MARSHALL DAY Acoustics

GULLEN RANGE WIND FARM
ASSESSMENT OF WIND FARM OPERATIONAL NOISE

Rp 001 2014544SY | 17 July 2015

MARSHALL DAY Acoustics

6 Gipps Street
Collingwood 3066 Victoria Australia
T: +613 9416 1855 F: +613 9416 1231
A.C.N. 006 675 403
www.marshallday.com

Project: **GULLEN RANGE WIND FARM**

Prepared for: **New Gullen Range Wind Farm**
Level 23, 201 Elizabeth St
Sydney NSW 2000
Australia

Attention: **Tom Frood**

Report No.: **Rp 001 2014544SY**

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EXECUTIVE SUMMARY

As required by Project Approval (07/00846), determined under Part 3A of the *Environmental Planning and Assessment Act* 1979 (Project Approval) operational wind farm noise monitoring has been carried out in the vicinity of the Gullen Range Wind Farm as specified in the Noise Compliance Plan prepared in accordance with Condition 2.21 of the Project Approval.

Based on measurements, listening studies and analysis conducted for the period 9 December 2014 to 24 June 2015 it has been concluded that the project complies with the noise requirements outlined in Conditions 2.15, 2.19 and 2.20 of the Project Approval.

Specifically the following outcomes are noted:

- Compliance has been demonstrated at all seventeen (17) locations where the Noise Compliance Plan specified a requirement to conduct monitoring
- The results of sixty-eight (68) listening studies distributed across the seventeen (17) monitoring locations, in combination with objective analysis where required, demonstrate that "annoying characteristics" as defined by the Project Approval and Noise Compliance Plan are not a feature of the wind farm. Accordingly, adjustments relating to annoying characteristics are not applicable.
- Analysis of the measurement results enabled noise levels to be estimated for an additional twenty-four (24) locations defined as related receivers, and demonstrated compliance with the applicable limits

In addition to the above, the results of the noise monitoring are consistent with the findings of the Revised Noise Assessment prepared in accordance with Condition 2.16 of the Project Approval. This outcome supports that compliance is therefore also expected to be achieved at the much broader range of locations identified and considered in the Revised Noise Assessment.

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1.0 INTRODUCTION

The Gullen Range Wind Farm (GRWF) site is located approximately 20km northwest of Goulburn, towards Crookwell in New South Wales. The wind farm is owned and operated by New Gullen Range Wind Farm Pty Ltd (NGRWF).

The wind farm received planning approval in 2010 and construction was completed in December 2014. The wind farm's Project Approval, reference S07/00846, provides overarching performance criteria for the project, including criteria and commissioning requirements applicable to operational noise associated with the wind farm.

This report commissioned by NGRWF presents the results of an assessment of operational noise from the Gullen Range Wind Farm to satisfy relevant conditions of the Project Approval.

The primary objective of this survey is to assess the wind farm's compliance with the operational noise criteria established by the Project Approval. For this purpose, compliance has been directly assessed on the basis of noise measurements at seventeen (17) monitoring locations by comparing measured noise levels with applicable noise limits, and assessing the presence of annoying characteristics in the wind farm sound.

The results obtained from the seventeen (17) monitoring locations have also been used to inform an assessment of compliance at other receiver locations. Specifically, the results obtained at the monitoring locations have been used to estimate noise levels, and assess compliance, at other dwelling locations where noise limits have been defined on the basis of pre-construction background noise measurement data at the seventeen (17) monitoring locations. The results also enable a broad assessment of the performance of the project against the predicted assessment outcomes, as required by the Project Approval, having regard to all other receiver locations considered in the pre-construction noise assessments for the project.

The basic quantities used within this document to describe noise adopt the conventions outlined in ISO 1996-1:2003 *Acoustics - Description measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures.* Accordingly, all frequency weighted sound pressure levels are expressed as decibels (dB) in this report. For example, sound pressure levels measured using an "A" frequency weighting are expressed as L_A dB. Alternative ways of expressing A-weighted decibels such as dBA or dB(A) are therefore not used within this report

Acoustic terminology used throughout this report is presented in Appendix A. Site layout and relevant coordinates are detailed in Appendix B.

2.0 WIND FARM DETAILS

GRWF is made up of 73 Goldwind wind turbines. A combination of two (2) different turbine models has been used at the site; fifty six (56) GW100-2500 turbines, and seventeen (17) GW82-1500 turbines.

Performance details of both turbines are outlined in Table 1 below.

Table 1: Wind turbine details

	GW100-2500	GW82-1500
Rated Power KW	2500	1500
Rotor Diameter (m)	100	82.3
Hub Height (m)	80	85
Generator	Direct Drive	Direct Drive
Rotor speed (rpm)	6.5 to 14.5	10.0 to 17.3
Cut-in Wind Speed (hub height, m/s)	3	3
Rated Wind Speed (hub height, m/s)*	12.5	12.5
Cut-out Wind Speed (hub height, m/s)	25	22
Sound Power L_{WA} at 9ms (hub height, dB, based on measured plus uncertainty values)	104.0	103.9

* Rated power wind speeds have been updated since the Gullen Range Wind Farm Revised Noise Impact Assessment (ref Rp 002 R06 2012154SY) dated 18 December 2014 to account for site-specific power curves and performance (confirmed by email from NGWRF on 15 April 2015)

3.0 CRITERIA

3.1 Overview

The key criteria for assessing operational noise from the GRWF are documented in the wind farm's Project Approval, reference S07/00846, issued by the Land and Environment Court of NSW in 2010.

The Project Approval and other associated documents relevant to the commissioning works are outlined in Table 2.

Table 2: Guidance Documentation

Document	Date	Items addressed
Project Approval, reference S07/00846	August 2010	Overarching performance criteria for the development including operational noise criteria and noise commissioning requirements.
The 2003 South Australia EPA document *Environmental noise guidelines: Wind Farms*	2003	General assessment methodology for operational wind farm noise including procedures for deriving noise limits and conducting compliance measurements
Gullen Range Wind Farm Noise Compliance Plan	4 October 2013	Project specific requirements for conducting compliance measurements for operational wind farm noise
Gullen Range Wind Farm Revised Noise Impact Assessment (ref Rp 002 R06 2012154SY)	18 December 2014	Derivation of the applicable wind farm noise limits based on hub-height wind speeds as required by the Project Approval. Neighbouring receiver locations around the wind farm were confirmed and updated predicted noise levels were presented for Goldwind turbines installed at the site.

Each of these documents is discussed in more detail in pursuant subsections.

3.2 Project Approval

The Project Approval sets out noise commissioning requirements in its subsection titled *Verification of Operational Noise Performance.* Specifically, Condition 2.21 states the following:

> *The Proponent shall prepare a Noise Compliance Plan which shall be submitted to the Director-General prior to commissioning of the wind turbines. The Noise Compliance Plan shall include, but not be limited to:*
>
> *a) an assessment of the performance of the project against the noise predictions contained in conditions 2.15 and 2.16;*
>
> *b) a commitment to operate the Project in accordance with any Noise Operating Strategy that is implemented in accordance with condition 2.17;*
>
> *c) a commitment that noise compliance monitoring will be undertaken within three months of the commissioning of the wind turbines. If prevailing meteorological conditions do not allow the required monitoring to be undertaken in this period, the Director-General shall be notified and an extension of time may be sought; and*
>
> *d) a requirement that all noise compliance monitoring results are submitted to the Director-General within one month of completion of the monitoring. The Director-General may request that additional noise compliance monitoring be undertaken and completed within a specified timeframe.*
>
> *The Noise Compliance Assessment shall be undertaken generally in accordance with the procedures presented in SA Guidelines 2003, except that all sounds power levels and wind speeds shall be referenced to hub height.*

The structure of the noise limits applicable to the project is described in Project Approval Condition 2.15 which states:

> *Subject to conditions 2.15 to 2.20 the Proponent shall design, operate and maintain the project to ensure that the equivalent noise level ($L_{Aeq\ (10\text{-}minute)}$) from the project does not exceed at each of the residential receiver locations identified in Section 5 of the Noise Impact Assessment prepared by Marshall Day Acoustics, dated 5 June 2008 (Section 3.2 of EA Attachments), or any other relevant receiver in existence or the subject of a valid development consent at the date of this approval:*
>
> *a) 35* [dB]*; or*
>
> *b) the existing background noise level ($L_{A90\ (10minute)}$) correlated to the integer wind speed at hub height at the wind farm site by more than 5* [dB]
>
> *whichever is the greater, for each integer wind speed (measured at hub height) from cut-in to rated power of the wind turbine generator, when determined in accordance with the methodology provided in the Wind Farms: Environmental Noise Guidelines (SA EPA, 2003)…*

The Noise Compliance Plan and SA Guidelines 2003 referred to above are described in the following sections. A copy of the relevant, noise related conditions of the Project Approval document is provided in Appendix C.

3.3 SA EPA Environmental Noise Guidelines: Wind Farms (2003)

The SA Guidelines 2003 set out a methodology for assessing operational wind farm noise. The methodology is similar to that outlined in the guidelines for assessing ambient noise levels during the planning stage of a wind farm project, prior to construction, and relies on correlating noise level measurements with wind farm wind speeds. The SA Guidelines 2003 require noise levels to be measured under free-field conditions, which are not significantly influenced by reflections from vertical structures. To evaluate whether operational wind farm noise complies with applicable noise limits, measurement data collected in accordance with the SA Guidelines 2003 can be compared with the noise limits that have been established in accordance with the Project Approval[1].

3.4 Noise compliance plan

As required by Condition 2.21 of the Project Approval document, a Noise Compliance Plan has been prepared for the wind farm (reference AECOM report *Management and Noise Compliance Plan_R3* subsequently referred to herein as the *Noise Compliance Plan*). The Noise Compliance Plan documents the number of locations where commissioning works are to be carried out, and provides supplementary detail to assist in applying the SA Guidelines 2003 to the Gullen Range Wind Farm project.

3.5 Revised noise impact assessment

3.5.1 Noise limits

The revised noise impact assessment report (reference MDA report Rp 002 R06 2012154SY dated 18 December 2014 subsequently referred to herein as the *RNA*) documents the applicable noise limits for all locations relevant to this commissioning noise assessment. The noise limits are defined for each integer wind speed from the speed at which the turbines start to generate power (known as the *cut-in* speed) to the speed at which the turbines generate their maximum rated power. The reference wind speeds for these limits are at a height of 80m above ground level (AGL) at the original locations of the meteorological masts available during the planning stage of the project.

The applicable noise limits are presented in tabulated form in Appendix J of this report.

As noted in Section 3.2 above and also in Condition 2.15 of the Project Approval, the noise limits comprise two parts; a base noise limit of 35 dB, and a background dependent noise limit which is *the existing background noise level correlated to the integer wind speed at hub height at the wind farm site* plus 5 dB, whichever is the greater.

3.5.2 Associated receivers

In relation to receiver locations where a noise agreement is in place between the owner of a residence and the wind farm owner, Condition 2.20 of the Project Approval notes:

> […]*the noise limits specified*[…]*do not apply to any residence where a noise agreement is in place between the Proponent and the respective owner(s) of those residences in relation to noise impacts and/or noise limits. For this condition to take effect, the noise agreements shall satisfy the requirements of Guidelines for Community Noise (WHO, 1999) and Section 2.3 of the SA Guidelines 2003.*

For this noise assessment, a minimum guideline noise limit of 45dB is adopted for associated receivers, consistent with the approach detailed in the RNA. Relevant noise limits for associated locations are also presented in tabulated form in Appendix J of this report.

[1] A more detailed discussion of the methodology used for assessing operational wind farm noise is provided in Section 4.0

4.0 METHODOLOGY

4.1 Overview

The general methodology for these commissioning works is described in Section 4.1 of the SA Guidelines 2003, which state:

> *Ambient noise levels with the wind farm operating are measured at relevant receiver locations, over continuous 10-minute intervals and over at least the range of wind speeds at which the* [wind turbines] *operate. The data must cover approximately 2000 intervals.*
>
> *Wind speed is measured at* [hub height] *and in intervals that correlate with the ambient noise measurements.*
>
> *Compliance checking should collect data associated with the worst case wind direction from the wind farm to the relevant receiver. A wind direction spread of 45 degrees either side of the direct line between the nearest WTG and the relevant receiver is considered acceptable* [...]

The simultaneously measured noise level and site wind speed for each 10 minute measurement period are plotted on a chart of noise levels versus wind speeds.

The methodology documented in the SA Guidelines 2003 is supported by the Noise Compliance Plan which, as noted above, documents the number of monitoring locations included in the study and provides supplementary detail to assist in applying the SA Guidelines 2003 to this assessment. In addition to the Noise Compliance Plan, further technical aspects of the methodology have been documented[2] by MDA in a memo to NGRWF. The relevant technical clarifications from this memo are reproduced in Appendix D. This additional information has been used in parallel with the Noise Compliance Plan as a methodology for quantifying the operational noise of the wind farm.

4.2 Receivers

In the Noise Compliance Plan, all those receivers where pre-construction noise monitoring was undertaken[3] have been used to collect data to assess compliance of the operational wind farm. For each monitoring location, measurement results have been used to directly evaluate whether operational noise from the wind farm satisfies relevant noise limits.

The measurement results at these monitoring locations have been used to provide an assessment of compliance at other related receivers shown in Table 3.

This assessment of operational wind farm noise includes consideration of compliance at both monitoring locations and related receivers.

[2] Mm 002 2014544SY Gullen Range Wind Farm - *Noise Level Analysis Method Statement* (Memo), 4 December 2014

[3] As documented in the RNA

4.3 Measured noise levels

It is important to recognise that the noise levels measured at receivers will include the contribution of both:

- Operational wind farm noise, and
- Residual noise, meaning the noise from all other sound sources around the measurement location

The measured or 'total' noise level will be equal to or greater than the operational wind farm noise level in all cases. In some instances, particularly at increased wind speeds, total measured noise levels may be dominated by residual noise and, as a result, the contribution of the turbines will be significantly less than the total measured noise level.

Conversely, the noise criteria for this project which are specified in the Project Approval relate to the level of noise from the wind farm only, without contribution from any residual noise.

4.4 Analysis

The analysis of measurement data includes a number of filtering procedures which are generally intended to improve the representation of wind farm noise in the total noise levels by excluding periods which are likely to be affected by extraneous noise sources which are commonly present during environmental noise measurements. The filtering procedures include consideration of rainfall, high local wind speeds at the microphone, distinctive occurrences of extraneous noise such as insect activity and the speed and direction of wind at the wind farm. These procedures are discussed further in Section 5.4.2.

A regression analysis of the filtered data set is carried out to determine a regression curve (a line of best fit). This line of best fit is then compared with the noise limit at each applicable integer wind speed for an initial assessment of compliance:

- If the initial assessment indicates the line of best fit to the total measured noise levels is below the applicable limits at each integer wind speed, the noise contribution of the wind farm will also be below the limits and the result is sufficient to demonstrate that the wind farm is compliant. This is considered to represent a comparatively conservative assessment of wind farm noise due to the potential contribution of non-wind farm related (residual) noise to the total measured noise levels.
- If the line of best fit to the total measured noise levels is above the limit at any of the relevant integer wind speeds, this may be a result of residual noise not related to the wind farm. In these instances, an assessment of compliance requires further analysis to investigate the contribution that may be solely attributed to the operation of the wind farm.

This second point is recognised in Section 4.6 of the SA Guidelines 2003 which states:

> *The EPA recognises that measurements in a windy environment are technically difficult and subject to variation. Exceeding the compliance checking criteria may be the result of varying* [residual] *background noise, rather than of excessive wind farm noise.*
>
> *It is expected that there will be natural variations in background noise throughout the year, with different prevailing wind directions, foliage on trees, atmospheric conditions and possibly with changes to local conditions such as buildings, trees or topography that may affect compliance with the criteria. Where this may be the case, the onus of responsibility for proof resides with the developer.*

4.5 Annoying characteristics

The SA Guidelines 2003 were developed in recognition of the inherent noise characteristics of a correctly functioning modern wind farm which are described as including aerodynamic noise from passing blades, referred to as "swish" and infrequent braking noise. In instances when the noise of a wind farm at relevant assessment locations includes atypical noise characteristics, Section 4.5 of the SA Guidelines 2003 requires that these be rectified.

Concurrently, Condition 2.19 of the Project Approval states:

> *For the purposes of conditions 2.15 and 2.16 of this approval, 5* [dB] *shall be applied to measured noise levels where tonality is present. The presence of tonality shall be determined using the methodology detailed in Wind Turbine Generator Systems- Part 11: Acoustic Noise Measurement Techniques IEC 61400-11:2002 or its latest edition.*

The Noise Compliance Plan also details a number of considerations relating to annoying characteristics and recommends carrying out subjective evaluation to assess their presence in the wind farm sound near receptor locations. The assessment methodology adopted for the compliance survey therefore involves a number of attended site observations to subjectively evaluate the presence of annoying characteristics.

If the attended studies indicate the potential presence of a characteristic which could attract an adjustment to the measured noise level, in accordance with Condition 2.19 of the Project Approval, objective analysis has then been used to quantify whether the characteristic is sufficiently prominent to warrant the application of the adjustment.

5.0 MEASUREMENTS

5.1 Monitoring locations

A total of seventeen (17) properties were selected as monitoring locations to establish typical background noise levels during the planning stages of the project. These seventeen (17) locations were also referenced in the RNA to establish the applicable noise limits.

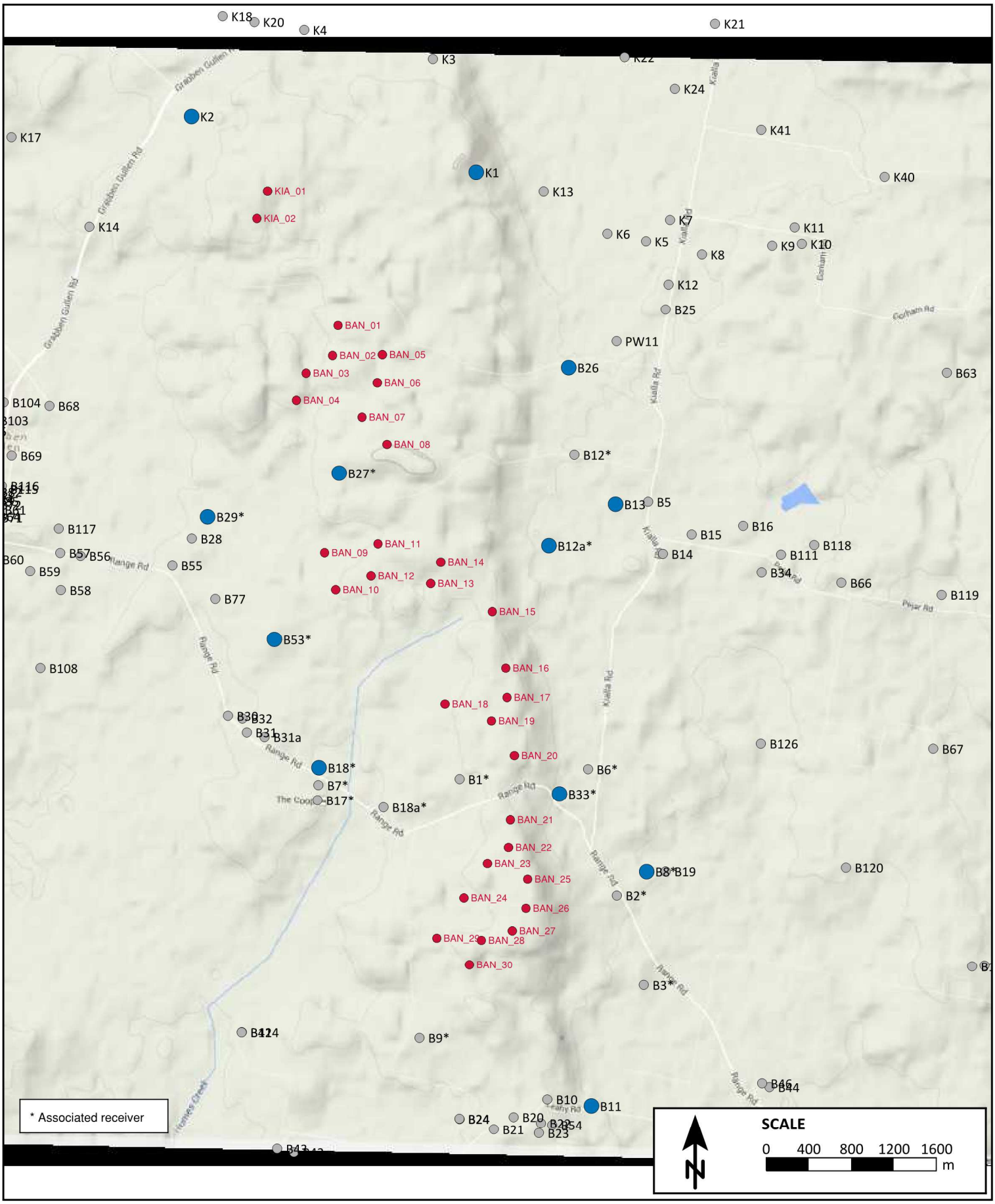
In accordance with the Noise Compliance Plan, noise monitoring has been conducted at the same seventeen (17) locations for this study of operational wind farm noise. These locations are illustrated in blue in Figure 1 and Figure 2 on the following pages, and are detailed in Table 3 in the following section.

5.1.1 Monitoring positions

Section 11.2 of the Noise Compliance Plan states the following in regards to the position of measurement equipment at each monitoring location:

> *The microphone of the noise logger will be set up at the same location as used previously for the background noise monitoring, or if at a location where background noise monitoring has not previously been conducted, set up in accordance with the requirements of the SA Guidelines 2003 and the Project Approval.*

In accordance with this requirement, noise monitoring has been carried out at the same position that was used for pre-construction noise monitoring wherever possible. In some cases however, it was not practically possible to place equipment at the pre-construction monitoring location. For example, the vegetation around residence B8 had grown significantly in close proximity to the pre-construction monitoring. In instances such as this, a nearby, alternative measurement location has been selected in accordance with the SA Guidelines 2003 and the Project Approval.



LEGEND

- Receiver
- Turbine
- Monitoring location

Project: Gullen Range Windfarm Noise Commissioning

Project number: 2014544SY

Client name: New Gullen Range Wind Farm

Version: SoundPLAN 7.3

Prediction method: [not applicable]

Model number: 16

Run number: 0 [not applicable]

File: Gullen north section-topographical - Monitoring lo

Noise monitoring locations

Gullen Range Wind Farm: North Section

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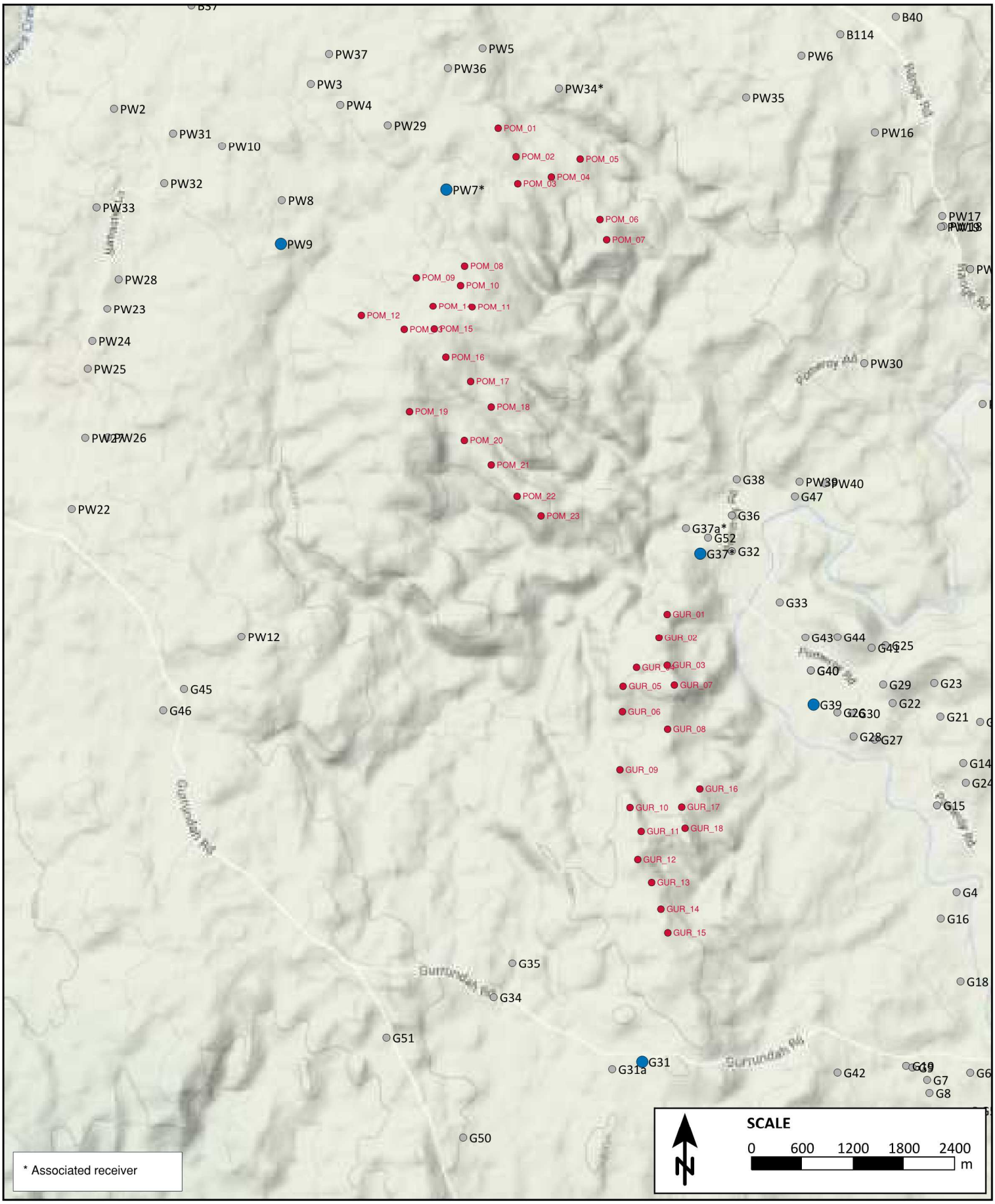

LEGEND

- Receiver
- Turbine
- Monitoring location

Project: Gullen Range Windfarm Noise Commissioning

Project number: 2014544SY

Client name: New Gullen Range Wind Farm

Version: SoundPLAN 7.3

Prediction method: [not applicable]

Model number: 16

Run number: 0 [not applicable]

File: Gullen south section-topographical - Monitoring lo

Noise monitoring locations

Gullen Range Wind Farm: South Section

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The seventeen (17) monitoring locations for the current study are shown in Table 3 below. Further details of the monitoring locations, including photographs of the noise monitoring positions, are provided in Appendix E.

Table 3: Noise monitoring locations

Monitoring Location	Co-ordinates**		Related receiver locations
	Easting (m)	Northing (m)	
B8*	725764	6171873	B2*, B3*, B19
B11	725245	6169673	B9*
B12a*	724847	6174932	-
B13	725472	6175320	-
B18*	722690	6172850	B1*, B7*, B17*, B18a*, B31, B31a, B32
B26	725032	6176603	B12*
B27*	722879	6175614	-
B29*	721644	6175203	B28, B55
B33*	724946	6172602	B6*
B53*	722272	6174050	B77
G31	727533	6155921	-
G37*	728219	6161915	G32, G33, G37a*, G52
G39	729555	6160133	-
K1	724165	6178433	-
K2	721493	6178960	-
PW7*	725225	6166206	PW5, PW29, PW34*, PW36
PW9	723273	6165569	-

* Associated Receiver

** All coordinates in MGA94 Zone 55 datum. B8 and B18 are not listed as associated receivers in the RNA, however their involvement was confirmed by email correspondence from NGRWF on 30 April 2015.

Table 3 above also presents the set of related receivers which were identified in the RNA as referencing a noise monitoring location for establishing the background dependent component of noise limits. The total noise level measurements carried out for the seventeen (17) monitoring locations are also used to indicatively evaluate compliance at these related receivers. Details of this additional assessment are provided in Section 6.0.

5.1.2 Worst case wind directions

As described in Section 4.1, the compliance assessment is based on data collected during downwind conditions. The downwind direction for each receiver location is defined on the basis of the orientation of the nearest wind turbine. Specifically, Section 11.2 of the Noise Compliance Plan states:

> *The worst case wind direction refers to the scenario where the wind direction is +/- 45 degrees from the direction that places the receptor directly downwind of the nearest wind turbines.*

Table 4 shows the worst case wind direction range for each monitoring location as specified by the SA Guidelines 2003. The downwind range of directions is subsequently used for data filtering as described in Section 5.4.2.

Table 4: Worst Case Wind Direction

Location	Lower Limit (°)	Upper Limit (°)
B8	221	311
B11	274	364
B12a	176	266
B13	184	274
B18	18	108
B26	229	319
B27	14	104
B29	62	152
B33	197	287
B53	6	96
G31	326	56
G37	164	254
G39	233	323
K1*	195	285
K2	90	180
PW07	40	130
PW09	87	177

* Adjusted downwind range to encompass KIA_01 and BAN_05

As noted in Table 4, an adjusted downwind range has been used for monitoring location K1. The nearest turbine to K1 is BAN_05 which is positioned to the south-west of the dwelling with a worst case wind direction of 162° to 252°. This wind direction range excludes downwind sound propagation from turbines KIA_01 and KIA_02 which are located at the north end of the wind farm. Calculations indicate that the KIA_01 and KIA_02 turbines contribute significantly to predicted wind farm noise levels at K1. It is therefore considered that they should be included in the assessed range of downwind directions. To achieve this, the adjusted downwind direction has been centred at 240°, with a range of 195° to 285° which includes downwind propagation from turbines KIA_01, KIA_02 and BAN_05.

5.2 Monitoring Duration

Data capture targets for the noise monitoring campaign are as follows:

- A minimum of 2000 data points should be collected during the measurement survey at each monitoring location
- As a minimum, the measurements should include at least 500 data points that are downwind from the wind farm, consistent with approach documented in the SA Guidelines 2009[4].

Noise monitoring commenced on Tuesday 9 December 2014 and has been split into three (3) stages, as detailed in Table 5 below. Monitoring was undertaken for a minimum period of four (4) weeks at each location in order to obtain at least 2000 data points across a range of weather conditions.

In instances where four (4) weeks of monitoring was not sufficient to fulfil the data capture targets outlined above, further noise monitoring has been carried out. As a guide to the duration of the extended surveys, reference was made to the Draft NSW Guideline[5] which states the following:

> *If it appears to be impractical to collect 500 valid data points under the worst-case wind direction conditions then data collection should continue for up to 6 weeks and the valid data collected in this period shall be deemed to be an acceptable quantity.*

Accordingly, survey durations were extended to a period of approximately six (6) weeks when additional data was required. Across the monitoring survey, at least 500 data points were able to be collected under downwind conditions at all seventeen (17) monitoring locations.

As noted in Table 5, monitoring has been completed at all locations.

Table 5: Time line of noise monitoring works

Stage	Date		No of monitoring locations	Comments
	Start	End		
1	9 Dec 2014	8 Jan 2015	6	
2	7 Jan 2015	13 Feb 2015	10	
3a	12 Feb 2015	17 Apr 2015	1 + 9 extended	Monitoring was extended at nine (9) locations from Stage 1 and 2 to obtain additional downwind data.
3b	9 Mar 2015	15 Apr 2015	2 extended	Monitoring was extended at two (2) locations, B18 and B53, as initial monitoring results were inconclusive. These locations are discussed further in Section 6.0
3c	21 May 2015	24 Jun 2015	1 extended	Monitoring was extended at one (1) location from Stage 3a, K2, as initial monitoring results were inconclusive. This location is discussed further in Section 6.0.

[4] The South Australia EPA document *Wind farms environmental noise guidelines* (2009). Refer to Appendix D for further discussion of minimum data requirements.

[5] Draft NSW Planning Guidelines: Wind Farms 2011 (Draft NSW Guidelines)

5.3 Data Collection

5.3.1 Sound levels

Low noise floor class/type 1 01dB DUO and CUBE Smart Noise Monitoring Terminals have been used to collect noise level data. The noise loggers include a combination primary proprietary wind shield and secondary wind shield to reduce noise generation from wind over the microphone.

Details of all noise monitors including serial numbers, wind shield, and microphones are presented in Appendix F.

The noise monitors were configured to measure 1 s L_{Aeq} sound levels including one-third octave bands. This data has been post-processed to determine L_{A90} sound pressure levels, including one-third octave band spectral data, for contiguous 10 minute intervals.

5.3.2 Local Weather Data

Daily rainfall data was collected using Vaisala WXT520 weather stations in conjunction with the DUO noise monitoring equipment. This system was time synchronised with the measured noise data.

The weather stations were situated at two (2) locations during each of the three (3) noise monitoring rounds, as seen in the following table.

Table 6: Local weather monitoring locations

Period	Dates	Location 1	Location 2
Round 1	9 Dec 2014 to 8 Jan 2015	G37	PW07
Round 2	9 Jan 2015 to 11 Feb 2015	B18	B12a
Round 3(a), 3(b)	12 Feb 2015 to 14 Apr 2015	G37	B12a
Round 3(c)	21 May 2015 to 24 Jun 2015	K2	-

During each round of monitoring, the two locations where the local weather has been monitored were chosen with a view to representing likely worst case local wind speeds at microphone height, while concurrently being as close as practical to other noise monitoring equipment in the area. A single weather station was deployed during Round 3(c) as only one compliance monitoring location was included in the round.

Charts showing the daily rainfall during each round of monitoring are detailed in Appendix G.

5.3.3 Met Mast Data

The noise limits presented in the RNA were derived using wind speed data from three reference met masts that were operational at site during the planning phase of the development, as detailed in Table 7 below. As required by the Project Approval, these noise limits used wind speed data referenced to 80m AGL[6].

[6] AGL Above Ground Level

Table 7: Reference met masts

	Co-ordinates**	
Mast	**Easting (m)**	**Northing (m)**
Bannister	724434	6172019
Gurrundah	727540	6158661
Kialla	723729	6178571

** All coordinates in MGA94 Zone 55 datum

There were four (4) operating met masts at the site during noise compliance testing. The operating met masts were correlated with the reference met masts prior to the latter being decommissioned.

The total measured operational noise levels must be correlated with wind speed data that is referenced to the same height and location as the noise limits that are applicable to the wind farm. Accordingly, NGRWF has provided wind speed data referenced to 80m AGL for the duration of the noise monitoring campaign for the three (3) reference mast locations. This data is based on synthesis of the available data at the four (4) operational met masts, adjusted for the differences in mast heights and locations. The wind data analysis which produced the synthesised data sets has been carried out by DNV GL Pty Ltd (DNV). Details of the assessment process are outlined in their letter dated 14 July 2015, which is included as Appendix H to this report.

For each monitoring location, the reference met mast location used for the derivation of noise limits has also been used for quantifying wind speeds to assess operational wind farm noise.

5.3.4 Wind farm operational data

The operational status of each turbine at the wind farm is continually monitored. NGRWF has provided a summary of the operational status of each turbine during each 10 minute period of the monitoring campaign, which indicates whether the turbine was available to generate power. As detailed in Section 5.4.2, this data has been used to filter time periods with atypical turbine operation. For example, if a turbine is turned off for maintenance, operational data will identify the atypical period and it can be excluded from the data set for relevant monitoring locations.

