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Crookwell 3 Wind Farm

Noise Impact Assessment

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Noise Impact Assessment

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EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (**SLR Consulting**), formerly Heggies Pty Ltd, has completed a noise impact assessment of the Crookwell 3 Wind Farm. The methodology and criteria used in the assessment are supported by the South Australian Environmental Protection Authority (SA EPA) *Environment Noise Guidelines for Wind Farms (February 2003)* (**SA EPA Guideline**), World Health Organization (WHO) limits, construction noise guidelines (DECCW Interim Construction Noise Guideline 2009) and blasting impact (ANZECC guideline *Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration).*

Noise monitoring was conducted from 30th June to 16th July 2010 at eleven nearby locations to determine baseline conditions and establish indicative criteria for surrounding residential receivers. The previous noise monitoring data obtained for the Crookwell 2 wind farm has not been used as the reference height for wind speed monitoring has changed since this was obtained.

Predictions for cumulative WTG noise levels have been completed for two alternative possibilities;

- Existing Crookwell 1 Wind Farm and proposed Crookwell 3 Wind Farm
- Existing Crookwell 1 Wind Farm, approved Crookwell 2 Wind Farm and proposed Crookwell 3 Wind Farm

Noise predictions were made for receptors within a 6 km of each Wind Turbine Generator (WTG) proposed for the Crookwell 3 Wind Farm.

Four alternative WTG models were considered and assessed as part of this report as the final model selection for the proposed Crookwell 3 Wind Farm has not yet been made. The WTG models considered and assessed are:

- GE 2.5xl, 100m rotor diameter, 100m hub height, 2.5 MW
- Vestas V90, 90m rotor diameter, 105m hub height, 2.0 MW
- Vestas V100, 100m rotor diameter,95m hub height, 1.8 MW
- Repower MM92, 93m rotor diameter, 100m hub height, 2.0 MW

Where modelling was conducted for the purposes of this assessment, the modelled hub height represents the maximum height in the range being considered for that particular WTG model.

Cumulative WTG noise from existing Crookwell 1 and proposed Crookwell 3 Wind farms was predicted and assessed. Exceedances of the SA EPA Guideline limit were predicted for all four investigated WTGs, with the Vestas V90 WTG layout resulting in 2 exceedances. A mitigated operation scenario was considered where one WTG is turned off and a select few WTG's are operated in a 'low noise' mode for a limited range of wind speeds. The predicted reduction in noise levels resulted in no exceedances of the SA EPA Guideline limit.

Cumulative WTG noise from the existing Crookwell 1, approved Crookwell 2 and proposed Crookwell 3 Wind farms was predicted and assessed. Exceedances of the SA EPA Guideline limit were predicted for all four investigated WTGs, with the Vestas V90 WTG layout resulting in 8 exceedances.

The proponent proposes to negotiate noise agreements with House 8, House 20, House 66 and House 67 as well with as the host properties.

EXECUTIVE SUMMARY

A mitigated operation scenario was considered where a select few WTGs (Vestas V90) from both the approved Crookwell 2 Wind Farm and the proposed Crookwell 3 Wind Farm are operated in a 'low noise' mode. The resulting reduction in cumulative noise levels at potentially affected receptors was sufficient to reduce the total number of cumulative noise exceedances to 1 (House 70 exceedance of 0.3 dBA at 8.2 m/s) which would be considered only marginal.

It should be noted that the noise modelling procedure relies on a number of conservative assumptions, the foremost being that noise propagates downwind from each source. This will overestimate the predicted noise level where receptors have WTGs located around them in more than a singular direction or quadrant as wind is not able to blow in more than one directional quadrant simultaneously. This exact scenario describes the relative positioning the receptors identified as exceeding SA EPA Guideline levels have with respect to WTGs from Crookwell 2 and Crookwell 3. The degree to which this conservative assumption potentially over-estimates noise levels has been evaluated by predicting noise at compliance critical receptors using alternative algorithms and specific wind directions of easterly and westerly versus all downwind. The predicted degree of conservatism of the all downwind assumption is expected to be greater than the predicted exceedances.

During commissioning of the proposed Crookwell 3 Wind Farm the actual received WTG noise level will need to be verified and determined through extensive monitoring. In addition, an adaptive noise management plan will need to be developed and implemented whereby WTGs will be turned down to 'low noise' mode or alternatively turned off during conditions where actual exceedances are identified. The most effective approach to developing an adaptive noise management plan where multiple wind farms contribute to the cumulative noise impact is to assess received WTG noise levels through the collaborative and coordinated WTG "on-off" testing which removes much of the variability of non wind farm influences. Directional noise monitoring might also be a feasible means of monitoring noise from multiple projects and determining the most effective mitigation strategy.

To ensure the reliable long term operation of the wind farm with respect to minimising impacts the proponent will commit to routine noise monitoring, assessment and reporting at compliance critical locations to ensure that the ongoing operation of the proposed Crookwell 3 Wind Farm remains vigilant in minimising noise impacts.

Construction noise impact has been assessed and the 'worst case' scenarios modelled were found to be generally acceptable.

Blasting impact has been assessed and found to be acceptable. With a maximum instantaneous charge (MIC) of up to 21 kg, the airblast overpressure is anticipated to be below the acceptable level of 115 dB Linear for all existing residences.

Construction traffic noise impact has been assessed and the 'worst case' maximum construction traffic generated scenario modelled would increase existing traffic noise levels when measured along local roads by up to 3-7 dBA. However, due to the typically large setback of dwellings from the road network in the area, it is considered that the construction traffic noise would result in noise level that would be considered acceptable under the NSW DECCW *Environmental criteria for Road Traffic Noise* (ECRTN).

Subsequent to a request by the Director General due consideration has been paid to a number of the additional requirements of the proposed *Draft NSW Planning Guidelines Wind Farms – Appendix B: NSW wind farm noise guidelines* released by the NSW Department of Planning and Infrastructure in December 2011.

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1 INTRODUCTION

SLR Consulting Australia Pty Ltd (**SLR Consulting**), formerly Heggies Pty Ltd, have been engaged by Crookwell Development Pty Ltd (**CDPL**) as the acoustical consultants for the proposed Crookwell 3 Wind Farm. The proposed Crookwell 3 Wind Farm is located 30km north west of Goulburn on the Crookwell Road and Woodhouselee Road, in NSW. The project sites are adjacent to the approved Crookwell 2 Wind Farm and also in the same general area as the existing Crookwell 1 Wind Farm.

1.1 Objectives

This report describes the methodology and findings of the Noise Impact Study (**NIS**) for the Crookwell 3 Wind Farm forming part of the Environmental Assessment Report for the proposed project.

This report details the main aspects of the proposed wind farm project, the acoustic criteria, the background noise measurements and the predicted noise level at all potentially impacted receivers from the operation of the proposed wind farm.

It also addresses the acoustic impact of the wind farm during the construction phase, including blasting and transportation noise.

1.2 Methodology

1.2.1 Acceptability Limit Criteria

The methodology and acceptability limit criteria that have been applied to this study are based upon the *South Australia Environment Protection Authority (SA EPA) Noise Guidelines for Wind Farms (February 2003)* (**SA EPA Guidelines**). The principal acceptability limit criteria is that the wind farm $L_{A90(10\ min)}$ noise should not exceed the greater of:

- an amenity limit of 35 dBA; or
- the pre-existing background noise by more than 5 dBA (for any given wind speed).

The project requirements and wind farm acceptability limit criteria are discussed in more detail in **Section 7**.

The SA EPA Guidelines have been developed to minimise the impact on the amenity of premises that do not have an agreement with wind farm developers.

1.2.2 Wind Farm Noise Level Prediction

The noise emission model used in this study to predict wind farm noise levels at sensitive receptors is based on ISO 9613, as implemented in the SoundPLAN computer noise model. The model predicts noise levels through spherical spreading and includes the effect of air absorption (as per ISO 9613), ground attenuation and shielding.

Predicted L_{Aeq} noise levels were calculated based upon sound power levels determined in accordance to the recognised standard IEC-61400-11 (*Wind Turbine Generator Systems - Part 11: Acoustic Noise Measurement Techniques*), where available, for the wind range 6 to 10 m/s.

The noise character of Wind Turbine Generator (**WTG**) noise emissions is also assessed for any special audible characteristics, such as tonality or low frequency content, which would be deemed more annoying or offensive. If characteristics such as tonality are identified then the predicted noise level is penalised by the addition of 5 dBA for assessment purposes to account for the additional noise impacts resulting from this. It should be noted that the characteristic noise level modulation of WTGs, commonly referred to as 'swish', is considered to be a fundamental part of wind farm noise and is taken into account by the SA EPA Guideline assessment procedure.

1.2.3 Ambient Noise Monitoring

In order to establish the intrusive noise limit, background noise monitoring is required to establish the pre-existing ambient noise environment as a function of wind speed. As wind speed increases, the ambient noise level at most receivers also generally increases as natural sources such as wind in trees etc begin to dominate. The variation of background noise present at particular wind speeds is usually quite site specific and related to various physical characteristics such as topographic shielding and the extent and height of exposed vegetation.

Noise monitoring is completed for a period of approximately 2 weeks and is correlated to synchronous wind speed and direction data from the wind farm monitoring mast. The captured data is screened for validity, with data monitored during periods of rain, or where the average wind speed at the microphone position likely exceeded 5 m/s, being discarded from the data set. Other data that was obviously affected by external noise sources (eg. pond pumps, grass mowing, birds at dawn etc) was also removed from the data set. A regression analysis of all valid data is used to determine a line of 'best fit' from which the noise limit is established.

1.2.4 Assessment Procedure

In general, the assessment procedure contains the following steps:

- Predict and plot the L_{Aeq} 35 dBA noise level contour from the wind farm under reference conditions. Receivers outside the contour are considered to be within acceptable wind farm noise levels.
- Establish the pre-existing background noise level at each of the relevant assessment receivers within the L_{Aeq} 35 dBA noise level contour through background noise monitoring.
- Predict wind farm noise levels at all relevant assessment receivers for the wind range from cut-in of the WTG to approximately 10 m/s.
- Assess the acceptability of wind farm noise at each relevant assessment receiver to the established limits.

In addition, where the assessment of a receiver has predicted unacceptable resulting wind farm noise levels, a process of noise mitigation and alternative wind farm layouts is considered and Steps 3 and 4 are repeated until an acceptable arrangement is developed.

A brief explanation and description of the acoustic terminology used in this report is included in **Appendix D**

2 WIND TURBINE OPERATIONAL NOISE CRITERIA

2.1 Introduction

The environmental assessment requirements (**DGRs**) issued by the Director-General of the Department of Planning (**DOP**) in relation to the project require the Environmental Assessment Report (**EA**) to address the following in relation to noise impacts:

- → *include a comprehensive noise assessment of all phases and components of the project including, but not limited to, turbine operation, the operation of the electrical substation, construction, and traffic noise. The assessment must identify noise sensitive locations (including approved but not yet developed dwellings), baseline conditions based on monitoring results, the levels and character of noise (e.g. tonality, impulsiveness etc) generated by noise sources, noise criteria, modelling assumptions and worst case and representative noise impacts;*
- → *in relation to wind turbine operation, determine the noise impacts under operating meteorological conditions (i.e. wind speeds from cut in to rated power), including impacts under meteorological conditions that exacerbate impacts (including varying atmospheric stability classes and the van den Berg effect for wind turbines). The probability of such occurrences must be quantified;*
- → *include monitoring to ensure that there is adequate wind speed/profile data and ambient background noise data that is representative for all sensitive receptors;*
- → *provide justification for the nominated average background noise level used in the assessment process, considering any significant difference between daytime and night time background noise levels;*
- → *include an assessment of vibration impacts associated with the project;*
- → *if any noise agreements with residents are proposed for areas where noise criteria cannot be met, provide sufficient information to enable a clear understanding of what has been agreed and what criteria have been used to frame any such agreements;*
- → *clearly outline the noise mitigation, monitoring and management measures that would be applied to the project. This must include an assessment of the feasibility, effectiveness and reliability of proposed measures and any residual impacts after these measures have been incorporated; and*
- → *include a contingency strategy that provides for additional noise attenuation should higher noise levels than those predicted result following commissioning and/or noise agreements with landowners not eventuate.*

The assessment must be undertaken consistent with the following guidelines:

- → *Wind Turbines - the South Australian Environment Protection Authority's Wind Farms - Environmental Noise Guidelines (2003);*
- → *Site Establishment and Construction – Interim Construction Noise Guidelines (DECC, 2009);*
- → *Traffic Noise – Environmental Criteria for Road Traffic Noise (NSW EPA, 1999); and*
- → *Vibration – Assessing Vibration: A Technical Guideline (DECC, 2006).*

It is noted that whilst the NSW *Industrial Noise Policy* (EPA 2000) is not explicitly included in the DGRs it is the relevant policy to assess operational noise from the substation.

Each of the noise impact DGRs have been addressed by this report.

2.2 SA EPA Wind Farm Noise Guidelines

The South Australia EPA Noise Guidelines for Wind Farms (**SA EPA Guidelines**) recommends the following noise criteria for new wind farms:

> "*The predicted equivalent noise level ($L_{Aeq,\ 10min}$), adjusted for tonality in accordance with these guidelines, should not exceed:*
>
> - 35 dBA, or
> - the background noise level by more than 5 dBA,
>
> *whichever is the greater, at all relevant receivers for each integer wind speed from cut-in to rated power of the WTG.*"

The SA EPA Guideline also provide information on measuring the background noise levels, monitoring locations, requirements relating to the number of valid data points to be obtained and the methodology for excluding invalid data points. The SA EPA Guideline also outlines the process for determining lines of best fit for the background data, and the determination of the noise limit.

The SA EPA Guideline explicitly states that the "swish" or modulation noise from wind turbines is a fundamental characteristic of such turbines. The SA EPA Guideline specifies that any tonal or annoying characteristics of turbine noise in addition to the "swish" should be penalised with a 5 dBA penalty being applied to the measured noise level if an "authorised" officer determines that tonality is an issue and that tonality should be assessed in a way acceptable to the EPA.

The SA EPA Guideline does not provide an assessment for the potential of low frequency noise or infrasound, as it states that recent turbine designs do not appear to generate significant levels of infrasound, in contrast to the earlier turbine models.

The SA EPA Guideline accepts that wind farm developers commonly enter into agreements with private landowners in which they are provided compensation. The SA EPA Guideline is intended to be applied to premises that do not have an agreement with the wind farm developers and not to properties which have entered into such an agreement. This does not absolve the obligations of the wind farm developer entirely as appropriate action can be taken under the environmental protection legislation applying in the relevant jurisdiction if a development 'unreasonably interferes' with the amenity of an area. The guideline lists that there is unlikely to be unreasonable interference if;

- a formal agreement is documented between the parties;
- the agreement clearly outlines to the landowner the expected impact of the noise from the wind farm and its effect on the landowner's amenity; and
- the likely impact of exposure will not result in adverse health impacts (e.g. the level does not result in sleep disturbance).

The proponent, Crookwell Development Pty Ltd, proposes to enter into agreements with the residents on whose property the turbines proposed for the Crookwell 3 Wind Farm would be located on (**Host Properties**). The owners of the Host Properties have been provided copies of the Noise Assessment for their information, and have been advised that SA EPA Guidelines may be exceeded under certain turbine configurations.

The agreements to be entered into between Crookwell Development Pty Ltd and the owners of the Host Properties would specify:

- that Crookwell Development Pty Ltd would ensure that the properties met the World Health Organisation noise guidelines (see **Section 2.4**); and

- that Crookwell Development Pty Ltd would implement an adaptive management approach which could include the use of building treatments and turbine operation / management strategies if operational noise causes significant impact to the amenity of involved residents.

2.3 NSW Industrial Noise Policy (INP)

The NSW Industrial Noise Policy (INP) requirements would be applicable to non turbine related operational noise sources, such as the electrical substation.

The proposed site for the Crookwell 3 Wind Farm is in a rural area and therefore the Amenity Criteria for rural residential receivers, as detailed in Table 2.1 in the NSW INP, is applicable.

The criteria vary as a function of time of day. The Day, Evening and Night Periods are defined as,

Day Period	7:00 am - 6:00 pm 8:00 am - 6:00 pm (Sundays and Public Holidays)
Evening Period	6:00 pm - 10:00 pm
Night Period	10:00 pm - 7:00 am 10:00 pm - 8:00 am (Sundays and Public Holidays)

The Amenity Criteria (L_{Aeq} level) for the residential noise sensitive locations for the Crookwell 3 wind farm project are,

Day Period	50 dBA
Evening Period	45 dBA
Night Period	40 dBA

The Intrusiveness Criterion in the INP is based on the rating background level (RBL), where the Criterion is,

- $L_{Aeq,\ 15\ min} \leq$ RBL + 5 dBA

The INP states where the measured RBL is less than 30 dBA, then the RBL is considered to be 30 dBA.

2.4 World Health Organisation

As discussed in **Section 2.2**, the proponent intends to enter into noise agreements with the owners of project-involved residences in accordance with World Health Organisation guidelines, as it is necessary to ensure that the project does not result in an 'unreasonable interference' with the amenity of these areas or cause any adverse health affects.

The World Health Organisation (WHO) publication '*Guidelines for Community Noise'* identifies the main health risks associated with noise and derives acceptable environmental noise limits for various activities and environments.

