APPENDIX H MET MAST CORRELATIONS

DNV·GL

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

Re: Preliminary Energy Results

Dear Tom Nielsen,

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

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

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

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

Sincerely
for Garrad Hassan Pacific Pty Ltd

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1 METHODOLOGY

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

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

2 RESULTS

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

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

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

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

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

APPENDIX I FILTERING FOR EXTRANEOUS NOISE

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

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

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

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

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

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

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

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

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

APPENDIX J TABULAR RESULTS

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

Table 33: B8 results summary

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

Table 34: B11 results summary

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

Table 35: B12a results summary

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

Table 36: B13 results summary

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

Table 37: B18 results summary

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

Table 38: B26 results summary

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

Table 39: B27 results summary

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

Table 40: B29 results summary

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

Table 41: B33 results summary

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

Table 42: B53 results summary

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

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

Table 43: G31 results summary

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

Table 44: G37 results summary

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

Table 45: G39 results summary

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

Table 46: K1 results summary

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

Table 47: K2 results summary

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

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

Table 48: PW07 results summary

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

Table 49: PW09 results summary

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

APPENDIX K SUPPLEMENTARY DATA ANALYSIS FOR B26 & B27

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

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

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

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

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

[15] To one decimal place.

APPENDIX L SUPPLEMENTARY DATA ANALYSIS FOR B53

L1 B53 Intermediate monitoring

Methodology

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

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

Measurements

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

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

Table 50: B53 Intermediate Location details

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

Photographs of the monitoring location are shown below.

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

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

[17] Relative to the nearest wind turbine, BAN10

Figure 24: B53 Intermediate Location site photos

Results

Results are summarised in Table 53 and Figure 19 below.

