Stockyard Hill Wind Farm

Post-Construction Noise Assessment

Environment Protection Regulation 131D

S3425.2C30

July 2023

sonus.

Chris Turnbull
Principal
Phone: +61 (0) 417 845 720
Email: ct@sonus.com.au
www.sonus.com.au

sonus.

Document Title	Stockyard Hill Wind Farm Post-Construction Noise Assessment Environment Protection Regulation 131D
Client	Goldwind Australia Pty Ltd
Document Reference	S3425.2C30
Date	July 2023
Author	Chris Turnbull, MAAS

© Sonus Pty Ltd. All rights reserved.

This report may not be reproduced other than in its entirety. The report is for the sole use of the client for the particular circumstances described in the report. Sonus accepts no responsibility to any other party who may rely upon or use this report without prior written consent.

sonus.

CONTENTS

1 INTRODUCTION

Regulation 131D of the *Environment Protection Regulations 2021* (the **Regulations**), as reproduced below, requires a post-construction noise assessment for the facility to be conducted in accordance with the New Zealand Standard 6808:2010, *Acoustics – Wind Farm Noise* (the **Standard**).

> ***131D Post-construction noise assessment***
>
> *(1) An operator of a wind energy facility that commences operation on or after 1 November 2021 must ensure that a post-construction noise assessment for the facility is conducted—*
>
> *(a) within 12 months of the commencement of operation of the facility; or*
>
> *(b) in the case of a facility that commences operation in stages as set out in the authorising document for that facility, within 12 months of each stage being completed.*
>
> *(2) A post-construction noise assessment must—*
>
> *(a) be conducted in accordance with NZS 6808:2010 by a suitably qualified and experienced acoustician; and*
>
> *(b) demonstrate whether or not the wind energy facility complies with the noise limit for that facility.*
>
> *(3) The operator must—*
>
> *(a) ensure that a report of the post-construction noise assessment is prepared; and*
>
> *(b) engage an environmental auditor to prepare a report under regulation 164(ca)(i) in relation to the post-construction noise assessment.*
>
> *(4) The operator must give a copy of each report referred to in subregulation (3) to the Authority within 10 business days of the completion of the auditor's report.*

Sonus has been engaged by Goldwind Australia Pty Ltd to conduct the post-construction testing in accordance with the Regulations to determine compliance for the Stockyard Hill Wind Farm (the **Wind Farm**), comprised of 149 Goldwind GW3S turbines.

This report, prepared in accordance with the Regulations and Section 8.3 of the Standard, summarises the assessment of operational noise levels at nine residences selected in accordance with sections 7.1.3, 7.2.6, and 7.5.1 of the Standard. Appendix A outlines where the information required in accordance with Section 8.3 of the Standard can be located in this report. The assessment includes analysis of noise monitoring at the residential locations, intermediate locations between the residences and Wind Farm, and nearfield locations around six nominated turbines, consisting of one of each configuration of turbine installed at the Wind Farm. The assessment also includes an assessment of the special audible characteristics of tonality and amplitude modulation in accordance with the Standard.

2 TEST METHODOLOGY

Subregulation 2 of regulation 131D states that a post-construction assessment must:

(a) be conducted in accordance with NZS 6808:2010 by a suitable qualified and experienced acoustician; and

(b) demonstrate whether or not the wind energy facility complies with the noise limit for that facility.

Nine residential logging locations were identified where noise levels from operation of the Wind Farm are to be measured to determine compliance with the Regulations. There were two of the nominated residential logging locations where access was not granted (B029 and B121), therefore the noise monitoring was conducted at backup locations (B328 and B118, respectively). The coordinates shown are those of where each logger was placed at the testing location. Where the Wind Farm is shown to be compliant with the noise limit at the test locations, the Wind Farm is considered to be compliant with the Regulations. The nine locations are shown in Table 1 and graphically in Figure 1 and Figure 2. All locations except B061 are neighbour dwellings that are owned by non-participant landowners not on the wind farm site and, in accordance with the Standard, are noise sensitive locations.

Table 1: Testing Locations

Nominated Location	Backup Location	Actual Monitoring Location	Coordinates (WGS 84 Zone 54)	
			Easting	Northing
B006	B113	B006	706600	5851418
B029	B328	B328	712410	5850536
B061(S)	B060	B061(S)	711425	5846996
B065	B099	B065	710655	5841001
B083	B079	B083	712071	5835637
B111	B006	B111	706546	5850423
B114	B113	B114	703299	5849525
B121	B118	B118	698301	5850411
B171	B167	B171	697410	5837887

(S) – This location is understood to be a stakeholder owned by Goldwind

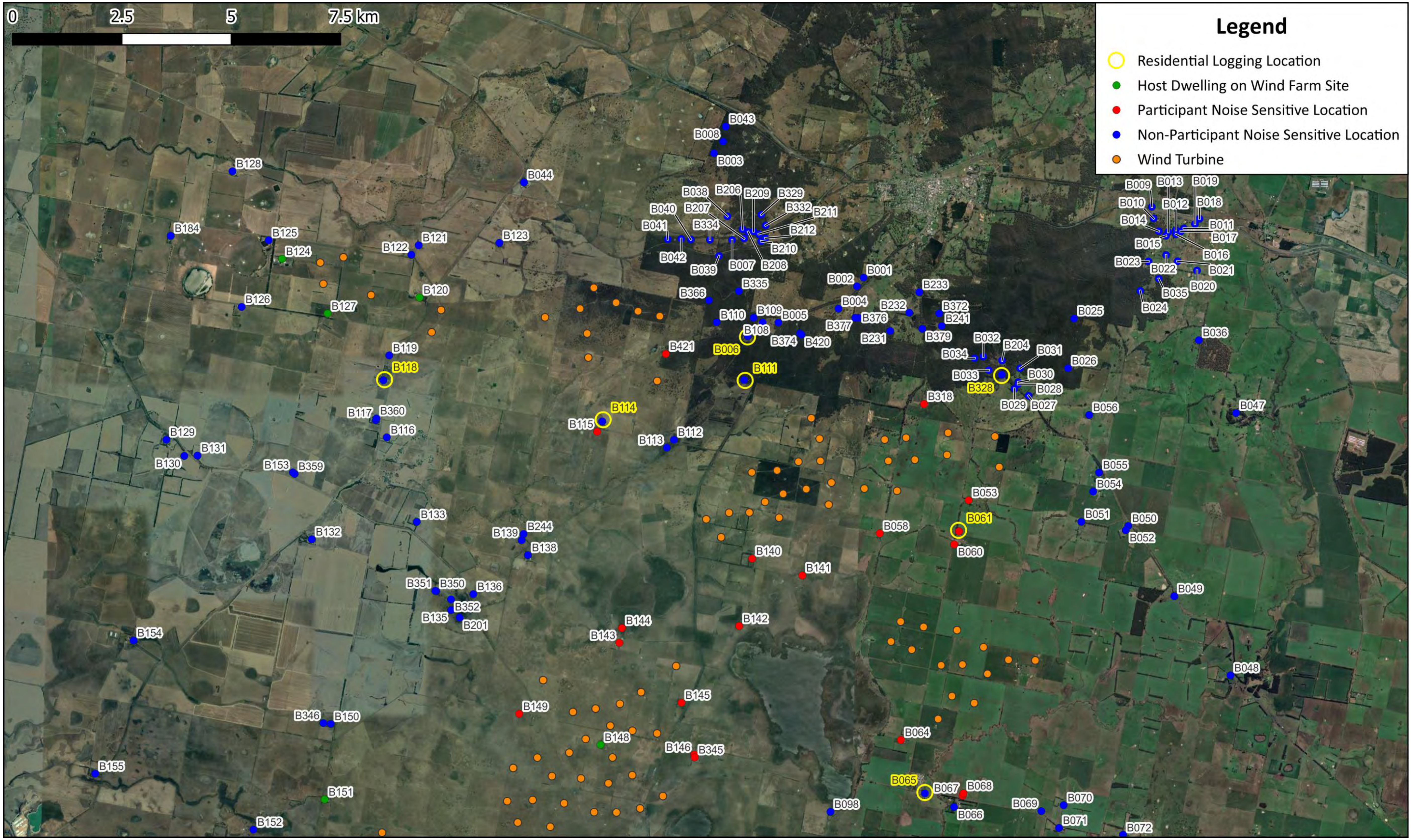


Figure 1: Monitoring Points and Noise Sensitive Locations (North Section)

sonus.

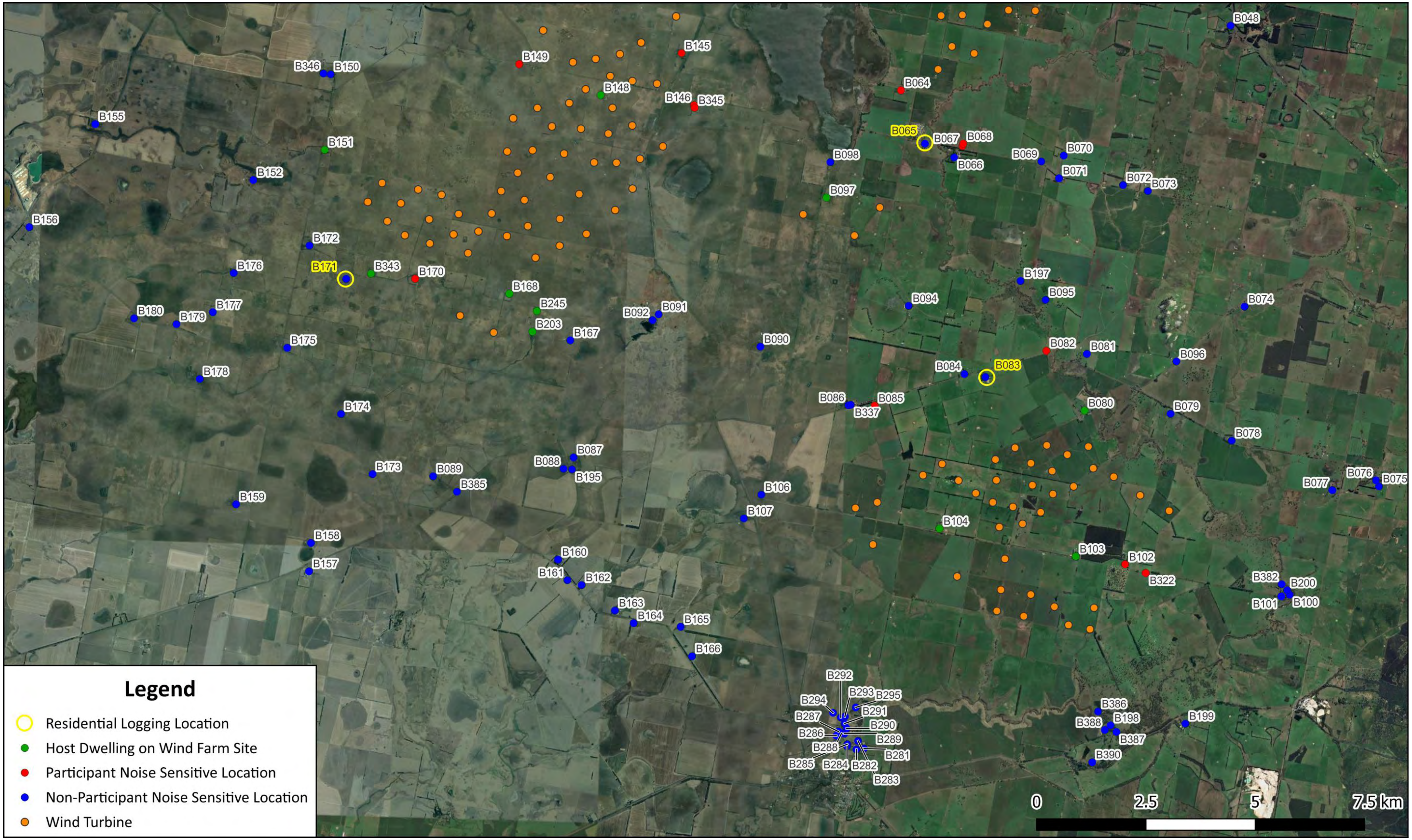


Figure 2: Monitoring Points and Noise Sensitive Locations (South Section)

The noise limit for the facility is determined by the Regulations with reference to the *relevant noise standard* for the facility. The relevant noise standard for a wind energy facility that is the subject of an authorising document can be determined with reference to the below table, reproduced from the Regulations.

Table–Relevant noise standard for wind energy facilities

Column 1 *Item*	*Column 2* *Authorising document applying to the wind energy facility*	*Column 3* *Relevant noise standard*
1	An authorising document issued before 1 January 2011, unless item 2(b) applies	NZS 6808:1998
2	(a) An authorising document issued on or after 1 January 2011; or (b) Any authorising document that has been amended to require compliance with NZS 6808:2010	NZS 6808:2010
3	An authorising document that sets out conditions to modify or replace either NZS 6808:1998 or NZS 6808:2010 in relation to wind turbine noise	Either NZS 6808:1998 or NZS 6808:2010 as specified in items 1 and 2, as modified or replaced by the authorising document

The authorising document for the Wind Farm, in this case the planning permit, was originally issued prior to 1 January 2011 but was amended to require (amongst other things) compliance with NZS 6808:2010 in 2017. In addition, the authorising document sets out conditions to modify NZS 6808:2010 in relation to wind turbine noise. Therefore, as per the Regulations, Item 3 will apply, meaning the relevant noise standard for the facility is NZS 6808:2010, as modified by the planning permit, Planning Permit No. PL-SP/05/0548/D (the **Planning Permit**). It is noted that the noise limits for non-participant dwellings as outlined in the Planning Permit are in accordance with the Standard. The noise limits for participant dwelling represents a modification of the Standard, as the Standard does not differentiate between participant and non-participant dwellings.

Sonus conducted a pre-construction noise assessment[1] of the Wind Farm that included determining the criteria which apply at residences in the vicinity of the Wind Farm. Table 2 is from the pre-construction noise assessment and summarises the criteria for the compliance monitoring locations. It is noted that the criteria in this table have been determined in accordance with the Standard, as modified by the Planning Permit.

Table 2: Criteria

Residential Logging Location	Criteria dB(A), at Integer Hub Height Wind Speed, m/s											
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
B006	40	40	40	40	40	40	40	40	40	40	40	40
B061(S)	45	45	45	45	45	45	45	45	45	45	48	51
B065	40	40	40	40	40	40	40	42	44	45	47	49
B083	40	40	40	40	40	40	40	40	41	44	46	49
B111	40	40	40	40	40	40	40	40	40	40	42	44
B114	40	40	40	40	40	40	40	40	41	43	45	46
B118	40	40	40	40	40	40	40	40	40	40	43	46
B171	40	40	40	40	40	40	40	40	42	45	47	49
B328	40	40	40	40	40	40	41	42	43	44	45	46

(S) – This location is understood to be a stakeholder owned by Goldwind

To assist with demonstrating whether or not the Wind Farm complies with the noise limit for the facility, additional monitoring was conducted at nearfield and intermediate locations. This was for the purpose of determining the character of noise (tonality and amplitude modulation) from the turbines and enabling extraneous noise from other sources to be excluded from the data analysis (in accordance with Section 7.2.4 of the Standard). The testing was conducted at locations where the noise from other sources in the environment is minimised (in comparison to the noise level from wind turbines) and therefore the results can assist in determining compliance at the residential logging locations, when the noise from turbines is masked by other extraneous sources.

[1] Summarised in the Sonus report with reference S3425.2C3, dated October 2017.

3 NEARFIELD AND INTERMEDIATE MEASUREMENTS

Nearfield and intermediate testing has been conducted for the purpose of determining the character of the noise from the turbines and enabling noise from other sources to be excluded from the noise at residential logging locations.

The results of the nearfield measurements and analysis for each integer wind speed from cut-in to the wind speed at rated power include:

- The apparent sound power level;
- The tonal adjustment and tonal frequency for any tones present;
- An indication of the possible presence of amplitude modulation.

The apparent sound power levels were used to determine the wind speed at which the highest sound power level was emitted from the turbines. If the noise at residential logging locations were to continue to increase at wind speeds above the wind speed of highest noise emission, this would indicate that the noise is from sources other than the turbines (most commonly wind in trees for high wind speed conditions).

The tonal adjustment and tonal frequency were used to assist in determining the wind speeds and frequencies of potential tones at residential logging locations that would require further analysis.

The assessment for amplitude modulation was used to determine whether such a characteristic would be present at the residential logging locations. If the data were to indicate a measurable modulation trace at the blade pass frequency that exceeds the objective criteria in Section B3.2 of the Standard for the overall A-weighted noise level, longer term testing at the residential logging locations would be required.

The results of the intermediate testing, which occurred concurrently with the residential logging, have been used to assist in determining the contribution of noise from the Wind Farm.

3.1 NEARFIELD MEASUREMENTS

Nearfield testing has been conducted at six turbines, understood to comprise one of each configuration of turbine installed at the site. The testing was done for the purpose of determining the apparent sound power level of the turbines and the presence of tonality or amplitude modulation in the noise profile of the turbine. The table below indicates the turbines tested, the dates the testing was conducted, the configuration of the turbines, the highest sound power level measured, and the report where the results are summarised. The location of the tested turbines, as well as the configuration of the turbines on the site can be seen in Figure 3 below. The nearfield reports have been included as Appendix G of this report.

Table 3: Nearfield Testing Locations

Turbine	Testing Dates (inclusive)		Turbine Configuration	Maximum Sound Power Level		Report Reference
	Start	End		Sound Power	Wind Speed	
18	10/01/2022	12/01/2022	GW140/3570 V5	111 dB(A)	10m/s	S3425.2C17
22	27/08/2022	29/08/2022	GW140/3570 Only 3/4/5	111 dB(A)	12m/s	S3425.2C25
83	27/08/2022	29/08/2022	GW140/3000 V5	112 dB(A)	14m/s	S3425.2C26
93	07/07/2022	09/07/2022	GW140/3400 V5	111 dB(A)	12m/s	S3425.2C24
141	21/07/2022	22/07/2022	GW140/3570 V4	114 dB(A)	15m/s	S3425.2C21
149	18/07/2022	21/07/2022	GW140/3570 Clean Blades	111 dB(A)	9m/s	S3425.2C23

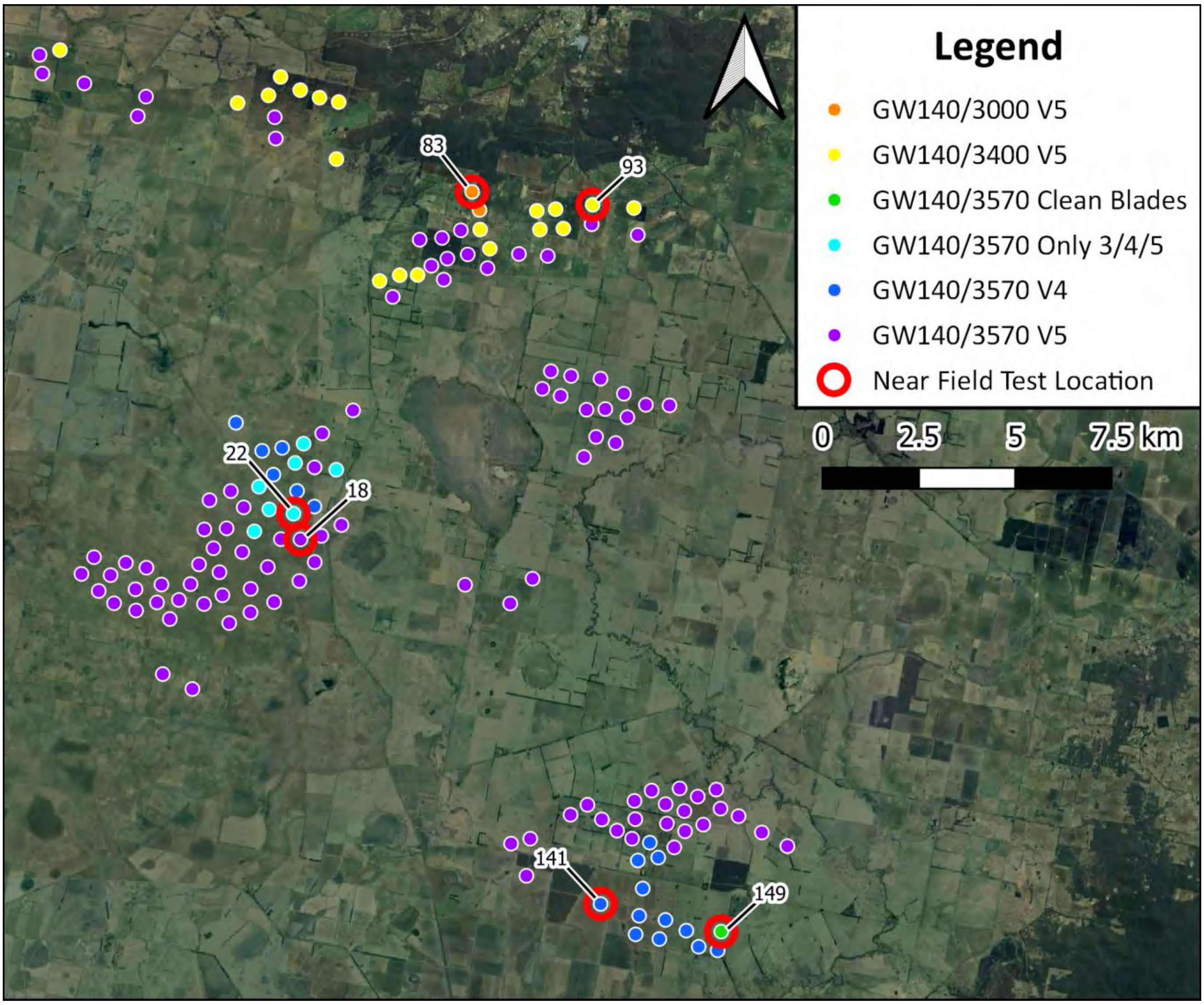


Figure 3: Near Field Test Locations

The near field testing was conducted in general accordance with the procedure outlined in the International Standard *IEC 61400-11: 2012 Wind turbines – Part 11: Acoustic noise measurements techniques* (**IEC 61400**). While it is noted that IEC 61400 requires the sound power level to be determined for every integer and half-integer wind speed, the compliance assessment in accordance with the Standard only requires the integer wind speeds to be considered. As such, the near field analysis was only conducted for the integer wind speeds.

The results of the nearfield special audible characteristics testing, conducted in accordance with Appendix B of the Standard, have been used to inform the post-construction analysis summarised in this report. The apparent sound power levels indicate that there is no clear wind speed at which the noise from the turbines reaches a maximum. As a result, the assessment in this report includes all data at high wind speeds. No tonality was identified at any of the nearfield locations, based on the conducted analysis. Likewise, no regular amplitude modulation was found in the overall A-weighted levels. In addition to the objective testing, tonality and amplitude modulation were subjectively assessed close to turbines and at residential locations. The subjective assessments confirmed that the conclusions of the near field special audible characteristic testing were representative of the wind farm overall.

The near field test locations are spread throughout the wind farm, covering all turbine configurations and providing a range of different conditions based on the topography of the area. As the tested turbines represent each of the turbine configurations, are from a variety of locations around the Wind Farm, and do not exhibit any characteristics different from other turbines, it is considered that the six measured turbines are demonstrative of the noise produced at the other turbines not tested.

The sound power level results have been used to update the noise model used for the initial compliance assessment in order to revise the predicted noise levels for locations surrounding the wind farm. It is noted that these predictions do not demonstrate either compliance or non-compliance. They have simply been provided, upon request, for comparison with those produced for the initial compliance report. Figure 4 below shows the predicted noise level contours for the Wind Farm, for a wind speed of 11m/s. It is also noted that the predictions below consider only the noise from the wind farm, which is not the case in practice, where other sources of noise can influence measured results.

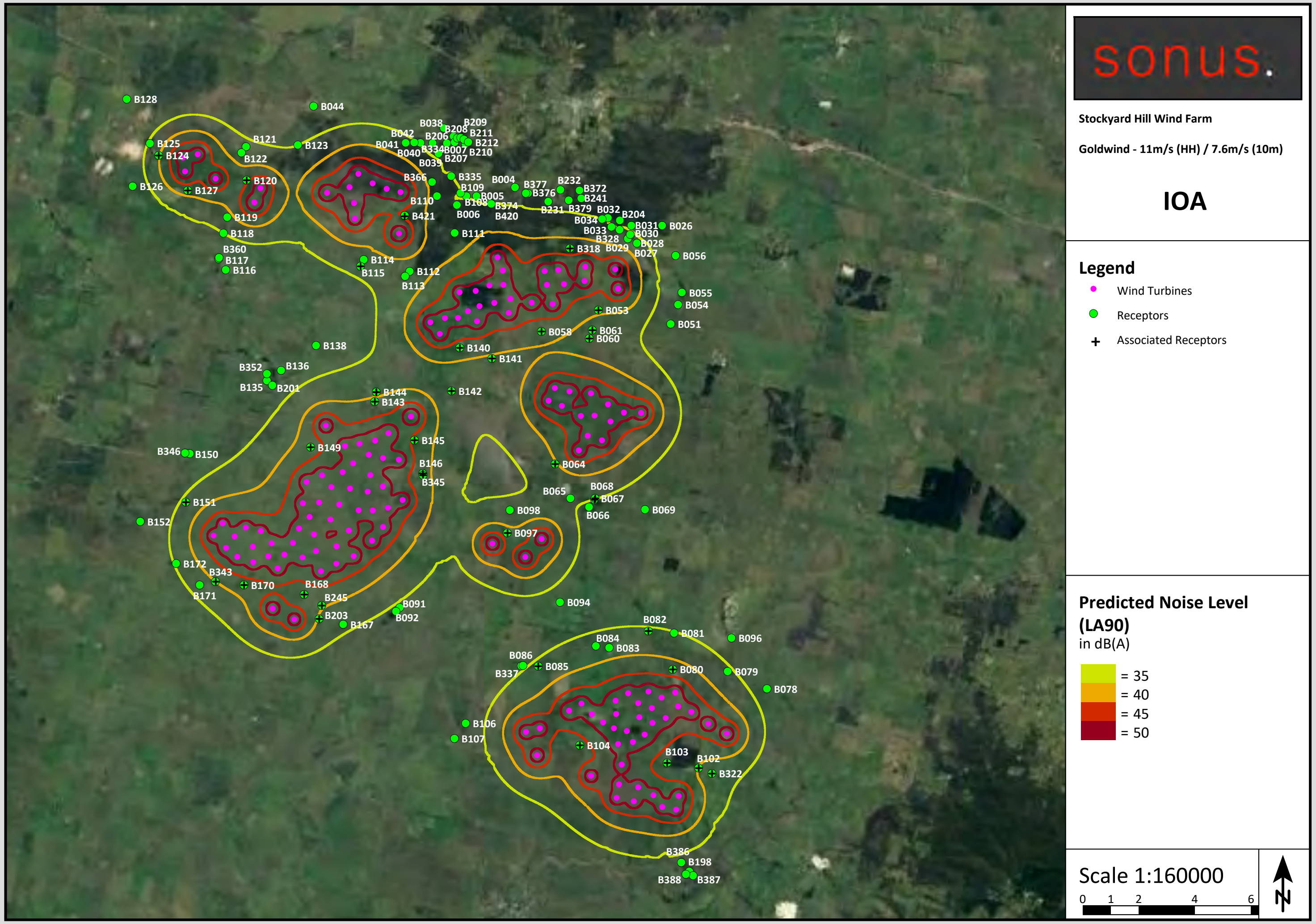


Figure 4: Predicted Noise Level Contours

3.2 INTERMEDIATE MEASUREMENTS

The noise level from the Wind Farm was measured simultaneously at the residential logging locations as well at intermediate locations. The intermediate locations were chosen because they:

- were between the Wind Farm and the residence being assessed; and,
- had a higher predicted Wind Farm noise level to background noise level ratio (the noise level from the Wind Farm is more likely to be measurable above the level of background noise).

Data filtering has been used to remove time periods where noise data collected at an intermediate position confirms that the source of the noise at a residential logging location is not the wind turbines, and is further outlined in Section 4.1. For example, noise data collected in a particular 10-minute interval at a residential logging location may be removed:

- if the noise measured in the same period at the intermediate position (closer to the turbines) is at a lower level; or
- if the frequency content of the noise at the receptor is not consistent with the frequency content at the intermediate position.

The intermediate measurement equipment was located between the residential logging locations and the Wind Farm, in open spaces away from structures and trees. They have also been located such that they can be used as an *alternative monitoring point*, if required, for future assessments against the Regulations.

The noise level was measured at the intermediate locations using NATA calibrated Rion NL-21 and Rion NL-22 Class 2 sound level meters, in compliance with Section 7.2.2 of the Standard. The coordinates of the intermediate locations and the serial numbers of the sound level meters used are provided in Table 4 and the calibration certificates are attached in Appendix B.

Table 4: Intermediate Logging Locations

Intermediate Logging Location	Coordinates		Sound Level Meter Serial Number
	Easting	Northing	
B006-B111 Intermediate A	706879	5850046	00354109
B006-B111 Intermediate B	705793	5850868	01298933
B061(S) Intermediate	711443	5847469	00709523
B065 Intermediate A	710654	5841416	00877043
B065 Intermediate B	710161	5840479	00683866
B083 Intermediate	711948	5835259	00709526
B114 Intermediate	703294	5849702	01298930
B118 Intermediate	698442	5850531	01298931
B171 Intermediate	697992	5838288	01298928
B328 Intermediate	710988	5849917	01298929

(S) – This location is understood to be a stakeholder owned by Goldwind

An aerial photograph showing the residential logging locations, the turbine layout, meteorological masts, and the intermediate locations is provided below:

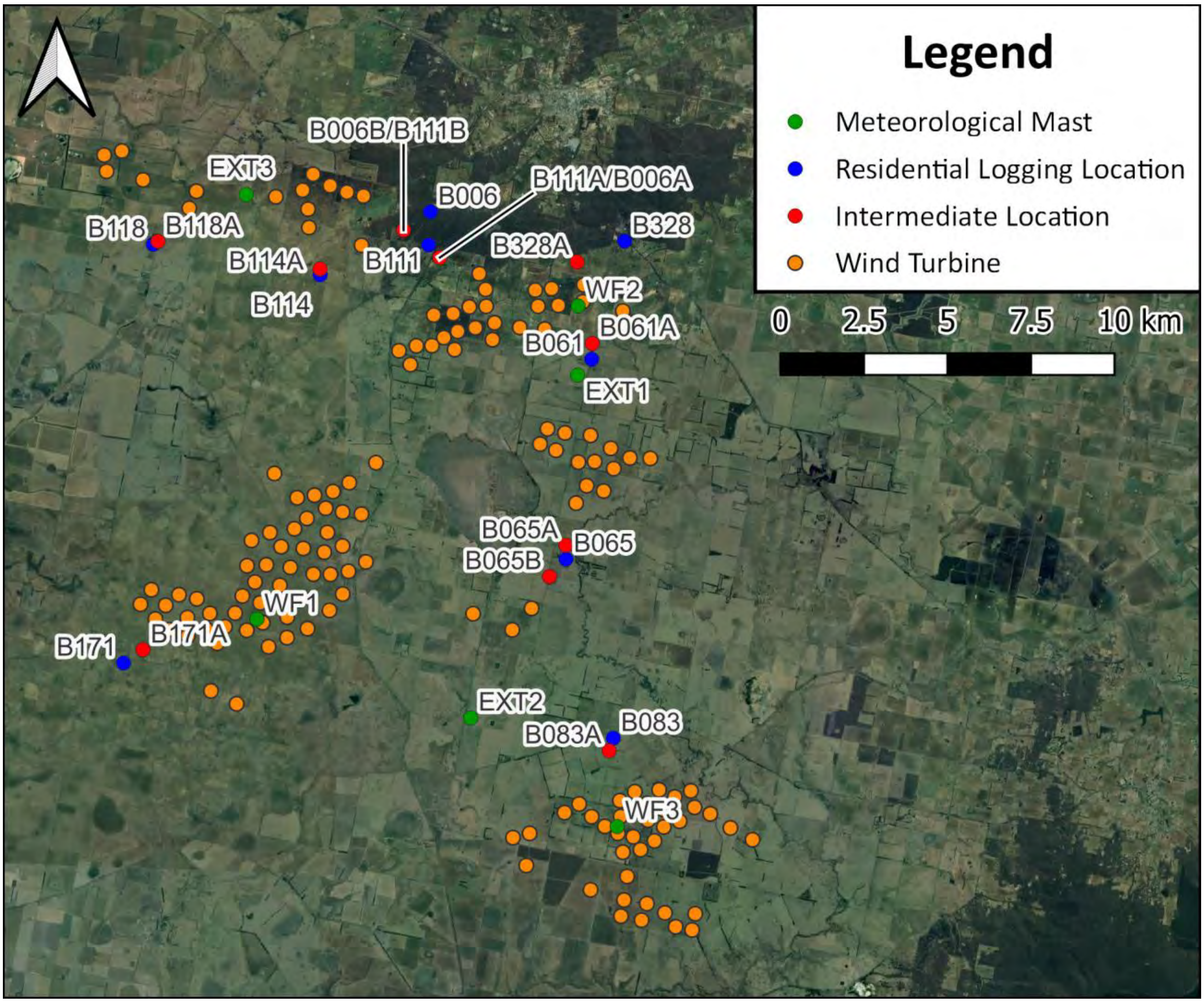


Figure 5: Aerial View of the Site

The use of the intermediate location measurements is discussed further in Section 4.

4 RESIDENTIAL LOGGING

The A-weighted noise levels (L_{A90}) at each of the residential logging locations were measured continuously in 10-minute intervals over a number of periods between 6 July and 8 September 2022, summarised in Table 5, which resulted in at least 6 weeks of data not affected by operational constraints of the Wind Farm.

Table 5: Sound Level Meter Serial Numbers

Residential Logging Location	Noise Monitoring Period		Sound Level Meter Serial Number
	Start Date	End Date	
B006	07/07/2022	25/08/2022	00320657
B061(S)	06/07/2022	25/08/2022	00710394
B065	06/07/2022	24/08/2022	00710391
B083	07/07/2022	25/08/2022	00220543
B111	07/07/2022	25/08/2022	00320648
B114	07/07/2022	25/08/2022	00320647
B118	07/07/2022	25/08/2022	00320649
B171	07/07/2022	08/09/2022	00710393
B328	06/07/2022	25/08/2022	00710427

(S) – This location is understood to be a stakeholder owned by Goldwind

At each of the monitoring locations, Rion NL-52 or NL-42, NATA calibrated, Class 1 or 2 sound level meters with a noise floor of less than 20 dB(A) were deployed, in compliance with Section 7.2.2 of the Standard. The serial numbers of the sound level meters are provided in Table 5 and the calibration certificates are provided in Appendix B.

The sound level meters were calibrated before and after the background noise monitoring regime with either a Class 1 Rion NC-74 calibrator or a Class 1 Rion NC-75 calibrator (with serial numbers 35094478 and 34913547, respectively) and the microphones were fitted with Rion WS-15 all-weather wind shields.

The position of noise loggers, in all instances, were on the Wind Farm side of the dwelling and at least 5m from the building facade, to remove the effects of reflecting surfaces, in accordance with Section 7.1.6 of the Standard. A photograph of the noise logging equipment at each residential logging location is provided in Appendix C.

At each of the residential logging locations, noise monitoring equipment was placed at the equivalent position to the background noise monitoring location, prior to construction of the Wind Farm, with the exception of B114, as required by Section 7.5.1 of the Standard. An air-conditioning unit had been installed near this location since the pre-construction assessment was completed, so the noise monitoring equipment was located away from this unit, while still fulfilling the positioning requirements noted above.

In addition to the noise logging, local wind speed logging was conducted at 3 locations (B061, B114 and B171) using Rainwise wind data loggers. Local rainfall data were collected using a combination of Rainwise and Hobo rain loggers at 2 locations (B114 and B171). The local weather loggers were at B061 and B114 for the duration of the noise logging period and at B171 from 25 August until the end of the monitoring period. The rainfall data and the measured wind speed at the microphone height were used to identify periods when data might have been adversely affected by weather. For locations where the local weather logging equipment was not deployed, data from the closest weather logger has been used in the analysis. A measurable amount of rain was recorded on a number of days, including: 07/07/2022 – 09/07/2022, 11/07/2022 – 13/07/2022, 17/07/2022, 18/07/2022, 23/07/2022, 25/07/2022 – 28/07/2022, 31/07/2022 – 03/08/2022, 06/08/2022, 07/08/2022, 11/08/2022 – 20/08/2022, 22/08/2022 – 27/08/2022, 29/08/2022, 02/09/2022, 04/09/2022, and 07/09/2022 – 09/09/2022, all inclusive.

During the noise monitoring regime, wind speed and direction were monitored at three meteorological masts located around the Wind Farm (Operational Masts). The wind speed data were then referenced back to the additional three locations where masts were previously located during the pre-construction noise monitoring (Development Masts). This was conducted based on correlations between the wind masts when all masts were operating, prior to the operation of the Wind Farm and was completed by GHD. The details of analysis are summarised in the technical memorandum prepared by GHD and titled "Derivation of Wind Reference Data", dated 7 September 2022. This has been used to provide a hub height (108.5m) data set in 10-minute intervals, free of wake effects at each of the six masts used for the pre-construction noise monitoring. A hub height of 108.5m is the same as that used for the pre-construction assessment. The locations of the meteorological masts are provided in Table 6. It is noted that the location for WF3 in the technical memorandum is incorrect and has been corrected for this report. A wind rose has been prepared for both the noise monitoring period as well as a long-term period preceding the post-construction monitoring. These can be seen in Appendix D and show that the most and least frequent wind directions remain the same between these two periods. This indicates that the wind conditions experienced during the monitoring period are representative of all conditions experienced on the site.

Table 6: Meteorological Mast Locations

Mast Location		Coordinates (WGS 84 Zone 54)		Anemometer Height
		Easting	Northing	
Development Masts	WF1	701402	5839204	82m
	WF2	711017	5848595	82m
	WF3	712188	5832983	82m
Operational Masts	EXT1	711003	5846520	80m
	EXT2	707804	5836241	80m
	EXT3	701085	5851932	80m

4.1 DATA ANALYSIS

Section 7.2.4 of the Standard allows extraneous noise sources to be removed. This has been implemented as follows:

- Filtering out time periods:
  - affected by rain, hail or wind based on a weather logger placed at an equivalent location to one of the noise loggers. Data is adversely affected where precipitation occurs in a 10-minute period, or the period either side, or where a wind speed greater than 5 m/s is exceeded for 90% of a 10-minute period (conducted at all locations);
  - when sufficient WTGs are not operational to influence the measured level during the current 10-minute period (conducted at all locations);
  - where the wind speed is below the cut-in wind speed (conducted at all locations); and
  - considered abnormal, such as during local construction or maintenance activities, or during the setup or collection of equipment (conducted at all locations).
- The subtraction of the background noise levels from the compliance noise measurements (conducted at all locations, except B111).
- Filtering out time periods where noise data collected at an intermediate location confirms that the source of the noise at a receptor is not the wind turbines (conducted at B111).

It is noted that:

- The wind farm was shut down for select periods during the noise monitoring period. The dates of these periods, as well as the monitoring locations impacted can be seen in Table 7. Data points during these periods have been removed from the analysis. For periods where only some of the wind turbines were off, the predictions have been consulted to determine the contribution that these turbines would have had on the locations used for the compliance assessment. At these locations, the contribution of the off turbines was no more than 11 dB(A), which is at least 20 dB(A) below the total predicted noise level at these locations, thus indicating that these turbines do not influence the noise level at these locations. Therefore, the wind farm operating at less than full capacity had no impact on the compliance assessment. It is noted that it is common for one or more turbines to be taken off-line periodically to allow routine servicing or in response to non-scheduled maintenance requirements.

Table 7: Wind Farm Shut Down Periods

Start Time	End Time	Shutdown Reason	Affected Locations
22/07/2022 9:30am	03/08/2022 4:30pm	AEMO	B006, B061(S), B111, B114, B118, B328
25/07/2022 6:40am	30/07/2022 4:30pm	AEMO	B065, B171, B083
05/09/2022 4:30am	08/09/2022 12:00pm	HV Maintenance	B171

(S) – This location is understood to be a stakeholder owned by Goldwind

- Section 7.5.3 of the Standard requires that the contribution of the background sound be removed from the analysis. It notes that this can be achieved by logarithmically subtracting the background noise level from the residential logging results. This has been done at all locations except for B111, where the intermediate data was used to filter noise from other sources, as this method is no longer valid in this case. It is noted that the subtraction of background noise has been limited such that the measured noise level is reduced by no more than 3 dB.
- As noted above, data filtering was conducted at B111 based on the results at the intermediate locations. Time periods where the noise level at both intermediate locations was lower than the measured level at B111 have been filtered out. A series of audio recordings made during the monitoring period at B111 were reviewed to identify the cause of the higher noise level and it was determined that the noise from frogs and insects was the predominant contributor.

Following the data removal process, the remaining noise data were correlated with the hub height referenced wind speed data for each residential logging location, in line with Section 7.5.2 and the procedure outlined in Section 7.4 of the Standard. The hub height wind speed used for the correlation was taken from the same meteorological mast location as the pre-construction background noise assessments. The following table provides the number of valid data points following the filtering of data and identifies the wind mast location which has been used for the correlations at each residential logging location.

Table 8: Number of Valid Data Pairs and Relevant Wind Mast

Testing Location	Valid Data Points	Relevant Mast
B006	4507	EXT3
B061(S)	5585	WF2
B065	5427	EXT2
B083	5579	WF3
B111	3355	WF2
B114	4516	EXT3
B118	4466	EXT3
B171	5901	WF1
B328	4731	WF2

(S) – This location is understood to be a stakeholder owned by Goldwind

A third order polynomial regression analysis was performed on the correlations to determine the noise levels for comparison with the criteria.

4.2 SPECIAL AUDIBLE CHARACTERISTICS

4.2.1 Tonality Adjustments

As noted in the nearfield measurement section, conducted in accordance with Section B2 of the Standard, no excessive tonality was identified in close proximity to the turbines. Therefore, excessive tonality, as a result of the wind farm, is highly unlikely to be present at the residential logging locations, requiring no further assessment. Nonetheless, a subjective assessment for tonality was also conducted at each residence while placing and collecting the noise monitoring equipment. Excessive tonality was not identified on any of these occasions. No adjustments are therefore made for the special audible characteristic of tonality.

4.2.2 Modulation Adjustments

The nearfield section of this report indicated that no regular amplitude modulation of the overall A-weighted level is present in the noise profile of the turbines. Therefore, excessive amplitude modulation, due to the wind farm, is highly unlikely to be present at the residential logging locations, requiring no further assessment. Nonetheless, a subjective assessment for amplitude modulation was also conducted at each residence while placing and collecting the noise monitoring equipment. Excessive amplitude modulation was not identified on any of these occasions. For completeness, an additional assessment has been conducted at each non-associated monitoring site in accordance with the Standard.

As per the Standard, the special audible characteristic of amplitude modulation is present when the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis or when the one-third octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency.

The overall noise levels at each non-associated residential logging location were analysed for a number of periods covering a large wind speed range. The selected periods to be analysed were based upon the following criteria:

- The residential logging location was downwind of the closest turbine during the period;
- Local weather did not affect the measurement period; and
- The measurement period was generally at night.

A one-third octave band analysis was conducted for one measurement period during the night period for each residence. The measurement period which showed the highest overall A-weighted variation at a regular interval was selected.

The figures in Appendix F show the results for:

- the overall A-weighted level for a range of wind speeds, with horizontal lines at 5 dB(A) intervals for ease of modulation identification; and
- the variation in noise level for each one-third octave band for one example, with horizontal lines at 6 dB(A) intervals for ease of modulation identification.

The analysis found variation greater than 6 dB(A) at low frequencies (25Hz – 63Hz) in almost all cases, as well as variation in some cases in the higher frequency bands. The analysis findings are discussed further in the following sections.

Low frequency Modulation

Although the analysis found variations in noise level greater than 6 dB(A) at low frequencies (25Hz – 63Hz) in almost all cases, none of these were on a regular basis in respect of the blade pass frequency.

Although the low frequency variation is not on a regular basis at the blade pass frequency, a comparison has been made with the variation in low frequency time traces with the Wind Farm shut off. The comparison is shown in Figure 6 below. The figure shows no significant difference in the low frequency variation with the Wind Farm on or off. This confirms that the Wind Farm did not result in low frequency one-third octave band peak to trough levels exceeding 6 dB on a regular basis in respect of the blade pass frequency.

High Frequency Modulation

Digital audio files have been analysed to understand the noise sources for the higher frequency variation. Where appropriate, the sources of the noise identified have been labelled on the figures. The presence of noise from insects, frogs, birds, and dogs explains the high frequency variation in one-third octave bands greater than 6 dB.

Periods of variation from the turbines

The analysis found some periods of variation in the one-third octave band levels which were attributable to the Wind Farm. The Standard states that for measured one-third octave band results, the peak to trough levels must "exceed 6 dB on a regular basis in respect of the blade pass frequency" to be considered a special audible characteristic. The periods identified did not exceed 6 dB on a regular basis in respect of the blade pass frequency, and therefore have not been considered special audible characteristics.

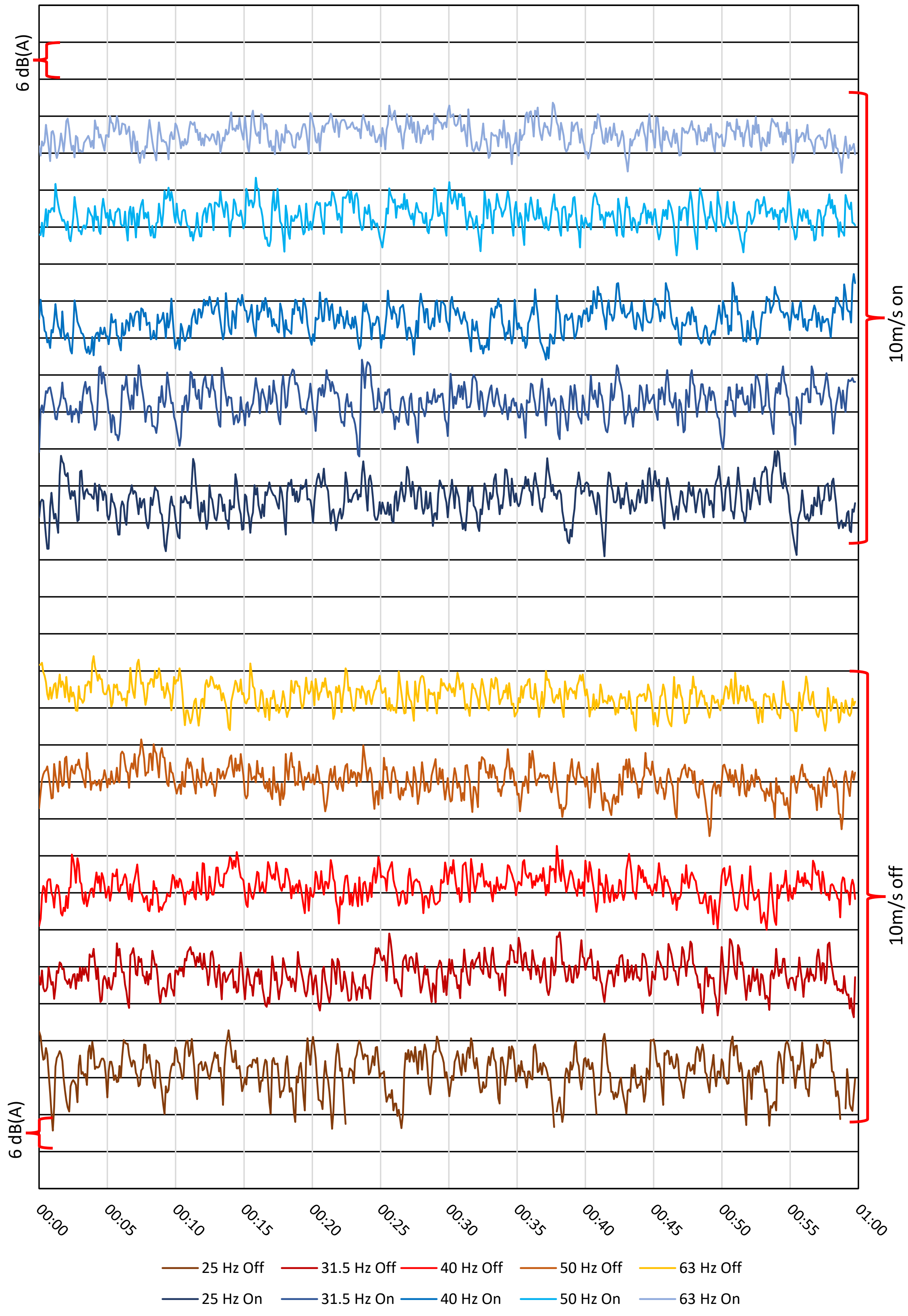


Figure 6: B006 Amplitude Modulation On and Off Comparison

4.3 RESIDENTIAL LOGGING RESULTS

The correlation graphs with the regression curve and criteria are provided in Figure 7 to Figure 15. The measured noise levels and criteria for each integer hub height wind speed from 3m/s to 14m/s have also been tabulated in Table 9.

The results indicate that the noise from the Wind Farm is less than the noise limit specified in the Regulations, determined in accordance with the Standard as modified by the Planning Permit, at all integer wind speeds. The criteria for non-participant dwellings are defined as 40 dB(A), except where the background sound level is greater than 35 dB(A), in which case the criteria will be the background sound level plus 5 dB. For example, for B065, where the background sound level at an integer wind speed of 13m/s is 42 dB(A), the criterion for this wind speed will therefore be 47 dB(A), indicating that a measured sound level of 42 dB(A) will be in compliance for this location at this integer wind speed. This has been determined through the subtraction of the pre-construction background noise levels for most locations and the filtering of data points based on the intermediate noise measurements for B111. The correlation graphs for each background noise monitoring location can be seen in Appendix E. As no penalties were required for special audible characteristics, the Wind Farm is therefore compliant with the noise criteria.

sonus.

