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25 August 2016

Ryan Corner Development Pty Ltd
Suite 403, 68 York Street
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Attention: Shaq Mohajerani

Dear Shaq

HAWKESDALE WIND FARM - PROJECT AMENDMENT

The Hawkesdale Wind Farm received planning approval in 2008.

On 21 August 2008, Planning Permit No. 20060221 was issued for the Hawkesdale Wind Farm for the 'use and development of land for a Wind Energy Facility'. Condition 3 of the permit details the specifications of the wind farm, including the number and scale of the turbines. The permit originally specified the tower height of the wind turbines at 78 metres, with an overall height of 121.5 metres above ground level (AGL).

On 12 August 2010, the Minister for Planning approved a minor amendment to the specifications of the wind turbines for the wind farm to allow a tower height of 80 metres and overall height of 126.3 metres AGL.

In 2013, Marshall Day Acoustics (MDA) was commissioned by Ryan Corner Development Pty Ltd (the Proponent) to prepare a noise impact assessment for the approved wind farm at the request of the Department of Transport, Planning and Local Infrastructure[1]. It was specifically requested that the noise impact assessment be carried out in accordance with NZS 6808:2010[2] and the results of the assessment are detailed in MDA Report No. Rp 003 2010165ML dated 11 September 2013 (MDA 2013 Report).

Approval is now sought by the Proponent to further vary the turbine specifications as detailed on the permit. The following amendments are proposed:

- Increase of the tower height to 117 metres, the rotor diameter to 130 metres, and overall tip height to 180 metres AGL. This would result in an overall increase in height of up to 53.7 metres from natural ground level
- Micrositing of a number of turbines and realigning of access tracks
- Reduction in the number of turbines on the Hawkesdale Wind Farm site from the approved thirty-one (31) to twenty-six (26).

The Proponent has commissioned MDA to prepare a revised noise assessment for the Hawkesdale Wind Farm, incorporating the proposed amendments, in accordance with the New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS 6808:2010), as required by the Victorian Government's *Policy and planning guidelines for development of wind energy facilities in Victoria* dated January 2016. MDA has prepared a revised noise assessment with the study being detailed in report Rp 002 R03 2014362ML *Hawkesdale Wind Farm - NZS 6808:2010 Noise Assessment* dated 25 August 2016 (MDA 2016 Report).

[1] Now the Department of Environment, Land, Water & Planning

[2] New Zealand Standard 6808:2010 *Acoustics – wind farm noise* (NZS 6808:2010)

The MDA 2013 Report and MDA 2016 Report are appended to this letter in Appendix A and Appendix B respectively.

Full details of the assessment inputs, methodology and outcomes are documented separately in each report.

A summary of the difference in outcomes between the 2013 and 2016 assessments is provided in Table 1 below. In particular, the table compares the highest predicted noise levels of:

- One (1) candidate turbine considered for the MDA 2013 Report
- Three (3) new candidate turbines considered in the MDA 2016 Report.

Table 1: Comparison of predicted noise levels, dB

Property	Maximum predicted noise levels (L_{A90}*) from MDA Report 003 2010165ML	Predicted noise levels (L_{A90}*) from MDA Report 002 R03 2014362ML			Maximum difference
		Vestas V126	Senvion 3.0M122	GE 3.2-130	
48 (S)	33.5	34.4	32.8	35.0	+1.5
53	34.8	36.4	34.9	37.0	+2.2
58	35.2	35.8	34.3	36.4	+1.2
59	36.6	37.4	35.9	38.0	+1.4
60	36.4	37.2	35.6	37.8	+1.4
61 (S)	39.0	38.9	37.4	39.5	+0.5
62	35.8	36.1	34.6	36.8	+1.0
89	37.7	37.7	36.2	38.3	+0.6
90 (S)	42.0	41.4	39.9	42.0	-
101	36.5	38.2	36.7	38.8	+2.3
164 (S)	38.1	38.9	37.3	39.4	+1.3
165	37.8	37.7	36.2	38.3	+0.5
166 (S)	38.5	39.0	37.4	39.5	+1.0
169	37.2	38.9	37.4	39.5	+2.3
170+	n/a	35.9	34.4	36.5	n/a

* Section C6.2.1 of NZS 6808:2010 states that, *for the purposes of this Standard, the predicted wind farm* [L_{Aeq}] *at any receiver location is deemed to be equivalent to the* [L_{A90}] *value*

\+ This dwelling has been built recently and therefore it was not included within the MDA Report 003 2010165ML

It can be seen from Table 1 that the proposed amendments are predicted to increase wind farm noise levels by up to 2.3 dB based on the proposed candidate turbine models. It is additionally noted that the MDA 2016 Report concludes the following:

- Compliance with the lowest possible NZS 6808:2010 noise limit is achieved at all wind speeds at all identified noise sensitive locations for all three (3) assessed candidate turbine models
- Compliance with the raised ETSU-R-97 noise limit is achieved at all wind speeds at all stakeholder properties for all candidate turbine models
- Compliance with the lowest possible NZS 6808:2010 noise limit is achieved at all wind speeds at all remaining properties in the vicinity of the wind farm for all candidate turbine models
- The cumulative noise assessment indicates that, for receiver locations where predicted noise levels from the Hawkesdale Wind Farm are greater than the Woolsthorpe Wind Farm, predicted cumulative noise levels satisfy the relevant base noise limit applicable to the Hawkesdale Wind Farm. Where predicted noise levels are dominated by the Woolsthorpe Wind Farm, the contribution from the Hawkesdale Wind Farm is not more than 0.4 dB.

It is understood that the Department of Environment, Land, Water & Planning has also requested for the following information to be provided:

> *Revised noise contour made to show the township of Hawkesdale*
>
> *Assessment as to whether the township zone falls within the 35dBA contour in the predictive noise assessment, and whether a 'high amenity area noise limit' should apply*

The noise contours showing the highest predicted wind farm noise levels, using the GE 3.2-130 turbine model, presented in Figure E3 of Appendix E of the MDA 2016 Report has been reproduced in Appendix C together with a zoning map[3] of the area surrounding the Hawkesdale township. It can be seen from Appendix C that predicted noise levels from the Hawkesdale Wind Farm are below 35 dB L_{A90} within the Township Zone of Hawkesdale.

Section 6.1 of the MDA 2016 Report also provides the following comment regarding the applicability of the high amenity area noise limit in the vicinity of the Hawkesdale wind Farm:

> *The Moyne Planning Scheme dated 4 July 2016 does not specify the Farming Zone and Township Zone as promoting a higher degree of protection of amenity related to the sound environment.*
>
> *Following guidance from VCAT determination for the Cherry Tree Wind Farm, as required by the Victorian Guidelines, the high amenity noise limit detailed in NZS 6808:2010 is therefore not considered to be applicable for residential properties in the vicinity of the Hawkesdale Wind Farm.*

We trust this information is satisfactory. If you have any further questions please do not hesitate to contact us.

Yours faithfully

MARSHALL DAY ACOUSTICS PTY LTD

Christophe Delaire

Associate

[3] The zoning map was downloaded from the Department of Environment, Land, Water & Planning *Planning Maps Online* website on 8 August 2016.

APPENDIX A MDA REPORT No. Rp 002 R03 2014362ML

MARSHALL DAY Acoustics

HAWKESDALE WIND FARM
NZS 6808:2010 NOISE ASSESSMENT

Rp 002 R03 2014362ML | 25 August 2016

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Project: **HAWKESDALE WIND FARM**
NZS 6808:2010 Noise Assessment

Prepared for: **Ryan Corner Development Pty Ltd**
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Attention: **Shaq Mohajerani**

Report No.: **002 R03 2014362ML**

Document Control

Status:	Rev:	Comments	Date:	Author:	Reviewer:
Final			16 Dec. 2015	C. Delaire	J. Adcock
Final	01	Minor amendment	23 Dec. 2015	C. Delaire	J. Adcock
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Final	02	Minor amendments	3 Aug 2016	C. Delaire	D. Griffin
Final	03	Includes consideration for Hawkesdale township	25 Aug 2016	C. Delaire	D. Griffin

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1.0 INTRODUCTION

This report, commissioned by Ryan Corner Development Pty Ltd (the Proponent), details the results of a noise assessment for the Hawkesdale Wind Farm in accordance with the New Zealand Standard 6808:2010 *Acoustics – Wind farm noise,* which is the guidance document for noise assessment that is referenced in the Victorian Government's *Policy and planning guidelines for development of wind energy facilities in Victoria* dated January 2016.

The assessment is being carried out to inform potential amendments to the project's planning permit regarding the number, size and location of turbines that may be included in the project.

This assessment also considers cumulative wind farm noise impacts with the proposed Woolsthorpe Wind Farm which is situated to the south-east of the Hawkesdale Wind Farm.

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

2.0 PROJECT DESCRIPTION

2.1 Wind farm layout

The Hawkesdale Wind Farm has been approved for development with planning permit No. 20060221 having been issued on 12 August 2008.

The wind farm is located near the township of Hawkesdale, Victoria, between Hamilton and Warrnambool.

A plan of a proposed twenty-six (26) turbine layout for the wind farm is presented in Appendix B together with coordinates for the wind turbines and nearby residential properties.

2.2 Wind turbines

2.2.1 Turbine type

Three candidate turbine models have been selected for this project as detailed in Table 1 below.

Table 1: WTG manufacturer specifications

Detail	Vestas V126	Senvion 3.0M122	GE 3.2-130
Make	Vestas	Senvion	GE Wind
Model	V126	M122	3.2-130
Rated power (MW)	3.3	3.0	3.2
Rotor Diameter (m)	126	122	130
Hub Height (m)	117	117	110
Overall Tip Height (m)	180	178	175
Serrated trailing edge	Yes	No	Yes
Rotor speed (rpm)	5.3-16.5	5.1-11.3	7.6-12.1
Wind Speed range (hub height, m/s)	3.0-22.5	3.0-22.0	3.0-25.0
Rated Wind Speed (hub height, m/s)	12.0	11.50	12.0
Sound Power L_{WA} at 10m/s (hub height, dB)	106.5*	105.5**	107.0**
Tonal audibility ($\Delta L_{a,k}$>0 dB)	Up to 0.96 dB	No[+]	No [+]

* Measured sound power level, including a margin to account for the combined uncertainty (See Section 2.2.2)
** Sound power levels include a 1 dB margin to account for uncertainties (See Section 2.2.2)
[+] See Section 2.2.3

2.2.2 Sound power levels

Sound power levels used in the assessment have been sourced from the documents presented in Table 2, for each of the candidate turbine models.

Table 2: Reference documents

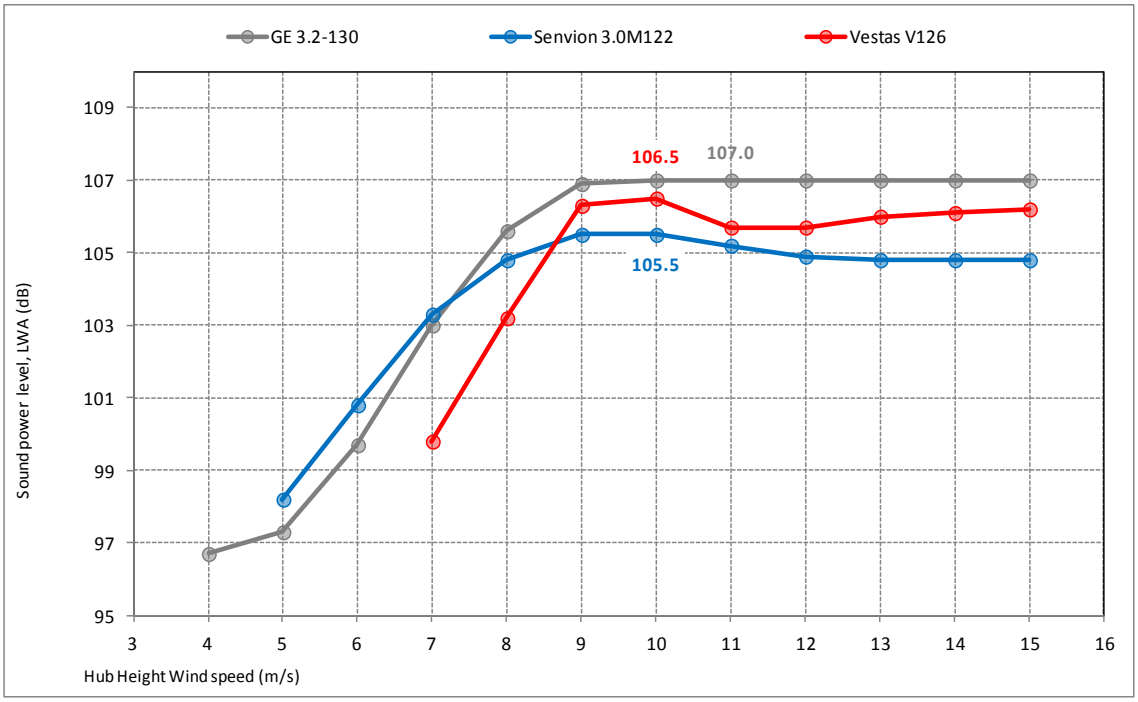
Model	Reference document
Vestas V126	DNV-GL Test Report No. GLGH-4286 14 12099 293-A-0005-A *Vestas V126-3.3MW IEC3A, mode 0, V201503 Results of acoustic noise measurements according to IEC 612400-11 Edition 3* dated 5 November 2014 (Vestas Test Report)
Senvion 3.0M122	Senvion document No. SD-3.5-WT.PC.00-A-D-EN *Power Curve & Sound Power Level 3.0M122 [50Hz]* dated 20 January 2014 (Senvion Document)
GE 3.2-130	GE Power & Water *Product Acoustic Specifications - Normal Operation according to IEC Incl. Octave Band Spectra and 1/3rd Octave Band Spectra* (GE Specification)

For each of the candidate turbines, the sound power level values used for this assessment have been derived from the above documents. The following details are noted:

- Vestas V126: The Vestas Test Report presents sound power levels based on results of measurements from one turbine. The report also includes details of the measurement uncertainty. Data used in this assessment for the Hawkesdale Wind Farm has been determined by adding the uncertainty values to the reported sound power levels.
- Senvion 3.0M122: The Senvion document provides guaranteed sound power levels excluding measurement uncertainty. For the current assessment, 1 dB has been added to the guaranteed levels as a nominal allowance for measurement uncertainty.
- GE 3.2-130: The GE document provides a performance specification for turbine sound power levels along with guidance on determining uncertainty levels. For the current assessment, 1 dB has been added to the specification data as a nominal allowance for measurement uncertainty.

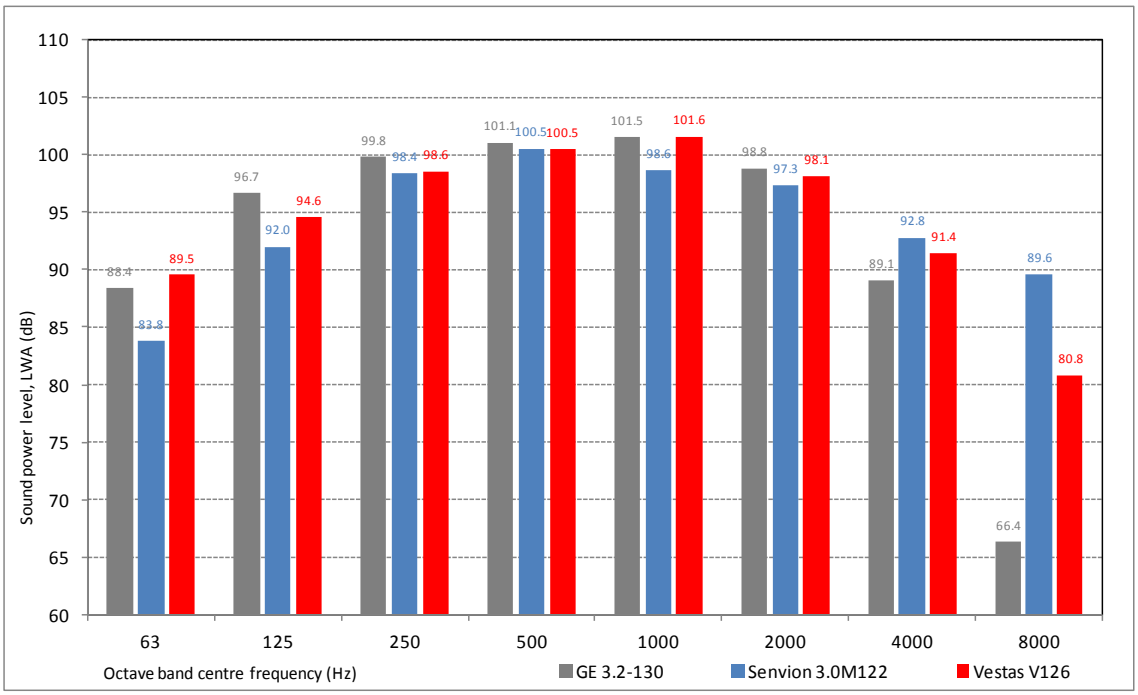
The profile of A-weighted sound power levels as a function of hub height wind speed is presented in Figure 1, for each of the candidate turbine models including the uncertainty tolerances outlined above.

Figure 1: Sound power levels vs. hub height wind speed



The octave band values provided in the reference documents have been adjusted to the highest sound power level detailed in Figure 1 and are presented in Figure 2, for each of the candidate turbine models.

Figure 2: A-weighted octave band sound power level spectra



Tabular values are also presented in Appendix G.

2.2.3 Tonality

For each of the candidate turbines, tonal audibility values ($\Delta L_{a,k}$) are specified in the reference documents as follows:

- Vestas V126: The Vestas Test Report presents values of tonal audibility up to 0.96 dB at the hub height wind speed of 6.5 m/s
- Senvion 3.0M122: Senvion SE warrants tonal audibility $\Delta L_{a,k} < 0$ dB (for wind speeds above 6 m/s at 10 m AGL)
- GE 3.2-130: Test report No. SE14009B2 prepared by Wintest Grevenbroich GmbH for GE Wind Energy GmbH and dated 10 July 2014 presents a summary of results from sound power level testing of GE 2.5-120 turbines in accordance with IEC 61400-11[1], including tonal audibility values below 0 dB at all measured wind speeds. We have been advised by the manufacturer that the GE 3.2-130 is the latest evolution of the same turbine platform and therefore tonal audibility values for the GE 2.5-120 may be used to inform the potential for tonality for the GE 3.2-130 turbine model.

2.3 Residential properties

One-hundred and sixty-six (166) residential properties have been identified by the Proponent in the vicinity of the proposed wind farm, of which six (6) are stakeholders. These properties are presented in Appendix B.

3.0 NOISE CRITERIA

At the time of approval of the Hawkesdale Wind Farm, wind farm noise was assessed in accordance the New Zealand Standard 6808:1998 *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS 6808:1998). Condition 18 of the planning permit requires that compliance with the NZS 6808:1998 criteria be achieved at *any dwelling existing on land in the vicinity of the proposed wind energy facility as at 11 April 2007*.

The current noise assessment is being carried out to inform potential amendments to the project's planning permit regarding the number, size and location of turbines that may be included in the project. New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS 6808:2010) has therefore been referenced for this assessment as it is the guidance document that is currently prescribed by the Victorian Government's *Policy and planning guidelines for development of wind energy facilities in Victoria* dated January 2016 (Victorian Guidelines).

3.1 Objective

Section C1.1 of NZS 6808:2010 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 NZS 6808:2010 reads as follows:

> *This Standard provides suitable methods for the prediction, measurement, and assessment of sound from wind turbines. In the context of the Resource Management Act*[2]*, application of this Standard will provide reasonable protection of health and amenity at noise sensitive locations.*

To deliver on this objective the standard specifies noise criteria which are used to assess wind farm noise.

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[1] IEC 61400-11 *Wind turbines - Part 11: Acoustic noise measurement techniques*

[2] The Resource Management Act is a New Zealand legislative act for planning and environmental management.

3.2 Noise limit

Section 5.2 *Noise limit* of NZS 6808:2010 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 5 dB, or a level of 40 dB $L_{A90(10\,min)}$, whichever is the greater.*

This arrangement of noise limits, which is generally consistent with the planning permit, 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 30-35 dB.

Compliance with the criteria may result in wind turbine noise being audible at some locations for some of the time. The foreword of NZS 6808:2010 notes that:

> *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.*

3.3 High amenity areas

Section 5.3.1 of NZS 6808:2010 states that the base noise limit of 40 dB L_{A90} detailed in Section 3.2 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 NZS 6808:2010 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 Victoria. Section 5.3 of NZS 6808:2010 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 NZS 6808:2010, wind farm noise levels (L_{A90}) during evening and nigh-time periods should not exceed the background noise level (L_{A90}) by more than 5 dB or 35 dB L_{A90}, whichever is the greater, for wind speeds below 6 m/s at hub height. High amenity noise limits are not applicable during the daytime period.

