Rion	NH-25	21006
Microphone	Rion	UC-59	03885

This is to certify that the instrument was tested and calibrated at the Manufacturer's factory according to their specification and that the product satisfied all the relevant requirements of the following Standards:

IEC 61672-1:2002 Class 1.

The instrument also received a functional check by ANV Measurement Systems prior to despatch in the UK, in accordance with our standard procedures.

Signed ..... Position Calibration Manager Date 23.10.2012

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ACOUSTICS NOISE AND VIBRATION LIMITED. REGISTERED IN ENGLAND NO. 3549028. REGISTERED OFFICE AS ABOVE.

CERTIFICATE OF CALIBRATION

ISSUED BY AV CALIBRATION

Date of issue 29 July 2013 Certificate N° 1307319

AV Calibration
2 Warren Court
Chicksands, Shefford
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www.avcalibration.co.uk
Acoustics Noise and Vibration Ltd trading as AV Calibration

Signed

G. Parry [ ] B. Baker [ ]

CLIENT	24 Acoustics Ltd Pepper Mill Barn Old Salisbury Lane Romsey Hampshire SO51 0GD
F.A.O.	Linda Haskell
ORDER No	- Job No TRAC13/07161/01
DATE OF RECEIPT	24 July 2013
PROCEDURE	AV Calibration Engineer's Handbook section 2
IDENTIFICATION	Sound Calibrator Brüel & Kjær type 4231 serial number 2253117 with one-inch housing and adapter type UC 0210 for half-inch microphone
CALIBRATED ON	29 July 2013
PREVIOUS CALIBRATION	Calibrated on 27 July 2012, Certificate No. 1207326 issued by this laboratory.

The measurements detailed herein are traceable to units of measurement realised at the National Physical Laboratory.
This certificate may not be reproduced other than in full, except with the prior written approval of AV Calibration.

OTECH ENGINEERING INC.

ANEMOMETER CALIBRATION REPORT

Test Date: 7 May 2012 Revision No: 0

630 Peña Drive, Suite 800
Davis, CA 95618-7726
Office: (530) 757-2264
http://www.otechwind.com

Customer Information

NRG Systems, Inc.
110 Riggs Road
Hinesburg, VT 05461
USA

Instrument Under Test (IUT)

Model No: NRG #40 Sine
Serial No: 179500204887
Output: Sine Wave
IUT Power: 0 VDC
Heater Power: 0 VDC
Mount Diameter: 12.7 mm
Test Procedure: OTECH-CP-001

Wind Tunnel Test Facility

Otech Tunnel ID: WT1C
Type: Eiffel (open circuit, suction)
Test Section Size: 0.61 m x 0.61 m x 1.22 m
Manufacturer: Engineering Laboratory Design, Inc.

Data Acquisition

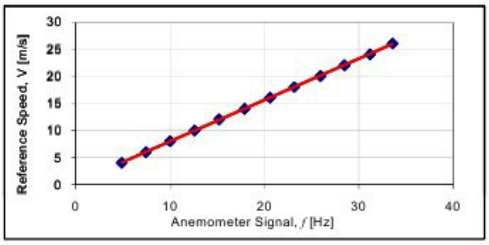
Hardware: National Instruments CDAQ-9172 USB 2.0 chassis with NI 9205 32-chan 16-bit AI module
Software: National Instruments LabVIEW 2010
Signal Reduction Method for IUT: FFT Analysis

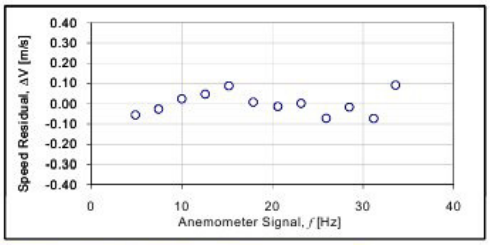
Measuring Equipment

Reference Speed: Four United Sensor Type PA Pitot-static tubes sensed by an MKS Barotron Type 220D Differential Pressure Transducer (NIST traceable)
Amb. Pressure: Setra Model 270 Barometer (NIST traceable)
Amb. Temperature: OMEGA HX94 SS Probe (NIST traceable)
Relative Humidity: OMEGA HX94 SS Probe (NIST traceable)

Test Conditions

Reference Speed Position Correction = 1
Reference Speed Blockage Correction = 1.00735
Mean Ambient Pressure = 101,292 Pa
Mean Ambient Temperature = 22.5 deg C
Mean Relative Humidity = 30.1% RH
Mean Density = 1.1900 kg/cubic meter



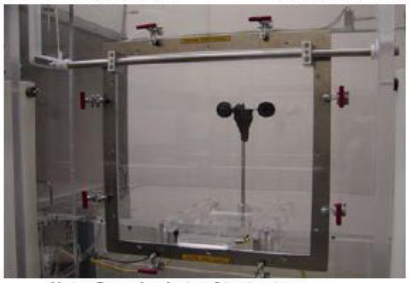


Transfer Function Test Results: **V [m/s] = 0.764 f [Hz] + 0.38**

Regression Parameters

r = 0.99997
slope =0.764 m/s per Hz
offset =0.38 m/s
std. err. estimate =0.0579 m/s
std. err. slope =0.00184 m/s per Hz
std. err. offset =0.03919 m/s

Reference Speed [m/s]	Anemometer Output [Hz]	Residual [m/s]	Ref. Speed Uncertainty
4.051	4.878	-0.055	0.753%
8.050	10.006	0.024	0.643%
12.078	15.190	0.088	0.627%
16.102	20.586	-0.013	0.612%
20.112	25.908	-0.072	0.603%
24.137	31.174	-0.073	0.601%
26.131	33.568	0.091	0.597%
22.125	28.471	-0.018	0.608%
18.072	23.144	0.001	0.611%
14.056	17.884	0.007	0.624%
10.050	12.591	0.047	0.636%
6.033	7.433	-0.027	0.681%



***Note**: Generic photo of test set-up*

Approved by: Adam Havner, Staff Engineer

This document reports that the above IUT was tested at Otech Engineering, Inc., a wind tunnel laboratory accredited in accordance with the recognised International Standard ISO/IEC 17025:2005 (Certificate number CL-126). This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer joint ISO-ILAC-IAF Communiqué dated January 2009). Uncertainties estimated at 95 % confidence level. This report shall not be reproduced except in full, without written approval from Otech Engineering, Inc.