Relevant monitoring locations are those where the noise contribution from any turbines operating atypically has a significant influence on the overall level of wind farm noise at that location. The process for determining whether a turbine's influence is significant at a given monitoring location is consistent with the general methodology presented in the Noise Compliance Plan, as detailed further in the discussion of filtering processes presented in Section 5.4.2.

NGRWF has also advised[7] of two instances of periodic turbine curtailment.

[7] Advice provided by NGRWF by email, received 6 February 2015

Firstly, the following wind turbines were not operational during the evening and night-time periods in order to address a Project Approval requirement that is not related to operational noise.

- POM_03
- POM_04
- POM_06
- POM_07

Curtailment periods for these turbines differ across the different months of the monitoring survey according to changes in daylight hours. The periods of turbine shut down are presented in Table 8 below.

Table 8: Shut down periods

	December	January	February	March
Start	18:00	18:10	17:42	17:00
Finish	05:52	06:21	06:48	07:13

Secondly, three wind turbines were running in a reduced noise operation mode for a portion of the monitoring campaign. Details of the turbines and their period of curtailment are presented in Table 9.

Table 9: Turbine curtailment

		End curtailment	
Turbine	**Start Curtailment**	**Date**	**Time**
BAN_10	Turbine initialisation*	19.01.15	14:30
BAN_12	Turbine initialisation*	19.01.15	15:00
BAN_13	Turbine initialisation*	19.01.15	15:10

* Initialisation of all turbines occurred prior to commencement of the noise commissioning works which began on 9 December 2014.

For each of these cases, the periods of atypical turbine operation have been excluded from the regression analysis at relevant monitoring locations.

It is understood that no additional curtailments were active during the noise measurement campaign[8].

[8] As advised by NGRWF by email on 8 July 2015

5.4 Data analysis

5.4.1 Timestamps

All noise monitoring equipment used during noise measurements was set to Australian Eastern Savings Time:

- Noise measurements collected between 9 December 2014 and 0300 hrs on 5 April 2015 have been referenced to Australian Eastern Daylight Savings Time (AEDT)
- Noise measurements collected from 0300 hrs on 5 April 2015 (AEDT) until the completion of monitoring works have been referenced to Australian Eastern Standard Time (AEST)

NGRWF has advised that the wind farm data is referenced to Australian Eastern Standard Time (AEST). For noise measurements referenced to AEDT, the wind farm data has been corrected by one (1) hour prior to any detailed analysis.

Additionally, it is understood that the time stamps relating to the wind farm data refer to the start of each 10 min period. Therefore no related adjustment has been included.

5.4.2 Data filtering

As required by the SA Guidelines 2003, filtering of the monitored noise level data has taken place to account for certain extraneous noise sources influencing the data set.

Data filtering is generally based on local weather data, permanent met mast data and wind farm operational data. The collection of this data is described above in Section 5.3. In advance of carrying out the regression analysis described in the above section, collected noise level data is filtered for occurrences of rain, out of range wind speeds and other factors which are not representative of either typical wind farm operation or the underlying ambient noise environment in the area around the wind farm. Filtering methods are detailed in Table 10.

Table 10: Data filtering

Issue	Comment
Worst case directions	Section 11.2 of the Noise Compliance Plan states the following regarding the calculation method of the worst case wind direction. *The worst case wind direction refers to the scenario where the wind direction is +/- 45 degrees from the direction that places the receptor directly downwind of the nearest wind turbines.* In accordance with the above statement, data collected during wind directions of +/- 45 from the bearing of the nearest turbine to the receiver has been considered as representative for the typical worst case wind direction for noise propagation from the wind farm. Wind direction data outside this range have been excluded from the regression analysis.
Rainfall	Where it is considered likely that rainfall has occurred at the monitoring locations, associated noise and wind speed data points have been removed from the analysis.
Wind speeds below cut-in	Section 4.2 of the SA Guidelines 2003 states that all data below the cut-in wind speed should not be included in the regression analysis. The data has therefore been excluded from the analysis presented herein.
Wind speeds above rated power	Section 4.2 of the SA Guidelines 2003 states that all data with wind speeds above rated power should not be included in the regression analysis. The data has therefore been excluded from the analysis presented herein.

Issue	Comment
Wind at the microphone	The SA Guidelines 2003 require monitoring of wind speeds at the microphone position to limit the influence of wind generated noise across the microphone. To address contamination of noise measurements by high levels of wind induced noise over microphones, any noise measurement data when local wind speeds exceeded 5m/s at the local reference points for each period of noise monitoring exceeded have been excluded from the regression analysis. Additionally, secondary wind shield systems comprising an inner solid screen and outer hollow screen have been used for all noise measurements. These systems are designed to reduce the effect of wind generated noise over the microphone for the measurement of A-weighted noise levels in windy conditions. The design of the secondary wind shield was based on the recommendations detailed in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* dated May 2013. Refer to Appendix F for further details.
Turbine operational performance	Any periods that are considered to be affected by turbine shut down or curtailment have been excluded from the regression analysis. Specifically, based on the requirements set out in the Noise Compliance Plan, the expected noise levels from the turbines at each monitoring location were grouped for different directions in 45 degree wide octants. The estimated noise contribution for each octant of turbines was determined on the basis of a noise model for the wind farm*. At each monitoring location, the octant of turbines with the highest predicted noise level was defined. Any wind turbine (from all octants) with an individual predicted noise level that is within 10dB of the noise level associated with the highest octant was deemed to affect noise levels at the monitoring location. Wind farm operational records supplied by NGRWF for the duration of the monitoring campaign were then reviewed, and any ten minute period in which a turbine was shut down or curtailed and deemed to have affected noise levels at the monitoring location was removed from the analysis.
Extraneous noise	Extraneous noise can in some circumstances significantly affect noise measurements. The SA Guidelines 2003 define extraneous noise as noise from animals, excessive wind effects, insects, birds, aircraft or unusual traffic conditions or any other infrequently occurring component of the ambient noise. Measured one-third octave band levels have been used to identify data when extraneous noise, such as insects, may have significantly influenced the measurement period using the method detailed in Appendix I. Periods identified as being potentially influenced by extraneous noise are excluded from the regression analysis. It should be noted that this filtering procedure has been adopted for the purpose of automated and preliminary filtering of large measurement datasets. The procedure is therefore adopted as a cautious process to remove periods affected by distinctive sources of extraneous noise. There will be many instances where extraneous noise sources significantly affect or dominate the measured noise levels, but will not be automatically identified and removed by this filtering process. Accordingly, the filtered dataset will still include periods in which the total measured noise levels are attributable to the combined influence of the ambient noise environment and operation of the wind farm.

* Refer to the RNA for details of the noise model.

The filtering processes outlined above are used to reduce the influence of significant sources of variation in residual noise levels, such as seasonal variations in insect noise. However, in some instances, particularly at increased wind speeds, the filtered dataset will still be still be significantly affected by residual noise. In such instances, the actual contribution of the turbines will be significantly lower than indicated by the analysis of the filtered data set. Accordingly, the assessment of total measured noise levels provided in this report represents a conservative evaluation of the operational noise solely related to the wind farm.

5.5 Turbine firmware

NGRWF has advised that the Goldwind GW82 turbines have been operating throughout the noise commissioning period without any changes to turbine firmware.

NGRWF has also advised that the firmware for the GW100 turbines has been updated four (4) times over the course of the commissioning period. Details of these changes and a discussion of the potential for firmware changes to affect sound levels produced by the turbines is provided in Appendix P.

6.0 RESULTS

Monitoring periods, the number of data points collected and the number of data points included in the analysis are presented in the following sections together with the coefficient of determination (R^2) and the regression order for each plot.

The noise monitoring data for each measurement location is illustrated as follows:

- analysed total measured noise levels are shown as blue dots
- measured noise levels that have been excluded from the analysis due to filtering are shown as grey dots
- line of best fit from a regression analysis of the filtered data is shown as a solid red line
- wind farm noise limits specified in the RNA in accordance with the Project Approval are shown in black

Tabulated results are presented in Appendix J.

It is important to note that the line of best fit relates to the total measured noise levels and therefore includes the contribution of both operational wind farm noise levels and noise from all other residual sources as discussed in Section 4.3 above. In contrast, the noise limit applies only to the contribution that is attributable to the operation of the wind farm. Accordingly, the assessment of total measured noise levels presented here is a conservative evaluation of the operational noise from the wind farm.

It is also noted that, at several monitoring locations, a significant amount of data has been filtered from the analysis. This is shown graphically on the charts in this section by a large number of grey dots. Unless otherwise noted, a large amount of filtering is generally due to the requirement for measurements to assess worst case downwind directions in accordance with the SA Guidelines 2003.

In particular, as easterly winds were comparatively more common during the measurement campaign, the duration of monitoring surveys at locations on the east of the wind farm (for which westerly's are downwind) has generally been extended in order to capture 500 downwind data points. In many cases, it has been necessary to extend the monitoring surveys by 4 to six weeks to obtain the necessary number of data points downwind.

6.1 B8

Table 11: Summary of parameters – B8

Monitoring period	9.12.14 to 7.01.15
Sound Level Logging Device	DUO10499
Total number of data points collected	4127
Number of data points removed*	3328
Number of data points used for analysis (min 500 points required)	799
Total measured noise level regression line of best fit R^2	0.75
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

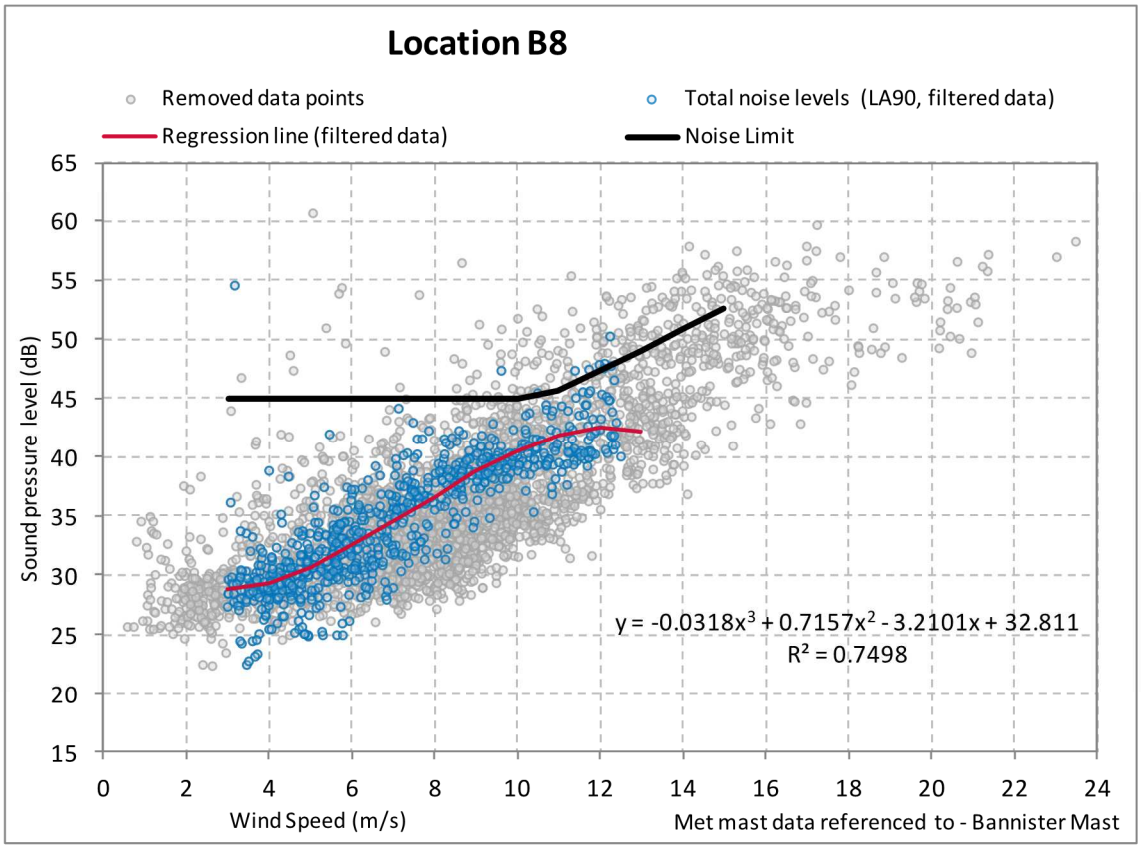


Figure 3: B8 Total noise level vs. wind speed

It can be seen from Figure 3 that the line of best fit to the total measured noise levels at property B8 lies below the wind farm limits for an associated receiver between cut-in and rated power. The contribution of the wind farm to noise levels at B8 therefore complies with the limits.

As detailed in Table 3, the noise limits at property B8 are the basis of noise limits at selected neighbouring properties: B2, B3 and B19. The total measured noise levels at property B8 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at these three (3) properties. Refer to Appendix J for further details.

6.2 B11

Table 12: Summary of parameters – B11

Monitoring period	7.01.14 to 14.04.15
Sound Level Logging Device	DUO10388 & DUO10394
Total number of data points collected	13853
Number of data points removed*	12926
Number of data points used for analysis (min 500 points required)	927
Total measured noise level regression line of best fit R^2	0.48
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

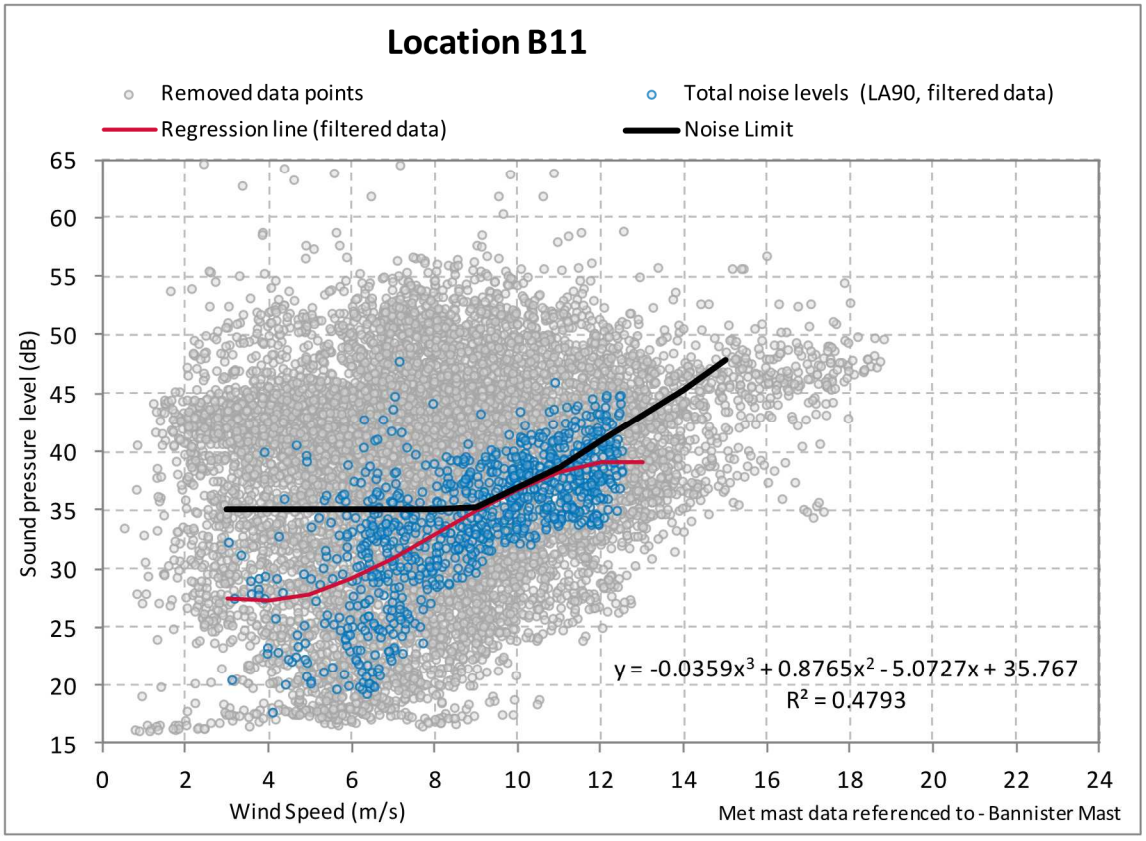


Figure 4: B11 Total noise level vs. wind speed

The raw measurement data (grey points) exhibit a very wide range of variation in noise levels. This is indicative of an environment that is significantly affected by local sources of extraneous noise. The large volume of data that has been filtered from the analysis relates to the extended measurement duration that was required to obtain a suitable number of measurement points under worst case wind directions as defined by the SA Guidelines 2003.

It can be seen from Figure 4 that the line of best fit to the total measured noise levels at property B11 lies below the wind farm limits between cut-in and rated power. The contribution of the wind farm to noise levels at B11 therefore complies with the limits.

As detailed in Table 3, the noise limits at property B11 are the basis of noise limits at neighbouring property B9. The total measured noise levels at property B11 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at property B9. Refer to Appendix J for further details.

6.3 B12a

Table 13: Summary of parameters – B12a

Monitoring period	8.01.14 to 5.04.15
Sound Level Logging Device	DUO10498
Total number of data points collected	12470
Number of data points removed*	11475
Number of data points used for analysis (min 500 points required)	995
Total measured noise level regression line of best fit R^2	0.71
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

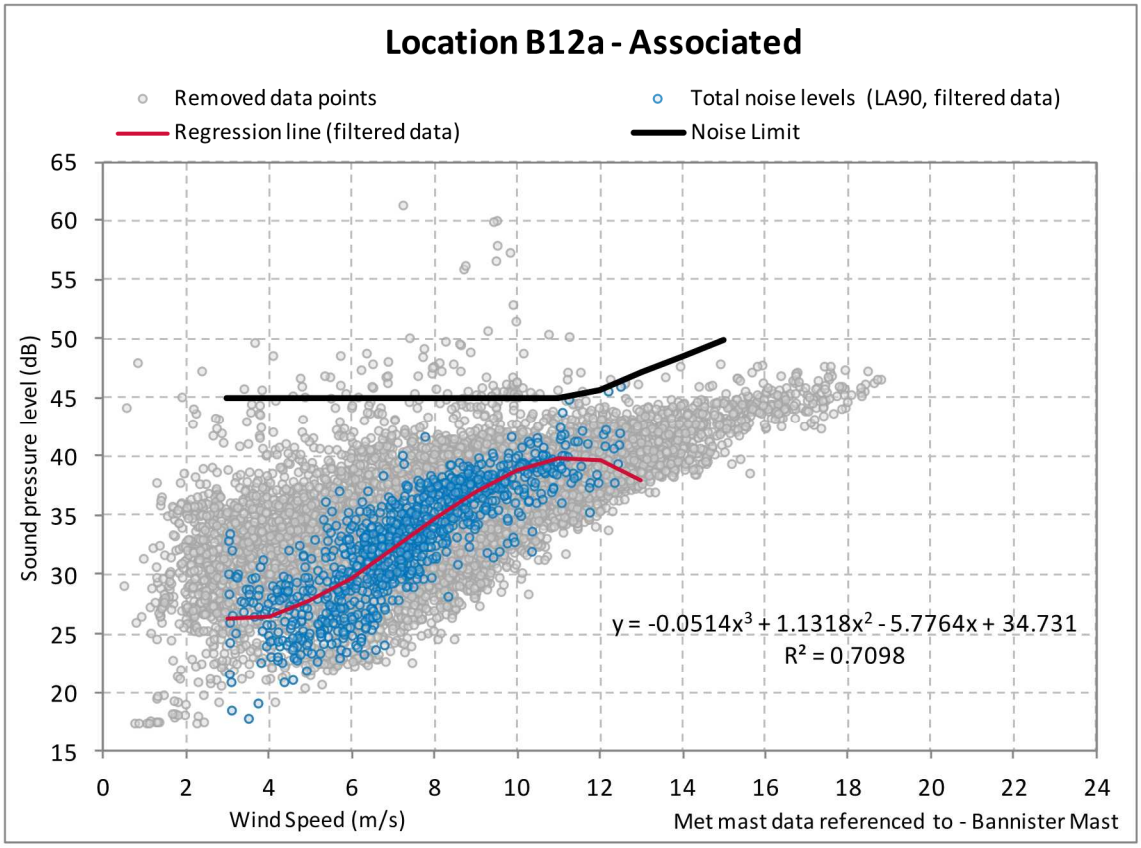


Figure 5: B12a Total noise level vs. wind speed

It can be seen from Figure 5 that the line of best fit to the total measured noise levels at property B12a lies below the wind farm limits for an associated receiver between cut-in and rated power. The contribution of the wind farm to noise levels at B12a therefore complies with the limits.

6.4 B13

Table 14: Summary of parameters – B13

Monitoring period	8.01.15 to 2.04.15
Sound Level Logging Device	DUO10499
Total number of data points collected	12107
Number of data points removed*	11094
Number of data points used for analysis (min 500 points required)	1013
Total measured noise level regression line of best fit R^2	0.54
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

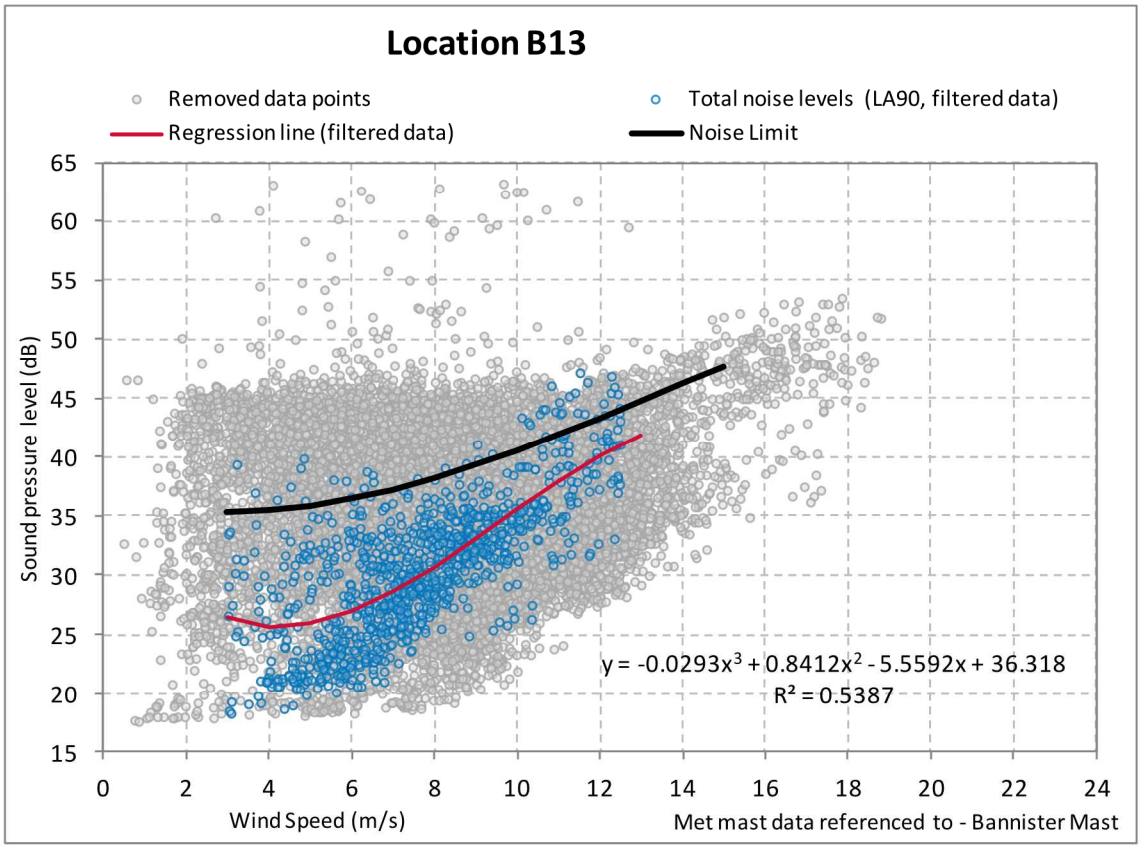


Figure 6: B13 Total noise level vs. wind speed

The raw measurement data (grey points) exhibit a very wide range of variation in noise levels. This is indicative of an environment that is significantly affected by local sources of extraneous noise. The large volume of data that has been filtered from the analysis relates to the extended measurement duration that was required to obtain a suitable number of measurement points under worst case wind directions as defined by the SA Guidelines 2003.

It can be seen from Figure 6 that the line of best fit to the total measured noise levels at property B13 lies below the wind farm limits between cut-in and rated power. The contribution of the wind farm to noise levels at B13 therefore complies with the limits.

6.5 B18

Table 15: Summary of parameters – B18

Monitoring period	8.01.15 to 11.02.15 & 9.03.15 to 14.04.15
Sound Level Logging Device	DUO10392
Total number of data points collected	9966
Number of data points removed*	7092
Number of data points used for analysis (min 500 points required)	2874
Total measured noise level regression line of best fit R^2	0.65
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

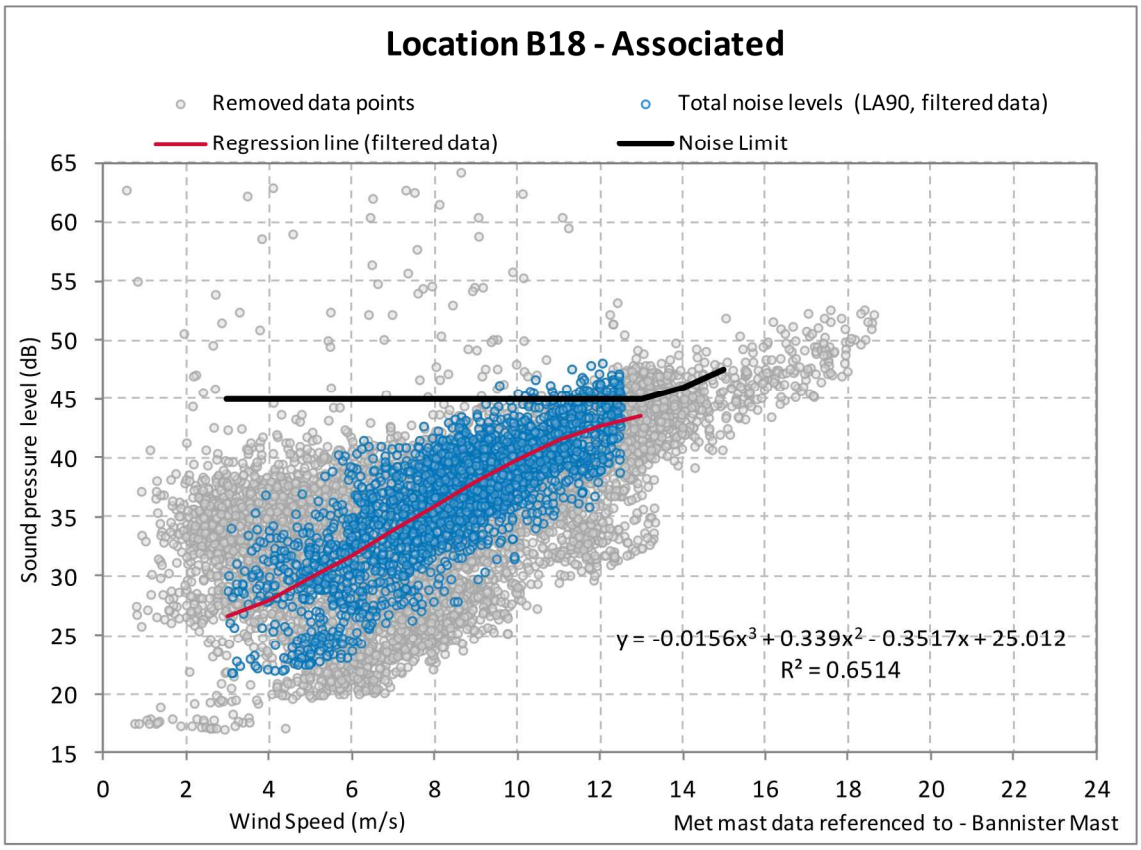


Figure 7: B18 Total noise level vs. wind speed

Results from the initial monitoring period at this location were not conclusive and indicated that total measured noise levels may be affected by extraneous noise. On this basis, monitoring equipment was redeployed at this location for a further period of approximately six (6) weeks. As a result, data analysis at this location includes a large number of data points after filtering.

It can be seen from Figure 7 that the line of best fit to the total measured noise levels at property B18 are below the wind farm limits for an associated receiver between cut-in and rated power. The contribution of the wind farm to noise levels at B18 therefore complies with the limits.

As detailed in Table 3, the noise limits at property B18 are the basis of noise limits at selected neighbouring properties: B1, B7, B17, B18a, B31, B31a and B32. The total measured noise levels at property B18 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at these seven (7) properties. Refer to Appendix J for further details.

6.6 B26

Table 16: Summary of parameters – B26

Monitoring period	7.01.15 to 13.04.2015
Sound Level Logging Device	DUO389 & DUO10499
Total number of data points collected	13809
Number of data points removed*	12584
Number of data points used for analysis (min 500 points required)	1225
Total measured noise level regression line of best fit R^2	0.52
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

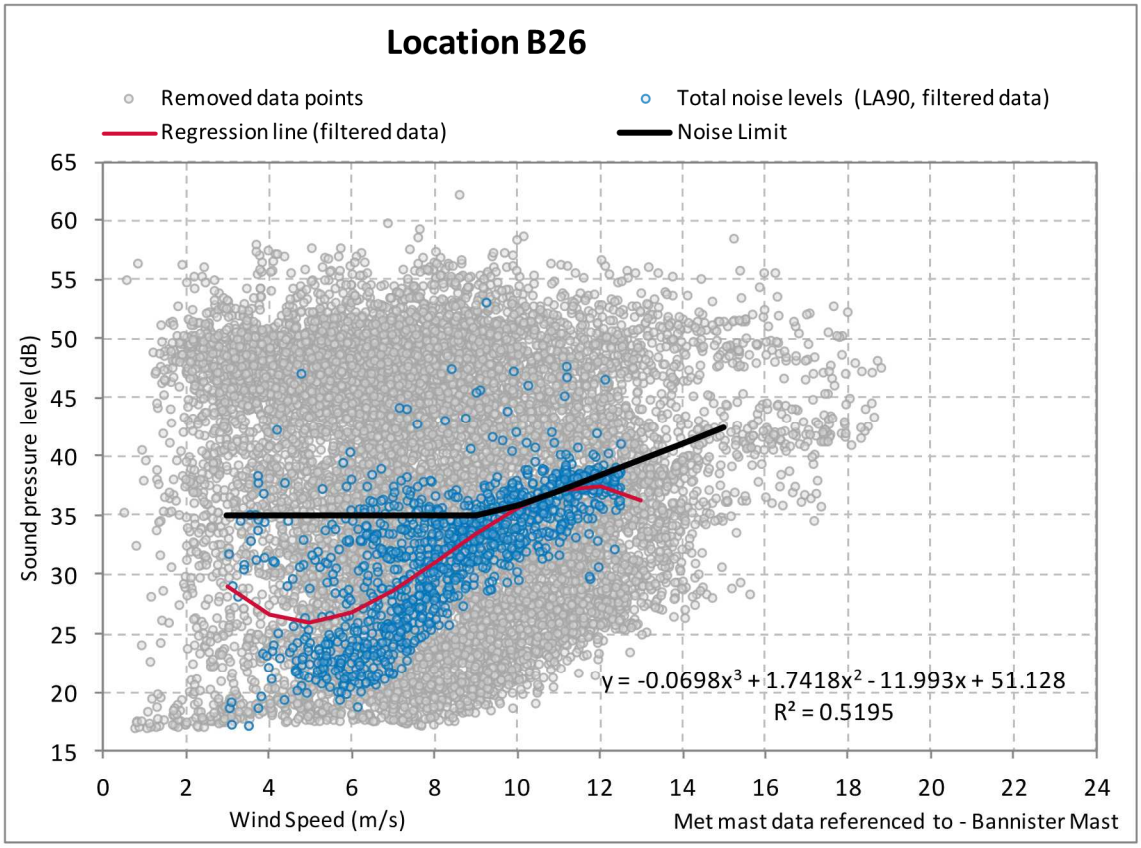


Figure 8: B26 Total noise level vs. wind speed

The raw measurement data (grey points) exhibits a very wide range of variation in noise levels. This is indicative of an environment that is significantly affected by local sources of extraneous noise. The large volume of data that has been filtered from the analysis relates to the extended measurement duration (greater than 3 months) that was required to obtain a suitable number of measurement points under worst case wind directions as defined by the SA Guidelines 2003.

Notwithstanding the above, it can be seen from Figure 8 that the line of best fit to the total measured noise levels at property B26 lies at[9] or below the wind farm limits at each integer wind speed. The contribution of the wind farm to noise levels at B26 therefore complies with the limits. Further information about the extent to which the total measured noise levels have been influenced by the residual sound environment is provided in Appendix K.

As detailed in Table 3, the noise limits at property B26 are the basis of noise limits at neighbouring property B12. The total measured noise levels at property B26 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at B12. Refer to Appendix J for further details.

[9] To one decimal place.

6.7 B27

Table 17: Summary of parameters – B27

Monitoring period	8.01.15 to 11.02.15
Sound Level Logging Device	DUO10418
Total number of data points collected	4898
Number of data points removed*	3624
Number of data points used for analysis (min 500 points required)	1274
Total measured noise level regression line of best fit R^2	0.69
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

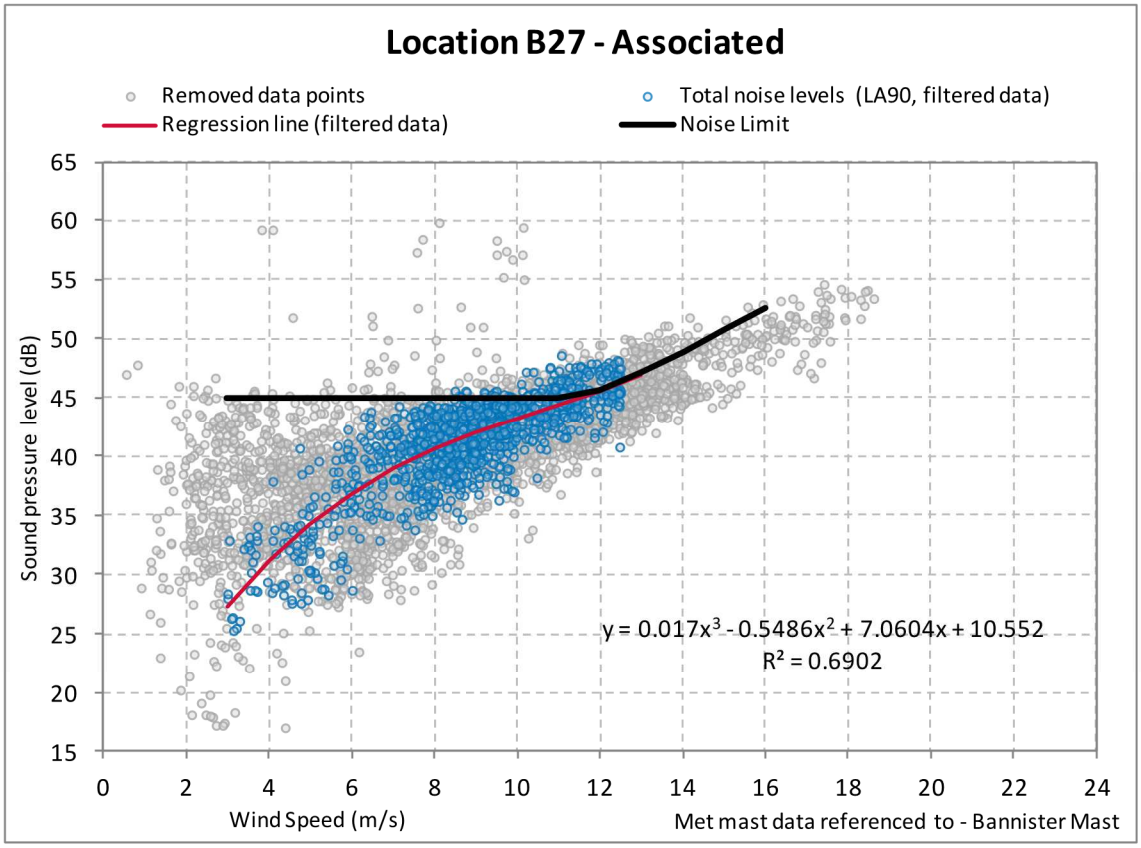


Figure 9: B27 Total noise level vs. wind speed

It can be seen from Figure 9 that the line of best fit to the total measured noise levels at property B27 lies at[10] or below the wind farm limits at each integer wind speed. The contribution of the wind farm to noise levels at B27 therefore complies with the limits. Further information about the extent to which the total measured noise levels have been influenced by the residual sound environment is provided in Appendix K.