Table 9: Resultant Wind Farm Noise Levels (dB(A))

Testing Location	3m/s		4m/s		5m/s		6m/s		7m/s		8m/s		9m/s		10m/s		11m/s		12m/s		13m/s		14m/s	
	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion	Measured	Criterion
B006	19	40	21	40	22	40	24	40	26	40	28	40	30	40	31	40	33	40	34	40	35	40	36	40
B061(S)	25	45	26	45	29	45	31	45	34	45	36	45	39	45	41	45	43	45	45	45	46	48	47	51
B065	25	40	26	40	27	40	29	40	31	40	33	40	35	40	37	42	39	44	41	45	42	47	44	49
B083	24	40	25	40	26	40	28	40	30	40	32	40	33	40	34	40	36	41	37	44	39	46	41	49
B111	26	40	27	40	29	40	31	40	32	40	34	40	36	40	37	40	38	40	39	40	40	42	41	44
B114	28	40	29	40	31	40	32	40	34	40	36	40	37	40	39	40	40	41	42	43	43	45	45	46
B118	21	40	23	40	26	40	28	40	30	40	32	40	33	40	35	40	36	40	36	40	37	43	38	46
B171	25	40	27	40	30	40	32	40	34	40	36	40	37	40	39	40	40	42	41	45	42	47	43	49
B328	25	40	26	40	27	40	29	40	31	40	32	40	34	41	35	42	37	43	38	44	39	45	39	46

(S) – This location is understood to be a stakeholder owned by Goldwind

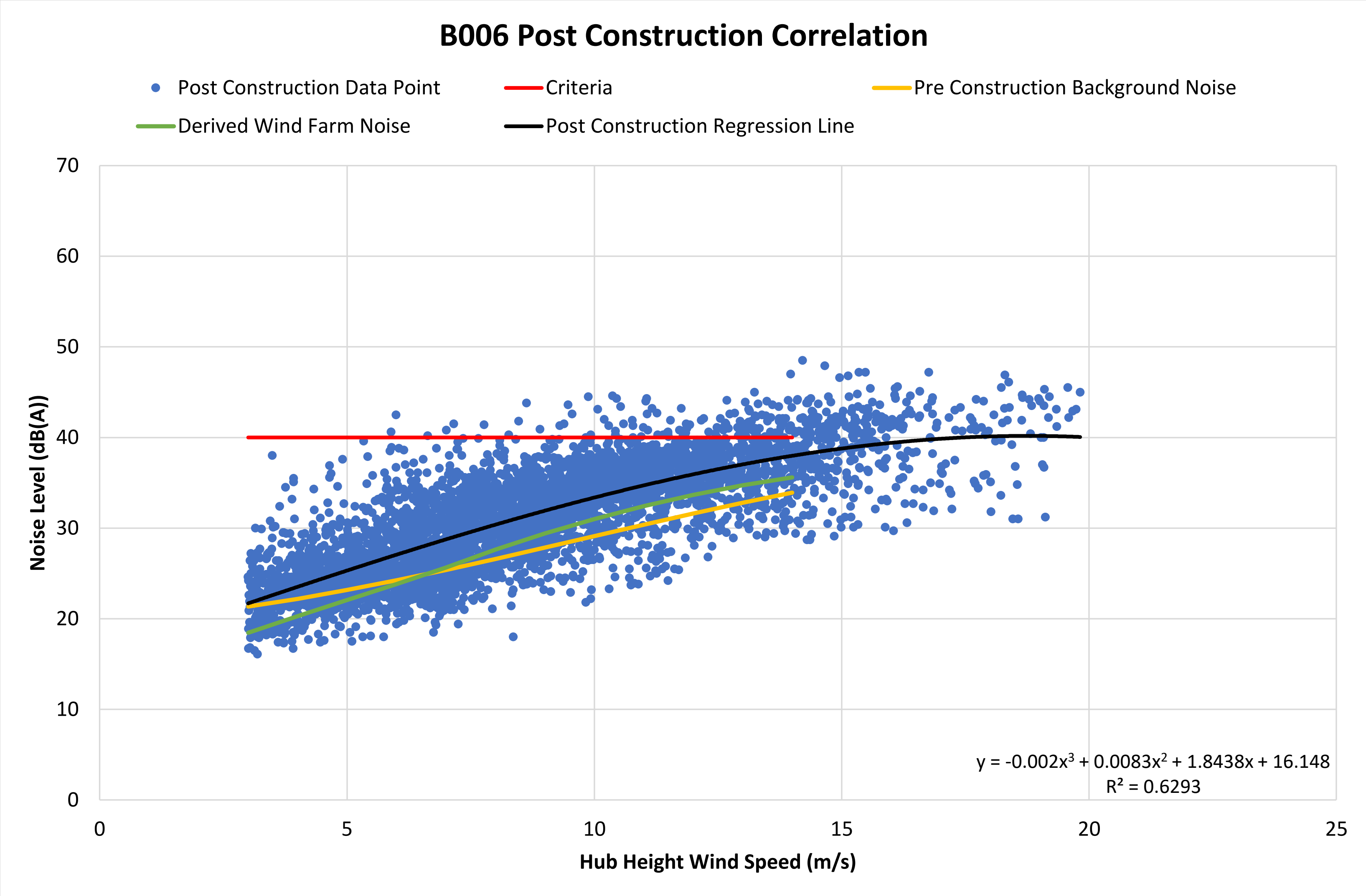


Figure 7: Correlation Between Noise Level and Wind Speed at B006

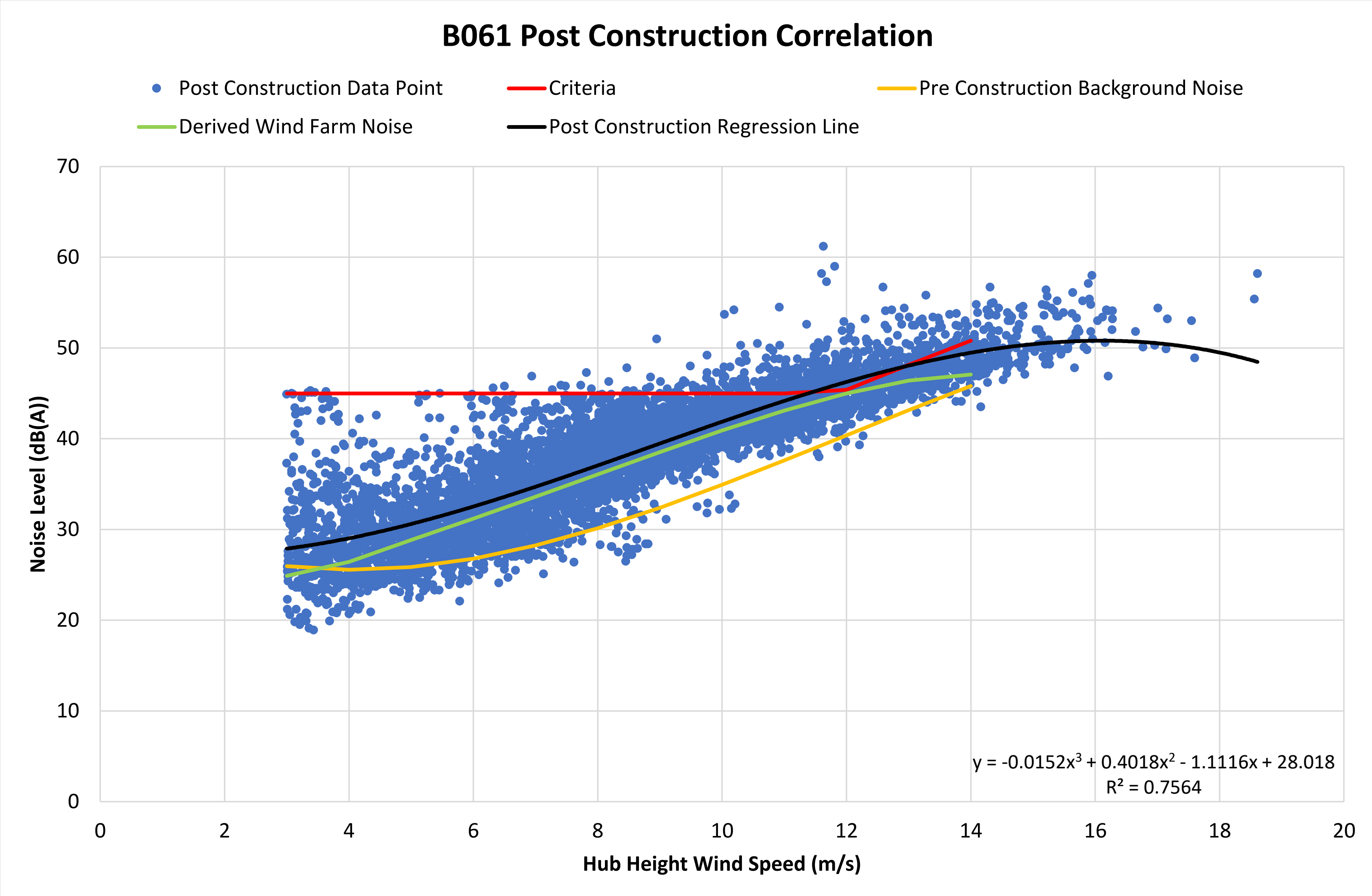


Figure 8: Correlation Between Noise Level and Wind Speed at B061(S)

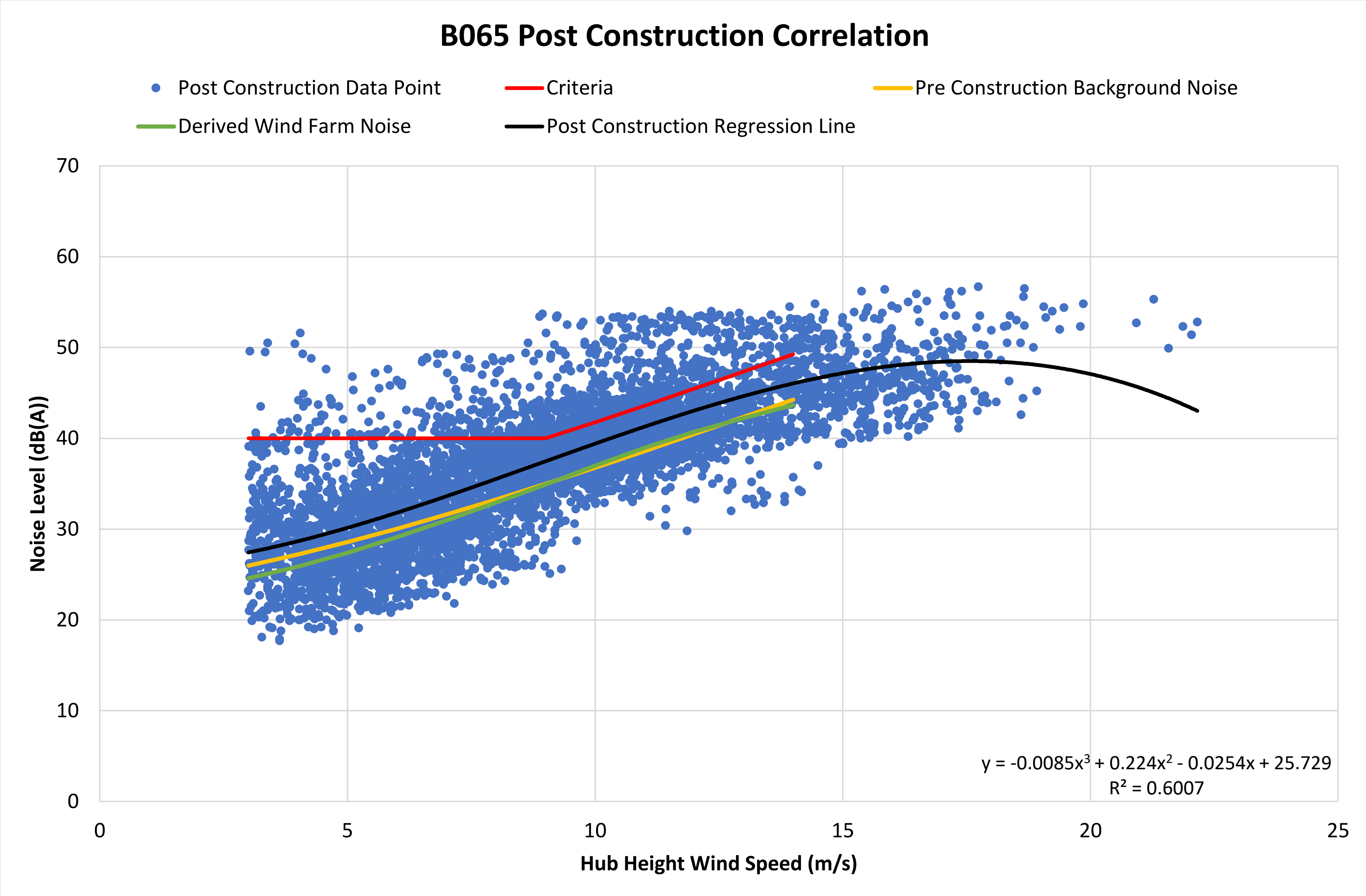


Figure 9: Correlation Between Noise Level and Wind Speed at B065

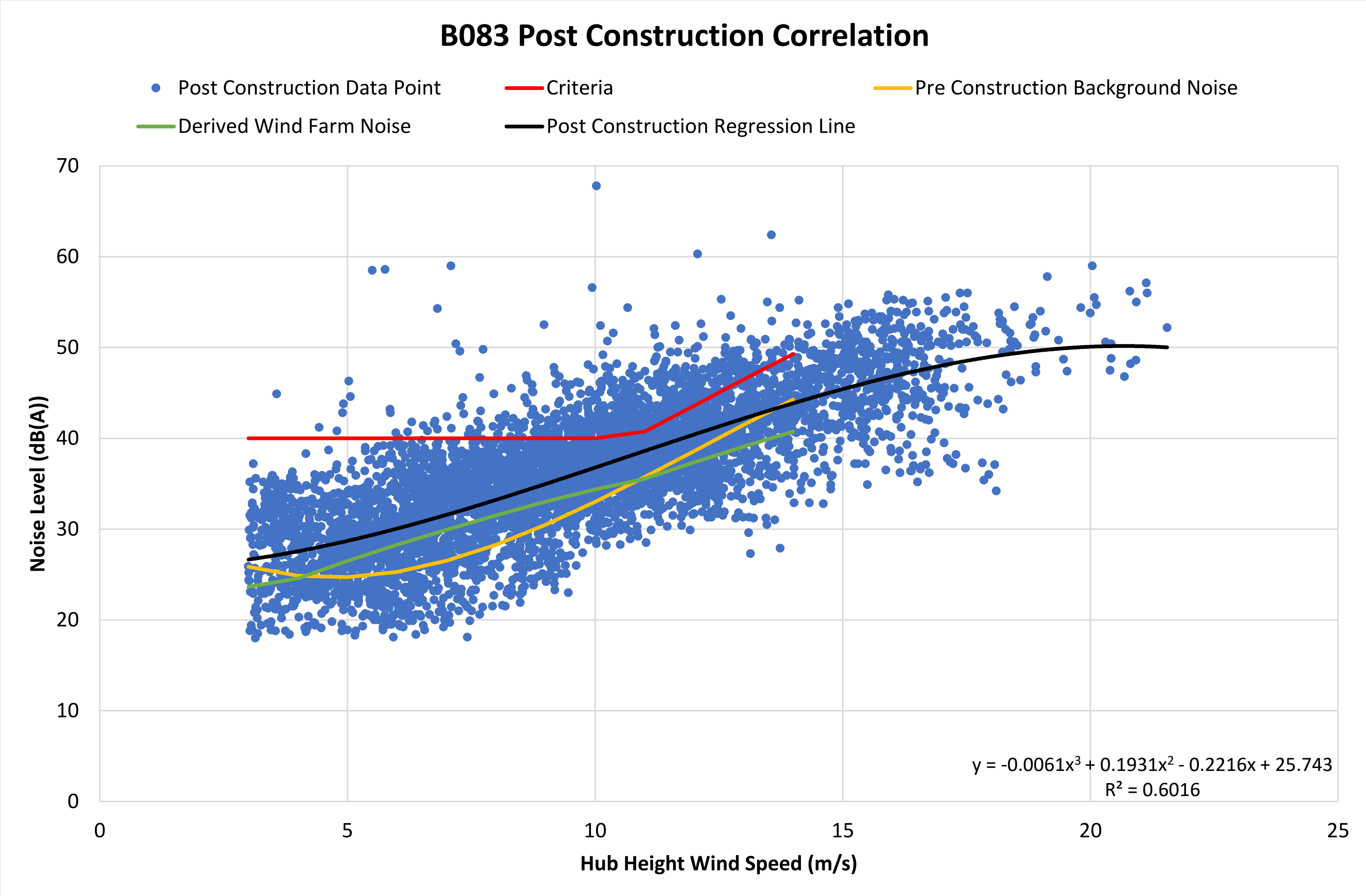


Figure 10: Correlation Between Noise Level and Wind Speed at B083

sonus.

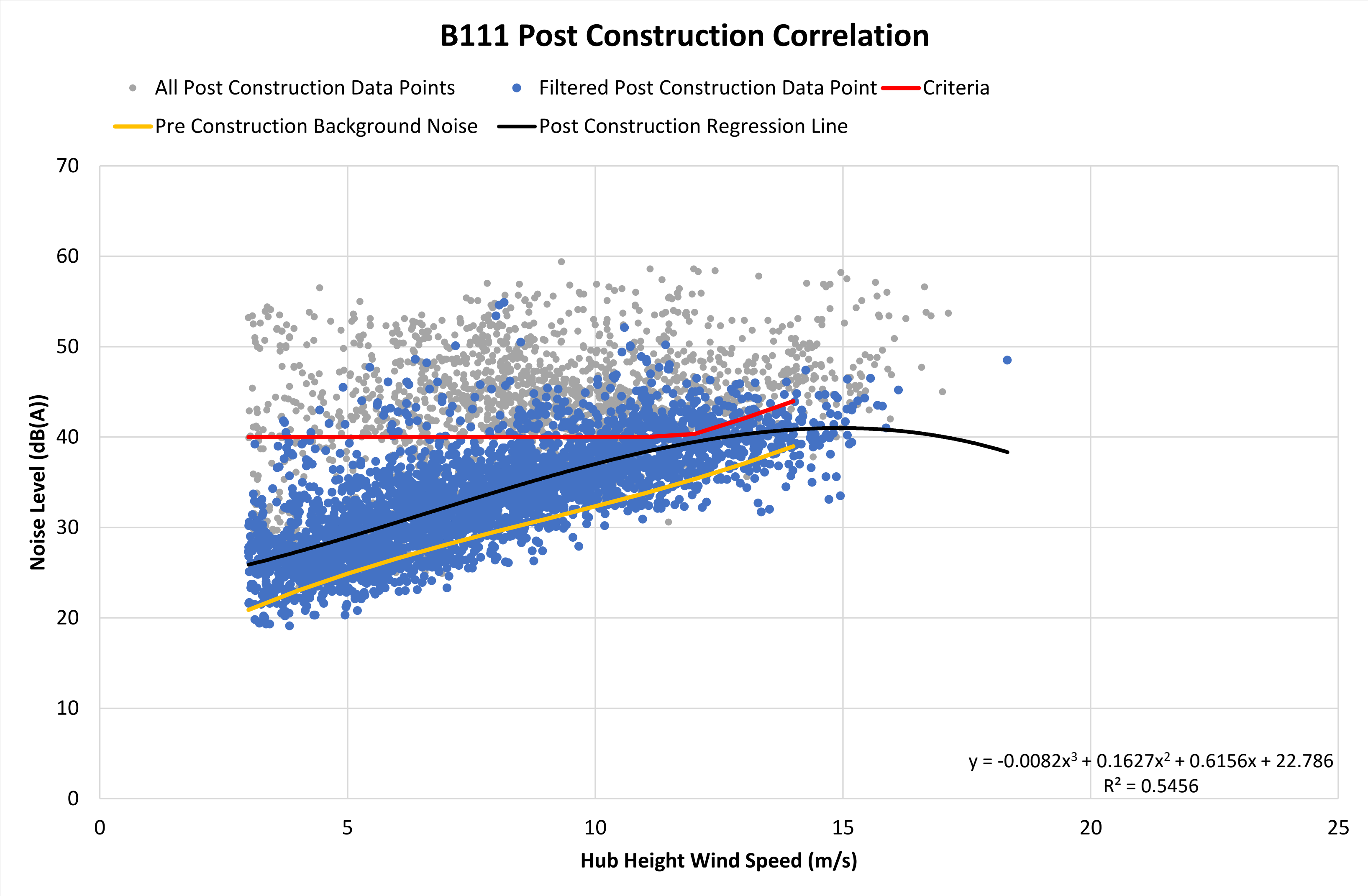


Figure 11: Correlation Between Noise Level and Wind Speed at B111

sonus.

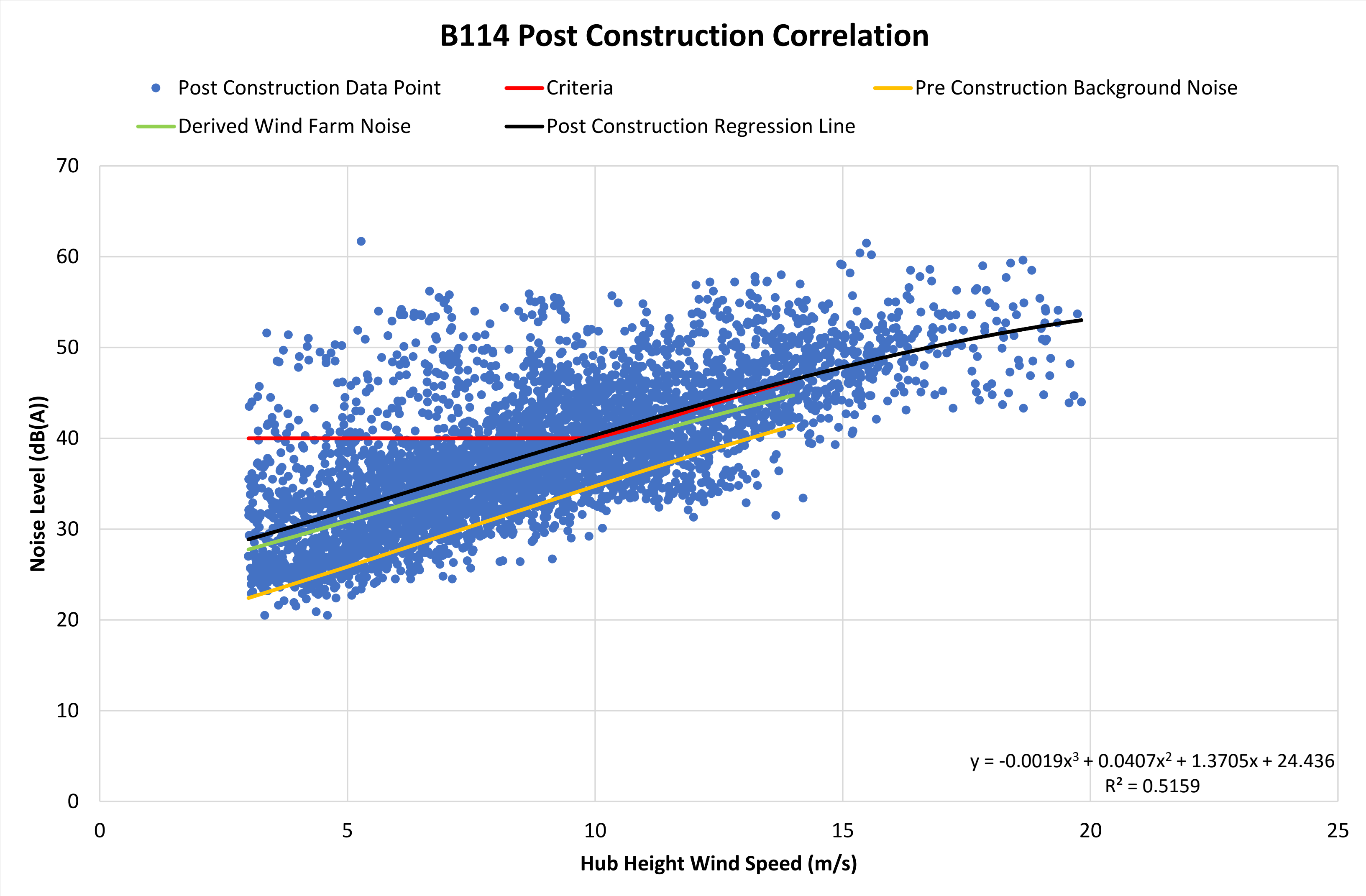


Figure 12: Correlation Between Noise Level and Wind Speed at B114

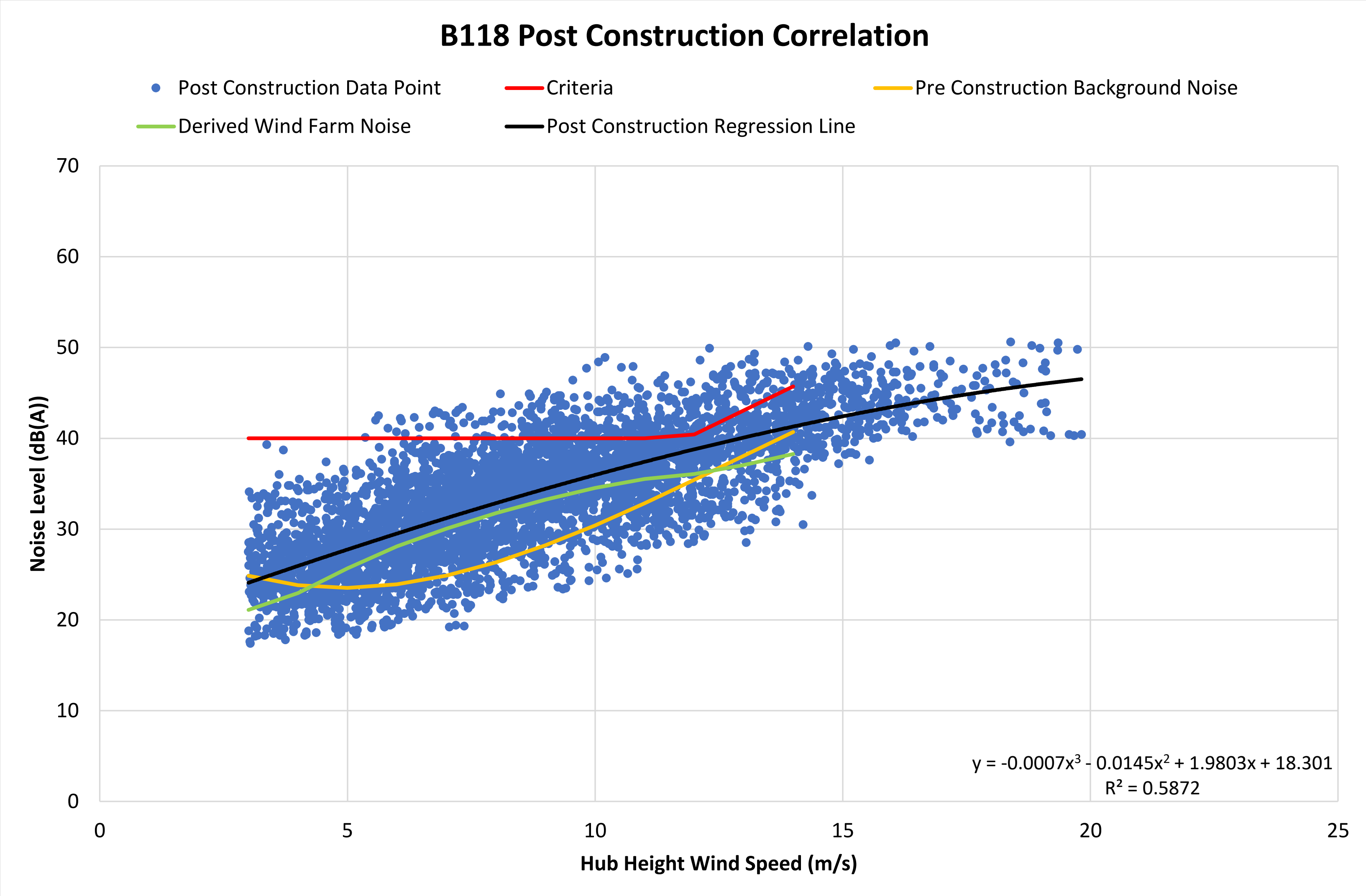


Figure 13: Correlation Between Noise Level and Wind Speed at B118

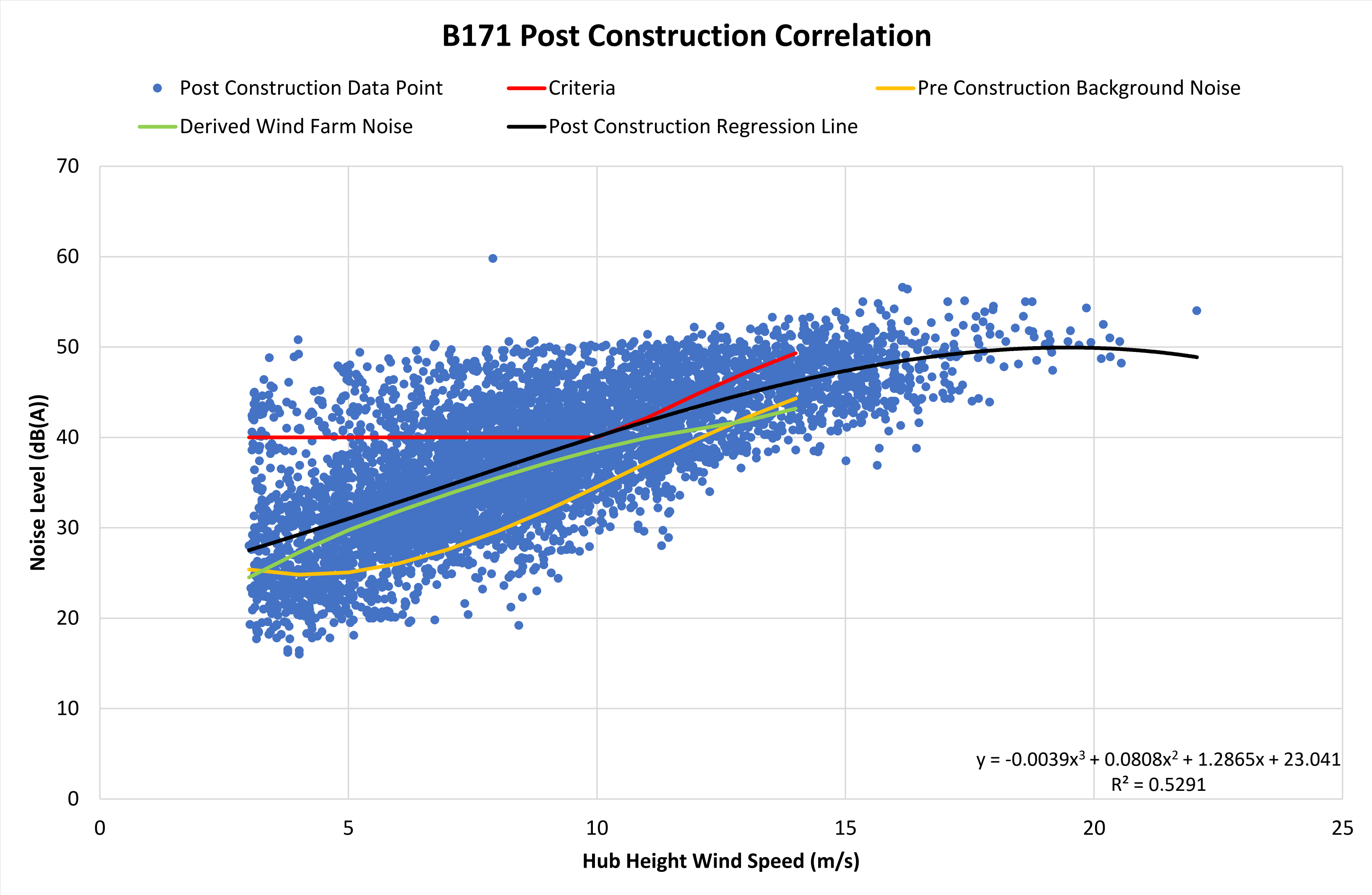


Figure 14: Correlation Between Noise Level and Wind Speed at B171

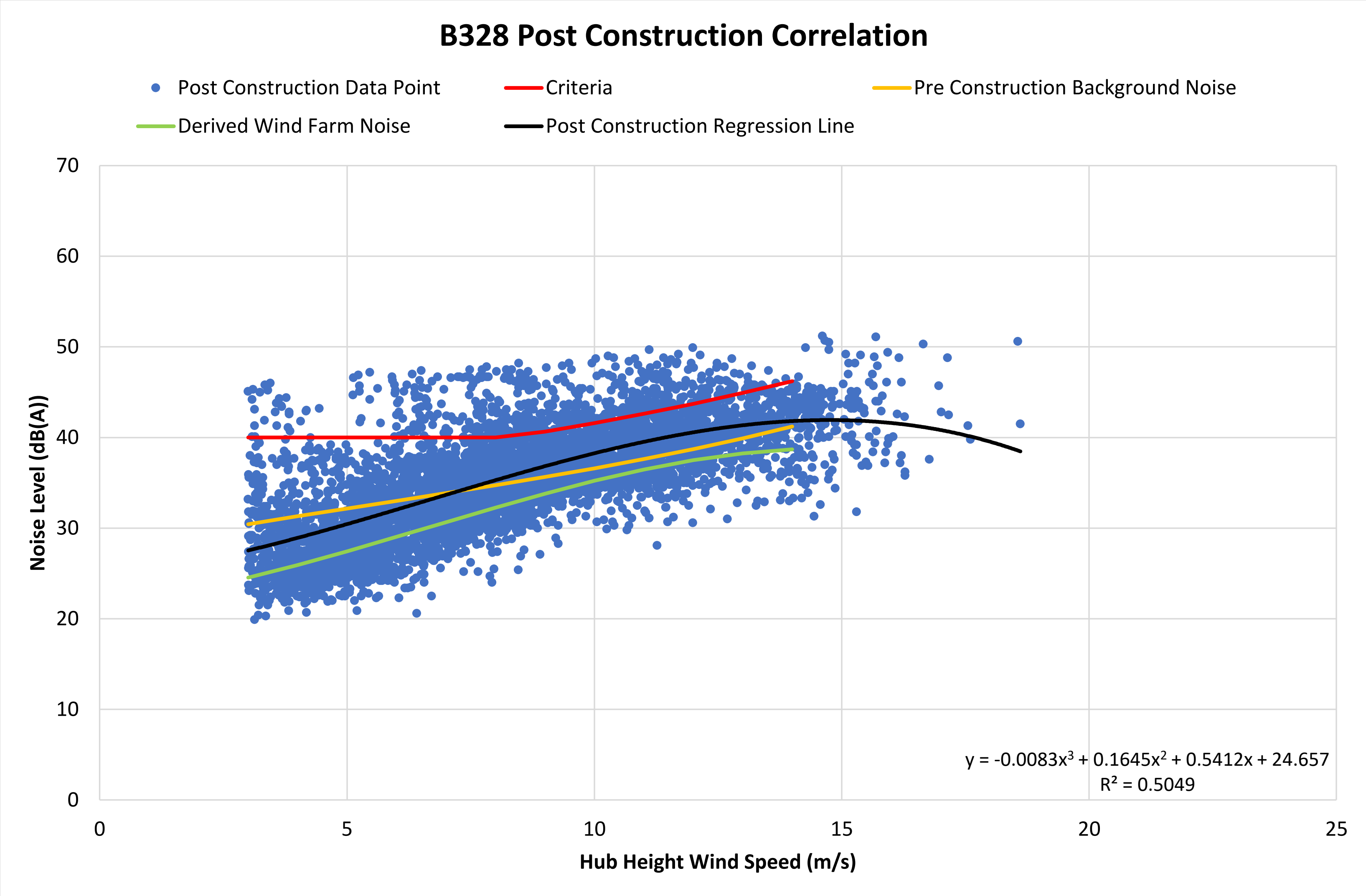


Figure 15: Correlation Between Noise Level and Wind Speed

5 CONCLUSION

Post construction noise testing has been conducted for the Stockyard Hill Wind Farm in accordance with the requirements of Regulation 131D.

The testing included noise measurements at nine residential logging locations in the vicinity of the Wind Farm, intermediate locations between these locations and the Wind Farm, and in the nearfield of representative turbines for each or the six turbine configurations. The results of these measurements have been used to confirm that the noise from operation of the Wind Farm does not exceed the noise criteria, established in accordance with the Standard and Regulations, at all surrounding dwellings. No penalties were found to be warranted for the special audible characteristics of tonality or amplitude modulation.

The Project therefore complies with the noise limits determined in accordance with Regulation 131BA, with reference to the Standard and the Planning Permit, as required.

6 APPENDIX A: SECTION 8.3 REQUIREMENTS

Section 8.3 of the Standard provides the following requirements for the report:

Any report of wind farm post-installation sound level measurements and compliance assessment, other than on/off tests, made in accordance with this Standard shall refer to this Standard and provide the following:

- *(a) Description of the sound monitoring equipment including any ancillary equipment;*
- *(b) A statement confirming the use of A-frequency-weighting;*
- *(c) The location of sound monitoring positions;*
- *(d) Description of the anemometry equipment including the height AGL of the anemometer;*
- *(e) Position of wind speed measurements;*
- *(f) Make and model of the wind turbines;*
- *(g) Number of operational wind turbines;*
- *(h) Time and duration of monitoring period;*
- *(i) Averaging period for both sound and wind speed measurements;*
- *(j) Atmospheric conditions: the wind speed and direction at the wind farm position and rainfall shall be recorded;*
- *(k) Number of data pairs measured (wind speed in m/s, sound in L90);*
- *(l) Description of the regression analysis;*
- *(m) Graphical plots showing the data scatter and the regression lines;*
- *(n) Graphical plots showing the data scatter and the regression lines for both the background and the wind farm in operation;*
- *(o) Assessment of special audible characteristics; and*
- *(p) A statement that the wind farm complies with relevant noise limits – or not – as determined from the results of the measurements.*

The location in the report where each of the above points have been addressed can be seen in the below table:

Table 10: Location Where Section 8.3 Requirements are Addressed

Requirement	Section Numbers
(a)	4
(b)	4
(c)	2, 3.2, 8
(d)	4
(e)	3.2, 4
(f)	1
(g)	1
(h)	4
(i)	4
(j)	4, 9
(k)	4.1
(l)	4.1
(m)	4.2
(n)	4.2
(o)	3.1, 4.3, 10
(p)	4.2, 5

7 APPENDIX B: CALIBRATION CERTIFICATES

Acoustic Research Labs Pty Ltd
Unit 36/14 Loyalty Rd
North Rocks NSW AUSTRALIA 2151
Ph: +61 2 9484 0800 A.B.N. 65 160 399 119
www.acousticresearch.com.au

Sound Level Meter
IEC 61672-3.2013

Calibration Certificate

Calibration Number C20538

Client Details Sonus Pty Ltd
17 Ruthven Avenue
Adelaide SA 5000

Equipment Tested/ Model Number : Rion NL-52
Instrument Serial Number : 00320657
Microphone Serial Number : 03435
Pre-amplifier Serial Number : 10665

Pre-Test Atmospheric Conditions		Post-Test Atmospheric Conditions	
Ambient Temperature :	21.5°C	Ambient Temperature :	21.4°C
Relative Humidity :	49.4%	Relative Humidity :	47.4%
Barometric Pressure :	99.92kPa	Barometric Pressure :	99.96kPa

Calibration Technician : Jeff Yu
Calibration Date : 23 Sep 2020
Secondary Check: Max Moore
Report Issue Date : 6 Oct 2020

Approved Signatory : Ken Williams

Clause and Characteristic Tested	Result	Clause and Characteristic Tested	Result
12: Acoustical Sig. tests of a frequency weighting	*Pass*	17: Level linearity incl. the level range control	*Pass*
13: Electrical Sig. tests of frequency weightings	*Pass*	18: Toneburst response	*Pass*
14: Frequency and time weightings at 1 kHz	*Pass*	19: C Weighted Peak Sound Level	*Pass*
15: Long Term Stability	*Pass*	20: Overload Indication	*Pass*
16: Level linearity on the reference level range	*Pass*	21: High Level Stability	*Pass*

The sound level meter submitted for testing has successfully completed the class 1 periodic tests of IEC 61672-3:2013, for the environmental conditions under which the tests were performed.

As public evidence was available, from an independent testing organisation responsible for approving the results of pattern evaluation test performed in accordance with IEC 61672-2:2013, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2013, the sound level meter submitted for testing conforms to the class 1 requirements of IEC 61672-1:2013.

Least Uncertainties of Measurement -

Acoustic Tests		Environmental Conditions	
125Hz	*±0.12dB*	*Temperature*	*±0.2°C*
1kHz	*±0.11dB*	*Relative Humidity*	*±2.4%*
8kHz	*±0.13dB*	*Barometric Pressure*	*±0.015kPa*
Electrical Tests	*±0.10dB*		

All uncertainties are derived at the 95% confidence level with a coverage factor of 2.

This calibration certificate is to be read in conjunction with the calibration test report.

Acoustic Research Labs Pty Ltd is NATA Accredited Laboratory Number 14172.
Accredited for compliance with ISO/IEC 17025 - calibration.

The results of the tests, calibrations and/or measurements included in this document are traceable to SI units.

NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration and inspection reports.

Page 1 of 1

sonus.

RION CO., LTD.

3-20-41 Higashimotomachi Kokubunji Tokyo 185-8533
Phone:042(359)7888, Facsimile:042(359)7442

Certificate of Calibration

Name	: **Sound Level Meter, Class 1**			
Model	: **NL-52**	**S/No.**	:	**00710394**
Date of Calibration	: **August, 20, 2021**			

We hereby certify that the above product was tested and calibrated according to the prescribed Rion procedures, and that it fulfills specification requirements.
The measuring equipment and reference devices used for testing and calibrating this unit are managed under the Rion traceability system and are traceable according to official Japanese standards and official standards of countries belonging to the International Committee of Weights and Measures.

RION CO., LTD.

K. Ikeda

Manager, Quality Control Department

RION CO., LTD.

3-20-41 Higashimotomachi Kokubunji Tokyo 185-8533
Phone:042(359)7888, Facsimile:042(359)7442

Certificate of Calibration

Name	:	**Sound Level Meter, Class 1**
Model	:	**NL-52** **S/No. : 00710391**
Date of Calibration	:	**August, 25, 2021**

We hereby certify that the above product was tested and calibrated according to the prescribed Rion procedures, and that it fulfills specification requirements.
The measuring equipment and reference devices used for testing and calibrating this unit are managed under the Rion traceability system and are traceable according to official Japanese standards and official standards of countries belonging to the International Committee of Weights and Measures.

RION CO., LTD.

K. Ikeda

Manager, Quality Control Department

sonus.

Acoustic Research Labs Pty Ltd
Unit 36/14 Loyalty Rd
North Rocks NSW AUSTRALIA 2151
Ph: +61 2 9484 0800 A.B.N. 65 160 399 119
www.acousticresearch.com.au

Sound Level Meter

IEC 61672-3.2013

Calibration Certificate

Calibration Number C20535

Client Details Sonus Pty Ltd
17 Ruthven Avenue
Adelaide SA 5000

Equipment Tested/ Model Number : Rion NL-52
Instrument Serial Number : 00220543
Microphone Serial Number : 03377
Pre-amplifier Serial Number : 10543

Pre-Test Atmospheric Conditions		Post-Test Atmospheric Conditions	
Ambient Temperature :	22.4°C	Ambient Temperature :	22.1°C
Relative Humidity :	50.1%	Relative Humidity :	47%
Barometric Pressure :	99.81kPa	Barometric Pressure :	99.87kPa

Calibration Technician : Jeff Yu
Calibration Date : 22 Sep 2020
Secondary Check: Max Moore
Report Issue Date : 6 Oct 2020

Approved Signatory : Ken Williams

Clause and Characteristic Tested	Result	Clause and Characteristic Tested	Result
12: Acoustical Sig. tests of a frequency weighting	*Pass*	17: Level linearity incl. the level range control	*Pass*
13: Electrical Sig. tests of frequency weightings	*Pass*	18: Toneburst response	*Pass*
14: Frequency and time weightings at 1 kHz	*Pass*	19: C Weighted Peak Sound Level	*Pass*
15: Long Term Stability	*Pass*	20: Overload Indication	*Pass*
16: Level linearity on the reference level range	*Pass*	21: High Level Stability	*Pass*

The sound level meter submitted for testing has successfully completed the class 1 periodic tests of IEC 61672-3:2013, for the environmental conditions under which the tests were performed.

As public evidence was available, from an independent testing organisation responsible for approving the results of pattern evaluation test performed in accordance with IEC 61672-2:2013, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2013, the sound level meter submitted for testing conforms to the class 1 requirements of IEC 61672-1:2013.

Least Uncertainties of Measurement -

Acoustic Tests		Environmental Conditions	
125Hz	*±0.12dB*	*Temperature*	*±0.2°C*
1kHz	*±0.11dB*	*Relative Humidity*	*±2.4%*
8kHz	*±0.13dB*	*Barometric Pressure*	*±0.015kPa*
Electrical Tests	*±0.10dB*		

All uncertainties are derived at the 95% confidence level with a coverage factor of 2.

This calibration certificate is to be read in conjunction with the calibration test report.

NATA
ACCREDITATION

Acoustic Research Labs Pty Ltd is NATA Accredited Laboratory Number 14172
Accredited for compliance with ISO/IEC 17025 - calibration

The results of the tests, calibrations and/or measurements included in this document are traceable to SI units.

NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration and inspection reports.

PAGE 1 OF 1

Acoustic Research Labs Pty Ltd
Unit 36/14 Loyalty Rd
North Rocks NSW AUSTRALIA 2151
Ph: +61 2 9484 0800 A.B.N. 65 160 399 119
www.acousticresearch.com.au

Sound Level Meter

IEC 61672-3.2013

Calibration Certificate

Calibration Number C20537

Client Details Sonus Pty Ltd
17 Ruthven Avenue
Adelaide SA 5000

Equipment Tested/ Model Number : Rion NL-52
Instrument Serial Number : 00320648
Microphone Serial Number : 03397
Pre-amplifier Serial Number : 10656

Pre-Test Atmospheric Conditions		Post-Test Atmospheric Conditions	
Ambient Temperature :	22.1°C	**Ambient Temperature :**	22.1°C
Relative Humidity :	49.1%	**Relative Humidity :**	49.5%
Barometric Pressure :	99.94kPa	**Barometric Pressure :**	99.93kPa

---

Calibration Technician : Jeff Yu
Calibration Date : 23 Sep 2020
Secondary Check: Max Moore
Report Issue Date : 6 Oct 2020

Approved Signatory : Ken Williams

Clause and Characteristic Tested	Result	Clause and Characteristic Tested	Result
12: Acoustical Sig. tests of a frequency weighting	*Pass*	17: Level linearity incl. the level range control	*Pass*
13: Electrical Sig. tests of frequency weightings	*Pass*	18: Toneburst response	*Pass*
14: Frequency and time weightings at 1 kHz	*Pass*	19: C Weighted Peak Sound Level	*Pass*
15: Long Term Stability	*Pass*	20: Overload Indication	*Pass*
16: Level linearity on the reference level range	*Pass*	21: High Level Stability	*Pass*

The sound level meter submitted for testing has successfully completed the class 1 periodic tests of IEC 61672-3.2013, for the environmental conditions under which the tests were performed.

As public evidence was available, from an independent testing organisation responsible for approving the results of pattern evaluation test performed in accordance with IEC 61672-2:2013, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2013, the sound level meter submitted for testing conforms to the class 1 requirements of IEC 61672-1:2013.

Least Uncertainties of Measurement -

Acoustic Tests		Environmental Conditions	
125Hz	*±0.12dB*	*Temperature*	*±0.2°C*
1kHz	*±0.11dB*	*Relative Humidity*	*±2.4%*
8kHz	*±0.13dB*	*Barometric Pressure*	*±0.015kPa*
Electrical Tests	*±0.10dB*		

All uncertainties are derived at the 95% confidence level with a coverage factor of 2.

This calibration certificate is to be read in conjunction with the calibration test report.

Acoustic Research Labs Pty Ltd is NATA Accredited Laboratory Number 14172.
Accredited for compliance with ISO/IEC 17025 - calibration

The results of the tests, calibrations and/or measurements included in this document are traceable to SI units.

NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration and inspection reports.

PAGE 1 OF 1

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM32790

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-52	**Serial No:**	00320647
Mic. Type:	UC-59	**Serial No:**	03401
Pre-Amp. Type:	NH-25	**Serial No:**	54465

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 1. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	993 hPa ±1 hPa	**Date of Receipt :**	03/06/2022
Temperature	21 °C ±1° C	**Date of Calibration :**	06/06/2022
Relative Humidity	43 % ±5%	**Date of Issue :**	06/06/2022

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....
Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.
This report applies only to the item identified in the report and may not be reproduced in part.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.2 Rev.2.0 14/04/2021

NATAcoustic

Acoustic Calibration & Testing Laboratory
Level 1, 418A Elizabeth Street., Surry Hills NSW 2010 AUSTRALIA
Ph: (02) 8218 0570 email: service@natacoustic.com.au website: www.natacoustic.com.au
A division of Renzo Tonin & Associates (NSW) Pty Ltd ABN 29 117 462 861

Certificate of Calibration
Sound Level Meter

Calibration Date	11/02/2021	Job No	RB856	Operator	AM
Client Name	SONUS PTY LTD				
Client Address	17 RUTHVEN AVE, ADELAIDE SA 5000				

Test Item

Instrument Make	RION	Model	NL-52	Serial No	#00320649
Microphone Make	RION	Model	UC-59	Serial No	#03398
Preamplifier Make	RION	Model	NH-25	Serial No	#20834
Ext'n Cable Make	Nil	Model	N/A	Serial No	N/A
Accessories	Nil			Firmware	2.0

SLM Type	1
Filters Class	N/A

Environmental Conditions	Measured Start	Measured End
Air Temp. (°C)	23.7	23.6
Rel. Humidity (%)	58.7	59.1
Air Pressure (kPa)	100.6	100.5

Applicable Standards:
Periodic tests were performed in accordance with procedures from IEC 61672-3 :2013 and IEC 61260-3 :2016

Applicable Work Instruction:
RWI-08 SLM & Calibrator Verification

Laboratory Equipment :
B&K4226 Multifunction Acoustic Calibrator SN 2288472
Agilent Function Generator Model 33220A SN MY43004013
Agilent Digital Multimeter Model 34401A SN MY41004386

Traceability:
The results of the tests and measurements included in this document are traceable via the test methods described under each test, and by the use of the above equipment, which has been calibrated by NATA accredited calibration facilities.
This document shall not be reproduced, except in full.

Scope:
This certificate is issued on the basis that the instrument complies with the manufacturer's specification.
See "Sound Level Meter Verification - Summary of Tests" page for an itemised list of results for each test.

Uncertainty:
The uncertainty is stated at a confidence level of 95% using a k factor of 2.

Calibration Statement:
The sound level meter submitted for testing has successfully completed the periodic tests of IEC 61672-3:2013 and IEC 61260-3:2016, for the environmental conditions under which the tests were performed. However, no general statement or conclusion can be made about conformance of the sound level meter to the full specifications of IEC 61672-1:2013 and IEC 61260-1:2014 because (a) evidence was not publicly available, from an independent testing organization responsible for pattern approvals, to demonstrate that the model of sound level meter fully conformed to the class 1 specifications in IEC 61672-1:2013 and IEC 61260-1:2014 or correction data for acoustical test of frequency weighting were not provided in the Instruction Manual and (b) because the periodic tests of IEC 61672-3:2013 and IEC 61260-3:2016 cover only a limited subset of the specifications in IEC 61672-1:2013 and IEC 61260-1:2014.

NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory Number 14966

Accredited for compliance with ISO/IEC 17025 - Calibration

Authorized Signatory:

Print Name: Ariel Michael   Date: 15/02/2021

Template Document Name: RQT-05 (rev 72) SLM ISO Verification

RION CO., LTD.

3-20-41 Higashimotomachi Kokubunji Tokyo 185-8533
Phone:042(359)7888, Facsimile:042(359)7442

Certificate of Calibration

Name	:	**Sound Level Meter, Class 1**		
Model	:	**NL-52**	**S/No.** :	**00710393**
Date of Calibration	:	**August, 20, 2021**		

We hereby certify that the above product was tested and calibrated according to the prescribed Rion procedures, and that it fulfills specification requirements.
The measuring equipment and reference devices used for testing and calibrating this unit are managed under the Rion traceability system and are traceable according to official Japanese standards and official standards of countries belonging to the International Committee of Weights and Measures.

RION CO., LTD.

K. Okeda

Manager, Quality Control Department

RION CO., LTD.

3-20-41 Higashimotomachi Kokubunji Tokyo 185-8533
Phone:042(359)7888, Facsimile:042(359)7442

Certificate of Calibration

Name	:	**Sound Level Meter, Class 1**		
Model	:	**NL-52**	**S/No.** :	**00710427**
Date of Calibration	:	**September, 01, 2021**		

We hereby certify that the above product was tested and calibrated according to the prescribed Rion procedures, and that it fulfills specification requirements.
The measuring equipment and reference devices used for testing and calibrating this unit are managed under the Rion traceability system and are traceable according to official Japanese standards and official standards of countries belonging to the International Committee of Weights and Measures.

RION CO., LTD.

K. Ikeda

Manager, Quality Control Department

sonus.

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM32823

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	00354109
Mic. Type:	UC-52	**Serial No:**	101436
Pre-Amp. Type:	NH-21	**Serial No:**	14744

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	1001	hPa ±1 hPa	**Date of Receipt :**	06/06/2022
Temperature	21	°C ±1° C	**Date of Calibration :**	08/06/2022
Relative Humidity	35	% ±5%	**Date of Issue :**	08/06/2022

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3

CHECKED BY: ...KB... **AUTHORISED SIGNATURE:** ....

Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev.2.0 14/04/2021

Certificate Of Calibration

Certificate No: SLM 29997

Equipment Tested: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	01298933
Mic. Type:	UC-52	**Serial No:**	127252
Pre-Amp. Type:	NH-21	**Serial No:**	31528

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

Conditions Of Test:

Ambient Pressure	1006	hPa ±1 hPa	**Date of Receipt :**	07/07/2021
Temperature	25	°C ±1° C	**Date of Calibration :**	08/07/2021
Relative Humidity	36	% ±5%	**Date of Issue :**	08/07/2021

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3

Checked by: .... **Authorised Signature:** ....

Accredited for compliance with ISO/IEC 17025 - Calibration

Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave, Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.3 Rev.2.0 14/04/2021

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM32789

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	00709523
Mic. Type:	UC-52	**Serial No:**	130539
Pre-Amp. Type:	NH-21	**Serial No:**	33539

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	998	hPa ±1 hPa	**Date of Receipt :**	03/06/2022
Temperature	23	°C ±1° C	**Date of Calibration :**	06/06/2022
Relative Humidity	40	% ±5%	**Date of Issue :**	06/06/2022

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3

CHECKED BY: ...... **AUTHORISED SIGNATURE:** ....

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev 2.0 14/04/2021

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM32821

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	00877043
Mic. Type:	UC-52	**Serial No:**	116416
Pre-Amp. Type:	NH-21	**Serial No:**	24441

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	995	hPa ±1 hPa	**Date of Receipt :**	06/06/2022
Temperature	24	°C ±1° C	**Date of Calibration :**	07/06/2022
Relative Humidity	37	% ±5%	**Date of Issue :**	08/06/2022

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3

CHECKED BY: ...YKB... **AUTHORISED SIGNATURE:** ....
Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev.2.0 14/04/2021

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM32815

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-22	**Serial No:**	00683866
Mic. Type:	UC-52	**Serial No:**	120591
Pre-Amp. Type:	NH-21	**Serial No:**	27972

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	996	hPa ±1 hPa	**Date of Receipt :**	06/06/2022
Temperature	23	°C ±1° C	**Date of Calibration :**	07/06/2022
Relative Humidity	37	% ±5%	**Date of Issue :**	08/06/2022

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....
Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.
This report applies only to the item identified in the report and may not be reproduced in part.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev.2.0 14/04/2021

sonus.

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM30671

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	00709526
Mic. Type:	UC-52	**Serial No:**	130600
Pre-Amp. Type:	NH-21	**Serial No:**	33542

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	1003	hPa ±1 hPa	**Date of Receipt :**	23/09/2021
Temperature	23	°C ±1° C	**Date of Calibration :**	23/09/2021
Relative Humidity	39	% ±5%	**Date of Issue :**	23/09/2021

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3.

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....

Jack Kielt

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.
This report applies only to the item identified in the report and may not be reproduced in part.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev 2.0 14/04/2021

Certificate Of Calibration

Certificate No: SLM 29998

Equipment Tested: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	01298930
Mic. Type:	UC-52	**Serial No:**	127249
Pre-Amp. Type:	NH-21	**Serial No:**	31525

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

Conditions Of Test:

Ambient Pressure	1006	hPa ±1 hPa	**Date of Receipt :**	07/07/2021
Temperature	25	°C ±1° C	**Date of Calibration :**	08/07/2021
Relative Humidity	36	% ±5%	**Date of Issue :**	08/07/2021

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3.

Checked by: .... **Authorised Signature:** ....
Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.
This report applies only to the item identified in the report and may not be reproduced in part.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.3 Rev.2.0 14/04/2021

sonus.

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM30672

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	01298931
Mic. Type:	UC-52	**Serial No:**	127250
Pre-Amp. Type:	NH-21	**Serial No:**	31526

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	1002	hPa ±1 hPa	**Date of Receipt :**	23/09/2021
Temperature	24	°C ±1° C	**Date of Calibration :**	23/09/2021
Relative Humidity	39	% ±5%	**Date of Issue :**	23/09/2021

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3.

CHECKED BY: ...... **AUTHORISED SIGNATURE:** ....

Jack Kielt

Accredited for compliance with ISO/IEC 17025 - Calibration

Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave, Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev.2.0 14/04/2021

sonus.

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: SLM32816

EQUIPMENT TESTED: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	01298928
Mic. Type:	UC-52	**Serial No:**	127247
Pre-Amp. Type:	NH-21	**Serial No:**	31523

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

CONDITIONS OF TEST:

Ambient Pressure	996	hPa ±1 hPa	**Date of Receipt :**	06/06/2022
Temperature	23	°C ±1° C	**Date of Calibration :**	07/06/2022
Relative Humidity	37	% ±5%	**Date of Issue :**	08/06/2022

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3.

CHECKED BY: HB **AUTHORISED SIGNATURE:** Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev.2.0 14/04/2021

sonus.

Certificate Of Calibration

Certificate No: SLM30669

Equipment Tested: Sound Level Meter

Manufacturer:	Rion		
Type No:	NL-21	**Serial No:**	01298929
Mic. Type:	UC-52	**Serial No:**	127248
Pre-Amp. Type:	NH-21	**Serial No:**	31524

Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000

Tests Performed: IEC 61672-3:2013

Comments: All Tests passed for Class 2. (See overleaf for details)

Conditions Of Test:

Ambient Pressure	1004	hPa ±1 hPa	**Date of Receipt :**	23/09/2021
Temperature	23	°C ±1° C	**Date of Calibration :**	23/09/2021
Relative Humidity	39	% ±5%	**Date of Issue :**	23/09/2021

Acu-Vib Test Procedure: AVP10 (SLM) based on IEC 61672-3.

Checked by: .... **Authorised Signature:** ....

Jack Kielt

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED
ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave, Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT10.11 Rev.2.0 14/04/2021

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: C32783

EQUIPMENT TESTED : Sound Level Calibrator

Manufacturer: Rion
Type No: NC-74 **Serial No:** 35094478
Owner: Sonus Pty Ltd
17 Ruthven Ave
Adelaide SA 5000
Tests Performed: Measured Output Pressure level, Frequency & Distortion
Comments: See Details overleaf. All Test Passed.

Parameter	Pre-Adj	Adj Y/N	Output: (dB re 20 µPa)	Frequency (Hz)	THD&N (%)
Level:	NA	N	94.13 dB	1001.90 Hz	1.12 %
Uncertainty			±0.11 dB	±0.05%	±0.20 %
Uncertainty (at 95% c.l.) k=2					

CONDITION OF TEST:

Ambient Pressure	1001	hPa ±1 hPa	**Date of Receipt :**	03/06/2022
Temperature	23	°C ±1° C	**Date of Calibration :**	03/06/2022
Relative Humidity	38	% ±5%	**Date of Issue :**	06/06/2022

Acu-Vib Test Procedure: AVP02 (Calibrators)
Test Method: AS IEC 60942 - 2017

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....
Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

This report applies only to the item identified in the report and may not be reproduced in part.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

NATA
WORLD RECOGNISED ACCREDITATION
Accredited Lab No. 9262
Acoustic and Vibration Measurements

Acu-Vib Electronics
CALIBRATIONS SALES RENTALS REPAIRS

Head Office & Calibration Laboratory
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
(02) 9680 8133
www.acu-vib.com.au

Page 1 of 2 Calibration Certificate
AVCERT02.1 Rev 2.0 14.04.2021

Certificate No. D213662E

ilac-MRA IAJapan JCSS JCSS 0197

CALIBRATION CERTIFICATE

Product	:	SOUND CALIBRATOR
Type	:	NC-75
Serial number	:	34913547
Manufacturer	:	RION CO., LTD.
Calibration quantities	:	Sound pressure level (with reference standard microphone)
Calibration method	:	Measured by specified secondary standard microphone according to JCSS calibration procedure specified by RION
Ambient conditions	:	Temperature 22.3 ℃, Relative humidity 55 %, Static pressure 100.1 kPa
Calibration date	:	03/09/2021 (DD/MM/YYYY)
Calibration location	:	3-20-41 Higashimotomachi, Kokubunji, Tokyo 185-8533, Japan RION CO., LTD. Calibration Room

We hereby certify that the results of this calibration were as follows.

Issue date : 08/09/2021 (DD/MM/YYYY)

Junichi Kawamura
Manager
Quality Assurance Section,
Quality Assurance Department,
Environmental Instrument Division,
RION CO., LTD.
3-20-41 Higashimotomachi, Kokubunji,
Tokyo 185-8533, Japan

This certificate is based on article 144 of the Measurement Law and indicates the result of calibration in accordance with measurement standards traceable to Primary Measurement Standards (National Standards) which realizes the physical units of measurement according to the International System of Units (SI).
The accreditation symbol is attestation of which the result of calibration is traceable to Primary Measurement Standards (National Standards).
The certificate shall not be reproduced except in full, without the written approval of the issuing laboratory.
The calibration laboratory who issued this calibration certificate conforms to ISO/IEC 17025:2017.
This calibration certificate was issued by the calibration laboratory accredited by IAJapan who is a signatory to the Mutual Recognition Arrangement (MRA) of International Laboratory Accreditation Cooperation (ILAC) and Asia Pacific Accreditation Cooperation (APAC). This (These) calibration result(s) may be accepted internationally through ILAC/APAC MRA.

RION

8 APPENDIX C: LOGGER LOCATION PHOTOS

Figure 16: B006 – First View

Figure 17: B006 – Second View

Figure 18: B006 – Third View

Figure 19: B006 – Fourth View

Figure 20: B061(S) – First View

Figure 21: B061(S) – Second View

Figure 22: B061(S) – Third View

Figure 23: B061(S) – Fourth View

Figure 24: B065 – First View

Figure 25: B065 – Second View

Figure 26: B065 – Third View

Figure 27: B065 – Fourth View

Figure 28: B083 – First View

Figure 29: B083 – Second View

Figure 30: B083 – Third View

Figure 31: B083 – Fourth View

Figure 32: B111 – First View

Figure 33: B111 – Second View

Figure 34: B111 – Third View

Figure 35: B111 – Fourth View

Figure 36: B114 – First View

Figure 37: B114 – Second View

Figure 38: B114 – Third View

Figure 39: B114 – Fourth View

Figure 40: B118 – First View

Figure 41: B118 – Second View

Figure 42: B118 – Third View

Figure 43: B118 – Fourth View

Figure 44: B171 – First View

Figure 45: B171 – Second View

Figure 46: B171 – Third View

Figure 47: B171 – Fourth View

Figure 48: B328 – First View

Figure 49: B328 – Second View

Figure 50: B328 – Third View

Figure 51: B328 – Fourth View

9 APPENDIX D: WIND ROSES

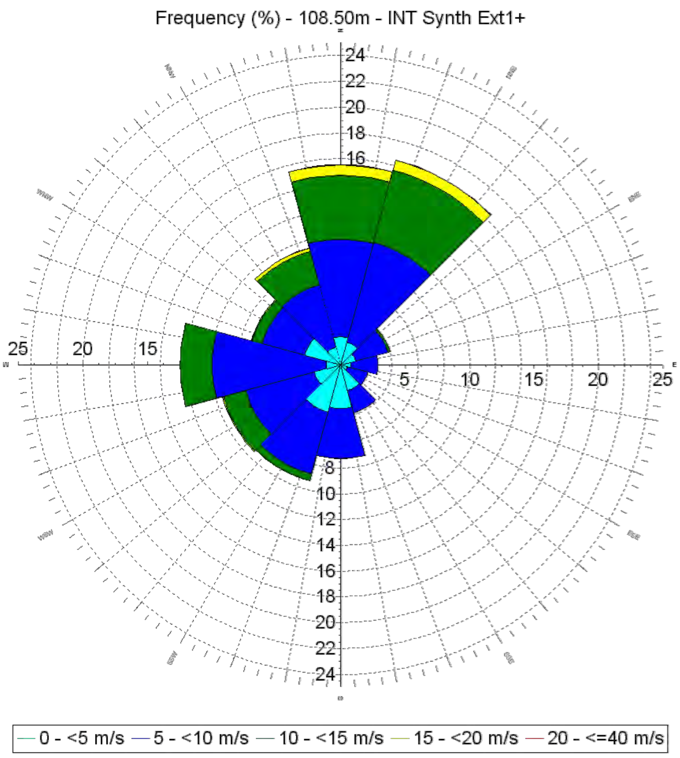


Figure 52: EXT1 – Hub Height Monitoring Period Wind Rose

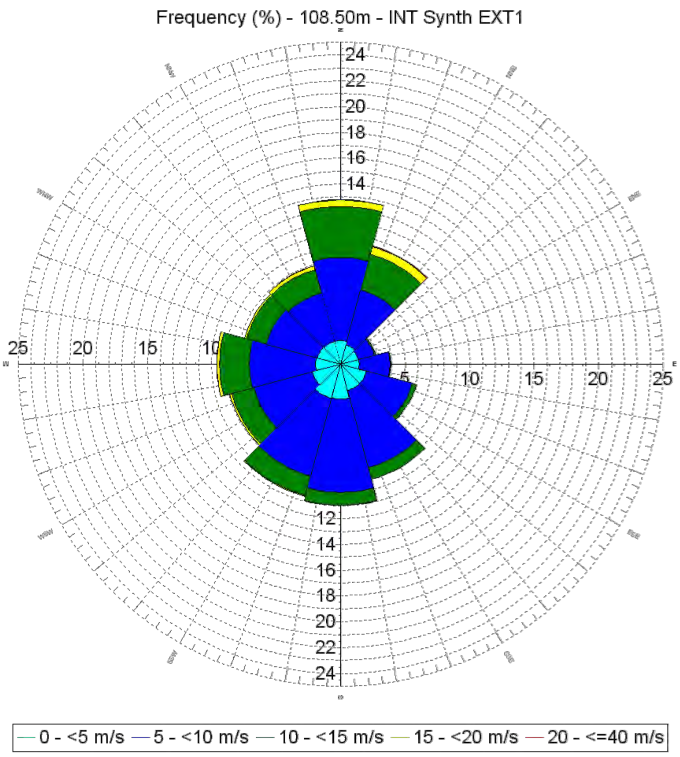


Figure 53: EXT1 – Hub Height Long Term Wind Rose

sonus.