IAS ACCREDITED

References available upon request. Page 1 of 1 179500204887_2012-05-07.pdf

APPENDIX C - RECEPTOR NOISE LEVEL SUMMARY TABLES

1. Locks Court

Daytime

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	41.3	42.2	43.2	44.2	45.4
ETSU-R-97 Noise Limit (dB)	46.3	47.2	48.2	49.2	50.4
Predicted Noise Level (dB)	38.9	41.3	42.2	42.8	42.9
Difference Between Predicted and Limit (dB)	-7.4	-5.9	-6.0	-6.4	-7.5

Night-time

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	35.8	37.4	39.2	41.3	43.4
ETSU-R-97 Noise Limit (dB)	43.0	43.0	44.2	46.3	48.4
Predicted Noise Level (dB)	38.9	41.3	42.2	42.8	42.9
Difference Between Predicted and Limit (dB)	-4.1	-1.7	-2.1	-3.5	-5.5

2. Coates Court

Daytime

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	41.3	42.2	43.2	44.2	45.4
ETSU-R-97 Noise Limit (dB)	46.3	47.2	48.2	49.2	50.4
Predicted Noise Level (dB)	38.3	40.6	41.5	42.1	42.2
Difference Between Predicted and Limit (dB)	-8.0	-6.6	-6.6	-7.1	-8.2

Night-time

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	35.8	37.4	39.2	41.3	43.4
ETSU-R-97 Noise Limit (dB)	43.0	43.0	44.2	46.3	48.4
Predicted Noise Level (dB)	38.3	40.6	41.5	42.1	42.2
Difference Between Predicted and Limit (dB)	-4.7	-2.4	-2.7	-4.1	-6.1

3. 27 Albion Street

Daytime

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	40.6	41.7	42.8	43.8	44.9
ETSU-R-97 Noise Limit (dB)	45.6	46.7	47.8	48.8	49.9
Predicted Noise Level (dB)	36.9	39.2	40.1	40.7	40.8
Difference Between Predicted and Limit (dB)	-8.7	-7.5	-7.6	-8.1	-9.0

Night-time

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	35.1	36.6	38.2	39.9	41.8
ETSU-R-97 Noise Limit (dB)	43.0	43.0	43.2	44.9	46.8
Predicted Noise Level (dB)	36.9	39.2	40.1	40.7	40.8
Difference Between Predicted and Limit (dB)	-6.1	-3.8	-3.1	-4.2	-5.9

4. 29 Victoria Road

Daytime

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	40.6	41.7	42.8	43.8	44.9
ETSU-R-97 Noise Limit (dB)	45.6	46.7	47.8	48.8	49.9
Predicted Noise Level (dB)	35.2	37.5	38.4	39.0	39.1
Difference Between Predicted and Limit (dB)	-10.4	-9.2	-9.3	-9.8	-10.7

Night-time

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	35.1	36.6	38.2	39.9	41.8
ETSU-R-97 Noise Limit (dB)	43.0	43.0	43.2	44.9	46.8
Predicted Noise Level (dB)	35.2	37.5	38.4	39.0	39.1
Difference Between Predicted and Limit (dB)	-7.8	-5.5	-4.8	-5.9	-7.6

5. 5 Colebrook Road

Daytime

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	41.3	42.2	43.2	44.2	45.4
ETSU-R-97 Noise Limit (dB)	46.3	47.2	48.2	49.2	50.4
Predicted Noise Level (dB)	33.0	35.3	36.2	36.8	36.9
Difference Between Predicted and Limit (dB)	-13.3	-11.9	-11.9	-12.4	-13.5

Night-time

Wind Speed (m/s)	6	7	8	9	10
Background Noise Level (dB)	35.8	37.4	39.2	41.3	43.4
ETSU-R-97 Noise Limit (dB)	43.0	43.0	44.2	46.3	48.4
Predicted Noise Level (dB)	33.0	35.3	36.2	36.8	36.9
Difference Between Predicted and Limit (dB)	-10.0	-7.7	-8.0	-9.4	-11.4

APPENDIX D - NOISE SOURCE LEVEL DATA DOCUMENTS

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ARESSE ENGINEERING

DYNAMICS & VIBROACOUSTICS

TECHNICAL REPORT

REPORT NUMBER	TR-13-015c

DEWI SP- NORVENTO NED100 ED3.0

TARGET:

The objective of this report is to characterize acoustic power and tonalities emitted according to IEC 61400-11 Ed 3.0 by Norvento nED100 wind turbine placed in Cervo, Lugo.

CONCLUSSIONS AND COMMENTS:

Sound power levels are between **96.41dBA** and **100.92dBA** depending on the wind speed.

Tones have not been found during the wind turbine operation.

INDEX:

1. DEFINITIONS....2
2. LOCATION AND MEASUREMENT POSITIONS....2
3. INSTRUMENTATION....3
4. METHODOLOGY....3
5. RESULTS ANALYSIS....4
5.1 Registered data and sound power determination....4
5.2 Apparent sound power level....5
5.3 One-third octave band analysis....6
APPENDIX A. Tonal analysis....13

KEY WORDS:	Norvento, nED100, 61400-11 Ed.3.0				
DISTRIBUTION: Iñigo López Joseba Ripa Gorka Gainza Acoidan Betancort	Project Time Frame FROM: 05/03/2013 TO: 19/06/2013	REQUESTED BY:	Joseba Ripa	WRITTEN BY:	Acoidan Betancort
		STATUS:	CLOSED	APPROVED BY:	G. Gainza

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ARESSE ENGINEERING	DYNAMICS & VIBROACOUSTICS	REPORT NUMBER	TR-13-035c
	DEWI SP- NORVENTO NED100 ED3.0		

1. DEFINITIONS

D	Rotor diameter
H	Height of rotor centre
$L_{Aeq,k}$	Equivalent continuous A-weighted sound pressure level at each integer wind speed, where k = 6, 7, 8, 9, 10
$L_{Aeq,c}$	Equivalent continuous A-weighted sound pressure level corrected for background noise at each integer wind speed and corrected to reference conditions
L_n	Equivalent continuous sound pressure level of the background noise
L_s	Equivalent continuous sound pressure level of only wind turbine noise
L_{s+n}	Equivalent continuous sound pressure level of combined wind turbine and background noise
$L_{WA,k}$	Apparent sound power level, where k = 6, 7, 8, 9, 10
R_0	Reference distance
R_1	Slant distance, from rotor centre to measurement position
S_0	Reference area, $S_0 = 1m^2$

2. LOCATION AND MEASUREMENT POSITIONS

Test was performed from 8th to 10th April 2013. The measurement starts day 8, after the site evaluation. Two measuring positions have been used. Both of these positions are placed at a distance of **55m** from the rotor (R_1).

The first measuring position is placed at a standard distance of 42m from the base of the wind turbine (R_0), and at an angle of **226°** in the north direction. The second measuring position is placed at a standard distance of 44m from the base of the wind turbine (R_0), and at angle of **204°** in the north direction.