The appropriate guideline limits are listed in **Table 1.**

Table 1 WHO Guideline values for environmental noise in specific environments

Specific Environment	Critical Health Effect(s)	L_{Aeq} (dBA)	Time base (hours)	L_{AMax} (dBA, Fast)
Outdoor living area	Serious Annoyance, daytime & evening	55	16	-
	Moderate annoyance, daytime & evening	50	16	-
Dwelling indoors	Speech Intelligibility & moderate annoyance, daytime & evening	35	16	
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance – window open, night-time	45	8	60

For the assessment of project involved residences the adopted external criteria of 45 dBA or the level given by the SA EPA Guideline criteria, where higher, will be adopted. Effectively this becomes 45 dBA or background + 5 dBA, whichever is the higher.

2.5 Construction Noise Guidelines

The DECCW issued the "*Interim Construction Noise Guideline"* in July 2009. The main objectives of the guideline are stated in Section 1.3, a portion of which is presented below:

- promote a clear understanding of ways to identify and minimise noise from construction works.
- focus on applying all 'feasible' and 'reasonable' work practices to minimise construction noise impacts.
- encourage construction to be undertaken only during the recommended standard hours unless approval is given for works that cannot be undertaken during these hours.

The guideline sets out Noise Management Levels (NMLs) at residences, and how they are to be applied, as presented in **Table 2**. This approach intends to provide respite for residents exposed to excessive construction noise outside the recommended standard hours whilst allowing construction during the recommended standard hours without undue constraints.

Table 2 Noise at Residences Using Quantitative Assessment

Time of Day	Management Level $L_{Aeq(15minute)}$[1]	How to Apply
Recommended standard hours: Monday to Friday 7.00 am to 6.00 pm Saturday 8.00 am to 1.00 pm No work on Sundays or public holidays	Noise affected RBL + 10 dBA	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq(15minute)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to minimise noise. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details
	Highly noise affected 75 dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the proponent should consider very carefully if there is any other feasible and reasonable way to reduce noise to below this level. If no quieter work method is feasible and reasonable, and the works proceed, the proponent should communicate with the impacted residents by clearly explaining the duration and noise level of the works, and by describing any respite periods that will be provided.
Outside recommended standard hours	Noise affected RBL + 5 dBA	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5 dBA above the noise affected level, the proponent should negotiate with the community.

Note 1: Noise levels apply at the property boundary that is most exposed to construction noise. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence.

2.6 Vibration Guidelines

Impacts from vibration can be considered both in terms of effects on building occupants (human comfort) and the effects on the building structure (building damage). Of these considerations, the human comfort limits are the most stringent. Therefore, for occupied buildings, if compliance with human comfort limits is achieved, it will follow that compliance will be achieved with the building damage objectives.

The DECCW's *Assessing Vibration: A Technical Guideline* provides acceptable values for continuous and impulsive vibration based upon guidelines contained in BS 6472–1992, *Evaluation of human exposure to vibration in buildings (1–80 Hz)*.

Both preferred and maximum vibration limits are defined for various locations and are shown in **Table 3**, with the preferred night-time PPV criteria of 0.2 mm/s being the most relevant to the project.

Table 3 Preferred and maximum values for continuous and impulsive vibration

Location	Assessment period[1]	Preferred values RMS acceleration m/s^2		Maximum values RMS acceleration m/s^2		Peak Velocity PPV mm/s	
		z-axis	x- and y-axes	z-axis	x- and y-axes	Preferred	Maximum
Continuous vibration							
Critical areas[2]	Day- or night-time	0.0050	0.0036	0.010	0.0072	0.14	0.28
Residences	Daytime	0.010	0.0071	0.020	0.014	0.28	0.56
	night-time	0.007	0.005	0.014	0.010	0.20	0.40
Offices, schools, educational institutions and places of worship	Day- or night-time	0.020	0.014	0.040	0.028	0.56	1.1
Workshops	Day- or night-time	0.04	0.029	0.080	0.058	1.1	2.2
Impulsive vibration							
Critical areas[2]	Day- or night-time	0.0050	0.0036	0.010	0.0072	0.14	0.28
Residences	Daytime	0.30	0.21	0.60	0.42	8.6	17.0
	night-time	0.010	0.0071	0.020	0.014	2.8	5.6
Offices, schools, educational institutions and places of worship	Day- or night-time	0.64	0.46	1.28	0.92	18.0	36.0
Workshops	Day- or night-time	0.64	0.46	1.28	0.92	18.0	36.0

1 Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am

2 Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specified above. Stipulation of such criteria is outside the scope of this policy, and other guidance documents (e.g. relevant standards) should be referred to. Source: BS 6472–1992

These limits relate to a long-term (16 hours for daytime), continuous exposure to vibration sources. Where vibration is intermittent, a higher level of vibration is typically acceptable.

2.6.1 Building Damage

In regard to potential building damage, the German Standard DIN4150 recommends a limit of 10 mm/s PPV within any building and the British Standard BS7385: Part 2 - 1993 sets a limit within buildings which depends upon the vibration frequency, but is as low as 7.5 mm/s PPV (at 4.5Hz). For the purposes of ensuring a reasonable factor of safety a conservative limit of approximately 5 mm/s PPV has been applied for this project.

2.7 Blasting Criteria

The ground vibration and airblast levels which cause concern or discomfort to residents are generally lower than the relevant building damage limits.

The DECC advocates the use of the Australian and New Zealand Environment Conservation Council (ANZECC) guideline *"Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration"* for assessing potential residential disturbance arising from blast emissions. The ANZECC guidelines for control of blasting impact at residences are as follows:

- The recommended maximum level for airblast is 115 dB Linear. The level of 115 dB Linear may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 120 dB Linear at any time.
- The recommended maximum for ground vibration is 5 mm/s, Peak Vector Sum (PVS) vibration velocity. It is recommended however, that 2 mm/s (PVS) be considered as the long term regulatory goal for the control of ground vibration. The PVS level of 5 mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 10 mm/s at any time.
- Blasting should generally only be permitted during the hours of 9:00 am to 5:00 pm Monday to Saturday. Blasting should not take place on Sundays and public holidays.
- Blasting should generally take place no more than once per day.

The Australian Standard 2187.2-1993 "*Explosives - Storage, Transport and Use. Part 2: Use of Explosives*" does not present human comfort criteria for ground vibration from blasting. It does however make mention of human comfort level for airblast in saying "a limit of 120 dB for human comfort is commonly used". This is consistent with the ANZECC guidelines.

AS 2187.2-1993 nominates building damage assessment criteria as presented in **Table 24**.

Table 4 Blast Emission Building Damage Assessment Criteria (AS 2187)

Building Type	Vibration Level	Airblast Level (dB re 20 µPa)
Sensitive (and Heritage)	PVS 5 mm/s	133 dB(Linear) Peak
Residential	PVS 10 mm/s	133 dB(Linear) Peak
Commercial/Industrial	PVS 25 mm/s	133 dB(Linear) Peak

2.8 Traffic Noise

The NSW *Environmental Criteria for Road Traffic Noise* (ECRTN May 1999) presents guidelines for the assessment of road traffic noise arising from new or redeveloped roads. The document provides road traffic noise guidelines for a range of road or residential developments, as well as guidelines that apply for other nominated sensitive land uses.

- The road traffic guidelines recommended are based on the functional categories of the subject roads, as applied by the Roads Traffic Authority (RTA).
- The functional categories are as follows:
- Arterial roads (including freeways) carrying predominantly through-traffic from one region to another, forming principal avenues of communication for urban traffic movements.
- Sub-arterial roads connecting the arterial roads to areas of development and carrying traffic from one part of a region to another. They may also relieve traffic on arterial roads in some circumstances.
- Collector roads connecting the sub-arterial roads to the local road system in developed areas.
- Local roads, which are the subdivisional roads within a particular developed area. These are used solely as local access roads
- For this project, traffic associated with the construction stage has the potential to increase noise levels on existing arterial and local roads during the day (no night period construction proposed). As such, the relevant traffic noise criteria, as provided in Table 1 of ECRTN, are provided in **Table 5** below.

Table 5 Road Traffic Noise Criteria

Type of Development	Criteria	
	Day 7am - 10pm (dBA)	**Where Criteria are Already Exceeded**
Redevelopment of existing freeway/arterial road	$L_{Aeq(15hour)}$ 60 dBA	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dBA.
Redevelopment of existing local roads	$L_{Aeq(1hour)}$ 55 dBA	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dBA.

3 GENERAL SITE DESCRIPTION

The Crookwell 3 Wind Farm and is located approximately 30km north west of Goulburn on the Crookwell Road, in NSW. The project sites are adjacent to the approved Crookwell 2 Wind Farm and also in the same general area as the existing Crookwell 1 Wind Farm.

The proposed wind farm project is to be located on two separate land parcels known as Crookwell 3 East (with an area of 1100 Hectares) and Crookwell 3 South (with an area of 400 Hectares). Crookwell 3 East and Crookwell 3 South may be developed in stages

The general location of the Crookwell 3 Wind Farm is shown in **Figure 1** and the orientation of as Crookwell 3 East and Crookwell 3 South with respect to local roads and surrounding dwellings is in **Figure 2**.

Figure 1 Location of proposed Crookwell 3 Wind Farm

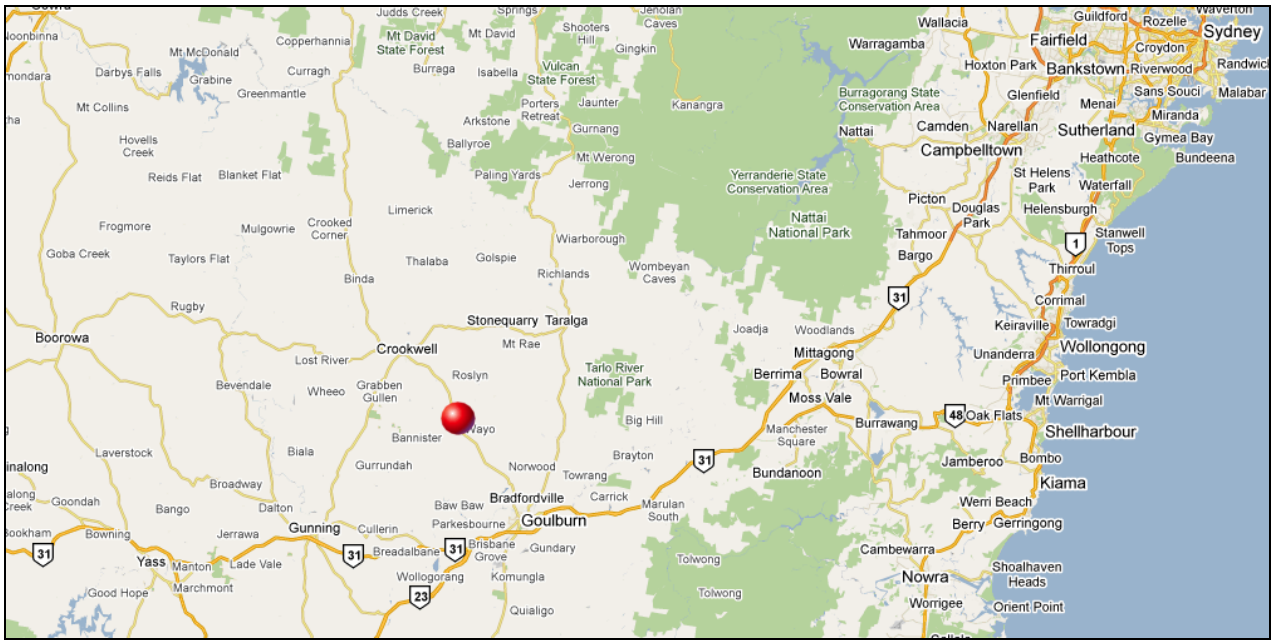


Image courtesy of Google Maps

3.1 Characteristics of the site

The proposed site incorporates the farming properties Wollondilly, Leeston, and Hillview Park. These Host Properties include residential dwellings, however, as agreements are proposed to be entered into between Crookwell Development Pty Ltd and the owners of the Host Properties on the terms outlined above, these Host Properties have not been subject to the formal assessment process. However, an indicative assessment has been carried out in relation to the Host Properties to ensure no unreasonable impact and to provide the basis of the agreements to be entered into between Crookwell Development Pty Ltd and the owners of the Host Properties.

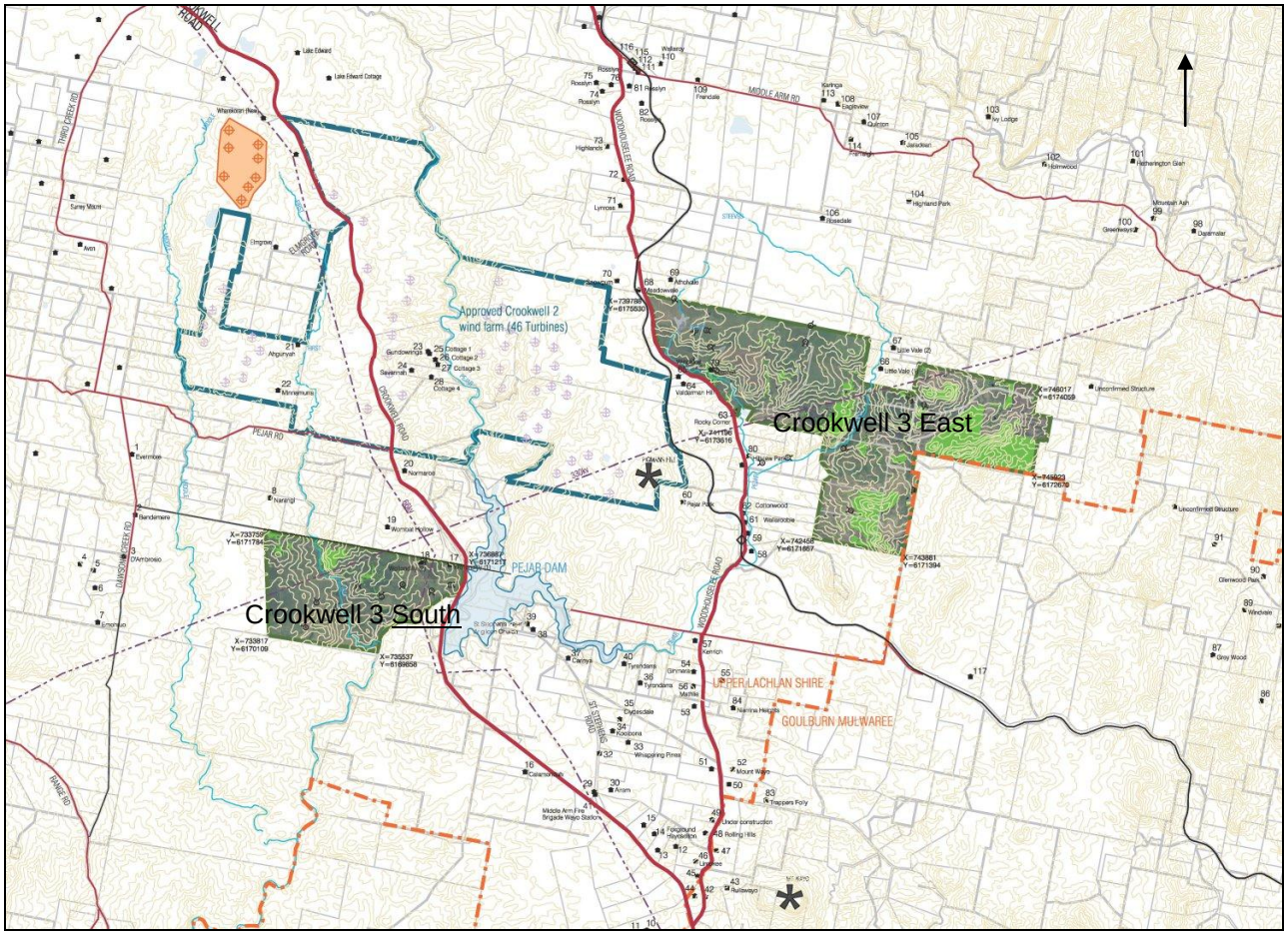
Topographically the two proposed sites broadly includes two raised ridges / plateau areas. At the centre of the site is a valley that contains the Wollondilly River which feeds Pejar Dam. A 330 kV high voltage transmission line crosses the site.

The district is primarily used for agricultural (grazing) purposes and the surrounding landscape and properties are largely cleared of trees, with the exception of wind breaks and isolated stands.

Road traffic on both Crookwell Road and Woodhouselee Road is intermittent and all residential dwellings surrounding the proposed site have an ambient background noise environment that is determined by predominantly natural sources which are largely wind influenced.

The prevailing wind is from the West and North West and the district receives only a minimal amount of rainfall.

Figure 2 Dwelling Locations



3.2 Dwelling Locations

Properties surrounding and including the proposed Crookwell 3 Wind Farm are generally located along or accessed from Crookwell Road and Woodhouselee Road. The assessment locations include all dwellings located within 6 km of a proposed WTG and are located as generally indicated on the map in **Figure 2**, with Crookwell 3 South shown in more detail in **Figure 3** and Crookwell 3 East shown in more detail in **Figure 4.**

Table 6 lists the dwellings located on both Host Properties and off-site and their position. Other dwellings located beyond 6 km of a proposed WTG are not considered within this assessment, primarily as WTG noise is unlikely to be audible at these distances and compliance to noise criteria is more critical at closer receivers.