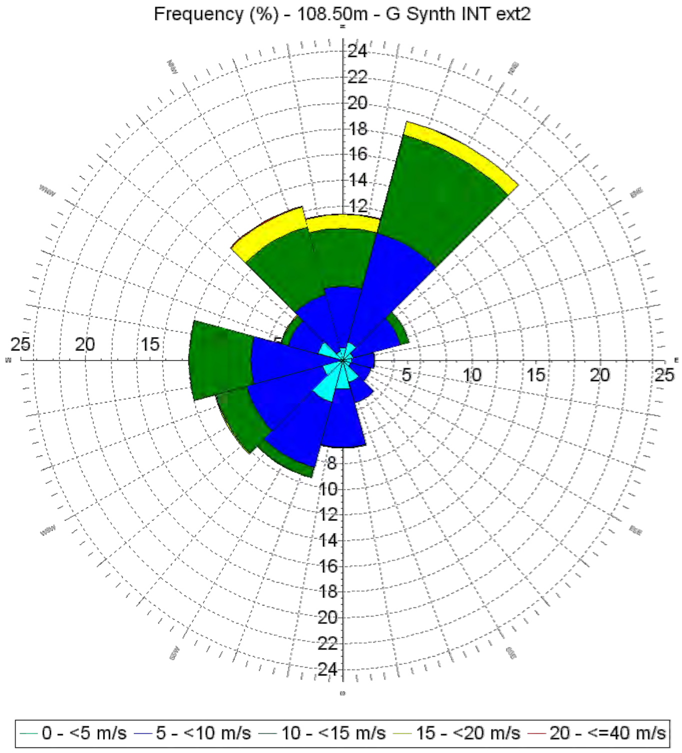


Figure 54: EXT2 – Hub Height Monitoring Period Wind Rose

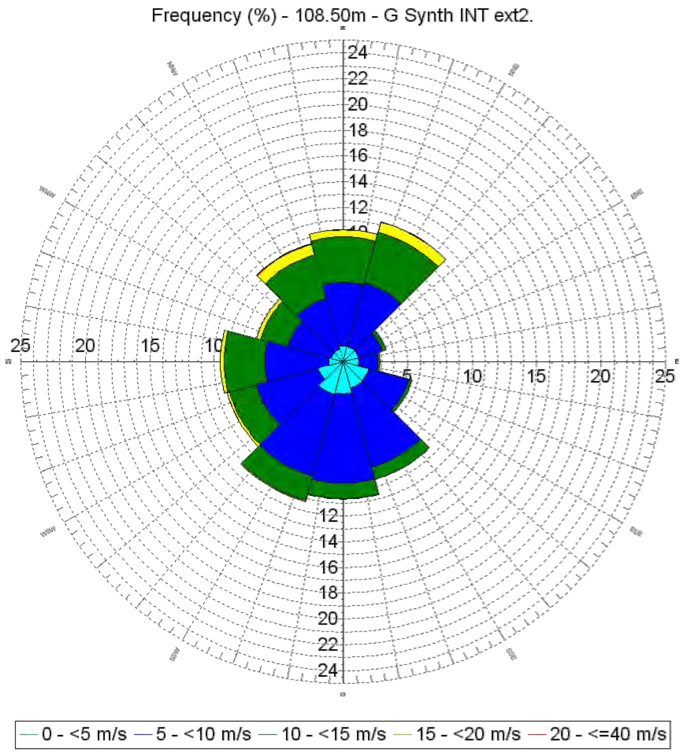


Figure 55: EXT2 – Hub Height Long Term Wind Rose

Frequency (%) - 108.50m - G Synth INT EXT3

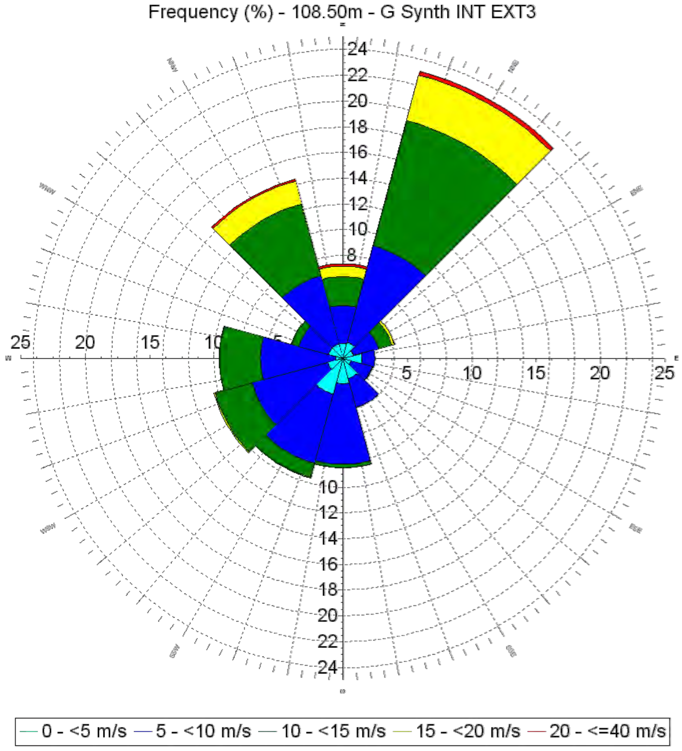


Figure 56: EXT3 – Hub Height Monitoring Period Wind Rose

Frequency (%) - 108.50m - G Synth INT EXT3.

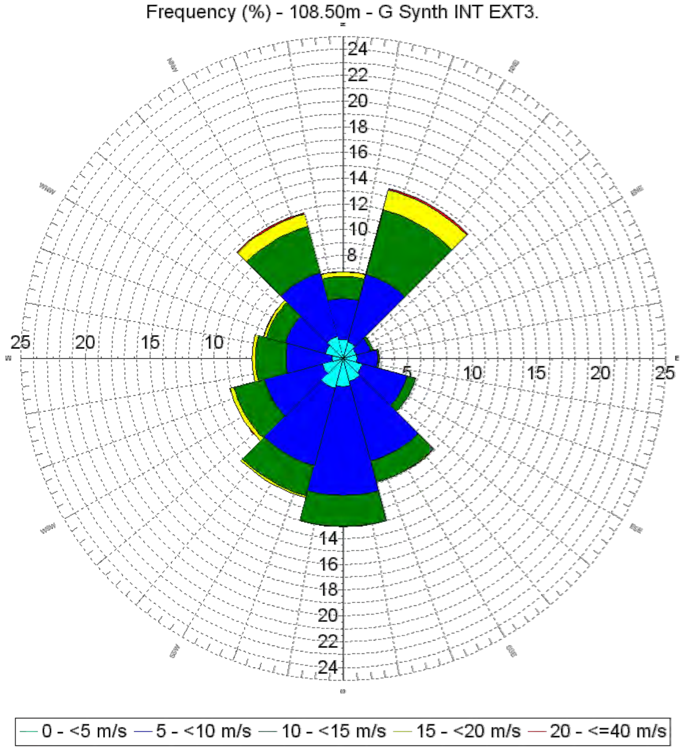


Figure 57: EXT3 – Hub Height Long Term Wind Rose

10 APPENDIX E: BACKGROUND NOISE CORRELATIONS

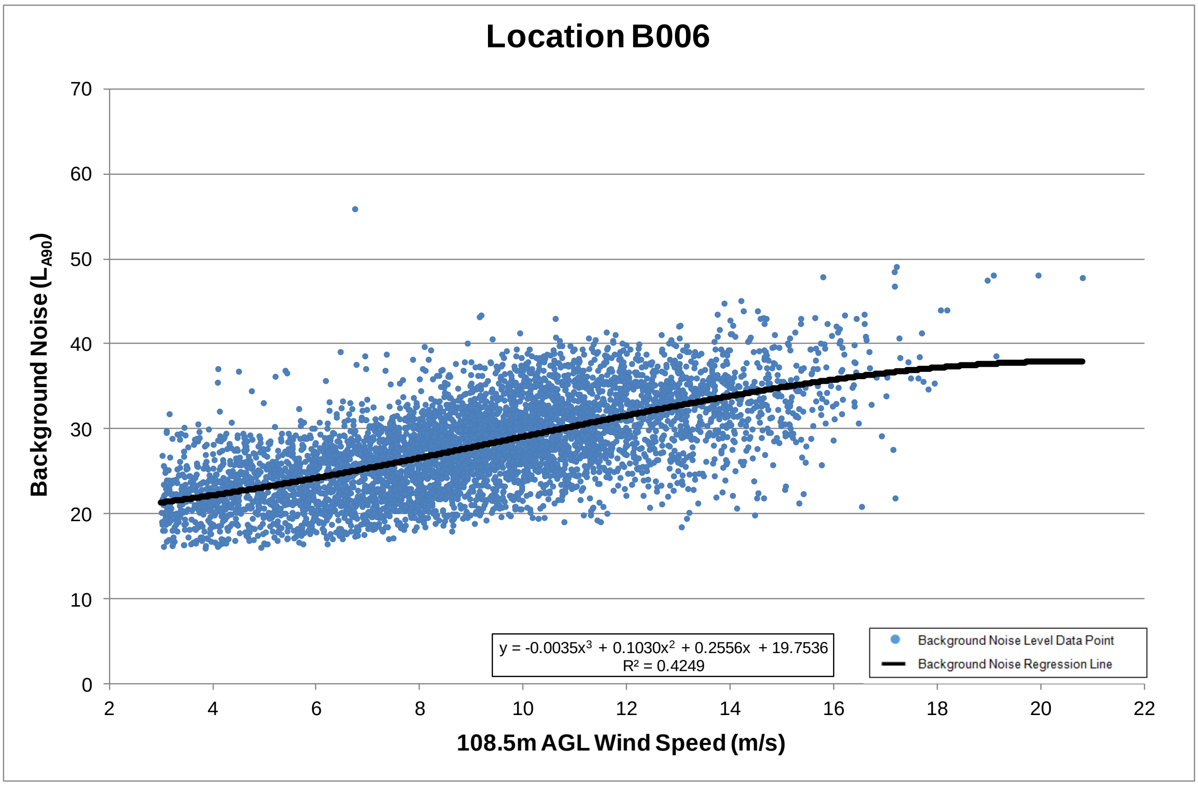


Figure 58: B006 Background Noise Correlation Graph

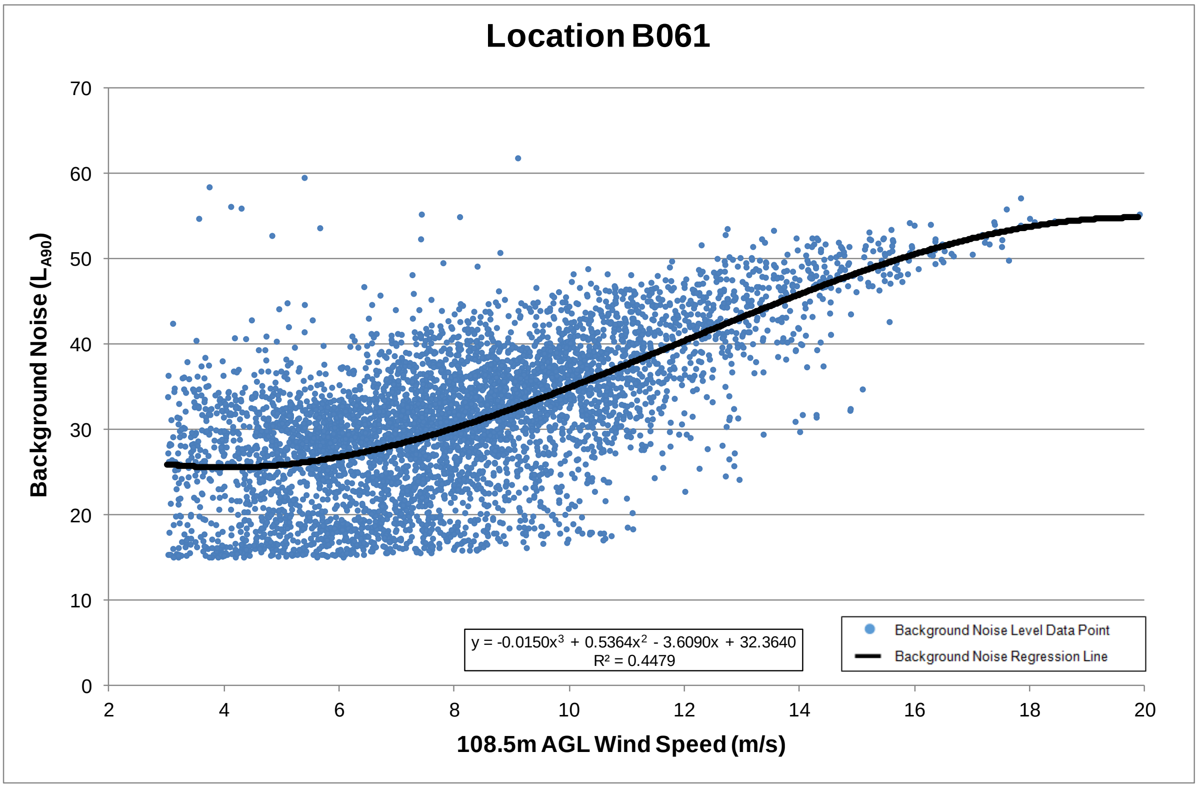


Figure 59: B061 Background Noise Correlation Graph

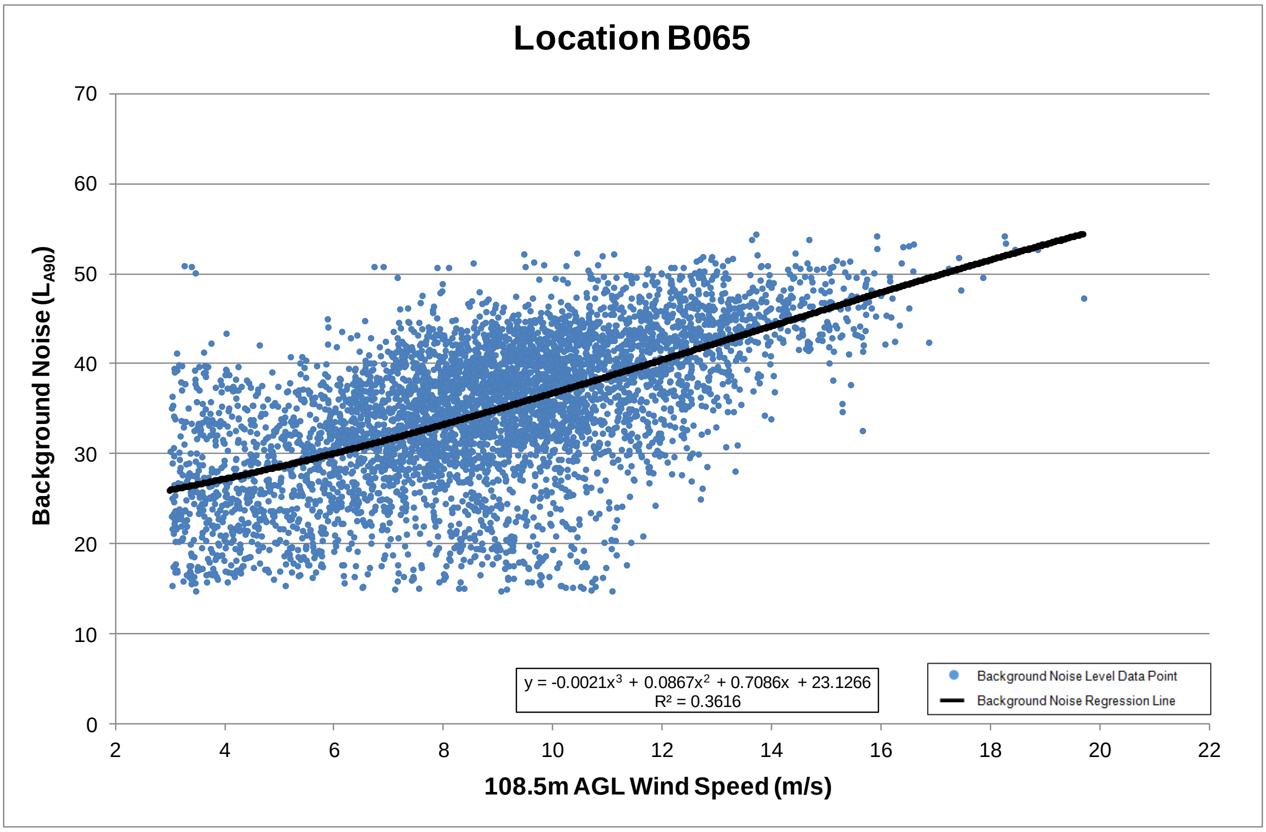


Figure 60: B065 Background Noise Correlation Graph

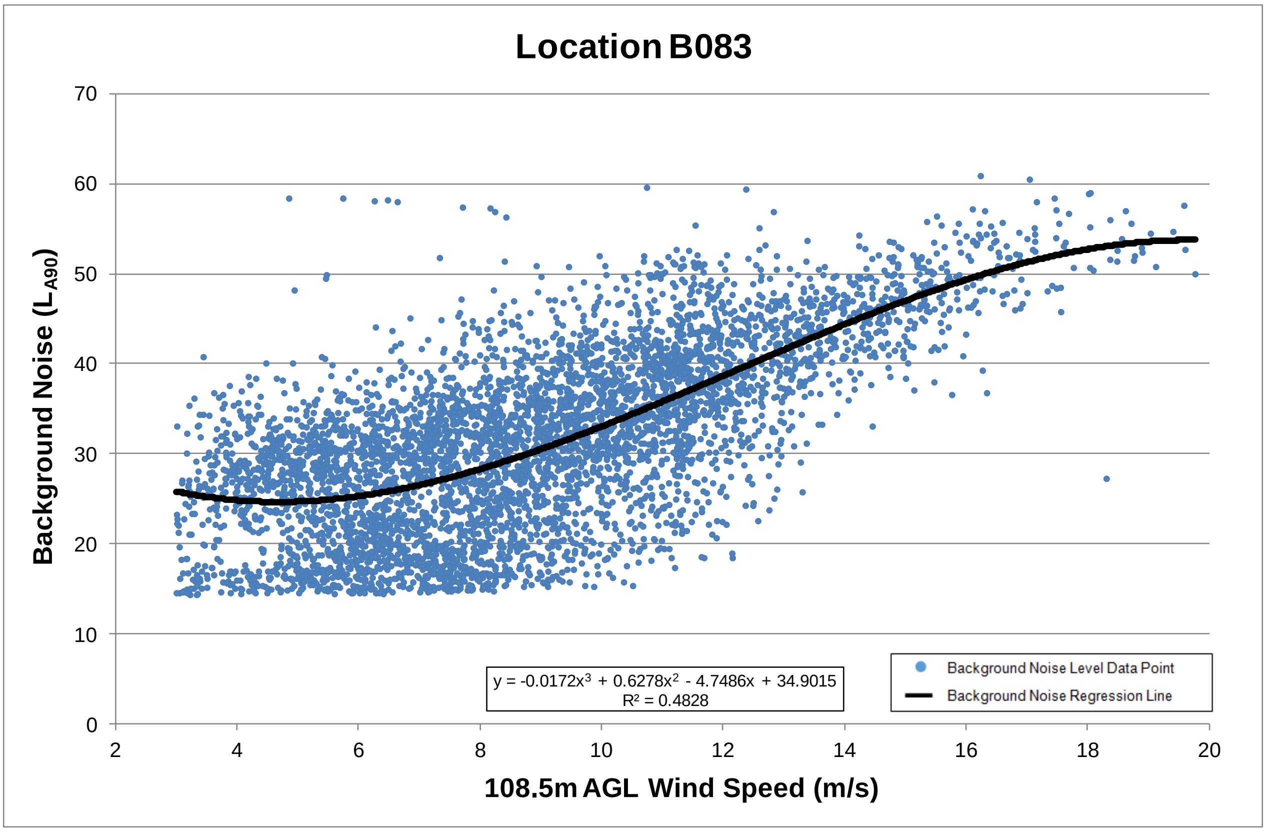


Figure 61: B083 Background Noise Correlation Graph

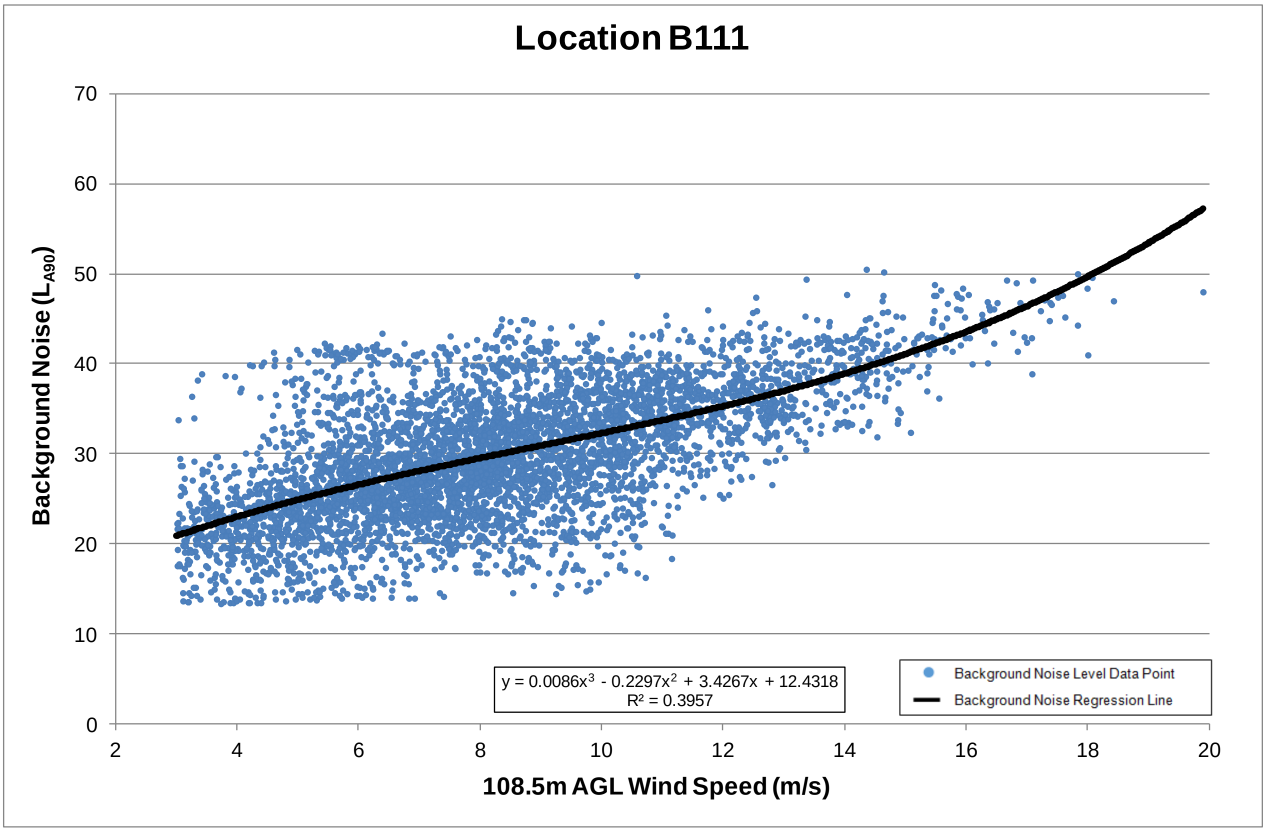


Figure 62: B111 Background Noise Correlation Graph

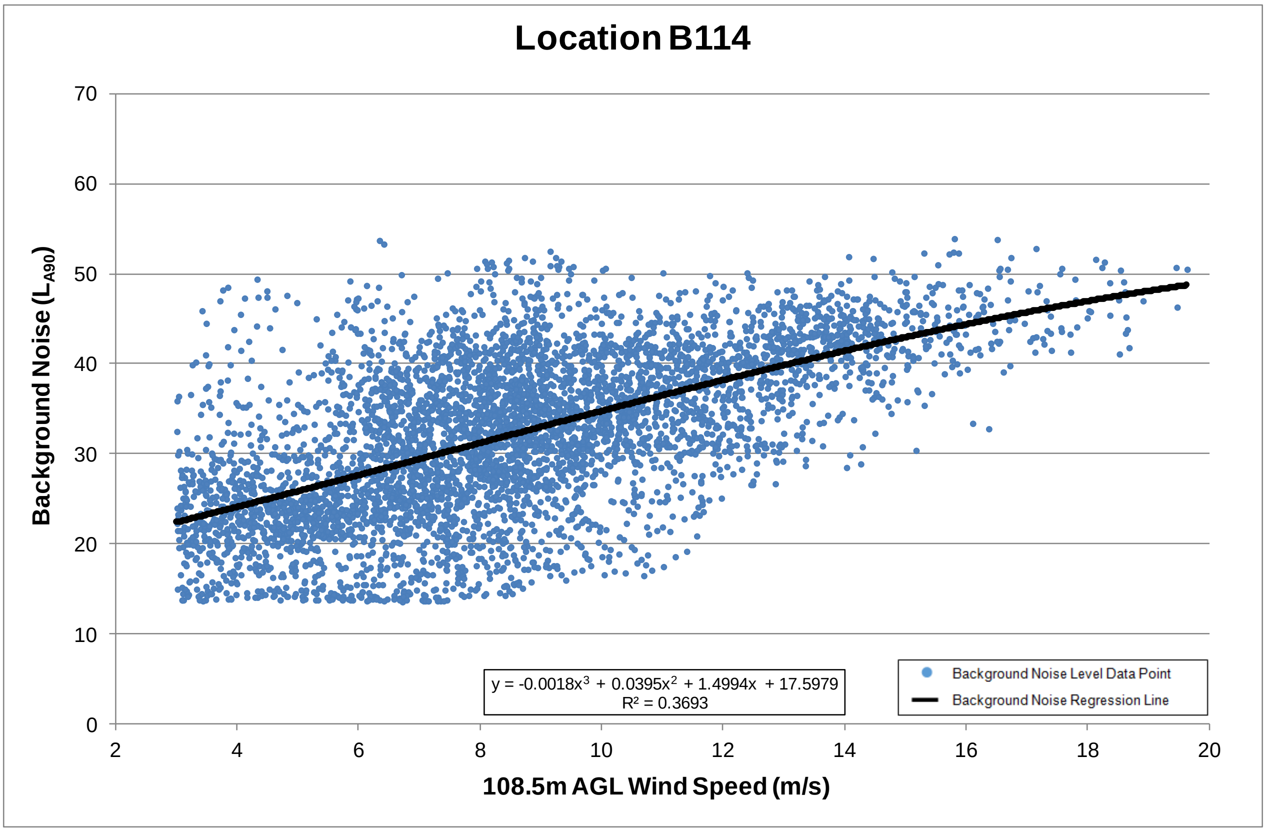


Figure 63: B114 Background Noise Correlation Graph

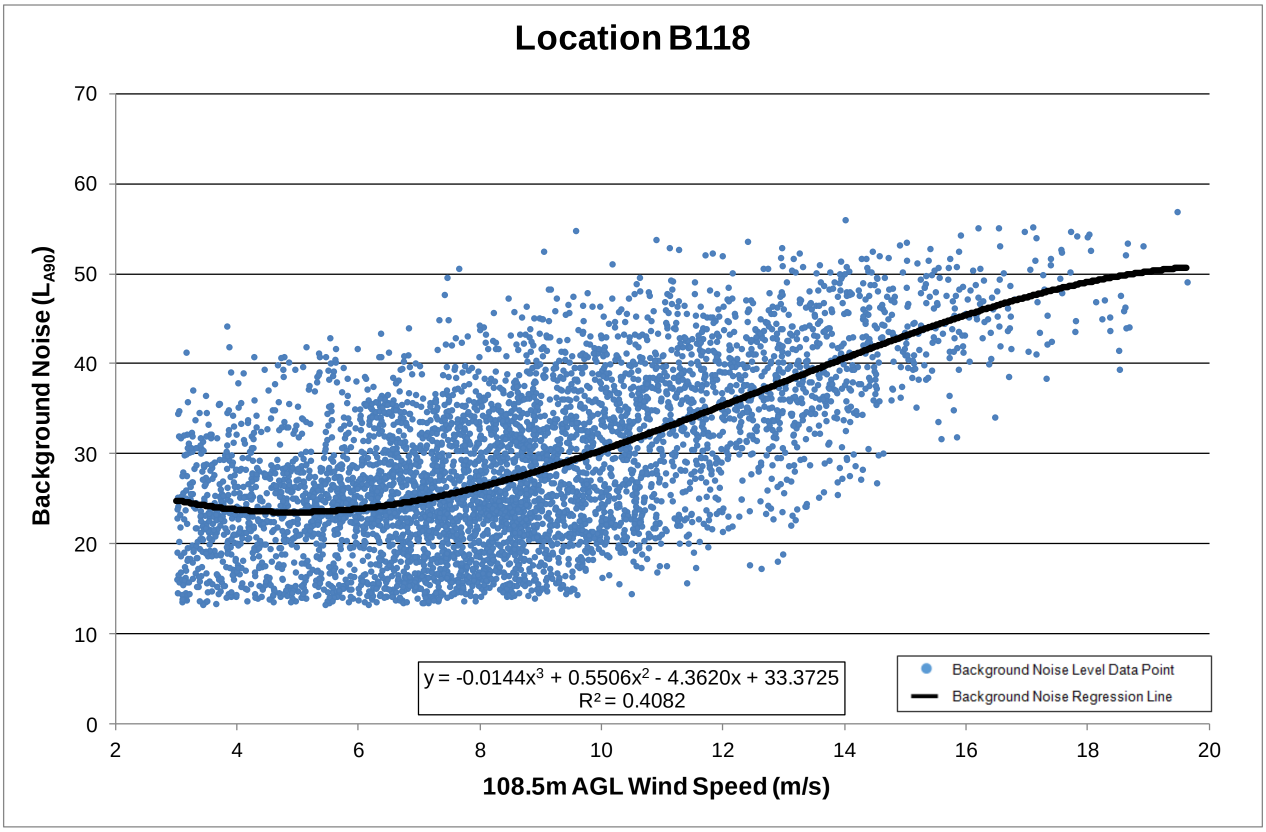


Figure 64: B118 Background Noise Correlation Graph

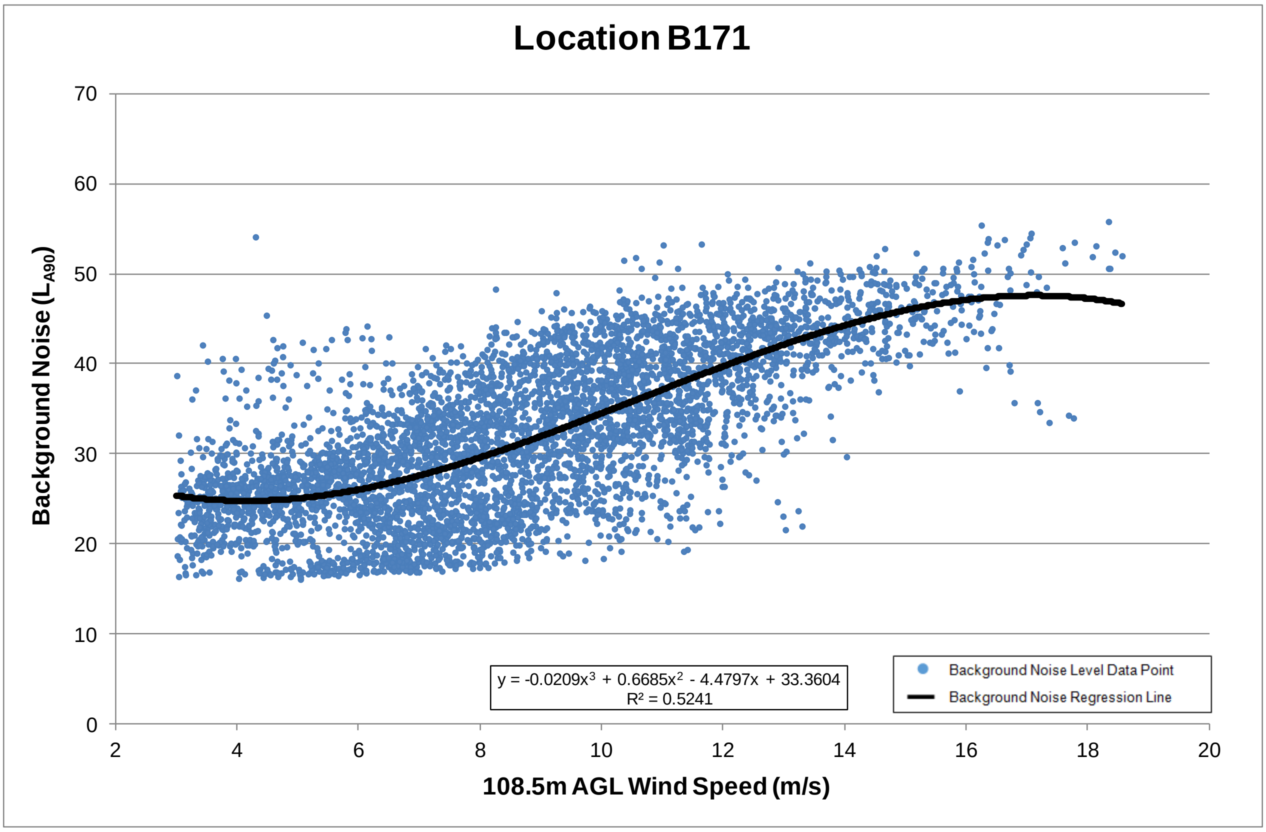


Figure 65: B171 Background Noise Correlation Graph

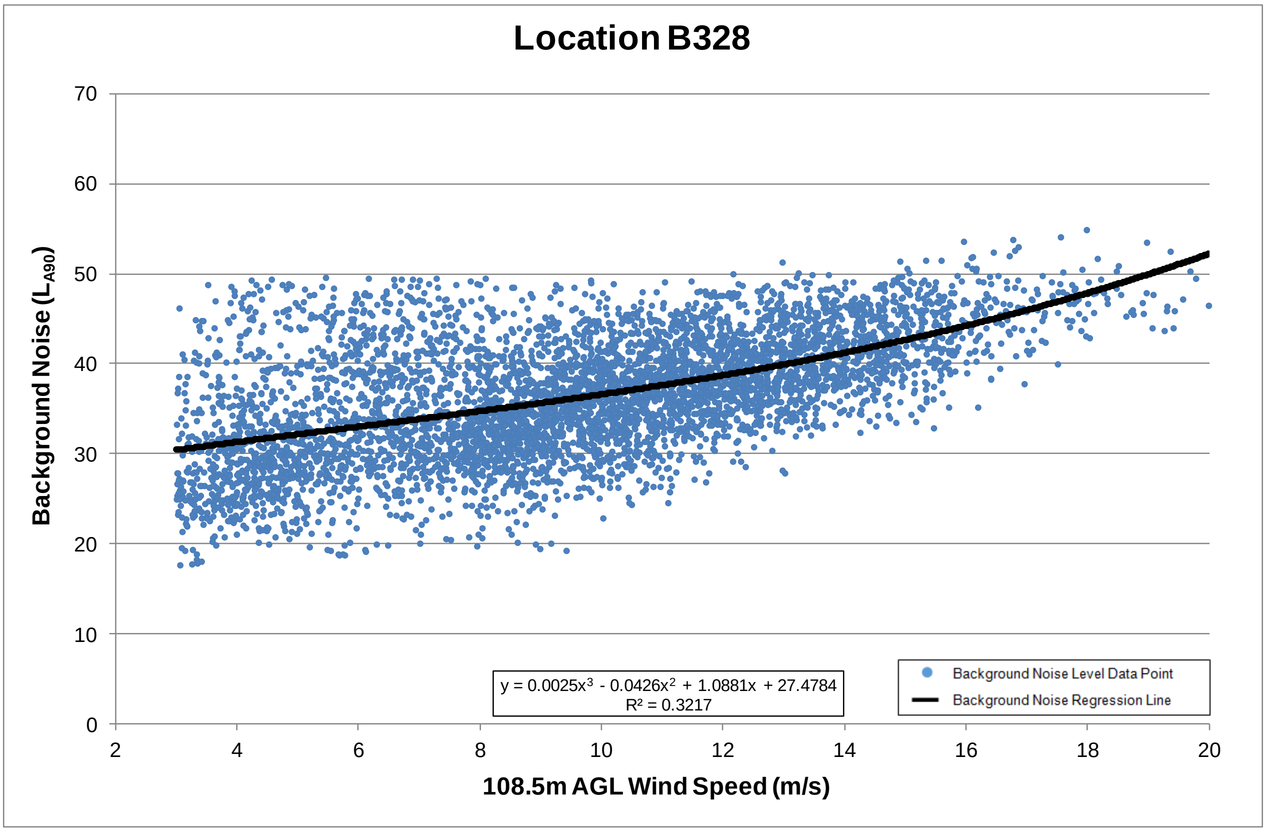


Figure 66: B328 Background Noise Correlation Graph

sonus.

11 APPENDIX F: AMPLITUDE MODULATION GRAPHS

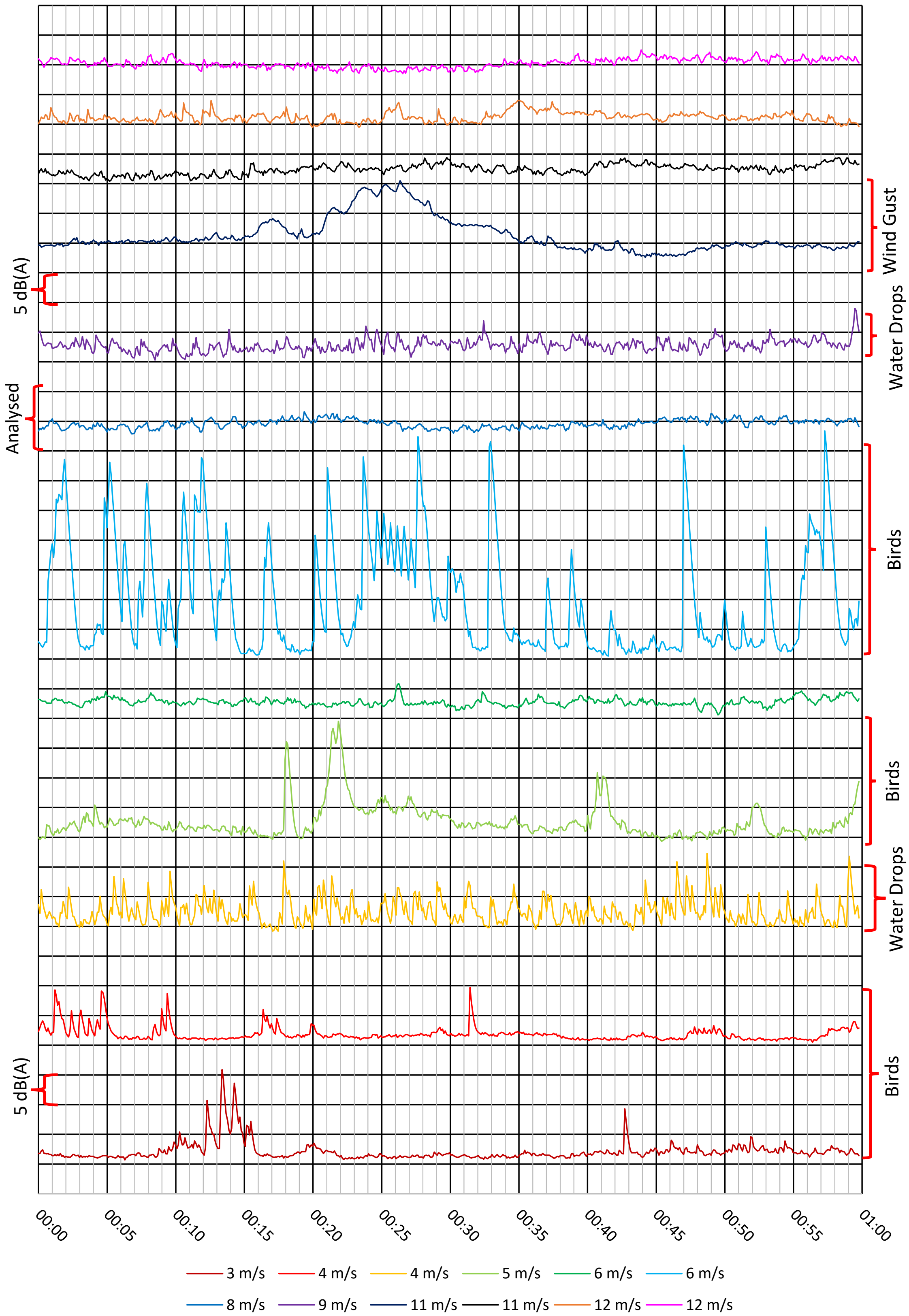


Figure 67: B006 Overall Amplitude Modulation

sonus.

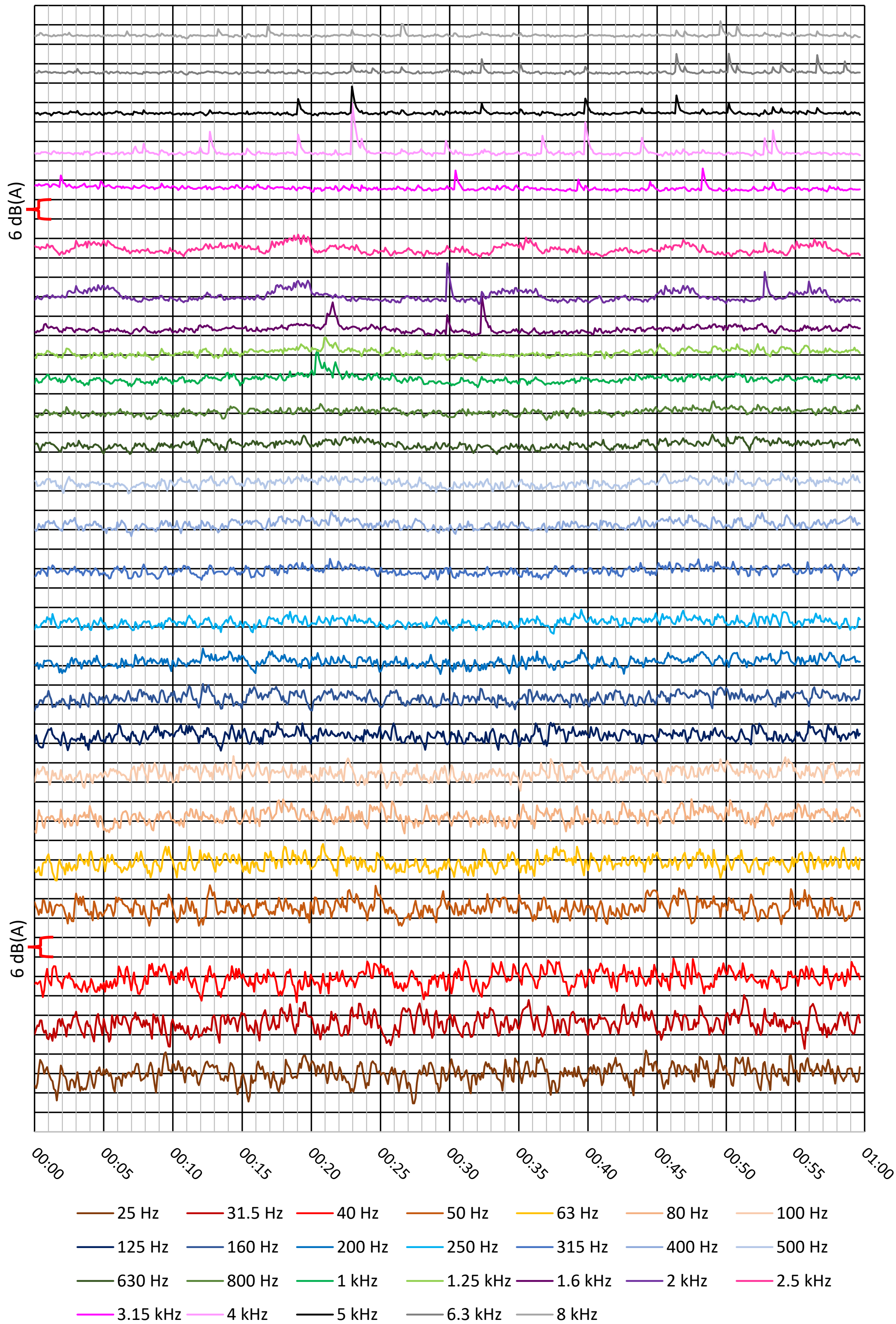


Figure 68: B006 8m/s Amplitude Modulation

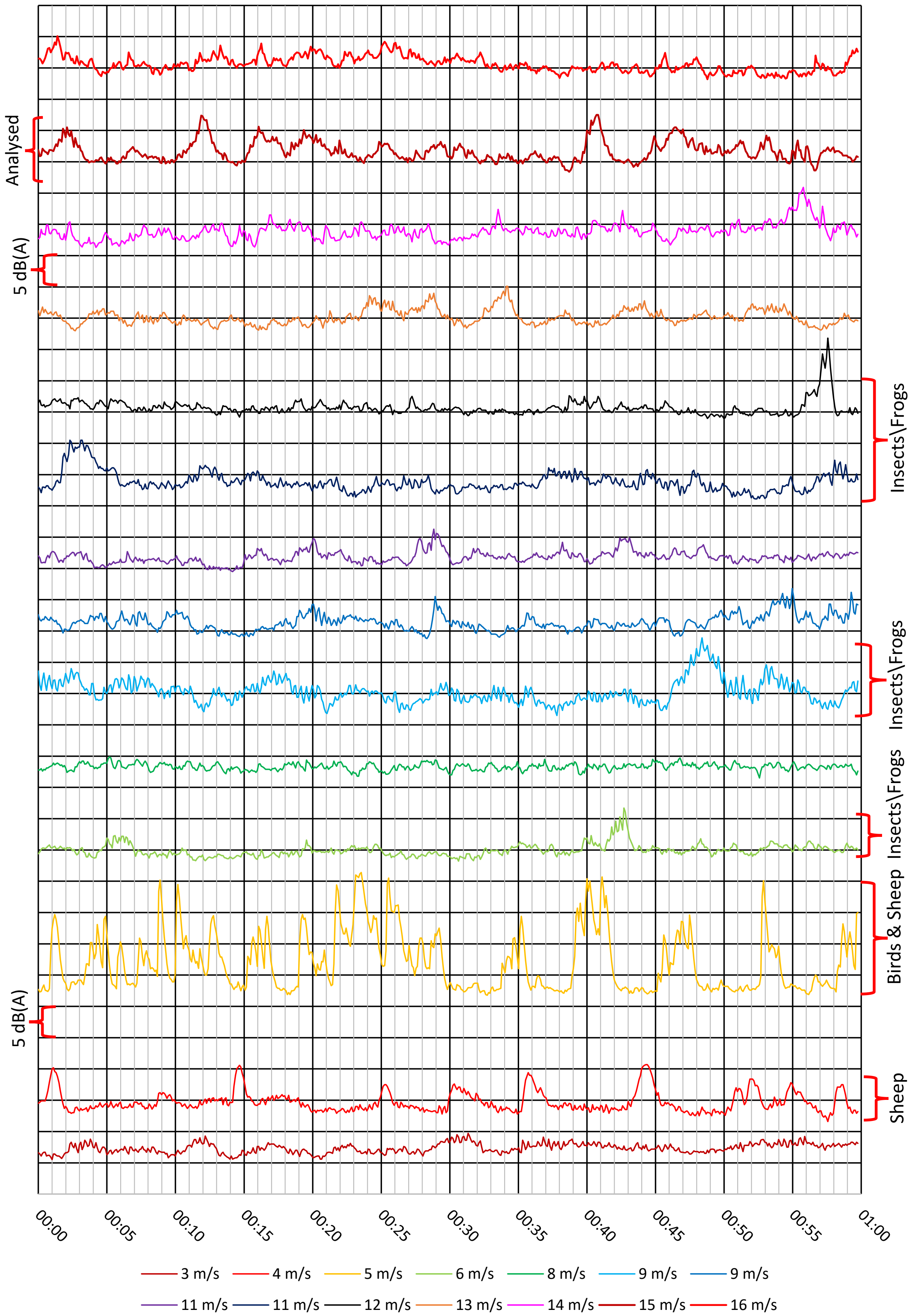


Figure 69: B065 Overall Amplitude Modulation

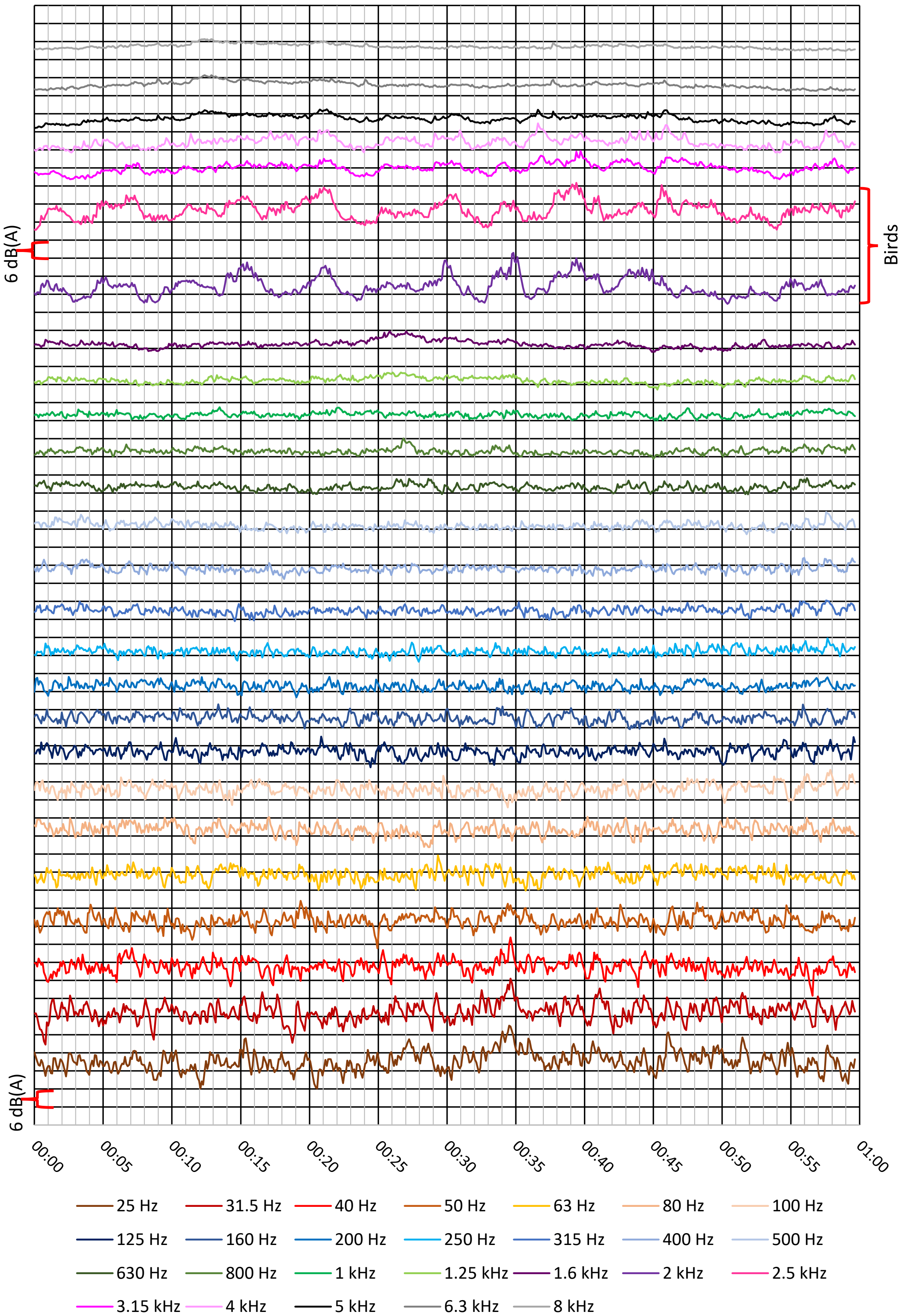


Figure 70: B065 15m/s Amplitude Modulation

sonus.

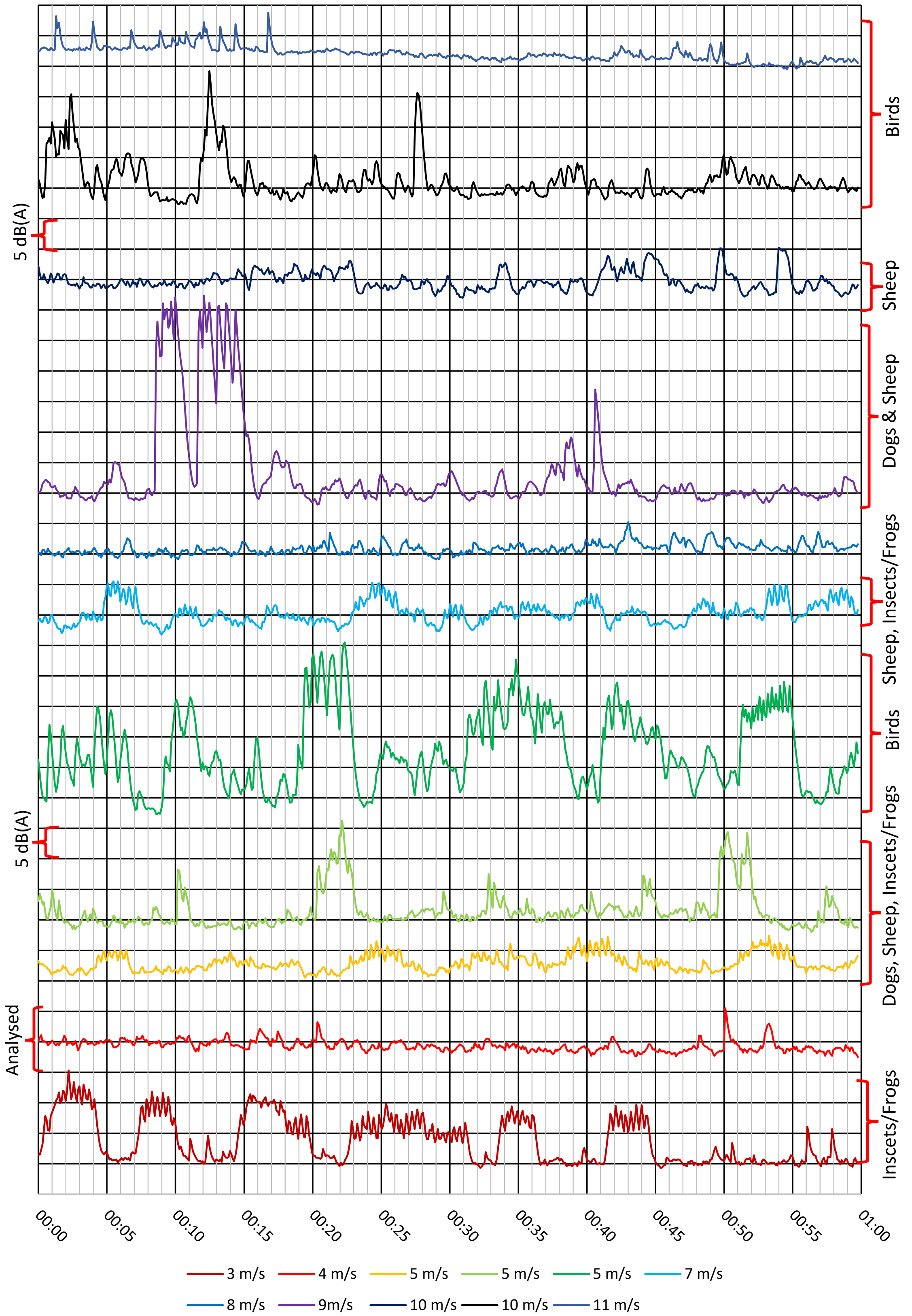


Figure 71: B083 Overall Amplitude Modulation

sonus.

