Lord Howe Island Renewable Energy Project

LORD HOWE ISLAND BOARD

Wind Turbine Generator Noise Impact Assessment

Revision 4

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Lord Howe Island Renewable Energy Project

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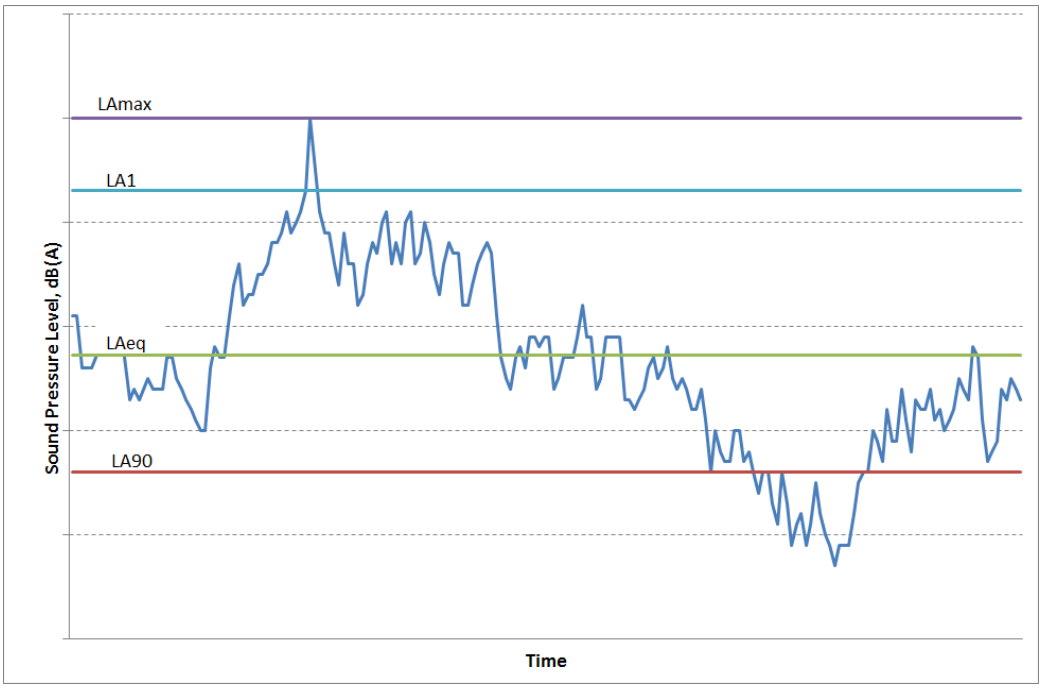
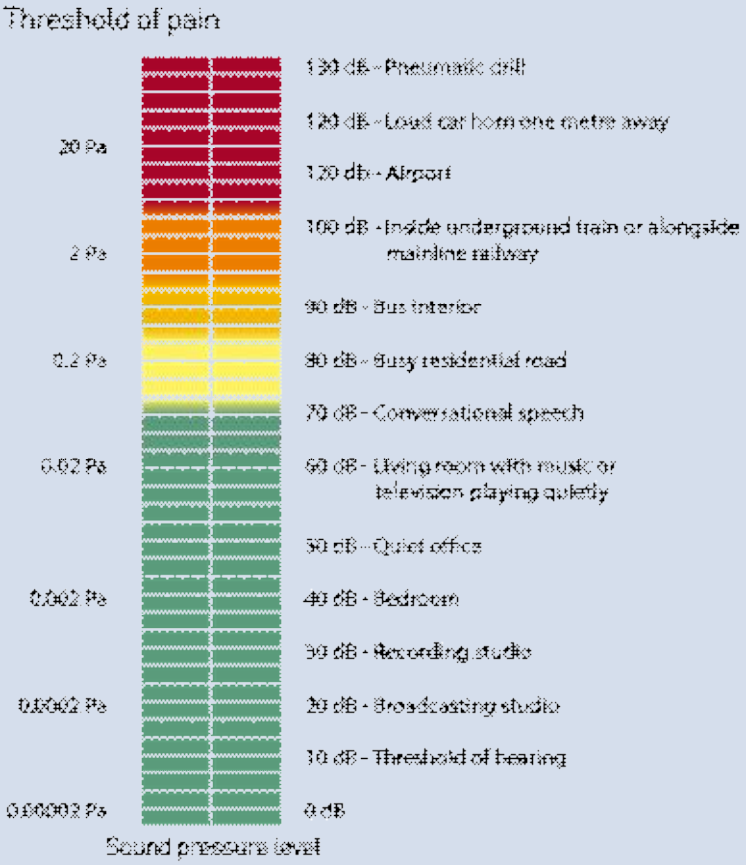
4	23/04/2015	Changed names of three of the logger locations as per client request	D. Pollington	D. Pollington	23-4-15

Contents

Definition of terms

Assessment period	The period in a day over which assessments are made. In this case: • day (0700 to 2200 h), • night (2200 to 0700 h).
Background noise	The underlying level of noise present in the ambient noise, excluding the noise source under investigation, when extraneous noise is removed. This is described using the L_{A90} descriptor.
Decibel (dB)	A measure of sound equivalent to 20 times the logarithm (to base 10) of the ratio of a given sound pressure to a reference pressure, and 10 times the logarithm (to base 10) of the ratio of a given sound power to a reference power.
dB(A)	Unit used to measure 'A-weighted' sound pressure levels. A-weighting is an adjustment made to sound-level measurement to approximate the response of the human ear.
Extraneous noise	Noise resulting from activities that are not typical of the area such as construction, and traffic generated by holiday periods or special events such as concerts or sporting events. Normal daily traffic is not considered to be extraneous.
Feasible and reasonable measures	Feasibility relates to engineering considerations and what is practical to build; reasonableness relates to the application of judgement in arriving at a decision, taking into account the following factors: • noise mitigation benefits (noise reduction provided, people protected) • cost of mitigation (cost of mitigation versus benefit provided) • community views (aesthetic impacts and community wishes) • noise levels for affected land uses (existing and future levels)
Hub height	The hub height is the distance from the turbine platform to the rotor of a wind turbine and indicates how high the turbine stands above the ground, not including the length of the turbine blades.
Intrusive noise	Refers to noise that intrudes above the background level by more than 5 dB(A).
Low frequency noise	A noise with perceptible and definite content in the audible frequency range below 250 Hz
Noise level statistics	L_{A90} - The A-weighted sound pressure level exceeded 90% of the monitoring period. This is considered to represent the background noise. L_{Aeq} - The equivalent continuous A-weighted noise level—the level of noise equivalent to the energy average of noise levels occurring over a measurement period. L_{A1} – The A-weighted sound pressure level exceeded 1% of the monitoring period. L_{Amax} – The maximum A-weighted noise level associated with the measurement period. 

Predicted noise level	The L_{A10} wind farm noise level at a receiver predicted in accordance with AS4959
Receiver	Premises that may be affected by the noise source, other than premises on the same land as the noise source
Receiver catchment	A defined area in which all receivers are considered to experience similar levels of background noise and for which a single receiver would be representative of all
Sound Power Level	The A-weighted sound power level is a logarithmic ratio of the acoustic power output of a source relative to 10^{-12} watts and expressed in decibels. Sound power level is calculated from measured sound pressure levels and represents the level of total sound power radiated by a sound source.
Sound Pressure Level	This is the level of noise, usually expressed in dB(A), as measured by a standard sound level meter with a pressure microphone. The sound pressure level in dB(A) gives a close indication of the subjective loudness of noise. A technical definition for the sound pressure level, in decibels, is 20 times the logarithm (base 10) of the ratio of any two quantities related to a given sound pressure to a reference pressure (typically 20 µPa equivalent to 0 dB). Examples of typical sound pressure levels are shown below.  Source: https://www.osha.gov/dts/osta/otm/noise/health_effects/soundpropagation.html
Tonal noise	Noise with perceptible and definite pitch or tone
WTG	Wind Turbine Generator

Executive Summary

A hybrid renewable energy system is proposed to be installed on Lord Howe Island to reduce its reliance on imported diesel for electricity generation. Jacobs was engaged by the Lord Howe Island Board (the Board) to measure background noise levels and complete an assessment of wind turbine generator (WTG) noise impacts on the Lord Howe Island community.

Two 275 kW WTGs are proposed to be installed in a cleared section near Transit Hill, at a relative height of approximately 60 - 70 m above sea level. Geographical coordinates of the WTGs are proposed to be:

- WTG1 – Easting 507064 m, Northing 6511667 m
- WTG2 – Easting 507157 m, Northing 6511661 m

The WTG site overlooks the Pinetrees Lodge to the east, which is at a relative height of around 5 m, and closest to residences to the north, at a relative height of around 35 m above sea level.

For the purpose of this assessment, the Island was divided into four receiver catchments, accommodating all relevant receivers. Background noise levels were measured at a single location within each receiver catchment concurrently with wind speed and direction over a period of approximately four weeks in January and February 2015. Data were used to establish the correlation between the $L_{A90\ 10\ minute}$ background noise level and wind speed on the island during the entire 24-hour period as well as separate night and day periods.

Based on this correlation, which is influenced by wind in the trees, ocean and insect noise, $L_{Aeq,\ 10\ minute}$ noise assessment criteria were derived for each relevant receiver at 1 m/s wind speed intervals over the range at which the WTGs cut in (4 m/s) and reach rated power (13 m/s)..

Noise levels from the proposed WTGs were predicted at relevant receivers using an acoustic model, Soundplan. Model results incorporated noise emission data provided by the equipment manufacturer as well as island topography and wind blowing from source to receiver (worst-case meteorological conditions).

Predictions from the model indicate that WTG noise levels, whilst likely to be audible, would meet the assessment criteria at all relevant receivers, as summarised in the table below, which depicts the maximum predicted noise levels for each of the assessed catchments on the island.

Derived $L_{Aeq,\ 10\ minute}$ noise criteria, dB(A), for relevant receivers

Receiver catchment	Period	Wind speed at hub-height, m/s								
		4	5	6	8	9	10	11	12	13
Eastern coastal	Predicted noise level	31	31	31	38	40	41	48	49	50
	Criteria at all times	56	55	56	57	59	60	60	59	56
	Criteria at night only	49	50	51	52	52	53	54	55	57
Central / Joy's Shop area	Predicted noise level	25	25	25	32	34	35	42	43	44
	All times	47	48	49	49	50	50	50	50	49
	Night only	40	43	44	45	44	44	45	46	48
Western coastal	Predicted noise level	37	27	27	34	36	37	44	45	45
	All times	46	47	47	48	48	49	50	51	53
	Night only	41	42	42	43	43	44	45	46	48
Southern	Predicted noise level	16	16	16	24	26	26	34	35	35
	All times	47	48	49	49	50	50	50	50	49
	Night only	40	43	44	45	44	44	45	46	48

Due to their proximity, noise levels at receivers to the north of the WTG site are predicted to be higher than those in other areas; however should still meet the assessment criteria. Noise levels at receivers to the west of the WTG site are predicted to be just within the assessment criteria, around 1 dB(A) lower, at hub-height wind speeds of 11 – 12 m/s.

Predicted noise levels in the more densely populated island centre and the southern section of the island, are within the noise criteria for the night period and therefore these areas are not expected to be adversely affected by WTG noise at any time of the day.

The noise assessment criteria account for the noise level of the WTGs and reasonable levels of “swish”, discrete tones and low frequency noise. It is unlikely that excessive tonality or low frequency noise will be a feature of modern wind turbines. Excessive levels of these ‘annoying’ characteristics have not been specifically addressed in this report; however the assumption that these characteristics are not excessive should be confirmed during commissioning.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to measure background noise levels on Lord Howe Island and assess noise from operation of Wind Turbine Generators in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

Constraints on this assessment included seasonal insect noise during noise monitoring, which may influence background noise levels and availability of sound power data for emissions from the proposed turbines, particularly values at hub height.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party

1. Introduction

1.1 Overview

Lord Howe Island is developing a hybrid renewable energy system to reduce its reliance on imported diesel for electricity generation. The proposed system would consist of a solar (photovoltaic) farm of 450 kW; two wind turbine generators (WTG) of 275 kW each and battery storage. The system is expected to significantly reduce the Island's diesel fuel needs for the generation of electricity.

Given the Island's environmental and spatial constraints, options for WTG locations are limited and the potential for noise impacts on residents due to the proximity of the WTG siting is a concern to the Board, some residents and business owners.

The Lord Howe Island Board (LHIB) has therefore commissioned Jacobs to assess the potential for noise generated by the proposed WTGs to result in adverse impacts on the community's amenity. The assessment consisted of background noise and meteorological monitoring, prediction of WTG noise on relevant receivers and recommendations for appropriate management.

1.2 Scope of work

This report details the methodologies and findings of the noise impact assessment, which form the scope of work, and includes:

- description of the proposed WTG locations and identification of potentially affected receivers
- description of the proposed WTG operational parameters;
- background noise and meteorology monitoring;
- applicable noise monitoring guidelines and assessment criteria;
- predicted noise levels at relevant sensitive receivers with comparison against noise assessment goals;
- modifications or operating strategy that may be necessary to address unforeseen non-compliances.

2. Proposed WTG location and operational parameters

2.1 Site description

Lord Howe Island is located around 600 km east of Port Macquarie in NSW, with a length of around 10 km and a width between 0.3 km and 2 km. The island's topography is characterised by numerous hills, including Mt Eliza in the far north, Malabar Hill, Transit Hill near the airport, Intermediate Hill, and the two higher peaks, Mount Lidgbird and Mount Gower in the south.

