MARSHALL DAY Acoustics

BERRYBANK WIND FARM
POST CONSTRUCTION NOISE MONITORING

Rp 002 20200683 | 3 August 2022

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Project: **BERRYBANK WIND FARM**

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EXECUTIVE SUMMARY

This report presents the results from the first phase of post-construction monitoring and compliance assessment for the Berrybank Wind Farm.

This assessment is based on noise monitoring carried out on in the vicinity of Stage 1 of the Berrybank Wind Farm, between 21 June and 20 September 2021. The monitoring was undertaken in accordance with the NZS 6808:2010[1], as required by the planning permit.

The noise monitoring comprised the following:

- Unattended measurements at eleven (11) locations; and
- Attended observations to inform an assessment of the noise characteristics of the wind farm.

The results of the noise monitoring demonstrated that operation of Stage 1 of the Berrybank Wind Farm complied with the noise requirements of the planning permit. Specifically, total noise levels at all monitoring locations were below the relevant noise limits.

The attended observations did not indicate the presence of SACs warranting objective assessment, and in particular, was inaudible on most occasions. As such, no penalties were applied.

However, the results of near-field testing indicated tonality was a characteristic of the test turbine. In accordance with the NCTP, an objective assessment of tonality is to be conducted for the second phase of monitoring to investigate whether this characteristic is present at the receivers.

Additional post-construction noise monitoring is to be undertaken before 20 September 2022.

[1] New Zealand Standard 6808:2010 *Acoustics – Wind turbine noise*

TABLE OF CONTENTS

1.0 INTRODUCTION

The Berrybank Wind Farm consists of two (2) stages of development:

- Stage 1 which is operational, and comprises forty-three (43) wind turbines; and
- Stage 2 which is under construction, and comprises twenty-six (26) wind turbines.

The planning permit[2] for the Berrybank Wind Farm includes conditions for the control of environmental noise from the development. Specifically, the planning permit requires noise from the wind farm to comply with the criteria detailed in NZS 6808:2010[3]. The planning permit specifies that noise compliance monitoring is to be undertaken following the construction of the wind farm, and that the results must be submitted with a statement of compliance to the Minister for Planning.

In accordance with Condition 19 of the planning permit, the noise compliance monitoring procedures for the Berrybank Wind Farm are presented in the Noise Compliance Test Plan[4] (NCTP).

Marshall Day Acoustics Pty Ltd (MDA) has been engaged by Global Power Generation Australia Pty Ltd (GPG) to undertake the first phase of post-construction monitoring and compliance assessment for Stage 1 of the Berrybank Wind Farm. This report presents our findings.

Acoustic terminology used throughout this report is detailed in Appendix A.

Site layout information is detailed in Appendix B.

A detailed list of the turbines and their relevant location is detailed in Appendix C.

2.0 WIND FARM DETAILS

Stage 1 of the Berrybank Wind Farm consists of forty-three (43) Vestas V136 wind turbines.

The Vestas V136 is a variable speed wind turbine, with the speed of rotation and the amount of power generated by the turbines being regulated by control systems which vary the pitch of the turbine blades (the angular orientation of the blade relative to its axis)

Details of the installed wind turbines are provided in Table 1.

Table 1: Berrybank Wind Farm wind turbine model

Detail	Description
Make and model	Vestas V136
Rated power	4.2 MW
Rotor diameter	136 m
Hub height	112 m
Blade orientation	Upwind
Turbine regulation method	Variable blade pitch
Cut-in wind speed (hub height)	3.0 m/s
Rated power wind speed (hub height)	13.0 m/s
Cut-out wind speed (hub height)	25.0 m/s

[2] Planning Permits No. 20092821–A and 20092820-A, issued 4 February 2018 (the planning permit)

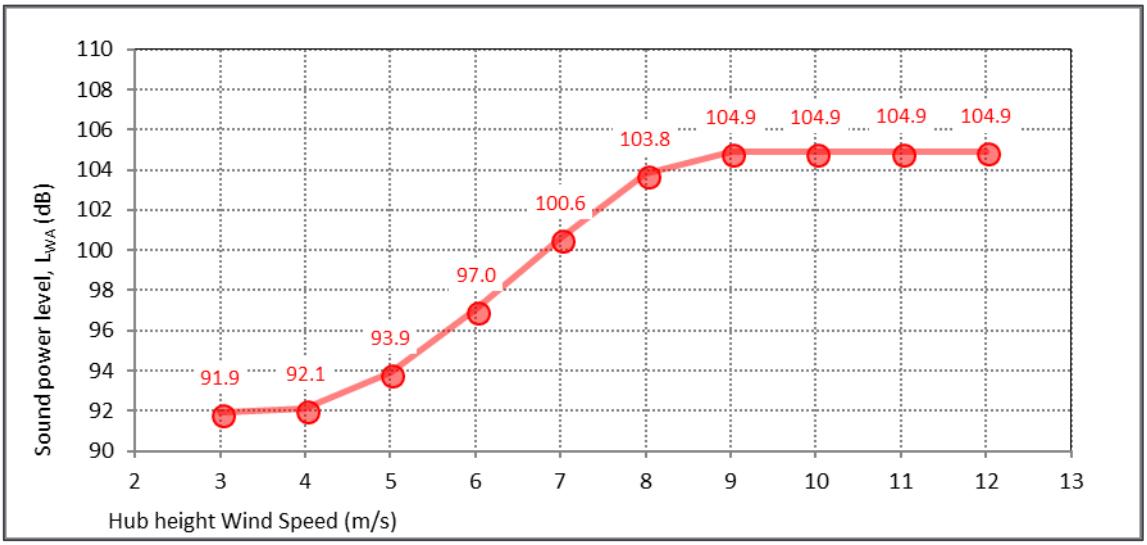
[3] New Zealand Standard 6808:2010 *Acoustics –Wind turbine noise* (NZS 6808:2010)

[4] MDA report Rp 001 R04 20180495 *Berrybank Wind Farm - Noise Compliance Test Plan*, dated 15 April 2019

For modern variable speed pitch regulated wind turbines, including the Vestas V136, the sound power level profile as a function of wind speed typically increases until it reaches rated power.

At wind speeds approaching the speed of rated power (around 9 m/s at a height of 112 m), the sound power level[5] of the turbine no longer increases with increasing wind speed, as shown Figure 1.

Figure 1: Vestas V136-4.2MW sound power level versus hub height wind speed, dB L_{WA}



[5] Sourced from specification data detailed in Vestas document No. 0067-4732_02 *V136-4.0/4.2 MW Third octave noise emission*, dated 20 March 2018

3.0 NOISE MONITORING LOCATIONS

The NCTP nominates a total of seventeen (17) preferred noise sensitive receivers for conducting post-construction monitoring, as detailed in Table 2, subject to permission being granted by the landowners. The NCTP also notes that if permission is not able to be obtained for the monitoring, alternative locations shall be considered.

Table 2: Preferred noise compliance monitoring locations

Location	Direction from nearest turbine	Distance from nearest turbine (m)
9	NNE	1,150
10	NW	1,141
18	NNW	1,071
27	NW	1,099
56*	W	1,141
57	W	1,298
58	W	1,149
63	NE	1,416
69	SSW	1,114
70*	SW	1,171
72	E	1,247
73	ESE	1,220
79*	SSW	1,093
80	SW	1,091
83	E	1,128
102	SSE	1,196
103	NNE	1,159

* The inclusion of these noise sensitive receivers was requested by DELWP

As detailed in the background noise monitoring report[6], permission to undertake monitoring was not able to be obtained at all locations, either as a result of the landowner declining to participate in the survey or the dwelling being uninhabited. As such, consistent with the NCTP, substitute locations were selected for conducting background noise monitoring consisting of either a nearby receiver, where available, or an intermediate location positioned between the wind farm site and the original preferred noise compliance monitoring location.

Background noise monitoring was carried out at a total of sixteen (16) locations, comprising:

- Six (6) receivers; and
- Ten (10) intermediate locations between non-involved receivers and the wind farm

  These are identified with the suffix “i" following the reference of representative receiver (e.g., location 9i identifies the intermediate location representative of receiver 9.)

[6] MDA report Rp 003 20180495 *Berrybank Wind Farm - Background Noise Monitoring,* dated 1 July 2020

As specified in Section 6.3 of the NCTP, which was prepared for the whole wind farm (Stages 1 and 2), operational noise levels at some noise sensitive locations may not yet be at a level which would enable a meaningful assessment of operational noise of the wind farm as a whole. In such instances, and as relevant for this survey when only Stage 1 was operational, it may be appropriate to defer the monitoring at some noise sensitive locations until subsequent stages of the compliance monitoring.

In these circumstances, evidence must be provided that predicted noise levels at the monitoring locations to be deferred are at least 5 dB lower than the highest predicted noise level detailed in the pre-construction noise report. The predicted wind turbine noise contribution from Stage 1 and Stage 2 at the sixteen (16) locations where background noise monitoring was undertaken are presented in Appendix D.

The modelling results presented in Appendix D indicate that the predicted noise level of Stage 1 was 5 dB or more lower than that of the completed wind farm, either at the receiver or the applicable substitute location, for six (6) of the receivers nominated as preferred noise monitoring locations in the NCTP. Accordingly, noise monitoring was only conducted at eleven (11) of the seventeen (17) locations for this first phase of noise monitoring.

Details of the noise monitoring locations and the associated substitute locations, where applicable, are detailed in Table 3, including the eleven (11) monitoring locations relevant for the assessment of Stage 1 of the Berrybank Wind Farm.

Table 3: Monitoring locations

NCTP location	Substitute location	Reason for substitution	Notes
9	9i	Permission to monitor at receiver not provided. Intermediate location selected in lieu of an alternative nearby receiver.	
10	10i	Permission to monitor at receiver not provided. Intermediate location selected in lieu of an alternative nearby receiver.	
18	18i	Permission to monitor at receiver not provided – no resident (abandoned). Intermediate location selected in lieu of an alternative nearby receiver.	Relevant to assessment of Stage 2, not measured as part of Stage 1 monitoring. Predicted noise of Stage 1 is 5 dB lower than for the complete wind farm at the intermediate location.
27	-	No substitute required	Relevant to assessment of Stage 2, not measured as part of Stage 1 monitoring. Predicted noise of Stage 1 is 5 dB lower than for the complete wind farm at the receiver.
56*	56i	Permission to monitor at receiver not provided – no resident (abandoned). Intermediate location selected in lieu of an alternative nearby receiver.	The monitoring location is closer to the wind farm than the NCTP location

NCTP location	Substitute location	Reason for substitution	Notes
57	55 (S)	Permission to monitor at receiver not provided – no resident (abandoned). Alternative receiver selected across the road, at a similar distance to the wind farm.	
58	58i	Permission to monitor at receiver not provided – no response. Intermediate location selected in lieu of an alternative nearby receiver.	Relevant to assessment of Stage 2, not measured as part of Stage 1 monitoring. Predicted noise of Stage 1 is 5 dB lower than for the complete wind farm at the intermediate location.
63	63i	Permission to monitor at receiver not provided. Intermediate location selected in lieu of an alternative nearby receiver.	
69	-	No substitute required	
70*	-	No substitute required	
72	108	Permission to monitor at receiver not provided. Receiver 108 adopted as an appropriate representation based on proximity.	
73	73i	Permission to monitor at receiver not provided. Intermediate location selected in lieu of an alternative nearby receiver.	Relevant to assessment of Stage 2, not measured as part of Stage 1 monitoring. Predicted noise of Stage 1 is 5 dB lower than for the complete wind farm at the intermediate location.
79*	80	Permission to monitor at receiver not provided – no resident (abandoned). Receiver 80 adopted as an appropriate representation based on proximity.	
80	-	No substitute required	
83	83i	Permission to monitor at receiver not provided – no response. Intermediate location selected in lieu of an alternative nearby receiver.	Relevant to assessment of Stage 2, not measured as part of Stage 1 monitoring. Predicted noise of Stage 1 is 5 dB lower than for the complete wind farm at the intermediate location.
102	-	No substitute required	
103	103i	Permission to monitor at receiver not provided – no resident (abandoned). Intermediate location selected in lieu of an alternative nearby receiver.	

* The inclusion of these noise sensitive receivers was requested by DELWP

The noise monitoring equipment was positioned at the same location where the background noise monitoring was undertaken:

- Not less than 3.5 m from vertical reflecting surface;
- On the wind farm side of the dwelling and, as far as practically possible, within 20 m from the dwelling (where applicable) while avoiding reflecting surfaces and localised sources of background noise; and
- As far as practically possible from streams, watercourse and vegetation which may result in localised increases in background noise levels.

Coordinates and photographs for the eleven (11) monitoring locations are provided in Appendix H to Appendix R.

4.0 NOISE CRITERIA

4.1 Planning Permit

Condition 17 of the planning permit requires operational noise levels of the wind energy facility to comply with NZS 6808:2010.

The noise criteria detailed in NZS 6808:2010 are defined using a combination of fixed values limits and background noise related limits. Section 5.2 of the NZS 6808:2010 specifies that wind farm sound levels at noise sensitive locations should not exceed the background sound level by more than 5dB, or a level of 40 dB $L_{A90,}$ whichever is greater.

The applicable noise limits in accordance with NZS 6808:20120 are therefore defined as 40 dB L_{A90} or the background noise level L_{A90} + 5dB, whichever is higher.

Background noise levels have previously been measured at multiple receivers in the vicinity of the wind farm and have been referenced herein in order to:

- Determine operational noise limits in accordance with the planning permit; and
- Assist the analysis of noise data obtained from compliance monitoring after the wind farm commences operating.

4.2 Background noise levels

The tabulated data presented in Table 4 and Table 5 summarises the background noise levels measured at the eleven (11) relevant monitoring locations, for the all-time and night-time periods respectively. Distinct separate trends for the night period were only identified at one (1) of the eleven (11) locations. Accordingly, separate data for the night is only provided for location 103i.

Table 4: Derived background noise levels, dB L_{A90} - all-time period

Location	Hub height wind speed , m/s [1]												
	3	4	5	6	7	8	9	10	11	12	13	14	15
69	29.2	29.3	29.8	30.7	32.0	33.5	35.3	37.4	39.5	41.7	44.0	46.2	48.4
70	26.6	26.8	27.5	28.7	30.3	32.3	34.6	37.1	39.7	42.4	45.2	47.8	50.4
80	25.9	26.0	26.4	27.2	28.3	29.8	31.4	33.2	35.2	37.2	39.3	41.4	43.4
102	23.9	24.3	25.1	26.2	27.6	29.3	31.1	33.1	35.2	37.3	39.5	41.8	43.9
108	30.2	30.4	31.1	32.2	33.7	35.4	37.4	39.5	41.8	44.0	46.2	48.3	50.2
55 (S)	- [2]	27.5	27.9	28.8	30.1	31.8	33.8	36.1	38.5	41.1	43.7	46.2	48.7
9i	21.8	22.0	22.3	22.9	23.7	24.6	25.7	27.0	28.3	29.8	31.4	33.1	34.9
10i	25.5	26.2	26.9	27.8	28.8	29.8	31.0	32.3	33.6	35.1	36.6	38.2	39.9
56i	24.8	24.9	25.3	26.0	27.0	28.3	29.8	31.4	33.2	35.2	37.2	39.3	41.5
63i	21.9	22.2	22.6	23.2	23.9	24.8	25.8	27.0	28.3	29.8	31.4	33.1	34.9
103i	22.7	23.8	25.0	26.4	27.8	29.3	30.9	32.5	34.1	35.7	37.3	38.8	40.3

1 112 m above ground level at 719773 E, 5800689 N (MGA 94 Zone 54)

2 Outside valid range of regression analysis

Table 5: Derived background noise levels, dB L_{A90} - night-time period (2200 to 0500 hours)

Location	Hub height wind speed , m/s [1]												
	3	4	5	6	7	8	9	10	11	12	13	14	15
103i	18.3	18.8	19.8	21.1	22.7	24.4	26.3	28.2	30.1	32.0	33.6	35.0	- [2]

1 112 m above ground level at 719773 E, 5800689 N (MGA 94 Zone 54)

2 Outside valid range of regression analysis

4.3 Noise limits

The applicable noise limits summarised in Table 3 are based on measured background noise levels presented in Section 4.2 and the status of each receiver at the time of preparation of this report. In particular, the receivers are considered uninvolved locations and the minimum limit is therefore set at 40 dB L_{A90} in accordance with the planning permit and NZS 6808:2010.

Table 6: All-hours period operational wind farm noise limits (dB L_{A90})

Location	Hub height wind speed , m/s [1]												
	3	4	5	6	7	8	9	10	11	12	13	14	15
55 (S)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.1	43.5	46.1	48.7	51.2	53.7
69	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.4	44.5	46.7	49.0	51.2	53.4
70	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.1	44.7	47.4	50.2	52.8	55.4
80	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.2	42.2	44.3	46.4	48.4
102	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.2	42.3	44.5	46.8	48.9
108	40.0	40.0	40.0	40.0	40.0	40.4	42.4	44.5	46.8	49.0	51.2	53.3	55.2

1 112 m above ground level at 719773 E, 5800689 N (MGA 94 Zone 54)

Section 7.1.5 of NZS 6808 states:

> *When considering a group of noise sensitive locations it is acceptable to conduct background sound level measurements at a representative location. these measurements shall then be used to define noise limits that apply to every noise sensitive location in that group. The sound generating features at the representative location shall be similar in proximity and character to those at other noise sensitive locations represented by that location.*

Considering that permission to monitor was not granted at receiver 57, receiver 55 (S) was selected as a representative location in accordance with Section 7.1.5 of NZS 6808. Specifically, receiver 55 (S) is located across the road from receiver 57, at a similar distance to the wind farm. Furthermore, the area around receiver 55 (S) is less vegetated than at receiver 57, providing a more conservative assessment.

As such, the noise limit derived at receiver 55 (S) is applicable at the representative receiver (57).

As receiver 55 (S) is a stakeholder in the project, the noise limit does that apply at this receiver.

At substitute locations, where total noise levels (background noise and wind turbine noise) can be shown to be below base limits, compliance with the planning permit requirements can be inferred at the representative NCTP location.

5.0 NOISE SURVEY AND ANALYSIS METHOD

5.1 Survey description

The survey comprised noise measurements and attended observations. Key elements of the survey are summarised in Table 7.

Table 7: Summary of key elements of the post construction noise survey

Item	Description
Monitoring locations	Eleven (11) locations as described in Section 3.0.
Monitoring period	The monitoring for the initial forty-three (43) turbines consisted of monitoring at a total of eleven (11) locations from 21 June 2021 to 18 August 2021 for nine (9) locations, with two (2) locations (80 and 63i) extended to 20 September 2021. The planning permit specifies the requirements for monitoring in accordance with NZS 6808:2010. The planning permit does not specify the duration of each round of monitoring. However, NZS 6808:2010 indicates the measurements should be made for a representative range of wind speeds and directions for the site, and that a minimum of 1,440 individual 10-minute measurements, equivalent to 10 days of monitoring, is normally required to obtain a satisfactory range.
Attended observations	Two (2) visits were undertaken by a qualified acoustic engineer with experience in the assessment of wind farm sound to conduct a subjective assessment of whether the sound contained special audible characteristics (SACs), comprising of identifying any clearly audible amplitude modulation, impulsiveness or tonality. Note the NCTP requires three (3) SAC assessments be undertaken, including one (1) during the night period. As the night SAC assessment was not undertaken during this first phase of monitoring, additional SAC assessments during the night period are required as part of subsequent noise monitoring.
Sound level meters	Class 1 automated sound loggers (most accurate class rating for field use). Microphones mounted at approximately 1.5 m above ground level and fitted with enhanced wind shielding systems based on the design recommendations detailed in the UK IOA good practice guide. See equipment specifications and calibration records in Appendix E.
Noise measurement data	A-weighted average and statistical sound pressure levels for consecutive 10-minute periods with the time interval commencing on the hour, based on instantaneous sound pressure levels (fast response) recorded in 100 ms resolution. One-third octave band frequency noise levels and a 2-minute audio sample every 10-minutes to aid the identification of extraneous noise influences.
Local wind speed and rainfall data	A weather station was installed beside two (2) of the noise monitoring locations during the monitoring period, to concurrently record rainfall and wind speeds at microphone height. This data was recorded to identify periods when local weather conditions may have resulted in excessive extraneous noise at the microphone (i.e. rainfall). The data contains the average wind speed, direction and rainfall at the weather station for consecutive 10-minute periods with the time interval commencing on the hour.

Item	Description
Site wind speed data	Wind speed data at 112 m above ground level, corresponding to the hub height of the turbines, was sourced from Turbine 6 based on the proximity to the met mast location used for the background monitoring. The wind speed data consisted of measured and synthesised data from wind turbine data located in close proximity to the background noise monitoring met mast location. The data contains the average wind speed and direction for consecutive 10-minute periods with the time interval commencing on the hour. The reference met mast location used for the background noise monitoring survey is indicated on the site layout provided in Appendix B. Further details of the site wind speed data are provided in Appendix F.