Figure 3 Crookwell 3 South

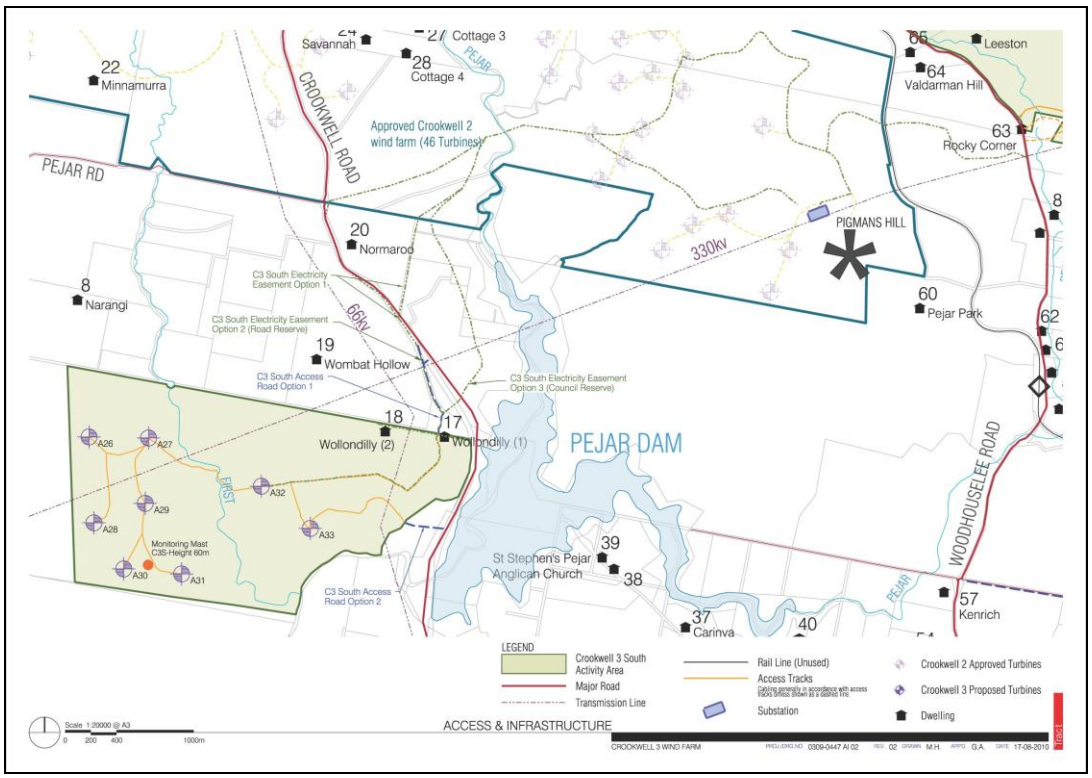


Figure 4 Crookwell 3 East

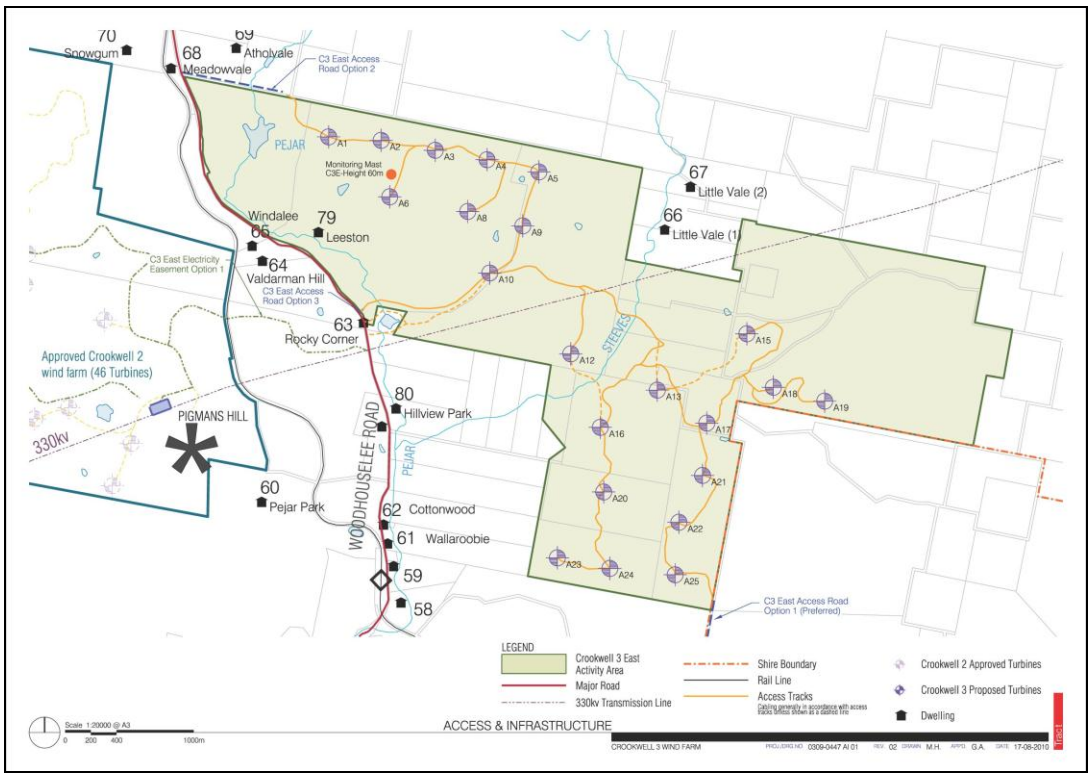


Table 6 Surrounding Receivers

Number	Name	Easting	Northing	Distance to nearest WTG
House 1	Evermore	731647	6172983	2.9
House 2	Bendemere	731698	6172026	2.4
House 3	D'Ambrosio	731516	6171362	2.4
House 4		730825	6171246	3.1
House 5		731037	6171145	2.9
House 6		731060	6170869	2.9
House 7	Emohruo	731103	6170322	2.9
House 8	Narangi	733838	6172296	1.1
House 12		740272	6166772	5.6
House 13		739985	6166712	5.8
House 14	Foxground Hayeselton	739932	6166971	5.6
House 15		739764	6167108	5.3
House 16	Calamondah	737882	6167951	3.4
House 17 *	Wollondilly (1)	736692	6171234	1.3
House 18 *	Wollondilly (2)	736232	6171276	1.0
House 19	Wombat Hollow	735698	6171835	1.1
House 20	Normaroo	735970	6172727	2.0
House 21	Ahgunyah	733928	6173990	2.8
House 22	Minnamurra	733964	6173999	2.8
House 23	Gundowringa	736342	6174616	3.9
House 24	Savannah	736082	6174316	3.5
House 25	Cottage 1 (Gundowringa)	736368	6174580	3.9
House 26	Cottage 2 (Gundowringa)	736458	6174487	3.8
House 27	Cottage 3 (Gundowringa)	736496	6174408	3.8
House 28	Cottage 4 (Gundowringa)	736395	6174209	3.5
House 29		738978	6167634	4.4
House 30	Airam	739244	6167665	4.6
House 31	Youanmite	739448	6167994	4.6
House 32		739063	6168245	4.1
House 33	Whispering Pines	739518	6168420	4.4
House 34	Kooloona	739270	6168600	4.1
House 35	Clydesdale	739384	6168786	4.1
House 36	Tyrendarra	739709	6169363	3.8
House 37	Carinya	738567	6169756	3.0
House 38		738011	6170209	2.4
House 39	St Stephen's Pejar Anglican Church	737919	6170298	2.3
House 40	Tyrendarra	739452	6169668	3.9
House 41	Middle Arm Fire Brigade Wayo Station	738995	6167592	4.4
House 43	Rullawayo	741086	6166113	5.9
House 45		740618	6166300	5.9
House 46	Limokee	740589	6166536	5.7
House 47		740918	6166707	5.4
House 48	Rolling Hills	740743	6166982	5.2
House 49		740850	6167190	5.0
House 50		741118	6167758	4.3

Number	Name	Easting	Northing	Distance to nearest WTG
House 51		740840	6167997	4.2
House 52	Mount Wayo	741178	6167993	4.1
House 53		740567	6168992	3.5
House 54	Ginmara	740557	6169539	3.1
House 55		741001	6169408	2.9
House 56	Mathlie	740550	6169310	3.3
House 57	Kenrich	740578	6170029	2.8
House 58		741473	6171450	1.3
House 59		741415	6171733	1.3
House 60	Pejar Park	740389	6172231	2.3
House 61	Wallaroobie	741369	6171908	1.3
House 62	Cottonwood	741337	6172055	1.4
House 63	Rocky Corner	741181	6173622	1.0
House 64	Balvardarman Hill	740395	6174100	1.1
House 65	Windalee	740315	6174217	1.0
House 66	Little Vale 1	743524	6174343	1.0
House 67	Little Vale 2	743724	6174675	1.2
House 68	Meadowvale	739684	6175594	1.3
House 69	Atholvale	740191	6175752	1.0
House 70	Snowgum	739339	6175736	1.7
House 71	Lynross	739396	6176926	2.4
House 72		739448	6177340	2.7
House 73	Highlands	739184	6177867	3.3
House 74	Rosslyn	739107	6178738	4.1
House 75	Rosslyn	739013	6178876	4.3
House 76	Rosslyn	739250	6178840	4.1
House 77	Bellevue Park	738837	6180318	5.6
House 79 *	Leeston	740830	6174323	0.6
House 80 *	Hillview Park	741434	6172956	1.3
House 81	Rosslyn	739537	6178821	4.0
House 82	Rosslyn	739732	6178548	3.7
House 83	Trappers Folly	741707	6167504	4.4
House 84	Nierrina Heights	741184	6168967	3.2
House 87	Grey Wood	748793	6169806	5.1
House 88	Ghost Gum Gully	749841	6170267	5.8
House 89	Windvale	749291	6170516	5.2
House 90	Glenwood Park	749595	6171049	5.2
House 91		748820	6171555	4.3
House 93	Pearces Hill	750414	6171045	6.0
House 96		750652	6172926	5.9
House 97		748494	6176524	5.1
House 98	Daramalar	748494	6176524	5.1
House 99	Mountain Ash	747850	6176725	4.8
House 100	Greenways	747569	6176543	4.5
House 101	Hetherington Glen	747522	6177634	5.3
House 102	Holmwood	746121	6177583	4.5

Number	Name	Easting	Northing	Distance to nearest WTG
House 103	Ivy Lodge	745231	6178338	4.4
House 104	Highland Park	743973	6176996	2.6
House 105	Jaradean	743875	6177928	3.4
House 106	Rosedale	742598	6176726	1.9
House 107	Quinton	743258	6178256	3.5
House 108	Eagleview	742847	6178538	3.7
House 109	Frendale	740622	6178917	3.9
House 110	Wallaroy	740029	6179174	4.2
House 111	Community Hall	739678	6179037	4.2
House 112	Roslyn Community Hall	739674	6179055	4.2
House 113	Karinga	742622	6178593	3.7
House 114	Frenleigh	743051	6177981	3.2
House 115	Roslyn Bush Fire Brigade	739626	6179103	4.2
House 116	Railway House	739578	6179174	4.3

Note: * Denotes that the dwelling is a Host Property.

4 PROPOSED WIND FARM LAYOUT

The proponent has developed a base turbine layouts for the 30 WTGs currently proposed for the Crookwell 3 Wind Farm. The proposed layout of the 30 WTGs is listed in **Table 7.**

Table 7 Crookwell 3 Proposed 30 WTG Layout

Name	Easting	Northing	Elevation	Wind Farm Region
A1	740910	6175065	911	CW3 - East
A2	741318	6175038	911	CW3 - East
A3	741739	6174961	919	CW3 - East
A4	742142	6174888	923	CW3 - East
A5	742545	6174793	916	CW3 - East
A6	741385	6174600	905	CW3 - East
A8	741992	6174487	911	CW3 - East
A9	742420	6174375	913	CW3 - East
A10	742163	6174009	900	CW3 - East
A12	742793	6173382	886	CW3 - East
A13	743466	6173101	868	CW3 - East
A15	744163	6173538	889	CW3 - East
A16	743023	6172812	871	CW3 - East
A17	743851	6172845	880	CW3 - East
A18	744369	6173123	903	CW3 - East
A19	744768	6173016	930	CW3 - East
A20	743049	6172311	880	CW3 - East
A21	743818	6172439	896	CW3 - East
A22	743634	6172076	904	CW3 - East
A23	742689	6171800	861	CW3 - East
A24	743097	6171718	872	CW3 - East
A25	743605	6171669	933	CW3 – East
A26	733928	6171235	825	CW3 – South
A27	734391	6171227	791	CW3 – South
A28	733966	6170569	799	CW3 – South
A29	734365	6170720	819	CW3 – South
A30	734198	6170212	810	CW3 – South
A31	734648	6170173	824	CW3 – South
A32	735268	6170853	803	CW3 – South
A33	735649	6170525	799	CW3 – South

5 WTG TYPE AND DETAILS

The WTG manufacturer and model has not yet been finalised, and accordingly it is necessary to nominate each of the models currently being considered for the noise impact investigation. The 30 WTG wind farm layout has been assessed using the four different WTG models under consideration being:

- GE 2.5xl 2.5 MW turbines;
- Vestas V90 2.0 MW turbines;
- Vestas V100 1.8 MW turbines; and
- Repower MM92 2.0 MW turbines.

All turbines are three bladed, upwind, pitch-regulated and active yaw.

A number of hub height options are being considered for each WTG model, however, for the purposes of the noise modelling conducted the highest available in the range has been considered. This approach may be considered marginally more conservative as the additional elevation results in less potential screening and ground attenuation losses.

In addition to the operating noise resulting from the 30 WTGs proposed for the Crookwell 3 Wind Farm, the SA EPA Guideline requires the cumulative impact of other operating (Crookwell 1) and approved (Crookwell 2) wind farms to be assessed. Crookwell 1 turbines are Vestas V47 660 kW two speed turbines. Crookwell 2 is yet to be built and selection of WTG model has not yet been finalised, however, previous noise modelling has shown that a layout comprised of Vestas V90 2.0 MW turbines at 80 metre hub height have demonstrated compliance on the Crookwell 2 project and hence for the purposes of this assessment this assumption has been maintained.

Table 8 summarises the relevant turbine input data used for noise level prediction.

Table 8 WTG Manufacturers Data

Make, model, power	**GE 2.5xl, 2.5 MW**	**Vestas V90, 2.0 MW**	**Vestas V100, 1.8 MW**	**Repower MM92, 2.0 MW**
Rotor diameter	100 m	90 m	100 m	93 m
Hub height *(modelled height in italics)*	85 m *100 m*	80 m 95 m *105 m*	80 m *95 m*	80 m *100 m*
Cut-in wind speed	3.5 m/s	2.5 m/s	4 m/s	3 m/s
Rated wind speed	12.5 m/s	13 m/s	12 m/s	13 m/s
'Standard Mode' Sound Power Level, $L_{WA,ref}$	104.6 dBA	102.8 dBA	105 dBA	104.2 dBA

The noise emissions for the proposed WTGs as set out in **Table 8** have been provided by the WTG manufacturers and have either been independently tested according to International Standard IEC 61400-11 or are warranted noise levels calculated in accordance with the International Standard.

A copy of the certification test for the Vestas V90 2.0 MW WTG that gives the sound power level variation with wind speed, frequency spectra and tonality assessment are contained in **Appendix C.** If an alternative WTG were to be selected for the wind farm the relevant documentation would be provided in the pre-construction noise assessment.

6 OPERATIONAL NOISE LEVELS

6.1 Introduction

As discussed in **Section 1.2.2**, a three-dimensional computer noise model was used to predict L_{Aeq} noise levels from all WTGs at all surrounding residential dwellings.

The ISO 9613 noise model incorporates a 'hard ground' assumption and includes one-third octave band calculated effects for air absorption, ground attenuation and topographic shielding. It is noted that ISO 9613 equations predict for average downwind propagation conditions and also hold for average propagation under a well-developed moderate ground-based temperature inversion.

The estimated accuracy of the prediction model is approximately ±3 dBA.

Predictions for cumulative WTG noise levels have been completed for two alternative possibilities;

- Existing Crookwell 1 Wind Farm and proposed Crookwell 3 Wind Farm
- Existing Crookwell 1 Wind Farm, approved Crookwell 2 Wind Farm and proposed Crookwell 3 Wind Farm

6.2 Crookwell 1 and Crookwell 3 Wind Farm WTG Noise

For indicative purposes, the cumulative operational WTG noise level is the noise resulting from the proposed Crookwell 3 Wind Farm and the existing Crookwell 1 Wind Farm. The resulting WTG cumulative operational noise levels are listed in **Table 9** and were calculated using the reference wind condition of 8 m/s at 10 m AGL or 11.1 m/s measured at a height of 80 metres. 80 metres is the height of the tallest wind monitoring mast on the CDPL project sites in this region and is indicative of the preferred hub height.

4 separate predicted noise contour plots of the cumulative WTG operational noise levels were prepared for each turbine model currently being considered for the Crookwell 3 Windfarm:

- GE 2.5xl (2.5MW) is depicted in **Figure 5;**
- Vestas V90 (2.0 MW) is depicted in **Figure 6;**
- Vestas V100 (1.8 MW) is depicted in **Figure 7**; and
- Repower MM92 (2.0 MW) is depicted in **Figure 8**.

