MARSHALL DAY Acoustics

MT EMERALD WIND FARM
POST-CONSTRUCTION NOISE MONITORING

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Project: **MT EMERALD WIND FARM**

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EXECUTIVE SUMMARY

This report presents the results of the first stage of noise monitoring undertaken at six (6) receiver locations in the vicinity of the Mt Emerald Wind Farm.

The monitoring was carried out in accordance with the procedures detailed in the Noise Monitoring Plan (Marshall Day Acoustics' reference Rp 001 20171526 dated 15 March 2019) which outlines the measurement and analysis procedures to be used for assessing operational noise compliance in accordance with the Development Permit. The procedures detailed in the NMP are based on Australian Standard AS 4959-2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators,* as specified in the Development Permit, and *State code 23: Wind farm development – Planning guideline* dated July 2017 (the Queensland guideline).

The noise monitoring comprised:

- Unattended measurements at six (6) residential locations
- Attended observations to inform an assessment of the noise characteristics of the wind farm.

The results of the noise monitoring demonstrated:

- Total measured noise levels were lower than the noise criteria which apply to the wind farm
- The noise of the wind farm at the property did not exhibit any special audible characteristics.

The assessment results demonstrate that, during the survey period, operational noise levels associated with the Mt Emerald Wind Farm complied with the noise requirements outlined in Condition 4 of the Development Permit.

In accordance with the Noise Monitoring Plan and the Queensland guideline, the wind farm's compliance is to be verified by a second stage of monitoring.

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1.0 INTRODUCTION

The Mt Emerald Wind Farm is a fifty-three (53) turbine development located between Mareeba and Atherton in Far North Queensland.

A Development Permit[1] for the wind farm was originally granted in April 2015, subject to a set of conditions which were amended by the Notice of the Minister for State Development, Manufacturing, Infrastructure and Planning on 14 March 2018. The Development Permit includes conditions for the control of operational noise associated with the project and establishes a requirement for a *compliance noise assessment report* (compliance report) to be submitted following the construction of the wind farm.

The monitoring and assessment methodology to address the noise related requirements of the Development Permit are detailed in the Mt Emerald Wind Farm Noise Monitoring Plan[2] (NMP).

Marshall Day Acoustics Pty Ltd (MDA) was commissioned to conduct post-construction noise monitoring at noise sensitive receiver locations around the wind farm and assess wind farm noise levels in general accordance with the NMP.

This report presents the results of the first stage of post-construction noise monitoring carried out in accordance with the NMP between 1 May 2019 and 27 September 2019.

This report is to be read in conjunction with the NMP.

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

Site layout information is detailed in Appendix B.

The noise related Development Permit conditions that are relevant to the preparation of the compliance report are reproduced in Appendix C.

[1] *Schedule 1: Conditions of Approval* of the Development Permit, as amended by the notice of the Minister for State Development, Manufacturing, Infrastructure and Planning dated 14 March 2018.

[2] MDA report Rp 001 20171526 *Mt Emerald Wind Farm - Noise Monitoring Plan* dated 15 March 2019

2.0 WIND FARM DETAILS

The Mt Emerald Wind Farm consists of fifty-three (53) Vestas wind turbines. Two types of Vestas wind turbines have been used as follows:

- Sixteen (16) V112-3.3MW turbines; and
- Thirty-seven (37) V117-3.45MW turbines

Details of the installed turbines are outlined in Table 1 below.

Table 1: Wind turbine details

Detail	V112-3.3MW	V117-3.45MW
Rotor diameter	112 m	117 m
Hub height	84 m	90 m
Blade orientation	Upwind	Upwind
Turbine regulation method	Variable blade pitch	Variable blade pitch
Maximum rated power generating capacity	3.3 MW	3.45 MW
Cut-in wind speed (hub height)	3 m/s	3 m/s
Rated power wind speed (hub height)	13 m/s (approximately)	13 m/s (approximately)
Cut-out wind speed (hub height)	25 m/s	25 m/s

The Vestas V112-3.3MW and V117-3.45MW are variable speed pitch-regulated turbines which are able to be operated in a variety of modes for the purposes of power regulation and noise control. To address operational noise requirements, the Mt Emerald Wind Farm implements an operating strategy which involves a number of turbines operating in reduced sound modes for specific wind speeds, wind directions and time periods.

3.0 NOISE CRITERIA

Schedule 1 of the Development Permit for the Mt Emerald Wind Farm includes conditions of approval which establish operational noise requirements for the project.

Full details of the relevant conditions are reproduced in Appendix C. The noise limits defined by Condition 4 of the Development Permit are summarised in Table 2. The limits apply to the A-weighted noise level that is solely attributable to the operation of the wind farm.

Table 2: Development Permit – summary of noise limits

Period	Metric	Development Permit requirement
Day (0600-2200 hrs)	A-weighted noise levels	$L_{Aeq} \leq 37$ dB or background L_{A90} + 5dB, whichever is higher
Night (2200-0600 hrs)	A-weighted noise levels	$L_{Aeq} \leq 35$ dB or background L_{A90} + 5dB, whichever is higher

The Development Permit requirements are specified in terms of:

- a noise limit based on the L_{Aeq} parameter[3]
- a minimum limit that applies at a receiver location
- increased limits that apply when background noise levels are sufficiently high
- a penalty for the presence of special audible characteristics.

The applicable noise limits determined in accordance with Condition 4 of the Development Permit are detailed in Section 3.0 of the NMP for the six (6) nearest dwellings to the wind farm.

The noise limits are reproduced in Table 3.

Table 3: Daytime receiver limits, dB L_{Aeq}

Receiver	Site wind speed (m/s) at 90 m AGL at reference mast location										
	3	4	5	6	7	8	9	10	11	12	13
R02	37.0	37.0	37.0	37.0	37.0	37.4	38.1	38.6	39.0	39.1	39.1
R05	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	38.5	40.7
R36	37.0	37.0	37.0	37.0	37.9	39.0	40.1	40.9	41.5	41.6	41.6
R48	37.0	37.0	38.2	39.6	40.9	42.1	43.1	43.8	44.3	44.4	44.4
R49	37.0	37.0	37.0	37.0	37.0	37.6	38.8	39.7	40.4	40.6	40.6
R78	37.0	37.0	37.0	37.0	37.0	37.3	38.8	40.0	40.5	40.5	40.5

[3] In accordance with the Queensland guideline, the measured L_{A90} noise levels for each ten (10) minute period shall be used as a proxy for the assessment of L_{Aeq} noise levels associated with the operation of the wind farm.

Table 4: Night-time receiver noise limits, dB L_{Aeq}

Receiver	Site wind speed (m/s) at 90 m AGL at reference mast location										
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
R02	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.8	39.9
R05	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.4	38.0	41.4
R36	35.0	35.0	35.0	35.0	35.2	35.6	36.0	36.5	37.0	37.5	38.1
R48	35.0	35.0	35.1	35.3	35.5	35.7	35.9	36.3	36.8	37.6	38.8
R49	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.3	36.5
R78	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.6	37.1	38.7

4.0 NOISE SURVEY & ANALYSIS METHOD

This section provides a brief summary of:

- the noise monitoring locations
- the noise survey method; and
- the noise analysis method.

Full details are documented in the NMP.

4.1 Noise monitoring location

Noise monitoring was carried out at the six (6) locations listed in Table 5 below.

Table 5: Noise monitoring location details

Receiver reference	Direction from wind farm	Approximate distance from nearest turbine
R02	Nearest residential property to the west	2140 m
R05	Nearest residential property to the southwest.	1780 m
R36	Nearest residential property to the northeast	1880 m
R48	Among a group of residential properties to the east	2720 m
R49	Nearest residential property to the east.	1850 m
R78	Nearest residential property to the north	1730 m

The monitoring locations were generally as specified in Section 3.0 of the NMP. However, due to practical constraints the following location changes were required:

- R05: the noise monitor was relocated approximately 80 m to the southeast on 22 July 2018 following a request from the resident
- R49: the noise monitoring was originally intended to occur at the background monitoring location but was moved to a suitable location approximately 700 m north due to construction work.

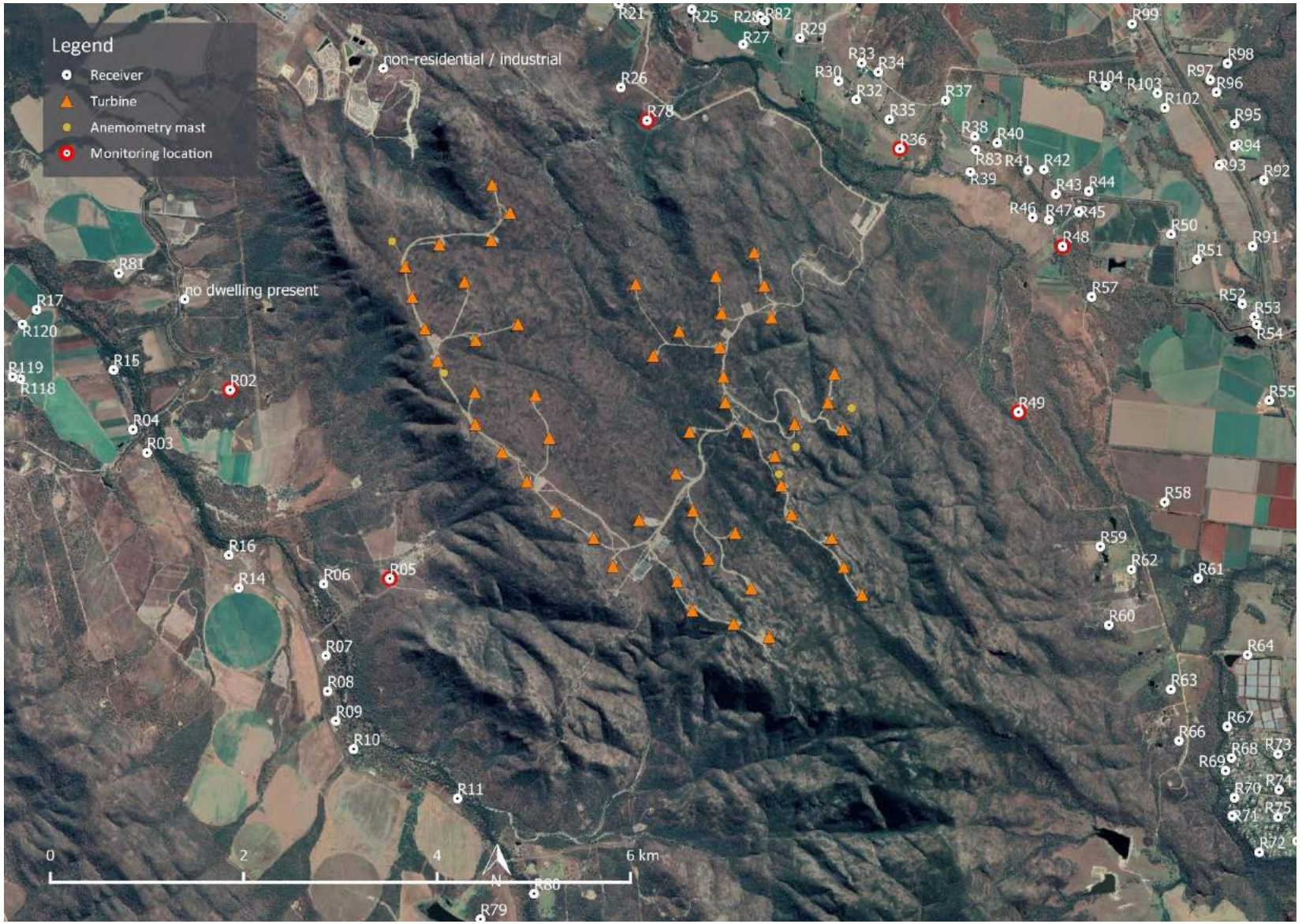
In both cases the new location was a similar distance from the wind farm and similar elevation, and therefore expected to experience similar wind farm noise levels.

The receiver locations where monitoring was carried out are illustrated on the following page in Figure 1. Coordinates and photographs for the noise monitoring location are provided in Appendix F to Appendix K.

The positioning of the equipment at each noise monitoring location was generally as close as practically possible to that of the background noise monitoring carried out before the wind farm was developed (where applicable). In relation to the monitoring at receiver locations, the equipment was positioned:

- Not less than 3.5 m from a vertical reflecting surface
- On the wind farm side of the dwelling, and as near as practical to a distance of 20 m from the dwelling while avoiding reflecting surfaces and localised sources of background noise.

Figure 1: Monitoring location relative to the Mt Emerald Wind Farm



4.2 Survey description

The survey comprised noise measurements and attended observations as specified in Section 4.4.2 of the NMP. Key elements of the survey are summarised in Table 6 below.

Due to practical operational restrictions, not all wind farm turbines were in continuous operation during the monitoring period. There are two main reasons that this downtime has occurred, both of which normally occur in the operation of a wind farm:

1. The wind farm regularly has constraints applied to its operations by the energy market regulator. These constraints affected a large number of the turbines that are relevant to the noise assessment.
2. Turbine servicing and maintenance required individual turbines to be turned off. An example of this occurred during the monitoring period at WTG 1, which resulted in an intermittent fault causing the turbine to stop. This fault initially presented on 15/08/19 and continued beyond the noise monitoring period.

As a result, the survey was significantly extended to obtain data for periods that were representative of normal operation of the wind farm.

Table 6: Summary of key elements of the post construction noise survey

Item	Description
Monitoring period	1 May 2019 to 27 September 2019 equating to between 19 and 21 weeks of noise monitoring at all locations. The monitoring period was significantly longer than the six (6) week period specified in the NMP, due to the operational restrictions which were in place during the monitoring.
Attended observations	Three (3) visits by a qualified acoustic engineer with experience in the assessment of wind farm sound to inform an assessment of the noise characteristics of the wind farm.
Sound level meters	Class 1 automated sound loggers (most accurate class rating for field usage). Microphone mounted at approximately 1.5 m above ground level and fitted with an enhanced wind shielding system based on the design recommendations detailed in the UK Institute of Acoustics publication *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (the UK IOA good practice guide). See equipment specifications and calibration records in Appendix D.
Noise measurement data	A-weighted average and statistical sound pressure levels for consecutive ten (10) minute periods. One-third octave band frequency noise levels and a brief audio sample every ten (10) minutes to aid the identification of extraneous noise influences. In accordance with the NMP and the Queensland guideline, the measured L_{A90} noise levels for each 10-minute period are used as a proxy for the assessment of L_{Aeq} noise levels associated with the operation of the wind farm.
Local wind speed and rainfall data	A weather station was installed beside each noise monitoring location to concurrently record rainfall and wind speeds at microphone height.

Item	Description
Site wind speed data	De-waked hub-height wind speed data corresponding to the reference mast positions from the noise background studies, derived from four (4) permanent met masts. Data was provided as the average wind speed and direction for consecutive ten (10) minute periods. The derived data was prepared by the site wind engineer (WSP). See further details in Appendix E. The reference mast locations and applicable receivers are detailed in Section 3.0 of the NMP.

4.3 Data analysis

Section 5.0 of the NMP specifies the applicable analysis procedures and are based on the requirements of the Development Permit and the methods detailed in the Queensland guideline.

This analysis 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
- Filtering the data for the range of hub height wind speeds from cut-in to rated power of the wind turbine generator
- Filtering the data to remove any periods in which the wind farm was not operating normally (e.g. due to external grid constraints)
- Filtering the data where necessary to account for site wind directions
- Plotting a chart of noise levels versus wind speeds and determining the line of best fit to the post-construction noise level data
- Adjust the post-construction line of best fit for the influence of background noise levels (if required to demonstrate compliance)

A summary of the key steps in the analysis of the data is presented in Table 7.

Table 7: 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. In accordance with the NPM, any 10-minute sample in which recorded rainfall is greater than 0.2 mm, or the average local wind speed is greater than 5 m/s is removed from the analysis.

Process	Description
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[4] 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}. In addition to the above, periods of significant extraneous noise were also identified in selected data samples using audio recordings. If extraneous noise was confirmed by listening to the audio for representative samples, that sample and associated data samples (i.e. those from around the same time with similar noise levels) were removed from the analysis.
Turbine shut-downs and atypical operation	Wind farm operational records supplied by RATCH-Australia Corporation for the duration of the monitoring campaign were reviewed, and any 10-minute period in which any relevant turbines[5] were not available to generate power, or operated in an atypical mode of operation, were removed from the analysis. See Section 5.4 of the NMP for further details of this filtering process.
Time periods	The measured noise levels have been separately correlated with the derived site wind speeds for the day and night periods as follows: • Day: 0600-2200 hrs • Night: 2200-0600 hrs.
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.
Background adjustment	The background noise levels documented in the background noise monitoring report is used to adjust compliance monitoring results for the influence of background noise levels. The adjustment is applied by logarithmically subtracting the pre-construction (background noise monitoring) regression line from the post-construction (operational noise monitoring) regression line to determine the derived wind farm noise. This adjustment is only applied where the combined total wind farm and background noise levels are higher than the noise limit that applies solely to the contribution of the wind farm.

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

[5] Relevant turbines for each receiver location are listed in Table 24 in Appendix B

The NMP specifies procedures for analysing the wind farm operational data to identify and remove time periods characterised by reduced or atypical operation which could affect the monitoring results (i.e. time periods when the operational noise level of the wind farm may be significantly lower than would otherwise occur during normal operation of the wind farm).

Analysis of the turbine operational data found that the majority of measured data points did not satisfy the threshold criteria set for determining normal operating conditions, as detailed in Section 5.4 of the NMP. Consequently, after operational filtering and other filtering was applied (as described in Table 7), the remaining data set contained a small number of data points compared to the total number of data points collected.

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
- Noise complaints recorded in the site's complaint handling and management system.

If objective assessment is warranted, the applicable procedures are listed in Table 8, as specified in Section 4.4.4 of the NMP.

Table 8: 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	Queensland guideline

5.0 SURVEY RESULTS

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

It is important to note that the measured post-construction noise levels are a combination of:

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

The measured total noise level 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, total measured operational noise levels will be dominated by residual noise and, as a result, the contribution of the turbines will be significantly less than the total measured noise level. This is particularly the case at low wind speeds when the wind farm is producing little or no noise, and at high wind speeds when the noise of wind disturbed vegetation is significant. However, the noise criteria apply solely to the noise level that is attributable the operation of the wind farm. This is an important point of context when comparing total measured noise levels with the noise criteria. For this reason, corrections for the influence of background noise are sometimes required to assess whether the contribution of the wind farm is compliant.

The noise criteria are specified in terms of the equivalent noise level L_{Aeq} attributable to the operation of the wind farm. However, the Queensland guideline states:

> *Although the guideline requires noise modelling to be conducted using the L_{Aeq} descriptor, it is not usually practical to measure the noise from a wind farm using the L_{Aeq} descriptor because intermittent noise from sources such as wind gusts in trees, vehicles, birds and insects are included. To minimise the interference from the intermittent noise sources, the L_{A90} descriptor is used as a proxy for the L_{Aeq} for the purposes of operational noise monitoring.*

In accordance with the Queensland guideline, and as specified in the NMP, the measured L_{A90} noise levels have been used as a proxy for the assessment of L_{Aeq} noise levels associated with the operation of the wind farm. Specifically, results are presented in terms of the L_{A90} noise level for comparison with the noise criteria.

5.1 Measured noise levels

5.1.1 Daytime

The results of the daytime unattended measurement data analysis for the six (6) receiver locations are summarised in Table 9. The summary results correspond to the value of the line of best fit applied to the noise level versus hub height wind speed chart. The results presented are derived from the filtered data set (i.e. following removal of periods affected by extraneous noise or that are not representative of normal operating conditions of the wind farm).

For simplicity, the presented data relates to the measured post-construction noise levels which are a combination of the operational wind farm noise and the residual noise of the local area.

The detailed measurement and analysis results are presented in Appendix F to Appendix K and includes information such as the 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 described in Section 4.3, a significant number of data points required removal on account of atypical wind farm operations which were not representative of normal operating conditions (i.e. turbine shutdowns).

Table 9: Post-construction noise levels – daytime, dB L_{A90}

Location	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	- [1]	- [1]	32.4	32.9	34.3	35.7	36.8	37.1	- [1]	- [1]	- [1]
R05	- [1]	29.6	29.9	31.1	32.7	34.3	35.8	36.8	37.2	- [1]	- [1]
R36	- [1]	31.3	32.7	34.0	35.2	36.2	37.1	37.7	38.1	38.3	- [1]
R48	- [1]	31.9	33.6	35.1	36.4	37.5	38.4	39.1	39.5	39.7	- [1]
R49	- [1]	30.2	31.9	33.3	34.5	35.5	36.4	37.2	38.0	38.8	39.7
R78	- [1]	29.7	29.7	30.3	31.8	33.7	35.7	37.6	39.2	40.2	40.4

Note 1: Outside of valid wind speed range for line of best fit

Despite the extended survey duration, as a result of the filtering process, there was not sufficient assessable data available for the full wind speed range, as noted in Table 9.

As per the requirements of the NMP, the analysis included a review of the relationship between noise levels and wind speeds to identify any distinctive trends which would warrant assessment of a subset of the measurement data. No distinctive trends were identified that would warrant the analysis of data subsets.

5.1.2 Night-time

The results of the night-time unattended measurement data analysis for the six (6) receiver locations are summarised in Table 10.