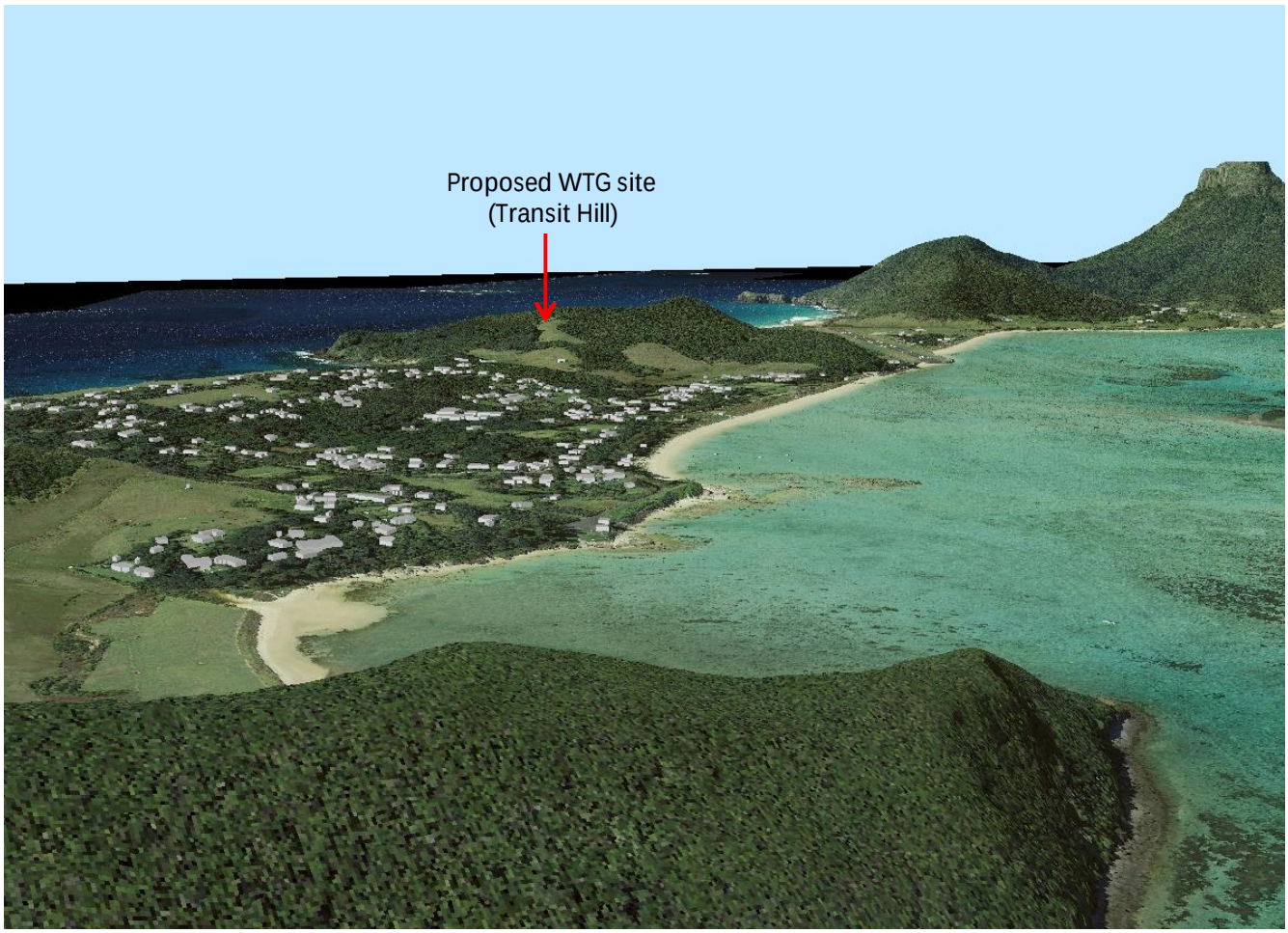
The majority of the island's population of around 390 residents and up to 400 tourists resides in the lower-lying northern part of the island, with the south consisting mostly of forested hills.

The WTGs are proposed to be installed in a cleared section of land near Transit Hill at a relative height of approximately 60 - 70 m above sea level. Geographical coordinates of the WTGs are proposed to be:

- WTG1 – Easting 507064 m, Northing 6511667 m
- WTG2 – Easting 507157 m, Northing 6511661 m

The WTG site overlooks the Pinetrees Lodge to the east, which is at a relative height of around 5 m, and closest to residences to the north, at a relative height of around 35 m above sea level.

Figure 2-1 3D illustration of Lord Howe Island terrain and the proposed WTG siting



2.2 Operating specifications

The LHIB proposes to install two Vergnet GEV MP R 275 kW turbines, an example of which is shown for Coral Bay, WA in Figure 2-2. The turbines would be mounted on tilt up/down 55 m high towers. Manufacturer specifications are listed in Table 2-1.

Figure 2-2 Visual example of Vergnet GEV MP R turbines (Coral Bay WA) source: www.Vergnet.com

Table 2-1 Vergnet, WTG manufacturer specifications

	Details
Make	Vergnet
Model	GEV MP R
Rated power,	275 kW
Number of blades	2
Rotor diameter	32 m
Rotor speed, max	31 rpm
Hub height	55 m
Orientation	Upwind
Gear box	2 stage
Cut-in wind speed	3.5 m/s
Rated wind speed	12.0 m/s
Cut-out wind speed	25.0 m/s

2.3 Sound power levels

Sound power data for the WTGs has been provided by the manufacturer, Vergnet. Measurement was undertaken at the manufacturer's test site in France in 2010 in line with the IEC 61400-11 standard *Wind turbine generator systems – Part 11: Acoustic noise measurement techniques* and a copy of the documentation is included in Appendix A.

Sound power levels (SWLs) were derived for wind speeds between 3 m/s and 12 m/s, referenced to 10 m above ground level (AGL) and are presented in Table 2-2. Octave band noise spectra for each integer wind speed are also provided.

Australian Standard AS4959-2010 recommends referencing all sound power to hub height wind speeds. Sound Power data provided by the manufacturer, referencing wind speed at 10 m AGL, was adjusted for the WTG hub height of 55 m using a site specific shear factor of 0.42 for the proposed WTG location (see Section 3.3). Wind speed at hub height was derived from the equation in AS4959-2010:

$$V_{HH} = V_{10m}/(H_{10m}/H_{HH})^{\alpha}$$

Where a = shear factor, V_{HH} = wind speed at hub height, H_{HH} = Height at hub height.

Derived hub height wind speeds at 55 m are shown in Table 2-2 alongside the associated wind speeds at 10 m. Of the available manufacturer's data, SWLs for wind speeds between 6 m/s and 13 m/s (rated power) at hub height will be used in the prediction. For wind speeds between 3.5 m/s (cut in) and 6 m/s, the SWL for 6 m/s has been used as a conservative measure.

Table 2-2 Sound power data for Vergnet GEV MP R (Vergnet 2010)

Wind speed at 10 m (m/s)	Derived wind speed, m/s, at hub height, (with shear factor 0.42)	SWL at octave band centre frequency (Hz)								
		63	125	250	500	1000	2000	4000	8000	A-weighted SWL
3	**6**	72.4	79.4	84.8	85.4	83.4	84.7	78.6	63.5	91.3
4	**8**	ND	75.2	89.5	89.3	85.0	81.8	74.9	60.3	93.6
5	**9**	72.7	79.3	90.5	90.4	85.8	80.4	73.5	ND	94.5
6	**10**	73.7	80.7	89.9	90.3	86.9	82.2	74.7	ND	94.6
7	**11**	81.8	89.4	95.5	98.9	98.9	93.4	87.5	75.4	103.6
8	**12**	83.6	91.3	96.9	100.0	98.9	94.5	89.6	78.7	104.5
9	**13**	83.7	91.5	97.0	100.0	98.7	94.6	89.8	79.1	104.5
10	-	83.6	91.7	96.8	99.8	98.3	94.8	90.7	ND	104.3
11	-	84.0	91.8	96.4	99.8	98.3	95.7	91.1	ND	104.4
12	-	83.4	91.5	96.3	99.3	97.9	95.2	91.2	78.7	104.0

ND = No data

3. Existing environment

3.1 Relevant receivers

The proximity of the WTG site to nearby receivers means that a number of residential receivers and accommodation providers may be affected by WTG noise and are relevant to this study. Relevant receivers are those where predicted WTG noise levels exceed the base noise level of 35 dB(A) (the most stringent criterion – see section 3.2) and may be adversely affected by WTG noise under some meteorological conditions.

To determine which receivers are relevant, a screening assessment was completed, with noise levels of the WTG, operating at a hub height wind speed of 12 m/s, predicted. The resulting 35 dB(A) contour line was overlaid on an image of the island and those receivers inside the contour line are considered relevant, with noise levels exceeding 35 dB(A). Receivers outside the contour line are unlikely to be adversely impacted by WTG noise. The contour line is illustrated in Figure 3-1.

The majority of relevant receivers are northwest of the WTG location. Receivers to the south are screened by the island's topography and are predicted to experience noise levels lower than the minimum noise level, hence are not considered relevant to this study. However, a number of these have been included to provide a comprehensive assessment. A schedule of relevant receivers is provided in Appendix B and a larger scale map showing these receivers is provided in Appendix C.

Considering the locations of relevant receivers to the WTG site, winds from the southeast would likely impact the greatest proportion of the island's population to the north and northwest of the WTG site. Easterly winds would also represent a risk of adverse impact to Pinetrees Lodge to the west of the WTG site, as seen in Figure 3-1.

Figure 3-1 Lord Howe Island WTG locations and sensitive receivers for hub height wind speed12 m/s

3.2 Background noise and wind speed monitoring

3.2.1 Methodology

Background noise monitoring was undertaken at four locations representative of relevant receivers, as illustrated in Figure 3-1 and summarised in Table 3-1. Sequential 10 minute $L_{A90, (10\ min)}$ background noise measurements were taken at each relevant receiver concurrently with 10 minute average speed and direction measurements on the wind farm site. Clocks on all monitoring equipment were set to match the time of the Lord Howe Island meteorological mast, which is set to Lord Howe Island Standard Time (half hour ahead of AEST).

Table 3-1 Background monitoring locations for noise and meteorology

Location	Easting, m	Northing, m	Elevation above sea level, m	Distance to closest WTG location, m	Distance to meteorological mast, m	Representative of:
M1 Cobby's Corner	507351	6510050	4.5	1600	1570	Southern coastal receivers
M2 Rear of Pinetrees	506697	6511462	5.5	480	580	West coastal receiver
M3 Palm Haven	507023	6511924	32.5	280	370	East coastal receivers
M4 Near Joy's shop	506522	6511939	13.5	680	800	Central island receivers / Joy's Shop area
Main meteorological mast	507261	6511613	81 (mast base – anemometer heights included 10m, 30 m and 45 m)	100	n/a	n/a
Microphone-level meteorological station	506522	6511939	13.5	680	800	N/a

In compliance with AS4959-2010 and DP&I (2011), monitoring was undertaken using Ngara environmental noise loggers, which are capable of collecting data between 10 Hz and 4000Hz and have an inherent noise floor of no greater than 20 dB(A). Loggers were placed within 30 m of sensitive non-associated receivers and in the direction of the WTG site. The microphone was positioned 1.2 – 1.5 m above ground and at least 5 m from any reflecting surface, remote from any extraneous noise sources. Photographs of each monitoring location are provided in Table 3-1.

Monitoring commenced on 6 January 2015 and continued until 4 February 2015. Winds were initially from a non-worst-case direction (northerly) requiring an additional two weeks of monitoring to satisfy the requirements of DP&I, AS 4959-2010 and SA EPA. That is, approximately 2,000 intervals, with at least 500 intervals in the worst-case direction. Noise was measured for wind speeds across the range at which the WTGs operate (cut in - 3.5 m/s to rated power - 12 m/s).

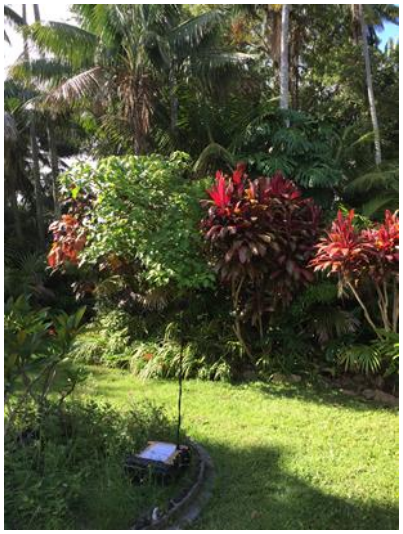
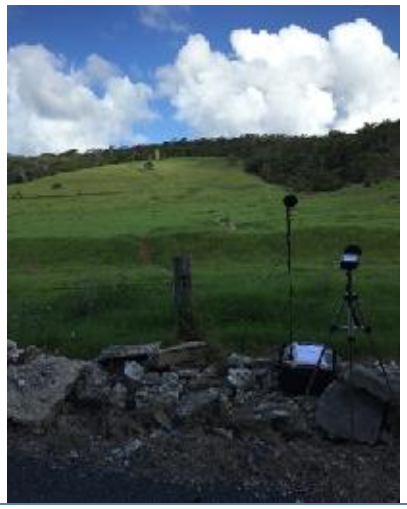
A weather station was operated at one location (M4) to identify the wind speed at microphone height and to measure rainfall during the monitoring period. This allowed data collected during rain and at wind speeds (at microphone height) 6 m/s or greater to be excluded to avoid excessive wind- or rain-induced noise. The monitoring period was relatively dry and only a small number of data have been excluded due to rain.

During deployment of the Ngara noise loggers, operator-attended monitoring was also undertaken to characterise the typical existing noise environment, noting dominant noise sources. Monitoring was performed with a Bruel and Kjaer 2250 sound level meter during the day and night periods for 15 minutes in each location.

3.2.2 Operator-attended monitoring observations

A summary of observations and measured noise levels is provided in Table 3-2.

Table 3-2 Long-term monitoring locations and attended monitoring observations

Monitoring location	Photograph of monitoring position	Recorded LAeq,15 minute noise parameters		Observations
		L_{A90}	L_{Aeq}	
M1 Cobby's Corner		41	51	**DAY** Time: 3:50 pm Conditions: Calm, Partly cloudy, around 28°C. • Cicadas in the trees dominant when active in the daytime (L_{Aeq} ~54 dB(A) at 4 - 6kHz) • When cicadas silent, wave noise, voices and occasional car passing by ~40 dB(A)
		34	39	**NIGHT** Time: 10:20 pm Conditions: very light breeze from east, calm and partly cloudy, ~21°C. • Lapping of waves on beach • Some insects (not cicadas) • Distant waves • A little breeze in the trees
M2 Rear of Pinetrees		41	45	**DAY** Time: 4:50 pm Conditions: Light easterly breeze, partly cloudy • Breeze in trees is dominant when it fills in. • Laundry/chiller facilities are audible (part of local noise feature) • Distant cicadas (~40 dB(A) at 4 – kHz) • General accommodation noise eg voices, banging, laughter

Monitoring location	Photograph of monitoring position	Recorded LAeq,15 minute noise parameters		Observations
		L_{A90}	L_{Aeq}	
		35	38	**NIGHT** Time: 10:45 pm Conditions: very light breeze from E/ESE, partly cloudy, ~21°C. • Distant power station audible in east if wind drops out • Crickets • Laundry building fans / chiller including just audible 100 Hz tone • Breeze picks up from time to time - noise from rustling of leaves and branches in trees
M3 Palm Haven	 	44	52	**DAY** Time: 5:35 pm Conditions: Gentle easterly breeze, Partly cloudy, ~ 26°C. • Site is surrounded by trees. • Surf quite audible to east, laying a continuous baseline of noise • Birds in trees ~40 dB(A) at 2 – 3 kHz • A little local traffic • Nearby diesel power station inaudible
		42	45	**NIGHT** Time: 11:34 pm Conditions: very light breeze from east, calm and partly cloudy, ~21°C. • Waves dominant – continuous broadband noise ~42 dB(A) • Some breeze in trees • Birds • Power station not audible over waves and breeze

Monitoring location	Photograph of monitoring position	Recorded LAeq,15 minute noise parameters		Observations
		L_{A90}	L_{Aeq}	
M4 Near Joy's shop		45	53	**DAY** Time: 9:33 am Conditions: Gentle E/NE breeze, partly cloudy, ~23°C • Open space tree-fringed • Joy's shop nearby – no audible chillers • Cicadas in trees ~50-52 dB(A) at 2-3 kHz • Breeze in trees when it picks up • A little local traffic • Distant waves when wind is calm
		36	38	**NIGHT** Time: 11:05 pm Conditions: very light breeze from E/SE, partly cloudy, ~21°C. • Some breeze in palms • Distant waves • Insects

3.2.3 Data analysis

Measured L_{A90} noise levels over the monitoring period have been plotted against wind speed data at the proposed hub-height (55 m) to obtain a background noise versus wind speed characteristic for each relevant receiver.