Table 51: Summary of parameters – B53 Intermediate Location

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

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

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

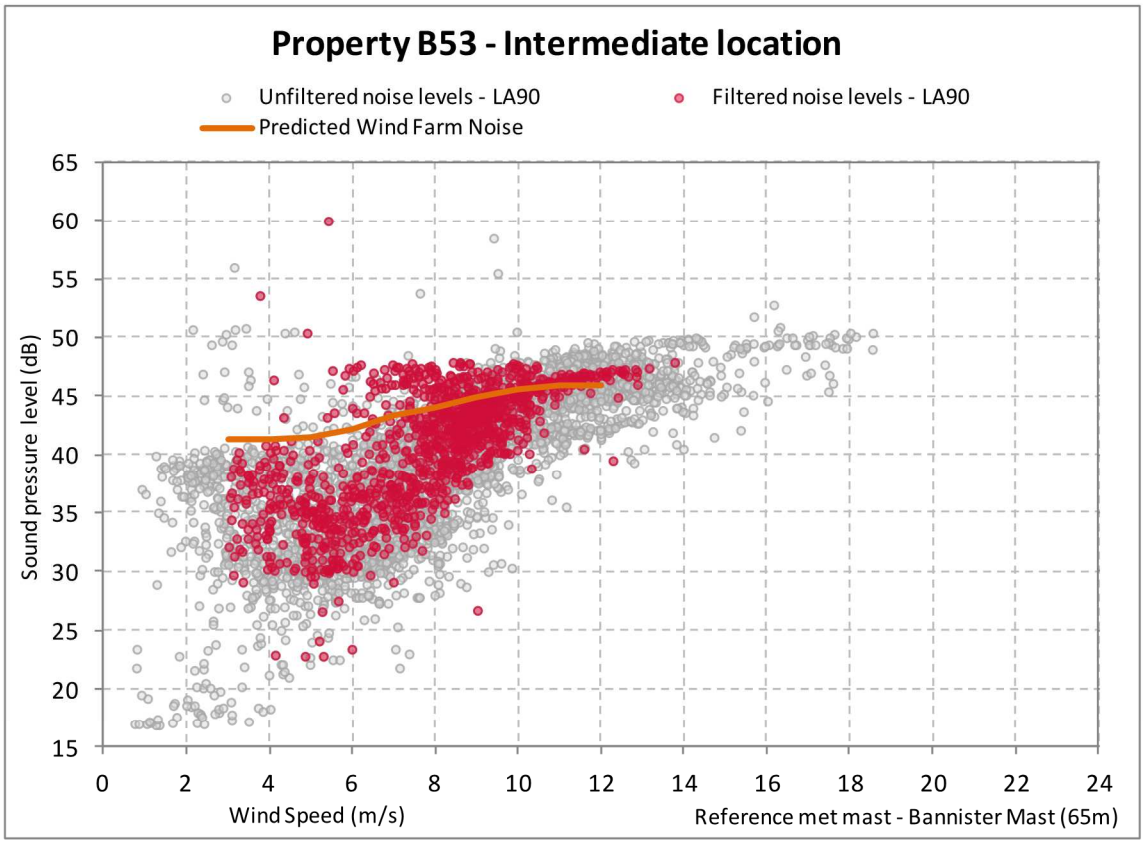

Figure 25: B53 Intermediate Location Total noise level vs. wind speed

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

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

L2 Time history snapshots

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

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

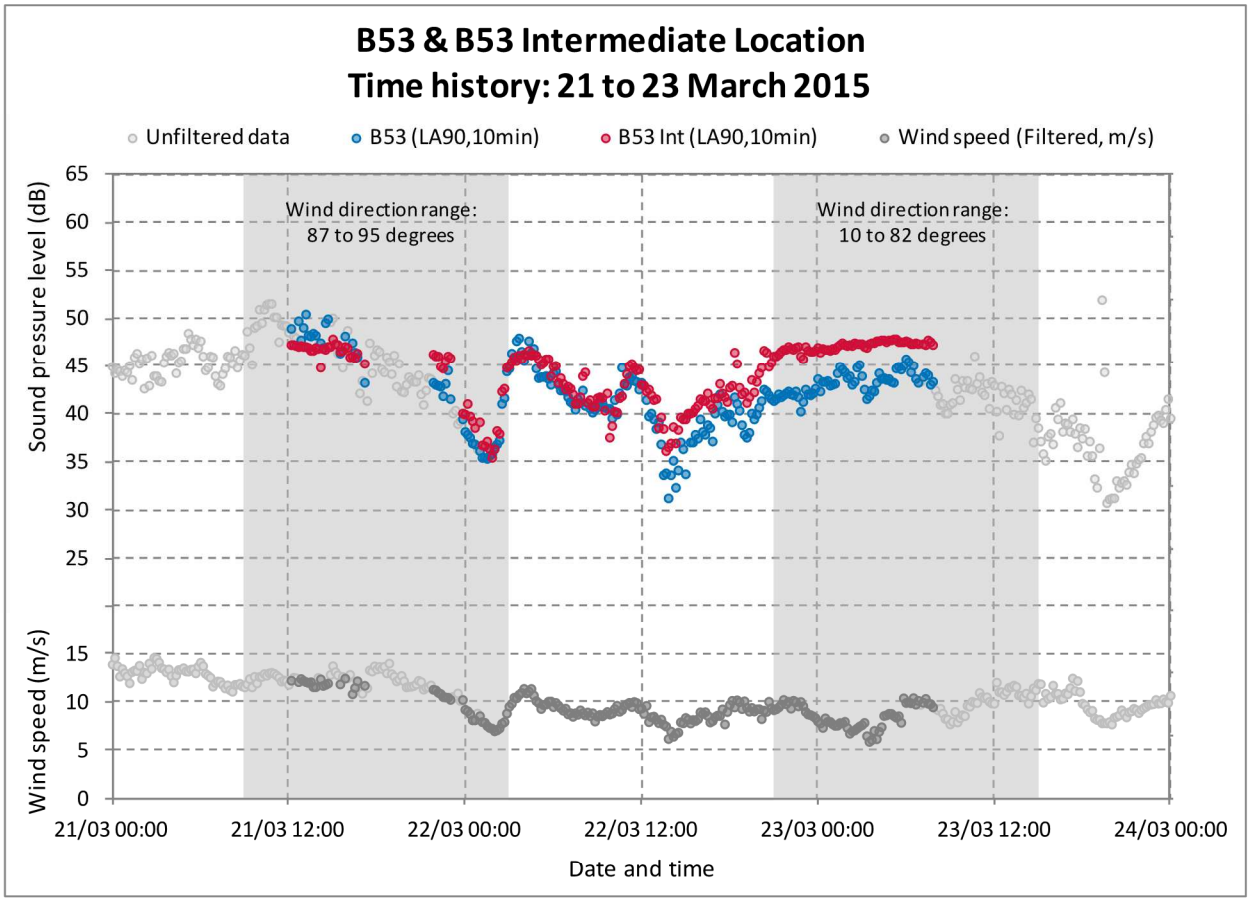

Figure 26: Time history snap shot of concurrent monitoring for property B53