These measurements are made using an electronic telemeter (spyglass prepared for measuring distances).

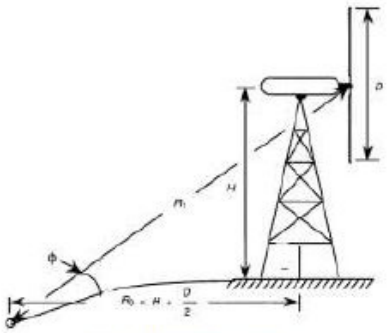

Fig. 1. Microphone position

During the test, noise data produced by sources outside the object of study (aircrafts, people, cars, animals, etc.) are discarded and the same is done when wind direction does not meet the 15° around the measuring position.

The right image shows wind turbine and measuring positions.

UTM COORDINATES	X	Y	DISTANCE TO WTGS (M)
Wind turbine	626865	4838857	0
Met Mast	626881	4838841	24
Position 1	626899	4838889	42
Position 2	626884	4838900	44



Fig. 2. Wind turbine and measurement positions

REPORT DATE: 19/06/2013	STATUS: CLOSED	WRITTEN BY: A.Betancort	Page 2 of 19

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5. RESULTS ANALYSIS

5.1 Registered data and sound power determination

The figure shows the sound pressure level measurement bins vs wind speed referenced at hub height. Operating wind turbine measurements (blue dots) and background noise (red dots) are represented.

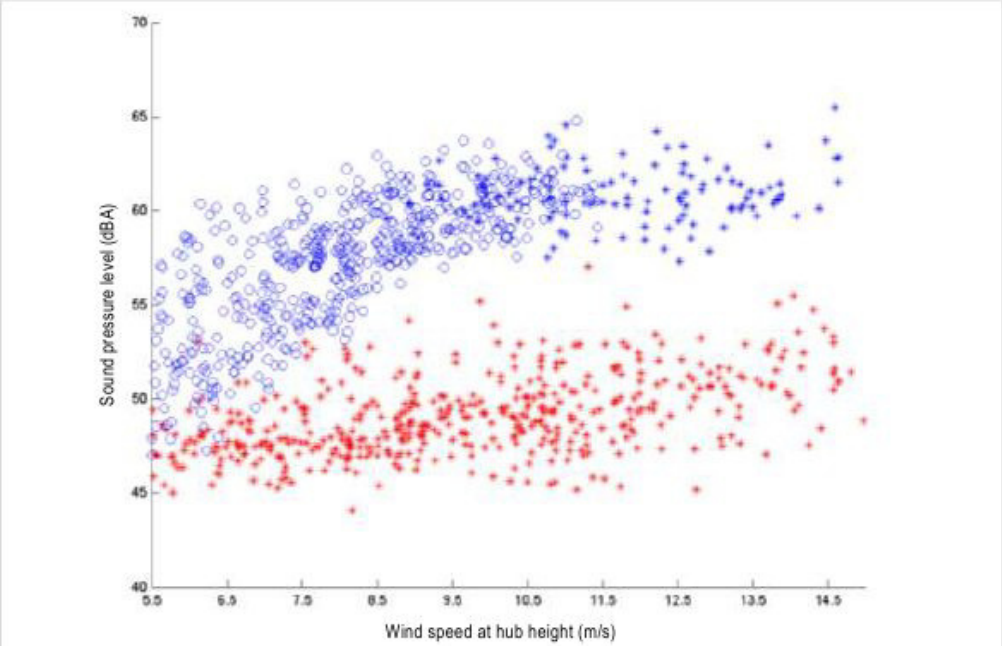

Fig. 3. Sound pressure level in dBA

Wind speed at hub height (m/s)	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Wind turbine noise datasets	60	67	50	58	36	49	33	34	15	12	17	10
Background noise datasets	27	32	27	44	26	23	47	35	22	26	13	16

Table 1. Registered data for each of the wind speed bins

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5.2 Apparent sound power level

Wind turbine acoustic power results are obtained for each of the bins. Overall results are presented in sound power (dBA) in the following figure and table:

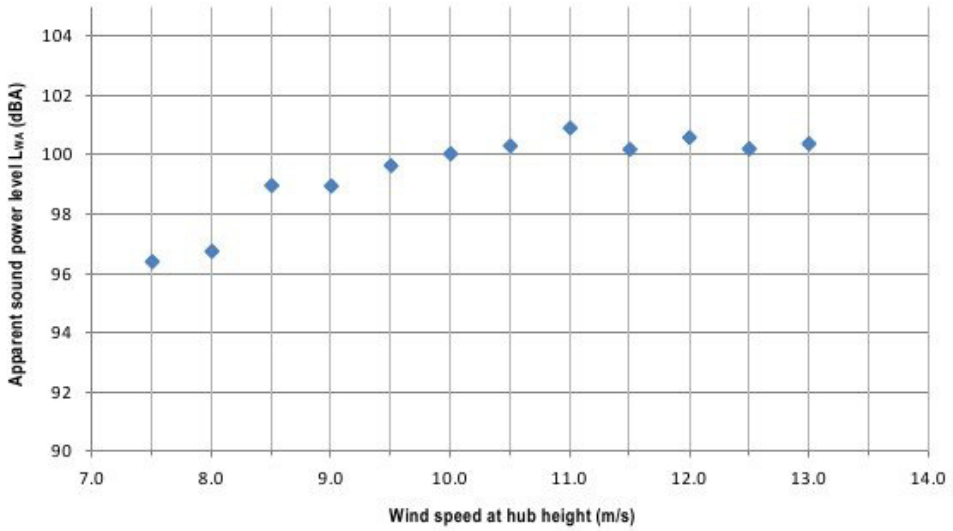

Fig. 4. Apparent sound power level

Wind speed at hub height (m/s)	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Wind speed at 10m (m/s)	6.0	6.4	6.8	7.2	7.7	8.1	8.5	8.9	9.3	9.7	10.1	10.5
Laeq Wind Turbine (dBA)	57.28	57.55	59.55	59.55	60.19	60.65	60.86	61.40	60.80	61.21	60.81	61.01
Laeq background (dBA)	48.95	48.84	48.71	49.18	49.25	50.2	49.72	49.45	50.43	50.78	50.13	50.63
Laeq corrected (dBA)	56.61	56.96	59.18	59.16	59.85	60.25	60.52	61.12	60.40	60.80	60.42	60.59
Apparent power level (dBA)	**96.41**	**96.76**	**98.98**	**98.96**	**99.65**	**100.05**	**100.32**	**100.92**	**100.20**	**100.60**	**100.22**	**100.39**
Uncertainty (dBA)	0.95	0.87	0.84	0.74	0.86	0.73	0.75	0.70	0.71	0.93	1.01	1.15

Table 2. Apparent sound power level and uncertainty

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5.3 One-third octave band analysis

A-weighted 1/3 octave band spectra are measured synchronously with the overall sound pressure levels as the energy average over 10s periods. Wind speed is referenced at hub height.