For simplicity, the presented data relates to the total measured wind farm and background noise levels.

The detailed measurement and analysis results are also presented in Appendix F to Appendix K and includes information such as the number of data points collected, the number of data points included in the analysis. The graphical plot for the night-time period illustrates all measured noise levels during the survey, and the retained data points after applying all relevant filtering as described in Section 4.3.

Table 10: Filtered post-construction operational noise levels – night-time, dB L_{A90}

Location	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
R02	- [1]	- [1]	25.8	26.5	27.8	29.6	31.5	33.3	34.9	36.0	- [1]
R05	- [1]	- [1]	25.6	26.3	27.6	29.2	31.2	33.5	35.9	38.4	- [1]
R36	- [1]	- [1]	- [1]	- [1]	33.7	33.8	34.0	34.3	34.8	35.3	36.0
R48	- [1]	- [1]	- [1]	32.1	32.2	32.7	33.6	34.8	35.9	36.6	36.8
R49	- [1]	- [1]	- [1]	30.6	30.9	31.7	32.9	34.1	35.4	36.5	37.2
R78	- [1]	- [1]	- [1]	28.4	28.7	30.1	32.1	34.3	36.2	37.3	- [1]

Note 1: Outside of valid wind speed range for line of best fit

Despite the extended survey duration, as a result of the filtering process, there was not sufficient assessable data available for the full wind speed range, as noted in Table 10.

5.2 Special audible characteristics

This section presents the findings of the attended observations which were carried out to inform an assessment of whether special audible characteristics were evident in the noise of the wind farm.

The findings of the attended observations are summarised in Table 11, along with the operational status of the wind farm at the times when the observations were made. For consistency, the wind speed and direction has been taken from the met mast MM9530 anemometer readings. The comments note if the receiver was upwind/downwind/crosswind of the windfarm at the time of the observations.

Table 11: Summary of subjective assessments

Date	Location	Total turbines operating	Hub height wind speed and direction (m/s, degrees) [1]	Subjective assessment/Comments
30/04/2019 5:00 PM	R36	52	-[2]	Wind farm clearly audible.
1/05/2019 9:35 AM	R78	45	8.2, 82	Wind farm inaudible. Crosswind conditions.
1/05/2019 12:00 PM	R02	46	7, 91	Wind farm faintly audible. Downwind conditions.
1/05/2019 3:00 PM	R48	49	7.6, 101	Wind farm inaudible. Upwind conditions.
1/05/2019 4:20 PM	R49	49	8.6, 98	Wind farm audible. Upwind conditions.
1/05/2019 12:45 PM	R05	46	7.4, 85	Wind farm inaudible. Construction/farm activity noise audible. Downwind conditions
31/05/2019 11:30 AM	R48	33	7.2, 96	Wind farm inaudible. Raining. Upwind conditions.
30/05/2019 6:00 PM	R49	34	9, 100	Wind farm inaudible. Upwind conditions.
31/05/2019 2:15 PM	R36	34	7.9, 99	Wind farm faintly audible. Steady rain, birds, insects, construction activity. Crosswind conditions.
31/05/2019 1:30 PM	R78	34	9.1, 93	Wind farm faintly audible (inconsistent). Rain noise masking wind farm. Crosswind conditions.
31/05/2019 2:45 PM	R02	35	7.6, 104	Wind farm inaudible. Steady rain. Downwind conditions.
31/05/2019 3:30 PM	R05	35	9.8, 109	Wind farm inaudible. Steady rain. Downwind conditions.
22/07/2019 3:45 PM	R05	35	6.5, 104	Wind farm inaudible. Steady rain. Downwind conditions.
22/07/2019 4:15 PM	R02	36	6.8, 99	Wind farm inaudible. Downwind conditions.
22/07/2019 5:00 PM	R78	36	6.1, 107	Wind farm inaudible. Crosswind conditions.

Date	Location	Total turbines operating	Hub height wind speed and direction (m/s, degrees) [1]	Subjective assessment/Comments
22/07/2019 5:30 PM	R36	36	6.4, 103	Wind farm inaudible. Crosswind conditions.
22/07/2019 5:45 PM	R48	36	7.3, 104	Wind farm inaudible. Upwind conditions.
22/07/2019 6:30 PM	R49	38	10, 109	Wind farm faintly audible. Upwind conditions.

Note 1: Wind speed data based on development mast MM9530
Note 2: Data not available for this time (outside noise survey data collection period)

The observations outlined in above table indicate that the wind farm was inaudible at most locations. Additional observations to those listed in the table above were made at the time of equipment retrieval, after data collection had ended. Those observations noted that the wind farm was audible but that no noise character was present.

Special audible characteristics were not evident in the noise of the wind farm at the receiver locations. Further investigation of special audible characteristics, or the application of penalties in relation to special audible characteristic, was therefore determined to be not warranted. As a secondary reference, it is also understood that the site records for the wind farm (e.g. observations by site personnel or feedback registered via the site's complaint handling system) do not suggest the potential presence of special audible characteristics.

5.3 Compliance assessment

The following sub-sections present an assessment of compliance at each noise monitoring location.

In the simplest of cases, the assessment compares the total post-construction noise levels (as presented previously in Section 5.1), with the applicable noise criteria. If the total post-construction noise levels (which include the operational wind farm noise levels) are below the applicable noise criteria, then no further analysis is required to demonstrate compliance.

However, in some cases an assessment of compliance requires the noise level of the wind farm to be estimated by accounting for the potential influence of background noise. In these cases, an adjustment has been applied by logarithmically subtracting the pre-construction (background noise levels) from the post-construction noise levels, as outlined in the Queensland guideline and the NMP. For consistency with the Queensland guideline, the resulting levels are referred to as the 'derived wind farm noise levels' in the compliance assessment tables below.

Special audible characteristics were not identified during the attended observations and therefore no penalties have been applied.

5.3.1 Receiver R02

Table 12: Receiver R02 – Daytime compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	- [1]	32.4	32.9	34.3	35.7	36.8	37.1	- [1]	- [1]	- [1]
Noise limit[2], L_{Aeq}	37.0	37.0	37.0	37.0	37.0	37.4	38.1	38.6	39.0	39.1	39.1
Minimum compliance margin[3]	- [1]	- [1]	-4.6	-4.1	-2.7	-1.7	-1.3	-1.5	-1.9	-2.0	- [1]

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

Table 13: Receiver R02 – Night-time compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	- [1]	25.8	26.5	27.8	29.6	31.5	33.3	34.9	36.0	- [1]
Noise limit[2], L_{Aeq}	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	36.8	39.9
Minimum compliance margin[3]	- [1]	- [1]	-9.2	-8.5	-7.2	-5.4	-3.5	-1.7	-0.1	-0.8	- [1]

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

The results in Table 12 and Table 13 demonstrate that compliance with the daytime and night-time noise limits is achieved at all assessed wind speeds.

5.3.2 Receiver R05

Table 14: Receiver R05 – Daytime compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	29.6	29.9	31.1	32.7	34.3	35.8	36.8	37.2	- [1]	- [1]
Pre-construction noise levels, L_{A90}	26.0	27.1	27.9	28.5	29.0	29.4	30.0	30.8	32.0	33.5	35.7
Derived wind farm noise levels, L_{A90}	- [1]	- [1]	- [1]	- [1]	30.3	32.6	34.4	35.5	35.6	- [1]	- [1]
Noise limit[2], L_{Aeq}	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	38.5	40.7
Compliance margin[3]	- [1]	-7.4[4]	-7.1[4]	-5.9[4]	-6.7	-4.4	-2.6	-1.5	-1.4	- [1]	- [1]

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit
Note 4: Compliance based on post-construction noise level in the absence of derived wind farm noise levels.

Table 15: Receiver R05 – Night-time compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	- [1]	25.6	26.3	27.6	29.2	31.2	33.5	35.9	38.4	- [1]
Pre-construction noise levels, L_{A90}	24.1	24.8	25.2	25.6	25.9	26.4	27.2	28.5	30.4	33.0	36.4
Derived wind farm noise levels, L_{A90}	- [1]	- [1]	- [1]	- [1]	- [1]	- [1]	29.0	31.8	34.5	37.0	- [1]
Noise limit[2], L_{Aeq}	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.4	38.0	41.4
Compliance margin[3]	- [1]	- [1]	-9.4[4]	-8.7[4]	-7.4[4]	-5.8[4]	-6.0	-3.2	-0.9	-1.0	- [1]

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit
Note 4: Compliance based on post-construction noise level in the absence of derived wind farm noise levels.

The results in Table 14 and Table 15 demonstrate that compliance with the daytime and night-time noise limits is achieved at all assessed wind speeds.

5.3.3 Receiver R36

Table 16: Receiver R36 – Daytime compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	31.3	32.7	34.0	35.2	36.2	37.1	37.7	38.1	38.3	- [1]
Noise limit[2], L_{Aeq}	37.0	37.0	37.0	37.0	37.9	39.0	40.1	40.9	41.5	41.6	41.6
Minimum compliance margin[3]	- [1]	-5.7	-4.3	-3.0	-2.7	-2.8	-3.0	-3.2	-3.3	-3.3	- [1]

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

Table 17: Receiver R36 – Night-time compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	- [1]	- [1]	- [1]	33.7	33.8	34.0	34.3	34.8	35.3	36.0
Noise limit[2], L_{Aeq}	35.0	35.0	35.0	35.0	35.2	35.6	36.0	36.5	37.0	37.5	38.1
Minimum compliance margin[3]	- [1]	- [1]	- [1]	- [1]	-1.4	-1.8	-2.0	-2.2	-2.2	-2.2	-2.1

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

The results in Table 16 - Table 17 demonstrate that compliance with the daytime and night-time noise limits is achieved at all assessed wind speeds.

5.3.4 Receiver R48

Table 18: Receiver R48 – Daytime compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	31.9	33.6	35.1	36.4	37.5	38.4	39.1	39.5	39.7	- [1]
Noise limit[2], L_{Aeq}	37.0	37.0	38.2	39.6	40.9	42.1	43.1	43.8	44.3	44.3	44.3
Minimum compliance margin[3]	- [1]	-5.1	-4.6	-4.4	-4.5	-4.6	-4.7	-4.8	-4.8	-4.6	- [1]

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

Table 19: Receiver R48 – Night-time compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	- [1]	- [1]	32.1	32.2	32.7	33.6	34.8	35.9	36.6	36.8
Noise limit[2], L_{Aeq}	35.0	35.0	35.1	35.3	35.5	35.7	35.9	36.3	36.8	37.6	38.8
Minimum compliance margin[3]	- [1]	- [1]	- [1]	-3.2	-3.4	-3.0	-2.3	-1.5	-1.0	-1.0	-2.0

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

The results in Table 18 - Table 19 demonstrate that compliance with the daytime and night-time noise limits is achieved at all assessed wind speeds.

5.3.5 Receiver R49

Table 20: Receiver R49 – Daytime compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	30.2	31.9	33.3	34.5	35.5	36.4	37.2	38.0	38.8	39.7
Noise limit[2], L_{Aeq}	37.0	37.0	37.0	37.0	37.0	37.6	38.8	39.7	40.4	40.6	40.6
Minimum compliance margin[3]	- [1]	-6.8	-5.1	-3.7	-2.5	-2.1	-2.4	-2.5	-2.4	-1.7	-0.9

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

Table 21: Receiver R49 – Night-time compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	- [1]	- [1]	30.6	30.9	31.7	32.9	34.1	35.4	36.5	37.2
Pre-construction noise levels, L_{A90}	25.3	25.5	25.8	26.1	26.5	27.0	27.7	28.4	29.3	30.3	31.5
Derived wind farm noise levels, L_{A90}	- [1]	- [1]	- [1]	28.6	28.9	29.9	31.3	32.8	34.2	35.2	35.8
Noise limit[2], L_{Aeq}	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.3	36.5
Compliance margin[3]	- [1]	- [1]	- [1]	-6.4	-6.1	-5.1	-3.7	-2.2	-0.8	-0.1	-0.7

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

The results in Table 20 to Table 21 demonstrate that compliance with the daytime and night-time noise limits is achieved at all assessed wind speeds.

5.3.6 Receiver R78

Table 22: Receiver R78– Daytime compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	29.7	29.7	30.3	31.8	33.7	35.7	37.6	39.2	40.2	40.4
Noise limit[2], L_{Aeq}	37.0	37.0	37.0	37.0	37.0	37.3	38.8	40.0	40.5	40.5	40.5
Minimum compliance margin[3]	- [1]	-7.3	-7.3	-6.7	-5.2	-3.7	-3.2	-2.4	-1.3	-0.3	-0.2

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

Table 23: Receiver R78 – Night-time compliance assessment, dB

Description	Hub height wind speeds (m/s)										
	3	4	5	6	7	8	9	10	11	12	13
Post-construction noise levels, L_{A90}	- [1]	- [1]	- [1]	28.4	28.7	30.1	32.1	34.3	36.2	37.3	- [1]
Pre-construction noise levels, L_{A90}	22.3	22.8	23.5	24.4	25.4	26.5	27.8	29.2	30.6	32.1	33.7
Derived wind farm noise levels, L_{A90}	- [1]	- [1]	- [1]	26.2	26.0	27.6	30.1	32.7	34.8	35.7	- [1]
Noise limit[2], L_{Aeq}	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.6	37.1	38.7
Compliance margin[3]	- [1]	- [1]	- [1]	-8.8	-9.0	-7.4	-4.9	-2.3	-0.8	-1.4	- [1]

Note 1: Outside of valid wind speed range for line of best fit
Note 2: Refer to Table 3
Note 3: Negative values of compliance margin indicate the noise level is below the applicable limit

The results in Table 22 - Table 23 demonstrate that compliance with the daytime and night-time noise limits is achieved at all assessed wind speeds.

6.0 SUMMARY

Operational wind farm noise monitoring has been carried out in the vicinity of the Mt Emerald Wind Farm to assess compliance with the operational noise requirements specified in Condition 4 of the Mt Emerald Wind Farm Development Permit.

The monitoring was carried out in accordance with the procedures detailed in the Noise Monitoring Plan.

The assessment results demonstrate that, during the survey period, operational noise levels associated with the Mt Emerald Wind Farm complied with the noise requirements outlined in Condition 4 of the Development Permit.

Specifically, the following outcomes are noted:

- The results of the noise monitoring demonstrate that noise levels associated with the wind farm were below the noise limits applicable at each assessment location
- Attended observations and subjective assessments of the noise associated with the wind farm did not identify the presence of special audible characteristics warranting the application of a penalty
- Despite the extended survey duration, and because of filtering process applied, there was not sufficient data available for assessment over the full wind speed range, most notably at the lower and higher ends of the assessable range.

In accordance with the Noise Monitoring Plan and the Queensland guideline, the wind farm's compliance is to be verified by a second stage of monitoring. It is recommended that the period of the second-round monitoring be selected to minimise the likelihood of significant data losses as a result of external grid constraints.

APPENDIX A GLOSSARY OF TERMINOLOGY

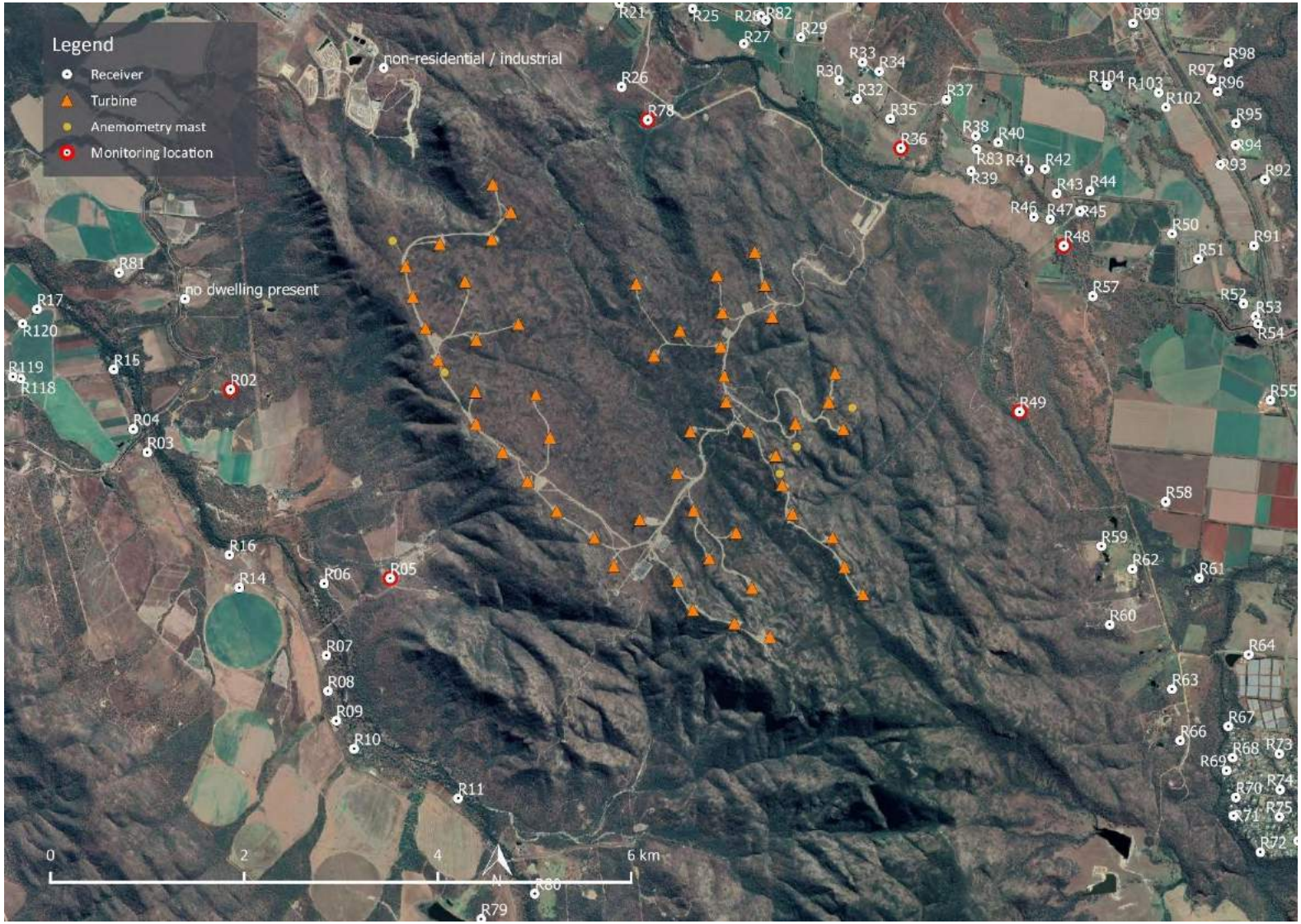
Ambient noise	The total, encompassing sound.
Frequency	Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals. Sound is generally described over the frequency range from 63Hz to 4000Hz (4kHz). This is roughly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

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

L_{A90}	The A-weighted noise level equalled or exceeded for 90% of the measurement period.

APPENDIX B SITE LAYOUT

Figure 2: Site layout



The following table sets out the coordinates of the fifty-three (53) turbine layout of the Mt Emerald Wind Farm. The table also lists the receiver locations where the turbine is considered to be contributing to receiver noise levels. This has been used in the turbine shut-down and atypical operational analysis.