[10] To one decimal place.

6.8 B29

Table 18: Summary of parameters – B29

Monitoring period	9.01.15 to 11.02.15
Sound Level Logging Device	DUO10392
Total number of data points collected	5072
Number of data points removed*	3186
Number of data points used for analysis (min 500 points required)	1886
Total measured noise level regression line of best fit R^2	0.60
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

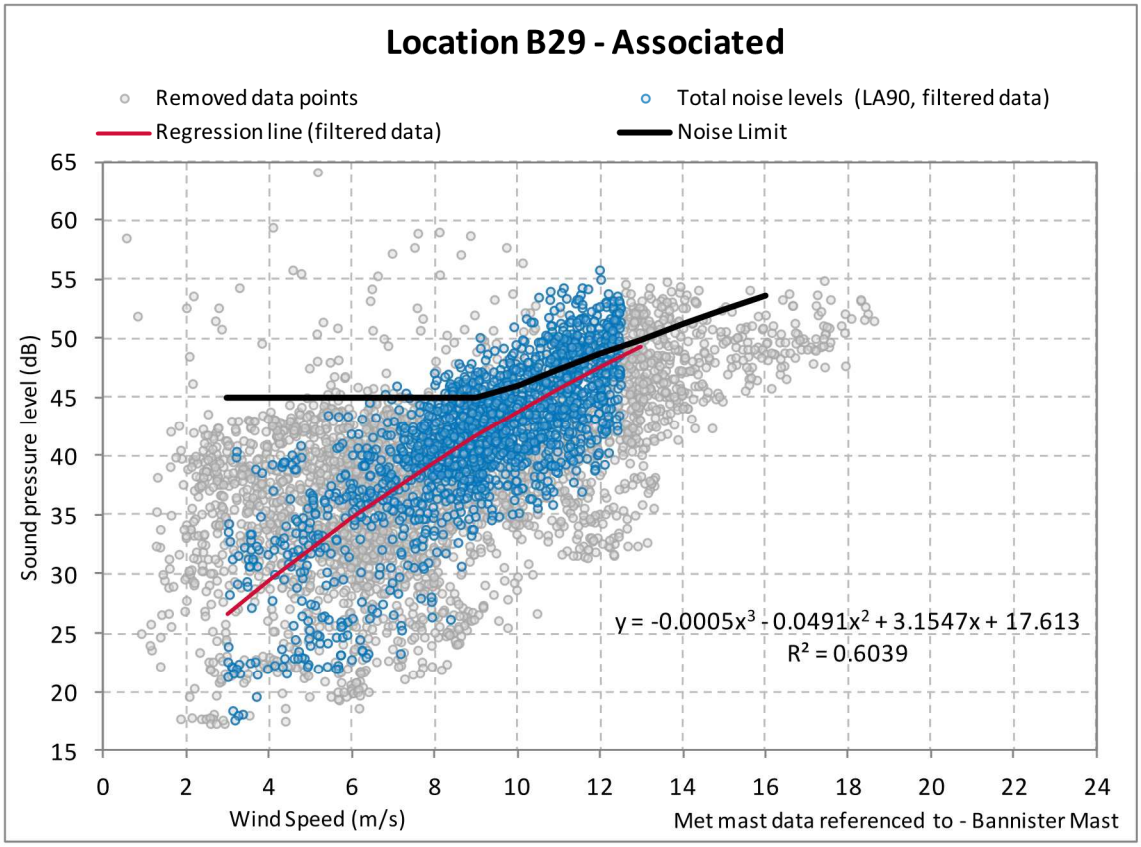


Figure 10: B29 Total noise level vs. wind speed

It can be seen from Figure 10 that the line of best fit to the total measured noise levels at property B29 lies below the wind farm limits for an associated receiver between cut-in and rated power. The contribution of the wind farm to noise levels at B29 therefore complies with the limits.

As detailed in Table 3, the noise limits at property B29 are the basis of noise limits at selected neighbouring properties: B28 and B55. The total measured noise levels at property B29 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at these two (2) properties. Refer to Appendix J for further details.

6.9 B33

Table 19: Summary of parameters – B33

Monitoring period	8.01.15 to 11.02.15
Sound Level Logging Device	DUO10394
Total number of data points collected	4916
Number of data points removed*	4215
Number of data points used for analysis (min 500 points required)	701
Total measured noise level regression line of best fit R^2	0.80
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

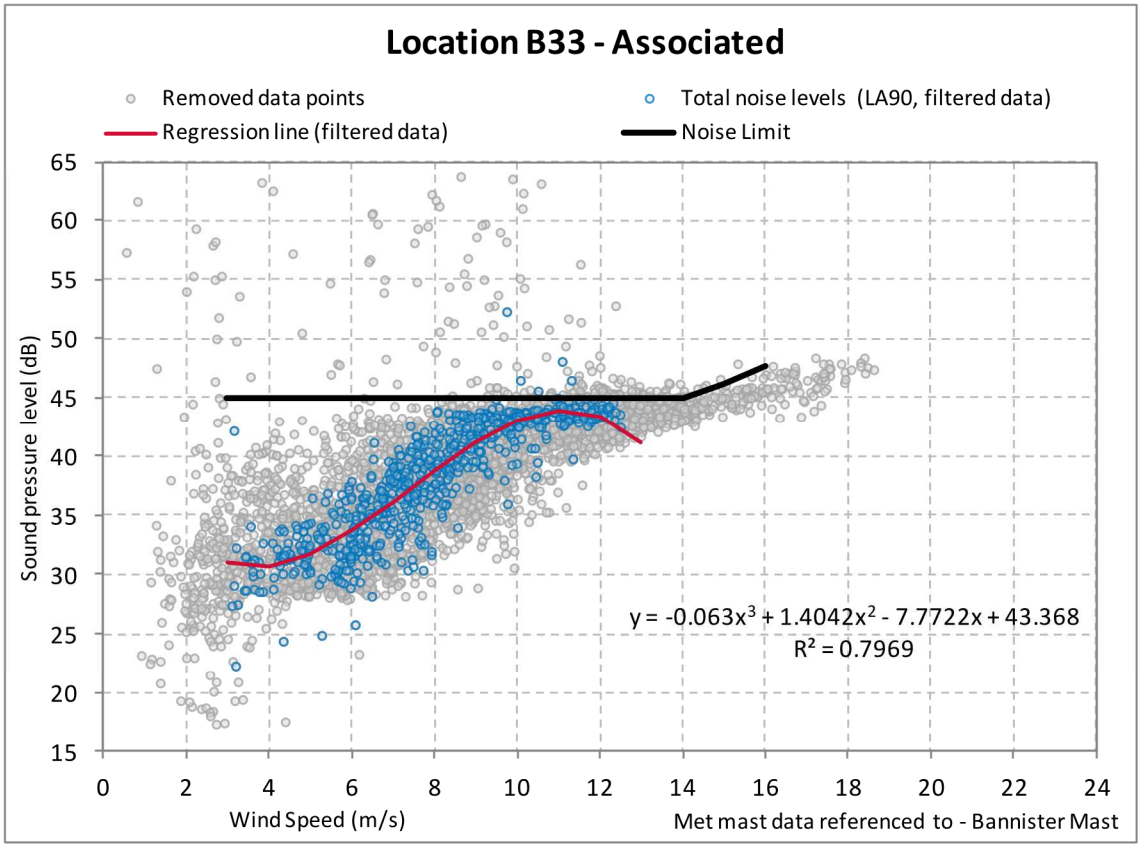


Figure 11: B33 Total noise level vs. wind speed

It can be seen from Figure 11 that the line of best fit to the total measured noise levels at property B33 lies below wind farm limits for an associated receiver between cut-in and rated power. The contribution of the wind farm to noise levels at B33 therefore complies with the limits.

As detailed in Table 3, the noise limits at property B33 are the basis of noise limits at neighbouring property B6. The total measured noise levels at property B33 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at property B6. Refer to Appendix J for further details.

6.10 B53

Table 20: Summary of parameters – B53

Monitoring period	7.01.15 to 12.02.15 & 9.03.15 to 14.04.15
Sound Level Logging Device	DUO10391
Total number of data points collected	10348
Number of data points removed*	8058
Number of data points used for analysis (min 500 points required)	2290
Total measured noise level regression line of best fit R^2	0.69
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

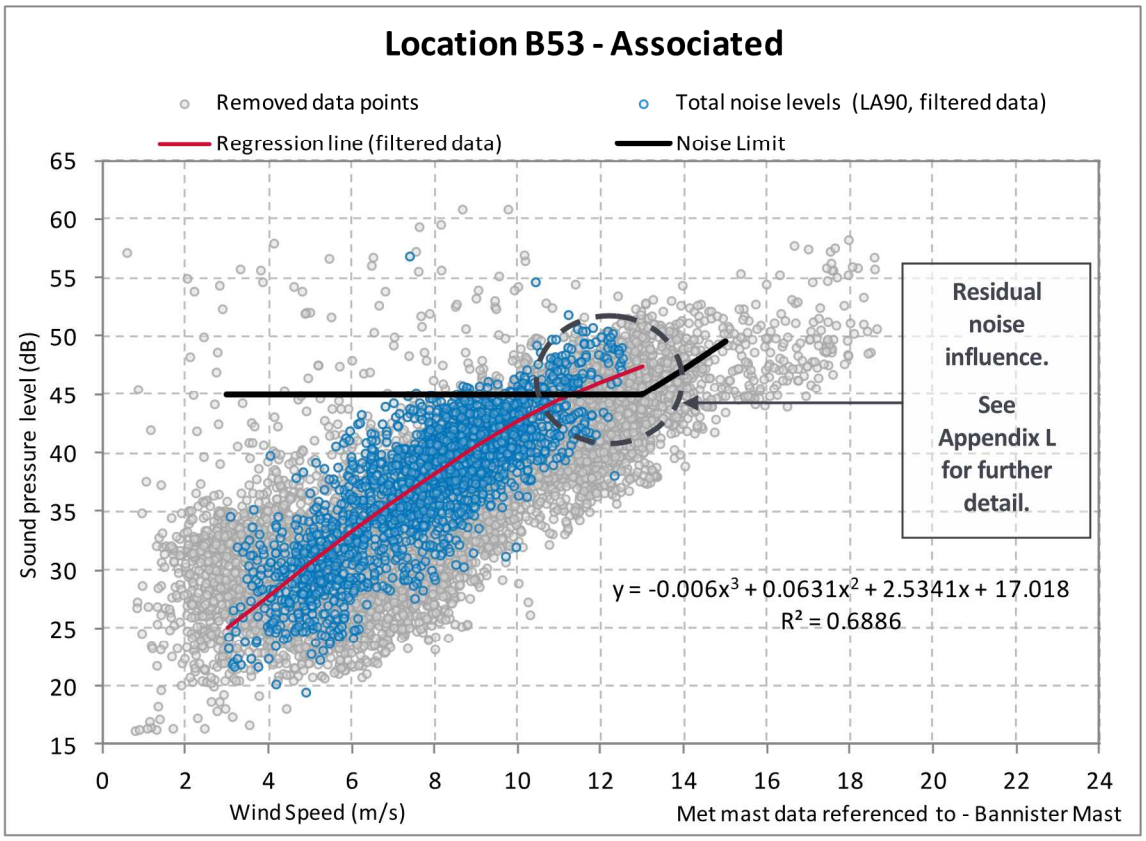


Figure 12: B53 Total noise level vs. wind speed

It can be seen from Figure 12 that the line of best fit to the total measured noise levels at property B53 generally lies below the wind farm limits for an associated receiver at each integer wind speed. The exception is at 12m/s where the line of best fit is above the limit by 1 dB to 2 dB.

A detailed analysis of noise levels above 10 m/s has demonstrated that the contribution attributable to the operation of the wind farm is at least 1 dB to 2 dB lower than the total measured noise level, and therefore supports that the contribution of the wind farm to noise levels at B53 complies with the applicable limits. This analysis is based on consideration of a range of factor related to variations in noise levels with wind direction and wind speed, in addition to supplementary data obtained at an intermediate location between the wind farm and the monitoring location. The outcomes of this analysis demonstrated that the increased noise levels at high wind speeds are consistent with residual noise effects rather than the operation of the wind farm. Full details of the analysis are provided in Appendix L.

As detailed in Table 3, the noise limits at property B53 are the basis of noise limits at neighbouring property B77. The total measured noise levels at property B53 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at property B77. Refer to Appendix J for further details.

6.11 G31

Table 21: Summary of parameters – G31

Monitoring period	9.12.14 to 8.01.15
Sound Level Logging Device	DUO10302
Total number of data points collected	4339
Number of data points removed*	3701
Number of data points used for analysis (min 500 points required)	638
Total measured noise level regression line of best fit R^2	0.1
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

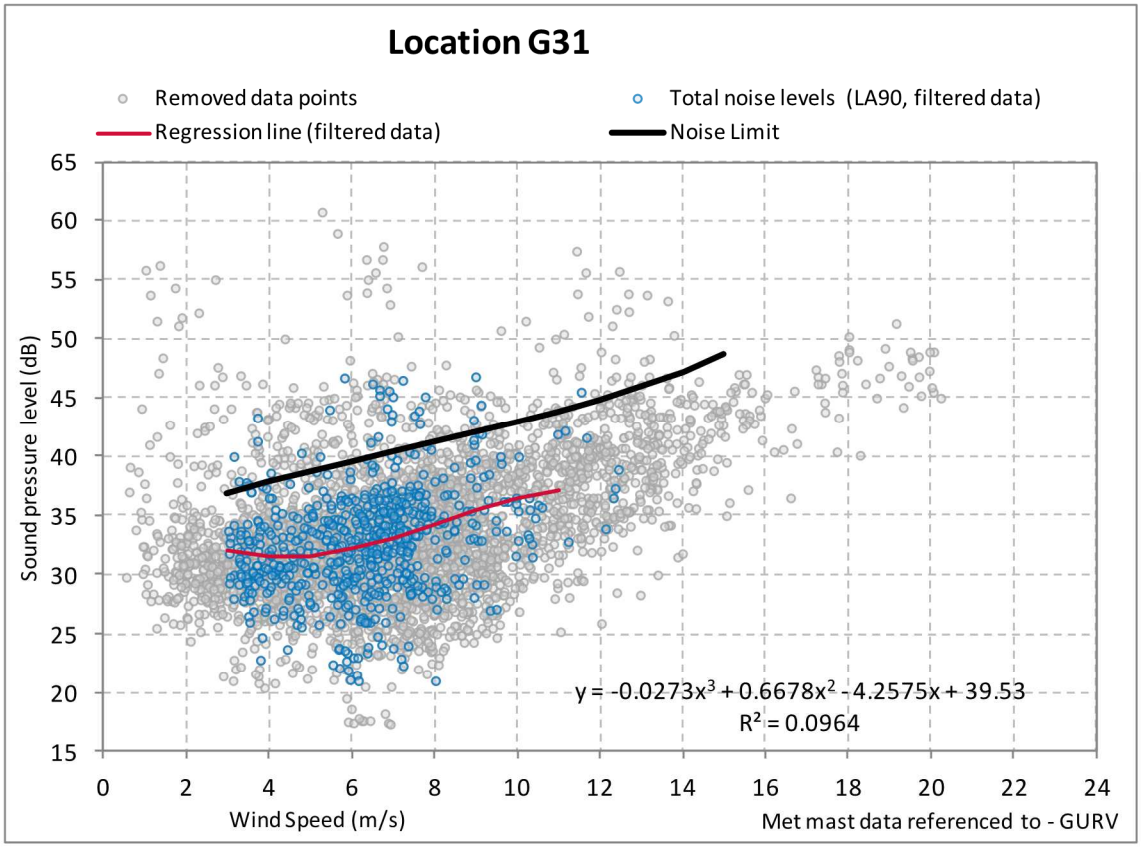


Figure 13: G31 Total noise level vs. wind speed

It can be seen from Figure 13 that the line of best fit to the total measured noise levels at property G31 lies below the wind farm limits at each integer wind speed between cut-in and rated power. The contribution of the wind farm to noise levels at G31 therefore complies with the limits.

6.12 G37

Table 22: Summary of parameters – G37

Monitoring period	9.12.14 to 7.01.15 & 12.02.15 to 14.04.15
Sound Level Logging Device	DUO10417 & DUO10194
Total number of data points collected	13083
Number of data points removed*	12328
Number of data points used for analysis (min 500 points required)	755
Total measured noise level regression line of best fit R^2	0.11
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

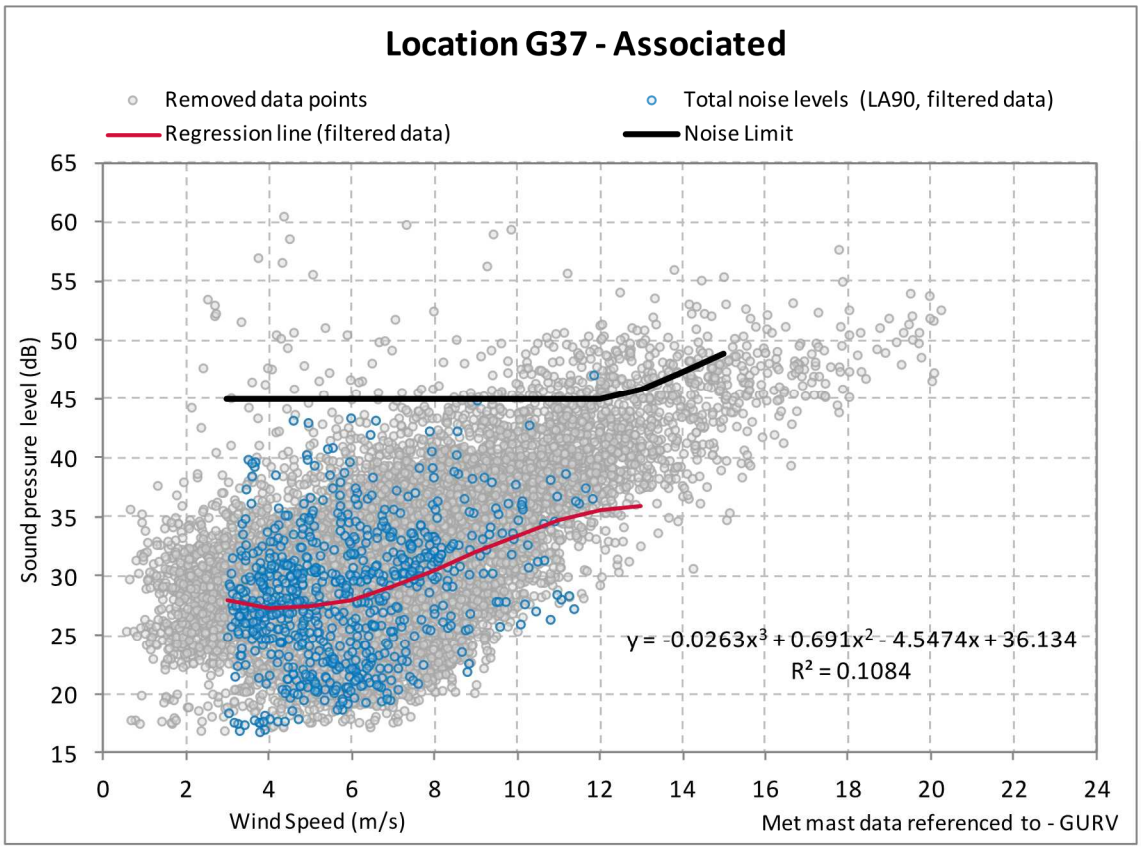


Figure 14: G37 Total noise level vs. wind speed

It can be seen from Figure 14 that the line of best fit to the total measured noise levels at property G37 lies below the wind farm limits for an associated receiver between cut-in and rated power. The contribution of the wind farm to noise levels at G37 therefore complies with the limits.

As detailed in Table 3, the noise limits at property G37 are the basis of noise limits at selected neighbouring properties: G32, G33, G37a and G52. The total measured noise levels at property G37 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at these four (4) properties. Refer to Appendix J for further details.

6.13 G39

Table 23: Summary of parameters – G39

Monitoring period	9.12.14 to 8.01.15
Sound Level Logging Device	DUO10498
Total number of data points collected	4330
Number of data points removed*	3550
Number of data points used for analysis (min 500 points required)	780
Total measured noise level regression line of best fit R^2	0.08
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

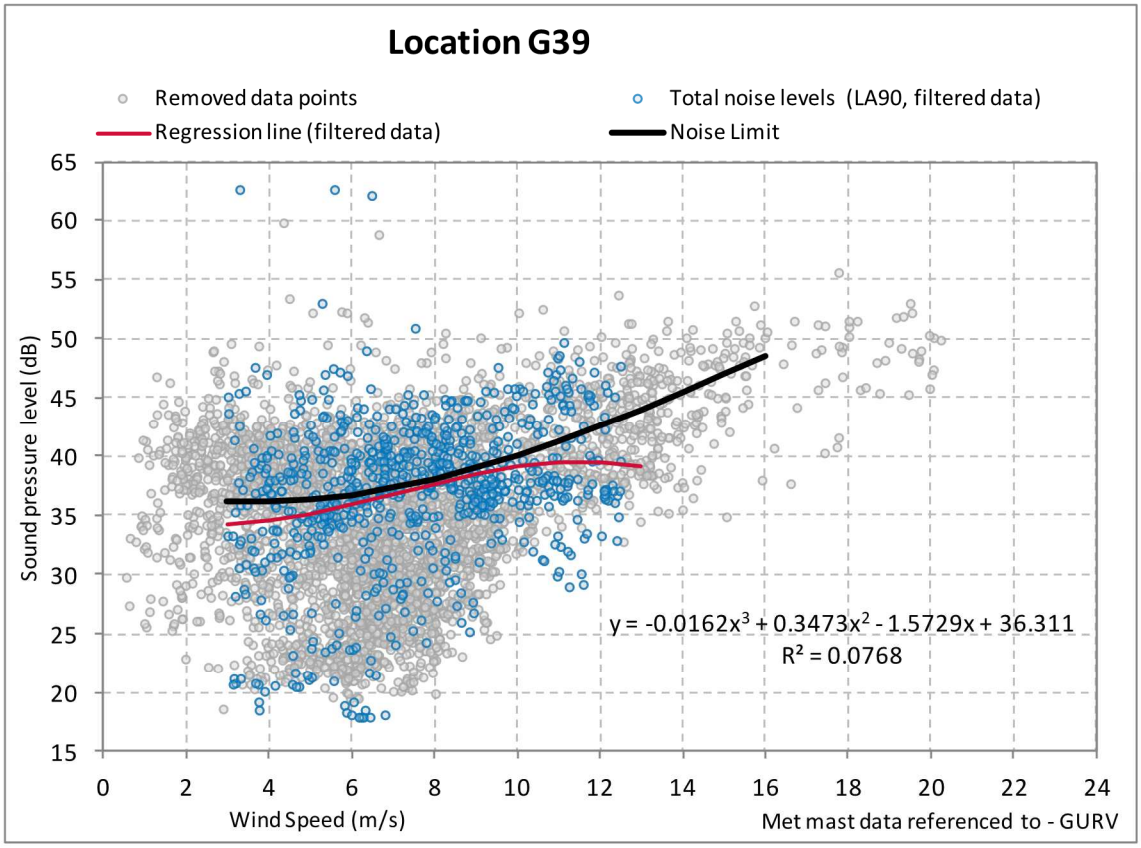


Figure 15: G39 Total noise level vs. wind speed

The data in Figure 15 indicates significant variation in measured noise levels across the wind speed range. This variation is indicative of an environment that is significantly affected by local sources of extraneous noise.

It can be seen that the line of best fit to the total measured noise levels at property G39 lies below the wind farm limits between cut-in and rated power. The contribution of the wind farm to noise levels at G37 therefore complies with the limits.

6.14 K1

Table 24: Summary of parameters – K1

Monitoring period	7.01.15 to 12.02.15
Sound Level Logging Device	DUO10391
Total number of data points collected	5173
Number of data points removed*	4567
Number of data points used for analysis (min 500 points required)	606
Total measured noise level regression line of best fit R^2	0.41
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

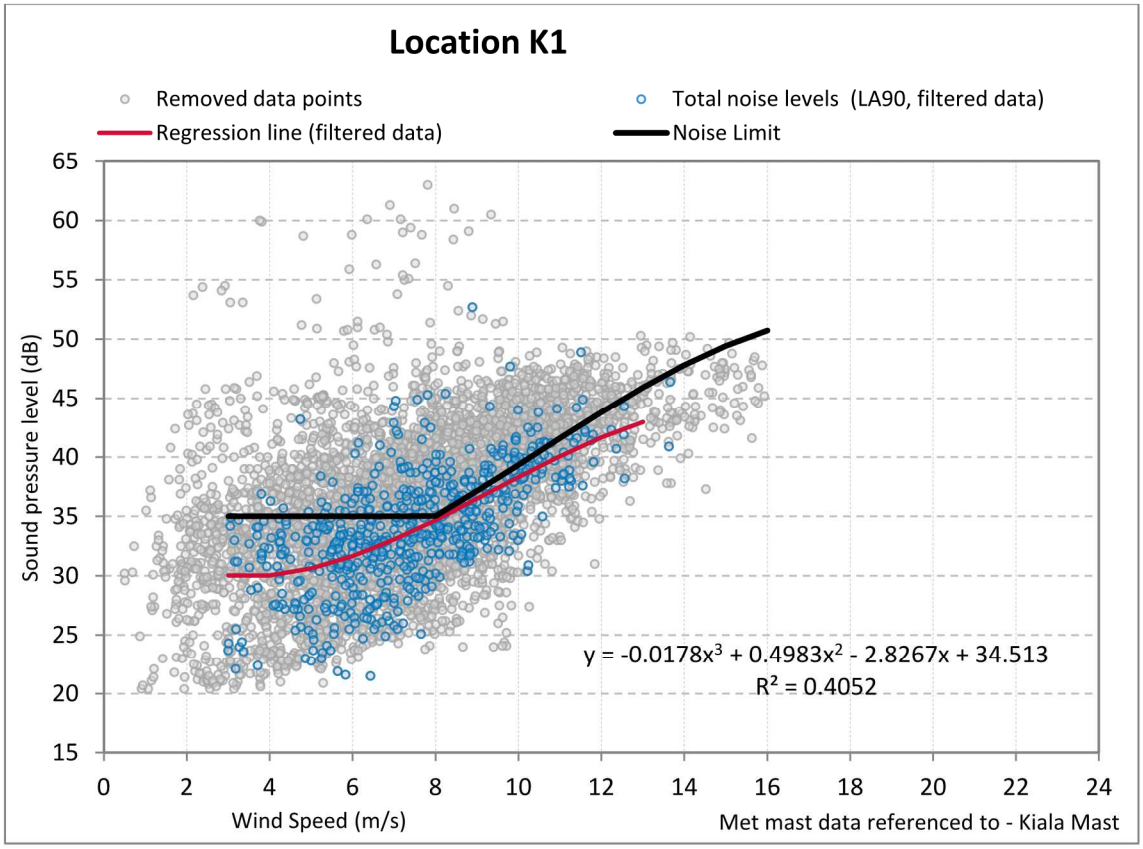


Figure 16: K1 Total noise level vs. wind speed

It can be seen that the line of best fit to the total measured noise levels at property K1 lies below the wind farm limits between cut-in and rated power. The contribution of the wind farm to noise levels at K1 therefore complies with the limits.

6.15 K2

Table 25: Summary of parameters – K2

Monitoring period	12.02.15 to 14.04.15 & 21.05.15 to 24.06.15
Sound Level Logging Device	DUO10447 & DUO10433
Total number of data points collected	13670
Number of data points removed*	11067
Number of data points used for analysis (min 500 points required)	2603
Total measured noise level regression line of best fit R^2	0.64
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

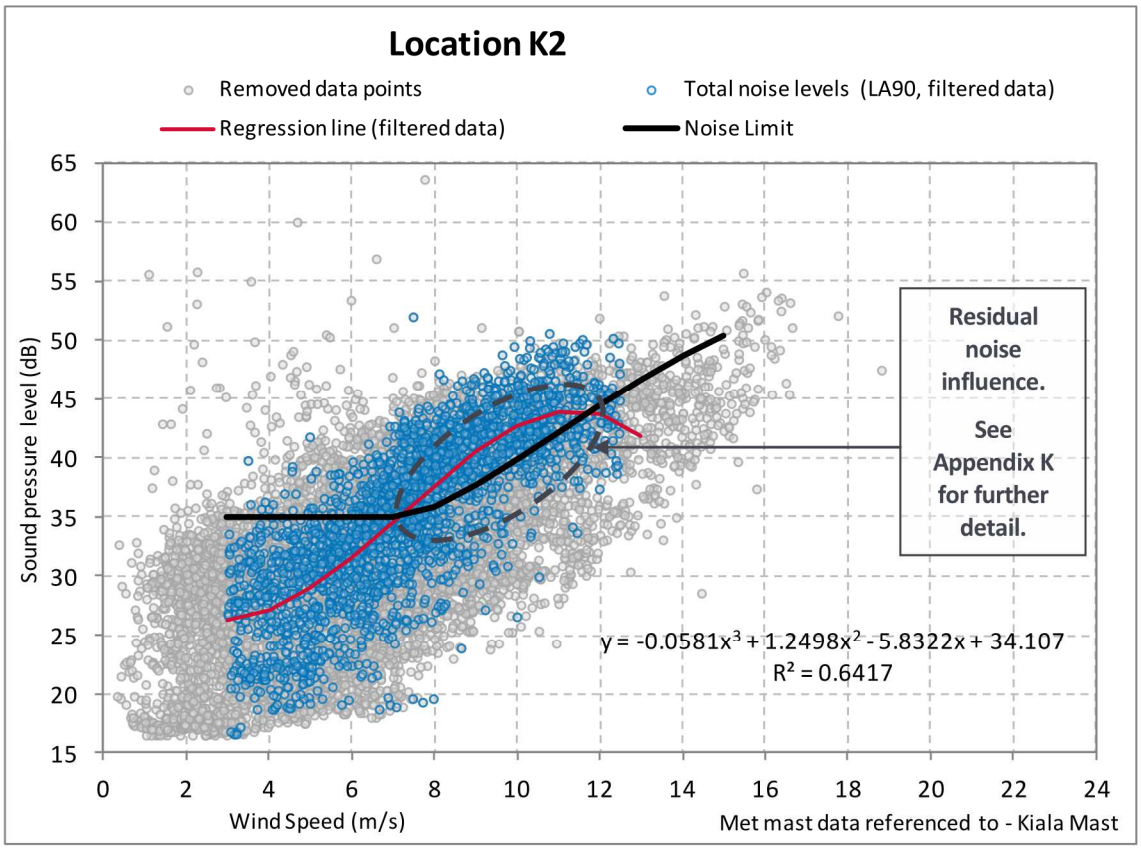


Figure 17: K2 Total noise level vs. wind speed

It can be seen from Figure 17 that the line of best fit to the total measured noise levels at property K2 lies below the wind farm limits for integer wind speeds below and including 7 m/s. At higher wind speeds the total measured noise levels are above the wind farm limits by 2 dB to 3 dB. Accordingly, further analysis has been required to establish the relative noise contribution of the wind farm and the residual sound environment.

A detailed analysis of noise levels across the wind speed range has demonstrated that the component of the noise data that lies above the limit curve is significantly influenced by extraneous noise. The results of this analysis provide a clear indication that the noise contribution attributable to the operation of the wind farm complies with the applicable limits. This analysis is based on consideration of a range of factors related to variations in noise levels with wind direction and wind speed, in addition to supplementary data obtained at an intermediate location between the wind farm and the monitoring location. Full details of the analysis are provided in Appendix M.

6.16 PW07

Table 26: Summary of parameters – PW07

Monitoring period	10.12.14 to 9.03.15
Sound Level Logging Device	DUO10418
Total number of data points collected	7636
Number of data points removed*	6614
Number of data points used for analysis (min 500 points required)	1020
Total measured noise level regression line of best fit R^2	0.27
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

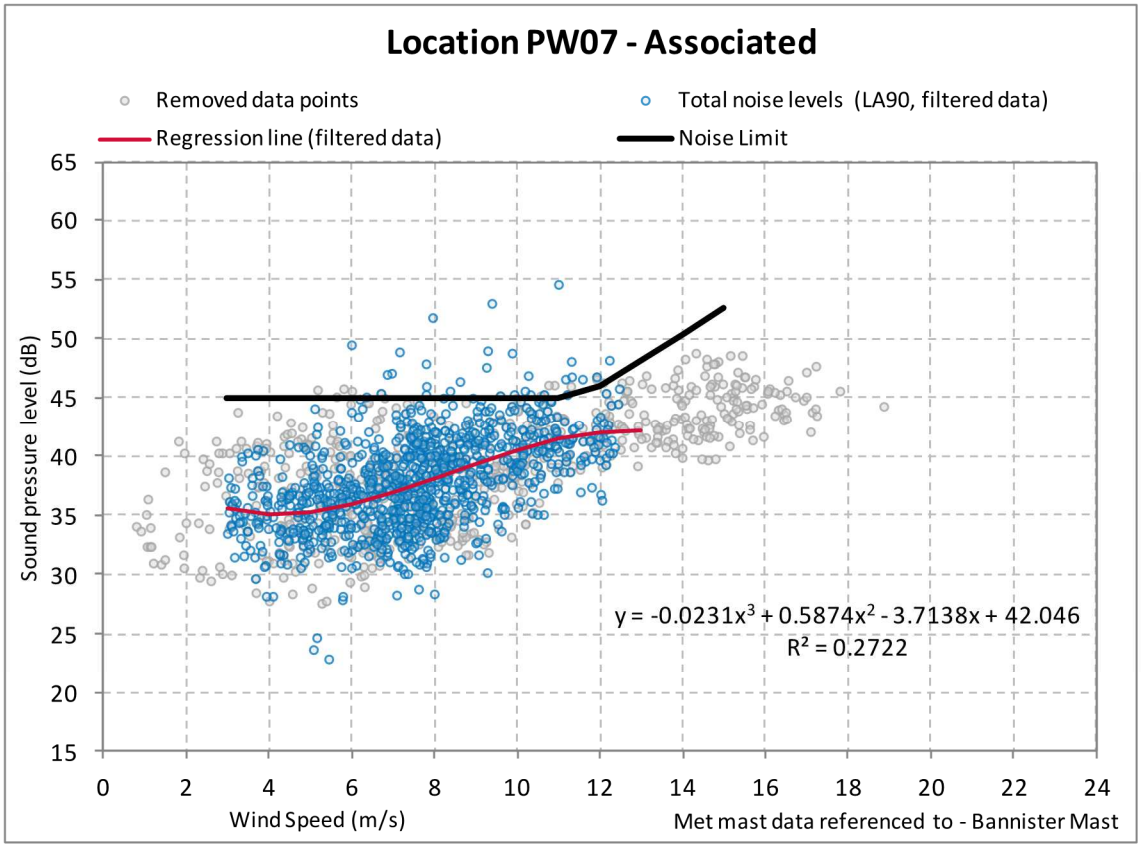


Figure 18: PW07 Total noise level vs. wind speed

It can be seen from Figure 18 that the line of best fit to the total measured noise levels at property PW07 lies below the wind farm limits between cut-in and rated power. The contribution of the wind farm to noise levels at PW07 therefore complies with the limits.