3.4 Special audible characteristics

Section 5.4.2 of NZS 6808:2010 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 +6 dB 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.*

While the standard emphasises assessment of special audible characteristics during the post-construction measurement phase of a project, an assessment of tonality is possible pre-construction, using tonality assessments carried out according to IEC61400-11.

3.5 Cumulative assessment

NZS 6808:2010 requires that a unique noise limit apply at each noise sensitive location for the cumulative impact from all affecting wind farms, as stated in Section 5.6.1:

> *The noise limits* [defined in Section 3.2 above] *should apply to the cumulative sound level of all wind farms affecting any noise sensitive location.*

4.0 NOISE ASSESSMENT METHODOLOGY

There are several key stages involved in carrying out a noise assessment for a proposed wind farm in accordance with NZS 6808:2010.

Firstly, preliminary wind farm noise predictions[3] are carried out for all identified residential properties around the wind farm. The results of the preliminary analysis are used for the following:

- Identification of *noise sensitive locations,* where predicted wind farm noise levels exceed 35 dB L_{A90}
- Identification of selected *noise sensitive locations* where background noise monitoring should be undertaken, if required

The background noise surveys allow quantification of the existing ambient noise environment around the proposed site. Section 7.1.4 of NZS 6808:2010 notes the following:

> *If there are no noise sensitive locations within the 35 dB $L_{A90(10\,min)}$ predicted wind farm sound level contour then background sound level measurements are not required.*

Having identified noise sensitive locations and carried out any background noise monitoring that may be required, applicable limits for wind farm noise are determined.

Once noise limits have been established, further wind farm predictions are carried out. Compliance is assessed by comparing the predicted wind farm noise levels with the noise limits over a range of wind speeds.

[3] See Section 7.0

5.0 NOISE SENSITIVE LOCATIONS

NZS 6808:2010 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 therefore include residential dwellings, schools and hotels located outside the wind farm site where predicted wind farm noise levels exceed 35 dB L_{A90}.

As stakeholder properties are located within the wind farm site, they are not considered as noise sensitive locations as part of an assessment in accordance with NZS 6808:2010. However, they have been considered as part of this assessment for informative purpose.

5.1 Preliminary noise predictions

Preliminary noise predictions have been undertaken at the one hundred and sixty-six (166) residential properties identified by the Proponent in the vicinity of the Hawkesdale Wind Farm using the noise prediction methodology detailed in Section 7.0.

Preliminary noise predictions corresponding to the highest sound power levels for each candidate turbine model (as detailed in Section 2.2.2) are presented in Table 3. The results are presented for those locations where predicted wind farm levels exceed 35 dB L_{A90} for at least one of the three (3) candidate turbine models.

Table 3: Preliminary noise predictions, L_{A90} dB

House	Vestas V126	Senvion 3.0M122	GE 3.2-130
48 (S)	34	33	35
53	36	35	37
58	36	34	36
59	37	36	38
60	37	36	38
61 (S)	39	37	40
62	36	35	37
89	38	36	38
90 (S)	41	40	42
101	38	37	39
164 (S)	39	37	39
165	38	36	38
166 (S)	39	37	40
169	39	37	40
170	36	34	37

(S) Stakeholder property

It can be seen from Table 3 that predicted noise levels at fifteen (15) of the identified residential properties in the vicinity of the proposed wind farm are above 35 dB L_{A90}, including five (5) of the stakeholder properties, based on the candidate turbine model providing the highest noise levels.

Ten (10) properties are therefore considered as noise sensitive locations in accordance with NZS 6808:2010.

5.2 Background noise monitoring

Background noise monitoring was undertaken in March 2006 at seven (7) properties.

Results of this survey are presented in MDA Report No. 2005034 001 R2 dated 24 July 2006 together with the relevant noise limits derived in accordance with NZS 6808:1998, applicable at the time of the assessment.

6.0 NOISE LIMITS

6.1 High amenity areas

A discussion of high amenity area limits and their application to Victorian wind farms is provided in Appendix C. As detailed in the appendix, the area surrounding the proposed Hawkesdale Wind Farm is generally zoned Farming Zone.

The Moyne Planning Scheme dated 4 July 2016 does not specify the Farming Zone and Township Zone as promoting a higher degree of protection of amenity related to the sound environment.

Following guidance from VCAT determination for the Cherry Tree Wind Farm, as required by the Victorian Guidelines, the high amenity noise limit detailed in NZS 6808:2010 is therefore not considered to be applicable for residential properties in the vicinity of the Hawkesdale Wind Farm.

6.2 Stakeholder property

The definition given in NZS 6808:2010 of noise sensitive locations specifically excludes dwellings within the wind farm site boundary. For these properties, it is current practice to use the recommendations outlined in the final report by *The European Working Group on Noise from Wind Turbines* (ETSU-R-97) which allows for an increased base noise limit of 45 dB L_{A90} in lieu of the 40 dB L_{A90} minimum noise limit.

6.3 Applicable noise limits

The noise limits detailed in MDA Report No. 2005034 R2 were derived in accordance with the 1998 version of NZS 6808 using background noise levels collected in 2006.

For the purpose of this assessment, the NZS 6808:2010 base noise limit of 40 dB L_{A90} at all wind speeds has been used for all noise sensitive locations. This provides a conservative assessment.

The base noise limit of 45 dB L_{A90} has been used for stakeholder properties.

7.0 NOISE PREDICTIONS

Noise from the Hawkesdale Wind Farm has been predicted using ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO 9613-2:1996) as implemented in version 7.4 of SoundPLAN. Predictions have been carried out using the sound power level data presented in Section 2.2.2.

Section C6.2.1 of NZS 6808:2010 states that, *for the purposes of this Standard, the predicted wind farm* [L_{Aeq}] *at any receiver location is deemed to be equivalent to the* [L_{A90}] *value*.

Calculations have been performed using octave band data from 63 Hz to 8 kHz and each wind turbine has been modelled as a point source at hub height. All noise predictions use a receiver height of 1.5 m AGL. Possible screening effects from the landscape are considered using 10m elevation contour information provided by the proponent. Atmospheric attenuation has been modelled using a temperature of 10 °C and 70 % humidity as recommended by NZS 6808:2010.

The hardness of the ground between the sources and the receivers needs to be defined in accordance with ISO 9613-2:1996. 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 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/50 % soft. 50 % soft ground (G=0.5) has been used in the predictions.

Further details regarding the use of ISO 9613-2 for wind farm noise predictions and the use of G=0.5 is presented in Appendix D.

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.

Noise levels from the Hawkesdale Wind Farm predicted at all noise sensitive locations are presented in Table 4 to Table 6 for each of the candidate turbine models, based on the highest sound power level presented in Section 2.2.2.

Predicted noise levels are compared with the relevant base noise limits, as detailed in Section 6.3.

Table 4: Predicted noise from the Hawkesdale Wind Farm – Vestas V126, dB

House	L_{A90}	Compliance with applicable noise limits?	House	L_{A90}	Compliance with applicable noise limits?
48 (S)	34.4	✓	90 (S)	41.4	✓
53	36.4	✓	101	38.2	✓
58	35.8	✓	164 (S)	38.9	✓
59	37.4	✓	165	37.7	✓
60	37.2	✓	166 (S)	39.0	✓
61 (S)	38.9	✓	169	38.9	✓
62	36.1	✓	170	35.9	✓
89	37.7	✓			

(S) Stakeholder

Table 5: Predicted noise from the Hawkesdale Wind Farm – Senvion 3.0M122, dB

House	L_{A90}	Compliance with applicable noise limits?	House	L_{A90}	Compliance with applicable noise limits?
48 (S)	32.8	✓	90 (S)	39.9	✓
53	34.9	✓	101	36.7	✓
58	34.3	✓	164 (S)	37.3	✓
59	35.9	✓	165	36.2	✓
60	35.6	✓	166 (S)	37.4	✓
61 (S)	37.4	✓	169	37.4	✓
62	34.6	✓	170	34.4	✓
89	36.2	✓			

(S) Stakeholder

Table 6: Predicted noise from the Hawkesdale Wind Farm – GE3.2-130, dB

House	L_{A90}	Compliance with applicable noise limits?	House	L_{A90}	Compliance with applicable noise limits?
48 (S)	35.0	✓	90 (S)	42.0	✓
53	37.0	✓	101	38.8	✓
58	36.4	✓	164 (S)	39.4	✓
59	38.0	✓	165	38.3	✓
60	37.8	✓	166 (S)	39.5	✓
61 (S)	39.5	✓	169	39.5	✓
62	36.8	✓	170	36.5	✓
89	38.3	✓			

(S) Stakeholder

It can be seen from the above tables that predicted noise levels from the Hawkesdale Wind Farm comply with the applicable NZS 68080:2010 limit at all noise sensitive locations for all three (3) assessed candidate turbine models.

Predicted noise levels at all stakeholder properties comply with the recommended ETSU-R-97 noise limit for all candidate turbine models.

Wind farm noise at all residential properties further from the wind farm will be lower than 35 dB L_{A90} and therefore also comply with the lowest possible NZS 6808:2010 noise limit at all wind speeds.

Noise contour maps are presented in Appendix E for the highest sound power levels for each of the candidate turbine models.

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

7.1 Special audible characteristics

Based on the available tonal audibility information discussed in Section 2.2.3, a penalty for tonality has not been applied for any of the assessed wind speeds.

Notwithstanding the above, it is recommended that the procurement contract for the site should stipulate that the turbines must not produce emissions which would attract a penalty when assessed in accordance with the relevant noise criteria and any associated conditions of consent.

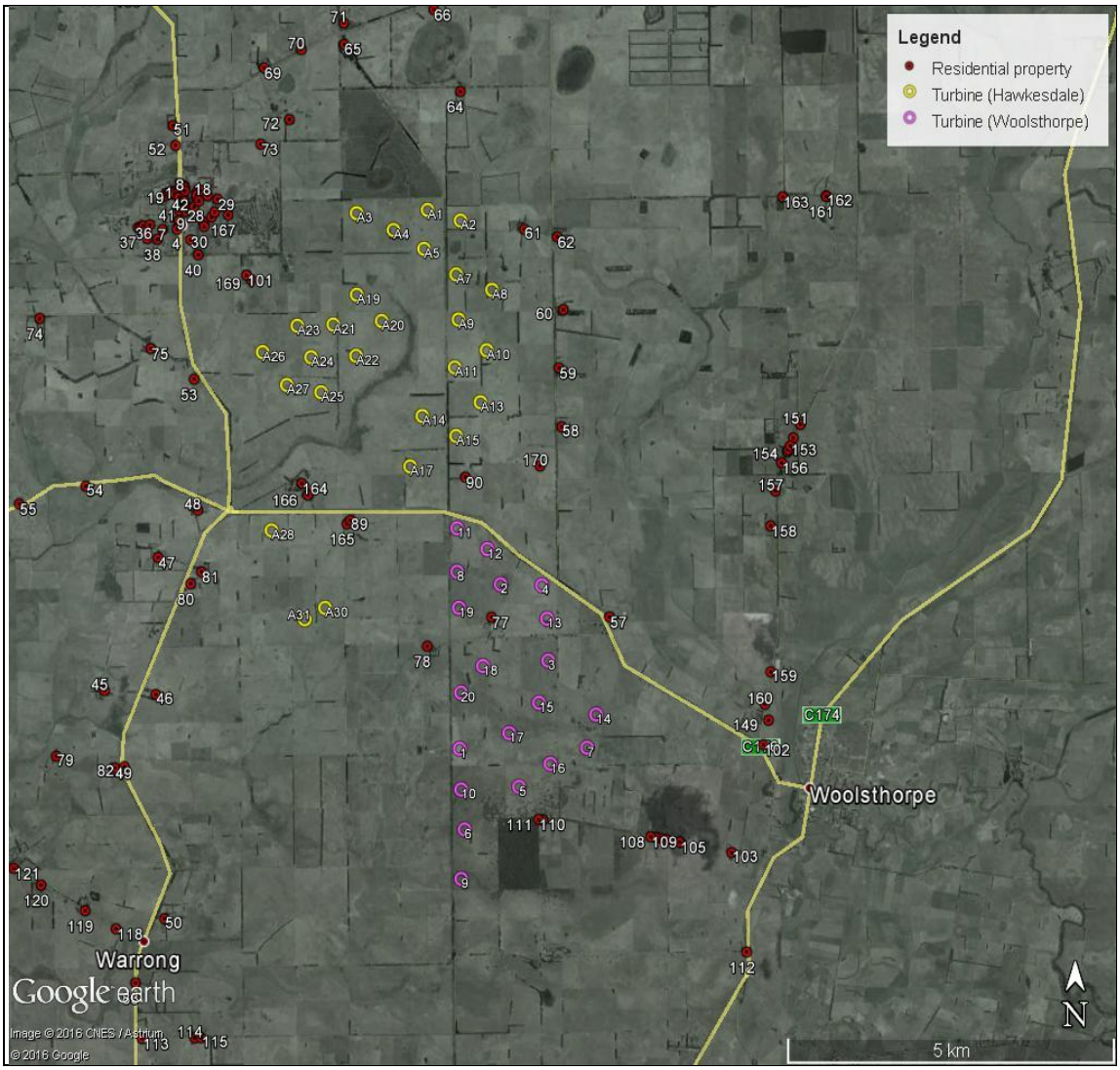
8.0 CUMULATIVE ASSESSMENT

The Proponent has advised that there is one other proposed wind farm in the Hawkesdale area, the Woolsthorpe Wind Farm. Cumulative noise levels from these two (2) proposed projects are assessed in this section.

8.1 Woolsthorpe Wind Farm

Woolsthorpe Wind Farm is a proposed wind farm being developed by Wind Farm Developments and it is located to the south-east of the Hawkesdale Wind Farm. The Woolsthorpe Wind Farm received planning approval in 2008. A site plan showing the relative positions of both the Hawkesdale and Woolsthorpe Wind Farms is presented in Figure 3. The separation distance between the nearest turbine from each wind farm is approximately 1,100 m.

Figure 3: Hawkesdale (green) and Woolsthorpe (red) site layouts



8.1.1 Wind farm layout

The Proponent has provided a revision of the noise assessment letter and report for the Woolsthorpe Wind Farm[4] that was released to the Proponent by the Department of Environment, Land, Water and Planning for the purposes of cumulative assessment. Details of the wind farm layout, turbine sound levels and receiver locations from the Woolsthorpe Wind Farm noise assessment have been used to inform the cumulative assessment of noise levels detailed in this section. The proposed Woolsthorpe Wind Farm layout is tabulated in Appendix F.

8.1.2 Candidate turbine models

As detailed in the Woolsthorpe Wind Farm Noise Assessment, the wind farm is proposed to comprise twenty (20) turbines with a hub height of up to 98 m. The following wind turbine models are considered in the Woolsthorpe Wind Farm noise assessment:

- Senvion 3.4M114 with 93 m hub height
- Senvion 3.4M140 with 98 m hub height
- GE 2.75-120 with 98 m hub height
- GE 3.4-137 with 98 m hub height

8.1.3 Sound power data

Sound power data for each of the candidate turbine models is detailed in Tables 2-7 through 2-10, from Section 2.6 of the Woolsthorpe Wind Farm Noise Assessment. Of the four (4) candidate turbines, the GE 3.4-137 has the highest reported sound power level, 106.0 dB L_{WA}. For the current cumulative noise assessment, this sound level data has been used to represent potential noise levels from Woolsthorpe Wind Farm.

It is understood that the sound data detailed in the Woolsthorpe Wind Farm noise assessment does not directly account for measurement uncertainties. For consistency with the Hawkesdale Wind Farm sound power level data detailed in Section 2.2.2, 1 dB has been added to the Woolsthorpe Wind Farm sound power level data as a nominal allowance for measurement uncertainty. The resulting octave band spectrum used for Woolsthorpe Wind Farm turbines in this cumulative noise assessment presented in Table 7, with an overall sound power level of 107 dB L_{WA}.

Table 7: Highest GE 3.4-137 sound power level spectrum including a 1 dB margin for uncertainties

		Octave Band Centre Frequency (Hz)							
	Overall	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
L_{WA}, dB	107.0	88.4	96.4	99.6	101.4	101.9	97.8	87.8	64.0

8.1.4 Tonality

The Woolsthorpe Wind Farm Noise Assessment does not discuss the potential presence of tonality for the selected candidate turbines.

Following the discussion detailed in Section 2.2.3 above, it has been assumed that the advice from GE regarding tonality for the GE 3.2-130 turbine model is also valid for the GE 3.4-137 turbine model. Therefore, a penalty for tonality has not been applied for predicted noise levels using the GE 3.4-137 turbine model for this cumulative assessment.

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[4] Resonate Acoustics letter A16008LT1 *Woolsthorpe Wind Farm – Review of Woolsthorpe Wind Farm Acoustic Assessment* dated 17 May 2016Woolsthorpe Wind Farm; and
Wind Farm Developments report *Revised noise assessment for Woolsthorpe Wind Farm: For peer review* dated 27 April 2016 (the Woolsthorpe Wind Farm Noise Assessment)

8.1.5 Receivers

The Woolsthorpe Wind Farm Noise Assessment provides coordinates for eleven (11) non-stakeholder receiver locations that are considered as part of the assessment.

Of these eleven (11) locations, ten (10) are generally consistent with receiver locations that have been considered for the HDWF. The remaining receiver is not included in the HDWF receiver set but is considered in this cumulative assessment.

8.2 Noise criteria

As detailed in Section 3.4 above, NZS 6808:2010 requires that a unique noise limit apply at each noise sensitive location for the cumulative impact from all affecting wind farms.

For consistency with the noise limit arrangement detailed in Section 5.2, the NZS 6808:2010 base noise limit of 40 dB L_{A90} is referenced for all wind speeds and all noise sensitive locations.

With regards to high amenity area noise limits:

- For the Hawkesdale Wind Farm they have been determined as not applicable
- The Woolsthorpe Wind Farm Noise Assessment does not explicitly discuss the applicability of high amenity area limits, nor does it apply them for any of the eleven (11) receivers considered in that study.

On the basis of these findings, high amenity area noise limits are not applied for this cumulative assessment.

A base noise limit of 45 dB L_{A90} is used for stakeholder properties where applicable.

8.3 Predicted cumulative noise levels

Noise levels from the Hawkesdale and Woolsthorpe Wind Farms have been predicted in accordance with NZS 6808:2010, as detailed in Section 7.0, and have been compared with noise levels at all identified receiver locations from each wind farm.

Results are presented for the highest sound power level of the turbine models considered for the Hawkesdale Wind Farm. The results are detailed in Section F4 of Appendix F for the three (3) proposed candidate turbine models considered for the Hawkesdale Wind Farm. Each table includes twenty (20) receivers where the highest predicted wind farm noise level for either Hawkesdale or Woolsthorpe is 35 dB L_{A90} or greater.

From the results presented in Appendix F , the following aspects are noted relative to Table 10 which presents the highest predicted noise levels:

- For receiver locations where predicted noise levels from the Hawkesdale Wind Farm are greater than the Woolsthorpe Wind Farm, predicted cumulative noise levels satisfy the relevant base noise limit applicable to the Hawkesdale Wind Farm
- Fifteen (15) of the twenty (20) assessed receiver locations have predicted cumulative noise levels which are less than or equal to the NZS 6808:2010 base noise limit of 40 dB
- Of the five (5) assessed receiver locations with predicted cumulative noise levels which are higher than the 40 dB base noise limit, the predicted contribution of the Hawkesdale Wind Farm is higher than 40 dB at one (1) receiver location ,House 90, which is a stakeholder in that project. The predicted level of noise from the Woolsthorpe Wind Farm at this location is less than 40 dB.

- For the remaining four (4) receiver locations, predicted noise levels from the Hawkesdale Wind farm are all less than 33 dB and the predicted contribution of the Woolsthorpe Wind Farm is greater than 42 dB. This means that the contribution from the Hawkesdale wind Farm to predicted cumulative noise levels is up to 0.4 dB, relative to the noise contribution from the Woolsthorpe Wind Farm.

9.0 CONCLUSION

The Hawkesdale Wind Farm is proposed to consist of twenty-six (26) turbines.

An assessment has been undertaken, using three (3) candidate turbine models with a hub height of up to 117 m, in accordance with NZS 6808:2010 as required by the current Victorian Guidelines.

One-hundred and sixty-six (166) residential properties identified by the Proponent in the vicinity of the project have been considered in this assessment.

Wind farm noise levels predicted using ISO 9613-2:1996, for each candidate turbine model, have been assessed against a base noise limit of 40 dB L_{A90} for non-stakeholder properties identified as noise sensitive locations in accordance with NZS 6808:2010. A review of land zoning surrounding the proposed site indicates that high amenity noise limits are not applicable.

For stakeholders, a base noise limit of 45 dB L_{A90} was used as recommended by supplementary guidance commonly referenced in Victoria (ETSU-R-97).

