Appendix 7

Mt Emerald Wind Farm – Noise Impact Assessment

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MT EMERALD WIND FARM

Noise impact assessment

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1.0 INTRODUCTION

This report, commissioned by RATCH-Australia Corporation Limited, details a noise impact assessment of the Mount Emerald Wind Farm (MEWF) which is proposed to be located near Atherton in the Tablelands region of northern Queensland. The assessment primarily relates to operational noise associated with the proposed wind turbine generators. Noise associated with construction of the wind farm, or ancillary power infrastructure, has not been considered as part of this study.

The wind farm is proposed to consist of up to seventy (70) wind turbines. A plan of the proposed layout is presented in Appendix A.

This noise assessment recognises the requirements of applicable regional and state noise guidance, including the Tablelands Regional Council Planning Scheme Amendment *01/11 – Wind Farms - Mareeba Shire Planning Scheme 2004*. The amendment requires that a proposed wind farm be designed, constructed and operated in accordance with recognised standards for the assessment of environmental noise. In relation to recognised standards, New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010) and the Queensland Government's Environment Projection (Noise) Policy 2008 (EPP 2008) are specifically noted in the planning scheme.

As the state government's noise guidance documents, including EPP 2008, apply to general noise sources, they do not offer guidance for sources with sound levels that vary with wind speed, as is typical of wind turbines. To address this issue directly, NZS6808:2010 serves as the primary guidance document referenced for this noise assessment.

There are several key stages involved with a noise assessment according to NZS6808:2010. Firstly, preliminary wind farm noise predictions are carried out for all identified residential properties around the wind farm. The results of the preliminary analysis can be used to identify relevant noise sensitive locations and establish suitable noise limits across a range of wind speeds relevant to the wind farms operation. Once noise limits have been established, further wind farm predictions are carried out and compliance is assessed by comparing the predicted wind farm noise levels with the noise limits over a range of wind speeds.

Additionally, an assessment of low frequency noise levels and a qualitative review of infrasound are included in this assessment to address the requirements of the Queensland EPA Ecoaccess draft document *Guideline: Assessment of low frequency noise* (LFN Guideline).

Acoustic terminology used throughout this report is presented in Appendix B. Note that wind speeds are referenced to hub height unless otherwise noted.

2.0 NOISE CRITERIA

2.1 Tablelands Regional Council

The Tablelands Regional Council (TRC) Planning Scheme Amendment *01/11 – Wind Farms - Mareeba Shire Planning Scheme 2004* (PSA 01/11) commenced on 30 September 2013.

Key noise related aspects of the amendment are outlined below.

2.1.1 Wind farm code

The PSA 01/11 includes a wind farm code, titled *Division 23 – Wind Farm Code*, annotated as document Section 6. The code includes the following statement of intent:

> *The intent of the code is to facilitate the establishment of new wind farms or expansion of existing wind farms, in appropriate locations.*
>
> *Wind farm development will not have unacceptably adverse impacts on the environment and on existing amenity (at both a local and wider area scale), and will have social, environmental and economic benefits to the community at both the local and regional level.*

To satisfy this intent, Section 6.2 of the wind farm code provides the following compliance requirements:

> *Development that achieves the overall outcomes in section 6.3 and specific outcomes in section 6.4, complies with the Wind Farm Code.*

2.1.2 Overall outcomes

Wind farm code Section 6.3 provides a list of ten intended overall outcomes. The following noise related overall outcomes are noted:

> *(f) Any variation to existing amenity, visual, light, noise, electromagnetic interference and aircraft safety conditions or circumstances as a result of the wind farm is maintained within acceptable limits.*
>
> […]
>
> *{h) The operation of wind farms is controlled by site specific management plans that adequately control and monitor variable impacts such as turbine noise* […] *over the operational life of the wind farm.*

2.1.3 Specific outcomes

Section 6.4 of the wind farm code identifies a set of specific outcomes. Outcomes regarding noise impact are described in subsection S5 and are as follows:

> *(a) Wind farm turbines and associated infrastructure are located, designed, constructed and operated in accordance with recognised standards with respect to noise emissions.*
>
> *(b) Audible and inaudible noise emissions resulting from wind farms that potentially impact on existing urban and rural development do not result in unacceptable levels (including cumulative impacts) of:*
> *(i) nuisance*
> *(ii) risk to human health or wellbeing*
> *(iii) ability to sleep or relax*

The *Probable Solutions* associated with subsection S5 are documented as follows:

> *PS5 No probable solution provided.*
>
> ***Editors note** - development should consider the Environment Protection (Noise) Policy 2008 and the New Zealand Standard Acoustics – Wind farm noise (NZS6808:2010).*

Key aspects of NZS6808:2010 are outlined below. A summary of the Queensland Government's state noise policies, including Environment Protection (Noise) Policy 2008 (EPP 2008) is provided in Appendix C.

2.2 NZS6808:2010

2.2.1 Objectives

Section C1.1 of NZS6808:2010 discusses the intent of the standard, which is:

> [...] *to avoid adverse noise effects on people caused by the operation of wind farms while enabling sustainable management of natural wind resources.*

The *Outcome Statement* of NZS6808:2010 expresses this intention in a planning context as follows:

> *This Standard provides suitable methods for the prediction, measurement, and assessment of sound from wind turbines. In the context of the* [New Zealand] *Resource Management Act, application of this Standard will provide reasonable protection of health and amenity at noise sensitive locations.*

The standard seeks to address health and amenity at noise sensitive locations by specifying noise criteria which are used to assess wind farm noise, as outlined below.

2.2.2 Noise limit

Section 5.2 *Noise limit* of NZS6808:2010 defines acceptable noise limits as follows:

> *As a guide to the limits of acceptability at a noise sensitive location, at any wind speed wind farm sound levels ($L_{A90(10\,min)}$) should not exceed the background sound level by more than 5dB, or a level of 40dB $L_{A90(10\,min)}$, whichever is the greater.*

This arrangement of noise limits requires the noise associated with wind farms to be restricted to a permissible level above background noise, except in instances when both the background and source noise levels are low. In this respect, the criteria indicate that it is not necessary to continue to adhere to a margin above background when the background values are below the range of 30-35dB.

It should be noted that compliance with the NZS6808:6808:2010 criteria may result in wind turbine noise being audible at some locations for some of the time

2.2.3 High amenity areas

Section 5.3.1 of NZS6808:2010 states that the baseline noise limit of 40dB L_{A90} detailed in Section 2.2.2 above is "*appropriate for protection of sleep, health, and amenity of residents at most noise sensitive locations*." It goes on to note that high amenity areas may require additional consideration:

> […] *In special circumstances at some noise sensitive locations a more stringent noise limit may be justified to afford a greater degree of protection of amenity during evening and night-time. A high amenity noise limit should be considered where a plan promotes a higher degree of protection of amenity related to the sound environment of a particular area, for example where evening and night-time noise limits in the plan for general sound sources are more stringent than 40 dB $L_{Aeq(15\ min)}$ or 40 dBA L_{10}. A high amenity noise limit should not be applied in any location where background sound levels, assessed in accordance with section 7, are already affected by other specific sources, such as road traffic sound.*

The definition of a high amenity area provided in NZS6808:2010 is specific to New Zealand planning legislation and guidelines. A degree of interpretation is therefore required when determining how to apply the concept of high amenity in Queensland.

Section 5.3 of NZS6808:2010 provides details of high amenity noise limits, requiring that where a residential property is deemed to be located within a high amenity area as defined in Sections 5.3.1 and 5.3.2 of NZS6808:2010, wind farm noise levels (L_{A90}) during evening and nigh-time periods should not exceed the background noise level (L_{A90}) by more than 5dB or 35dB L_{A90}, whichever is the greater, for wind speeds below 6m/s at hub height. High amenity noise limits are not applicable during the daytime period.