5.2 Data analysis

5.2.1 Overview

Analysis procedures in accordance with the planning permit and NZS 6808:2010 broadly involves:

- Collating the measured noise levels, site wind speeds and local weather data into a single dataset;
- Filtering the data set to remove measurement results affected by extraneous or atypical noise (e.g. rainfall, agricultural machinery, atypically high insect noise in the vicinity of the microphone);
- Filtering the data for the range of site wind speeds in which the turbines are operational;
- Filtering the data where necessary to account for site wind directions; and
- Plotting a chart of noise levels versus wind speeds and determining the line of best fit to the data.

A summary of the key steps in the analysis of the data is presented in Table 8.

Table 8: Noise data analysis summary

Process	Description
Data collation	Time stamps for each source of measurement data are reviewed to clarify start or end times and measurement time zone. Measured noise levels, site wind speeds and local weather conditions are then collated for each 10-minute measurement interval.
Local weather data filtering	10-minute intervals are identified and filtered from the analysis if rainfall was identified for any 10-minute measurement interval.
Extraneous noise filtering	The measured sound frequencies (one-third octave bands) in each 10-minute interval are used to identify periods that are significantly affected by bird or insect sounds. 10-minute intervals have been identified, and filtered from the analysis, when the following conditions[7] are satisfied: • The highest A-weighted one-third octave band noise level is within 5 dB of the broadband A-weighted noise level for that interval; and • The identified one-third octave band A-weighted noise level is greater than a level of 20 dB L_{A90}.

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

Process	Description
Turbine shut-downs	Any periods significantly affected by turbine shut-downs have been excluded from the regression analysis. Wind farm operational records supplied by Vestas for the duration of the monitoring campaigns were reviewed. In general, any 10-minute period in which any relevant turbines[8] were not operating were removed from the analysis. Further information is provided in Section 5.2.2
Time periods	The data sets are considered for all-time periods (i.e., day and night combined), with the exception of locations where trends were identified as part of background noise monitoring (i.e., 2200 – 0500 hrs at locations 83i and 103i).
Regression analysis	Two datasets are plotted on a chart of noise levels versus wind speeds: • All data points that have been removed from the analysis using the above processes • The filtered dataset comprising all retained measurement data. The chart of filtered noise levels versus wind speed is reviewed to determine if there are any distinctive trends or gaps in the data which could warrant separation of the measurement results into subgroups (e.g., subgroups for time of day or wind direction). A line of best fit is determined for the filtered data and, where applicable, any subgroups of the filtered data. The line of best fit is determined using a regression analysis of the range of noise levels and wind speeds or, where necessary, analysis of noise levels at individual wind speeds.

5.2.2 Operating configuration

The objective of the analysis is to assess whether the noise levels of the wind farm comply with the requirements of the planning permit when all of the wind turbines are operating normally. It is therefore necessary to identify and remove any periods when noise levels may have been lower as a result of turbines being shut-down or operating at reduced power levels (e.g. due to maintenance related issues or external energy market restrictions on the amount of power able to be generated by the site).

To establish the profile of normal operations associated with the wind farm, a review of the data recorded by the site's supervisory control and data acquisition (SCADA) system was undertaken. The SCADA data contains information about a range of turbine parameters including the average power output and the turbine nacelle wind speed (distinct from the hub height wind speed at the reference mast used for the assessment) in consecutive 10-minute periods with the time interval commencing on the hour.

The review of the turbines' operational data involved generating average power versus nacelle wind speed plots for each turbine for the duration of the noise monitoring period. An example plot is provided below in Figure 2. The trends of these plots were reviewed to identify the typical range of power outputs for each turbine for each integer nacelle wind speed. If the SCADA data then indicated that the power output of a turbine in a given 10-minute period was below the typical range, the turbine's operational status was designated as atypical for the period in question.

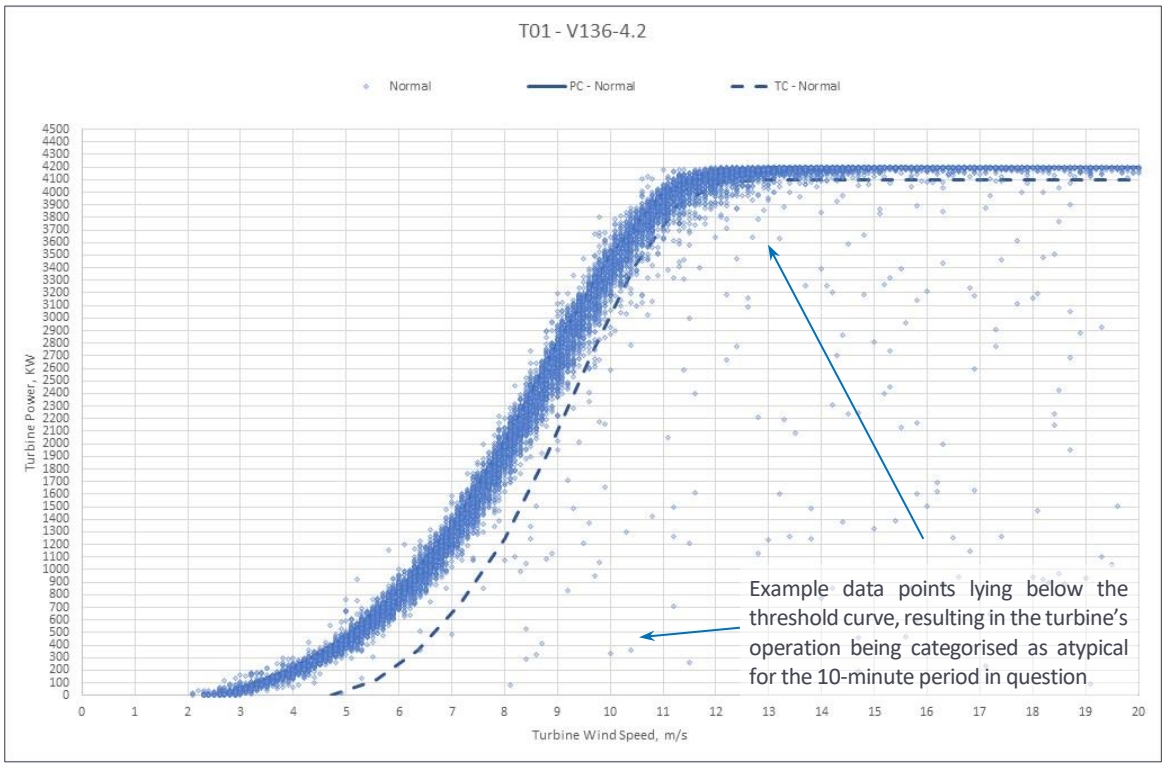
[8] Relevant turbines are those which are most likely to contribute to the total wind farm noise level at a measurement location

For the purposes of this analysis, a 'threshold curve' was determined which could be used to define whether each turbine's operation was typical or not in any given 10-minute period. The threshold curve was determined by:

- Overlaying the power curve of the turbines (the relationship between turbine power and wind speed) on the plots for each turbine;
- Creating a new curve by applying offsets to the power curve (i.e. adjusting the position of the curve on the plots, by adjusting the power and/or wind speed values); and
- Iteratively adjusting the position of the new curve until it lies below all 10-minute data points (for all turbines) when the output of the turbine was consistent with the power curve, allowing for a notional margin below the power curve to reflect normal variations in turbine power relative the power curve (relative to nacelle wind speed).

Each turbine's power output for each 10-minute period was then compared to the threshold curve and determined to be typical or atypical, according to whether the power output was above or below the threshold curve. The power curve and threshold curve are illustrated on the chart in Figure 2. As an example of the analysis carried out for each turbine, Figure 2 also includes the 10-minute power data for turbine T-01 during the monitoring period.

Figure 2: Example power versus nacelle wind speed plot (Turbine 01)



To determine whether a 10-minute period needed to be removed from the noise assessment, it was necessary to assess if any of the turbines flagged as atypical were 'relevant' to the total noise of the wind farm at the monitoring locations (i.e. whether a turbine flagged as atypical had the potential to change the total noise level at a noise monitoring location or, conversely, whether the turbine was far enough away to be inconsequential).

For this purpose, the 3-dimensional noise model of the site was used to rank the relative noise contributions of each turbine to the total noise level at each monitoring location, and then classify the turbines as either 'relevant' or 'non-relevant'. Non-relevant turbines for each monitoring location are those turbines with the lowest predicted noise levels which collectively result in a predicted noise level 15 dB lower than the total predicted noise level of the wind farm at the location in question.

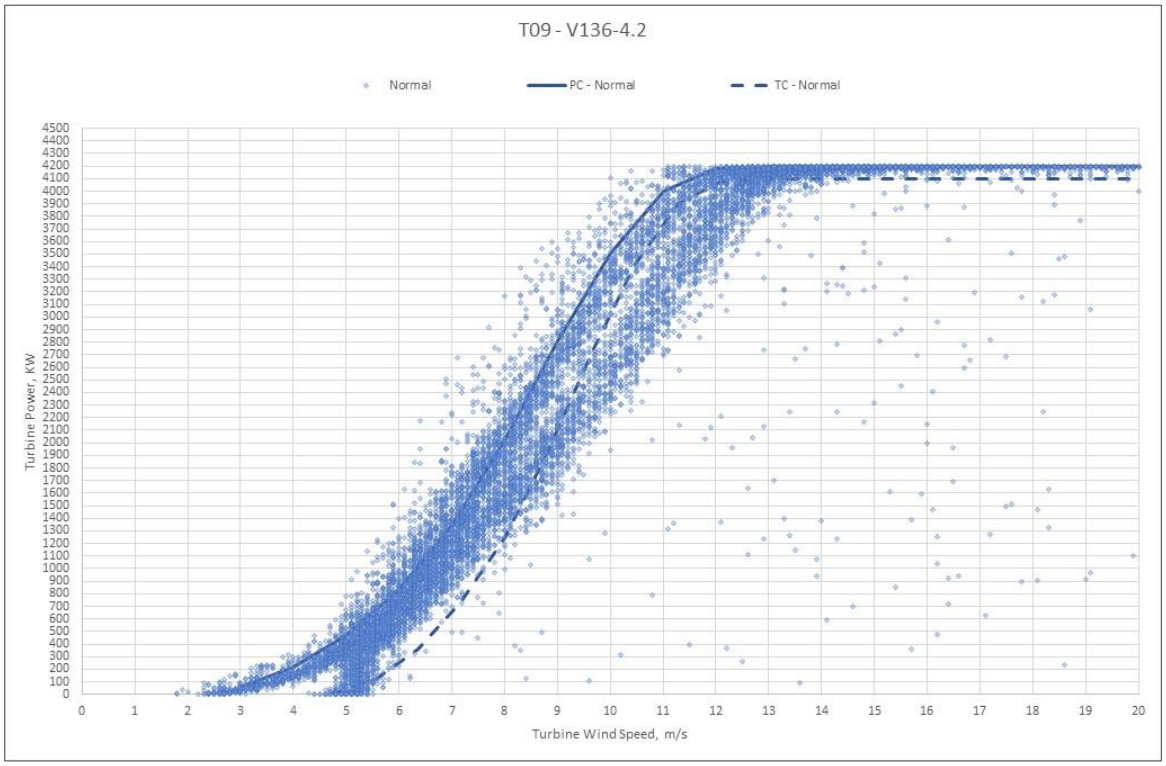
This means that if any or all of the non-relevant turbines were not operating in a given measurement period, the reduction in total noise level would be limited to 0.1 dB or less, and would therefore be inconsequential to the assessment outcome. Conversely, it means that the majority of the turbines in each 10-minute period must not be flagged as atypical in order for the period to be considered valid for noise assessment purposes.

It was identified during the monitoring period that turbine 09 had a misalignment on the anemometer resulting in a skewed power output of the turbine in relation to the wind speed. A copy of the power curve for power versus nacelle wind speed for the turbine is included in Figure 3. Since the anemometer misalignment was identified during the monitoring period and the turbine is identified as relevant at four (4) monitoring locations, the operational status for turbine 09 has not been included in the analysis.

This approach introduces the possibility that data points may be included in the analysis when turbine 09 may not have been operating. Based on the predicted contribution of turbine 09, this means that the data retained in the analysis could include 10-minute periods when the noise level of the wind farm was up to 0.5 dB lower than it would otherwise be with turbine 09 operating.

This uncertainty has therefore been accounted for in the compliance assessment for intermediate locations 9i and 56i, and for receivers 55 (S) and 102.

Figure 3: Power versus nacelle wind speed plot (Turbine 09)



5.2.3 Special audible characteristics

The data analysis also involves an objective assessment of special audible characteristics (SACs) if their potential presence is indicated by:

- The attended observations conducted as part of the survey;
- Observations by site personnel at the wind farm; and
- Noise complaints recorded in the site's complaint handling and management system.

If objective assessment is warranted, the applicable procedures are listed in Table 9.

Table 9: SAC objective assessment procedures

SAC	Objective assessment procedure
Amplitude modulation	UK Institute of Acoustics' Amplitude Modulation Working Group publication *Final Report - A Method for Rating Amplitude Modulation in Wind Turbine Noise Version 1* dated 9 Aug. 2016 (UK IOA AM procedure)
Impulsiveness	Australian Standard AS 1055:2018 *Description and measurement of environmental noise* (AS 1055:2018) The method defined in Appendix E (informative) *Objective method for application of an impulse adjustment to receiver noise*
Tonality	International Standard ISO 1996-2:2017 *Acoustics — Description, measurement and assessment of environmental noise — Part 2: Determination of sound pressure levels* 2017 (ISO 1996-2:2017) The narrow band method defined in Annex J *Objective method for assessing the audibility of tones in noise — Engineering method* (Annex J) is to be used

6.0 SURVEY RESULTS

This section presents the results of the measurements and attended observations, and an assessment of compliance with the noise criteria.

It is important to note that the total measured noise levels at all locations are a combination of:

- Operational wind farm noise; and
- Background noise (i.e. the noise from all other sound sources not related to the wind farm).

The measured total noise levels will therefore be equal to, or greater than, the noise level that is solely attributable to the operation of the wind farm.

In some instances, particularly at low or high wind speeds, total measured noise levels will be controlled by background noise and, as a result, the contribution of the turbines could be significantly less than the total measured noise levels. However, the noise criteria only apply to the noise level that is solely attributable to the operation of the wind farm.

6.1 Measured noise levels

The results of the unattended measurement data analysis for the eleven (11) locations are summarised in Table 10 for the all-time periods (24 hour) and night-time period (2200 – 0500 hrs) for location 103i.

The summary results correspond to the value of the line of best fit to the total noise level versus hub height wind speed chart. Importantly, the line of best fit is applied to the data points that have been retained for analysis after applying the filtering procedures described in Section 5.2.1 (i.e. for extraneous noise, rainfall and atypical wind farm operation).

The detailed measurement and analysis results are presented in Appendix H to Appendix R and include information such as the total number of data points collected, the number of data points included in the analysis, and statistical details relating to the line of best fit to the measurement data.

As per the requirements of NZS 6808:2010, the analysis included a review of the relationship between measured noise levels and wind speeds to identify any distinctive trends which would warrant assessment of a subset of the measurement data. These types of trends are not evident; the variation that is evident in the measured noise levels at the receivers is indicative of background noise level variations rather than wind turbine noise.

Table 10: Total post-construction measured noise levels at receivers, dB L_{A90} – all time periods

Location	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
55 (S)	-	-	31.6	32	32.6	33.5	34.6	35.9	37.3	38.9	40.5	42.3	44.2
69	-	-	35.3	35.5	36.0	36.6	37.4	38.4	39.4	40.5	41.6	42.7	43.7
70	31.3	31.9	32.6	33.4	34.3	35.4	36.5	37.6	38.8	39.9	41.1	42.2	43.3
80	28.2	29.5	30.9	32.2	33.5	34.8	36.0	37.1	38.2	39.2	40.1	40.8	41.4
102	29.1	30.8	32.4	33.9	35.3	36.7	37.9	39.1	40.0	40.9	41.6	42.1	42.4
108	-	-	34.0	34.7	35.6	36.6	37.6	38.7	39.9	41.2	42.5	43.8	45.2

Table 11: Total post-construction measured noise levels at intermediate locations, dB L_{A90} – all time periods

Location	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
9i	26.1	28.8	31.1	32.9	34.3	35.4	36.3	37.0	37.5	38.0	38.5	39.1	39.8
10i	33.6	36.4	38.7	40.7	42.3	43.6	44.5	45.3	45.9	46.3	46.6	46.8	47.0
56i	31.3	33.0	34.3	35.3	36.2	36.9	37.5	38.1	38.7	39.3	40.1	41.1	42.3
63i	28.4	29.4	30.5	31.6	32.6	33.7	34.8	35.8	36.7	37.5	38.2	38.8	39.2
103i	-	31.6	32.1	32.8	33.7	34.8	35.8	36.9	37.8	38.7	39.3	39.6	-

Table 12: Total post-construction measured noise levels, dB L_{A90} – night-time periods

Location	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
103i	-	28.2	29.0	30.2	31.6	33.1	34.6	36.0	37.3	38.2	38.8	38.9	-

6.2 Special audible characteristics

This section presents the findings of the attended observations which were carried out to subjectively assess whether special audible characteristics (SACs) were evident in the noise of the wind energy facility (and therefore whether objective assessments were warranted).

The findings of the attended observations and subjective assessments at receivers are summarised in Table 13, along with the number of operational turbines and the site wind speeds at the times when the observations were made.

Table 13: Special audible characteristics, attended site measurements - Receivers

Date and Local Time	Location	Turbines operating	Wind speed at hub height, m/s	Wind direction at hub height, degrees	Subjective assessment and comments
21/06/2021 1250 hrs	80	27 visible, 4 operating	-	-	Wind farm inaudible
22/06/2021 1153 hrs	102	Some turbines operating, below rated power	10.1	23	Wind farm just audible - swoosh audible but not modulating significantly
18/08/2021 0900 hrs	55 (S)	All visible	5.1	296	Low frequency very faint. Seems to be gearbox hum
17/08/2021 1042 hrs	69	All visible except 1	7.0	242	Wind farm faintly audible, extraneous noise dominant
17/08/2021 1117 hrs	70	All visible except 1	7.6	231	Wind farm inaudible
17/08/2021 1335 hrs	80	All visible except 2	6.8	227	Wind farm inaudible

Date and Local Time	Location	Turbines operating	Wind speed at hub height, m/s	Wind direction at hub height, degrees	Subjective assessment and comments
17/08/2021 1545 hrs	102	All visible	6.4	230	Gearbox noise faintly audible
17/08/2021 1000 hrs	108	All visible	7.3	238	Wind farm inaudible

It was evident in the attended observations at receivers that tonality or amplitude modulation was not present at any of the measurement locations and has not warranted an objective assessment.

Considering that intermediate locations are, by definition, located closer to the wind turbines than their representative receivers, the findings of the attended observations and subjective assessments at intermediate locations are summarised in Table 13 for information only.

Table 14: Special audible characteristics, attended site measurements - Intermediate locations

Date and Local Time	Location	Turbines operating	Wind speed at hub height, m/s	Wind direction at hub height, degrees	Subjective assessment and comments
22/06/2021 1030 hrs	9i	All visible except 2	10.8	20	Wind farm just audible, Swoosh audible but no unusual modulation
21/06/202 1630 hrs	10i	Some turbines operating, below rated power	4.6	356	Wind farm just audible, very faint hum, low to mid frequency.
22/06/2021 1350 hrs	10i	Some turbines operating, below rated power	7.8	27	Wind farm clearly audible, Hum and swoosh audible but not modulating significantly
18/08/2021 1110 hrs	9i	All visible except 2	5.4	297	Gearbox hum audible during nulls
17/08/2021 0901 hrs	10i	All visible except 2	7.5	243	Low/mid frequency tone faintly audible
17/08/2021 0730 hrs	56i	All visible	7.8	253	Swoosh from turbine audible
17/08/2021 1335 hrs	103i	All visible except 2	6.8	227	Wind farm inaudible

Although the attended observations did not warrant an objective assessment of SACs, the results of near-field testing[9] indicated tonality was a characteristic of the test turbine. In accordance with the NCTP, an objective assessment of tonality is to be conducted for the second phase of monitoring to investigate whether this characteristic is present at the receivers.

[9] See MDA document Lt 002 20200683 - *Berrybank Wind Farm - Near-field Compliance Testing Report*, dated 3 August 2022

6.3 Compliance assessment

The following section presents an assessment for compliance at the monitoring locations based on either:

- total measured noise levels being a combination of wind turbine noise and background noise; or
- estimated wind farm noise levels, adjusted to account for the influence of background noise on the total noise levels, as detailed in Section 7.6 of the NCTP.

It is noted that the total measured noise levels include the contribution of background noise and, as such, wind farm noise would be lower. An assessment of compliance using total noise levels is conservative.

As detailed in Section 6.2, SAC penalties have not been applied.

The results presented in this section total noise levels or estimated wind farm noise levels are below the applicable noise limits at all assessed locations.

Therefore, wind turbine noise levels from Stage 1 of the Berrybank Wind Farm complied with the applicable noise criteria at all locations and time periods during this monitoring.

6.3.1 Location 55 (S)

The results presented in Table 13 demonstrate total measured noise levels below the applicable noise limit for all wind speeds and time periods by more than the 0.5 dB uncertainty due to the misalignment on the anemometer of turbine 09.