The line of best fit for data from each monitoring location has been determined using linear, second order (quadratic) and third order (cubic) polynomials. The correlation coefficient (R^2 value) for each line of best fit has been reported and the line with highest R^2 value used.

Correlation coefficients for 24-hour data ranged from 0.02 to 0.14, which indicates that background noise levels, though increasing with wind speed, are not purely determined by local wind conditions. This may be due to the location being influenced by insects (cicadas in the day and evening) and the nearby waves on surrounding reefs, beaches and rocks. Insects are likely to be a seasonal influence. In addition, the monitoring locations may be sheltered from the wind in comparison to the WTG location.

The guidelines do not recommend a minimum cut-off value for correlation; however AS4959 – 2010 recommends carrying out separate correlations at different times of the day and the DP&I (2011) requires day and night correlations to be considered.

Analysis of night time background noise versus wind data shows stronger correlation, between 0.09 and 0.25. The regression line for night-only data is typically lower than the overall and daytime values by around 3 – 7 dB and varies from location to location. The reduced night noise levels are likely due to lower wind speeds as well as reductions in insect noise. Graphs of the plotted measured data and regression lines for each monitoring location are provided in Appendix D.

A summary of analysis for each relevant receiver is provided in Table 3-3.

Table 3-3 Long-term monitoring details

Location	Monitoring period	Noise logger serial no.	Total monitoring intervals	No. of valid data points		Best fit correlation coefficient, R^2, for all data			Best fit correlation coefficient, R^2, for	
				All	Night	Linear	2nd order	3rd order	Day 3rd order	Night 3rd order
M1 Cobby's Corner	5 Jan 2015 – 4 Feb 2015	ARL Ngara 8780C0	3369	2544	1070	0.13	0.14	0.14	0.15	0.25
M2 Pinetrees	5 Jan 2015 – 31 Jan 2015	ARL Ngara 8780A5	2978	2756	1065	0.06	0.06	0.06	0.05	0.2
M3 Palm Haven	5 Jan 2015 – 26 Jan 2015	ARL Ngara 8780A4	2846	2450	992	0.03	0.03	0.04	0.06	0.12
M4 Joy's shop	6 Jan 2015 – 4 Feb 2015	ARL Ngara 8780BA	4019	2227	917	0.02	0.02	0.02	0.06	0.09

3.3 Wind shear

Appendix E provides a curve of wind shear at the met mast location, with an average wind shear factor of 0.42. An analysis of wind shear vs wind direction indicates that easterly winds strongly influence this value. The Board's meteorological monitoring mast has been in use since November 2014 and this value may change over time, hence should be reviewed when a full year of meteorological data is available.

4. Noise assessment criteria

4.1 WTG noise sources

Wind is a clean, cheap and inexhaustible source of energy and can provide sustainable solutions to communities that are isolated from the electricity grid. However, it is widely recognised that wind farms have a noise output that varies with wind speed and unique noise generating characteristics that can be annoying to some people.

Traditionally, the major sources of noise on a WTG were the gearbox and the fast moving blades (aerodynamic noise). Gearboxes on modern WTGs are generally very quiet; leaving wind moving across the blade as the dominant noise source for most turbines.

Air moving across the blade produces acoustic waves at the trailing edge and tip, which are often perceived as a "swishing" or "thumping" sound. This noise can vary in intensity, called amplitude modulation (the difference between minimum and maximum noise levels).

Other historically annoying aspects of WTG noise include tonal and low frequency characteristics. Tonal noise, the emergence of discrete frequency bands in the broader spectrum, can be developed by vortices around the blade. These do not typically occur in larger (>10 kW) well designed and maintained wind turbines.

Low frequency noise is typically not a significant feature of modern wind turbine noise and is usually less than that of other environmental noise sources such as wind and the ocean.

4.2 Wind farm noise guidelines

The NSW Department of Planning and Infrastructure (DP&I) released the *Draft NSW Planning Guidelines for Wind Farms* for consultation in December 2011. The document contains noise guidelines intended to provide guidance on how to measure and assess environmental impacts from wind farms under the *Environmental Planning and Assessment Act 1997*. The draft guideline was developed with consideration of other guidelines used widely around Australia, including New Zealand; however methodologies and practices in the document most closely follow the South Australian EPA (2009) *Wind farms environmental noise guidelines* and Australian Standard *AS4959 – 2010 Acoustics – Measurement, prediction and assessment of noise from wind turbine generators*. Therefore, even though the NSW guideline is in draft form, noise criteria from this document will be used in this assessment since it adopts other recognised and widely used guidelines and is suitably stringent.

A characteristic of wind farms is that the noise level from each WTG rises as the wind speed at the site increases. This increase is generally complemented by an equal or greater increase in the background noise level, which may substantially or even completely mask the WTG noise.

Noise guidelines have been developed to account for fundamental characteristics of wind turbine noise, as described above, and have been established for sensitive receivers located in quiet rural areas. Considering the wind speed at the site, the predicted equivalent noise level ($L_{eq,\ 10\ minute}$), adjusted for any excessive levels of tonality, amplitude modulation or low frequency, should not exceed the greater of:

35 dB(A)

OR

The background (L90) noise level by more than 5 dB(A)

This goal:

- applies at all relevant receivers not associated with the wind farm,
- applies for wind speeds from cut-in to rated power of the WTG and each integer wind speed in between.

DP&I (2011) also requires criteria to be established on the basis of separate daytime (7am to 10pm) and night time (10pm to 7am) periods.

4.3 Project-specific noise assessment criteria

Based on analysis of background noise level and wind speed data for each relevant receiver, noise assessment criteria have been derived from the 3rd order best fit regression line for night and day, since this presented the highest correlation coefficient. Criteria are summarised in Table 4-1. Plotted noise criteria are shown in Figure 4-1 to Figure 4-4.

Table 4-1 Derived $L_{Aeq,\ 10\ minute}$ noise criteria for relevant receivers

Receiver catchment	Period	Equation describing assessment criteria	Wind speed at hub-height, m/s								
			4	5	6	7	8	9	10	11	12
Eastern coastal receivers	All times	$y=-0.0819x^3 + 1.7872x^{\wedge 2} -11.47x+78.11$	56	55	56	57	59	60	60	59	56
	Night only	$y = 0.0205x^3 -0.4687x^2 +4.1876x+38.38$	49	50	51	52	52	53	54	55	57
Central receivers	All times	$y = -0.0039x^3-0.0336x^2+1.6729x+40.64$	47	48	49	49	50	50	50	50	49
	Night only	$y = 0.0744x^3 - 1.8x^2 + 14.292x + 7.18$	40	43	44	45	44	44	45	46	48
Western coastal receivers	All times	$y = 0.0093x^3-0.1753x^2+1.5769x+41.36$	46	47	47	48	48	49	50	51	53
	Night only	$y = 0.022x^3 - 0.474x^2 + 3.8983x + 31.17$	41	42	42	43	43	44	45	46	48
Southern island receivers	All times	$y = -0.0089x^3+ 0.3021x^2-1.7583x+49.48$	47	48	49	49	50	50	50	50	49
	Night only	$y = -0.007x^3 + 0.1668x^2+0.0916x+39.67$	40	43	44	45	44	44	45	46	48

The acoustic environment of Lord Howe Island is influenced by noise sources other than local wind conditions. Insect noise, particularly during the day and evening, and waves, provide a relatively constant background level. The background noise level is several decibels louder during the day than observed during the night when insects are not as prevalent.

Noise criteria are intended to preserve the amenity on the island for residents and visitors, particularly during the night period where activities such as sleep and relaxation rely on a quieter environment. WTG noise levels exceeding suitable levels at night may create annoyance and reduce well-being.

Therefore, the recommendation in AS4959-2010 and the DP&I (2011) requirement to consider separate noise goals for the night period, has been adopted in this assessment, as shown in Table 4-1.

4.4 Seasonal variation

The influence of insects on the background noise level was substantial during the day and evening periods of the monitoring study and is likely to decrease into the winter months. It can be argued that monitoring during winter may be necessary to derive noise criteria in the absence of insects.

However, in lieu of further monitoring, night criteria determined during the summer period, which were not heavily influenced by insects, provide a suitable basis for the assessment of noise impacts with regard to the potential for sleep disturbance and reduced amenity. In addition, monitoring during this time allowed for the seasonal worst-case wind direction from the southeast to be considered.

Therefore, with the adoption of a night time noise assessment criteria for each relevant receiver, the potential impact on the amenity of the island can be appropriately assessed without further monitoring.