Table 24: Mt Emerald Wind Farm as constructed turbine coordinates – MGA 94 zone 55

Turbine	Easting	Northing	Turbine model	Receiver location where turbine noise is considered to be relevant for analysis
1	328792	8102560	V117	R05,R36,R48,R49,R78
2	328903	8102219	V117	R05,R36,R48,R49,R78
3	328983	8101892	V117	R05,R36,R48,R49,R78
4	328466	8101926	V117	R02,R05,R36,R48,R49,R78
5	328402	8102310	V117	R02,R05,R36,R48,R49,R78
6	328458	8101575	V117	R02,R05,R36,R48,R49,R78
7	328031	8101732	V117	R02,R05,R36,R48,R49,R78
8	327768	8101472	V117	R02,R05,R36,R48,R49,R78
9	327574	8102211	V112	R02,R05,R36,R48,R49,R78
10	329242	8100793	V117	R02,R05,R36,R48,R49,R78
11	329740	8100745	V117	R05,R36,R48,R49,R78
12	329582	8101020	V117	R05,R36,R48,R49,R78
13	329643	8101321	V117	R05,R36,R48,R49,R78
14	328498	8101272	V117	R02,R05,R36,R48,R49,R78
15	328521	8101006	V112	R02,R05,R36,R48,R49,R78
16	328753	8100703	V112	R02,R05,R36,R48,R49,R78
17	329044	8100459	V112	R05,R36,R48,R49,R78
18	329115	8100157	V112	R02,R05,R36,R48,R49,R78
19	329228	8099859	V117	R02,R05,R36,R48,R49,R78
20	329647	8099621	V117	R02,R05,R36,R48,R78
21	329776	8099322	V117	R05,R36,R48,R78
22	329970	8099041	V117	R05,R36,R48,R78
23	328157	8100695	V117	R02,R05,R36,R48,R49,R78
24	328024	8100262	V117	R02,R05,R36,R48,R49,R78
25	328206	8099881	V117	R02,R05,R36,R48,R49,R78
26	328648	8099655	V117	R02,R05,R36,R48,R49,R78
27	328824	8099088	V117	R02,R05,R36,R48,R78
28	327652	8099773	V117	R02,R05,R36,R48,R49,
29	328377	8099385	V117	R02,R05,R36,R48,R49,R78

Turbine	Easting	Northing	Turbine model	Receiver location where turbine noise is considered to be relevant for analysis
30	328056	8099149	V112	R02,R05,R36,R48,
31	328217	8098850	V117	R02,R05,R36,R48,R78
32	328647	8098717	V117	R02,R05,R36,R48,R78
33	329018	8098587	V112	R02,R05,R36,R48,R78
34	327392	8099290	V117	R02,R36,
35	327187	8099577	V117	R02,R49,
36	326793	8099845	V112	R02,R49,
37	326708	8100606	V117	R02,R05,R36,R49,R78
38	326556	8101046	V117	R02,R05,R36,R49,R78
39	326484	8100150	V112	R02,R49,
40	326222	8100448	V112	R02,R49,
41	325941	8100734	V112	R02,R49,
42	325931	8101065	V112	R02,R49,
43	325539	8101383	V112	R02,R49,
44	325930	8101603	V117	R02,R05,R49,R78
45	326364	8101775	V117	R02,R05,R36,R49,R78
46	325803	8102201	V117	R02,R05,R49,R78
47	325402	8101713	V112	R02,R49,
48	325266	8102037	V112	R02,R49,
49	325187	8102350	V117	R02,R49,R78
50	325535	8102587	V112	R02,R49,R78
51	326072	8102642	V117	R02,R05,R49,R78
52	326263	8102926	V117	R02,R05,R36,R49,R78
53	326071	8103211	V117	R02,R05,R36,R49,R78

APPENDIX C DEVELOPMENT PERMIT CONDITIONS

The following operational noise requirements are reproduced from *Schedule 1: Conditions of Approval* of the Development Permit, as amended by the Notice of Decision issued by the Minister for State Development, Manufacturing, Infrastructure and Planning dated 14 March 2018.[6]

4.	*The wind farm development must be designed and operated to ensure that:*	*Prior to commencement of use and then to be maintained.*
	(a) The outdoor night-time (10pm to 6am) equivalent noise level ($L_{Aeq,10\ minutes}$) at existing and approved sensitive land uses at the date of this approval, does not exceed the higher of:	
	(i) 35dB(A); or	
	(ii) The background noise level (L_{A90}) plus 5dB(A);	
	and	
	(b) The outdoor day-time equivalent noise level ($L_{Aeq,10\ minutes}$) at existing and approved sensitive land uses at the date of this approval, does not exceed the higher of:	
	(i) 37dB(A); or	
	(ii) The background noise level (L_{A90}) plus 5dB(A)	
	(c) The equivalent noise levels (L_{Aeq}) are to be assessed at all existing and approved sensitive land uses at the date of this approval for all integer hub height wind speeds from cut-in to rated power of the wind turbine generator.	
	(d) Measurements of background noise or operational noise from wind turbine generators for the operation shall be in accordance with Australian Standard AS4959-2010 Acoustics – Measurement, prediction and assessment of noise from wind turbine generators (AS4959-2010) at any existing and approved sensitive land uses at the date of this approval. If an alternative standard or guideline to AS4959-2010 is to be followed for the assessment of Special Audible Characteristics, then reasons for the selection of the alternative are to be provided.	

[6] The NMP makes reference to an earlier Notice of Decision (dated 31 January 2017). While the Notice of Decision referred to above is more recent, the conditions relating to noise have not changed.

5.	(a)	*Submit to the chief executive administering the SPA a revised noise assessment report, certified by a suitably qualified acoustic consultant, demonstrating that the proposed wind farm can meet the noise levels specified in condition 4 of this approval. The report is to:* *i. Model the acoustic impacts of the wind farm based on the revised Turbine Location and Development Footprint Plan submitted in accordance with condition 2 of this approval.* *The noise modelling should take into account the varied topography between the turbine locations and existing and approved sensitive land use receptors at the date of this approval and any impacts that may have on predicted noise levels, and include an assessment of Special Audible Characteristics including tonality, impulsivity and amplitude modulation.* *ii. Identify any design specifications or operational restrictions that may be necessary to ensure compliance with the noise levels specified in condition 4, such as turbine types or limitations on hours of operation of specific turbines.*	*(a) Prior to the commencement of site / operational / building work*
	(b)	*Submit to the chief executive administering the SPA a compliance noise assessment report, by a suitably qualified acoustic consultant, demonstrating that the proposed wind farm meets the noise levels specified in condition 4 of this approval. The report is to:* *i. Measure the acoustic impacts of the wind farm based on the final Turbine Location and Development Footprint Plan submitted in accordance with condition 2 of this approval.* *The noise measurements should take into account the turbine locations and any existing and approved sensitive land use receptors at the date of this approval; and include an assessment of Special Audible Characteristics including tonality, impulsivity and amplitude modulation. Assessment of Special Audible Characteristics should be carried out using an appropriate international standard or guideline. Reasons for the selection of the standard or guideline are to be provided with the noise assessment report. The assessment should determine whether Special Audible Characteristics are excessive and require an adverse character adjustment (adj) to specific measurement period.*	*(c) Within twelve (12) months of the completion of construction and then to be maintained*

APPENDIX D SURVEY INSTRUMENTATION

Table 25: Sound level measurement instrumentation summary

Item	Description
Equipment type	Automated/unattended integrating sound level monitor
Make & model	01dB CUBE
Instrumentation class	Class 1 (precision grade) in accordance with AS/IEC 61672.1:2019[7]
Instrumentation noise floor	Less than 20 dB
Time synchronisation	Internal GPS clock
Wind shielding	Enhanced wind shielding system based on the design recommendations detailed in the UK IOA good practice guide. The system comprises an inner solid primary wind shield and an outer secondary large diameter hollow wind shield

Table 26: Sound level meter installation records

Receiver	System	Unit serial number	Microphone serial number	Independent calibration date [1]	Calibration drift [2,3]
R02	01dB CUBE	10521	#207208	15/2/2019	+0.63/+0.51
R05	01dB CUBE	10523	#207224	29/11/2017	+0.69/+0.97
R36	01dB Duo	10496	#141230	5/7/2018	+0.46/+0.41
R48[4]	01dB Duo	10495	#330630	6/8/2018	+0.17/+0.3
	01dB Duo	10339	#144938	5/7/2018	
R49[4]	01dB Duo	10497	#144850	07/09/2018	+0.12/+0.29
	01dB Duo	10197	#141100	13/05/2019	
R78	01dB CUBE	10651	#207209	15/02/2019	-0.11/+.45

Note 1: Independent (laboratory) calibration date to be within 2 years of measurement period as per AS 1055:2018[8]
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
Note 4: Initial logger deployed was replaced due to unit failure

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

Table 27: Wind speed measurement instrumentation

Wind speeds	Description
Local wind speeds	6 x Vaisala WXT 520 (one at each monitoring location)
Site wind speeds	Third party owned and operated system comprising a meteorological mast with anemometry at multiple heights Further information provided in Appendix E

[7] AS/IEC 61672.1-2019 *Electroacoustics - Sound level meters Specifications*, which is identical to IEC 61672.1:2.0 *Electroacoustics - Sound Level Meters - Part 1: Specifications* published 2013

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

APPENDIX E SITE WIND DATA

E1 Derivation of reference mast wind speeds

De-waked hub-height wind speed data, corresponding to the reference mast positions from the noise background studies, was derived from four (4) permanent met masts. The derived data was prepared by the site wind engineer (WSP).

Reference masts applicable to each receiver are listed in Table 6 of the NMP.

Further details of the derivation method are provided in Section E3 below.

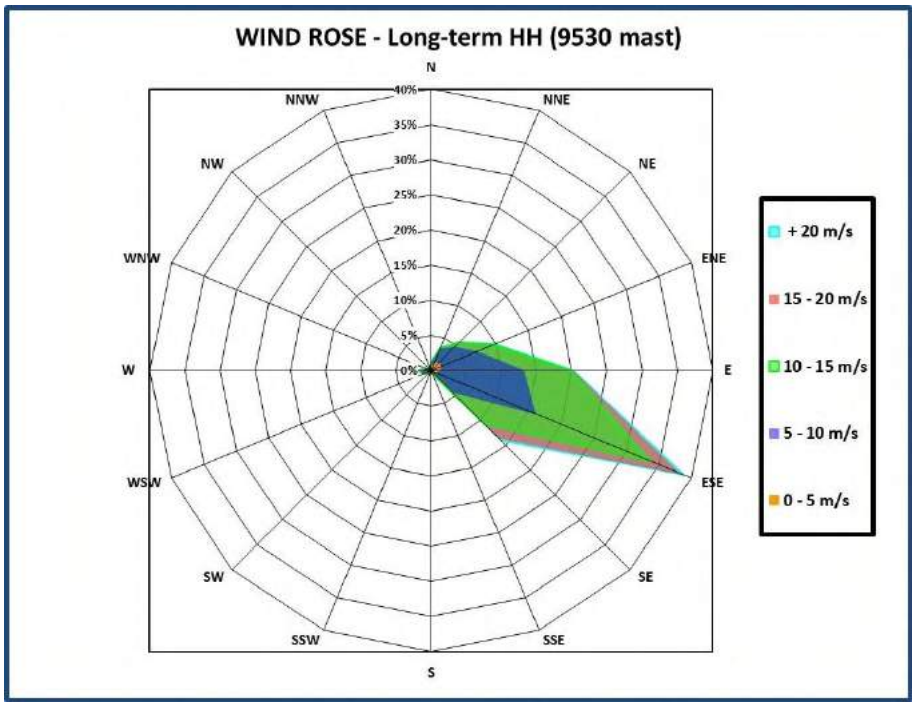
E2 Site wind speed and direction trends

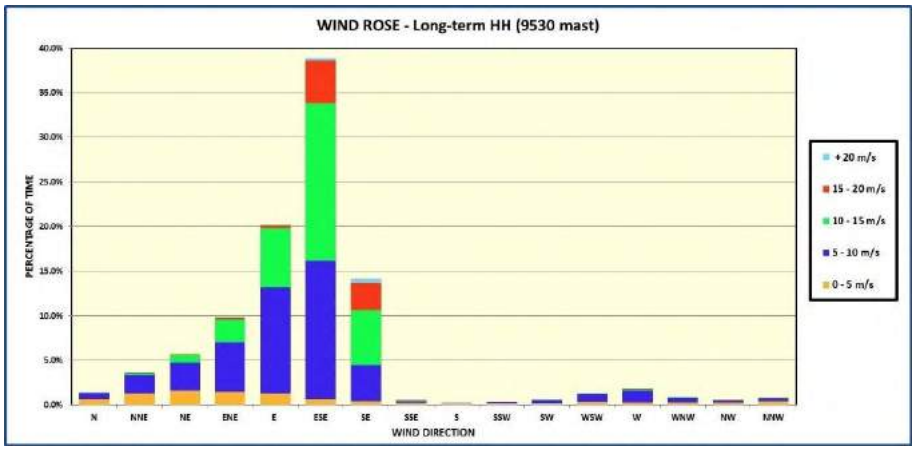
E2.1 Historic data

Historic wind speed and direction data was provided in Appendix G of the Noise Management Plan and is reproduced here for reference purposes. The historic data corresponded to a period of 8 years and was presented as an indication of general trends at the site.

Wind data shown below has been extrapolated to 90 m AGL based on wind speed and direction measured at 80 m AGL at met mast 9530, located within the wind farm site.

Figure 3: Wind rose – Long term trend (8 year period)





E2.2 Post-construction survey period

The trend of the site wind direction and wind speed data (wind speed corresponding to hub-heights) referenced in the analysis of the noise survey period are illustrated in Figure 4 (met mast 9530) and Figure 5 (met mast 9531).

The wind directions during the survey period are consistent with the historic trend data shown in the preceding sections. In particular, both sets of data demonstrate the prevalence of east to east-southeast wind directions. The wind directions that occurred during the survey period are therefore considered typical for the location.

Figure 4: Wind rose for met mast 9530 – (Derived wake-free data 1 May to 27 September 2019)

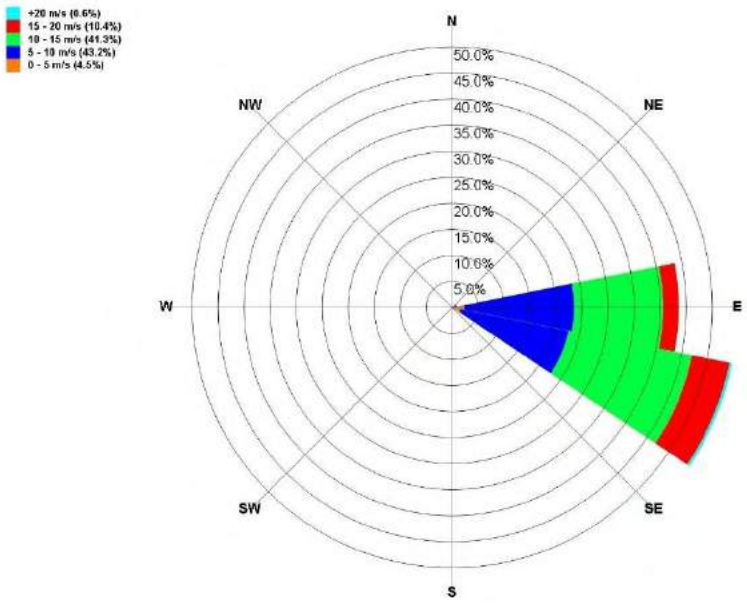
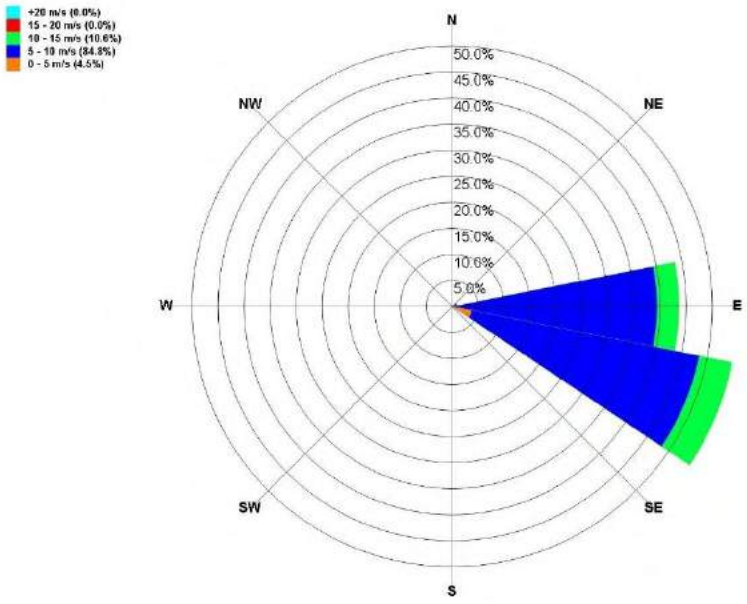


Figure 5: Wind rose for met mast 9531 – (Derived wake-free data 1 May to 27 September 2019)



E3 Site wind speed data derivation– WSP correspondence

wsp

MEMO

TO:	Terry Johannesen (Ratch Australia Corporation Ltd)
FROM:	Michael Kane (WSP Australia Pty Ltd)
SUBJECT:	**Mount Emerald Wind Farm – Derived Wake Free Datasets**
OUR REF:	PS101382-WIN-MEM-002 RevA.docx
DATE:	**31 October 2019**

1. INTRODUCTION

Ratch Australia Corporation Ltd (RAC) has developed and constructed the Mount Emerald Wind Farm (MEWF), located approximately 48 km southwest of Cairns, in North Queensland. At the request of RAC, WSP Australia Pty Ltd (WSP) has derived two (2) wind datasets at the development mast locations. The development masts were decommissioned in October 2018, however RAC has requested datasets consisting of wake free wind speed and wind direction at these locations for after the decommissioning date for the purposes of noise modelling at MEWF covering the period 1 May 2019 to 22 September 2019.

A summary of the development masts and power curve verification masts site masts, along with respective wind data provided is detailed in Table 1.1 and illustrated in [1] [2] [3] [4] [5].

Table 1.1 MEWF Site Masts – WGS84 UTM Zone 55K

MAST	STATUS	EASTING	NORTHING	PRIMARY INSTRUMENT HEIGHT	DATA START	DATA END
		m		m	dd/mm/yy	
9530	Development	329088	8100271	81.0	27/07/2017	14/10/2018
9531	Development	325608	8101256	49.6	27/07/2017	13/10/2018
MM22	Permanent	330111	8099256	90.0	14/05/2018	22/09/2019
MM1112	Permanent	329825	8100965	90.0	22/03/2018	22/09/2019

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Figure 1.1 Monitoring Mast Locations at MEWF

1.1 METHODOLOGY

Detailed below is a high-level summary of the approach WSP has undertaken to produce the derived datasets at the MEWF development mast locations:

- Sector-wise linear regression models have been derived for wind speed measurements between the development masts and permanent power curve verification masts using a period of concurrent data (01/05/2018-20/08/2018). WSP understands this period was not subjected to WTG operation at MEWF, and therefore should be free of wake deficits from WTG operation.
- The linear regression models have been applied to the permanent power curve verification mast data to derive estimated wind speeds at the development mast locations (synthetic datasets).
- The above process has been performed for each permanent power curve verification and development mast pairing (MM22 and MM1112 to 9530, and MM22 and MM1112 to 9531). Two (2) Synthetic datasets have been produced at each development mast location.
- The synthetic datasets have been filtered of wind directions for which wake impacts are expected [6]. Subsequent to this filtering, the synthetic datasets have been combined using a hierarchical combination method. Synthetic datasets with a higher correlation/reduced standard error have been preference over lower correlating datasets.
- The final combined dataset may be considered a 'best estimate' of wind speeds at the development mast locations, based on the data provided to WSP at the time of writing. Wake free sectors for the development mast locations have been derived for 7.5-174.7 degrees. All data from non-wake free sectors has been removed from the datasets. This approach was deemed acceptable due to the easterly directional nature of the site. The removed non-wake free data accounted for approximately 1% of the overall dataset.

WSP has not applied any model to adjust wind direction data from the permanent power curve verification masts to the development mast locations. As such it is assumed for the purpose of this assessment that wind direction does not vary across the site.

1.2 ASSUMPTIONS

WSP has made the following assumptions as part of this analysis:

- Wake affected sectors were calculated using methodology outlined in *IEC61400-12-1* [6]
- Wind direction at the permanent power curve verification mast locations is representative of wind direction at the development mast location
- Wind speed correlations created using linear transfer functions is suitable for the purposes of this application, and the short term model is representative of long term
- WTG operation has been considered and wind data measured after first generation at MEWF was removed from the development mast datasets

1.3 LIMITATIONS

The derived wake free datasets contain a high level of uncertainty. WSP recommends that the derived wake free datasets created at the development met mast locations are not used for any other purpose than noise assessment. Datasets are estimates, not considered fit for purpose energy modelling and are to be treated as indicative only.

Michael Kane
Wind Engineer

2. REFERENCES

[1] Ratch Australia Corporation Limited, *MEWF New Masts.zip*, 2019.

[2] Ratch Australia Corporation Ltd, *NRGData - SD Card 9210.zip*, 2019.

[3] Ratch Australia Corporation Ltd, *NRGData - SD Card 9523.zip*, 2019.

[4] Ratch Australia Corporation Ltd, *MEWF MM22 Mast data 20190430-20190923.xlsx*.

[5] Ratch Australia Corporation Ltd, *MEWF MM1112 Mast data 20190430-20190923.xlsx*.

[6] International Electrotechnical Commission, *iec61400-12-1{ed2.0}b.pdf*, 201.