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

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

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

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

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

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

L3 Wind direction investigation

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

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

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

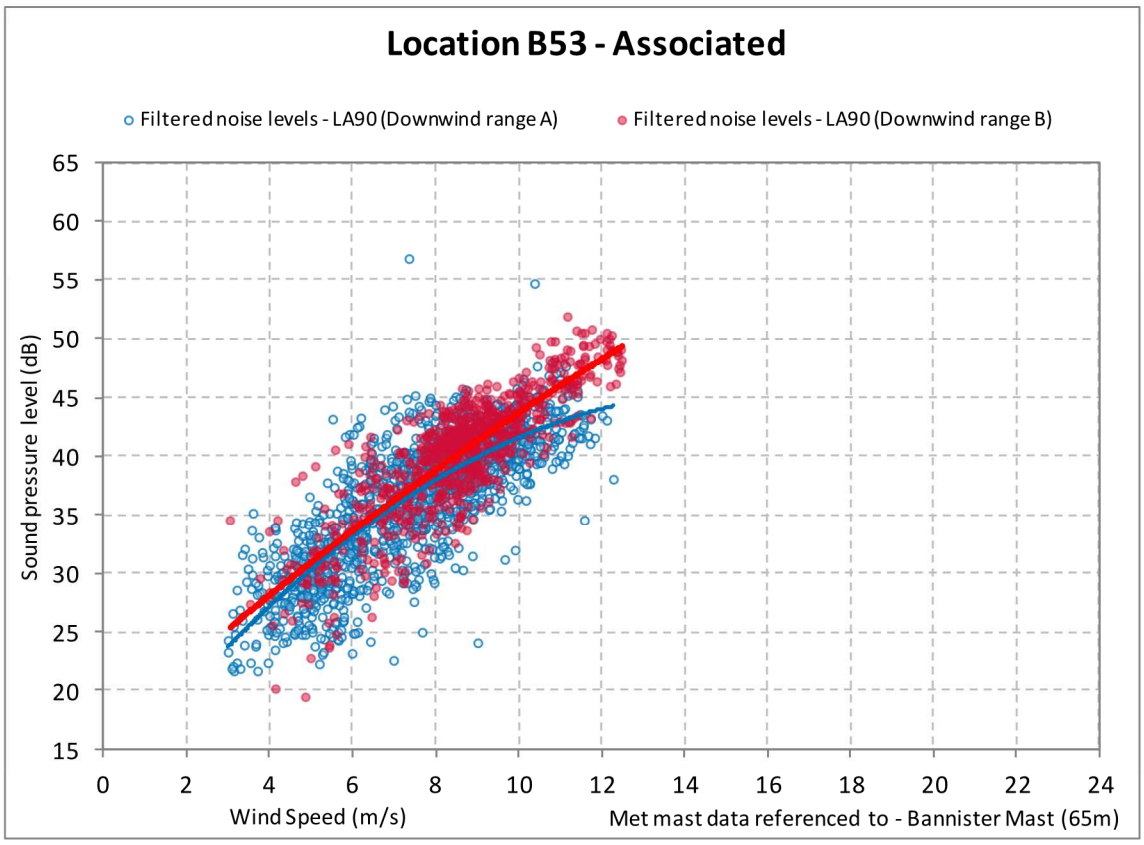

Figure 27: Total measured noise levels vs wind speeds for property B53, by wind direction