Figure 4-1 Derived noise criteria for eastern coastal receivers

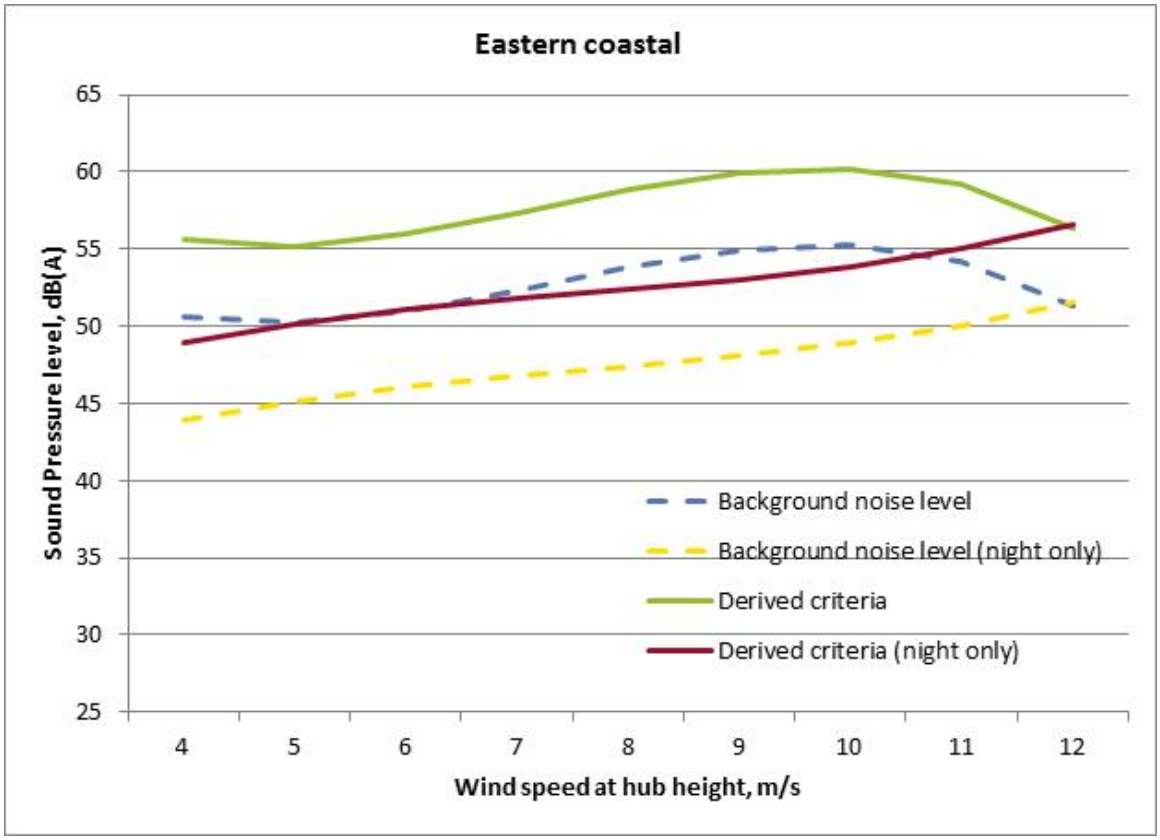


Figure 4-2 Derived noise criteria for central / Joy's Shop area-centre receivers

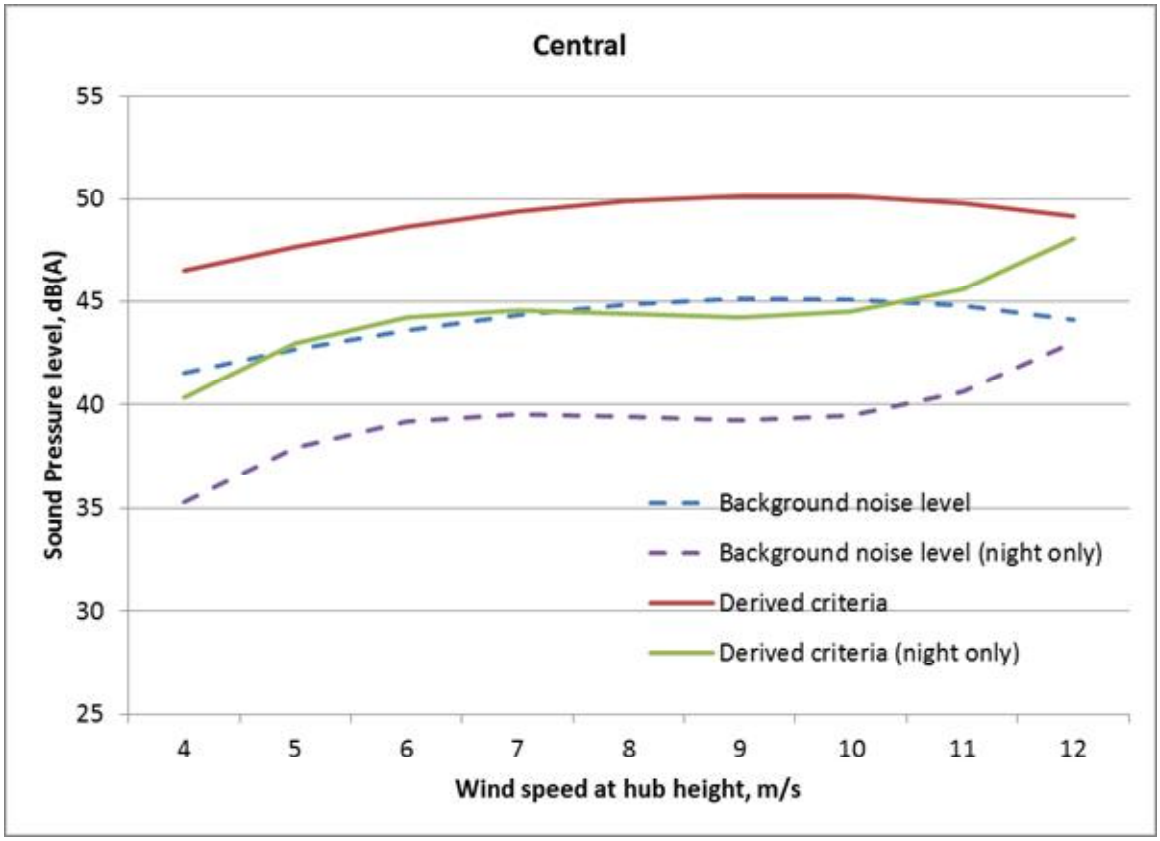


Figure 4-3 Derived noise criteria for western coastal receivers

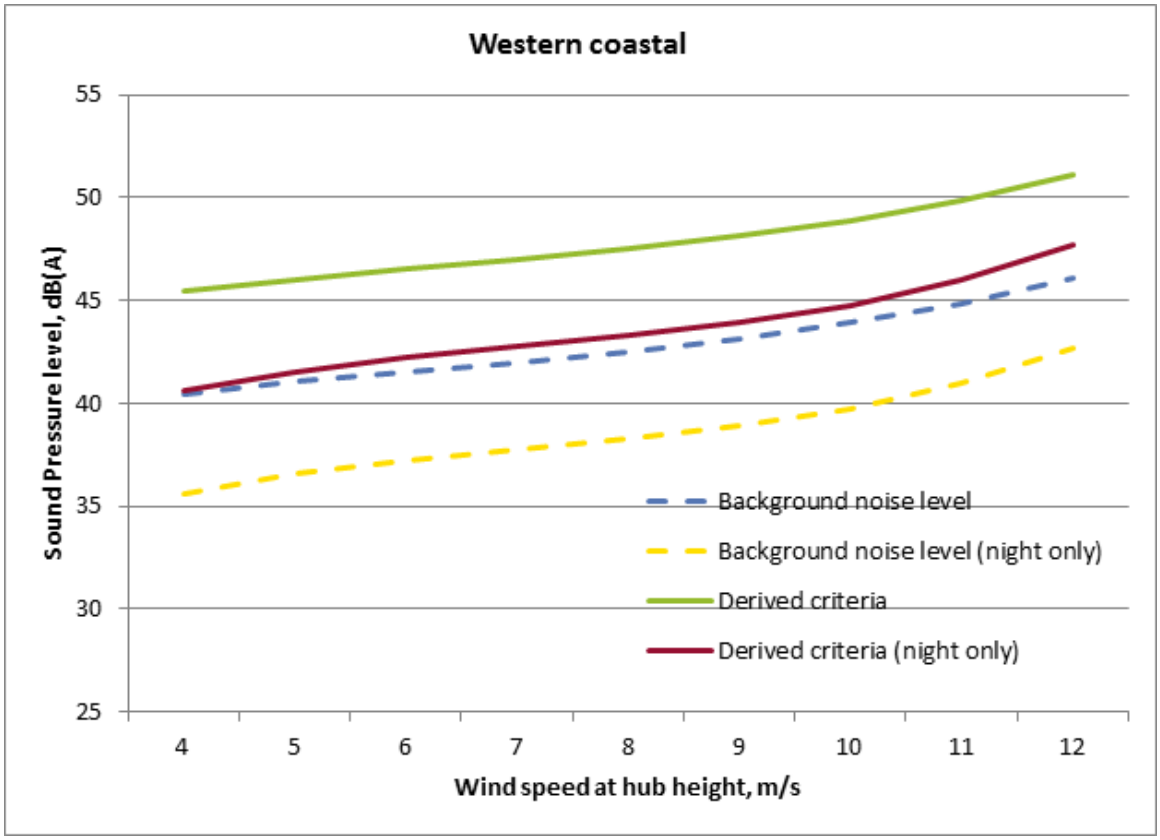
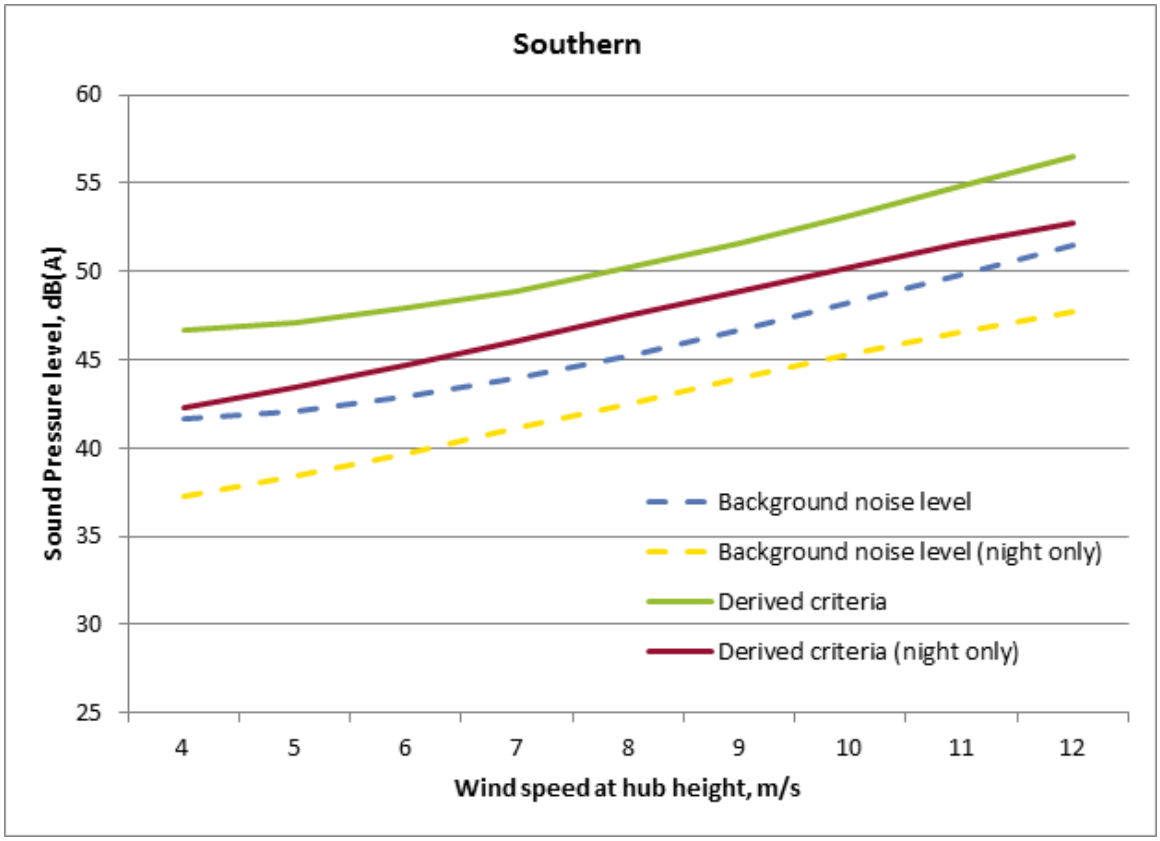


Figure 4-4 Derived noise criteria for southern receivers



5. Noise prediction

5.1 Noise model selection and development

SoundPlan v7.2 was used to develop a 3D model of Lord Howe Island and to predict the propagation of WTG noise to all relevant receivers. Predictions included sound power levels of both WTGs, atmospheric and ground absorption as well as any structural or topographical screening. Detailed topography was created based on LIDAR data (a remote sensing technology that measures distance with a laser and analyses the reflected light.) for the island.

The calculation algorithms recommended by the DP&I and associated guidelines include ISO 9613-2 and CONCAWE. Studies (eg Bowder *et al* 2009, ETSU 2000) have shown that these algorithms provide varying levels of accuracy depending on the terrain, ground absorption conditions and wind speed; however the ISO9613-2 algorithm, in particular the octave band prediction method, is most widely used and typically represents the most accurate result. Estimated confidence levels of this method are 85% that noise levels in practice would not exceed the calculated level by more than 1 dB(A). This method is also the only algorithm specifically referred to in AS4959 so will be adopted for this assessment.

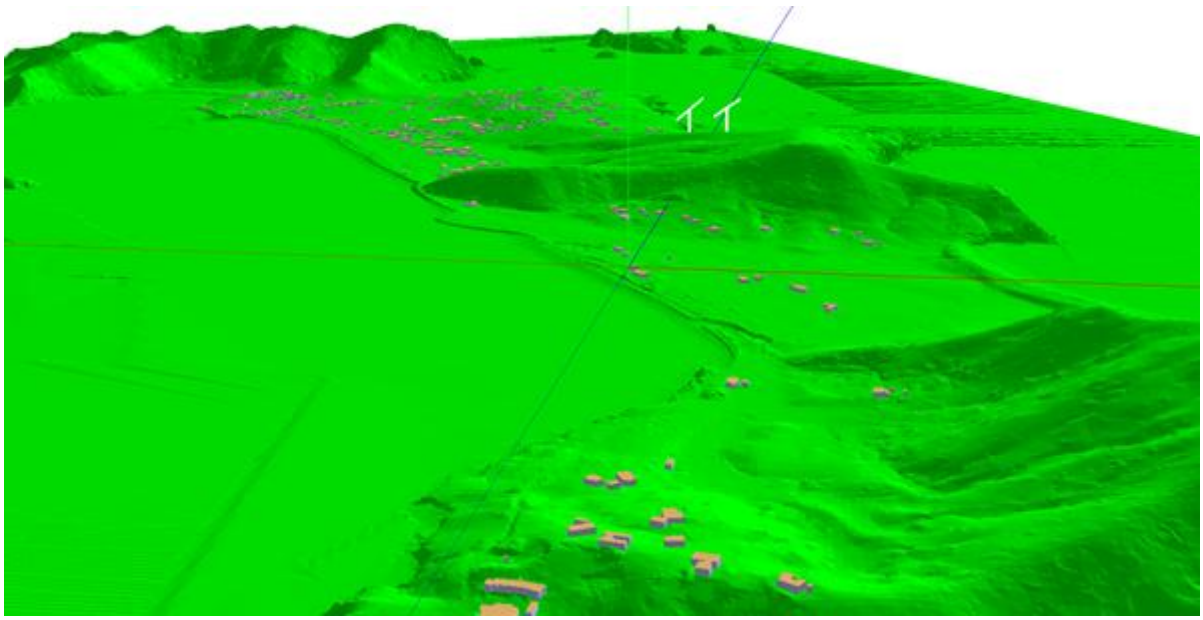
The parameters included in the acoustic model are specified in Table 5-1. Noise levels were predicted using sound power levels for all integer wind speeds between cut-in (3.5 m/s) and rated (12 m/s) wind speeds.

Table 5-1 Modelled parameters

Parameter	Value
Sound power level	Test levels provided by manufacture (see Section 2.3)
Atmospheric conditions (temperature / relative humidity)	10°C / 80%
Ground factors	0 (hard ground)
Barrier attenuation	No barrier attenuation assumed
Wind speed and direction	1 m/s to 5 m/s source to receiver
Estimated model accuracy	±1.5 dB

An illustration of the 3D acoustic model is provided in

Figure 5-1 3D acoustic model



5.2 Predicted results

Results for each relevant receiver with two WTGs operating at once are provided in Appendix A and show predicted levels for each integer wind speed between 4 m/s and 12 m/s (at 10 m AGL).

A summary of predicted results is presented for each of the four representative receiver catchments, with the highest predicted noise level and worst-affected receivers for each catchment shown in Table 5-2. Refer to Appendix C for the locations of each of these worst-affected receivers.

Predictions indicate that, while WTGs are likely to be audible at many receivers, with levels close to or exceeding the background noise level for specific wind speed intervals, the criteria for the total period (day and night) or for night only would not be exceeded. Hence the risk of adverse impacts on the amenity of the island is low.

Noise levels at receivers 30 and 31 in the eastern coastal catchment are predicted to be higher than in other catchments due to their proximity to the WTG site. However, higher background noise levels should reduce the overall impacts in this location and predicted noise levels are below the criteria.

Noise levels at receivers 164 and 165, to the west of the WTG, site are predicted to be closest to the assessment criteria, only around 1 dB(A) less than the criteria at wind speeds of 11 – 12 m/s at hub height.

Predicted noise levels in the more densely populated island centre, represented by receivers 95 and 101, are within the noise criteria for the night period and therefore this catchment is not expected to be adversely affected by WTG noise. Similarly, predicted levels at southern receivers, are below the criteria.

As discussed in Section 4.1, typical characteristics of WTG noise are accounted for in the noise criteria and it is unlikely that tonality or low frequency noise will be present, an assumption supported by manufacturer's data. Therefore, these characteristics have not been included in the predicted results. However the assumption that these characteristics are not present should be validated during commissioning of the WTGs.

Table 5-2 Derived $L_{Aeq,\ 10\ minute}$ noise criteria for relevant receivers

Receiver catchment	Worst-affected receiver(s)	Period	Wind speed at hub-height, m/s								
			4	5	6	8	9	10	11	12	13
Eastern coastal	30, 31	Predicted noise level	31	31	31	38	40	41	48	49	50
		Criteria at all times	56	55	56	57	59	60	60	59	56
		Criteria at night only	49	50	51	52	52	53	54	55	57
Central / Joy's Shop area	95, 101	Predicted noise level	25	25	25	32	34	35	42	43	44
		All times	47	48	49	49	50	50	50	50	49
		Night only	40	43	44	45	44	44	45	46	48
Western coastal	164, 165	Predicted noise level	37	27	27	34	36	37	44	45	45
		All times	46	47	47	48	48	49	50	51	53
		Night only	41	42	42	43	43	44	45	46	48
Southern	190-192	Predicted noise level	16	16	16	24	26	26	34	35	35
		All times	47	48	49	49	50	50	50	50	49
		Night only	40	43	44	45	44	44	45	46	48

6. Contingency strategy

Where it is demonstrated through compliance monitoring during commissioning of the WTGs or in response to a complaint, that the WTGs exceed noise predicted noise levels at the relevant criteria, noise management strategies may be considered. The specific management strategy adopted would depend on the conditions which cause the exceedances and should be appropriately investigated. Options include:

- Identify the conditions and times that lead to undue impacts.
- Turn off one or both WTGs that are identified as causing undue impacts during specific conditions (wind directions and strengths), a mitigation process called sector management.
- Consult with the manufacturer to identify noise control options of the turbines such as:
  - variable speed;
  - changes to the pitch regulation regime;
  - vortex generators and/or
  - trailing edge serrations.

Appendix A. Manufacturer sound power data

VERGNET EOLIEN

GEV MP
Acoustic characterization

1. SOUND POWER LEVEL

Measurement of Acoustic Noise Emission of the GEV MP 32/275 has been performed following the IEC 61400-11 standard "Wind turbine generator systems – Part 11: Acoustic noise measurement techniques".

MEASNET member (http://www.measnet.com/members.html) CENER (http://www.cener.com), who did proceed to measurement of the Acoustic Noise Emission of the GEV MP wind turbine installed on our test site in Gommerville, close to Orléans, France, certified the following values in its report ("No. 21.1603.0-AN-R" dated 05/05/2010).