As detailed in Table 3, the noise limits at property PW07 are the basis of noise limits at selected neighbouring properties: PW05, PW29, PW34 and PW36. The total measured noise levels at property PW07 are considered sufficient to demonstrate that operational wind farm noise also satisfies the relevant noise limits at these four (4) properties. Refer to Appendix J for further details.

6.17 PW09

Table 27: Summary of parameters – PW09

Monitoring period	9.12.14 to 7.01.15 & 13.04.15 to 17.04.15
Sound Level Logging Device	DUO419 & DUO10499
Total number of data points collected	4734
Number of data points removed*	4154
Number of data points used for analysis (min 500 points required)	580
Total measured noise level regression line of best fit R^2	0.10
Regression order	3rd

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

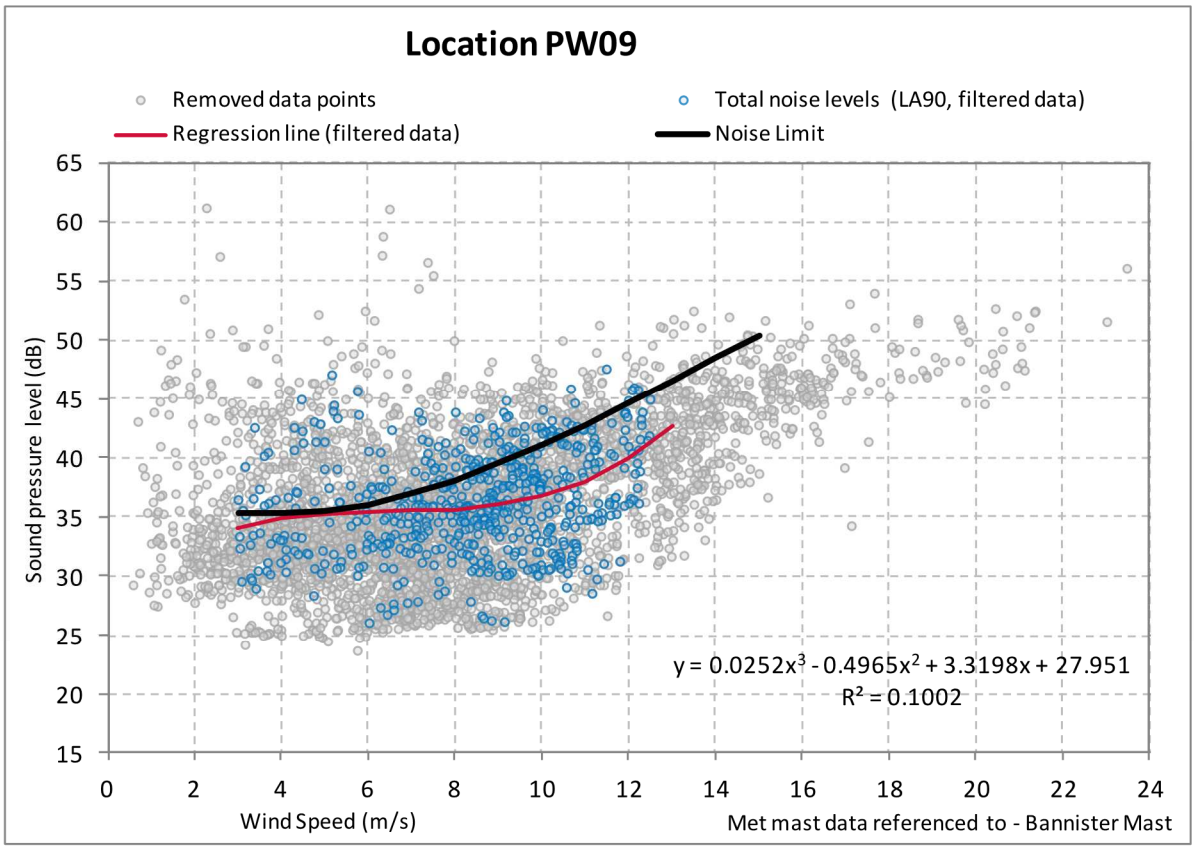


Figure 19: PW09 Total noise level vs. wind speed

The data in Figure 19 indicates significant variation in measured noise levels across the wind speed range. This variation is indicative of an environment that is significantly affected by local sources of extraneous noise. Notwithstanding this, it can be seen from that the line of best fit to the total measured noise levels at property PW09 lies below the wind farm limits between cut-in and rated power. The contribution of the wind farm to noise levels at PW09 therefore complies with the limits.

6.18 Discussion

The results presented in the preceding sections, in conjunction with the supplementary analysis presented in Appendix K to Appendix M, demonstrate that operational noise levels associated with the Gullen Range Wind Farm comply with the noise limits at all seventeen (17) locations where compliance monitoring was carried out.

A summary of results for the seventeen (17) locations is as follows:

- At fifteen (15) locations compliance is directly demonstrated by the measured total noise levels being at or below the limits at all assessable wind speeds
- At two (2) properties (B53 and K2) compliance has been demonstrated through a combination of detailed analysis and reference to supplementary data obtained at intermediate monitoring locations.

The collected noise data from the seventeen (17) monitoring locations specified in the Noise Compliance Plan has also been used as the basis for assessing compliance at twenty-four (24) related receivers identified in the RNA. Specifically, noise levels for the additional twenty-four (24) related receivers have been conservatively estimated using a combination of measurement data and, where necessary, adjustments for the predicted difference in wind farm noise levels at the monitoring locations and related receivers. Based on the analysis and interpretation of the data as detailed in Appendix N, the results support that wind farm noise levels are compliant with the applicable limits at the related receiver locations. Notably at the majority of sites located further from the wind farm than the monitoring locations compliance is able to be demonstrated on the basis of a simple, conservative comparison of directly measured total noise levels with the applicable limits.

In addition to the above, item (a) from Condition 2.21 of the Project Approvals requires:

> *…an assessment of the performance of the project against the noise predictions contained in conditions 2.15 and 2.16*

Predicted levels of noise from the Gullen Range Wind Farm satisfying the requirements of Conditions 2.15 and 2.16 are detailed in the RNA which concludes that the predicted levels for "…the proposed turbine models and layout of the Gullen Range wind farms is expected to comply with the requirements of Project Approval condition 2.15." Similarly, the assessment of operational wind farm noise detailed above for seventeen (17) monitoring locations demonstrates compliance with the relevant noise limits that are documented in the RNA. In this context, the results of this assessment of operational wind farm noise are consistent with the noise predictions referred to in Condition 2.21.

7.0 ANNOYING CHARACTERISTICS

7.1 Listening studies

Listening studies have been carried out at each of the seventeen (17) assessment locations to subjectively evaluate the presence of audible characteristics in wind farm sound. While the scope of these studies is to identify any unique and potentially annoying characteristics of wind farm sound, particular attention was given to assessing the potential presence of tonality, amplitude modulation, low frequency noise and impulsiveness.

The listening studies were conducted during five (5) visits to site for placement and retrieval of the noise monitors. At least one experienced acoustic consultant was on-site for each assessment. For each study a form was completed to document the wind conditions, general noise environment and any potential noise characteristics which were identified as originating from the turbines. Additionally, audio recordings were taken during each assessment as a record of the observed sound environment and to enable objective assessment works if necessary.

The Noise Compliance Plan nominates four (4) listening studies for each monitoring location with a duration of at least 10 minutes, equating to sixty eight (68) studies in total. Across the five (5) visits to site during the monitoring campaign, it was possible to carry out sixty-eight (68) listening studies, covering a range of times of day, wind speeds and directions.

7.2 Results

The results of the subjective assessments are summarised in Table 28 below. Further details of the assessments are provided in Appendix O including the weather conditions during each listening test and comments regarding the ambient noise environment and the character of the wind farm sound.

Table 28: Summary of listening studies

Property	No. of assessments	Objective assessment required?	Adjustment for annoying characteristics?
B8	4	yes (tonality)	no
B11	4	no	no
B12a	5	no	no
B13	4	yes (tonality)	no
B18	4	no	no
B26	4	no	no
B27	3	no	no
B29	4	no	no
B33	4	no	no
B53	4	no	no
G31	4	no	no
G37	4	yes (tonality)	no
G39	4	no	no
PW07	4	no	no
PW09	4	no	no
K1	4	no	no
K2	4	no	no

The majority of the listening studies, sixty-four (64) out of sixty-eight (68), did not indicate the presence of any annoying characteristics requiring further assessment.

In four (4) instances across February and May 2015, relating to three (3) separate monitoring locations, tonality was identified and deemed to warrant further analysis. In accordance with the Project Approval and Noise Compliance Plan, tonal audibility levels have been calculated for each of these four (4) instances using IEC 61400-11[11]. This assessment and the associated outcomes are documented in Appendix P. For these instances, the combined results of measurements, listening studies and objective analysis in accordance with the Noise Compliance Plan are considered to demonstrate that tonality is not a determining factor in the assessment of the wind farm's compliance.

As no other annoying characteristics were subjectively identified during the listening studies, the results of testing in accordance with the Noise Compliance Plan demonstrate that an adjustment for annoying characteristics is not applicable.

[11] IEC 61400 *Wind turbines – Part 11: Acoustic noise measurement techniques* (2012)

8.0 CONCLUSION

As required by Project Approval document S07/00846, operational wind farm noise monitoring has been carried out in the vicinity of the Gullen Range Wind Farm as specified in the Noise Compliance Plan prepared in accordance with Condition 2.21 of the Project Approval.

Based on measurements, listening studies and analysis conducted for the period 9 December 2014 to 24 June 2015 it has been concluded that the project complies with the noise requirements outlined in Conditions 2.15, 2.19 and 2.20 of the Project Approval.

Specifically the following outcomes are noted:

- Compliance has been demonstrated at seventeen (17) locations where the Noise Compliance Plan specified a requirement to conduct monitoring
- The results of sixty-eight (68) listening studies distributed across the seventeen (17) monitoring locations, in combination with objective analysis where required, demonstrate that annoying characteristics as defined by the Project Approval and Noise Compliance Plan are not a feature of the wind farm. Accordingly, adjustments relating to annoying characteristics were not deemed to be applicable.
- Analysis of the measurement results enabled noise levels to be estimated for an additional twenty-four (24) locations defined as related receivers, and demonstrated compliance with the applicable limits

In addition to the above, the results of the noise monitoring are consistent with the findings of the Revised Noise Assessment prepared in accordance with Condition 2.16 of the Project Approval. This outcome supports that compliance is therefore also expected to be achieved at the much broader range of locations identified and considered in the Revised Noise Assessment.

APPENDIX A ACOUSTIC TERMINOLOGY

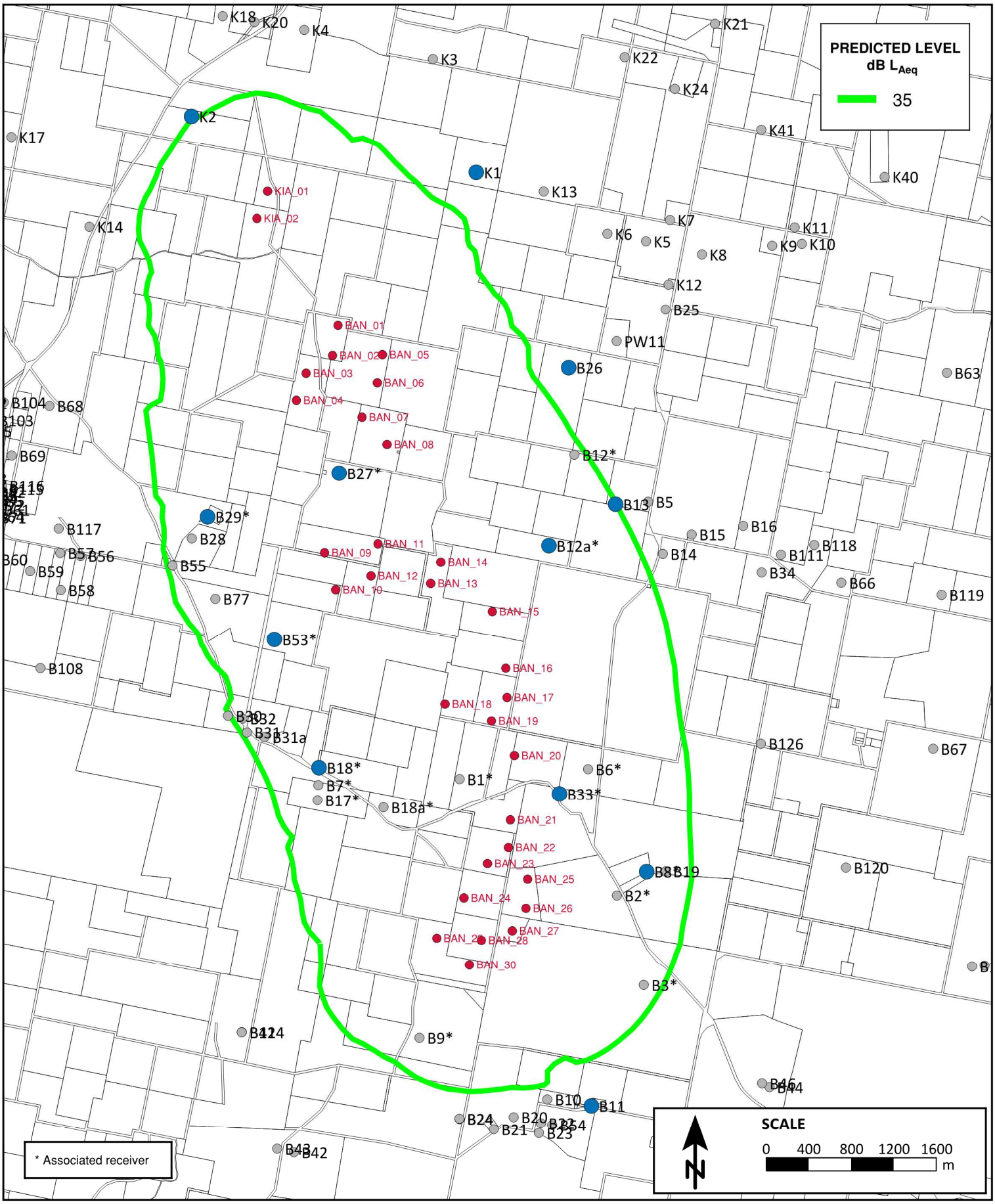
Ambient noise	The total, encompassing sound.
Frequency	Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals. Sound is generally described over the frequency range from 63Hz to 4000Hz (4kHz). This is roughly equal to the range of frequencies on a piano.
Hertz (Hz)	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
Octave Band	A range of frequencies where the highest frequency included is twice the lowest frequency. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.
Residual noise	The total, encompassing sound without the sound of interest.
Sound Pressure Level (L_P)	A logarithmic ratio of a sound pressure measured at distance, relative to the threshold of hearing (20 µPa RMS) and expressed in decibels.
dB	Decibel. The unit of sound level.
A-weighting	The A-weighting approximates the response of the human ear
L_{Aeq}	The equivalent continuous (time-averaged) A-weighted sound level. This is commonly referred to as the average noise level.

Noise is often not steady. Traffic noise, music noise and the barking of dogs are all examples of noises that vary over time. When such noises are measured, the noise level can be expressed as an average level, or as a statistical measure, such as the level exceeded for 90% of the time.

L_{A90}	The A-weighted noise level equalled or exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.

APPENDIX B SITE LAYOUT

B1 Site map



LEGEND

- Receiver
- Turbine
- Monitoring location

Project: Gullen Range Windfarm Noise Commissioning

Project number: 2014544SY

Client name: New Gullen Range Wind Farm

Version: SoundPLAN 7.3

Prediction method: ISO9613-2:1996

Model number: 16

Run number: 200

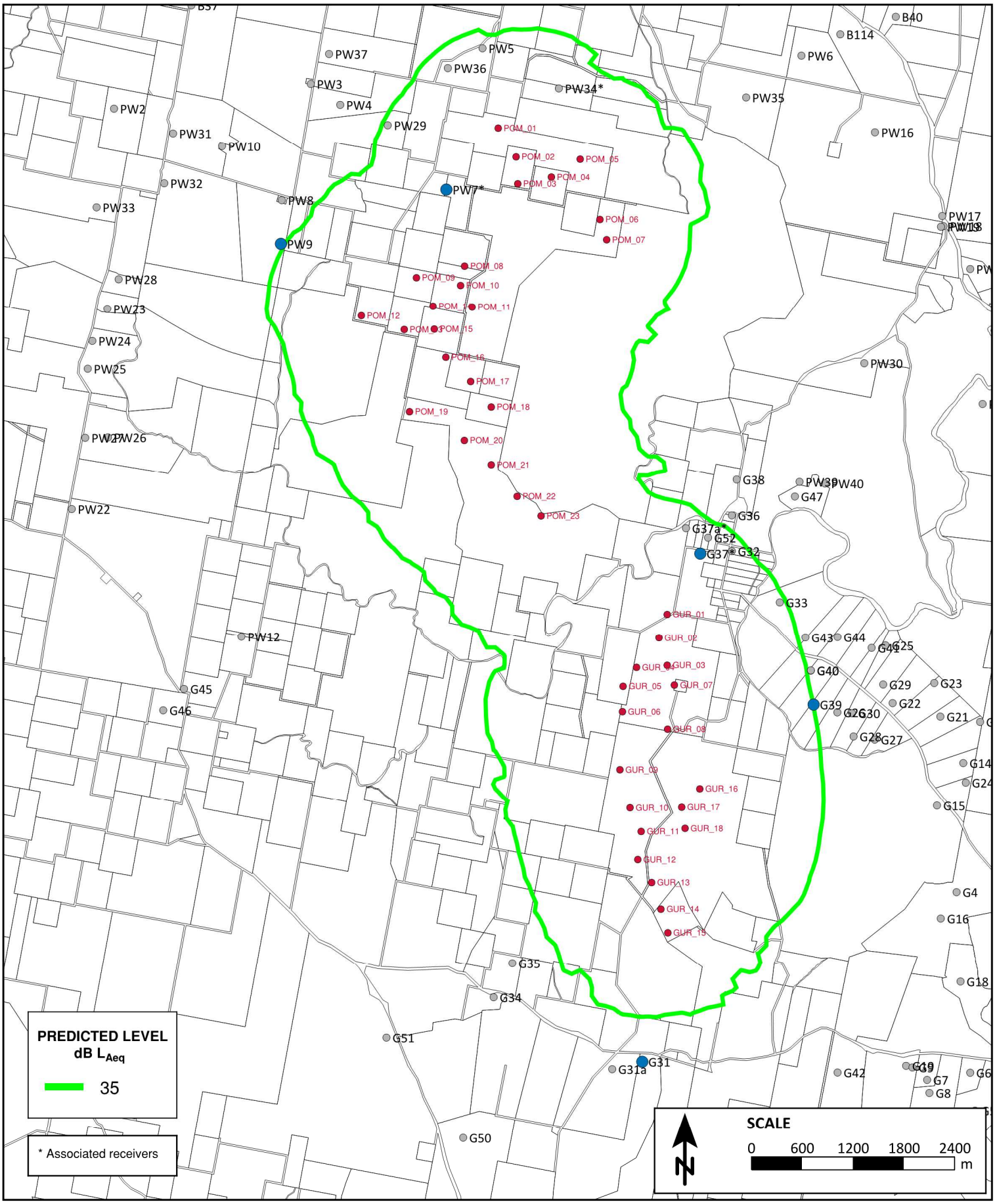
File: Gullen north section-cadastral - Monitoring locatio

Prediction Height: 1.5 m

35dB LAeq contour at 11m/s (hub-height)

Gullen Range Wind Farm: North Section

MARSHALL DAY Acoustics



LEGEND

- Receiver
- Turbine
- Monitoring location

Project: Gullen Range Windfarm Noise Commissioning

Project number: 2014544SY

Client name: New Gullen Range Wind Farm

Version: SoundPLAN 7.3

Prediction method: ISO9613-2:1996

Model number: 16

Run number: 200

File: Gullen south section-cadastral - Monitoring locatio

Prediction Height: 1.5 m

35dB LAeq contour at 11m/s (hub-height)

Gullen Range Wind Farm: South Section

MARSHALL DAY Acoustics

B2 Turbine coordinates (GDA94 Zone 55)

Turbine	Model	Hub Height	Easting	Northing
BAN_01	GW100-2500	80	722867	6177000
BAN_02	GW100-2500	80	722816	6176718
BAN_03	GW100-2500	80	722567	6176552
BAN_04	GW100-2500	80	722477	6176299
BAN_05	GW100-2500	80	723284	6176726
BAN_06	GW100-2500	80	723235	6176463
BAN_07	GW100-2500	80	723092	6176141
BAN_08	GW100-2500	80	723327	6175886
BAN_09	GW100-2500	80	722740	6174867
BAN_10	GW100-2500	80	722846	6174519
BAN_11	GW100-2500	80	723242	6174950
BAN_12	GW100-2500	80	723177	6174649
BAN_13	GW100-2500	80	723736	6174579
BAN_14	GW100-2500	80	723832	6174779
BAN_15	GW100-2500	80	724314	6174314
BAN_16	GW100-2500	80	724441	6173780
BAN_17	GW100-2500	80	724453	6173505
BAN_18	GW100-2500	80	723870	6173444
BAN_19	GW82-1500	85	724307	6173286
BAN_20	GW82-1500	85	724521	6172964
BAN_21	GW82-1500	85	724485	6172357
BAN_22	GW82-1500	85	724466	6172100
BAN_23	GW82-1500	85	724269	6171949
BAN_24	GW82-1500	85	724049	6171628
BAN_25	GW100-2500	80	724647	6171804
BAN_26	GW100-2500	80	724630	6171532
BAN_27	GW82-1500	85	724502	6171321
BAN_28	GW100-2500	80	724213	6171232
BAN_29	GW82-1500	85	723793	6171252
BAN_30	GW82-1500	85	724099	6171000
GUR_01	GW100-2500	80	727827	6161200
GUR_02	GW100-2500	80	727730	6160921

Turbine	Model	Hub Height	Easting	Northing
GUR_03	GW82-1500	85	727826	6160598
GUR_04	GW82-1500	85	727464	6160571
GUR_05	GW82-1500	85	727307	6160350
GUR_06	GW100-2500	80	727298	6160051
GUR_07	GW82-1500	85	727912	6160363
GUR_08	GW100-2500	80	727832	6159846
GUR_09	GW100-2500	80	727269	6159369
GUR_10	GW100-2500	80	727389	6158918
GUR_11	GW100-2500	80	727520	6158639
GUR_12	GW100-2500	80	727479	6158308
GUR_13	GW100-2500	80	727642	6158039
GUR_14	GW100-2500	80	727753	6157727
GUR_15	GW100-2500	80	727834	6157450
GUR_16	GW100-2500	80	728211	6159145
GUR_17	GW100-2500	80	727997	6158925
GUR_18	GW100-2500	80	728036	6158675
KIA_01	GW100-2500	80	722206	6178258
KIA_02	GW100-2500	80	722106	6178003
POM_01	GW100-2500	80	725833	6166934
POM_02	GW100-2500	80	726044	6166594
POM_03	GW100-2500	80	726063	6166277
POM_04	GW100-2500	80	726461	6166355
POM_05	GW100-2500	80	726800	6166565
POM_06	GW100-2500	80	727033	6165858
POM_07	GW100-2500	80	727112	6165618
POM_08	GW82-1500	85	725438	6165310
POM_09	GW82-1500	85	724870	6165173
POM_10	GW82-1500	85	725390	6165082
POM_11	GW82-1500	85	725525	6164826
POM_12	GW100-2500	80	724220	6164723
POM_13	GW100-2500	80	724725	6164560
POM_14	GW82-1500	85	725064	6164835
POM_15	GW100-2500	80	725079	6164566

Turbine	Model	Hub Height	Easting	Northing
POM_16	GW100-2500	80	725216	6164233
POM_17	GW100-2500	80	725509	6163949
POM_18	GW100-2500	80	725752	6163649
POM_19	GW100-2500	80	724788	6163595
POM_20	GW100-2500	80	725434	6163257
POM_21	GW100-2500	80	725752	6162969
POM_22	GW100-2500	80	726057	6162593
POM_23	GW100-2500	80	726339	6162361

B3 Property coordinates (GDA94 Zone 55)

Table 29:Monitoring locations

Property	Easting	Northing
B8*	725764	6171873
B11	725245	6169673
B12a*	724847	6174932
B13	725472	6175320
B18*	722690	6172850
B26	725032	6176603
B27*	722879	6175614
B29*	721644	6175203
B33*	724946	6172602
B53*	722272	6174050
G31	727533	6155921
G37*	728219	6161915
G39	729555	6160133
KI	724165	6178433
K2	721493	6178960
PW7*	725225	6166206
PW9	723273	6165569

* Associated Receiver

Table 30: Related receivers

Property	Easting	Northing
B2*	725485	6171650
B3*	725737	6170809
B19	725942	6171875
B9*	723633	6170313
B1*	724008	6172742
B7*	722684	6172685
B17*	722675	6172543
B18a*	723294	6172476
B31	722012	6173179
B31a	722179	6173136
B32	721971	6173309
B12*	725086	6175790
B28	721496	6174999
B55	721314	6174747
B6*	725214	6172835
B77	721717	6174433
G32	728590	6161946
G33	729155	6161340
G37a*	728049	6162215
G52	728309	6162105
PW5	725649	6167872
PW29	724533	6166968
PW34*	726550	6167402
PW36	725240	6167640

* Associated Receiver

APPENDIX C PROJECT APPROVAL

C1 Operational Noise Criteria

2.15 Subject to conditions 2.15 to 2.20 the Proponent shall design, operate and maintain the project to ensure that the equivalent noise level ($L_{Aeq\ (10\text{-}minute)}$)from the project does not exceed at each of the residential receiver locations identified in Section 5 of the Noise Impact Assessment prepared by Marshall Day Acoustics, dated 5 June 2008 (Section 3.2 of EA Attachments), or any other relevant receiver in existence or the subject of a valid development consent at the date of this approval:

a) 35 dB(A); or

b) the existing background noise level ($L_{A90\ (10minute)}$) correlated to the integer wind speed at hub height at the wind farm site by more than 5 dB(A)

*whichever is the greater, for each integer wind speed (measured at hub height) from cut-in to rated power of the wind turbine generator, when determined in accordance with the methodology provided in the Wind Farms: Environmental Noise Guidelines (SA EPA, 2003) ('**SA Guidelines 2003**').*

2.16 The Proponent shall prepare a revised Noise Assessment for the final turbine model and turbine layout selected, which shall be submitted to the director-General prior to commissioning of the wind turbines. The assessment shall demonstrate consistency with the EA and the ability of the final turbine model and layout to meet the requirements of condition 2.15. The revised Noise Assessment shall include the following:

a) noise predictions of the final turbine model and layout selected at each of the receiver locations;

b) method and modelling inputs employed to carry out the noise level predictions according to the SA Guidelines 2003 except that all sounds power levels and wind speeds shall be referenced to hub height;

c) an assessment of the suitability of background noise level data to cover the range of wind speeds and directions generally expected at the site; and

d) noise predictions shall be conducted by an acoustic engineer defined for the purposes of this condition as an engineer who is eligible for membership of both the Australian Acoustical Society and the institution of Engineers Australia.

2.17 Where noise predictions are found to exceed the limits specified in condition 2.15 the Proponent shall develop and implement a Noise Operating Strategy that identifies specific methods of noise reductions to restore the levels back to the limits in Condition 2.15 at any receiver location for all wind directions including worst case-scenarios. The strategy shall include noise modelling verification that demonstrates the predicted noise reductions can be achieved.

2.18 Noise from the project is to be measured at the most affected point within the residential boundary, or at the most affected point within 20 metres of the dwelling, where the dwelling is more than 20 metres from the boundary, to determine compliance with the noise level limits in conditions 2.15 and 2.16. Under this Condition "dwelling" means one in existence or the subject of a valid development consent at the date of this approval.

2.19 For the purposes of conditions 2.15 and 2.16 of this approval, 5 dB(A) shall be applied to measured noise levels where tonality is present. The presence of tonality shall be determined using the methodology detailed in Wind Turbine Generator Systems- Part 11: Acoustic Noise Measurement Techniques IEC 61400-11:2002 or its latest edition.

2.20 Notwithstanding conditions 2.15 and 2.16 of this approval, the noise limits specified under those conditions do not apply to any residence where a noise agreement is in place between the Proponent and the respective owner(s) of those residences in relation to noise impacts and/or noise limits. For this condition to take effect, the noise agreements shall satisfy the requirements of Guidelines for Community Noise (WHO, 1999) and Section 2.3 of the SA Guidelines 2003.

C2 Verification of Operational Noise Performance

2.21 The Proponent shall prepare a Noise Compliance Plan which shall be submitted to the Director-General prior to commissioning of the wind turbines. The Noise Compliance Plan shall include, but not be limited to:

a) an assessment of the performance of the project against the noise predictions contained in conditions 2.15 and 2.16;

b) a commitment to operate the Project in accordance with any Noise Operating Strategy that is implemented in accordance with condition 2.17;

c) a commitment that noise compliance monitoring will be undertaken within three months of the commissioning of the wind turbines. If prevailing meteorological conditions do not allow the required monitoring to be undertaken in this period, the Director-General shall be notified and an extension of time may be sought; and

d) a requirement that all noise compliance monitoring results are submitted to the Director-General within one month of completion of the monitoring. The director-General may request that additional noise compliance monitoring be undertaken and completed within a specified timeframe.

The Noise Compliance Assessment shall be undertaken generally in accordance with the procedures presented in SA Guidelines 2003, except that all sounds power levels and wind speeds shall be referenced to hub height.

2.22 In the event that the Noise Compliance Plan indicates that noise from the wind turbines exceeds the noise limits specified under conditions 2.15 and 2.16, as relevant, the Proponent shall investigate and propose mitigation and management measures to achieve compliance with the noise limits. Details of the remedial measures and a timetable for implementation must be submitted to the Director-General for approval within such period as the Director-General may require. Remedial measures shall include, in the first instance, all reasonable and feasible measures to reduce noise from the project, including but not necessarily limited to reduced operation of wind turbines. Once all reasonable and feasible source controls are exhausted, remedial measures may include offering building acoustic treatments and/or noise screening to affected residences, but may only be used to address noise limit exceedances at the absolute discretion of the relevant landowner. The Proponent shall also demonstrate that the relevant landowner/resident has been made fully aware of the noise and other implications of making any agreement.

If there is no such agreement with the relevant landowner then the turbine(s) causing the exceedance(s) of the noise limits must be turned off until the turbine(s) can be operated in accordance with this approval.

2.23 The Proponent shall provide written notice to all landowners that are entitled to rights under condition 2.22 within 21 days of determining the landholdings to which these rights apply. For the purpose of condition 2.22, this condition only applies where operational noise levels have been confirmed in accordance with the conditions 2.15 and 2.16.

2.24 The Proponent shall bear the costs of any additional at-receiver mitigation measures implemented at an affected landowner or property.

APPENDIX D COMPLIANCE MONITORING PROCEDURE CLARIFICATIONS

The relevant technical clarifications from MDA's method statement Mm 002 2014544SY Gullen Range Wind Farm - *Noise Level Analysis Method Statement* (Memo) dated 4 December 2014, have been reproduced below.

MINIMUM DATA REQUIREMENTS

The Noise Compliance Plan provides the following comments concerning the capture of sufficient data during the measurements:

> *It is noted that to comply with the SA Guidelines 2003 a minimum of 2000 10-minute sound pressure level vs wind speed data points are required to be analysed for the worst case wind direction for each assessment location.*
>
> *The worst case wind direction refers to the scenario where the wind direction is +/- 45 degrees from the direction that places the receptor directly downwind of the nearest wind turbines. However, it may not be practical to obtain 2000 data points for the worst case direction if the prevailing winds are such that the noise monitoring location is generally upwind of the wind farm. The current (2009) version of the SA Guidelines recognises this and clarifies that the analysis requires 2000 data points in total, of which 500 must be for the worst case wind direction. Accordingly, it is proposed that 500 data points in the worst case direction would be considered sufficient for the purpose of the noise compliance monitoring.*

We consider that there is a degree of ambiguity concerning the amount of data to be included in the commissioning analysis. For clarity, our proposed approach is itemised as follows:

- A minimum of 2000 data points should be collected during noise measurements at each monitoring location
- Data collected during wind directions of +/- 45° from the bearing of the nearest turbine to the receiver is generally considered downwind. In some cases, a broader range of wind directions may be necessary to account for the noise levels contribution from all relevant nearby turbines. The need for a broader range of direction would be evaluated case by case.
- It is important that the measurements capture a representative amount of data under nominally worst case conditions, where the wind direction is from the wind farm to the receptor. As a minimum, the measurements should include at least 500 data points that are downwind from the wind farm, consistent with approach documented in the SA Guidelines 2009. Collecting 500 data points down wind is generally considered sufficient to carry out an analysis of wind farm noise levels.
- As a secondary target, measurements should aim to include 2000 data points that are downwind from the wind farm, consistent with approach documented in the SA Guidelines 2003. If 2000 data points are not able to be collected, analysis of wind farm noise levels would be carried out using the down wind data that is available (that is, a minimum of 500 data points as noted above)
- Data analysis will include determining a regression curve for measured noise levels. This analysis would be carried out using down wind data points only. The 'down wind' regression curve would be compared with the applicable noise limit to assess compliance.
- In circumstances where correction of the regression curve is necessary to estimate the influence of ambient noise sources, the level of ambient noise would be quantified using a regression curve from downwind data measured prior to the construction of the wind farm (refer to the next section for further details regarding this issue).

BACKGROUND NOISE CORRECTION

Recommended approach

Section 11.4 of the Noise Compliance Plan notes:

> *Where adequate monitoring of the Wind Farm noise cannot be undertaken at one or more of the above locations due to either background noise influences or the landowner not granting approval, then the Acoustic Engineer shall determine if the affected location may be excluded from the monitoring programme (due to the results of the noise monitoring at the other locations providing satisfactory evidence of noise compliance), or if noise monitoring at an alternative location is necessary to satisfactorily demonstrate compliance.*

As alluded to by these remarks, background noise from ambient sources other than the wind farm can, in some cases, significantly influence measured data. For example, in some cases results of unattended monitoring can exceed applicable noise limits due to extraneous noise. In these circumstances, it can be difficult to demonstrate compliance with applicable limits even when the contribution of wind farm noise is well below the limits.