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

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

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

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

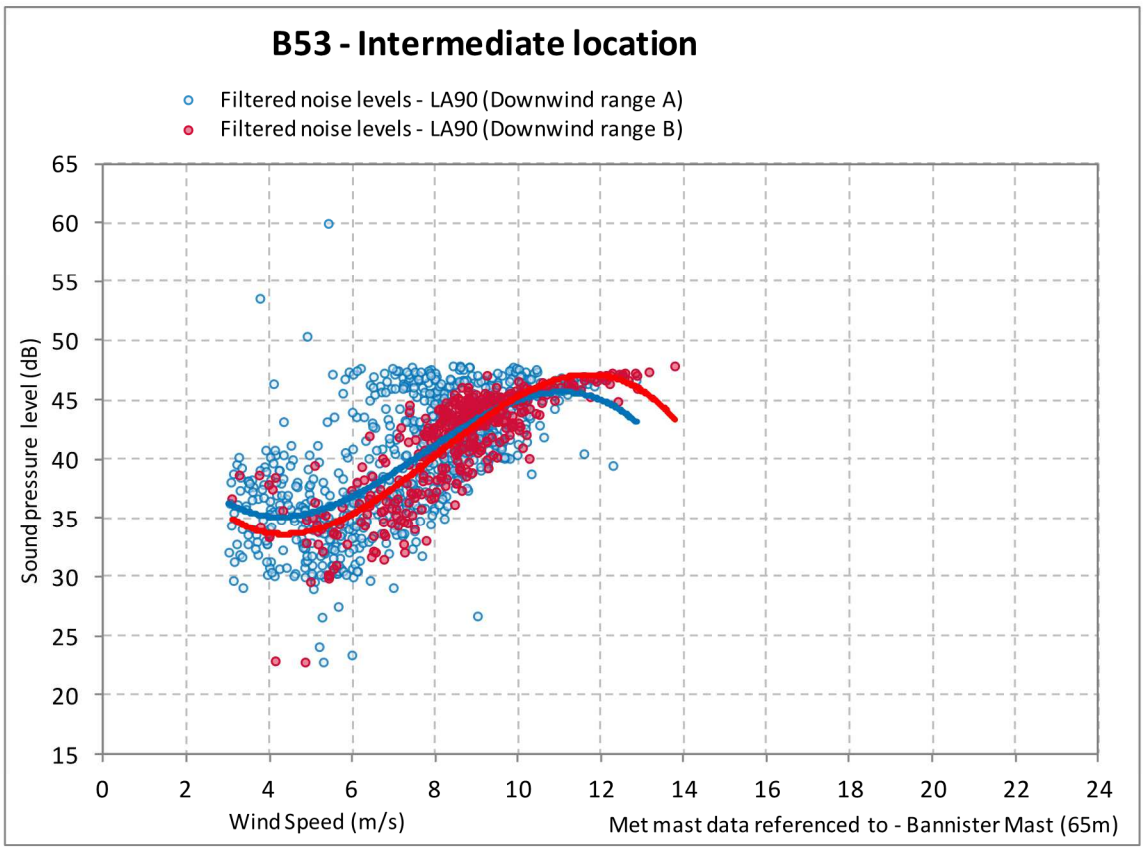

Figure 28: Total measured noise levels vs wind speeds for the B53 Intermediate Location, by wind direction

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

L4 High noise level filtering

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

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

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

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

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

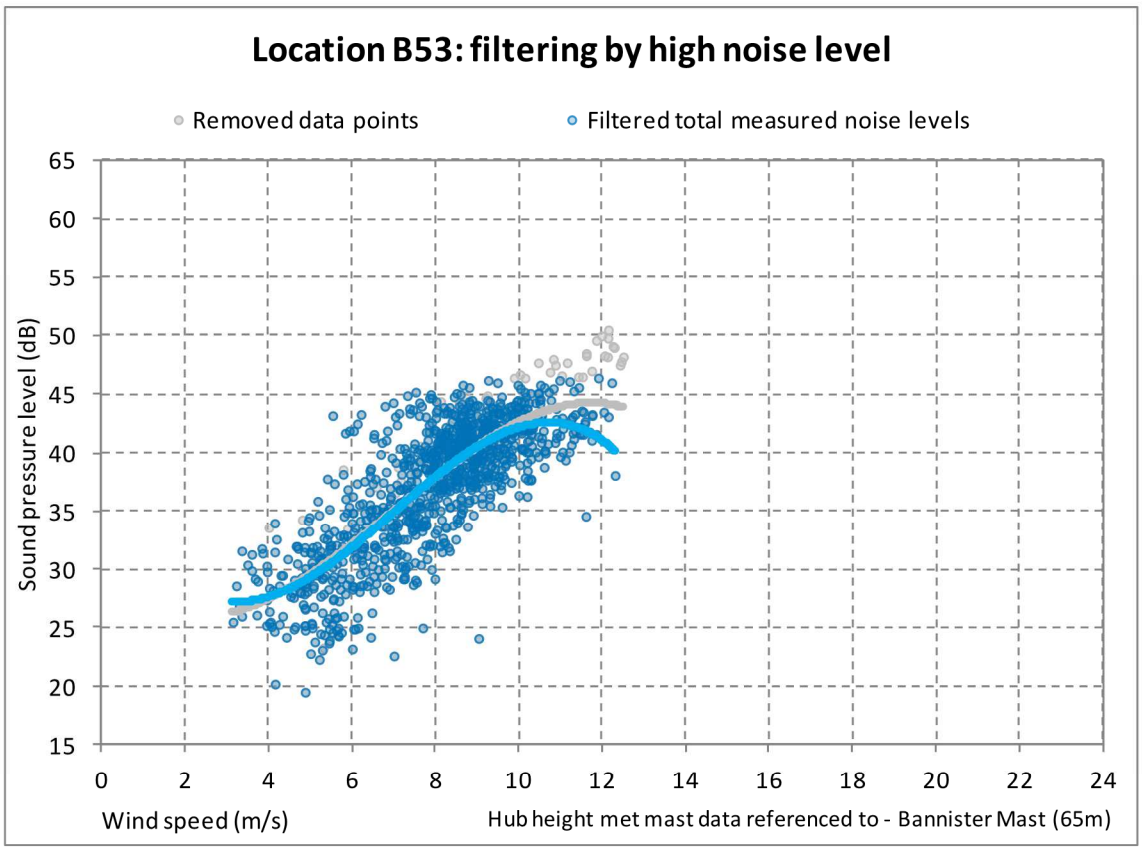

Figure 29: Total measured noise levels vs wind speeds for the B53, including high noise level filtering

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

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

L5 Discussion

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

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

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

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

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

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

APPENDIX M SUPPLEMENTARY DATA ANALYSIS FOR K2

M1 K2 Intermediate monitoring

Methodology

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

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

Measurements

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

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

Table 52: K2 Intermediate Location details

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

Photographs of the monitoring location are shown below.