Frequency (Hz)	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
20 Hz	49.52	51.15	52.97	54.36	52.27	56.20	57.30	56.86	57.00	52.36	62.88	58.68
25 Hz	53.59	55.23	57.08	58.51	56.78	59.36	61.97	61.00	60.63	56.98	64.88	62.57
31.5 Hz	57.48	59.01	60.70	61.72	60.76	62.81	64.70	64.21	64.65	61.47	68.87	65.73
40 Hz	62.07	62.26	65.07	64.90	64.35	65.63	67.20	67.05	67.19	65.11	71.87	67.60
50 Hz	64.74	65.21	68.05	67.24	66.97	68.38	69.44	69.41	69.34	68.11	73.70	70.11
63 Hz	67.67	68.09	70.71	70.02	69.79	70.71	71.42	72.73	72.75	71.44	75.90	72.84
80 Hz	69.95	69.90	73.38	72.82	72.56	72.90	73.45	75.55	74.68	74.57	77.20	75.20
100 Hz	71.87	71.82	75.90	74.96	75.75	75.49	76.86	77.88	76.90	76.99	78.64	78.04
125 Hz	74.29	74.36	77.91	76.97	78.00	78.01	78.70	80.23	78.82	78.77	80.39	79.35
160 Hz	75.37	75.46	78.64	77.98	78.94	79.36	79.64	81.08	80.02	79.26	80.86	80.20
200 Hz	77.71	77.48	80.21	79.85	81.00	81.38	81.78	82.80	81.72	81.35	81.78	82.00
250 Hz	81.80	81.84	84.47	84.10	85.12	85.74	86.01	87.06	85.55	84.93	85.65	85.50
315 Hz	84.26	84.53	86.91	86.70	87.64	88.31	88.57	89.41	88.11	87.47	87.86	87.93
400 Hz	85.16	85.52	87.95	87.73	88.62	89.24	89.50	90.38	89.11	88.43	89.03	88.65
500 Hz	86.46	86.87	89.51	89.19	90.20	90.69	91.02	91.92	90.48	90.46	90.47	90.21
630 Hz	86.26	86.55	88.50	88.83	89.83	90.05	90.52	90.88	90.02	90.72	89.52	90.62
800 Hz	86.25	86.66	88.56	88.81	89.62	90.04	90.25	90.69	90.02	90.96	89.56	90.77
1000 Hz	86.97	87.36	88.86	89.40	90.04	90.25	90.56	90.90	90.53	91.69	89.90	91.17
1250 Hz	87.68	88.00	89.71	90.01	90.48	90.63	90.93	91.29	91.09	92.00	90.85	91.29
1600 Hz	87.48	87.89	89.98	89.85	90.22	90.53	90.65	91.21	91.09	91.67	91.36	91.17
2000 Hz	85.14	85.66	88.43	88.05	88.32	88.79	88.74	89.42	89.23	89.41	89.94	89.19
2500 Hz	80.92	81.54	84.74	84.40	84.70	85.21	85.01	85.85	85.57	85.48	86.49	85.56
3150 Hz	77.37	78.07	80.32	80.69	80.83	80.97	81.15	81.60	81.39	82.04	82.07	81.46
4000 Hz	72.28	71.71	74.88	74.79	73.69	76.10	76.89	76.07	73.91	76.32	76.43	75.77
5000 Hz	71.58	67.76	71.76	70.03	70.79	74.38	76.50	72.54	70.10	71.48	73.18	72.12
6000 Hz	66.34	65.30	67.55	65.95	67.96	75.25	75.71	64.32	63.36	62.80	65.09	63.74
8000 Hz	63.16	60.78	70.07	62.37	63.13	68.94	69.80	62.08	61.21	60.34	62.03	61.07
10000 Hz	58.08	58.02	58.97	58.66	58.83	59.24	59.23	59.36	59.18	58.79	59.59	58.88

Table 3. One-third octave band spectra (A-weighted)

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One-third octave band at 12.5m/s