Furthermore, the cumulative WTG operational noise levels from the two wind farms were calculated for all integer wind speeds in the range of 6 to 10 m/s at 10 metres AGL (equivalent to 8 to 14 m/s at 80 metres AGL) at all surrounding assessment receivers within 6 km of a proposed turbine. Whilst the rated wind speed of the WTGs is typically 13 - 14 m/s, published manufacturers sound power level test data (IEC 61400-11) has only been generated as high as 10 m/s. It should be noted that noise produced by WTGs begins to 'plateau off' at higher wind speeds and because of the higher masking background noise level at higher wind speeds, noise impacts and compliance are a non issue at these speeds. The assessed wind range sufficiently covers the most noise critical operational conditions.

4 separate assessment graphs of cumulative WTG operational noise levels were prepared for each turbine model currently being considered for the Crookwell 3 Windfarm:

- GE 2.5xl (2.5MW) is depicted in **Appendix A1**;
- Vestas V90 (2.0 MW) is depicted in **Appendix A2**;
- Vestas V100 (1.8 MW) is depicted in **Appendix A3**; and
- Repower MM92 (2.0 MW) is depicted in **Appendix A4**.

Table 9 Crookwell 1 and Crookwell 3 Wind Farm L_{Aeq} noise level (dBA) at $V_{ref,10m}$ = 8 m/s, V_{80m} = 11.1 m/s

Receiver / Property	GE 2.5xl (2.5MW), 100m hub height	Vestas V90 (2 MW), 105m hub height	Vestas V100 (1.8 MW), 95m hub height	Repower MM92 (2 MW), 100m hub height
House 1 Evermore	29.3	25.8	24.6	29.3
House 2 Bendemere	30.6	26.3	25.3	30.6
House 3 D'Ambrosio	30.8	26.6	25.6	30.8
House 4	28.5	24.5	23.0	28.6
House 5	29.2	25.1	23.8	29.3
House 6	29.4	25.2	23.9	29.4
House 7 Emohruo	29.3	25.2	23.8	29.4
House 8 Narangi	38.1	34.3	34.9	38.2
House 12	26.3	22.4	17.0	26.1
House 13	24.3	20.8	15.2	24.1
House 14 Foxground Hayeselton	26.6	22.7	17.3	26.4
House 15	26.8	22.8	17.6	26.6
House 16 Calamondah	27.1	23.1	18.9	27.0
House 17 Wollondilly (1) *	36.0	32.0	32.1	36.1
House 18 Wollondilly (2) *	38.6	34.9	35.6	38.7
House 19 Wombat Hollow	38.4	34.5	35.0	38.5
House 20 Normaroo	33.6	29.4	28.4	33.6
House 21 Ahgunyah	28.1	24.5	22.6	28.1
House 22 Minnamurra	30.9	27.7	26.6	30.9
House 23 Gundowringa	25.3	21.9	18.3	25.2
House 24 Savannah	26.8	23.0	19.2	26.7
House 25 Cottage 1 (Gundowringa)	25.2	21.4	17.9	25.1
House 26 Cottage 2 (Gundowringa)	21.6	19.0	15.6	21.6
House 27 Cottage 3 (Gundowringa)	22.7	19.0	16.5	22.6
House 28 Cottage 4 (Gundowringa)	22.7	19.0	16.6	22.7
House 29	27.6	23.6	18.9	27.5
House 30 Airam	27.6	23.6	18.9	27.5
House 32	26.7	22.7	18.4	26.6
House 33 Whispering Pines	27.2	23.5	18.7	27.1
House 34 Kooloona	28.9	24.8	20.8	28.8
House 35 Clydesdale	27.6	23.5	19.3	27.5
House 36 Tyrendarra	30.1	25.9	22.4	30.0
House 37 Carinya	29.3	25.1	22.4	29.2

Receiver / Property	GE 2.5xl (2.5MW), 100m hub height	Vestas V90 (2 MW), 105m hub height	Vestas V100 (1.8 MW), 95m hub height	Repower MM92 (2 MW), 100m hub height
House 38	30.0	25.6	24.1	30.0
House 39 St Stephen's Pejar Anglican Church	30.2	25.9	24.6	30.3
House 40 Tyrendarra	29.7	25.4	21.9	29.6
House 41 Middle Arm Fire Brigade Wayo Station	27.5	23.5	18.8	27.4
House 43 Rullawayo	20.4	17.7	11.4	20.1
House 45	20.6	17.9	11.7	20.4
House 46 Limokee	21.2	18.4	12.5	21.0
House 47	26.3	22.4	17.0	26.1
House 48 Rolling Hills	26.7	22.8	17.6	26.5
House 49 Under construction	27.1	23.1	18.1	26.9
House 50	28.2	24.1	19.8	28.1
House 51	28.5	24.4	20.3	28.4
House 52 Mount Wayo	28.7	24.6	20.6	28.6
House 53	30.1	25.9	22.5	30.1
House 54 Ginmara	31.1	26.8	24.0	31.1
House 55	31.4	27.1	24.5	31.3
House 56 Mathlie	30.1	25.8	22.9	30.0
House 57 Kenrich	32.1	27.7	25.3	32.0
House 58	37.3	33.2	33.2	37.4
House 59	38.0	33.9	33.8	38.1
House 60 Pejar Park	35.0	30.7	29.6	35.1
House 61 Wallaroobie	38.1	34.0	33.9	38.2
House 62 Cottonwood	38.2	34.1	33.9	38.3
House 63 Rocky Corner	41.6	37.8	38.3	41.7
House 64 Balvardarman Hill	39.9	35.9	36.4	40.0
House 65 Windalee	39.8	35.9	36.4	39.9
House 66 Little Vale (1)	42.0	38.2	38.9	42.1
House 67 Little Vale (2)	39.6	36.0	36.2	39.7
House 68 Meadowvale	36.1	32.0	31.8	36.1
House 69 Atholvale	38.5	34.6	35.0	38.6
House 70 Snowgum	34.4	30.3	29.4	34.5
House 71 Lynross	31.8	27.8	26.1	31.8
House 72	31.1	27.0	24.9	31.1
House 73 Highlands	29.5	25.7	23.2	29.5
House 74 Rosslyn	21.9	19.7	17.9	21.8
House 75 Rosslyn	19.7	17.7	15.8	19.6
House 76 Rosslyn	21.4	19.2	17.5	21.3
House 77 Bellevue Park	18.5	17.3	16.5	18.4
House 79 Leeston *	42.5	39.1	40.2	42.6
House 80 Hillview Park *	39.8	35.9	36.0	39.9
House 81 Rosslyn	27.9	24.1	21.1	27.8
House 82 Rosslyn	28.7	24.8	22.0	28.6

Receiver / Property	GE 2.5xl (2.5MW), 100m hub height	Vestas V90 (2 MW), 105m hub height	Vestas V100 (1.8 MW), 95m hub height	Repower MM92 (2 MW), 100m hub height
House 83 Trappers Folly	27.9	23.9	19.6	27.8
House 84 Nierrina Heights	30.6	26.4	23.4	30.6
House 87 Grey Wood	18.0	15.0	10.2	17.8
House 88 Ghost Gum Gully	16.2	13.8	8.0	16.0
House 89 Windvale	16.6	13.2	8.7	16.4
House 90 Glenwood Park	16.9	13.9	8.8	16.7
House 91	18.0	14.2	10.4	17.9
House 93 Pearces Hill	17.1	15.0	8.0	16.8
House 96	17.0	14.7	8.0	16.7
House 98 Daramalar	17.6	14.8	9.7	17.4
House 99 Mountain Ash	18.3	15.3	10.4	18.1
House 100 Greenways	18.9	15.2	11.4	18.8
House 101 Hetherington Glen	17.8	15.0	9.9	17.7
House 102 Holmwood	21.6	18.2	13.7	21.5
House 103 Ivy Lodge	27.3	23.5	18.7	27.2
House 104 Highland Park	31.3	27.2	25.5	31.4
House 105 Jaradean	29.8	25.5	22.8	29.8
House 106 Rosedale	26.8	22.6	21.2	26.9
House 107 Quinton	29.1	24.8	22.5	29.1
House 108 Eagleview	28.9	24.5	21.8	28.8
House 109 Frendale	28.5	24.2	20.9	28.4
House 110 Wallaroy	19.9	17.5	16.0	19.8
House 111 Community Hall	20.2	17.9	16.6	20.1
House 112 Roslyn Community Hall	20.2	17.9	16.5	20.1
House 113 Karinga	28.6	24.5	21.6	28.6
House 114 Frenleigh	30.1	25.9	23.6	30.1
House 115 Roslyn Bush Fire Brigade	19.7	17.3	15.7	19.6
House 116 Railway House	19.4	17.0	15.3	19.4

Note: * Denotes that the dwelling is a Host Property

Figure 5 Crookwell 1 and Crookwell 3 Wind Farm – GE 2.5xl 2.5MW, L_{Aeq} Noise Contour Map

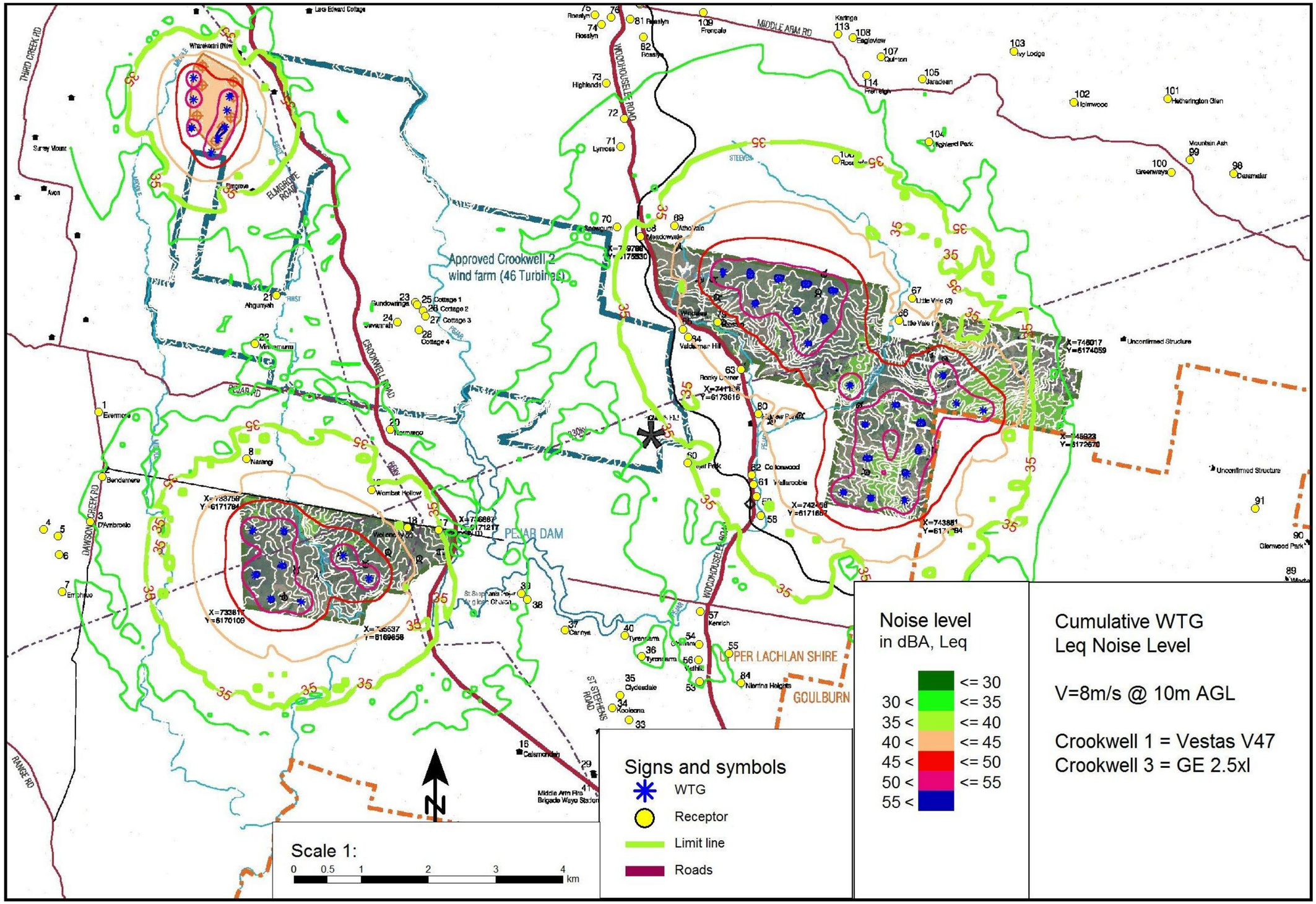


Figure 6 Crookwell 1 and Crookwell 3 Wind Farm - Vestas V90 2MW, L_{Aeq} Noise Contour Map

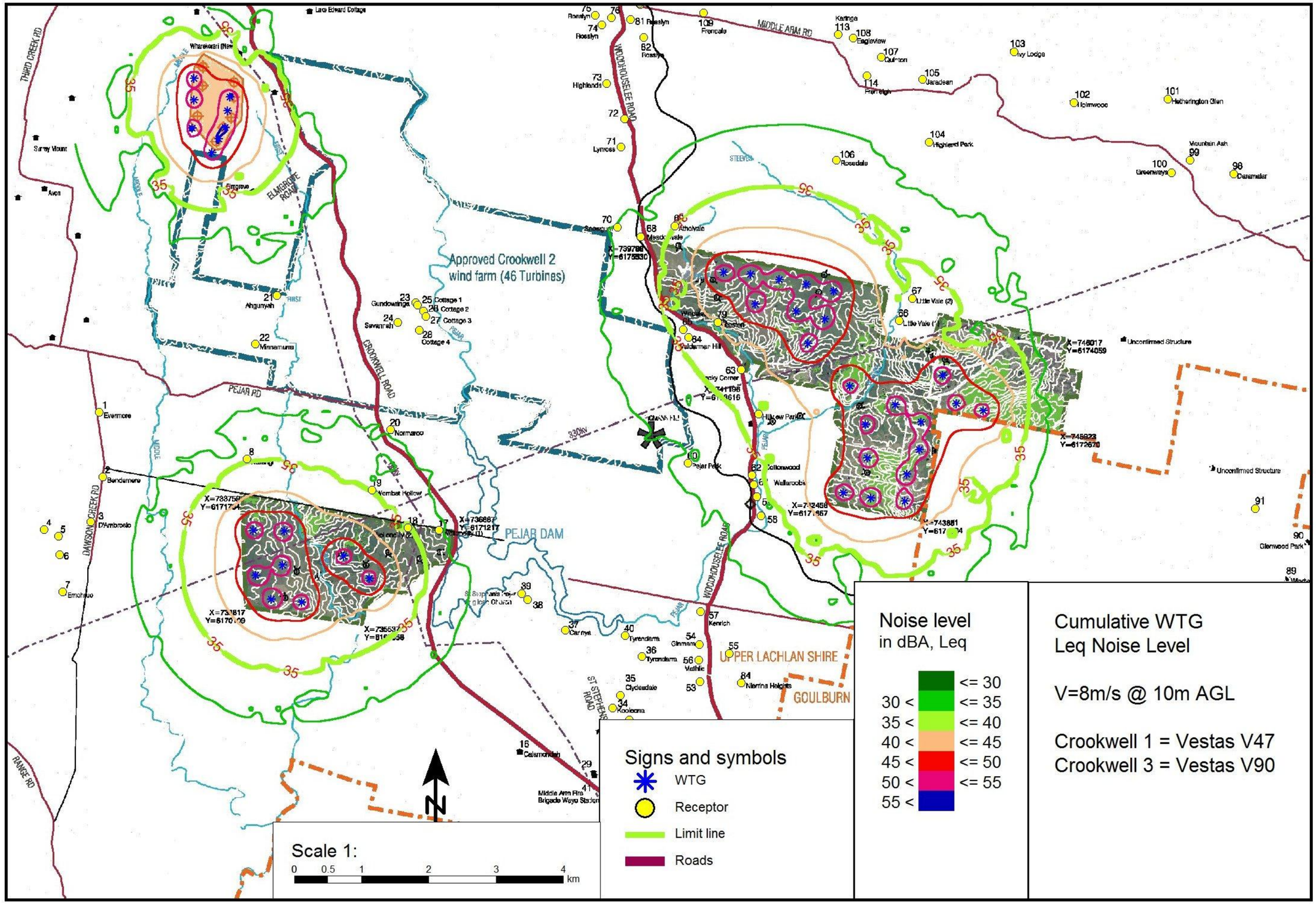


Figure 7 Crookwell 1 and Crookwell 3 Wind Farm - Vestas V100 1.8MW, L_{Aeq} Noise Contour Map