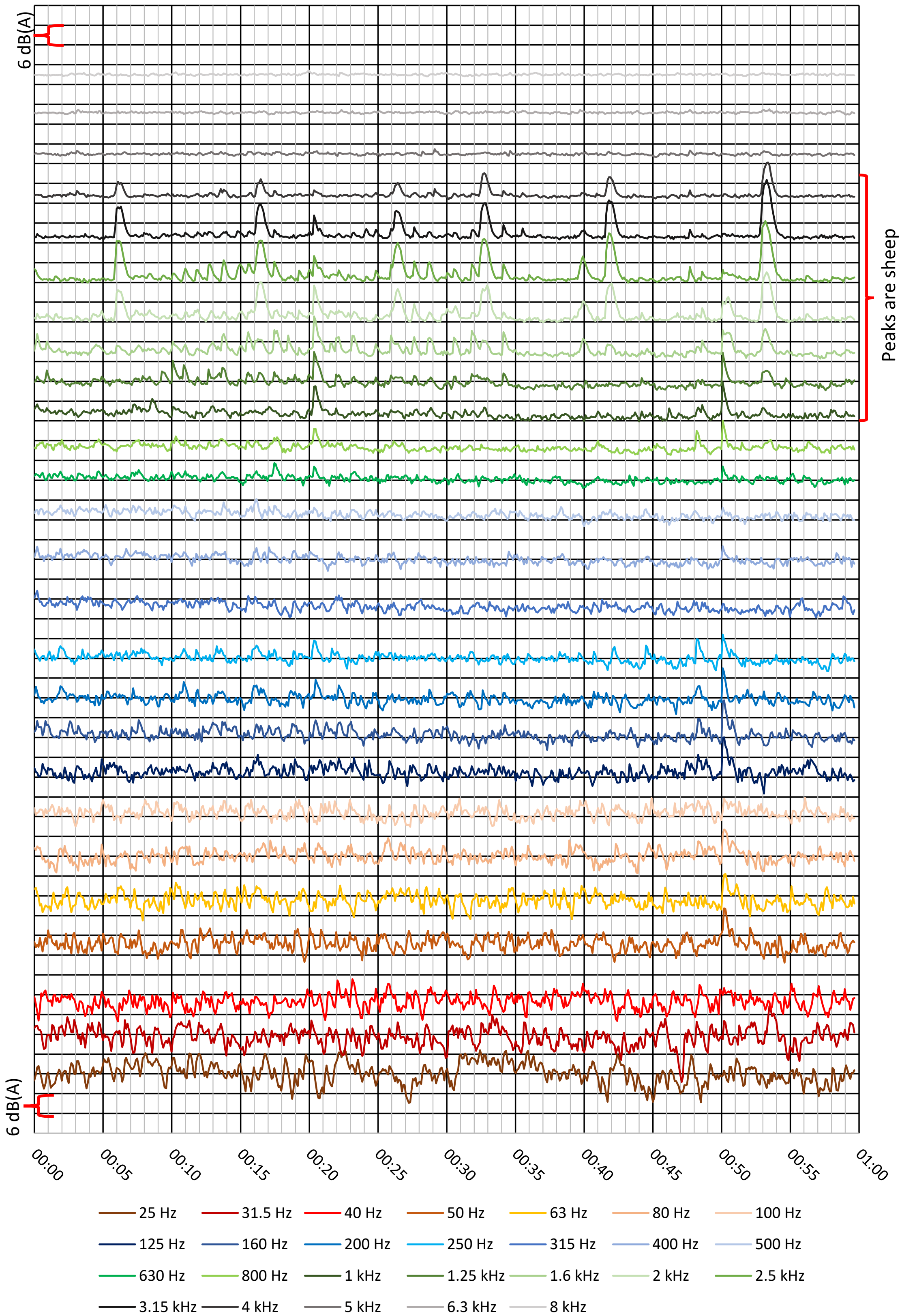


Figure 72: B083 4m/s Amplitude Modulation

sonus.

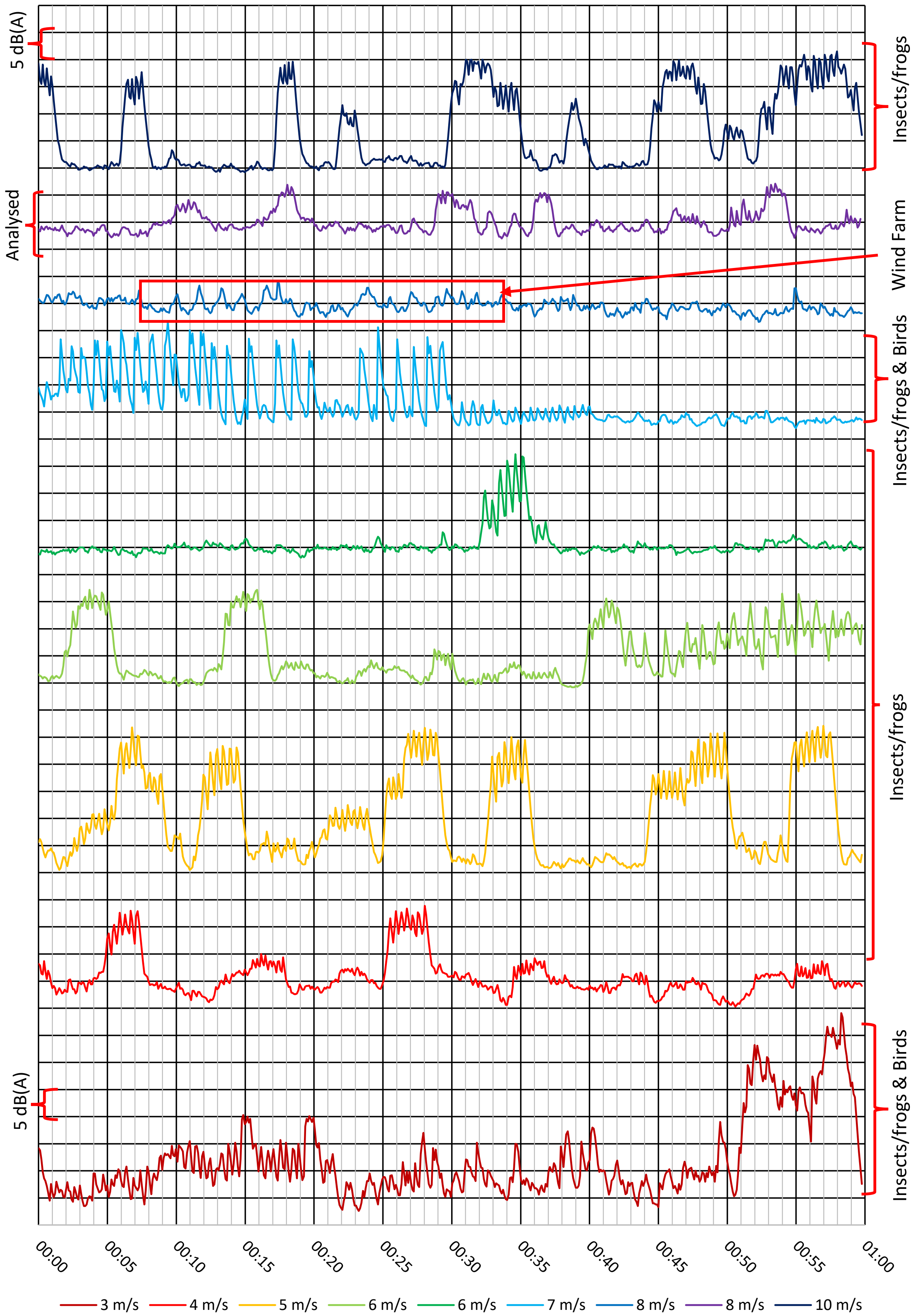


Figure 73: B111 Overall Amplitude Modulation

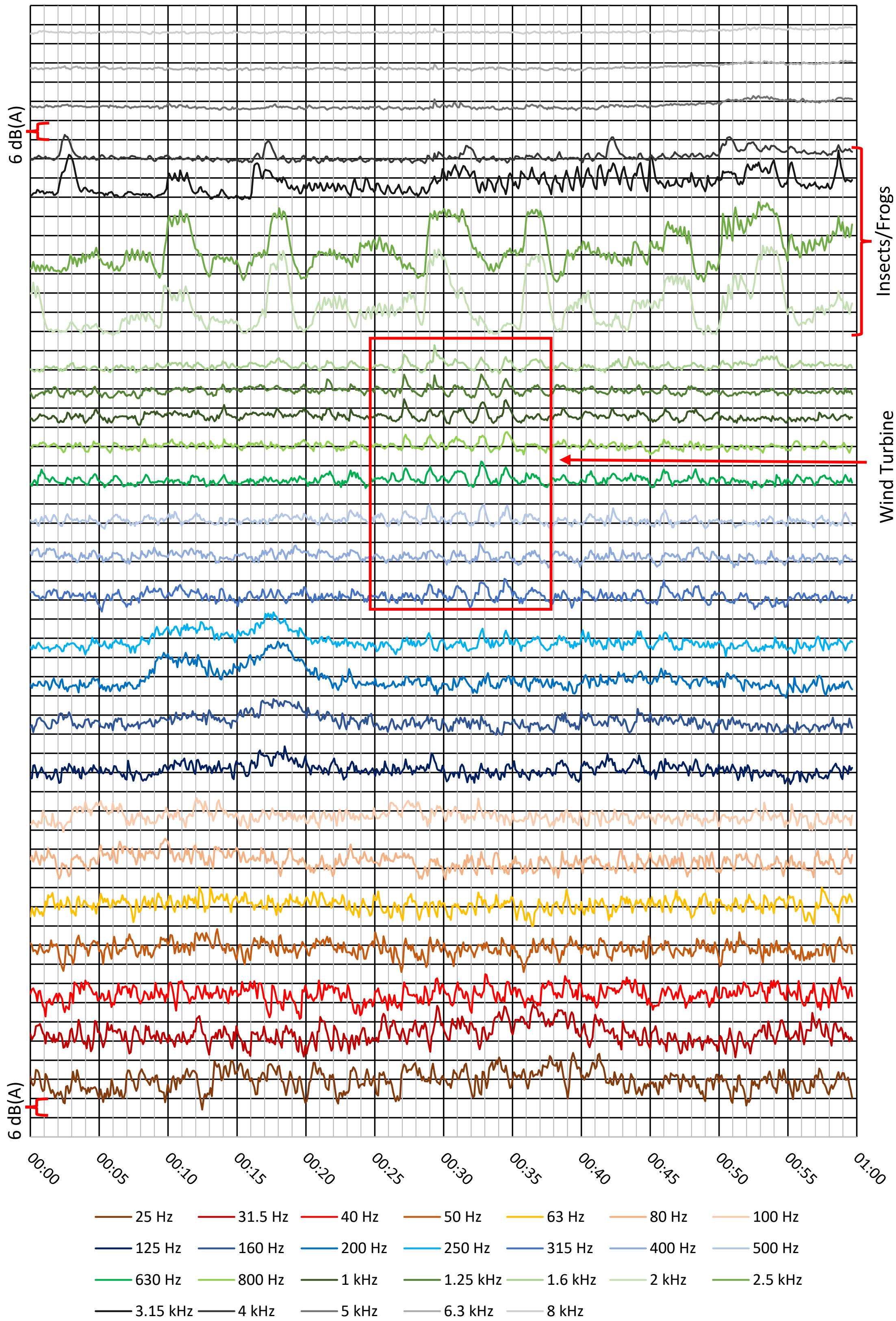


Figure 74: B111 8m/s Amplitude Modulation

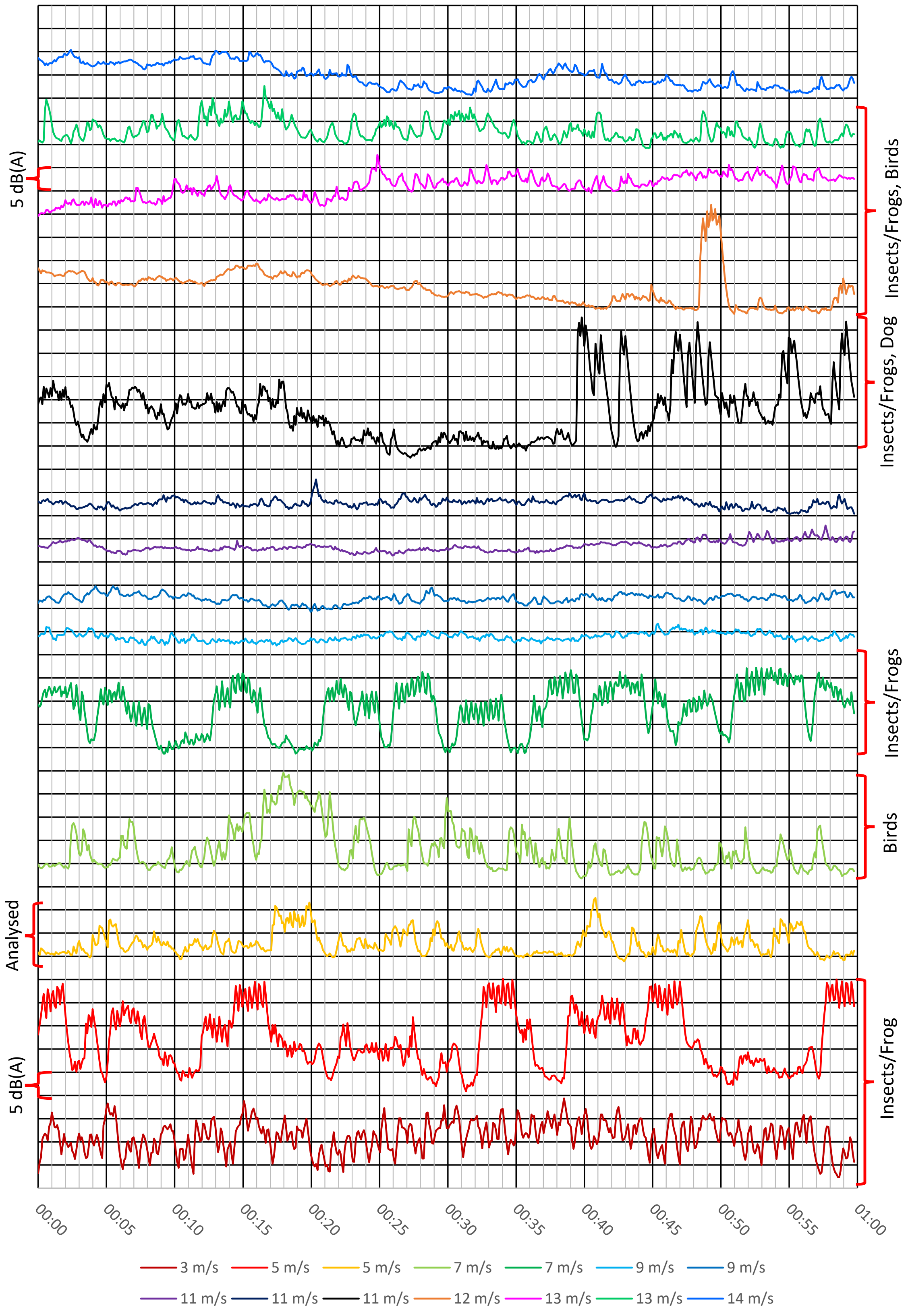


Figure 75: B114 Overall Amplitude Modulation

sonus.

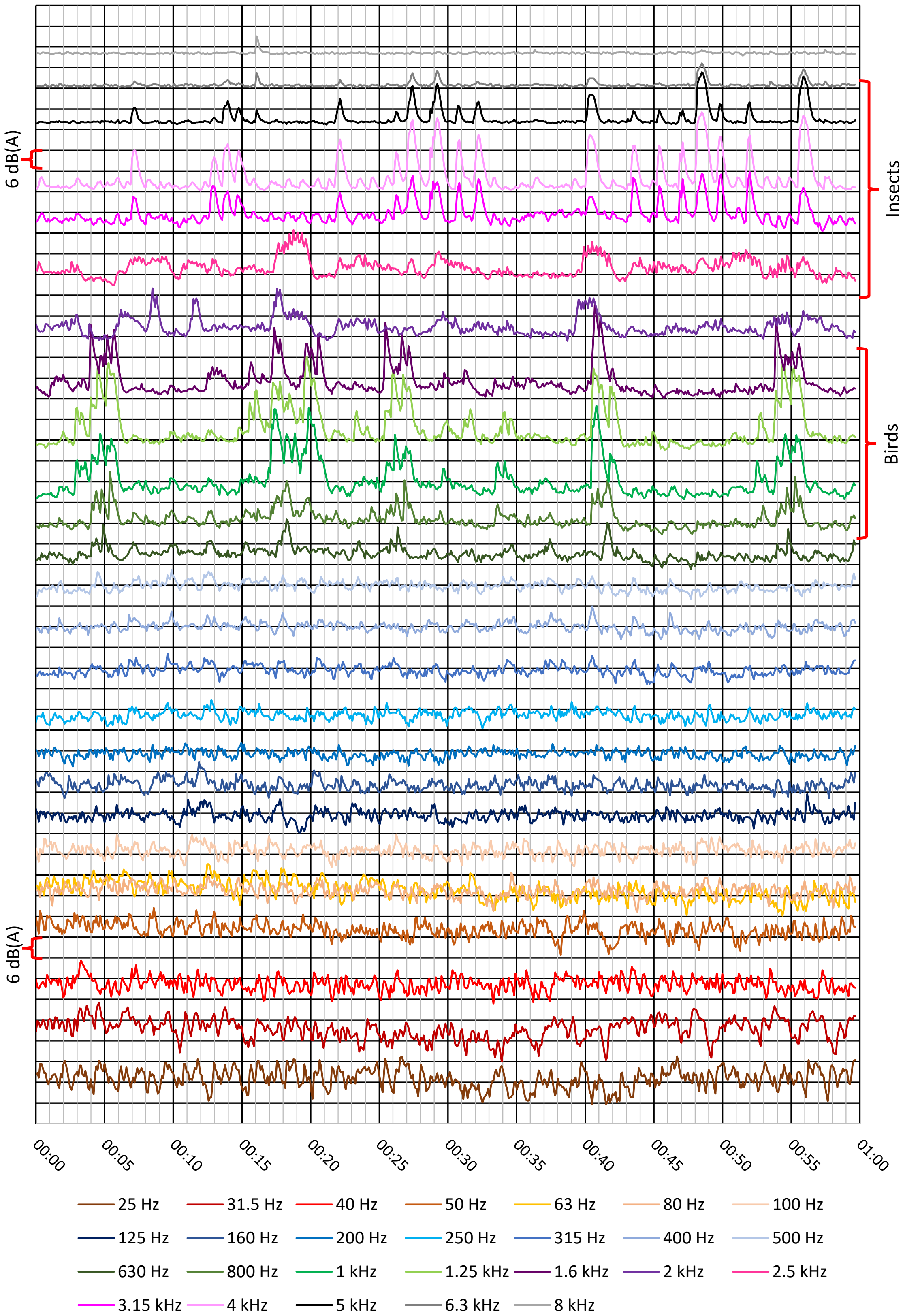


Figure 76: B114 5m/s Amplitude Modulation

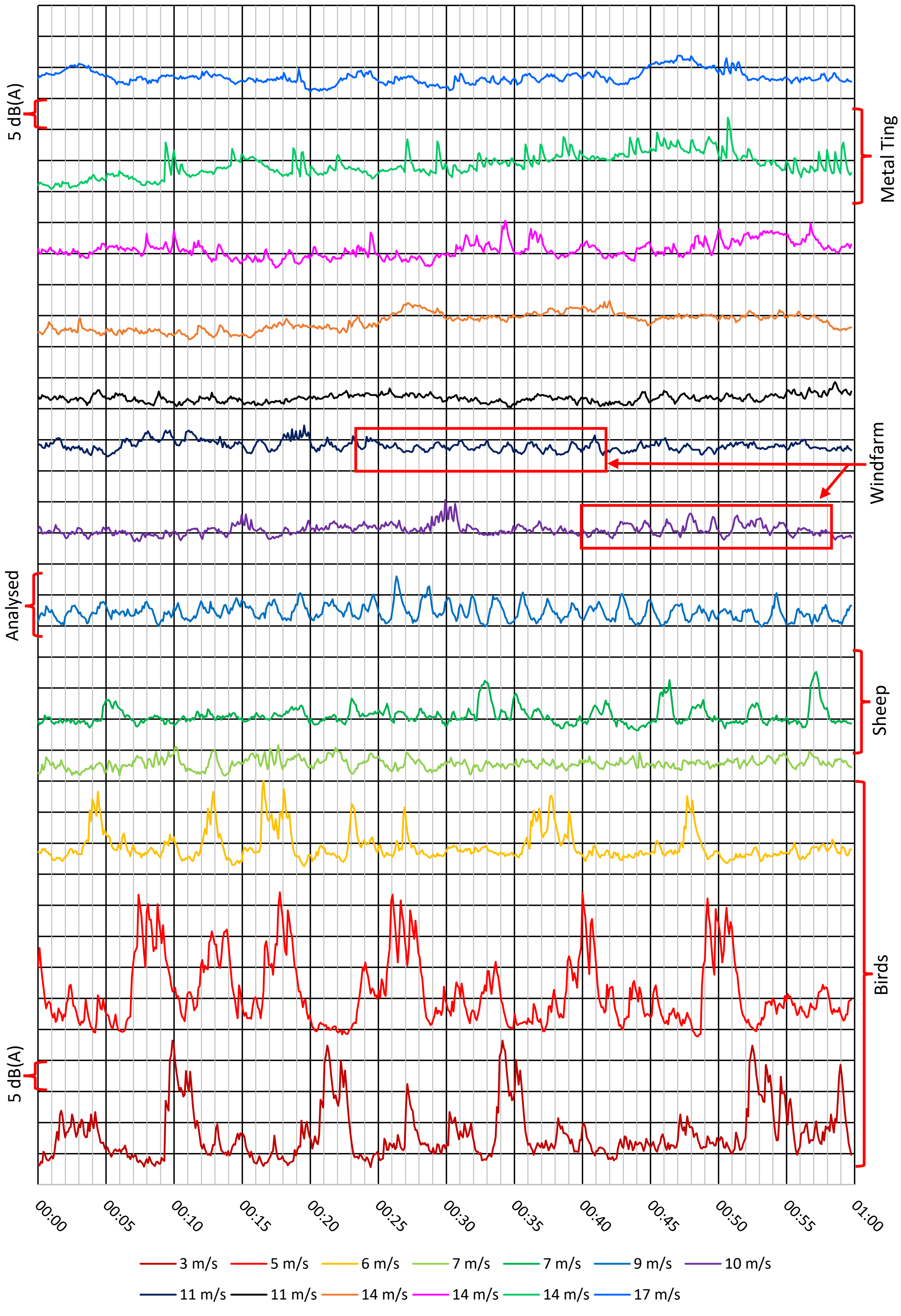


Figure 77: B118 Overall Amplitude Modulation

sonus.

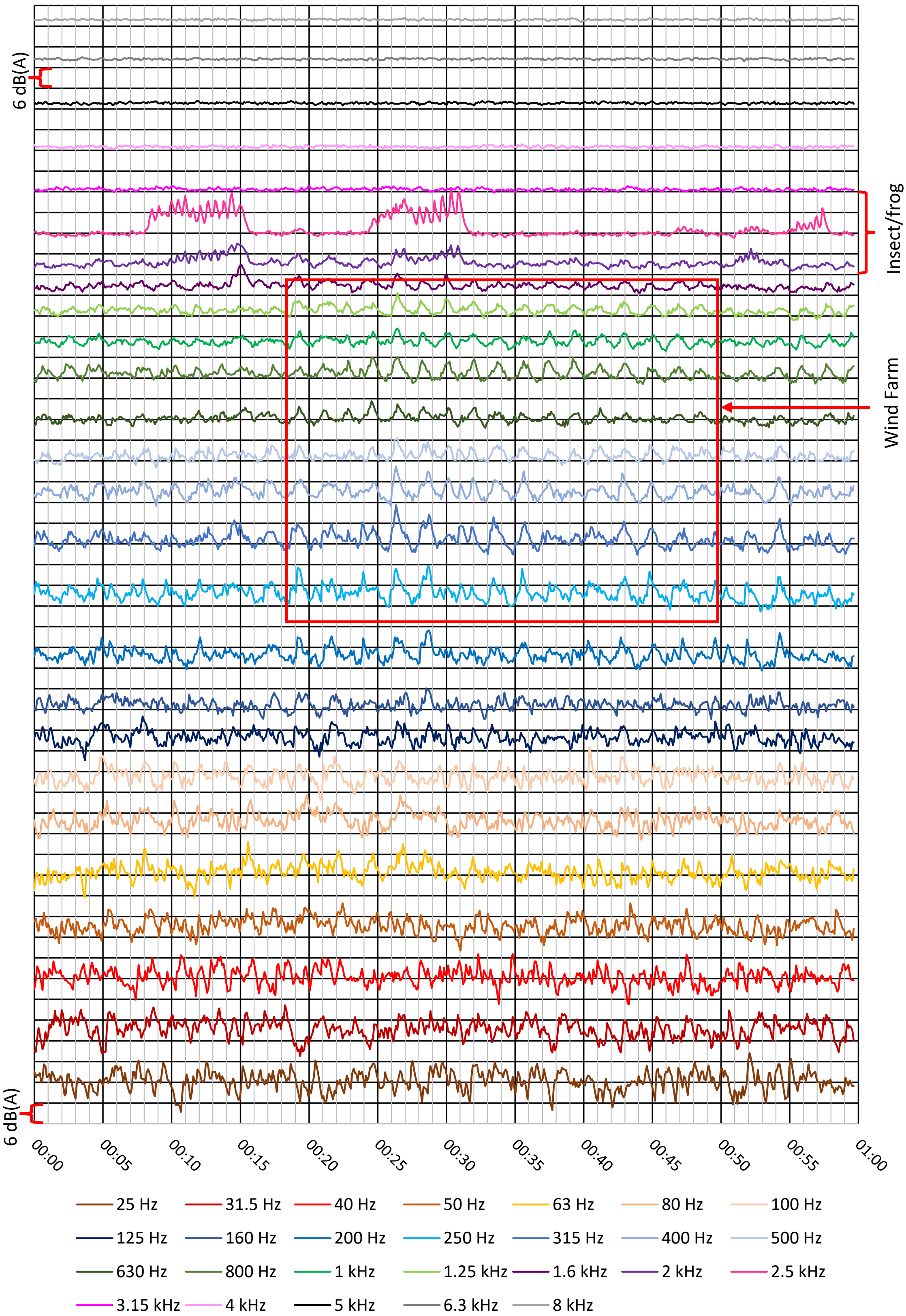


Figure 78: B118 9m/s Amplitude Modulation

sonus.

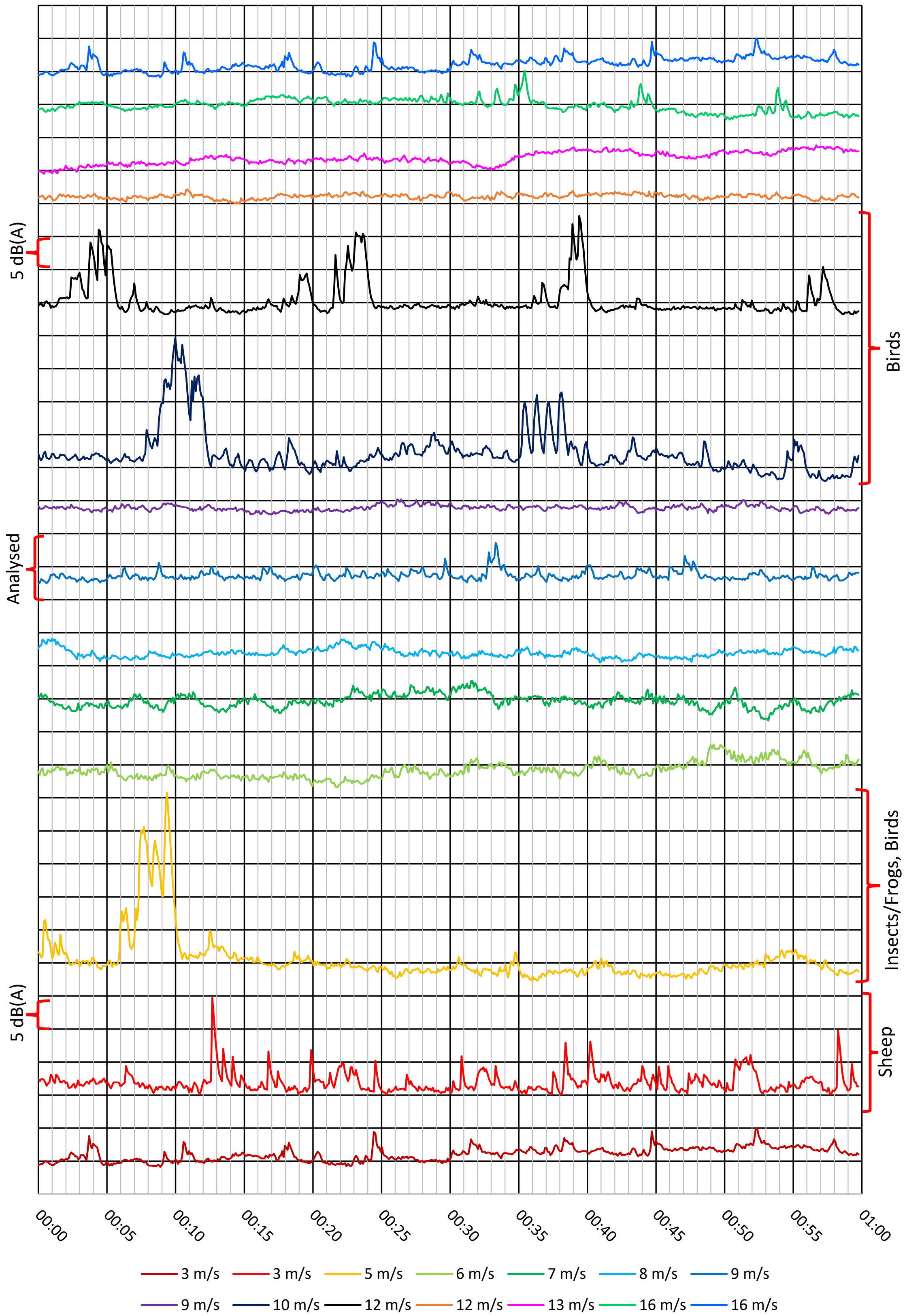


Figure 79: B171 Overall Amplitude Modulation

sonus.

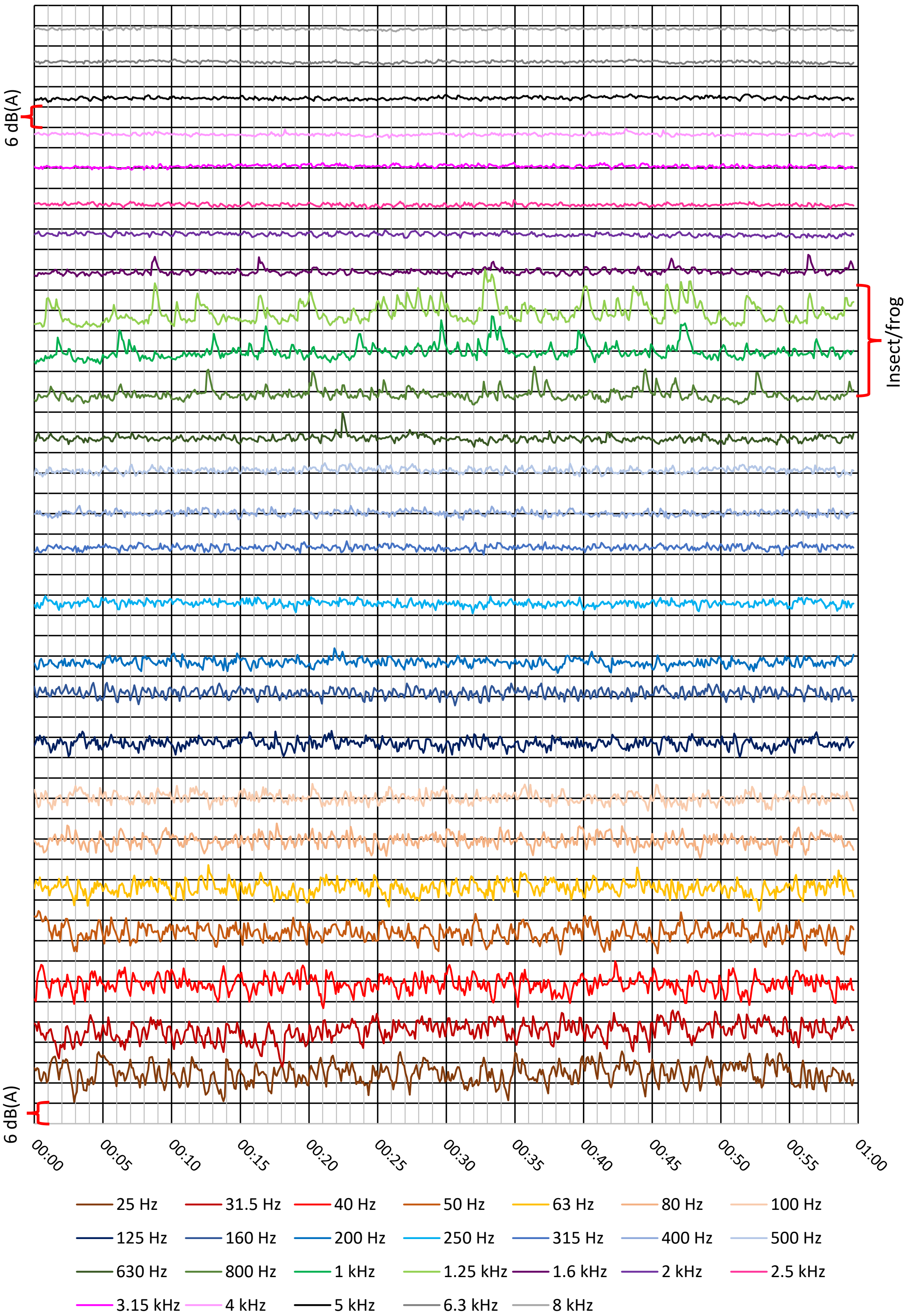


Figure 80: B171 9m/s Amplitude Modulation

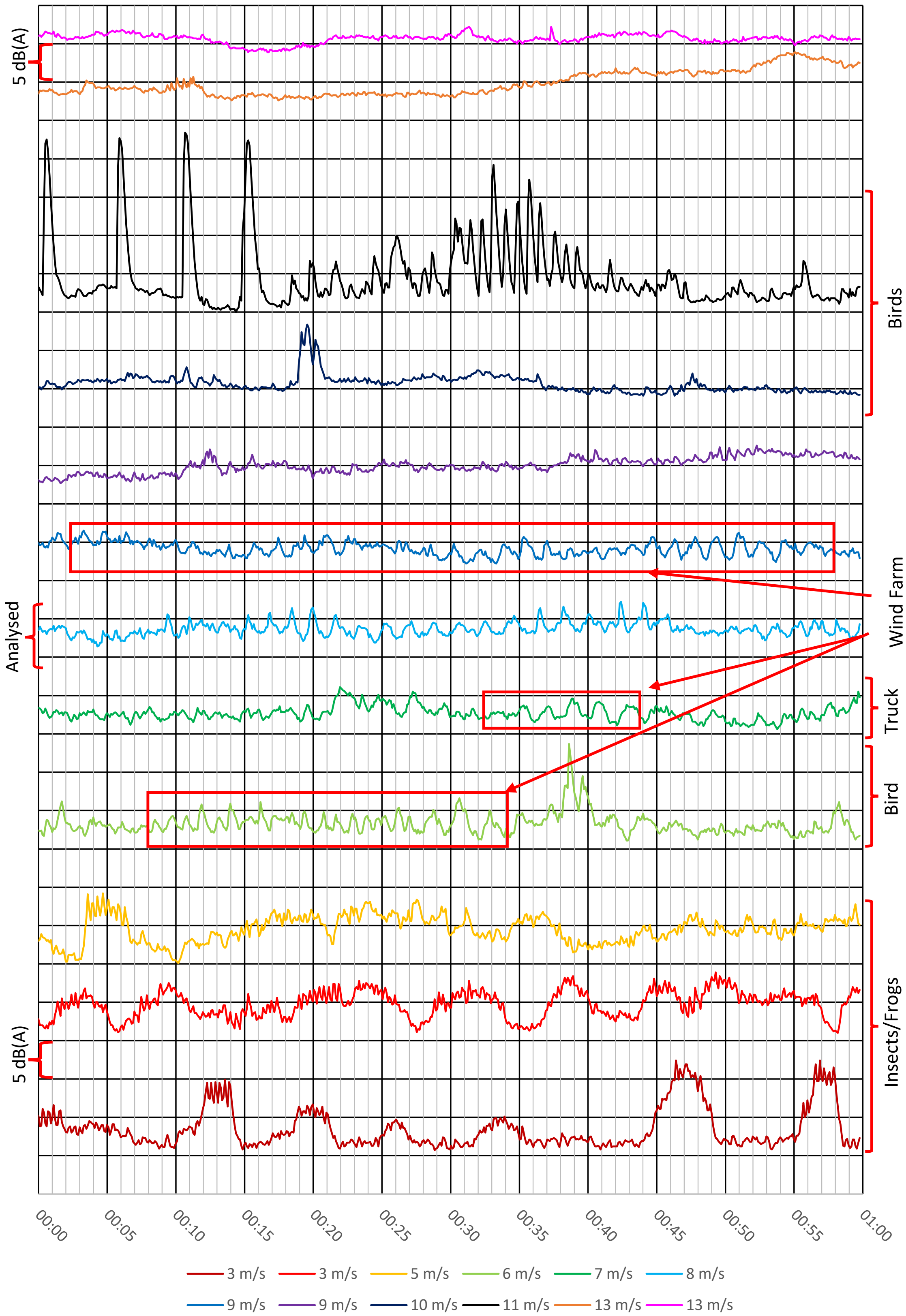


Figure 81: B328 Overall Amplitude Modulation

sonus.

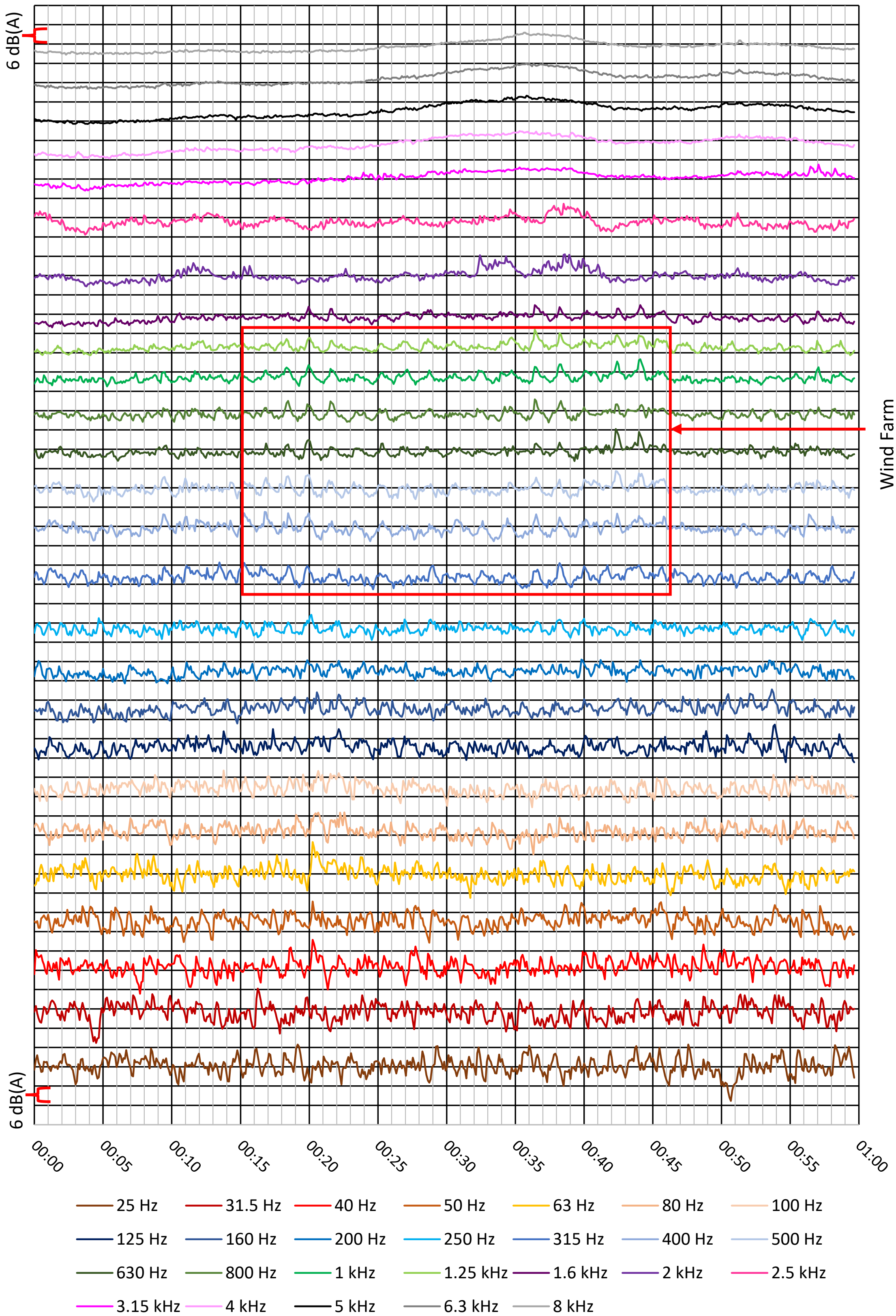


Figure 82: B328 8m/s Amplitude Modulation

12 APPENDIX G: NEAR FIELD TEST REPORTS

Stockyard Hill Wind Farm

Acoustic Analysis of Wind Turbine

Generator 18

S3425.2C17

October 2022

sonus.

Chris Turnbull
Principal
ct@sonus.com.au
+61 (0) 417 845 720

Sonus Pty Ltd
17 Ruthven Avenue
Adelaide 5000 SA
+61 (8) 8231 2100
www.sonus.com.au

sonus.

Document Title : Acoustic Noise Test of Wind Turbine Generator 18

Document Reference: S3425.2C17

Date: October 2022

Author : Chris Turnbull, MAAS

© Sonus Pty Ltd. All rights reserved.

This report may not be reproduced other than in its entirety. The report is for the sole use of the client for the particular circumstances described in the report. Sonus accepts no responsibility to any other party who may rely upon or use this report without prior written consent.

sonus.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1 INTRODUCTION

Sonus has been engaged by Goldwind Australia Pty Ltd to conduct noise testing of wind turbine generator 18 (WTG18) at the Stockyard Hill Wind Farm, Victoria.

The purpose of the testing was to determine the apparent sound power levels, tonality, and amplitude modulation of the installed wind turbine generator 18, type GW3S.

Noise measurements of WTG18 were conducted on 10 January 2022 to 12 January 2022. The data acquisition and subsequent analyses were conducted in general accordance with the approach of the following:

- the International Standard *IEC 61400-11: 2012 Wind turbines – Part 11: Acoustic noise measurements techniques* (IEC 61400-11:2012) - to derive the overall sound power levels;
- the New Zealand Standard *NZS 6808:2010 Acoustics – Wind Farm Noise* (NZS 6808:2010) - to determine the presence of excessive tonality and amplitude modulation; and,
- the International Standard *ISO 1996-2:2007 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels* (ISO 1996-2:2007) – as referenced by NZS 6808:2010 to assist in determining the presence of excessive tonality.

This report provides a summary of the noise testing and presents the results of the analyses.

sonus.

2 TEST SITE DESCRIPTION

The Stockyard Hill Wind Farm is located approximately 35km west of Ballarat. The location of the tested wind turbine is shown on Figure 1.

The ground surface on the wind farm site in the area of the noise measurements is generally grazed pasture. There are no significant reflecting structures at the wind farm or surrounding areas.

Figure 1: Tested wind turbine location.

sonus.

3 WIND TURBINE DETAILS

Table 1 provides the configuration of the tested wind turbine, WTG18.

Table 1: Details of WTG18.

Wind Turbine Details	
Manufacturer	Goldwind
Model	GW3S
Turbine ID	WTG18
Coordinates	703600 E 5840550 N
Operating Details	
Axis type	Horizontal
Rotor location	Upwind
Rotor diameter	140.2 m
Hub height	109 m (above ground level)
Tower type	Steel Tubular
Turbine speed	12 rpm
Rated power output	3570
Rated wind speed	11 m/s
Cut-in/cut-out wind speed	2.5 m/s 20 m/s
Control type	Blade Pitch
Rotor Details	
Blade manufacturer	Sinoma (Goldwind)
Blade type	Single piece fiberglass, with V5 TES
Number of blades	3
Gearbox Details	
Type	None
Generator Details	
Manufacturer	CRRC (Goldwind)
Type	Permanent Magnet Direct Drive
Maximum speed	12 + 10% rpm

4 INSTRUMENTATION

4.1 Noise Measurement

Noise measurements were made using two Type 1 Rion NL-52 sound level meters equipped with one-third octave band analysers. The sound level meters were calibrated before and after the measurements using a Type 1 Rion NC-74 calibrator, with negligible drift observed.

A secondary wind screen was used for each sound level meter and was positioned over the microphone on the measurement board. Figure 2 shows a typical example of the setup used to conduct the monitoring.

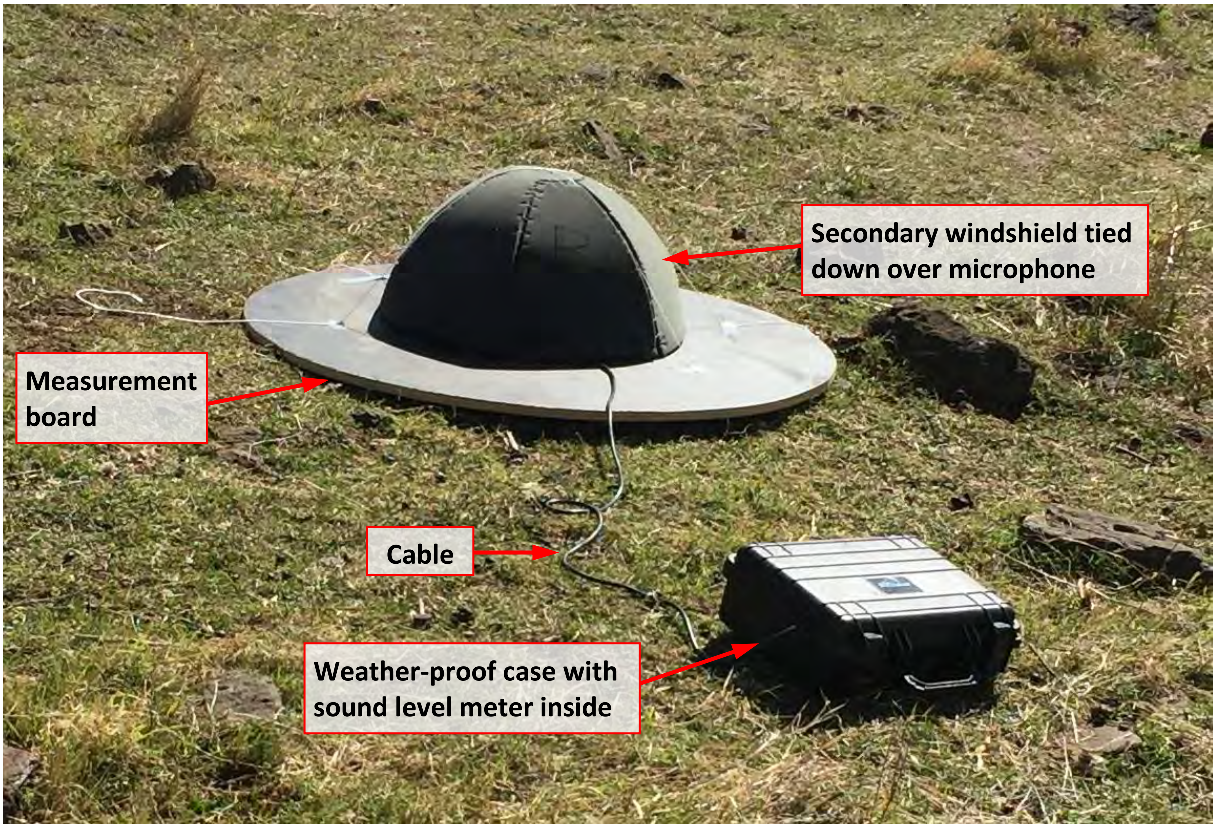


Figure 2: Microphone on the measurement board position with secondary screen.

The insertion loss of the secondary wind screen has been measured and is summarised in Table 2.

Table 2: Secondary wind screen insertion loss.

Frequency 1/3-octave band (Hz)	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
Insertion loss (dB)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.5	-0.3	-0.6	-0.2	-0.3
Frequency 1/3-octave band (Hz)	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**
Insertion loss (dB)	-0.3	0.1	0.3	1.2	2.0	2.7	1.9	0.9	1.1	2.1
Frequency 1/3-octave band (Hz)	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**		
Insertion loss (dB)	1.5	2.1	2.5	2.3	2.5	2.7	3.1	3.6		

Figure 3 shows the location of the noise measurement instrumentation, positioned in relation to WTG18.

Figure 3: Photograph of the tested wind turbine, WTG18.

4.2 Wind Data

Wind speed data during the testing period were obtained from the nacelle wind measurement instrumentation at WTG18. Wind direction data were obtained from the nacelle angle position instrumentation at WTG18. All sets of data were adjusted to match the 10 second period required by IEC 61400-11:2012.

4.3 Other Instrumentation

The operational status of the turbine was determined using the average generator speed. Goldwind indicated that whern the generator speed was less than 1 rpm, it can be considered to be off. As a check, the operational status was compared to the noise measurements. The results were as to be expected, with the noise level dropping while the turbine was not in operation and rising again once operation starts. It was therefore determined that this adjustment was sufficient to provide a good representation of the actual turbine status. Once again, the provided data was adjusted to match the 10 second period required by IEC 61400-11:2012.

Temperature and pressure data during the testing period were obtained from the *Bureau of Meteorology* website, for the weather station at the Ballarat Aerodrome. Rainfall data for the testing period were also obtained from the *Bureau of Meteorology* website, again for the weather station at the Ballarat Aerodrome.

5 ACOUSTIC DATA ACQUISITION

5.1 Measurement Position

Two sound level meters were placed simultaneously around the tested wind turbine, and spaced apart in an arc with respect to the wind turbine. The sound level meters were positioned in such a way that at least one was within 15° of the downwind position for the majority of the measurement period. The measurement positions are summarised in Table 3. The direction relative to the turbine corresponds to the degrees from north the measurement equipment is located at when observed from the turbine. As sufficient data were collected at Location 2, the measurements taken at this location have been used for this analysis.

Table 3: Microphone positions during the noise measurements.

Location	Coordinates		Slant Distance (m)	Direction Relative to Turbine (˚)
	Easting	Northing		
1	703484	5840668	200	315 (NW)
2	703444	5840608	201	290 (WNW)

5.2 Sound Pressure Level Data

The equivalent A-weighted sound pressure levels were measured continuously at the measurement positions during the measurement period. Each measurement was averaged over a period of 10 seconds.

During the measurement period, WTG18 was switched ‘off’ on several occasions to allow for background noise measurements to be conducted.

Prior to analysis, the following data were discarded:

- measurements with intruding intermittent background noise or activity such as when apparatus was being set-up;
- measurements within a period where rain was identified;
- measurements during start-up or shut-down of WTG18; and,
- measurements corresponding to non-downwind conditions.

Following data discard, the resultant number of sound pressure level data points in each wind speed bin (±0.25 m/s wide centred at integer hub height wind speed), for the wind speed range between 6m/s and 12m/s, are summarised in Table 4.

Table 4: Resultant number of noise data points.

Wind speed, V_{HH} (m/s)	Number of Noise Data Points	
	WTG18 ON	WTG18 OFF
6	132	72
7	401	100
8	1109	137
9	1133	135
10	884	124
11	542	74
12	225	19

6 NON-ACOUSTIC DATA ACQUISITION

6.1 Wind Data

6.1.1 Wind Speed Data

The wind speed during the measurement period was determined from the nacelle anemometer. The SCADA system recorded 3 second average wind speeds, approximately every 7 seconds. The first available 3 second average wind speed recorded within the 10 second noise average has been used for the correlations. The wind speed data was provided to Sonus by Goldwind and is understood to be comprised of measurements from the nacelle anemometer.

6.1.2 Wind Direction Data

IEC 61400-11:2012 requires the microphone measurement position to be within ± 15° of the nacelle direction. The nacelle direction data was recorded and provided by the SCADA computer program of the wind turbine. Noise measurements recorded when the measurement position was greater than ± 15° of the nacelle direction, were discarded. It is understood that the nacelle direction was not properly calibrated when installed and therefore the changes in nacelle direction are accurately recorded but the absolute nacelle direction is not. To provide the calibration, a photo was taken directly downwind of the turbine at the start of the monitoring period with the GPS coordinates and the time recorded. This indicated that an adjustment of 65° was required to the reported wind direction. At the end of the monitoring period, a second photo was taken, which confirmed that a 65° adjustment was required. The reported wind direction has therefore been adjusted by this amount. It is noted that any minor inaccuracies associated with this methodology is unlikely to change the measured levels in any material way.

6.2 Other Measurements and Non-acoustic Data

6.2.1 Meteorological Conditions

The prevailing meteorological conditions during the noise measurements are summarised in Table 5. The temperature and pressure observations were taken at 9am. Where rain was identified during the testing period, 30 minute observations recorded at the Ballarat Aerodrome were used to remove periods which were affected by rain noise.

Table 5: Prevailing meteorological conditions during the measurements.

Measurement Date	Observation	Prevailing Condition
10 January 2022	Barometric pressure	101.66kPA
	Air temperature	23.8°C
	Precipitation	0mm
11 January 2022	Barometric pressure	101.92kPA
	Air temperature	18.5°C
	Precipitation	0.4mm
12 January 2022	Barometric pressure	102.13kPA
	Air temperature	18.8°C
	Precipitation	0mm

6.2.2 Roughness Length

The test site is farmland generally covered with grass and some vegetation. The surface roughness for this site is taken to be 0.05 m, which has been used to derive the standardised wind speed, referenced at 10m above ground level.

7 ANALYSIS

7.1 Apparent Sound Power Level

The apparent sound power level at each integer wind speed has been derived using the general procedure outlined in Section 9 of the IEC 61400-11:2012.

7.1.1 Analysis Procedure

The steps taken to derive the apparent sound power level at each integer wind speed for WTG18 are provided below:

1. All measured equivalent sound pressure levels at each 1/3 octave band between 20 Hz to 10 kHz are normalised to the measured overall equivalent sound pressure level. The 1/3 octave band levels between 20Hz and 10kHz are logarithmically summed and its difference with the measured overall level is arithmetically added to each 1/3 octave band levels.
2. The 1/3 octave band equivalent sound pressure levels are corrected for the influence of the secondary wind screen. The secondary wind screen insertion losses provided in Section 4.1 are arithmetically added to the 1/3 octave band levels. The resultant overall sound pressure level is obtained by logarithmically summing the corrected one third octave sound pressure levels.
3. The 1/3 octave band equivalent sound pressure levels are sorted into wind speed bins, each ±0.25 m/s wide, centred at integer wind speeds. The total noise and background noise data are segregated into separate data sets.
4. The average 1/3 octave band equivalent sound pressure levels for each wind speed bin are determined logarithmically. The 1/3 octave band equivalent sound pressure levels at the bin centres are then calculated using linear interpolation between the bin average sound pressure level and wind speed values.
5. The background corrected wind turbine sound pressure levels are derived using the 1/3 octave band equivalent sound pressure levels (referenced to the bin centre) as follows:
    - “turbine off” sound levels are logarithmically subtracted from the “turbine on” sound levels where the “turbine off” level is at least 3 dB(A) below the “turbine on” 1/3 octave band equivalent sound pressure level.

- In the case where the "turbine off" sound level is within 3 dB(A) of the 1/3 octave band "turbine on" sound pressure level, 3 dB(A) has been subtracted from the 1/3 octave band "turbine on" equivalent sound pressure level. These values have been noted as being affected by background noise.
- Where the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine on" noise levels is within 3 dB(A) of the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine off" sound levels, the data has not been reported, in accordance with IEC 61400-11:2012.

6. The background corrected wind turbine sound pressure levels at each 1/3 octave band are used to calculate the apparent sound power levels at each integer wind speed using Equation (26) in the IEC 61400-11:2012. The slant distance for each measurement location is presented in Table 3.
7. The overall apparent sound power level at each integer wind speed is determined by logarithmically summing the 1/3 octave band apparent sound power levels.

7.1.2 Analysed Data Points

The data points (overall equivalent sound pressure levels) included in the analysis are shown in Figure 4.

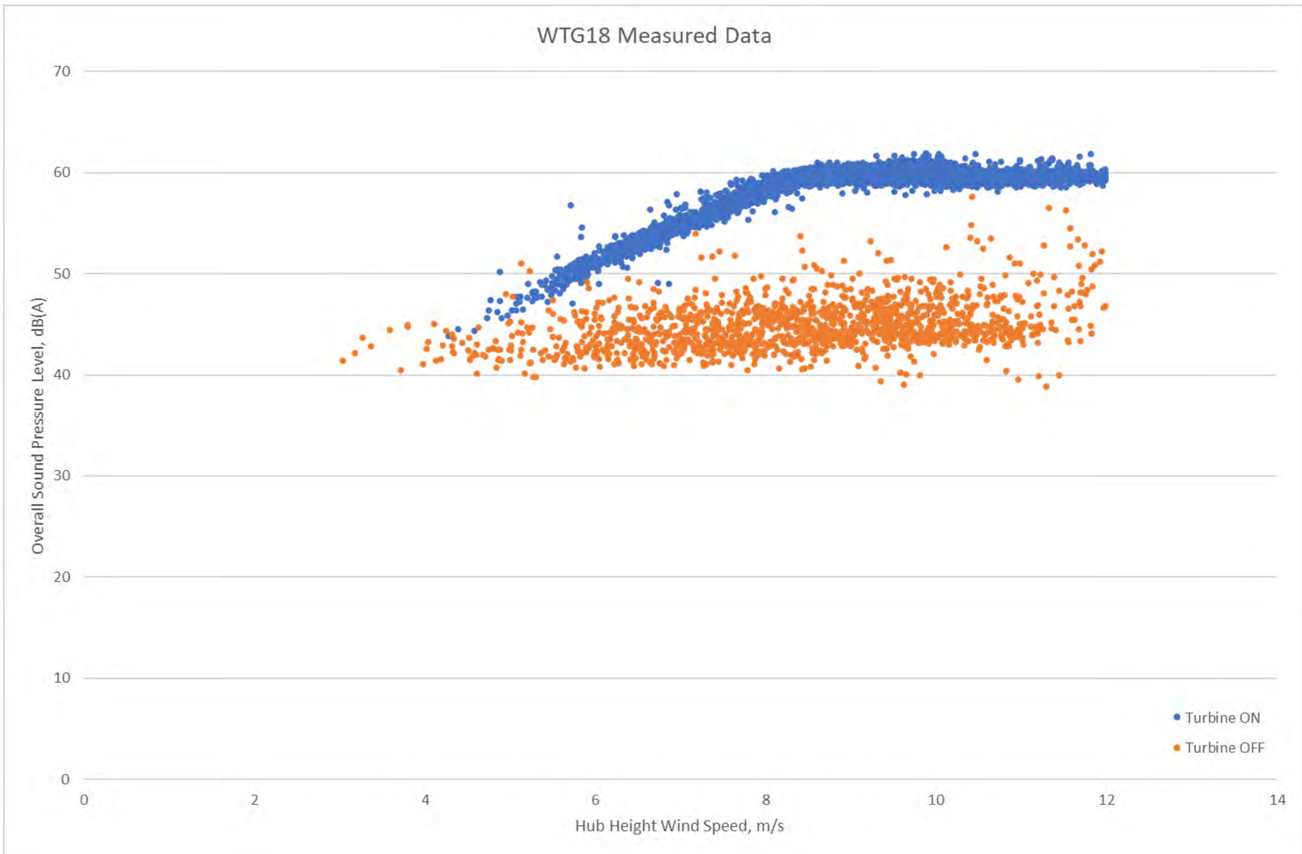


Figure 4: Analysed data points.