Accordingly, compliance with the planning permit can be inferred at the relevant NCTP location (57).

Table 15: Location 55 (S) compliance assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level	-	-	31.6	32	32.6	33.5	34.6	35.9	37.3	38.9	40.5	42.3	44.2
Noise limit	40.0	40.0	40.0	40.0	40.0	40.0	40.0	41.1	43.5	46.1	48.7	51.2	53.7

6.3.2 Location 69

The results presented in Table 16 demonstrate total measured noise levels below the noise limit for all wind speeds and time periods.

Compliance is therefore demonstrated at location 69.

Table 16: Location 69 compliance assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level	-	-	35.3	35.5	36	36.6	37.4	38.4	39.4	40.5	41.6	42.7	43.7
Noise limit	40.0	40.0	40.0	40.0	40.0	40.0	40.3	42.4	44.5	46.7	49.0	51.2	53.4

6.3.3 Location 70

The results presented in Table 17 demonstrate total measured noise levels below the applicable noise limit for all wind speeds and time periods.

Compliance is therefore demonstrated at location 70.

Table 17: Location 70 compliance assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level	31.3	31.9	32.6	33.4	34.3	35.4	36.5	37.6	38.8	39.9	41.1	42.2	43.3
Noise limit	40.0	40.0	40.0	40.0	40.0	40.0	40.0	42.1	44.7	47.4	50.2	52.8	55.4

6.3.4 Location 80

The results presented in Table 18 demonstrate total measured noise levels below the applicable noise limit for all wind speeds and time periods.

Compliance is therefore demonstrated at location 80.

Table 18: Location 80 compliance assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level	28.2	29.5	30.9	32.2	33.5	34.8	36.0	37.1	38.2	39.2	40.1	40.8	41.4
Noise limit	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.2	42.2	44.3	46.4	48.4

6.3.5 Location 102

The results presented in Table 19 demonstrate estimated wind farm noise levels below the applicable noise limit for all wind speeds and time periods by at least the 0.5 dB uncertainty due to the misalignment on the anemometer of turbine 09.

Compliance was therefore demonstrated at location 102.

Table 19: Location 102 compliance assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level	29.1	30.8	32.4	33.9	35.3	36.7	37.9	39.1	40.0	40.9	41.6	42.1	42.4
Background noise level	23.9	24.3	25.1	26.2	27.6	29.3	31.1	33.1	35.1	37.3	39.5	41.7	43.9
Estimated wind farm noise level	27.6	29.6	31.5	33.1	34.5	35.8	36.9	37.8	38.4	38.4	- [1]	- [1]	- [1]
Noise limit	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.2	42.3	44.5	46.8	48.9

[1] Estimated wind farm noise level cannot be estimated when the difference between total noise level and background noise level is less than 3 dB

6.3.6 Location 108

The results presented in Table 20 demonstrate total measured noise levels below the applicable noise limit for all wind speeds and time periods.

Compliance was therefore demonstrated at location 108.

Table 20: Location 108 compliance assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level	-	-	34.0	34.7	35.6	36.6	37.6	38.7	39.9	41.2	42.5	43.8	45.2
Noise limit	40.0	40.0	40.0	40.0	40.0	40.4	42.4	44.5	46.8	49.0	51.2	53.3	55.2

6.3.7 Location 9i

The results presented in Table 21 demonstrate total measured noise levels below the base noise limit 40 dB L_{A90} for all wind speeds and time periods by at least the 0.5 dB uncertainty due to the misalignment on the anemometer of turbine 09.

Accordingly, compliance with the planning permit can be inferred at the relevant NCTP location (9).

Table 21: Location 9i assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level	27.5	29.4	31.1	32.7	34.1	35.3	36.3	37.2	37.9	38.4	38.7	38.9	38.9

6.3.8 Location 10i

Noise levels at location 10 have been estimated based on measured total noise levels at the monitoring location 10i.

The total measured noise levels in Table 22 have been used to calculate the expected noise level of the wind farm at the NCTP location 10. The calculation is based on extrapolation of the noise level at the monitoring location (10i) using the method detailed in Section 7.7 of the NCTP.

The estimated noise levels at location 10 are below the base noise limit 40 dB L_{A90} for all wind speeds and time periods.

Accordingly, compliance with the planning permit can be inferred at the relevant NCTP location (10).

Table 22: Location 10i compliance assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level location 10i	33.6	36.4	38.7	40.7	42.3	43.6	44.5	45.3	45.9	46.3	46.6	46.8	47.0
Extrapolation correction	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5
Estimated noise level location 10	26.1	28.9	31.2	33.2	34.8	36.1	37.0	37.8	38.4	38.8	39.1	39.3	39.5

6.3.9 Location 56i

Noise levels at location 56 have been estimated based on the measured total noise levels at the monitoring location 56i.

The total measured noise levels in Table 23 have been used to calculate the expected noise level of the wind farm at the NCTP location 56. The calculation is based on extrapolation of the noise level at the monitoring location (56) using the method detailed in Section 7.7 of the NCTP.

The estimated noise level at location 56 are below the base noise limit 40 dB L_{A90} for all wind speeds and time periods by at least the 0.5 dB uncertainty due to the misalignment on the anemometer of turbine 09.

Accordingly, compliance with the planning permit can be inferred at the relevant NCTP location (56).

Table 23: Location 56i assessment, dB L_{A90} – all time periods

Description	Hub height wind speed, m/s												
	3	4	5	6	7	8	9	10	11	12	13	14	15
Total noise level location 56i	31.3	33.0	34.3	35.3	36.2	36.9	37.5	38.1	38.7	39.3	40.1	41.1	42.3
Extrapolation correction	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
Estimated noise level location 56	28.5	30.2	31.5	32.5	33.4	34.1	34.7	35.3	35.9	36.5	37.3	38.3	39.5

6.3.10 Location 63i

The results presented in Table 24 demonstrate total measured noise levels below the base noise limit 40 dB L_{A90} for all wind speeds and time periods.

Accordingly, compliance with the planning permit can be inferred at the relevant NCTP location (63).

Table 24: Location 63i assessment, dB L_{A90} – all time periods

Description	Hub height wind speed , m/s												
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Total noise level	28.4	29.4	30.5	31.6	32.6	33.7	34.8	35.8	36.7	37.5	38.2	38.8	39.2

6.3.11 Location 103i

The results presented in Table 25 demonstrate total measured noise levels below the base noise limit 40 dB L_{A90} for all wind speeds and during the all-time periods and night-time periods respectively.

Accordingly, compliance with the planning permit can be inferred at the relevant NCTP location (103).

Table 25: Location 103i assessment, dB L_{A90}

Description	Hub height wind speed , m/s												
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Total noise level all-time period	-	31.6	32.1	32.8	33.7	34.8	35.8	36.9	37.8	38.7	39.3	39.6	-
Total noise level night-time period	-	28.2	29.0	30.2	31.6	33.1	34.6	36.0	37.3	38.2	38.8	38.9	-

7.0 SUMMARY

A post-construction noise compliance assessment for Stage 1 of the Berrybank Wind Farm was carried out in general accordance with the endorsed NCTP to address the requirements of the wind farm's planning permit, based on noise monitoring carried out between June and September 2021.

The results demonstrate compliance with Condition 17 of the planning permit.

In accordance with the NCTP, the next stage of monitoring is scheduled to commence before 20 September 2022.

Considering the results of near-field testing indicated tonality was a characteristic of the test turbine, an objective assessment of tonality is to be conducted for the second phase of monitoring to investigate whether this characteristic is present at the receivers.

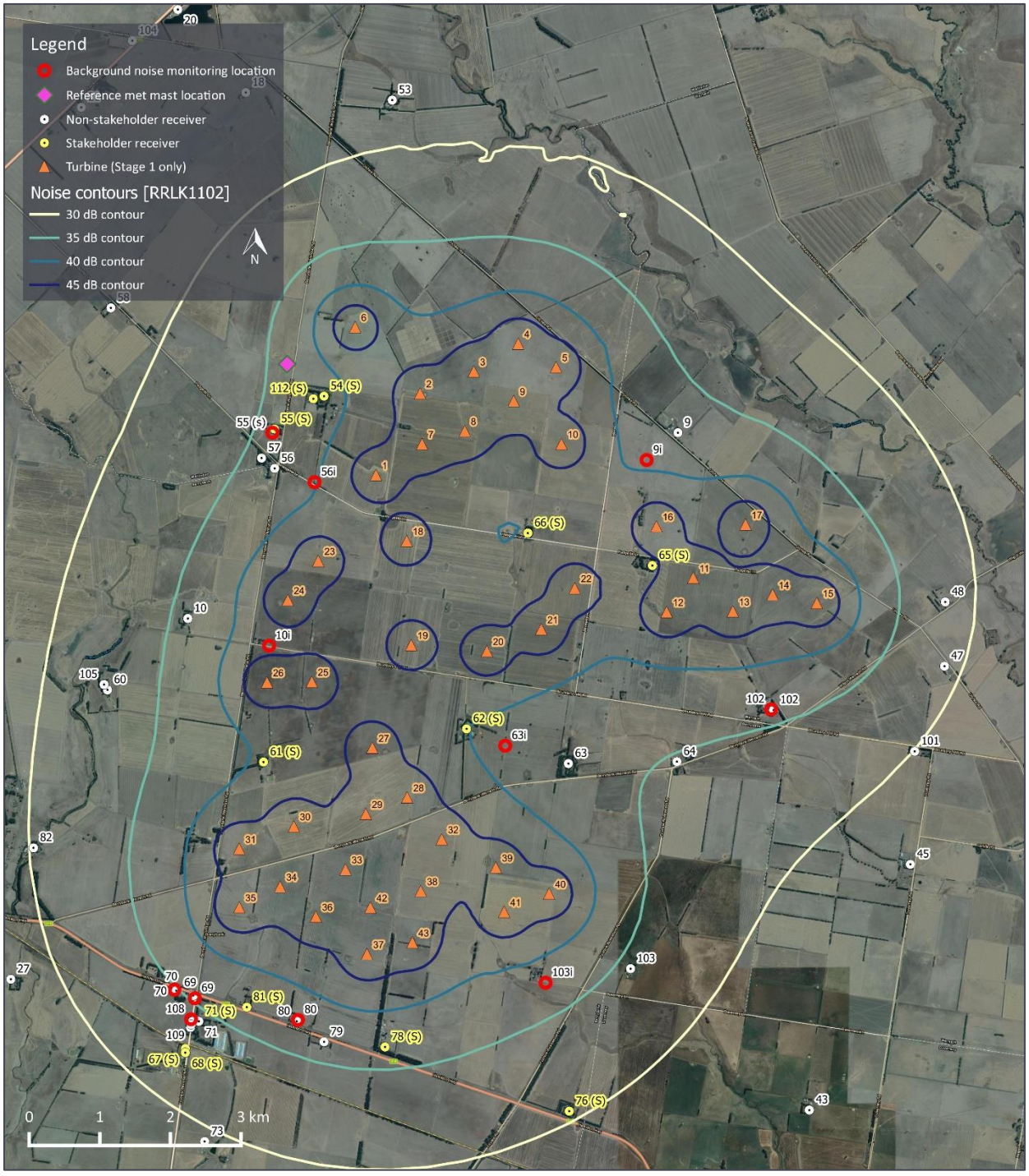
APPENDIX A GLOSSARY OF TERMINOLOGY

The basic quantities used within this document to describe noise adopt the conventions outlined in ISO 1996-1:2016 *Acoustics - Description measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures*.

Accordingly, all frequency weighted sound pressure levels are expressed as decibels (dB) in this report. For example, sound pressure levels measured using an "A" frequency weighting are expressed as dB L_A. Alternative ways of expressing A-weighted decibels such as dBA or dB(A) are therefore not used within this report (unless quoting directly from a document which uses this terminology).

Amplitude Modulation	Sound that is characterised by a rhythmic and higher than normal rise and fall in sound level at regular intervals.
A-weighting	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear.
dB	Decibel. The unit of sound level.
Frequency	The number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz).
Hertz (Hz)	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
Impulsiveness	Sound that is characterised by a distinct and very rapid rise in sound level (e.g. a car door closing or the impact sound of a hammer)
L_{A90}	The A-weighted noise level equalled or exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.
L_W	The sound power level. The level of total sound power radiated by a sound source.
L_{WA}	The "A" weighted sound power level.
Special Audible Characteristics	Features of a sound which, when present, increase the likelihood of adverse reaction the sound. These characteristics include tonality, impulsiveness and amplitude modulation.
Tonality	Sound characterized by a single frequency component or narrow-band components that emerge audibly from the total sound (e.g. whines or hissing sounds)

APPENDIX B SITE LAYOUT AND NOISE CONTOURS (STAGE 1 ONLY)



APPENDIX C TURBINE LOCATIONS (STAGE 1)

WTG ID	Easting, m	Northing, m	WTG ID	Easting, m	Northing, m
1	720733	5799429	23	720062	5798490
2	721251	5800323	24	719710	5798063
3	721859	5800552	25	719954	5797147
4	722364	5800847	26	719453	5797154
5	722780	5800575	27	720611	5796396
6	720545	5801081	28	720985	5795834
7	721258	5799760	29	720518	5795662
8	721740	5799891	30	719710	5795545
9	722296	5800211	31	719092	5795312
10	722817	5799718	32	721359	5795356
11	724250	5799189	33	720275	5795050
12	723942	5797816	34	719538	5794878
13	724683	5797804	35	719076	5794661
14	725133	5797978	36	719929	5794535
15	725624	5797870	37	720489	5794103
16	723854	5798772	38	721109	5794788
17	724851	5798766	39	721955	5795028
18	721057	5798686	40	722543	5794720
19	721076	5797527	41	722034	5794531
20	721921	5797435	42	720541	5794620
21	722535	5797663	43	721000	5794218
22	722922	5798109			

APPENDIX D PREDICTED WIND TURBINE NOISE LEVELS

Table 26: Predicted wind turbine noise contribution from Stages 1 and 2, dB L_{A90}

Monitoring location	Stage 1 only	Stage 2 only	Cumulative	Difference between cumulative level and level with Stage 1 only is at least 5 dB?
9i	39.3	23.9	39.4	No
10i	43.6	26.4	43.7	No
18i	28.1	42.8	42.9	Yes
27	28.3	34.0	35.0	Yes
55 (S)	35.9	33.4	37.8	No
56i	39.7	30.2	40.2	No
58i	29.8	42.6	42.8	Yes
63i	38.9	28.7	39.3	No
69	35.3	33.3	37.4	No
70	34.8	33.9	37.4	No
73i	29.6	39.4	39.8	Yes
80	37.4	33.4	38.9	No
83i	30.2	39.9	40.3	Yes
102	36.0	24.2	36.3	No
103i	37.5	44.2	45.0	Yes
108	34.0	34.3	37.2	No

APPENDIX E SURVEY INSTRUMENTATION

Table 27: Sound level measurement instrumentation summary

Item	Description
Equipment type	Automated/unattended integrating sound levels
Make & model	01dB CUBEs & DUOs
Instrumentation class	Class 1 (precision grade) in accordance with AS/IEC 61672.1:2019[10]
Instrumentation noise floor	Less than 20 dB
Time synchronisation	Internal GPS clocks
Wind shielding	Enhanced wind shielding system based on the design recommendations detailed in the UK good practice guide. The system comprises an inner solid primary wind shield and an outer secondary large diameter hollow wind shield

Table 28: Sound level meter installation records

Location	System	Unit serial number	Microphone serial number	Independent calibration date [1]	Calibration drift [2,3]
55 (S)	01dB DUO	10197	141100	24/05/2021	-0.03
69	01dB CUBE	10651	207209	23/02/2021	0.59
70	01dB DUO	10409	224184	01/06/2021	0.30
80	01dB DUO	10778	162059	16/09/2019	-1.10/-1.68
102	01dB DUO	10349	207229	21/02/2020	0.16
108	01dB CUBE	10419	144877	03/06/2021	0.02
9i	01dB CUBE	10511	255808	16/11/2020	-0.92
10i	01dB CUBE	11887	330712	28/08/2019	-0.48
56i	01dB DUO	10299	144871	07/06/2021	-1.48
63i	01dB DUO	10499	141223	14/01/2020	-0.48
103i	01dB CUBE	10516	141223	14/01/2020	0.53

Note 1: Independent (laboratory) calibration date to be within 2 years of measurement period as per AS 1055:2018[11]

Note 2: Difference between reference level checks during deployment and collection of instruments

Note 3: Calibration drift should not be greater than 1 dB as specified in AS 1055:2018

The reference calibration checks were conducted using a 01dB -Stell CAL21 calibrator during deployment and retrieval of the monitors.

Table 29: Local wind speed measurement instrumentation

Wind speeds	Description
Local wind speeds	Vaisala WXT 520 weather station positioned at location 69 (Serial No. H5020012) and location 102 (Serial No. W59)

[10] AS/IEC 61672.1-2019 *Electroacoustics - Sound level meters Specifications*

[11] AS 1055:2018 *Acoustics – Description and measurement of environmental noise*

APPENDIX F SITE WIND DATA

Site wind data for the site has been received from Vestas via GPG on 8 June 2022. The site wind data provided was for a total of three (3) turbines (4, 6 and 15), with turbine 6 selected with a correction factor applied to reference the previously measured background noise metrological mast location. The wind speed and direction data received has been synchronized by Vestas with the interval commencing on the hour and for each 10-minute interval. Correspondence from Vestas via email on 24 March 2022 details the process in which this data was obtained. This process is detailed below:

Below cut-in (~3-4 m/s) and above cut out (~22-30 m/s) the provided wind speed originates from the anemometers because in those wind speed intervals there is no generated power, hence wind speed estimation based on power is not possible. Below cut-in, wind speed is not used for turbine startup purposes; the turbines uses the wind direction to align itself with the wind and once the rotor speed is above a threshold then production initiates. Above cut-out, the anemometer-based wind speed estimation is used in the hysteresis used to avoid repetitive start-up/stop cycles if wind conditions are close to cut-out.

Wind Speed Estimator (WSE)

Wind Speed Estimator (WSE) is a software algorithm within the Vestas control system which uses the measured energy across the rotor plane combined with knowledge of pitch angle, rotor RPM, operation state and detailed aerodynamic knowledge of the blades, to reverse engineer a wind speed.

This wind speed is a more accurate measurement compared to the nacelle-mounted wind speed sensor measurement, which is only measured at the center of the rotor plane and is affected by changes in wind flow behind the rotor.

Using information from key operational parameters, such as power, pitch angle, and speed, Wind Speed Estimator is able to calculate the incoming wind speed over the entire rotor area based on how the turbine operates and performs under specific wind conditions. This information is then used to automatically replace the wind correlation parameters below rated power – and improve turbine operations.

How it works

The WSE replaces the ambient (FT measured) wind speed for controlling the turbine in partial load.

Thus, the FT sensor based wind speed is in normal situations not being used to control the turbine anymore. It will however still be used for:

a) upwind yaw control

b) determine when to cut-out due to high wind speeds

c) detecting failures of the WSE or the other FT sensor

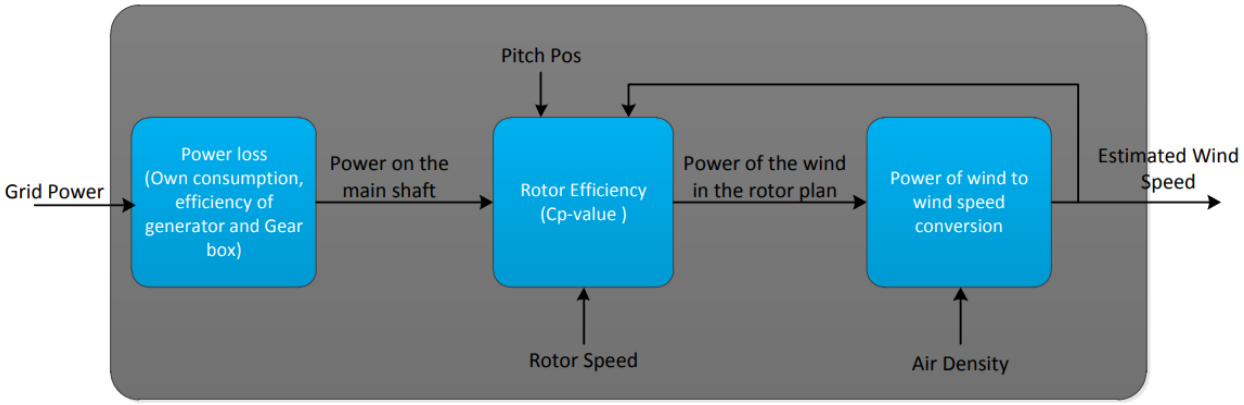
d) backup if WSE is not valid (low rotor speed / power, icing or errors).

The full load controller does not use the wind speed in its regulation of the rotor speed.

The wind speed is calculated from a set of parameters including production inclusive loss in drivetrain, own consumption, speed of the rotor and pitch angle.

These parameters will be held up against an internal table in the software which takes into account for ambient temperature, tower height and height above sea level.