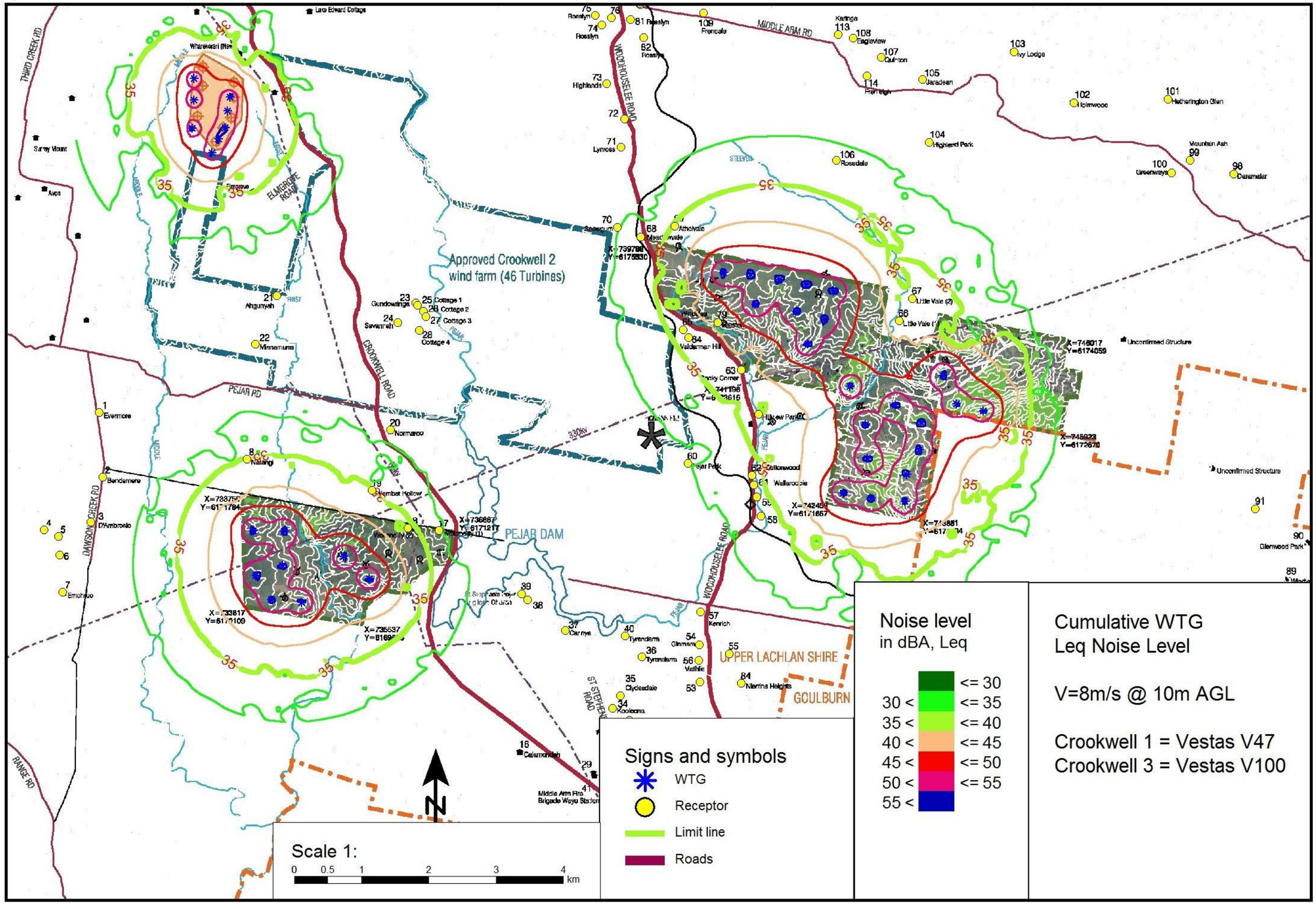
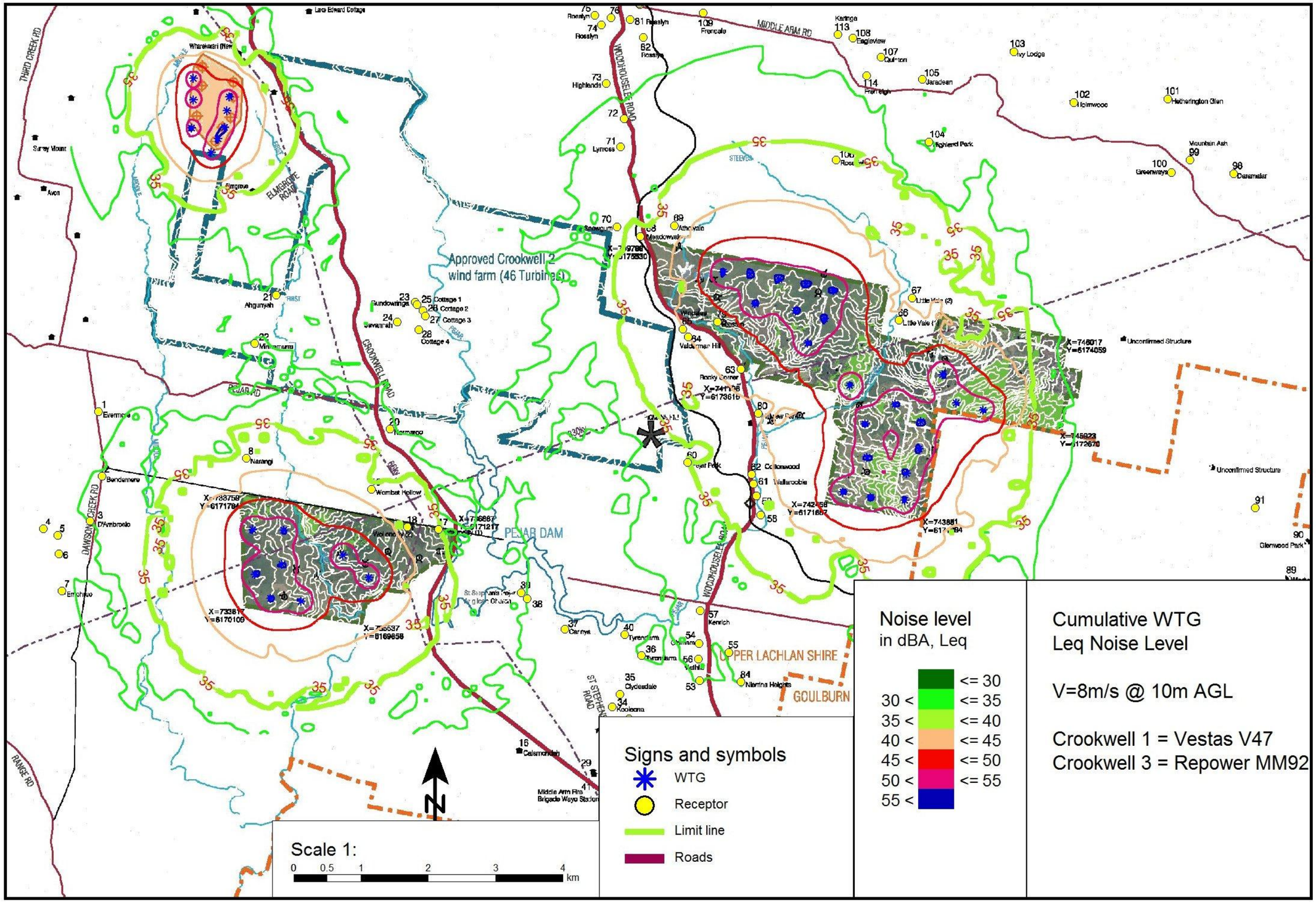


Figure 8 Crookwell 1 and Crookwell 3 Wind Farm - Repower MM92 2MW, L_{Aeq} Noise Contour Map



6.3 Crookwell 1 and Crookwell 2 and Crookwell 3 Wind Farm WTG Noise WTG Noise

For indicative purposes, the cumulative operational WTG noise level is the noise resulting from the existing Crookwell 1 Wind Farm, the approved Crookwell 2 Wind Farm; and the proposed Crookwell 3 Wind Farm. The resulting WTG cumulative operational noise levels are listed in **Table 10** and were calculated using the reference wind condition of 8 m/s at 10 m AGL or 11.1 m/s measured at a height of 80 metres. 80 metres is the height of the tallest wind monitoring mast on the CDPL project sites in this region and is indicative of the preferred hub height. The calculations include a conservative assumption of downwind noise propagation to all surrounding residential receivers from all noise sources.

4 separate predicted noise contour plots of the cumulative WTG operational noise levels were prepared for each turbine model currently being considered for the Crookwell 3 Windfarm:

- GE 2.5xl (2.5MW) is depicted in **Figure 9;**
- Vestas V90 (2.0 MW) is depicted in **Figure 10**;
- Vestas V100 (1.8 MW) is depicted in **Figure 11**; and
- Repower MM92 (2.0 MW) is depicted in **Figure 12**.

Furthermore, the cumulative WTG operational noise levels were calculated for all integer wind speeds in the range of 6 to 10 m/s at 10 metres AGL (equivalent to 8 to 14 m/s at 80 metres AGL) at all surrounding assessment receivers within 6 km of a proposed turbine. Whilst the rated wind speed of the WTGs is typically 13 - 14 m/s, published manufacturers sound power level test data (IEC 61400-11) has only been generated as high as 10 m/s. It should be noted that noise produced by WTGs begins to 'plateau off' at higher wind speeds and because of the higher masking background noise level at higher wind speeds, noise impacts and compliance are a non issue at these speeds. The assessed wind range sufficiently covers the most noise critical operational conditions.

4 separate assessment graphs of cumulative WTG operational noise levels were prepared for each turbine model currently being considered for the Crookwell 3 Windfarm:

- GE 2.5xl (2.5MW) is depicted in **Appendix B1**;
- Vestas V90 (2.0 MW) is depicted in **Appendix B2**;
- Vestas V100 (1.8 MW) is depicted in **Appendix B3**; and
- Repower MM92 (2.0 MW) is depicted in **Appendix B4**.

Table 10 Crookwell 1, Crookwell 2 and Crookwell 3 WTG L_{Aeq} noise level (dBA) at $V_{ref,10m}$ = 8 m/s, V_{80m} = 11.1 m/s

Receiver / Property	GE 2.5xl (2.5MW), 100m hub height	Vestas V90 (2 MW), 105m hub height	Vestas V100 (1.8 MW), 95m hub height	Repower MM92 (2 MW), 100m hub height
House 1 Evermore	33.7	32.8	32.6	33.7
House 2 Bendemere	33.0	31.0	30.8	33.0
House 3 D'Ambrosio	32.6	30.3	30.0	32.6
House 4	30.6	28.6	28.3	30.7
House 5	31.1	28.9	28.6	31.1
House 6	31.1	28.7	28.4	31.1
House 7 Emohruo	30.8	28.3	27.9	30.9
House 8 Narangi	39.4	36.8	37.4	39.4
House 12	27.7	25.3	23.4	27.6
House 13	26.0	23.9	22.2	25.8
House 14 Foxground Hayeselton	28.2	25.8	24.1	28.0
House 15	28.4	26.1	24.5	28.3
House 16 Calamondah	27.7	24.4	22.1	27.6
House 17 Wollondilly (1) *	37.5	35.1	35.4	37.6
House 18 Wollondilly (2) *	38.9	35.6	36.6	39.0
House 19 Wombat Hollow	39.5	36.9	37.4	39.6
House 20 Normaroo	39.0	38.1	38.1	39.0
House 21 Ahgunyah	42.1	42.0	42.0	42.1
House 22 Minnamurra	43.0	42.8	42.8	43.0
House 23 Gundowringa	44.5	44.4	44.4	44.5
House 24 Savannah	46.7	46.7	46.7	46.7
House 25 Cottage 1 (Gundowringa)	44.4	44.3	44.3	44.4
House 26 Cottage 2 (Gundowringa)	44.0	44.0	44.0	44.0
House 27 Cottage 3 (Gundowringa)	43.8	43.8	43.8	43.8
House 28 Cottage 4 (Gundowringa)	43.9	43.9	43.9	43.9
House 29	29.4	27.2	25.9	29.3
House 30 Airam	29.4	27.2	25.8	29.3
House 32	29.4	27.7	26.8	29.3
House 33 Whispering Pines	29.7	28.0	26.9	29.6
House 34 Kooloona	30.9	28.8	27.7	30.9
House 35 Clydesdale	30.3	28.6	27.8	30.3
House 36 Tyrendarra	31.5	28.9	27.6	31.4
House 37 Carinya	32.5	31.0	30.5	32.5
House 38	33.6	32.2	32.0	33.6
House 39 St Stephen's Pejar Anglican Church	33.6	32.1	31.9	33.6
House 40 Tyrendarra	30.4	27.1	25.4	30.3
House 41 Middle Arm Fire Brigade Wayo Station	29.3	27.1	25.8	29.2
House 43 Rullawayo	21.8	20.1	17.7	21.6
House 45	22.2	20.6	18.4	22.1
House 46 Limokee	22.8	21.1	19.0	22.6

Receiver / Property	GE 2.5xl (2.5MW), 100m hub height	Vestas V90 (2 MW), 105m hub height	Vestas V100 (1.8 MW), 95m hub height	Repower MM92 (2 MW), 100m hub height
House 47	27.6	25.0	23.1	27.4
House 48 Rolling Hills	28.0	25.5	23.6	27.9
House 49 Under construction	28.4	25.8	24.0	28.3
House 50	29.4	26.7	25.0	29.3
House 51	29.8	27.2	25.7	29.8
House 52 Mount Wayo	29.9	27.1	25.5	29.8
House 53	31.1	28.2	26.7	31.1
House 54 Ginmara	31.7	28.2	26.7	31.7
House 55	32.1	28.9	27.6	32.1
House 56 Mathlie	31.0	27.8	26.5	30.9
House 57 Kenrich	32.7	29.1	27.9	32.6
House 58	37.5	33.8	34.2	37.6
House 59	38.3	34.6	35.0	38.4
House 60 Pejar Park	35.8	32.6	32.2	35.9
House 61 Wallaroobie	38.4	34.8	35.0	38.5
House 62 Cottonwood	38.4	34.6	34.8	38.5
House 63 Rocky Corner	41.8	38.3	39.1	41.9
House 64 Balvardarman Hill	41.1	38.5	39.0	41.2
House 65 Windalee	41.0	38.5	39.0	41.1
House 66 Little Vale (1)	42.0	38.2	39.3	42.1
House 67 Little Vale (2)	39.6	36.0	36.6	39.7
House 68 Meadowvale	37.9	35.6	35.7	37.9
House 69 Atholvale	39.8	37.2	37.7	39.8
House 70 Snowgum	38.8	37.7	37.6	38.8
House 71 Lynross	35.4	34.0	33.7	35.4
House 72	34.3	32.9	32.5	34.3
House 73 Highlands	33.2	31.9	31.5	33.2
House 74 Rosslyn	27.5	27.0	26.7	27.5
House 75 Rosslyn	27.8	27.6	27.4	27.8
House 76 Rosslyn	26.0	25.4	25.1	26.0
House 77 Bellevue Park	25.5	25.3	25.2	25.5
House 79 Leeston *	42.9	40.0	41.2	43.0
House 80 Hillview Park *	40.0	36.5	36.9	40.1
House 81 Rosslyn	29.6	27.4	26.4	29.5
House 82 Rosslyn	31.4	29.7	29.1	31.3
House 83 Trappers Folly	29.0	26.2	24.4	28.9
House 84 Nierrina Heights	31.6	28.6	27.3	31.6
House 87 Grey Wood	18.0	15.0	10.7	17.8
House 88 Ghost Gum Gully	16.2	13.8	8.5	16.0
House 89 Windvale	16.6	13.2	9.2	16.4
House 90 Glenwood Park	16.9	13.9	9.2	16.7
House 91	18.0	14.2	11.0	17.9

Receiver / Property	GE 2.5xl (2.5MW), 100m hub height	Vestas V90 (2 MW), 105m hub height	Vestas V100 (1.8 MW), 95m hub height	Repower MM92 (2 MW), 100m hub height
House 93 Pearces Hill	17.1	15.0	8.6	16.8
House 96	17.0	14.7	8.6	16.7
House 98 Daramalar	17.6	14.7	10.2	17.4
House 99 Mountain Ash	18.4	15.5	11.5	18.2
House 100 Greenways	19.1	15.6	12.7	19.0
House 101 Hetherington Glen	17.9	15.3	11.1	17.9
House 102 Holmwood	21.8	18.7	15.5	21.7
House 103 Ivy Lodge	27.4	23.7	19.9	27.3
House 104 Highland Park	31.4	27.4	26.3	31.5
House 105 Jaradean	29.9	25.8	23.9	29.9
House 106 Rosedale	27.2	23.7	22.9	27.3
House 107 Quinton	29.2	25.1	23.5	29.2
House 108 Eagleview	29.0	24.9	23.0	28.9
House 109 Frendale	30.2	27.8	26.7	30.1
House 110 Wallaroy	22.5	21.4	20.9	22.5
House 111 Community Hall	23.7	22.8	22.4	23.6
House 112 Roslyn Community Hall	23.7	22.8	22.4	23.6
House 113 Karinga	28.8	24.9	22.9	28.8
House 114 Frenleigh	30.3	26.3	24.8	30.3
House 115 Roslyn Bush Fire Brigade	24.3	23.6	23.3	24.3
House 116 Railway House	24.6	24.0	23.7	24.6

Note: * Denotes that the dwelling is a Host Property

Figure 9 Crookwell 1, Crookwell 2 and Crookwell 3 Wind Farm – GE 2.5xl 2.5MW, L_{Aeq} Noise Contour Map