7.1.3 Analysis Results

The derived apparent sound power levels are summarised in Table 6.

Table 6: Derived apparent sound power levels.

V_{HH} (m/s)	V_{10} (m/s)	L_{WA} (dB(A))	Sound Power Level (dB(A)) at each 1/3 Octave Band (Hz)																											
			20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
6	4.1	101.6	53.9	59.1	65.1	68.7	72.4	77.0	79.7	[79.8]	83.2	85.8	85.7	88.2	89.3	91.1	91.7	92.9	92.4	91.7	90.3	91.0	88.1	86.2	[82.0]	#	#	#	#	#
7	4.8	105.6	56.3	61.4	66.2	70.5	74.3	77.5	81.6	83.4	86.7	88.8	89.6	91.1	92.3	94.4	95.3	96.9	96.8	96.3	95.0	95.6	92.5	90.7	87.5	[83.5]	#	#	#	#
8	5.5	109.3	57.1	62.3	66.9	71.5	76.4	78.9	82.4	85.3	89.0	91.2	92.4	93.9	95.4	97.4	98.2	100.2	100.6	100.5	99.4	100.0	96.8	94.8	91.8	#	#	#	#	#
9	6.2	110.7	59.1	64.2	68.7	72.9	77.0	80.4	84.1	87.2	90.6	92.7	93.9	95.4	96.8	98.7	99.5	101.5	102.0	101.9	100.9	101.5	98.3	96.4	93.6	89.0	[83.5]	[78.8]	#	#
10	6.9	110.9	59.7	64.9	69.2	73.5	77.5	81.0	84.9	88.2	91.5	93.2	94.4	95.7	97.0	98.9	99.6	101.5	102.1	102.1	101.1	101.6	98.4	96.5	93.9	89.7	85.0	[80.0]	[78.4]	#
11	7.6	110.5	59.4	64.7	69.1	73.3	77.3	80.5	84.3	87.5	90.8	92.6	93.7	95.3	96.6	98.5	98.6	100.4	101.3	101.7	101.1	101.9	98.9	97.1	94.2	89.3	[83.6]	[79.8]	#	#
12	8.3	110.3	58.9	64.5	68.9	73.2	77.4	80.7	84.7	87.6	91.3	93.0	94.1	95.6	96.9	98.8	96.4	100.0	100.5	100.9	100.5	101.6	99.1	98.1	95.7	89.7	#	#	#	#

- The background noise is higher than the total noise.

[ ] - The background noise is within 3 dB of the total noise.

V_{HH} is the hub height (109m) wind speed.

V_{10} is the standardised wind speed, referenced at 10m above ground level.

7.2 Tonality

The results of the testing period have been analysed to determine any presence of excessive tonality, in accordance with Annex C of ISO 1996-2:2007.

ISO 1996-2:2007 provides the following method, generally summarised into three steps:

1. *Narrow-band frequency analysis (preferably FFT-analysis);*
2. *Determination of the average sound pressure level of the tone(s) and of the masking noise within the critical band around the tone(s);*
3. *Calculation of the tonal audibility and the adjustment.*

Audio recordings were made continuously during the testing period, with each recording being one minute long. A selection of these audio recordings that best represent the noise at each integer wind speed were chosen, such that they were not influenced by extraneous noise sources such as birds or insects and were as close as possible to the integer wind speed for the full minute period.

Based on the approach provided in ISO 1996-2:2007, the selected audio recordings were analysed using an automated program for the presence of excessive tonality. This program has been designed to determine whether a character penalty is warranted in accordance with the method outlined in ISO 1996-2:2007. This method considers the audibility of any potential tones with respect to any masking noise and determines their impact through the use of a character penalty. The program reports any frequencies at which a character penalty is warranted. After running the program, no character penalties were reported at any wind speed or frequency and as such, no tones are considered to be present. It can therefore be determined that tonality was not present.

7.3 Amplitude Modulation

The results of the testing period have been analysed to determine any presence of excessive amplitude modulation, in general accordance with the interim test method presented in NZS 6808:2010.

NZS 6808:2010 states the following:

> *No objective test for amplitude modulation has been standardised. If a local authority enforcement officer or an acoustics advisor to a local authority considers that a wind farm creates sound with a clearly audible amplitude modulation at a noise sensitive location, an adjustment of +5 dB shall be applied to the wind farm sound level at that location for the wind conditions under which the modulation occurs.*
>
> *In making an assessment under B3.1 [the above], modulation special audible characteristics are deemed to exist if the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis, or if the measured third-octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency.*

As for the tonality assessment, a representative period for each integer wind speed has been analysed for excessive amplitude modulation. The graphs below show an example of the results of this analysis for each integer wind speed. It is noted that these graphs have generally been limited in scale to 5 dB to illustrate compliance with the requirements of NZS 6808:2010 for the overall A-weighted level. As the total modulation, not just the regular peak to trough level, is contained within this scale, no amplitude modulation is considered to be present. It is noted that while the graph for 10m/s uses a 6 dB scale, the peak to trough level does not exceed 5 dB in any case, thus ensuring compliance with the requirements. As such, it can be determined that excessive amplitude modulation is not present in the noise profile of the wind turbine.

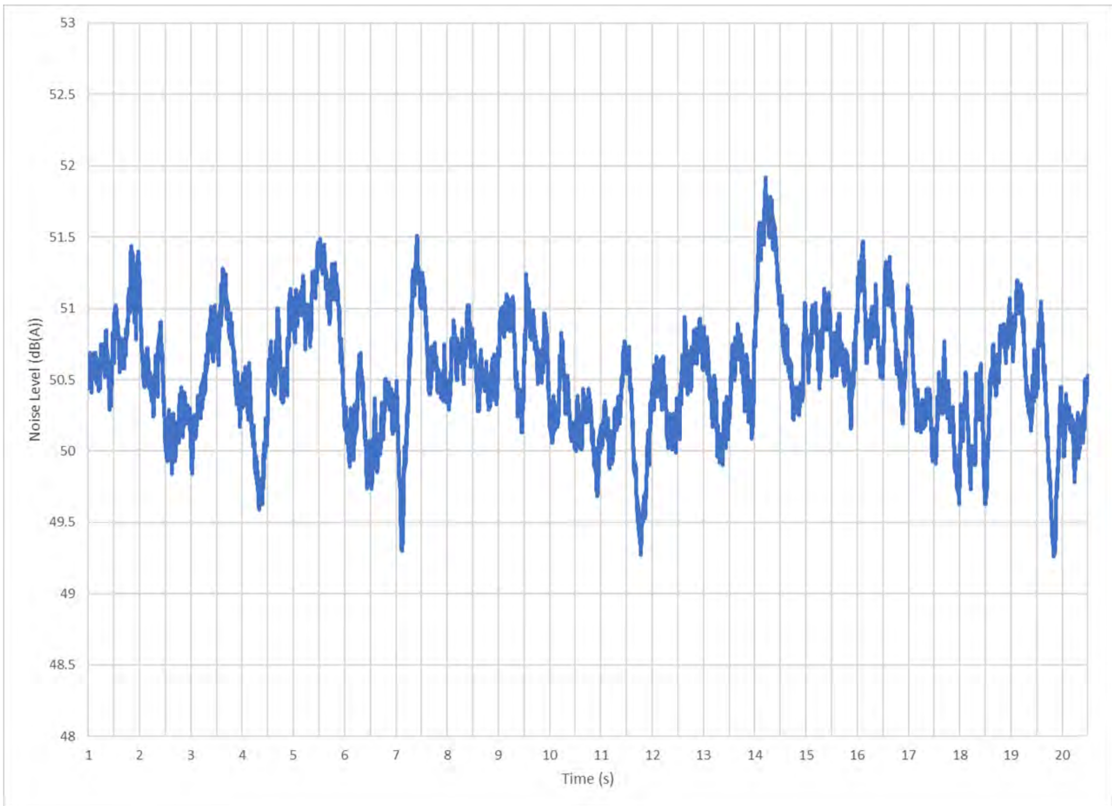


Figure 5: Amplitude modulation analysis – 6 m/s.

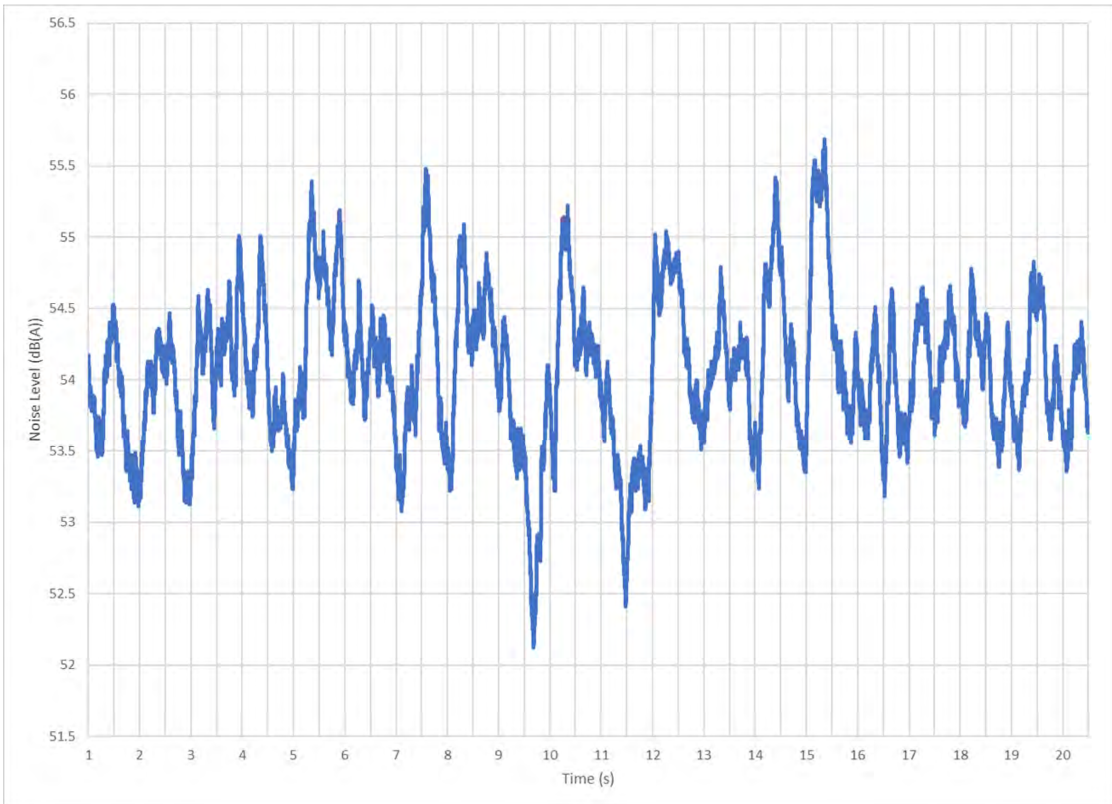


Figure 6: Amplitude modulation analysis – 7 m/s.

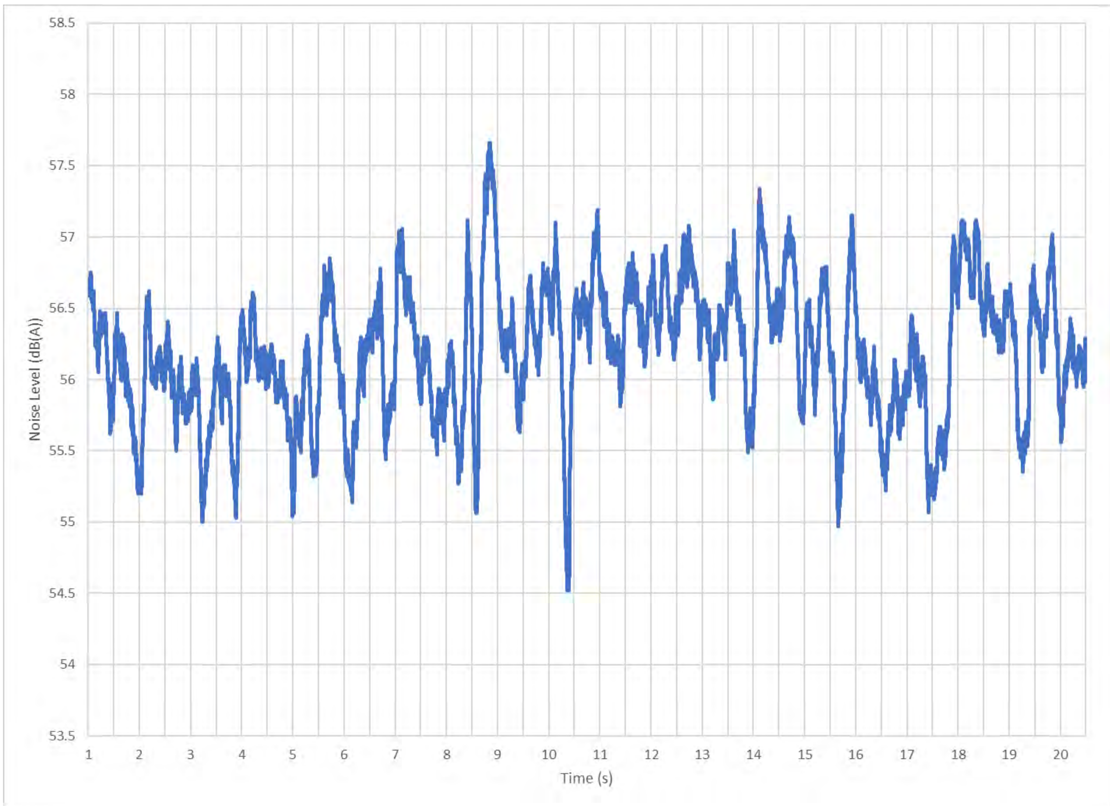


Figure 7: Amplitude modulation analysis – 8 m/s.

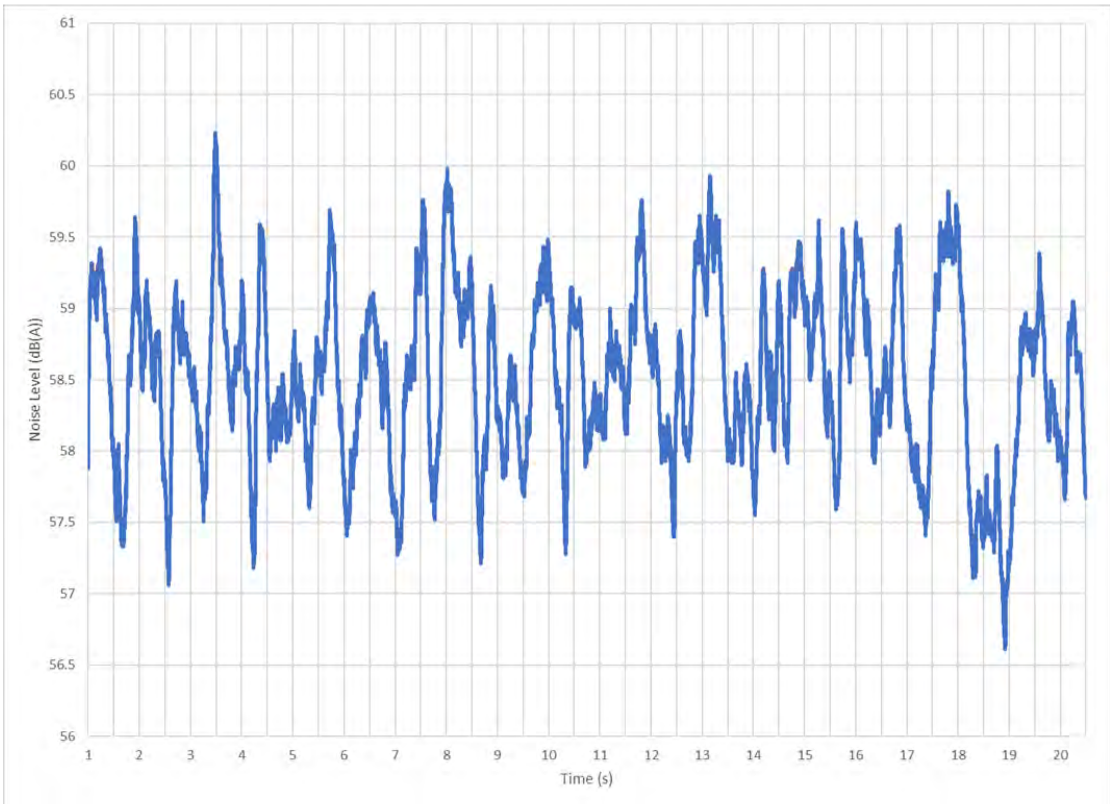


Figure 8: Amplitude modulation analysis – 9 m/s.

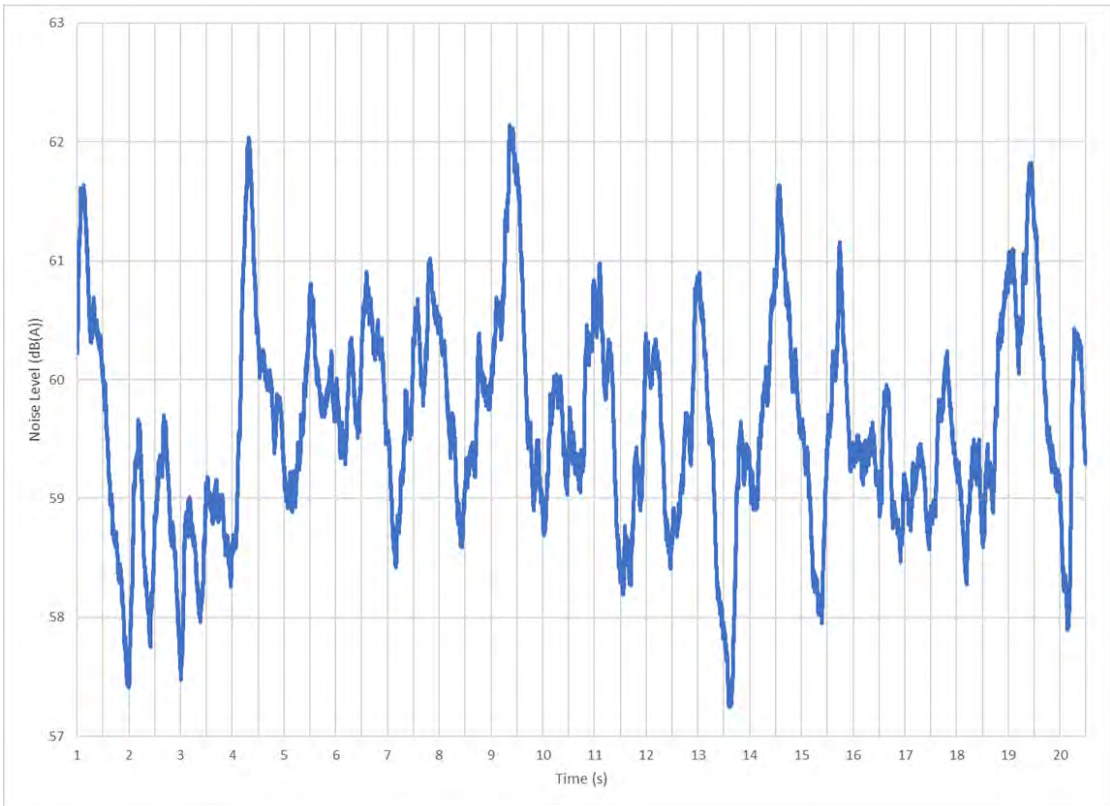


Figure 9: Amplitude modulation analysis – 10 m/s.

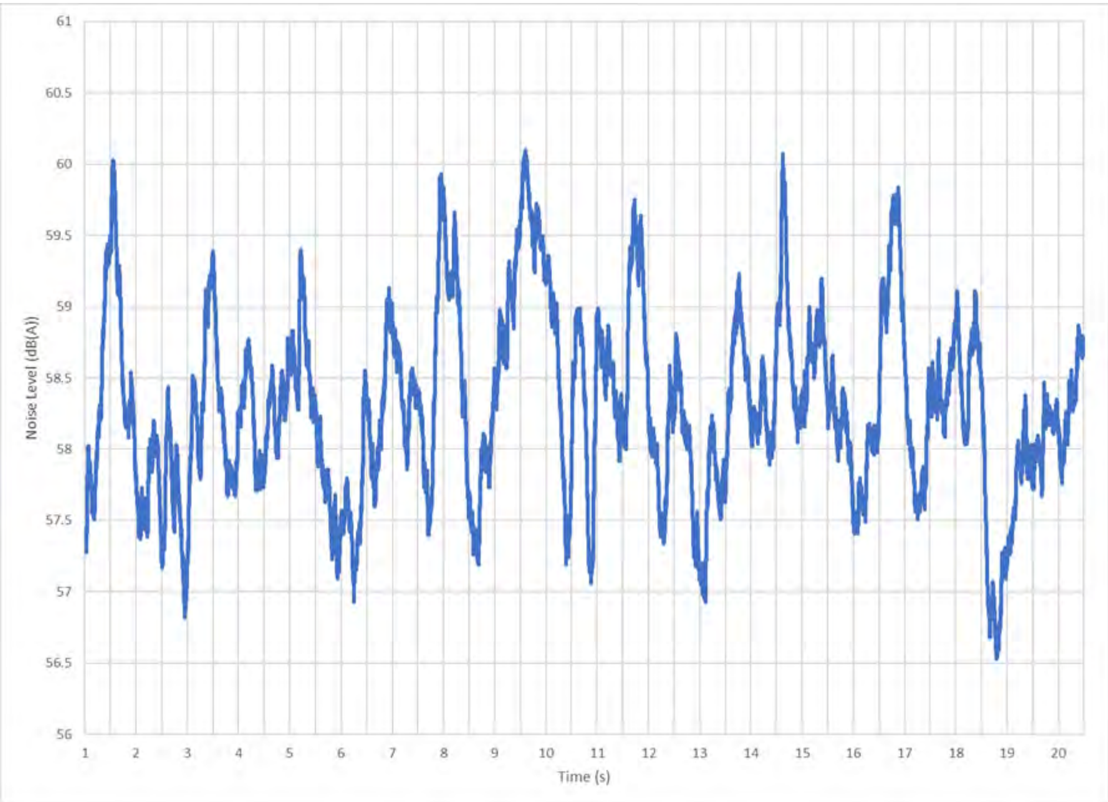


Figure 10: Amplitude modulation analysis – 11 m/s.

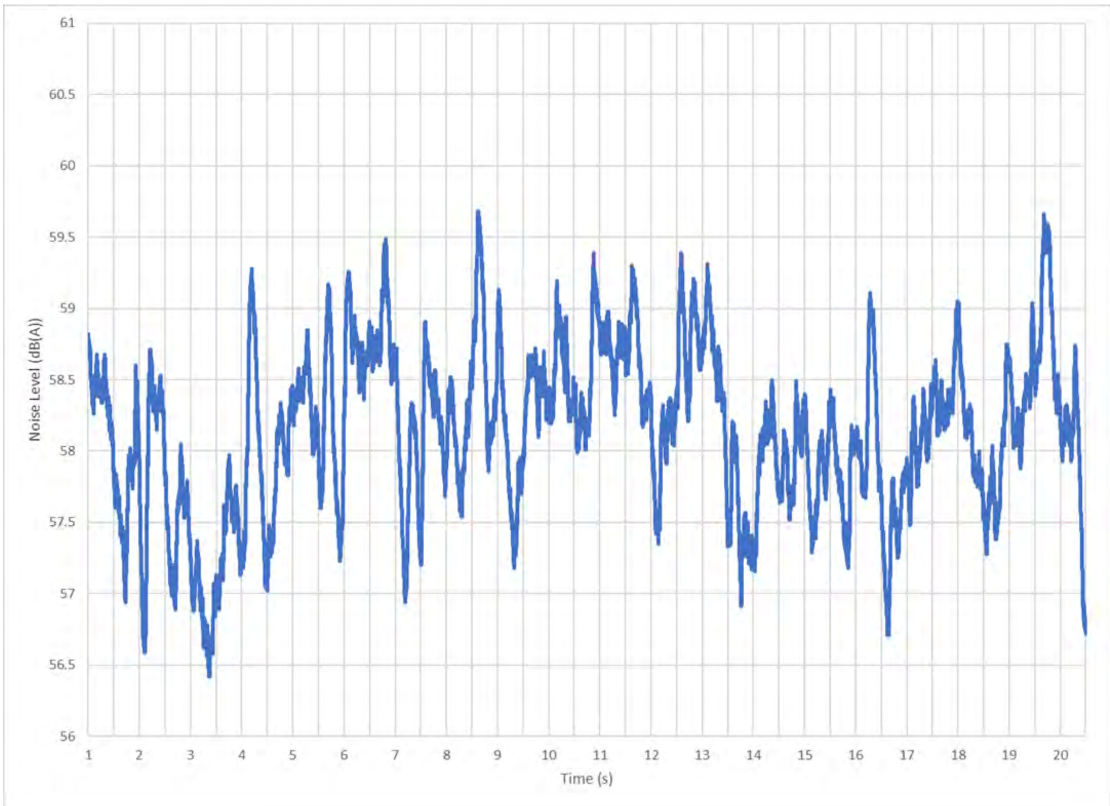


Figure 11: Amplitude modulation analysis – 12 m/s.

Stockyard Hill Wind Farm

Acoustic Analysis of Wind Turbine

Generator 22

S3425.2C25

October 2022

sonus.

Chris Turnbull
Principal
ct@sonus.com.au
+61 (0) 417 845 720

Sonus Pty Ltd
17 Ruthven Avenue
Adelaide 5000 SA
+61 (8) 8231 2100
www.sonus.com.au

sonus.

Document Title : Acoustic Noise Test of Wind Turbine Generator 22

Document Reference: S3425.2C25

Date: October 2022

Author : Chris Turnbull, MAAS

© Sonus Pty Ltd. All rights reserved.

This report may not be reproduced other than in its entirety. The report is for the sole use of the client for the particular circumstances described in the report. Sonus accepts no responsibility to any other party who may rely upon or use this report without prior written consent.

---

sonus.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1 INTRODUCTION

Sonus has been engaged by Goldwind Australia Pty Ltd to conduct noise testing of wind turbine generator 22 (WTG22) at the Stockyard Hill Wind Farm, Victoria.

The purpose of the testing was to determine the apparent sound power levels, tonality, and amplitude modulation of the installed wind turbine generator 22, type GW3S.

Noise measurements of WTG22 were conducted on 27 August 2022 to 29 August 2022. The data acquisition and subsequent analyses were conducted in general accordance with the approach of the following:

- the International Standard *IEC 61400-11: 2012 Wind turbines – Part 11: Acoustic noise measurements techniques* (IEC 61400-11:2012) - to derive the overall sound power levels;
- the New Zealand Standard *NZS 6808:2010 Acoustics – Wind Farm Noise* (NZS 6808:2010)) – to determine the presence of excessive tonality and amplitude modulation; and,
- the International Standard *ISO 1996-2:2007 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels* (ISO 1996-2:2007) – as referenced by NZS 6808:2010 to assist in determining the presence of excessive tonality.

This report provides a summary of the noise testing and presents the results of the analyses.

2 TEST SITE DESCRIPTION

The Stockyard Hill Wind Farm is located approximately 35km west of Ballarat. The location of the tested wind turbine is shown on Figure 1.

The ground surface on the wind farm site in the area of the noise measurements is generally cropped. There are no significant reflecting structures at the wind farm or surrounding areas.

Figure 1: Tested wind turbine location.

3 WIND TURBINE DETAILS

Table 1 provides the configuration of the tested wind turbine, WTG22.

Table 1: Details of WTG22.

Wind Turbine Details	
Manufacturer	Goldwind
Model	GW3S
Turbine ID	WTG22
Coordinates	703420 E 5841212 N
Operating Details	
Axis type	Horizontal
Rotor location	Upwind
Rotor diameter	140.2 m
Hub height	109 m (above ground level)
Tower type	Steel Tubular
Turbine speed	12 rpm
Rated power output	3570
Rated wind speed	11 m/s
Cut-in/cut-out wind speed	2.5 m/s 20 m/s
Control type	Blade Pitch
Rotor Details	
Blade manufacturer	Sinoma (Goldwind)
Blade type	Single piece fiberglass, with Only 3/4/5 TES
Number of blades	3
Gearbox Details	
Type	None
Generator Details	
Manufacturer	CRRC (Goldwind)
Type	Permanent Magnet Direct Drive
Maximum speed	12 + 10% rpm

4 INSTRUMENTATION

4.1 Noise Measurement

Noise measurements were made using two Type 1 Rion NL-52 sound level meters, both equipped with one-third octave band analysers. The sound level meters were calibrated before and after the measurements using a Type 1 Rion NC-74 calibrator, with negligible drift observed.

A secondary wind screen was used for each sound level meter and was positioned over the microphone on the measurement board. Figure 2 shows a typical example of the setup used to conduct the monitoring.

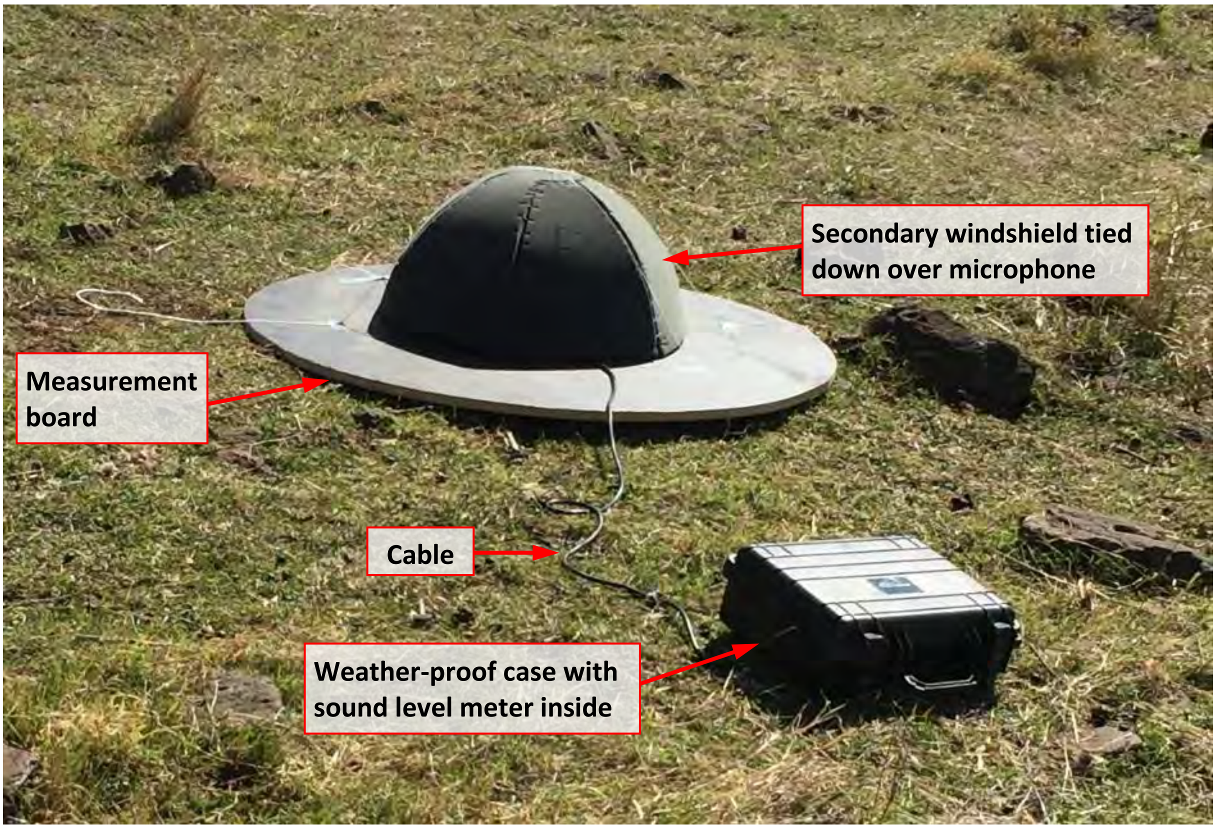


Figure 2: Microphone on the measurement board position with secondary screen.

sonus.

The insertion loss of the secondary wind screen has been measured and is summarised in Table 2.

Table 2: Secondary wind screen insertion loss.

Frequency 1/3-octave band (Hz)	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
Insertion loss (dB)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frequency 1/3-octave band (Hz)	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**
Insertion loss (dB)	0.0	0.0	0.0	1.3	3.1	5.5	5.1	1.4	3.1	4.1
Frequency 1/3-octave band (Hz)	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**		
Insertion loss (dB)	3.3	3.8	3.7	5.6	8.6	12.7	12.1	13.0		

Figure 3 shows the location of the noise measurement instrumentation, positioned in relation to WTG22.

Figure 3: Photograph of the tested wind turbine, WTG22.

4.2 Wind Data

Wind speed data during the testing period were obtained from the nacelle wind measurement instrumentation at WTG22. Wind direction data were obtained from the nacelle angle position instrumentation at WTG22. All sets of data were adjusted to match the 10 second period required by IEC 61400-11:2012.

4.3 Other Instrumentation

The operational status of the turbine was determined using the “W.T.G. Operation Status” identifier, as reported by the SCADA system for the turbine. It is understood from previous analysis that a value of “5” indicates that the turbine is operating and a value of “2” indicates that it is not operating. It is noted that the turbine was considered to be not operating for some additional periods where the turbine was ramping up or down from or to an ‘off’ state. Once again, the provided data were adjusted to match the 10 second period required by IEC 61400-11:2012.

Temperature, pressure, and rainfall data during the testing period were obtained from the *Bureau of Meteorology* website, for the weather station at the Ballarat Aerodrome.

5 ACOUSTIC DATA ACQUISITION

5.1 Measurement Position

Two sound level meters were placed simultaneously around the tested wind turbine, and spaced apart in an arc with respect to the wind turbine. The sound level meters were positioned in such a way that at least one was within 15° of the downwind position for the majority of the measurement period. The measurement positions are summarised in Table 3. The direction relative to the turbine corresponds to the degrees from north the measurement equipment is located at when observed from the turbine. As sufficient data were collected at Location 2, the measurements taken at this location have been used for this analysis.

Table 3: Microphone positions during the noise measurements.

Location	Coordinates		Slant Distance (m)	Direction Relative to Turbine (˚)
	Easting	Northing		
1	703294	5841108	197	230 (SW)
2	703359	5841063	194	202 (SSW)

5.2 Sound Pressure Level Data

The equivalent A-weighted sound pressure levels were measured continuously at the measurement positions during the measurement period. Each measurement was averaged over a period of 10 seconds.

During the measurement period, WTG22 was switched ‘off’ on several occasions to allow for background noise measurements to be conducted.

Prior to analysis, the following data were discarded:

- measurements with intruding intermittent background noise or activity such as when apparatus was being set-up, or when rain occurred;
- measurements where other nearby turbines were on;
- measurements during start-up or shut-down of WTG22; and,
- measurements corresponding to non-downwind conditions.

Following data discard, the resultant number of sound pressure level data points in each wind speed bin (±0.25 m/s wide centred at integer hub height wind speed), for the wind speed range between 6m/s and 12m/s, are summarised in Table 4.

Table 4: Resultant number of noise data points.

Wind speed, V_{HH} (m/s)	Number of Noise Data Points	
	WTG22 ON	WTG22 OFF
6	23	50
7	71	70
8	80	42
9	80	28
10	50	12
11	11	-
12	37	-

6 NON-ACOUSTIC DATA ACQUISITION

6.1 Wind Data

6.1.1 Wind Speed Data

The wind speed during the measurement period was determined from the nacelle anemometer. The SCADA system recorded 3 second average wind speeds, approximately every 6 seconds. The first available 3 second average wind speed recorded within the 10 second noise average has been used for the correlations. The wind speed data was provided to Sonus by Goldwind and is understood to be comprised of measurements from the nacelle anemometer.

6.1.2 Wind Direction Data

IEC 61400-11:2012 requires the microphone measurement position to be within ± 15° of the nacelle direction. The nacelle direction data was recorded and provided by the SCADA computer program of the wind turbine. In order to check the accuracy of the wind direction measurements, they were compared against the wind direction measured at the nearest meteorological mast. Based on this, the field labelled "Angle Difference between Nacelle and North Direction" has been taken to be an accurate measure of the wind direction and has been used for the purpose of this analysis. Noise measurements recorded when the measurement position was greater than ± 15° of the nacelle direction, were discarded.

6.2 Other Measurements and Non-acoustic Data

6.2.1 Meteorological Conditions

The prevailing meteorological conditions during the noise measurements are summarised in Table 5. The temperature and pressure observations were taken at 9am. Where rain was identified during the testing period, 30-minute observations recorded at the Ballarat Aerodrome were used to remove periods which were potentially affected by rain noise.

Table 5: Prevailing meteorological conditions during the measurements.

Measurement Date	Observation	Prevailing Condition
27 August 2022	Barometric pressure	102.91kPA
	Air temperature	8.7°C
	Precipitation	0.2mm
28 August 2022	Barometric pressure	102.46kPA
	Air temperature	11.1°C
	Precipitation	0mm
29 August 2022	Barometric pressure	101.76kPA
	Air temperature	11.8°C
	Precipitation	0.8mm

6.2.2 Roughness Length

The test site is farmland generally covered with grass and some vegetation. The surface roughness for this site is taken to be 0.05 m, which has been used to derive the standardised wind speed, referenced at 10m above ground level.

7 ANALYSIS

7.1 Apparent Sound Power Level

The apparent sound power level at each integer wind speed has been derived using the general procedure outlined in Section 9 of the IEC 61400-11:2012.

7.1.1 Analysis Procedure

The steps taken to derive the apparent sound power level at each integer wind speed for WTG22 are provided below:

1. All measured equivalent sound pressure levels at each 1/3 octave band between 20 Hz to 10 kHz are normalised to the measured overall equivalent sound pressure level. The 1/3 octave band levels between 20Hz and 10kHz are logarithmically summed and its difference with the measured overall level is arithmetically added to each 1/3 octave band levels.

2. The 1/3 octave band equivalent sound pressure levels are corrected for the influence of the secondary wind screen. The secondary wind screen insertion losses provided in Section 4.1 are arithmetically added to the 1/3 octave band levels. The resultant overall sound pressure level is obtained by logarithmically summing the corrected one third octave sound pressure levels.

3. The 1/3 octave band equivalent sound pressure levels are sorted into wind speed bins, each ±0.25 m/s wide, centred at integer wind speeds. The total noise and background noise data are segregated into separate data sets.

4. The average 1/3 octave band equivalent sound pressure levels for each wind speed bin are determined logarithmically. The 1/3 octave band equivalent sound pressure levels at the bin centres are then calculated using linear interpolation between the bin average sound pressure level and wind speed values.

5. The background corrected wind turbine sound pressure levels are derived using the 1/3 octave band equivalent sound pressure levels (referenced to the bin centre) as follows:

    - “turbine off” sound levels are logarithmically subtracted from the “turbine on” sound levels where the “turbine off” level is at least 3 dB(A) below the “turbine on” 1/3 octave band equivalent sound pressure level.

- In the case where the “turbine off” sound level is within 3 dB(A) of the 1/3 octave band “turbine on” sound pressure level, 3 dB(A) has been subtracted from the 1/3 octave band “turbine on” equivalent sound pressure level. These values have been noted as being affected by background noise.
- Where the logarithmic sum of each 1/3 octave band sound pressure level for the “turbine on” noise levels is within 3 dB(A) of the logarithmic sum of each 1/3 octave band sound pressure level for the “turbine off” sound levels, the data has not been reported, in accordance with IEC 61400-11:2012.
- Where no “turbine off” sound level data was available, the “turbine on” sound levels were used with no adjustment.

6. The background corrected wind turbine sound pressure levels at each 1/3 octave band are used to calculate the apparent sound power levels at each integer wind speed using Equation (26) in the IEC 61400-11:2012. The slant distance for each measurement location is presented in Table 3.
7. The overall apparent sound power level at each integer wind speed is determined by logarithmically summing the 1/3 octave band apparent sound power levels.

7.1.2 Analysed Data Points

The data points (overall equivalent sound pressure levels) included in the analysis are shown in Figure 4.

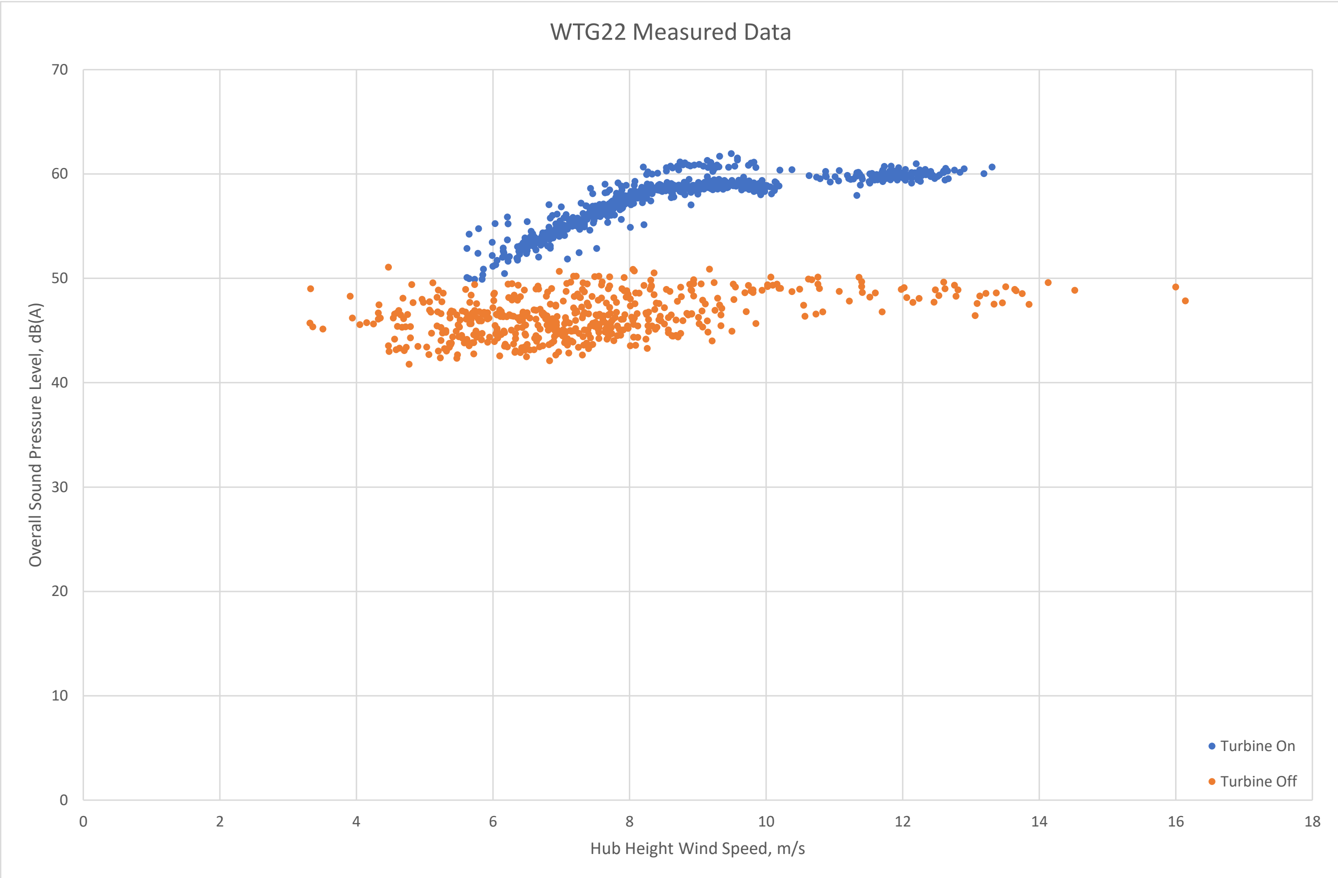


Figure 4: Analysed data points.

sonus.

7.1.3 Analysis Results

The derived apparent sound power levels are summarised in Table 6.

Table 6: Derived apparent sound power levels.

V_{HH} (m/s)	V_{10} (m/s)	L_{WA} (dB(A))	Sound Power Level (dB(A)) at each 1/3 Octave Band (Hz)																										
			20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
6	4.1	102.3	[55.3]	61.1	66.0	70.4	74.5	78.4	82.0	83.9	85.5	86.8	87.0	89.7	91.0	89.2	89.1	92.5	93.8	93.1	91.0	92.9	88.5	87.4	84.3	[85.4]	[83.6]	77.2	[69.1]	[66.7]
7	4.8	105.0	60.1	65.2	69.8	73.9	77.7	81.2	84.3	86.7	88.3	89.7	89.6	92.4	93.3	91.7	91.7	95.1	96.4	95.9	94.0	95.8	91.4	90.4	86.6	[85.6]	[83.9]	79.0	[69.7]	[66.7]
8	5.5	108.2	63.6	68.7	72.9	76.8	80.7	84.2	86.8	89.2	91.0	92.5	92.4	95.3	96.2	94.7	94.9	98.3	99.5	99.1	97.3	99.2	94.8	93.9	90.4	[87.4]	[85.3]	81.4	71.3	[66.9]
9	6.2	109.6	64.1	69.1	73.5	77.3	81.0	84.4	87.3	89.8	91.9	93.3	93.5	96.6	97.6	96.1	96.3	99.8	101.2	100.7	98.9	100.7	96.2	95.2	92.2	[89.6]	[87.1]	82.3	73.4	[67.2]
10	6.9	109.2	63.8	68.6	72.8	76.6	80.4	83.7	86.8	89.3	91.5	93.1	93.2	96.1	97.2	95.6	95.8	99.4	100.8	100.4	98.6	100.5	96.1	95.1	91.7	[88.2]	[85.6]	82.0	72.9	[67.1]
11	7.6	110.5	63.8	69.3	73.5	77.2	81.0	84.2	87.6	90.1	92.5	94.7	94.7	97.7	98.3	96.9	97.0	100.5	101.8	101.4	99.9	101.9	97.3	96.2	92.7	91.4	88.1	82.5	74.6	70.1
12	8.3	110.7	63.7	69.1	73.5	77.4	81.2	84.4	87.9	90.6	93.1	94.8	95.1	98.0	98.6	97.1	97.4	100.7	101.8	101.4	100.0	102.1	97.9	97.0	93.1	91.3	87.8	82.3	74.1	70.0

[ ] - The background noise is within 3 dB of the total noise.

V_{HH} is the hub height (109m) wind speed.

V_{10} is the standardised wind speed, referenced at 10m above ground level.

7.2 Tonality

The results of the testing period have been analysed to determine any presence of excessive tonality, in accordance with NZS 6808:2010. NZS 6808:2010 provides two methods to objectively assess the presence of excessive tonality, the simplified test method and the reference test method, outlined in sections B2.2 and B2.3, respectively.

7.2.1 Reference Test Method

NZS 6808:2010 does not provide specific instructions for the reference test method, but instead references the method outlined in Annex C of ISO 1996-2:2007, or another similar method. As such, ISO 1996-2:2007 has been used to inform this assessment.

Annex C of ISO 1996-2:2007 provides the following method, generally summarised into three steps:

1. *Narrow-band frequency analysis (preferably FFT-analysis);*
2. *Determination of the average sound pressure level of the tone(s) and of the masking noise within the critical band around the tone(s);*
3. *Calculation of the tonal audibility and the adjustment.*

Audio recordings were made continuously during the testing period. A selection of these audio recordings, each one minute long, that best represent the noise at each integer wind speed were chosen, such that they were not influenced by extraneous noise sources such as birds or insects and were as close as possible to the integer wind speed for the full minute period.

Based on the approach provided in ISO 1996-2:2007, the selected audio recordings were analysed using an automated program for the presence of excessive tonality. This program has been designed to determine whether a character penalty is warranted in accordance with the method outlined in ISO 1996-2:2007. This method considers the audibility of any potential tones with respect to any masking noise and determines their impact through the use of a character penalty. For a potential tone to be audible, the tonal audibility must be greater than or equal to 4 dB. After running the program, no potential tones were identified at any wind speed and therefore no character penalties were applicable. The results of this program can be seen in the below table. As no character penalties were reported at any wind speed or frequency, no tones are considered to be present.

Table 7: Tonality analysis results.

Wind speed (m/s)	Tonal Audibility (dB)	Frequency (Hz)	Tonal Adjustment (dB)
6	-	-	0
7	-	-	0
8	-	-	0
9	-	-	0
10	-	-	0
11	-	-	0
12	-	-	0

7.2.2 Simplified Test Method

Section B2.2 of NZS 6808:2010 provides an alternate method for determining the presence of tonality. This method has been used as an additional check for the presence of excessive tonality and was conducted for all “Turbine On” data points, the points shown in blue in Figure 4.

Section B2.2 of NZS 6808:2010 provides the following method, reproduced below:

A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one-third octave-bands in the Z-frequency-weighted sound spectrum. An adjustment for tonality shall be applied if the sound level in a Z-frequency-weighted one-third octave-band exceeds the arithmetic mean of the sound levels in both adjacent bands by more than the values given in table B1. For the purposes of this method linear, zero, or flat frequency-weighting shall be equivalent to Z-frequency-weighting.

Table B1 – One-third octave-band level differences

One-third octave-band	*Level difference*
25 – 125 Hz	*15 dB*
160 – 400 Hz	*8 dB*
500 – 10000 Hz	*5 dB*
NOTE – At frequencies below 500 Hz the level difference could be too severe and tones might be identified when none is actually audible. For complex spectra the method is often inadequate and the reference method should be used (see B2.3).	

The results of this additional check indicate that no tonal penalty is required. This is consistent with the outcome of the reference test method, indicating that the operation of the turbine does not exhibit excessive tonality.

7.3 Amplitude Modulation

The results of the testing period have been analysed to determine any presence of excessive amplitude modulation, in general accordance with the interim test method presented in NZS 6808:2010.

NZS 6808:2010 states the following:

> *No objective test for amplitude modulation has been standardised. If a local authority enforcement officer or an acoustics advisor to a local authority considers that a wind farm creates sound with a clearly audible amplitude modulation at a noise sensitive location, an adjustment of +5 dB shall be applied to the wind farm sound level at that location for the wind conditions under which the modulation occurs.*
>
> *In making an assessment under B3.1 [the above], modulation special audible characteristics are deemed to exist if the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis, or if the measured third-octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency.*

As for the tonality assessment, a representative period for each integer wind speed has been analysed for excessive amplitude modulation. The graphs below show an example of the results of this analysis for each integer wind speed. It is noted that the horizontal lines are spaced 5 dB apart to illustrate compliance with the requirements of NZS 6808:2010 for the overall A-weighted level. As the regular peak to trough level does not exceed 5 dB for any integer wind speed, it can be determined that excessive amplitude modulation is not present in the noise profile of the wind turbine.

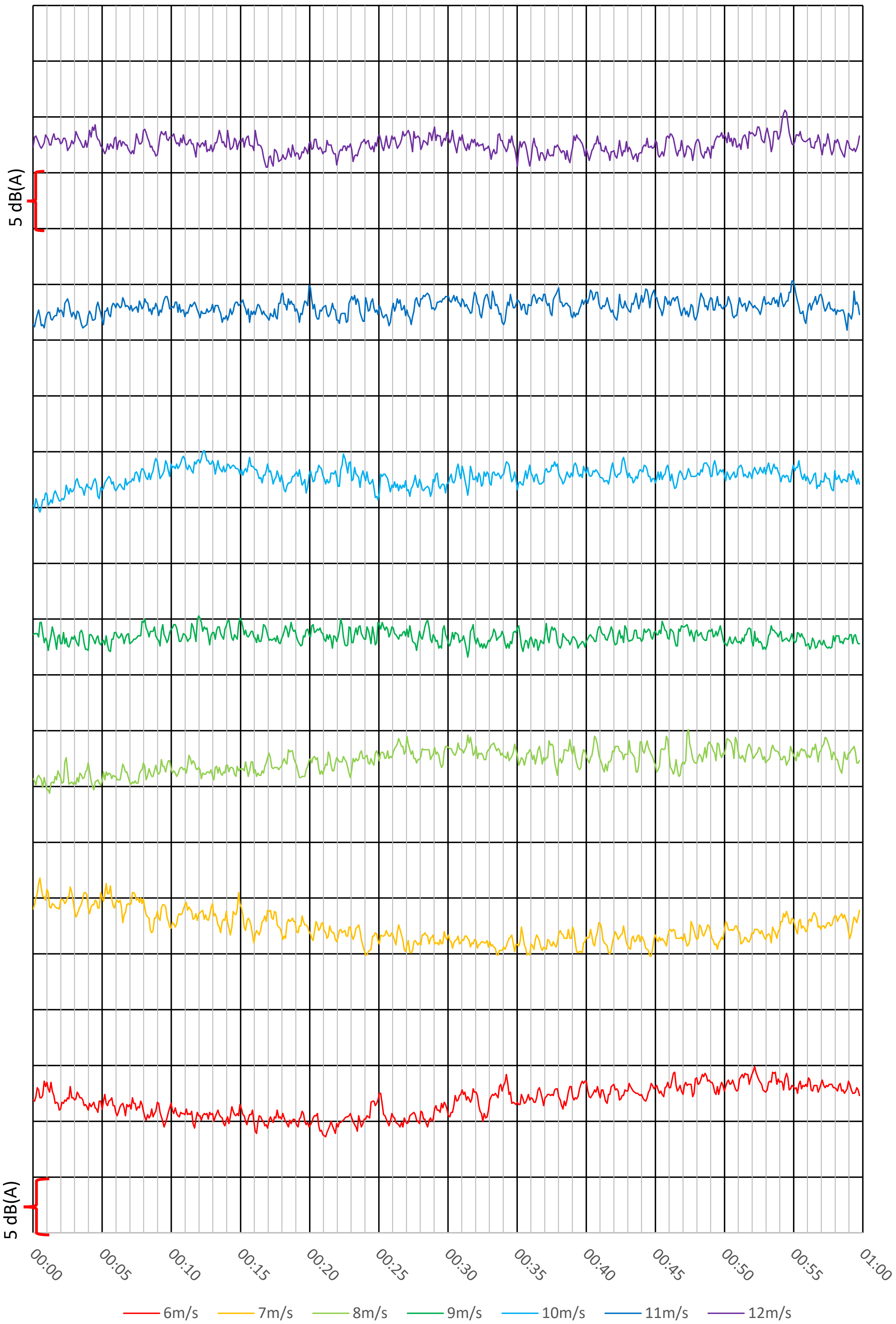


Figure 5: Amplitude modulation graphs.

Stockyard Hill Wind Farm

Acoustic Analysis of Wind Turbine

Generator 83

S3425.2C26

October 2022

sonus.

Chris Turnbull
Principal
ct@sonus.com.au
+61 (0) 417 845 720

Sonus Pty Ltd
17 Ruthven Avenue
Adelaide 5000 SA
+61 (8) 8231 2100
www.sonus.com.au

sonus.

Document Title :	Acoustic Noise Test of Wind Turbine Generator 83
Document Reference:	S3425.2C26
Date:	October 2022
Author :	Chris Turnbull, MAAS

© Sonus Pty Ltd. All rights reserved.

This report may not be reproduced other than in its entirety. The report is for the sole use of the client for the particular circumstances described in the report. Sonus accepts no responsibility to any other party who may rely upon or use this report without prior written consent.

sonus.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

sonus.

1 INTRODUCTION

Sonus has been engaged by Goldwind Australia Pty Ltd to conduct noise testing of wind turbine generator 83 (WTG83) at the Stockyard Hill Wind Farm, Victoria.

The purpose of the testing was to determine the apparent sound power levels, tonality, and amplitude modulation of the installed wind turbine generator 83, type GW3S.

Noise measurements of WTG83 were conducted on 27 August 2022 to 29 August 2022. The data acquisition and subsequent analyses were conducted in general accordance with the approach of the following:

- the International Standard *IEC 61400-11: 2012 Wind turbines – Part 11: Acoustic noise measurements techniques* (IEC 61400-11:2012) - to derive the overall sound power levels;
- the New Zealand Standard *NZS 6808:2010 Acoustics – Wind Farm Noise* (NZS 6808:2010)) – to determine the presence of excessive tonality and amplitude modulation; and,
- the International Standard *ISO 1996-2:2007 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels* (ISO 1996-2:2007) – as referenced by NZS 6808:2010 to assist in determining the presence of excessive tonality.

This report provides a summary of the noise testing and presents the results of the analyses.

2 TEST SITE DESCRIPTION

The Stockyard Hill Wind Farm is located approximately 35km west of Ballarat. The location of the tested wind turbine is shown on Figure 1.

The ground surface on the wind farm site in the area of the noise measurements is generally cropped. There are no significant reflecting structures at the wind farm or surrounding areas.

Figure 1: Tested wind turbine location.

sonus.

3 WIND TURBINE DETAILS

Table 1 provides the configuration of the tested wind turbine, WTG83.

Table 1: Details of WTG83.