2.2.4 Special audible characteristics

Section 5.4.2 of NZS6808:2010 requires the following:

> *Wind turbine sound levels with special audible characteristics (such as tonality, impulsiveness and amplitude modulation) shall be adjusted by arithmetically adding up to +6dB to the measured level at the noise sensitive location.*

Notwithstanding this, the standard requires that wind farms be designed with no special audible characteristics at nearby residential properties while concurrently noting in Section 5.4.1 that:

> […] *as special audible characteristics cannot always be predicted, consideration shall be given to whether there are any special audible characteristics of the wind farm sound when comparing measured levels with noise limits.*

Tonality

While the standard emphasises assessment of special audible characteristics during the post-construction measurement phase of a project, an assessment of tonality can be carried out pre-construction, using tonality audibility results that are commonly provided by manufacturers with their sound power level specifications based on IEC61400-11[1].

[1] *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques* (IEC61400-11)

Low frequency noise and infrasound

Section 5.5 of NZS6808:2010 provides the following comments regarding low frequency noise and infrasound.

> *5.5.1 Although wind turbines may produce some sound at (ultrasound and infrasound) frequencies considered to be outside the normal range of human hearing these components will be well below the threshold of human perception.*
>
> *5.5.2 Claims have been made that low frequency sound and vibration from wind turbines have caused illness and other adverse physiological effects among a very few people worldwide living near wind farms. the paucity of evidence does not justify at this stage, any attempt to set a precautionary limit more stringent than those recommended in 5.2 and 5.3.*

Notwithstanding these comments, further consideration of low frequency noise and infrasound from wind turbines is considered as part of the assessment, to address the reference to inaudible noise included in Section 6.4 S5(b) of the PSA 01/11 wind farm code. Refer to Appendix F for further details.

2.2.5 Cumulative assessment

NZS6808:2010 requires that a unique noise limit apply at each noise sensitive location for cumulative impact from all affecting wind farms, as stated in Section 5.6.1:

> *The noise limits* [defined in Section 2.2 above] *should apply to the cumulative sound level of all wind farms affecting any noise sensitive location.*

2.3 Assessment approach

A brief comparison of NZS6808:2010 and applicable Queensland state noise policies, including Environment Protection (Noise) Policy 2008 (EPP 2008), is provided in Appendix C. As noted in the appendix, on balance, it is considered that an assessment of audible wind farm noise in accordance with NZS6808:2010 is likely to provide an outcome that is broadly consistent with the noise management approaches described in the Queensland Government's noise policy documents, including EPP 2008.

Importantly, NZS6808:2010 is better equipped to address the fundamental variations in noise level with changes in wind speed that occur with a wind farm, as noted in Section 1.4 of the Standard:

> *This Standard deals specifically with the measurement of sound from wind farms in the presence of wind. The procedure involves measuring changes in wind farm sound levels and background sound levels as wind conditions change over time. This goes beyond the procedures described in more general measurement Standards* […]

Section 6.4 S5(b) of PSA 01/11 requires that a wind farm not result in unacceptable levels of nuisance, risk to human health or ability to sleep and relax. In relation to this the forwarding comments of the Standard note:

> *Wind farm sound may be audible at times at noise sensitive locations, and this Standard does not set limits that provide absolute protection for residents from audible wind farm sound. Guidance is provided on noise limits that are considered reasonable for protecting sleep and amenity from wind farm sound received at noise sensitive locations.*

NZS6808:2010 is used herein as the primary guidance document for assessment of audible, operational noise from the proposed Mount Emerald Wind Farm.

To address the additional PSA 01/11 requirement for consideration of inaudible noise, a supplementary assessment of low frequency noise and infrasound is also detailed in this report, referencing both the criteria detailed in the LFN Guideline and other relevant guidance documents..

3.0 PROJECT DESCRIPTION

The Mount Emerald Wind Farm is proposed to consist of up to seventy (70) wind turbines. A plan of the proposed layout is presented in Appendix A along with GPS coordinates for the wind turbines.

3.1 Wind turbines

3.1.1 Turbine type

A final turbine selection for the project is likely to be made during the detailed design and procurement phase. In lieu of a final selection, this assessment considers the emissions of a range of viable candidate turbine models for the site.

Specifically, three (3) candidate turbine models are considered here to represent the range of turbines which could be considered for the site. All of the candidate turbines comprise three upwind rotor blades with variable blade pitch to control rotational speed, power generation and noise emissions. Details of the proposed turbine models are summarised in Table 1 below.

Table 1: WTG manufacturer specifications

	Details		
Make	REpower	Siemens	Siemens
Model	3XM104	SWT-3.0-101	SWT-3.0-108
Rated electrical power (MW)	3.4	3	3
Rotor Diameter (m)	104	101	108
Hub Height (m)	80	80	80
Rotor orientation	Upwind	Upwind	Upwind
Rotor speed (rpm)	6.9-13.8	6-16	6-16
Cut-in Wind Speed (hub height, m/s)	3.5	3	3-5
Rated Wind Speed (hub height, m/s)	13.5	12	11-12
Cut-out Wind Speed (hub height, m/s)	25	22	25
Sound Power L_{WA} at 10m/s (10m AGL^{+}, dB)	105.6	107	107
Tonality audibility ($\Delta L_{a,k}$>0dB)*	No*	-**	-**

* Refer to Section 3.1.3 for further details

** Tonal audibility levels have not been provided for the Siemens turbine. Refer to Section 3.1.3 for further details.

$^{+}$ Above ground level (AGL)

3.1.2 Sound power levels

Sound power data for the candidate turbines has been sourced from the following documents.

Table 2: Candidate turbine sound level source documentation

Turbine	Documents
Repower 3XM104	*Sound Power Level REpower 3.4M104 [3.4M/104/50Hz] SD-3.1-WT.SL.01-A-EN* dated 25 February 2011 Windtest document WT8140/10 (extract from WT 8139/10) *Summary of results of the noise emission measurement, in accordance with IEC61400-11, of a WTGS of the type Repower 3.4M,104* dated 29 April 2010
Siemens SWT-3.0-101	Siemens document *Standard acoustic emission, SWT-3.0-101 rev 4, Hub Height 79.5m* dated 9 May 2013 Document ID: E W EN OEN DES TLS 7-10-0000-1023-00 Siemens document *Standard acoustic emission, SWT-3.0-101 rev 4, Hub Height 79.5m* dated 9 May 2013 Document ID: E W EN OEN DES TLS 7-10-0000-1194-00
Siemens SWT-3.0-108	Siemens document *Standard acoustic emission, SWT-3.0-108, Hub Height 79.5m* Document ID: E W EN OEN DES TLS-10-0000-0423-00 HST, SN / 2012.06.13 Siemens document *Standard acoustic emission, SWT-3.0-108 rev 1, Hub Height 79.5m* Document ID: E W EN OEN DES TLS 7-10-0000-1195-00 HallT / 2013.09.19

Figure 1 and Table 3 below present the reported sound power level data for each candidate turbine at standardised 10m AGL wind speeds.

Table 3 concurrently references wind speeds to non-integer hub height wind speeds[2] as well as presenting the sound power level data extrapolated to integer hub height wind speeds. As suggested by NZS6808:2010, hub height referenced sound power level data for integer wind speeds is used for this noise assessment.

[2] Based on a standardised roughness length of $z_0 = 0.05$, according to IEC 61400-11.