We propose the following assessment process for addressing the potential influence of extraneous noise during the unattended noise commissioning works at GRWF:

1. Determine an appropriate noise level regression curve for each assessment location, using data collected during the unattended noise commissioning measurements
2. Compare these regression curve levels with applicable noise limits at each integer wind speed
3. If the regression curve levels satisfy the applicable noise limit, compliance is demonstrated and no further works are required
4. If regression curve levels exceed applicable noise limits for some integer wind speeds, the excess could be due to either wind farm noise or other ambient noise sources. Additional assessment work is therefore required to determine whether compliance is demonstrated
5. If recent pre-construction background noise level data is available (in this case, less than two to three years old) which is relevant to the assessment location, this data would be used to calculated estimated wind farm noise levels using the process outlined in the subsequent subsection
6. If estimated wind farm noise levels satisfy applicable noise limits, compliance is demonstrated and no further works are required
7. If estimated wind farm noise levels exceed applicable noise limits or, alternatively, if appropriate pre-construction background noise level data is unavailable meaning estimated wind farm noise levels cannot be calculated then additional assessment work would be required to determine whether compliance can be demonstrated. The specific nature of the assessment works required would vary case-by-case, but may involve additional measurements and site assessment.

APPENDIX E NOISE MONITORING LOCATIONS

All photos are tiled in a clockwise direction looking North, East, South, & West respectively.

The final section of this appendix presents a tabular summary of the positioning of noise monitoring equipment for this assessment of operational wind farm noise relative to the monitoring positions used for the pre-construction noise measurements detailed in the RNA.

E1 B8

E2 B11

E3 B12a

E4 B13

E5 B18

E6 B26

E7 B27

E8 B29

E9 B33

E10 B53

E11 G31

E12 G37

E13 G39

E14 K1

E15 K2

E16 PW7

E17 PW9

E18 Summary of monitoring positions

Table 31 provides a summary of the positioning of noise monitoring equipment for this assessment of operational wind farm noise relative to the monitoring positions used for the pre-construction noise measurements detailed in the RNA.

Table 31: Notes outlining changes in monitoring position for the assessment of operational wind farm noise

Property	Equipment position		Measurement position is the same as used previously?*	Approximate change in position (m)	Comment
	Easting	Northing			
B8	725754	6171841	-	5	Original position not available due to flora growth.
B11	725239	6169702	-	5	Original position not available due to flora growth.
B12a	724827	6174890	-	25	Original measurement position was chosen before the dwelling was built and is not considered representative of the final dwelling location
B13	725432	6175344	-	25	Original position not available due to flora growth. The nearest appropriate measurement position has chosen to the north west of the dwelling.
B18	722705	6172886	✓	-	-
B26	725003	6176613	-	10	Original position not available due to flora growth. The nearest appropriate measurement position was chosen.
B27	722835	6175608	✓	-	-
B29	721663	6175195	✓	-	-
B33	724938	6172625	-	25	Original position unavailable due to flora growth. The nearest appropriate location was chosen for commissioning measurements.
B53	722296	6174050	✓	-	-
G31	727570	6155937	✓	-	-
G37	728209	6161956	-	30	Original position is considered to be partially shielded from some turbines by the dwelling. The nearest appropriate measurement position was chosen west of the dwelling.
G39	729542	6160135	✓	-	-
K1	724161	6178420	5	5	Original position unavailable due to flora growth. The nearest appropriate measurements position was chosen.

Property	Equipment position		Measurement position is the same as used previously?*	Approximate change in position (m)	Comment
	Easting	Northing			
K2	721509	6178922	40	40	Original position unavailable due to flora. The nearest appropriate location was chosen for commissioning monitoring.
PW7	725264	6166197	-	20	Following discussions with the owner, the nearest appropriate measurement position was chosen east of the dwelling, facing the nearest relevant turbines.
PW9	723298	6165533	✓	-	-

* The measurement position for the current study is within ±3m of the position used for pre-construction noise measurements as detailed in the RNA.

APPENDIX F MEASUREMENT EQUIPMENT

F1 Details of equipment used during the measurement campaign

Table 32: Details of measurement equipment

Equipment	Monitoring location	Make	Model	Serial number
Sound level meter, with associated microphone and digital sound recorder	B8	01dB	DUO	10499
	B11	01dB	DUO	10388, 10394
	B12a	01dB	DUO	10498
	B13	01dB	DUO	10302
	B18	01dB	DUO	10194, 10392
	B26	01dB	DUO	10389, 10499
	B27	01dB	CUBE	10418
	B29	01dB	DUO	10392
	B33	01dB	DUO	10394
	B53	01dB	DUO	10499, 10391
	G31	01dB	DUO	10302
	G37	01dB	DUO	10417, 10194
	G39	01dB	DUO	10498
	K1	01dB	DUO	10391
	K2	01dB	DUO	10447, 10433
	PW7	01dB	DUO/CUBE	10194, 10418
	PW9	01dB	DUO	10419,10499
Weather Station		Vaisala	WXT520	K1850003
		Vaisala	WXT520	K1850005
Acoustic calibrator	Calibrator 1	01dB	Cal21	34924044
	Calibrator 2	01dB	Cal21	34134142

F2 Secondary wind shields

Secondary wind shield systems have been used for all noise measurements. The shields comprise:

- a proprietary inner foam wind shield, provided with the monitoring equipment
- a bespoke outer foam wind shield ,separated from the inner shield by approximately 30 mm.

These systems are designed to reduce the effect of wind generated noise over the microphone for the measurement of A-weighted noise levels in windy conditions. The design has been based on the recommendations detailed in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* dated May 2013.

The use of secondary wind shields has the potential to increase the insertion loss of the material around the microphone which, in turn, can affect measured sound levels. This aspect of the secondary wind shield systems has been investigated[12] with the following key outcomes:

- In comparison with the insertion loss of the proprietary wind shield, the relative insertion loss of the secondary wind shield system is negligible at the low and mid frequencies that are most relevant to the measurement of operational wind turbine noise.
- The relative insertion loss of the secondary wind shield system may result in a reduction in A-weighted noise levels in situations where higher frequency sounds represent a greater component of the ambient noise environment. These reductions are, however, marginal. In the context of wind farm noise commissioning, they are not expected to be significant as high frequency wind farm noise is more efficiently attenuated during propagation and is generally not a significant component of wind farm noise at typical Australasian residential separation distances.

The investigations also demonstrated significant benefits of the secondary wind shields for the control of wind induced noise at two (2) different field locations. In this context and for the study sites investigated, the measurement variation related to insertion loss could be considered negligible in comparison.

[12] Adcock, J., Delaire, C., Griffin, D., & Jiggins, M. (2015). Study of secondary wind shield performance in the field. *Wind Turbine Noise 2015.* Glasgow: INCE.

APPENDIX G RAINFALL ITENSITY DURING THE MONITORING CAMPAIGN

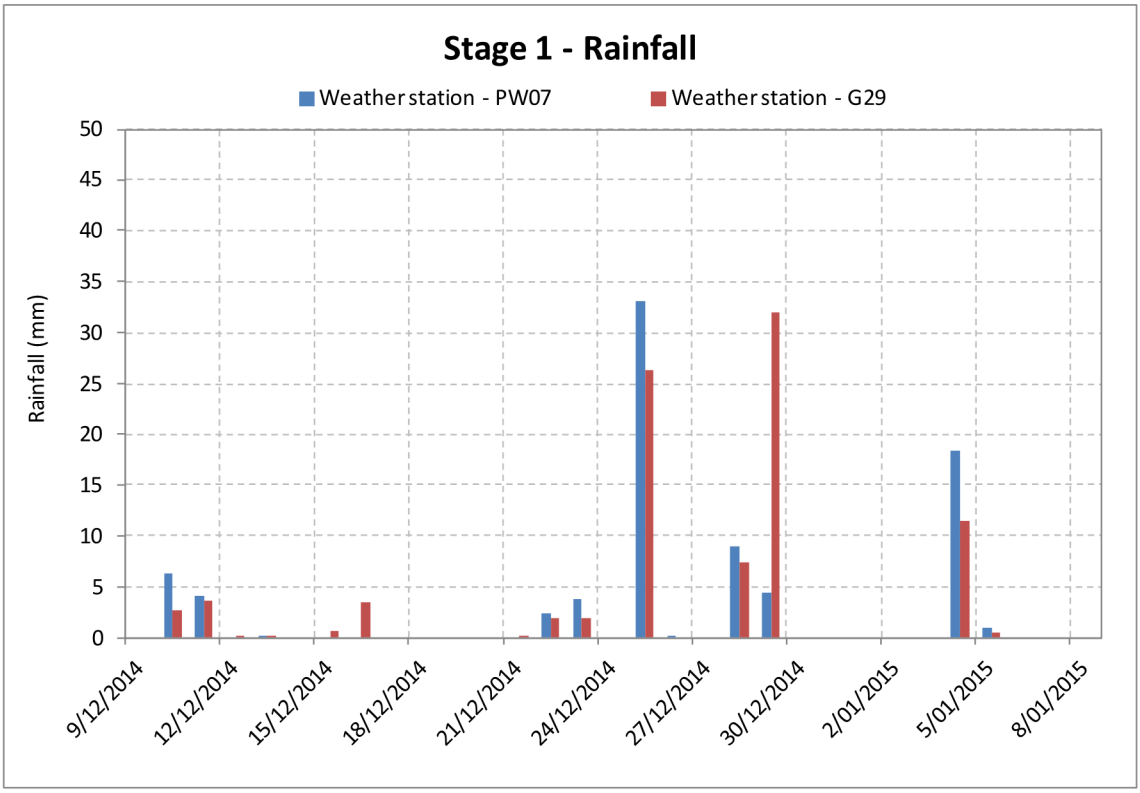


Figure 20: Stage 1 rainfall

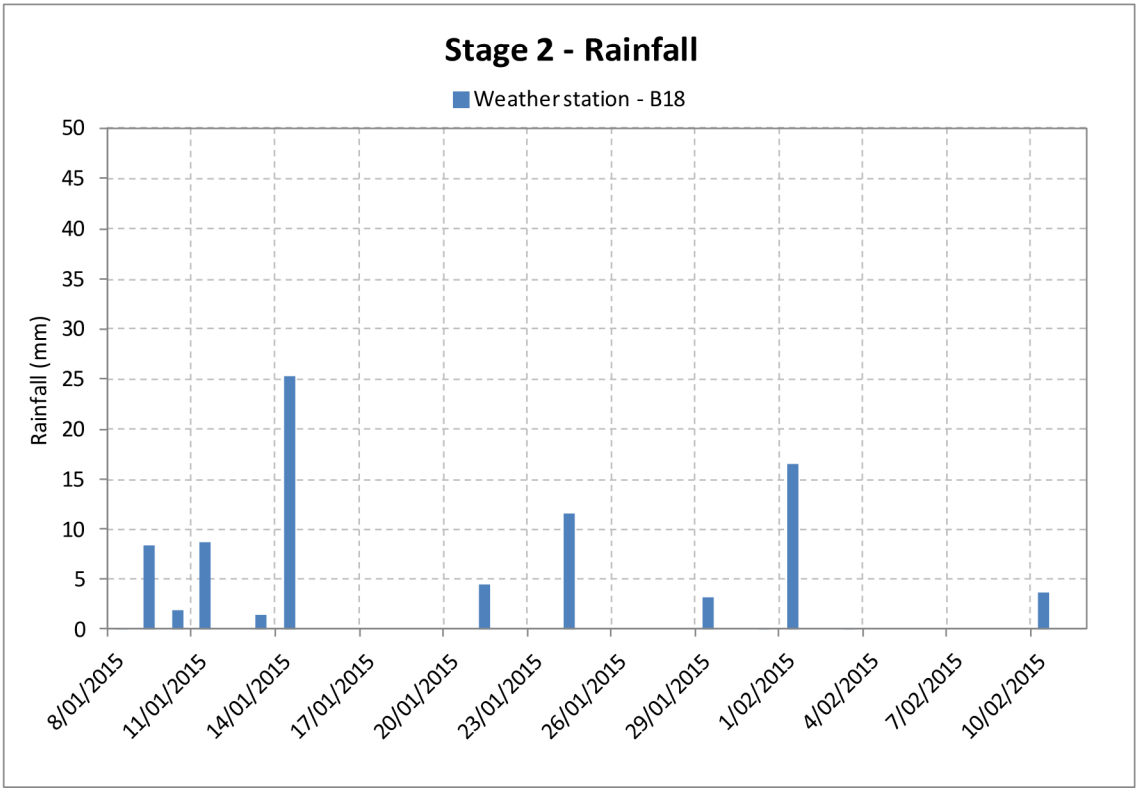


Figure 21: Stage 2 rainfall

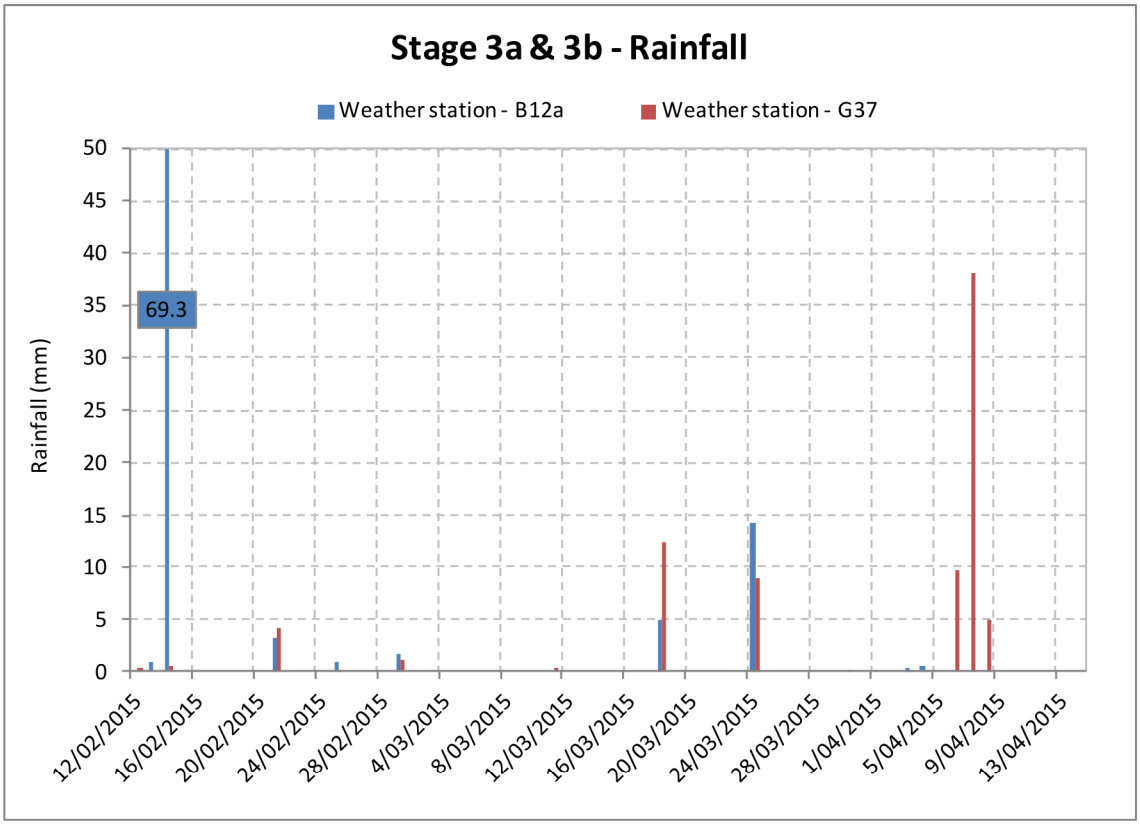


Figure 22: Stage 3a and 3b rainfall

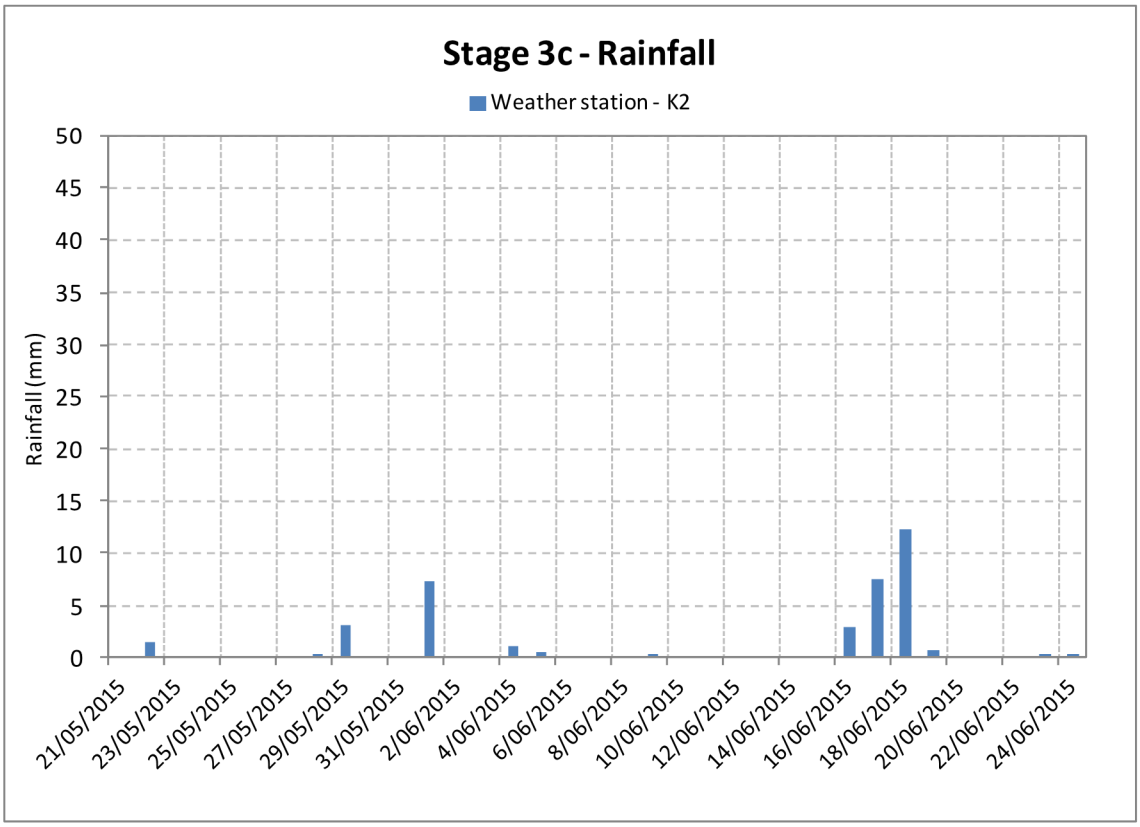


Figure 23: Stage 3c rainfall

APPENDIX H MET MAST CORRELATIONS

DNV·GL

Gullen Range Wind Farm
Level 3, 201 Elizabeth St
Sydney NSW 2000
Australia

DNV GL – Energy
Renewables Advisory
Suite 25, Level 8
401 Docklands Drive
Docklands
Victoria 3008
Tel: 03 9600-1993
Fax: 03 9602-1714
ABN 19 094 520 760

Date:	**Our reference:**	**Your reference:**
14/07/2015	170461-AUME-L-01-B	

Re: Preliminary Energy Results

Dear Tom Nielsen,

DNV GL has been commissioned by Gullen Range Wind Farm Pty Ltd ('the Client') to synthesise a time series of wind speed data at the three decommissioned pre-construction meteorological masts (Bannister, Gurrundah and Kialla) at the Gullen Wind Farm site over the 9 December 2014 to 25 June 2015 period.

The analysis involved performing correlations between the three decommissioned pre-construction masts outlined above and four currently operating meteorological masts (BAN010203, BAN2429, Met_KIA01 and Perm Met Mast 2). As the period of interest occurs after the construction of the wind farm, a methodology has been developed to minimise the effects of turbine wakes from the data recorded at these masts. As the measurement periods of all the masts do not coincide, intermediate correlations have been performed where necessary, as detailed below.

However, it is noted that it has not been possible to eliminate the use of wake affected data entirely, which increases the uncertainty associated with the final synthesised wind speed datasets.

The methodology employed to perform this task is outlined below and the resulting time series are provided in the attached '170461PC03 Gullen DeWaked Synthesised Time Series.txt' file.

Sincerely
for Garrad Hassan Pacific Pty Ltd

Jessica McMahon
Engineer
jessica.mcmahon@dnvgl.com

Trenton Gilbert
Senior Engineer
trenton.gilbert@dnvgl.com

1 METHODOLOGY

In order to synthesise data at the Bannister, Gurrundah and Kialla masts representing the 9 December 2014 to 25 June 2015 period, the following steps were undertaken:

- Correlation relationships by direction sector were established between wind speed data recorded at each of three permanent masts – BAN010203, BAN2429 and Met_KIA01 – and two of the pre-construction masts – Gurrundah and Bannister – for which there was overlap in the measurement periods. This overlapping period occurred prior to the commissioning of the Biala and Kiala wind turbines at the site and so it could be assumed that the data were not wake affected.
- Wind speed data recorded at Masts BAN010203, BAN2429, Met_KIA01 and Perm Met Mast 2 in the 9 December 2014 to 25 June 2015 period were adjusted to account for possible wake effects due to nearby turbines, using wake effects predicted by the DNV GL WindFarmer modelling software. This period occurred following commissioning of the Bannister and Kiala wind turbines and so was assumed to be wake affected.
- The correlation relationships established above were used to synthesise wind speed data representing the Gurrundah and Bannister masts at the measurement height of 65 m over the 9 December 2014 to 25 June 2015 period, from the wake-adjusted BAN010203, BAN2429 and Met_KIA01 datasets.
- Wind speed data was also synthesised at the Gurrundah and Bannister masts at the measurement height of 65 m from the wake-adjusted Perm Met Mast 2 wind speed data for the period, via an intermediate correlation between Perm Met Mast 2 and Mast BAN2429 over the 9 December 2014 to 25 June 2015 period.
- Wind speed data was synthesised at the Kialla mast at the measurement height of 10 m for the period from the wake-adjusted datasets recorded at the four permanent masts, via an intermediate correlation between the Bannister and Kialla masts.
- Directional wind speed ratios obtained from a wind shear analysis at the Gurrundah and Bannister masts were used to extrapolate the synthesised wind speed time series from measurement height to the specified hub height of 80 m.
- Directional wind speed ratios derived from a hub height time series developed by Epuron for the period from July 2007 to April 2008 for the Kiala mast (which included wind speeds at 80 m and 10 m), were used to extrapolate the synthesised wind speed time series at 10 m at the Kiala mast to the specified hub height of 80 m.
- By this method, wind speed datasets synthesised from the four permanent masts at each of the Gurrundah, Bannister and Kialla masts over the 9 December 2014 to 25 June 2015 period at a hub height of 80 m, were created.
- The four datasets were combined into a single dataset representing each mast. This was achieved by taking the average of all valid synthesised wind speed data from direction sectors not influenced by wake effects. Where data not affected by wake effects was not available, an average of the wake-adjusted data was taken.

2 RESULTS

The above analysis resulted in the creation of four synthesised time series at the Bannister, Gurrundah and Kialla masts over the 9 December 2014 to 25 June 2015 period.

As the data recorded at the four permanent masts over this period are influenced by wake effects from surrounding turbines, an attempt has been made to correct the wake-affected data and to selectively average synthesised data from the permanent masts in order to minimise the inclusion of wake-affected data in the final datasets. However, for some direction sectors it has not been possible to eliminate the use of data influenced by turbine wakes and the results are therefore dependent on wake-adjusted data derived from corrections obtained from the WindFarmer modelling software. There is uncertainty associated with the wake model implemented in WindFarmer and therefore there is uncertainty associated with the final wind data sets.

It should be noted that some of the correlations between masts were based on less than one year of data and therefore may be subject to seasonal biases. This increases the uncertainty associated with the resulting correlations and therefore the final wind data sets.

It should also be noted that data from each all of the currently operating masts used in the analysis did not extend to the end date of the period under consideration (25 June 2015). The end dates for the data from each of the masts used to generate the synthesised time series is specified below. The uncertainty associated with the wind speed time series may be increased in periods following the end date for each mast, as the likelihood of obtaining wake free measurements from at least one mast is reduced.

Mast	End Date
BAN010203	24 June 2015
BAN2429	6 May 2015
Met_KIA01	25 June 2015
Perm Met Mast 2	18 June 2015

APPENDIX I FILTERING FOR EXTRANEOUS NOISE

Extraneous noise can in some circumstances significantly affect noise measurements[13].

The SA Guidelines 2003 define extraneous noise as noise from animals, excessive wind effects, insects, birds, aircraft or unusual traffic conditions or any other infrequently occurring component of the ambient noise. In accordance with this definition measured one-third octave band levels have been used to identify data when extraneous noise, such as insects, may have significantly influenced the measurement period.

Periods are identified as being potentially influenced by extraneous noise when both of the following conditions are satisfied[14].

- the maximum one-third octave band A-weighted noise level (L_{A90}) for a given time interval is within 5 dB of the broadband A-weighted background noise level for that interval; and
- the identified one-third octave band A-weighted noise level (L_{A90}) is greater than a nominal minimum level, 20 dB.

Any data identified as being influenced by extraneous noise in this way has been excluded from the regression analysis.

It should however be noted that this filtering procedure has been adopted for the purpose of automated and preliminary filtering of large measurement datasets. The procedure is therefore adopted as a cautious process to remove periods affected by distinctive sources of extraneous noise. There will be many instances where extraneous noise sources significantly affect or dominate the measured noise levels, but will not be automatically identified and removed by this filtering process. Accordingly, the filtered dataset will still include periods in which the total measured noise levels are attributable to the combined influence of the residual noise environment and operation of the wind farm.

The amount of data identified as extraneous using this filtering method will vary from site to site on account of local factors influencing the ambient noise environment such as the influence of insect noise and the proximity to any domestic mechanical equipment. For the monitoring data collected as part of the current assessment, the filtering method has generally identified likely extraneous noise sources at high frequencies around 1 kHz and greater. This is broadly consistent with observations of the general ambient noise environment around the wind farm site that were made during the deployment and collection of noise monitoring equipment and also during the listening studies. In particular, significant high frequency extraneous noise was observed from insects and bird song. High frequency wind farm noise was not observed as a significant component of the ambient noise environment at noise monitoring locations.

[13] Delarie, C., Griffin, D., Adcock, J., & McArdle, S. (2013). Wind farm noise commissioning methods: A review of methods based on measuring at receiver locations. *Fifth International Meeting on Wind Turbine Noise.* Denver.

[14] Griffin, D., Delaire, C., & Pischedda, P. (2013). Methods of identifying extraneous noise during unattended noise measurements. *20th International Congress of Sound & Vibration.* Bangkok.

APPENDIX J TABULAR RESULTS

Sound levels in environmental assessment work are typically reported to the nearest integer to reflect the practical use of measurement and prediction data. However, in the case of wind farm noise assessments, significant layout modifications may only give rise to fractional changes in the predicted or measured noise levels. This is a result of the relatively large number of sources influencing the total predicted or measured noise levels, as well as the typical separating distances between the turbine locations and surrounding assessment positions. It is therefore necessary to consider the wind farm limits, and the regression analysis of wind farm compliance data, at a finer resolution than can be perceived or reliably measured in practice. It is for this reason that the levels presented in this section are reported to one decimal place.

Table 33: B8 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.6	47.3
Measured L_{A90} dB	28.8	29.4	30.7	32.5	34.5	36.7	38.7	40.5	41.8	42.5
Compliance margin dB	16.2	15.6	14.3	12.5	10.5	8.3	6.3	4.5	3.8	4.9

Table 34: B11 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	35.0	35.0	35.0	35.0	35.0	35.0	35.3	36.9	38.7	40.8
Measured L_{A90} dB	27.5	27.2	27.8	29.1	30.9	32.9	34.9	36.8	38.2	39.0
Compliance margin dB	7.5	7.8	7.2	5.9	4.1	2.1	0.4	0.1	0.5	1.8

Table 35: B12a results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.7
Measured L_{A90} dB	35.1	35.1	35.2	36.0	37.1	37.9	38.6	39.4	39.7	39.6
Compliance margin dB	9.9	9.9	9.8	9.0	7.9	7.1	6.4	5.6	5.3	6.1

Table 36: B13 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	35.3	35.4	35.8	36.4	37.2	38.2	39.4	40.6	41.9	43.3
Measured L_{A90} dB	26.4	25.7	25.9	26.9	28.6	30.7	33.1	35.5	37.9	40.1
Compliance margin dB	8.8	9.8	9.9	9.5	8.7	7.6	6.3	5.1	4.0	3.3

Table 37: B18 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Measured L_{A90} dB	26.6	28.0	29.8	31.7	33.8	35.9	38.0	39.8	41.5	42.7
Compliance margin dB	18.4	17.0	15.2	13.3	11.2	9.1	7.0	5.2	3.5	2.3

Table 38: B26 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.9	37.1	38.3
Measured L_{A90} dB	28.9	26.6	26.0	26.8	28.6	30.9	33.4	35.6	37.1	37.4
Compliance margin dB	6.1	8.4	9.0	8.2	6.4	4.1	1.6	0.3	0.0	0.9

Table 39: B27 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.6
Measured L_{A90} dB	27.3	31.1	34.3	36.8	38.9	40.6	42.0	43.3	44.4	45.6
Compliance margin dB	17.7	13.9	10.7	8.2	6.1	4.4	3.0	1.7	0.6	0.0

Table 40: B29 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit LAeq dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	46.0	47.3	48.6
Measured LA90 dB	26.6	29.4	32.1	34.7	37.1	39.5	41.7	43.8	45.7	47.5
Compliance margin dB	18.4	15.6	12.9	10.3	7.9	5.5	3.3	2.2	1.6	1.1

Table 41: B33 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Measured L_{A90} dB	31.0	30.7	31.7	33.7	36.1	38.8	41.2	43.0	43.9	43.4
Compliance margin dB	14.0	14.3	13.3	11.3	8.9	6.2	3.8	2.0	1.1	1.6

Table 42: B53 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Measured L_{A90} dB	25.0	27.8	30.5	33.2	35.8	38.3	40.6	42.7	44.5	46.1
Compliance margin dB	20.0	17.2	14.5	11.8	9.2	6.7	4.4	2.3	0.5	-1.1*

* Residual noise influence. See Section 6.10 and Appendix L for further comment.

Table 43: G31 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	36.9	37.8	38.7	39.5	40.4	41.2	42.0	42.9	43.8	44.8
Measured L_{A90} dB	32.0	31.4	31.5	32.1	33.1	34.2	35.4	36.4	37.1	37.4
Compliance margin dB	4.8	6.4	7.2	7.4	7.3	7.0	6.6	6.5	6.7	7.5

Table 44: G37 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
Measured L_{A90} dB	26.9	27.1	27.5	28.1	29.0	30.2	31.6	33.3	35.2	37.4
Compliance margin dB	18.1	17.9	17.5	16.9	16.0	14.8	13.4	11.7	9.8	7.6

Table 45: G39 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	36.2	36.2	36.3	36.7	37.3	38.0	39.0	40.0	41.2	42.6
Measured L_{A90} dB	33.5	34.4	35.3	36.1	36.9	37.6	38.3	38.9	39.5	40.0
Compliance margin dB	2.7	1.8	1.0	0.6	0.4	0.4	0.7	1.2	1.8	2.6

Table 46: K1 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	35.0	35.0	35.0	35.0	35.0	35.0	37.1	39.4	41.6	43.8
Measured L_{A90} dB	30.0	30.0	30.6	31.7	33.1	34.7	36.5	38.3	40.1	41.7
Compliance margin dB	5.0	5.0	4.4	3.3	1.9	0.3	0.6	1.0	1.5	2.2

Table 47: K2 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	35.0	35.0	35.0	35.0	35.0	35.8	37.7	39.8	42.1	44.4
Measured L_{A90} dB	26.3	27.1	28.9	31.5	34.6	37.7	40.5	42.6	43.8	43.6
Compliance margin dB	8.7	7.9	6.1	3.5	0.4	-1.9*	-2.8*	-2.8*	-1.7*	0.8

* Residual noise influence. See Section 6.15 and Appendix M for further comment.

Table 48: PW07 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.9
Measured L_{A90} dB	35.6	35.1	35.3	35.9	36.9	38.1	39.3	40.5	41.5	42.1
Compliance margin dB	9.4	9.9	9.7	9.1	8.1	6.9	5.7	4.5	3.5	3.9

Table 49: PW09 results summary

Description	Hub height wind speed (m/s)									
	3	4	5	6	7	8	9	10	11	12
Noise Limit L_{Aeq} dB	35.3	35.3	35.5	36.1	36.9	38.1	39.5	41.1	42.8	44.6
Measured L_{A90} dB	34.1	34.9	35.3	35.4	35.5	35.7	36.0	36.7	38.0	39.9
Compliance margin dB	1.2	0.4	0.2	0.6	1.4	2.4	3.5	4.3	4.8	4.7

APPENDIX K SUPPLEMENTARY DATA ANALYSIS FOR B26 & B27

The tabular summary in Appendix J shows that for both location B26 and B27 total measured noise levels generally lies below the wind farm limits at each integer wind speed. The exception is at 11m/s and 12m/s respectively where the line of best fit and the wind farm limit have the same value[15].

In each case, it is not possible from the available data to determine the noise level that is solely attributable to the wind farm. However, the following considerations support that the wind farm contribution would be lower than the measured total noise level and therefore lower than the wind farm limits.

- The data indicates that measured total noise levels continue to rise above 10 m/s. In contrast, measurement results at locations which indicate a clear influence from the wind farm suggest that noise levels associated with the wind farm remain relatively constant between 10 m/s and 12 m/s (see measurement location B33 and the data indicated in Figure 11). This is consistent with the characteristics of a modern pitch regulated variable speed turbine.

- Background noise levels of up to 10 dB less than the total measured noise level would results in an increase in total measured noise level of more than 0.5 dB. For locations B26 and B27 this would mean that the background noise levels would be required to be below 30dB and 35dB respectively to not result in a change in total noise level. The background noise levels measured during the planning stage of the assessments are not sufficiently recent to enable specific background corrections to be applied. However, the previous measurements did indicate background noise levels higher than 30dB at 11m/s for location B26, and 35dB at 12m/s for location B27.

Based on these considerations, the results are considered sufficient to support that the contribution of the wind farm to noise levels at both locations B26 and B27 comply with the limits.

[15] To one decimal place.

APPENDIX L SUPPLEMENTARY DATA ANALYSIS FOR B53

L1 B53 Intermediate monitoring

Methodology

Results from the initial period of monitoring at B53 were inconclusive and appeared to be significantly influenced by extraneous noise. An extension of monitoring was therefore undertaken at this location, in conjunction with concurrent monitoring at a location intermediate between B53 and the nearest wind turbine, BAN_10 to the northeast of the wind farm.

The intention of monitoring at intermediate locations is to measure sound levels where the contribution for wind farm noise is expected to be greater (that is, a better signal to noise ratio) and, additionally, where there is a greater separation distance to potential sources of extraneous noise.

Measurements

Monitoring and associated analysis at the B53 Intermediate Location have been carried out in general agreement with the methodology and process outlined in Section 4.0 and Section 5.0 above.

The position of the B53 Intermediate Location is detailed in Table 50 below. The location was selected as being in an area where the highest level of predicted wind farm noise[16] is approximately 44-47dB. The difference in predicted wind farm noise level between B53 and the Intermediate location is approximately 5 decibels.

Table 50: B53 Intermediate Location details

	Co-ordinates**	
Monitoring Location	**Easting (m)**	**Northing (m)**
B53 Intermediate Location	722606	6174342

Photographs of the monitoring location are shown below.

Analysis of the total measured noise levels at the Intermediate Location B53 includes filtering the data set as per the details in Table 4 and Section 5.4.2 above. This includes filtering to remove periods likely affected by rainfall, high local wind speeds at the microphone and filtering based on the operational status of relevant turbines. It also includes filtering to identify those periods where the monitoring position was located downwind from the wind farm. As the intention of measuring at the Intermediate Location is to better inform results at B53, the ±45° wind direction filter for B53[17] has also been used for the Intermediate Location. That is, a downwind range of directions 6° to 96° has been used.