The Wind Estimator (Wind Speed Estimator or also know as Rotor Equivalent Wind Speed) is part of the Wind Sensing System. The purpose of the Wind Estimator is to give a reliable estimate of the rotor-equivalent wind speed. Current methods rely on rotor power-equivalent methods and, because of this, it is only valid when the turbine is producing power for at least a short period of time (stabilization). The wind estimate is used to improve power production during partial load. The Wind Estimator is also used as input for fault detection and diagnosis of the anemometers.



The basic principle of the Wind Estimator is to use the power delivered to the main shaft of the turbine. This is done by adding the turbines own electrical consumption, ice removal/prevention energy consumption, and losses in drivetrain, to the measured grid power. The power of the wind in the rotor field is then estimated by dividing the Main Shaft Power with the efficiency of the rotor. The efficiency of the rotor depends on the pitch positions of the blades and the ratio between the tip speed of the blades and the wind speed. Because the wind speed is unknown the previous estimate of the wind speed is used as input.

APPENDIX G SUMMARY OF POST CONSTRUCTION NOISE LEVELS

Table 30: Regression equation coefficients – All time periods

	Regression equation coefficients for background noise equation of best fit $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
Location	**a**	**b**	**c**	**d**	**R^2**	**Valid wind speed range, m/s**
55 (S)	-0.0038	0.1926	-1.371	34.06	0.48	5 – 15
69	-0.0062	0.2323	-1.792	39.24	0.26	5 – 15
70	-0.0035	0.1162	-0.1305	30.75	0.26	3 – 15
80	-0.0025	0.03637	1.155	24.49	0.32	3 – 15
102	-0.0021	-0.004	1.761	23.92	0.34	3 – 15
108	-0.0015	0.07817	0.03975	32.0	0.31	5 – 15
9i	-	-0.08554	2.48861	20.83	0.17	3 – 15
10i	0.00688	-0.3044	4.676	22.1	0.46	3 – 15
56i	0.00919	-0.2685	3.181	23.94	0.51	3 – 15
63i	-0.0034	0.06566	0.6724	25.9	0.64	3 – 15
103i	-0.0109	0.2844	-1.413	33.42	0.38	4 – 14

Table 31: Regression equation coefficients – night time periods

	Regression equation coefficients for background noise equation of best fit $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
Location	**a**	**b**	**c**	**d**	**R^2**	**Valid wind speed range, m/s**
103i	-0.0163	0.3959	-1.694	29.65	0.79	4 – 14

APPENDIX H LOCATION 55 (S)

H1 Location 55 (S) data

Table 32: Location 55 (S) dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Dwelling location	719613	5799970
Noise monitoring location	719588	5799930

Figure 4: Location 55 (S) aerial view – dwelling and noise monitor locations

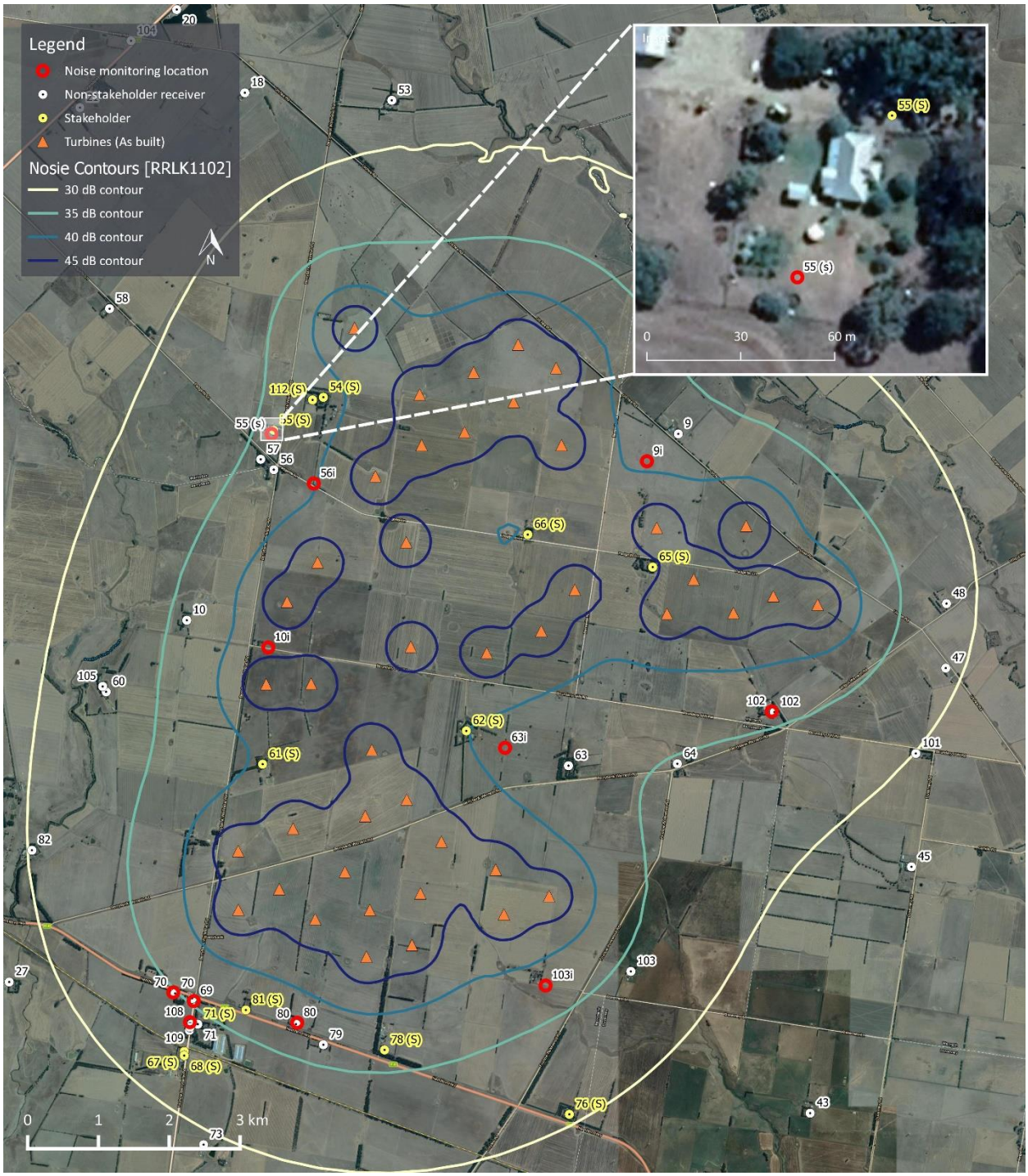


Table 33: Location 55 (S) monitor installation photos

Looking North	Looking East
	
Looking South	**Looking West**
	

H2 Location 55 (S) measurement data summary

Table 34: Location 55 (S) noise level analysis summary

Data points	All-time (day & night combined)
Collected	8068
Removed [1]	6296
Retained	1772

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 5: Location 55 (S) post construction noise level and wind speed time history

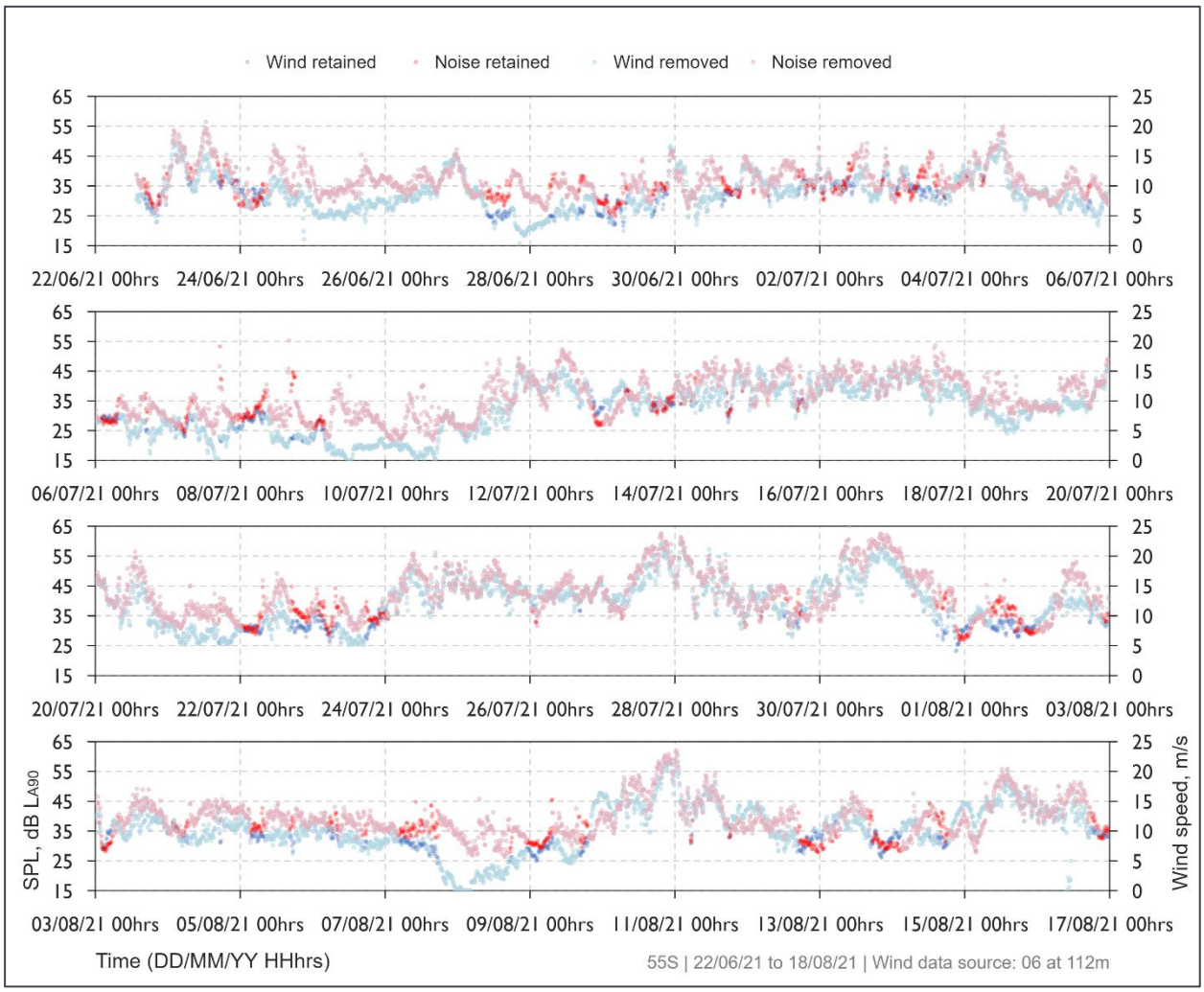
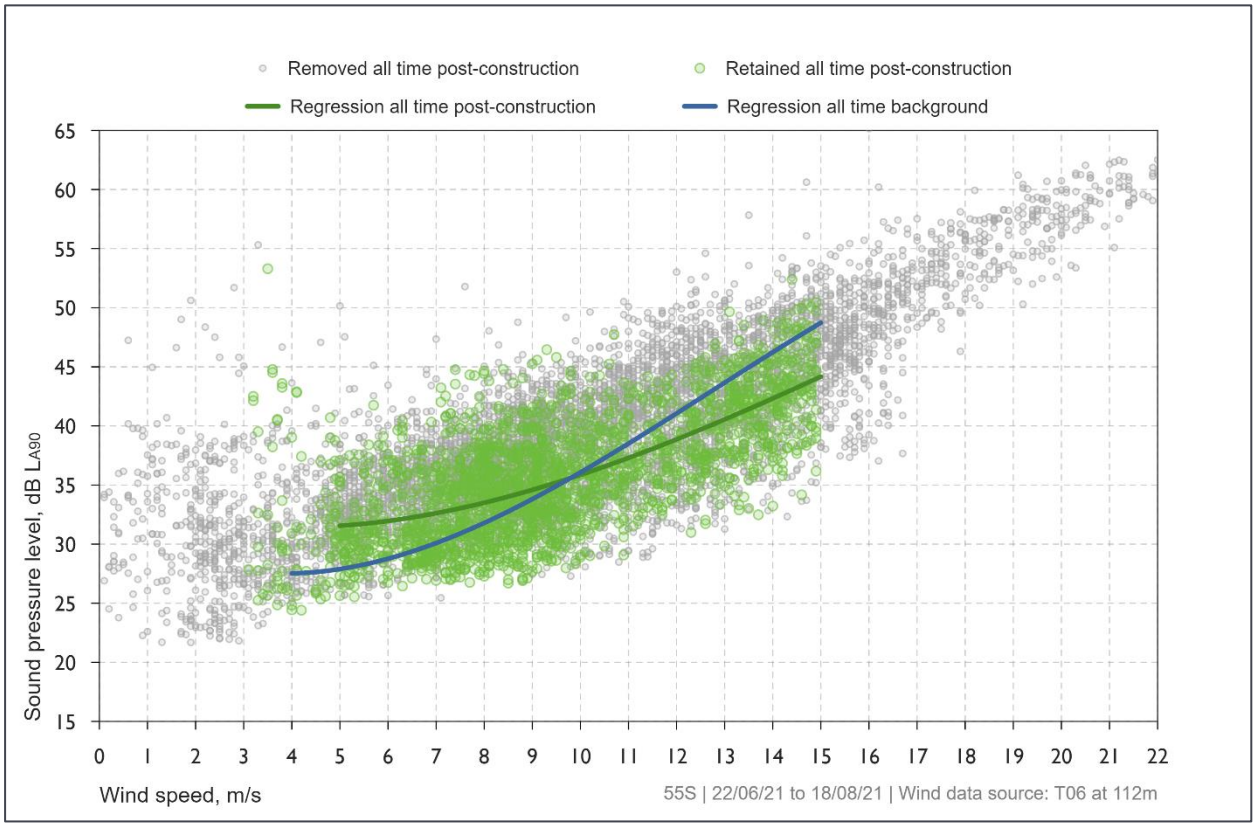


Figure 6: Location 55 (S) all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX I LOCATION 69

I1 Location 69 data

Table 35: Location 69 dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Dwelling location	718535	5793693
Noise monitoring location	718550	5793663

Figure 7: Location 69 aerial view – dwelling and noise monitor locations

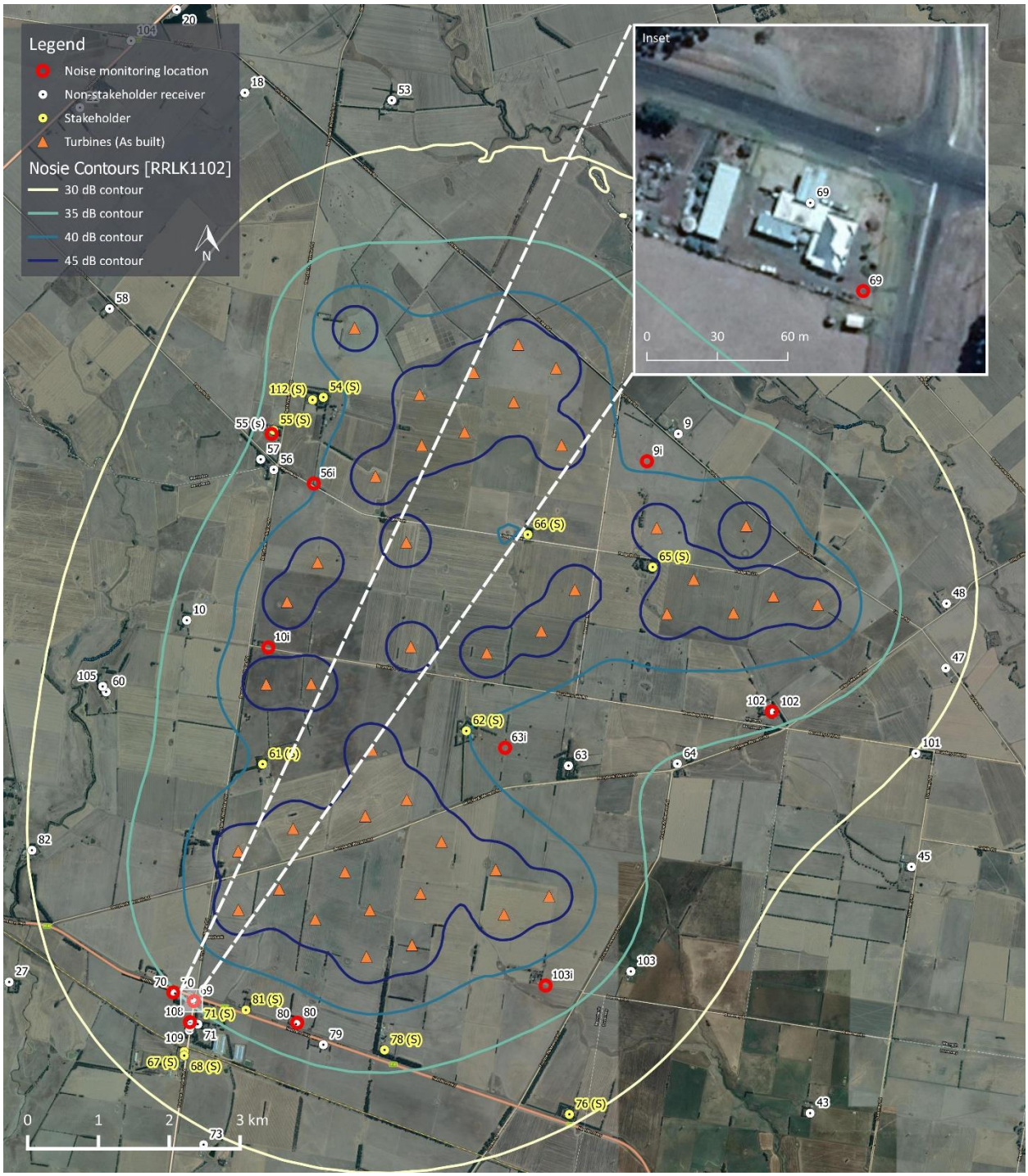


Table 36: Location 69 monitor installation photos

Looking North	Looking East
	
Looking South	**Looking West**
	

I2 Location 69 measurement data summary

Table 37: Location 69 noise level analysis summary

Data points	All-time (day & night combined)
Collected	6359
Removed [1]	4345
Retained	2014

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 8: Location 69 post construction noise level and wind speed time history