Results of the NZS 6808:2010 noise assessment are as follows:

- Compliance with the lowest possible NZS 6808:2010 noise limit is achieved at all wind speeds at all identified noise sensitive locations for all three (3) assessed candidate turbine models
- Compliance with the raised ETSU-R-97 noise limit is achieved at all wind speeds at all stakeholder properties for all candidate turbine models
- Compliance with the lowest possible NZS 6808:2010 noise limit is achieved at all wind speeds at all remaining properties in the vicinity of the wind farm for all candidate turbine models
- The cumulative noise assessment indicates that, for receiver locations where predicted noise levels from the Hawkesdale Wind Farm are greater than the Woolsthorpe Wind Farm, predicted cumulative noise levels satisfy the relevant base noise limit applicable to the Hawkesdale Wind Farm. Where predicted noise levels are dominated by the Woolsthorpe Wind Farm, the contribution from the Hawkesdale Wind Farm is not more than 0.4 dB.

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

10.0 SUMMARY OF PARAMETERS

Documentation of relevant parameters as required by NZS 6808:2010 is contained in Appendix G.

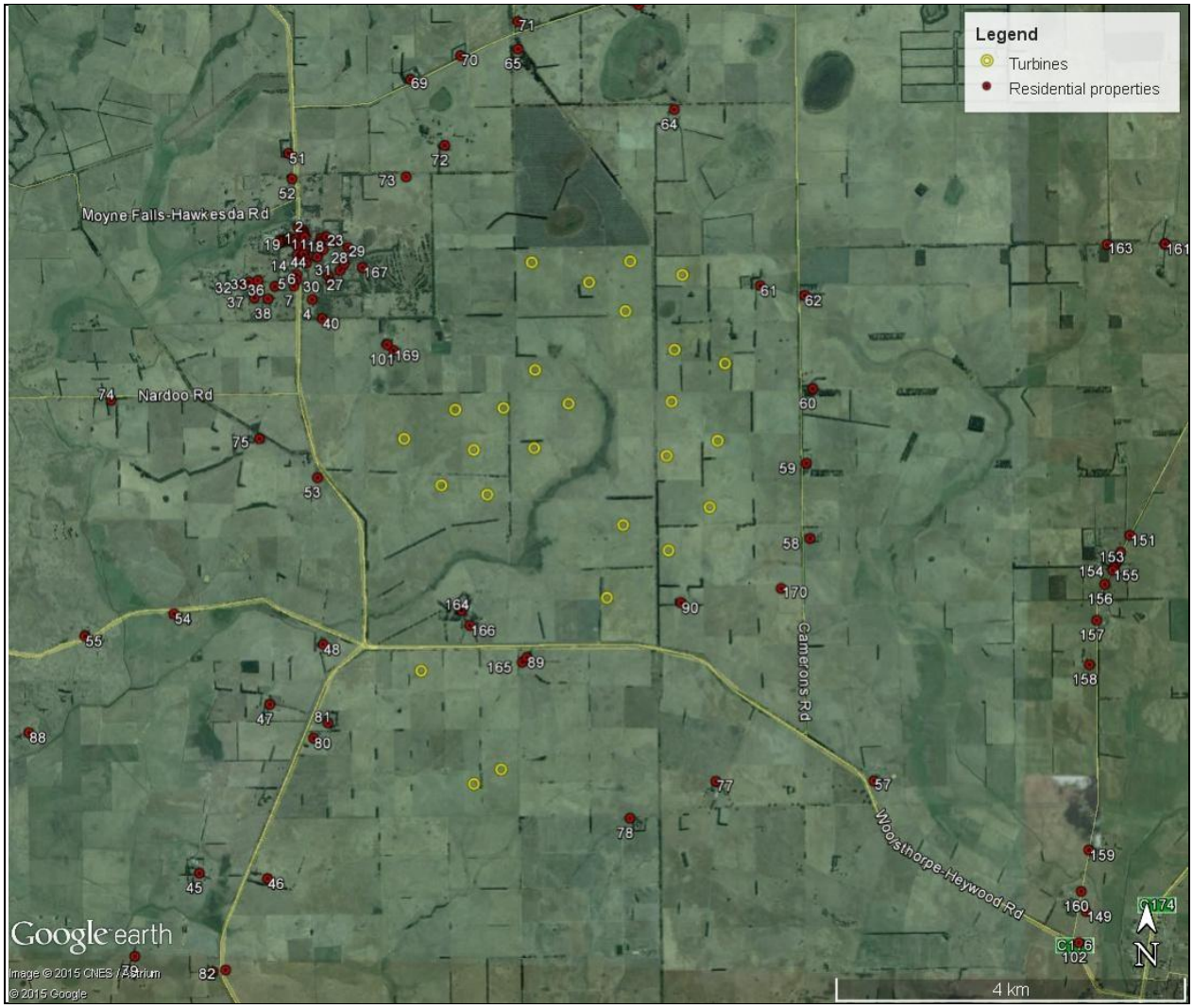
APPENDIX A GLOSSARY OF TERMINOLOGY

Ambient	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.
dB	Decibel. The unit of sound level.
dBA	A-weighted decibel. The A-weighting approximates the response of the human ear
Frequency	Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals. Sound is generally described over the frequency range from 63Hz to 4000Hz (4kHz). This is roughly equal to the range of frequencies on a piano.
Octave band	Sound, which can occur over a range of frequencies, may be divided into octave bands for analysis. The audible frequency range is generally divided into 7 octave bands. The octave band frequencies are 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz and 4kHz.

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

L_{A90}	The noise level exceeded for 90% of the measurement period, measured in dBA. This is commonly referred to as the background noise level.
L_{Aeq}	The equivalent continuous sound level. This is commonly referred to as the average noise level and is measured in dBA.

APPENDIX B HAWKESDALE WIND FARM LAYOUT



B1 Turbine coordinates (AGD66 Zone 54)

Turbine	Easting	Northing	Turbine	Easting	Northing	Turbine	Easting	Northing
A1	619551	5780999	A11	619933	5778714	A23	617535	5779352
A2	620052	5780838	A13	620319	5778204	A24	617739	5778894
A3	618466	5780969	A14	619427	5778019	A25	617885	5778384
A4	619026	5780716	A15	619939	5777722	A26	617000	5778978
A5	619489	5780437	A17	619230	5777292	A27	617363	5778498
A7	619974	5780059	A19	618450	5779788	A28	617098	5776397
A8	620518	5779829	A20	618826	5779402	A30	617900	5775264
A9	619999	5779406	A21	618085	5779362	A31	617587	5775103
A10	620423	5778955	A22	618427	5778904			

B2 Dwellings coordinates (AGD66 Zone 54)

Property	Easting	Northing	Distance to nearest turbine (m)	Property	Easting	Northing	Distance to nearest turbine (m)
1	615838	5781370	2639	88	612592	5775761	4552
2	615848	5781395	2652	89	618315	5776542	1188
3	615834	5781422	2673	90 (s)	620082	5777137	612
4	615931	5780634	1974	91	609818	5776327	7281
5	615756	5780855	2254	92	621472	5785306	4689
6	615758	5780919	2307	93	621474	5785983	5339
7	615724	5780789	2218	94	621478	5786033	5388
8	615856	5781340	2604	95	621470	5786016	5370
9	615864	5781092	2402	96	622628	5784873	4788
10	615842	5781151	2465	97	623372	5784951	5287
11	615849	5781196	2501	98	624002	5785036	5765
12	615763	5781254	2593	99	624716	5785077	6303
13	615769	5781149	2498	100	625114	5785071	6600
14	615767	5781061	2423	101	616777	5780110	1077
15	615777	5781451	2734	102	624578	5773200	6479
16	615758	5781323	2656	103	624070	5771647	7153
17	615667	5781316	2693	104	623289	5771802	6406
18	616198	5781270	2290	105	623278	5771810	6393
19	615696	5781301	2666	106	623077	5771849	6203
20	615693	5781334	2696	107	622969	5771875	6099
21	615650	5781325	2710	108	622910	5771882	6046
22	615613	5781316	2721	109	622836	5771893	5978
23	616107	5781342	2391	110	621126	5772170	4471
24	616031	5781282	2449	111	621198	5772157	4532
25	616035	5781322	2459	112	624280	5770203	8144
26	615567	5781315	2744	113	615019	5769085	6544
27	616255	5780958	2057	114	615823	5769083	6274
28	616306	5781031	2084	115	615920	5769083	6247
29	616351	5781214	2132	116	618059	5768498	6623
30	616143	5780822	2027	117	614544	5767596	8101
31	616122	5780897	2097	118	614645	5770679	5314
32	615127	5780823	2631	119	614176	5770948	5377
33	615311	5780860	2531	120	613508	5771329	5558
34	615208	5780848	2592	121	613091	5771578	5714
35	615164	5780814	2599	122	611897	5772988	6071
36	615505	5780789	2351	123	610950	5774098	6565

Property	Easting	Northing	Distance to nearest turbine (m)	Property	Easting	Northing	Distance to nearest turbine (m)
37	615269	5780664	2419	124	612490	5771532	6224
38	615425	5780649	2299	125	612127	5771538	6522
39	615667	5781316	2693	126	611550	5771536	7013
40	616044	5780416	1730	127	610124	5771401	8331
41	615869	5781047	2360	128	609517	5771181	8973
42	616066	5781195	2359	129	609637	5771358	8789
43	616024	5781252	2430	130	609850	5775326	7328
44	615994	5781113	2343	131	611067	5775711	6071
45	614522	5774130	3218	132	611067	5775684	6074
46	615305	5774062	2511	133	610954	5775313	6240
47	615365	5776046	1772	134	610585	5774627	6750
48 (s)	615985	5776720	1164	135	614750	5784569	5175
49	614661	5773009	3600	136	614815	5784191	4871
50	615388	5770814	4821	137	614815	5784191	4871
51	615686	5782292	3081	139	612203	5782565	5991
52	615720	5782004	2937	140	612150	5782659	6090
53	615956	5778615	1111	141	611937	5782969	6448
54	614278	5777092	2906	142	607581	5782800	10165
55	613253	5776851	3873	143	608527	5782800	9296
57	622253	5775083	3512	144	606776	5781497	10530
58	621562	5777844	1299	145	606771	5780585	10355
59	621532	5778697	1144	146	608491	5779620	8534
60	621614	5779538	1139	147	609063	5779604	7962
61 (s)	621034	5780713	996	148	611109	5779583	5923
62	621538	5780594	1280	149	624663	5773553	6301
64	620085	5782720	1805	150	626173	5785005	7406
65	618319	5783428	2466	151	625211	5777826	4908
66	619699	5783912	2919	152	625103	5777633	4819
67	620013	5784514	3547	153	625053	5777517	4785
68	620679	5784116	3317	154	625022	5777463	4762
69	617091	5783106	2543	155	625006	5777433	4751
70	617664	5783364	2528	156	624915	5777276	4690
71	618321	5783738	2775	157	624819	5776868	4695
72	617467	5782352	1710	158	624733	5776364	4783
73	617023	5782003	1779	159	624705	5774253	5896
74	613607	5779530	3439	160	624611	5773783	6112
75	615301	5779069	1705	161	625657	5781121	5300
77	620450	5775106	2506	162	625657	5781121	5300

Property	Easting	Northing	Distance to nearest turbine (m)	Property	Easting	Northing	Distance to nearest turbine (m)
78	619464	5774701	1666	163	624991	5781122	4657
79	613767	5773192	4273	164 (s)	617577	5777085	845
80	615861	5775655	1447	165	618261	5776488	1172
81 (s)	616027	5775828	1218	166 (s)	617669	5776914	778
82	614807	5773023	3474	167	616510	5780986	1932
83	614930	5769891	5851	168	615558	5781279	2718
84	615001	5784248	4772	169	616848	5780043	980
85	614084	5786998	7454	170	621225	5777282	1297
86	615119	5784218	4666				
87	612261	5777081	4886				

(S) Stakeholder property

APPENDIX C HIGH AMENITY AREA NOISE LIMITS

C1 NZS 6808:2010 requirements

The concept of a high amenity area was introduced in the 2010 version of NZS 6808. Section 5.3 of NZS 6808:2010 provides details of high amenity noise limits, requiring that where a noise sensitive location is situated within a high amenity area, as defined in Sections 5.3.1 and 5.3.2 of NZS 6808:2010, wind farm noise levels (L_{A90}) during evening and nigh-time periods should not exceed the background noise level (L_{A90}) by more than 5 dB or 35 dB L_{A90}, whichever is the greater, for wind speeds below 6 m/s at hub height. High amenity noise limits are not applicable during the daytime period.

Section 5.3 of NZS 6808:2010 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…*

Subsequent to this, Section C5.3.1 of the Standard provides a calculation procedure for evaluating whether relevant background noise levels for a potential high amenity area are sufficiently low to confirm the application of a high amenity noise limit.

C2 Victorian requirements

High amenity noise limits are explicitly referenced in the Victorian Guidelines, with Section 5.1.2.a stating the following.

> *Under section 5.3 of the Standard, a 'high amenity noise limit' of 35 decibels applies in special circumstances. All wind farm applications must be assessed using section 5.3 of the Standard to determine whether a high amenity noise limit is justified for specific locations, following procedures outlined in clause C5.3.1 of the Standard. Guidance can be found on this issue in the VCAT determination for the Cherry Tree Wind Farm.*

The definition of a high amenity area provided in NZS 6808:2010 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 area in Victoria, specifically in order to satisfy Section 5.1.2.a of the guidelines. In particular it is unclear whether the Victorian Guidelines intend for an assessment of high amenity area to explicitly include an evaluation using Section C5.3.1 of the Standard or whether an evaluation based on planning legislation only may be appropriate in some cases. Due to this ambiguity, the means of applying the Victoria Guidelines requirements to an assessment of high amenity area for a Victorian wind farm is, to some degree, uncertain.

C3 VCAT Cherry Tree determination

The VCAT determination detailed in the Cherry Tree Wind Farm Pty Ltd v Mitchell Shire Council decision[5], as referenced by the Victorian Guidelines, does however provide some additional context to this issue. Paragraph 53 of the Cherry Tree Wind Farm Decision states the following:

> *The Tribunal does not accept that the permit conditions need to refer to the High Amenity Area provisions of the New Zealand standard because it has not been established that any such area could reasonably be identified within the environs of this wind energy facility.* […]

Justification for this statement was provided in Paragraphs 107 to 109 of the Cherry Tree Wind Farm Interim Decision:

> *107. We were invited by the respondents to treat the subject land and the locality as a high amenity area. This invitation meets with the immediate conundrum that the language of the standard is not translatable to the Victorian planning framework. The "plan" referred to in section 5.3 is a plan as defined by the Resources Management Act of New Zealand. Section 43AA of that Act defines "plan" to mean "a regional plan or a district plan". No such animals exist under the Victorian legislation.*
>
> *108. Applying the standard mutatis mutandis to the Victorian experience we treat the plan referred to in the standard as a planning scheme approved under the Planning and Environment Act 1987. The Mitchell Planning Scheme does not anywhere expressly or by implication "promote a higher degree of protection of amenity related to the sound environment of a particular area". Approaching the matter by a process of elimination it can be seen with certainty that the controls contained within the Farming zone, which includes most of the locality, do not answer this description. The purpose of the Farming zone is to encourage agricultural use, which is not an inherently quiet land use. In fact reference to the zone purposes confirms that agricultural use is to be preferred to residential use if there is potential conflict between the two.*
>
> *109. Accordingly the Tribunal concludes that the subject land and its locality is not capable of designation as a high amenity area because it does not possess the necessary characteristics of such an area as specified in the NZ standard.*

As detailed in Paragraph 108, for the land surrounding the wind farm to be considered a high amenity area, the zoning of the land must be identified in the relevant planning scheme as *promoting a higher degree of protection of amenity related to the sound environment*.

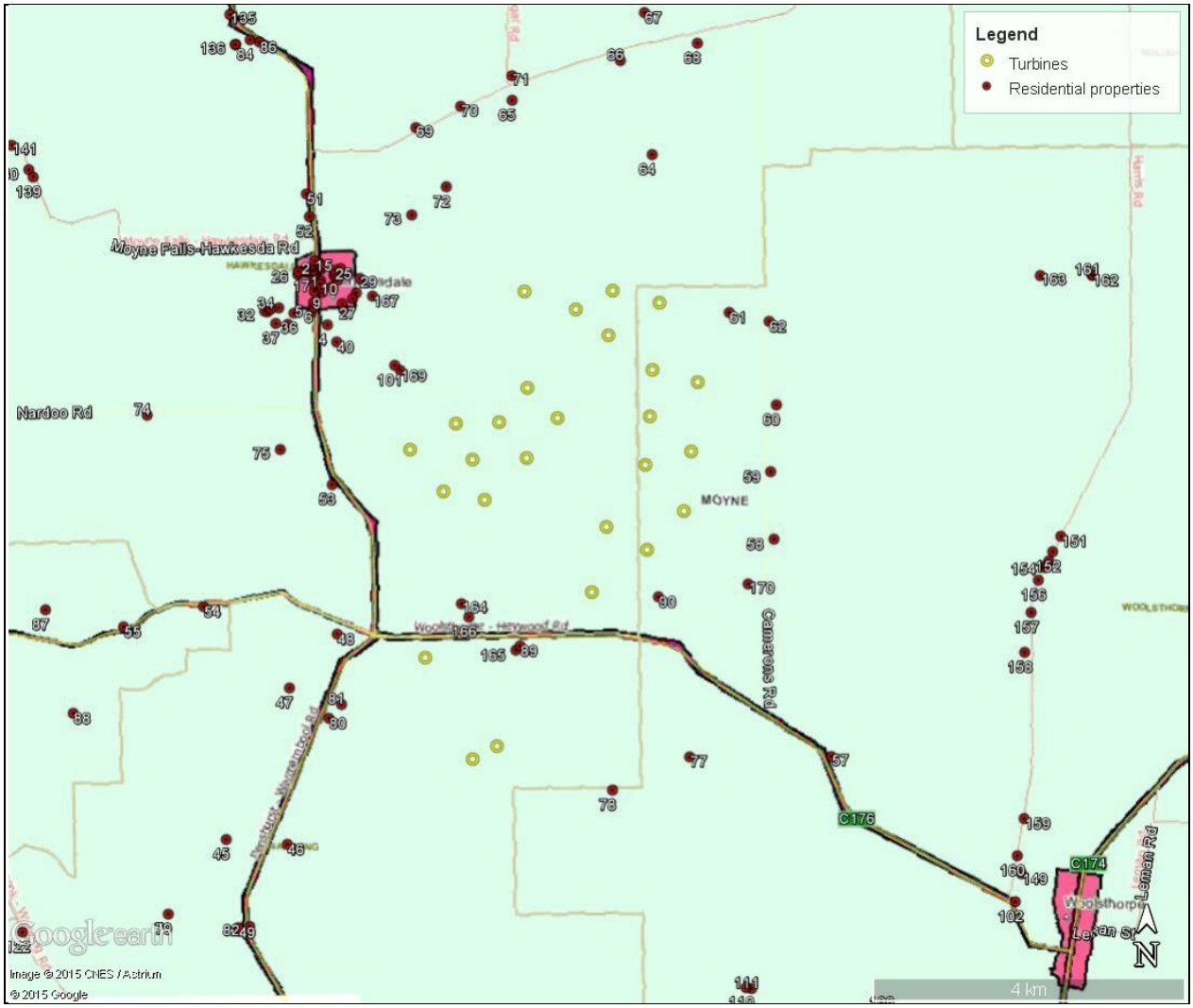
[5] Mitchell Shire Council interim decision dated 4 April 2013 (the Cherry Tree Wind Farm Interim Decision) and Mitchell Shire Council decision dated 27 November 2013 (the Cherry Tree Wind Farm Decision)

C4 Planning considerations

NZS 6808:2010 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.

The area surrounding the proposed Hawkesdale Wind Farm is generally zoned Farming Zone as shown in the planning map in Figure 1, with Hawkesdale zoned as Township Zone (see Figure 2).