APPENDIX F RECEIVER R02 DATA

F1 Receiver R02 location data

Table 28: Receiver R02 dwelling and noise monitor coordinates – MGA 94 Zone 55

Location	Easting	Northing
Dwelling location	323251	8101012
Noise monitoring location	323286	8101032

Figure 6: Receiver R02 aerial view – dwelling and noise monitor location

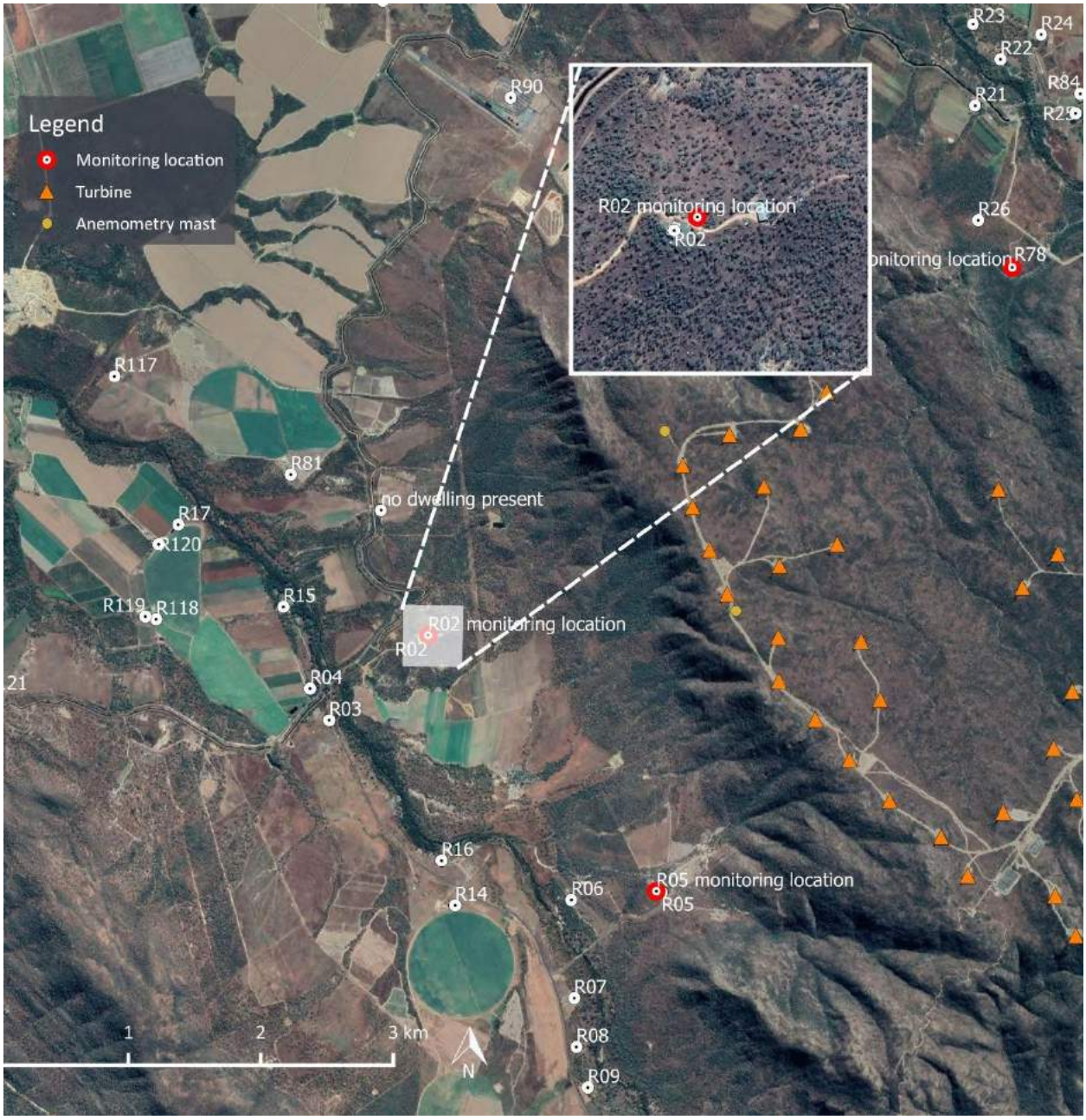

Table 29: Receiver R02 monitor installation photos

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

F2 Receiver R02 measurement data summary

Table 30: Receiver R02 noise level analysis summary

Data points	Daytime	Night-time
Total collected points	13123	7786
Removed [1]	2427	1780
Operational filtering [2]	10118	5228
Total retained	**578**	**778**

Notes: [1] Removed data points due to rain, extraneous noise, or wind speeds outside assessment range
[2] Removed data points as detailed in Section 5.4 of the NMP.

For the night-time period audio was reviewed across a range of wind speeds – in all cases, the data points where levels were greater than 40 dB were dominated by background or extraneous noise and the influence of the wind farm was generally not discernible. Accordingly, all points greater than 40 dB are considered to have been caused by factors not related to the wind farm and removed from the analysis.

Figure 7: Receiver R02 measured noise level and site wind speed time history - Daytime

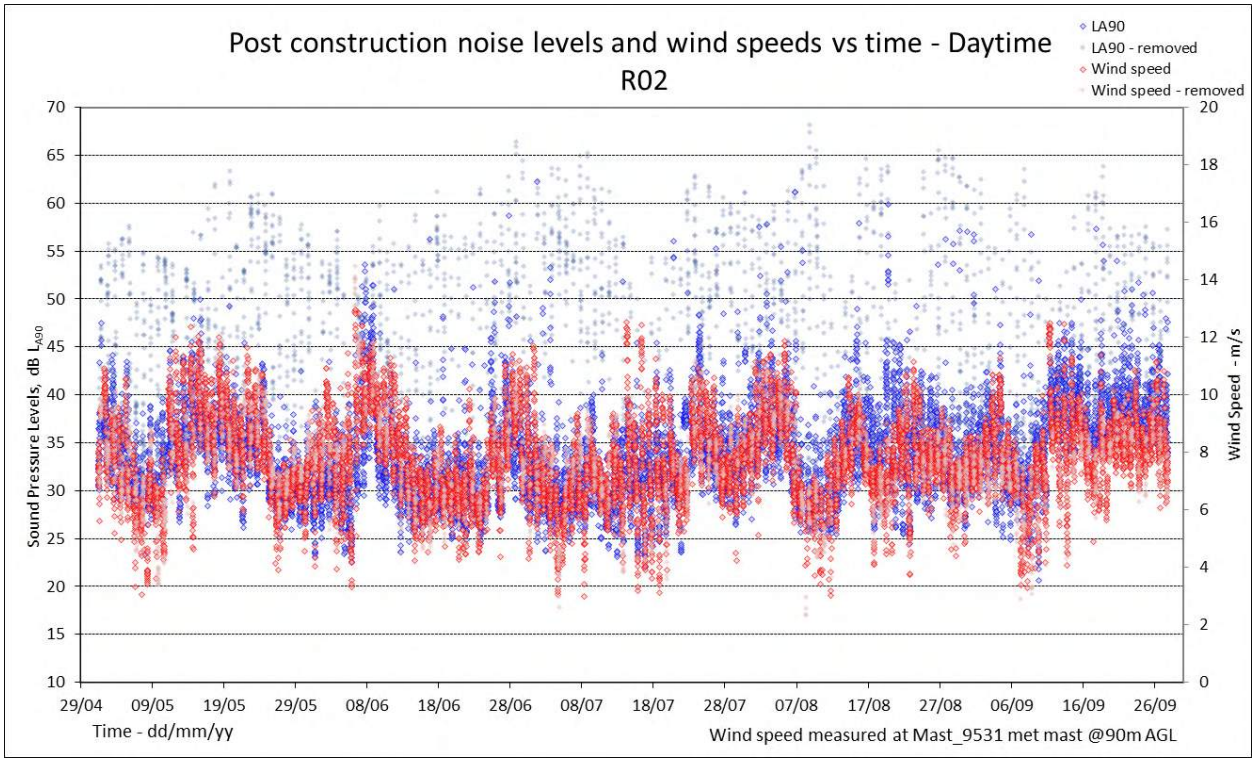

Figure 8: Receiver R02 measured noise level and site wind speed time history – Night-time

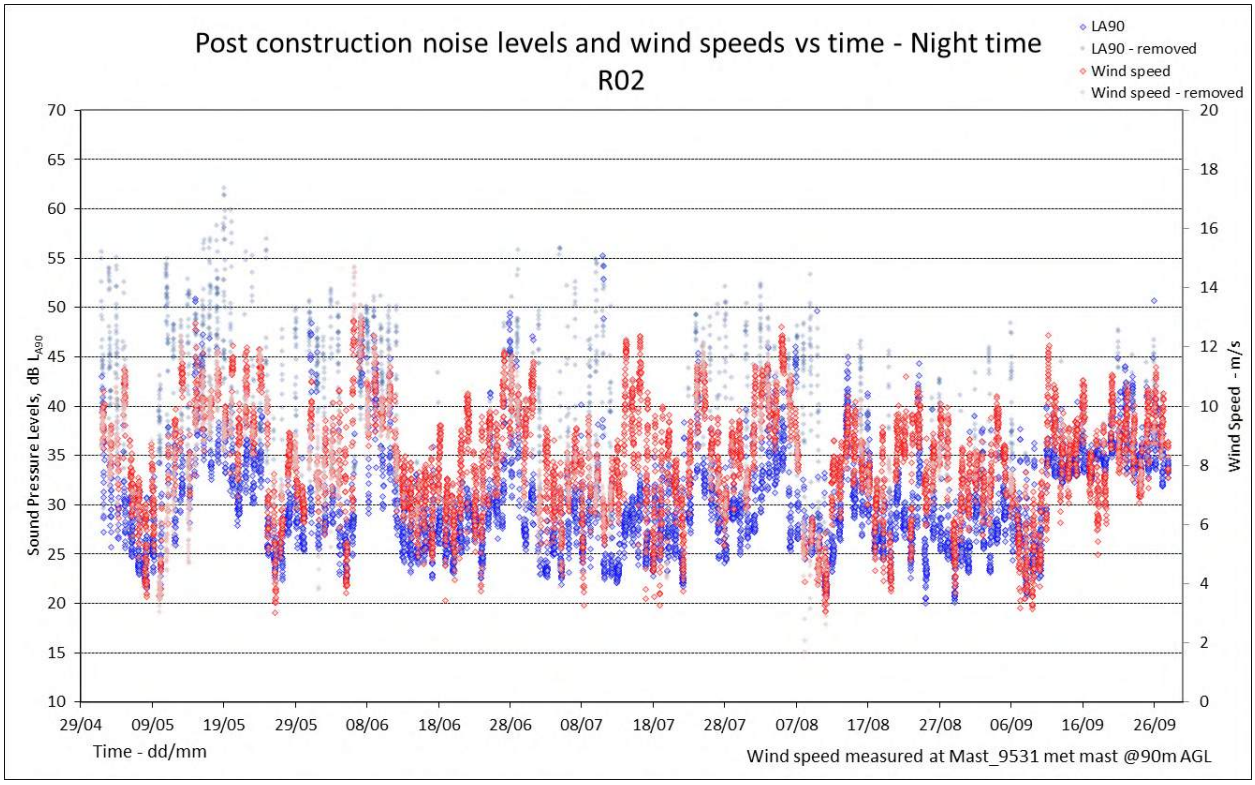

Figure 9: Receiver R02 daytime periods - post-construction noise levels and noise limits versus site wind speed

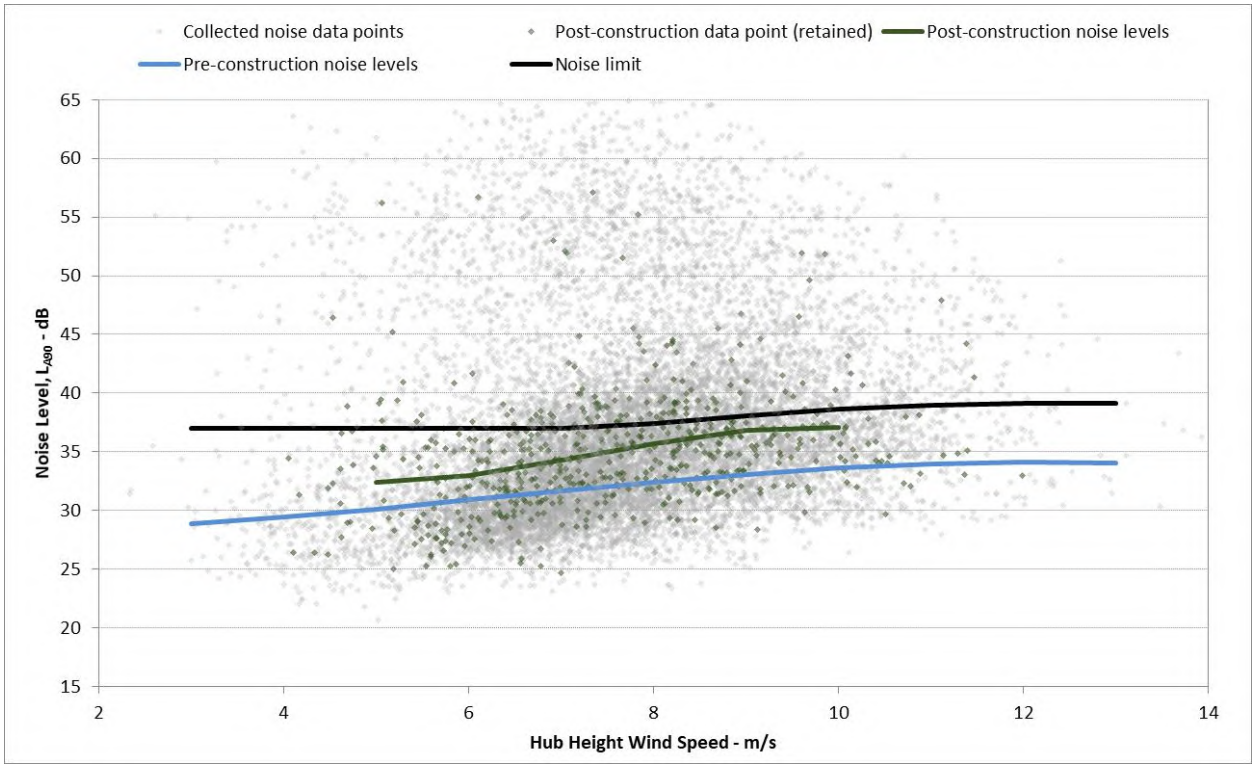

Figure 10: Receiver R02 night-time periods - post-construction noise levels and noise limits versus site wind speed

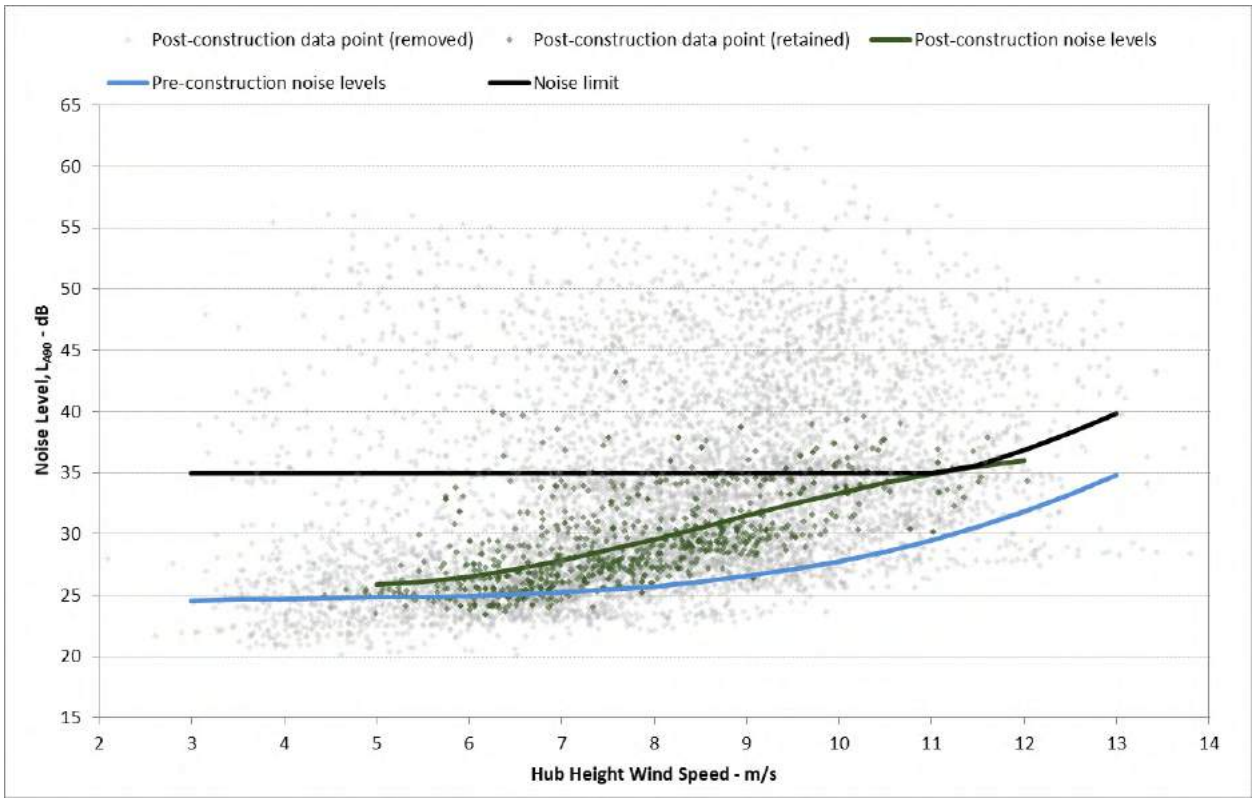

Table 31: Receiver R02 derived wind farm noise levels – line of best fit

Period	Regression equation coefficients $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
	a	b	c	d	R^2	Valid wind speed range
Daytime	-0.0749	1.6270	-10.3188	52.4574	0.1064	5-10
Night-time	-0.0383	1.0098	-6.9345	40.0623	0.4063	5-12

APPENDIX G RECEIVER R05 DATA

G1 Receiver R05 location data

Table 32: Receiver R05 dwelling and noise monitor coordinates – MGA 94 Zone 55

Location	Easting	Northing
Dwelling location	325084	8099119
Noise monitoring location (up to 22/7)	325043	8099129
Noise monitoring location (after 22/7)	325102	8099083

Figure 11: Receiver R05 aerial view – dwelling and noise monitor location

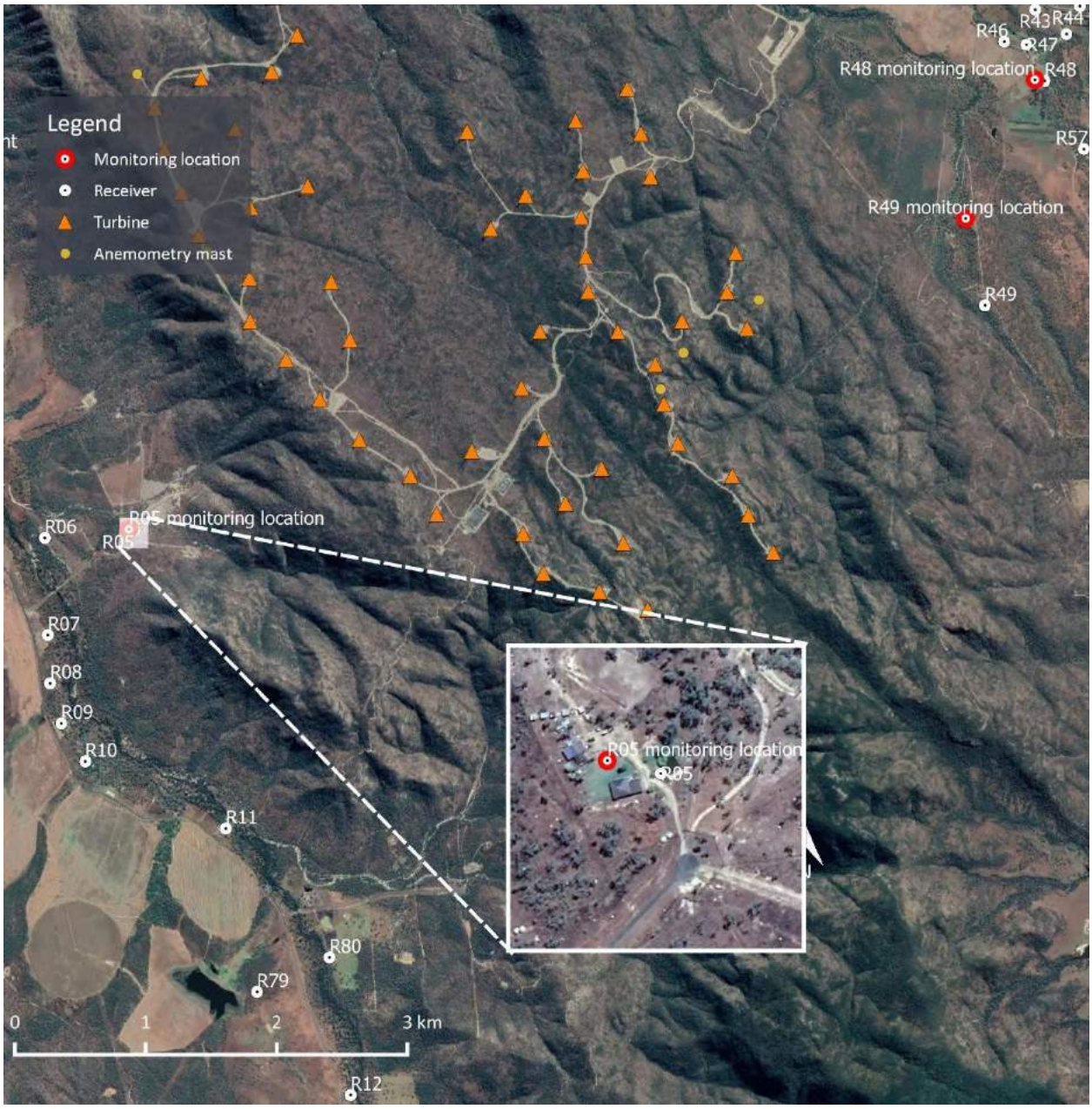

Table 33: Receiver R05 monitor installation photos

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

G2 Receiver R05 measurement data summary

Table 34: Receiver R05 noise level analysis summary

Data points	Daytime	Night-time
Total collected points	13107	7774
Removed [1]	1489	1452
Operational filtering [2]	10890	5545
Total retained	**728**	**777**

Notes: [1] Removed data points due to rain, extraneous noise, or wind speeds outside assessment range
[2] Removed data points as detailed in Section 5.4 of the NMP.

For the night-time period audio was reviewed across a range of wind speeds – in all cases, the data points where levels were greater than 40 dB were dominated by background or extraneous noise and the influence of the wind farm was generally not discernible. Accordingly, all points greater than 40 dB are considered to have been caused by factors not related to the wind farm and removed from the analysis.