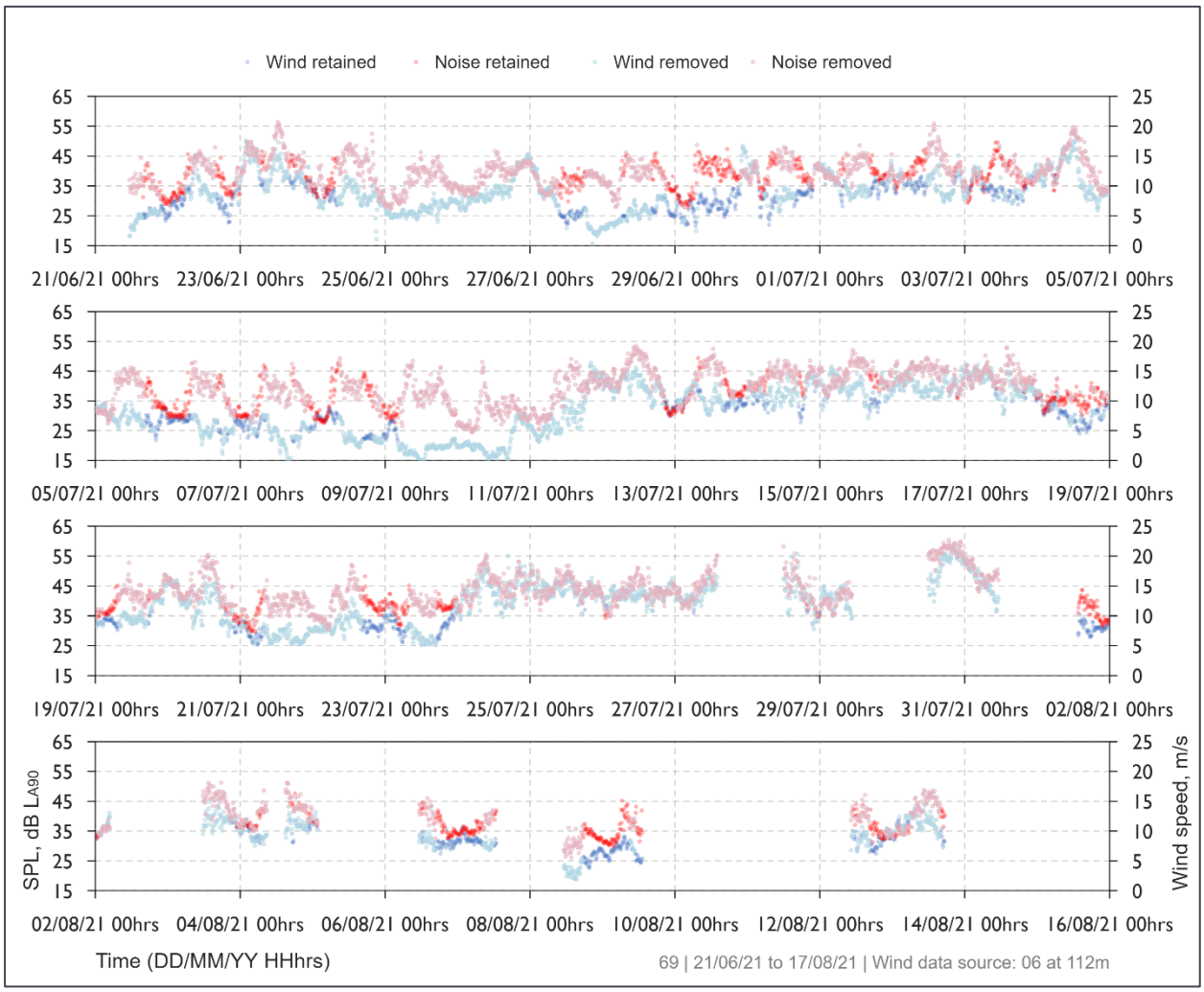
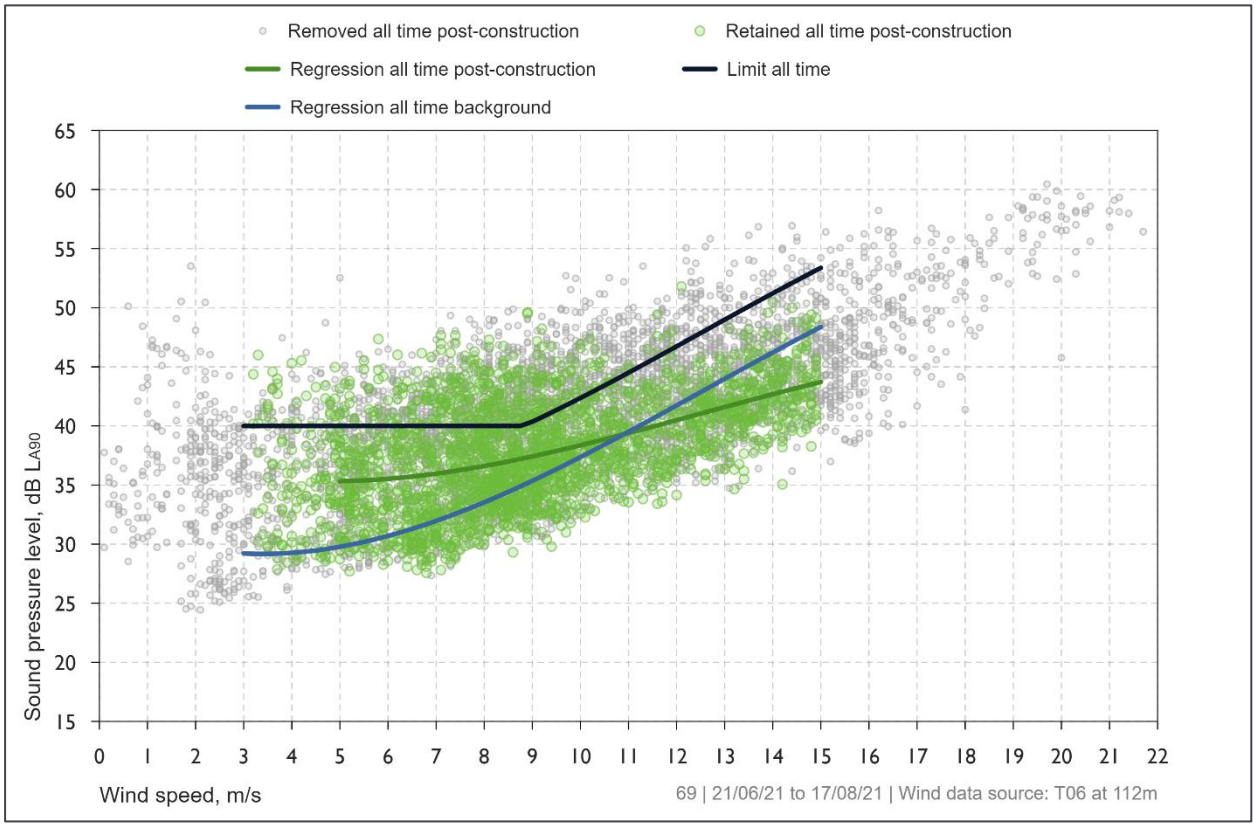


Figure 9: Location 69 all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX J LOCATION 70

J1 Location 70 data

Table 38: Location 70 dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Dwelling location	718346	5793752
Noise monitoring location	718327	5793766

Figure 10: Location 70 aerial view – dwelling and noise monitor locations

Table 39: Location 70 monitor installation photos

Looking North	Looking East
	
Looking South	**Looking West**
	

J2 Location 70 measurement data summary

Table 40: Location 70 noise level analysis summary

Data points	All-time (day & night combined)
Collected	8048
Removed [1]	5628
Retained	2420

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 11: Location 70 post construction noise level and wind speed time history

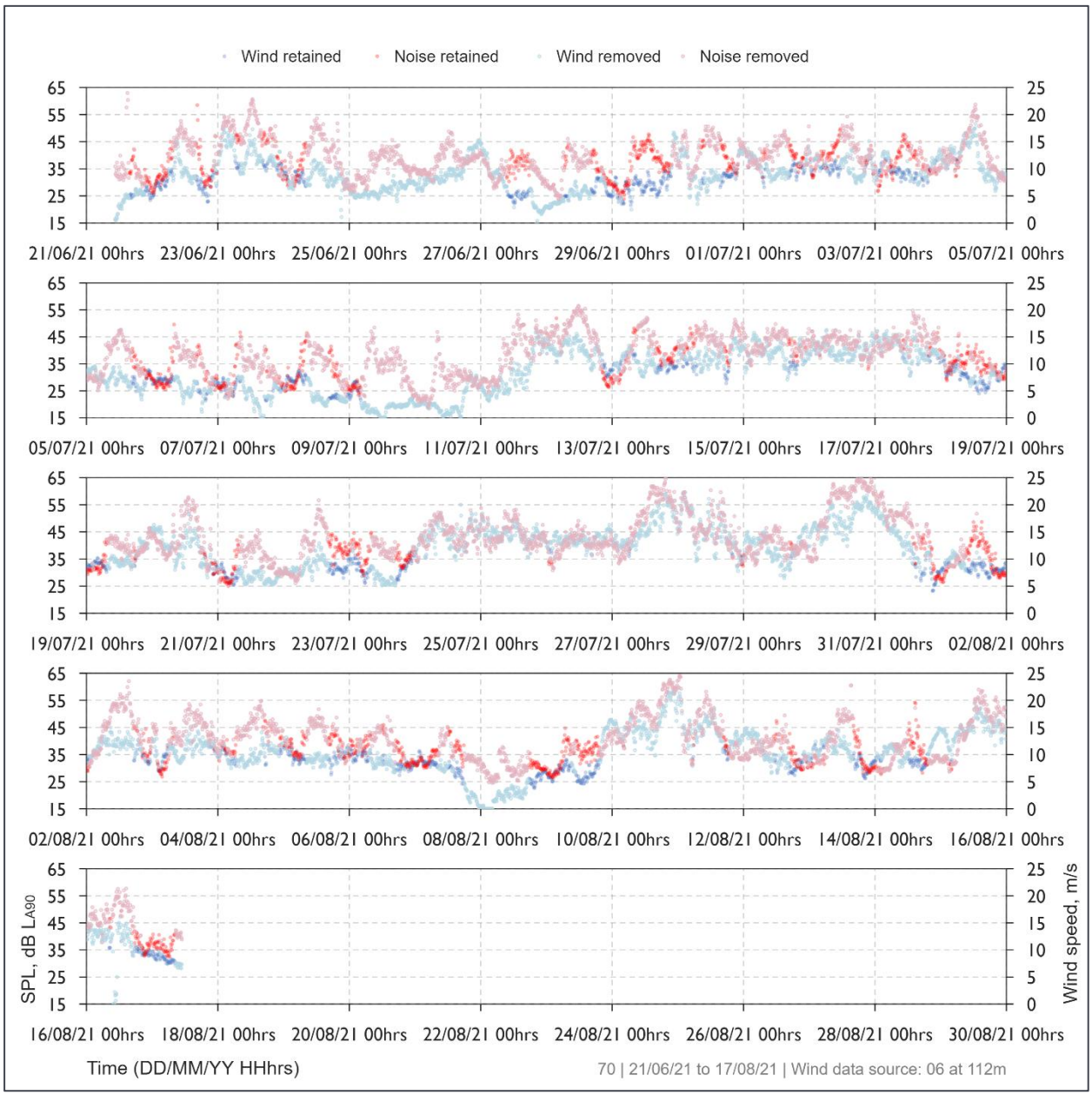
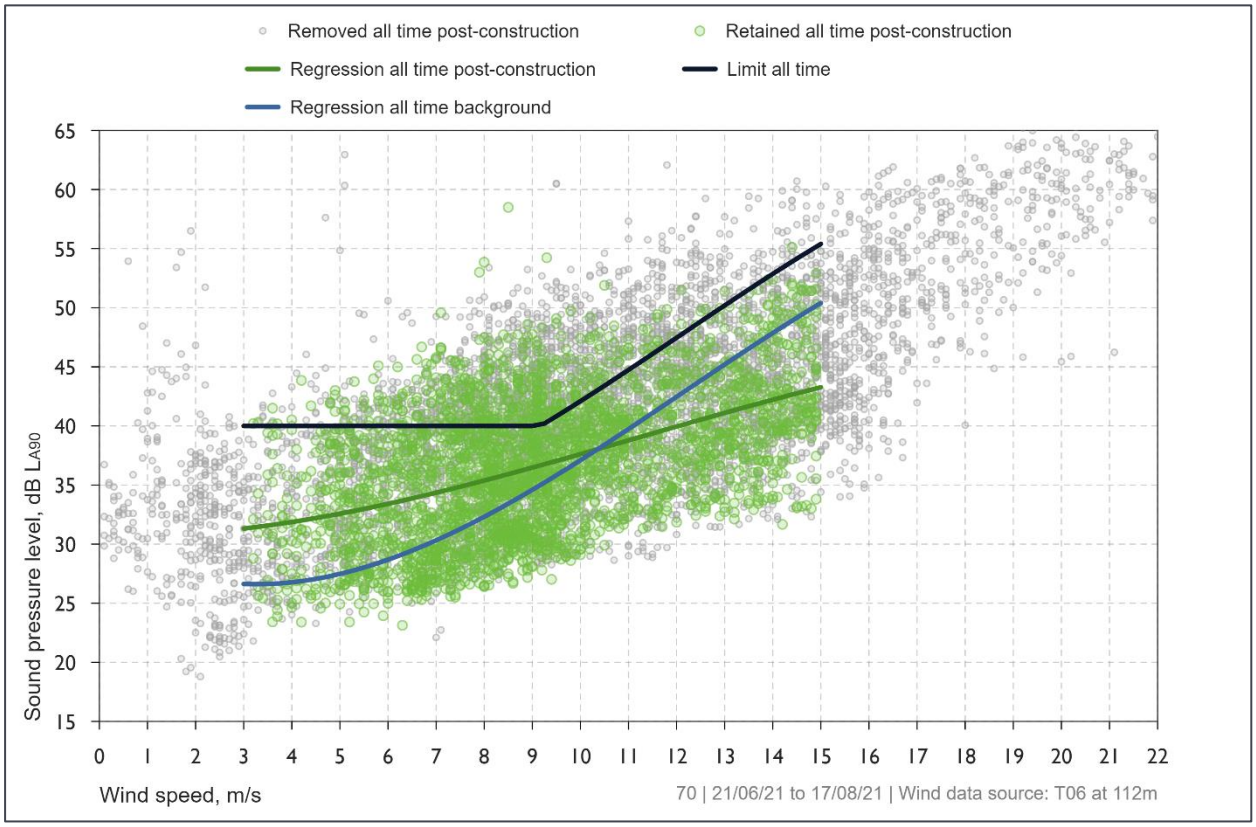


Figure 12: Location 70 all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX K LOCATION 80

K1 Location 80 data

Table 41: Location 80 dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Dwelling location	719684	5793375
Noise monitoring location	719713	5793387

Figure 13: Location 80 aerial view – dwelling and noise monitor locations

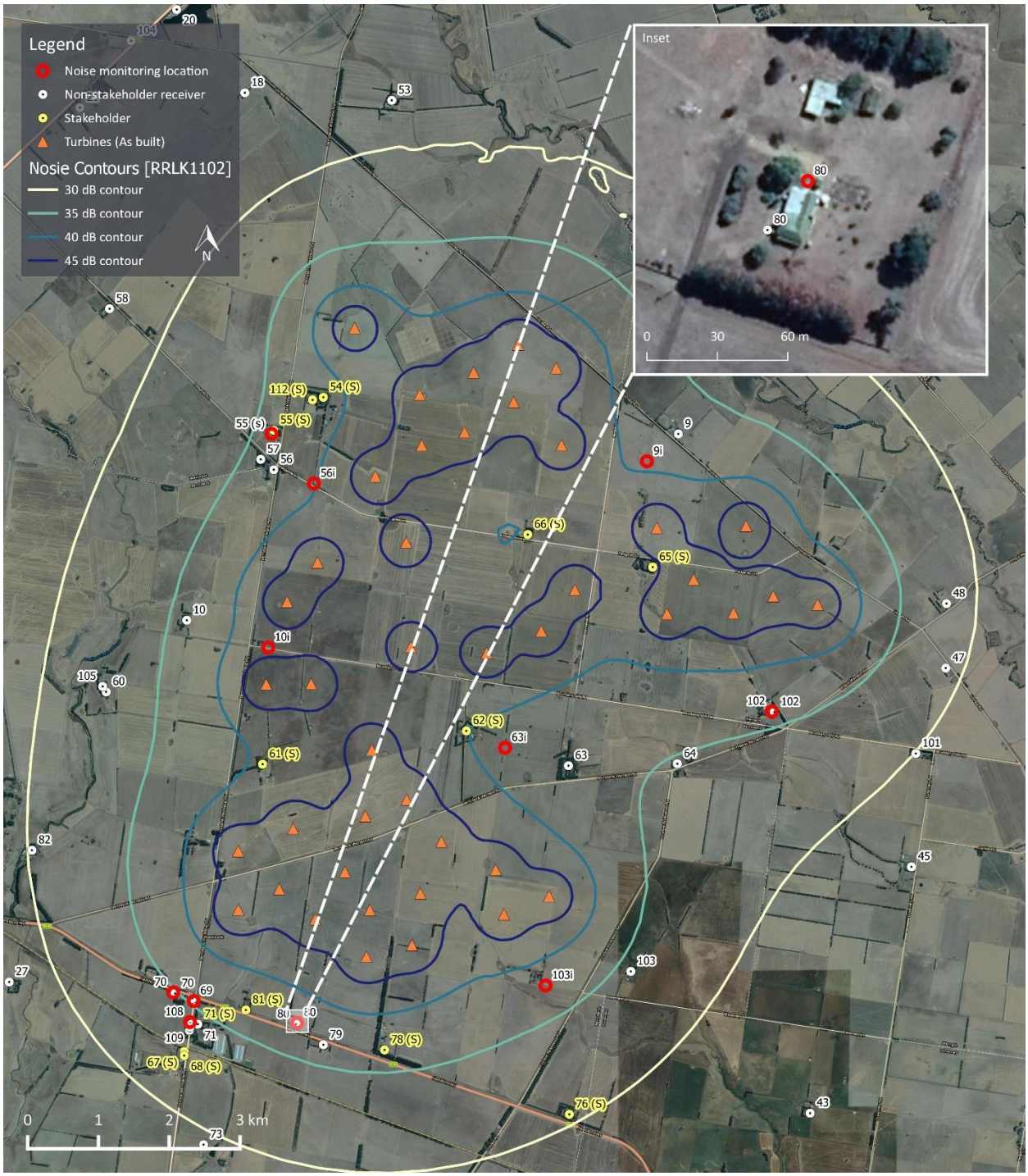


Table 42: Location 80 monitor installation photos

Looking North	Looking East
	
Looking South	**Looking West**
	

K2 Location 80 measurement data summary

Table 43: Location 80 noise level analysis summary

Data points	All-time (day & night combined)
Collected	9587
Removed [1]	6209
Retained	3378

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 14: Locarion 80 post construction noise level and wind speed time history

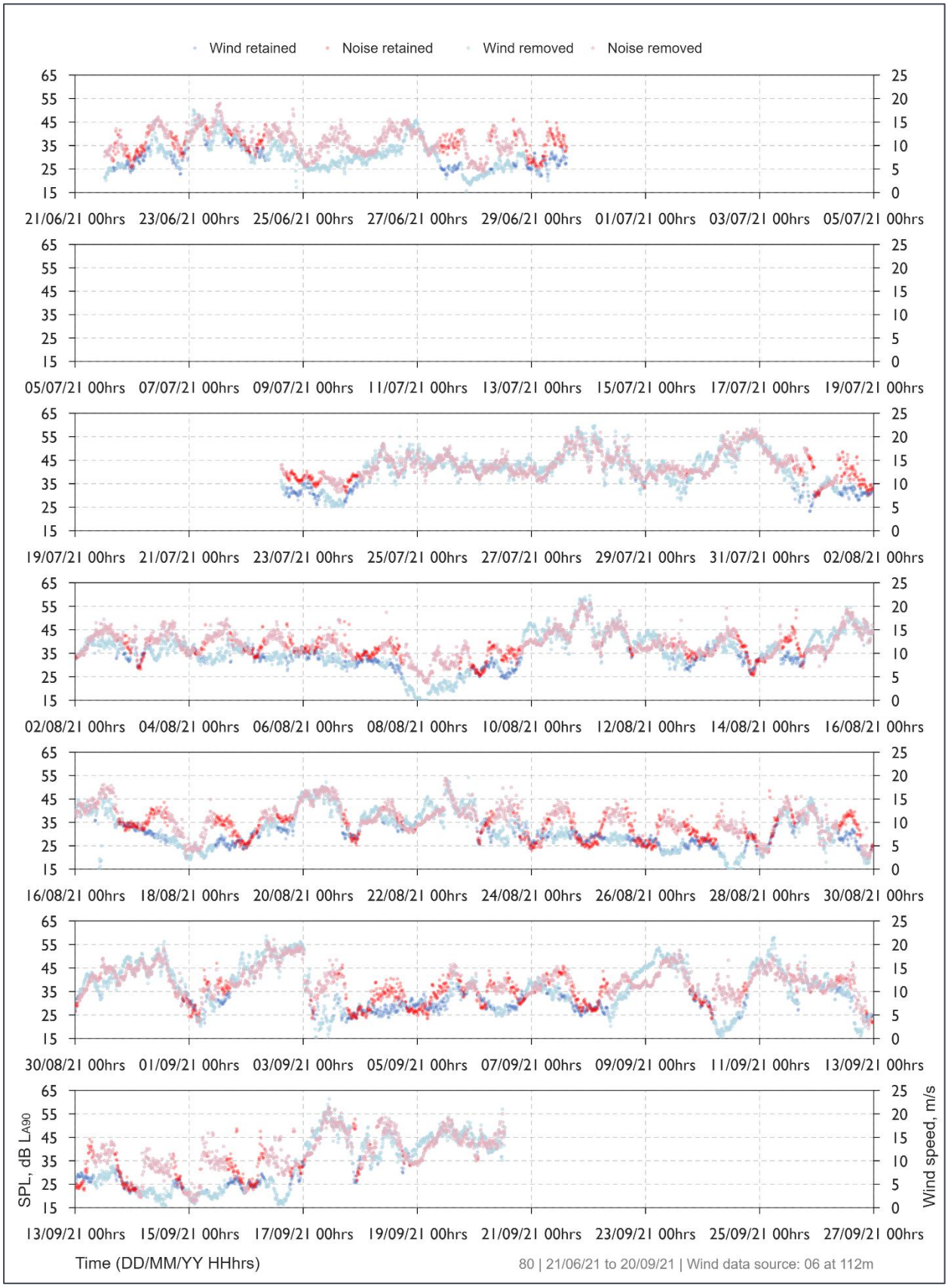
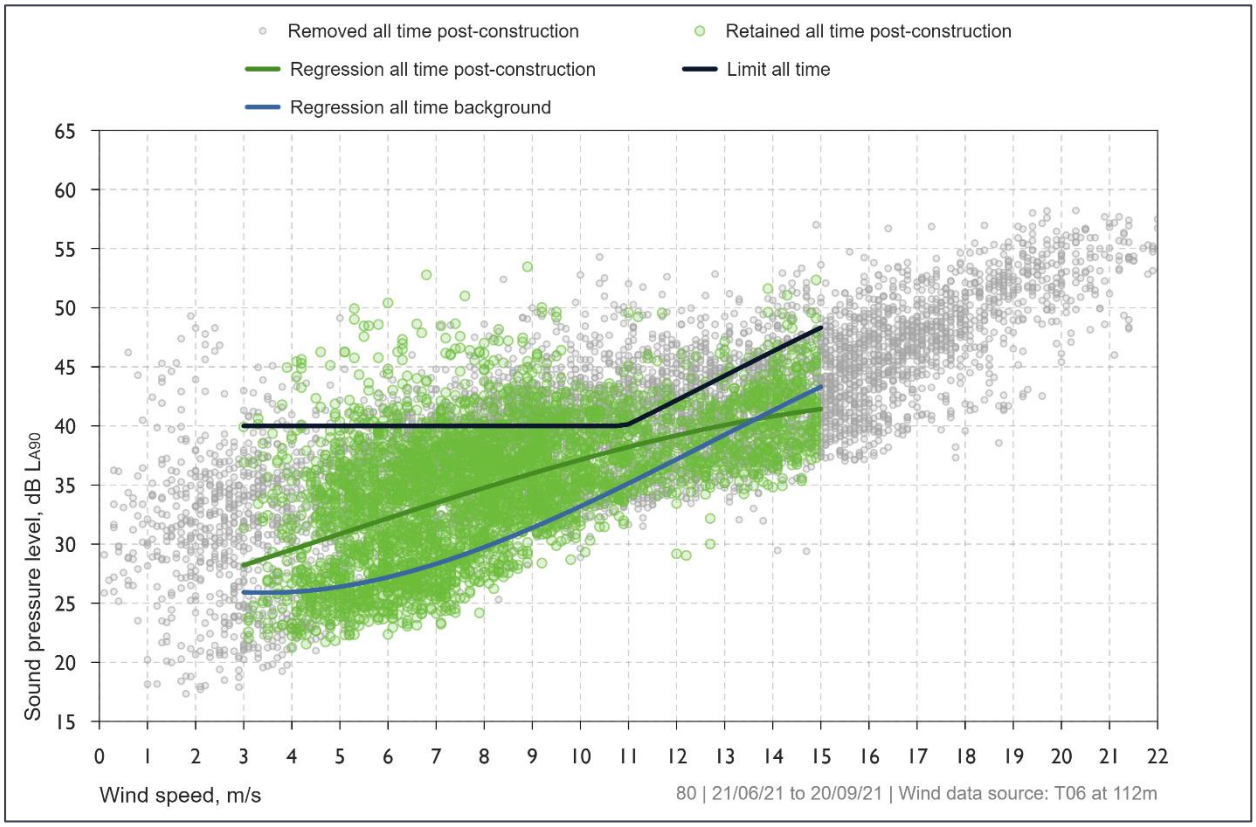