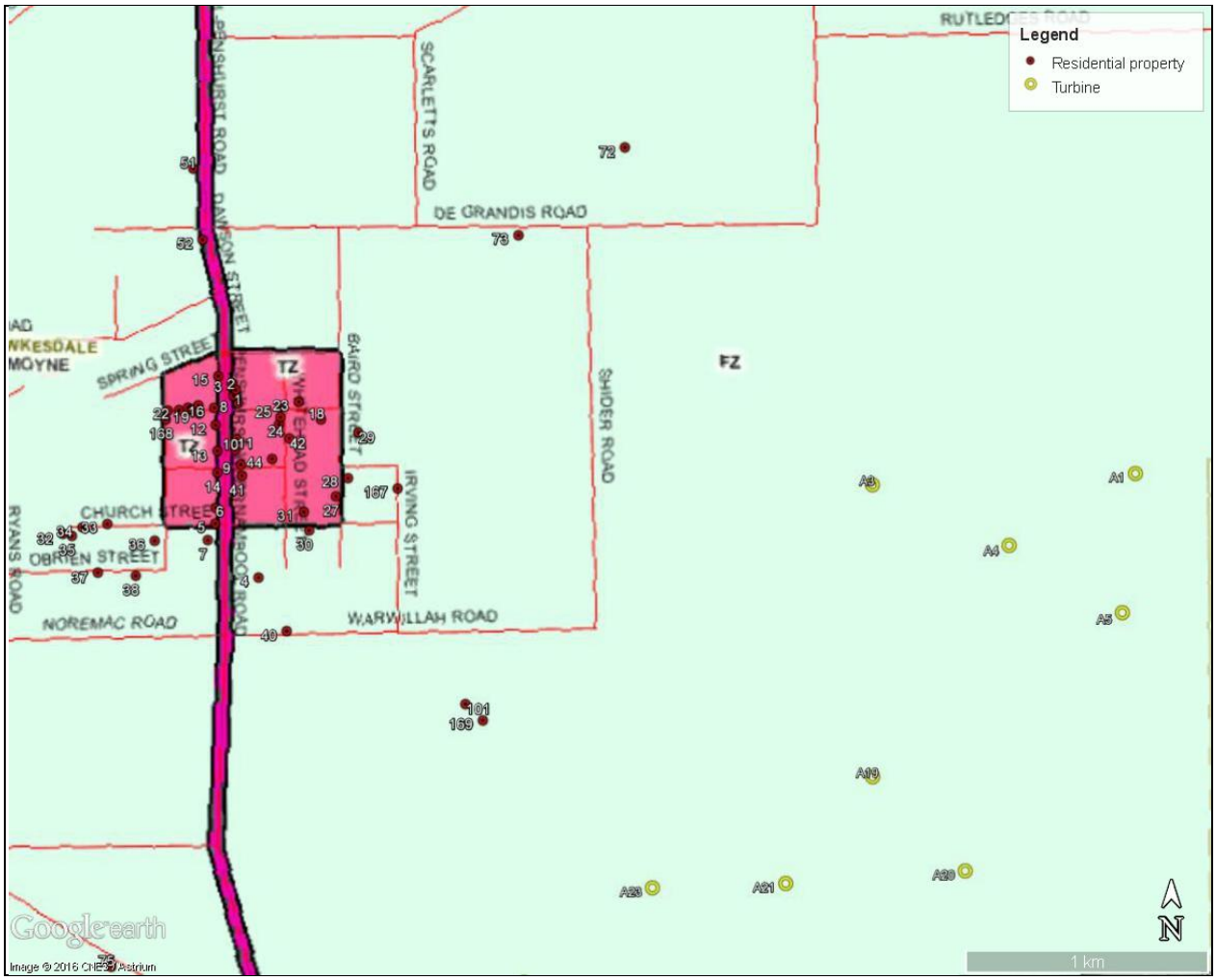
Figure 1: Planning map[6]



Legend: Light green – Farming Zone
Pink – Township Zone

[6] The zoning map was downloaded from the Department of Environment, Land, Water & Planning *Planning Maps Online* website on 21 August 2015.

Figure 1: Planning map (Hawkesdale township)[7]



Legend: Light green – Farming Zone
Pink – Township Zone

The Moyne Planning Scheme dated 4 July 2016 does not specify the Farming Zone and Township Zone as promoting a higher degree of protection of amenity related to the sound environment.

Following guidance from VCAT determination for the Cherry Tree Wind Farm, as required by the Victorian Guidelines, the high amenity noise limit detailed in NZS 6808:2010 is therefore not considered to be applicable for residential properties in the vicinity of the Hawkesdale Wind Farm.

[7] The zoning map was downloaded from the Department of Environment, Land, Water & Planning *Planning Maps Online* website on 8 August 2016.

APPENDIX D NOISE PREDICTION MODEL

Operational wind farm noise levels are predicted at all residential dwellings considered within this assessment using a three-dimensional noise model generated in SoundPLAN® version 7.4 software. Specifically, predictions have been carried out using the SoundPLAN implementation of ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO 9613-2:1996) to calculate noise propagation from the wind farm to each receiver location.

The use of this method is supported by international research publications, measurement studies conducted by Marshall Day Acoustics and direct reference to the standard in NZS 6808:2010 *Acoustics – Wind farm noise* (NZS 6808:2010).

The standard specifies an engineering method for calculating noise at a known distance from a variety of sources under meteorological conditions favourable to sound propagation. The standard defines favourable conditions as downwind propagation where the source blows from the source to the receiver within an angle of +/-45 degrees from a line connecting the source to the receiver, at wind speeds between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground. Equivalently, the method accounts for average propagation under a well-developed moderate ground based thermal inversion. In this respect, it is noted that at the wind speeds relevant to noise levels from wind turbines, atmospheric conditions do not favour the development of thermal inversions throughout the propagation path from the source to the receiver.

To calculate far-field noise levels according to the ISO 9613-2:1996, the noise levels of each turbine are firstly characterised in the form of octave band frequency levels. A series of octave band attenuation factors are then calculated for a range of effects including:

- Geometric divergence
- Air absorption
- Reflecting obstacles
- Screening
- Vegetation
- Ground reflections

The octave band attenuation factors are then applied to the sound power level data to determine the corresponding octave band and total calculated noise level at relevant receiver locations.

Calculating the attenuation factors for each effect requires a relevant description of the environment into which the sound propagation such as the physical dimensions of the environment, atmospheric conditions and the characteristics of the ground between the source and the receiver.

Wind farm noise propagation has been the subject of considerable research in recent years. These studies have provided support for the reliability of engineering methods such as ISO 9613-2:1996 when a certain set of input parameters are chosen in combination.

A number of Australian and international studies support the assignment of a ground absorption factor of G=0.5 for the source, middle and receiver ground regions between a wind farm and a calculation point. This ground absorption factor of G=0.5 is adopted in combination with several cautious assumptions; specifically all turbines operating at identical wind speeds, emitting sound levels equal to the test measured levels plus a margin for uncertainty (or guaranteed values), at a temperature of 10 degrees and relative humidity of 70 % (conditions which give rise to low atmospheric absorption). The studies demonstrate that applying the ISO 9613-2:1996 prediction methodology in this way provides a reliable representation of the upper noise levels expected in practice.

The following specific adjustments have been made:

- In instances where the ground terrain provides marginal or partial acoustic screening, the barrier effect should be limited to not more than 2 dB
- Screening attenuation calculated based on the screening expected for the source located at the tip height of the turbine (in contrast to hub height in non-adjusted ISO 9613 predictions)
- In instances where the ground falls away significantly between the source and receiver, such as valleys, an adjustment of 3 dB should be added to the calculated sound pressure level. A terrain profile in which the ground falls away significantly is defined as one where the mean sound propagation height is at least 50 % greater than would occur over flat ground

In support of the use of ISO 9613-2:1996 and the choice of G=0.5 as an appropriate ground characterisation, the following references are noted:

- A factor of G=0.5 is frequently applied in Australia for general environmental noise modelling purposes as a way of accounting for the potential mix of ground porosity which may occur in regions of dry/compacted soils or in regions where persistent damp conditions may be relevant
- NZS 6808:2010 refers to ISO 9613-2:1996 as an appropriate prediction methodology for wind farm noise, and notes that soft ground conditions should be characterised by a ground factor of G=0.5
- In 1998, a comprehensive study, part funded by the European Commission, Development of a Wind Farm Noise Propagation Prediction Model[8] found that the ISO 9613-2:1996 model provided a robust representation of upper noise levels which may occur in practice, and provided a closer agreement between predicted and measured noise levels than alternative standards such as CONCAWE and ENM. Specifically, the report indicated the ISO 9613-2:1996 method generally tends to marginally over predict noise levels expected in practice
- The UK Institute of Acoustics journal dated March/April 2009 published a joint agreement between practitioners in the field of wind farm noise assessment, including consultants routinely employed on behalf of both developers and community opposition groups, and indicated the ISO 9613-2:1996 method as the appropriate standard and specifically designated G=0.5 as the appropriate ground characterisation. It is noted that this publication specifically refers to predictions made to receiver heights of 4 m in the interest of representing 2-storey dwellings which are more common in the UK. Predictions in Australia are generally based on a lower prediction height of 1.5 m which tends to result in higher ground attenuation factors, however conversely, predictions in Australia do not generally incorporate a -2 dB factor (as applied in the UK) to represent the relationship between L_{Aeq} and L_{A90} noise levels. The result is that these differences tend to balance out to a comparable approach and thus supports the use of G=0.5 in the context of Australian prediction methodologies.
- A range of comparative measurement and prediction studies[9, 10, 11] for wind farms in which Marshall Day Acoustics' staff have been involved in have provided further support for the use of ISO 9613-2:1996 and G=0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

---

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

[9] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions: The Risks of Conservatism*; Presented at the Second International Meeting on Wind Turbine Noise in Lyon, France September 2007.

[10] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions and Comparisons with Measurements*; Presented at the Third International Meeting on Wind Turbine Noise in Aalborg, Denmark June 2009.

[11] Delaire, Griffin, & Walsh – *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*; Presented at the Fourth International Meeting on Wind Turbine Noise in Rome, April 2011.

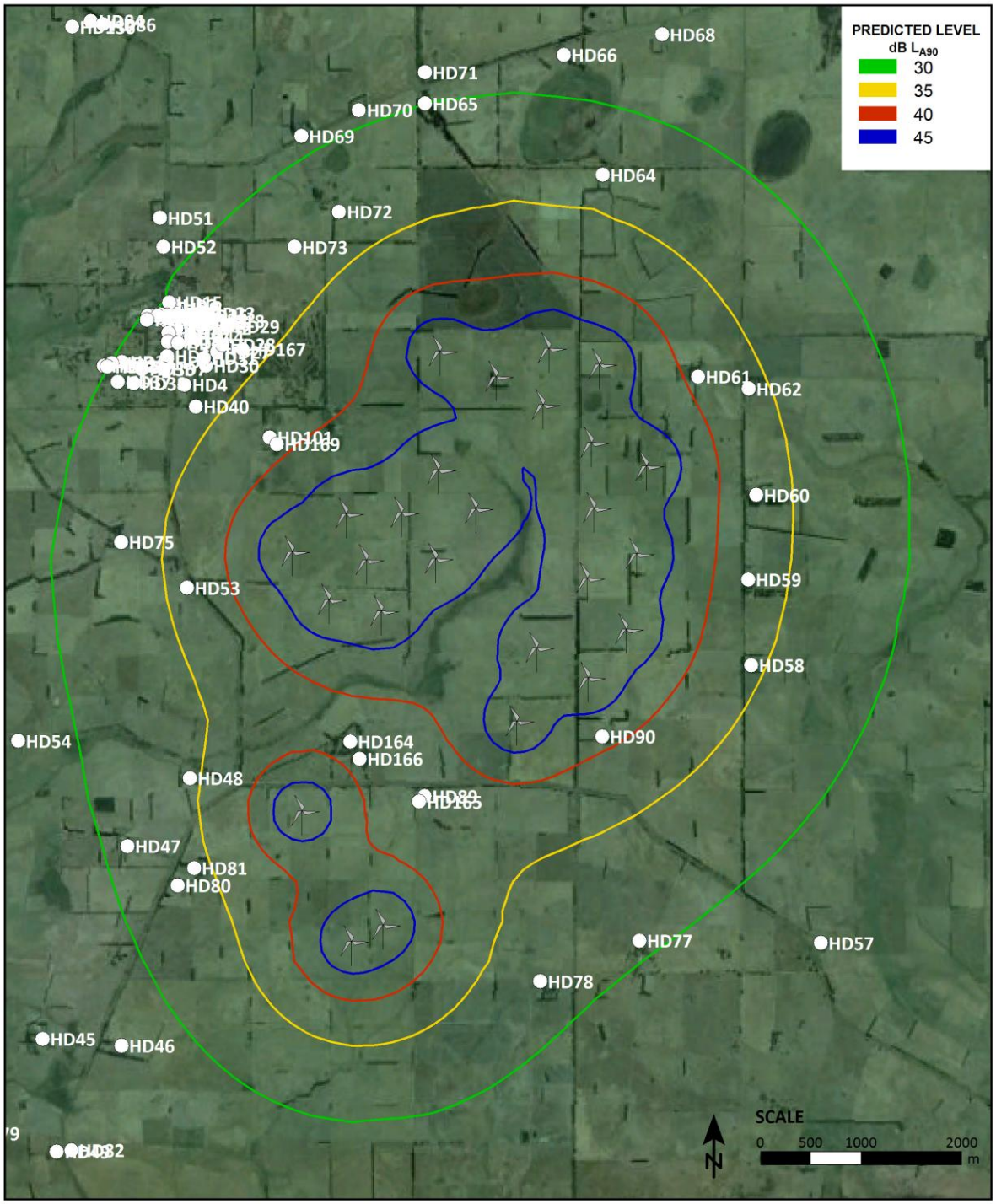
The key findings of these studies demonstrated the suitability of the ISO 9613-2:1996 method to predict the propagation of wind turbine noise for:

- The types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30 m maximum source heights considered in the original ISO 9613
- The types of environments in which wind farms are typically developed, and the range of atmospheric conditions and wind speeds typically observed around wind farm sites. Importantly, this supports the extended scope of application to wind speeds in excess of 5 m/s.

ISO 9613-2:1996 is primarily intended for the prediction of total A-weighted noise levels.

APPENDIX E NOISE CONTOUR MAP

E1 Vestas V126



LEGEND

- Residential porperty
- Wind turbine

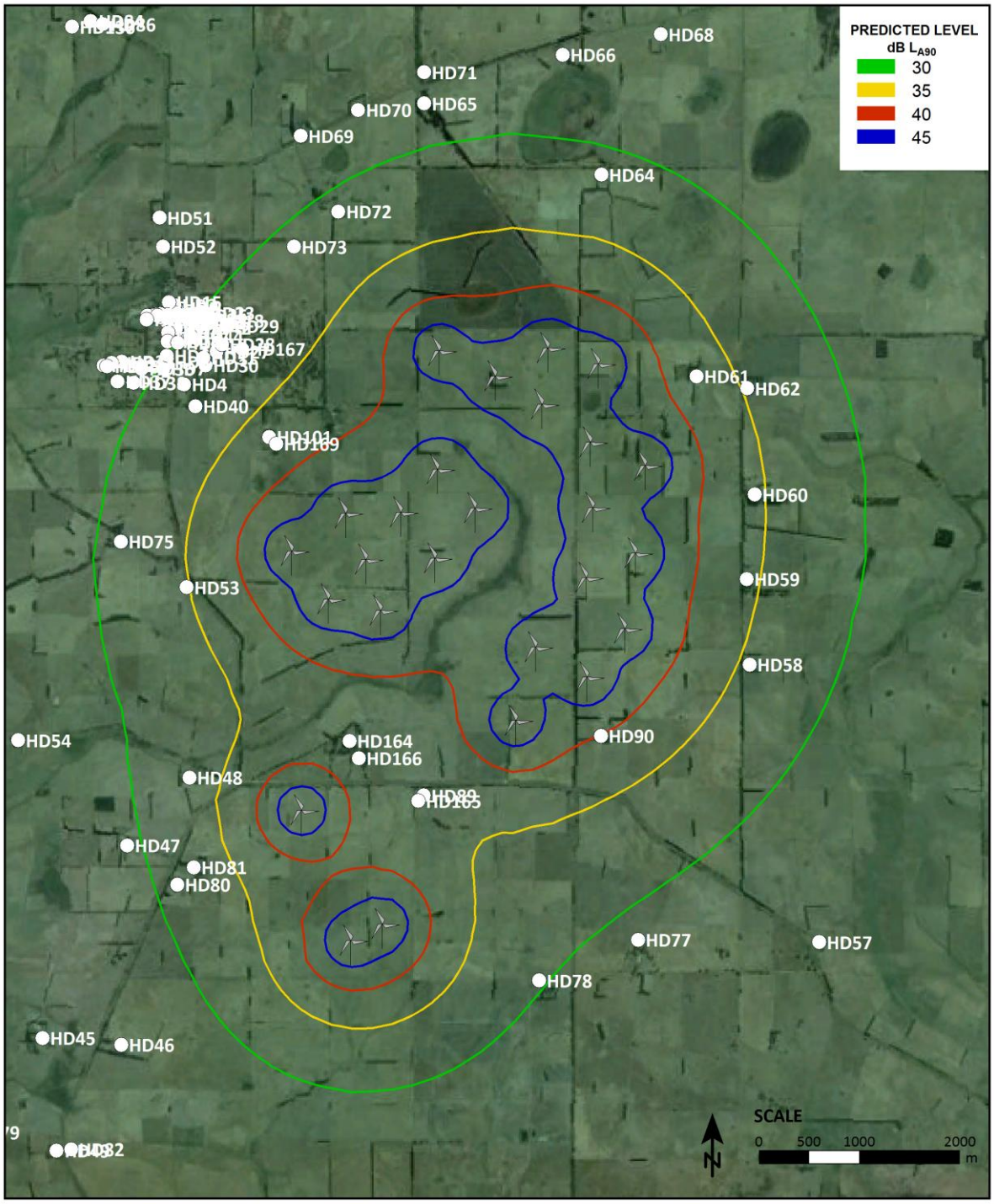
Project: Hawkesdale Wind Farm	
Project number: 2014362ML	
Client name: UFWA	
Version: SoundPLAN 7.4	
Prediction method: ISO 9613-2:1996 (IoA UK)	
Model number: MDL04	
Run number: 2002	
File: HD V126	
Prediction Height: 1.5 m	

HAWKESDALE WIND FARM

26 x Vestas V126 turbines

MARSHALL DAY Acoustics

E2 Senvion 3.0M122



LEGEND

- Residential porperty
- Wind turbine

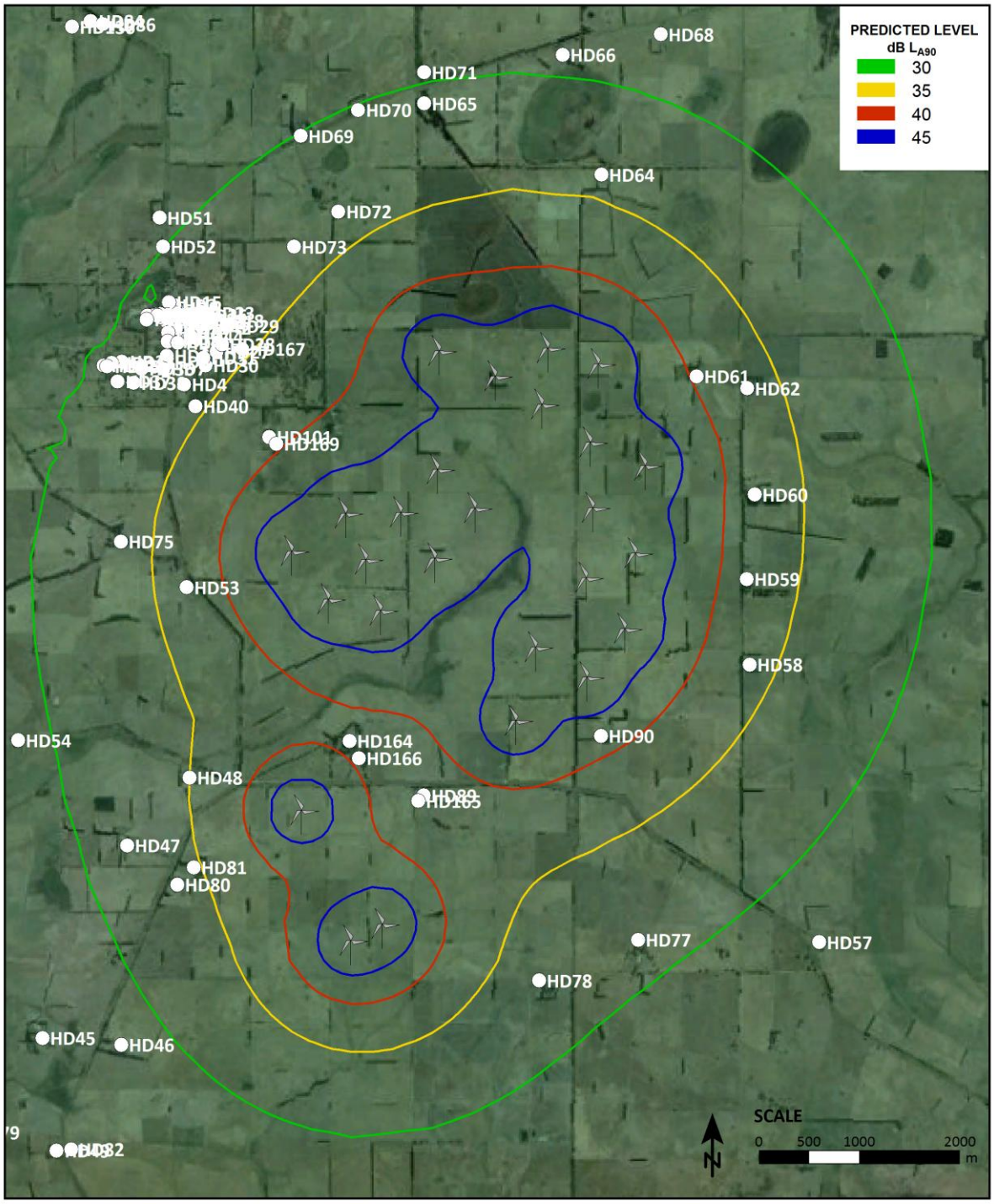
Project: Hawkesdale Wind Farm	
Project number: 2014362ML	
Client name: UFWA	
Version: SoundPLAN 7.4	
Prediction method: ISO 9613-2:1996 (IoA UK)	
Model number: MDL04	
Run number: 2001	
File: HD 30M122	
Prediction Height: 1.5 m	