Similarly, for the daytime period, all data points where levels were greater than 45 dB were dominated by background or extraneous noise and were removed from the analysis.

Figure 12: Receiver R05 measured noise level and site wind speed time history - Daytime

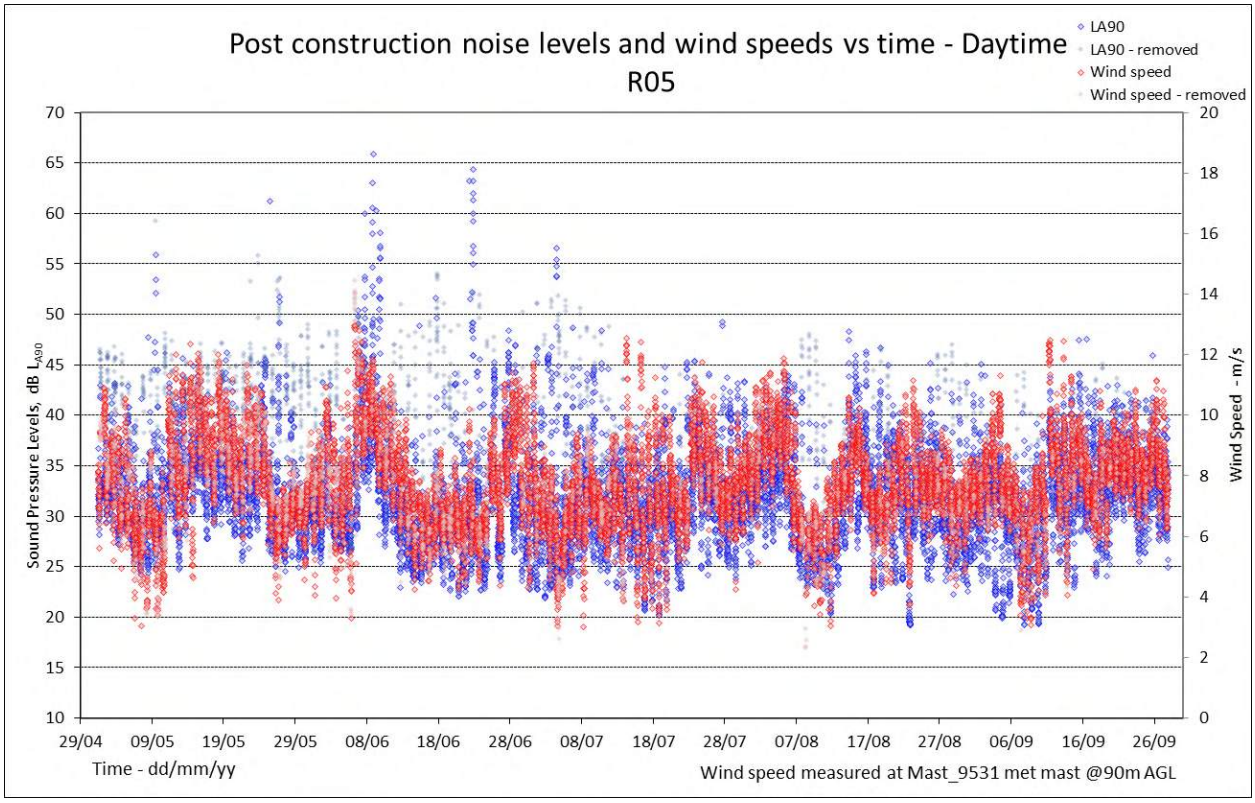

Figure 13: Receiver R05 measured noise level and site wind speed time history – Night-time

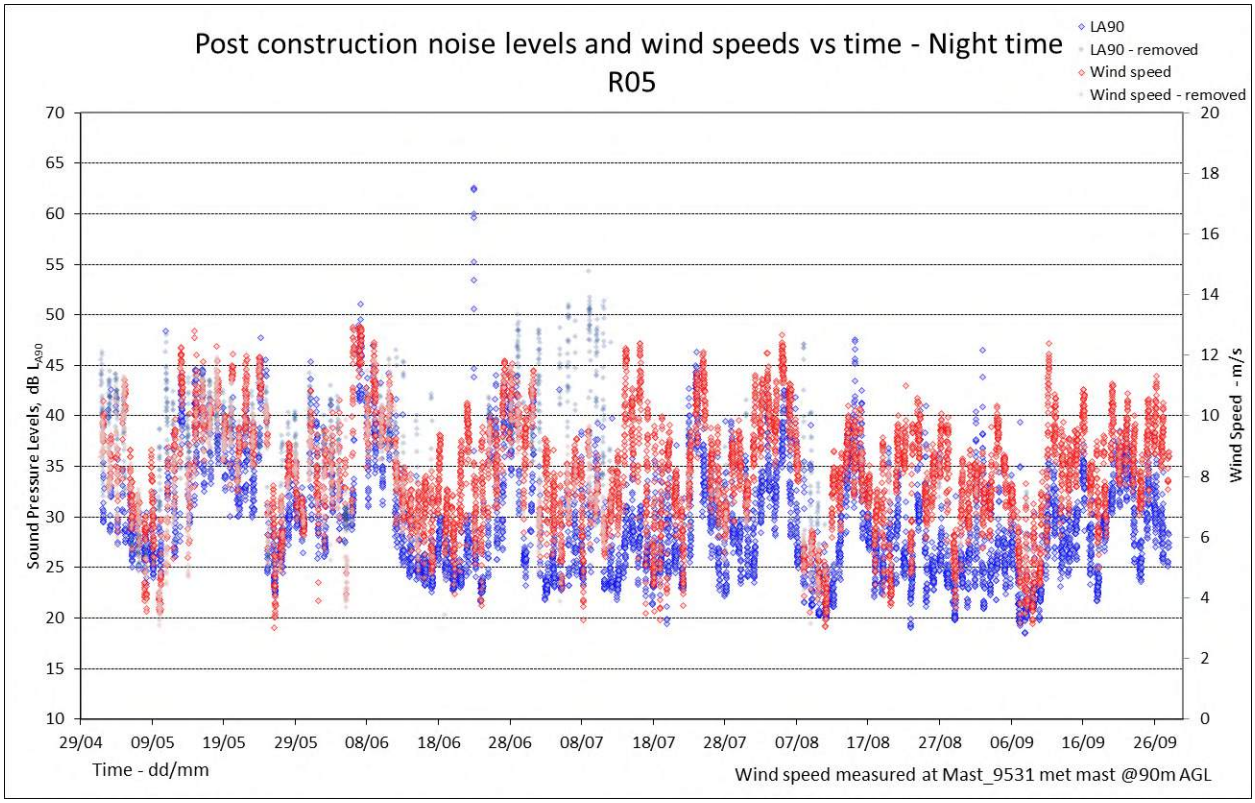

Figure 14: Receiver R05 daytime periods - post-construction noise levels and noise limits versus site wind speed

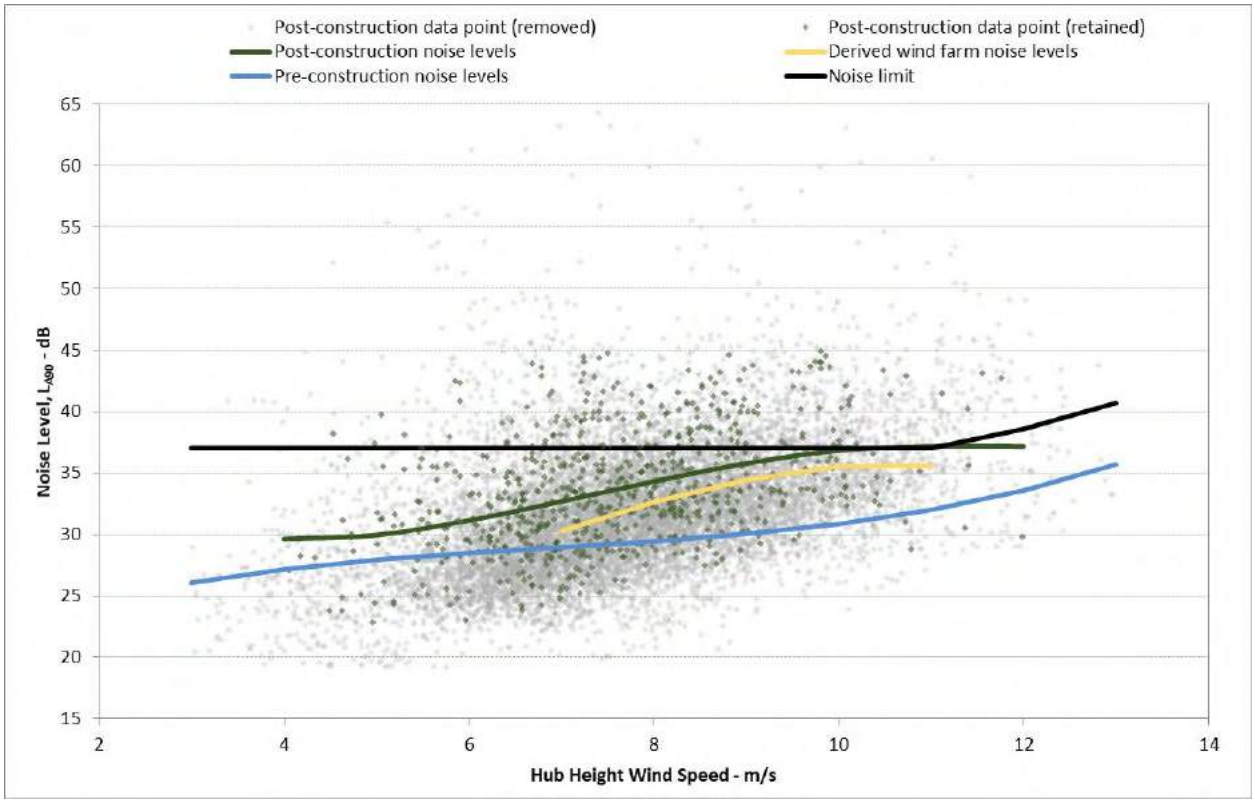

Figure 15: Receiver R05 night-time periods - post-construction noise levels and noise limits versus site wind speed

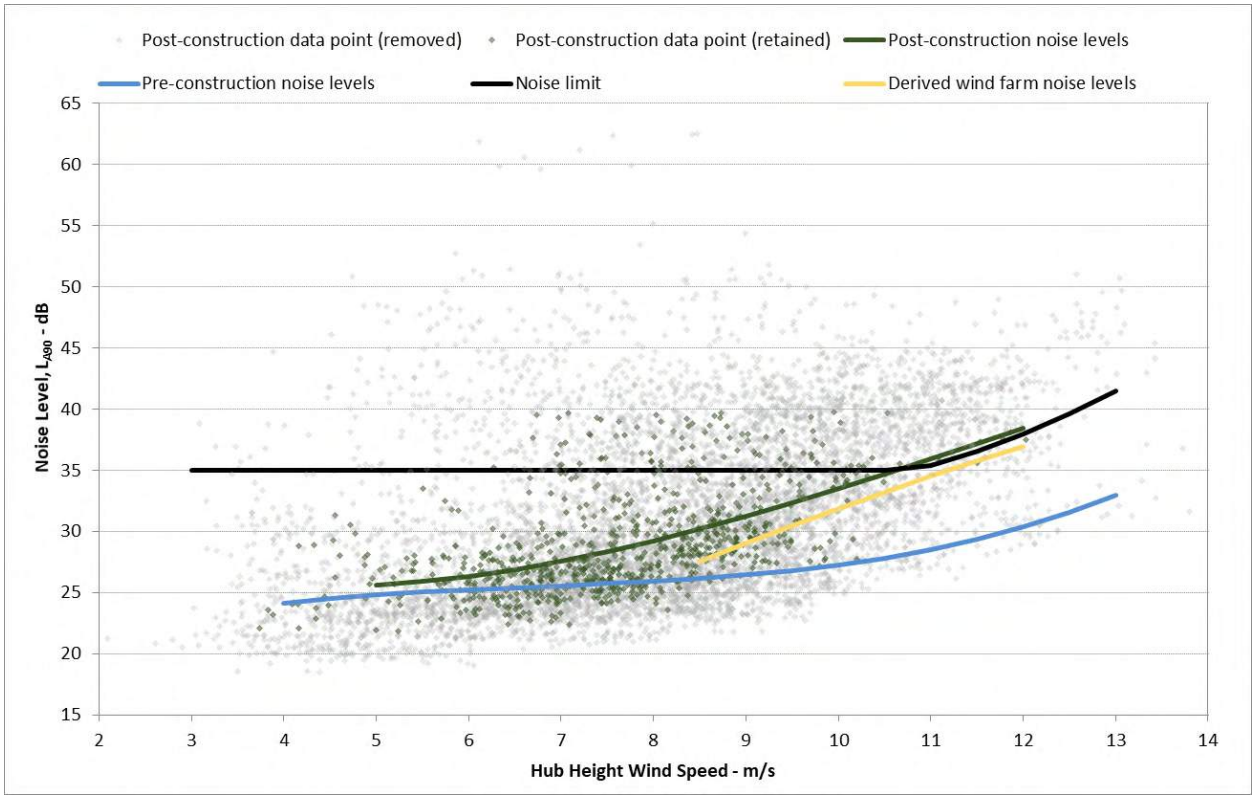

Table 35: Receiver R05 post-construction noise levels – line of best fit

Period	Regression equation coefficients $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
	a	b	c	d	R^2	Valid wind speed range
Daytime	-0.0431	0.9498	-5.3318	38.2425	0.1714	4 -12 m/s
Night-time	-0.0146	0.5226	-3.7076	32.9390	0.3095	5 -12 m/s

APPENDIX H RECEIVER R36 DATA

H1 Receiver R36 location data

Table 36: Receiver R36 dwelling and noise monitor coordinates – MGA 94 Zone 55

Location	Easting	Northing
Dwelling location	330281	8103655
Noise monitoring location	330276	8103621

Figure 16: Receiver R36 aerial view – dwelling and noise monitor location

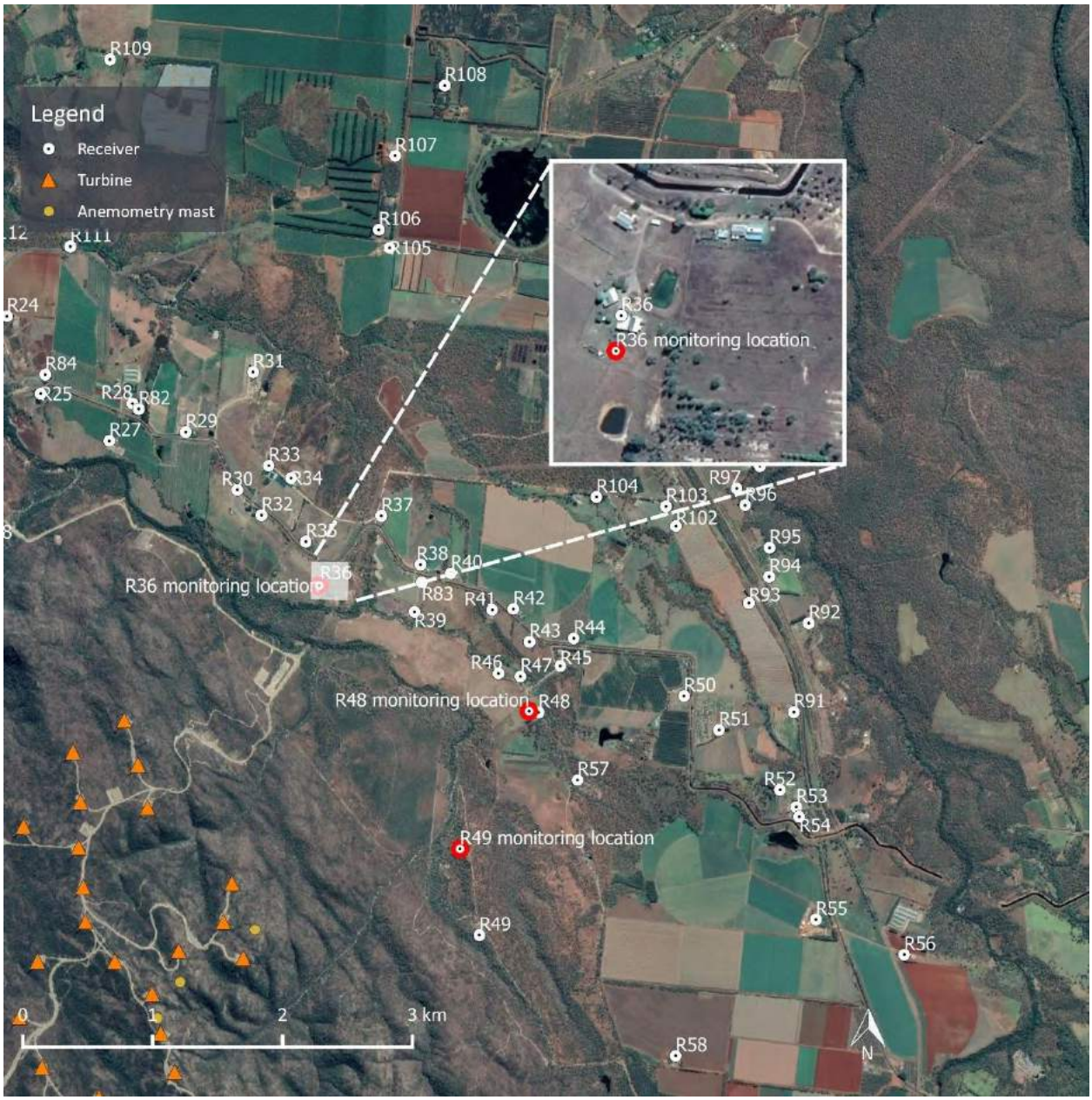

Table 37: Receiver R36 monitor installation photos

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

H2 Receiver R36 measurement data summary

Table 38: Receiver R36 noise level analysis summary

Data points	Daytime	Night-time
Total collected points	13205	7858
Removed [1]	3027	3409
Operational filtering [2]	9153	3395
Total retained	**1025**	**1054**

Notes: [1] Removed data points due to rain, extraneous noise, or wind speeds outside assessment range
[2] Removed data points as detailed in Section 5.4 of the NMP

Figure 17: Receiver R36 measured noise level and site wind speed time history - Daytime

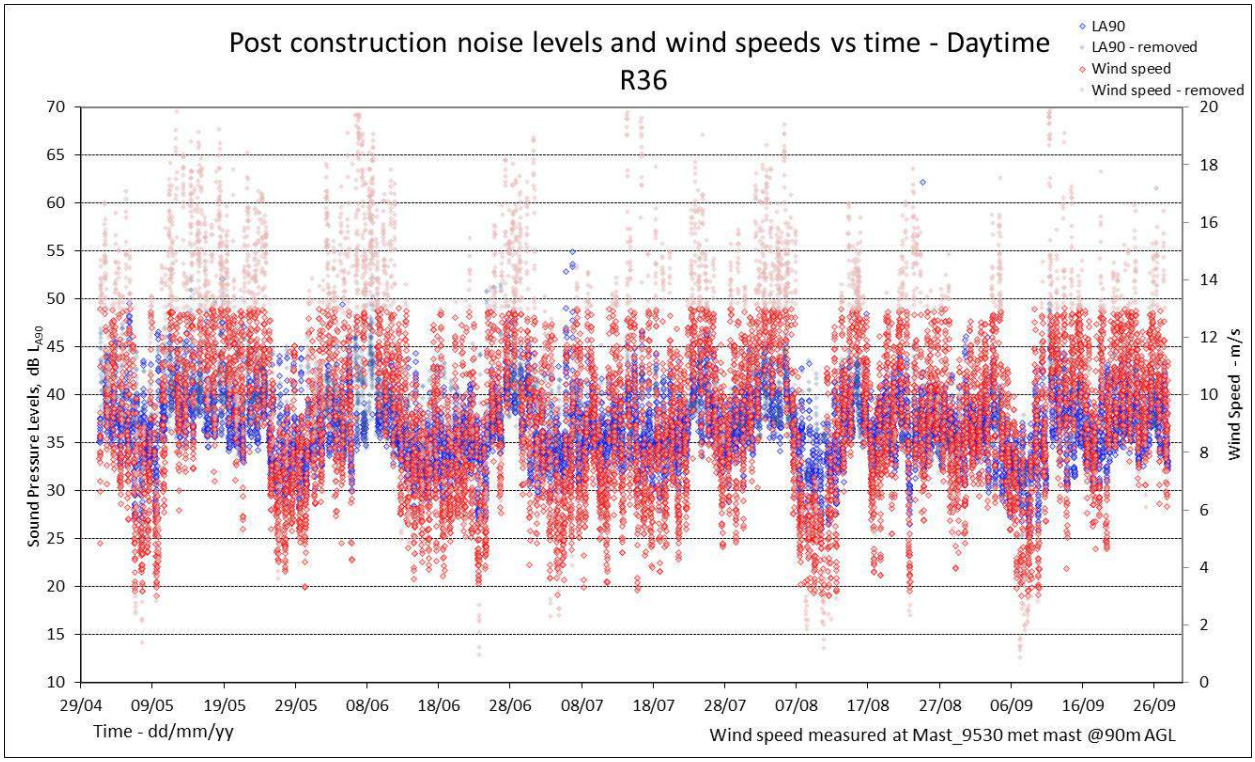

Figure 18: Receiver R36 measured noise level and site wind speed time history – Night-time