Wind Turbine Details	
Manufacturer	Goldwind
Model	GW3S
Turbine ID	WTG83
Coordinates	708058 E 5849561 N
Operating Details	
Axis type	Horizontal
Rotor location	Upwind
Rotor diameter	140.2 m
Hub height	109 m (above ground level)
Tower type	Steel Tubular
Turbine speed	12 rpm
Rated power output	3000
Rated wind speed	11 m/s
Cut-in/cut-out wind speed	2.5 m/s 20 m/s
Control type	Blade Pitch
Rotor Details	
Blade manufacturer	Sinoma (Goldwind)
Blade type	Single piece fiberglass, with V5 TES
Number of blades	3
Gearbox Details	
Type	None
Generator Details	
Manufacturer	CRRC (Goldwind)
Type	Permanent Magnet Direct Drive
Maximum speed	12 + 10% rpm

4 INSTRUMENTATION

4.1 Noise Measurement

Noise measurements were made using a Type 1 Rion NL-52 sound level meter and a Type 1 Rion NA-28 sound level meter, both equipped with one-third octave band analysers. The sound level meters were calibrated before and after the measurements using a Type 1 Rion NC-74 calibrator, with negligible drift observed.

A secondary wind screen was used for each sound level meter and was positioned over the microphone on the measurement board. Figure 2 shows a typical example of the setup used to conduct the monitoring.

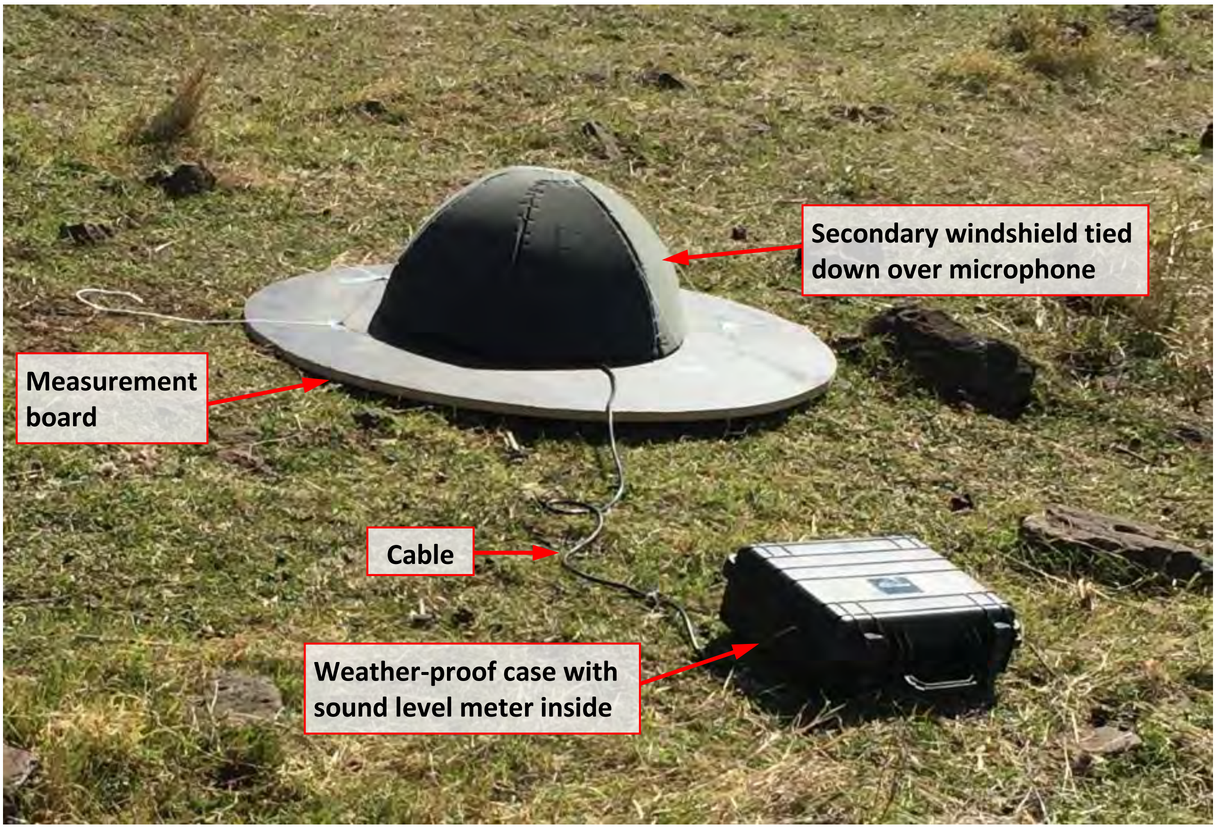


Figure 2: Microphone on the measurement board position with secondary screen.

The insertion loss of the secondary wind screen has been measured and is summarised in Table 2.

Table 2: Secondary wind screen insertion loss.

Frequency 1/3-octave band (Hz)	20	25	31.5	40	50	63	80	100	125	160
Insertion loss (dB)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frequency 1/3-octave band (Hz)	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**
Insertion loss (dB)	0.0	0.0	0.0	1.3	3.1	5.5	5.1	1.4	3.1	4.1
Frequency 1/3-octave band (Hz)	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**		
Insertion loss (dB)	3.3	3.8	3.7	5.6	8.6	12.7	12.1	13.0		

Figure 3 shows the location of the noise measurement instrumentation, positioned in relation to WTG83.

Figure 3: Photograph of the tested wind turbine, WTG83.

4.2 Wind Data

Wind speed data during the testing period were obtained from the nacelle wind measurement instrumentation at WTG83. Wind direction data were obtained from the nacelle angle position instrumentation at WTG83. All sets of data were adjusted to match the 10 second period required by IEC 61400-11:2012.

4.3 Other Instrumentation

The operational status of the turbine was determined using the "W.T.G. Operation Status" identifier, as reported by the SCADA system for the turbine. It is understood from previous analysis that a value of "5" indicates that the turbine is operating and a value of "2" indicates that it is not operating. It is noted that the turbine was considered to be not operating for some additional periods where the turbine was ramping up or down from or to an 'off' state. Once again, the provided data were adjusted to match the 10 second period required by IEC 61400-11:2012.

Temperature, pressure, and rainfall data during the testing period were obtained from the *Bureau of Meteorology* website, for the weather station at the Ballarat Aerodrome.

5 ACOUSTIC DATA ACQUISITION

5.1 Measurement Position

Two sound level meters were placed simultaneously around the tested wind turbine, and spaced apart in an arc with respect to the wind turbine. The sound level meters were positioned in such a way that at least one was within 15° of the downwind position for the majority of the measurement period. The measurement positions are summarised in Table 3. The direction relative to the turbine corresponds to the degrees from north the measurement equipment is located at when observed from the turbine. As sufficient data were collected at Location 2, the measurements taken at this location have been used for this analysis.

Table 3: Microphone positions during the noise measurements.

Location	Coordinates		Slant Distance (m)	Direction Relative to Turbine (˚)
	Easting	Northing		
1	707940	5849431	210	221 (SW)
2	708028	5849402	206	190 (S)

5.2 Sound Pressure Level Data

The equivalent A-weighted sound pressure levels were measured continuously at the measurement positions during the measurement period. Each measurement was averaged over a period of 10 seconds.

During the measurement period, WTG83 was switched 'off' on several occasions to allow for background noise measurements to be conducted.

Prior to analysis, the following data were discarded:

- measurements with intruding intermittent background noise or activity such as when apparatus was being set-up, or when rain occurred;
- measurements where other nearby turbines were on;
- measurements during start-up or shut-down of WTG83; and,
- measurements corresponding to non-downwind conditions.

Following data discard, the resultant number of sound pressure level data points in each wind speed bin (±0.25 m/s wide centred at integer hub height wind speed), for the wind speed range between 9m/s and 14m/s, are summarised in Table 4.

sonus.

Table 4: Resultant number of noise data points.

Wind speed, V_{HH} (m/s)	Number of Noise Data Points	
	WTG83 ON	WTG83 OFF
9	14	90
10	95	37
11	129	49
12	25	-
13	58	-
14	29	-

6 NON-ACOUSTIC DATA ACQUISITION

6.1 Wind Data

6.1.1 Wind Speed Data

The wind speed during the measurement period was determined from the nacelle anemometer. The SCADA system recorded 3 second average wind speeds, approximately every 6 seconds. The first available 3 second average wind speed recorded within the 10 second noise average has been used for the correlations. The wind speed data was provided to Sonus by Goldwind and is understood to be comprised of measurements from the nacelle anemometer.

6.1.2 Wind Direction Data

IEC 61400-11:2012 requires the microphone measurement position to be within ± 15° of the nacelle direction. The nacelle direction data was recorded and provided by the SCADA computer program of the wind turbine. In order to check the accuracy of the wind direction measurements, they were compared against the wind direction measured at the nearest meteorological mast. Based on this, the field labelled "Angle Difference between Nacelle and North Direction" has been taken to be an accurate measure of the wind direction and has been used for the purpose of this analysis. Noise measurements recorded when the measurement position was greater than ± 15° of the nacelle direction, were discarded.

6.2 Other Measurements and Non-acoustic Data

6.2.1 Meteorological Conditions

The prevailing meteorological conditions during the noise measurements are summarised in Table 5. The temperature and pressure observations were taken at 9am. Where rain was identified during the testing period, 30-minute observations recorded at the Ballarat Aerodrome were used to remove periods which were potentially affected by rain noise.

Table 5: Prevailing meteorological conditions during the measurements.

Measurement Date	Observation	Prevailing Condition
27 August 2022	Barometric pressure	102.91kPA
	Air temperature	8.7°C
	Precipitation	0.2mm
28 August 2022	Barometric pressure	102.46kPA
	Air temperature	11.1°C
	Precipitation	0mm
29 August 2022	Barometric pressure	101.76kPA
	Air temperature	11.8°C
	Precipitation	0.8mm

6.2.2 Roughness Length

The test site is farmland generally covered with grass and some vegetation. The surface roughness for this site is taken to be 0.05 m, which has been used to derive the standardised wind speed, referenced at 10m above ground level.

7 ANALYSIS

7.1 Apparent Sound Power Level

The apparent sound power level at each integer wind speed has been derived using the general procedure outlined in Section 9 of the IEC 61400-11:2012.

7.1.1 Analysis Procedure

The steps taken to derive the apparent sound power level at each integer wind speed for WTG83 are provided below:

1. All measured equivalent sound pressure levels at each 1/3 octave band between 20 Hz to 10 kHz are normalised to the measured overall equivalent sound pressure level. The 1/3 octave band levels between 20Hz and 10kHz are logarithmically summed and its difference with the measured overall level is arithmetically added to each 1/3 octave band levels.
2. The 1/3 octave band equivalent sound pressure levels are corrected for the influence of the secondary wind screen. The secondary wind screen insertion losses provided in Section 4.1 are arithmetically added to the 1/3 octave band levels. The resultant overall sound pressure level is obtained by logarithmically summing the corrected one third octave sound pressure levels.
3. The 1/3 octave band equivalent sound pressure levels are sorted into wind speed bins, each ±0.25 m/s wide, centred at integer wind speeds. The total noise and background noise data are segregated into separate data sets.
4. The average 1/3 octave band equivalent sound pressure levels for each wind speed bin are determined logarithmically. The 1/3 octave band equivalent sound pressure levels at the bin centres are then calculated using linear interpolation between the bin average sound pressure level and wind speed values.
5. The background corrected wind turbine sound pressure levels are derived using the 1/3 octave band equivalent sound pressure levels (referenced to the bin centre) as follows:
   - "turbine off" sound levels are logarithmically subtracted from the "turbine on" sound levels where the "turbine off" level is at least 3 dB(A) below the "turbine on" 1/3 octave band equivalent sound pressure level.

- In the case where the "turbine off" sound level is within 3 dB(A) of the 1/3 octave band "turbine on" sound pressure level, 3 dB(A) has been subtracted from the 1/3 octave band "turbine on" equivalent sound pressure level. These values have been noted as being affected by background noise.
- Where the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine on" noise levels is within 3 dB(A) of the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine off" sound levels, the data has not been reported, in accordance with IEC 61400-11:2012.
- Where no "turbine off" sound level data was available, the "turbine on" sound levels were used with no adjustment.

6. The background corrected wind turbine sound pressure levels at each 1/3 octave band are used to calculate the apparent sound power levels at each integer wind speed using Equation (26) in the IEC 61400-11:2012. The slant distance for each measurement location is presented in Table 3.
7. The overall apparent sound power level at each integer wind speed is determined by logarithmically summing the 1/3 octave band apparent sound power levels.

7.1.2 Analysed Data Points

The data points (overall equivalent sound pressure levels) included in the analysis are shown in Figure 4.

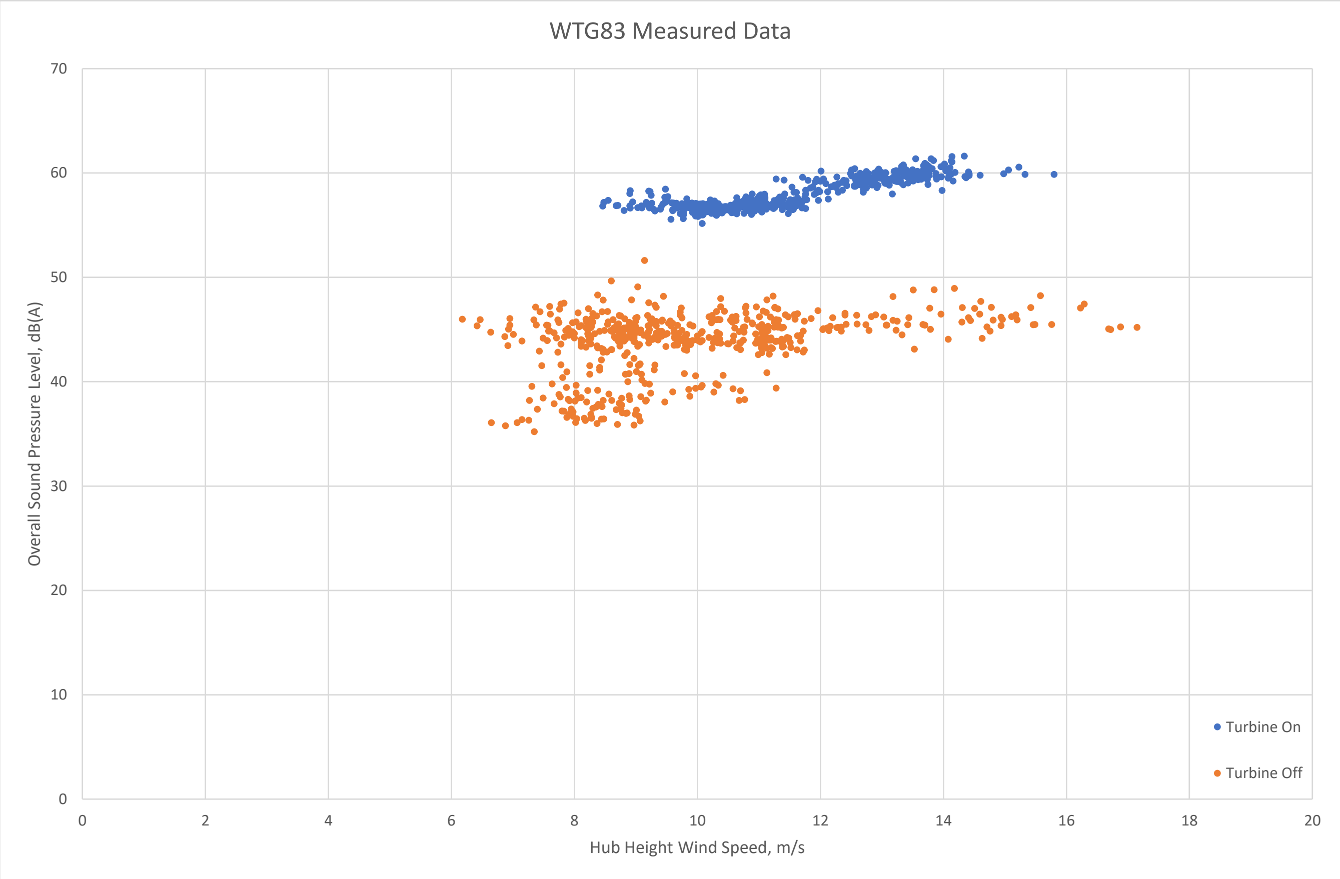


Figure 4: Analysed data points.

7.1.3 Analysis Results

The derived apparent sound power levels are summarised in Table 6.

Table 6: Derived apparent sound power levels.

V_{HH} (m/s)	V_{10} (m/s)	L_{WA} (dB(A))	Sound Power Level (dB(A)) at each 1/3 Octave Band (Hz)																											
			20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
9	6.2	108.4	58.2	62.7	67.9	71.7	75.8	79.9	84.1	86.9	89.1	91.1	92.1	93.7	93.7	93.1	96.7	100.2	101.1	98.5	98.2	98.3	95.5	93.4	90.3	88.9	87.2	84.5	74.2	[67.8]
10	6.9	107.7	59.5	64.5	68.8	73.1	76.6	80.4	84.0	87.0	89.0	90.9	92.0	93.3	92.8	91.8	95.4	99.0	100.2	97.5	97.7	98.1	95.5	93.4	90.3	88.6	86.8	83.4	72.7	[67.9]
11	7.6	108.0	59.4	64.6	69.1	73.6	77.6	81.7	85.3	88.2	90.1	91.9	93.0	94.3	93.6	92.3	95.6	99.2	100.3	97.7	98.0	98.2	95.7	93.8	90.6	89.0	86.4	82.5	[71.2]	[67.7]
12	8.3	109.9	62.9	68.0	72.5	76.5	80.5	84.4	88.0	91.2	93.2	94.8	95.3	96.6	95.7	94.8	98.0	101.4	102.2	99.1	99.2	99.5	97.3	95.1	91.9	90.8	88.7	84.8	76.1	71.2
13	9.0	110.8	63.1	68.7	73.3	77.6	81.6	85.7	89.5	92.7	94.6	96.1	96.4	97.6	96.9	96.0	99.2	102.4	103.2	100.0	100.0	100.3	98.0	96.1	92.8	91.6	88.6	85.2	76.0	70.9
14	9.6	111.5	63.5	69.0	73.6	78.3	82.7	87.1	90.6	93.8	95.5	96.7	97.1	98.4	97.7	96.9	100.1	103.2	103.9	100.6	100.5	100.8	98.5	96.7	93.5	92.2	89.1	85.7	76.3	70.9

[ ] - The background noise is within 3 dB of the total noise.

V_{HH} is the hub height (109m) wind speed.

V_{10} is the standardised wind speed, referenced at 10m above ground level.

7.2 Tonality

The results of the testing period have been analysed to determine any presence of excessive tonality, in accordance with NZS 6808:2010. NZS 6808:2010 provides two methods to objectively assess the presence of excessive tonality, the simplified test method and the reference test method, outlined in sections B2.2 and B2.3, respectively.

7.2.1 Reference Test Method

NZS 6808:2010 does not provide specific instructions for the reference test method, but instead references the method outlined in Annex C of ISO 1996-2:2007, or another similar method. As such, ISO 1996-2:2007 has been used to inform this assessment.

Annex C of ISO 1996-2:2007 provides the following method, generally summarised into three steps:

1. *Narrow-band frequency analysis (preferably FFT-analysis);*
2. *Determination of the average sound pressure level of the tone(s) and of the masking noise within the critical band around the tone(s);*
3. *Calculation of the tonal audibility and the adjustment.*

Audio recordings were made continuously during the testing period. A selection of these audio recordings, each one minute long, that best represent the noise at each integer wind speed were chosen, such that they were not influenced by extraneous noise sources such as birds or insects and were as close as possible to the integer wind speed for the full minute period.

Based on the approach provided in ISO 1996-2:2007, the selected audio recordings were analysed using an automated program for the presence of excessive tonality. This program has been designed to determine whether a character penalty is warranted in accordance with the method outlined in ISO 1996-2:2007. This method considers the audibility of any potential tones with respect to any masking noise and determines their impact through the use of a character penalty. For a potential tone to be audible, the tonal audibility must be greater than or equal to 4 dB. After running the program, no potential tones were identified at any wind speed and therefore no character penalties were applicable. The results of this program can be seen in the below table. As no character penalties were reported at any wind speed or frequency, no tones are considered to be present.

Table 7: Tonality analysis results.

Wind speed (m/s)	Tonal Audibility (dB)	Frequency (Hz)	Tonal Adjustment (dB)
9	-	-	0
10	-	-	0
11	-	-	0
12	-	-	0
13	-	-	0
14	-	-	0

7.2.2 Simplified Test Method

Section B2.2 of NZS 6808:2010 provides an alternate method for determining the presence of tonality. This method has been used as an additional check for the presence of excessive tonality and was conducted for all "Turbine On" data points, the points shown in blue as identified in Figure 4.

Section B2.2 of NZS 6808:2010 provides the following method, reproduced below:

> *A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one-third octave-bands in the Z-frequency-weighted sound spectrum. An adjustment for tonality shall be applied if the sound level in a Z-frequency-weighted one-third octave-band exceeds the arithmetic mean of the sound levels in both adjacent bands by more than the values given in table B1. For the purposes of this method linear, zero, or flat frequency-weighting shall be equivalent to Z-frequency-weighting.*

Table B1 – One-third octave-band level differences

One-third octave-band	*Level difference*
25 – 125 Hz	*15 dB*
160 – 400 Hz	*8 dB*
500 – 10000 Hz	*5 dB*
NOTE – At frequencies below 500 Hz the level difference could be too severe and tones might be identified when none is actually audible. For complex spectra the method is often inadequate and the reference method should be used (see B2.3).	

The results of this additional check indicate that no tonal penalty is required. This is consistent with the outcome of the reference test method, indicating that the operation of the turbine does not exhibit excessive tonality.

7.3 Amplitude Modulation

The results of the testing period have been analysed to determine any presence of excessive amplitude modulation, in general accordance with the interim test method presented in NZS 6808:2010.

NZS 6808:2010 states the following:

> *No objective test for amplitude modulation has been standardised. If a local authority enforcement officer or an acoustics advisor to a local authority considers that a wind farm creates sound with a clearly audible amplitude modulation at a noise sensitive location, an adjustment of +5 dB shall be applied to the wind farm sound level at that location for the wind conditions under which the modulation occurs.*
>
> *In making an assessment under B3.1 [the above], modulation special audible characteristics are deemed to exist if the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis, or if the measured third-octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency.*

As for the tonality assessment, a representative period for each integer wind speed has been analysed for excessive amplitude modulation. The graphs below show an example of the results of this analysis for each integer wind speed. It is noted that the horizontal lines are spaced 5 dB apart to illustrate compliance with the requirements of NZS 6808:2010 for the overall A-weighted level. As the regular peak to trough level does not exceed 5 dB for any integer wind speed, it can be determined that excessive amplitude modulation is not present in the noise profile of the wind turbine.

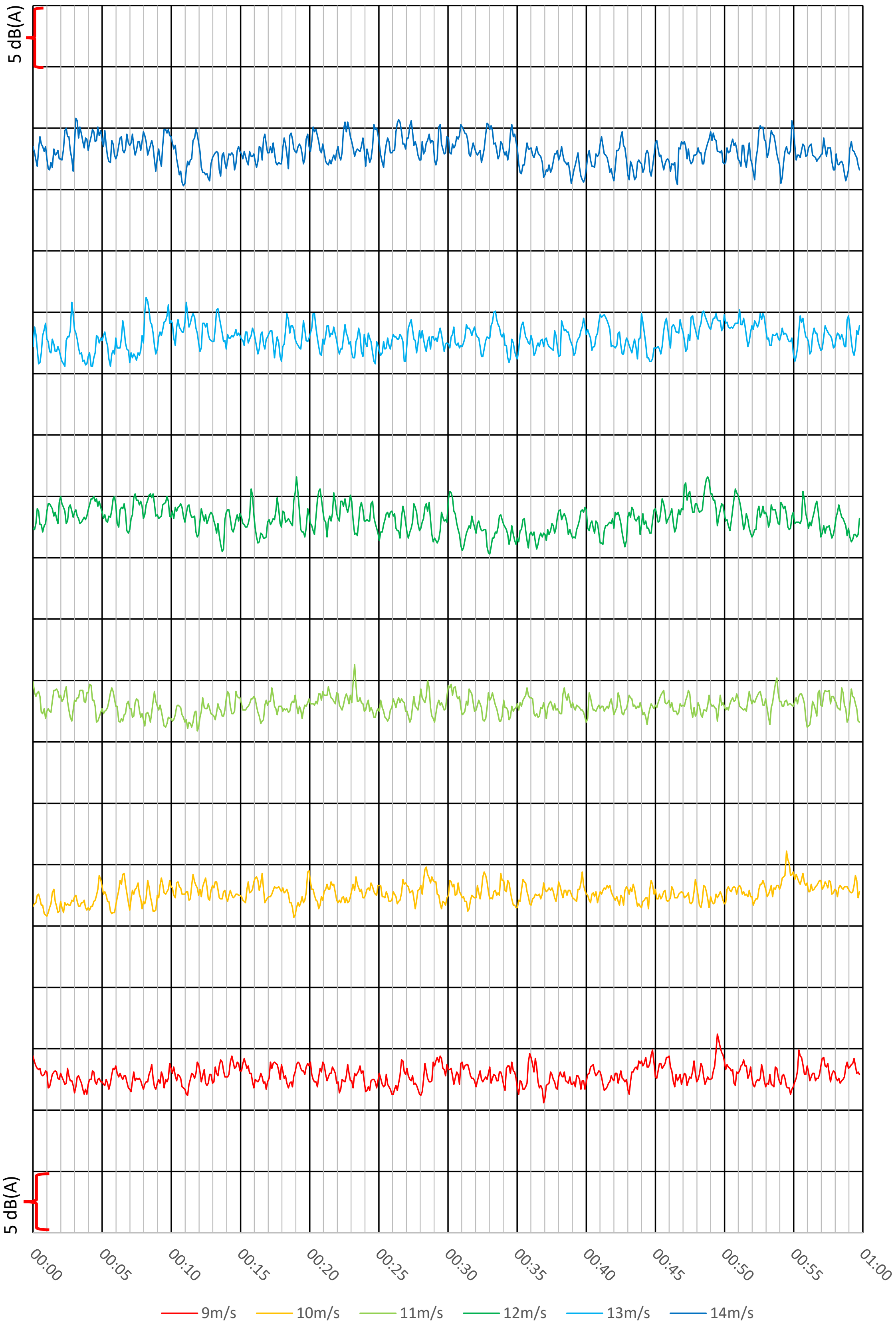


Figure 5: Amplitude modulation graphs.

Stockyard Hill Wind Farm

Acoustic Analysis of Wind Turbine

Generator 93

S3425.2C24

October 2022

sonus.

Chris Turnbull
Principal
ct@sonus.com.au
+61 (0) 417 845 720

Sonus Pty Ltd
17 Ruthven Avenue
Adelaide 5000 SA
+61 (8) 8231 2100
www.sonus.com.au

sonus.

Document Title : Acoustic Noise Test of Wind Turbine Generator 93

Document Reference: S3425.2C24

Date: October 2022

Author : Chris Turnbull, MAAS

© Sonus Pty Ltd. All rights reserved.

This report may not be reproduced other than in its entirety. The report is for the sole use of the client for the particular circumstances described in the report. Sonus accepts no responsibility to any other party who may rely upon or use this report without prior written consent.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1 INTRODUCTION

Sonus has been engaged by Goldwind Australia Pty Ltd to conduct noise testing of wind turbine generator 93 (WTG93) at the Stockyard Hill Wind Farm, Victoria.

The purpose of the testing was to determine the apparent sound power levels, tonality, and amplitude modulation of the installed wind turbine generator 93, type GW3S.

Noise measurements of WTG93 were conducted on 7 July 2022 to 9 July 2022. The data acquisition and subsequent analyses were conducted in general accordance with the approach of the following:

- the International Standard *IEC 61400-11: 2012 Wind turbines – Part 11: Acoustic noise measurements techniques* (IEC 61400-11:2012) - to derive the overall sound power levels;
- the New Zealand Standard *NZS 6808:2010 Acoustics – Wind Farm Noise* (NZS 6808:2010)) – to determine the presence of excessive tonality and amplitude modulation; and,
- the International Standard *ISO 1996-2:2007 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels* (ISO 1996-2:2007) – as referenced by NZS 6808:2010 to assist in determining the presence of excessive tonality.

This report provides a summary of the noise testing and presents the results of the analyses.

sonus.

2 TEST SITE DESCRIPTION

The Stockyard Hill Wind Farm is located approximately 35km west of Ballarat. The location of the tested wind turbine is shown on Figure 1.

The ground surface on the wind farm site in the area of the noise measurements is generally cropped. There are no significant reflecting structures at the wind farm or surrounding areas.

Figure 1: Tested wind turbine location.

sonus.

3 WIND TURBINE DETAILS

Table 1 provides the configuration of the tested wind turbine, WTG93.

Table 1: Details of WTG93.

Wind Turbine Details	
Manufacturer	Goldwind
Model	GW3S
Turbine ID	WTG93
Coordinates	711186 E 5849226 N
Operating Details	
Axis type	Horizontal
Rotor location	Upwind
Rotor diameter	140.2 m
Hub height	109 m (above ground level)
Tower type	Steel Tubular
Turbine speed	12 rpm
Rated power output	3400
Rated wind speed	11 m/s
Cut-in/cut-out wind speed	2.5 m/s to 20 m/s
Control type	Blade Pitch
Rotor Details	
Blade manufacturer	Sinoma (Goldwind)
Blade type	Single piece fiberglass, with V5 TES
Number of blades	3
Gearbox Details	
Type	None
Generator Details	
Manufacturer	CRRC (Goldwind)
Type	Permanent Magnet Direct Drive
Maximum speed	12 + 10% rpm

4 INSTRUMENTATION

4.1 Noise Measurement

Noise measurements were made using two Type 1 Rion NL-52 sound level meters, both equipped with one-third octave band analysers. The sound level meters were calibrated before and after the measurements using a Type 1 Rion NC-74 calibrator, with negligible drift observed.

A secondary wind screen was used for each sound level meter and was positioned over the microphone on the measurement board. Figure 2 shows a typical example of the setup used to conduct the monitoring.

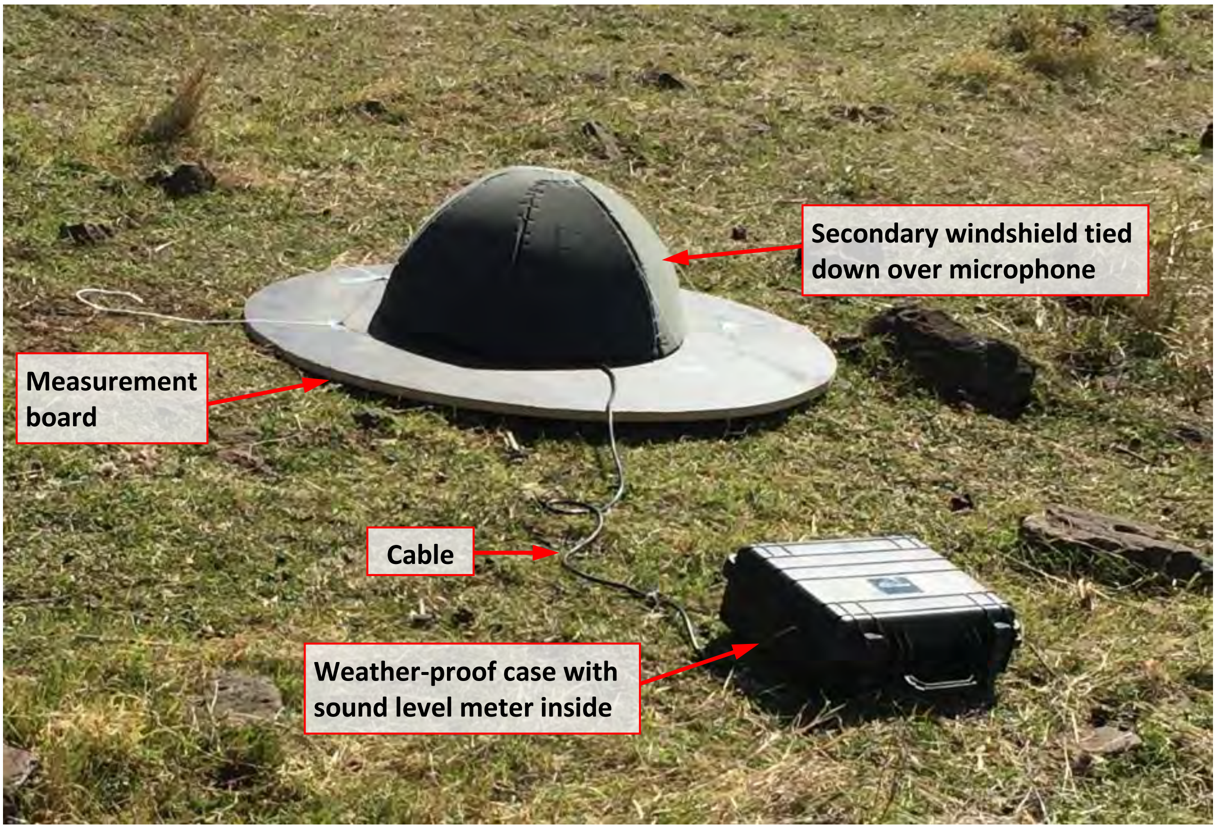


Figure 2: Microphone on the measurement board position with secondary screen.

The insertion loss of the secondary wind screen has been measured and is summarised in Table 2.

Table 2: Secondary wind screen insertion loss.

Frequency 1/3-octave band (Hz)	20	25	31.5	40	50	63	80	100	125	160
Insertion loss (dB)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.5	-0.3	-0.6	-0.2	-0.3
Frequency 1/3-octave band (Hz)	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**
Insertion loss (dB)	-0.3	0.1	0.3	1.2	2.0	2.7	1.9	0.9	1.1	2.1
Frequency 1/3-octave band (Hz)	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**		
Insertion loss (dB)	1.5	2.1	2.5	2.3	2.5	2.7	3.1	3.6		

Figure 3 shows the location of the noise measurement instrumentation, positioned in relation to WTG93.

Figure 3: Photograph of the tested wind turbine, WTG93.

4.2 Wind Data

Wind speed data during the testing period were obtained from the nacelle wind measurement instrumentation at WTG93. Wind direction data were obtained from the nacelle angle position instrumentation at WTG93. All sets of data were adjusted to match the 10 second period required by IEC 61400-11:2012.

4.3 Other Instrumentation

The operational status of the turbine was determined using the "W.T.G. Operation Status" identifier, as reported by the SCADA system for the turbine. It is understood from previous analysis that a value of "5" indicates that the turbine is operating and a value of "2" indicates that it is not operating. For periods where the "W.T.G. Operation Status" is not provided, operational status has been determined from the grid-side active power as reported by the SCADA system. For the purpose of this assessment, it has been assumed that the turbine is not operating where the grid-side active power is negative. It is noted that the turbine was considered to be not operating for some additional periods where the power data indicated that the turbine was ramping up or down from or to an 'off' state. Once again, the provided data were adjusted to match the 10 second period required by IEC 61400-11:2012.

Temperature, pressure, and rainfall data during the testing period were obtained from the *Bureau of Meteorology* website, for the weather station at the Ballarat Aerodrome.

5 ACOUSTIC DATA ACQUISITION

5.1 Measurement Position

Two sound level meters were placed simultaneously around the tested wind turbine, and spaced apart in an arc with respect to the wind turbine. The sound level meters were positioned in such a way that at least one was within 15° of the downwind position for the majority of the measurement period. The measurement positions are summarised in Table 3. The direction relative to the turbine corresponds to the degrees from north the measurement equipment is located at when observed from the turbine. As sufficient data were collected at Location 2, the measurements taken at this location have been used for this analysis.

Table 3: Microphone positions during the noise measurements.

Location	Coordinates		Slant Distance (m)	Direction Relative to Turbine (˚)
	Easting	Northing		
1	711274	5849358	194	32 (NNE)
2	711326	5849302	194	60 (ENE)

5.2 Sound Pressure Level Data

The equivalent A-weighted sound pressure levels were measured continuously at the measurement positions during the measurement period. Each measurement was averaged over a period of 10 seconds.

During the measurement period, WTG93 was switched ‘off’ on several occasions to allow for background noise measurements to be conducted.

Prior to analysis, the following data were discarded:

- measurements with intruding intermittent background noise or activity such as when apparatus was being set-up, or when rain occurred;
- measurements where other nearby turbines were on;
- measurements during start-up or shut-down of WTG93; and,
- measurements corresponding to non-downwind conditions.

Following data discard, the resultant number of sound pressure level data points in each wind speed bin (±0.25 m/s wide centred at integer hub height wind speed), for the wind speed range between 4m/s and 16m/s, are summarised in Table 4.

Table 4: Resultant number of noise data points.

Wind speed, V_{HH} (m/s)	Number of Noise Data Points	
	WTG93 ON	WTG93 OFF
4	930	82
5	931	110
6	963	109
7	1045	102
8	1055	72
9	639	54
10	416	39
11	155	27
12	48	10

6 NON-ACOUSTIC DATA ACQUISITION

6.1 Wind Data

6.1.1 Wind Speed Data

The wind speed during the measurement period was determined from the nacelle anemometer. The SCADA system recorded 3 second average wind speeds, approximately every 7 seconds. The first available 3 second average wind speed recorded within the 10 second noise average has been used for the correlations. The wind speed data was provided to Sonus by Goldwind and is understood to be comprised of measurements from the nacelle anemometer.

6.1.2 Wind Direction Data

IEC 61400-11:2012 requires the microphone measurement position to be within ± 15° of the nacelle direction. The nacelle direction data was recorded and provided by the SCADA computer program of the wind turbine. Noise measurements recorded when the measurement position was greater than ± 15° of the nacelle direction, were discarded. While it is understood that the nacelle direction has previously been inaccurate, based on observations made on site while placing the monitoring equipment, it appears that the wind direction measured was accurate during this testing period. As such, no adjustment has been made to the measured data for this assessment.

6.2 Other Measurements and Non-acoustic Data

6.2.1 Meteorological Conditions

The prevailing meteorological conditions during the noise measurements are summarised in Table 5. The temperature and pressure observations were taken at 9am. Where rain was identified during the testing period, 30-minute observations recorded at the Ballarat Aerodrome were used to remove periods which were affected by rain noise.

Table 5: Prevailing meteorological conditions during the measurements.

Measurement Date	Observation	Prevailing Condition
7 July 2022	Barometric pressure	101.93kPA
	Air temperature	6°C
	Precipitation	0.4mm
8 July 2022	Barometric pressure	101.74kPA
	Air temperature	6.8°C
	Precipitation	1.2mm
9 July 2022	Barometric pressure	102.26kPA
	Air temperature	5.3°C
	Precipitation	4mm

6.2.2 Roughness Length

The test site is farmland generally covered with grass and some vegetation. The surface roughness for this site is taken to be 0.05 m, which has been used to derive the standardised wind speed, referenced at 10m above ground level.

7 ANALYSIS

7.1 Apparent Sound Power Level

The apparent sound power level at each integer wind speed has been derived using the general procedure outlined in Section 9 of the IEC 61400-11:2012.

7.1.1 Analysis Procedure

The steps taken to derive the apparent sound power level at each integer wind speed for WTG93 are provided below:

1. All measured equivalent sound pressure levels at each 1/3 octave band between 20 Hz to 10 kHz are normalised to the measured overall equivalent sound pressure level. The 1/3 octave band levels between 20Hz and 10kHz are logarithmically summed and its difference with the measured overall level is arithmetically added to each 1/3 octave band levels.
2. The 1/3 octave band equivalent sound pressure levels are corrected for the influence of the secondary wind screen. The secondary wind screen insertion losses provided in Section 4.1 are arithmetically added to the 1/3 octave band levels. The resultant overall sound pressure level is obtained by logarithmically summing the corrected one third octave sound pressure levels.
3. The 1/3 octave band equivalent sound pressure levels are sorted into wind speed bins, each ±0.25 m/s wide, centred at integer wind speeds. The total noise and background noise data are segregated into separate data sets.
4. The average 1/3 octave band equivalent sound pressure levels for each wind speed bin are determined logarithmically. The 1/3 octave band equivalent sound pressure levels at the bin centres are then calculated using linear interpolation between the bin average sound pressure level and wind speed values.
5. The background corrected wind turbine sound pressure levels are derived using the 1/3 octave band equivalent sound pressure levels (referenced to the bin centre) as follows:
   - "turbine off" sound levels are logarithmically subtracted from the "turbine on" sound levels where the "turbine off" level is at least 3 dB(A) below the "turbine on" 1/3 octave band equivalent sound pressure level.

- In the case where the “turbine off” sound level is within 3 dB(A) of the 1/3 octave band “turbine on” sound pressure level, 3 dB(A) has been subtracted from the 1/3 octave band “turbine on” equivalent sound pressure level. These values have been noted as being affected by background noise.
- Where the logarithmic sum of each 1/3 octave band sound pressure level for the “turbine on” noise levels is within 3 dB(A) of the logarithmic sum of each 1/3 octave band sound pressure level for the “turbine off” sound levels, the data has not been reported, in accordance with IEC 61400-11:2012.
- Where no “turbine off” sound level data was available, the “turbine on” sound levels were used with no adjustment.

6. The background corrected wind turbine sound pressure levels at each 1/3 octave band are used to calculate the apparent sound power levels at each integer wind speed using Equation (26) in the IEC 61400-11:2012. The slant distance for each measurement location is presented in Table 3.
7. The overall apparent sound power level at each integer wind speed is determined by logarithmically summing the 1/3 octave band apparent sound power levels.

7.1.2 Analysed Data Points

The data points (overall equivalent sound pressure levels) included in the analysis are shown in Figure 4.

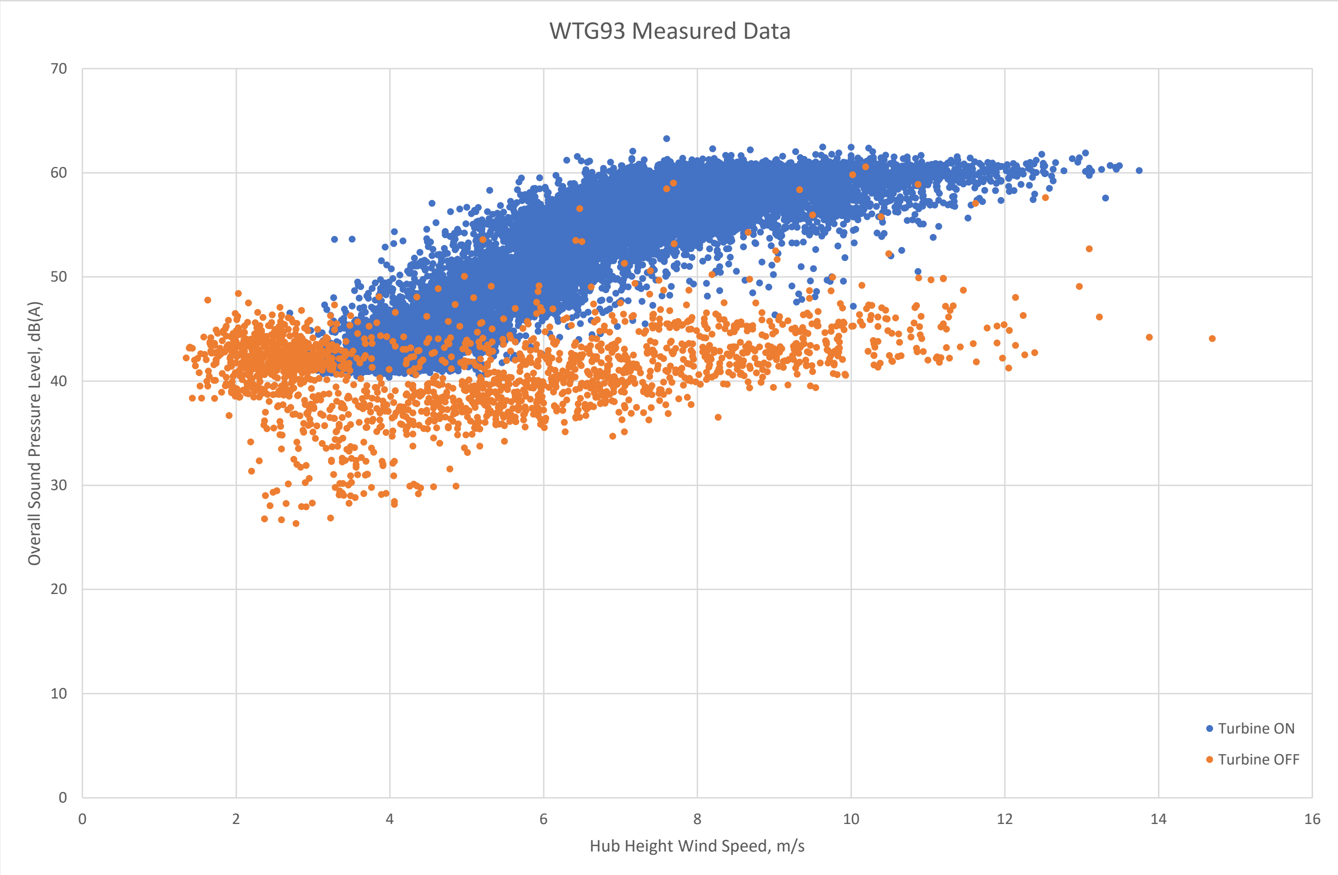


Figure 4: Analysed data points.

sonus.

7.1.3 Analysis Results

The derived apparent sound power levels are summarised in Table 6.

Table 6: Derived apparent sound power levels.

V_{HH} (m/s)	V_{10} (m/s)	L_{WA} (dB(A))	Sound Power Level (dB(A)) at each 1/3 Octave Band (Hz)																											
			20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
4	2.8	92.8*	[48.6]	63.5	63.0	[62.6]	[66.8]	[69.0]	[71.7]	[73.2]	[75.6]	[76.0]	77.0	79.2	80.5	80.9	82.0	84.1	83.8	84.2	80.9	81.6	79.0	78.3	75.9	73.0	68.8	[64.1]	#	#
5	3.4	97.6	52.9	61.0	66.9	66.5	71.1	74.8	77.0	78.0	80.3	80.4	79.9	83.2	84.4	84.2	84.8	89.5	89.6	90.1	86.7	86.4	83.5	82.5	79.6	76.2	[71.8]	[66.3]	#	#
6	4.1	103.4	58.8	64.0	69.3	72.4	75.8	79.0	81.8	83.0	84.8	85.1	85.4	88.0	89.7	89.7	91.2	94.3	94.5	95.3	93.8	94.1	90.8	89.4	86.2	82.4	77.6	70.6	#	#
7	4.8	106.7	62.1	67.1	71.6	75.6	79.0	81.8	84.9	86.4	88.1	88.2	88.3	90.9	92.4	92.4	93.9	97.3	97.9	98.8	97.4	97.7	94.4	92.9	89.6	85.8	80.7	74.2	#	#
8	5.5	108.5	63.5	68.6	73.1	77.1	80.6	83.5	86.6	88.3	90.0	90.0	90.0	92.5	93.9	93.8	95.3	98.8	99.5	100.6	99.3	99.6	96.3	94.9	91.6	87.6	82.3	75.2	#	#
9	6.2	109.4	64.5	69.5	74.0	78.0	81.6	84.5	87.6	89.4	91.1	91.1	91.1	93.6	94.9	94.8	96.1	99.7	100.4	101.6	100.3	100.6	97.4	96.0	92.7	88.5	83.1	75.6	#	#
10	6.9	109.5	64.6	69.8	74.2	78.1	81.7	84.7	87.9	89.8	91.4	91.4	91.4	94.0	95.2	94.9	96.2	99.7	100.5	101.6	100.5	100.7	97.4	96.0	92.3	87.7	82.1	[74.3]	#	#
11	7.6	109.8	64.0	69.2	73.7	77.7	81.5	84.7	88.2	90.3	92.0	91.9	92.0	94.6	95.7	95.2	96.2	99.7	100.5	101.7	100.6	101.0	98.1	97.1	94.1	89.1	83.1	75.4	#	#
12	8.3	110.6	65.1	70.0	74.5	78.4	82.2	85.4	88.8	90.8	92.7	92.7	92.8	95.5	96.7	96.2	97.1	100.5	101.2	102.4	101.2	101.7	98.7	97.9	95.2	90.5	84.1	76.6	#	#

- The background noise is higher than the total noise.

[ ] - The background noise is within 3 dB of the total noise.

* - The difference between the sum of the 1/3-octave bands of the total noise and the sum of the 1/3-octave bands of the background noise is between 3 and 6 dB.

V_{HH} is the hub height (109m) wind speed.

V_{10} is the standardised wind speed, referenced at 10m above ground level.

7.2 Tonality

The results of the testing period have been analysed to determine any presence of excessive tonality, in accordance with NZS 6808:2010. NZS 6808:2010 provides two methods to objectively assess the presence of excessive tonality, the simplified test method and the reference test method, outlined in sections B2.2 and B2.3, respectively.

7.2.1 Reference Test Method

NZS 6808:2010 does not provide specific instructions for the reference test method, but instead references the method outlined in Annex C of ISO 1996-2:2007, or another similar method. As such, ISO 1996-2:2007 has been used to inform this assessment.

Annex C of ISO 1996-2:2007 provides the following method, generally summarised into three steps:

1. *Narrow-band frequency analysis (preferably FFT-analysis);*
2. *Determination of the average sound pressure level of the tone(s) and of the masking noise within the critical band around the tone(s);*
3. *Calculation of the tonal audibility and the adjustment.*

Audio recordings were made continuously during the testing period. A selection of these audio recordings, each one minute long, that best represent the noise at each integer wind speed were chosen, such that they were not influenced by extraneous noise sources such as birds or insects and were as close as possible to the integer wind speed for the full minute period.

Based on the approach provided in ISO 1996-2:2007, the selected audio recordings were analysed using an automated program for the presence of excessive tonality. This program has been designed to determine whether a character penalty is warranted in accordance with the method outlined in ISO 1996-2:2007. This method considers the audibility of any potential tones with respect to any masking noise and determines their impact through the use of a character penalty. For a potential tone to be audible, the tonal audibility must be greater than or equal to 4 dB. After running the program, no potential tones were identified at any wind speed and therefore no character penalties were applicable. The results of this program can be seen in the below table. As no character penalties were reported at any wind speed or frequency, no tones are considered to be present.

Table 7: Tonality analysis results.

Wind speed (m/s)	Tonal Audibility (dB)	Frequency (Hz)	Tonal Adjustment (dB)
4	-	-	0
5	-	-	0
6	-	-	0
7	-	-	0
8	-	-	0
9	-	-	0
10	-	-	0
11	-	-	0
12	-	-	0

7.2.2 Simplified Test Method

Section B2.2 of NZS 6808:2010 provides an alternate method for determining the presence of tonality. This method has been used as an additional check for the presence of excessive tonality and was conducted for all "Turbine On" data points, the points shown in blue in Figure 4.

Section B2.2 of NZS 6808:2010 provides the following method, reproduced below:

A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one-third octave-bands in the Z-frequency-weighted sound spectrum. An adjustment for tonality shall be applied if the sound level in a Z-frequency-weighted one-third octave-band exceeds the arithmetic mean of the sound levels in both adjacent bands by more than the values given in table B1. For the purposes of this method linear, zero, or flat frequency-weighting shall be equivalent to Z-frequency-weighting.

Table B1 – One-third octave-band level differences

One-third octave-band	*Level difference*
25 – 125 Hz	*15 dB*
160 – 400 Hz	*8 dB*
500 – 10000 Hz	*5 dB*
NOTE – At frequencies below 500 Hz the level difference could be too severe and tones might be identified when none is actually audible. For complex spectra the method is often inadequate and the reference method should be used (see B2.3).	

The results of this additional check indicate that no tonal penalty is required. This is consistent with the outcome of the reference test method, indicating that the operation of the turbine does not exhibit excessive tonality.

7.3 Amplitude Modulation

The results of the testing period have been analysed to determine any presence of excessive amplitude modulation, in general accordance with the interim test method presented in NZS 6808:2010.

NZS 6808:2010 states the following:

> *No objective test for amplitude modulation has been standardised. If a local authority enforcement officer or an acoustics advisor to a local authority considers that a wind farm creates sound with a clearly audible amplitude modulation at a noise sensitive location, an adjustment of +5 dB shall be applied to the wind farm sound level at that location for the wind conditions under which the modulation occurs.*
>
> *In making an assessment under B3.1 [the above], modulation special audible characteristics are deemed to exist if the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis, or if the measured third-octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency.*

As for the tonality assessment, a representative period for each integer wind speed has been analysed for excessive amplitude modulation. The graphs below show an example of the results of this analysis for each integer wind speed. It is noted that the horizontal lines are spaced 5 dB apart to illustrate compliance with the requirements of NZS 6808:2010 for the overall A-weighted level. As the regular peak to trough level does not exceed 5 dB for any integer wind speed, it can be determined that excessive amplitude modulation is not present in the noise profile of the wind turbine.

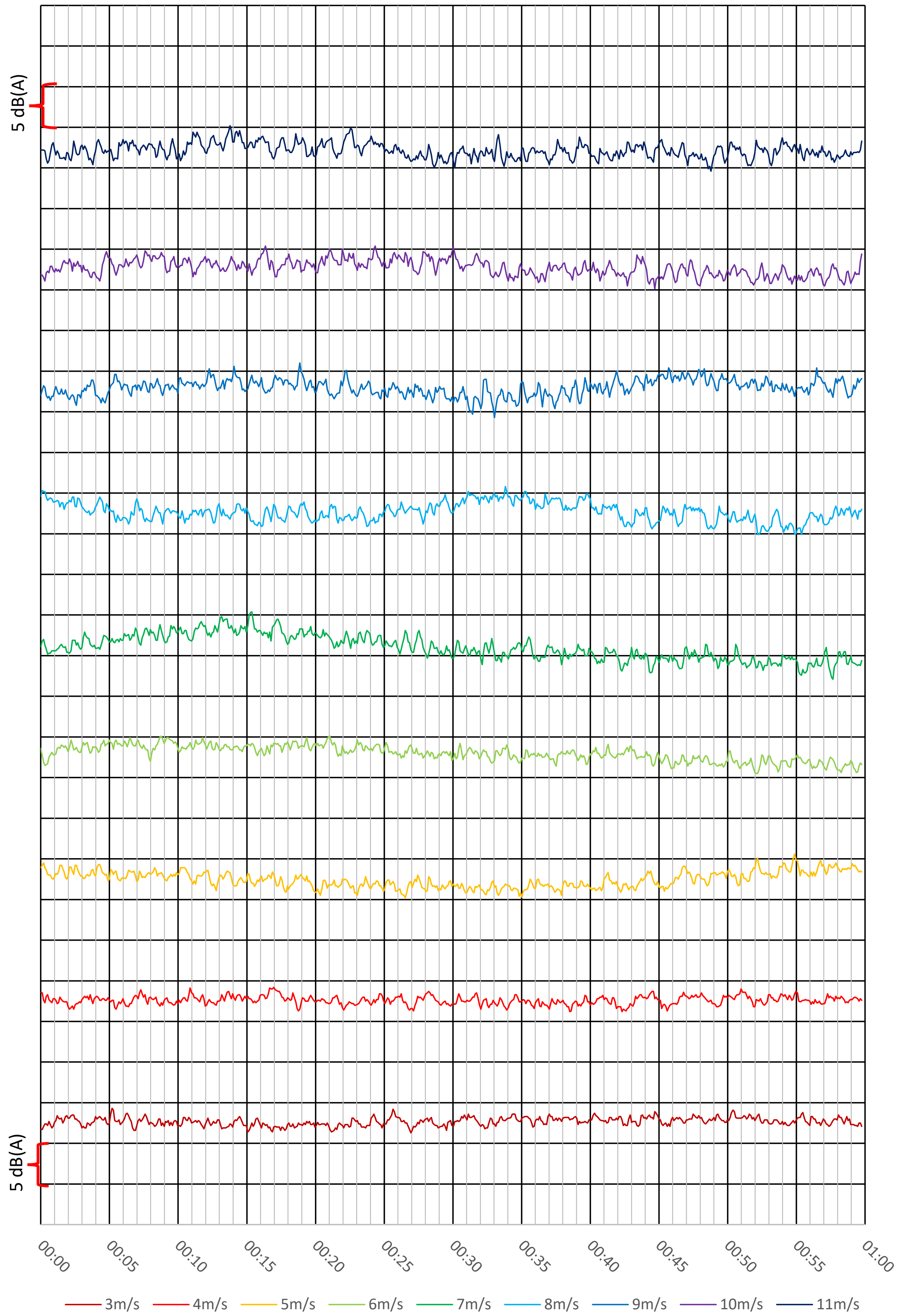


Figure 5: Amplitude modulation graphs.

Stockyard Hill Wind Farm

Acoustic Analysis of Wind Turbine

Generator 141

S3425.2C21

October 2022

sonus.

Chris Turnbull
Principal
ct@sonus.com.au
+61 (0) 417 845 720

Sonus Pty Ltd
17 Ruthven Avenue
Adelaide 5000 SA
+61 (8) 8231 2100
www.sonus.com.au

sonus.

Document Title : Acoustic Noise Test of Wind Turbine Generator 141

Document Reference: S3425.2C21

Date: October 2022

Author : Chris Turnbull, MAAS

© Sonus Pty Ltd. All rights reserved.

This report may not be reproduced other than in its entirety. The report is for the sole use of the client for the particular circumstances described in the report. Sonus accepts no responsibility to any other party who may rely upon or use this report without prior written consent.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1 INTRODUCTION

Sonus has been engaged by Goldwind Australia Pty Ltd to conduct noise testing of wind turbine generator 141 (WTG141) at the Stockyard Hill Wind Farm, Victoria.

The purpose of the testing was to determine the apparent sound power levels, tonality, and amplitude modulation of the installed wind turbine generator 141, type GW3S.

Noise measurements of WTG141 were conducted on 21 July 2022 to 22 July 2022. The data acquisition and subsequent analyses were conducted in general accordance with the approach of the following:

- the International Standard *IEC 61400-11: 2012 Wind turbines – Part 11: Acoustic noise measurements techniques* (IEC 61400-11:2012) - to derive the overall sound power levels;
- the New Zealand Standard *NZS 6808:2010 Acoustics – Wind Farm Noise* (NZS 6808:2010)) – to determine the presence of excessive tonality and amplitude modulation; and,
- the International Standard *ISO 1996-2:2007 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels* (ISO 1996-2:2007) – as referenced by NZS 6808:2010 to assist in determining the presence of excessive tonality.

This report provides a summary of the noise testing and presents the results of the analyses.

2 TEST SITE DESCRIPTION

The Stockyard Hill Wind Farm is located approximately 35km west of Ballarat. The location of the tested wind turbine is shown on Figure 1.

The ground surface on the wind farm site in the area of the noise measurements is generally cropped. There are no significant reflecting structures at the wind farm or surrounding areas.