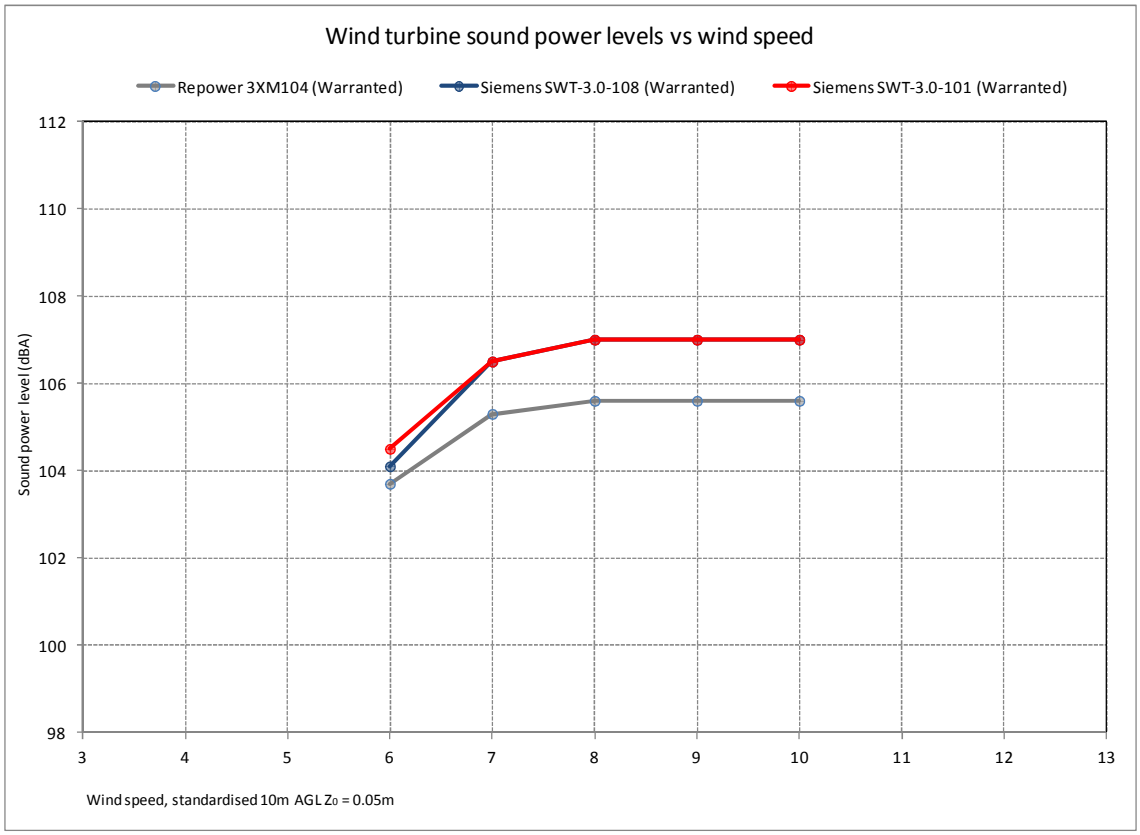

Figure 1: Sound power level vs. wind speed (10m AGL) for the candidate wind turbine models

Table 3: Sound power levels, L_{AW} dB, vs wind speed for the candidate turbine models

Wind speed (m/s)	**10m AGL standardised**	**6**	**7**	**8**	**9**	**10**		
	Hub height	**8.4**	**9.7**	**11.1**	**12.5**	**13.9**		
Repower 3XM104*		103.7	105.3	105.6	105.6	105.6		
Siemens SWT-3.0-101*		104.5	106.5	107	107	107		
Siemens SWT-3.0-108*		104.5	106.5	107	107	107		
Extrapolated Integer hub height wind speed (m/s)		**8**	**9**	**10**	**11**	**12**	**13**	**14**
Repower 3XM104		102.9	104.6	105.4	105.6	105.6	105.6	105.6
Siemens SWT-3.0-101		103.6	105.6	106.7	107	107	107	107
Siemens SWT-3.0-108		102.9	105.6	106.7	107	107	107	107

* Warranted sound power levels

Predicted wind farm noise levels are calculated for the range of wind speeds between turbine cut-in and rated power. As sound power level data is not available for hub height wind speeds below approximately 8 m/s, the sound power level for each turbine at 8m/s is used here to estimate levels at lower wind speeds and, therefore, for assessment of wind speeds between cut-in and 8 m/s. In our experience, this assumption is considered to be conservative (i.e. the assumed sound power level of the turbines at these wind speeds is expected to be higher than the actual emissions in practice).

For each turbine type, predicted wind farm noise levels incorporate octave band sound power level data for the turbine being considered. Reference A-weighted octave band sound power spectra for each turbine type, adjusted to the maximum sound power level value, are presented in Figure 2.

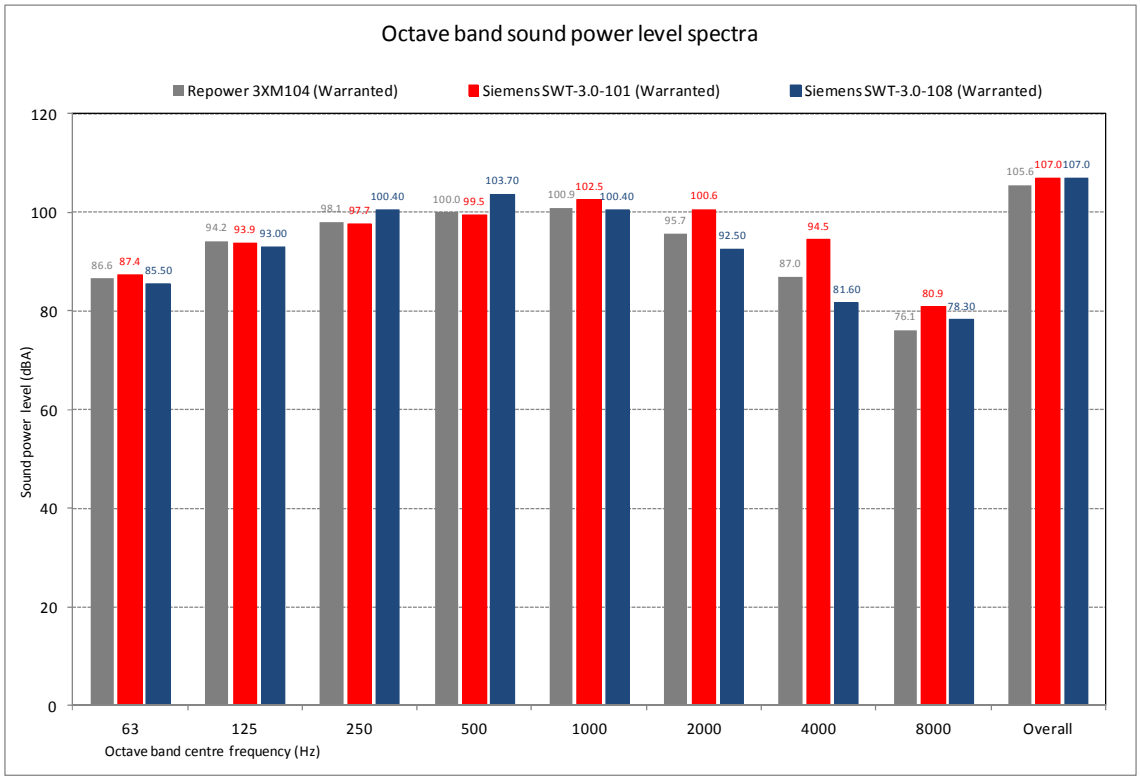

Figure 2: Reference A-weighted octave band sound power level spectra for candidate turbines

Tabular octave band values are presented in Table 4.

Table 4: Reference A-weighted octave band sound power levels for the candidate turbines

	Octave Band Centre Frequency (Hz)								
L_{WA} (dB)	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Overall**
Repower 3XM104	86.6	94.2	98.1	100.0	100.9	95.7	87.0	76.1	105.6
Siemens SWT-3.0-101	87.4	93.9	97.7	99.5	102.5	100.6	94.5	80.9	107
Siemens SWT-3.0-108	85.5	93.0	100.4	103.7	100.4	92.5	81.6	78.3	107

The available documentation for each turbine type only provides one octave band spectrum, which corresponds to a single wind speed condition. In the absence of detailed spectral information across the assessable range of wind speeds, the available spectral data presented in Table 4 has been scaled across the wind speed range to match the sound power levels as detailed in Table 3 above.