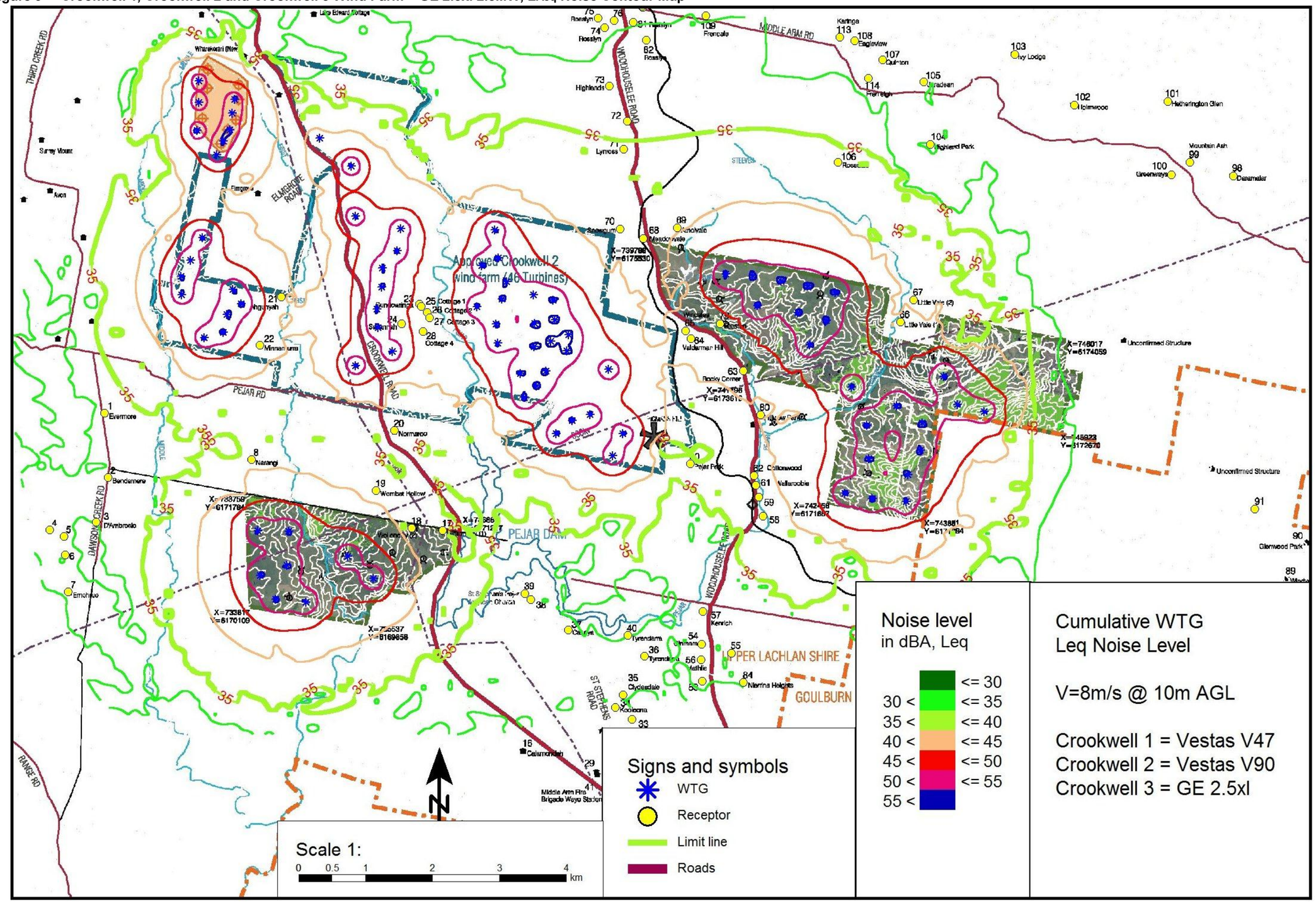


Figure 10 Crookwell 1, Crookwell 2 and Crookwell 3 Wind Farm - Vestas V90 2MW, L_{Aeq} Noise Contour Map

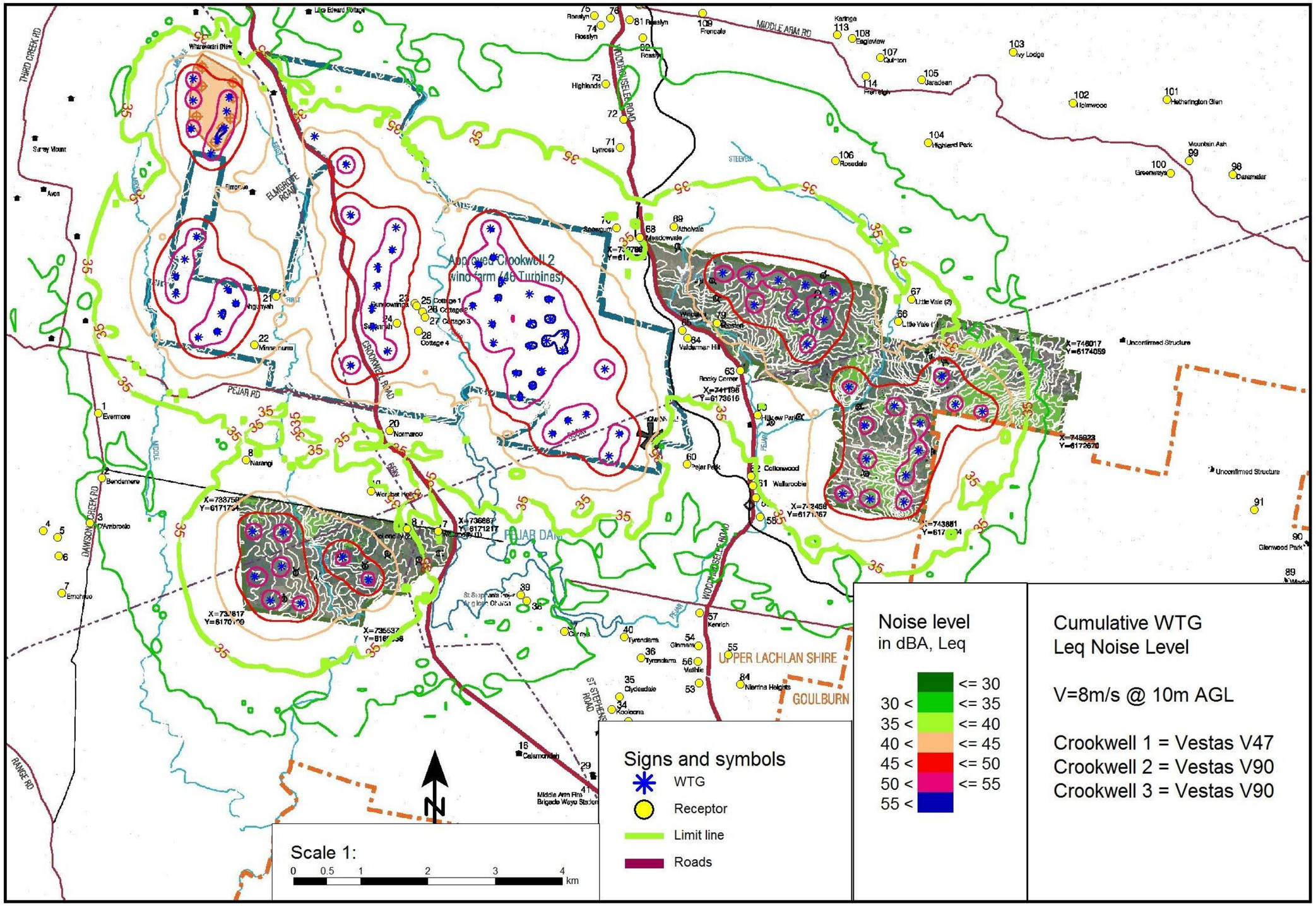


Figure 11 Crookwell 1, Crookwell 2 and Crookwell 3 Wind Farm - Vestas V100 1.8MW, L_{Aeq} Noise Contour Map

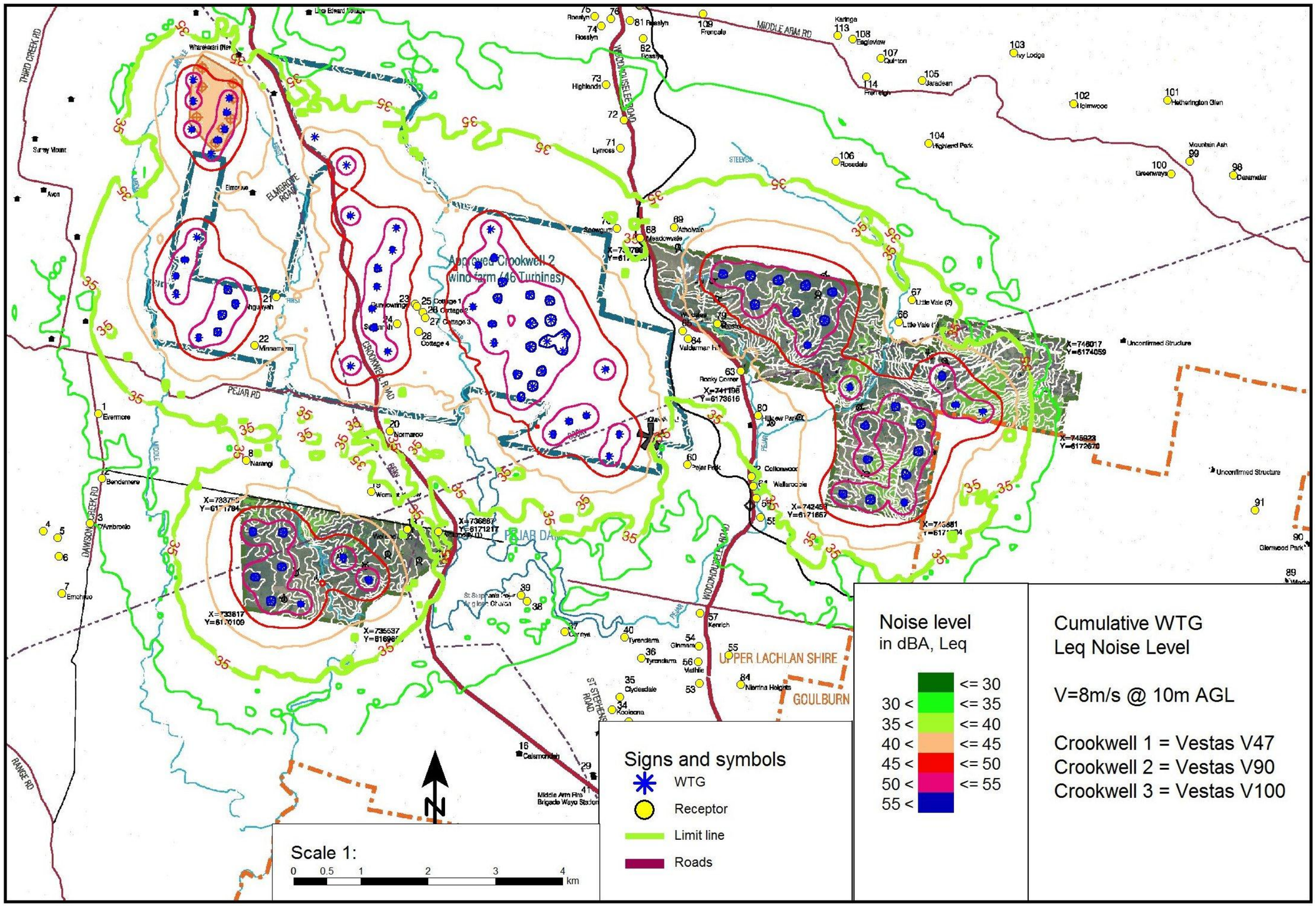
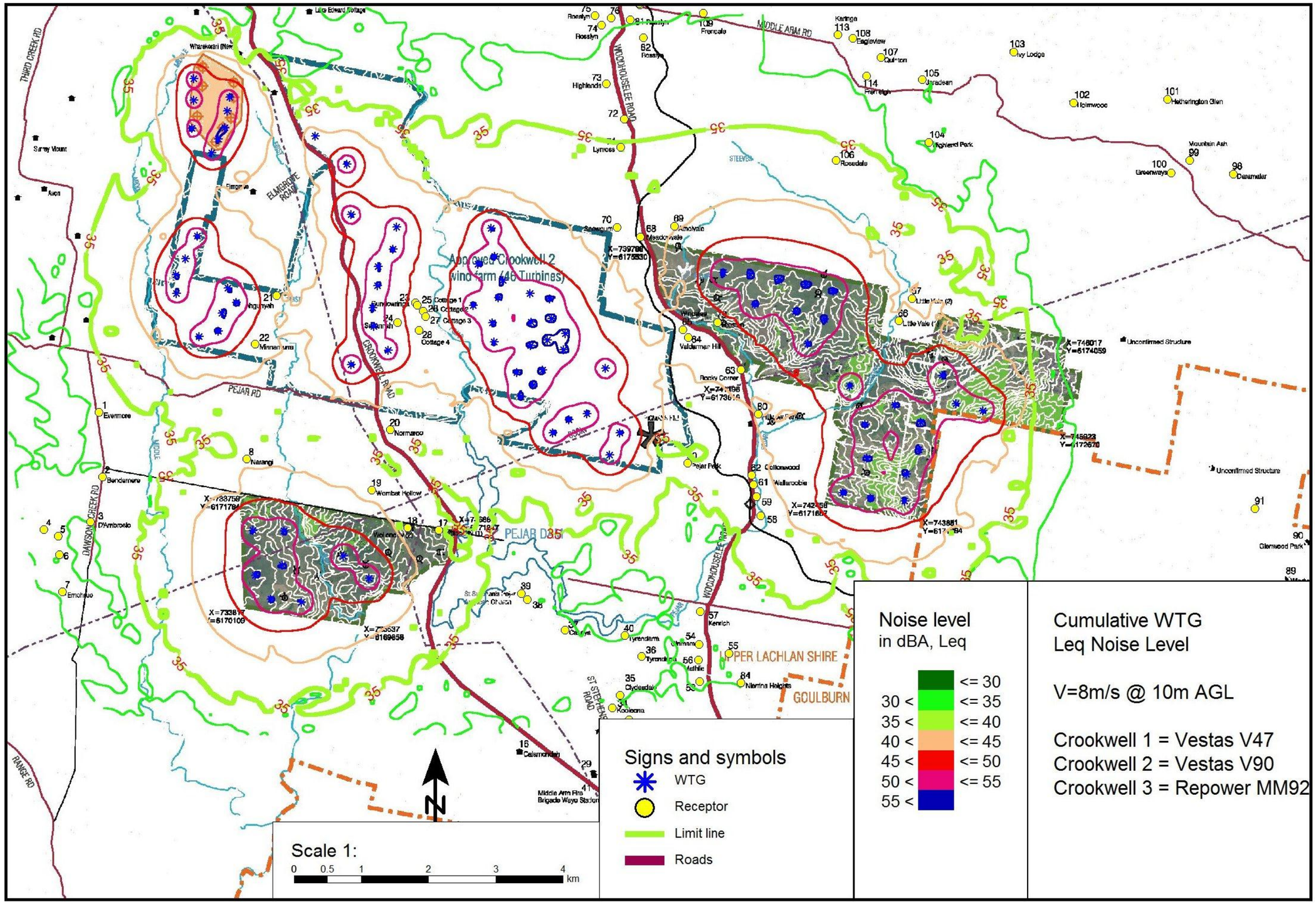


Figure 12 Crookwell 1, Crookwell 2 and Crookwell 3 Wind Farm - Repower MM92 2MW, L_{Aeq} Noise Contour Map



6.4 Substation Transformer Noise Levels

It is proposed that the connection substation for Crookwell 2 Wind Farm will be used for the Crookwell 3 Wind Farm. The substation was initially sized for additional capacity and as such it will require minimal upgrades to cater for the proposed Crookwell 3 WTGs.

Substation transformer noise was already assessed and found to meet NSW Industrial Noise Policy limits under adverse propagation conditions during the Noise Impact Investigation for Crookwell 2 Wind Farm. The upgrades necessary to cater for the proposed Crookwell 3 WTGs will not result in any additional noise being generated by the substation.

7 BACKGROUND LEVELS AND NOISE LIMITS

7.1 Measurement Locations

The locations for the background noise measurements were chosen based on the potential for acoustic impact to the nearest residential receivers, as recommended by Table 3.1 of the NSW INP. The SA EPA Guidelines recommend that the measurement locations should be located at least 5 metres from a reflecting surface (other than the ground) and locations within 20 metres of a residence are generally appropriate.

Monitoring equipment was generally placed in the vicinity of the residence at a suitable location that would be protected from the prevailing wind direction in order to protect the microphone from wind induced noise effects. Care was taken not to place the equipment in locations that would be affected by extraneous noise sources.

Background noise monitoring locations were selected based on the predicted wind farm noise level from the preliminary layout at reference conditions. Many of the potentially impacted locations have had background monitoring completed.

Generally a selected monitoring location was used to provide an indicative background for representative locations in the vicinity. The relative proximity of some receiver locations to one another and their similar wind exposure and surrounding environment meant that background noise monitoring could be conducted at one representative location and be considered indicative of other similar locations.

A total of 11 locations were monitored around the proposed wind farm site. These are listed in **Table 11**.

Previous noise monitoring conducted in the region as part of the assessment work for Crookwell 2 was not able to be directly utilised as the reference height for wind measurements and assessment purposes has been changed from 10 metres to 80 metres.