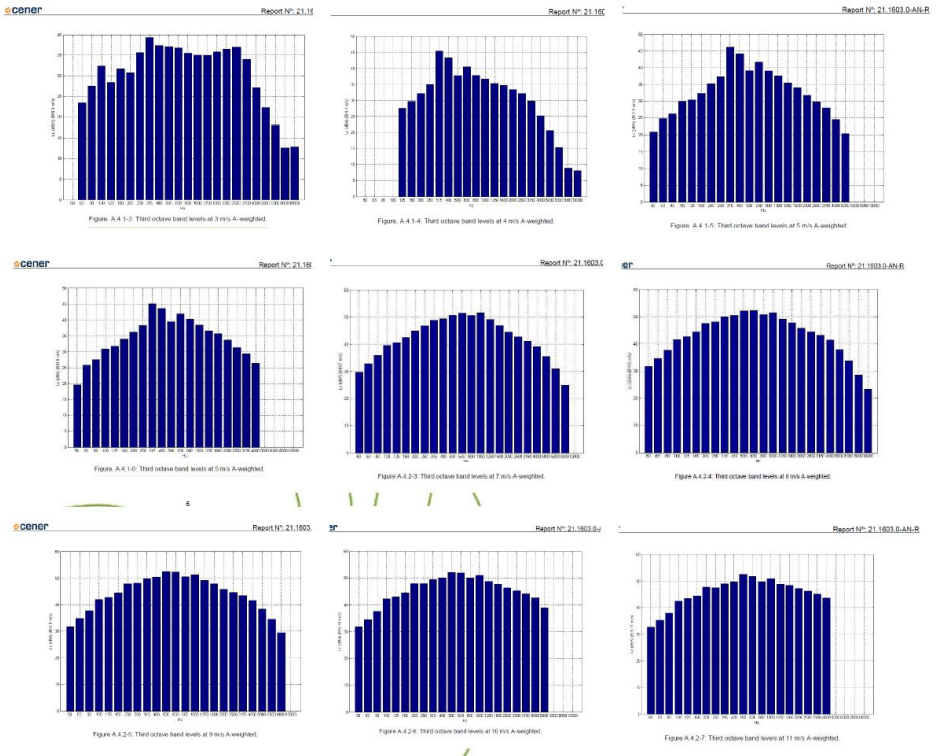
We hereby report sound power level (Lw) obtained.

Lw (dB(A))	*3m/s (*)*	*4m/s*	*5m/s*	*6m/s*	*7m/s*	*8m/s*	*9m/s*	*10m/s*	*11m/s*
at Low Speed (LS)	*86.30*	*92.86*	*94.62*	*95.41*					
at High Speed (HS)					*103.36*	*104.42*	*104.64*	*104.22*	*104.03*

(*) wind speed measured at 10m (32' 10")

2. OCTAVE BAND NOISE SPECTRUM

Measurement of Octave band noise spectrum of the GEV MP 32/275 has also been performed by CENER, following the IEC 61400-11 standard "Wind turbine generator systems – Part 11: Acoustic noise measurement techniques". The final report ("No. 21.1603.0-AN-R" dated 05/05/2010) shows the 3rd octave band spectrum from 3 to 11m/s:



Date	Status	Release	Author	Checker	Approved by	Page
29/07/2010	Update Source DE-RE258a - MP noise CENER 21.1603.0-AN-R	7	PVE	EVA	DSA	1/2

Appendix B. Relevant receivers

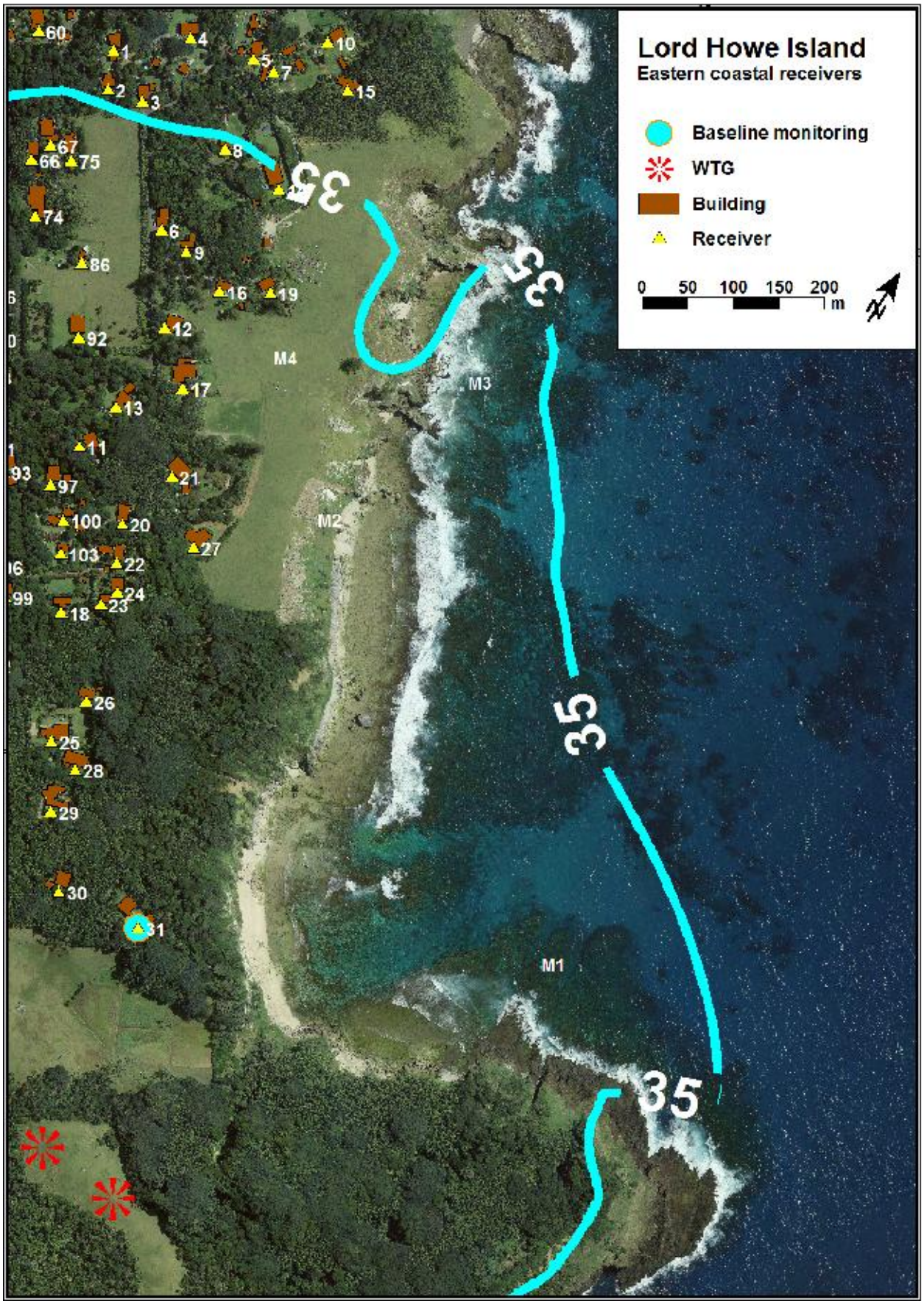
Catchment	Receiver	Easting, m	Northing, y	Elevation, m	Distance from nearest WTG, m
Eastern Coastal	1	506475	6512714	41	1205
	2	506494	6512675	43	1162
	3	506533	6512684	46	1151
	4	506538	6512771	42	1227
	5	506609	6512789	39	1215
	6	506627	6512578	46	1014
	7	506635	6512790	38	1206
	8	506637	6512690	44	1112
	9	506662	6512572	45	995
	10	506667	6512849	34	1251
	11	506680	6512330	47	771
	12	506688	6512490	49	909
	13	506690	6512388	49	816
	14	506710	6512685	41	1082
	15	506714	6512817	35	1206
	16	506717	6512555	45	958
	17	506740	6512445	51	847
	18	506763	6512166	44	589
	19	506764	6512585	42	970
	20	506766	6512285	47	691
	21	506783	6512358	44	751
	22	506784	6512245	47	648
	23	506794	6512198	43	602
	24	506802	6512218	44	616
	25	506831	6512043	36	452
	26	506839	6512100	36	497
	27	506845	6512305	46	680
	28	506869	6512031	35	423
	29	506872	6511978	39	376
	30	506927	6511910	36	293
	31	507021	6511923	33	276
Central island	32	505720	6512667	22	1679
	33	505736	6512582	20	1617
	34	505736	6512532	19	1588
	35	505748	6512631	22	1635
	36	505794	6512635	20	1601
	37	505828	6512530	13	1512
	38	505865	6512642	17	1549
	39	505909	6512399	15	1372
	40	505959	6512450	17	1359
	41	505970	6512505	17	1383
	42	505981	6512528	17	1388
	43	505996	6512507	19	1363
	44	506031	6512527	19	1349
	45	506032	6512565	17	1373
	46	506049	6512366	5	1238
	47	506059	6512529	18	1329
	48	506151	6512582	11	1298
	49	506153	6512417	6	1187
	50	506178	6512471	5	1202
	51	506192	6512667	16	1332
	52	506240	6512500	6	1179
	53	506287	6512631	16	1244
	54	506294	6512775	23	1354
	55	506300	6512529	12	1158
	56	506330	6512703	27	1274
	57	506341	6512181	10	895
	58	506388	6512554	28	1120
	59	506390	6512728	33	1261
	60	506396	6512687	33	1223
	61	506402	6512462	24	1040

Catchment	Receiver	Easting, m	Northing, y	Elevation, m	Distance from nearest WTG, m
Central island	62	506406	6512111	13	802
	63	506409	6512525	28	1084
	64	506420	6512474	28	1038
	65	506439	6512484	31	1033
	66	506466	6512565	35	1083
	67	506475	6512589	36	1098
	68	506478	6512350	24	906
	69	506481	6512082	12	725
	70	506487	6512132	16	750
	71	506492	6512330	26	882
	72	506500	6512044	12	688
	73	506502	6512359	30	897
	74	506503	6512515	35	1022
	75	506503	6512588	39	1082
	76	506507	6512414	33	937
	77	506514	6512335	30	871
	78	506520	6512135	20	726
	80	506534	6512374	34	889
	81	506543	6512040	18	650
	82	506545	6511982	17	617
	83	506551	6512336	35	848
	84	506559	6511930	16	580
	85	506572	6512296	38	804
	86	506574	6512500	41	971
	87	506591	6511945	20	558
	88	506592	6512056	26	620
	89	506592	6512248	39	754
	90	506594	6511988	23	578
	91	506598	6512274	41	770
	92	506615	6512430	42	890
	93	506626	6512261	43	743
	94	506647	6512023	33	557
	95	506662	6511938	26	496
	96	506675	6512169	45	641
	97	506677	6512277	46	728
	98	506678	6511997	35	516
	99	506702	6512148	46	607
	100	506710	6512253	48	690
	101	506713	6512017	39	504
	102	506713	6512065	41	538
	103	506727	6512221	48	654
Western coastal	105	505570	6512688	14	1814
	109	505587	6512735	16	1826
	110	505598	6512515	15	1698
	111	505609	6512875	9	1895
	112	505610	6512602	21	1732
	113	505613	6512710	18	1791
	114	505626	6512647	19	1744
	115	505650	6512807	18	1820
	116	505652	6512829	18	1832
	117	505654	6512776	18	1798
	118	505662	6512448	12	1609
	119	505663	6512671	20	1727
	120	505668	6512539	18	1650
	121	505669	6512591	21	1677
	122	505705	6512394	9	1546
	123	505791	6512282	11	1419
	124	505800	6512308	11	1423
	125	505819	6512352	12	1426
	126	505821	6512267	10	1385
	127	505826	6512382	12	1435
	128	505833	6512295	12	1387
	129	505862	6512266	9	1348
	130	505903	6512315	11	1335

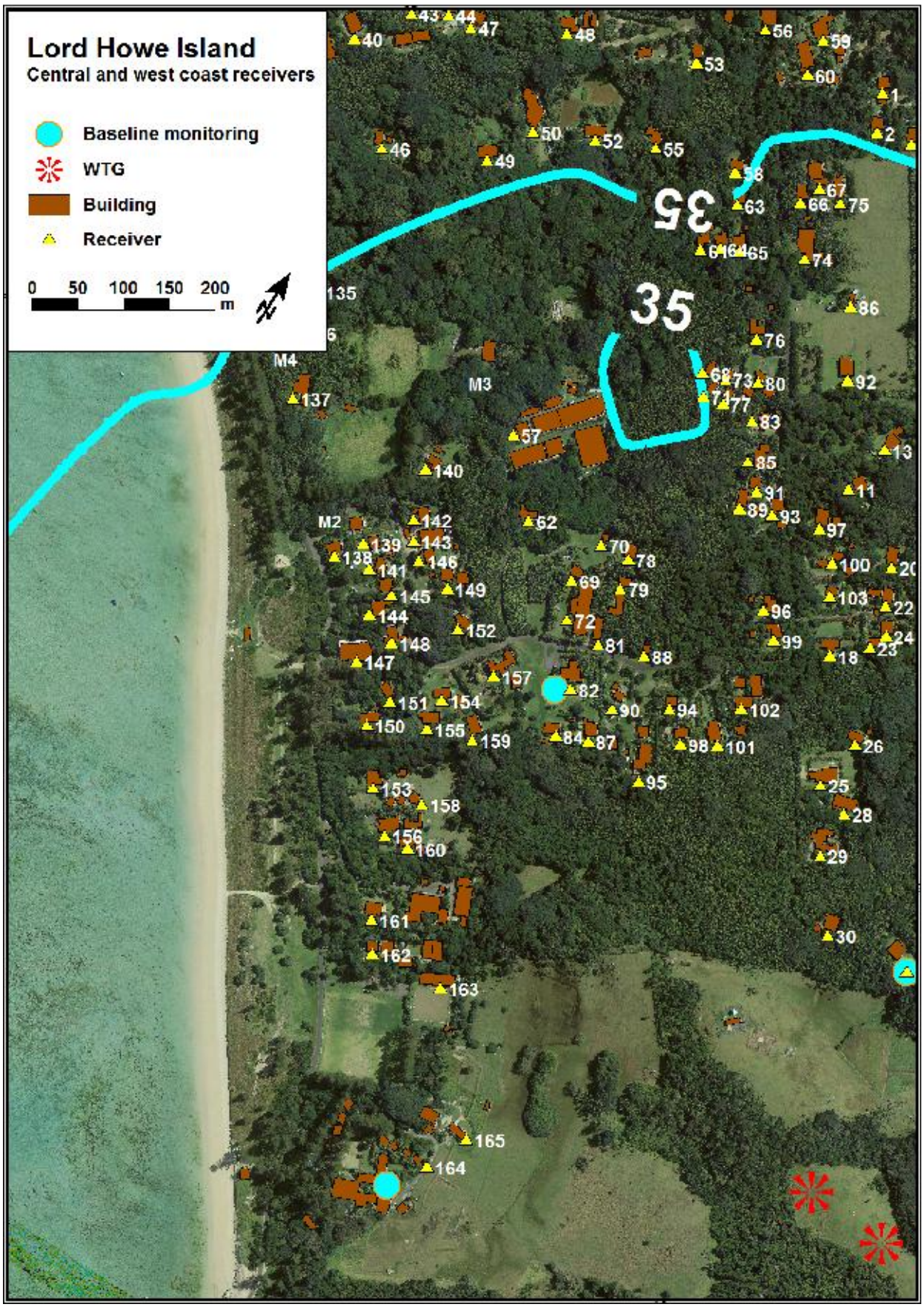
Catchment	Receiver	Easting, m	Northing, y	Elevation, m	Distance from nearest WTG, m
Western coastal	131	505933	6512261	6	1284
	132	505974	6512244	5	1239
	133	506011	6512215	5	1194
	134	506042	6512177	5	1149
	135	506077	6512196	5	1127
	136	506082	6512147	5	1100
	137	506117	6512083	5	1042
	138	506248	6511963	6	876
	139	506268	6511992	6	868
	140	506281	6512097	7	902
	141	506289	6511972	6	842
	142	506300	6512044	6	860
	143	506313	6512024	5	840
	144	506316	6511930	6	802
	145	506325	6511961	6	805
	146	506329	6512010	5	820
	147	506332	6511880	6	772
	148	506353	6511918	5	764
	149	506372	6512000	5	778
	150	506379	6511828	6	713
	151	506387	6511863	6	715
	152	506406	6511969	8	734
	153	506422	6511774	6	661
	154	506433	6511895	6	681
	155	506437	6511859	6	667
	156	506461	6511737	6	619
	157	506466	6511948	7	671
	158	506477	6511788	6	611
	159	506485	6511877	5	628
	160	506490	6511739	6	590
	161	506499	6511652	6	577
	162	506521	6511621	6	558
	163	506603	6511630	6	477
	164	506697	6511459	6	437
	165	506717	6511507	6	399
Southern coastal	167	507247	6509707	19	1971
	168	507262	6509553	41	2124
	169	507284	6509720	17	1961
	170	507301	6509529	46	2151
	171	507328	6509606	35	2079
	172	507339	6509538	42	2147
	173	507356	6510050	5	1646
	174	507372	6509510	44	2179
	175	507375	6509509	44	2180
	179	507438	6509479	47	2220
	183	507517	6510003	16	1727
	187	507334	6510529	6	1174
	188	507474	6510389	6	1346
	190	507068	6510985	18	689
	191	507087	6510971	17	704
	192	507095	6510936	13	739
	193	507117	6510972	18	704