3.1.3 Tonality

REpower 3XM104

Results of a tonality assessment undertaken in accordance with IEC61400-11 *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques* (IEC61400-11) for the REpower turbine are provided in the documentation detailed in Section 3.1.2.

Tonal audibility ($\Delta L_{a,k}$) levels are provided for the most prevalent tone at each integer wind speed in the range 6-10 m/s at 10m AGL. The largest reported value for $\Delta L_{a,k}$, for measurements made close to the turbine at a distance of approximately 150m, is -3.29dB at 10m/s.

Siemens SWT-3.0-101 and SWT-3.0-108

Tonal audibility ($\Delta L_{a,k}$) levels determined in accordance with IEC61400-11 are not provided in the technical information provided by Siemens.

For the purposes of this assessment it is assumed that the turbines will have tonal audibility levels ($\Delta L_{a,k}$) of no greater than -3dB at all assessed wind speeds.

To confirm the appropriateness of this assumption, a tonal audibility assessment would be required from Siemens, and this noise impact assessment updated, before proceeding with any site works using this turbine.

3.2 Assessed receivers

RATCH has identified one hundred and twenty-three (123) receiver locations around the site of the proposed wind farm site. Geographic coordinates for the identified receivers are presented in Appendix A.

This noise assessment considers all of these identified receivers.

The project does not include any stakeholder receivers.

4.0 NOISE LIMITS

4.1 Base noise levels

As noted in Section 0 above, NZS6808:2010 states that a "*high amenity noise limit should be considered where a plan promotes a higher degree of protection of amenity related to the sound environment of a particular area* […].

We have reviewed the applicable planning documents for the Mareeba Shire Council, Atherton Shire Council and Tablelands Regional Council with a summary of this review provided in Appendix D. Across these three planning schemes, the land for the proposed MEWF and surrounding area is generally zoned for primary or rural production activities, typically with a rural zoning.

It is considered that the identified zonings do no promote a higher degree of protection of amenity related to the sound environment. On this basis, a 40 dB L_{Aeq} base noise level limit is used for this noise assessment and the high amenity noise limit has not been applied.

4.2 Noise sensitive locations

NZS6808:2010 requires that the noise assessment be undertaken at all noise sensitive locations in the vicinity of the proposed wind farm which it defines as follows:

> *The location of a noise sensitive activity, associated with a habitable space or education space in a building not on the wind farm site.*

Noise sensitive locations include residential dwellings, schools and hotels located outside the wind farm site where predicted wind farm noise levels exceed 35dB L_{A90}.

Preliminary predictions of noise from the proposed wind farm have been calculated in accordance with NZS6808:2010 as well as the methodology outlined in Section 5.0 below to identify noise sensitive locations.

Table 5 below presents the preliminary predicted wind farm noise levels at the forty-four (44) locations with predicted wind farm noise levels of 35dB L_{A90} or greater.

Table 5: Evaluation of noise sensitive locations

House	Applicable base criterion* (dB)	Distance to nearest turbine (m)	Angle of nearest turbine (°)	Predicted noise level, L_{Aeq} (dB)+		
				3XM104	SWT-3.0-101	SWT-3.0-108
R78	40	1104	155	39.3	39.5	41.6
R26	40	1531	151	37.8	38.0	40.2
R49	40	1829	263	37.9	38.0	40.0
R89	40	1056	125	37.1	37.3	39.9
R05	40	1739	54	37.5	37.6	39.5
R36	40	1848	234	37.3	37.4	39.1
R32	40	1897	213	37.0	36.9	38.8
R35	40	1959	225	36.8	36.8	38.5
R30	40	1973	205	36.8	36.8	38.5
R27	40	1875	196	36.4	36.5	38.3
R02	40	2113	71	35.7	35.8	37.9
R29	40	2178	210	35.8	35.8	37.7
R39	40	2385	249	35.9	36.0	37.6
R33	40	2251	209	35.8	35.9	37.6
R82	40	2179	200	35.6	35.6	37.6
R06	40	2279	42	35.6	35.6	37.5
R34	40	2262	214	35.7	35.9	37.5
R28	40	2203	198	35.6	35.6	37.4
R25	40	2157	179	35.3	35.4	37.3
R84	40	2305	180	35.2	35.3	37.2
R21	40	2035	230	35.0	35.0	37.1
R83	40	2524	244	35.4	35.3	36.9
R37	40	2527	231	35.0	35.1	36.8
R38	40	2577	241	35.0	35.0	36.7
R46	40	2610	231	35.0	35.0	36.7
R40	40	2756	245	34.7	34.8	36.4
R48	40	2701	240	34.7	34.7	36.2
R47	40	2731	233	34.7	34.6	36.2
R13	40	2316	81	33.9	33.9	36.2

House	Applicable base criterion* (dB)	Distance to nearest turbine (m)	Angle of nearest turbine (°)	Predicted noise level, L_{Aeq} (dB)+		
				3XM104	SWT-3.0-101	SWT-3.0-108
R22	40	2410	226	34.0	34.1	36.1
R57	40	2776	252	34.4	34.5	36.1
R41	40	2904	223	34.5	34.5	36.1
R59	40	2250	244	33.8	33.7	36.0
R24	40	2764	228	33.8	33.8	35.9
R16	40	2887	61	33.8	33.8	35.8
R07	40	2751	48	33.9	33.9	35.7
R42	40	3024	225	34.0	34.1	35.7
R31	40	2849	214	33.9	34.0	35.7
R43	40	2947	230	34.2	34.1	35.7
R14	40	2975	54	33.6	33.6	35.6
R60	40	2132	265	33.0	32.9	35.5
R23	40	2461	218	33.6	33.5	35.4
R45	40	3030	236	33.8	33.8	35.4
R08	40	2994	43	33.1	33.1	35.0

+ at a hub height wind speed of 11m/s

* See Section Section 4.1

4.3 Background noise monitoring

Section 7.1.4 of NZS6808:2010 recommends that background noise monitoring be carried out at noise sensitive locations around a proposed wind farm where predicted wind farm noise levels exceed 35dB L_{A90}.

A background noise level measurement campaign has previously been carried out for this project, as detailed in Noise Mapping Australia document 090815ND02 dated 16 March 2012 (NMA report). Monitoring was carried out at six (6) locations which were designated as follows: R05, R06, R16, R26, R31 and R32[3].

[3] The NMA Report does not provide GPS coordinates for these receiver locations, however a visual inspection of layout maps in the NMA Report indicates that the location designations are consistent with those used here.

As noted in the NMA Report, the results of the two-week monitoring surveys show comparatively low levels of correlation between background noise levels and wind speed. The NMA Report notes that the poor correlations may be due to the significant difference in elevation, approximately 300m, between the wind farm met mast and the noise monitoring locations. It should also be noted that the background noise levels were measured at 15 minute intervals rather than the 10 minute intervals required by NZS6808:2010.

In light of these issues it is considered appropriate at this stage that predicted noise from the MEWF be assessed using the 40 dB L_{Aeq} base noise level limit at all relevant wind speeds.

Notwithstanding this approach to the assessment, further background noise monitoring will likely be worthwhile at a later stage, in order to quantify the existing baseline noise environment in the area, which can inform and be integrated into any required post-construction noise monitoring.

4.4 Noise limits

As noted above, this assessment is based on compliance with a base noise limit of 40 dB L_{Aeq} at all identified receiver locations.

5.0 ASSESSMENT OF WIND FARM NOISE

5.1 Noise predictions

Noise from the Mount Emerald Wind Farm has been predicted using the implementation of ISO9613-2:1996[4] with SoundPLAN version 7.2 noise modelling software. Predictions have been carried out using the sound power level data presented in Section 3.1.2.

The ISO 9613-2:1996 method has been used with input parameters specifically chosen for the purpose of modelling wind farm noise, taking account of a range of national and international research publications. These publications include a comprehensive 1998 study[5] (commonly cited as the Joule Report) part funded by the European Commission which found the ISO 9613 model provides a robust representation of upper noise levels which may occur in practice.