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

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

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

Figure 30: K2 Intermediate Location site photos

Results

Results are summarised in Table 53 and Figure 31 below.

Table 53: Summary of parameters – K2 Intermediate Location

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

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

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

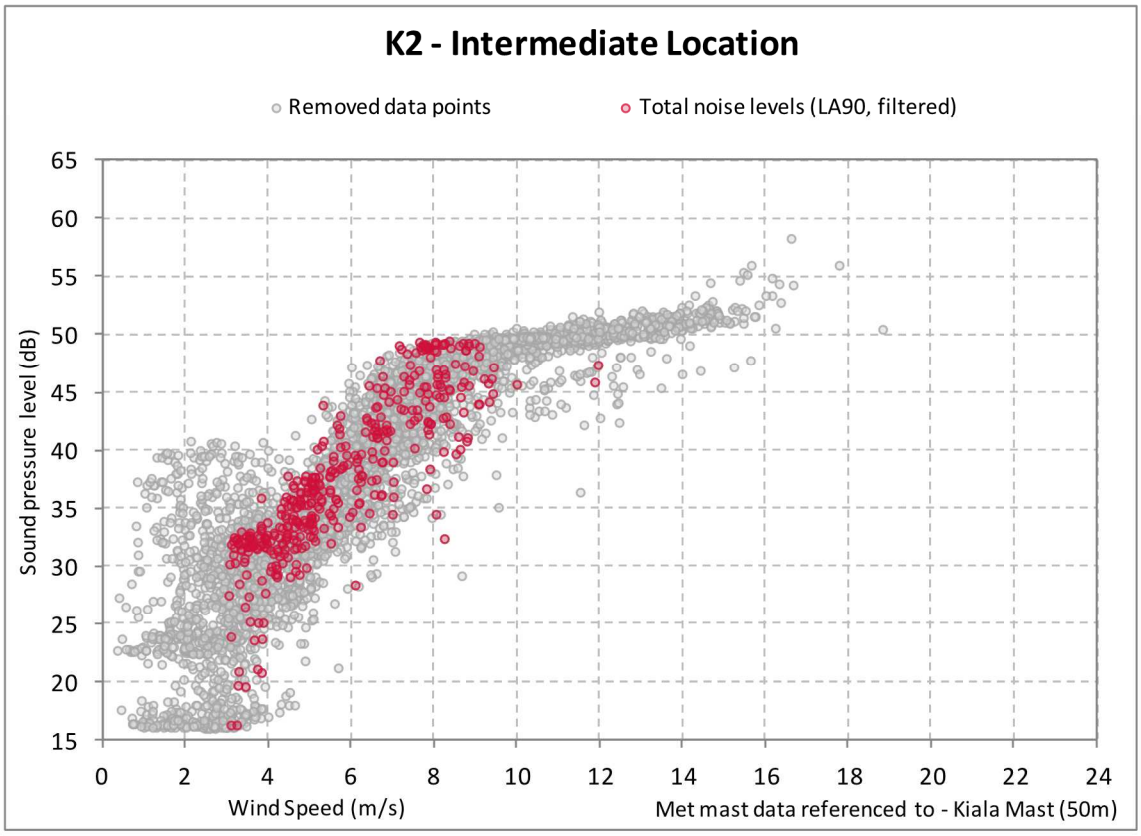

Figure 31: B53 Intermediate Location Total noise level vs. wind speed

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

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

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

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

M2 Wind direction investigation

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

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

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

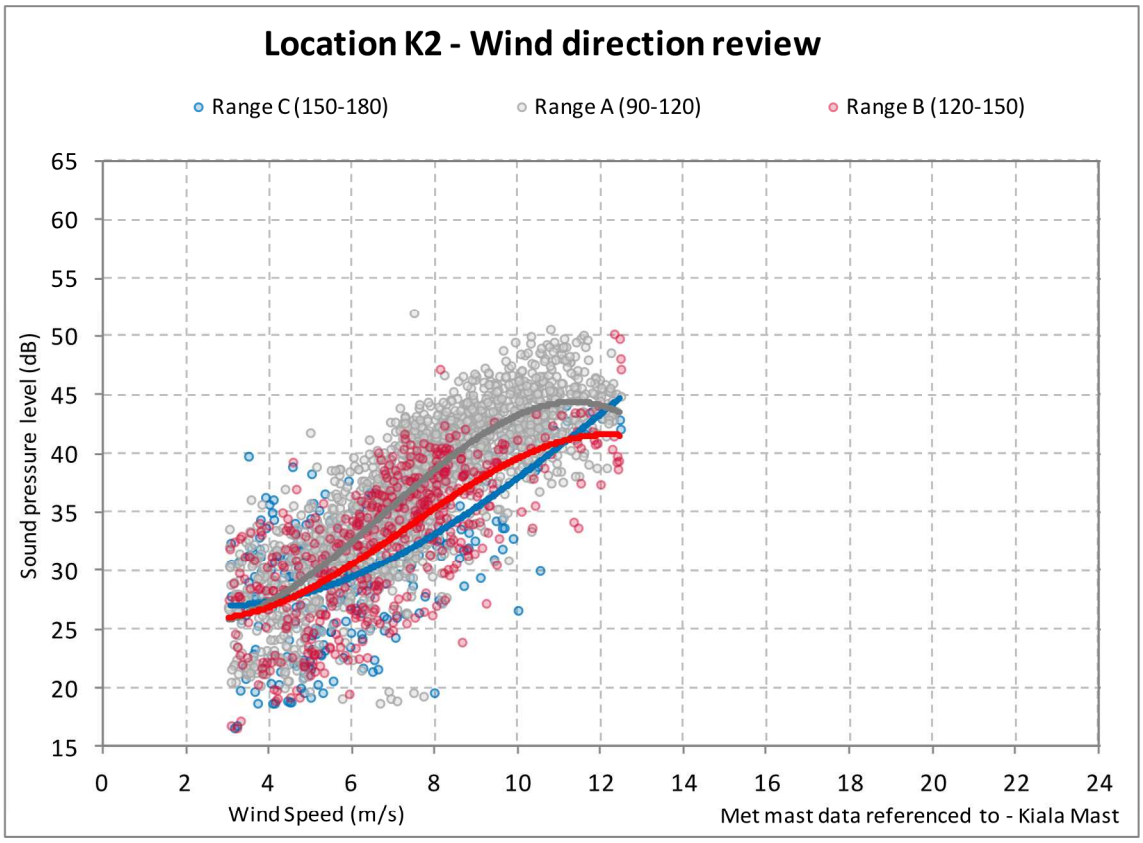

Figure 32: Total measured noise levels vs wind speeds for property K2, by wind direction