Appendix C. Relevant receivers map

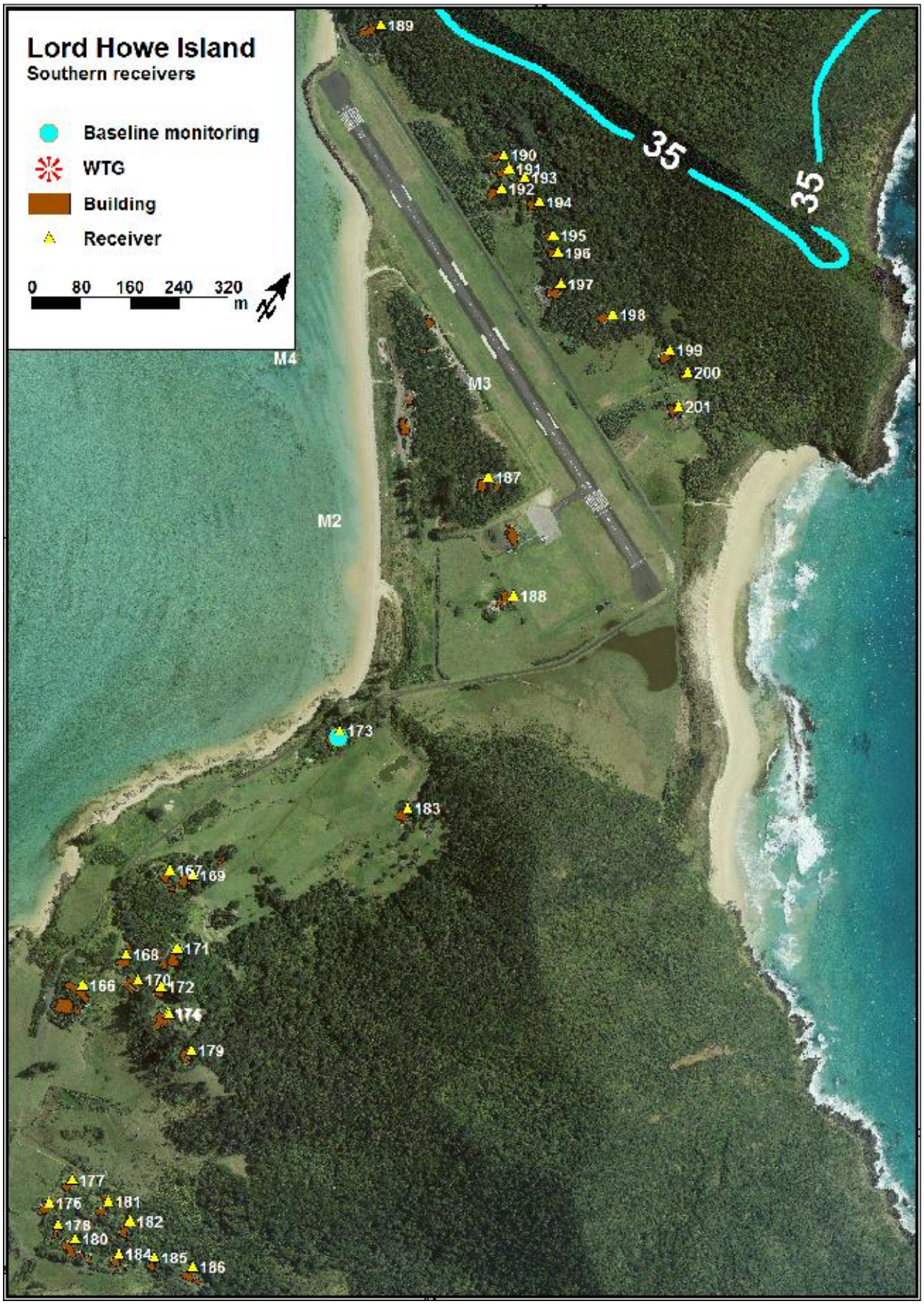
C.1 East coastal receivers



C.2 Central and west coastal receivers



C.3 Southern receivers


Lord Howe Island
Southern receivers
Baseline monitoring
WTG
Building
Receiver
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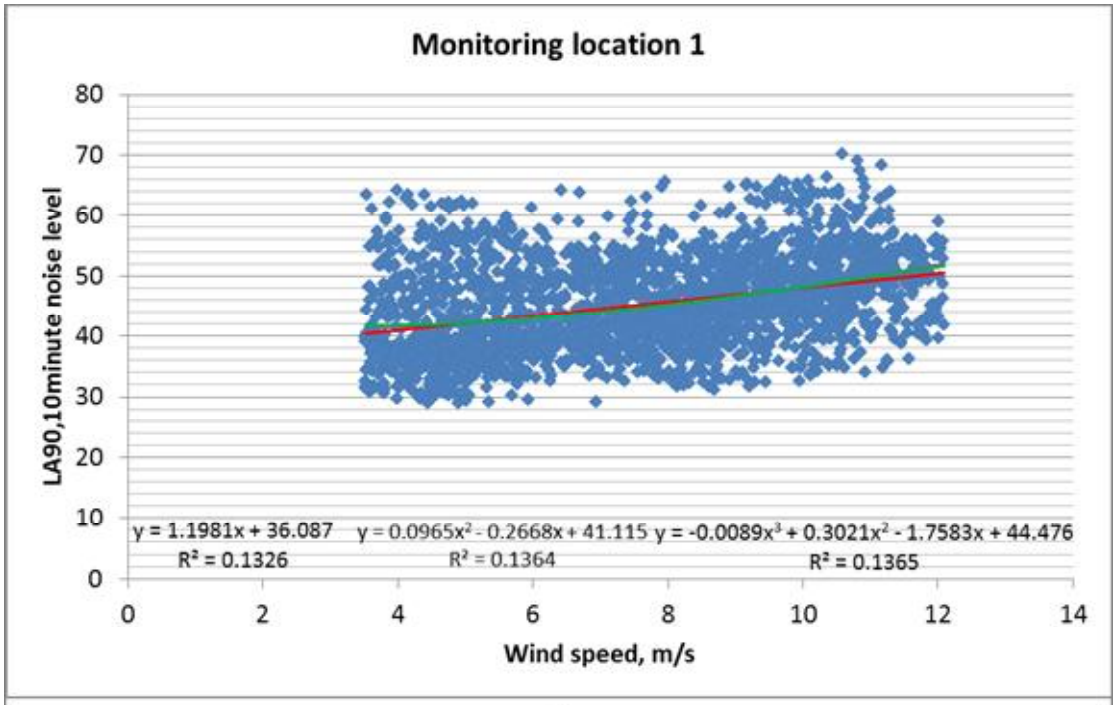
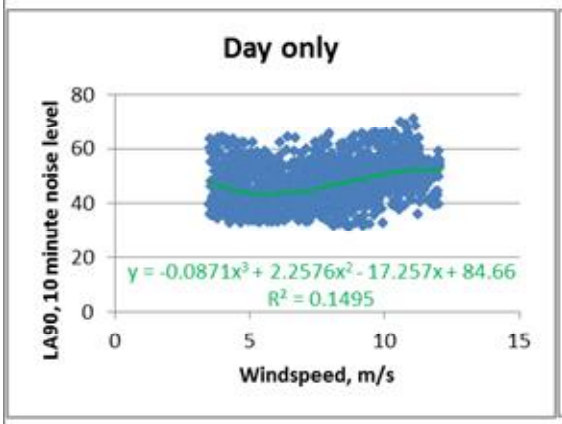
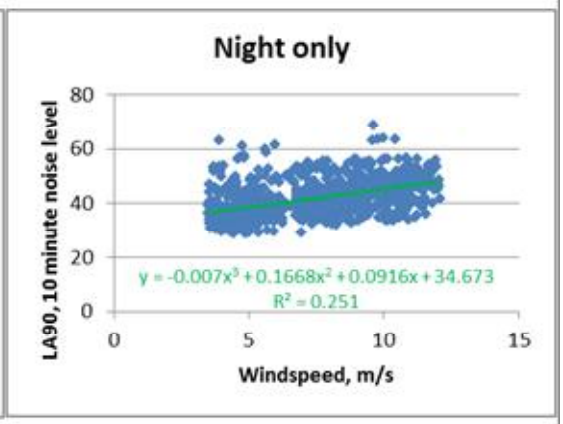
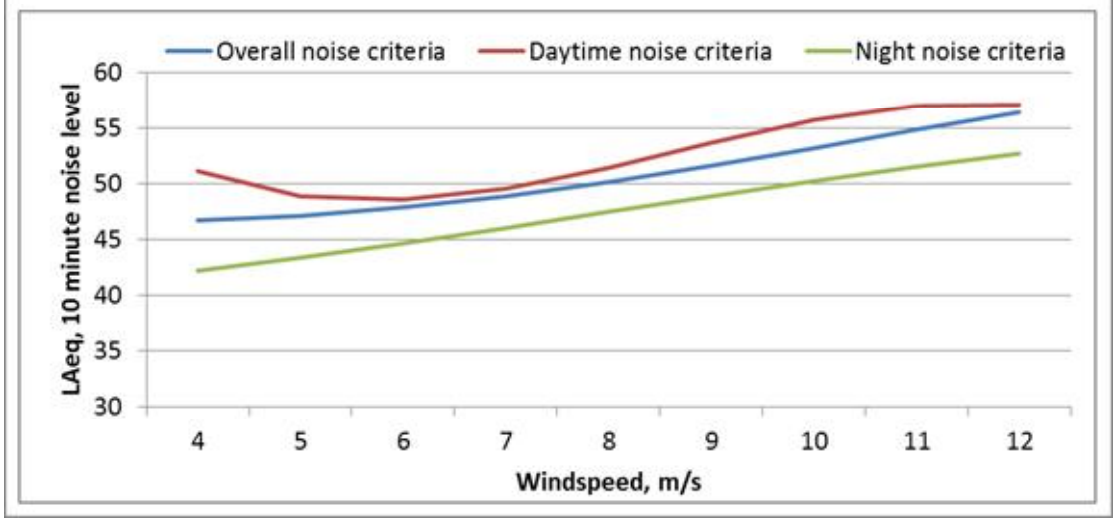
Appendix D. Background noise and wind data analysis