[16] Predictions in accordance with the methodology detailed in the RNA.

[17] Relative to the nearest wind turbine, BAN10

Figure 24: B53 Intermediate Location site photos

Results

Results are summarised in Table 53 and Figure 19 below.

Table 51: Summary of parameters – B53 Intermediate Location

Monitoring period	9.03.15 to 14.04.15
Sound Level Logging Device	DUO10389
Total number of data points collected	5157
Number of data points removed*	3954
Number of data points used for analysis	1203

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

Figure 19 presents the total measured noise levels at the Intermediate Location comprising unfiltered noise levels (grey points) and filtered noise levels (red points). It is noted that the total measured noise levels include the contribution of both operational wind farm noise levels and noise from all other extraneous sources as discussed in Section 4.1 above. The chart also illustrates predicted wind farm noise levels at the intermediate position as a function of wind speed. It can be observed that for some periods the total measured noise levels are greater than the predicted wind farm noise level. The magnitude of this difference is generally small, within a few decibels, and is likely due to the influence of residual noise.

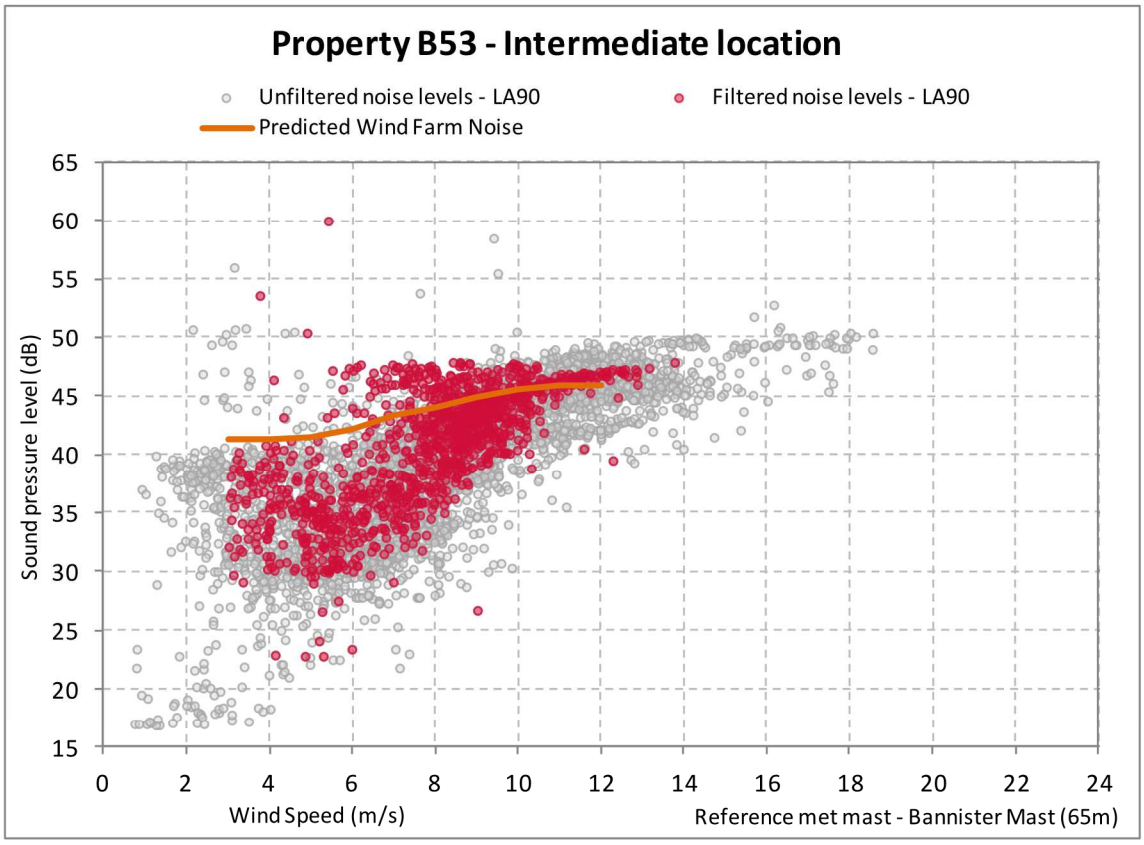


Figure 25: B53 Intermediate Location Total noise level vs. wind speed

It is apparent that total measured noise levels above 10m/s do not vary significantly with wind speed, a trend that broadly matches the change in predicted wind farm noise levels within this wind speed range. This observation is consistent with the characteristics of a modern pitch regulated variable speed turbine and suggests that, at the intermediate location:

- wind farm noise is a significant component of the total measured noise levels
- residual noise is not the primary factor determining the level of total measured noise

L2 Time history snapshots

As the monitoring extension at B53 and the monitoring at the Intermediate Location were carried out concurrently, the time history of measured noise levels at each location can be compared to assist in evaluating the variation in noise levels between positions. Figure 20 below presents an informative snapshot from the set of time history data.

The figure illustrates a 72 hour section of the monitoring period during which several distinct data trends can be observed. The blue dots on the figure present the measured noise levels at B53, the red dots present the measured noise levels for the Intermediate Location. The dark grey dots illustrate the wind speed at the wind farm and the data points that have been removed from the analysis through filtering are shown by the light grey dots.

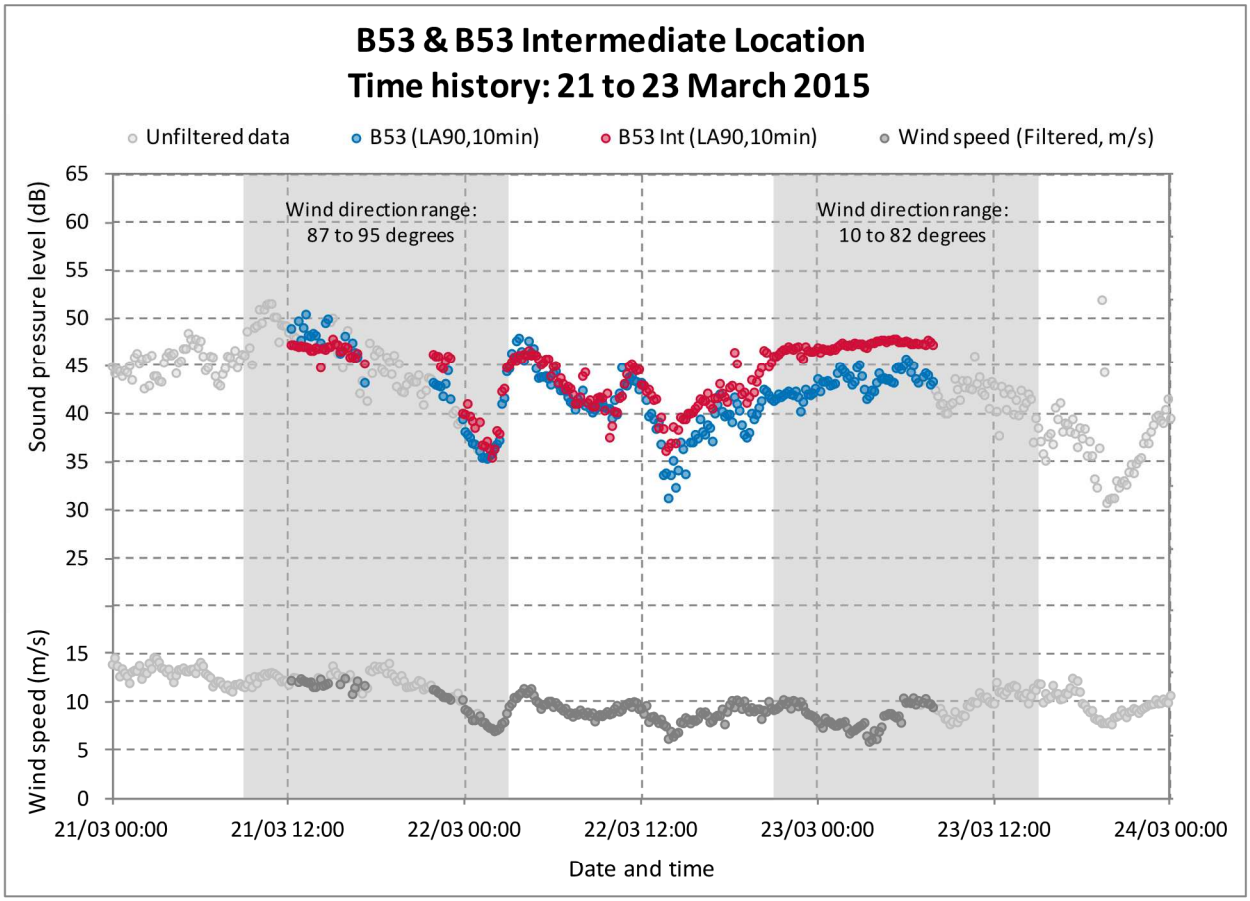


Figure 26: Time history snap shot of concurrent monitoring for property B53

Two areas of interest on the figure are highlighted by the grey shaded regions.

1. The first of these, a period of just over 12 hours from about midday to midnight on 21 March, shows that during periods when wind speeds and ambient noise levels are generally elevated[18] the total measured noise levels at B53 can be greater than at the Intermediate Location. This trend is contrary to what could be expected if wind farm noise was the controlling component of measured noise levels at both locations and therefore suggests that total measured noise levels at B53 may be significantly influenced by residual noise during some time periods.

[18] For example, where wind farm wind speeds are greater than 10 m/s and ambient noise levels are greater than 40 dBA.

2. The second highlighted period of interest also spans just over 12 hours from about midnight on 23 March until midday on 24 March. During this period, total measured noise levels at the B53 Intermediate Location are relatively constant, suggesting that the nearby turbines are a dominant component of the measured noise levels and that they are operating at or above the wind speed of rated where turbine sound emissions are comparatively constant. Concurrently, the total measured noise levels at B53 are generally less than at the B53 Intermediate Location, by a margin of 2dB to 5dB.

   This indicates that wind farm noise is a relevant component of the total measured noise levels at B53 during some periods, particularly where the total measured noise levels are broadly 5dB less than at the intermediate location, consistent with the expected sound level difference estimated by predictions.

As noted on the figure, the filtered range of downwind directions at the nearest reference met mast during the first highlighted period is 87° to 95°. The filtered downwind range during the second highlighted period is 10° to 82°. This grouping of wind directions suggests that potential extraneous noise sources at B53 vary with wind direction and are more significant for the range of downwind directions of approximately 85° to 95°.

L3 Wind direction investigation

Analysis of the time history plot in the preceding section suggests extraneous noise sources may be more significant at B53 under certain wind directions. However, as the time history snapshot only covers at 72 hours period, it may not be representative of the broader trend across the larger analysed data set. To investigate this in more detail, we have carried out further assessment of total measured noise levels at B53, dividing the downwind direction range into two intervals:

- Downwind range A: 6° to 85°
- Downwind range B: 86° to 96°.

The results of this analysis are presented in Figure 27 below.

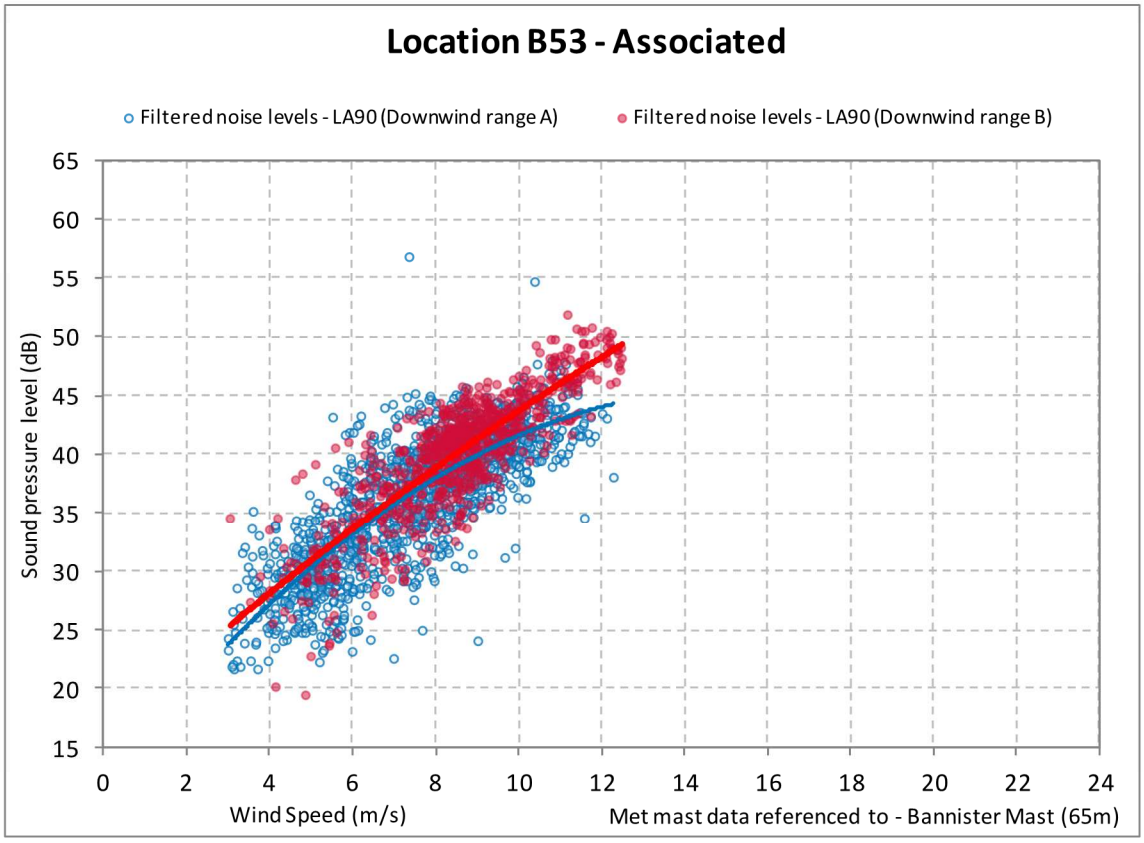


Figure 27: Total measured noise levels vs wind speeds for property B53, by wind direction

It can be seen that the total measured noise levels for downwind range B are up to approximately 5dB higher than range A at wind speeds above 10m/s while the total measured noise levels for each direction are approximately equivalent for wind speeds below approximately 8 m/s.

This observed trend is in contrast to what could be expected from directional variations in operational wind farm noise. Specifically, while the level of operational wind farm noise is likely to vary with wind direction, the changes would not be expected to vary with wind speed. For example, if there is a variation in operational wind farm noise levels of 3dB between two particular wind directions, that variation is expected to be the same across the assessed range of wind speeds[19].

Figure 28 below shows total measured noise levels at the B53 Intermediate Location versus wind speed for the same division of wind directions considered in Figure 27.

[19] As the Gullen Range Wind Farm comprises two different wind turbine models, each with its own profile of sound levels vs wind speeds it is possible that, at some locations, the wind speed profile of sound levels may vary with wind direction. For the specific case of the B53 Intermediate Location, the eight closest turbines relevant for downwind propagation are all of the same type (GW100) and have the same wind speed profile. On this basis, differences in operational wind farm sound levels with direction are not expected to vary with wind speed.

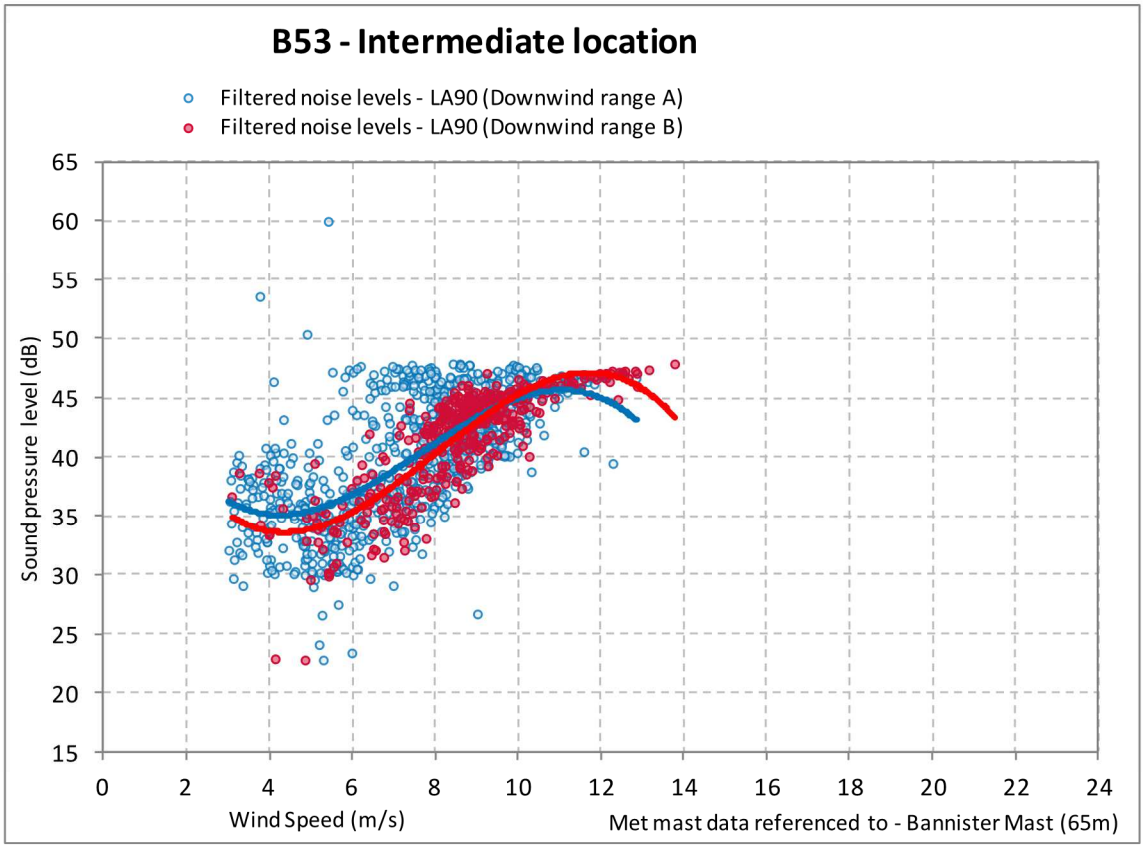


Figure 28: Total measured noise levels vs wind speeds for the B53 Intermediate Location, by wind direction

It can be seen in this figure that variation in measured noise levels with wind direction is less pronounced than in Figure 27. The variation observed is generally within approximately ±2dB across the assessed range of wind speeds which is broadly consistent with expected levels of variability for unattended measurements of environmental noise.

L4 High noise level filtering

A further observation from Appendix L2 above is that, during some periods, the total measured noise levels at B53 are higher than at the Intermediate Location. This trend in noise levels is generally a clear indicator that extraneous noise is influencing the total measured noise levels.

To evaluate the potential influence of these periods on the regression analysis, we have carried out further, indicative review employing a coarse noise level filter as follows:

- Periods will be removed from the data set where the total measured noise level at B53 is higher than the total measured noise level at the Intermediate Location during the same period.

This filter is expected to provide a conservative means of removing data from analysis that is highly likely to be affected by extraneous noise.

As the filter requires having synchronised data across both measurement locations, it has only been applied to that portion of the data collected during the second stage of monitoring when the intermediate logger was deployed. Results of this analysis for the relevant data set are shown in Figure 29 below.

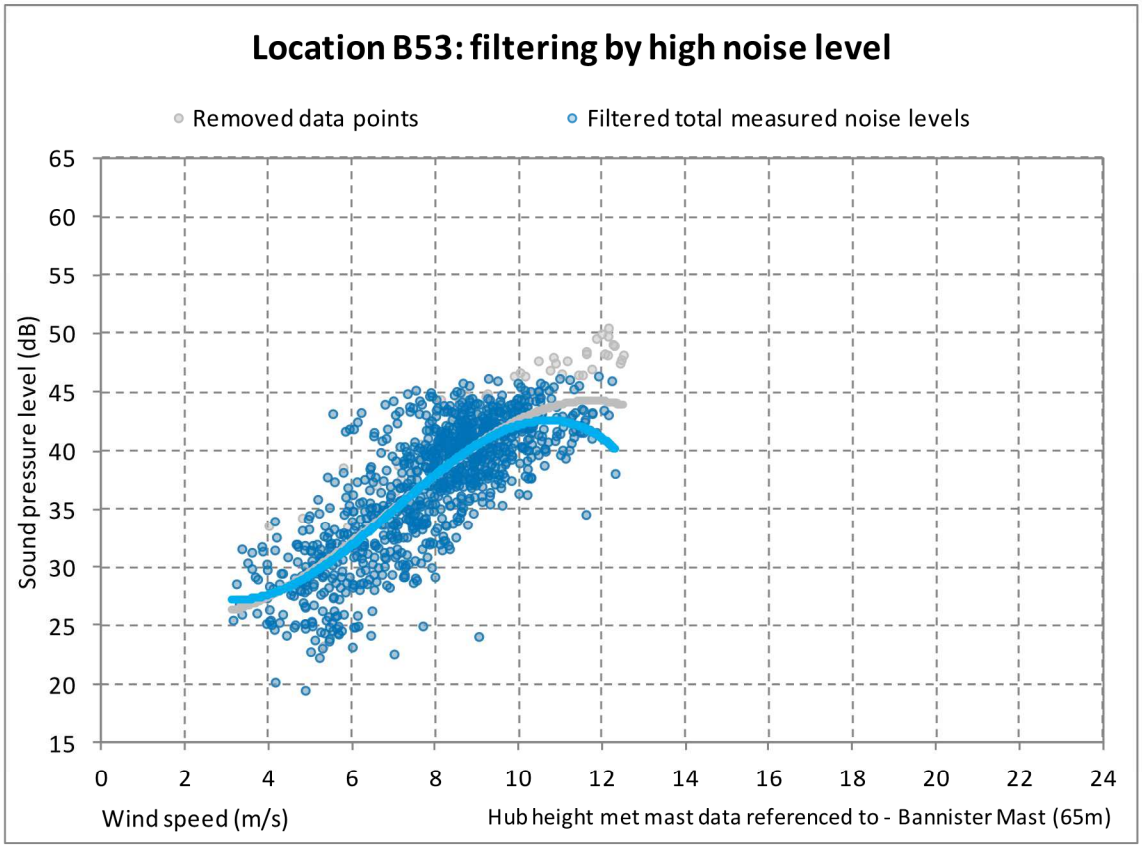


Figure 29: Total measured noise levels vs wind speeds for the B53, including high noise level filtering

It can be seen that, in the wind speed range 10 m/s to 12 m/s, the regression curve for the data set with filtering for high noise levels is up to approximately 3dB to 4dB lower than the data set with the high noise level periods included.

As noted above, this analysis only relates to a portion of the total amount of measured noise levels collected at B53. Additionally, it applies a coarse filter which is not documented in the SA Guidelines 2003 which are the primary guideline for this assessment and accordingly, the regression curves presented in Figure 23 may not be suitable for direct comparison with relevant noise limits. Nonetheless, this analysis provides an indication of the significance of extraneous noise at B53, including an estimated lower bound on the magnitude of the affect, being in the order of 3db to 4dB.

L5 Discussion

As unattended noise monitoring is generally not a reliable means of identifying particular sources of noise, or the levels of noise due to a specific source. It is therefore difficult to state with absolute certainty that extraneous noise, or indeed any other noise source, is a controlling component of total measured noise levels at a monitoring location.

Notwithstanding these limitations of unattended monitoring, the analysis detailed in the preceding sections generally indicates that residual noise is likely to be affecting total measured noise levels at B53 by a significant margin during periods where wind speeds are in the range 10 m/s to 12 m/s. In particular the above analysis indicates that:

- The profile of total measured noise levels vs wind speed at B53 does not match the profile that would be expected if operational wind farm noise was the controlling component of total measured noise levels
- The profile of total measured noise levels vs wind speed at the Intermediate Location is generally consistent with predicted levels of operational wind farm noise at that location, particularly in the wind speed range 10 m/s to 12 m/s
- Variations in total measured noise levels at B53 due to wind direction demonstrate disparate wind speed profiles, in contrast to expected trends based on predictions of operational wind farm noise. Similar trends are not as prominent at the Intermediate Location.
- Applying a coarse filter to remove high noise level events that are likely affected by extraneous noise, based on concurrent measurements at the Intermediate Location, suggests that the magnitude of the extraneous noise effects is 3dB to 4db or possibly more.

While individually these observations are not sufficient to directly account for the potential affects of residual noise in the total measured noise levels, their combined appraisal strongly suggests the relevance of residual noise.

In particular, the likely extraneous noise appears to be directional with greater prominence toward the southern components of the downwind direction range. This is consistent with noted sources of extraneous noise on-site, namely a row or large trees (Cyprus or similar) to the south east of the dwelling as illustrated in Appendix E.

On balance it is therefore considered highly likely that extraneous noise is influencing the total measured noise levels in the wind speed range 10 m/s to 12 m/s by a margin of at least 1.5dB and that the level of operational wind farm noise would be at least 1.5dB less than the total measured noise levels in this range.

APPENDIX M SUPPLEMENTARY DATA ANALYSIS FOR K2

M1 K2 Intermediate monitoring

Methodology

Results from the initial period of monitoring at K2were inconclusive and appeared to be significantly influenced by extraneous noise. An extension of monitoring was therefore undertaken at this location, in conjunction with concurrent monitoring at a location intermediate between K2 and the nearest wind turbine, KIA_01 at the northern end of the wind farm.

The intention of monitoring at intermediate locations is to measure sound levels where the contribution for wind farm noise is expected to be greater (that is, a better signal to noise ratio) and, additionally, where there is a greater separation distance to potential sources of extraneous noise.

Measurements

Monitoring and associated analysis at the K2 Intermediate Location have been carried out in general agreement with the methodology and process outlined in Section 4.0 and Section 5.0 above.

The position of the K2 Intermediate Location is detailed in Table 52 below. The location was selected as being in an area where the highest level of predicted wind farm noise[20] is approximately 45-48dB. The difference in predicted wind farm noise level between K2 and the Intermediate location is approximately 12 decibels.

Table 52: K2 Intermediate Location details

	Co-ordinates**	
Monitoring Location	**Easting (m)**	**Northing (m)**
K2 Intermediate Location	721946	6178297

Photographs of the monitoring location are shown below.

Analysis of the total measured noise levels at the K2 Intermediate Location includes filtering the data set as per the details in Table 4 and Section 5.4.2 above. This includes filtering to remove periods likely affected by rainfall, high local wind speeds at the microphone and filtering based on the operational status of relevant turbines. It also includes filtering to identify those periods where the monitoring position was located downwind from the wind farm.

Site constraints required that the monitoring equipment for the Intermediate Location was not able to be positioned in line with K2 and turbine KIA_01. The final choice for the monitoring location was to the west of the line between K2 and turbine KIA_01. The downwind direction for the Intermediate Location is 95° with a corresponding downwind range of 50° to 140°. There is a difference of approximately forty (40) degrees between the downwind direction for the Intermediate Location and the downwind direction for K2 (90° to 180°). As the intention of measuring at the Intermediate Location is to better inform results at K2, an adjusted downwind range has been applied to filter data from the Intermediate Location, 90° to 140°.

[20] Predictions in accordance with the methodology detailed in the RNA.

Figure 30: K2 Intermediate Location site photos

Results

Results are summarised in Table 53 and Figure 31 below.

Table 53: Summary of parameters – K2 Intermediate Location

Monitoring period	21.05.15 to 23.06.15
Sound Level Logging Device	DUO10394
Total number of data points collected	4709
Number of data points removed*	4312
Number of data points used for analysis	397

* removed due to periods of rain, wind speeds below cut-in, wind speeds above rated power, identified extraneous noise and wind directions outside the downwind range. Refer to Section 5.4.2 for details.

Figure 31 presents the total measured noise levels at the Intermediate Location comprising unfiltered noise levels (grey points) and filtered noise levels (red points). It is noted that the total measured noise levels include the contribution of both operational wind farm noise levels and noise from all other extraneous sources as discussed in Section 4.1.

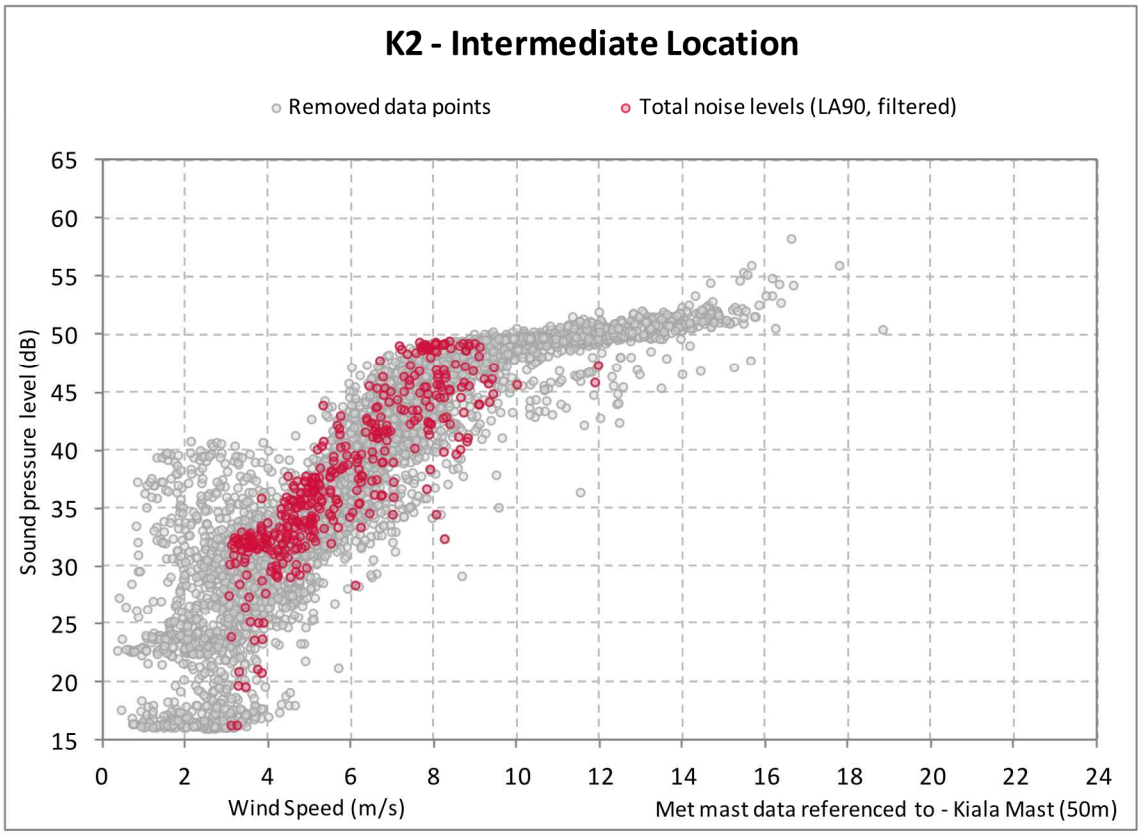


Figure 31: B53 Intermediate Location Total noise level vs. wind speed

As shown on the figure, only a limited amount data was able to be collected above approximately 9 m/s in the downwind direction (red dots). Reviewing this data, in conjunction with the data points that have been removed from the analysis (grey dots), it is apparent that the available total measured noise levels above 7 m/s do not vary significantly with wind speed. Across both sets of data (the grey and red dots) the upper bound of total measured noise levels at the Intermediate Location does not vary by more than a few decibels in the wind speed range 7 m/s to 12 m/s. This observation is consistent with the characteristics of a modern pitch regulated variable speed turbine and is comparable to measurement results at other locations around the wind farm which indicate a clear influence from the wind farm (see measurement location B33 and the Intermediate Monitoring Location for B53).

The results in Figure 31 suggest that, at the intermediate location:

- wind farm noise is a notable component of the total measured noise levels
- residual noise is not the only factor determining the level of total measured noise

These results are notably different to the observed trend of measurements at K2, where the regression curve of total measured noise levels increases by approximately nine decibels in the wind speed range 7 m/s to 12 m/s as shown in Figure 17 in Section 6.15.

M2 Wind direction investigation

To further investigate the potential presence of residual or extraneous noise sources influencing the measurement data at K2, an additional wind direction study has been carried out. This study has involved dividing the downwind direction range for K2 (90° to 180°) into three equal sections of 30°:

- Downwind Range A: 90° to 120°
- Downwind Range B: 120° to 150°
- Downwind Range C: 150° to 180°

The collected data within each section has been considered separately, including a regression analysis. Results are presented in Figure 32. It is evident that a large portion of the collected data falls within Range A, however at least 300 data points are included in each of the three sections.

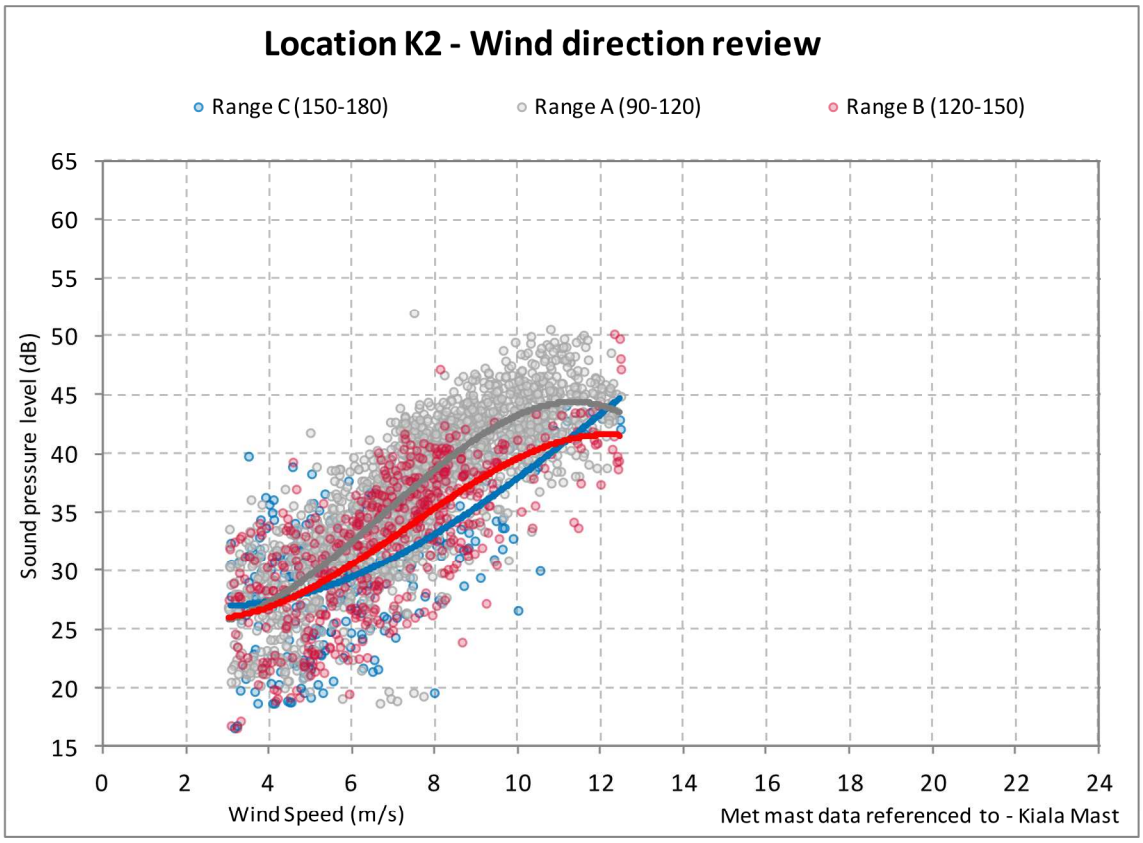


Figure 32: Total measured noise levels vs wind speeds for property K2, by wind direction

It can be observed that the regression curves for each section differ by up to five decibels in the wind speed range 7 m/s to 12 m/s.