Calculations have been performed using octave bands from 63Hz to 8kHz and each wind turbine has been modelled as a point source at hub height. All noise predictions use a receiver height of 1.5m AGL.

Atmospheric attenuation has been modelled using a temperature of 10°C and 70% humidity as recommended by NZS6808:210.

ISO9613-2:1996 requires that hardness of the ground between the sources and the receivers be characterised. 100% hard ground (G=0) is considered to be fully reflective as would occur with concrete or asphalt, while 100% soft ground (G=1) would be considered to absorptive and be appropriate for fields and grass. Our experience is that, in rural areas, it is appropriate to assume that the ground is 50% hard and 50% soft (G=0.5). A ground factor of G=0.5 has been used in the predictions.

The ISO 9613 predictions have been applied with the terrain adjustments recommended in the Joule Report.

Further details regarding the use of ISO9613-2 for wind farm nose predictions and the use of G=0.5 are provided in Appendix E.

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

[4] ISO9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO9613-2:1996)

[5] Bass, Bullmore and Sloth - Development of a wind farm noise propagation prediction model; Contract JOR3-CT95-0051, Final Report, January 1996 to May 1998.

5.2 REpower 3XM104

Predicted levels of wind farm operational noise based on installation of REpower 3XM104 turbines is presented in Table 6 for the range of receiver locations referenced in Table 5 and for each integer wind speed between turbine cut-in and rated power.

Table 6: Predicted noise from the Mount Emerald Wind Farm, L_{Aeq} dB, 3XM104 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	36.6	36.6	38.3	39.1	39.3	39.3	39.3	39.3	✓
R26	35.1	35.1	36.8	37.6	37.8	37.8	37.8	37.8	✓
R49	35.2	35.2	36.9	37.7	37.9	37.9	37.9	37.9	✓
R89	34.4	34.4	36.1	36.9	37.1	37.1	37.1	37.1	✓
R05	34.8	34.8	36.5	37.3	37.5	37.5	37.5	37.5	✓
R36	34.6	34.6	36.3	37.1	37.3	37.3	37.3	37.3	✓
R32	34.3	34.3	36.0	36.8	37.0	37.0	37.0	37.0	✓
R35	34.1	34.1	35.8	36.6	36.8	36.8	36.8	36.8	✓
R30	34.1	34.1	35.8	36.6	36.8	36.8	36.8	36.8	✓
R27	33.7	33.7	35.4	36.2	36.4	36.4	36.4	36.4	✓
R02	33.0	33.0	34.7	35.5	35.7	35.7	35.7	35.7	✓
R29	33.1	33.1	34.8	35.6	35.8	35.8	35.8	35.8	✓
R39	33.2	33.2	34.9	35.7	35.9	35.9	35.9	35.9	✓
R33	33.1	33.1	34.8	35.6	35.8	35.8	35.8	35.8	✓
R82	32.9	32.9	34.6	35.4	35.6	35.6	35.6	35.6	✓
R06	32.9	32.9	34.6	35.4	35.6	35.6	35.6	35.6	✓
R34	33.0	33.0	34.7	35.5	35.7	35.7	35.7	35.7	✓
R28	32.9	32.9	34.6	35.4	35.6	35.6	35.6	35.6	✓
R25	32.6	32.6	34.3	35.1	35.3	35.3	35.3	35.3	✓
R84	32.5	32.5	34.2	35.0	35.2	35.2	35.2	35.2	✓
R21	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R83	32.7	32.7	34.4	35.2	35.4	35.4	35.4	35.4	✓
R37	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R38	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R46	32.3	32.3	34.0	34.8	35.0	35.0	35.0	35.0	✓
R40	32.0	32.0	33.7	34.5	34.7	34.7	34.7	34.7	✓
R48	32.0	32.0	33.7	34.5	34.7	34.7	34.7	34.7	✓
R47	32.0	32.0	33.7	34.5	34.7	34.7	34.7	34.7	✓
R13	31.2	31.2	32.9	33.7	33.9	33.9	33.9	33.9	✓

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R22	31.3	31.3	33.0	33.8	34.0	34.0	34.0	34.0	✓
R57	31.7	31.7	33.4	34.2	34.4	34.4	34.4	34.4	✓
R41	31.8	31.8	33.5	34.3	34.5	34.5	34.5	34.5	✓
R59	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R24	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R16	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R07	31.2	31.2	32.9	33.7	33.9	33.9	33.9	33.9	✓
R42	31.3	31.3	33.0	33.8	34.0	34.0	34.0	34.0	✓
R31	31.2	31.2	32.9	33.7	33.9	33.9	33.9	33.9	✓
R43	31.5	31.5	33.2	34.0	34.2	34.2	34.2	34.2	✓
R14	30.9	30.9	32.6	33.4	33.6	33.6	33.6	33.6	✓
R60	30.3	30.3	32.0	32.8	33.0	33.0	33.0	33.0	✓
R23	30.9	30.9	32.6	33.4	33.6	33.6	33.6	33.6	✓
R45	31.1	31.1	32.8	33.6	33.8	33.8	33.8	33.8	✓
R08	30.4	30.4	32.1	32.9	33.1	33.1	33.1	33.1	✓

It can be seen from Table 6 that predicted noise levels from the proposed wind farm comply with the 40 dB L_{Aeq} base criterion within the range of assessed wind speeds at each of the listed receiver locations. Wind farm noise at all other identified receiver locations in the vicinity of the wind farm are predicted to be 5dB or more below the 40 dB L_{Aeq} base criterion and therefore also demonstrate compliance with NZS6808:2010 across the range of assessed wind speeds.

A representative noise level contour map relating to this turbine model is provided in Appendix F.

5.3 Siemens SWT-3.0-101

Predicted levels of wind farm operational noise based on installation of Siemens SWT-3.0-101 turbines is presented in Table 7 for the range of receiver locations referenced in Table 5 and for each integer wind speed between turbine cut-in and rated power.

Table 7: Predicted noise from the Mount Emerald Wind Farm, L_{Aeq} dB, SWT-3.0-101 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	36.1	36.1	38.1	39.2	39.5	39.5	39.5	39.5	✓
R26	34.6	34.6	36.6	37.7	38.0	38.0	38.0	38.0	✓
R49	34.6	34.6	36.6	37.7	38.0	38.0	38.0	38.0	✓
R89	33.9	33.9	35.9	37.0	37.3	37.3	37.3	37.3	✓
R05	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R36	34.0	34.0	36.0	37.1	37.4	37.4	37.4	37.4	✓
R32	33.5	33.5	35.5	36.6	36.9	36.9	36.9	36.9	✓
R35	33.4	33.4	35.4	36.5	36.8	36.8	36.8	36.8	✓
R30	33.4	33.4	35.4	36.5	36.8	36.8	36.8	36.8	✓
R27	33.1	33.1	35.1	36.2	36.5	36.5	36.5	36.5	✓
R02	32.4	32.4	34.4	35.5	35.8	35.8	35.8	35.8	✓
R29	32.4	32.4	34.4	35.5	35.8	35.8	35.8	35.8	✓
R39	32.6	32.6	34.6	35.7	36.0	36.0	36.0	36.0	✓
R33	32.5	32.5	34.5	35.6	35.9	35.9	35.9	35.9	✓
R82	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R06	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R34	32.5	32.5	34.5	35.6	35.9	35.9	35.9	35.9	✓
R28	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R25	32.0	32.0	34.0	35.1	35.4	35.4	35.4	35.4	✓
R84	31.9	31.9	33.9	35.0	35.3	35.3	35.3	35.3	✓
R21	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓
R83	31.9	31.9	33.9	35.0	35.3	35.3	35.3	35.3	✓
R37	31.7	31.7	33.7	34.8	35.1	35.1	35.1	35.1	✓
R38	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓
R46	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓
R40	31.4	31.4	33.4	34.5	34.8	34.8	34.8	34.8	✓
R48	31.3	31.3	33.3	34.4	34.7	34.7	34.7	34.7	✓
R47	31.2	31.2	33.2	34.3	34.6	34.6	34.6	34.6	✓
R13	30.5	30.5	32.5	33.6	33.9	33.9	33.9	33.9	✓