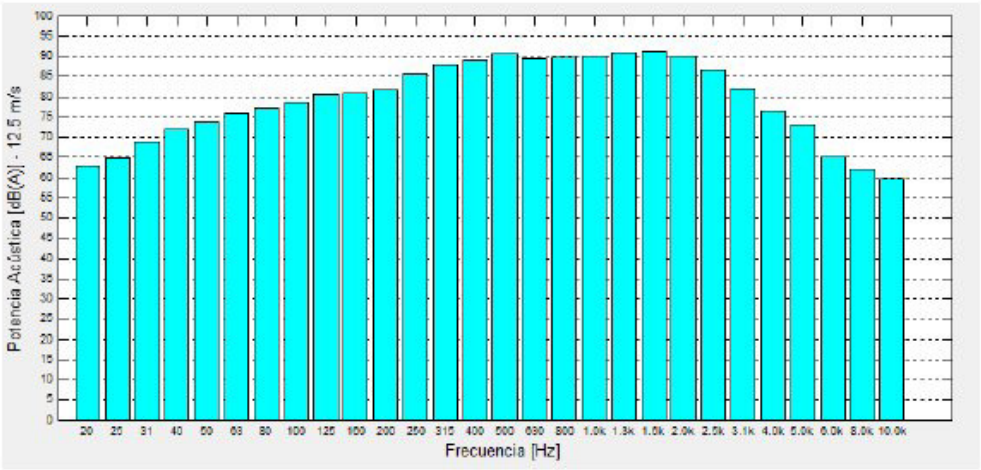

Fig. 15. One-third octave band at 12.5m/s

One-third octave band at 13.0m/s

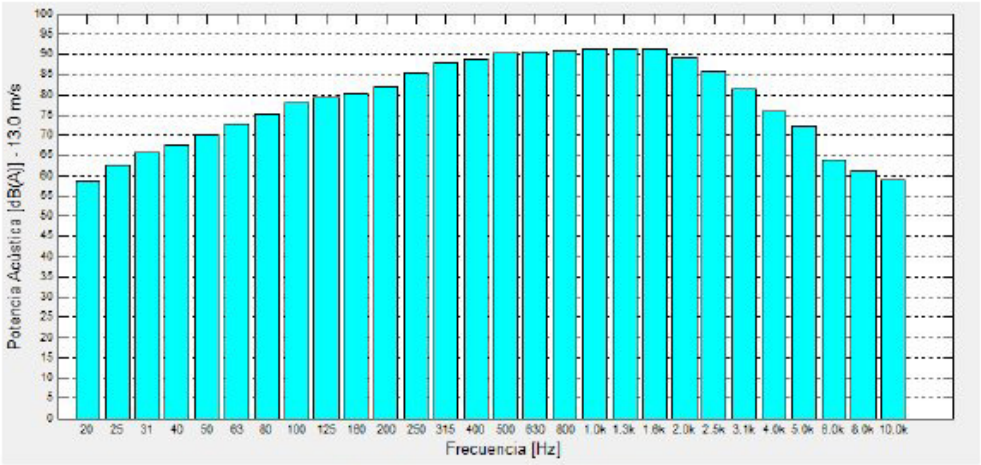

Fig. 16. One-third octave band at 13.0m/s

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As a result of this analysis, tones have not been found during the wind turbine operation. The following table shows the summary of the tonal analysis.

Wind speed at hub height (m/s)	Vs	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Center frecuency (Hz)	F	3228	3248	3248	3244	3246	3248	3250	3252	3250	3248	3250	3246
Tonal Audibility (dBA)	ΔLa,k	-7.9251	-7.2459	-6.5824	-8.2504	-9.2361	-9.2853	-9.1667	-10.5912	-11.7380	-10.9142	-10.7788	-13.3039
Comments		< -3	< -3	< -3	< -3	< -3	< -3	< -3	< -3	< -3	< -3	< -3	< -3