Table 11 Measurement Locations

Location	Indicative of	Notes / Similar Characteristic for wind induced noise
H20 Normaroo		Geographic proximity, exposure to wind
H8 Narangi	H2, H3, H4, H5, H6, H7	Geographic proximity, exposure to wind
H18 Wollondilly 2 *	H17, H19	Geographic proximity, exposure to wind
H62 Cottonwood	H60, H61	Geographic proximity, exposure to wind
H79 Leeston *	H63, H80	Geographic proximity, exposure to wind
H70 Snowgums	H68, H69	Geographic proximity, exposure to wind
H71 Lynross	H72, H73, H74, H75, H76, H81, H82, H109, H110, H111, H112, H115, H116	Geographic proximity, exposure to wind
H66 Little Vale	H67	Geographic proximity, exposure to wind
H106 Rosedale	H103, H104, H105, H107, H108, H113, H114	Geographic proximity, exposure to wind.
H64 Valdarnam Hill	H65	Geographic proximity, exposure to wind
H58 650 Woodhouslee Rd	H59	Geographic proximity, exposure to wind

Note: * Denotes that the dwelling is a Host Property

It is anticipated that further baseline background noise monitoring will be conducted before project commissioning in order to obtain more comprehensive data at the above locations (including alternative seasons) and to collect data at some alternative locations.

At each selected location noise monitoring equipment was placed in the vicinity of the residence and the position of the monitoring equipment was documented with photographs.

A weather station was placed at Valdarnam Hill, capable of measuring wind speed, direction, rainfall, temperature and humidity. This data was used to identify and exclude any data collected during rain periods, which may have affected the background noise levels. The measured data for rain confirmed that the monitoring periods were generally dry with some limited periods of data obtained on the 6^{th,} 12th and 13th July 2010 rejected due to rain.

The SA EPA Guidelines require measurements to be conducted in 10 minute intervals, while the NSW INP require 15 minute interval data. Given that almost all wind data, including the wind farm site monitored data, is in 10 minute intervals, this period was used for all measurements.

Simultaneous noise monitoring and wind monitoring was conducted during the period from 30th June to 16th July 2010.

The local noise data is correlated to the wind speed at a reference wind monitoring mast. Whilst it is usual for the wind correlation to be from measurements made at a height 10 metres above ground level, the process has been adapted to use wind data measured at 80 metres (which is indicative of the preferred hub height of a WTG).

7.2 Measurement Details

The measurement location, monitoring period, equipment type and serial number of the noise logger are summarised in **Table 12**.

The SA EPA Guidelines require a set of approximately 2,000 valid data points. All data points below the cut-in wind speed of the proposed turbines and any adversely affected data (rain, external extraneous noise sources etc) should be excluded. The cut-in wind speed for the proposed turbines is 3 m/s. The number of valid data points for each location is also shown in **Table 12.**

The measured background noise levels (L_{A90}) are then plotted against the extrapolated 80 metre (hub height) wind speed to obtain a background versus wind speed characteristic for each location.

The line of best fit for the data set is then determined, as required by the SA EPA Guideline using a linear, second order (quadratic) or third order (cubic) polynomial. The guideline requires that the correlation coefficient for each line type be reported and the one with the highest correlation coefficient used. As required, the R^2 value, which is a measure of the correlation coefficient for each of the three type of line of best fit are also shown. At each location the cubic polynomial gave the highest correlation and was therefore used for the line of best fit. The SA EPA Guideline does not specify a minimum acceptable correlation coefficient.

Table 12 Measurement Details for each Location

Measurement Location	Measurement Period	Noise Logger Model # Serial number	Total No. of monitoring intervals	No. of valid data points for 'all data' analysis	No. of valid data points for 'night' analysis	Correlation Coefficient (R^2)		
						Linear	Quad.	Cubic
H20 Normaroo	30-06-2010 - 15:50 16-07-2010 - 10:30	ARL EL-315 #15-203-517	2274	1868	713	.717	.739	.751
H8 Narangi	30-06-2010 - 15:50 16-07-2010 - 10:30	ARL EL-316 #16-207-005	2247	1932	747	.616	.657	.678
H18 Wollondilly 2 *	30-06-2010 - 16:42 16-07-2010 - 11:04	ARL EL-316 #16-004-049	2268	1923	750	.429	.502	.518
H62 Cottonwood	30-06-2010 - 15:40 16-07-2010 - 9:30	ARL Ngara #878037	2267	1898	750	.545	.551	.561
H79 Leeston *	1-07-2010 - 9:00 16-07-2010 - 12:20	ARL Ngara #878053	2179	1848	692	.559	.561	.561
H70 Snowgums	1-07-2010 - 10:10 16-07-2010 - 13:30	Svan 957 #20668	2182	1850	700	.656	.667	.685
H71 Lynross	1-07-2010 - 11:20 16-07-2010 - 15:20	Svan 957 #20669	2186	1844	699	.632	.635	.641
H66 Little Vale	1-07-2010 - 13:20 16-07-2010 - 14:30	Svan 957 #20670	2169	1834	701	.538	.556	.559
H106 Rosedale	1-07-2010 - 14:17 16-07-2010 - 16:25	ARL EL-315 #15-004-032	2173	1827	701	.554	.554	.560
H64 Valdarnam Hill	1-07-2010 - 16:10 16-07-2010 - 12:40	Svan 957 #20667	2139	1810	700	.639	.641	.649
H58 650 Woodhouslee Rd	1-07-2010 - 17:13 16-07-2010 - 12:08	ARL EL-316 #16-299-426	2130	1803	695	.605	.657	.660

* Denotes that the dwelling is a Host Property

The Rating Background Level (RBL) for each location during each time period is shown in **Table 13,** for each monitoring campaign, as per the requirements.

Table 13 RBL for each Period at each Location

	Rating Background Level (dBA)		
Location	**Day**	**Evening**	**Night**
H20 Normaroo	32.1	23.9	22.4
H8 Narangi	24.7	21.7	21.5
H18 Wollondilly 2 *	28.3	24.1	22.2
H62 Cottonwood	25.5	26.4	22.6
H79 Leeston *	25.8	37.3	27.1
H70 Snowgums	24.4	23.2	19.0
H71 Lynross	26.9	23.6	20.5
H66 Little Vale	21.0	23.0	19.0
H106 Rosedale	31.5	32.7	30.8
H64 Valdarnam Hill	22.4	33.2	19.2
H58 650 Woodhouslee Rd	30.2	29.9	27.7

* Denotes that the dwelling is a Host Property

The entire set of noise logger results, showing the measured L_{A90}, L_{Aeq} and L_{A10} noise levels, together with wind speed, are shown in **Appendix D.**

The horizontal distance between each of the assessment location WTGs for the proposed layouts are shown in **Appendix E.**

7.3 H20 – Normaroo

The property of Normaroo is located directly to the north-east of the proposed Crookwell 3 South Wind Farm, approximately 2 km from the nearest proposed WTG.

The residence is relatively protected from the west by topography and trees and an established garden. The measurement location, just to the east of the house was chosen as it was previously used for monitoring for Crookwell 2 wind farm. The monitoring location is shown in **Figure 13.**

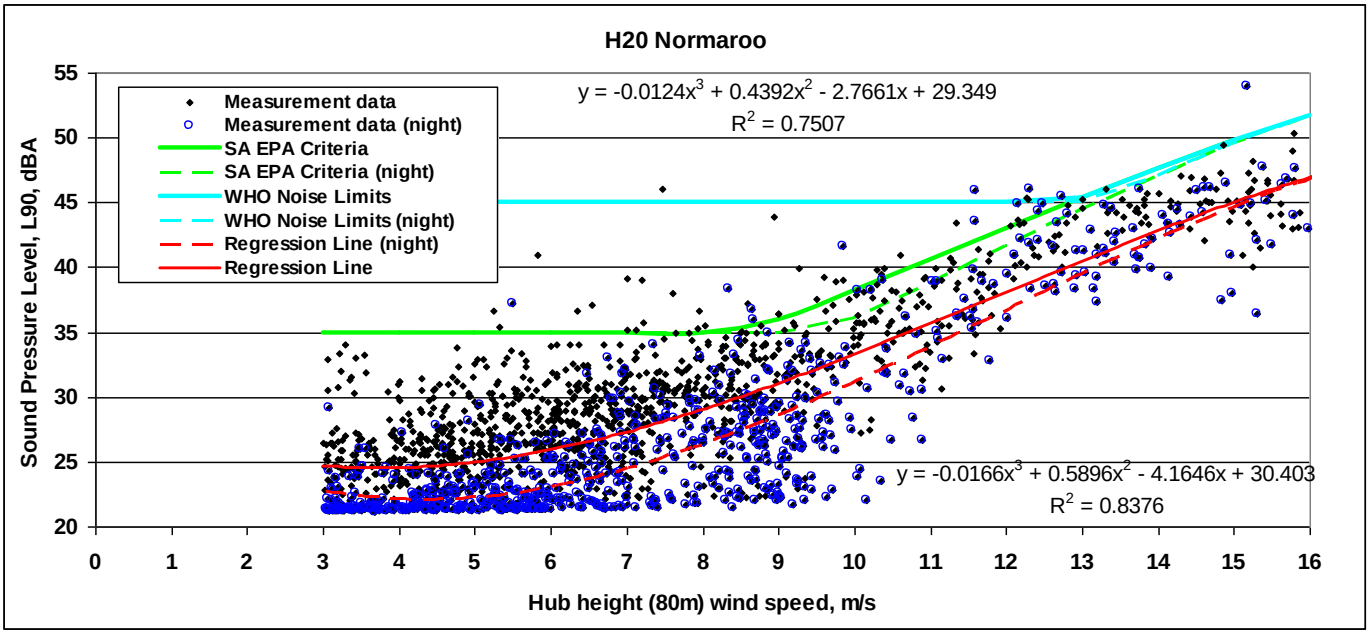
Figure 13 Normaroo Measurement Location

The results of the background noise monitoring taken in June-July 2010, showing the data points, line of best fit and the Noise Criteria Curves for the 'all data' and 'night' period are shown in **Figure 14.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D**.

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 14 Background Noise Measurements and Noise Criteria Curve - Normaroo

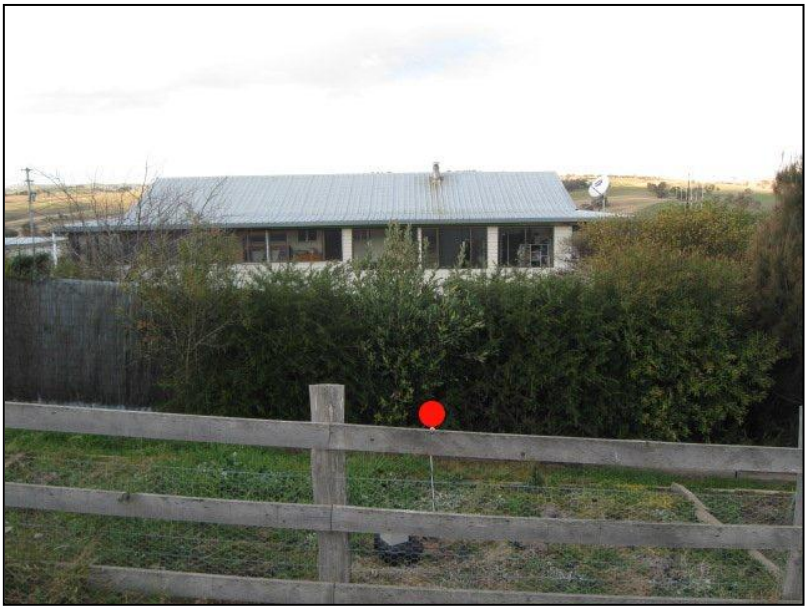


7.4 H8 - Narangi

The property of Narangi is located directly to the north of the proposed Crookwell 3 South Wind Farm, approximately 1.1 km from the nearest proposed WTG.

The residence is relatively protected from the west by topography a large stand of mature trees and an established garden. The measurement location, just to the west of the house was chosen such that any noise produced by a spa pump would not influence the result. The monitoring location is shown in **Figure 15.**

Figure 15 Narangi Measurement Location

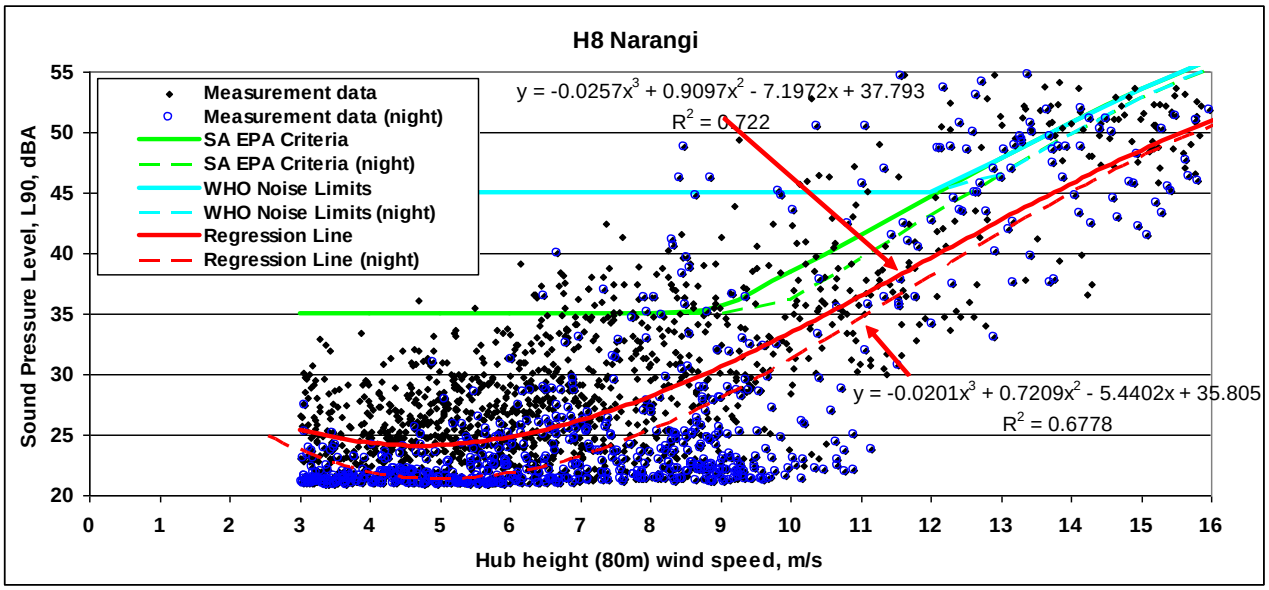


The results of the background noise monitoring taken in June-July 2010, showing the data points, line of best fit and the Noise Criteria Curves for the 'all data' and 'night' period are shown in **Figure 16.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D**.

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 16 Background Noise Measurements and Noise Criteria Curve - Narangi

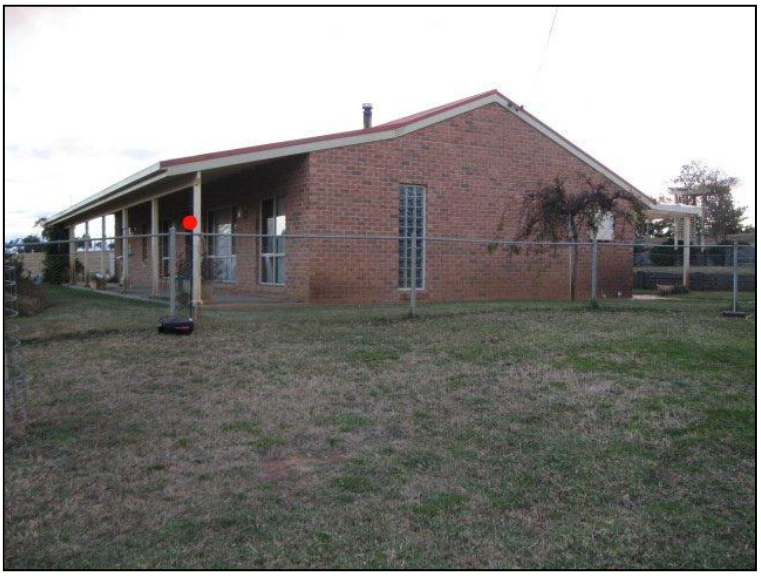


7.5 H18 - Wollondilly 2

The property of Wollondilly is located to the east of the proposed Crookwell 3 South Wind Farm, approximately 0.95 km from the nearest proposed WTG. There are two residences on the property and the noise monitoring was conducted on the property closest to the proposed wind farm. This property is a Host Property.