HAWKESDALE WIND FARM

26 x Senvion 3.0M122 turbines

MARSHALL DAY Acoustics

E3 GE 3.2-130



LEGEND

- Residential porperty
- Wind turbine

Project: Hawkesdale Wind Farm	
Project number: 2014362ML	
Client name: UFWA	
Version: SoundPLAN 7.4	
Prediction method: ISO 9613-2:1996 (IoA UK)	
Model number: MDL04	
Run number: 2000	
File: HD GE130	
Prediction Height: 1.5 m	

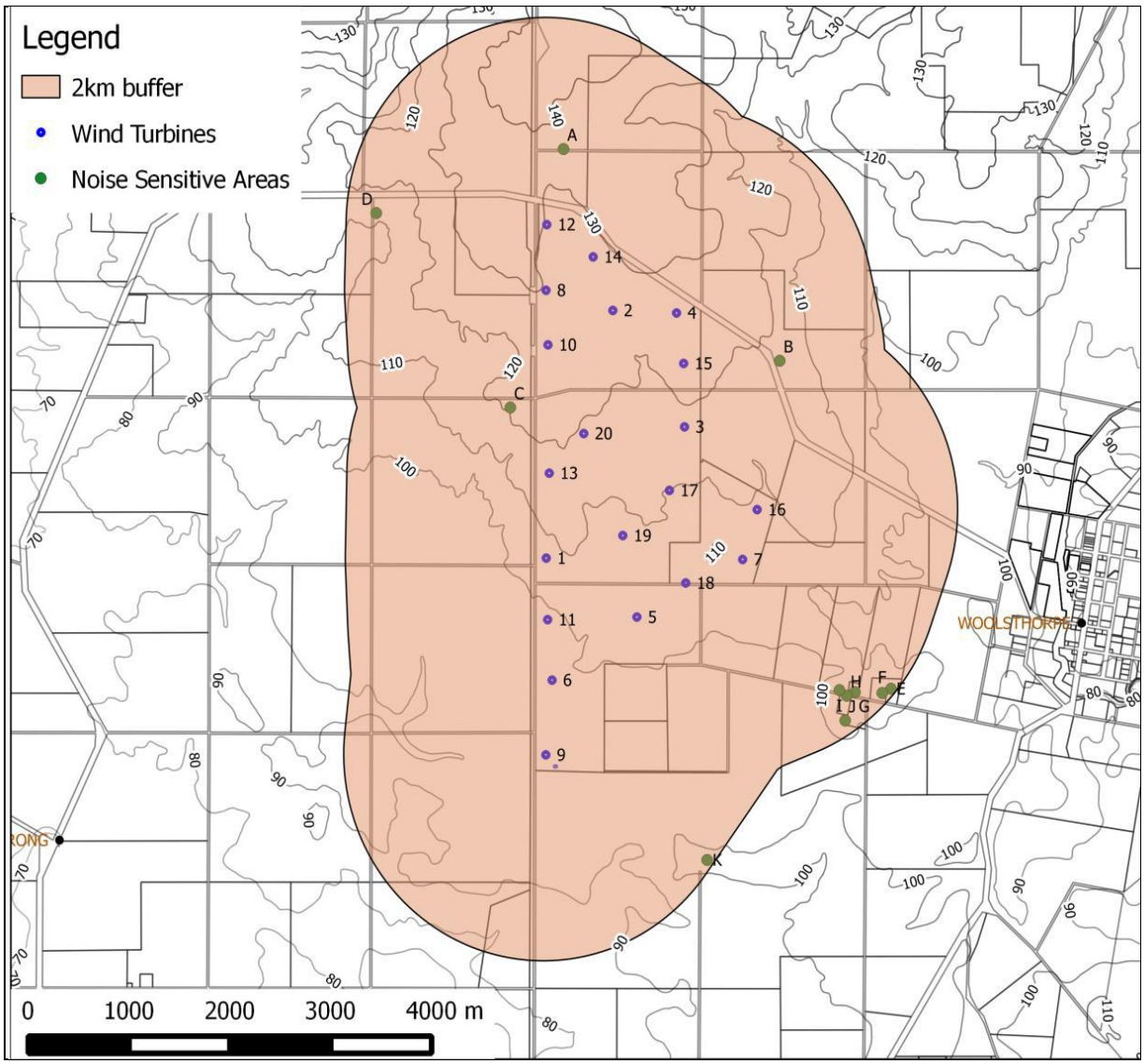
HAWKESDALE WIND FARM

26 x GE 3.2-130 turbines

MARSHALL DAY Acoustics

APPENDIX F WOOLSTHORPE WIND FARM LAYOUT

F1 Woolsthorpe Wind Farm Site Layout



(Figure 1-2 extracted from the Woolsthorpe Wind Farm Noise Assessment)

F2 Woolsthorpe Wind Farm turbine coordinates (AGD66 Z54)

Turbine	Easting	Northing	Turbine	Easting	Northing
1	619928	5773195	11	619934	5776387
2	620588	5775566	12	620393	5776078
3	621299	5774451	13	621290	5775058
4	621220	5775541	14	622020	5773660
5	620827	5772631	15	621149	5773843
6	619986	5772027	16	621311	5772957
7	621875	5773182	17	620687	5773411
8	619926	5775758	18	620300	5774387
9	619924	5771312	19	619945	5775236
10	619942	5772606	20	619959	5774008

F3 Woolsthorpe Wind Farm assessed residential properties (AGD66 Z54)

Property	Easting	Northing	Corresponding Hawkesdale WF property reference*	Nearest Hawkesdale Turbine	Nearest Woolsthorpe Turbine
A	620142	5777128	90 (S)	A15 at 637 m	11 at 777 m
B	622243	5775085	57	A15 at 3,503 m	13 at 960 m
C	619497	5774622	78	A30 at 1,725 m	19 at 768 m
D	618243	5776497	165	A28 at 1,154 m	11 at 1,698 m
E	623342	5771937	104	A30 at 6,379 m	7 at 1,927 m
F	623259	5771905	105	A30 at 6,326 m	7 at 1,886 m
G	622989	5771912	107	A30 at 6,095 m	7 at 1,693 m
H	622907	5771878	108	A30 at 6,045 m	7 at 1,666 m
I	622864	5771915	109	A30 at 5,989 m	7 at 1,611 m
J	622892	5771645	106	A30 at 6,167 m	7 at 1,846 m
K	621524	5770200	-	A30 at 6,228 m	9 at 1,951 m

* The correspondence of residential properties is based on MDA's review of aerial photography

F4 Predicted cumulative noise levels

Table 8 : Cumulative noise predictions – Vestas V126 (Hawkesdale) and GE 3.4-137 (Woolsthorpe)

House		Maximum predicted noise levels, L_{A90} dB			
Hawkesdale reference	**Woolsthorpe reference**	**Hawkesdale only**	**Woolsthorpe only**	**Cumulative**	**Increase***
Highest noise contribution from Hawkesdale Wind Farm					
48 (S)	-	34.4	26.4	35.0	0.6
53	-	36.4	24.2	36.7	0.3
58	-	35.8	32.3	37.4	1.6
59	-	37.4	29.3	38.0	0.6
60	-	37.2	26.8	37.6	0.4
61 (S)	-	38.9	24.3	39.0	0.1
62	-	36.1	24.4	36.4	0.3
89	-	37.7	34.0	39.2	1.5
90 (S)	A	41.4	39.3	43.5	2.1
101	-	38.2	23.1	38.3	0.1
164 (S)	-	38.9	30.0	39.4	0.5
165	D	37.7	33.8	39.2	1.5
166 (S)	-	39.0	30.6	39.6	0.6
169	-	38.9	23.3	39.0	0.1
170	-	35.9	35.6	38.8	2.9
Highest noise contribution from Woolsthorpe Wind Farm					
57	B	27.2	39.7	39.9	0.2
77	-	30.5	46.4	46.5	0.1
78	C	31.9	42.3	42.7	0.4
110	-	23.7	43.1	43.1	0.0
111	-	23.6	42.6	42.7	0.1

(S) Stakeholder property
* Increase relative to the highest contributor

Table 9: Cumulative noise predictions – Senvion 3.0M122 (Hawkesdale) and GE 3.4-137 (Woolsthorpe)

House		Maximum predicted noise levels, L_{A90} dB			
Hawkesdale reference	**Woolsthorpe reference**	**Hawkesdale only**	**Woolsthorpe only**	**Cumulative**	**Increase***
Highest noise contribution from Hawkesdale Wind Farm					
48 (S)	-	32.8	26.4	33.7	0.9
53	-	34.9	24.2	35.3	0.4
58	-	34.3	32.3	36.4	2.1
59	-	35.9	29.3	36.8	0.9
60	-	35.6	26.8	36.1	0.5
61 (S)	-	37.4	24.3	37.6	0.2
62	-	34.6	24.4	35	0.4
89	-	36.2	34	38.2	2
90 (S)	A	39.9	39.3	42.6	2.7
101	-	36.7	23.1	36.9	0.2
164 (S)	-	37.3	30	38	0.7
165	D	36.2	33.8	38.2	2
166 (S)	-	37.4	30.6	38.2	0.8
169	-	37.4	23.3	37.6	0.2
Highest noise contribution from Woolsthorpe Wind Farm					
57	B	25.3	39.7	39.9	0.2
77	-	28.9	46.4	46.5	0.1
78	C	30.3	42.3	42.6	0.3
110	-	21.4	43.1	43.1	0.0
111	-	21.3	42.6	42.6	0.0
170	-	34.4	35.6	38.1	2.5

(S) Stakeholder property
* Increase relative to the highest contributor

Table 10: Cumulative noise predictions – GE 3.2-130 (Hawkesdale) and GE 3.4-137 (Woolsthorpe)

House		Maximum predicted noise levels, L_{A90} dB			
Hawkesdale reference	**Woolsthorpe reference**	**Hawkesdale only**	**Woolsthorpe only**	**Cumulative**	**Increase***
Highest noise contribution from Hawkesdale Wind Farm					
48 (S)	-	35	26.4	35.6	0.6
53	-	37	24.2	37.2	0.2
58	-	36.4	32.3	37.8	1.4
59	-	38	29.3	38.5	0.5
60	-	37.8	26.8	38.1	0.3
61 (S)	-	39.5	24.3	39.6	0.1
62	-	36.8	24.4	37.0	0.2
89	-	38.3	34	39.7	1.4
90 (S)	A	42	39.3	43.9	1.9
101	-	38.8	23.1	38.9	0.1
164 (S)	-	39.4	30	39.9	0.5
165	D	38.3	33.8	39.6	1.3
166 (S)	-	39.5	30.6	40.0	0.5
169	-	39.5	23.3	39.6	0.1
170	-	36.5	35.6	39.1	2.6
Highest noise contribution from Woolsthorpe Wind Farm					
57	B	28	39.7	40.0	0.3
77	-	31.3	46.4	46.5	0.1
78	C	32.6	42.3	42.7	0.4
110	-	24.4	43.1	43.2	0.1
111	-	24.3	42.6	42.7	0.1

(S) Stakeholder property
* Increase relative to the highest contributor

APPENDIX G DOCUMENTATION

G1 Predictions

(a) Map of the site showing topography, turbines and residential properties: See Appendix B and Appendix F

(b) Noise sensitive locations: See Section 5.0, Table B2 of Appendix B and Table F3 of Appendix F

(c) Wind turbine sound power levels, L_{WA} dB (also refer to Section 2.2.2 and Section 8.2)

Sound power levels (including a margin for uncertainty)

	Hub height wind speed (m/s)											
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
GE 3.2-130	96.7	97.3	99.7	103	105.6	106.9	107	107	107	107	107	107
Senvion 3.0M122	-	98.2	100.8	103.3	104.8	105.5	105.5	105.2	104.9	104.8	104.8	104.8
Vestas V126	-	-	-	99.8	103.2	106.3	106.5	105.7	105.7	106.0	106.1	106.2

Reference octave band spectrum

	Octave Band Centre Frequency (Hz)							
	63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
GE 3.2-130	88.4	96.7	99.8	101.1	101.5	98.8	89.1	66.4
Senvion 3.0M122	83.8	92.0	98.4	100.5	98.6	97.3	92.8	89.6
Vestas V126	89.5	94.6	98.6	100.5	101.6	98.1	91.4	80.8
GE 3.4-137*	88.4	96.4	99.6	101.4	101.9	97.8	87.8	64.0

* *See Section 8.2*

(d) Wind turbine model: Refer to Table 1 of Section 2.2.1 and Section 8.1

(e) Turbine hub height: Refer to Table 1 of Section 2.2.1 and Section 8.1

(f) Distance of noise sensitive locations from the wind turbines: See Table B2 of Appendix B and Table F3 of Appendix F

(g) Calculation procedure used: ISO 9613-2:1996 prediction algorithm as implemented in SoundPLAN v7.4 (See Section 7.0 and Appendix D)

(h) Meteorological conditions assumed:

Temperature: 10 °C Relative humidity: 70 % Atmospheric pressure: 101.325 kPa

(i) Air absorption parameters:

	Octave band mid frequency (Hz)							
Description	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Atmospheric attenuation (dB/km)	0.12	0.41	1.04	1.93	3.66	9.66	32.8	116.9

(j) Topography/screening: 10 m elevation contours, screening effects in accordance with ISO 9613-2:1996 prediction algorithm as detailed in Appendix D

(k) Predicted far-field wind farm sound levels: See Table 4 of Section 7.0, Appendix E and Section 8.3

APPENDIX B MDA REPORT No. Rp 003 2010165ML

MARSHALL DAY Acoustics

HAWKESDALE WIND FARM

NZS6808:2010 Noise Impact Assessment

003 2010165ML

11 September 2013

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Project: **HAWKESDALE WIND FARM**
Noise Impact Assessment

Prepared for: **Union Fenosa Wind Australia Pty Ltd**
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Attention: **Shaq Mohajerani**

Report No.: **003 2010165ML**

Document control

Status:	Rev:	Comments	Date:	Author:	Reviewer:
Final	-		11/09/2013	C. Delaire	D. Griffin

TABLE OF CONTENTS

1.0 INTRODUCTION

A planning permit, No. 20060221 (the Planning permit), for the development of the Hawkesdale Wind Farm was issued on 12 August 2008. The project proponent, Union Fenosa Wind Australia Pty Ltd (UFWA), was granted Secondary Consent Approval on 12 August 2010 to vary the turbine dimensions in Condition 3 of the Planning permit. This allows the proponent to propose alternative wind turbine models for the project.

To assist with assessment of variation in turbine dimensions, a Consolidated Report (001 R01 2010165ML, titled *Hawkesdale Wind Farm - Consolidated Pre-Construction and Noise Impact Assessment Report*) was prepared for the Department of Transport, Planning and Local Infrastructure[1] (DTPLI), and issued 24 January 2012. The Consolidated Report is a standalone summary of noise assessment material presented in reports prepared in 2006[2] and 2011[3, 4].

The methodologies and assessment presented in the Consolidated Report are consistent with the Planning permit requirements, specifically, prepared in accordance with the New Zealand Standard 6808:1998 – *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS6808:1998).

Although the Planning permit requires the wind farm to comply with NZS6808:1998, we understand that the DTPLI has requested an informative revised noise impact assessment undertaken in accordance with the New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010) as required by the current Victorian Government's *Policy and planning guidelines for development of wind energy facilities in Victoria* dated August 2012.

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

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1 Known as the Department for Planning and Community Development (DPCD) at the time the report was issued.

2 Report No. 2005034 001 R2 titled *Hawkesdale Wind Farm - Noise Impact Assessment*, dated 24 July 2006

3 Report No. 002 R03 2009051 titled *Hawkesdale Wind Farm – revised Wind Turbines Selection*, dated 1 April 2011

4 Letter report Lt001 R02 2009051 titled *Woolsthorpe Wind Farm Cumulative Noise Impact*, dated 1 April 2011 provided as an addendum to Report No. 002 R03 2009051

2.0 WIND FARM LAYOUT

2.1 Turbine arrangements

The Hawkesdale Wind Farm is to be located near the township of Hawkesdale, Victoria, between Hamilton and Warrnambool. The wind farm will consist of thirty-one (31) wind turbines.

A plan of the proposed wind farm is presented in Appendix B together with GPS coordinates for the wind turbines.

UFWA has selected two (2) candidate wind turbine models for the project, as presented in Table 1.

Table 1: Selected wind turbine models

Model	Power output	Hub height	Rotor Diameter
Vestas V90	2.0MW	80m	90m
REpower MM92	2.0MW	80m	92.5m

2.2 Sound power levels

Manufacturer's sound power data specification derived from measurement in accordance with IEC61400-11[5], used for this assessment have been sourced from the documents detailed in Table 2.

Table 2: Reference documents

Model	Sound Power Level	Reference spectrum
Vestas V90	Document No. 0004-6207 V05 *General Specification V90–1.8/2.0 MW 50 Hz VCS* dated 19 November 2010	AECOM report titled *Vestas V90 1.8/2.0 MW – Wind Turbine Sound Power Level* dated 20 August 2013
REpower MM92	REpower document titled *Power Curve & Sound Power Level – REpower MM92 [2050kW] Guaranteed* dated 11 May 2009	WindTest report D-2.9-VM-SM-16-B Rev A-EN dated 18 March 2009

Sound power level data for the Vestas V90 and REpower MM92 turbines are presented in Figure 1.

[5] IEC61400-11 *Wind turbine generator systems – Part 11: Acoustic noise measurement techniques*

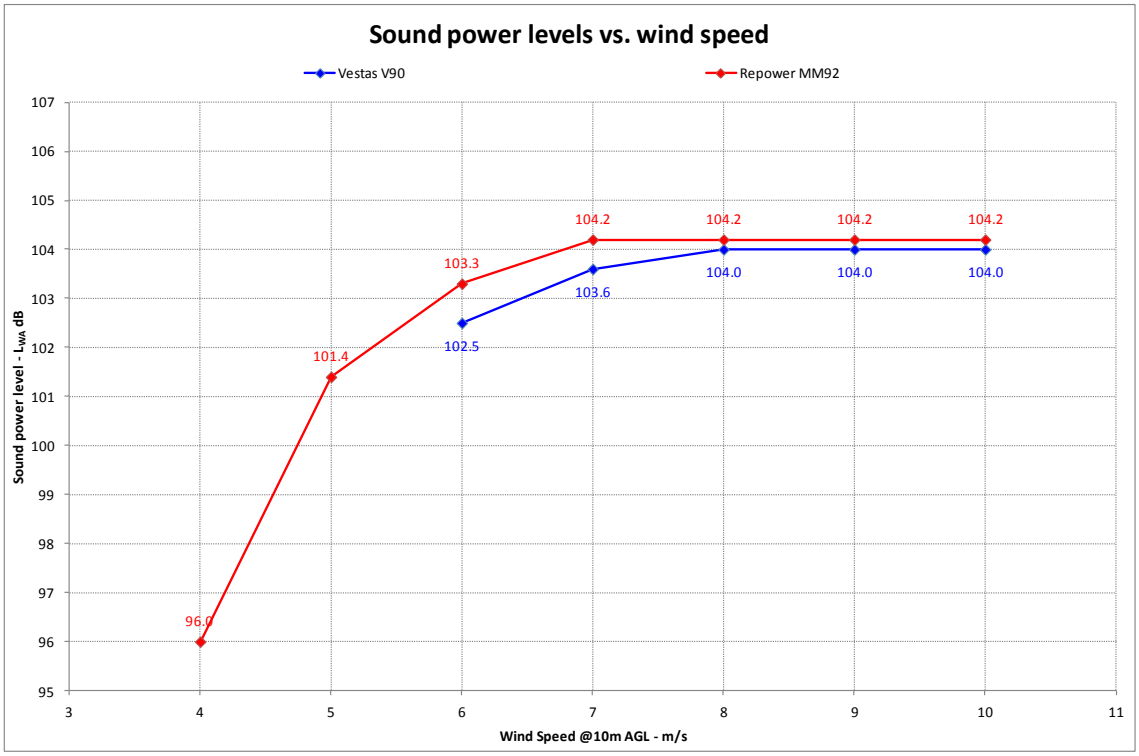


Figure 1: Sound power level data

2.2.1 Reference sound power spectrum

Reference sound power spectrum data adjusted to the highest sound power level presented in Figure 1 for Vestas V90 and REpower MM92 turbines are presented in Figure 2.