Table 4. Sumary of tonal analysis results for wind speed at hub height

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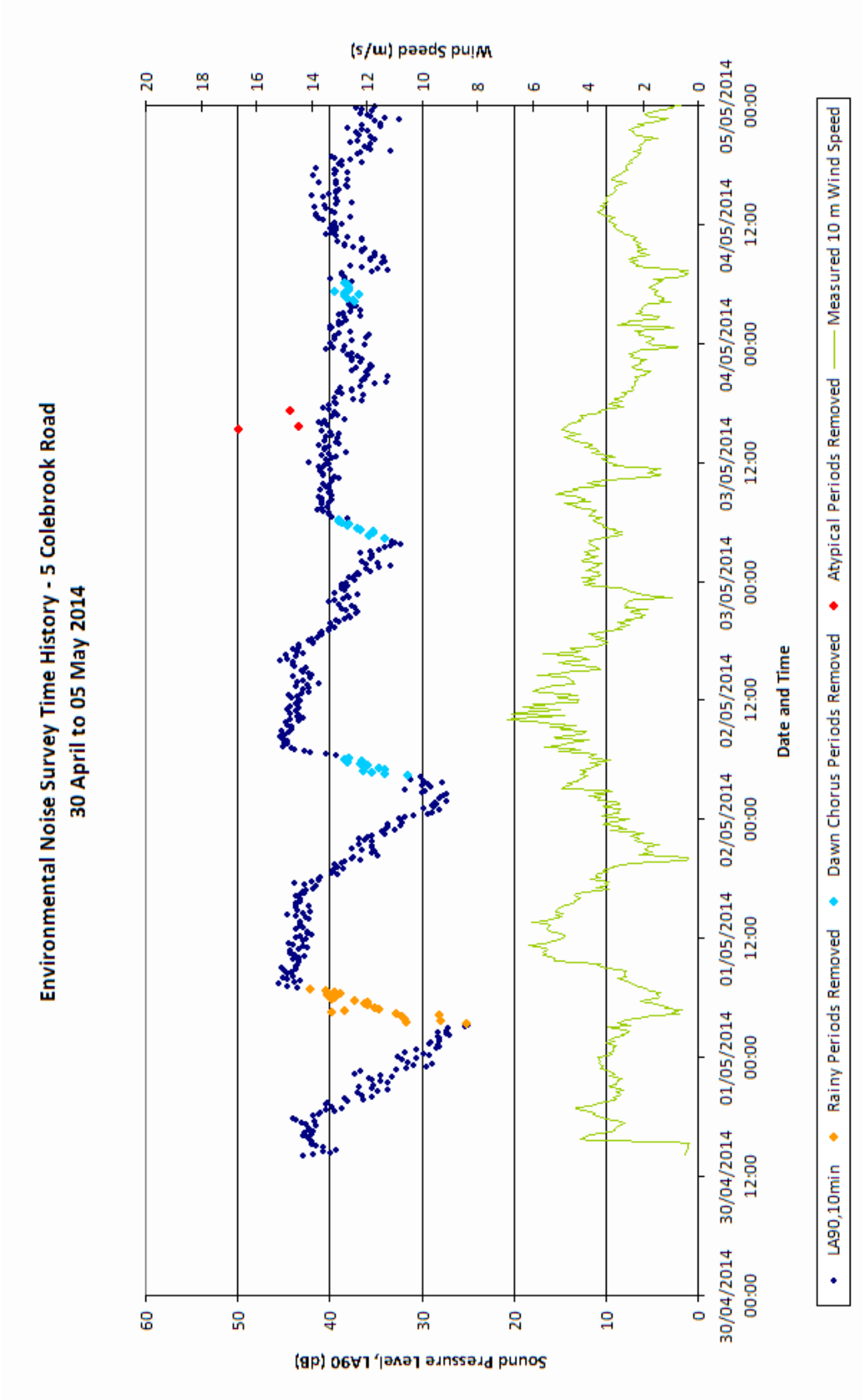