The regression curve for Range B (120° to 150°) which encompasses the immediate downwind direction to KIA_01 is lower than the regression curve for Range A (90° to 120°) by between approximately 2 dB and 4 dB in this wind speed range.

This observation is consistent with a noted source of extraneous noise on-site, namely a row or large trees (Cyprus or similar) to the east of the K2 dwelling and to the north-east of the K2 monitoring position, as illustrated in Appendix E. A further analysis of wind directions has been carried out to consider this potential extraneous noise source in more detail, by assessing the following ranges:

- Downwind Range A: 90° to 120°
- Wind Direction Range (60° to 90°): 60° to 90°

The collected data within each section has been considered separately, including a regression analysis. Results are presented in Figure 33.

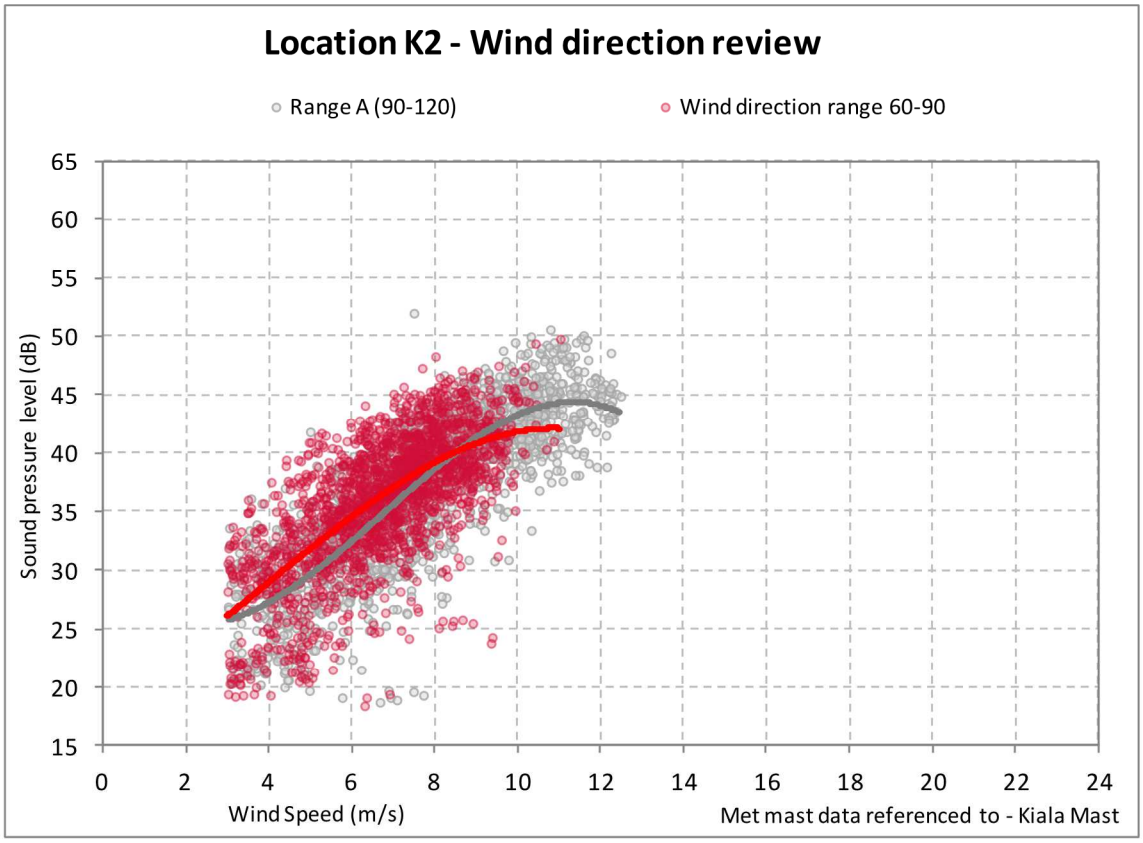


Figure 33: Total measured noise levels vs wind speeds for property K2, by wind direction

The Wind Direction Range (60° to 90°) lies outside of the ±45° downwind interval for K2. Wind farm operational noise is not expected to be a significant component of the overall noise environment for the Wind Direction Range (60° to 90°). Relative to the position of monitoring equipment at K2, several of the noted large trees are encompassed by the Wind Direction Range (60° to 90°).

It can be observed that the regression curve for the alternative range is comparable with, and moderately higher than, the regression curve for Range A in the wind speed range 7 m/s to 9 m/s. Above 9 m/s, there is only a sparse amount of data available in the alternative range and the regression curve may be less representative of the total measured noise levels.

The observed similarity of these two regression curves is again consistent with the noted large trees to the north-east of the monitoring location being a potentially significant source of extraneous noise during the measurements.

M3 Revised assessment with adjusted downwind range

The preceding analysis indicates that selected sections of the downwind range of directions are being significantly influenced by residual or extraneous noise whereas in other sections the influence is comparatively less.

The ±45° range that is used as the basis for downwind directions, as detailed in Table 4 above, is consistent with the requirements of the SA Guidelines 2003 which notes:

> *Compliance checking should collect data associated with the worst case wind direction from the wind farm to the relevant receiver. A wind direction spread of 45 degrees either side of the direct line between the nearest WTG and the relevant receiver is considered acceptable* […] *This will not always be practical, given prevailing wind conditions*

It is understood that the ±45° range is proposed as a practical balance between: on the one hand, assessing operational wind farm noise in conditions with the wind directed from the turbines towards a measurement location and; on the other hand, collecting a sufficient amount of measurement data without the need for prolonged measurement campaigns. It could in turn be reasoned that a narrower range of directions may also be an acceptable basis for a downwind range provided a sufficient number of data points can be practicably collected and that a narrowing of the range does not obviously exclude significant downwind components of operational wind farm noise.

For the K2 monitoring location the most significant turbines influencing the level of wind farm noise[21] at K2 are KIA_01 and KIA_02. From K2, the downwind direction to KIA_01 is 135° and to KIA_02 is 147°. Given the similarity of these downwind directions, it is considered that narrowing of the ±45° range would still offer an acceptable basis for assessment provided a sufficient number of data points are included (that is, at least 500).

Figure 34 presents the results of an assessment of total measured noise levels at K2 with an adjusted, ±25°range of downwind directions (110° to 160°). This narrower range has been selected with a view to:

- Centring the downwind range relative to the nearest turbine
- Excluding potentially significant sources of extraneous noise from the assessment
- Retaining a sufficient number of data points in the assessment

With this adjusted downwind range, the assessment includes 817 data points (shown as blue dots on the figure).

[21] Based on predicted wind farm noise levels according to the model detailed in the RNA

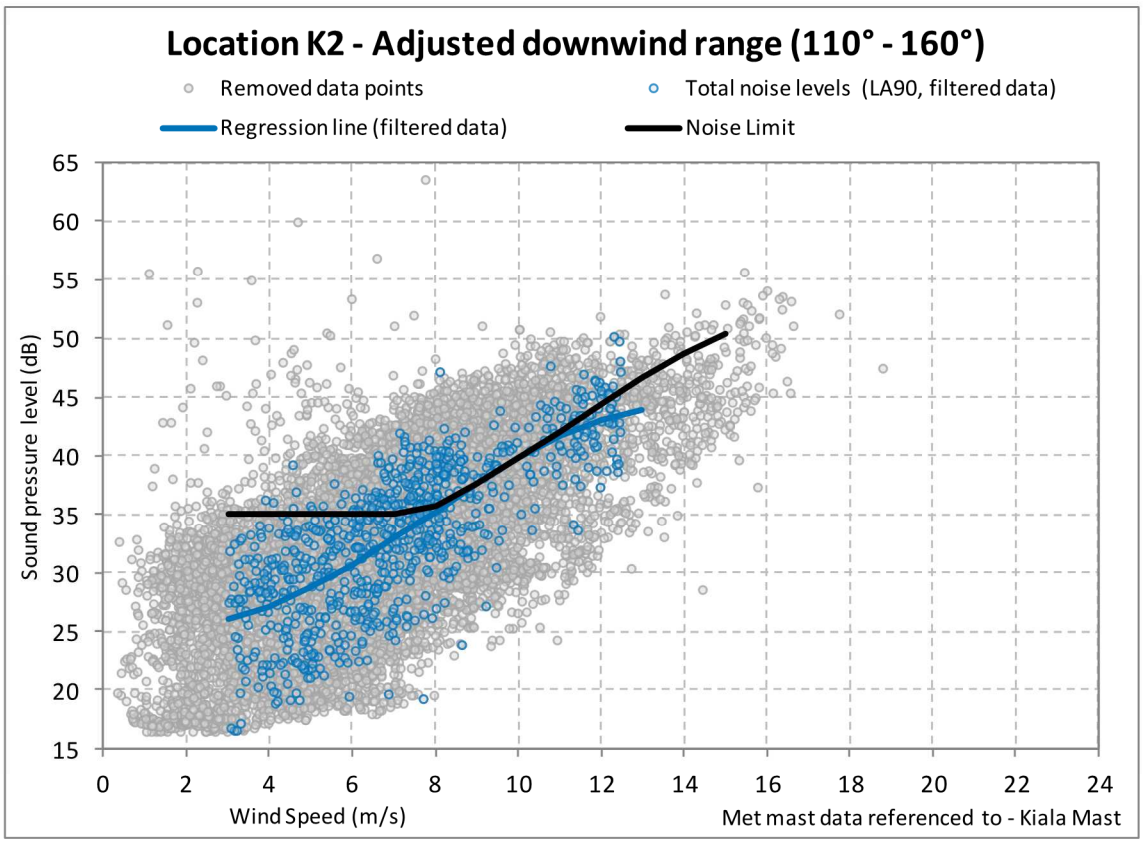


Figure 34: K2 Total noise level vs. wind speed (Adjusted downwind range)

It can be seen from Figure 34 that the line of best fit to the total measured noise levels at property K2 lies at[22] or below the wind farm limits at each integer wind speed. The contribution of the wind farm to noise levels at K2 therefore complies with the limits.

M4 Discussion

The analysis detailed in the preceding sections indicates that residual noise is likely to be affecting total measured noise levels at K2 by a significant margin particularly for the wind speed range 7 m/s to 12 m/s. In particular the above analysis indicates that:

- The profile of total measured noise levels vs wind speed at K2 does not match the profile that would be expected if operational wind farm noise was the controlling component of total measured noise levels
- The profile of total measured noise levels vs wind speed at the Intermediate Location is generally consistent with predicted levels of operational wind farm noise at that location, particularly in the wind speed range 7 m/s to 12 m/s
- Applying a narrower downwind direction filter results in an assessment that demonstrates compliance with the applicable noise limits and provides the clearest indication of residual noise levels being the cause of excess levels above the limit.

Collectively these observations support that compliance has been achieved at monitoring location K2.

[22] To one decimal place.

APPENDIX N COMPLIANCE ASSESSMENT FOR RELATED RECEIVERS

As detailed in the RNA, wind farm noise limits at several noise monitoring locations are used as the basis for establishing noise limits at selected neighbouring properties (related receivers). Similarly, the commissioning noise measurements carried out for the current study of wind farm operational noise are used herein to inform the compliance outcomes at these related receivers.

Specifically, an indicative assessment of compliance at the related receivers has been carried out by considering the noise measurement data from the reference monitoring locations in two ways:

- Comparison of the unadjusted data from the monitoring locations with the limits that apply at related receivers.

  This comparison does not account for the influence of the background noise environment at the monitoring location, or the difference between wind farm noise levels at the monitoring locations and related receivers. In most instances, the related receivers are further from the wind farm than the monitoring locations. This method of assessment will therefore generally overstate the influence of the wind farm at the related receivers.

- Comparison of adjusted data from the monitoring locations with the limits that apply at related receivers.

  These adjustments have been primarily applied to account for the expected difference in wind farm noise levels between the monitoring location and related receivers. However, the adjustment does not account for the influence of background noise levels on the data obtained at the monitoring location. The adjusted levels will therefore generally represent an upper bound for the potential noise contribution of the wind farm.

Adopting the above methodology, tabular data and comparisons are provided in the following sections for the related receivers associated with each monitoring location. The grouping of monitoring locations and related receivers is identical to the RNA.

The values of the adjustments applied to the data from the monitoring locations have been derived on the basis of the arithmetic difference between the predicted wind farm noise levels for each location, as presented in Section 5.0 of the RNA. For each monitoring location and related receiver pair, the minimum and maximum differences in predicted noise levels across the assessable range of integer wind speed was determined. To provide a conservative assessment, the minimum difference has then generally been applied to the monitoring location data for all wind speeds, except at locations where the related receiver is nearer to the wind farm and the maximum difference is applied.

All noise limit and compliance monitoring data relates to A-weighted equivalent noise levels L_{Aeq}. However, in accordance with the SA Guidelines 2003, the method of evaluating the equivalent noise levels associated with the contribution of the wind farm is based on the measurement and analysis of the L_{A90} metric as a means of addressing the potential effect of ambient noise.

Sound levels in environmental assessment work are typically reported to the nearest integer to reflect the practical use of measurement and prediction data. However, in the case of wind farm noise assessments, significant layout modifications may only give rise to fractional changes in the predicted or measured noise levels. This is a result of the relatively large number of sources influencing the total predicted or measured noise levels, as well as the typical separating distances between the turbine locations and surrounding assessment positions. It is therefore necessary to consider the wind farm limits, and the regression analysis of wind farm compliance data, at a finer resolution than can be perceived or reliably measured in practice. It is for this reason that the levels presented in this section are reported to one decimal place.

N1 Related receivers for monitoring location B8

Table 54: Compliance summary for related receiver B2 based on measurement data from B8

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B2 - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.6	47.3
B8 - measured noise level	28.8	29.4	30.7	32.5	34.5	36.7	38.7	40.5	41.8	42.5
B2 - indicative compliance margin based on unadjusted levels measured at B8	16.2	15.6	14.3	12.5	10.5	8.3	6.3	4.5	3.8	4.9
Predicted wind farm noise - B2 assoc levels minus B8 levels	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
B2 - estimated upper bound for wind farm noise	30.9	31.5	32.8	34.6	36.6	38.8	40.9	42.6	43.9	44.6
B2 - indicative compliance margin based on estimated upper bound for wind farm noise	14.1	13.5	12.2	10.4	8.4	6.2	4.1	2.4	1.6	2.8

Table 55: Compliance summary for related receiver B3 based on measurement data from B8

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B3 - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.6	47.3
B8 - measured noise level	28.8	29.4	30.7	32.5	34.5	36.7	38.7	40.5	41.8	42.5
B3 - indicative compliance margin based on unadjusted levels measured at B8	16.2	15.6	14.3	12.5	10.5	8.3	6.3	4.5	3.8	4.9
Predicted wind farm noise - B3 assoc levels minus B8 levels	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
B3 - estimated upper bound for wind farm noise	27.2	27.8	29.1	30.9	32.9	35.1	37.2	38.9	40.2	40.9
B3 - indicative compliance margin based on estimated upper bound for wind farm noise	17.8	17.2	15.9	14.1	12.1	9.9	7.8	6.1	5.3	6.5

Table 56: Compliance summary for related receiver B19 based on measurement data from B8

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B19 - applicable limit	35.0	35.0	35.8	37.3	38.9	40.5	42.2	43.9	45.6	47.3
B8 - measured noise level	28.8	29.4	30.7	32.5	34.5	36.7	38.7	40.5	41.8	42.5
B19 - indicative compliance margin based on unadjusted levels measured at B8	6.2	5.6	5.1	4.8	4.3	3.8	3.4	3.3	3.8	4.9
Predicted wind farm noise - B19 levels minus B8 levels	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2
B19 - estimated upper bound for wind farm noise	27.6	28.2	29.5	31.3	33.3	35.5	37.5	39.3	40.6	41.3
B19 - indicative compliance margin based on estimated upper bound for wind farm noise	7.4	6.8	6.3	6.0	5.5	5.0	4.6	4.5	5.0	6.1

The above results demonstrate compliance with the applicable noise limits at all related receiver locations.

Notably, compliance at the related receivers B3 and B19 was able to be demonstrated on the basis of total noise levels measured directly at B8, without adjustment for the reduction in noise levels from B3 and B19.

Wind farm noise levels at related receiver B2 are expected to be higher than at B8, however when the expected increase is conservatively applied to the measurement data, compliance was still able to be demonstrated by a margin of at least 1.6dB. Importantly, this result is based on an estimated upper bound for the level of noise at B2 by applying the predicted increased in wind farm noise to the total measured noise levels at B8.

N2 Related receivers for monitoring location B11

Table 57: Compliance summary for related receiver B9 based on measurement data from B11

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B9 - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
B11 - measured noise level	27.5	27.2	27.8	29.1	30.9	32.9	34.9	36.8	38.2	39.0
B9 - indicative compliance margin based on unadjusted levels measured at B11	17.5	17.8	17.2	15.9	14.1	12.1	10.1	8.2	6.8	6.0
Predicted wind farm noise - B9 assoc levels minus B11 levels	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
B9 assoc - estimated upper bound for wind farm noise	33.0	32.8	33.4	34.7	36.5	38.5	40.5	42.3	43.8	44.6
B9 assoc - indicative compliance margin based on estimated upper bound for wind farm noise	12.0	12.2	11.6	10.3	8.5	6.5	4.5	2.7	1.2	0.4

The above results demonstrate compliance with the applicable noise limits at related receiver location B9.

Wind farm noise levels at related receiver B9 are expected to be higher than at B11, however when the expected increase is conservatively applied to the measurement data, compliance was still able to be demonstrated by a margin of at least 1.6dB. Importantly, this result is based on an estimated upper bound for the level of noise at B2 by applying the predicted increased in wind farm noise to the total measured noise levels at B11.

N3 Related receivers for monitoring location B18

Table 58: Compliance summary for related receiver B1 based on measurement data from B18

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B1 - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
B18 - measured noise level	29.2	28.1	28.3	29.5	31.4	33.7	36.0	38.2	39.9	40.7
B1 - indicative compliance margin based on unadjusted levels measured at B18	15.8	16.9	16.7	15.5	13.6	11.3	9.0	6.8	5.1	4.3
Predicted wind farm noise - B1 assoc levels minus B18 levels	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
B1 - estimated upper bound for wind farm noise	36.8	35.7	35.9	37.1	38.9	41.2	43.6	45.8	47.4	48.3
B1 - indicative compliance margin based on estimated upper bound for wind farm noise	8.2	9.3	9.1	7.9	6.1	3.8	1.4	-0.8*	-2.4*	-3.3*

* Residual noise influence. See further comment below.

Table 59: Compliance summary for related receiver B7 based on measurement data from B18

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B7 - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
B18 - measured noise level	29.2	28.1	28.3	29.5	31.4	33.7	36.0	38.2	39.9	40.7
B7 - indicative compliance margin based on unadjusted levels measured at B18	15.8	16.9	16.7	15.5	13.6	11.3	9.0	6.8	5.1	4.3
Predicted wind farm noise - B7 assoc levels minus B18 levels	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
B7 - estimated upper bound for wind farm noise	29.1	28.0	28.2	29.4	31.2	33.5	35.9	38.1	39.7	40.6
B7 - indicative compliance margin based on estimated upper bound for wind farm noise	15.9	17.0	16.8	15.6	13.8	11.5	9.1	6.9	5.3	4.4

Table 60: Compliance summary for related receiver B17 based on measurement data from B18

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B17 - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
B18 - measured noise level	29.2	28.1	28.3	29.5	31.4	33.7	36.0	38.2	39.9	40.7
B17 - indicative compliance margin based on unadjusted levels measured at B18	15.8	16.9	16.7	15.5	13.6	11.3	9.0	6.8	5.1	4.3
Predicted wind farm noise - B17 assoc levels minus B18 levels	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
B17 - estimated upper bound for wind farm noise	29.0	27.9	28.1	29.2	31.1	33.4	35.8	38.0	39.6	40.5
B17 - indicative compliance margin based on estimated upper bound for wind farm noise	16.0	17.1	16.9	15.8	13.9	11.6	9.2	7.0	5.4	4.5

Table 61: Compliance summary for related receiver B18a based on measurement data from B18

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B18a assoc - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
B18 - measured noise level	29.2	28.1	28.3	29.5	31.4	33.7	36.0	38.2	39.9	40.7
B18a - indicative compliance margin based on unadjusted levels measured at B18	15.8	16.9	16.7	15.5	13.6	11.3	9.0	6.8	5.1	4.3
Predicted wind farm noise - B18a assoc levels minus B18 levels	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
B18a - estimated upper bound for wind farm noise	32.0	30.9	31.1	32.3	34.2	36.5	38.8	41.0	42.7	43.5
B18a - indicative compliance margin based on estimated upper bound for wind farm noise	13.0	14.1	13.9	12.7	10.8	8.5	6.2	4.0	2.3	1.5

Table 62: Compliance summary for related receiver B31 based on measurement data from B18

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B31 - applicable limit	35.0	35.0	35.0	35.0	35.6	36.8	38.2	39.7	41.2	42.8
B18 - measured noise level	29.2	28.1	28.3	29.5	31.4	33.7	36.0	38.2	39.9	40.7
B31 - indicative compliance margin based on unadjusted levels measured at B18	5.8	6.9	6.7	5.5	4.2	3.2	2.2	1.5	1.3	2.1
Predicted wind farm noise - B31 levels minus B18 levels	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8
B31 - estimated upper bound for wind farm noise	27.5	26.3	26.5	27.7	29.6	31.9	34.3	36.4	38.1	38.9
B31 - indicative compliance margin based on estimated upper bound for wind farm noise	7.5	8.7	8.5	7.3	6.0	5.0	4.0	3.3	3.1	3.8

Table 63: Compliance summary for related receiver B31a based on measurement data from B18

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B31a - applicable limit	35.0	35.0	35.0	35.0	35.6	36.8	38.2	39.7	41.2	42.8
B18 - measured noise level	29.2	28.1	28.3	29.5	31.4	33.7	36.0	38.2	39.9	40.7
B31a - indicative compliance margin based on unadjusted levels measured at B18	5.8	6.9	6.7	5.5	4.2	3.2	2.2	1.5	1.3	2.1
Predicted wind farm noise - B31a levels minus B18 levels	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
B31a - estimated upper bound for wind farm noise	27.9	26.8	27.0	28.2	30.1	32.4	34.7	36.9	38.6	39.4
B31a - indicative compliance margin based on estimated upper bound for wind farm noise	7.1	8.2	8.0	6.8	5.5	4.5	3.5	2.8	2.7	3.4

Table 64: Compliance summary for related receiver B32 based on measurement data from B18

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B32 - applicable limit	35.0	35.0	35.0	35.0	35.6	36.8	38.2	39.7	41.2	42.8
B18 - measured noise level	29.2	28.1	28.3	29.5	31.4	33.7	36.0	38.2	39.9	40.7
B32 - indicative compliance margin based on unadjusted levels measured at B18	5.8	6.9	6.7	5.5	4.2	3.2	2.2	1.5	1.3	2.1
Predicted wind farm noise - B32 levels minus B18 levels	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
B32 - estimated upper bound for wind farm noise	27.6	26.5	26.7	27.8	29.7	32.0	34.4	36.6	38.2	39.1
B32 - indicative compliance margin based on estimated upper bound for wind farm noise	7.4	8.5	8.3	7.2	5.8	4.8	3.9	3.1	3.0	3.7

The above results generally demonstrate compliance with the applicable noise limits at the related receiver locations.

The exception is at related receiver B1 where the estimated upper bound provides an inconclusive assessment on the basis that the combined total levels lie above the limits at wind speeds equal to or greater than 10m/s. Wind farm noise levels at B1 are expected to be higher than measured at B18, however this expected increase has been conservatively applied in this assessment to the total measured noise level, including the influence of ambient noise sources not related to the operation of the wind farm. Accordingly, this comparison is limited by the uncertainty surrounding the actual influence of the residual sound environment during the survey. However, the following notes are made in relation to the observed differences between the upper bound levels and noise limits at B1:

- The indicative compliance margin is 0.8 dB at 10 m/s. This margin of difference is consistent with the scale of increase associated with a minor contribution from the residual sound environment. For example, based on the measured level of 38.2 dB at B18 at 10 m/s, a residual sound level of 31 dB or greater would be sufficient to influence the total measured noise level by more than 0.8 dB. The background noise levels measured during the planning stage were not directly undertaken at B1 and are not sufficiently recent to enable specific background corrections to be applied. However, the previous measurements at the representative background monitoring location B18 did indicate background noise levels higher than 31 dB (actual value was 33 dB)
- The trend of increasing total noise levels above 10 m/s is indicative of background related noise influences rather than the wind farm (see discussion in Appendix K of similar trends observed at B26 and B27).
- While B1 is nominated as a related receiver for B18, the closest nearby monitoring location is B33 which is positioned to the east of B1. Informatively, if B33 was taken as the related receiver, the indicative assessment of operational wind farm noise at B1 would demonstrate compliance were the associated receiver limit of 45dB at all assessed integer wind speeds.

Based on the balance of the above considerations, the results are considered sufficient to support that the contribution of the wind farm to noise levels at B1 complies with the limits, and the instances of where the upper bound level are above the limits primarily relate to the influence of the residual sound environment.

At related receivers B7, B17, B31, B31a and B32, wind farm noise levels are expected to be lower than measured at B18. Notably, compliance at these related receivers was able to be demonstrated on the basis of total noise levels measured directly at B18, without adjustment for the expected reduction in noise levels for each related receiver.

Wind farm noise levels at related receiver B18a are expected to be higher than at B18, however when the expected increase is conservatively applied to the measurement data, compliance was still able to be demonstrated by a minimum margin of 1.5dB at wind speed of 12m/s (at which the trend of measurement data suggests the results have been strongly influenced by the residual sound environment). Importantly, this result is based on an estimated upper bound for the level of noise at B18a by applying the predicted increased in wind farm noise to the total measured noise levels at B18.

N4 Related receivers for monitoring location B26

Table 65: Compliance summary for related receiver B12 based on measurement data from B26

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B12 - applicable limit	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
B26 - measured noise level	28.9	26.6	26.0	26.8	28.6	30.9	33.4	35.6	37.1	37.4
B12 - indicative compliance margin based on unadjusted levels measured at B26	16.1	18.4	19.0	18.2	16.4	14.1	11.6	9.4	7.9	7.6
Predicted wind farm noise - B12 levels minus B26 levels	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
B12 - estimated upper bound for wind farm noise	30.8	28.4	27.8	28.6	30.4	32.7	35.2	37.4	38.9	39.2
B12 - indicative compliance margin based on estimated upper bound for wind farm noise	14.2	16.6	17.2	16.4	14.6	12.3	9.8	7.6	6.1	5.8

The above results demonstrate compliance with the applicable noise limits at related receiver location B12.

Wind farm noise levels at related receiver B12 are expected to be higher than at B26, however when the expected increase is conservatively applied to the measurement data, compliance was still able to be demonstrated by a minimum margin of 5.8dB at a wind speed of 12m/s. Importantly, this result is based on an estimated upper bound for the level of noise at B12 by applying the predicted increased in wind farm noise to the total measured noise levels at B26.

N5 Related receivers for monitoring location B29

Table 66: Compliance summary for related receiver B28 based on measurement data from B29

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B28 - applicable limit	37.3	38.4	39.5	40.7	42.0	43.3	44.6	46.0	47.3	48.6
B29 - measured noise level	26.6	29.4	32.1	34.7	37.1	39.5	41.7	43.8	45.7	47.5
B28 - indicative compliance margin based on unadjusted levels measured at B29	10.6	8.9	7.4	6.1	4.9	3.8	3.0	2.2	1.6	1.1
Predicted wind farm noise - levels minus B29 levels	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
B28 - estimated upper bound for wind farm noise	25.6	28.4	31.1	33.7	36.1	38.5	40.7	42.8	44.7	46.5
B28 - indicative compliance margin based on estimated upper bound for wind farm noise	11.6	9.9	8.4	7.1	5.9	4.8	4.0	3.2	2.6	2.1

Table 67: Compliance summary for related receiver B55 based on measurement data from B29

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B55 - applicable limit	37.3	38.4	39.5	40.7	42.0	43.3	44.6	46.0	47.3	48.6
B29 - measured noise level	26.6	29.4	32.1	34.7	37.1	39.5	41.7	43.8	45.7	47.5
B55 - indicative compliance margin based on unadjusted levels measured at B29	10.6	8.9	7.4	6.1	4.9	3.8	3.0	2.2	1.6	1.1
Predicted wind farm noise - levels minus B29 levels	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0
B55 - estimated upper bound for wind farm noise	24.6	27.4	30.1	32.7	35.1	37.5	39.7	41.8	43.7	45.5
B55 - indicative compliance margin based on estimated upper bound for wind farm noise	12.6	10.9	9.4	8.1	6.9	5.8	5.0	4.2	3.6	3.1

The above results demonstrate compliance with the applicable noise limits at all related receiver locations.

Notably, compliance was able to be demonstrated on the basis of total noise levels measured directly at B29, without adjustment for the reduction in noise levels for B28 and B55.

N6 Related receivers for monitoring location B33

Table 68: Compliance summary for related receiver B6 based on measurement data from B33

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B6 - applicable limit (associated receiver)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
B33 - measured noise level	31.0	30.7	31.7	33.7	36.1	38.8	41.2	43.0	43.9	43.4
B6 - indicative compliance margin based on unadjusted levels measured at B33 assoc	14.0	14.3	13.3	11.3	8.9	6.2	3.8	2.0	1.1	1.6
Predicted wind farm noise - B6 assoc levels minus B33 assoc levels	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4
B6 - estimated upper bound for wind farm noise	28.6	28.4	29.4	31.3	33.8	36.4	38.9	40.7	41.5	41.0
B6 - indicative compliance margin based on estimated upper bound for wind farm noise	16.4	16.6	15.6	13.7	11.2	8.6	6.1	4.3	3.5	4.0

The above results demonstrate compliance with the applicable noise limits at related receiver location B6.

Notably, compliance was able to be demonstrated on the basis of total noise levels measured directly at B33, without adjustment for the reduction in noise levels for B6.

N7 Related receivers for monitoring location B53

Table 69: Compliance summary for related receiver B77 based on measurement data from B53

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
B77 - applicable limit	35.0	35.0	35.0	35.2	36.0	37.0	38.2	39.6	41.2	43.0
B53 - measured noise level (associated receiver)	24.6	27.5	30.4	33.1	35.8	38.2	40.5	42.6	44.5	46.2
B77 - indicative compliance margin based on unadjusted levels measured at B53 assoc	10.4	7.5	4.6	2.1	0.3	-1.2	-2.3	-3.0	-3.3	-3.2
Predicted wind farm noise - B77 levels minus B53 assoc levels	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
B77 - estimated upper bound for wind farm noise	21.6	24.5	27.4	30.1	32.8	35.2	37.5	39.6	41.5	43.2
B77 - indicative compliance margin based on estimated upper bound for wind farm noise	13.4	10.5	7.6	5.1	3.3	1.8	0.7	0.0*	-0.3*	-0.2*

* Residual noise influence. See further comment below.

The noise levels at related receiver B77 associated with operation of the wind farm are expected to be lower than those occurring at B53. As a result of this, and the uncertainty surrounding the potential influence of the residual sound environment on the total measured noise levels at B53, an indicative assessment of compliance based on unadjusted measured total noise levels at B53 was inconclusive.

However, when the expected reduction in noise level is conservatively applied to the total noise measurement data, compliance was able to be demonstrated for wind speeds up to and including 10m/s. At wind speeds above 10m/s, the estimated upper bound is not more than 0.3dB above the limits. This margin of difference is consistent with the scale of increase associated with a minor contribution from the residual sound environment. For example, based on the measured level of 44.5dB at B53 at 11m/s, a residual sound level of 34dB or greater would be sufficient to influence the total measured noise level by more than 0.3dB. The background noise levels measured during the planning stage were not directly undertaken at B77 and are not sufficiently recent to enable specific background corrections to be applied. However, the previous measurements at the representative background monitoring location B53 did indicate background noise levels higher than 34dB (actual value was 36dB).

In addition to the above, the trend of increasing total noise levels above 10m/s is indicative of background related noise influences rather than the wind farm (see discussion in Section 6.0 of similar trends observed at B26 and B27, and the contrasting trend of noise levels exhibited at location B33 where levels plateau above 10m/s, consistent with expectation for modern variable speed and pitch regulated turbine). Based on the balance of the above considerations, the results are considered sufficient to support that the contribution of the wind farm to noise levels at B77 complies with the limits.

N8 Related receivers for monitoring location G37

Table 70: Compliance summary for related receiver G32 based on measurement data from G37

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
G32 - applicable limit	35.0	35.0	35.0	36.2	37.5	38.8	40.2	41.5	42.9	44.4
G37 - measured noise level	26.9	27.1	27.5	28.1	29.0	30.2	31.6	33.3	35.2	37.4
G32 - indicative compliance margin based on unadjusted levels measured at G37	8.1	7.9	7.5	8.1	8.5	8.6	8.6	8.3	7.7	7.0
Predicted wind farm noise - G32 levels minus G37 levels	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
G32 - estimated upper bound for wind farm noise	25.3	25.5	25.9	26.5	27.4	28.6	30.0	31.7	33.6	35.8
G32 - indicative compliance margin based on estimated upper bound for wind farm noise	9.7	9.5	9.1	9.7	10.1	10.2	10.2	9.9	9.3	8.6

Table 71: Compliance summary for related receiver G33 based on measurement data from G37

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
G33 - applicable limit	35.0	35.0	35.0	36.2	37.5	38.8	40.2	41.5	42.9	44.4
G37 - measured noise level	26.9	27.1	27.5	28.1	29.0	30.2	31.6	33.3	35.2	37.4
G33 - indicative compliance margin based on unadjusted levels measured at G37	8.1	7.9	7.5	8.1	8.5	8.6	8.6	8.3	7.7	7.0
Predicted wind farm noise - G33 levels minus G37 levels	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9
G33 - estimated upper bound for wind farm noise	25.1	25.2	25.6	26.3	27.2	28.3	29.7	31.4	33.3	35.5
G33 - indicative compliance margin based on estimated upper bound for wind farm noise	9.9	9.8	9.4	9.9	10.3	10.5	10.4	10.1	9.6	8.9

Table 72: Compliance summary for related receiver G37a based on measurement data from G37

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
G37a - applicable limit (associated receiver)	35.0	35.0	35.0	36.2	37.5	38.8	40.2	41.5	42.9	44.4
G37 - measured noise level	26.9	27.1	27.5	28.1	29.0	30.2	31.6	33.3	35.2	37.4
G37a - indicative compliance margin based on unadjusted levels measured at G37	8.1	7.9	7.5	8.1	8.5	8.6	8.6	8.3	7.7	7.0
Predicted wind farm noise - G37a assoc levels minus G37 levels	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
G37a - estimated upper bound for wind farm noise	25.5	25.7	26.1	26.7	27.6	28.8	30.2	31.9	33.8	36.0
G37a - indicative compliance margin based on estimated upper bound for wind farm noise	9.5	9.3	8.9	9.5	9.9	10.0	10.0	9.7	9.1	8.4

Table 73: Compliance summary for related receiver G52 based on measurement data from G37

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
G52 - applicable limit	35.0	35.0	35.0	36.2	37.5	38.8	40.2	41.5	42.9	44.4
G37 - measured noise level	26.9	27.1	27.5	28.1	29.0	30.2	31.6	33.3	35.2	37.4
G52 - indicative compliance margin based on unadjusted levels measured at G37	8.1	7.9	7.5	8.1	8.5	8.6	8.6	8.3	7.7	7.0
Predicted wind farm noise - G52 levels minus G37 levels	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
G52 - estimated upper bound for wind farm noise	25.6	25.7	26.1	26.8	27.7	28.8	30.3	31.9	33.9	36.0
G52 - indicative compliance margin based on estimated upper bound for wind farm noise	9.4	9.3	8.9	9.4	9.8	10.0	9.9	9.6	9.1	8.3

The above results demonstrate compliance with the applicable noise limits at all related receiver locations.