D.1 Monitoring location 1 – Cobby's Corner

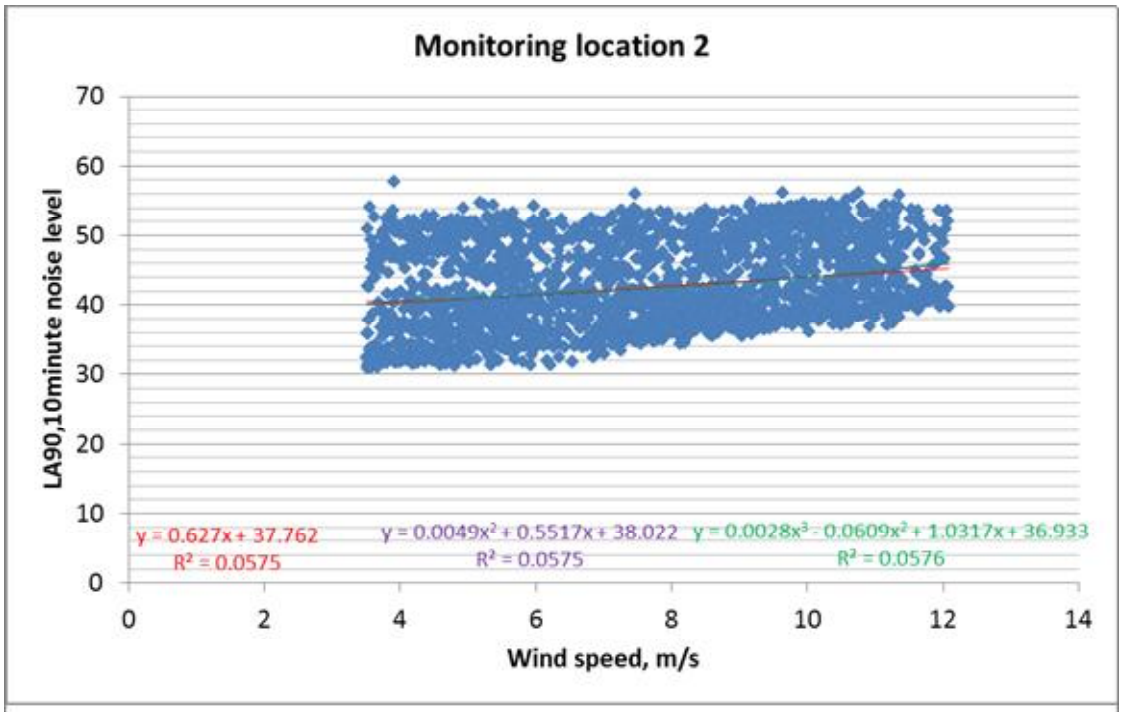


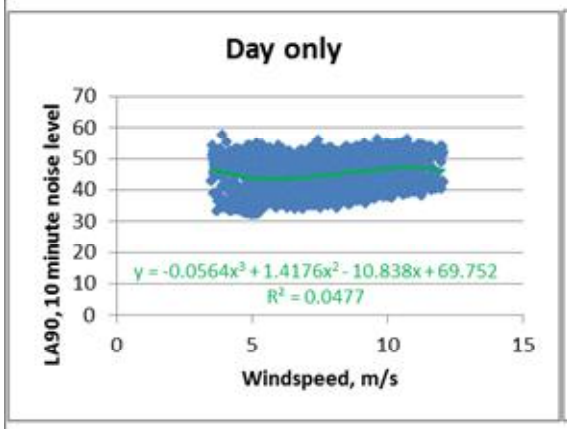


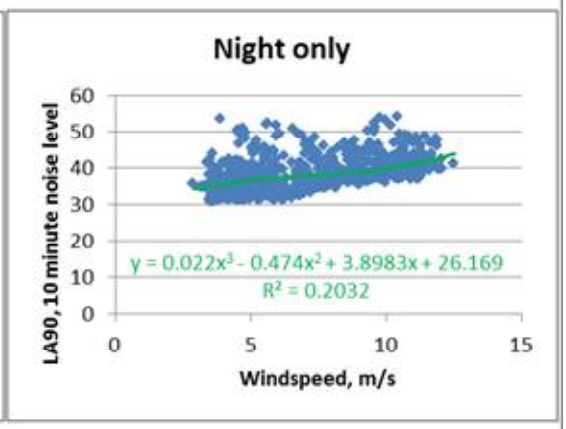


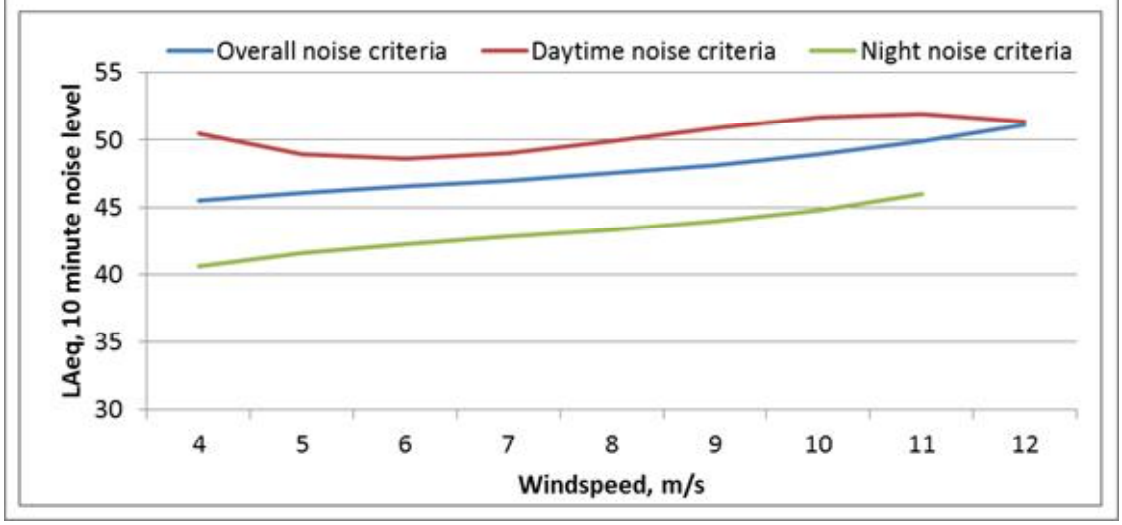


D.2 Monitoring location 2 – Pinetrees Lodge

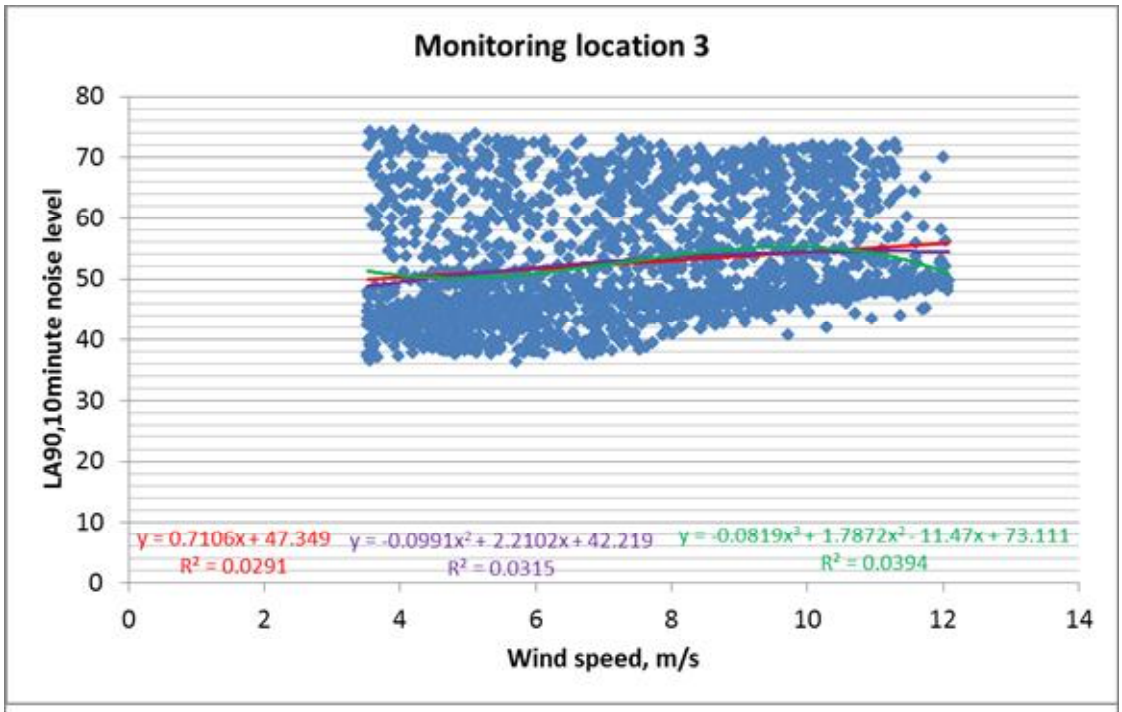


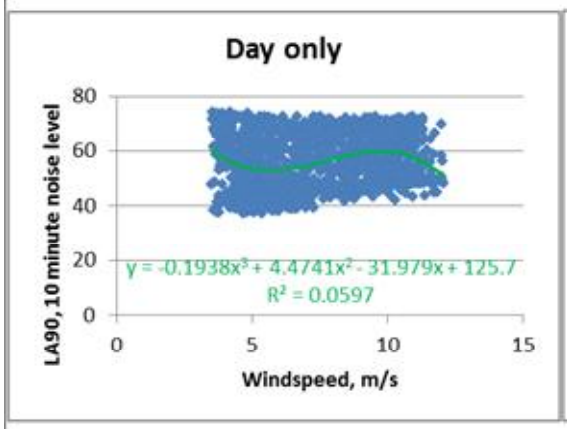


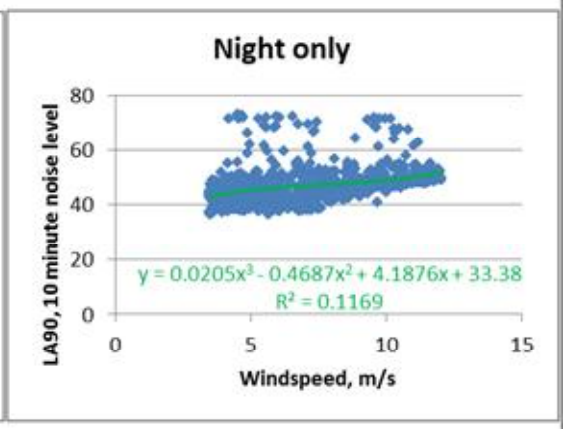


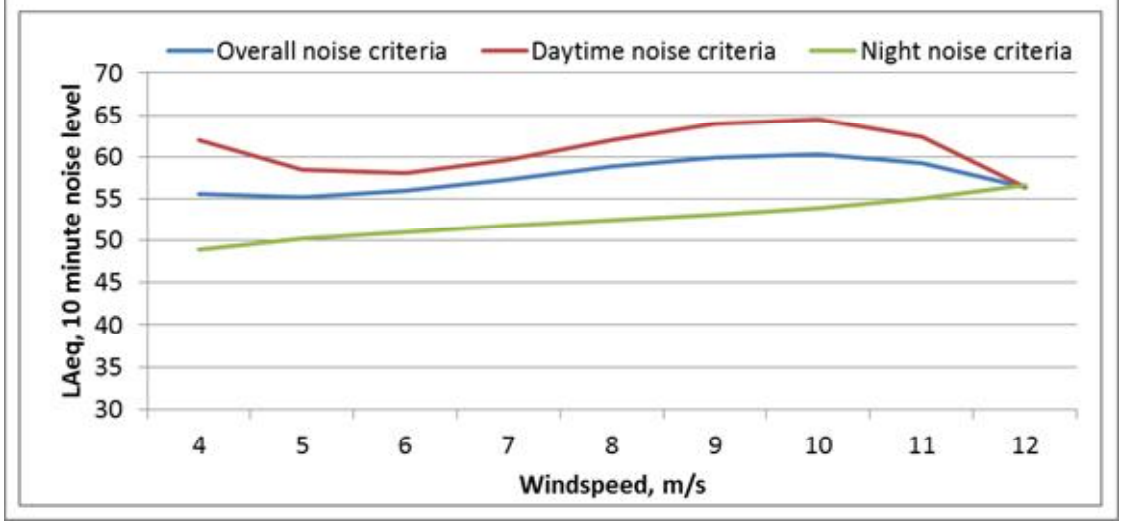


D.3 Monitoring location 3 – Palm Haven

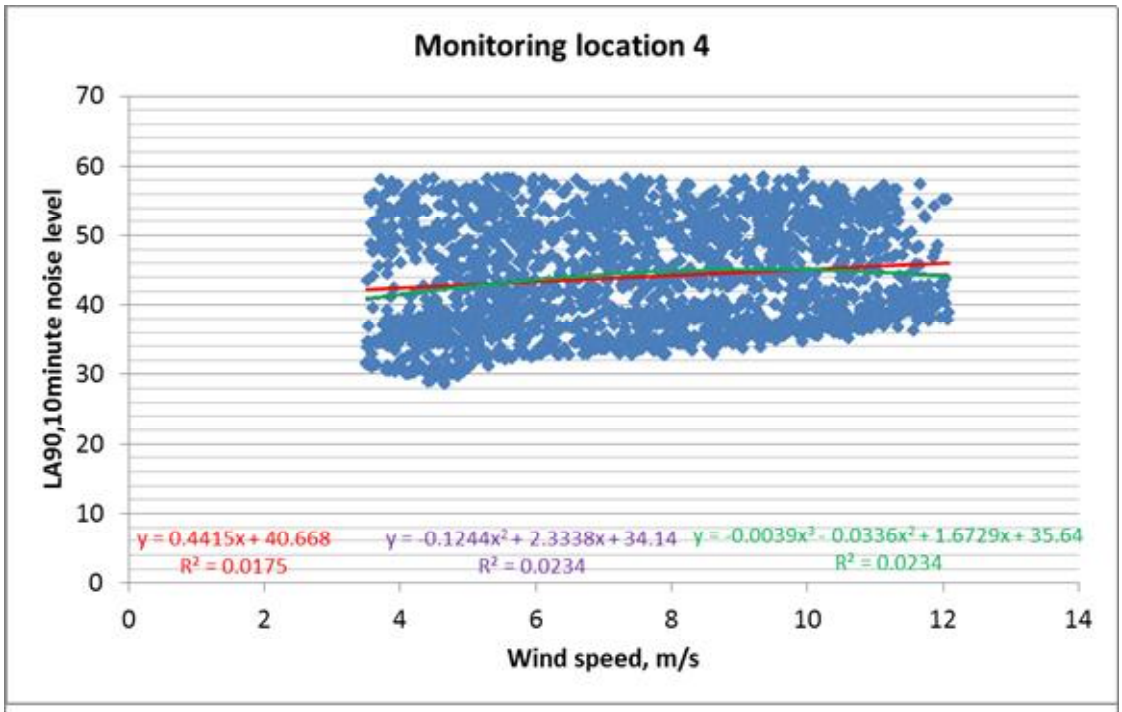


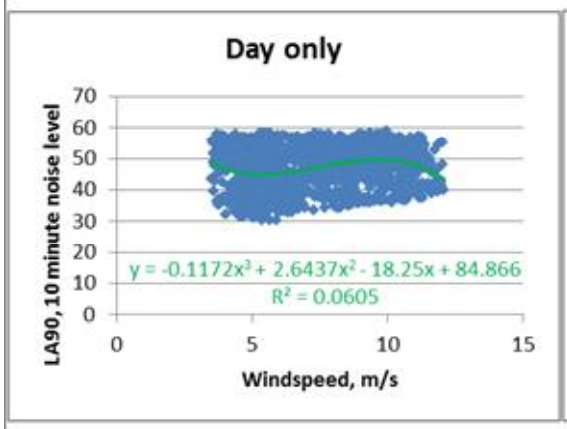


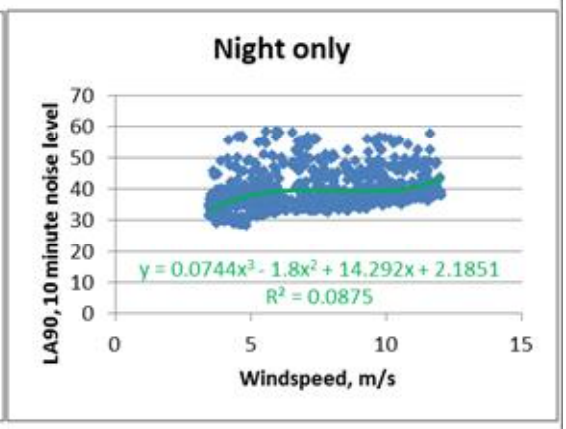


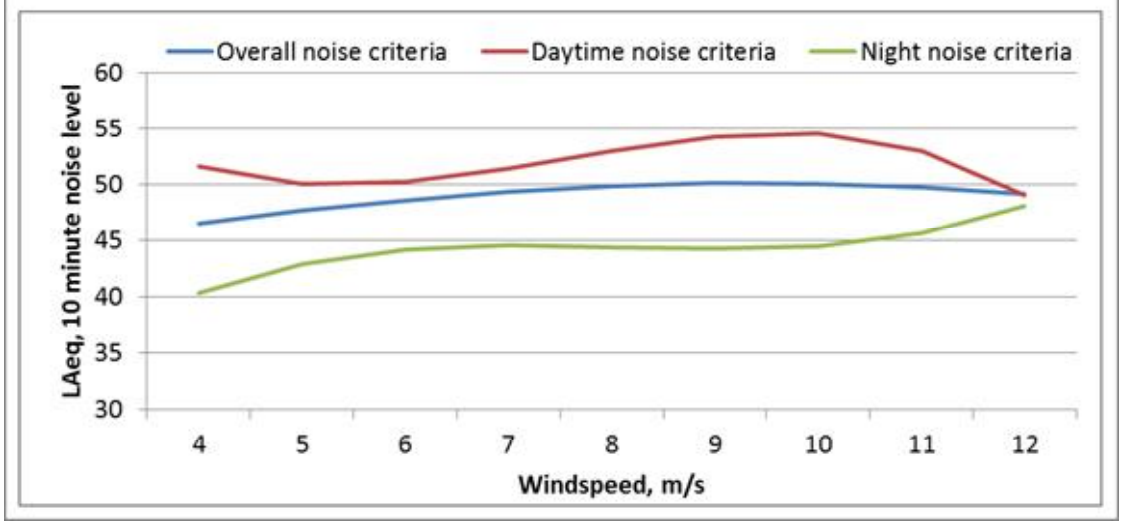


D.4 Monitoring location 4 – Joy's Shop

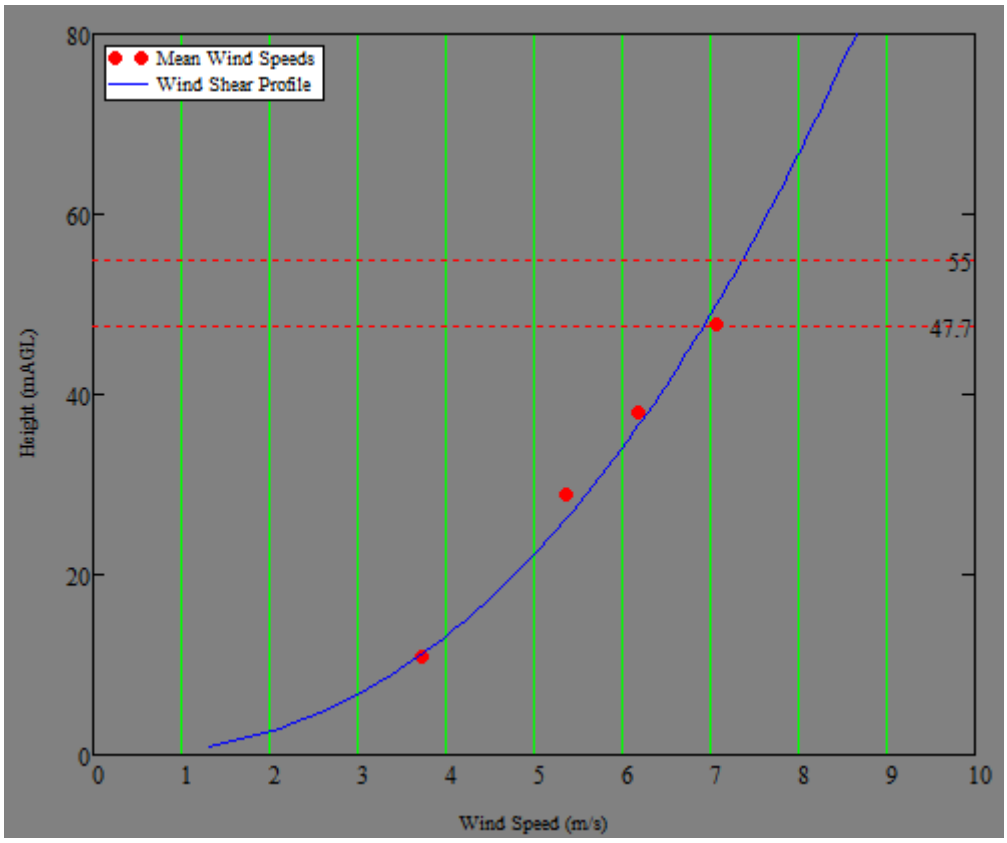


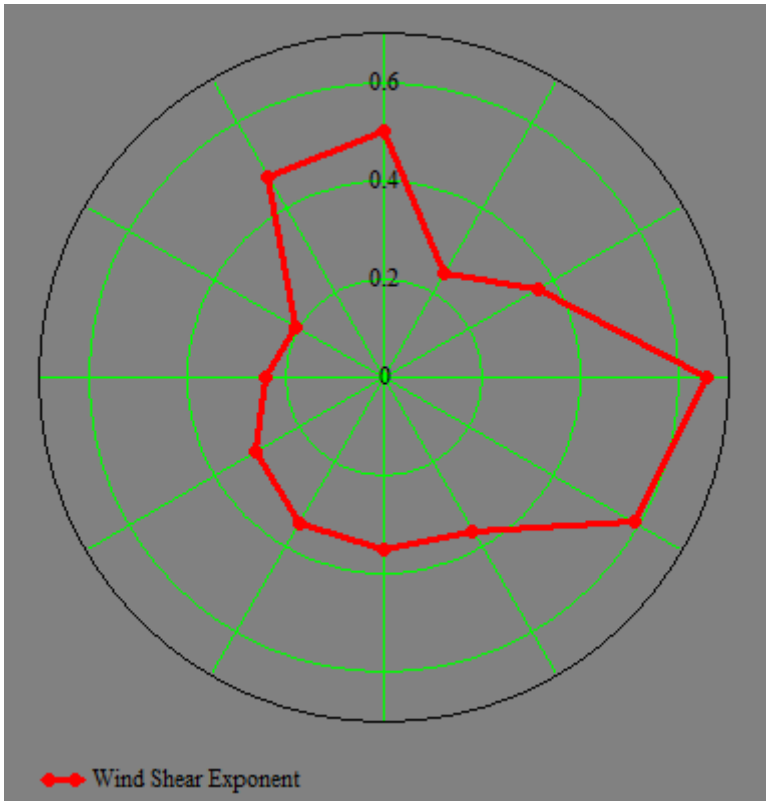






Appendix E. Wind shear





Appendix F. Noise predictions at all relevant receivers

F.1 East coastal receivers

East coastal receivers									
Wind speed at hub-height, m/s	4	5	6	8	9	10	11	12	13
Noise criteria (All times)	56	55	56	57	59	60	60	59	56
Noise criteria (Night only)	49	50	51	52	52	53	54	55	57
1	12	12	12	20	21	22	30	31	31
2	17	17	17	24	26	27	34	35	35
3	17	17	17	24	26	27	34	35	35
4	12	12	12	20	21	22	30	31	31
5	14	14	14	22	24	24	32	33	33
6	18	18	18	25	27	28	35	36	37
7	14	14	14	22	24	25	32	33	33
8	17	17	17	25	27	27	34	35	36
9	17	17	17	24	26	26	34	35	35
10	14	14	14	22	24	25	32	33	33
11	21	21	21	28	30	31	38	39	40
12	19	19	19	26	28	29	36	37	38
13	20	20	20	28	30	30	38	39	39
14	17	17	17	24	26	27	34	35	35
15	15	15	15	23	25	25	33	34	34
16	15	15	15	22	24	25	33	34	34
17	20	20	20	27	29	30	37	38	39
18	24	24	24	31	33	33	41	42	42
19	16	16	16	23	25	26	34	35	35
20	22	22	22	29	31	32	39	40	41
21	21	21	21	29	30	31	39	40	40
22	23	23	23	30	32	33	40	41	41
23	23	23	23	31	33	33	41	42	42
24	23	23	23	30	32	33	41	42	42
25	26	26	26	33	35	36	43	45	45
26	25	25	25	32	34	35	43	44	44
27	22	22	22	30	31	32	40	41	41
28	27	27	27	34	36	36	44	45	45
29	28	28	28	35	37	38	45	46	46
30	30	30	30	37	39	40	47	49	49
31	31	31	31	38	40	41	48	49	50

F.2 Central island receivers

Central island receivers									
Wind speed at hub-height, m/s	4	5	6	8	9	10	11	12	13
Noise criteria (All times)	47	48	49	49	50	50	50	50	49
Noise criteria (Night only)	40	43	44	45	44	44	45	46	48
32	13	13	13	20	22	23	30	31	31
33	13	13	13	21	22	23	30	31	32
34	13	13	13	21	23	23	30	31	32
35	13	13	13	20	22	23	30	31	31
36	13	13	13	21	23	23	30	31	32
37	14	14	14	21	23	24	31	32	32
38	13	13	13	21	23	24	31	32	32
39	15	15	15	22	24	25	32	33	33
40	15	15	15	22	24	25	32	33	33
41	12	12	12	20	22	22	30	31	31
42	11	11	11	18	20	21	29	30	30
43	14	14	14	21	23	24	31	32	33
44	15	15	15	22	24	25	32	33	34
45	12	12	12	20	22	22	30	31	31
46	16	16	16	23	25	26	33	34	34
47	15	15	15	23	25	25	32	33	34
48	15	15	15	23	25	25	33	34	34
49	16	16	16	24	26	26	34	35	35
50	16	16	16	24	26	26	33	35	35
51	15	15	15	23	25	25	32	34	34
52	16	16	16	24	26	26	34	35	35
53	12	12	12	19	21	22	29	30	30
54	10	10	10	18	20	20	27	29	29
55	15	15	15	22	24	25	33	34	34
56	15	15	15	22	24	25	32	33	34
57	19	19	19	26	28	29	36	37	37
58	17	17	17	24	26	27	34	35	35
59	13	13	13	21	23	23	31	32	32
60	13	13	13	20	22	22	30	31	31
61	18	18	18	25	27	28	35	36	36
62	20	20	20	28	30	30	38	39	39
63	16	16	16	24	26	26	34	35	35
64	18	18	18	25	27	28	35	36	36
65	17	17	17	25	27	28	35	36	36
66	17	17	17	25	27	27	35	36	36

Central island receivers									
Wind speed at hub-height, m/s	4	5	6	8	9	10	11	12	13
Noise criteria (All times)	47	48	49	49	50	50	50	50	49
Noise criteria (Night only)	40	43	44	45	44	44	45	46	48
67	17	17	17	25	27	27	34	36	36
68	16	16	16	24	25	26	34	35	35
69	21	21	21	29	31	31	39	40	40
70	21	21	21	28	30	31	38	39	40
71	17	17	17	24	26	26	35	35	36
72	22	22	22	29	31	32	39	40	40
73	18	18	18	25	27	28	36	37	37
74	18	18	18	25	27	28	35	36	37
75	17	17	17	25	27	27	35	36	36