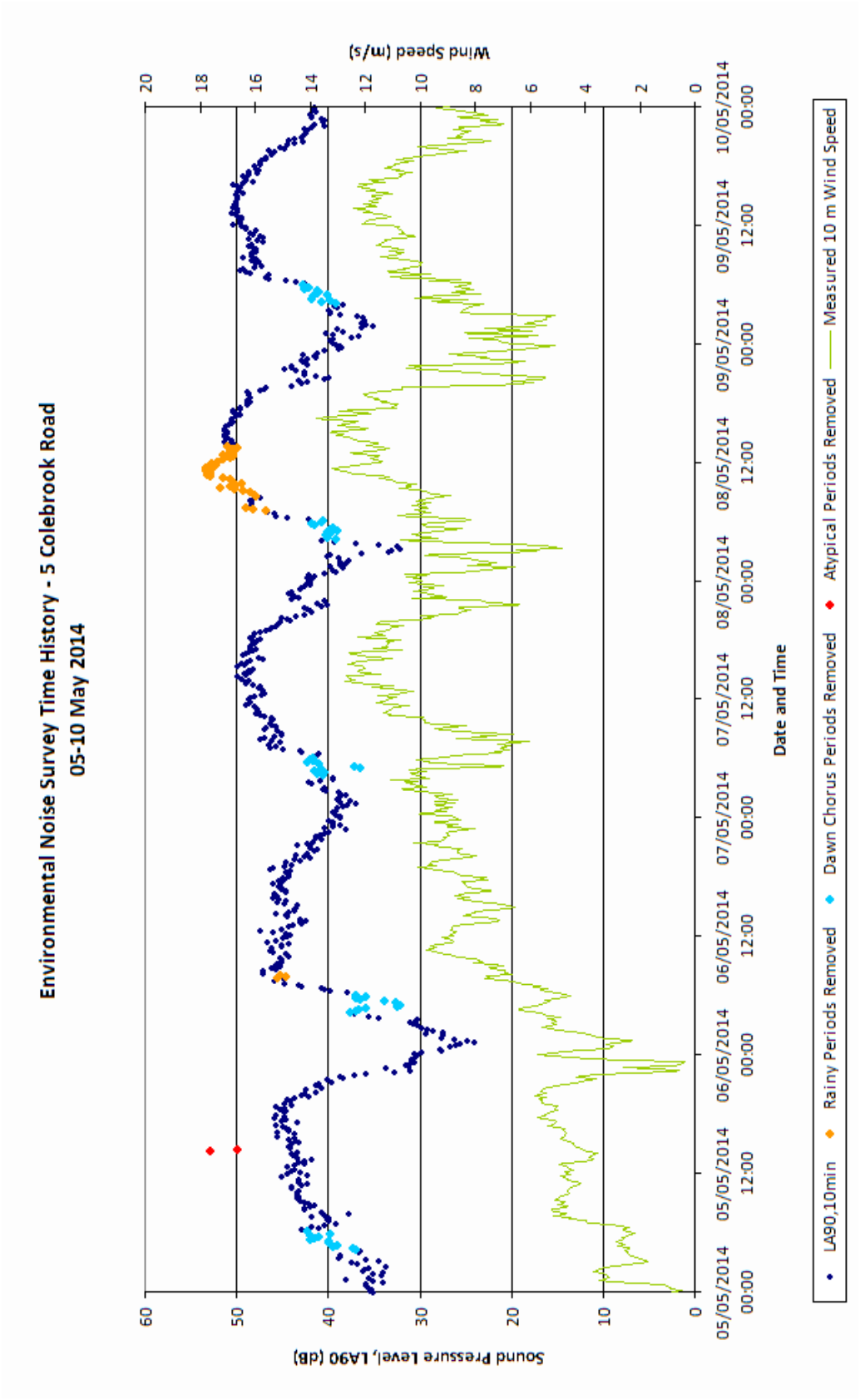
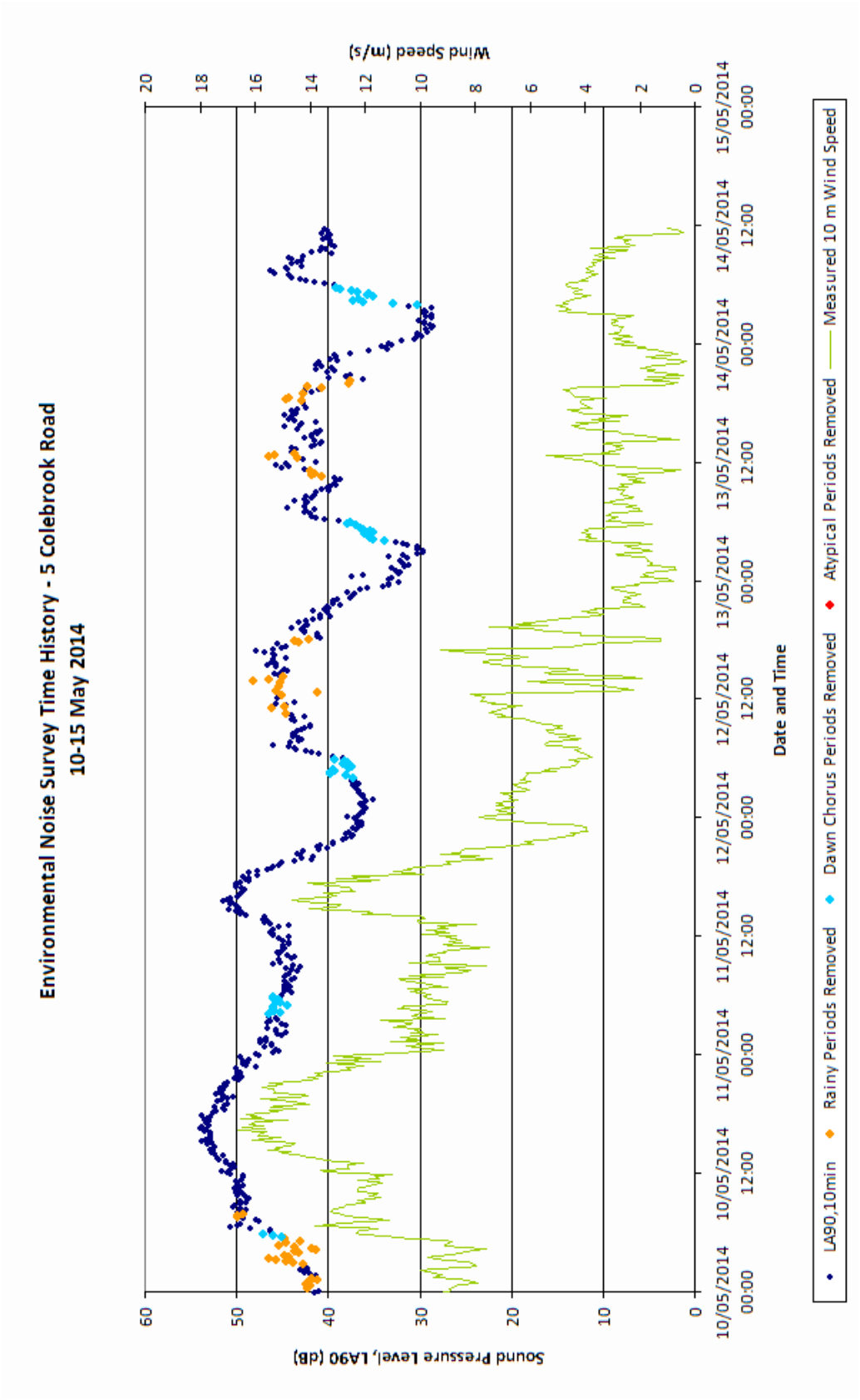
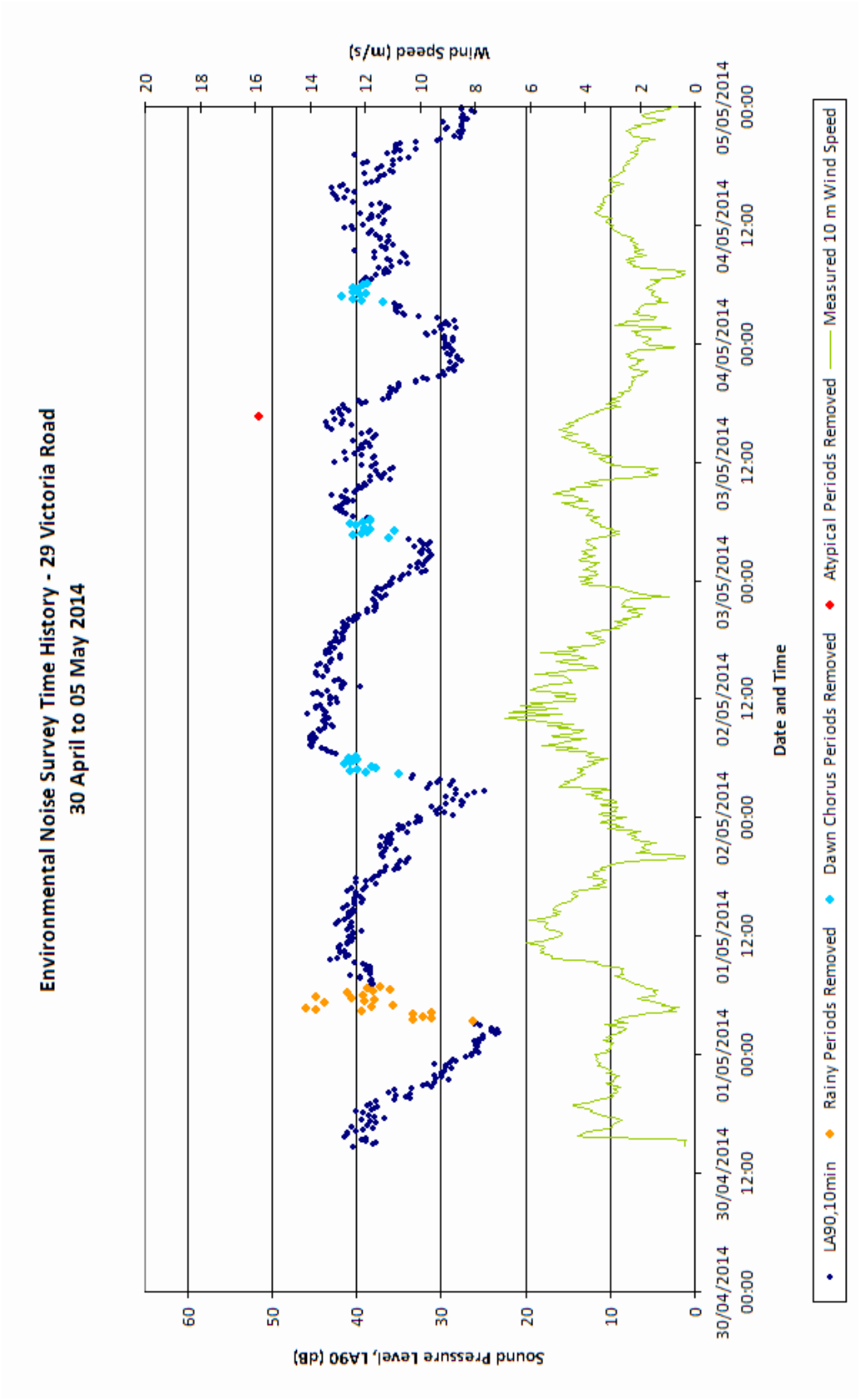
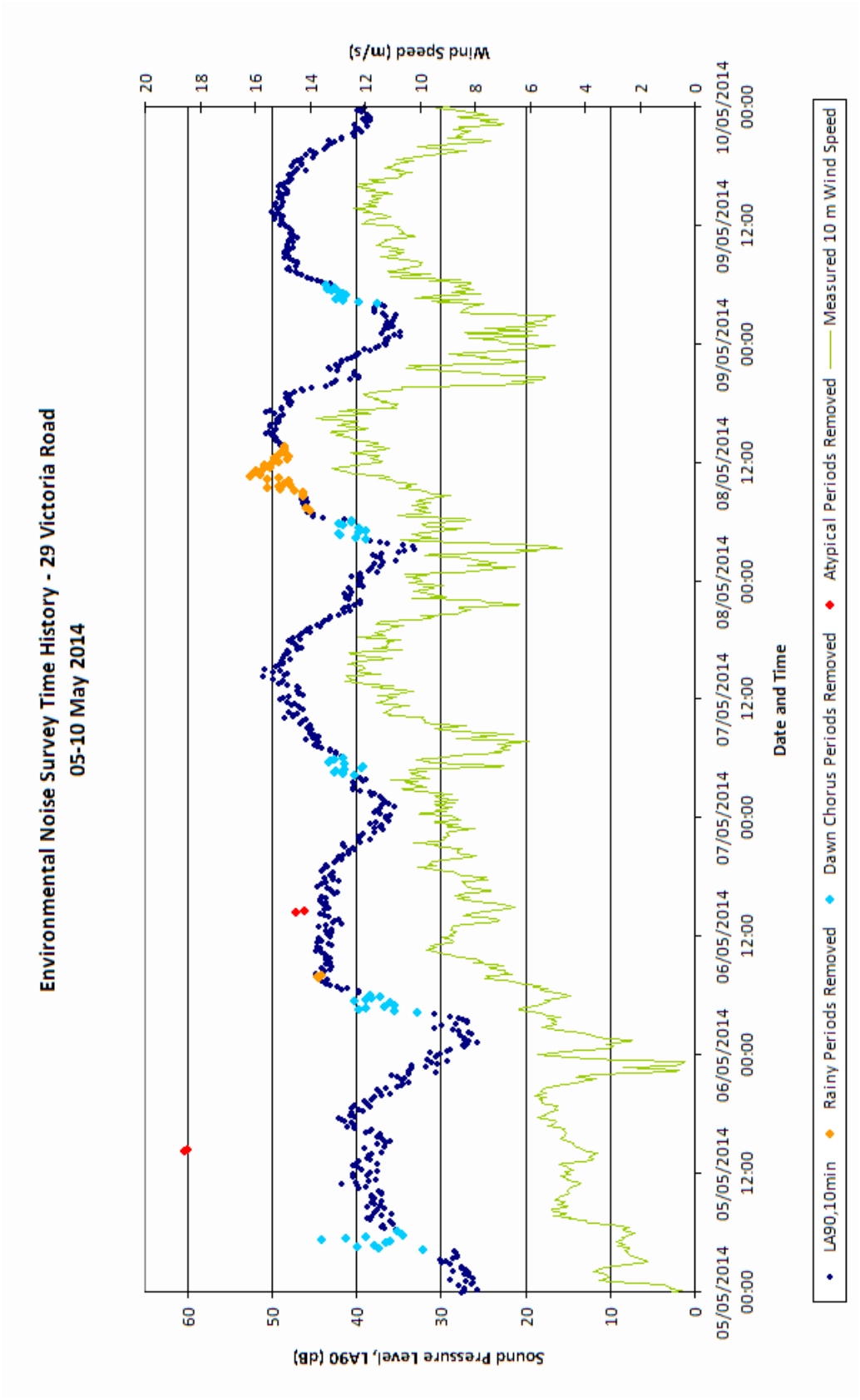
APPENDIX E - DATA TIME HISTORIES