Figure 1: Tested wind turbine location.

3 WIND TURBINE DETAILS

Table 1 provides the configuration of the tested wind turbine, WTG141.

Table 1: Details of WTG141.

Wind Turbine Details	
Manufacturer	Goldwind
Model	GW3S
Turbine ID	WTG141
Coordinates	711401 E 5831093 N
Operating Details	
Axis type	Horizontal
Rotor location	Upwind
Rotor diameter	140.2 m
Hub height	109 m (above ground level)
Tower type	Steel Tubular
Turbine speed	12 rpm
Rated power output	3570
Rated wind speed	11 m/s
Cut-in/cut-out wind speed	2.5 m/s to 20 m/s
Control type	Blade Pitch
Rotor Details	
Blade manufacturer	Sinoma (Goldwind)
Blade type	Single piece fiberglass, with V4 TES
Number of blades	3
Gearbox Details	
Type	None
Generator Details	
Manufacturer	CRRC (Goldwind)
Type	Permanent Magnet Direct Drive
Maximum speed	12 + 10% rpm

4 INSTRUMENTATION

4.1 Noise Measurement

Noise measurements were made using two Type 1 Rion sound level meters, a NL-52 and a NA-28, both equipped with one-third octave band analysers. The sound level meters were calibrated before and after the measurements using a Type 1 Rion NC-74 calibrator, with negligible drift observed.

A secondary wind screen was used for each sound level meter and was positioned over the microphone on the measurement board. Figure 2 shows a typical example of the setup used to conduct the monitoring.

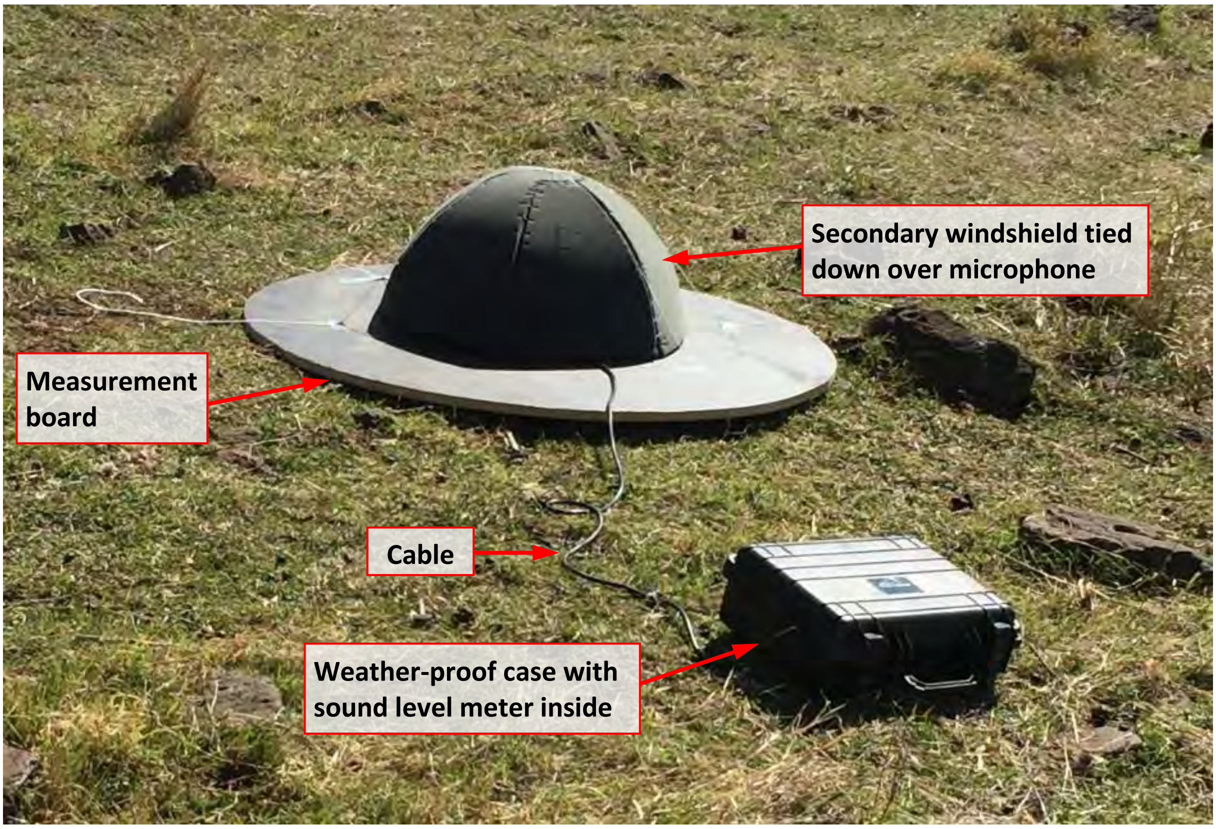


Figure 2: Microphone on the measurement board position with secondary screen.

The insertion loss of the secondary wind screen has been measured and is summarised in Table 2.

Table 2: Secondary wind screen insertion loss.

Frequency 1/3-octave band (Hz)	20	25	31.5	40	50	63	80	100	125	160
Insertion loss (dB)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.5	-0.3	-0.6	-0.2	-0.3
Frequency 1/3-octave band (Hz)	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**
Insertion loss (dB)	-0.3	0.1	0.3	1.2	2.0	2.7	1.9	0.9	1.1	2.1
Frequency 1/3-octave band (Hz)	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**		
Insertion loss (dB)	1.5	2.1	2.5	2.3	2.5	2.7	3.1	3.6		

Figure 3 shows the location of the noise measurement instrumentation, positioned in relation to WTG141.

Figure 3: Photograph of the tested wind turbine, WTG141.

4.2 Wind Data

Wind speed data during the testing period were obtained from the nacelle wind measurement instrumentation at WTG141. Wind direction data were obtained from the nacelle angle position instrumentation at WTG141. All sets of data were adjusted to match the 10 second period required by IEC 61400-11:2012.

4.3 Other Instrumentation

The operational status of the turbine was determined using the grid-side active power as reported by the SCADA system for the turbine. For the purpose of this assessment, it has been assumed that the turbine is not operating where the grid-side active power is negative. It is noted that the turbine was considered to be not operating for some additional periods where the power data indicated that the turbine was ramping up or down from or to an 'off' state. Once again, the provided data were adjusted to match the 10 second period required by IEC 61400-11:2012.

Temperature, pressure and rainfall data during the testing period were obtained from the *Bureau of Meteorology* website, for the weather station at the Ballarat Aerodrome.

5 ACOUSTIC DATA ACQUISITION

5.1 Measurement Position

Two sound level meters were placed simultaneously around the tested wind turbine, and spaced apart in an arc with respect to the wind turbine. The sound level meters were positioned in such a way that at least one was within 15° of the downwind position for the majority of the measurement period. The measurement positions are summarised in Table 3. The direction relative to the turbine corresponds to the degrees from north the measurement equipment is located at when observed from the turbine. As sufficient data were collected at Location 2, the measurements taken at this location have been used for this analysis.

Table 3: Microphone positions during the noise measurements.

Location	Coordinates		Slant Distance (m)	Direction Relative to Turbine (˚)
	Easting	Northing		
1	711275	5830976	194	225 (SW)
2	711341	5830935	194	197 (SSW)

5.2 Sound Pressure Level Data

The equivalent A-weighted sound pressure levels were measured continuously at the measurement positions during the measurement period. Each measurement was averaged over a period of 10 seconds.

During the measurement period, WTG141 was switched 'off' on several occasions to allow for background noise measurements to be conducted.

Prior to analysis, the following data were discarded:

- measurements with intruding intermittent background noise or activity such as when apparatus was being set-up;
- measurements during start-up or shut-down of WTG141; and,
- measurements corresponding to non-downwind conditions.

Following data discard, the resultant number of sound pressure level data points in each wind speed bin (±0.25 m/s wide centred at integer hub height wind speed), for the wind speed range between 4m/s and 15m/s, are summarised in Table 4.

Table 4: Resultant number of noise data points.

Wind speed, V_{HH} (m/s)	Number of Noise Data Points	
	WTG141 ON	WTG141 OFF
4	53	-
5	246	-
6	403	18
7	314	44
8	139	81
9	80	70
10	70	55
11	68	53
12	54	26
13	56	36
14	54	23
15	23	-

6 NON-ACOUSTIC DATA ACQUISITION

6.1 Wind Data

6.1.1 Wind Speed Data

The wind speed during the measurement period was determined from the nacelle anemometer. The SCADA system recorded 3 second average wind speeds, approximately every 7 seconds. The first available 3 second average wind speed recorded within the 10 second noise average has been used for the correlations. The wind speed data was provided to Sonus by Goldwind and is understood to be comprised of measurements from the nacelle anemometer.

6.1.2 Wind Direction Data

IEC 61400-11:2012 requires the microphone measurement position to be within ± 15° of the nacelle direction. The nacelle direction data was recorded and provided by the SCADA computer program of the wind turbine. Noise measurements recorded when the measurement position was greater than ± 15° of the nacelle direction, were discarded. While it is understood that the nacelle direction has previously been inaccurate, based on observations made on site while placing the monitoring equipment, it appears that the wind direction measured was accurate during this testing period. As such, no adjustment has been made to the measured data for this assessment.

6.2 Other Measurements and Non-acoustic Data

6.2.1 Meteorological Conditions

The prevailing meteorological conditions during the noise measurements are summarised in Table 5. The temperature and pressure observations were taken at 9am.

sonus.

Table 5: Prevailing meteorological conditions during the measurements.

Measurement Date	Observation	Prevailing Condition
21 July 2022	Barometric pressure	103.29kPA
	Air temperature	8.3°C
	Precipitation	0mm
22 July 2022	Barometric pressure	102.92kPA
	Air temperature	8.4°C
	Precipitation	0mm

6.2.2 Roughness Length

The test site is farmland generally covered with grass and some vegetation. The surface roughness for this site is taken to be 0.05 m, which has been used to derive the standardised wind speed, referenced at 10m above ground level.

7 ANALYSIS

7.1 Apparent Sound Power Level

The apparent sound power level at each integer wind speed has been derived using the general procedure outlined in Section 9 of the IEC 61400-11:2012.

7.1.1 Analysis Procedure

The steps taken to derive the apparent sound power level at each integer wind speed for WTG141 are provided below:

1. All measured equivalent sound pressure levels at each 1/3 octave band between 20 Hz to 10 kHz are normalised to the measured overall equivalent sound pressure level. The 1/3 octave band levels between 20Hz and 10kHz are logarithmically summed and its difference with the measured overall level is arithmetically added to each 1/3 octave band levels.
2. The 1/3 octave band equivalent sound pressure levels are corrected for the influence of the secondary wind screen. The secondary wind screen insertion losses provided in Section 4.1 are arithmetically added to the 1/3 octave band levels. The resultant overall sound pressure level is obtained by logarithmically summing the corrected one third octave sound pressure levels.
3. The 1/3 octave band equivalent sound pressure levels are sorted into wind speed bins, each ±0.25 m/s wide, centred at integer wind speeds. The total noise and background noise data are segregated into separate data sets.
4. The average 1/3 octave band equivalent sound pressure levels for each wind speed bin are determined logarithmically. The 1/3 octave band equivalent sound pressure levels at the bin centres are then calculated using linear interpolation between the bin average sound pressure level and wind speed values.
5. The background corrected wind turbine sound pressure levels are derived using the 1/3 octave band equivalent sound pressure levels (referenced to the bin centre) as follows:
   - "turbine off" sound levels are logarithmically subtracted from the "turbine on" sound levels where the "turbine off" level is at least 3 dB(A) below the "turbine on" 1/3 octave band equivalent sound pressure level.

- In the case where the "turbine off" sound level is within 3 dB(A) of the 1/3 octave band "turbine on" sound pressure level, 3 dB(A) has been subtracted from the 1/3 octave band "turbine on" equivalent sound pressure level. These values have been noted as being affected by background noise.
- Where the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine on" noise levels is within 3 dB(A) of the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine off" sound levels, the data has not been reported, in accordance with IEC 61400-11:2012.
- Where no "turbine off" sound level data was available, the "turbine on" sound levels were used with no adjustment.

6. The background corrected wind turbine sound pressure levels at each 1/3 octave band are used to calculate the apparent sound power levels at each integer wind speed using Equation (26) in the IEC 61400-11:2012. The slant distance for each measurement location is presented in Table 3.
7. The overall apparent sound power level at each integer wind speed is determined by logarithmically summing the 1/3 octave band apparent sound power levels.

7.1.2 Analysed Data Points

The data points (overall equivalent sound pressure levels) included in the analysis are shown in Figure 4.

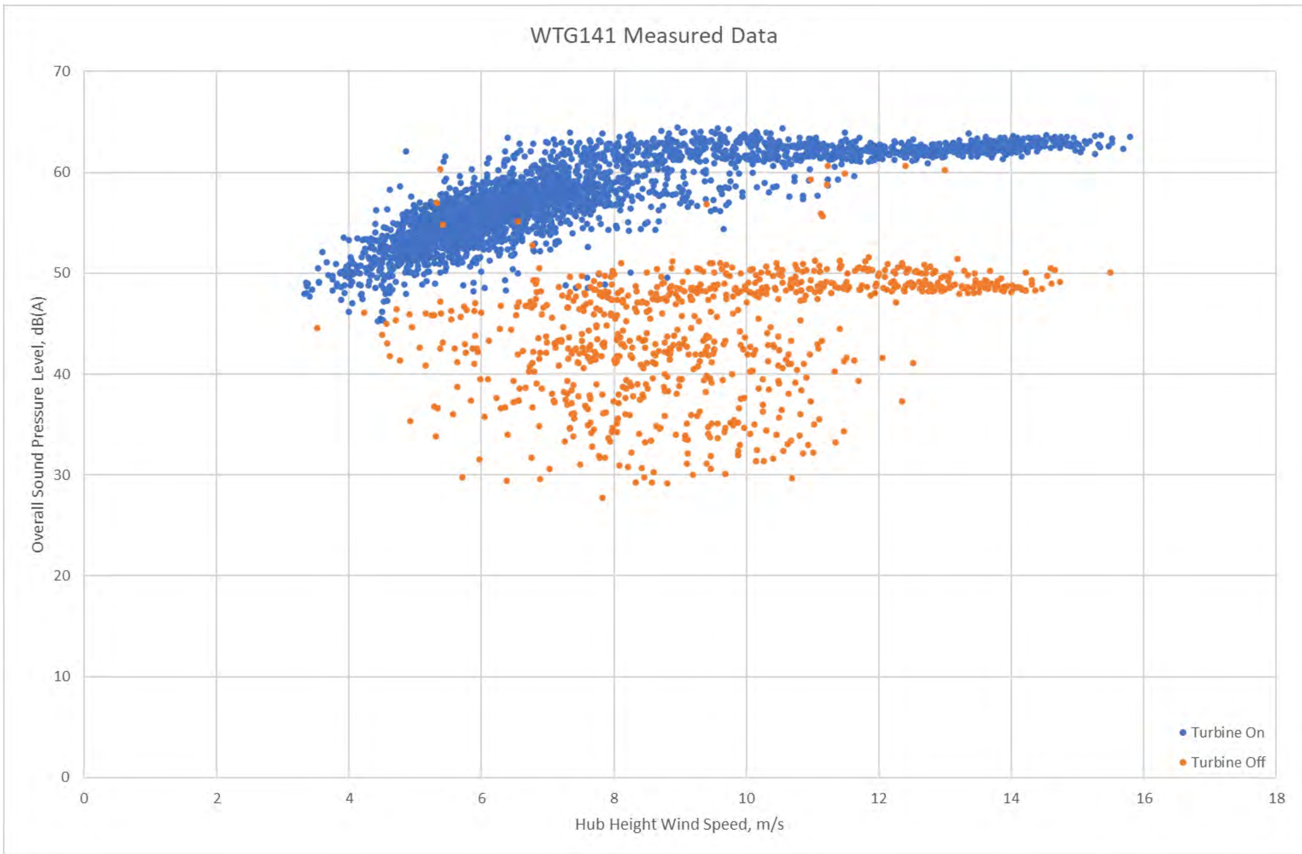


Figure 4: Analysed data points.

sonus.

7.1.3 Analysis Results

The derived apparent sound power levels are summarised in Table 6.

Table 6: Derived apparent sound power levels.

V_{HH} (m/s)	V_{10} (m/s)	L_{WA} (dB(A))	Sound Power Level (dB(A)) at each 1/3 Octave Band (Hz)																														
			20	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**
4	2.8	101.1	50.3	61.9	69.6	67.0	71.4	74.7	76.7	78.4	80.7	82.0	83.1	86.3	88.1	88.4	91.2	92.8	92.6	92.0	91.2	90.8	87.6	84.9	81.8	80.0	76.0	66.8	61.5	59.8
5	3.4	104.5	53.7	60.9	68.8	69.3	73.1	77.1	79.9	80.9	83.2	84.5	85.7	88.9	90.7	91.1	94.1	96.0	96.1	95.6	95.0	94.7	91.9	89.2	85.8	83.4	79.3	73.1	69.0	64.7
6	4.1	106.5	55.7	61.4	66.9	70.0	73.9	77.3	81.1	81.8	[82.0]	84.5	87.2	90.3	92.2	92.6	95.9	98.0	98.4	98.0	97.3	97.3	94.2	91.6	87.5	82.8	77.9	69.2	#	#
7	4.8	108.8	57.1	62.5	67.2	71.2	75.1	78.0	81.7	83.0	85.5	87.0	88.7	92.1	93.7	94.2	97.6	100.0	100.6	100.3	99.9	99.9	96.9	94.3	90.2	84.6	[78.1]	[72.2]	63.5	#
8	5.5	110.7	61.1	66.2	70.9	75.0	78.8	81.7	84.9	86.7	88.5	89.6	90.9	94.2	95.7	95.8	99.0	101.6	102.3	102.3	101.9	102.0	99.2	97.1	92.8	87.2	81.3	73.8	[64.6]	#
9	6.2	112.2	62.7	68.2	72.6	76.6	80.6	83.6	86.7	88.6	90.6	91.4	92.6	95.8	97.1	97.0	100.1	102.8	103.6	103.7	103.5	103.5	100.8	99.1	95.1	89.5	83.9	76.4	66.4	#
10	6.9	112.9	63.6	68.8	73.0	77.2	81.2	84.1	87.3	89.4	91.6	92.2	93.5	96.7	97.9	97.8	100.8	103.5	104.2	104.4	104.2	104.1	101.7	100.2	96.2	91.2	87.1	78.2	68.1	[60.6]
11	7.6	112.4	62.1	67.2	71.6	76.0	80.1	83.2	86.6	89.2	91.4	92.3	93.5	96.7	97.7	97.2	100.0	102.8	103.4	103.6	103.5	103.5	101.8	101.1	96.3	89.8	84.1	76.9	67.4	[60.1]
12	8.3	112.6	62.9	67.9	72.7	77.2	81.5	84.6	88.0	90.7	92.8	93.4	94.7	97.6	98.2	97.5	100.2	102.6	103.1	103.2	103.0	103.3	102.5	102.4	96.9	89.7	84.0	76.8	66.8	[59.8]
13	9.0	112.7	62.4	67.7	72.8	77.4	81.6	85.1	88.7	91.4	93.6	94.2	95.3	98.0	98.5	97.8	100.4	102.6	103.1	102.9	102.7	103.2	103.0	103.5	97.2	89.8	84.0	76.6	66.6	#
14	9.6	113.1	61.6	67.5	72.8	77.7	82.4	86.1	89.7	92.3	94.6	95.2	96.1	98.7	99.1	98.3	100.9	102.9	103.2	103.0	102.8	103.4	103.6	104.3	97.5	90.0	84.1	76.6	[66.7]	#
15	10.3	113.6	61.8	67.5	73.0	78.5	83.3	87.4	91.1	93.7	96.2	96.4	97.3	99.7	99.9	99.1	101.6	103.4	103.5	103.1	102.9	103.6	104.0	104.8	97.7	90.4	84.7	78.5	73.4	68.7

- The background noise is higher than the total noise.

[ ] - The background noise is within 3 dB of the total noise.

V_{HH} is the hub height (109m) wind speed.

V_{10} is the standardised wind speed, referenced at 10m above ground level.

7.2 Tonality

The results of the testing period have been analysed to determine any presence of excessive tonality, in accordance with NZS 6808:2010. NZS 6808:2010 provides two methods to objectively assess the presence of excessive tonality, the simplified test method and the reference test method, outlined in sections B2.2 and B2.3, respectively.

7.2.1 Reference Test Method

NZS 6808:2010 does not provide specific instructions for the reference test method, but instead references the method outlined in Annex C of ISO 1996-2:2007, or another similar method. As such, ISO 1996-2:2007 has been used to inform this assessment.

Annex C of ISO 1996-2:2007 provides the following method, generally summarised into three steps:

1. *Narrow-band frequency analysis (preferably FFT-analysis);*
2. *Determination of the average sound pressure level of the tone(s) and of the masking noise within the critical band around the tone(s);*
3. *Calculation of the tonal audibility and the adjustment.*

Audio recordings were made continuously during the testing period. A selection of these audio recordings, each one minute long, that best represent the noise at each integer wind speed were chosen, such that they were not influenced by extraneous noise sources such as birds or insects and were as close as possible to the integer wind speed for the full minute period.

Based on the approach provided in ISO 1996-2:2007, the selected audio recordings were analysed using an automated program for the presence of excessive tonality. This program has been designed to determine whether a character penalty is warranted in accordance with the method outlined in ISO 1996-2:2007. This method considers the audibility of any potential tones with respect to any masking noise and determines their impact through the use of a character penalty. For a potential tone to be audible, the tonal audibility must be greater than or equal to 4 dB. After running the program, one potential tone was identified at 9m/s, however, it was not sufficiently audible and therefore did not attract a character penalty. The results of this program can be seen in the below table. As no character penalties were reported at any wind speed or frequency, no tones are considered to be present.

Table 7: Tonality analysis results.

Wind speed (m/s)	Tonal Audibility (dB)	Frequency (Hz)	Tonal Adjustment (dB)
4	-	-	0
5	-	-	0
6	-	-	0
7	-	-	0
8	-	-	0
9	1.6	4037	0
10	-	-	0
11	-	-	0
12	-	-	0
13	-	-	0
14	-	-	0
15	-	-	0

7.2.2 Simplified Test Method

Section B2.2 of NZS 6808:2010 provides an alternate method for determining the presence of tonality. This method has been used as an additional check for the presence of excessive tonality and was conducted for all "Turbine On" data points, the points shown in blue in Figure 4.

Section B2.2 of NZS 6808:2010 provides the following method, reproduced below:

> *A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one-third octave-bands in the Z-frequency-weighted sound spectrum. An adjustment for tonality shall be applied if the sound level in a Z-frequency-weighted one-third octave-band exceeds the arithmetic mean of the sound levels in both adjacent bands by more than the values given in table B1. For the purposes of this method linear, zero, or flat frequency-weighting shall be equivalent to Z-frequency-weighting.*

Table B1 – One-third octave-band level differences

One-third octave-band	*Level difference*
25 – 125 Hz	*15 dB*
160 – 400 Hz	*8 dB*
500 – 10000 Hz	*5 dB*
NOTE – At frequencies below 500 Hz the level difference could be too severe and tones might be identified when none is actually audible. For complex spectra the method is often inadequate and the reference method should be used (see B2.3).	

The results of this additional check indicate that no tonal penalty is required. This is consistent with the outcome of the reference test method, indicating that the operation of the turbine does not exhibit excessive tonality.

7.3 Amplitude Modulation

The results of the testing period have been analysed to determine any presence of excessive amplitude modulation, in general accordance with the interim test method presented in NZS 6808:2010.

NZS 6808:2010 states the following:

> *No objective test for amplitude modulation has been standardised. If a local authority enforcement officer or an acoustics advisor to a local authority considers that a wind farm creates sound with a clearly audible amplitude modulation at a noise sensitive location, an adjustment of +5 dB shall be applied to the wind farm sound level at that location for the wind conditions under which the modulation occurs.*
>
> *In making an assessment under B3.1 [the above], modulation special audible characteristics are deemed to exist if the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis, or if the measured third-octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency.*

As for the tonality assessment, a representative period for each integer wind speed has been analysed for excessive amplitude modulation. The graphs below show an example of the results of this analysis for each integer wind speed. It is noted that the horizontal lines are spaced 5 dB apart to illustrate compliance with the requirements of NZS 6808:2010 for the overall A-weighted level. As the regular peak to trough level does not exceed 5 dB for any integer wind speed, it can be determined that excessive amplitude modulation is not present in the noise profile of the wind turbine.

sonus.

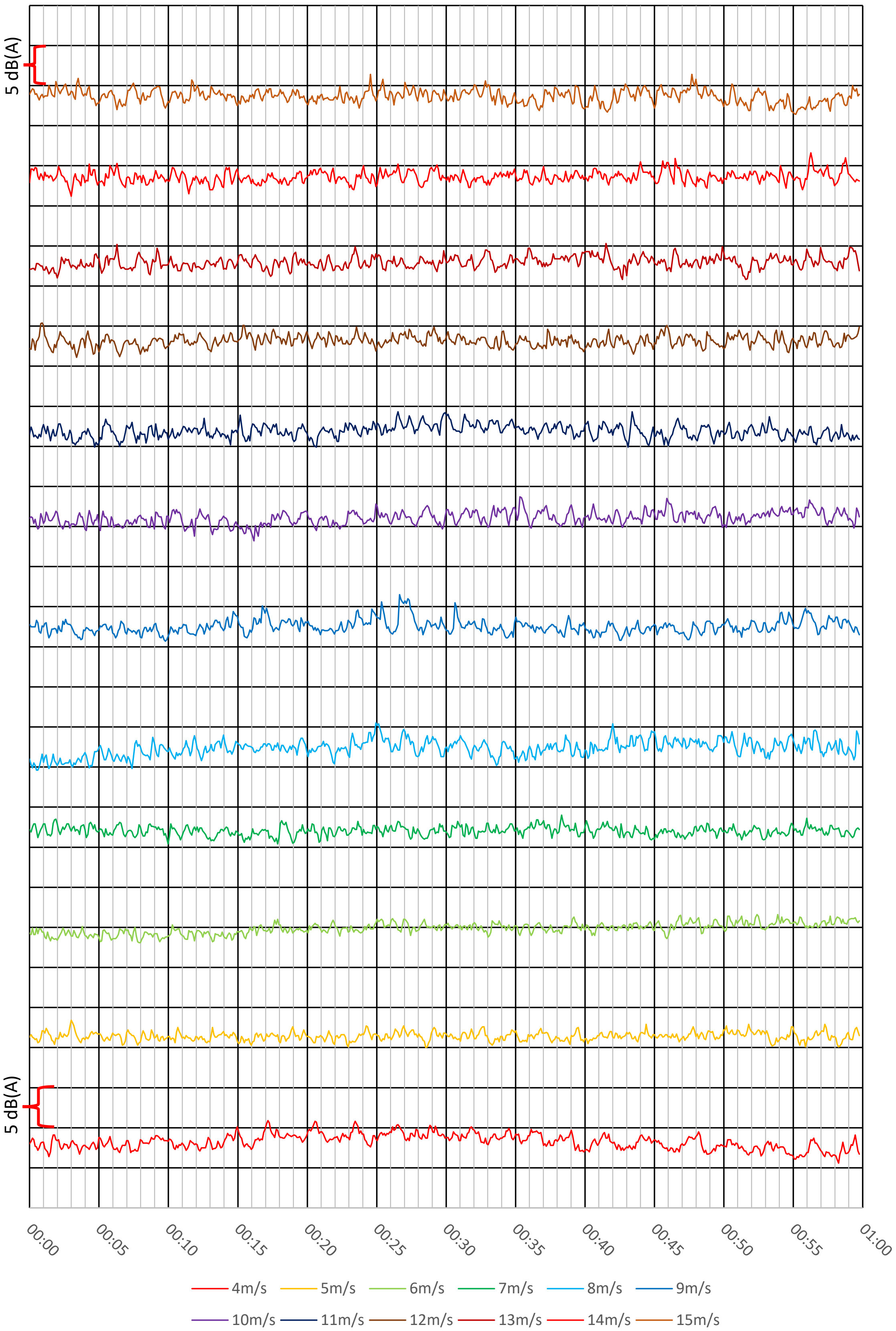


Figure 5: Amplitude modulation graphs.

Stockyard Hill Wind Farm

Acoustic Analysis of Wind Turbine

Generator 149

S3425.2C23

October 2022

sonus.

Chris Turnbull
Principal
ct@sonus.com.au
+61 (0) 417 845 720

Sonus Pty Ltd
17 Ruthven Avenue
Adelaide 5000 SA
+61 (8) 8231 2100
www.sonus.com.au

sonus.

Document Title : Acoustic Noise Test of Wind Turbine Generator 149

Document Reference: S3425.2C23

Date: October 2022

Author : Chris Turnbull, MAAS

© Sonus Pty Ltd. All rights reserved.

This report may not be reproduced other than in its entirety. The report is for the sole use of the client for the particular circumstances described in the report. Sonus accepts no responsibility to any other party who may rely upon or use this report without prior written consent.

sonus.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1 INTRODUCTION

Sonus has been engaged by Goldwind Australia Pty Ltd to conduct noise testing of wind turbine generator 149 (WTG149) at the Stockyard Hill Wind Farm, Victoria.

The purpose of the testing was to determine the apparent sound power levels, tonality, and amplitude modulation of the installed wind turbine generator 149, type GW3S.

Noise measurements of WTG149 were conducted on 18 July 2022 to 21 July 2022. The data acquisition and subsequent analyses were conducted in general accordance with the approach of the following:

- the International Standard *IEC 61400-11: 2012 Wind turbines – Part 11: Acoustic noise measurements techniques* (IEC 61400-11:2012) - to derive the overall sound power levels;
- the New Zealand Standard *NZS 6808:2010 Acoustics – Wind Farm Noise* (NZS 6808:2010)) – to determine the presence of excessive tonality and amplitude modulation; and,
- the International Standard *ISO 1996-2:2007 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels* (ISO 1996-2:2007) – as referenced by NZS 6808:2010 to assist in determining the presence of excessive tonality.

This report provides a summary of the noise testing and presents the results of the analyses.

2 TEST SITE DESCRIPTION

The Stockyard Hill Wind Farm is located approximately 35km west of Ballarat. The location of the tested wind turbine is shown on Figure 1.

The ground surface on the wind farm site in the area of the noise measurements is generally cropped. There are no significant reflecting structures at the wind farm or surrounding areas.

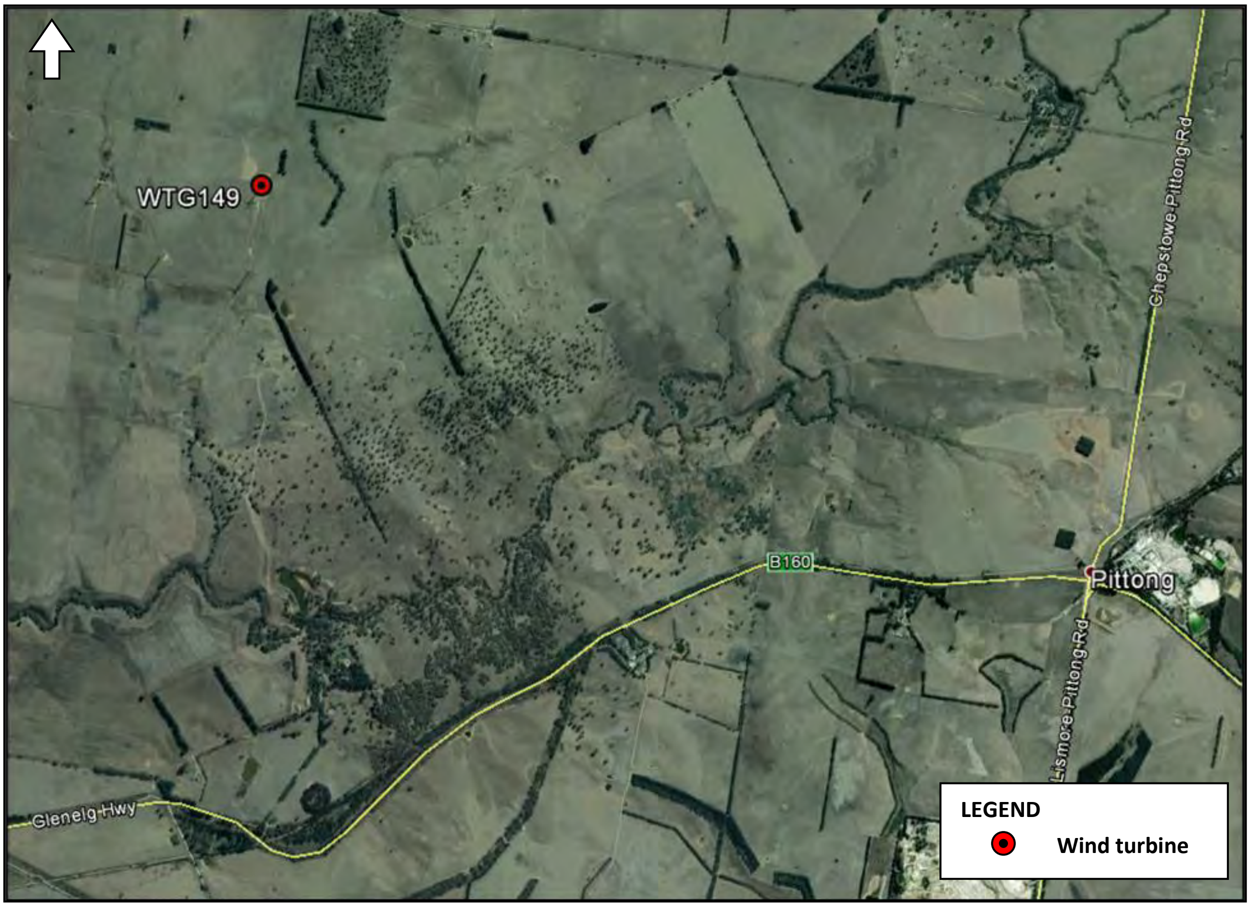


Figure 1: Tested wind turbine location.

sonus.

3 WIND TURBINE DETAILS

Table 1 provides the configuration of the tested wind turbine, WTG149.

Table 1: Details of WTG149.

Wind Turbine Details	
Manufacturer	Goldwind
Model	GW3S
Turbine ID	WTG149
Coordinates	714520 E 5830369 N
Operating Details	
Axis type	Horizontal
Rotor location	Upwind
Rotor diameter	140.2 m
Hub height	109 m (above ground level)
Tower type	Steel Tubular
Turbine speed	12 rpm
Rated power output	3570
Rated wind speed	11 m/s
Cut-in/cut-out wind speed	2.5 m/s 20 m/s
Control type	Blade Pitch
Rotor Details	
Blade manufacturer	Sinoma (Goldwind)
Blade type	Single piece fiberglass, with clean blades
Number of blades	3
Gearbox Details	
Type	None
Generator Details	
Manufacturer	CRRC (Goldwind)
Type	Permanent Magnet Direct Drive
Maximum speed	12 + 10% rpm

4 INSTRUMENTATION

4.1 Noise Measurement

Noise measurements were made using two Type 1 Rion sound level meters, a NL-52 and a NA-28, both equipped with one-third octave band analysers. The sound level meters were calibrated before and after the measurements using a Type 1 Rion NC-74 calibrator, with negligible drift observed.

A secondary wind screen was used for each sound level meter and was positioned over the microphone on the measurement board. Figure 2 shows a typical example of the setup used to conduct the monitoring.

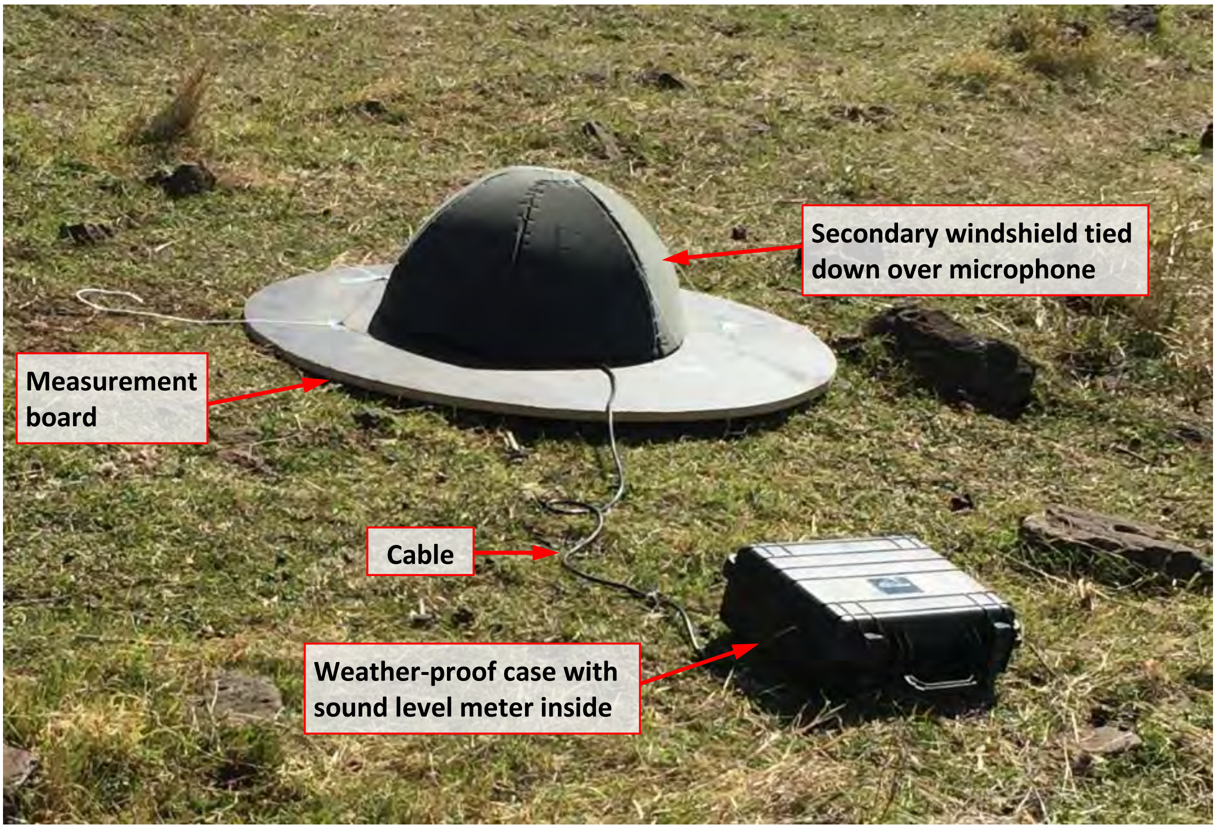


Figure 2: Microphone on the measurement board position with secondary screen.

The insertion loss of the secondary wind screen has been measured and is summarised in Table 2.

Table 2: Secondary wind screen insertion loss.

Frequency 1/3-octave band (Hz)	20	25	31.5	40	50	63	80	100	125	160
Insertion loss (dB)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.5	-0.3	-0.6	-0.2	-0.3
Frequency 1/3-octave band (Hz)	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**
Insertion loss (dB)	-0.3	0.1	0.3	1.2	2.0	2.7	1.9	0.9	1.1	2.1
Frequency 1/3-octave band (Hz)	**2000**	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**		
Insertion loss (dB)	1.5	2.1	2.5	2.3	2.5	2.7	3.1	3.6		

Figure 3 shows the location of the noise measurement instrumentation, positioned in relation to WTG149.

Figure 3: Photograph of the tested wind turbine, WTG149.

4.2 Wind Data

Wind speed data during the testing period were obtained from the nacelle wind measurement instrumentation at WTG149. Wind direction data were obtained from the nacelle angle position instrumentation at WTG149. All sets of data were adjusted to match the 10 second period required by IEC 61400-11:2012.

4.3 Other Instrumentation

The operational status of the turbine was determined using the grid-side active power as reported by the SCADA system for the turbine. For the purpose of this assessment, it has been assumed that the turbine is not operating where the grid-side active power is negative. It is noted that the turbine was considered to be not operating for some additional periods where the power data indicated that the turbine was ramping up or down from or to an 'off' state. Once again, the provided data were adjusted to match the 10 second period required by IEC 61400-11:2012.

Temperature, pressure, and rainfall data during the testing period were obtained from the *Bureau of Meteorology* website, for the weather station at the Ballarat Aerodrome.

5 ACOUSTIC DATA ACQUISITION

5.1 Measurement Position

Two sound level meters were placed simultaneously around the tested wind turbine, and spaced apart in an arc with respect to the wind turbine. The sound level meters were positioned in such a way that at least one was within 15° of the downwind position for the majority of the measurement period. The measurement positions are summarised in Table 3. The direction relative to the turbine corresponds to the degrees from north the measurement equipment is located at when observed from the turbine. Data from both locations has been used in the subsequent analysis.

Table 3: Microphone positions during the noise measurements.

Location	Coordinates		Slant Distance (m)	Direction Relative to Turbine (˚)
	Easting	Northing		
1	714544	5830211	194	170 (S)
2	714621	5830241	195	141 (SW)

5.2 Sound Pressure Level Data

The equivalent A-weighted sound pressure levels were measured continuously at the measurement positions during the measurement period. Each measurement was averaged over a period of 10 seconds.

During the measurement period, WTG149 was switched 'off' on several occasions to allow for background noise measurements to be conducted. In addition, the surrounding turbines WTG146, WTG147, and WTG148 were switched off for extended periods to facilitate the testing.

Prior to analysis, the following data were discarded:

- measurements with intruding intermittent background noise or activity such as when apparatus was being set-up, or when rain occurred;
- measurements where other nearby turbines were on;
- measurements during start-up or shut-down of WTG149; and,
- measurements corresponding to non-downwind conditions.

Following data discard, the resultant number of sound pressure level data points in each wind speed bin (±0.25 m/s wide centred at integer hub height wind speed), for the wind speed range between 4m/s and 16m/s, are summarised in Table 4.

Table 4: Resultant number of noise data points.

Wind speed, V_{HH} (m/s)	Number of Noise Data Points	
	WTG149 ON	WTG149 OFF
4	68	36
5	121	33
6	34	31
7	68	44
8	147	40
9	108	29
10	176	21
11	130	16
12	80	-
13	85	-
14	82	-
15	42	-
16	17	-

sonus.

6 NON-ACOUSTIC DATA ACQUISITION

6.1 Wind Data

6.1.1 Wind Speed Data

The wind speed during the measurement period was determined from the nacelle anemometer. The SCADA system recorded 3 second average wind speeds, approximately every 6 seconds. The first available 3 second average wind speed recorded within the 10 second noise average has been used for the correlations. The wind speed data was provided to Sonus by Goldwind and is understood to be comprised of measurements from the nacelle anemometer.

6.1.2 Wind Direction Data

IEC 61400-11:2012 requires the microphone measurement position to be within ± 15° of the nacelle direction. The nacelle direction data was recorded and provided by the SCADA computer program of the wind turbine. Noise measurements recorded when the measurement position was greater than ± 15° of the nacelle direction, were discarded. It is understood that the nacelle direction has previously been inaccurate, as such, while on site placing the monitoring equipment the calibration of the nacelle direction was checked. To this end, a photo was taken directly downwind of the turbine, and the time and location of this photo noted. This was then compared to the measured wind direction. The reported wind direction was then adjusted based on this comparison.

6.2 Other Measurements and Non-acoustic Data

6.2.1 Meteorological Conditions

The prevailing meteorological conditions during the noise measurements are summarised in Table 5. The temperature and pressure observations were taken at 9am. Where rain was identified during the testing period, 30-minute observations recorded at the Ballarat Aerodrome were used to remove periods which were affected by rain noise.

Table 5: Prevailing meteorological conditions during the measurements.

Measurement Date	Observation	Prevailing Condition
18 August 2022	Barometric pressure	100.88kPA
	Air temperature	8.8°C
	Precipitation	3mm
19 August 2022	Barometric pressure	101.58kPA
	Air temperature	6.5°C
	Precipitation	8mm
20 August 2022	Barometric pressure	102.09kPA
	Air temperature	7.8°C
	Precipitation	7.2mm
21 August 2022	Barometric pressure	102.62kPA
	Air temperature	6.5°C
	Precipitation	0.2mm

6.2.2 Roughness Length

The test site is farmland generally covered with grass and some vegetation. The surface roughness for this site is taken to be 0.05 m, which has been used to derive the standardised wind speed, referenced at 10m above ground level.

7 ANALYSIS

7.1 Apparent Sound Power Level

The apparent sound power level at each integer wind speed has been derived using the general procedure outlined in Section 9 of the IEC 61400-11:2012.

7.1.1 Analysis Procedure

The steps taken to derive the apparent sound power level at each integer wind speed for WTG149 are provided below:

1. All measured equivalent sound pressure levels at each 1/3 octave band between 20 Hz to 10 kHz are normalised to the measured overall equivalent sound pressure level. The 1/3 octave band levels between 20Hz and 10kHz are logarithmically summed and its difference with the measured overall level is arithmetically added to each 1/3 octave band levels.
2. The 1/3 octave band equivalent sound pressure levels are corrected for the influence of the secondary wind screen. The secondary wind screen insertion losses provided in Section 4.1 are arithmetically added to the 1/3 octave band levels[1]. The resultant overall sound pressure level is obtained by logarithmically summing the corrected one third octave sound pressure levels.
3. The 1/3 octave band equivalent sound pressure levels are sorted into wind speed bins, each ±0.25 m/s wide, centred at integer wind speeds. The total noise and background noise data are segregated into separate data sets.
4. The average 1/3 octave band equivalent sound pressure levels for each wind speed bin are determined logarithmically. The 1/3 octave band equivalent sound pressure levels at the bin centres are then calculated using linear interpolation between the bin average sound pressure level and wind speed values.
5. The background corrected wind turbine sound pressure levels are derived using the 1/3 octave band equivalent sound pressure levels (referenced to the bin centre) as follows:
   - "turbine off" sound levels are logarithmically subtracted from the "turbine on" sound levels where the "turbine off" level is at least 3 dB(A) below the "turbine on" 1/3 octave band equivalent sound pressure level.

[1] It is noted that the secondary wind shield was lost during the measurement period. For times after this occurred the measured noise levels have not been corrected for the presence of the secondary wind shield.

- In the case where the "turbine off" sound level is within 3 dB(A) of the 1/3 octave band "turbine on" sound pressure level, 3 dB(A) has been subtracted from the 1/3 octave band "turbine on" equivalent sound pressure level. These values have been noted as being affected by background noise.
- Where the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine on" noise levels is within 3 dB(A) of the logarithmic sum of each 1/3 octave band sound pressure level for the "turbine off" sound levels, the data has not been reported, in accordance with IEC 61400-11:2012.
- Where no "turbine off" sound level data was available, the "turbine on" sound levels were used with no adjustment.

6. The background corrected wind turbine sound pressure levels at each 1/3 octave band are used to calculate the apparent sound power levels at each integer wind speed using Equation (26) in the IEC 61400-11:2012. The slant distance for each measurement location is presented in Table 3.
7. The overall apparent sound power level at each integer wind speed is determined by logarithmically summing the 1/3 octave band apparent sound power levels.

7.1.2 Analysed Data Points

The data points (overall equivalent sound pressure levels) included in the analysis are shown in Figure 4.

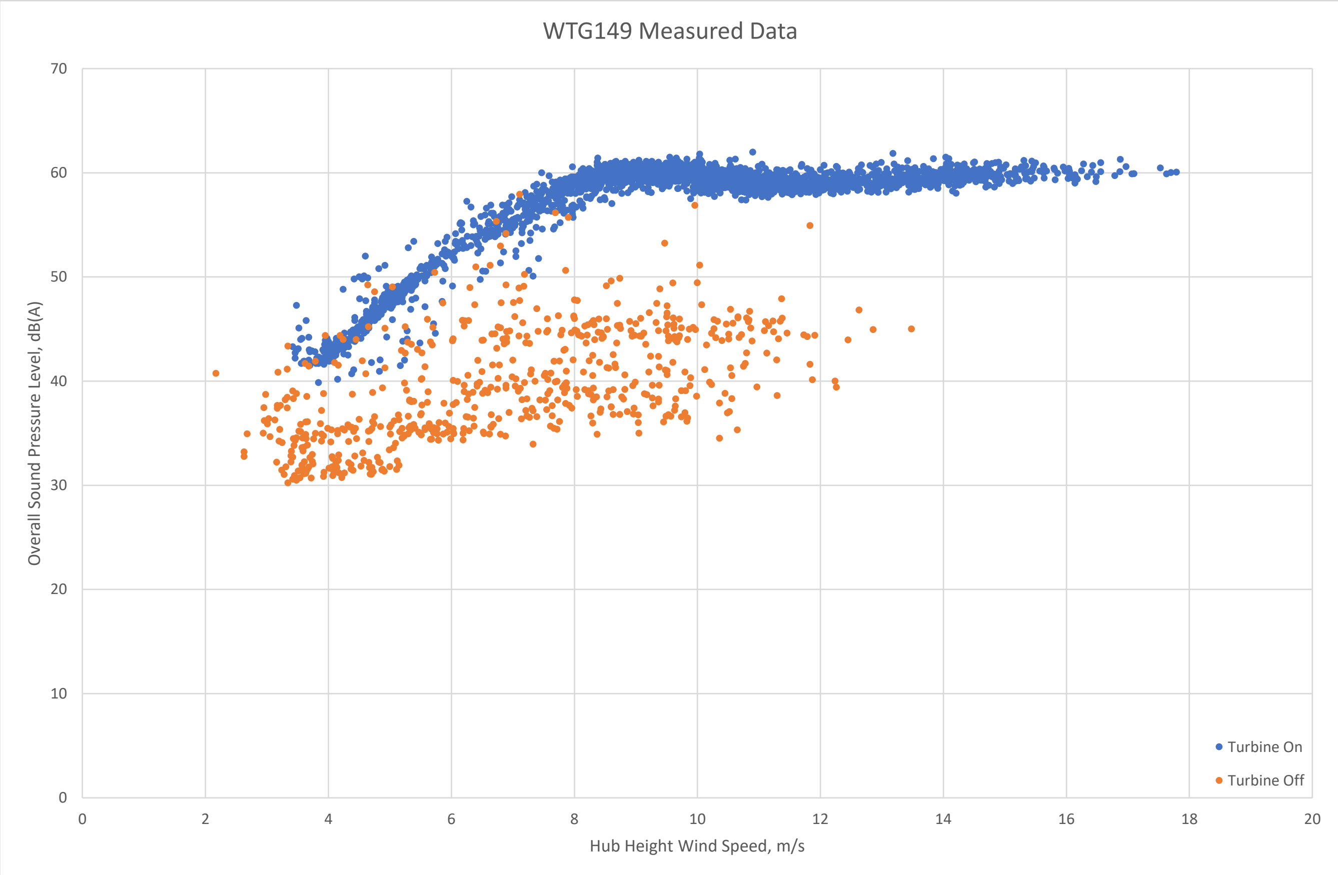


Figure 4: Analysed data points.

sonus.

7.1.3 Analysis Results

The derived apparent sound power levels are summarised in Table 6.

Table 6: Derived apparent sound power levels.

V_{HH} (m/s)	V_{10} (m/s)	L_{WA} (dB(A))	Sound Power Level (dB(A)) at each 1/3 Octave Band (Hz)																											
			20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
4	2.8	92.2*	48.7	65	[57.7]	59.7	68.5	66.8	69.6	73.6	76.9	80.0	81.6	82	82.9	83.3	82.5	81.4	80.8	80.3	80.1	[75.9]	[74.2]	#	#	#	#	[60.6]	[58.7]	#
5	3.4	98.0	54.5	62.0	72.0	66.1	69.3	74.1	75.7	79.3	82.6	86.6	87.4	88.3	89.1	89.6	88.9	88.0	86.9	85.0	[80.8]	78.1	78.4	75.3	71.8	[70.9]	66.0	#	#	#
6	4.1	103.5	62.9	68.1	70.3	73.7	76.7	80.5	83.7	85.6	88.0	91.2	93.0	94.3	94.5	94.8	94.0	93.3	92.3	91.3	88.3	84.7	83.0	77.9	74.7	[73.2]	[68.5]	#	#	#
7	4.8	106.0	63.9	68.3	72.1	74.5	77.5	80.4	83.7	86.5	89.1	93.4	94.6	96.1	97.4	98.4	97.9	96.0	94.4	93.0	[89.0]	87.3	[85.2]	[82.2]	[78.0]	#	#	#	#	#
8	5.5	109.4	63.9	68.5	72.3	75.9	79.7	82.7	85.8	89.2	91.9	95.3	97.2	98.9	100.1	101.5	101.2	99.5	97.9	98.0	95.8	93.3	91.8	88.9	84.6	80.2	72.9	64.3	#	#
9	6.2	110.7	65.3	70.1	74.3	77.9	81.5	84.7	88.0	90.9	93.7	96.6	98.3	100.0	101.4	102.5	102.0	100.6	98.7	100.3	97.8	95.7	93.9	91.3	87.3	83.3	78.8	72.9	[62.8]	#
10	6.9	110.4	64.8	69.9	74.1	77.6	81.3	84.4	87.7	90.7	93.6	96.5	98.1	99.8	101.1	102.3	101.8	100.3	98.3	99.9	97.4	95.3	93.3	90.8	87.4	83.1	78.4	69.8	#	#
11	7.6	109.7	64.6	69.9	73.9	77.7	81.5	84.7	88.0	90.8	93.4	95.9	97.3	99.1	100.2	101.1	100.4	99.0	97.4	99.5	97.3	96.0	94.2	93.1	89.8	83.6	76.9	70.3	[63.1]	[58.4]
12	8.3	109.9	65.3	70.4	74.5	78.4	82.0	85.1	88.5	91.3	94.0	96.5	97.7	99.5	100.4	100.9	100.1	98.9	97.3	99.8	97.7	96.2	94.9	94.5	92.5	86.2	79.2	74.1	68.1	62.1
13	9.0	110.0	65.7	70.6	74.8	78.6	82.3	85.4	88.9	91.6	94.3	96.6	97.7	99.6	100.4	100.5	99.2	98.5	97.0	100.4	98.0	96.6	95.6	96.3	94.4	87.4	79.6	71.6	65.4	61.3
14	9.6	110.5	66.5	71.3	75.3	79.0	82.6	85.9	89.4	92.1	94.9	97.3	98.4	100.3	100.9	100.7	99.2	98.5	97.0	100.6	98.3	96.9	96.3	98.0	96.3	89.2	81.6	75.1	69.1	63.3
15	10.3	110.7	66.4	71.1	75.3	79.1	82.7	85.9	89.5	92.3	95.2	97.6	98.6	100.5	101.0	100.8	99.1	98.3	96.8	100.3	98.2	96.9	96.5	99.1	97.4	88.7	80.1	72.3	65.9	62.2
16	11	110.7	66.7	71.7	75.8	79.5	83.2	86.1	89.6	92.1	95.2	97.5	98.5	100.5	101.0	100.9	99.5	98.6	96.8	100.3	98.4	97.3	96.9	98.9	96.0	88.2	82.2	75.9	70.4	66.6

- The background noise is higher than the total noise.

[ ] - The background noise is within 3 dB of the total noise.

* - The difference between the sum of the 1/3-octave bands of the total noise and the sum of the 1/3-octave bands of the background noise is between 3 and 6 dB.

V_{HH} is the hub height (109m) wind speed.

V_{10} is the standardised wind speed, referenced at 10m above ground level.

7.2 Tonality

The results of the testing period have been analysed to determine any presence of excessive tonality, in accordance with NZS 6808:2010. NZS 6808:2010 provides two methods to objectively assess the presence of excessive tonality, the simplified test method and the reference test method, outlined in sections B2.2 and B2.3, respectively.

7.2.1 Reference Test Method

NZS 6808:2010 does not provide specific instructions for the reference test method, but instead references the method outlined in Annex C of ISO 1996-2:2007, or another similar method. As such, ISO 1996-2:2007 has been used to inform this assessment.

Annex C of ISO 1996-2:2007 provides the following method, generally summarised into three steps:

1. *Narrow-band frequency analysis (preferably FFT-analysis);*
2. *Determination of the average sound pressure level of the tone(s) and of the masking noise within the critical band around the tone(s);*
3. *Calculation of the tonal audibility and the adjustment.*

Audio recordings were made continuously during the testing period. A selection of these audio recordings, each one minute long, that best represent the noise at each integer wind speed were chosen, such that they were not influenced by extraneous noise sources such as birds or insects and were as close as possible to the integer wind speed for the full minute period.

Based on the approach provided in ISO 1996-2:2007, the selected audio recordings were analysed using an automated program for the presence of excessive tonality. This program has been designed to determine whether a character penalty is warranted in accordance with the method outlined in ISO 1996-2:2007. This method considers the audibility of any potential tones with respect to any masking noise and determines their impact through the use of a character penalty. For a potential tone to be audible, the tonal audibility must be greater than or equal to 4 dB. After running the program, one potential tone was identified at 8m/s, however, it was not sufficiently audible and therefore did not attract a character penalty. The results of this program can be seen in the below table. As no character penalties were reported at any wind speed or frequency, no tones are considered to be present.

Table 7: Tonality analysis results.

Wind speed (m/s)	Tonal Audibility (dB)	Frequency (Hz)	Tonal Adjustment (dB)
4	-	-	0
5	-	-	0
6	-	-	0
7	-	-	0
8	-0.4	4040	0
9	-	-	0
10	-	-	0
11	-	-	0
12	-	-	0
13	-	-	0
14	-	-	0
15	-	-	0
16	-	-	0

7.2.2 Simplified Test Method

Section B2.2 of NZS 6808:2010 provides an alternate method for determining the presence of tonality. This method has been used as an additional check for the presence of excessive tonality and was conducted for all "Turbine On" data points, the points shown in blue in Figure 4.

Section B2.2 of NZS 6808:2010 provides the following method, reproduced below:

> *A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one-third octave-bands in the Z-frequency-weighted sound spectrum. An adjustment for tonality shall be applied if the sound level in a Z-frequency-weighted one-third octave-band exceeds the arithmetic mean of the sound levels in both adjacent bands by more than the values given in table B1. For the purposes of this method linear, zero, or flat frequency-weighting shall be equivalent to Z-frequency-weighting.*

Table B1 – One-third octave-band level differences

One-third octave-band	*Level difference*
25 – 125 Hz	*15 dB*
160 – 400 Hz	*8 dB*
500 – 10000 Hz	*5 dB*
NOTE – At frequencies below 500 Hz the level difference could be too severe and tones might be identified when none is actually audible. For complex spectra the method is often inadequate and the reference method should be used (see B2.3).	