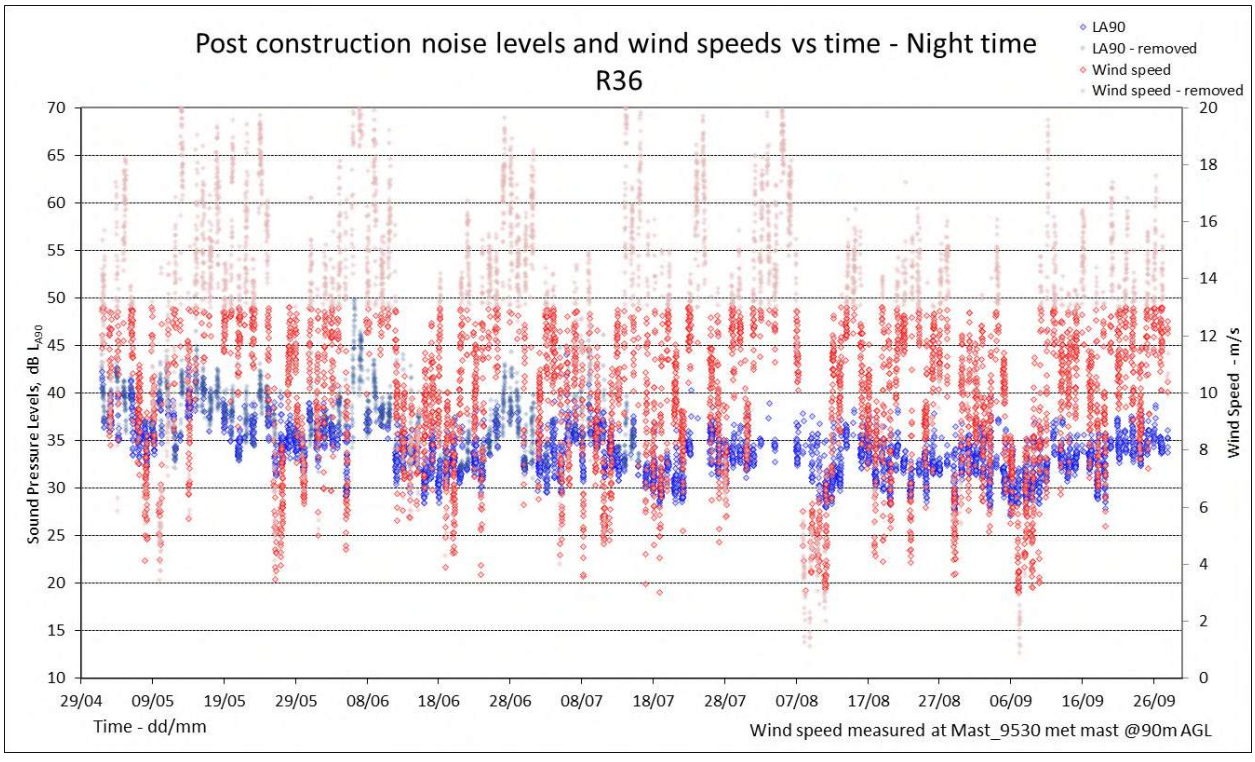

Figure 19: Receiver R36 daytime periods - post-construction noise levels and noise limits versus site wind speed

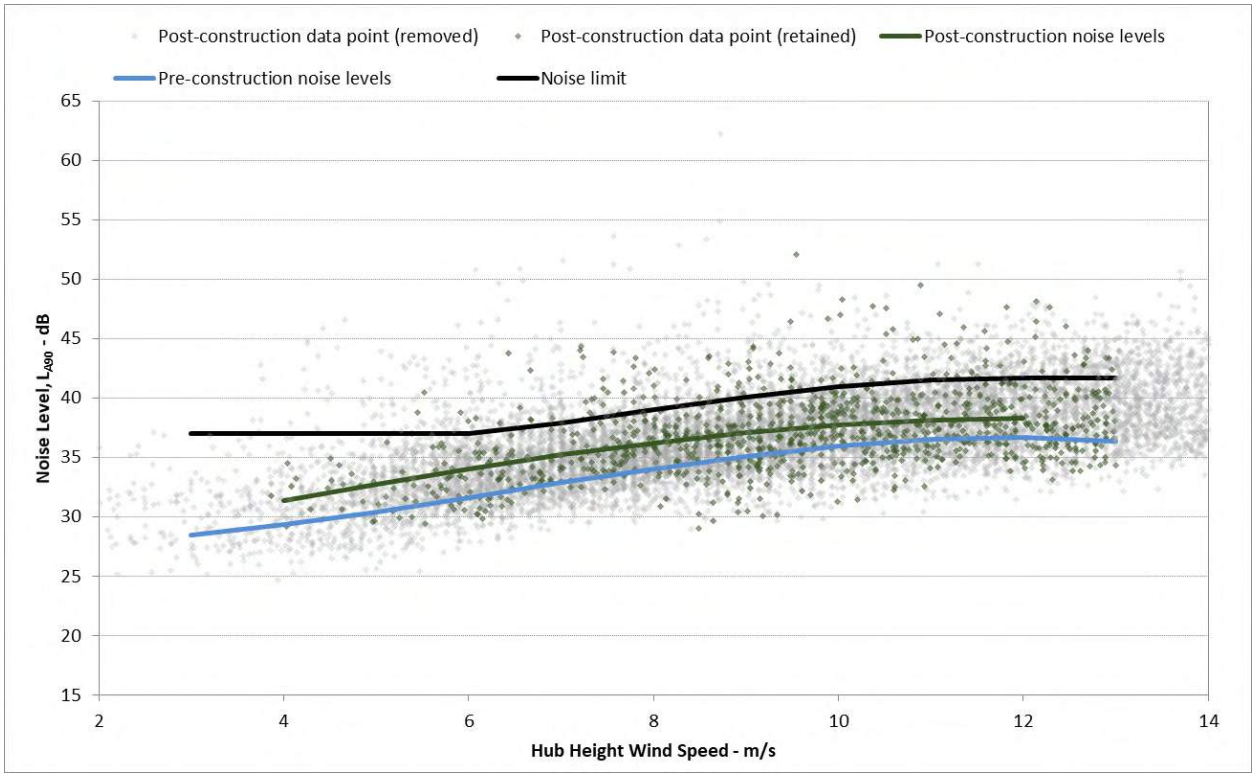

Figure 20: Receiver R36 night-time periods - post-construction noise levels and noise limits versus site wind speed

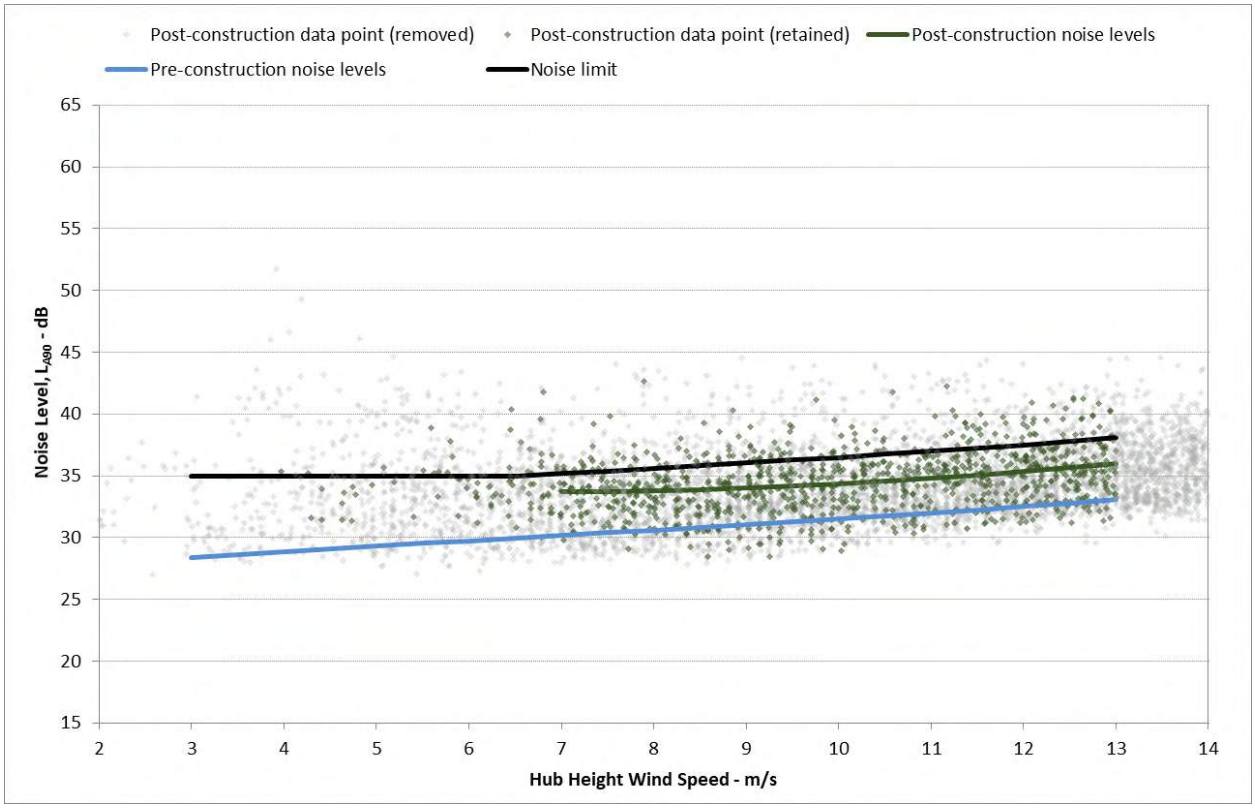

Table 39: Receiver R36 post-construction noise levels – line of best fit

Period	Regression equation coefficients $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
	a	b	c	d	R^2	Valid wind speed range
Daytime	-0.0047	0.0248	1.4518	25.4340	0.2086	4-12 m/s
Night-time	-0.0033	0.1555	-1.7304	39.3476	0.0922	7-13 m/s

APPENDIX I RECEIVER R48 DATA

I1 Receiver R48 location data

Table 40: Receiver R48 dwelling and noise monitor coordinates – MGA 94 Zone 55

Location	Easting	Northing
Dwelling location	331981	8102675
Noise monitoring location	331907	8102683

Figure 21: Receiver R48 aerial view – dwelling and noise monitor location

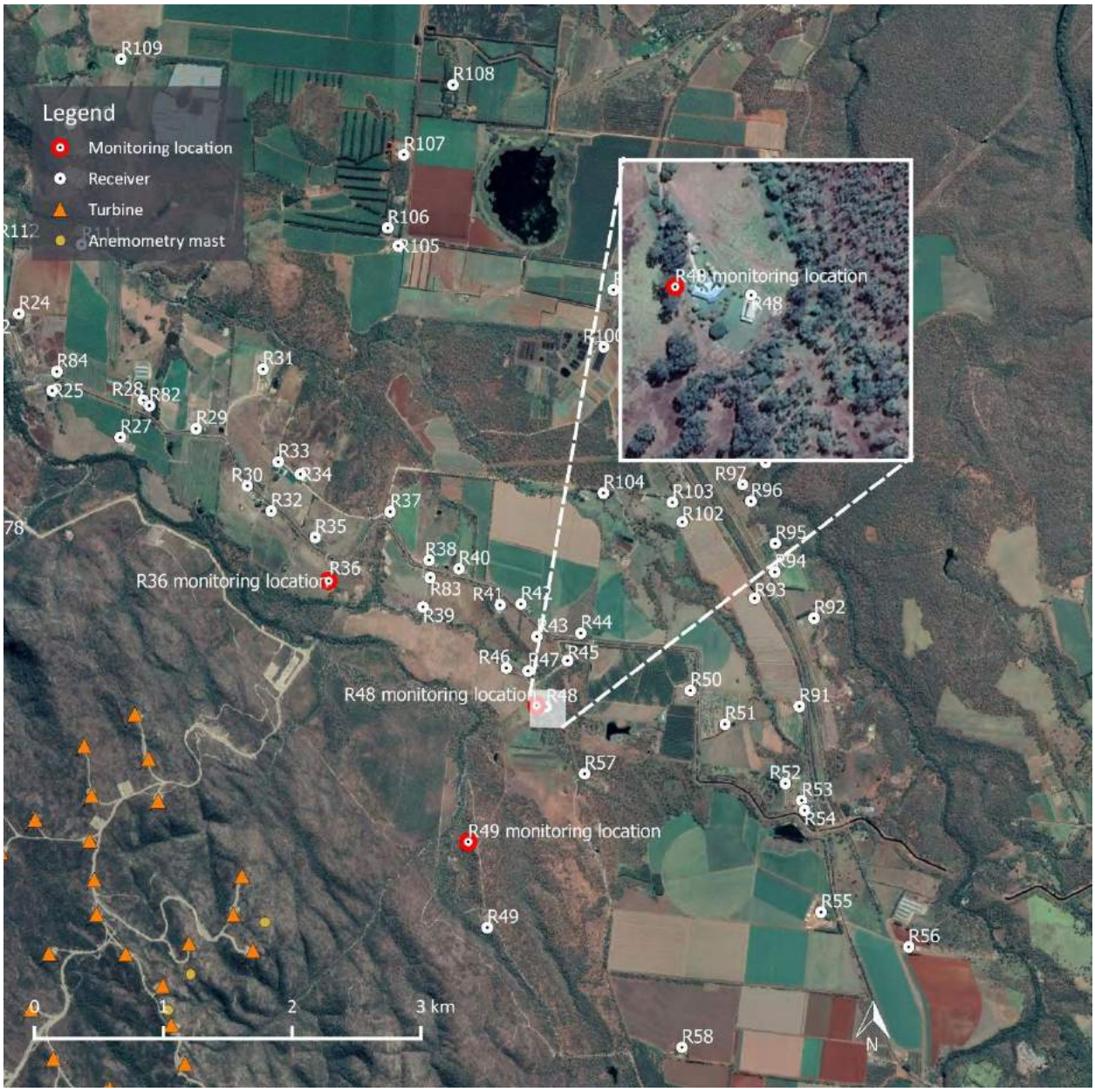

Table 41: Receiver R48 monitor installation photos

Looking North	Looking East
	
Looking South	Looking West
	

I2 Receiver R48 measurement data summary

Table 42: Receiver R48 noise level Figure 23analysis summary

Data points	Daytime	Night-time
Total collected points	11504	6876
Removed [1]	2932	2883
Operational filtering [2]	7936	3265
Total retained	**636**	728

Notes: [1] Removed data points due to rain, extraneous noise, or wind speeds outside assessment range
[2] Removed data points as detailed in Section 5.4 of the NMP

No data was recorded for some of the logging period due to equipment failure. This is shown as gaps in the plots in Figure 22 and Figure 23

Figure 22: Receiver R48 measured noise level and site wind speed time history - Daytime

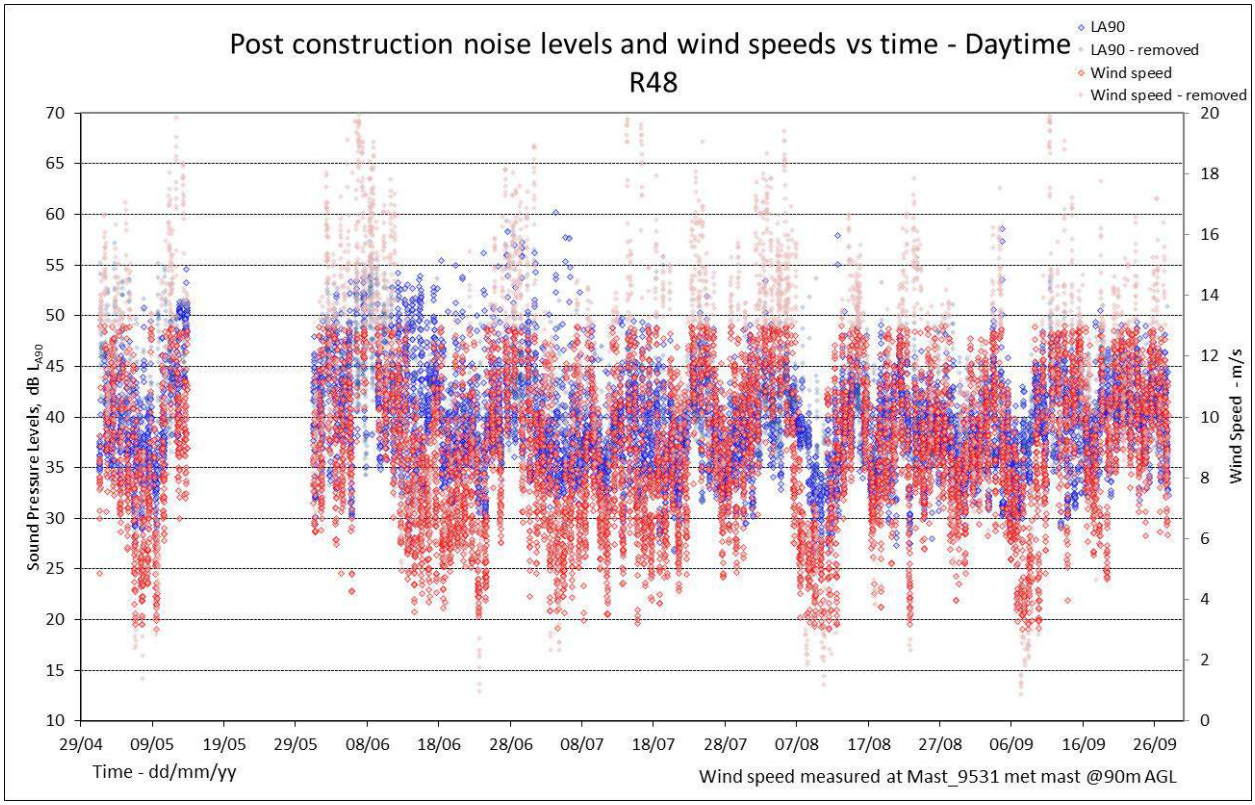

Figure 23: Receiver R48 measured noise level and site wind speed time history – Night-time

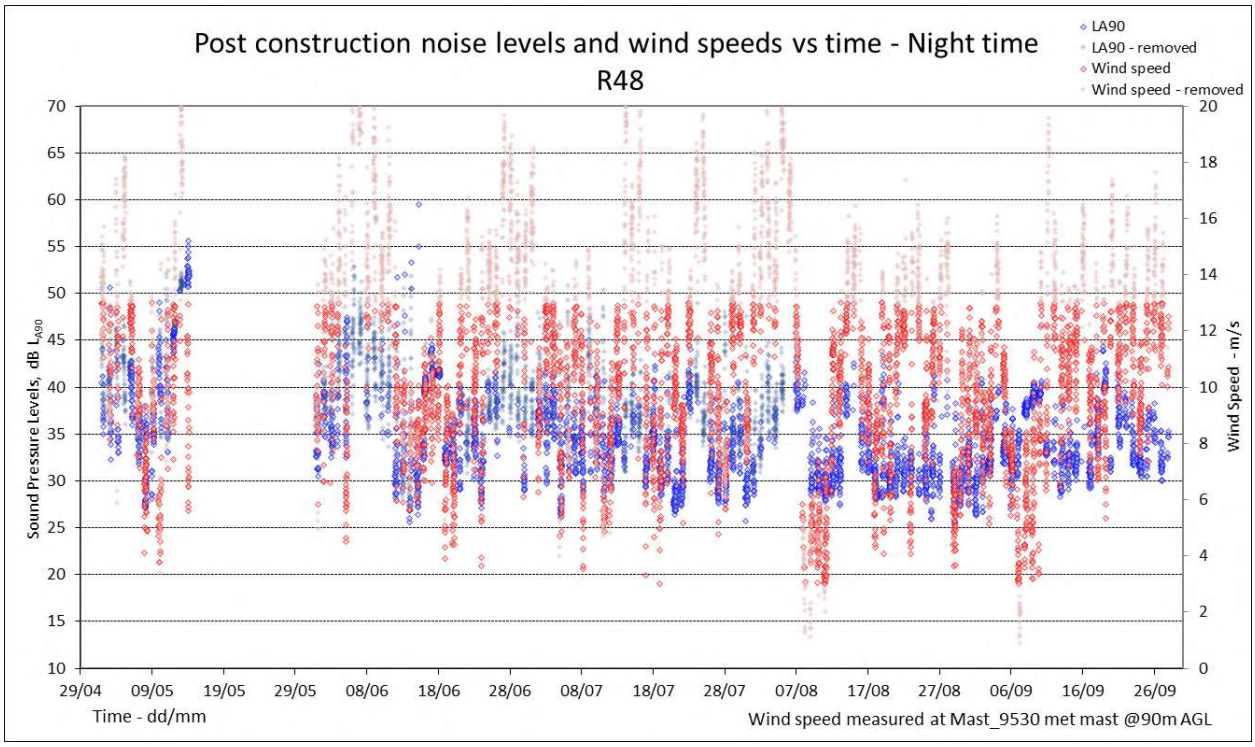

Figure 24: Receiver R48 daytime periods - post-construction noise levels and noise limits versus site wind speed