76	19	19	19	26	28	29	36	37	37
77	17	17	17	24	26	27	35	36	36
78	21	21	21	29	31	31	39	40	40
80	18	18	18	25	27	27	35	36	37
81	22	22	22	30	32	32	40	41	41
82	23	23	23	30	32	33	40	41	41
83	17	17	17	24	26	27	35	36	36
84	24	24	24	31	33	33	41	42	42
85	18	18	18	25	27	28	36	37	37
86	18	18	18	26	28	28	36	37	37
87	24	24	24	31	33	34	41	42	43
88	23	23	23	30	32	33	40	41	41
89	21	21	21	28	30	31	38	39	40
90	24	24	24	31	33	33	41	42	42
91	21	21	21	28	30	31	38	39	39
92	16	16	16	23	25	26	34	35	35
93	21	21	21	28	30	31	38	39	40
94	24	24	24	31	33	34	41	42	43
95	25	25	25	32	34	35	42	43	44
96	23	23	23	30	32	33	40	41	41
97	21	21	21	29	31	31	39	40	40
98	25	25	25	32	34	35	42	43	43
99	23	23	23	31	32	33	41	42	42
100	22	22	22	29	31	32	39	40	41
101	25	25	25	32	34	35	42	43	44
102	24	24	24	32	33	34	42	43	43
103	23	23	23	30	32	32	40	41	41

F.3 Western coastal receivers

West coastal receivers									
Wind speed at hub-height, m/s	4	5	6	8	9	10	11	12	13
Noise criteria (All times)	46	47	47	48	48	49	50	51	53
Noise criteria (Night only)	41	42	42	43	43	44	45	46	48
105	7	7	7	15	17	17	24	25	26
109	8	8	8	16	18	19	26	27	27
110	12	12	12	20	22	23	30	31	31
111	7	7	7	14	16	17	24	25	25
112	12	12	12	20	22	22	29	31	31
113	10	10	10	17	19	20	27	29	29
114	9	9	9	17	19	19	27	28	28
115	8	8	8	15	17	18	25	26	26
116	7	7	7	15	17	17	24	25	26
117	8	8	8	15	17	18	25	26	26
118	13	13	13	21	22	23	30	31	32
119	10	10	10	18	19	20	28	29	29
120	11	11	11	19	21	21	29	30	30
121	13	13	13	20	22	23	30	31	31
122	13	13	13	21	23	24	31	32	32
123	14	14	14	22	24	24	32	33	33
124	13	13	13	21	23	24	31	32	32
125	13	13	13	20	22	23	31	32	32
126	15	15	15	22	24	25	32	33	33
127	11	11	11	18	20	21	28	29	29
128	15	15	15	22	24	25	32	33	33
129	15	15	15	22	24	25	32	33	34
130	15	15	15	23	24	25	32	33	34
131	15	15	15	23	25	25	33	34	34
132	16	16	16	23	25	26	33	34	34
133	16	16	16	24	26	26	33	35	35
134	17	17	17	24	26	27	34	35	35
135	17	17	17	24	26	27	34	35	35
136	17	17	17	25	26	27	34	36	36
137	18	18	18	25	27	28	35	36	36
138	19	19	19	27	29	29	37	38	38
139	20	20	20	27	29	29	37	38	38
140	19	19	19	27	28	29	36	38	38
141	20	20	20	27	29	30	37	38	38
142	20	20	20	27	29	30	37	38	38

West coastal receivers									
Wind speed at hub-height, m/s	4	5	6	8	9	10	11	12	13
Noise criteria (All times)	46	47	47	48	48	49	50	51	53
Noise criteria (Night only)	41	42	42	43	43	44	45	46	48
143	20	20	20	27	29	30	37	38	39
144	20	20	20	28	30	30	38	39	39
145	20	20	20	28	30	30	38	39	39
146	20	20	20	27	29	30	37	39	39
147	21	21	21	28	30	31	38	39	39
148	21	21	21	28	30	31	38	39	39
149	21	21	21	28	30	31	38	39	39
150	21	21	21	29	31	31	39	40	40
151	21	21	21	29	31	31	39	40	40
152	21	21	21	29	30	31	39	40	40
153	22	22	22	30	31	32	40	41	41
154	22	22	22	29	31	32	39	40	41
155	22	22	22	29	31	32	39	41	41
156	23	23	23	30	32	33	40	41	42
157	22	22	22	29	31	32	39	40	41
158	23	23	23	30	32	33	40	41	42
159	23	23	23	30	32	33	40	41	41
160	23	23	23	31	32	33	41	42	42
161	24	24	24	31	33	33	41	42	42
162	24	24	24	31	33	34	41	42	43
163	25	25	25	33	34	35	43	44	44
164	26	26	26	33	35	36	44	45	45
165	27	27	27	34	36	37	44	45	46

F.4 Southern receivers

Southern coastal receivers									
Wind speed at hub-height, m/s	4	5	6	8	9	10	11	12	13
Noise criteria (All times)	47	47	48	49	50	52	53	55	56
Noise criteria (Night only)	42	43	45	46	47	49	50	52	53
167	11	11	11	19	21	21	28	30	30
168	11	11	11	18	20	21	28	29	29
169	11	11	11	19	21	22	28	30	30
170	11	11	11	18	20	21	28	29	29
171	11	11	11	18	20	21	28	29	29
172	11	11	11	18	20	21	28	29	29
173	13	13	13	21	22	23	30	31	31
174	10	10	10	18	20	21	27	29	29
175	10	10	10	18	20	21	27	29	29
179	10	10	10	18	20	20	27	28	29
183	8	8	8	15	17	18	25	26	26
187	13	13	13	20	22	23	30	31	31
188	11	11	11	18	20	21	28	29	30
190	16	16	16	24	26	26	33	35	35
191	16	16	16	24	26	26	34	35	35
192	16	16	16	24	26	26	34	35	35
193	16	16	16	23	25	26	33	34	34