The results of this additional check indicate that no tonal penalty is required. This is consistent with the outcome of the reference test method, indicating that the operation of the turbine does not exhibit excessive tonality.

7.3 Amplitude Modulation

The results of the testing period have been analysed to determine any presence of excessive amplitude modulation, in general accordance with the interim test method presented in NZS 6808:2010.

NZS 6808:2010 states the following:

> *No objective test for amplitude modulation has been standardised. If a local authority enforcement officer or an acoustics advisor to a local authority considers that a wind farm creates sound with a clearly audible amplitude modulation at a noise sensitive location, an adjustment of +5 dB shall be applied to the wind farm sound level at that location for the wind conditions under which the modulation occurs.*
>
> *In making an assessment under B3.1 [the above], modulation special audible characteristics are deemed to exist if the measured A-weighted peak to trough levels exceed 5 dB on a regularly varying basis, or if the measured third-octave band peak to trough levels exceed 6 dB on a regular basis in respect of the blade pass frequency.*

As for the tonality assessment, a representative period for each integer wind speed has been analysed for excessive amplitude modulation. The graphs below show an example of the results of this analysis for each integer wind speed. It is noted that the horizontal lines are spaced 5 dB apart to illustrate compliance with the requirements of NZS 6808:2010 for the overall A-weighted level. As the regular peak to trough level does not exceed 5 dB for any integer wind speed, it can be determined that excessive amplitude modulation is not present in the noise profile of the wind turbine.

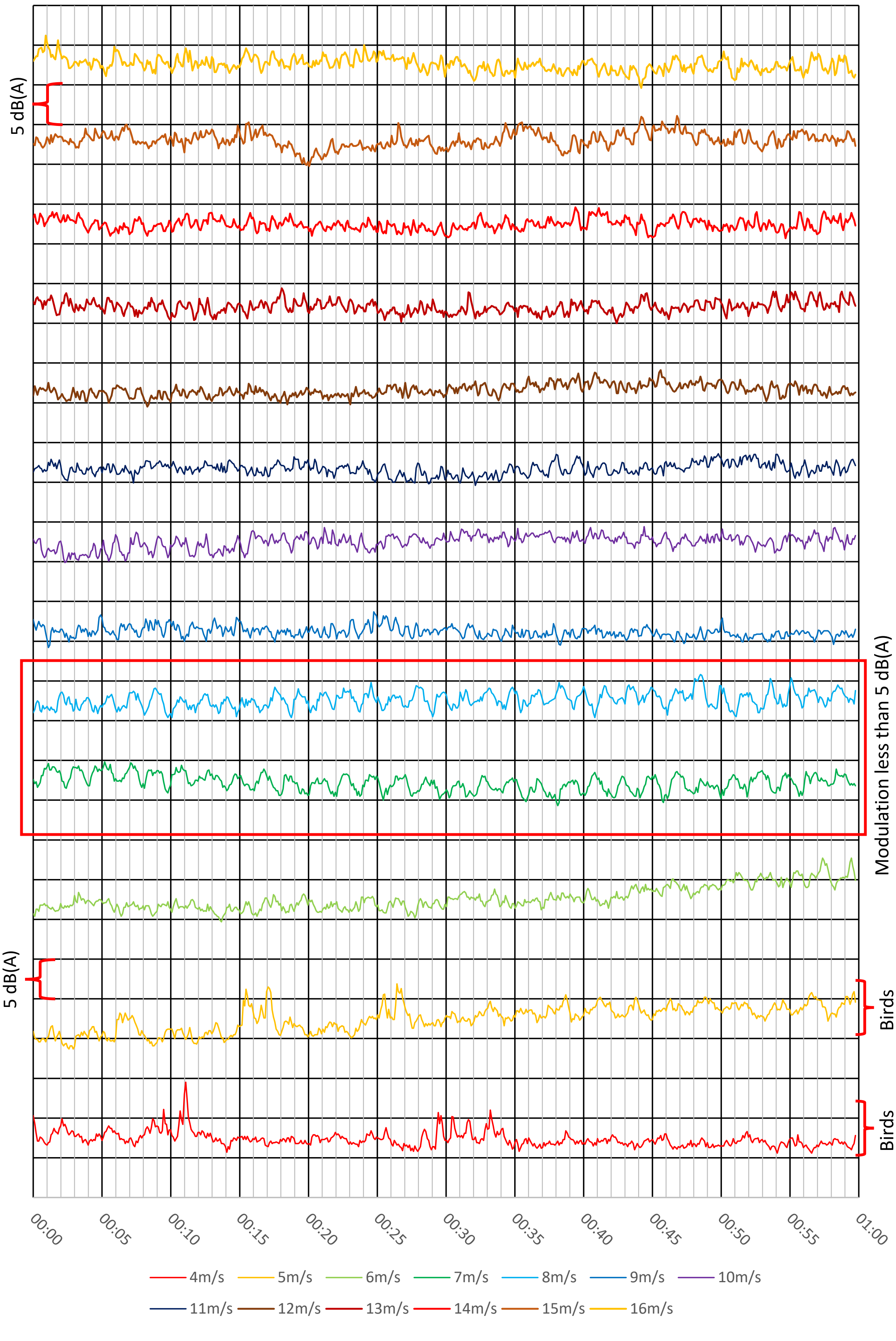


Figure 5: Amplitude modulation graphs.

13 APPENDIX H: ENDORSED NOISE COMPLIANCE TEST PLAN

Stockyard Hill Wind Farm

Noise Compliance Test Plan

January 2018

ENDORSED TO COMPLY
WITH CONDITION
26

OF PLANNING PERMIT
PL-SP/05/0548/A

sonus.

Chris Turnbull
Principal
Phone: +61 (0) 417 845 720
Email: ct@sonus.com.au
www.sonus.com.au

PLANNING AND ENVIRONMENT ACT 1987
PLANNING SCHEME PYRENEES
PERMIT NO. PL-SP/05/0548/A
ENDORSED PLAN
SHEET 1 OF 36
SIGNED S. Menzies FOR
MINISTER FOR PLANNING
DATE: 17/5/18

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 2 OF 36

Contents

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 3 OF 36

GLOSSARY

A weighting	Frequency adjustment representing the response of the human ear.
Background Noise Assessment	Contained in Sonus Report: Stockyard Hill Wind Farm Background Noise Monitoring S3425.2C3
dB(A)	A weighted noise level measured in decibels.
IEC61400-11	International Electrotechnical Commission Standard IEC61400-11 (Edition 3) 2012 Wind turbines – Part 11: Acoustic noise measurement techniques
Intermediate Position	An additional noise logger location between the wind farm and a receptor location. The intermediate position will be selected to minimise noise from sources other than the wind farm (such as wind in trees and road traffic).
ISO1996.2	International Standards Organisation ISO1996.2 (2007) Acoustics — Description, measurement and assessment of environmental noise — Part 2: Determination of environmental noise levels
L_{A90}	The A weighted sound pressure level that is exceeded for 90 per cent of the time over which a given sound is measured. The L_{A90} measured over a 10 minute time period is commonly termed "background sound level" and "post-installation sound level" with respect to wind farms.
The Permit	Permit Number: PL-SP/05/0548/A
NZS6808:2010	New Zealand Standard NZS 6808:2010 Acoustics – The assessment and measurement of sound from wind turbine generators
Residential Logging Locations	Locations where noise loggers are placed at residences

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 4 OF 36

1 PLANNING PERMIT CONDITIONS

The Permit provides conditions for the operation of the Stockyard Hill Wind Farm. This noise compliance test plan provides the procedure for determination of compliance with the operational noise conditions in accordance with Permit Condition 26. The relevant Permit Conditions are repeated below:

PERFORMANCE REQUIREMENT

21. The operation of the wind energy facility must comply with New Zealand Standard 6808:2010, Acoustics – Wind Farm Noise (the Standard) or as modified by this condition to the satisfaction of the Minister for Planning. The following requirements apply:

- *a) The operator must ensure that at any hub height integer wind speed, wind farm sound levels at non-participant dwellings existing on 12 May 2016 do not exceed a noise limit of 40dB LA90(10 min), provided that where the circumstances specified in Condition 21(b) apply, the noise limit of 40dB L A90(10 min) will be modified as specified in Condition 21(b).*
- *b) At the specified non-participant dwelling assessment positions referred to in Condition 28(b), the noise limit of 40dB LA90(10min) referred to in Condition 21(a) will be modified in the following way when the following circumstances exist:*
  - *i. where the background sound level is greater than 35 dB LA90(10 min), the noise limit will be the background sound level LA90(10 min) plus 5 dB;*
  - *ii. where a high amenity noise limit has been found to be justified, as defined by section 5.3 of the Standard, for specific locations determined to be high amenity areas following procedures outlined in clause C5.3.1 of the Standard.*
- *c) At the specified non-participant assessment positions referred to in Condition 28(b), the wind farm sound level at dwellings will be modified in the following way when the following circumstances exist: i. where special audible characteristics, including tonality, impulsive sound or amplitude modulation occur, the sound level will be modified by applying a penalty of up to + 6 dB L90 in accordance with section 5.4 of the Standard;*
- *d) The operator must ensure that at any hub height integer wind speed, wind farm sound levels at participant dwellings do not exceed a noise limit of 45dB LA90(10 min), provided that where the circumstances specified in Condition 21(e) apply, the noise limit of 45dB LA90(10 min) will be modified as specified in 21(e).*
- *e) At the specified participant dwelling assessment positions referred to in Condition 28(b), the noise limit of 45dB LA90(10min) referred to in Condition 21(c) will be modified where the background sound level is greater than 40 dB LA90(10 min), the noise limit will be the background sound level LA90(10 min) plus 5 dB.*
- *f) For the purpose of this condition, a participant dwelling means a dwelling on land listed in the Address of the Land in this permit or where the landowner has a written agreement relating to a dwelling on their land which addresses noise from the permitted wind turbines. A non-participant dwelling means any dwelling that is not a participant dwelling. Evidence of the agreement must be provided to the satisfaction of the Minister for Planning upon request, and must be in a form that applies to the land for the life of the wind energy facility.*

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 5 OF 36

NOISE COMPLIANCE TESTING PLAN

26. Before the wind energy facility is commissioned, a noise compliance testing plan must be prepared to the satisfaction of the Minister for Planning meeting the following requirements:

a) the noise compliance testing plan must be prepared by a suitably qualified and experienced acoustics expert;

b) the noise compliance testing plan must include a plan for noise monitoring to assess noise levels after construction of the wind energy facility and a plan for concurrent assessment of the presence or otherwise of special audible characteristics;

c) the noise compliance testing plan must include advice on timing of the assessment including defining when commissioning of the wind energy facility, or an identified stage of it, will occur, and when the compliance noise monitoring results will be provided to the Minister for Planning. That time must not be more than 120 days after commissioning unless with the further consent of the Minister for Planning;

d) if the Wind Energy Facility is to be constructed in stages a noise compliance testing plan may be prepared for each stage before the development of that stage commences and those plans submitted to the Minister for Planning for approval provided that where a dwelling might be affected by noise from more than one stage that is accounted for;

e) the noise compliance testing must be carried out at locations defined in accordance with the Standard, including consideration for alternative locations for assessment (if locations become inaccessible in future).

f) When approved, the plan will be endorsed by the Minister for Planning and will then form part of this permit.

g) The noise compliance testing plan must be accompanied by a report from an environmental auditor appointed under the Environment Protection Act 1970 with their opinion on the methodology and contained in the noise compliance testing plan. If a suitable auditor cannot be engaged, the proponent may seek the written consent of the Minister for Planning to obtain an independent peer review of the noise compliance testing plan instead.

27. The noise compliance testing shall be carried out by a suitably qualified and experienced acoustics expert in accordance with the approved testing plan under Condition 26, this testing must be:

- *generally in accordance with the Standard with the variations described in this permit; or*
- *subject to approval by the Minister for Planning by an 'on/off' or 'shutdown' method as referred to in sections 7.1.2 and 7.7.1 of the Standard.*

  If this method is used, it must have been earlier approved by the Minister for Planning as a part of the noise compliance testing plan and must be designed by a suitably qualified and experienced acoustics expert;

The presence or otherwise of special audible characteristics must be assessed concurrently at all the subject dwellings over a range of operational and meteorological conditions.

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 6 OF 26

NOISE COMPLIANCE ASSESSMENT

28. For the purposes of determining compliance, the following requirements apply:

a) Acoustic compliance reports shall be prepared by a suitably qualified and experienced independent acoustic engineer to demonstrate compliance with the noise limits specified in the Standard.

b) Noise assessment positions must be located according to the Standard, and shown on a map. The map shall clearly identify each noise assessment position as either a participant or non-participant dwellings.

c) An initial acoustic compliance report must be submitted within six months of the commissioning of the first turbine, and at six monthly intervals thereafter until full operation has commenced (following completion of construction and commissioning).

d) A final compliance report must be submitted to the Minister for Planning after a 12 month period following the commencement of full operation of the facility.

e) Compliance reports must be publicly available.

f) Following facility commissioning, all complaints shall be managed following procedures set out in Condition 29 and any plan endorsed under Condition 30.

g) All noise compliance reports must be accompanied by a report from an environmental auditor appointed under the Environment Protection Act 1970 with their opinion on the methodology and results contained in the noise compliance testing. If a suitable auditor cannot be engaged, the proponent may seek the written consent of the Minister for Planning to obtain an independent peer review of the noise compliance testing report instead.

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 7 OF 36

2 NEAR FIELD AND INTERMEDIATE TESTING

Near field and intermediate testing is proposed for the purpose of determining the character of the noise from the turbines and enabling noise from other sources to be excluded from the noise at Residential Logging Locations. The near field testing also provides an opportunity to confirm that the input assumptions for the pre-construction stage assessment before the total construction and commissioning of the wind farm.

The measurements will be in general accordance with IEC61400-11 Edition 3.0 (2012) including measurement locations and calculation of sound power level.

The tonality calculation will be conducted in accordance with Appendix C of ISO1996.2 (2007) for representative time periods at each integer wind speed.

An objective test for modulation has not been established by NZS6808:2010 or in any Australian jurisdiction. An "interim test method" was provided in NZS6808:2010 in the absence of a more robust method. The modulation testing procedure will be based on the interim method in NZS6808:2010 and will be conducted for representative time periods at each integer wind speed.

The outcome of the measurements and analysis for each integer wind speed from cut-in to the wind speed at rated power will be:

- The apparent sound power level (IEC61400-11);
- The tonal adjustment K_t (ISO1996.2) and tonal frequency for any tones present;
- An assessment of amplitude modulation (NZS6808 Interim Test Method)

The apparent sound power levels will be used to determine the wind speed at which the highest sound power level is emitted from the turbines. If the noise at Residential Logging Locations continues to increase at wind speeds above the wind speed of highest noise emission, this will indicate that the noise is from sources other than the turbines (most commonly wind in trees for high wind speed conditions.

The tonal adjustment and tonal frequency is used to assist in determining the wind speeds and frequencies of potential tones at Residential Logging Locations.

Where the data indicate a measurable modulation trace at the blade pass frequency that exceeds the objective criteria in Section B3.2 of the NZS6808:2010 for the overall A-weighted noise level, longer term testing at the Residential Logging Locations will be conducted.

Loggers may be placed at Intermediate Positions between the turbines and receptors. These loggers would operate at the same time as the residential loggers and would assist in determining the contribution of noise from the wind farm as well as providing a calibration point for any required noise modelling.

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 8 OF 36

3 NOISE COMPLIANCE TESTING

The near field and intermediate test data will be used to support the following noise compliance testing regime, to satisfy the operational noise related Permit Conditions.

3.1 Residential Logging Locations

Compliance testing will be conducted at the locations listed in Table 1 subject to permission for access being granted. The Residential Logging Locations have been selected using the following rationale:

- The closest non-associated residences have been preferred;
- The locations have been dispersed around the various turbine clusters; and
- A sufficient number of locations have been selected to test the pre-construction noise modelling.

Alternate house locations are also provided in the event that access to the proposed property is not available. If permission is not granted for access to the alternate house locations, further alternatives will be considered. These locations have also been overlayed on a map showing the permitted turbine layout in Figure 1.

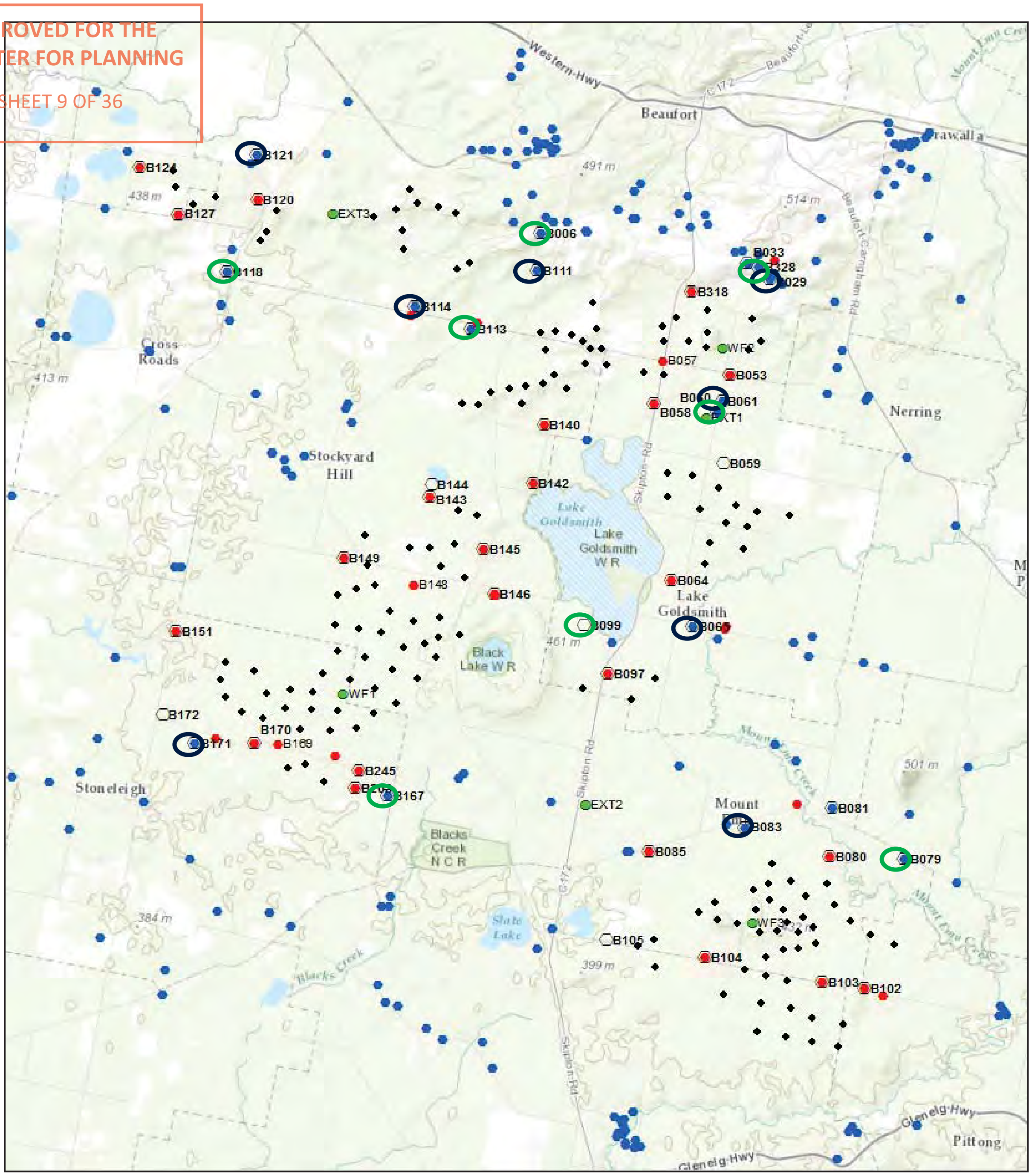
Table 1 Residential Logging Locations and Alternate Locations

House	Easting (m)	Northing (m)	Alternate House
B006	706598	5851419	B113
B029	712691	5850227	B328
B061	711425	5846998	B060
B065	710659	5841003	B099
B083	712071	5835637	B079
B111	706549	5850422	B006
B114	703278	5849504	B113
B121	699065	5853496	B118
B171	697412	5837902	B167

The location of the equipment will be consistent with the positions documented for the background noise assessment, subject to any changes to the local conditions that might result in modified results such as the construction of structures, change in vegetation or the installation of pumps or air conditioning units. The changes will be documented and the rationale provided for any alternative location.

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 9 OF 36



LEGEND

- Proposed location
- Alternate location
- Background noise location
- Wind mast
- Wind turbine (Permitted Layout)
- Participant dwelling
- Non-participant dwelling

Figure 1 Proposed and alternate locations for compliance noise logging

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 10 OF 36

3.2 Equipment

Sound level meters with a noise floor no greater than 20 dB(A) will be used. The equipment will be either Class 1 or Class 2 sound level meters in accordance with the Australian Standard *AS 1259-1990 Acoustics – Sound Level Meters and IEC 61672.1-2004 Electroacoustics – Sound Level Meters* as relevant.

A wind shield with a diameter of at least 100mm will be used to minimise noise on the microphone.

A calibrated reference sound source will be used before and after the compliance testing regime.

3.3 Data

The compliance testing will collect L_{90} data made continuously over 10 minute intervals.

Data filtering will remove time periods:

(i) affected by rain, hail or wind based on a weather logger placed at an equivalent location to one of the noise loggers. Data is adversely affected where precipitation occurs in a 10 minute period or where a wind speed greater than 5 m/s is exceeded for 90% of a 10 minute period;

(ii) when the closest WTGs have not been connected to the grid during the current 10 minute period; and

(iii) considered abnormal, such as during local construction or maintenance activities.

Further data filtering may remove time periods or frequency content where noise data collected at an Intermediate Position confirms that the source of the noise at a receptor is not the wind turbines. For example, noise data collected in a particular 10 minute interval at a receptor may be removed:

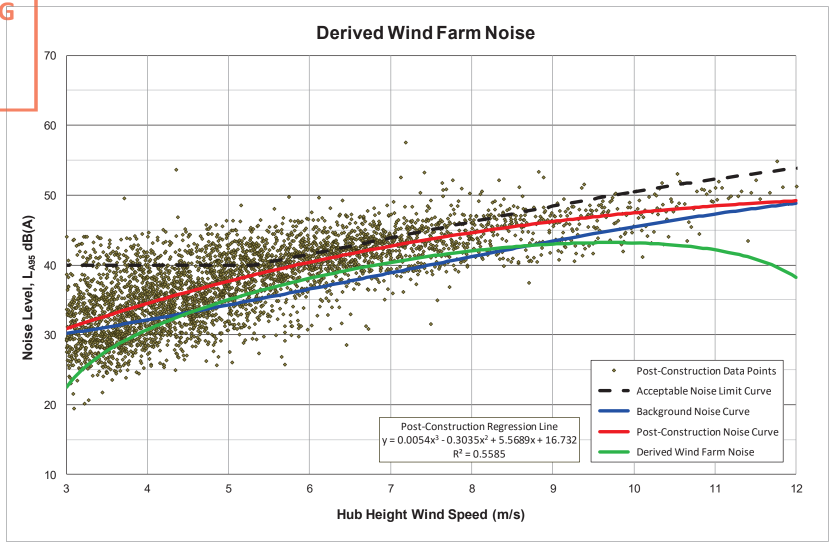
- if the noise measured in the same period at the intermediate position (closer to the turbines) is a lower level; or
- if the frequency content of the noise at the receptor is not consistent with the frequency content at the intermediate position.

Following removal of the data and application of applicable penalties for special audible characteristics (refer below), all of the remaining noise data for the full monitoring period will be correlated with the corresponding hub height wind speed data for each monitored receptor.

If the intermediate position has not been used to remove data points, the wind farm noise contribution at the Residential Logging Location will be derived by logarithmically subtracting the background noise curve from the curve generated by the compliance testing data correlation.

An example of a wind farm noise contribution line derived from the post-construction measured noise regression line and background noise curve is shown in the figure below.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 11 OF 36



3.4 Supplementary Testing

The residential logging method of NZS6808:2010 cannot be used in all circumstances to demonstrate compliance. This is primarily related to changes in local conditions or extraneous noise sources when compared to the conditions and noise sources that existed at the time of the original testing regime.

Where the residential logging method of NZS6808:2010 cannot be used to demonstrate compliance, then the alternate "on/off" compliance testing will be conducted as follows:

- Only at Residential Logging Locations where the primary test method cannot be used to demonstrate compliance;
- Only at integer wind speeds where the primary test method cannot be used to demonstrate compliance
- With the noise monitoring equipment at the same position where the primary test had been conducted, or if that position is considered to be a factor in the inability of the primary test to demonstrate compliance, at an equivalent position with respect to turbine noise at the Residential Logging Location, but which has a higher turbine to background noise level ratio;
- Conducted under a downwind condition. A downwind condition is defined as the wind direction at the relevant wind mast being within 45 degrees of the direct line from the closest turbine to the dwelling;
- Over a minimum interval of 2-minutes with the wind farm operational, then a measurement over the same interval with the wind farm shut off to obtain the background noise level;
- monitoring the wind speed and direction over the measurement intervals to identify the comparable "on" and "off" measurements.
- repeating the above "on" and "off" process to collect at least 3 intervals with comparable wind speed and direction conditions at each integer wind speed of interest.

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 12 OF 36

3.5 Special Audible Characteristics – Tonality

As the noise from wind farms reduces with distance, so too does the audibility of tones. Therefore, testing at Residential Logging Locations will only be conducted if the tonal adjustment at a near field test was greater than 0 at any wind speed. The testing will be conducted;

- in accordance with Appendix D of ISO1996.2;
- for the specific tonal frequencies identified in the near field tests as having a tonal adjustment greater than 0 dB;
- for each 10 minute period at the wind speeds where the tonal adjustment was greater than 0 dB in the near field tests.

For each 10 minute period where tonality is identified (and there is no evidence that the tone is from a source other than the wind farm), the relevant adjustment K_t from the near field tests will be added to the measured noise level, prior to correlation with wind speed.

3.6 Special Audible Characteristics – Amplitude Modulation

In a similar way as the tonality testing, amplitude modulation testing at Residential Logging Locations will be conducted if the objective criteria for the overall A-weighted noise level in Section B3.2 of the NZS6808:2010 are exceeded in the near field test.

The testing at Residential Logging Locations will be conducted:

- in accordance with Section B3.2 of the NZS6808:1998;
- for the specific wind speeds identified in the near field tests as having the special audible characteristic of amplitude modulation;

For each 10 minute period where excessive amplitude modulation is identified (and there is no evidence that the amplitude modulation is from a source other than the wind farm), an adjustment of 5 dB(A) will be added to the measured noise level, prior to correlation with wind speed.

It is recognised that the methodology outlined in NZS6808:2010 is an “interim test method”. Should a more widely accepted methodology become available prior to the above testing period, then subject to approval by the responsible authority, the framework outlined above might be superseded. For example, the UK Institute of Acoustics Amplitude Modulation Working Group (AMWG) Hybrid Method (August, 2016) could be considered.

3.7 Testing Schedule

Based on discussions with SHWF representatives, targeted commissioning dates are currently 15 April 2019 for the first turbine and 15 March 2020 for final turbine; however these dates are subject to change and may vary by up to 6 weeks either side of the target date.

sonus.

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 13 OF 36

Between commissioning of first turbine and commissioning of final turbine

The near field testing at a single turbine will commence within 5 months of the commissioning of the first turbine. The near field testing at one additional turbine will be repeated every 6 months from the date of the previous near field test until all turbines are commissioned. A preliminary report will be prepared and provided to the Minister within 1 month of each of the near field tests. These preliminary reports will indicate any potential concerns regarding achieving the criteria at residences based on the measured sound power levels.

Following commissioning of final turbine

Testing at Residential Logging Locations will commence within 1 month of the commissioning of the final turbine and will collect data for at least 6 weeks at each location. A report will be prepared and provided to the Minister within 120 days of commissioning of the final turbine.

12 months after final commissioning

A report will be prepared and provided to the Minister after 12 months of the final turbine commissioning. The report will summarise all noise compliance monitoring including near field testing, testing at Residential Logging Locations and any testing in the first 12 months following commissioning conducted in accordance with the Complaint Investigation and Response Plan.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 14 OF 36

Goldwind Capital (Australia) Pty Ltd

Stockyard Hill Wind Farm

Noise Assessment Peer Review and Compliance Assessment

R01

Issue | 23 March 2018

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 257886-00

Arup
Arup Pty Ltd ABN 18 000 966 165

Arup
Level 17
1 Nicholson Street
East Melbourne VIC 3002
Australia
www.arup.com

ARUP

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 15 OF 36

Document Verification

ARUP

Job title		Stockyard Hill Wind Farm			**Job number** 257886-00
Document title		Noise Assessment Peer Review and Compliance Assessment			**File reference**
Document ref		R01			
Revision	**Date**	**Filename**	001ReportKAB.docx		
Draft 1	12 Oct 2017	**Description**	First draft		
			Prepared by	Checked by	Approved by
		Name	Kym Burgemeister	David Spink	David Spink
		Signature			
Issue	23 Mar 2018	**Filename**	Report_Final		
		Description	Issue report, including Auditor's Declaration		
			Prepared by	Checked by	Approved by
		Name	Kym Burgemeister	David Spink	David Spink
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 16 OF 36

Issue Document Verification with Document ✓

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 17 OF 36

Contents

Appendices

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 18 OF 36

Auditor's Declaration

The report attached to this Declaration provides a summary of a peer review of documentation provided for assessment of compliance of the Stockyard Hill Wind Farm to be operated by GoldWind Capital (Australia) Pty Ltd (GoldWind) with the relevant requirements of the Planning Permit (Permit No PL-SP/05/0548/A) (Planning Permit) issued under the Pyrenees Planning Scheme' 8/6/2017.

Objective

The Planning Permit requires that an Environmental Auditor appointed under the *Environment Protection Act 1970* (or other appropriately qualified person approved by the Minister) is to be engaged to undertake a review and provide an opinion on the methodology and results contained in documentation supplied by GoldWind for:

- Condition 23 - Noise modelling assessment
- Condition 26 - Noise compliance testing plan

The Declaration and accompanying report has been prepared as specified in the *Policy and Planning Guidelines for Development of Wind Energy Facilities in Victoria* (DELWP, January 2016) (Guideline), for consideration by the Minister for Planning.

Review Process

The Auditor opinion on each of these conditions was based on the information provided by Goldwind noted below, with technical assistance provided by Dr Kym Bergemeister (Audit Specialist Support Team Member, Arup Pty Ltd).

With respect to the Guideline, the audit has been undertaken in a manner and format consistent with the accepted EPA Auditor requirements[1]. The report accompanying the Declaration is consistent with EPA Auditor requirements, and "thorough but concise" as noted in the Guideline.

Declaration

I, David Spink, declare that I and Dr Kym Bergemeister (Audit Specialist Support Team Member) have reviewed the following reports:

- *Stockyard Hill Wind Farm Background Noise Monitoring*, Sonus Report S3425.2C3, September 2017

[1] *Environmental auditor guidelines for appointment and conduct*, Environmental Protection Authority Victoria, Publication 865.12. December 2016.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 19 OF 36

- *Stockyard Hill Wind Farm Pre-Development Noise Assessment*, Marshall Day Acoustics Report 001 R01 20170840, 9 October 2017
- *Stockyard Hill Wind Farm Pre-Development Noise Assessment*, Marshall Day Acoustics Report 001 R02 20170840, 16 October 2017
- *Stockyard Hill Wind Farm Pre-Development Noise Assessment*, Marshall Day Acoustics Report 001 R04 20170840, 20 December 2017
- *Stockyard Hill Wind Farm*, Draft Noise Compliance Test Plan, Sonus Report S3425.2C4, September 2017.
- *Stockyard Hill Wind Farm*, Noise Compliance Test Plan, Sonus Report S3425.2C5, January 2018.

(Note that the original reference documentation has not been reviewed in detail, for example, the Turbine sound power reference information provided to MDA by Goldwind);

and assessed these against the relevant conditions of the Planning Permit Planning Permit PL-SP/05/0548/A, Pyrenees Planning Scheme, 8/6/2017, and relevant standards.

I hereby declare that I am of the opinion that the methodologies and findings contained in these reports comply with the relevant requirements of the Planning Permit. I found the reports to be comprehensive, complete, and appropriately applying industry standards, and that the findings can be reasonably relied on for assessment of the performance of the facility.

This determination comes with the following findings and qualifications provided in the accompanying report:

- **Background noise monitoring**

  Whilst this component is not strictly a condition of the Planning Permit, assessment of predicted operational noise levels requires appropriate confidence in the methodology and outcomes of the background noise monitoring.

  While the methodology used was not strictly in accordance with the applicable New Zealand standard, it was concluded that the approach taken was appropriate. Furthermore, the Noise Modelling Assessment (see below) adopted a conservative approach and only considers the minimum criteria value at each assessment location. Therefore, the background noise level data is less critical than it would otherwise be.

- **Noise modelling assessment (Condition 23)**

  Marshall Day Acoustics has undertaken the *Pre-Development Noise Assessment*. The assessment is generally undertaken in accordance with NZS 6808-2010 as required by the Victoria Planning Provisions.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 20 OF 36

It is noted that the adoption of a limit for participating landowners is not strictly considered under NZS 6808:2010, but is discussed in the Working Group on Noise from Wind Turbine recommendations (ETSU-R-97)[2] and the South Australian wind farm environmental guidelines[3]. The Auditor concurs with the audit finding that adopting a 45 dB(A) base noise limit for participating landowners is reasonable, on the basis of adopting best practice.

While background noise level measurements have been undertaken for the Project, the approach used in the assessment is to adopt the 'Base Limit' at all receivers regardless of whether higher noise levels might be allowable at high wind speeds using the 'background +5' approach. It is agreed that this is a conservative approach, and is being increasingly adopted in wind farm noise assessments.

The noise level predictions have been undertaken using the ISO 9613-2:1996 noise propagation model, which has been shown in national and international studies[4,5,6,7] to provide reasonable results for wind farm noise level predictions.

Table 6 of the assessment indicates that the wind farm sound levels are predicted to comply with the relevant criteria at all of the noise sensitive receivers. It is suggested that it would be helpful to also explicitly show the applicable noise criteria at each receiver location in addition to the highest predicted noise level within the table.

In addition, it is noted that noise level monitoring and noise assessment have been undertaken by separate independent acoustic consultants. This is a positive approach, and in line with recent recommendations of the Office of the National Wind Farm Commissioner[17].

- **Noise compliance testing plan (Condition 26)**

The *Noise Compliance Test Plan* has been prepared by Sonus.

---

2 *The Assessment and Rating of Noise from Wind Farms, The Working Group on Noise from Wind Turbines*, ETSU-R-97, UK Department of Trade and Industry, September 1996.

3 *Wind farms environmental noise guidelines,* Environment Protection Authority South Australia, July 2009.

4 Bass, J.H., Bullmore, A.J. and Sloth, E. *Development of a Wind Farm Noise Propagation Model*, Final Report for European Commission Contract JOR-3-CT95-0051, 1998.

5 Bullmore, A., Adcock, J., Jiggins, M. and Cand, M., *Wind Farm Noise Predictions and Comparison with Measurements*, Wind Turbine Noise 2009, Aalborg, Denmark, 2009.

6 Delaire, C., Griffin, D. and Walsh, D., *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*, Proc. 4th International Meeting on Wind Turbine Noise, Rome, Italy, 11-14 April 2011.

7 Evans, T. and Cooper, J., *Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms*, Proc. Acoustics 2011, Gold Coast, Australia, 2011.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 21 OF 36

The proposed compliance measurements will be undertaken in general accordance with IEC61400-11 (3), 2012.

The nearfield and intermediate testing (undertaken where necessary) will assess special audible characteristics, including;

- Tonality, in accordance with Annex C of ISO1996.2 (2007)
- Amplitude Modulation, using *interim test method*, of NZS6808:2010.

These tests are acceptable, but it is noted Amplitude Modulation testing could also be undertaken adopting the more recent UK Institute of Acoustics Amplitude Modulation Working Group (AMWG) Hybrid Method (August, 2016).

The proposed method for compliance measurement locations is in accordance with the requirements of NZS6808. Timing of commissioning and associated reporting comply with the requirements of the Planning Permit.

Comments on specific Planning Permit Conditions are provided in Attachment A of the report.

DATED: 23 March 2017

Signed:

David Spink
Environmental Auditor (Appointed pursuant to the *Environment Protection Act 1970*)

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 22 OF 36

1 Introduction

Goldwind Capital (Australia) Pty Ltd (Goldwind) is proposing to develop the Stockyard Hill Wind Farm (Project) in western Victoria. It is proposed to install up to 149 3.0–3.75MW wind turbines. The Project has been subject to an environmental assessment and approvals process, and been granted a Planning Permit by the Minister for Planning in June 2017 (Permit No. PL-SP/05/0548/A issued under the Pyrenees Planning Scheme, 8/6/2017).

Goldwind and their subconsultants, Sonus Pty Ltd (Sonus) and Marshall Day Acoustics (MDA) have undertaken background noise level measurements, and prepared the following in accordance with the planning permit conditions:

- Pre-development noise assessment (Condition 23)
- Noise compliance test plan (Condition 26)

These documents are required by the Planning Permit to be accompanied by a report by an environmental auditor appointed under the *Environment Protection Act 1970* with their opinion on the methodology and results.

Arup has been commissioned by Goldwind to undertake the environmental audit of the noise aspects against the relevant requirements of the Planning Permit, and to provide a Declaration and supporting documented assessment of compliance.

This audit has been undertaken in accordance with the requirements of the Planning Permit, and the *Policy and Planning Guidelines for Development of Wind Energy Facilities in Victoria* (DELWP, January 2016) (Guideline). The Guideline (page 30) state that the assessment of compliance is to consist of two documents;

- A Declaration by the EPA Appointed Environmental Auditor that the noise assessment meets the requirements of:
  - The appropriate standards;
  - The Guideline (as it relates to noise); and
  - The Planning Permit (or other regulatory instrument).
- A report accompanying the Declaration consistent with EPA Auditor requirements, and “thorough but concise” as noted in the Guideline.

With respect to the Guideline, the audit has been undertaken in a manner and format consistent with the accepted EPA Auditor requirements[8].

In this report;

- Section 2 provides a summary of the information that has been reviewed.

[8] *Environmental auditor guidelines for appointment and conduct*, Environment Protection Authority Victoria, Publication 865.12. December 2016.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 23 OF 36

- Section 3 provides a description of the relevant planning framework and associated standards and guidelines.
- Section 4 provides a technical review of the three primary noise measurement, assessment and draft compliance test plan reports.
- Appendix A provides a summary of the Audit of the Planning Condition Requirements.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 24 OF 36

2 Information Reviewed

The following project documentation has been reviewed;

- Planning permit PL-SP/05/0548/A, Pyrenees Planning Scheme, 8/6/2017
- *Stockyard Hill Wind Farm Background Noise Monitoring*, Sonus Report S3425.2C3, September 2017
- *Stockyard Hill Wind Farm Pre-Development Noise Assessment*, Marshall Day Acoustics Report 001 R01 20170840, 9 October 2017
- *Stockyard Hill Wind Farm Pre-Development Noise Assessment*, Marshall Day Acoustics Report 001 R02 20170840, 16 October 2017
- *Stockyard Hill Wind Farm Pre-Development Noise Assessment*, Marshall Day Acoustics Report 001 R04 20170840, 20 December 2017
- *Stockyard Hill Wind Farm*, Draft Noise Compliance Test Plan, Sonus Report S3425.2C4, September 2017.
- *Stockyard Hill Wind Farm*, Noise Compliance Test Plan, Sonus Report S3425.2C5, January 2018.

Note that the original reference documentation has not been reviewed in detail, for example, the Turbine sound power reference information provided to MDA by Goldwind.

APPROVED FOR THE MINISTER FOR PLANNING

SHEET 25 OF 36

3 Planning Requirements

The planning policy for wind farms in Victoria is given in *Victoria Planning Provisions for Wind Energy Facilities* Clause 52.32[9]. The application of the planning provisions is described in the general *Policy and Planning Guidelines for Development of Wind Energy Facilities in Victoria*[10].

For the Stockyard Hill Wind Farm, specific planning conditions are provided in the Planning Permit (Permit No. PL-SP/05/0548/A) under the Pyrenees Planning Scheme (8/6/17).

The planning provisions require the noise assessment for wind farm projects to be undertaken in accordance with NZS 6808:2010 (amendment VC78[11], 15 March 2011).

Specific guidelines such as NZS 6808:2010[12] have been developed to address the unique requirements for the prediction, measurement and assessment of sound from wind farms because the usual measurement and assessment standards adopted in Victoria (such as AS 1055[13] and SEPP N-1[14]) are unsuitable.

There are other standards and guidelines such as AS 4959, the draft National Guidelines[15], the UK ETSU-R-97[16] and the Annual Report of the National Wind Farm Commissioner[17] that can provide helpful background information and secondary guidance that can also assist with the assessment of projects where the New Zealand Standard does not provide detailed or explicit guidance.

In particular, the New Zealand Standard states that it does not set limits that provide *absolute* protection for residents from audible wind farm sound, but rather provides guidance on noise limits that are considered *reasonable* for protecting sleep and amenity from wind farm sound at noise sensitive locations.

---

9 Victoria Planning Provisions, Wind Energy Facility, Clause 52.32.

10 *Policy and planning guidelines for development of wind energy facilities in Victoria*, Victoria State Government, January 2016.

11 Advisory Note 35, Amendment VC 78 Wind energy facility provisions – Clause 52.32, March 2011.

12 New Zealand Standard 6808:2010 *Acoustics – Wind farm noise*, Standards New Zealand, 2010.

13 AS 1055.1-1997 *Acoustics - Description and measurement of environmental noise - General procedures*, Standards Australia, 1997.

14 *State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1*, Victoria Government Gazette No. S31, 1989.

15 *National Wind Farm Development Guidelines – Draft*, Environment Protection and Heritage Council, July 2010.

16 *The Assessment and Rating of Noise from Wind Farms*, UK Department of Trade and Industry, ETSU-R-97, September 1996.

17 *Annual Report to the Parliament of Australia*, Office of the National Wind Farm Commissioner, 31 March, 2017.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 26 OF 36

4 Technical Review

The technical review that follows addresses the three primary noise measurement, assessment and compliance test plan reports as required by the Planning Permit conditions.

4.1 Background Noise Monitoring

This component of the audit is not strictly a condition of the Planning Permit; however, assessment of predicted operational noise levels requires appropriate confidence in the methodology and outcomes of the background noise monitoring.

Background noise monitoring has been undertaken by Sonus at 45 locations between May and November 2012. Of the 45 background noise measurement locations, 23 are ‘participant dwellings’.

The background noise level data has been undertaken over a 6-week period (over 6,000 data points per location) which is considerably in excess of the minimum recommended requirement of 2-weeks (1,440 data points). The background measurements have been undertaken using appropriate equipment (including windshields) and include a traceable calibration.

Noise level measurement data with a local (ground level) wind speed > 5m/s have been removed from the analysis. While this is not strictly required by the New Zealand standard, it will result in a conservative assessment of the background noise level.

The background noise level data has been referenced to wind speed measurements undertaken at 6 representative meteorological masts installed on the proposed site. The correlated meteorological mast for each measurement site is provided in Table 3 of the report.

The masts provide at least 4 individual anemometer heights between 10–82 m. While the measurements have not been undertaken directly at the proposed turbine hub height of 108.5 m, the reference wind speed at this height has been calculated based on the individual 10-minute wind shear data for each correlated met-mast. This methodology is appropriate.

The 45 background noise measurement locations are shown on a map in Appendix A of the report as required. While not strictly required in accordance with the Standard, it would be helpful if the map also displayed the baseline 35 dB(A) wind farm sound prediction contour, to enable the selection of the measurement locations to be reviewed in relation to S7.1.4 of NZS6808-2010.

Again, while not strictly required, it would be helpful for the map in Appendix A to provide a scale reference, and north indication.

The background noise level and wind speed data has been analysed using a 3rd order polynomial regression, which is appropriate.

At this stage, the data has not been subject to any sub-analysis. The report indicates that splitting the data analysis by day/night periods was considered, but

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 27 OF 36

not found to provide better correlation. An examination of the measurement and analysis data shown in Appendix B does not show strong support for day/night scenario analysis, except perhaps at locations B033, B097.

Although not required by the New Zealand Standard, it could be helpful if a little more detail was provided about the individual measurement locations. For example, some other recent noise measurement reports provide photographs of individual measurement locations or more detailed individual aerial photographs to show the specific measurement locations.

Finally, it is noted that, notwithstanding the background noise level information documented in the *Background Noise Monitoring* report, the Noise Assessment (see Section 4.2 below) adopts a conservative approach and only considers the minimum criteria value at each assessment location. Therefore, the background noise level data is less critical than it would otherwise be.

4.2 Pre-Development Noise Assessment

Marshall Day Acoustics has undertaken the *Pre-Development Noise Assessment*. The assessment is generally undertaken in accordance with NZS 6808-2010 as required by the Victoria Planning Provisions.

Operational noise criteria adopted in the assessment are as required under Condition 21 a) and b) for non-participant dwellings, and 21 d) and e) for participant dwellings.

It is noted that the adoption of a limit for participating landowners is not strictly considered under NZS 6808:2010, but is discussed in the Working Group on Noise from Wind Turbine recommendations (ETSU-R-97)[18] and the South Australian wind farm environmental guidelines[19]. Arup therefore concur that adopting a 45 dB(A) base noise limit for participating landowners is reasonable, on the basis of adopting best practice.

While background noise level measurements have been undertaken for the Project, the approach used in the assessment is to adopt the ‘Base Limit’ at all receivers regardless of whether higher noise levels might be allowable at high wind speeds using the ‘background +5’ approach. It is agreed that this is a conservative approach, and is being increasingly adopted in wind farm noise assessments.

Arup concurs that the more conservative High Amenity Area noise limit considered in the New Zealand Standard should not apply. It is accepted that application of the High Amenity Area noise limit in the Victorian context is not straightforward because the provisions of NZS 6808:2010 are partly dependent on New Zealand specific planning legislation which separately identifies High Amenity Areas in their planning controls. Nevertheless, it is our experience that

[18] *The Assessment and Rating of Noise from Wind Farms, The Working Group on Noise from Wind Turbines*, ETSU-R-97, UK Department of Trade and Industry, September 1996.

[19] *Wind farms environmental noise guidelines*, Environment Protection Authority South Australia, July 2009.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 28 OF 36

the intent of the application of the High Amenity Area limit in NZS 6808:2010 is that it would only apply to a very small number of areas that have been identified as requiring additional protection over that which would be applied more generally – and it is accepted that the current Victorian planning zones in the region are not comparable to those in the New Zealand planning controls which would require it.

The noise level predictions have been undertaken using the ISO 9613-2:1996 noise propagation model, which has been shown in national and international studies[20,21,22,23] to provide reasonable results for wind farm noise level predictions. In our opinion, the calculation parameters that have been adopted for temperature, humidity and ground absorption are reasonable, and correspond to best practice.

Furthermore, the noise level predictions have adopted the following conservative assumptions;

- Barrier effect limited to 2 dB
- Screening based on turbine tip height, not hub height
- +3 penalty for 'concave' ground topography ('valley' effects).

The considerations are not explicitly required by NZS 6808:2010 or implemented in ISO9613, but are commonly adopted as good practice for wind farm noise assessment.

Section 6.2.1 of NZS6808 recommends that the source sound power level data for the turbines is based on power levels determined in accordance with IEC 61400-11. In this case, since the IEC data for the proposed turbines is not currently available, the assessment has been based on turbine sound power data determined theoretically by the turbine manufacturer.

The spectral (octave band) sound power data for the turbines is also currently unavailable, and so the spectral information used in the calculations has been based on the information provided for a Goldwind GW121 adjusted to correspond to the total sound power levels of the GW140-3000, GW140-3400 and GW140-3750 turbines.

It would be preferable to base the predictions on measured data for the actual turbines rather than rely on assumptions about similarities with other turbines. However, in the context of this assessment, it is considered that the data adopted by MDA is reasonable because of the similarities between the various turbines,

---

20 Bass, J.H., Bullmore, A.J. and Sloth, E. *Development of a Wind Farm Noise Propagation Model*, Final Report for European Commission Contract JOR-3-CT95-0051, 1998.

21 Bullmore, A., Adcock, J., Jiggins, M. and Cand, M., *Wind Farm Noise Predictions and Comparison with Measurements*, Wind Turbine Noise 2009, Aalborg, Denmark, 2009.

22 Delaire, C., Griffin, D. and Walsh, D., *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*, Proc. 4th International Meeting on Wind Turbine Noise, Rome, Italy, 11-14 April 2011.

23 Evans, T. and Cooper, J., *Comparison of predicted and measured wind farm noise levels and implications for assessments of new wind farms*, Proc. Acoustics 2011, Gold Coast, Australia, 2011.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 29 OF 36

and on the basis that further measurements and modelling will be carried out during commissioning stage to confirm that the wind farm noise levels meet the necessary limits.

Our review identified that in the original assessment the hub height used in the assessment and predictions was 100 m, which was not consistent with the 108.5 m hub height proposed for the wind farm or adopted in the background noise monitoring report prepared by Sonus. While this discrepancy was not likely to result in a significant difference in the predicted noise levels, the assessment has been updated to reflect the correct hub-height of 108.5 m.

Table 6 of the assessment indicates that the wind farm sound levels are predicted to comply with the relevant criteria at all of the noise sensitive receivers. It is suggested that it would be helpful to also explicitly show the applicable noise criteria at each receiver location in addition to the highest predicted noise level within the table.

In addition, it is noted that noise level monitoring and noise assessment have been undertaken by separate independent acoustic consultants. This is a positive approach, and in line with recent recommendations of the Office of the National Wind Farm Commissioner[17].

4.3 Noise Compliance Test Plan

The *Noise Compliance Test Plan* has been prepared by Sonus.

The test plan documents separate near field measurements to confirm the modelling input assumptions and intermediate testing to determine the character of the wind farm noise, where necessary.

However, the plan does not explicitly nominate how many turbines would be subject to nearfield testing.

The proposed compliance measurements will be undertaken in general accordance with IEC61400-11 (3), 2012.

The nearfield and intermediate testing (undertaken where necessary) will assess special audible characteristics, including;

- Tonality, in accordance with Annex C of ISO1996.2 (2007)
- Amplitude Modulation, using *interim test method*, of NZS6808:2010.

These tests are acceptable, but it is noted Amplitude Modulation testing could also be undertaken adopting the more recent UK Institute of Acoustics Amplitude Modulation Working Group (AMWG) Hybrid Method (August, 2016).

Compliance measurements are proposed at 9 locations, shown in Figure 1 of the report, with measurements undertaken for a minimum of six weeks at each location. The proposed method is in compliance with the requirements of NZS6808.

Where compliance cannot be positively demonstrated, it is proposed to adopt 'on-off testing'.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 30 OF 36

Tonality and AM testing for SACs are proposed only if intermediate screening test demonstrates tonality or AM. Test methodologies are acceptable.

Timing of commissioning and associated reporting comply with the requirements of the Planning Permit.

4.4 Planning Permit Conditions

A summary of observations and comments on specific conditions of the Planning Permit are provided in Appendix A.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 31 OF 36

5 Conclusion

The background noise monitoring, noise assessment and Noise Compliance Test Plan have been undertaken in compliance with the requirements of the Victorian Planning provisions, New Zealand Standard NZS6808-2010 and Conditions 21, 22, 23, 24, 25 and 26 of the Planning Permit No. PL-SP/05/0548/A.

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 32 OF 36

Appendix A

Planning Permit Condition Audit

APPROVED FOR THE MINISTER FOR PLANNING
SHEET 33 OF 36

A1

Planning Permit Condition	Complies?	Observations/Comments
PERFORMANCE REQUIREMENT		
21. The operation of the wind energy facility must comply with New Zealand Standard 6808:2010, Acoustics – Wind Farm Noise (the Standard) or as modified by this condition to the satisfaction of the Minister for Planning. The following requirements apply:	Y	NZS 6808 adopted for the assessment.
a) The operator must ensure that at any hub height integer wind speed, wind farm sound levels at non-participant dwellings existing on 12 May 2016 do not exceed a limit of 40 dB L-A90(10min), provided that where the circumstances specified in Condition 21(b) apply, the noise limit of 40dB LA90(10 min) will be modified as specified in Condition 21(b)	Y	These limits have been adopted and the assessment shows the noise limits will be met.
b) At the specified non-participant dwelling assessment positions referred to in Condition 28(b), the noise limit of 40dB LA90(10min) referred to in Condition 21(a) will be modified in the following way when the following circumstances exist: i. where the background sound level is greater than 35 dB LA90(10 min), the noise limit will be the background sound level LA90(10 min) plus 5 dB; ii. where a high amenity noise limit has been found to be justified, as defined by section 5.3 of the Standard, for specific locations to be high amenity areas following procedures outlined in clause 5.3.1 of the Standard.	Y	These limits have been adopted and the assessment shows the noise limits will be met.
c) At the specified non-participant assessment positions referred to in Condition 28(b), the wind farm sound level at dwellings will be modified in the following way when the following circumstances exist: i. where special audible characteristics, including tonality, impulsive sound or amplitude modulation occur, the sound level will be modified by applying a penalty of up to +6 dB L90 in accordance with section 5.4 of the Standard;	Y	

APPROVED FOR THE
MINISTER FOR PLANNING
SHEET 34 OF 36

Planning Permit Condition	Complies?	Observations/Comments
d) The operator must ensure that at any hub height integer wind speed, wind farm sound levels at participant dwellings to not exceed a noise limit of 45dB LA90(10 min), provided that where the circumstances specified in Condition 21(e) apply, the noise limit of 45dB LA90(10 min) will be modified as specified in 21(e).	Y	These limits have been adopted and the assessment shows the noise limits will be met.
e) At the specified participant dwelling assessment positions referred to in Condition 28(b), the noise limit of 45dB LA90(10min) referred to in Condition 21(c) will be modified where the background sound level is greater than 40 dB LA90(10 min), the noise will be the background sound level LA90(10 min) plus 5 dB.	Y	
f) For the purpose of this condition, a participant dwelling means a dwelling on land listed in the Address of the Land in this permit or where the landowner has a written agreement relating to a dwelling on their land which addresses noise from the permitted wind turbines. A non-participant dwelling means any dwelling that is not a participant dwelling. Evidence of the agreement must be provided to the satisfaction of the Minster for Planning upon request, and must be in a form that applies to the land for the life of the wind energy facility.	Y	
BACKGROUND NOISE TESTING		
22. The background noise testing must be carried out in accordance with the New Zealand Standard 6808:2010, Acoustics – Wind Farm Noise.	Y	NZS6808 adopted for background noise measurements.
NOISE MODELLING		
23. Before the development starts a noise modelling assessment must be prepared to the satisfaction of the Minister for Planning meeting the following requirements:	Y	Noise assessment prepared by MDA.
a) Noise modelling must be undertaken by a suitably qualified and experienced acoustics expert;	Y	

APPROVED FOR THE MINISTER FOR PLANNING

SHEET 35 OF 36

Planning Permit Condition	Complies?	Observations/Comments
b) If the wind energy facility is to be constructed in stages noise modelling may be carried out for each stage before the development of that stage commences and those results submitted successively to the Minister for Planning for approval provided that where a dwelling might be affected by noise from more than one stage that is accounted for;	N/A	Staging not proposed.
c) The modelling must include; i. The energy facility noise contours; and ii. Modelling of only the noise generated by the wind energy facility at those dwellings for which acceptable noise limit curves have been prepared;	Y	
d) The assessment must be accompanied by a report from an environmental auditor appointed under the Environment Protection Act 1970 with their opinion on the methodology and results contained in the noise modelling, If a suitable auditor cannot be engaged, the proponent may seek the written consent of the Minister for Planning to obtain an independent peer review of the noise modelling instead.	Y	This report.
24. The results of the noise modelling for each dwelling must: • Be overlaid on the acceptable noise limit curve for that dwelling; • Together with the comparison again the acceptable noise limit, be submitted to the Minister for Planning for approval as having demonstrated that noise compliance can be expected; and • When approved by the Minister for Planning, be made available publicly	Y	
25. Should the modelling required above not be done with the turbine finally selected for the wind energy facility that modelling must be repeated once the final turbine type is selected and resubmitted to the Minister for approval.	N/A	
NOISE COMPLIANCE TESTING PLAN		

APPROVED FOR THE
MINISTER FOR PLANNING

SHEET 36 OF 36

Planning Permit Condition	Complies?	Observations/Comments
26. Before the wind energy facility is commissioned, a noise compliance testing plan must be prepared to the satisfaction of the Minister for Planning meeting the following requirements:	Y	
a) the noise compliance testing plan must be prepared by a suitably qualified and experienced acoustics expert;	Y	Compliance test plan prepared by Sonus.
b) the noise compliance testing plan must include a plan for noise monitoring to assess noise levels after construction of the wind energy facility and a plan for concurrent assessment of the presence or otherwise of special audible characteristics;	Y	
c) the noise compliance testing plan must include advice on timing of the assessment including defining when commissioning of the wind energy facility, or an identified stage of it, will occur, and when the compliance noise monitoring results will be provided to the Minister for Planning. That time must not be more than 120 days after commissioning unless with the further consent of the Minister for Planning.	Y	
d) if the Wind Energy Facility is to be constructed in stages, a noise compliance testing plan may be prepared for each stage before the development of that stage commences and those plans submitted to the Minister for Planning for approval provided that where a dwelling might be affected by noise from more than one stage that is accounted for;	N/A	Staging not proposed.
e) the noise compliance testing must be carried out at locations defined in accordance with the Standard, including consideration for alternative locations for assessment (if locations become inaccessible in future).	Y	
f) When approved, the plan will be endorsed by the Minister for Planning and will then form part of this permit.	Y	
g) The noise compliance testing plan must be accompanied by a report from an environmental auditor appointed under the Environment Protection Act 1970 with their opinion on the methodology and contained in the noise compliance testing plan. If a suitable auditor cannot be engaged, the proponent may seek the written consent of the Minister for Planning to obtain an independent peer review of the noise compliance testing plan instead.	Y	This report.