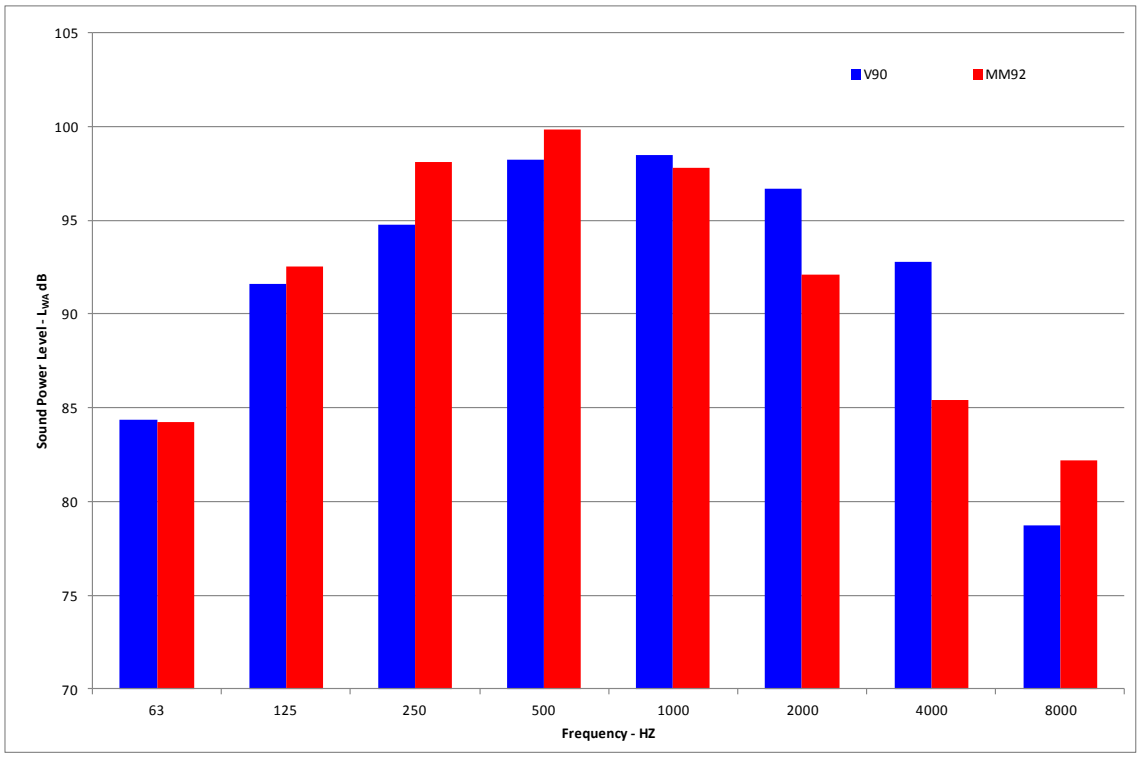


Figure 2: Reference octave band sound power spectrum

2.2.2 Tone audibility

The documents referenced in Table 2 include tonality test results for wind speeds in the range of 6-10m/s referenced at 10m above ground level (AGL)[6]. These results are summarised in Table 3.

Table 3: Summary of test report tonality results

	REpower MM92		Vestas V90	
Wind Speed* m/s	**Tone audibility ($\Delta L_{a,k}$) dB**	**Frequency Hz**	**Tone audibility ($\Delta L_{a,k}$) dB**	**Frequency Hz**
6	<-3	-	-0.6	158
			0.1	592
7	<-3	-	-2.1	166
8	<-3	-	-**	-
9	-2.96	160	-**	-
10	-**	-	-**	-

* at 10m AGL
** no reported value

IEC61400-11:2006 requires the reporting of identified tones where the tonal audibility, $\Delta L_{a,k}$ is higher than or equal to -3.0dB. It is important to note that the reporting requirements of IEC61400-11:2006 do not necessarily reflect the expected levels of audibility or annoyance from the assessed tones. Work by Zwicker and Fastl[7] indicates that:

- $\Delta L_{a,k}$ = -2dB is approximately the audibility threshold for a tone
- $\Delta L_{a,k}$ < 0dB the tone, while perhaps audible, is generally unlikely to cause significant issues

On the basis of the above we consider that, where $\Delta L_{a,k}$ < 0dB, identified tones are unlikely to be problematic at the IEC61400-11:2006 assessment location. Where $\Delta L_{a,k}$ > 0dB, identified tones are potentially audible at the IEC61400-11:2006 sound power test location near the turbine[8].

[6] It should be noted that the IEC61400-11:2006 mandatory reporting requirements for the sound power level testing, including tonality assessment, correspond to wind speeds between 6 and 10m/s at 10m AGL
This wind speed range is approximately equivalent to a wind speed range of 8.4-13.9m/s at hub height using the standard IEC61400-11:2006 roughness length of 0.05m.

[7] Fastl, H, Zwicker, E, (2007) Psycho-acoustics, Berlin, Springer

[8] This is consistent with comments from the recently released 3rd version of the IEC61400-11 standard, which states in Section 9.5.8 that a "*tone is audible if the tonal audibility is above 0 dB.*"

Audible tones identified during a sound power level testing in close proximity of a wind turbine are not necessarily audible at a neighbouring residential property. If a tone is not deemed audible in close proximity of a turbine (IEC61400-11:2006 assessment location), it is generally unlikely that it would be audible at a neighbouring residential property.

The available data for the candidate turbine models indicates the following:

- REpower MM92: the highest reported tone audibility is -2.96dB at 9m/s and therefore it is unlikely that tones would be audible at a receptor location
- Vestas V90: the highest reported tone audibility is 0.1dB at 6m/s in close proximity of the turbine. Although it is marginally over 0dB, it is considered unlikely that tones would be audible at a receptor location.

2.3 Residential properties

Fifteen (15) residential properties were identified for assessment in the Consolidated Report including four (4) stakeholder properties that are involved with the project development. The properties are presented in Table 4.

Table 4: Assessable residential properties (AGD66 Z54)

House	Easting	Northing	Distance to nearest turbine (m)
H48	615985	5776720	1162
H53	615956	5778615	1078
H58	621562	5777844	1206
H59	621532	5778697	1050
H60	621614	5779538	1045
H61 (S)	621034	5780713	720
H62	621538	5780594	1156
H81	616027	5775828	1215
H89	618315	5776542	1045
H90 (S)	620082	5777137	607
H101	616777	5780110	1075
H164 (S)	617577	5777085	843
H165	618261	5776488	974
H166 (S)	617669	5776914	776
H169	616848	5780043	978

(S) Stakeholder property

3.0 NOISE LIMIT CRITERIA

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 reads as follows:

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

To deliver on this intention, the standard specifies noise criteria which are used to assess wind farm noise.

3.1.1 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.

Compliance with the criteria may result in wind turbine noise being audible at some locations for some of the time. The forwarding comments of NZS 6808:2010 note that:

> *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.*

3.1.2 High amenity areas

Section 5.3.1 of NZS6808:2010 states that the baseline noise limit of 40dB L_{A90} detailed above in Section 3.1.1 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 Victoria.

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.

3.1.3 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.*

While the standard emphasises assessment of special audible characteristics during the post-construction measurement phase of a project, an assessment of tonality is possible pre-construction, using tonality assessments carried out according to IEC61400-11.

3.1.4 Cumulative assessment

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

> *The noise limits* [defined in Section 3.1.1 above] *should apply to the cumulative sound level of all wind farms affecting any noise sensitive location.*

4.0 NOISE ASSESSMENT METHODOLOGY

There are several key stages involved in a noise assessment undertaken in accordance with 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 are used for the following:

- Identification of *noise sensitive locations,* where predicted wind farm noise levels exceed 35dB L_{A90}
- Identification of selected *noise sensitive locations* where background noise monitoring should be undertaken

The background noise surveys allow quantification of the existing ambient noise environment around the proposed site. Section 7.1.4 of NZS6808:2010 notes the following:

> *If there are no noise sensitive locations within the 35dB $L_{A90(10\ min)}$ predicted wind farm sound level contour then background sound level measurements are not required.*

Having identified noise sensitive locations and carried out any background noise monitoring that may be required, applicable limits for wind farm noise may be determined.

Once noise limits have been established, further wind farm predictions are carried out. Compliance is assessed by comparing the predicted wind farm noise levels with the noise limits over a range of wind speeds.

Where required, alteration of the turbine layout or a noise management plan can be considered to achieve compliance with noise limits.

5.0 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}.

As stakeholder properties are located within the wind farm site, they are not considered as noise sensitive locations as part of an assessment in accordance with NZS6808:2010. However, they have been considered as part of this assessment for informative purpose.

The seven (7) identified noise sensitive locations are detailed in Table 5 of Section 7.0. All of these locations were considered in the Consolidated Report.

6.0 NOISE LIMITS

6.1 High amenity areas

The area surrounding the proposed wind farm is zoned Farming Zone (FZ) as in the planning map shown in Appendix C.

The Victoria Planning Provisions Practice Note prepared by the Department of Sustainability and Environment titled *Applying the rural zones* and dated March 2007 states the following regarding farming zones:

> *The Farming Zone is designed to encourage diverse farming practices, some of which can have significant off-site impacts. For this reason, the level of amenity that can be expected in this zone will usually not be compatible with sensitive uses, particularly housing.*

Based on the above, it is our understanding that the high amenity noise limit is not generally applicable for residential properties located within a Farming Zone. On this basis, the high amenity noise limit has not been applied in this assessment.

6.2 Assessment noise limits

Noise limits applicable for this project have previously been determined in accordance with NZS6808:1998, as required by the Planning permit. Background noise monitoring results and noise limit derivation are detailed in the Consolidated Report. A summary of noise limits is presented in tabular format in Appendix D.

Derivation of noise limits differs between NZS6808:1998 and NZS6808:2010, owing to differences in the methodology for background noise monitoring. The key differences are as follows:

- Use of L_{A90} parameter in accordance with NZS6808:2010 in comparison to the use of L_{A95} parameter in accordance with NZS6808:1998[9].
- Use of hub height reference for wind speeds in accordance with NZS6808:2010 in comparison to the use of 10m above ground level (AGL) in the Consolidated Report, in accordance with NZS6808:1998.

For simplicity, in this informative assessment, compliance with NZS6808:2010 is assessed against the baseline noise limit at all wind speeds. This approach is not dependant on the two key differences noted above and is considered conservative.

For consistency and ease of comparison with the findings presented in the Consolidated Report, all wind speeds are referenced to 10m AGL within this report.

6.3 Stakeholders

As stated in Section 5.0, stakeholder properties are not considered as part of an assessment in accordance with NZS6808:2010.

Notwithstanding this, as detailed in our Consolidated Report, a noise limit based on an increased baseline noise limit of 45dB has been recommended for stakeholder properties with an agreement with the proponent.

7.0 NOISE PREDICTIONS

Noise from the Hawkesdale Wind Farm has been predicted using ISO9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO9613-2:1996) as implemented in version 7.2 of SoundPLAN. Predictions have been carried out using the sound power level data presented in Section 2.2.

Calculations have been performed using octave band source data 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. For consistency with the Consolidated Report, possible screening effects from the landscape have not been considered in this assessment. Atmospheric attenuation has been modelled using a temperature of 10°C and 70% humidity as recommended by NZS6808:2010.

[9] NZS6808:2010 notes in Section C2.5: *The 1998 version of this Standard used the L95 descriptor. Since 1999 this has been updated in New Zealand Standards to the L90 descriptor. There is no significant difference between the L90 and L95 values of typical environmental sound so this change does not affect the recommended noise limits in this Standard*

The hardness of the ground between the sources and the receivers needs to be defined in accordance with ISO9613-2:1996. 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 be absorptive, appropriate for fields and grass. Our experience is that, in rural areas, generally with similar topography as the subject site, it is appropriate to assume that the ground is 50% hard/50% soft. 50% soft ground (G=0.5) has been used in the predictions.

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

Predicted noise levels at the assessable residences detailed in Table 4 are shown in Table 5 for the two (2) proposed turbine models, Vestas V90 and REpower MM92.

Table 5: Maximum predicted noise levels[10], L_{Aeq} dB

House	Noise sensitive location*	REpower MM92+	Vestas V90+
H48	No	33.5	32.3
H53	No	34.8	33.7
H58	Yes	35.2	34.0
H59	Yes	36.6	35.5
H60	Yes	36.4	35.3
H61 (S)	No	39.0	38.1
H62	Yes	35.8	34.6
H81	No	33.3	32.1
H89	Yes	37.7	36.7
H90 (S)	No	42.0	41.3
H101	Yes	36.5	35.4
H164 (S)	No	38.1	37.1
H165	Yes	37.8	36.7
H166 (S)	No	38.5	37.5
H169	Yes	37.2	36.1

(S) Stakeholder property
* As defined in Section 4.0
\+ based on sound power level at 8m/s at 10m AGL

[10] 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 presented levels are reported to one decimal place.

It can be seen from Table 5 that predicted noise levels at all noise sensitive locations comply with the NZS6808:2010 baseline noise limit of 40dB at all wind speeds with a tolerance of at least 2dB.

Predicted noise levels at stakeholder properties comply with the raised baseline noise limit of 45dB at all wind speeds with a tolerance of at least 3dB.

Wind farm noise at all residential properties further from the wind farm will be lower than 33dB L_{Aeq} and therefore comply with the NZS6808:2010 baseline noise limit at all wind speeds.

7.1 Special audible characteristics

Based on the information provided in Section 2.2.2, it is considered that a penalty for tonality would not be applicable for either of the candidate turbines at any of the assessed wind speeds.

8.0 CUMULATIVE ASSESSMENT

We understand that there is one other proposed wind farm in the Hawkesdale area, the Woolsthorpe Wind Farm. Cumulative noise levels from these two (2) projects are assessed in this section, for which to following items are noted:

- The noise impact assessment for the Woolsthorpe Wind Farm has not been provided to MDA for the preparation of the cumulative noise impact assessment. In lieu, this assessment is based on a turbine layout provided by the DPCD and turbine noise data sourced from UFWA.
- At present, the cumulative impact assessment only addresses assessable properties identified for the Hawkesdale Wind Farm. At such time as further details of the Woolsthorpe Wind Farm are available, including details of surrounding receiver locations, a further assessment should be carried out.
- Potential special audible characteristics (tonality) from the Woolsthorpe Wind Farm have not been assessed. Woolsthorpe Wind Farm noise levels are predicted below assuming that a penalty for special audible characteristics does not apply.

8.1 Woolsthorpe Wind Farm site layout

The approved Woolsthorpe Wind Farm, developed by Wind Farm Developments, is proposed to be located to the south-east of the approved Hawkesdale Wind Farm as shown in Figure 3.

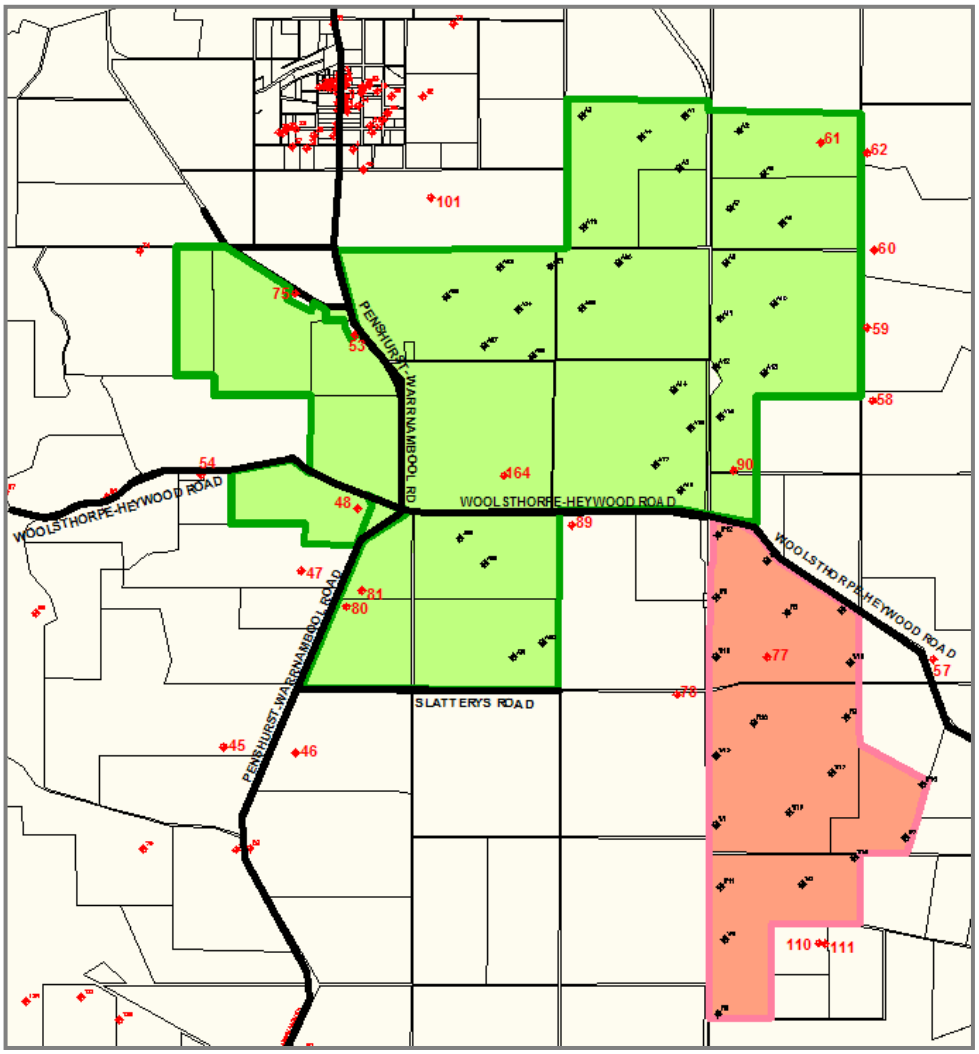


Figure 3: Hawkesdale (green) and Woolsthorpe (red) site layouts

The development plan layout for the Woolsthorpe Wind Farm is provided in Figure 4.

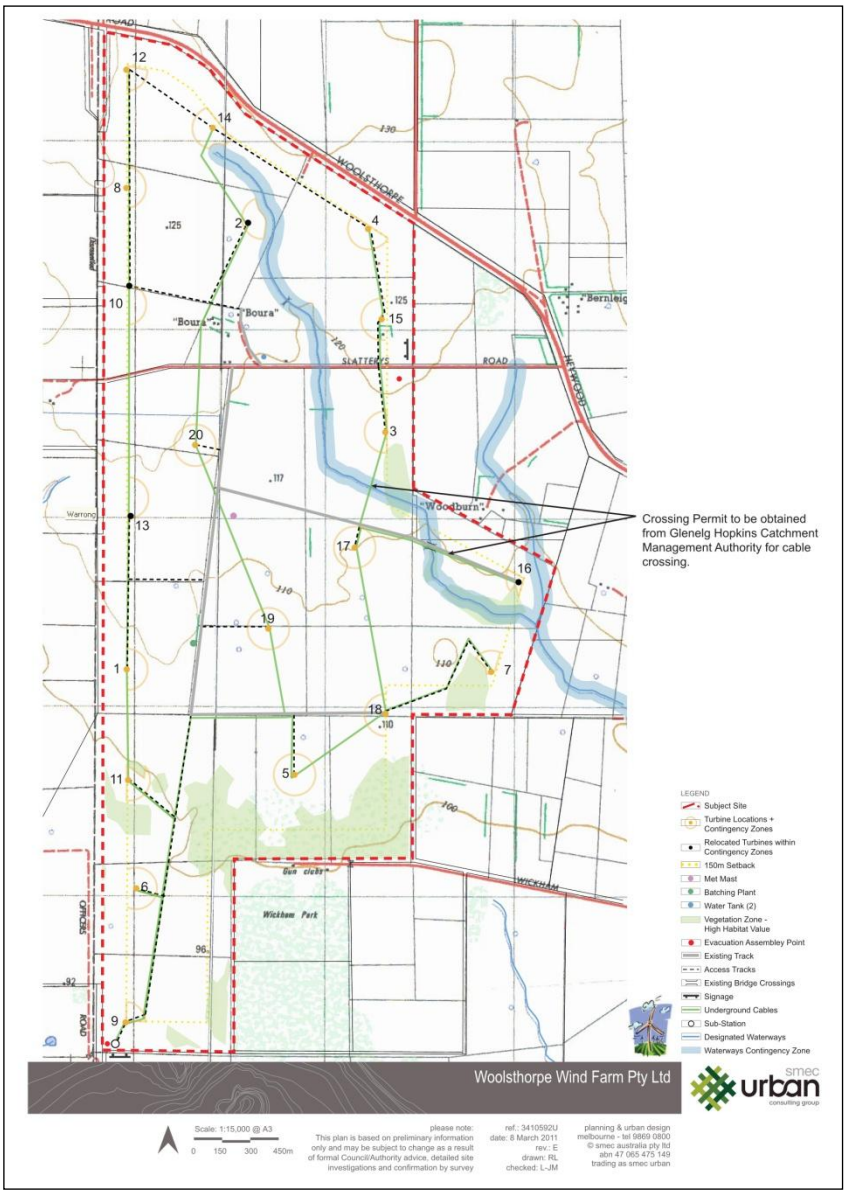


Figure 4: Woolsthorpe Wind Farm development plan layout

Based on information provided by the DPCD in two emails dated 26 and 27 October 2011, it is our understanding that the development plan for the Woolsthorpe Wind Farm is based on a layout comprising twenty (20) turbines with a hub height of 80m.