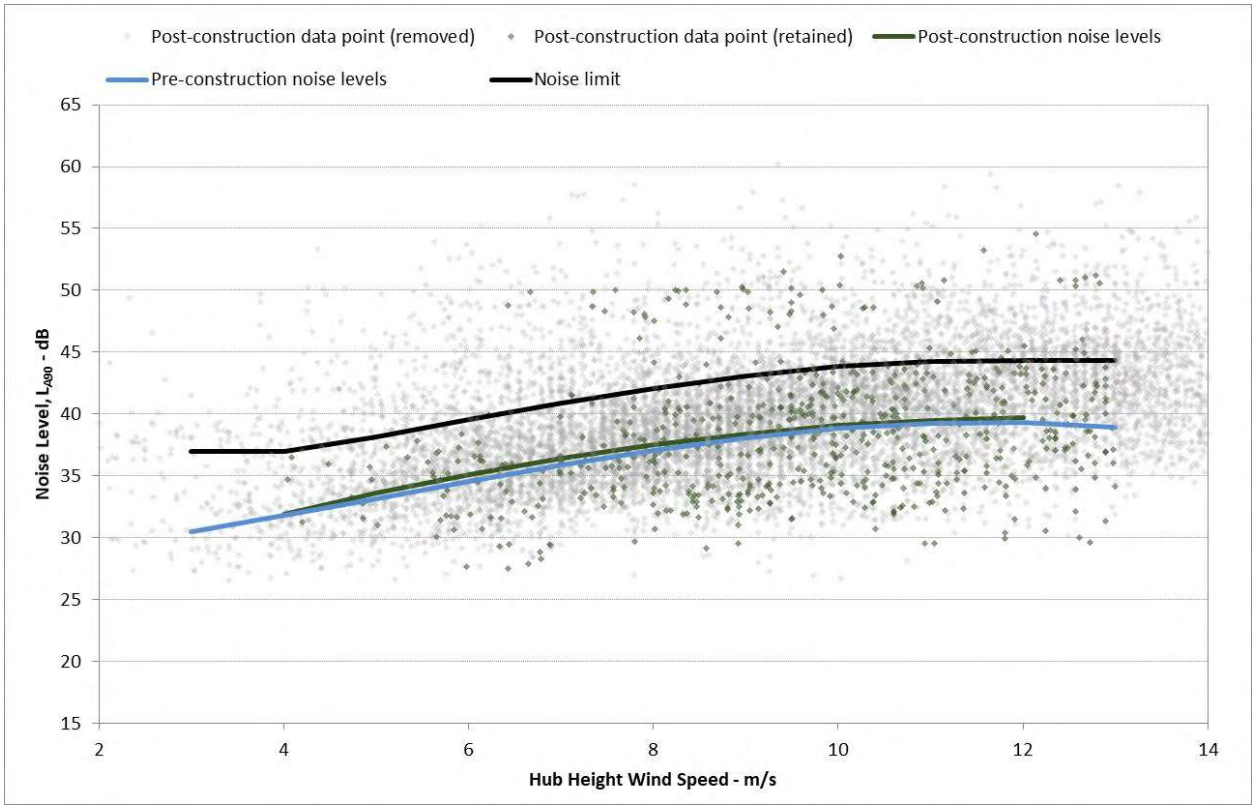

Figure 25: Receiver R48 night-time periods - post-construction noise levels and noise limits versus site wind speed

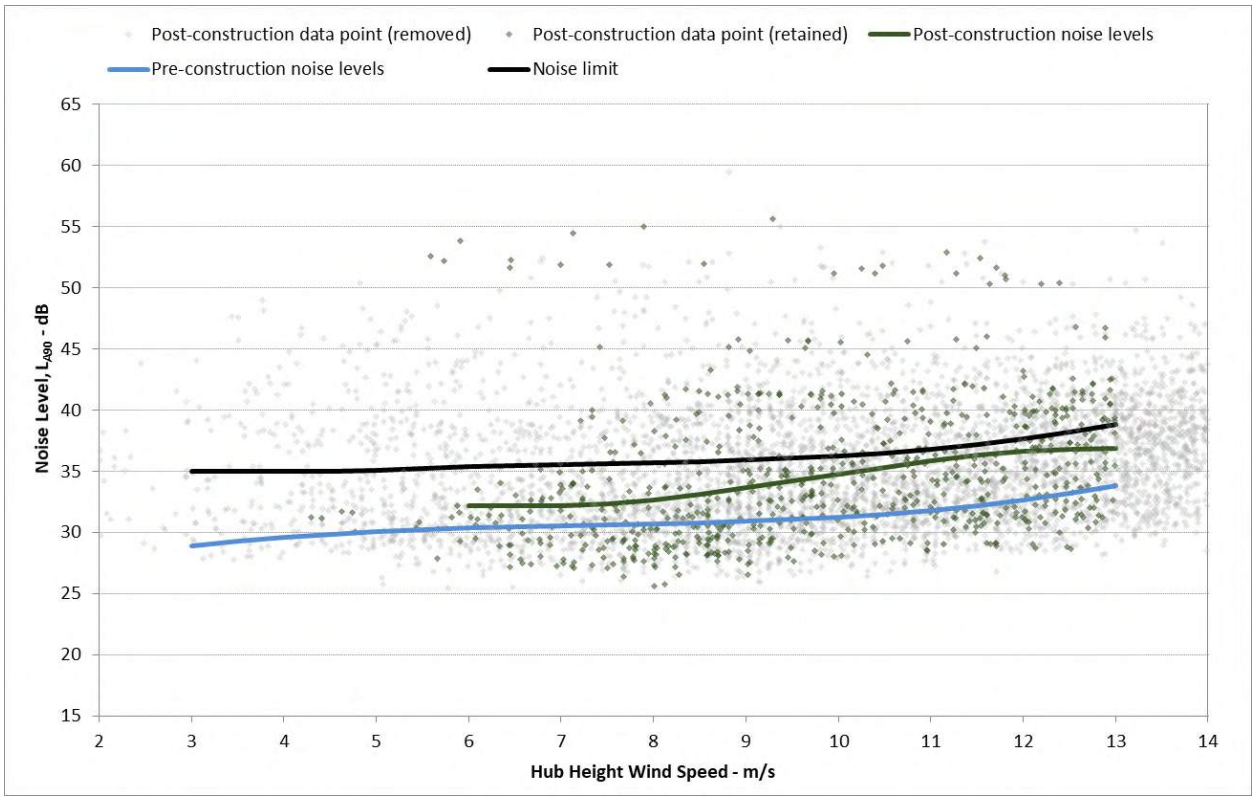

Table 43: Receiver R48 post-construction noise levels – line of best fit

Period	Regression equation coefficients $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
	a	b	c	d	R^2	Valid wind speed range
Daytime	-0.0007	-0.0911	2.5951	22.9799	0.0919	4 –12 m/s
Night-time	-0.0415	1.2125	-10.6618	61.5915	0.0931	6-13 m/s

APPENDIX J RECEIVER R49 DATA

J1 Receiver R49 location data

Table 44: Receiver R49 dwelling and noise monitor coordinates – MGA 94 Zone 55

Location	Easting	Northing
Dwelling location	331555	8100953
Noise monitoring location	331395	8101614

Figure 26: Receiver R49 aerial view – dwelling and noise monitor location

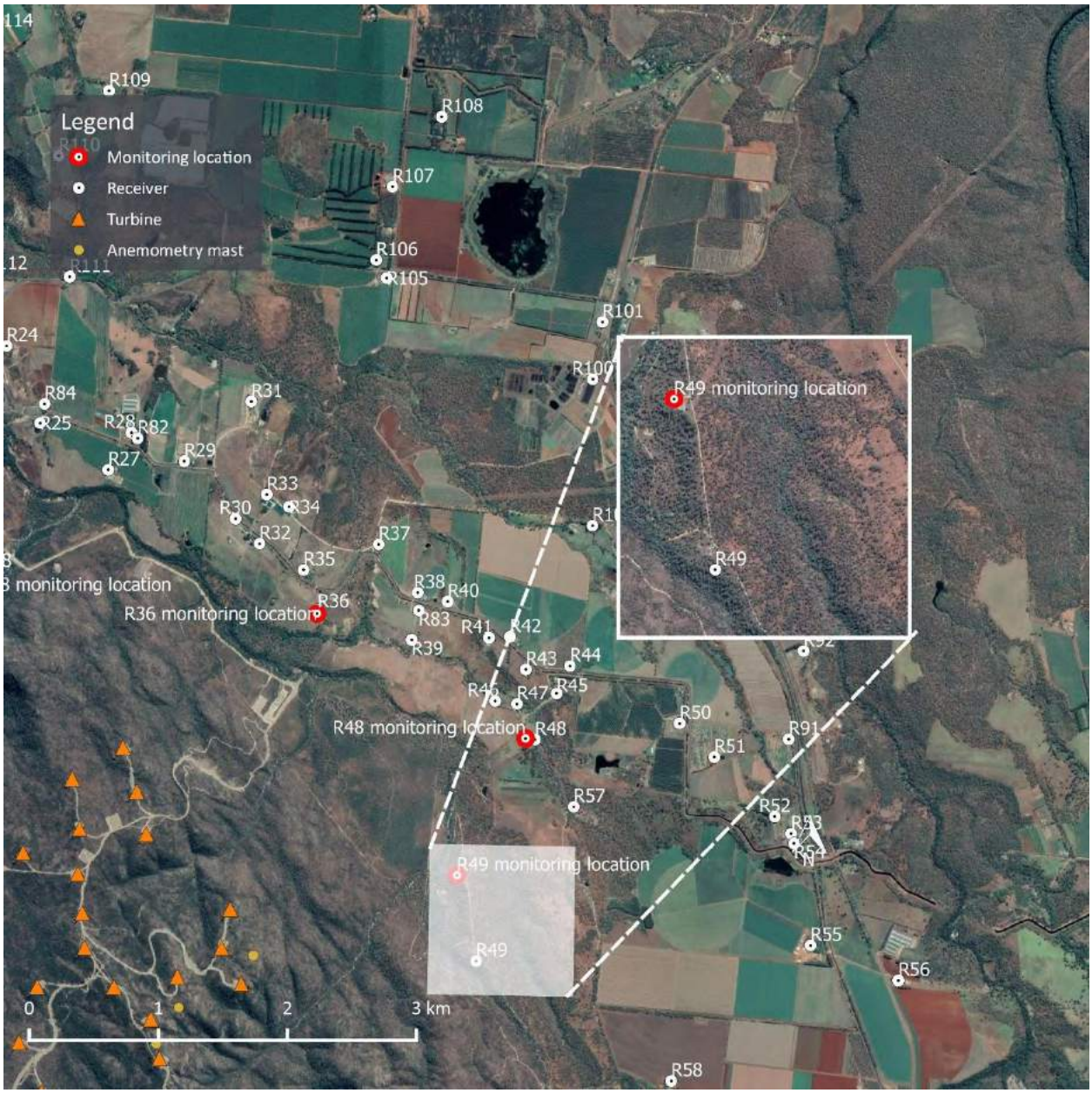

Table 45: Receiver R49 monitor installation photos

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

J2 Receiver R49 measurement data summary

Table 46: Receiver R49 noise level analysis summary

Data points	Daytime	Night-time
Total collected points	11464	6794
Removed [1]	2667	2570
Operational filtering [2]	7895	3172
Total retained	**902**	**1052**

Notes: [1] Removed data points due to rain, extraneous noise, or wind speeds outside assessment range
[2] Removed data points as detailed in Section 5.4 of the NMP.

For the night-time period audio was reviewed across a range of wind speeds – in all cases, the data points where levels were greater than 42 dB were dominated by background or extraneous noise and the influence of the wind farm was generally not discernible. Accordingly, all points greater than 42 dB are considered to have been caused by factors not related to the wind farm and removed from the analysis.

No data was recorded for some of the logging period due to equipment failure. This is shown as gaps in the plots in Figure 27 and Figure 28.

Figure 27: Receiver R49 measured noise level and site wind speed time history - Daytime

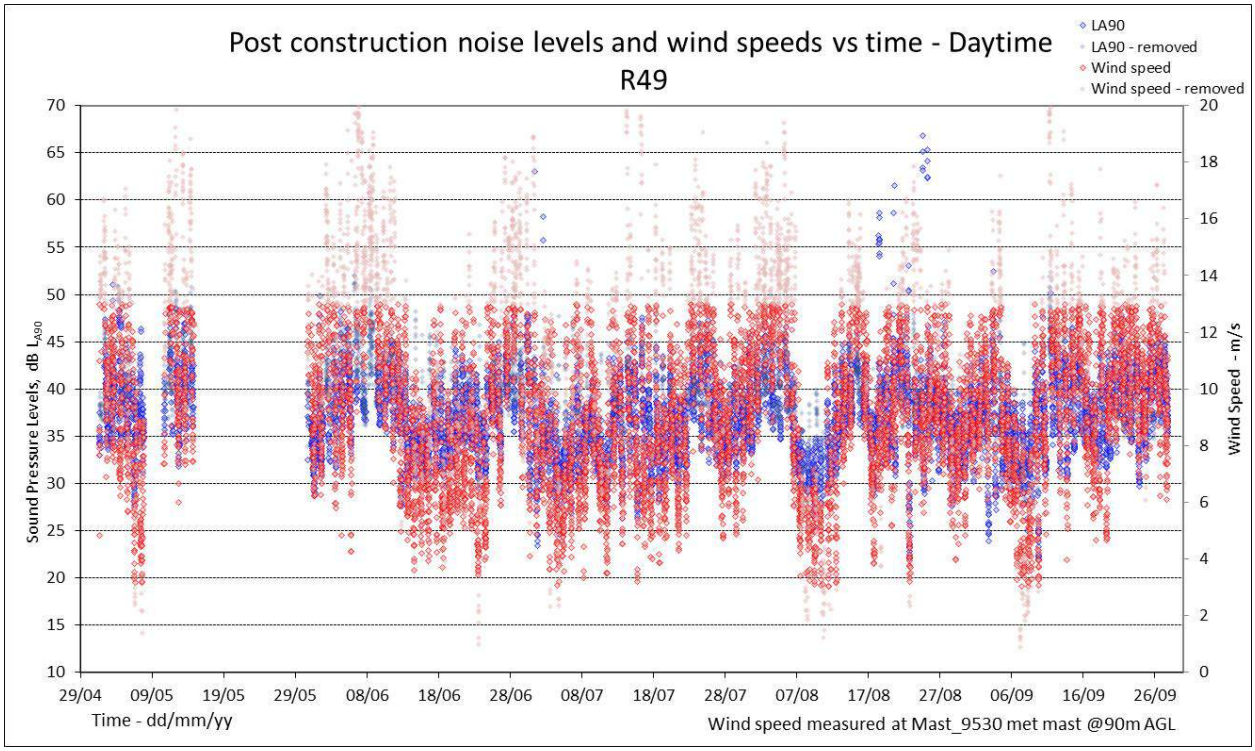

Figure 28: Receiver R49 measured noise level and site wind speed time history – Night-time

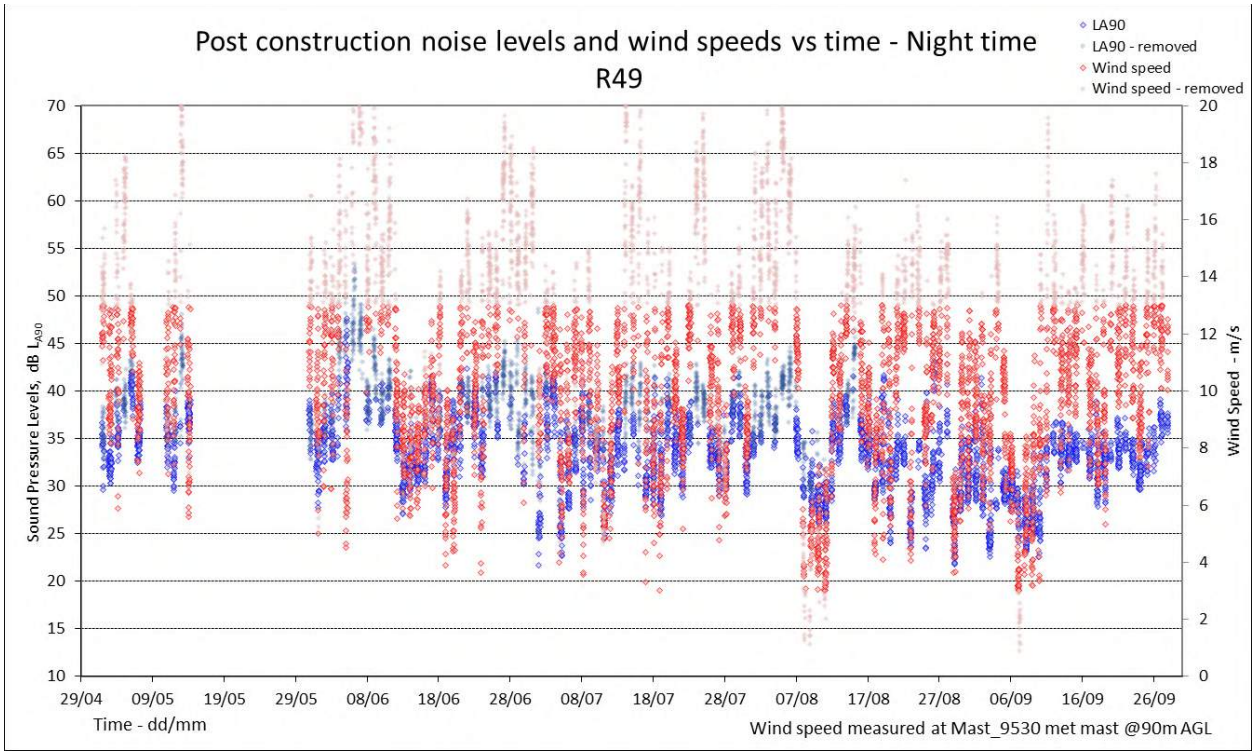

Figure 29: Receiver R49 daytime periods - post-construction noise levels and noise limits versus site wind speed

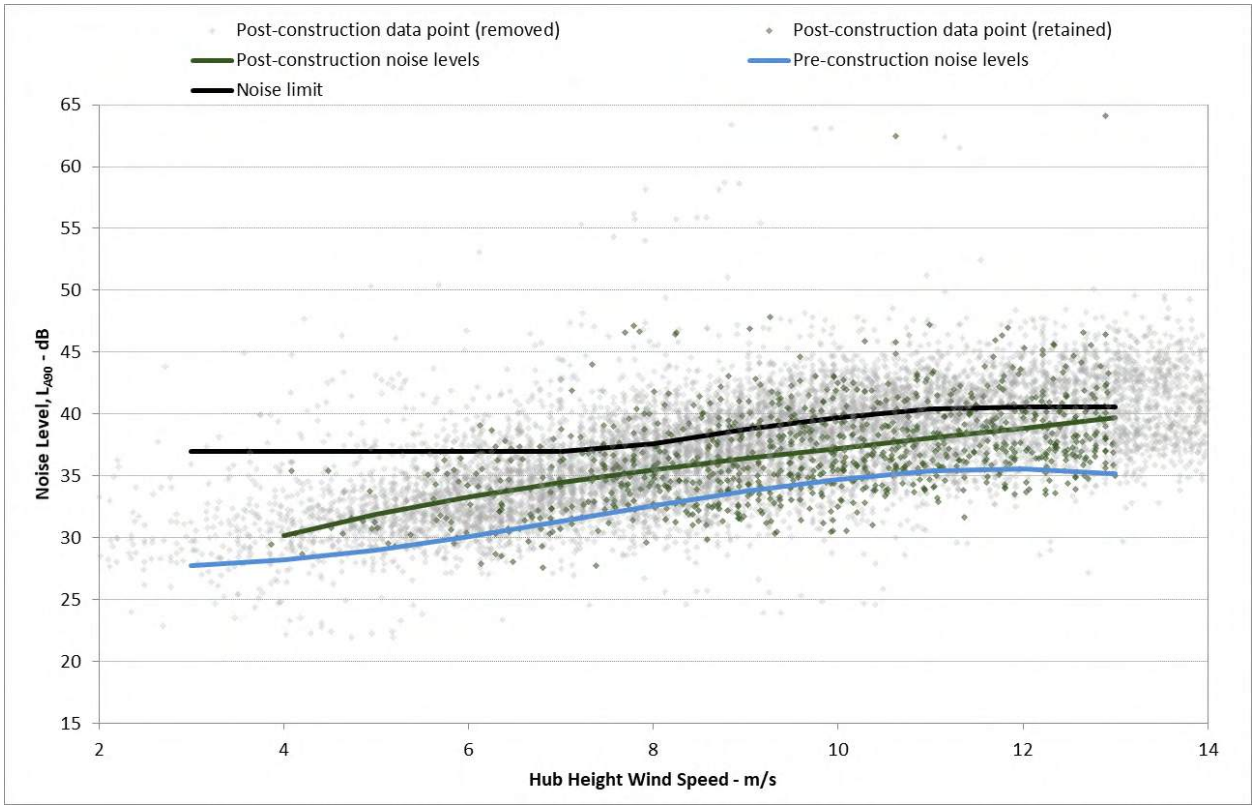

Figure 30: Receiver R49 night-time periods - post-construction noise levels and noise limits versus site wind speed