Figure 15: Location 80 all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX L LOCATION 102

L1 Location 102 data

Table 44: Location 102 dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Dwelling location	725109	5796692
Noise monitoring location	725090	5796701

Figure 16: Location 102 aerial view – dwelling and noise monitor locations

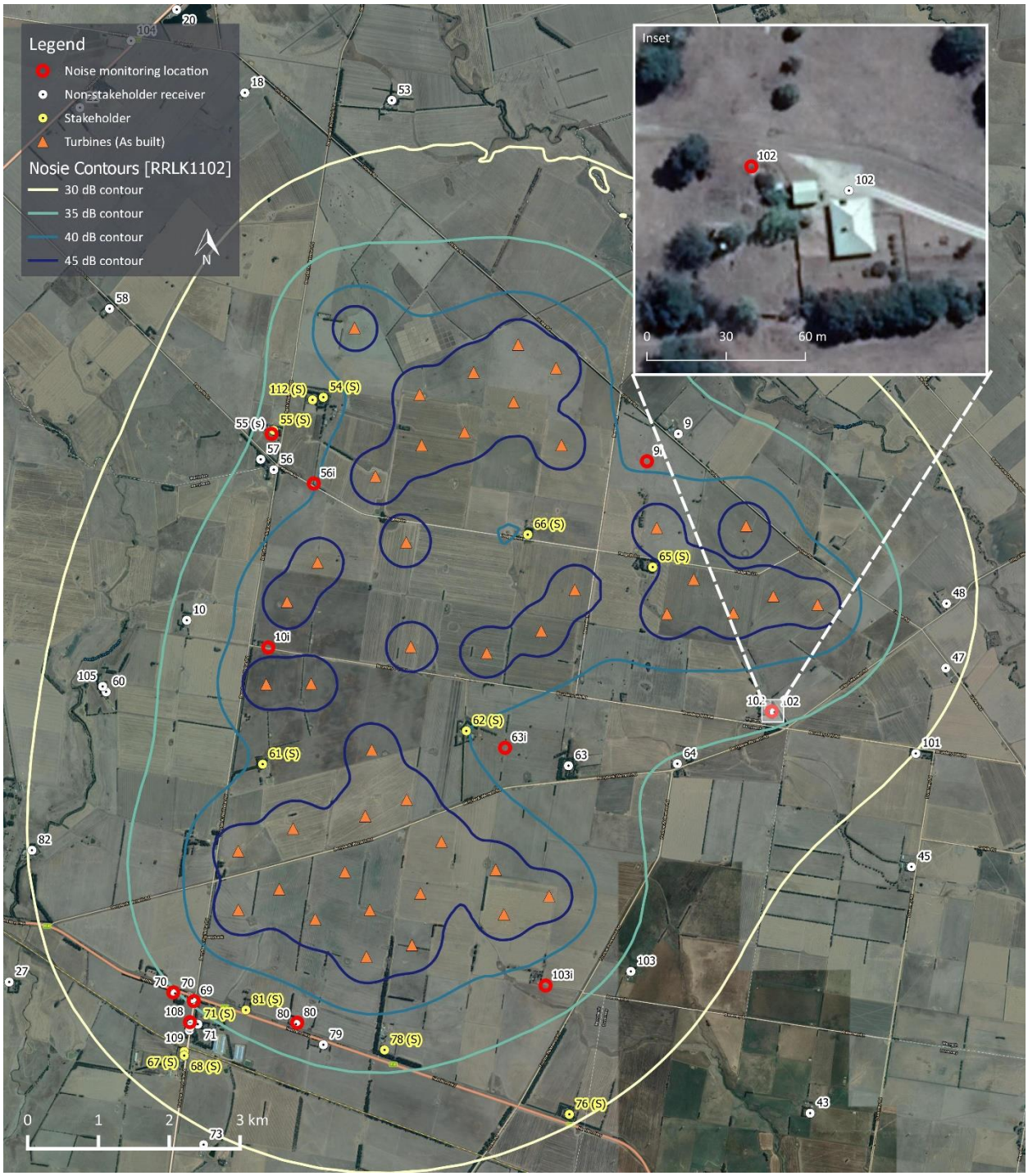


Table 45: Location 102 monitor installation photos

Looking North	Looking East
	
Looking South	**Looking West**
	

L2 Location 102 measurement data summary

Table 46: Location 102 noise level analysis summary

Data points	All-time (day & night combined)
Collected	8068
Removed [1]	6306
Retained	1762

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 17: Locarion 102 post construction noise level and wind speed time history

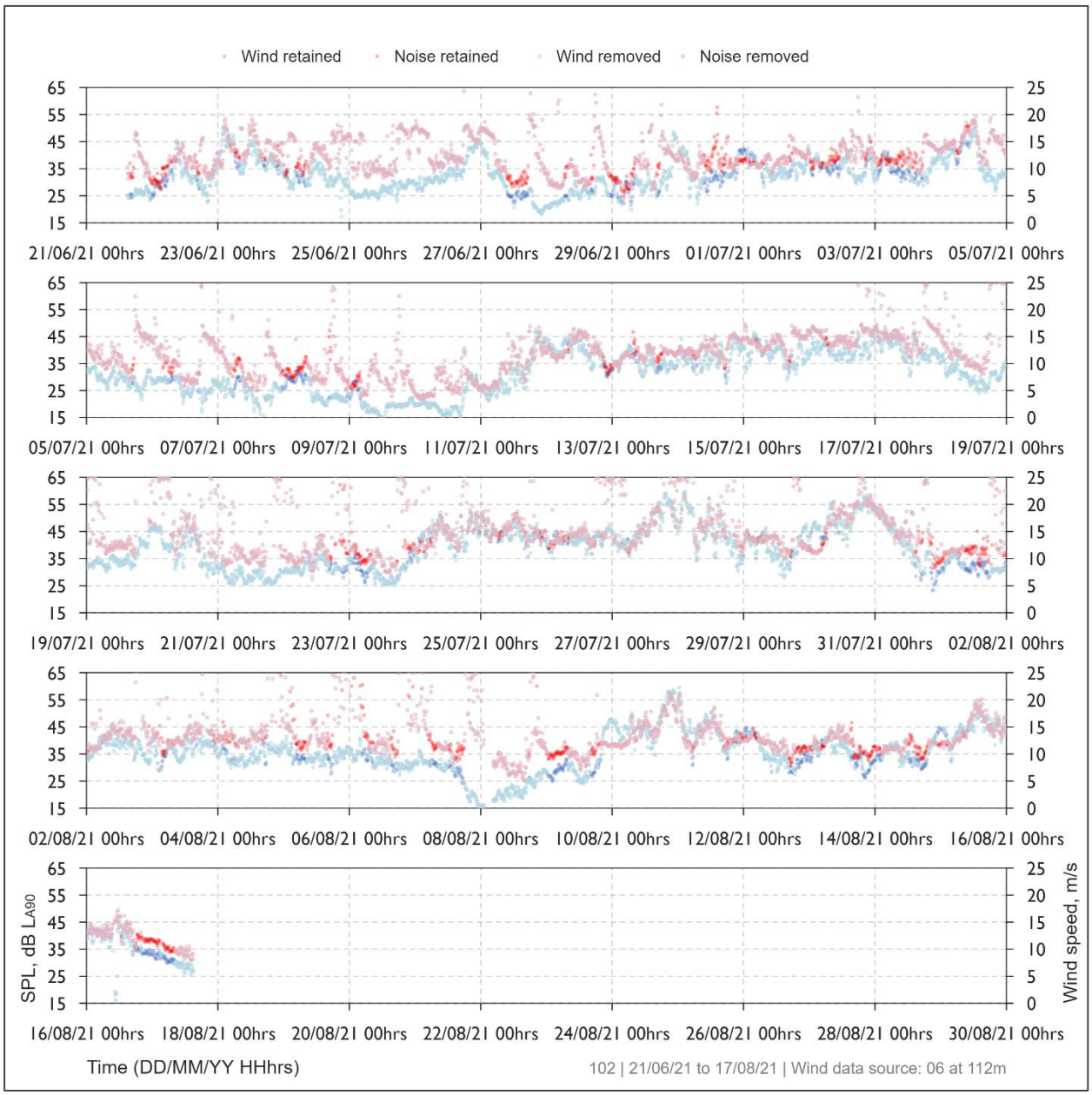
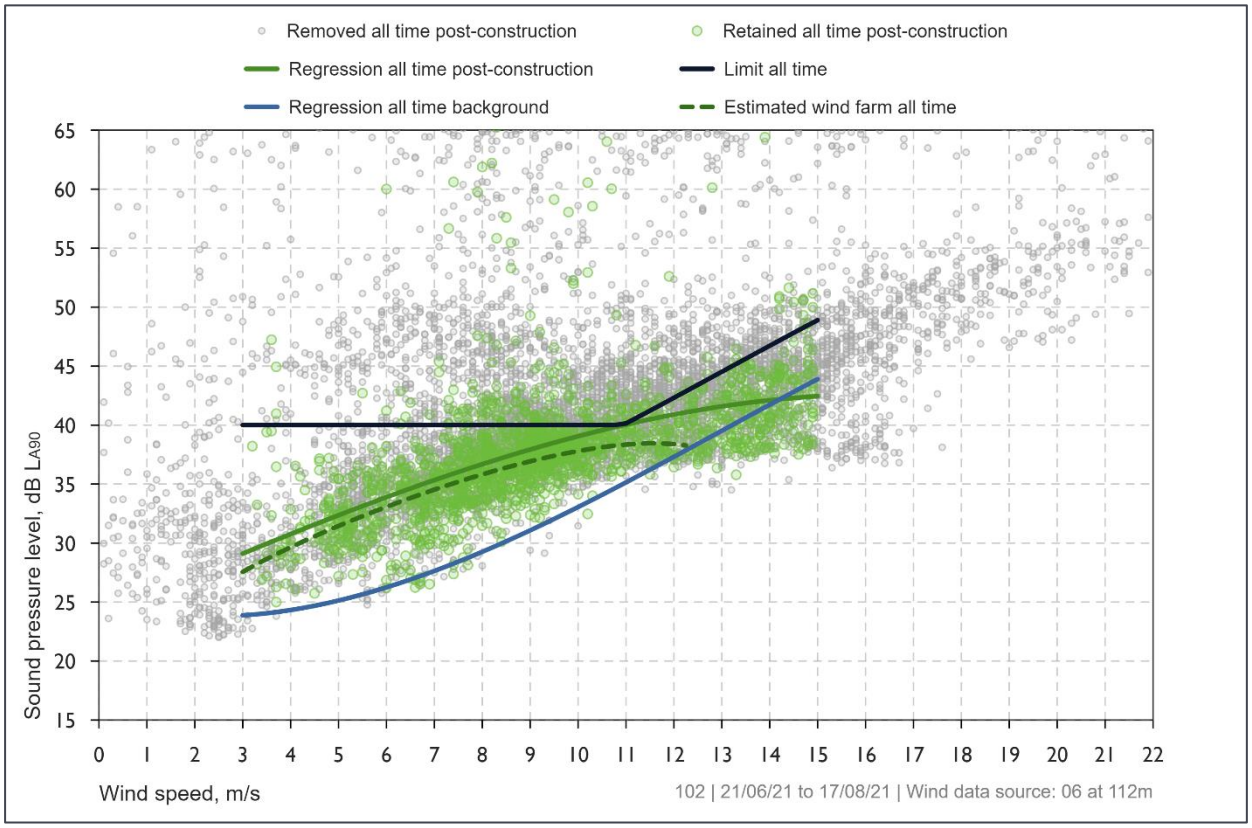


Figure 18: Location 102 all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX M LOCATION 108

M1 Location 108 location data

Table 47: Location 108 dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Dwelling location	718494	5793339
Noise monitoring location	718500	5793430

Figure 19: Location 108 aerial view – dwelling and noise monitor locations

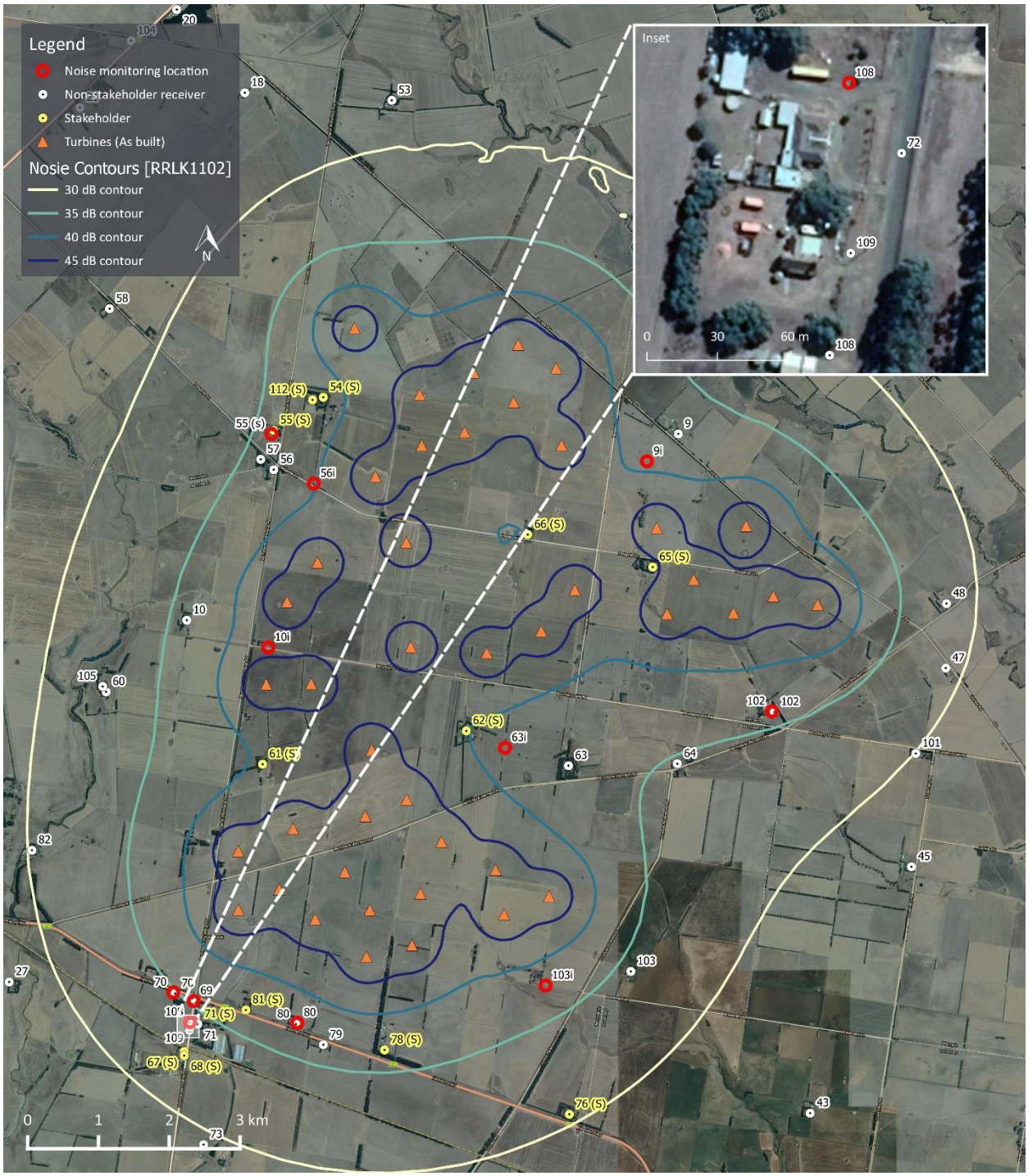


Table 48: Location 108 monitor installation photos

Looking North	Looking East
	
Looking South	**Looking West**
	

M2 Location 108 measurement data summary

Table 49: Location 108 noise level analysis summary

Data points	All-time (day & night combined)
Collected	7953
Removed [1]	5800
Retained	2153

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 20: Location 108 post construction noise level and wind speed time history