The following wind turbine models have been proposed:

- Siemens SWT 2.3
- Nordex N100

8.2 Woolsthorpe Wind Farm sound power data

Manufacturer's sound power data specification derived from measurement in accordance with IEC61400-11, used for this cumulative assessment has been sourced from the documents presented in Table 6.

Table 6: Noise data documents

Model	Sound Power Level	Reference spectrum
Siemens SWT 2.3	Siemens document No. E R WP-EN431-10-0000-0170-00 PE titled *SWT-2.3-101 Acoustic Emission* and dated 31 March 2009	
Nordex N100	Nordex document No. F008_228_A03_EN Rev 02 titled *NORDEX N100/25020 Noise levels* and dated 1 January 2009	Test report No. WICO 083SE408/02 (in German), prepared by WIND-consult GmbH and dated 23 January 2009

Sound power level data for the Siemens SWT 2.3 and Nordex N100 turbines are presented in Figure 5.

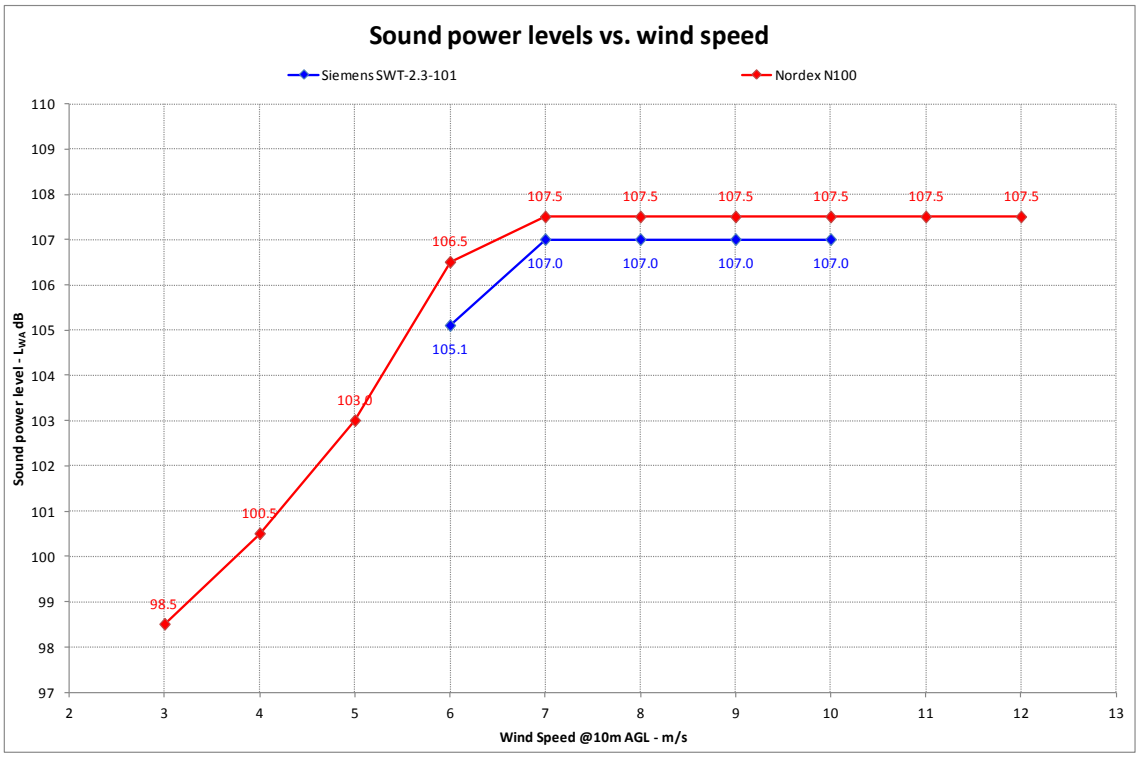


Figure 5: Woolsthorpe Wind Farm - Sound power level data

8.2.1 Reference sound power spectrum

Reference sound power spectrum data, adjusted for the maximum sound power level presented in Figure 5 for Nordex N100 and Siemens SWT 2.3 turbines, are presented in Figure 6.

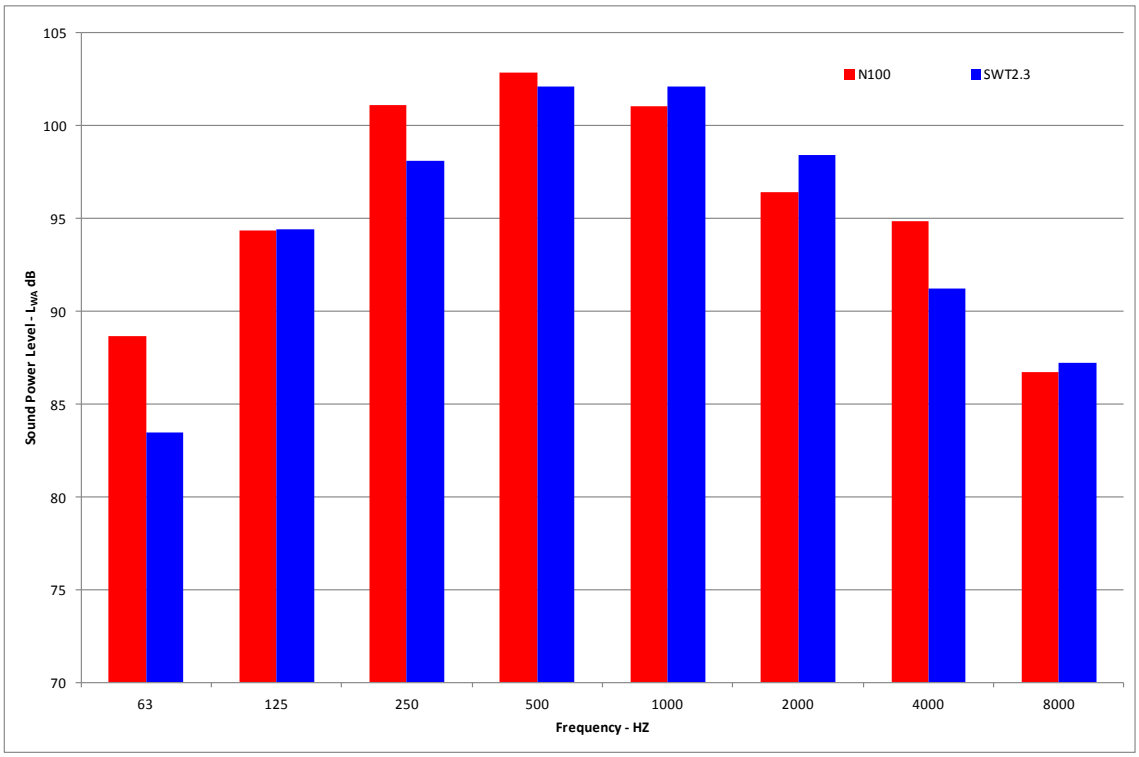


Figure 6: Woolsthorpe Wind Farm - Reference octave band sound power spectrum

It can be seen from Figure 5 and Figure 6 that sound power levels from the Nordex N100 turbine are higher than those of the Siemens SWT 2.3 turbine. As a conservative approach, the Nordex N100 sound power levels have been used for this cumulative noise assessment.

Noise levels from the Hawkesdale and Woolsthorpe wind farms have been predicted in accordance with NZS6808:2010, as detailed in Section 7.0, and have been compared with noise levels from the Hawkesdale Wind Farm alone at residential properties in the vicinity of the Hawkesdale Wind Farm. This comparison together with the cumulative noise compliance is presented in Table 7 and Table 8 for each of the two (2) proposed wind turbine models for the Hawkesdale Wind Farm.

Predicted noise levels shown in Table 7 and Table 8 are presented for the wind speed corresponding to the maximum sound power level of the considered turbine models (7m/s for V90/N100 and 8m/s for MM92/N100).

Table 7: Cumulative noise predictions (7m/s @ 10m AGL) Vestas V90 (Hawkesdale) and Nordex N100 (Woolsthorpe)

	Maximum predicted noise levels, L_{Aeq} dB		
House	**Hawkesdale only**	**Cumulative**	**Increase**
H48	32.3	33.4	1.1
H53	33.7	34.2	0.5
H58	34.0	36.5	2.5
H59	35.5	36.5	1.1
H60	35.3	36.0	0.7
H61 (S)	38.1	38.3	0.2
H62	34.6	35.1	0.4
H81	32.1	33.4	1.3
H89	36.7	38.7	2.0
H90 (S)	41.3	43.7	2.4
H101	35.4	35.7	0.3
H164 (S)	37.1	37.9	0.9
H165	36.7	38.7	2.0
H166 (S)	37.5	38.4	0.9
H169	36.1	36.4	0.2

Table 8: Cumulative noise predictions (8m/s @ 10m AGL) Repower MM92 (Hawkesdale) and Nordex N100 (Woolsthorpe)

	Maximum predicted noise levels, L_{Aeq} dB		
House	**Hawkesdale only**	**Cumulative**	**Increase**
H48	33.5	34.4	0.8
H53	34.8	35.2	0.4
H58	35.2	37.2	2.0
H59	36.6	37.4	0.9
H60	36.4	36.9	0.5
H61 (S)	39.0	39.2	0.2
H62	35.8	36.1	0.3
H81	33.3	34.3	1.1
H89	37.8	39.4	1.7
H90 (S)	42.0	44.1	2.1
H101	36.5	36.7	0.2
H164 (S)	38.1	38.8	0.7
H165	37.8	39.4	1.6
H166 (S)	38.5	39.2	0.7
H169	37.2	37.4	0.2

* based on non rounded values

It can be seen from Table 7 and Table 8 that noise levels from the Woolsthorpe Wind Farm are not predicted to increase noise levels at residential properties in the vicinity of the Hawkesdale Wind Farm above the applicable baseline noise limit.

For each of the wind turbine models and residences considered, the predicted cumulative noise levels from the Hawkesdale and Woolsthorpe wind farms comply with the relevant Hawkesdale Wind Farm baseline noise limits at all wind speeds.

9.0 CONCLUSION

Following the issuing of the Consolidated Report (001 R01 2010165ML) on 24 January 2012, the DTPLI requested an informative noise impact assessment for the Hawkesdale Wind Farm in accordance with NZS6808:2010.

Predicted noise levels have been calculated at all assessable properties identified in the Consolidated Report using the ISO9613-2:1996 algorithm.

It has been found that predicted wind farm noise complies with the relevant baseline noise limit at all wind speeds at all assessed properties for both candidate turbines.

For each of the Hawkesdale Wind Farm wind turbine models considered, the predicted cumulative noise levels from the Hawkesdale and Woolsthorpe wind farms at the Hawkesdale Wind Farm's identified properties comply with the relevant baseline noise limits at all wind speeds.

10.0 SUMMARY OF PARAMETERS

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

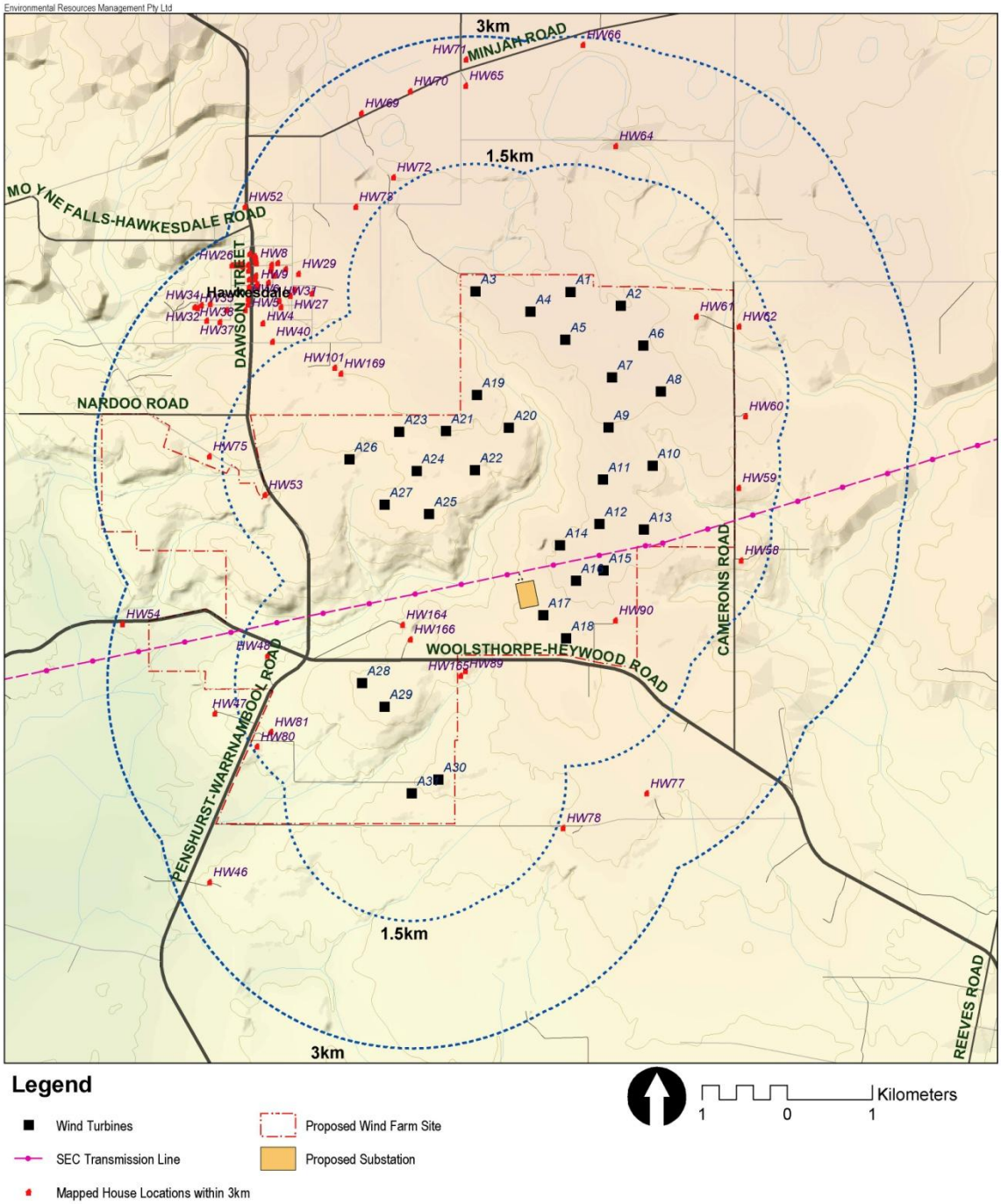
APPENDIX A **ACOUSTIC TERMINOLOGY**

Ambient	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.
dB	Decibel. The unit of sound level.
Frequency	Sound can occur over a range of frequencies extending from the very low, such as the rumble of thunder, up to the very high such as the crash of cymbals. Sound is generally described over the frequency range from 63Hz to 8000Hz (8kHz). This is roughly equal to the range of frequencies on a piano.
Octave band	Sound, which can occur over a range of frequencies, may be divided into octave bands for analysis. The audible frequency range is generally divided into eight (8) octave bands. The octave band frequencies are 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz and 8kHz.

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

L_{A90}	The A-weighted noise level exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.
L_{A95}	The A-weighted noise level exceeded for 95% of the measurement period. This is commonly referred to as the background noise level.
L_{Aeq}	The A-weighted equivalent continuous sound level. This is commonly referred to as the average noise level.

APPENDIX B **HAWKESDALE WIND FARM LAYOUT**



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Date:	25/05/06	Drawing size:	A3
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ERM

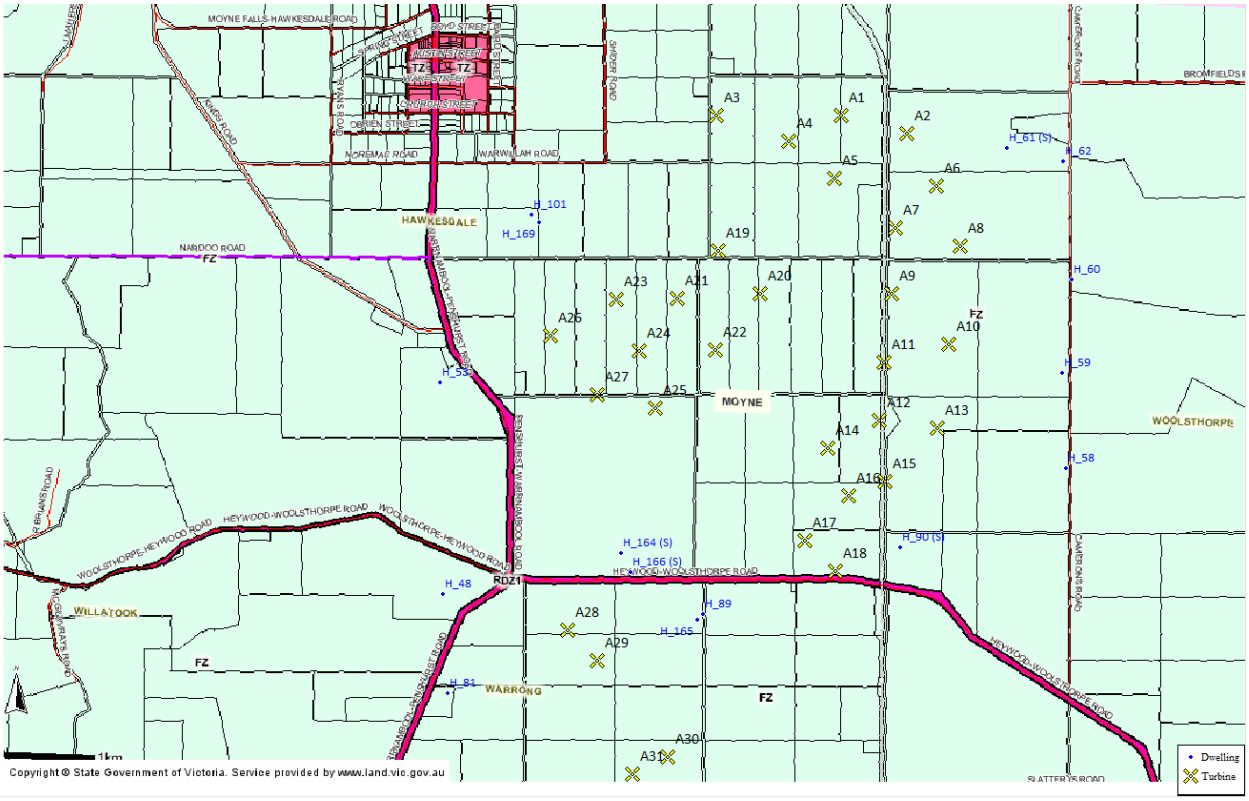
Mapped House Locations within 3km Viewshed

Hawkesdale Wind Farm

B1 Turbine coordinates (AGD66 Z54)

	Easting	Northing
A1	619551	5780999
A2	620143	5780838
A3	618431	5781005
A4	619080	5780769
A5	619489	5780437
A6	620407	5780368
A7	620041	5779992
A8	620613	5779829
A9	619999	5779406
A10	620517	5778955
A11	619933	5778794
A12	619892	5778268
A13	620414	5778204
A14	619427	5778020
A15	619940	5777722
A16	619615	5777601
A17	619230	5777197
A18	619500	5776923
A19	618450	5779788
A20	618826	5779402
A21	618085	5779362
A22	618427	5778904
A23	617535	5779352
A24	617739	5778894
A25	617885	5778385
A26	616947	5779031
A27	617364	5778498
A28	617098	5776397
A29	617363	5776122
A30	617996	5775264
A31	617682	5775103

APPENDIX C **ZONING MAP**



As downloaded from land.vic.gov.au on 29 July 2013.