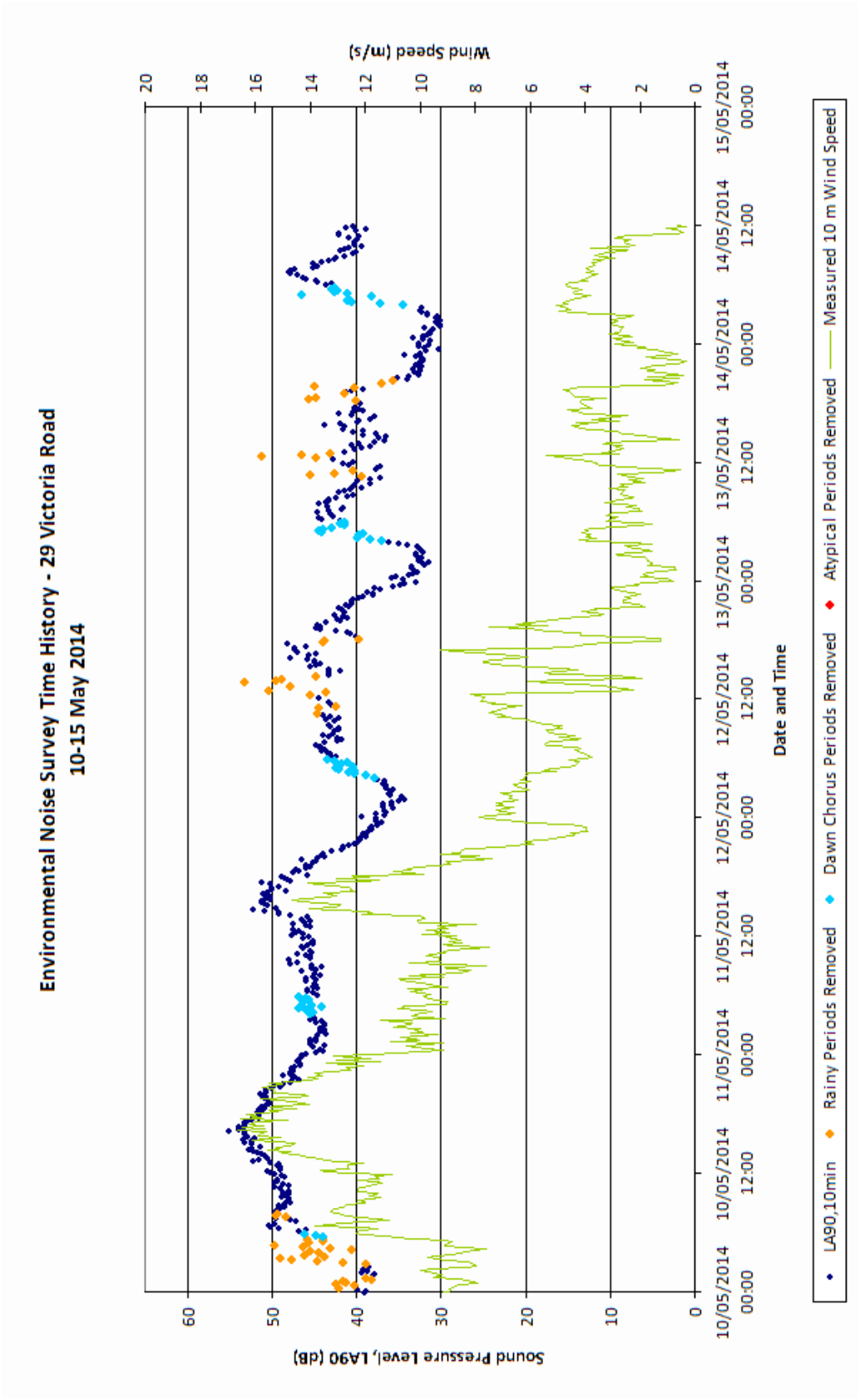



Environmental Noise Survey Time History - 5 Colebrook Road
05-10 May 2014
Sound Pressure Level, LA90 (dB)
Wind Speed (m/s)
Date and Time
LA90,10min
Rainy Periods Removed
Dawn Chorus Periods Removed
Atypical Periods Removed
Measured 10 m Wind Speed


Environmental Noise Survey Time History - 5 Colebrook Road
10-15 May 2014
Sound Pressure Level, LA90 (dB)
Wind Speed (m/s)
Date and Time
LA90,10min
Rainy Periods Removed
Dawn Chorus Periods Removed
Atypical Periods Removed
Measured 10 m Wind Speed


Environmental Noise Survey Time History - 29 Victoria Road
30 April to 05 May 2014
Sound Pressure Level, LA90 (dB)
Wind Speed (m/s)
Date and Time
LA90,10min
Rainy Periods Removed
Dawn Chorus Periods Removed
Atypical Periods Removed
Measured 10 m Wind Speed


Environmental Noise Survey Time History - 29 Victoria Road
05-10 May 2014
Sound Pressure Level, LA90 (dB)
Wind Speed (m/s)
Date and Time
LA90,10min
Rainy Periods Removed
Dawn Chorus Periods Removed
Atypical Periods Removed
Measured 10 m Wind Speed


Environmental Noise Survey Time History - 29 Victoria Road
10-15 May 2014
Sound Pressure Level, LA90 (dB)
Wind Speed (m/s)
Date and Time
LA90,10min
Rainy Periods Removed
Dawn Chorus Periods Removed
Atypical Periods Removed
Measured 10 m Wind Speed