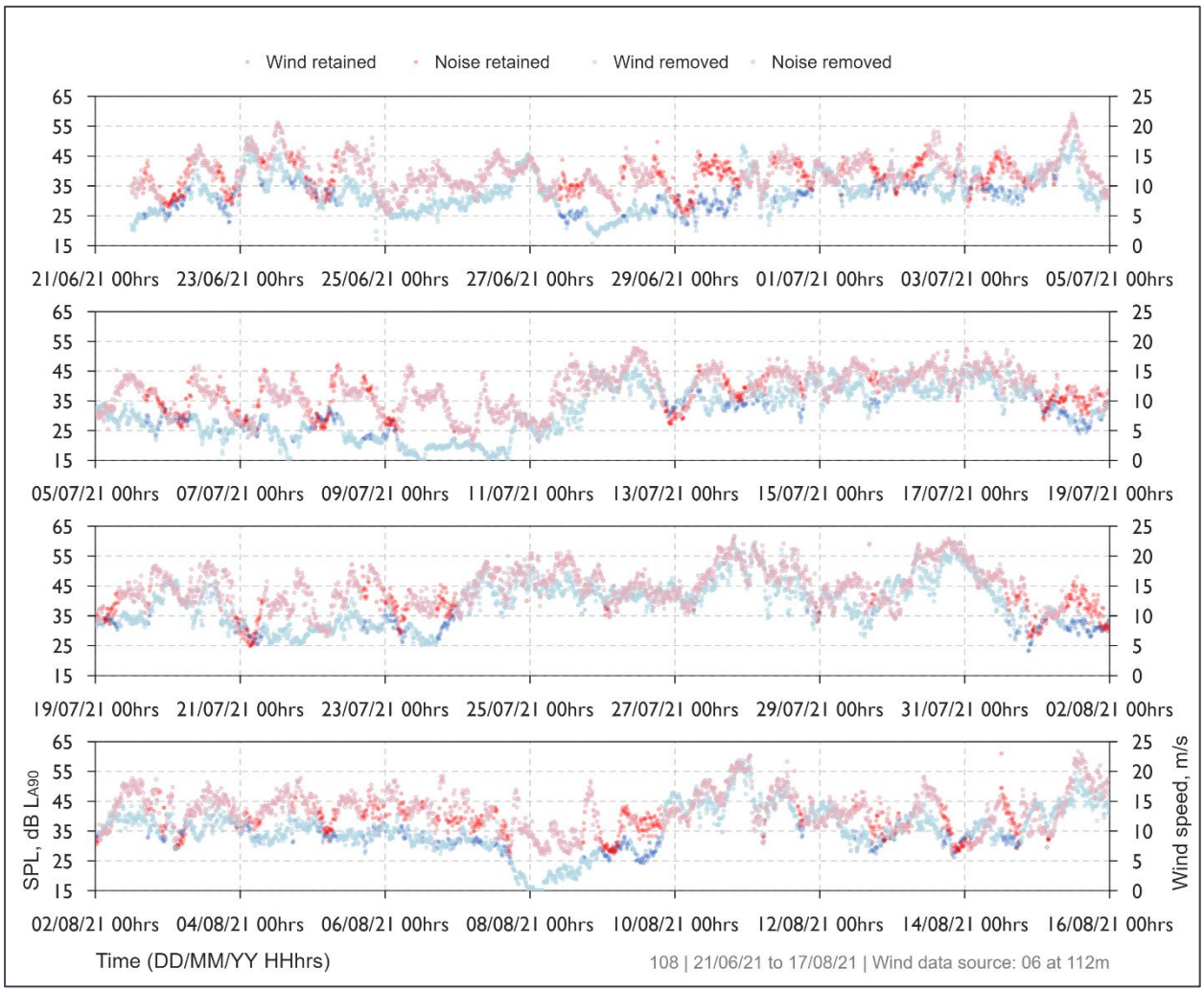
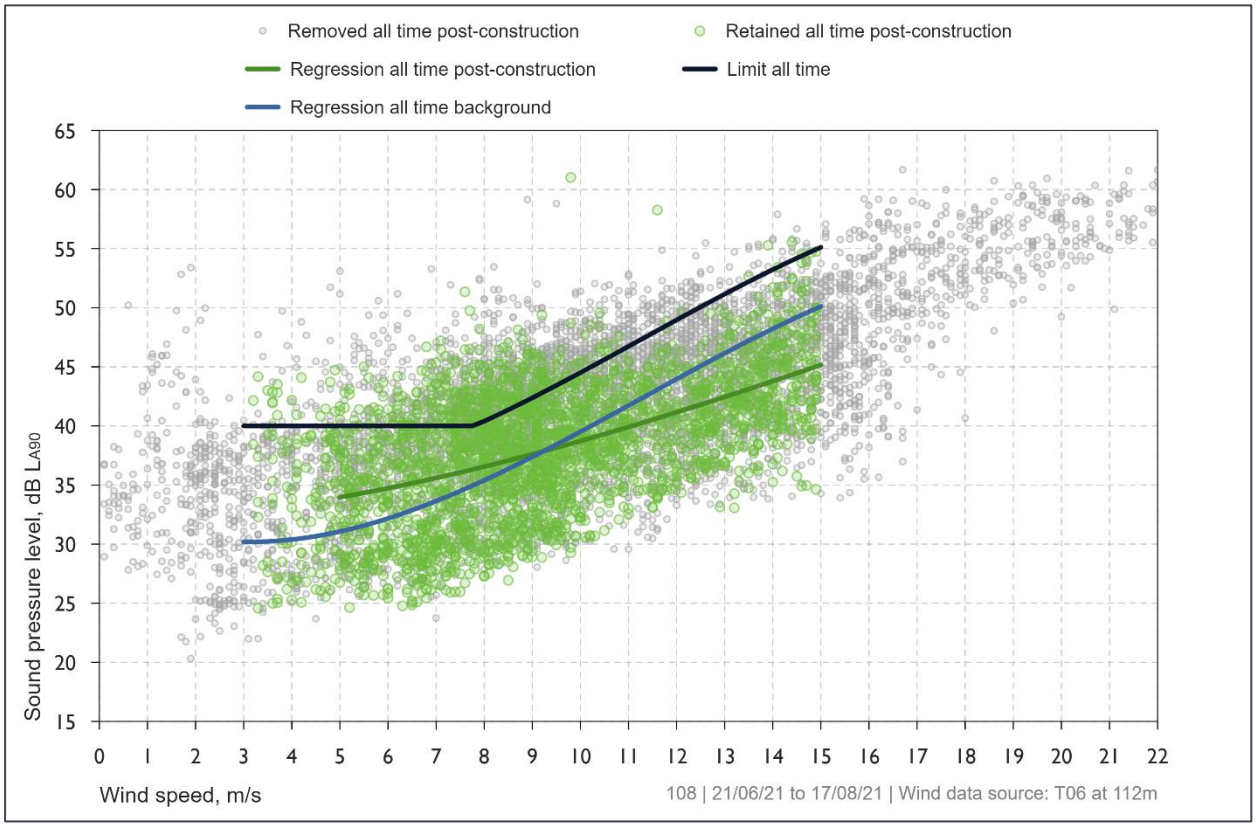


Figure 21: Location 108 all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX N LOCATION 9I

N1 Location 9i data

Table 50: Location 9i dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Noise monitoring location	723765	5799513

Table 51: Location 9i monitor installation photos

Looking North	Looking East
	
Looking South	Looking West
	

N2 Location 9i measurement data summary

Table 52: Location 9i noise level analysis summary

Data points	All-time (day & night combined)
Collected	8130
Removed [1]	5523
Retained	2607

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 22: Location 9i post construction noise level and wind speed time history

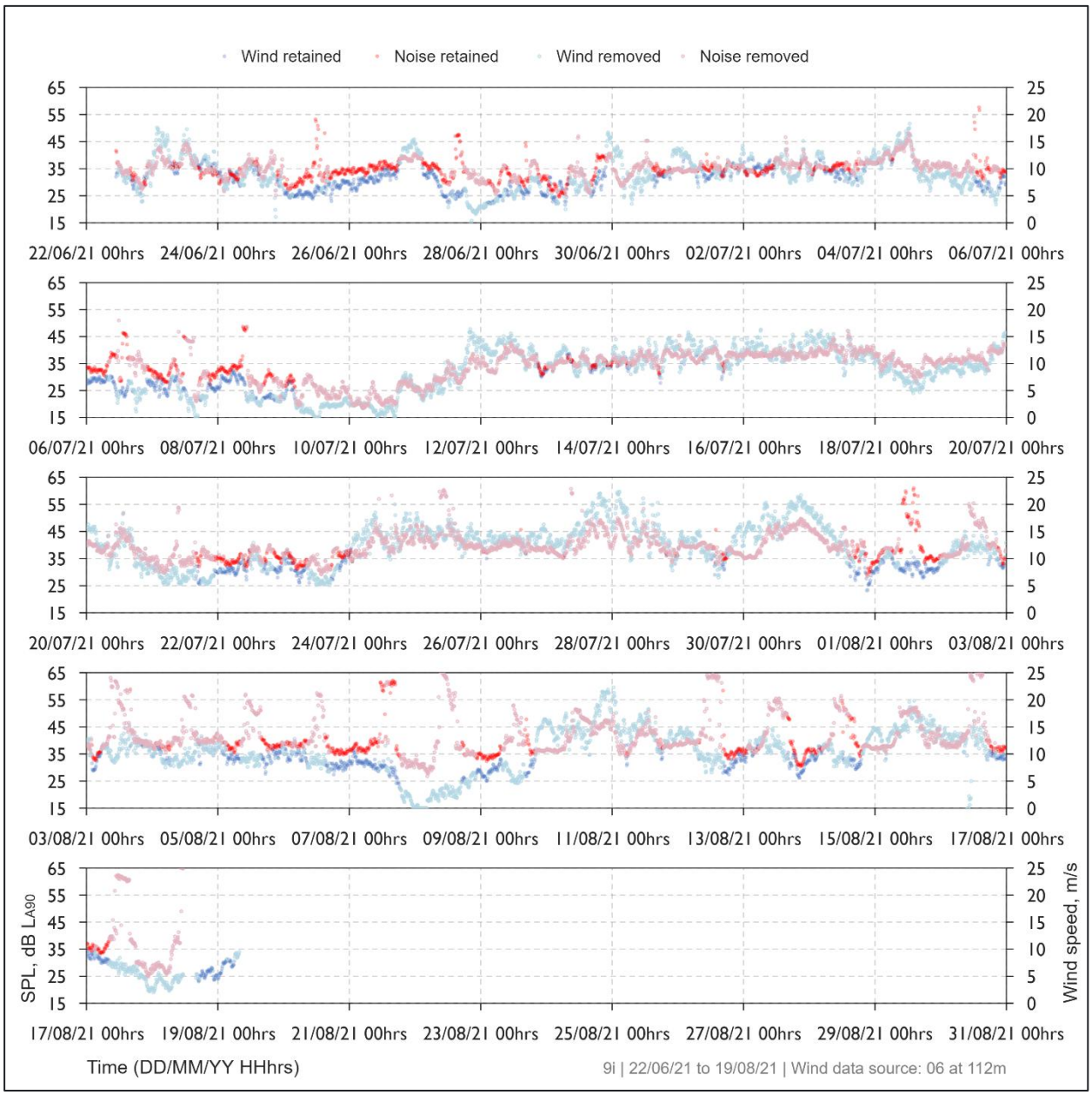
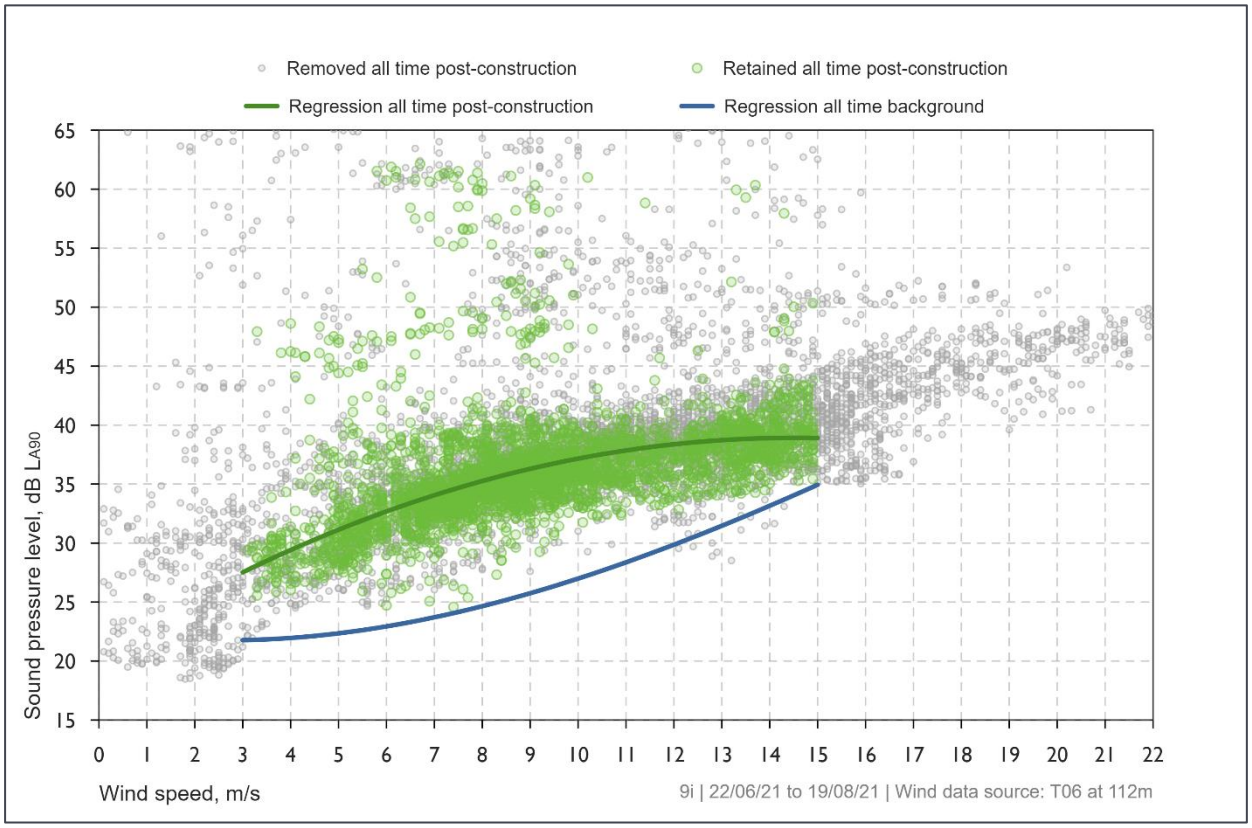


Figure 23: Location 9i all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX O LOCATION 10I

O1 Location 10i data

Table 53: Location 10i dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Noise monitoring location	719487	5797562

Table 54: Location 10i monitor installation photos

Looking North	Looking East
	
Looking South	Looking West
	

O2 Location 10i measurement data summary

Table 55: Location 10i noise level analysis summary

Data points	All-time (day & night combined)
Collected	7884
Removed [1]	6659
Retained	1225

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 24: Location 10i post construction noise level and wind speed time history

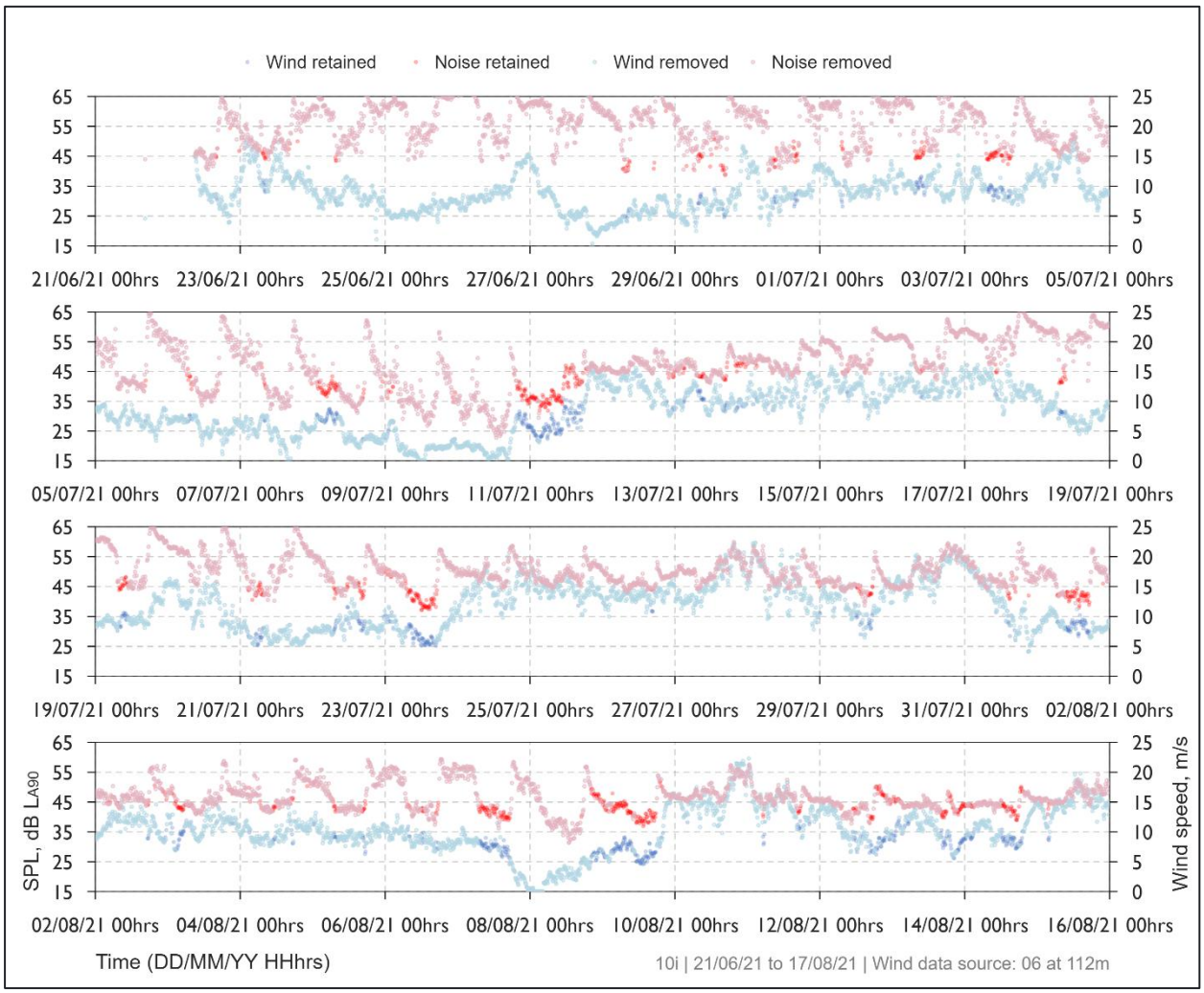
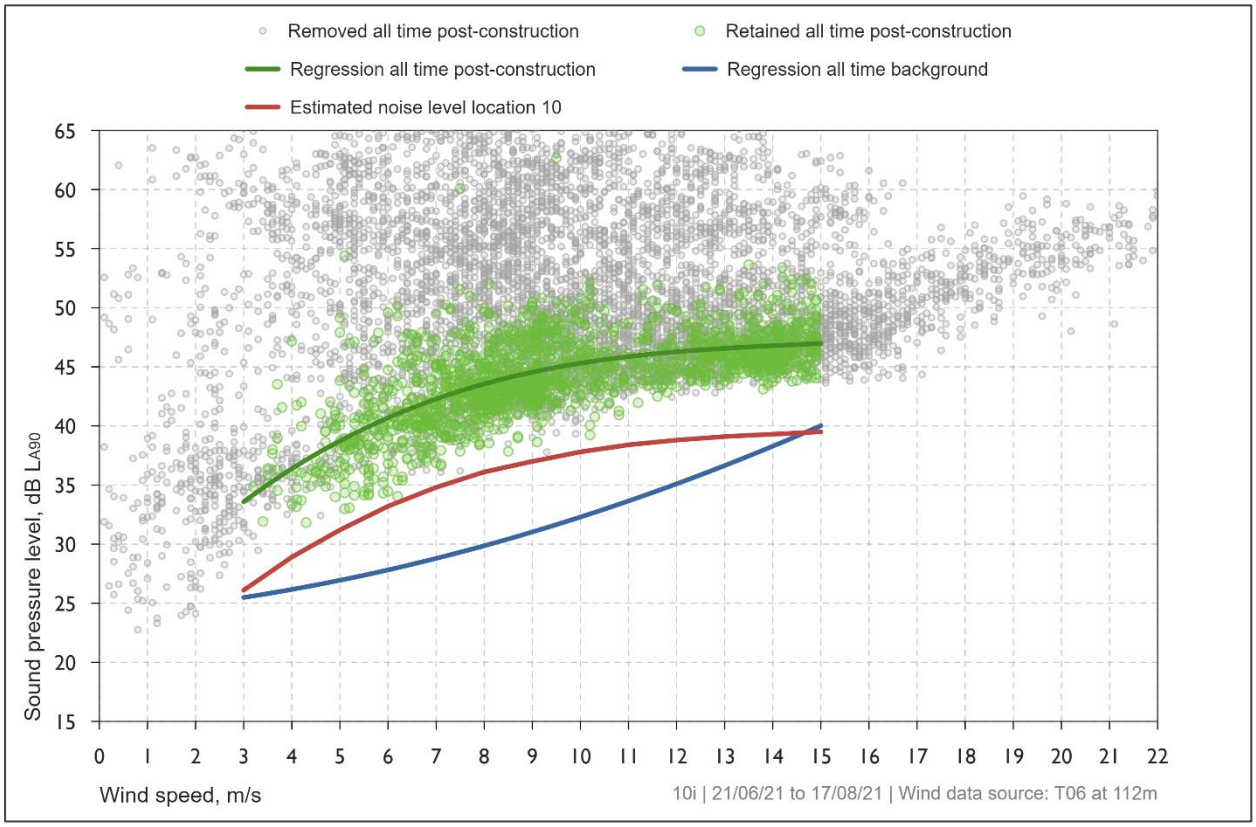


Figure 25: Location 10i all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX P LOCATION 56I

P1 Location 56i location data

Table 56: Location 56i dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Noise monitoring location	720044	5799367

Table 57: Location 56i monitor installation photos

Looking North	Looking East
	
Looking South	Looking West
	

P2 Location 56i measurement data summary

Table 58: Location 56i noise level analysis summary

Data points	All-time (day & night combined)
Collected	7975
Removed [1]	5786
Retained	2189

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 26: Location 56i post construction noise level and wind speed time history