APPENDIX D SUMMARY OF NOISE LIMITS

D1 24 hour noise limits, L_{A95} dB

	Wind speed @ 10m AGL (m/s)							
House	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
H48	40.7	42.4	44.0	45.4	46.3	46.6	46.6	46.6
H53	43.6	46.3	48.6	50.3	50.8	50.8	50.8	50.8
H58	40.7	42.4	44.0	45.4	46.3	46.6	46.6	46.6
H59	40.7	42.4	44.0	45.4	46.3	46.6	46.6	46.6
H60	40.7	42.4	44.0	45.4	46.3	46.6	46.6	46.6
H61 (S)	45.0	46.2	48.0	49.4	50.2	50.3	50.3	50.3
H62	44.1	46.2	48.0	49.4	50.2	50.3	50.3	50.3
H81	40.7	42.4	44.0	45.4	46.3	46.6	46.6	46.6
H89	46.3	47.8	48.7	48.8	48.8	48.8	48.8	48.8
H90 (S)	45.0	45.7	48.2	50.0	51.1	51.3	51.3	51.3
H101	41.6	43.7	45.7	47.3	48.4	48.8	48.8	48.8
H164 (S)	46.2	48.0	48.9	49.0	49.0	49.0	49.0	49.0
H165	46.3	47.8	48.7	48.8	48.8	48.8	48.8	48.8
H166 (S)	46.2	48.0	48.9	49.0	49.0	49.0	49.0	49.0
H169	41.6	43.7	45.7	47.3	48.4	48.8	48.8	48.8

(S) stakeholder in the project

D2 Night-time noise limits, L_{A95} dB

	Wind speed @ 10m AGL (m/s)							
House	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
H48	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
H53	41.2	43.7	44.9	44.9	44.9	44.9	44.9	44.9
H58	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
H59	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
H60	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
H61 (S)	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0
H62	41.6	42.2	42.2	42.2	42.2	42.2	42.2	42.2
H81	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
H89	48.2	49.5	49.5	49.5	49.5	49.5	49.5	49.5
H90 (S)	45.0	45.9	48.8	50.1	50.1	50.1	50.1	50.1
H101	40.6	41.9	42.1	42.1	42.1	42.1	42.1	42.1
H164 (S)	46.0	47.3	47.3	47.3	47.3	47.3	47.3	47.3
H165	48.2	49.5	49.5	49.5	49.5	49.5	49.5	49.5
H166 (S)	46.0	47.3	47.3	47.3	47.3	47.3	47.3	47.3
H169	40.6	41.9	42.1	42.1	42.1	42.1	42.1	42.1

(S) stakeholder in the project

APPENDIX E **NOISE PREDICTION MODEL**

Operational wind farm noise levels are predicted at all residential dwellings considered within this assessment using a three-dimensional noise model generated in SoundPLAN® version 7.2 software. Specifically, predictions have been carried out using the SoundPLAN implementation of ISO9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* (ISO9613-2:1996) to calculate noise propagation from the wind farm to each receiver location.

The use of this method is supported by international research publications, measurement studies conducted by Marshall Day Acoustics and direct reference to the standard in NZS6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010).

The standard specifies an engineering method for calculating noise at a known distance from a variety of sources under meteorological conditions favourable to sound propagation. The standard defines favourable conditions as downwind propagation where the source blows from the source to the receiver within an angle of +/-45 degrees from a line connecting the source to the receiver, at wind speeds between approximately 1m/s and 5m/s, measured at a height of 3m to 11m above the ground. Equivalently, the method accounts for average propagation under a well-developed moderate ground based thermal inversion. In this respect, it is noted that at the wind speeds relevant to noise levels from wind turbines, atmospheric conditions do not favour the development of thermal inversions throughout the propagation path from the source to the receiver.

To calculate far-field noise levels according to the ISO9613-2:1996, the noise levels of each turbine are firstly characterised in the form of octave band frequency levels. A series of octave band attenuation factors are then calculated for a range of effects including:

- Geometric divergence
- Air absorption
- Reflecting obstacles
- Screening
- Vegetation
- Ground reflections

The octave band attenuation factors are then applied to the sound power level data to determine the corresponding octave band and total calculated noise level at relevant receiver locations.

Calculating the attenuation factors for each effect requires a relevant description of the environment into which the sound propagation such as the physical dimensions of the environment, atmospheric conditions and the characteristics of the ground between the source and the receiver.

Wind farm noise propagation has been the subject of considerable research in recent years. These studies have provided support for the reliability of engineering methods such as ISO9613-2:1996 for the prediction of total A-weighted noise levels when a certain set of input parameters are chosen in combination.

A number of Australian and international studies support the assignment of a ground absorption factor of G=0.5 for the source, middle and receiver ground regions between a wind farm and a calculation point. This ground absorption factor of G=0.5 is adopted in combination with several cautious assumptions; specifically all turbines operating at identical wind speeds, emitting sound levels equal to the test measured levels plus a margin for uncertainty (or guaranteed values), at a temperature of 10 degrees and relative humidity of 70% (conditions which give rise to low atmospheric absorption). The studies demonstrate that applying the ISO9613-2:1996 prediction methodology in this way provides a reliable representation of the upper noise levels expected in practice.

In support of the use of ISO9613-2:1996 and the choice of G=0.5 as an appropriate ground characterisation, the following references are noted:

- A factor of G=0.5 is frequently applied in Australia for general environmental noise modelling purposes as a way of accounting for the potential mix of ground porosity which may occur in regions of dry/compacted soils or in regions where persistent damp conditions may be relevant
- NZS6808:2010 refers to ISO9613-2:1996 as an appropriate prediction methodology for wind farm noise, and notes that soft ground conditions should be characterised by a ground factor of G=0.5
- In 1998, a comprehensive study, part funded by the European Commission, Development of a Wind Farm Noise Propagation Prediction Model[11] found that the ISO9613-2:1996 model provided a robust representation of upper noise levels which may occur in practice, and provided a closer agreement between predicted and measured noise levels than alternative standards such as CONCAWE and ENM. Specifically, the report indicated the ISO9613-2:1996 method generally tends to marginally over predict noise levels expected in practice
- The UK Institute of Acoustics journal dated March/April 2009 published a joint agreement between practitioners in the field of wind farm noise assessment, including consultants routinely employed on behalf of both developers and community opposition groups, and indicated the ISO9613-2:1996 method as the appropriate standard and specifically designated G=0.5 as the appropriate ground characterisation. It is noted that this publication specifically referred to predictions made to receiver heights of 4m in the interest of representing 2-storey dwellings which are more common in the UK. Predictions in Australia are generally based on a lower prediction height of 1.5m which tends to result in higher ground attenuation factors for a given ground absorption factor, however conversely, predictions in Australia do not generally incorporate a -2dB factor (as applied in the UK) to represent the relationship between L_{Aeq} and L_{A90} noise levels. The result is that these differences tend to balance out to a comparable approach and thus supports the use of G=0.5 in the context of Australian prediction methodologies.

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

- The IoA document *A good practice guide to the application of ETSU-R-97 for the assessment and rating of wind turbine noise* (IOA GPG) published in May 2013 provides detailed descriptive advice to assist with the use of ETSU-R-97 for noise assessment of UK wind farm developments. The good practice guide recommends a ground factor of G = 0.5 when used in conjunction with the inputs described in the UK (IoA) journal article noted above.
- A range of comparative measurement and prediction studies[12, 13, 14] for wind farms in which Marshall Day Acoustics' staff have been involved in have provided further support for the use of ISO9613-2:1996 and G=0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

The key findings of these studies demonstrated the suitability of the ISO9613-2:1996 method to predict the propagation of wind turbine noise for:

- the types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30m maximum source heights considered in the original ISO9613
- the types of environments in which wind farms are typically developed, and the range of atmospheric conditions and wind speeds typically observed around wind farm sites. Importantly, this supports the extended scope of application to wind speeds in excess of 5m/s.

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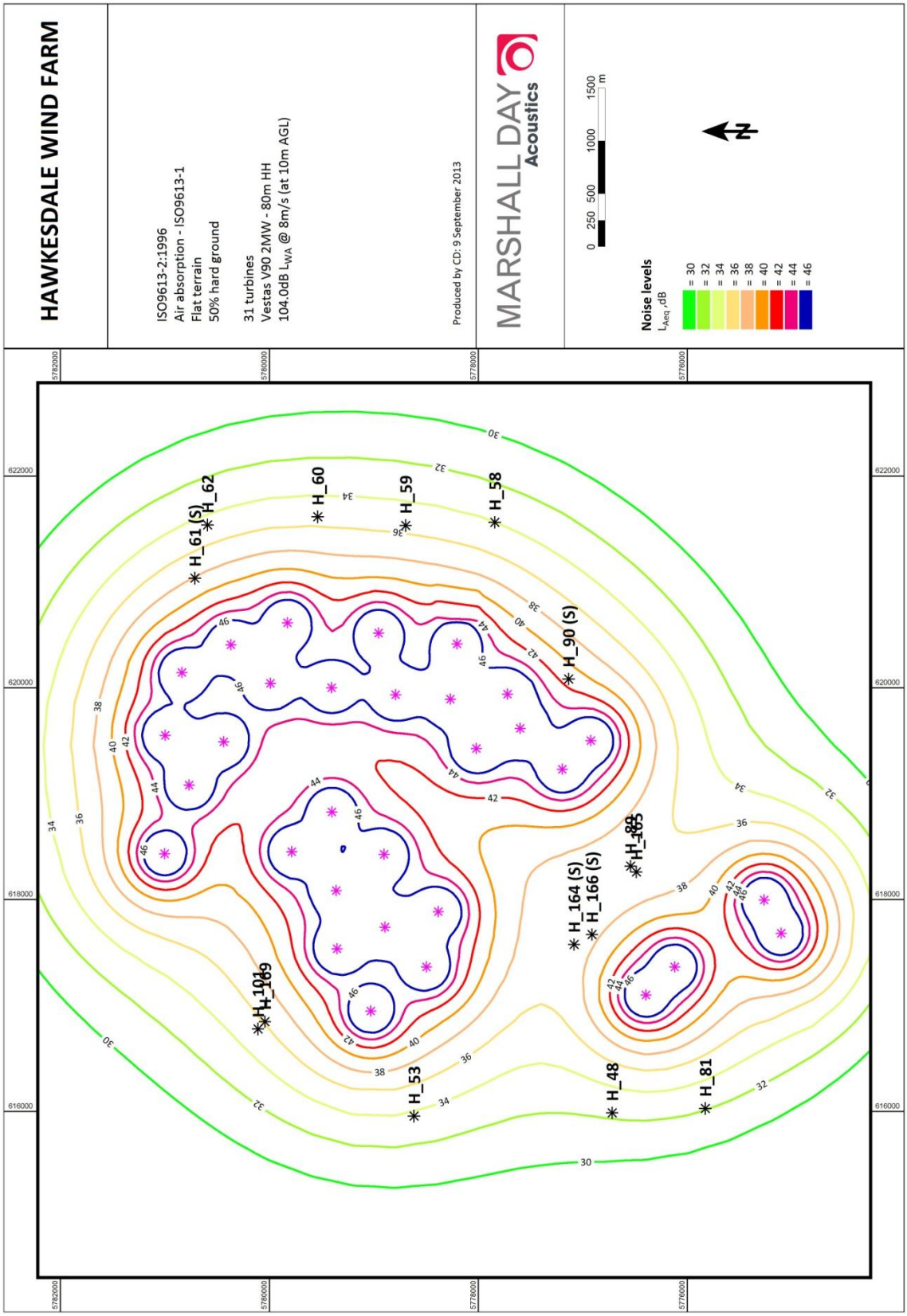
[12] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions: The Risks of Conservatism*; Presented at the Second International Meeting on Wind Turbine Noise in Lyon, France September 2007.

[13] Bullmore, Adcock, Jiggins & Cand – *Wind Farm Noise Predictions and Comparisons with Measurements*; Presented at the Third International Meeting on Wind Turbine Noise in Aalborg, Denmark June 2009.

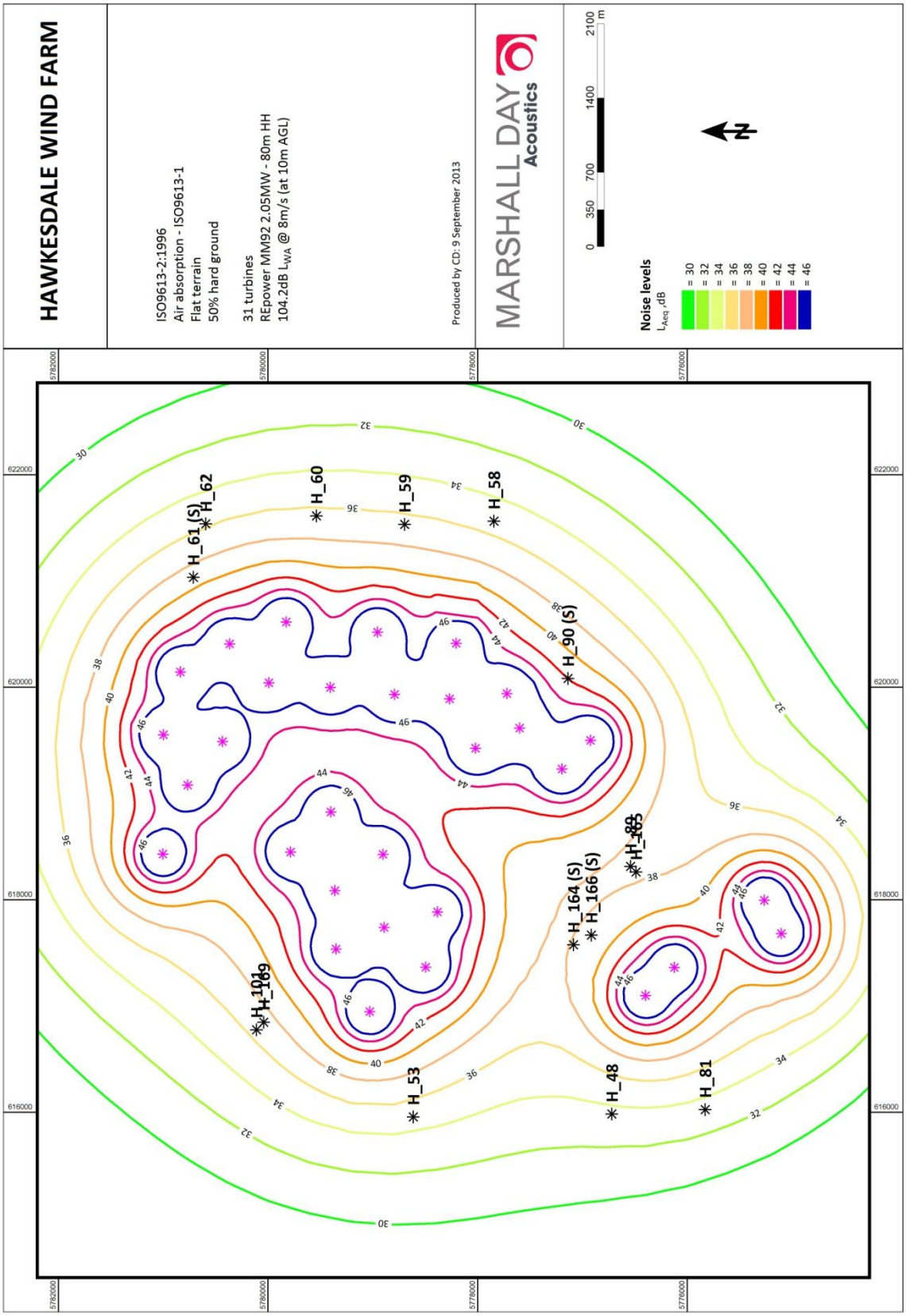
[14] Delaire, Griffin, & Walsh – *Comparison of predicted wind farm noise emission and measured post-construction noise levels at the Portland Wind Energy Project in Victoria, Australia*; Presented at the Fourth International Meeting on Wind Turbine Noise in Rome, April 2011.

APPENDIX F NOISE CONTOUR MAP

F1 Vestas V90



F2 REpower MM92



APPENDIX G WOOLSTHORPE WIND FARM INFORMATION

G1 Approved turbine coordinates (AGD66 Z54)

	Easting	Northing
1	620048	5773372
2	620708	5775743
3	621419	5774628
4	621340	5775718
5	620947	5772808
6	620106	5772204
7	621995	5773359
8	620046	5775935
9	620044	5771489
10	620065	5775413
11	620062	5772783
12	620054	5776564
13	620079	5774185
14	620513	5776255
15	621410	5775235
16	622140	5773837
17	621269	5774020
18	621431	5773134
19	620807	5773588
20	620420	5774564

APPENDIX H **DOCUMENTATION**

Predictions

(a) Map of the site showing topography, turbines and residential properties: See Appendix B

(b) Noise sensitive locations: See Section 5.0 and Appendix B

(c) Maximum sound power levels, L_{WA} dB (also refer to Section 2.2)

Turbine model	Octave Band Centre Frequency (Hz)								
	Overall	63	125	250	500	1000	2000	4000	8000
Vestas V90	104.0	84.3	91.6	94.8	98.2	98.5	96.7	92.8	78.7
REpower MM92	104.2	84.3	92.5	98.1	99.8	97.8	92.1	85.4	82.2

(d) Wind turbine models: Vestas V90 and REpower MM92 (see Section 2.1)

(e) Turbine hub height: 80m

(f) Distance of noise sensitive locations from the wind turbines: Table 4 of Section 2.3

(g) Calculation procedure used: ISO9613-2:1996 prediction algorithm as implemented in SoundPLAN v7.2 (See Section 7.0 and Appendix E)

(h) Meteorological conditions assumed:

- Temperature: 10°C
- Relative humidity: 70%
- Atmospheric pressure: 101.325 kPa

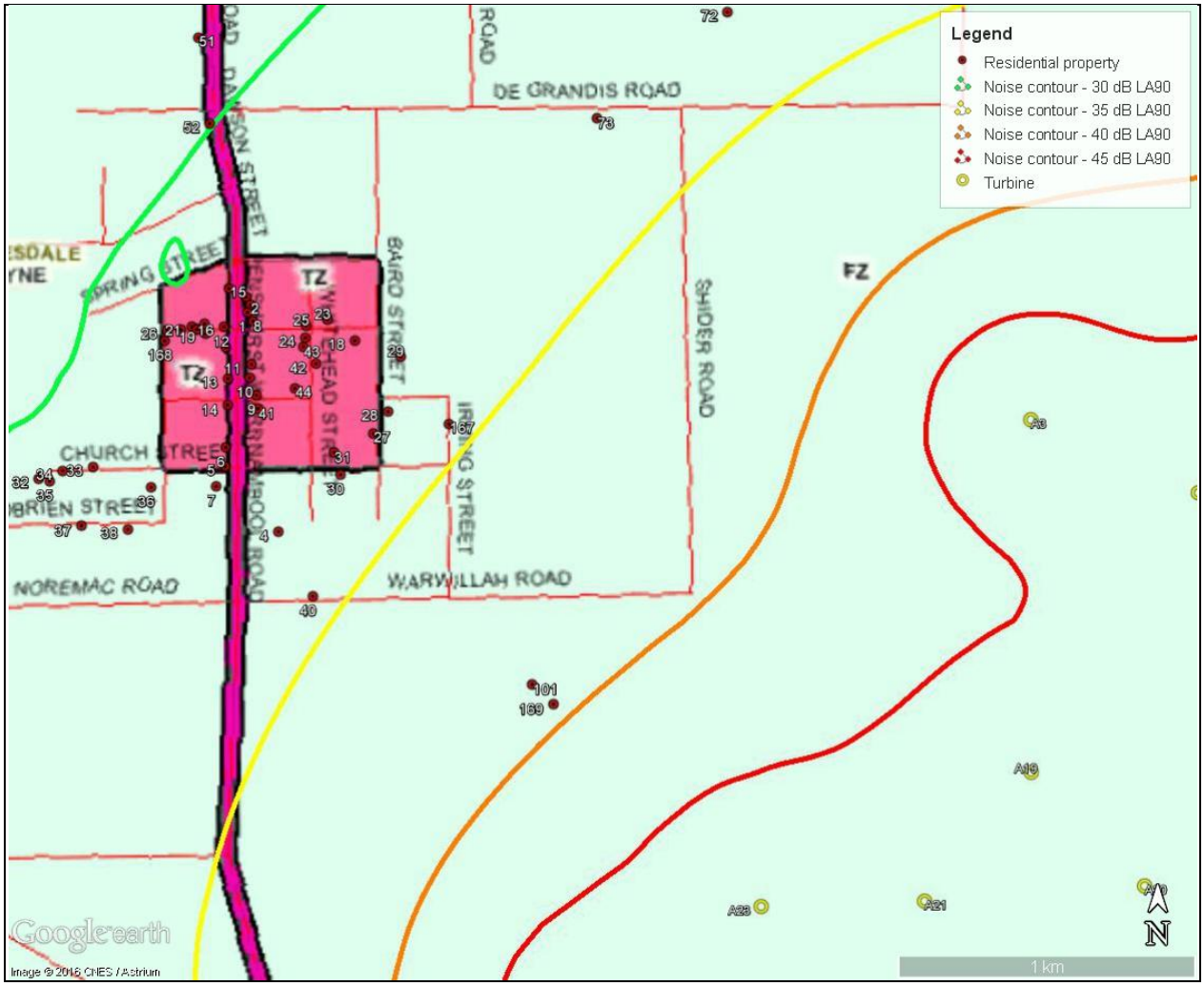
(i) Air absorption parameters:

	Octave band mid frequency (Hz)							
Description	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Atmospheric attenuation (dB/km)	0.12	0.41	1.04	1.93	3.66	9.66	32.8	116.9

(j) Topography/screening: No screening effects

(k) Predicted far-field wind farm sound levels: See Table 5 of Section 7.0

APPENDIX C NOISE CONTOUR MAP AROUND THE HAWKESDALE TOWNSHIP



Legend: Light green – Farming Zone
Pink – Township Zone
Yellow line – 35 dB L_{A90} noise contour