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R22	30.7	30.7	32.7	33.8	34.1	34.1	34.1	34.1	✓
R57	31.1	31.1	33.1	34.2	34.5	34.5	34.5	34.5	✓
R41	31.1	31.1	33.1	34.2	34.5	34.5	34.5	34.5	✓
R59	30.3	30.3	32.3	33.4	33.7	33.7	33.7	33.7	✓
R24	30.4	30.4	32.4	33.5	33.8	33.8	33.8	33.8	✓
R16	30.4	30.4	32.4	33.5	33.8	33.8	33.8	33.8	✓
R07	30.5	30.5	32.5	33.6	33.9	33.9	33.9	33.9	✓
R42	30.7	30.7	32.7	33.8	34.1	34.1	34.1	34.1	✓
R31	30.6	30.6	32.6	33.7	34.0	34.0	34.0	34.0	✓
R43	30.7	30.7	32.7	33.8	34.1	34.1	34.1	34.1	✓
R14	30.2	30.2	32.2	33.3	33.6	33.6	33.6	33.6	✓
R60	29.5	29.5	31.5	32.6	32.9	32.9	32.9	32.9	✓
R23	30.1	30.1	32.1	33.2	33.5	33.5	33.5	33.5	✓
R45	30.4	30.4	32.4	33.5	33.8	33.8	33.8	33.8	✓
R08	29.7	29.7	31.7	32.8	33.1	33.1	33.1	33.1	✓

It can be seen from Table 7 that predicted noise levels from the proposed wind farm comply with the 40 dB L_{Aeq} base criterion within the range of assessed wind speeds at each of the listed receiver locations. Wind farm noise at all other identified receiver locations in the vicinity of the wind farm are predicted to be 5dB or more below the 40 dB L_{Aeq} base criterion and therefore also demonstrate compliance with NZS6808:2010 across the range of assessed wind speeds.

A representative noise level contour map relating to this turbine model is provided in Appendix F.

5.4 Siemens SWT-3.0-108

Predicted levels of wind farm operational noise based on installation of Siemens SWT-3.0-108 turbines is presented in Table 8 for the range of receiver locations referenced in Table 5 and for each integer wind speed between turbine cut-in and rated power.

Table 8: Predicted noise from the Mount Emerald Wind Farm, L_{Aeq} dB, SWT-3.0-108 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	38.2	38.2	**40.2**	**41.3**	**41.6**	**41.6**	**41.6**	**41.6**	×
R26	36.8	36.8	38.8	39.9	**40.2**	**40.2**	**40.2**	**40.2**	×
R49	36.6	36.6	38.6	39.7	40.0	40.0	40.0	40.0	✓
R89	36.5	36.5	38.5	39.6	39.9	39.9	39.9	39.9	✓
R05	36.1	36.1	38.1	39.2	39.5	39.5	39.5	39.5	✓
R36	35.7	35.7	37.7	38.8	39.1	39.1	39.1	39.1	✓
R32	35.4	35.4	37.4	38.5	38.8	38.8	38.8	38.8	✓
R35	35.1	35.1	37.1	38.2	38.5	38.5	38.5	38.5	✓
R30	35.1	35.1	37.1	38.2	38.5	38.5	38.5	38.5	✓
R27	34.9	34.9	36.9	38.0	38.3	38.3	38.3	38.3	✓
R02	34.5	34.5	36.5	37.6	37.9	37.9	37.9	37.9	✓
R29	34.3	34.3	36.3	37.4	37.7	37.7	37.7	37.7	✓
R39	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R33	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R82	34.2	34.2	36.2	37.3	37.6	37.6	37.6	37.6	✓
R06	34.1	34.1	36.1	37.2	37.5	37.5	37.5	37.5	✓
R34	34.1	34.1	36.1	37.2	37.5	37.5	37.5	37.5	✓
R28	34.0	34.0	36.0	37.1	37.4	37.4	37.4	37.4	✓
R25	33.9	33.9	35.9	37.0	37.3	37.3	37.3	37.3	✓
R84	33.8	33.8	35.8	36.9	37.2	37.2	37.2	37.2	✓
R21	33.7	33.7	35.7	36.8	37.1	37.1	37.1	37.1	✓
R83	33.5	33.5	35.5	36.6	36.9	36.9	36.9	36.9	✓
R37	33.4	33.4	35.4	36.5	36.8	36.8	36.8	36.8	✓
R38	33.3	33.3	35.3	36.4	36.7	36.7	36.7	36.7	✓
R46	33.3	33.3	35.3	36.4	36.7	36.7	36.7	36.7	✓
R40	33.0	33.0	35.0	36.1	36.4	36.4	36.4	36.4	✓
R48	32.8	32.8	34.8	35.9	36.2	36.2	36.2	36.2	✓
R47	32.8	32.8	34.8	35.9	36.2	36.2	36.2	36.2	✓

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R13	32.8	32.8	34.8	35.9	36.2	36.2	36.2	36.2	✓
R22	32.7	32.7	34.7	35.8	36.1	36.1	36.1	36.1	✓
R57	32.7	32.7	34.7	35.8	36.1	36.1	36.1	36.1	✓
R41	32.7	32.7	34.7	35.8	36.1	36.1	36.1	36.1	✓
R59	32.6	32.6	34.6	35.7	36.0	36.0	36.0	36.0	✓
R24	32.5	32.5	34.5	35.6	35.9	35.9	35.9	35.9	✓
R16	32.4	32.4	34.4	35.5	35.8	35.8	35.8	35.8	✓
R07	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R42	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R31	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R43	32.3	32.3	34.3	35.4	35.7	35.7	35.7	35.7	✓
R14	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R60	32.1	32.1	34.1	35.2	35.5	35.5	35.5	35.5	✓
R23	32.0	32.0	34.0	35.1	35.4	35.4	35.4	35.4	✓
R45	32.0	32.0	34.0	35.1	35.4	35.4	35.4	35.4	✓
R08	31.6	31.6	33.6	34.7	35.0	35.0	35.0	35.0	✓

It can be seen from Table 8 that predicted noise levels from the proposed wind farm comply with the 40 dB L_{Aeq} base criterion within the range of assessed wind speeds at each of the listed receiver locations with the exception of R78 and R26.

Wind farm noise at all other identified receiver locations in the vicinity of the wind farm are predicted to be 5dB or more below the 40 dB L_{Aeq} base criterion and therefore also demonstrate compliance with NZS6808:2010 across the range of assessed wind speeds.

5.4.1 Operational noise mitigation option

To reduce predicted wind farm noise levels at receivers R78 and R26 to below the 40 dB L_{Aeq} base criterion, turbines T1, T2 and T62 have been excluded from the wind farm layout. In addition, turbines T61, T69 and T70 have been modelled based on a Noise Restricted Operation mode, using sound power level data as detailed in Table 9 and Table 10 below.

The information provided for noise restricted operations corresponds to a single reference wind speed of 8m/s at 10m AGL. As shown here, this reference value has been applied for all assessable wind speeds for the purposes of this assessment.

Table 9: '-5dB' Noise Restricted Operation Sound power levels L_{AW} (dB) vs wind speed for SWT-3.0-108

Wind speed (m/s)	10m AGL standardised	6	7	8	9	10		
	Hub height	8.4	9.7	11.1	12.5	13.9		
Siemens SWT-3.0-108* ('-5dB' mode)		102	102	102	102	102		
Extrapolated Integer hub height wind speed (m/s)		**8**	**9**	**10**	**11**	**12**	**13**	**14**
Siemens SWT-3.0-108 ('-5dB' mode)		102	102	102	102	102	102	102

* Warranted sound power levels

Table 10: Reference A-weighted octave band sound power levels for SWT-3.0-108 '-5dB' Noise Restricted Operation mode

	Octave Band Centre Frequency (Hz)								
L_{WA} (dB)	63	125	250	500	1000	2000	4000	8000	Overall
Siemens SWT-3.0-108	84.5	91.2	95.4	97.8	96	88.4	79.4	76.4	102

Revised wind farm noise predictions at R78 and R26 based on the updated wind farm arrangement are shown in Table 11 and it can be seen that the predicted levels comply with the 40 dB L_{Aeq} base criterion. For information, revised predicted noise levels are also presented in Table 11 at the four (4) other receiver locations in Table 8 where predicted levels are 39 dB L_{Aeq} or greater.