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

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

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

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

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

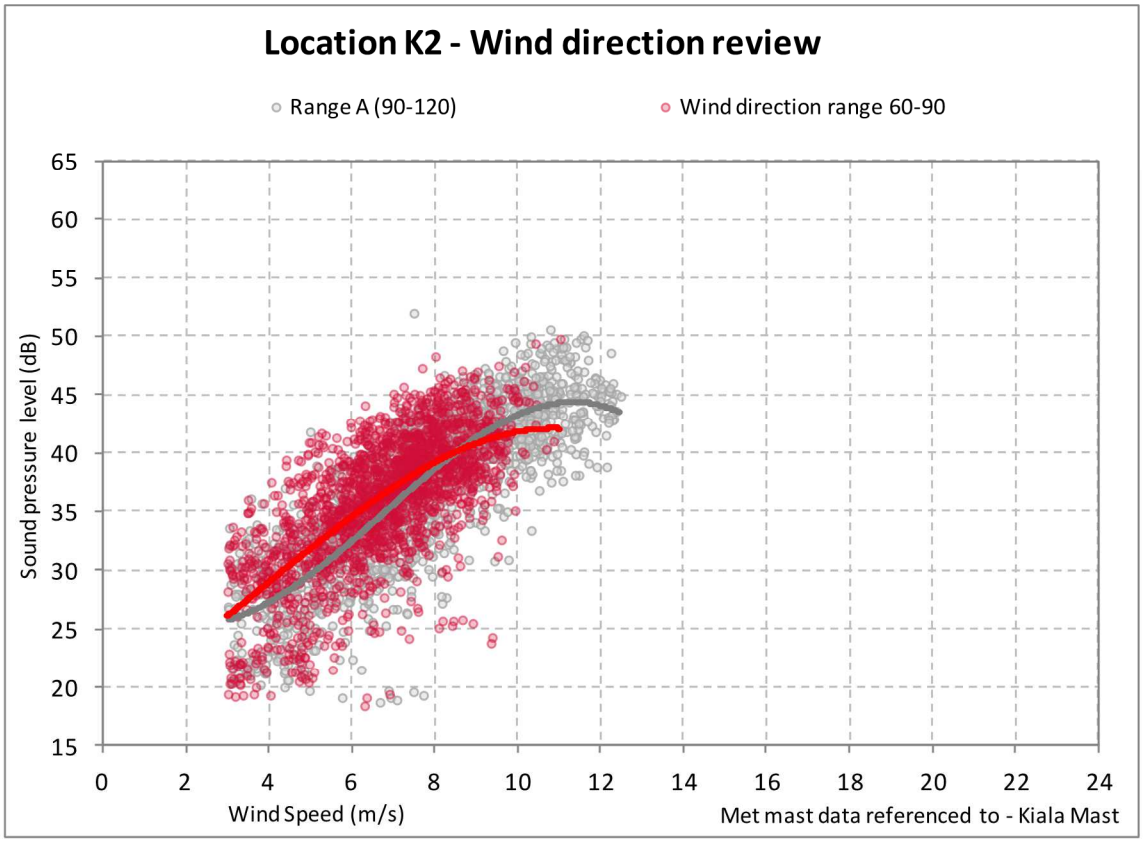

Figure 33: Total measured noise levels vs wind speeds for property K2, by wind direction

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

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

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

M3 Revised assessment with adjusted downwind range

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

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

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

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

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

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

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

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

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

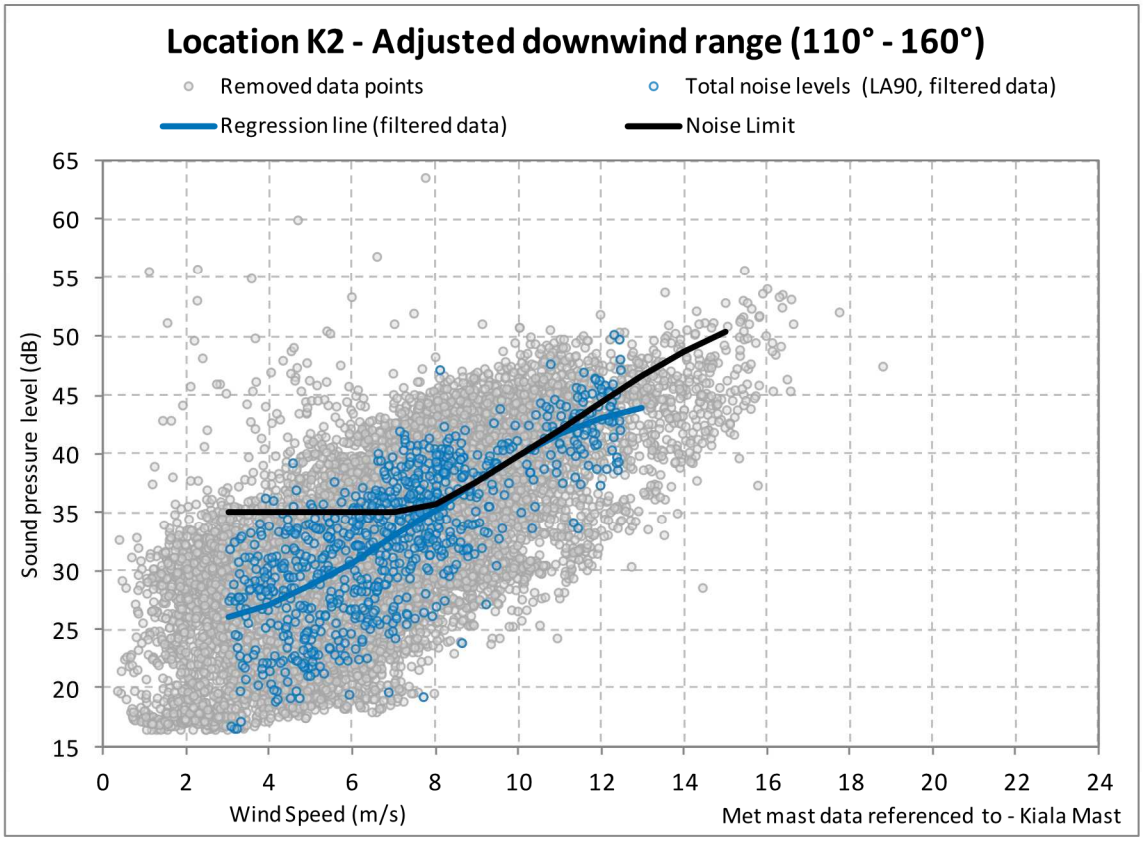

Figure 34: K2 Total noise level vs. wind speed (Adjusted downwind range)

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

M4 Discussion

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

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

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

[22] To one decimal place.

APPENDIX N COMPLIANCE ASSESSMENT FOR RELATED RECEIVERS

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

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

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

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

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

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

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

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

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

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

N1 Related receivers for monitoring location B8

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

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

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

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

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

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

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

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

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

N2 Related receivers for monitoring location B11

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

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

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

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

N3 Related receivers for monitoring location B18

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

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

* Residual noise influence. See further comment below.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

N4 Related receivers for monitoring location B26

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

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

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

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

N5 Related receivers for monitoring location B29

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

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

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

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

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

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

N6 Related receivers for monitoring location B33

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

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

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

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

N7 Related receivers for monitoring location B53

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

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

* Residual noise influence. See further comment below.