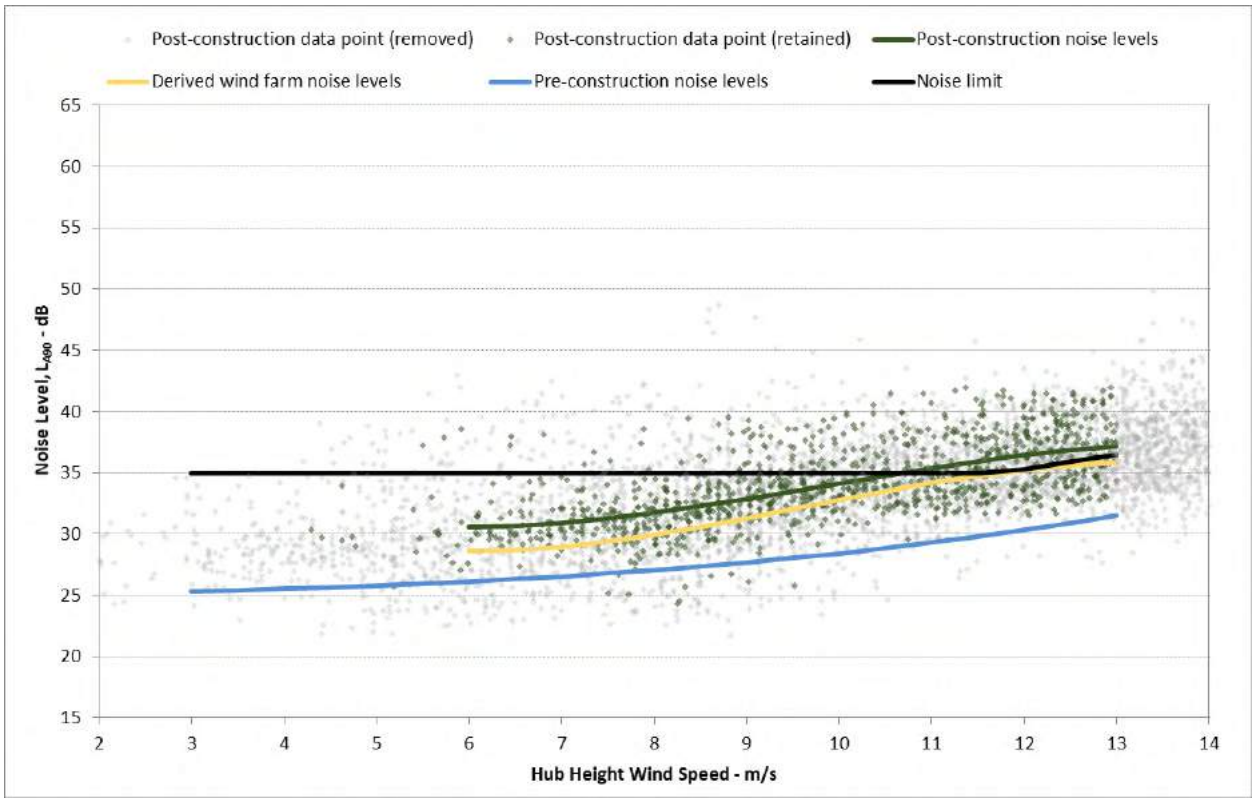

Table 47: Receiver R49 post-construction noise levels – line of best fit

Period	Regression equation coefficients $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
	a	b	c	d	R^2	Valid wind speed range
Daytime	0.0074	-0.2389	3.3727	20.0426	0.2133	4-13
Night-time	-0.0269	0.7977	-6.5913	47.1973	0.4195	6-13

APPENDIX K RECEIVER R78 DATA

K1 Receiver R78 location data

Table 48: Receiver R78 dwelling and noise monitor coordinates – MGA 94 Zone 55

Location	Easting	Northing
Dwelling location	327662	8103902
Noise monitoring location	327648	8103887

Figure 31: Receiver R78 aerial view – dwelling and noise monitor location

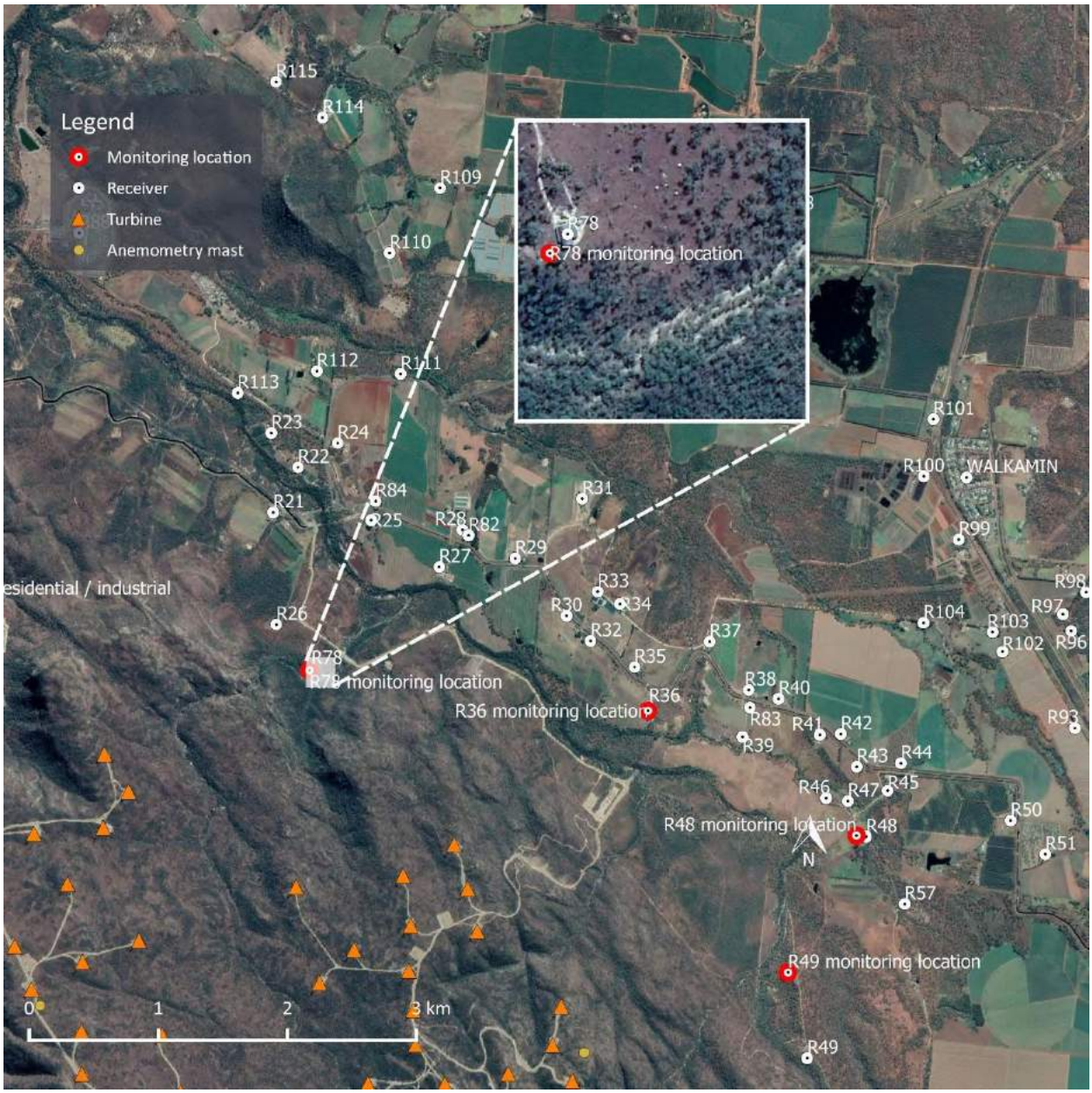

Table 49: Receiver R78 monitor installation photos

Looking North	Looking East
	
Looking South	Looking West
	

K2 Receiver R78 measurement data summary

Table 50: Receiver R78 noise level analysis summary

Data points	Daytime	Night-time
Total collected points	13101	7792
Removed [1]	998	513
Operational filtering [2]	11030	6084
Total retained	**1073**	**1195**

Notes: [1] Removed data points due to rain, extraneous noise, or wind speeds outside assessment range
[2] Removed data points as detailed in Section 5.4 of the NMP

Figure 32: Receiver R78 measured noise level and site wind speed time history - Daytime

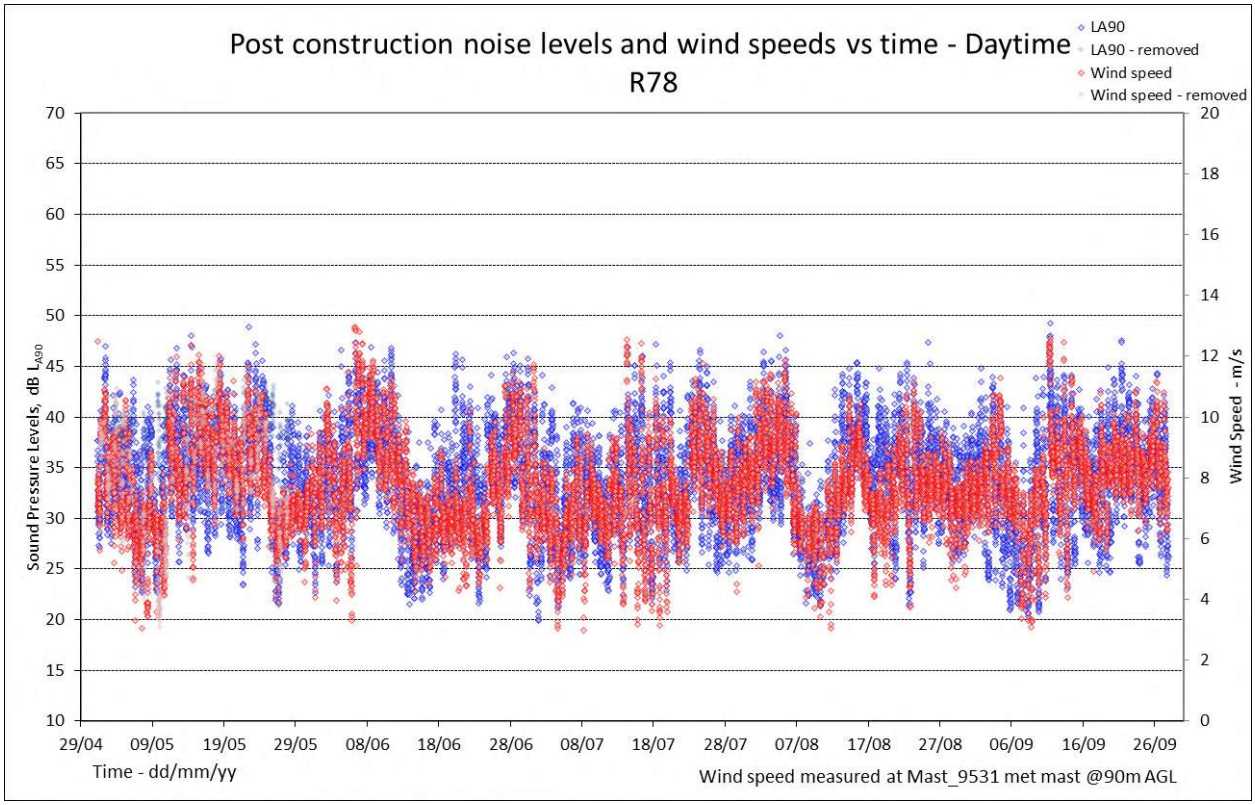

Figure 33: Receiver R78 measured noise level and site wind speed time history – Night-time

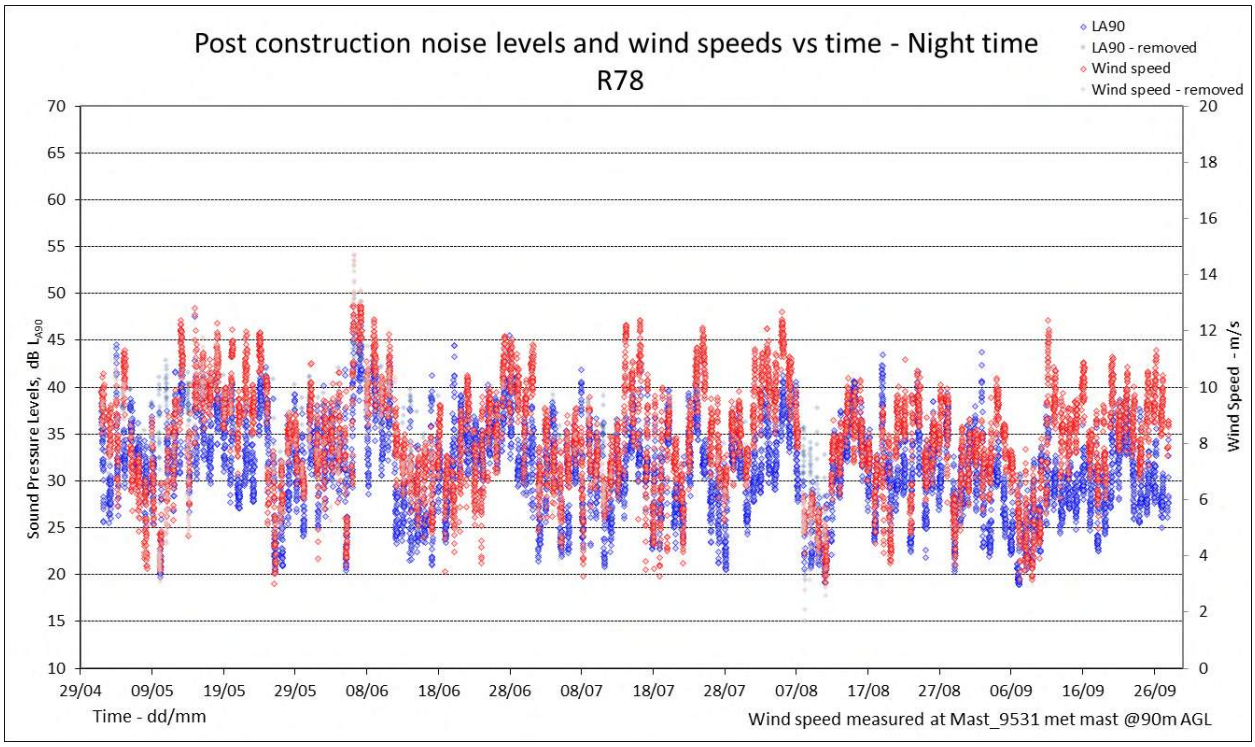

Figure 34: Receiver R78 daytime periods - post-construction noise levels and noise limits versus site wind speed

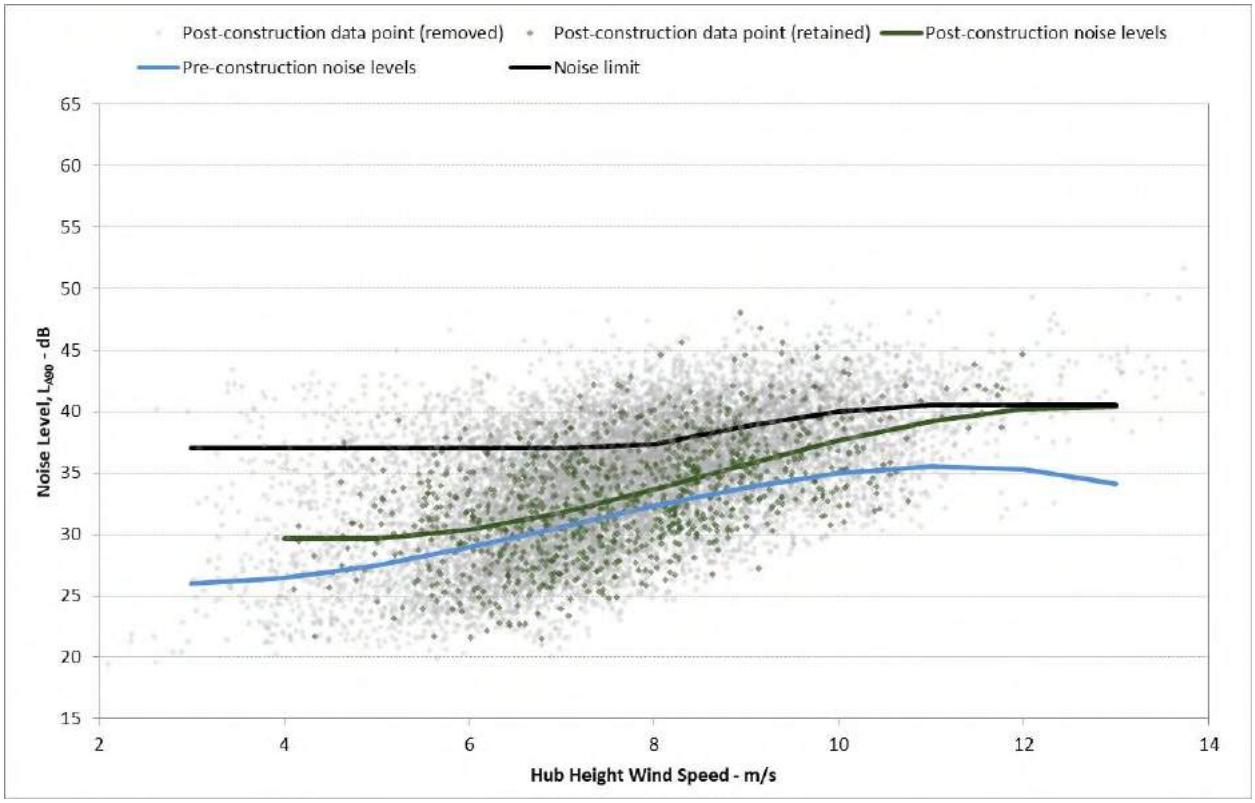

Figure 35: Receiver R78 night-time periods - post-construction noise levels and noise limits versus site wind speed

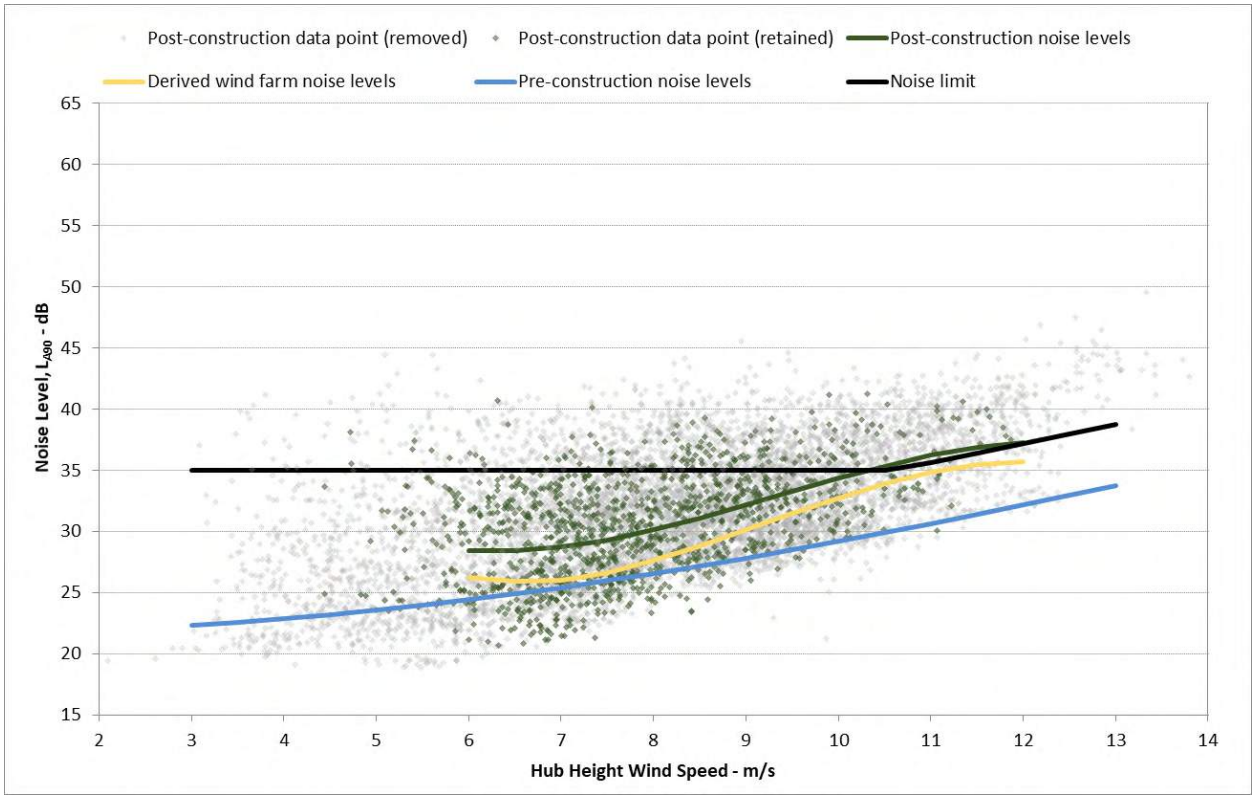

Table 51: Receiver R78 post-construction noise levels – line of best fit

Period	Regression equation coefficients $L_{A90} = ax^3+bx^2+cx+d$, where x = windspeed in m/s					
	a	b	c	d	R^2	Valid wind speed range
Daytime	-0.0420	1.0895	-7.3776	44.4576	0.2896	4-13
Night-time	-0.0790	2.2140	-18.4750	76.6618	0.2515	6-12