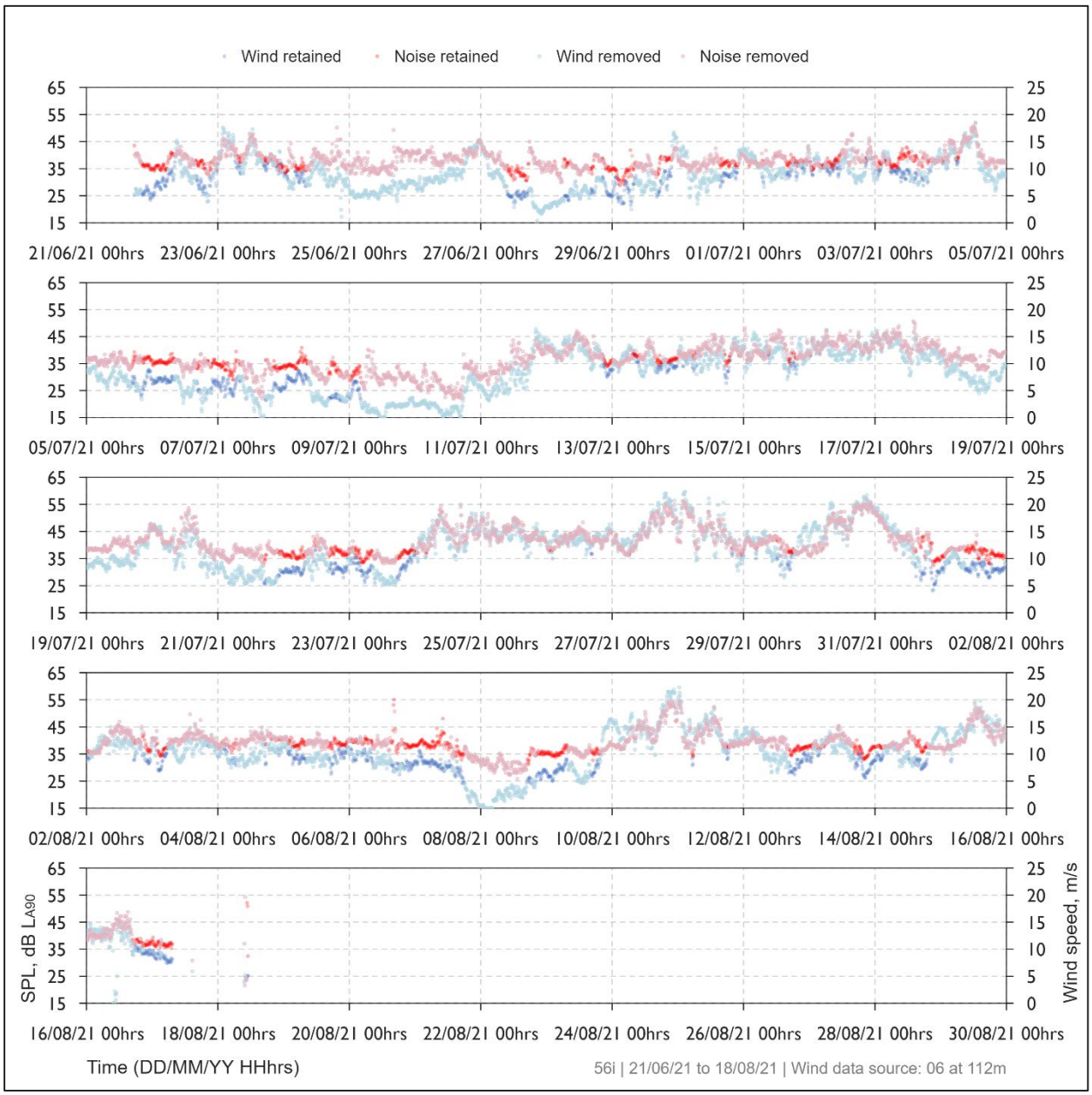
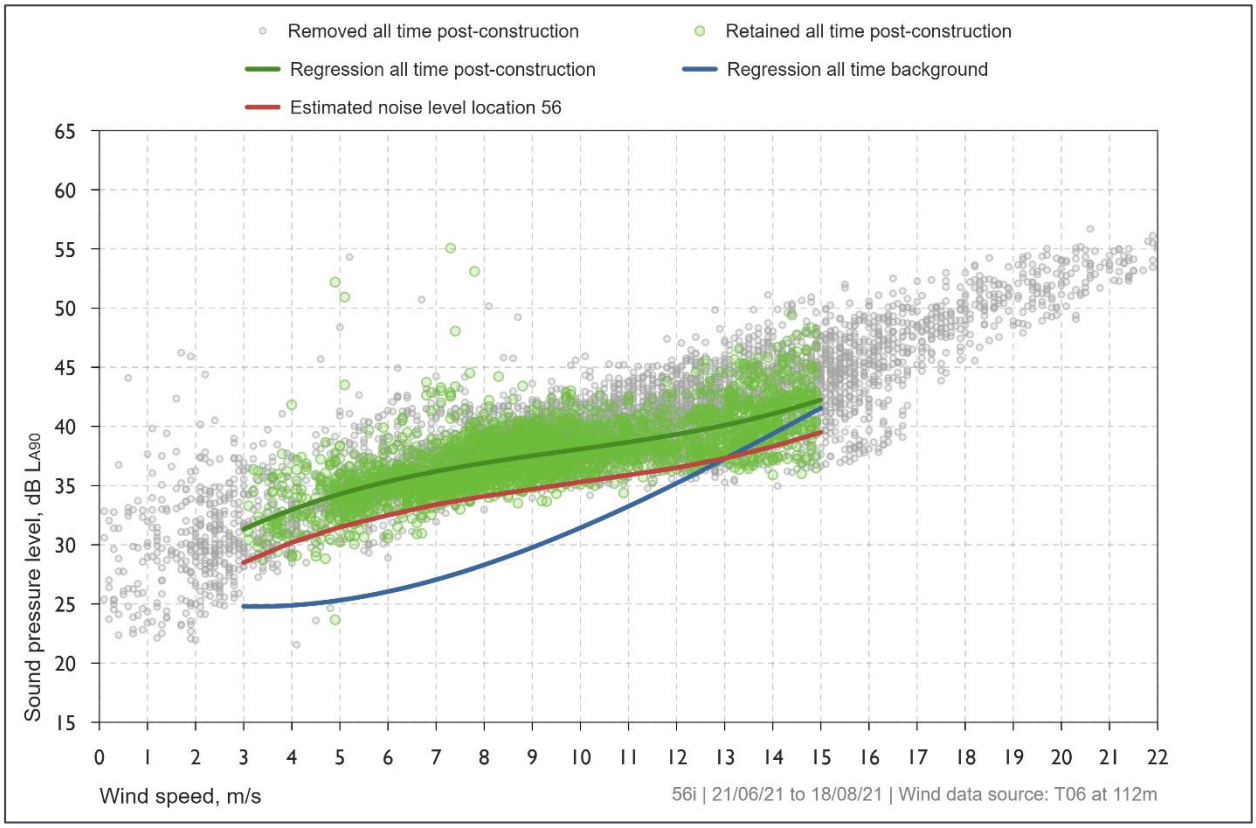


Figure 27: Location 56i all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX Q LOCATION 63I

Q1 Location 63i location data

Table 59: Location 63i dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Noise monitoring location	722097	5796377

Table 60: Location 63i monitor installation photos

Looking North	Looking East
	
Looking South	Looking West
	

Q2 Location 63i measurement data summary

Table 61: Location 63i noise level analysis summary

Data points	All-time (day & night combined)
Collected	8482
Removed [1]	6553
Retained	1929

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 28: Location 63i post construction noise level and wind speed time history

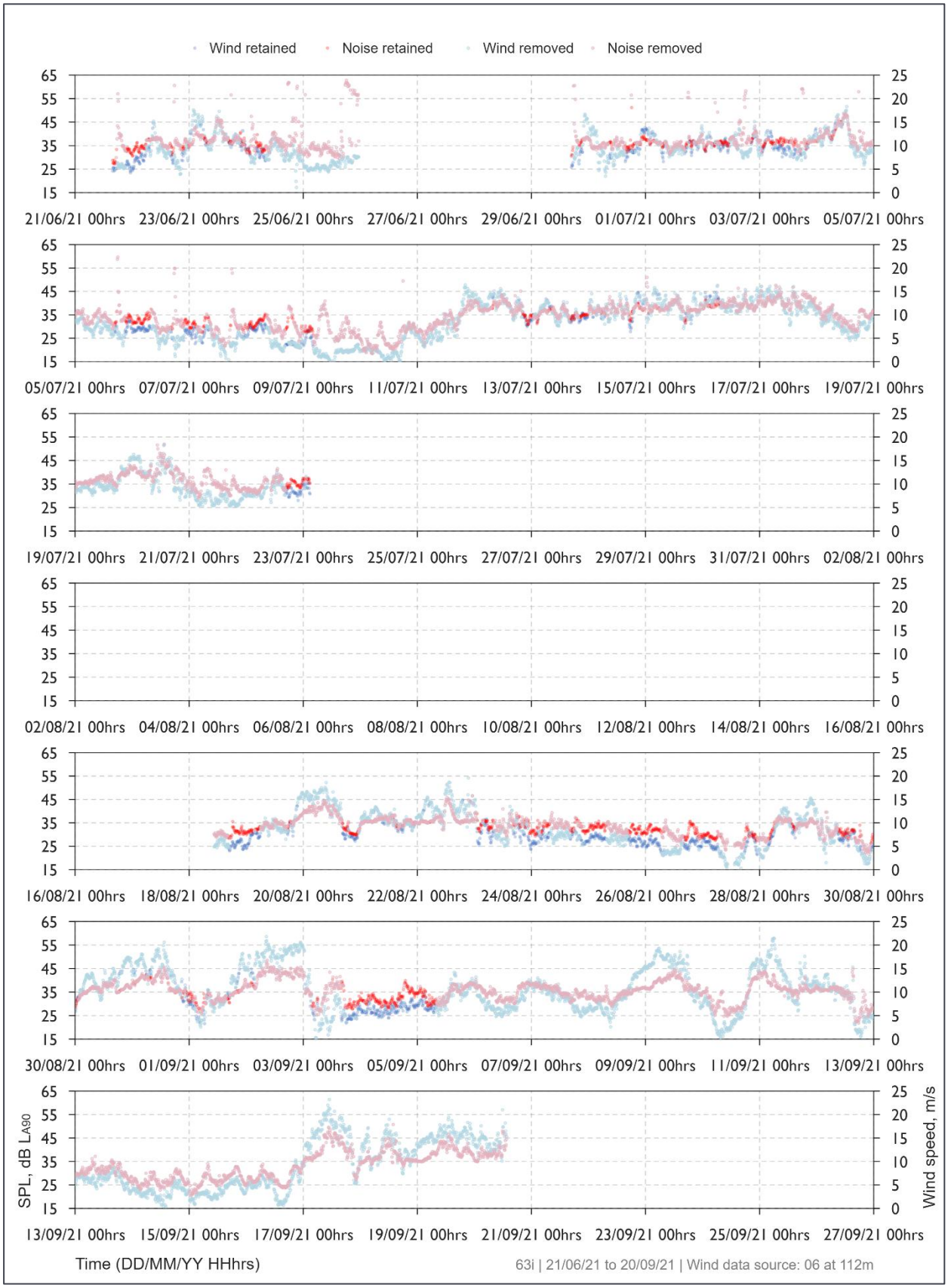
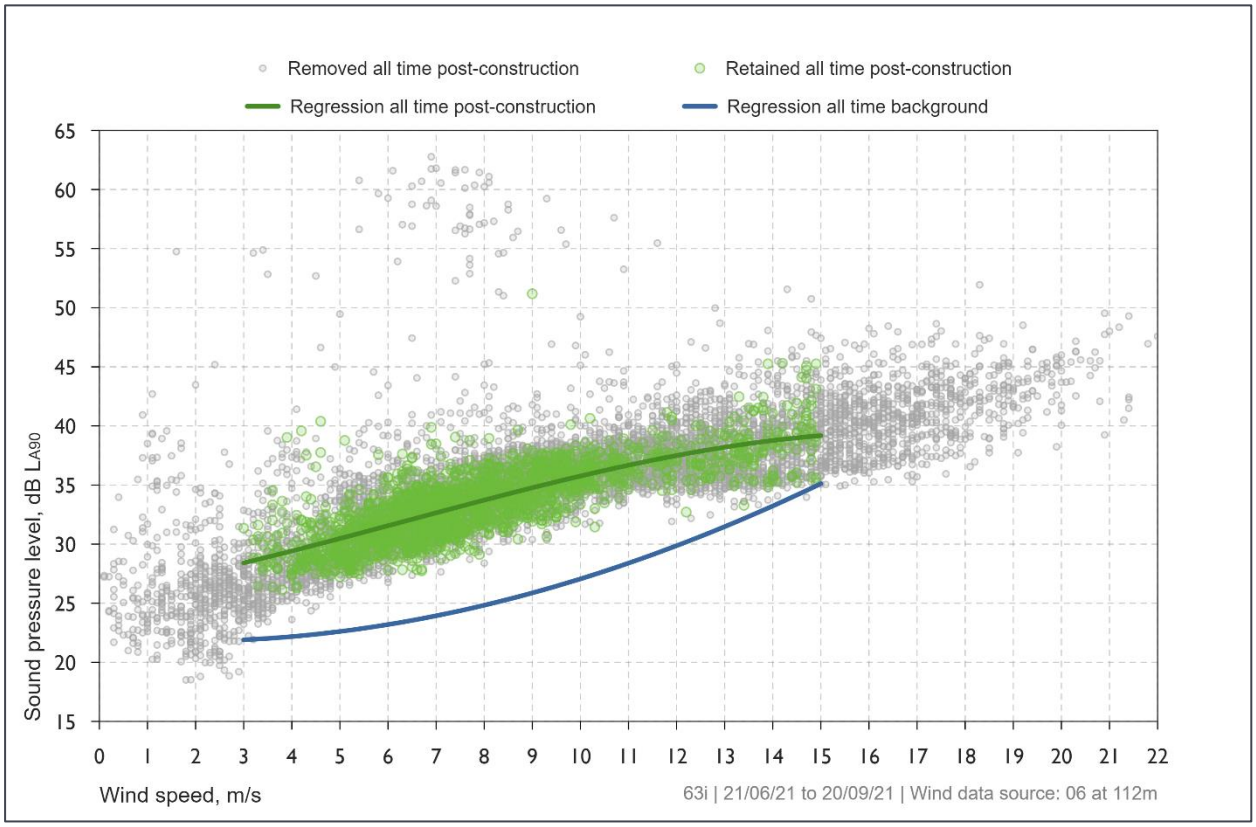


Figure 29: Location 63i all-time periods - post-construction noise levels and noise limits versus site wind speed



APPENDIX R LOCATION 103I

R1 Location 103i data

Table 62: Location 103i dwelling and noise monitor coordinates – MGA 94 Zone 54

Location	Easting, m	Northing, m
Noise monitoring location	722477	5793730

Table 63: Location 103i monitor installation photos

Looking North	Looking East
	
Looking South	Looking West
	

R2 Location 103i measurement data summary

Table 64: Location 103i noise level analysis summary

Data points	All-time (day & night combined)	Night-time
Collected	8019	2977
Removed [1]	5651	1866
Retained	2368	1111

Note 1: Removed data points due to rain, extraneous noise, atypical turbine operation, or wind speeds outside assessment range

Figure 30: Location 103i post construction noise level and wind speed time history

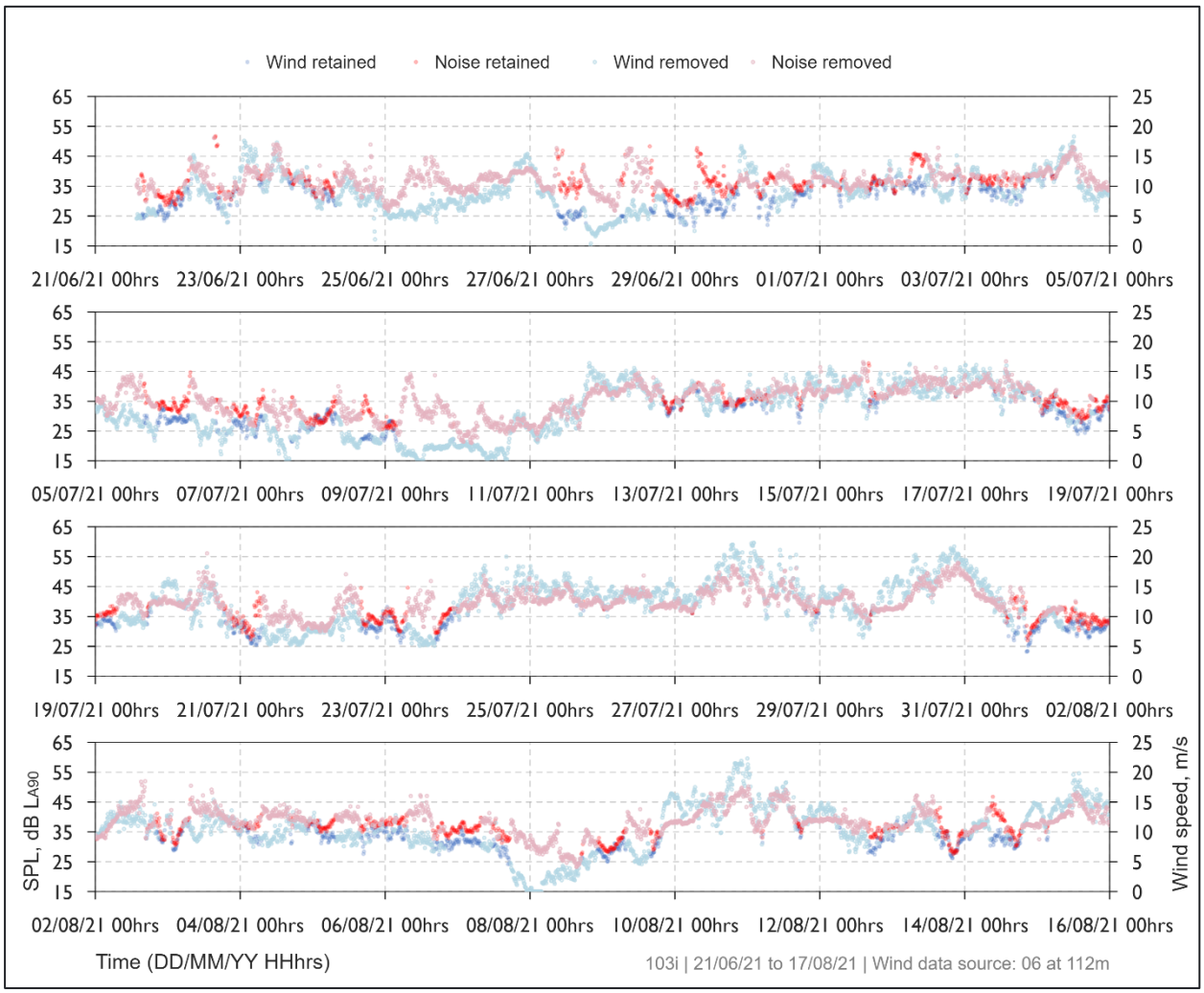


Figure 31: Location 103i all-time periods - post-construction noise levels and noise limits versus site wind speed

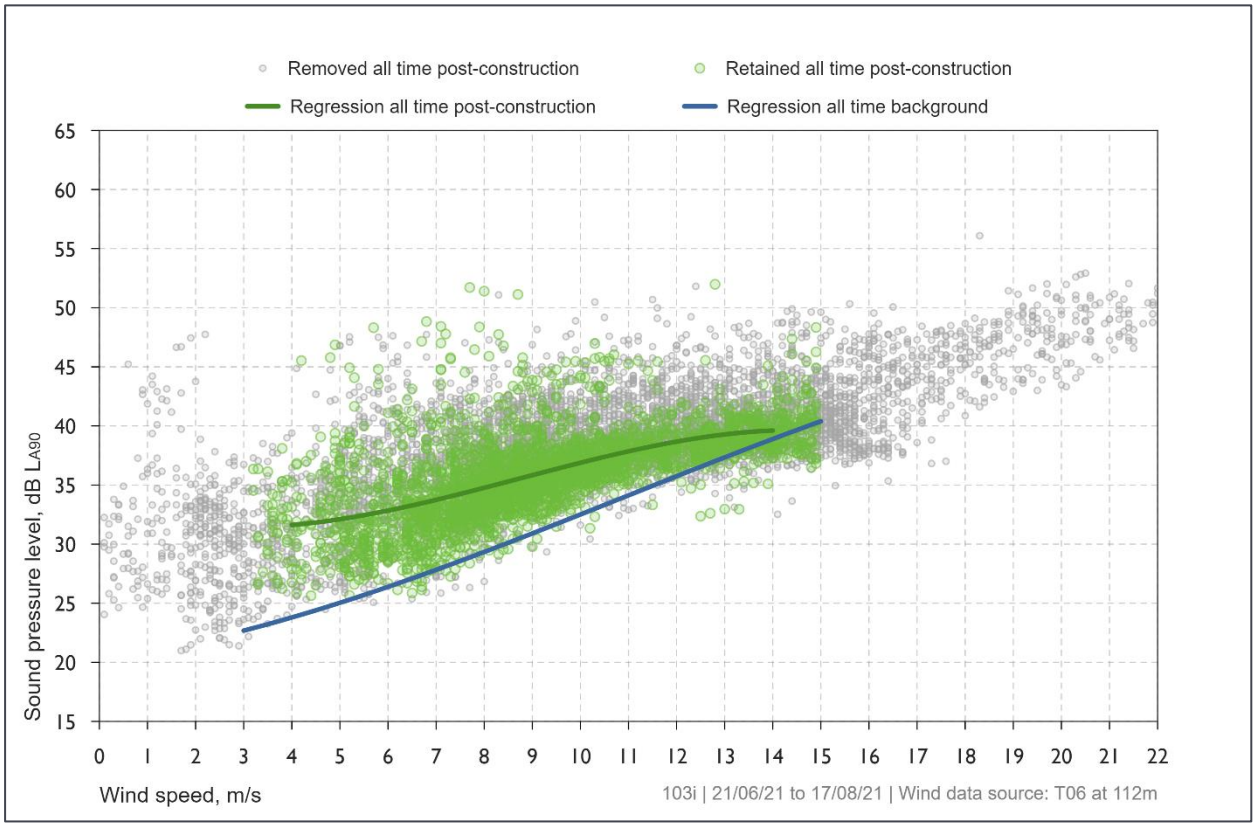


Figure 32: Location 103i night-time periods - post-construction noise levels and noise limits versus site wind speed