Table 11: Predicted noise from the Mount Emerald Wind Farm based on a 67 turbine layout*, L_{Aeq} dB, SWT-3.0-108 Turbine

House	Hub height wind speed (m/s)								Compliance with noise limits?
	<8	8	9	10	11	12	13	14	
R78	34.9	34.9	36.9	38.0	38.3	38.3	38.3	38.3	✓
R26	33.7	33.7	35.7	36.8	37.1	37.1	37.1	37.1	✓
R49	36.1	36.1	38.1	39.2	39.5	39.5	39.5	39.5	✓
R89	32.2	32.2	34.2	35.3	35.6	35.6	35.6	35.6	✓
R05	35.6	35.6	37.6	38.7	39.0	39.0	39.0	39.0	✓
R36	34.9	34.9	36.9	38.0	38.3	38.3	38.3	38.3	✓

* Turbines T1, T2 & T62 removed, T61, T69 and T70 constrained to '-5dB' power reduced mode.

A representative noise level contour map relating to this turbine model is provided in Appendix F.

5.5 Tonality and other characteristics

5.5.1 Tonality

Based on the tonal audibility levels and information detailed in Section 3.1.3, a 5dB penalty for annoying characteristics (tonality) has not been applied to the predicted wind farm noise levels detailed above.

Regarding the Siemens SWT-3.0-101 and SWT-3.0-108 turbines, a tonal audibility test report should be provided by Siemens prior to commencing any site works, to confirm the significance of any tones from their turbine model.

5.5.2 Low frequency noise and infrasound

Predicted low frequency noise levels and a qualitative review of infrasound levels are provided here. Additional discussions of prediction methods, sound power level data and estimated infrasound levels are provided for reference in Appendix F.

Low frequency noise

As described in Appendix F, of the four assessment phases detailed in the LFN Guideline, Phase 1 and Phase 2 are considered to apply to complaints of existing noise.

The LFN Guideline Phase 3 assessment relates to low frequency tonal noise, for which the tonality discussions in Section 3.1.3 and Section 5.5.1 above are applicable, for frequencies greater than 50 Hz. For frequencies in the range 10 Hz to 160 Hz, a one-third octave band tonality assessment of available turbine sound power level data is detailed in Appendix F, which does not indicate the presence of tones.

The Phase 4 assessment of non-tonal low frequency noise is addressed here for assessment of the LFN Guideline internal noise criterion of 20 dB $L_{pAL,F}$. Table 12 below presents predicted low frequency noise levels for the range of receiver locations listed in Table 5 based on the Danish EPA 1284 method[6]. For each candidate turbine, the predictions relate to the seventy (70) turbine wind farm layout. A brief description of the method is outlined in Appendix F along with details of the input sound power level data for each turbine type and a discussion of the limitations of this data.

[6] With adjustments to indoor-outdoor sound reduction as detailed in Appendix F

Table 12: Indicative low frequency internal noise levels from the Mount Emerald Wind Farm, $L_{pAL,F}$ dB

	Turbine model*			
House	3XM104	SWT-3.0-101	SWT-3.0-108	Satisfies the LFN Guideline?
R78	20	**21**	19	×
R26	19	20	18	✓
R05	18	19	17	✓
R49	17	18	16	✓
R89	18	18	17	✓
R36	17	18	16	✓
R32	17	17	16	✓
R30	17	17	16	✓
R35	17	17	16	✓
R27	17	18	16	✓
R06	17	17	16	✓
R02	16	17	15	✓
R29	16	17	15	✓
R33	16	17	15	✓
R82	16	17	15	✓
R25	16	17	15	✓
R39	16	17	15	✓
R34	16	17	15	✓
R28	16	17	15	✓
R84	16	17	15	✓
R21	17	17	15	✓
R83	16	16	15	✓
R46	15	16	14	✓
R37	15	16	14	✓
R38	15	16	14	✓
R40	15	16	14	✓
R13	15	16	14	✓
R48	15	16	14	✓

House	Turbine model*			Satisfies the LFN Guideline?
	3XM104	SWT-3.0-101	SWT-3.0-108	
R47	15	16	14	✓
R57	15	16	14	✓
R22	16	16	15	✓
R07	16	16	15	✓
R16	15	16	14	✓
R41	15	16	14	✓
R24	15	16	14	✓
R59	15	16	14	✓
R14	15	16	14	✓

* Predicted low frequency noise levels for each candidate turbine relate to wind speed with the highest overall A-weighted sound power level. For all three (3) candidate turbines this corresponds to a wind speed of approximately 11 m/s at hub height.

It can be seen that predicted wind farm low frequency noise levels are less than or equal to the nominated 20 dB $L_{pAL,F}$ criteria at all listed receivers locations with the exception of R78, where predicted $L_{pAL,F}$ noise levels exceed 20 dB for the SWT-3.0-101 turbine.

At all other receiver locations, predicted wind farm low frequency noise levels are predicted to be less than 20 dB $L_{pAL,F}$ and therefore also comply with the LFN Guideline criterion.

Predicted indicative wind farm low frequency noise levels at receiver R78 for the SWT-3.0-101 turbine model can comply with the 20 dB $L_{pAL,F}$ base criterion if turbines T1, T2 and T62 are removed from the wind farm layout, as shown in Table 13 below.

Table 13: Indicative low frequency noise levels from the Mount Emerald Wind Farm at R78 based on a 67 turbine layout (T1, T2 and T62 removed), L_{Aeq} dB, SWT-3.0-101 Turbine

House	Turbine model (Hub height wind speed (m/s))	Satisfies the LFN Guideline?
	SWT-3.0-101	
R78	20	✓

Infrasound

An early study[7] of infrasound in 1997 as part of a UK government funded investigation reported measured levels of infrasound, low frequency sound and vibration in the vicinity of a wind farm comprising 450 kW turbines. The results demonstrated noise levels complied with recommended residential criteria even on the wind turbine site itself, and the measured levels were below accepted levels of perception below 20Hz.

More recent measurements[8][9] have demonstrated that infrasound and low frequency sound produced by regularly encountered natural and man-made sources, such as the infrasound produced by the wind or distant traffic, is comparable to that of modern wind turbines, noting that:

> *Infrasound levels in the rural environment appear to be controlled by localised wind conditions. During low wind periods, levels as low as 40dB(G) were measured at locations both near to and away from wind turbines. At higher wind speeds, infrasound levels of 50 to 70dB(G) were common at both wind farm and non-wind farm sites*
>
> *Organised shutdowns of the wind farms adjacent to* [sic: measurement locations] *indicate that there did not appear to be any noticeable contribution from the wind farm to the G-weighted infrasound level measured at either house. This suggests that wind turbines are not a significant source of infrasound at houses located approximately 1.5 kilometres away from wind farm sites*

UK studies[10] have also indicated measured infrasound levels in the vicinity of modern multi-megawatt wind farms to be substantially lower than the threshold of hearing for even the most sensitive members of the population. With respect to infrasonic noise levels below the hearing threshold, the World Health Organization has stated[11] that:

> *There is no reliable evidence that infrasounds below the hearing threshold produce physiological or psychological effects*

In 2010, the UK Health Protection Agency published a report[12] on the health effects of exposure to ultrasound and infrasound. The exposures considered in the report related to medical applications and general environmental exposure. The report notes:

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[7] Snow - *Low Frequency Noise and Vibration Measurements Near a Modern Wind Farm* ; ETSU publication W/13/00392/REP

[8] Sonus report for Pacific Hydro - *Infrasound measurements from wind farms and other sources* – November 2010 - see http://www.pacifichydro.com.au/media/192017/infrasound_report.pdf

[9] Evans, T., Cooper, J. & Lenchine, V., *Infrasound levels near wind farms and in other environments*, South Australian Environment Protection Authority, Adelaide, 2013

[10] Former UK Department of Trade and Industry, Hayes Mckenzie Partnership - *The Measurement of Low Frequency Noise at Three UK Wind Farms*; contract number W/45/00656/00/00, 2006

[11] World Health Organization, Berglund, Lindvall - *Community Noise* - 1995

[12] Health Protection Agency UK – *Health Effects of Exposure to Ultrasound and Infrasound – Report of the independent Advisory Group on Non-ionising Radiation* - 2010

Infrasound is widespread in modern society, being generated by cars, trains and aircraft, and by industrial machinery, pumps, compressors and low speed fans. Under these circumstances, infrasound is usually accompanied by the generation of audible, low frequency noise. Natural sources of infrasound include thunderstorms and fluctuations in atmospheric pressure, wind and waves, and volcanoes; running and swimming also generate changes in air pressure at infrasonic frequencies.

[...]

For infrasound, aural pain and damage can occur at exposures above about 140 dB, the threshold depending on the frequency. The best-established responses occur following acute exposures at intensities great enough to be heard and may possibly lead to a decrease in wakefulness. The available evidence is inadequate to draw firm conclusions about potential health effects associated with exposure at the levels normally experienced in the environment, especially the effects of long-term exposures. The available data do not suggest that exposure to infrasound below the hearing threshold levels is capable of causing adverse effects.

In response to ongoing concerns regarding potential health effects associated with these types of emissions, the Australian Government's National Health and Medical Research Council issued a public statement in July 2010 titled *Wind Turbines and Health* supporting the view that there is no published scientific evidence to positively link wind turbines with direct health impacts.

Further material published in July 2010 by RenewableUK[13] reported the findings of three independent experts commissioned to investigate alleged issues relating to infrasound and low frequency noise from wind farms. The key reported conclusions from this study were that:

there is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects;

the ground-borne vibrations from wind turbines are too weak to be detected by, or to affect, humans; and

the sounds emitted by wind turbines are not unique. There is no reason to believe, based on the levels and frequencies of the sounds and the panel's experience with sound exposures in occupational settings, that the sounds from wind turbines could plausibly have direct adverse health consequences.

Also, a recent State Government of Victorian Department of Health document Wind farms, sound and health - Technical information concludes the following in relation to infrasound from wind farms:

Infrasound is audible when the sound levels are high enough. The hearing threshold for infrasound is much higher than other frequencies. Infrasound from wind farms is at levels well below the hearing threshold and is therefore inaudible to neighbouring residents.

These studies all indicate that infrasound levels from the MEWF are anticipated to be comparable with existing ambient levels. Estimated G-weighted noise levels are provided Appendix F for informative reference. These estimated levels satisfy the 90dBG criteria for infrasound nominated in the LFN Guideline at all assessed receiver locations.

[13] RenewableUK – *Wind Turbine Syndrome – An independent review of the state of knowledge about the alleged health condition* - 2010

5.6 Review of cumulative impact

Separate wind farm developments that are in close proximity to each other have the potential to impact on the same receiver. It is therefore necessary to assess any potential cumulative noise impact on receivers, where such circumstances exist

We understand that there are no other wind farm developments currently planned or operating within 10km of the proposed MEWF. On this basis, cumulative impacts of noise from more than one operating wind farm are not considered further.

6.0 OPERATIONAL CONSIDERATIONS

Item 6.3(h) of the PSA 01/11 requires the operation of the wind farm to be controlled and monitored by a site specific management plan which is to include turbine noise.

Methods for monitoring noise at an operational wind farm are provided in NZS6808:2010. These methods could be incorporated into the MEWF operational management plan to facilitate the measurement of operational noise as may be required.

Additionally, while it is expected, as detailed in Section 5.0, that the project will satisfy theNZS6808:210 noise criteria, consideration has been given to available contingency strategies to reduce noise levels if required. The following summarises the two key measures available to reduce the noise:

- Procurement contract: the procurement contract for the supply of turbines to the site will typically include specifications concerning the allowable sound power levels from the turbine, and the permissible characteristics of the turbine. In the event that turbine sound power levels are found to exceed the contracted values, the supplier will be required to implement measures to reduce the noise to the contracted value. This can include measures to rectify manufacturing defects or appropriate control settings.
- Noise reduction management strategy: modern wind farms include control systems which enable the operation of the turbines to be varied according to environmental constraints. Specifically, variable pitch turbines as proposed for this site include control functions which enable the sound power levels of the turbines to be selectively controlled; by adjusting the pitch of blade, the noise level of the turbine can be reduced. In addition, where required, the turbines can be selectively shut down under relevant wind speeds and directions. These types of control measures can be used separately, or in combination, to achieve noise reductions for predetermined wind speed ranges and directions.

7.0 CONCLUSION

It is proposed to develop the Mount Emerald Wind Farm near Atherton in northern Queensland, comprising up to (70) wind turbines. Three (3) candidate turbine models are currently being considered for this project: REpower 3XM104; Siemens SWT-3.0-101, and; Siemens SWT-3.0-108. One hundred and twenty-three (123) receiver locations have been identified in the area around the proposed wind farm.

Consistent with the Editor's note at Section 6.4 PS5 of the PSA 01/11, an assessment of operational wind farm noise has been carried out with consideration of NZS6808:2010 and the EPP 2008. This assessment has identified forty-four (44) noise sensitive locations where wind farm noise levels are predicted to be 35 dB L_{Aeq} or greater.

Predicted wind farm noise levels have been assessed against a base noise limit of 40 dB L_{Aeq} at all assessable wind speeds. Review of land zoning for the MEWF and surrounding area indicate that high amenity noise limits are not applicable.

Predicted broadband A-weighted noise levels have been calculated at all receiver locations using the ISO9613-2:1996 algorithm for the range of operating wind speeds between turbine cut-in and rated power. These predicted levels have been compared with the appropriate noise limits. It has been found that predicted broadband A-weighted wind farm noise complies with the proposed noise limits at all relevant receivers for the REpower 3XM104 and Siemens SWT-3.0-101 candidate turbines. For the Siemens SWT-3.0-108 candidate turbine, a reduced 67 turbine wind farm layout is required for predicted wind farm noise levels to comply with the applicable limits and, additionally, three (3) turbines would be required to operated in a '-5dB' noise restricted operational mode.

Tonal audibility data has been reviewed and, on the basis of the results, no penalty for tonality has been applied in this assessment. Notwithstanding this, further data for the Siemens turbines should be reviewed before commencing any works at site, to confirm levels of tonal audibility.

Low frequency noise levels have been predicted using the Danish EPA 1284 prediction method for $L_{pAL,F}$ levels, with appropriate variations to account for likely indoor-outdoor sound reductions away from the Danish context. Predicted wind farm noise levels ($L_{pAL,F}$) have been found to be less than the 20 dB internal criterion nominated in the LFN Guideline at all assessed locations with the exception of R78 for the SWT-3.0-101 turbine type. Compliance at this location, for this turbine type, can be achieved if turbines T1, T2 and T62 are excluded from the layout.

Additionally, a review of recent infrasound studies and measurements indicates that infrasound levels around the proposed wind farm are expected to be comparable to or less than existing ambient levels of infrasound. Estimated infrasound levels are below the LFN Guideline criteria values.

If the turbine selection and/or layout are to be changed, compliance with the relevant noise limit will need to be reassessed.

8.0 SUMMARY OF PARAMETERS

Documentation of relevant parameters as required by NZS6808:2010 is contained in Appendix A.