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

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

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

N8 Related receivers for monitoring location G37

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

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

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

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

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

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

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

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

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

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

N9 Related receivers for monitoring location PW7

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

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

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

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

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

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

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

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

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

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

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

APPENDIX O SUMMARY OF LISTENING STUDIES

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

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

O1 **B8**

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

* Reference to Bannister met mast

O2 **B11**

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

* Reference to Bannister met mast

O3 B12a

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

* Reference to Bannister met mast

O4 B13

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

* Reference to Bannister met mast

O5 **B18**

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

* Reference to Bannister met mast

O6 **B26**

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

* Reference to Bannister met mast

O7 **B27**

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

* Reference to Bannister met mast

O8 **B29**

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

* Reference to Bannister met mast

O9 **B33**

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

* Reference to Bannister met mast

O10 **B53**

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

* Reference to Bannister met mast

O11 G31

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

* Reference to Gurrunda met mast

O12 G37

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

* Reference to Gurrunda met mast

O13 G39

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

* Reference to Gurrunda met mast

O14 K1

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

* Reference to Kiala met mast

O15 K2

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

* Reference to Kiala met mast

O16 PW07

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

* Reference to Bannister met mast

O17 PW09

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

* Reference to Bannister met mast

APPENDIX P OBJECTIVE TONALITY ASSESSMENT

This Appendix provides:

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

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

P1 Tonality Assessment Procedures

P1.1 Overview

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

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

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

P1.2 Implementation of IEC 61400-11

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

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

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

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

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

P1.3

Adjustments for Tonality

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

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

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

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

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

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

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

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

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

P2 Turbine operation

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

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

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

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

Table 79: GW100 Firmware software versions

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

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

[24] Information provided by email 8 July 2015

P3 Listening Study & Objective Analysis Results

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

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

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

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

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

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

Note 1: Goldwind GW100 turbines only

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

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

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

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

P4 Near Field Testing Results

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

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

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

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

Figure 35: Near field measurement positions

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

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

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

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

Table 81: Firmware noise testing – measurement scenarios

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

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

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

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

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

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

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

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

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

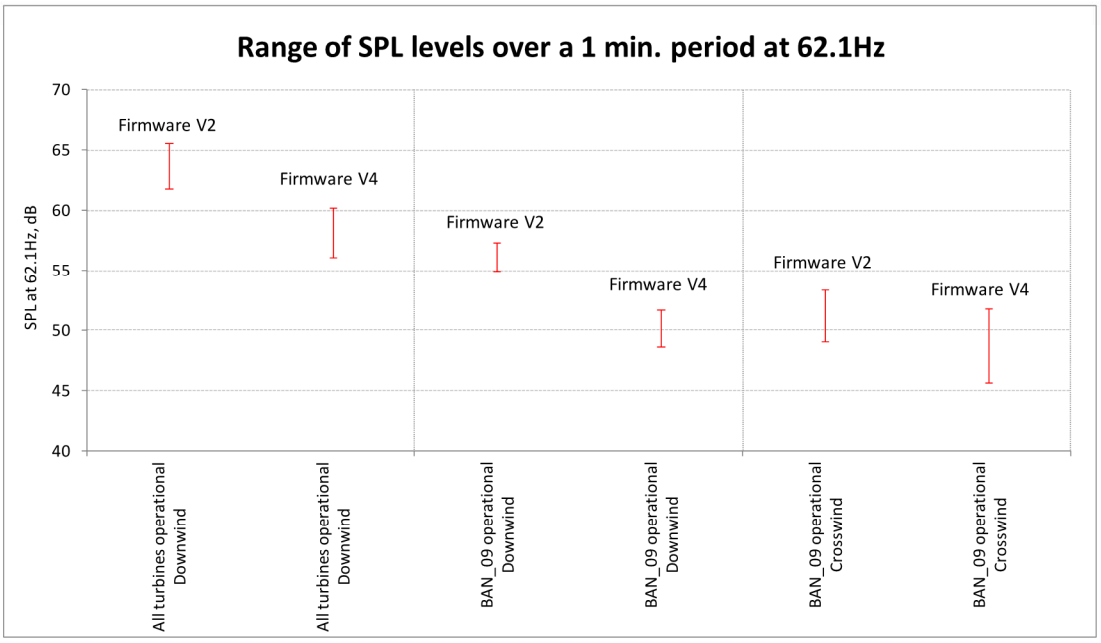

Figure 36: Range of sound pressure levels at 62.1Hz within the defined measurement period

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

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

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

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

P5 Discussion

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

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

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

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

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

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