Notably, compliance was able to be demonstrated on the basis of total noise levels measured directly at G37, without adjustment for the reduction in noise levels for G32, G33, G37a and G52.

N9 Related receivers for monitoring location PW7

Table 74: Compliance summary for related receiver PW5 based on measurement data from PW7

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
PW5 - applicable limit	35.0	35.0	35.0	35.7	36.9	38.3	40.0	41.8	43.8	45.9
PW7 assoc - measured noise level	35.6	35.1	35.3	35.9	36.9	38.1	39.3	40.5	41.5	42.1
PW5 - indicative compliance margin based on unadjusted levels measured at PW7 assoc	-0.6	-0.1	-0.3	-0.2	0.0	0.3	0.7	1.3	2.4	3.9
Predicted wind farm noise - PW5 levels minus PW7 assoc levels	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1	-4.1
PW5 - estimated upper bound for wind farm noise	31.4	31.0	31.1	31.8	32.8	33.9	35.2	36.4	37.3	37.9
PW5 - indicative compliance margin based on estimated upper bound for wind farm noise	3.6	4.0	3.9	4.0	4.2	4.4	4.8	5.5	6.5	8.0

Table 75: Compliance summary for related receiver PW29 based on measurement data from PW7

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
PW29 - applicable limit	35.0	35.0	35.0	35.7	36.9	38.3	40.0	41.8	43.8	45.9
PW7 assoc - measured noise level	35.6	35.1	35.3	35.9	36.9	38.1	39.3	40.5	41.5	42.1
PW29 - indicative compliance margin based on unadjusted levels measured at PW7 assoc	-0.6	-0.1	-0.3	-0.2	0.0	0.3	0.7	1.3	2.4	3.9
Predicted wind farm noise - PW29 levels minus PW7 assoc levels	-5.1	-5.1	-5.1	-5.1	-5.1	-5.1	-5.1	-5.1	-5.1	-5.1
PW29 - estimated upper bound for wind farm noise	30.4	30.0	30.1	30.8	31.7	32.9	34.2	35.4	36.3	36.9
PW29 - indicative compliance margin based on estimated upper bound for wind farm noise	4.6	5.0	4.9	5.0	5.2	5.4	5.8	6.5	7.5	9.0

Table 76: Compliance summary for related receiver PW34 based on measurement data from PW7

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
PW34 assoc - applicable limit	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.9
PW7 assoc - measured noise level	35.6	35.1	35.3	35.9	36.9	38.1	39.3	40.5	41.5	42.1
PW34 assoc - indicative compliance margin based on unadjusted levels measured at PW7 assoc	9.4	9.9	9.7	9.1	8.1	6.9	5.7	4.5	3.5	3.9
Predicted wind farm noise - PW34 assoc levels minus PW7 assoc levels	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
PW34 assoc - estimated upper bound for wind farm noise	34.6	34.2	34.3	35.0	36.0	37.1	38.4	39.6	40.5	41.1
PW34 assoc - indicative compliance margin based on estimated upper bound for wind farm noise	10.4	10.8	10.7	10.0	9.0	7.9	6.6	5.4	4.5	4.8

Table 77: Compliance summary for related receiver PW36 based on measurement data from PW7

Description	Hub height wind speeds (m/s)									
	3	4	5	6	7	8	9	10	11	12
PW36 - applicable limit	35.0	35.0	35.0	35.7	36.9	38.3	40.0	41.8	43.8	45.9
PW7 assoc - measured noise level	35.6	35.1	35.3	35.9	36.9	38.1	39.3	40.5	41.5	42.1
PW36 - indicative compliance margin based on unadjusted levels measured at PW7 assoc	-0.6	-0.1	-0.3	-0.2	0.0	0.3	0.7	1.3	2.4	3.9
Predicted wind farm noise - PW36 levels minus PW7 assoc levels	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0	-4.0
PW36 - estimated upper bound for wind farm noise	31.6	31.1	31.3	31.9	32.9	34.1	35.4	36.5	37.5	38.1
PW36 - indicative compliance margin based on estimated upper bound for wind farm noise	3.4	3.9	3.7	3.8	4.0	4.2	4.6	5.3	6.3	7.8

The noise levels at related receivers PW5, PW29, PW34 and PW36 associated with operation of the wind farm are expected to be lower than those occurring at PW7. As a result of this, and the uncertainty surrounding the potential influence of the residual sound environment on the total measured noise levels at PW7, an indicative assessment of compliance based on unadjusted measured total noise levels at PW5, PW29 and PW36 was inconclusive. This is a result of the total measured noise levels at PW7 being a maximum of 0.6dB above the limit which apply at the related receivers at a wind speed of 3m/s; a margin of difference that is consistent with the scale of increase associated with a minor contribution from the residual sound environment.

However, when the expected reduction in noise level is conservatively applied to the total noise measurement data, compliance was able to be demonstrated for all applicable wind speeds – notably, the minimum compliance margin for these adjusted levels is 3.4dB.

In relation to related receiver PW34, compliance was able to be demonstrated on the basis of total noise levels measured directly at PW7, without adjustment for the reduction in noise levels.

APPENDIX O SUMMARY OF LISTENING STUDIES

Presented in the tables below are the details of the listening studies conducted during the measurement campaign. In accordance with the Noise Compliance Plan these assessments were conducted at each compliance monitoring location, multiple times during varied meteorological conditions and times of day. A number of assessment attempts were unsuccessful as the nearest turbines to the property being tested were inactive due the wind speeds being below cut-in. These attempts are also identified in the tables below.

Wind speeds and directions presented below are referenced to the hub height (80m) at the nearest met mast location. Additional details of the methodology used for the met mast correlations are presented in Appendix H.

O1 B8

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	18:15	12	9	93	No	-
8.01.2015	Evening	-	-	-	-	Unable to conduct listening test due to lack of wind
12.02.2015	21:17	11	11	113	Yes	Low frequency tone clearly audible at a low level. Not considered sufficiently prominent to warrant a penalty.
15.04.2015	15:28	13	5	270	No	-
22.05.2015	9:28	12	11	178	Yes	Low frequency tone clearly audible at a low level consistent throughout test
			Penalty for annoying characteristics?		No	Not considered sufficiently prominent to warrant a penalty. However additional objective assessments undertaken to define the source of the tone.

* Reference to Bannister met mast

O2 B11

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10.12.14	11:32	11	6	294	No	-
8.01.2015	Afternoon	-	-	-	-	Unable to conduct listening test due to lack of wind
12.02.2015	22:28	12	12	115	No	-
9.03.2015	8:40	16	6	285	No	-
15.04.2015	15:52	14	5	296	No	-
			Penalty for annoying characteristics?		No	

* Reference to Bannister met mast

O3 B12a

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10.12.2014	17:25	14	4	239	No	Closest turbine (BAN_15) operating intermittently during assessment.
8.01.2015	15:02	12	5	296	No	-
12.02.2015	12:13	14	7	138	No	-
9.03.2015	13:36	20	-	-	No	-
15.04.2015	11:02	11	9	322	No	-
			Penalty for annoying characteristics?		No	-

* Reference to Bannister met mast

O4 B13

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	Morning	-	-	-	-	Unable to conduct listening test due to lack of wind
8.01.2015	16:32	11	7	282	No	-
12.02.2015	12:53	12	8	118	No	-
15.04.2015	12:04	12	12	312	No	-
22.05.2015	9:52	12	11	172	Yes	Low frequency tone clearly audible at a low level.
			Penalty for annoying characteristics?		No	Not considered sufficiently prominent to warrant a penalty.

* Reference to Bannister met mast

O5 B18

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10/12/14	13:15	10	7	313	No	-
8.01.2015	12:45	11	7	297	No	-
12.02.2015	21:48	11	12	118	No	-
9.03.2015	11:30	14	12	266	No	-
15.04.2015	Afternoon	-	-	-	-	Unable to conduct listening test due to lack of wind
			Penalty for annoying characteristics?		No	-

* Reference to Bannister met mast

O6 B26

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	Mid morning	-	-	-	-	Unable to conduct listening test due to lack of wind
8.01.2015	Evening	-	-	-	-	Unable to conduct listening test due to lack of wind
12.02.2015	13:50	13	8	108	No	-
10.03.2015	11:30	15	6	86	No	-
15.04.2015	12:28	22	12	314	No	-
22.05.2015	10:59	11	14	162	No	-
			Penalty for annoying characteristics?		No	-

* Reference to Bannister met mast

O7 B27

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	Morning	-	-	-	-	Unable to conduct listening test due to lack of wind
8.01.2015	18:11	12	7	307	No	-
12.02.2015	Morning	-	-	-	-	Unable to conduct listening test due to lack of wind
10.03.2015	9:30	16	8	81	No	-
15.04.2015	14:29	12	10	289	No	-
22.05.2015	Morning	-	-	-	-	Property could not be accessed in time available on site. Unable to conduct listening test.
			Penalty for annoying characteristics?		No	

* Reference to Bannister met mast

O8 B29

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10.12.2014	14:06	11	5	295	No	-
8.01.2015	Evening	-	-	-	-	Unable to conduct listening test due to lack of wind
12.02.2015	22:05	11	11	119	No	-
15.04.2015	14:05	11	11	292	No	-
22.05.2015	11:29	11	12	146	No	-
			Penalty for annoying characteristics?		No	

* Reference to Bannister met mast

O9 B33

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10.12.2014	12:27	10	7	302	No	-
8.01.2015	11:30	11	6	294	No	-
12.02.2015	21:32	11	12	116	No	-
9.03.2015	18:56	15	8	247	No	-
14.04.2015	Afternoon	-	-	-	-	Unable to conduct listening test due to lack of wind
			Penalty for annoying characteristics?		No	-

* Reference to Bannister met mast

O10 B53

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10.12.2014	13:36	11	7	307	No	-
8.01.2015	Evening	-	-	-	-	Unable to conduct listening test due to lack of wind
12.02.2015	Morning	-	-	-	-	Unable to conduct listening test due to lack of wind
9.03.2015	18:25	15	8	260	No	-
14.04.2015	11:56	12	5	318	No	-
15.4.2015	15:02	11	6	277	No	-
			Penalty for annoying characteristics?		No	

* Reference to Bannister met mast

O11 G31

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10.12.2014	18:45	11	5	69	No	-
8.01.2015	10:26	15	6	313	No	-
12.02.2015	23:33	12	9	106	No	-
15.04.2015	Afternoon	-	-	-	-	Unable to conduct listening test due to lack of wind
22.05.2015	8:00	15	10	163	No	-
			Penalty for annoying characteristics?		No	-

* Reference to Gurrunda met mast

O12 G37

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	15:25	10	3	234	No	-
8.01.2015	12:28	13	7	302	No	-
12.02.2015	19:38	11	11	119	Yes	Low frequency tone clearly audible at a low level. Not considered sufficiently prominent to warrant a penalty.
14.04.2015	15:14	12	4	287	No	-
			Penalty for annoying characteristics?		No	The sound character identified on 12.02.15 was of low magnitude and was not identified during other study times.

* Reference to Gurrunda met mast

O13 G39

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	13:20	11	5	252	No	-
8.01.2015	10:35	14	6	316	No	-
12.02.2015	20:22	11	11	116	No	-
14.04.2015	Evening	-	-	-	-	Unable to conduct listening test due to lack of wind
22.05.2015	8:45	11	10	173	No	-
			Penalty for annoying characteristics?		No	-

* Reference to Gurrunda met mast

O14 K1

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9/10.12.2014	-	-	-	-	-	Property access had not been arranged
8.01.2015	Evening	-	-	-	-	Unable to conduct listening test due to lack of wind
12.02.2015	14:43	12	9	121	No	-
10.03.2015	11:58	17	5	86	No	-
15.04.2015	13:05	11	14	304	No	-
22.05.2015	10:30	11	12	170	No	-
			Penalty for annoying characteristics?		No	-

* Reference to Kiala met mast

O15 K2

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	Early afternoon	-	-	-	-	Unable to conduct listening test due to lack of wind
8.01.2015	Evening	-	-	-	-	Unable to conduct listening test due to lack of wind
12.02.2015	16:11	11	10	126	No	-
9.03.2015	12:23	15	10	268	No	-
14.04.2015	13:38	13	4	286	No	-
15.04.2015	13:39	14	13	296	No	-
		Penalty for annoying characteristics?			No	-

* Reference to Kiala met mast

O16 PW07

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
10.12.2014	10:45	11	6	301	No	-
7.01.2015	18:50	12	7	81	No	-
12.02.2015	18:06	13	12	109	No	-
9.03.2015	9:57	16	9	265	No	-
14.04.2015	Mid morning	-	-	-	-	Unable to conduct listening test due to lack of wind
			Penalty for annoying characteristics?		No	-

* Reference to Bannister met mast

O17 PW09

Date	Time	Duration (min)	Wind Speed (m/s)*	Direction (°)*	Objective analysis warranted?	Comments
9.12.2014	16:30	12	8	151	No	-
7.01.2015	19:59	11	6	68	No	-
12.02.2015	23:00	11	11	115	No	-
14.04.2015	Morning	-	-	-	-	Unable to conduct listening test due to lack of wind
22.05.2015	11:58	11	14	145	No	-
			Penalty for annoying characteristics?		No	-

* Reference to Bannister met mast

APPENDIX P OBJECTIVE TONALITY ASSESSMENT

This Appendix provides:

- An overview of the tonality assessment procedures
- An overview of the operation of the turbines at the site during the noise monitoring campaign
- Detailed results of listening studies and, where required, objective analysis
- Detailed results from additional testing conducted near to a sample of turbines
- A discussion of the results

The results of the testing and analysis presented in this Appendix demonstrate that adjustments for tonality are not applicable.

P1 Tonality Assessment Procedures

P1.1 Overview

The Project Approval (Clause 2.19) specifies that a 5 dB adjustment shall be applied to measured noise levels where tonality is present. In turn, both the Project Approval and Test Plan specify the use of the latest version of the IEC 61400-11 (Edition 3.0 November 2012)[23] to determine the presence of tonality.

In accordance with the Test Plan, the commissioning assessment involves a number of attended listening studies to subjectively evaluate the presence of annoying characteristics including tonality. If the attended studies indicate the potential presence of a characteristic which could attract an adjustment to the measured noise level, in accordance with Condition 2.19 of the Project Approval, objective analysis has then been used to quantify whether the characteristic is sufficiently prominent to warrant the application of the adjustment.

Consideration is also given to the duration and regularity of an identified tone when determining whether an adjustment to the measured noise levels is warranted.

P1.2 Implementation of IEC 61400-11

IEC 61400-11 defines a detailed procedure to determine reportable tones on the basis of analysis of narrow bands of frequencies. The outcome of the IEC 61400-11 analysis is a calculated level of tonal audibility.

The method prescribed in IEC 61400-11 relates to sound power level testing in close proximity of a selected wind turbine, typically within 100 m to150 m of a turbine. Some adjustment of the method is required to apply the standard to the assessment of tonality near receptor locations. These adjustments are noted in Table 78.

[23] IEC 61400 *Wind turbines – Part 11: Acoustic noise measurement techniques* (2012)

Table 78: Deviations from the IEC 61400-11:2012 tonality assessment method for receptor assessments

Item	IEC 61400-11:2012 requirement	Deviation	Comment
Binning data	Binning the collected 10 s audio samples per integer wind speed interval. Within each wind speed bin, all audio is evaluated for the presence of tones.	Data collected during a single listening study, with a 10 min to 15 min duration, will be considered as a single wind speed bin for the purposes of assessment.	It is understood that the intention of standard's method of grouping data into integer wind speed bins is to provide an evaluation of the performance of the turbine under discrete, repeatable operating conditions. Binning by integer wind speed during the listening study could result in a sparse set of data on account of the limited total measurement duration. Each study is therefore treated as a single operating condition for the purposes of this analysis.
Ground board	Use of a microphone mounted on a ground board for sound level measurements. It is understood that this is intended to assist in reducing the influence of wind induced noise on the microphone and, additionally, to standardise the ground reflections around the microphone.	Sound level data, including audio has been collected from a sound level meter installed approximately 1.5 m AGL. The measurement chain included the use of a secondary wind shield system around the microphone.	Tonality assessment is a relative evaluation of sound levels (comparing tonal peaks with masking noise in the surrounding frequency range). Further, an assessment at receiver locations is intended to account for the actual sound propagation conditions, rather than standardised reflections incorporated into certified turbine emission data. For these reasons, the use of a microphone at 1.5 m AGL is considered suitable.
Wind speeds	It is recommended that wind speeds be determined from the turbine power curve in combination with the measured electrical output of the test turbine.	A single wind speed value for the 10 min period has been determined from the meteorological masts referenced in the broader compliance assessment.	As each listening study is assumed to represent a single weather condition, the precise determination of wind speeds is considered less critical. In particular, the precise method detailed in the standard relates to one turbine whereas the sound character encountered during the listening study will typically involve contributions from multiple surrounding turbines.
Shut down	Periodic turbine shut down during the measurement period to assess the residual sound at the measurement location and account for this sound during the analysis of sound power levels.	The monitoring does not include any specific periods of wind farm shut down.	Given the comparatively short duration of each listening study, it is not considered practicable to shut down the wind farm. Additionally, the purpose of the listening studies is to evaluate wind farm sound character rather than absolute level. Correcting measured levels for residual sound is therefore less critical.

P1.3

Adjustments for Tonality

IEC 61400-11 does not specify the level at which tonality is deemed to be present, nor does it specify a procedure for applying adjustments to measured noise levels. Instead, the standard specifies that if the calculated tonal audibility is less than -3 dB, then the outcome of the analysis shall be reported as no relevant tones. If the tonal audibility is equal to or greater than -3 dB, and is sufficiently prevalent in the measurement data, then the calculated value of the tonal audibility shall be reported.

That a tone is sufficient to be reportable according to IEC 61400-11 does not infer that the tone will be audible, nor does it infer that an adjustment for tonality should be applied. For example, while IEC 61400-11 does not specify adjustments to account for tonality, the standard notes, based on a typical listener and a steady tone, that a tone is audible if the tonal audibility is above 0 dB. Audibility is ultimately a complex characterisation of sound, due to variables related to the sound in question, the background sound conditions and, importantly, wide variations in hearing thresholds across the population. However, as a guide, based on the guidance contained in IEC 61400-11, a tone that is reportable may not be audible to a typical listener.

In the absence of guidance in the IEC with respect to adjustments to account for the presence of tonality, reference is made to methods in the following documents:

- The draft publication *NSW Planning Guidelines – Wind Farms* (Draft NSW Guidelines) dated 2011
- ISO 1996-2 *Acoustics — Description, measurement and assessment of environmental noise — Part 2: Determination of environmental noise levels* (ISO 1996)

The method in each document is based on identifying tonal components of the sound and then quantifying the prominence of the tones to determine adjustments to measured noise levels to account for tonality.

Based on the advice contained in IEC 61400-11, and the related guidance provided by the Draft NSW Guidelines and ISO 1996, if an analysis based on IEC 611400-11 identifies a reportable tone with tonal audibility less than 0 dB, an adjustment of the measured levels for tonality is not considered to be warranted. Further, tonal audibility levels marginally above 0 dB (of the order of 1-2 dB), are unlikely to warrant the application of the 5dB adjustment described in the Project Approval.

At higher levels of tonal audibility, an adjustment for tonality may be applicable, depending on both the magnitude and regularity of the tone. An objective choice concerning the magnitude of the tonal audibility that would warrant a 5 dB adjustment may ultimately require combined analysis of the tone according to both IEC 61400-11 and ISO 1996.

The Noise Compliance Plan also notes that the application of an adjustment is dependent on determining whether tonality is a repeated characteristic of the wind farm. In this respect, the Noise Compliance Plan notes:

> *A "repeated characteristic" shall be defined in accordance with the draft NSW Wind Farm Noise Guidelines, December 2011, as a characteristic which occurs in more than 10% of the measurement intervals during an assessment period (i.e. daytime 7am to 10pm or night-time 10pm to 7am).*

P2 Turbine operation

The wind farm comprises Goldwind GW82 and GW100 wind turbines. The GW100 model accounts for the majority of the turbines at the site and, from observations during the listening studies reported in subsequent sections, is believed to be the source of an observed tonal sound.

Further, site observations and subsequent investigations by NGRWF have indicated that the power conversion plant within the nacelle of the GW100 turbines represents the primary source of noise emissions in the frequency range of interest.

NGRWF has advised that the firmware that controls the GW100 turbines provides the means to alter the operational characteristics of the power conversion plant, in turn altering the associated noise emissions of the turbine. NGRWF has implemented a series of firmware updates to the GW100 turbines during the course of the noise monitoring campaign with the objective of reducing the noise emissions of the turbine in the frequency ranges of interest.

NGRWF has provided[24] the dates when the firmware was updated. These dates are provided in Table 79.

Table 79: GW100 Firmware software versions

Update	Implemented
Version 1	8 to 12 December 2014
Version 2	13 to 14 January 2015
Version 3	13 to 14 April 2015
Version 4	9 to 12 June 2015

There is potential for turbine sound levels to change across different versions of the firmware depending on the nature of the changes in the control software. It is understood that the software changes in Table 80 relate solely to the operation of the power conversion equipment in the nacelle and do not alter the blade pitch or rotor rotation speed; the two factors which determine the aerodynamic noise emissions of the turbines. Accordingly, the firmware updates are not expected to have altered the aerodynamic noise emissions which dominate the total A-weighted noise emissions of the turbines. This is consistent with the results of the testing presented in this section.

[24] Information provided by email 8 July 2015

P3 Listening Study & Objective Analysis Results

Section 7.0 and Appendix O detail the results of listening studies conducted for each of the seventeen (17) locations included in the compliance monitoring campaign, with sixty-eight (68) listening studies completed over the duration of the compliance monitoring.

The majority of the listening studies did not indicate tonality to be a characteristic of the wind farm requiring further investigation.

A limited number of the listening studies at houses B8, B13 and G37 were identified as warranting further objective analysis. Full details of the listening study results for these locations are provided in Appendix O. A summary of the listening studies and objective analysis for these locations is provided below in Table 80.

Given that firmware modifications for reducing tonal noise emissions of the GW100 turbines were implemented during the noise compliance monitoring period, Table 80 also details the firmware implemented at the site at the time of the listening studies. In practice, a range of environmental and operational factors, including the firmware of the turbines, will influence the outcomes of the listening studies and objective analysis.

Table 80: Summary of listening studies and objective analysis for houses B8, B13 and G37

Date	Location	Objective analysis of tonality warranted	Time	Audio duration	Frequency	Tonal Audibility (ΔLa,k)	Turbine Firmware Version [1]
9/12/14	B13	N/A [2]	-	-	-	-	1
	B8	no	-	-	-	-	1
	G37	no	-	-	-	-	1
8/01/15	B13	no	-	-	-	-	1
	B8	N/A [2]	-	-	-	-	1
	G37	no	-	-	-	-	1
12/02/15	B13	no	-	-	-	-	2
	B8	yes	21:18 to 21:28 hrs	2 x 5 minutes	62 Hz	5.5 dB to 6 dB	2
	G37	yes	19:39 to 19:48 hrs	2 x 5 minutes	64 Hz to 66 Hz	4.3 dB to 5.8 dB	2
14/04/15	G37	no	-	-	-	-	2 to 3
15/04/15	B13	no	-	-	-	-	3
	B8	no		-	-	-	3
22/05/15	B13	yes	09:53 to 10:03 hrs	2 x 5 minutes	62 Hz	-2.5 dB to -1 dB	3
	B8	yes	09:29 to 09:39 hrs	2 x 5 minutes	64 Hz to 68 Hz	-1.3 dB to -0.9 dB	3

Note 1: Goldwind GW100 turbines only

Note 2: Unable to conduct listening test due to lack of wind

It can be seen in Table 80 above that a reportable low frequency tone of varying magnitude was objectively identified for four (4) of the twelve (12) listening studies at the three (3) houses where the characteristic was identified subjectively. These four (4) results are summarised as follows:

- Two instances (February 2015) where the calculated tonal audibility was above 0 dB and could warrant adjustments to the measured noise levels if it was a repeated characteristic of the wind farm
- Two instances (May 2015) where the calculated tonal audibility was below 0 dB and therefore not sufficient to warrant adjustments to the measured noise levels

Accordingly, the only instances when tonal audibility levels were greater than 0 dB (a reportable value deemed audible according to IEC 61400-11) were in February 2015. Since February, NGRWF have implemented noise mitigation measures to the turbines with the objective of reducing tonality. Subsequent testing of these mitigation measures for a sample of turbines confirmed a measureable reduction in the content of the turbine's noise levels in the frequency range of interest, without any significant change to the overall total A-weighted noise emissions of the turbines. These results are discussed in further detail in the following section of this Appendix.

P4 Near Field Testing Results

To assess the effect of the firmware updates on noise emissions in the frequency range of interest, noise testing near a group of GW100 turbines at the site was conducted by Marshall Day Acoustics. The testing was conducted under controlled conditions for an identical group of turbines with and without the latest version of the firmware.

The specific objective of the near field test was to compare noise emissions of the turbines with firmware Version 2, operating during February's listening study, and firmware Version 4 which is presently operating on all GW100 turbines at the site.

To provide a direct comparison of these firmware versions a number of measurements were conducted near to the turbines in order to reduce sources of variation related to differences in the emissions of each turbine and noise propagation effects at greater distance. Measuring near to the turbine also provides the benefit of a higher signal to noise ratio (control group turbines versus remaining turbines at the site and background noise levels).

The measurements were conducted at two (2) locations approximately 110 meters from the base of the GW100 turbine designated as BAN_09. Figure 35 below depicts the two measurement positions as a red dot.

Figure 35: Near field measurement positions

The initial objective of the test was to use a control group of turbines near to houses B8 and B13, on account of their inclusion in the objective analysis presented in the preceding sections. However, practical constraints relating to weather conditions and the influence of turbines outside of the control group required an alternative group to be selected.

Turbine BAN_09 was selected as the primary test turbine on account of the relatively flat and consistent terrain near the turbine, and the prevailing westerly wind direction at the time of the testing. These combined factors reduced the influence of the noise of more distant wind turbines at the site, thus providing a good opportunity to measure noise levels related to the contribution of the control group of turbines being evaluated.

While on-site it was found that turbines BAN_10, BAN_11, and BAN_12 contributed significantly to the noise at both of the chosen measurement positions. Accordingly, the four (4) turbines BAN_09, BAN_10, BAN_11, and BAN_12 to BAN_12 were considered as the control group of turbines for one of the measurement scenarios. In other measurement scenarios, turbines BAN_10, BAN_11, and BAN_12 were switched off to suppress their influence on the noise measurements and allow a controlled test of noise changes solely related to turbine BAN_09.

The testing took place on 23 June 2015. The three (3) measurement scenarios for the testing are described in Table 81.

Table 81: Firmware noise testing – measurement scenarios

Scenario	Noise test location	Turbine control group firmware and operational status
1	Downwind location	BAN_09, BAN_10, BAN_11, and BAN_12 operational Firmware Version 2 and then Firmware Version 4
2	Downwind location	BAN_09 operational Firmware Version 2 and then Firmware Version 4 BAN_10, BAN_11, and BAN_12 not operational
3	Crosswind location	BAN_09 operational Firmware Version 2 and then Firmware Version 4 BAN_10, BAN_11, and BAN_12 not operational

Throughout the duration of this testing, all wind turbines at the Gullen Range Wind Farm outside of the control group remained operational with the current firmware Version 4.

Observations while on-site identified that with the Version 4 firmware installed, there was a noticeable reduction in the sound of the turbines at the frequencies corresponding to the tonal content identified during the listening studies reported in the previous sections.

Audio records were captured during the testing and a narrow band analysis of this data has been carried out for representative audio samples associated with each measurement scenario. These periods have been deemed to be the most representative time periods with the least contribution from extraneous noise sources. Table 82 on the following page presents the length of audio samples analysed for each measurement scenario.

Table 82: Length of audio sample analysed for each measurement scenario

Scenario	Firmware	Length of audio sample (minutes)
1 – All control group turbines operational (downwind location)	Version 2	5
	Version 4	10
2 – BAN_09 operational - remainder of control group off (downwind location)	Version 2	10
	Version 4	12
3 – BAN_09 operational - remainder of control group off (Crosswind location)	Version 2	10
	Version 4	5

The objective analysis presented in the preceding sections has indicated tonal content in the 62 Hz to 68 Hz frequency range. A targeted narrow band analysis was therefore carried out over a frequency range of 0 Hz to 150 Hz, with a band width of approximately 1.5 Hz.

A narrow band spectrum has been analysed for each minute within each defined period. The level in the 62.1 Hz narrow band frequency has been determined for each one (1) minute period, and a range of sound pressure levels (SPL) has been found for each measurement scenario.

Figure 2 illustrates the range in noise levels measured at 62.1 Hz recorded during the defined analysis period for each scenario. The average sound pressure levels for each measurement scenario are also presented in Table 83.

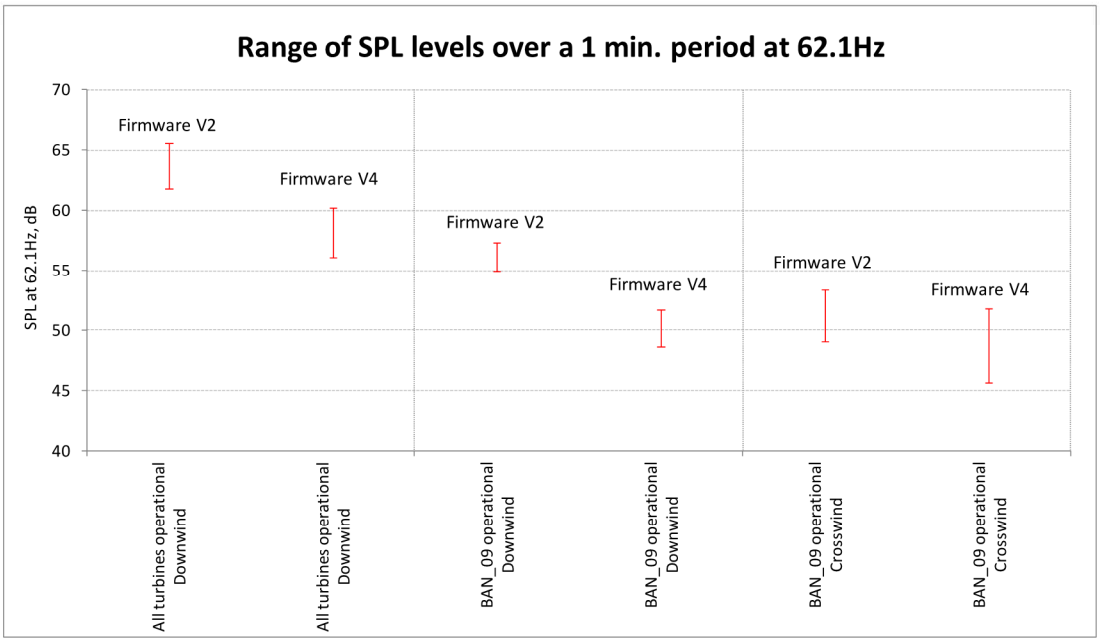


Figure 36: Range of sound pressure levels at 62.1Hz within the defined measurement period

Table 83: Average narrow band sound pressure levels for each measurement scenario

Scenario	Firmware	Average SPL dB at 62.1Hz narrow band
1 – All control group turbines operational (downwind location)	Version 2	63.7
	Version 4	58.2
2 – BAN_09 operational - remainder of control group off (downwind location)	Version 2	56.1
	Version 4	50.2
3 – BAN_09 operational - remainder of control group off (Crosswind location)	Version 2	51.2
	Version 4	48.7

The results presented in Figure 36 and Table 83 demonstrate the current firmware Version 4 results in a measureable reduction in the tonal content of the control group of turbines relative to firmware Version 2. The reduction observed for the control group of turbines equated to approximately 6 dB in the downwind direction and 2 to 3 dB in the cross wind direction.

Additionally, as part of this study, the broadband L_{Aeq} levels associated with each measurement scenario were compared. This comparison indicated relatively consistent L_{Aeq} levels, generally within the normal range of variation of turbine noise emission (less than 1dB variation between firmware changes). This result is consistent with expectations that the firmware changes primarily influence the tonal content of the sound related to the power conversion plant, rather than the overall broadband aerodynamic noise emissions of the turbines.

P5 Discussion

Listening studies were carried for each of the seventeen (17) receiver locations included in the compliance monitoring, equating to a total of more than sixty eight (68) listening studies as required by the Noise Compliance Plan.

The majority of the listening studies did not indicate the presence of tonality as a characteristic requiring further assessment. In four (4) instances in February and May 2015, relating to three (3) separate houses, tonality was identified and deemed to warrant further analysis.

In accordance with the Project Approval and Noise Compliance Plan, tonal audibility levels have been calculated for each of these four (4) instances using IEC 61400-11.

The combined results of measurements, listening studies and objective analysis in accordance with the Noise Compliance Plan are considered to demonstrate that tonality is not a determining factor in the assessment of the wind farm's compliance, based on the following.

- The results from the objective analysis of the data obtained during the listening studies in February 2015 indicated calculated tonal audibility levels greater than 0 dB at monitoring locations B8 and G37. Based on related guidance in ISO 1996 with respect to audibility levels and adjustments, the results at these locations do not provide a clear indication of the applicability of an adjustment to the measured noise levels. The outcome of the February listening study was also not repeated in the other listening studies at these houses
- The results from the analysis of the data obtained during the listening studies in May 2015 indicated calculated tonal audibility levels that were reportable but less than 0 dB at monitoring locations B8 and B13. These results are not sufficient to warrant adjustment to the measured noise levels.

Further, in the time since the February 2015 listening study, NGRWF has implemented site wide changes to the firmware of the GW100 wind turbines, primarily for the purpose of reducing noise emissions in the frequency range of the tonal content identified during the listening studies. The source of variations in listening study and objective analysis results may relate to a range of operational and environmental factors. However, the attended observations and measurements conducted in June 2015 for the current version of the firmware confirmed a reduction in noise levels in the frequency range of interest for a sample of turbines, without any significant change to the overall total A-weighted noise emissions of the turbines. The testing of these measures was conducted for an individual control turbine, and collectively for a cluster of control turbines, to investigate the potential effect of the firmware change that has been applied to all GW100 turbines at the site. The testing was based on assessing the differences between the firmware in place in February 2015 and the current firmware operating at the site which was implemented following the completion of the last listening study in May 2015. The 2 dB to 6 dB average reduction in measured noise levels was observed for both the individual control turbine and the combined noise of the control group of turbines. These results provide further support that tonality is not a determining factor in the assessment of the wind farm's compliance. The results of the testing and analysis presented in this Appendix demonstrate that adjustments for tonality are not applicable.