The monitored residence is relatively exposed to wind with only smaller trees and shrubs in the garden. The measurement location is shown in **Figure 17.**

Figure 17 Wollondilly 2 Measurement Location

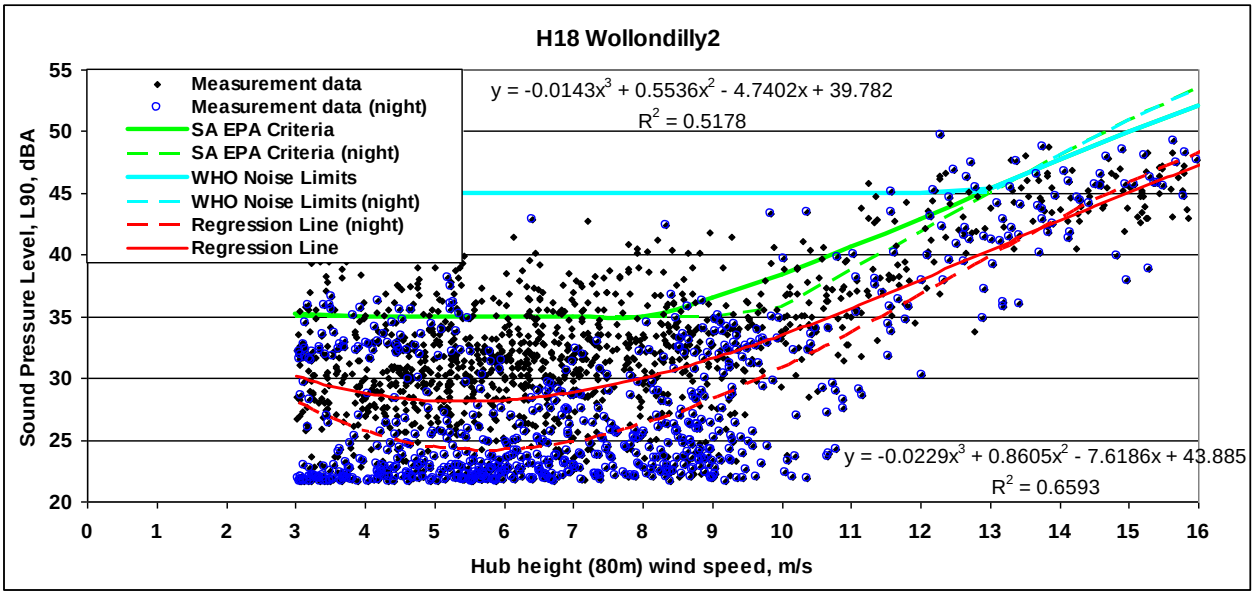


The results of the background noise monitoring taken in June-July 2010, showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 18.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 18 Background Noise Measurements and Noise Criteria Curve – Wollondilly

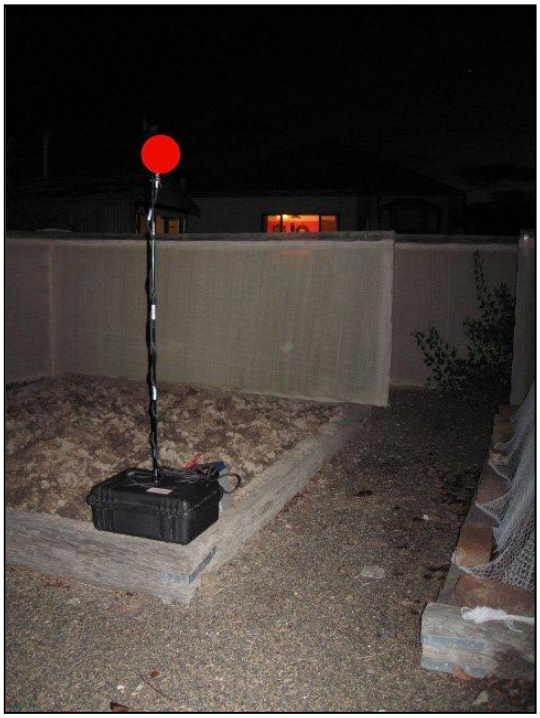


7.6 H 62 - Cottonwood

The residence of Cottonwood is located in the village Woodhouslee to the west of the proposed Crookwell 3 East Wind Farm approximately 1.4 km from the nearest proposed WTG.

The house is not so exposed to wind as it is situated in a north to south running valley and has a number of large trees and a well established garden around the house yard area. The measurement location was to the east of the house in the garden area and is shown in **Figure 19.**

Figure 19 Cottonwood Measurement Location

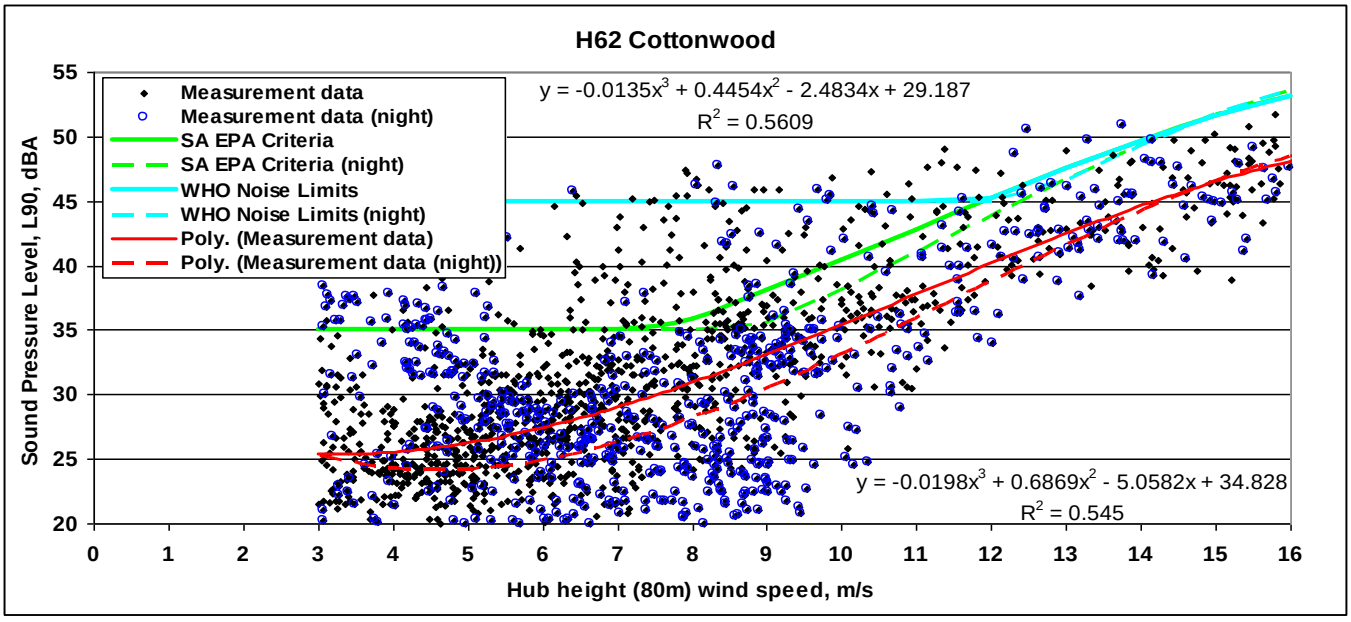


The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 20**.

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D**. Higher noise levels at dawn were a feature of this location and likely a result of birds**.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 20 Background Noise Measurements and Noise Criteria Curve – Cottonwood

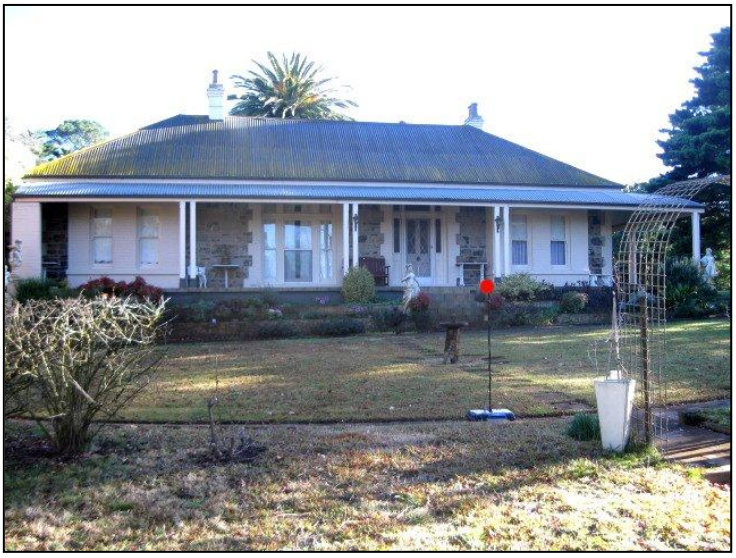


7.7 H79 - Leeston

The property of Leeston is located directly to the west of the proposed Crookwell 3 East Wind Farm approximately 0.6 km from the nearest proposed WTG. This property is a Host Property for proposed Crookwell 3 Wind Farm.

The house is not so exposed to wind as it is situated in a valley and has a large number of tall trees and a large well established garden around the house yard area. The measurement location was to the south of the house and is shown in **Figure 21.**

Figure 21 Leeston Measurement Location

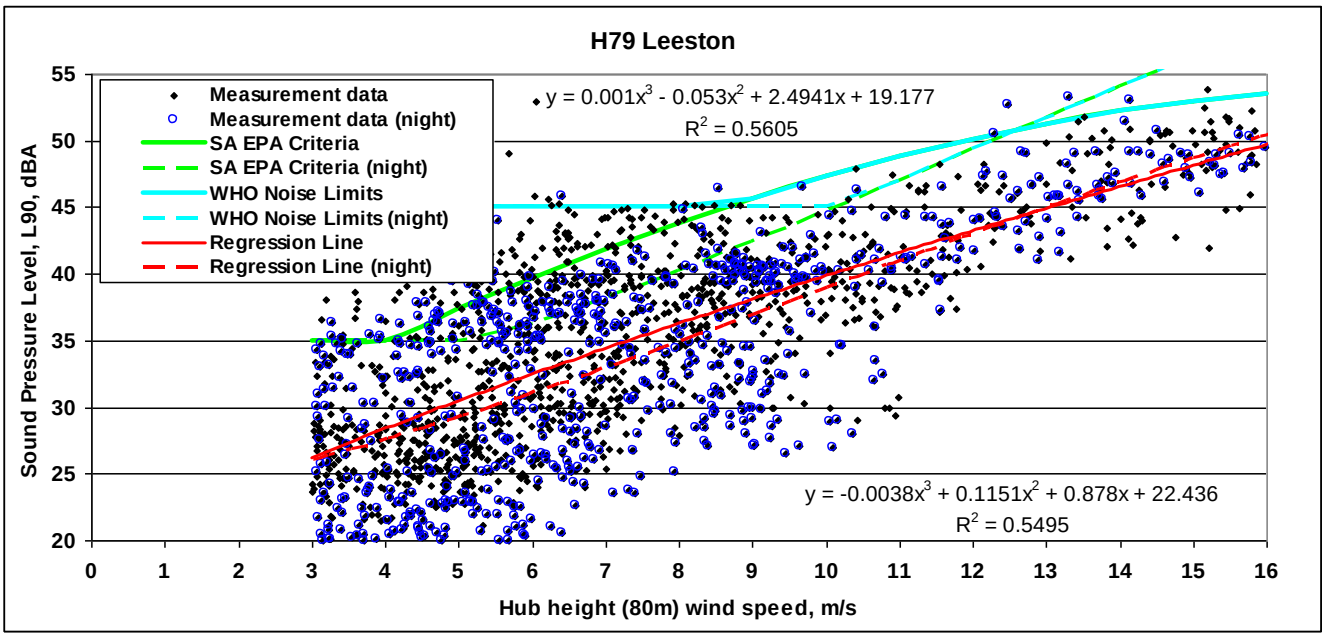


The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 22.**

Graphically represented noise statistical indices, are presented in **Appendix D.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 22 Background Noise Measurements and Noise Criteria Curve - Leeston



7.8 H70 - Snowgums

The Snowgums property is located to the north west of the proposed Crookwell 3 East Wind Farm, approximately 1.7 km from the nearest WTG. The residence is located in relatively exposed topography and has some surrounding trees.

The measurement location was chosen as it was previously used for monitoring for Crookwell 2 wind farm and is to the south of the house, is shown in **Figure 23.**

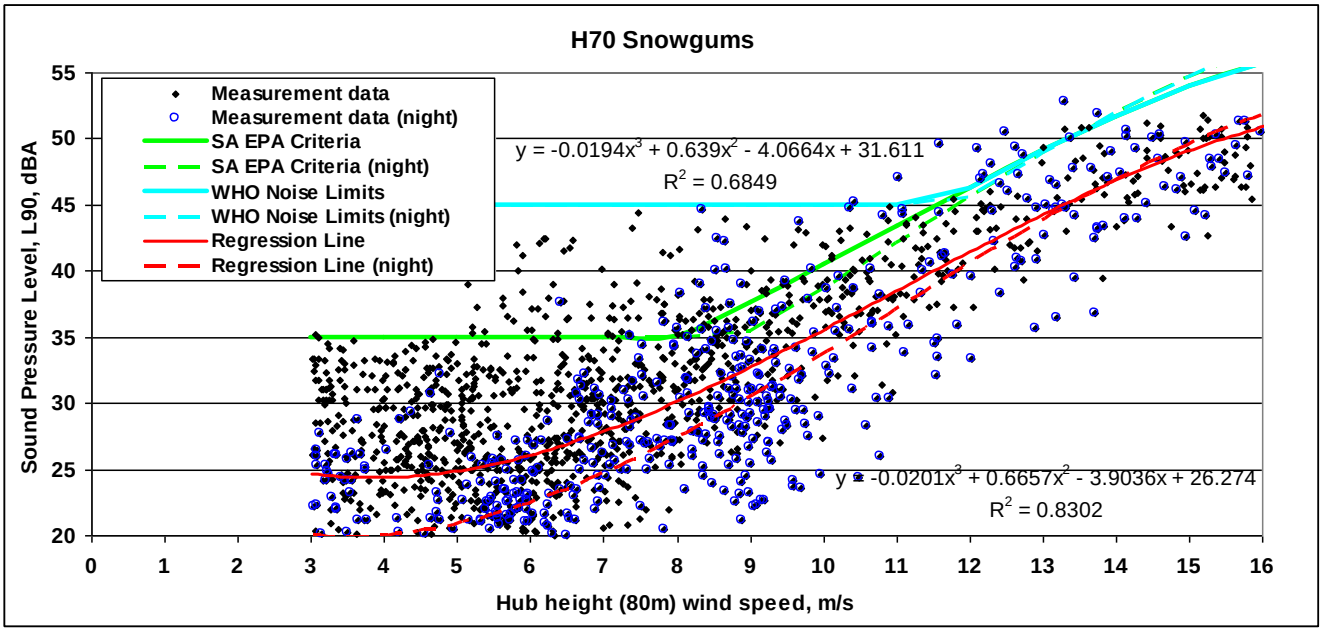
Figure 23 Snowgums Measurement Location

The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 24.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 24 Background Noise Measurements and Noise Criteria Curve – Snowgums



7.9 H71 - Lynross

The Lynross property is located to the northwest of the proposed Crookwell 3 East Wind Farm, approximately 2.4 km from the nearest WTG.

The residence is relatively well protected by large trees as windbreaks and an established garden. The noise monitoring equipment was positioned to the west of the house. The measurement location is shown in **Figure 25**

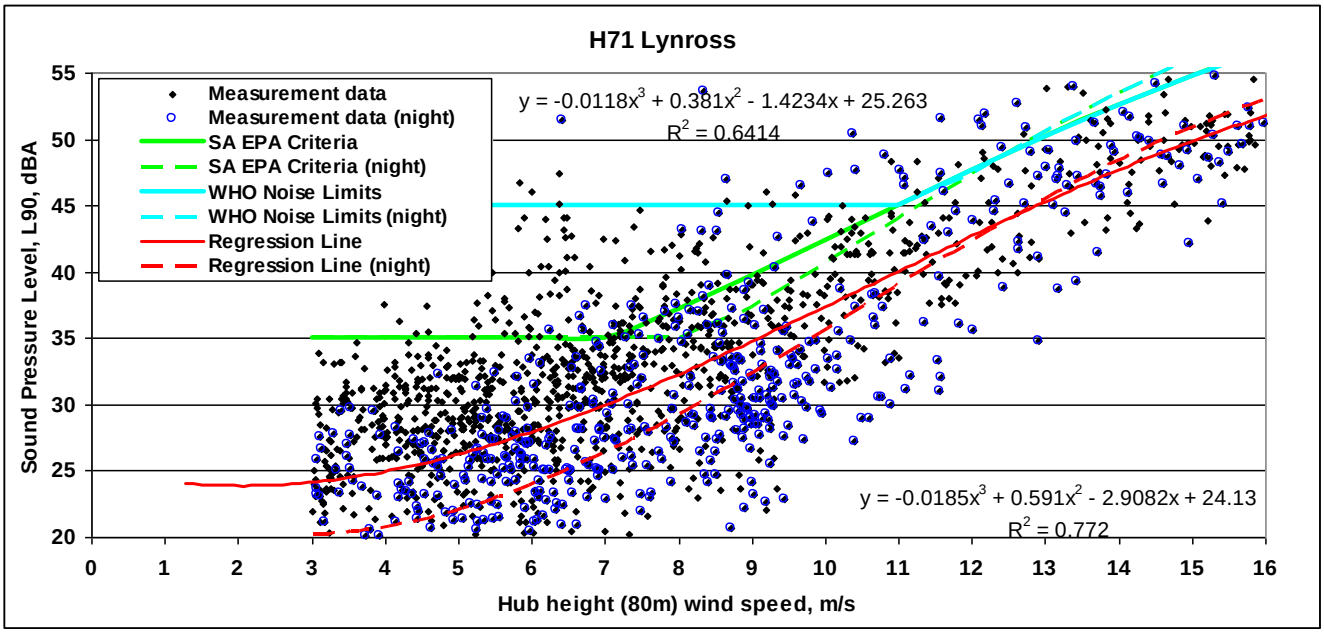
Figure 25 Measurement Location Lynross

The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 26.**

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 26 Background Noise Measurements and Noise Criteria Curve – Lynross



7.10 H66 - Little Vale

The property of Little Vale is located to the northeast of the proposed Crookwell 3 East Wind Farm approximately 1 km from the nearest proposed WTG. The property has two residences and monitoring was completed at the residence closest to WTGs.

The residence is well protected from the wind by surrounding topography and tall pine trees to the west however has only some smaller trees and shrubs around the garden. Noise monitoring equipment was placed to the south of the house, shown in **Figure 27** below.

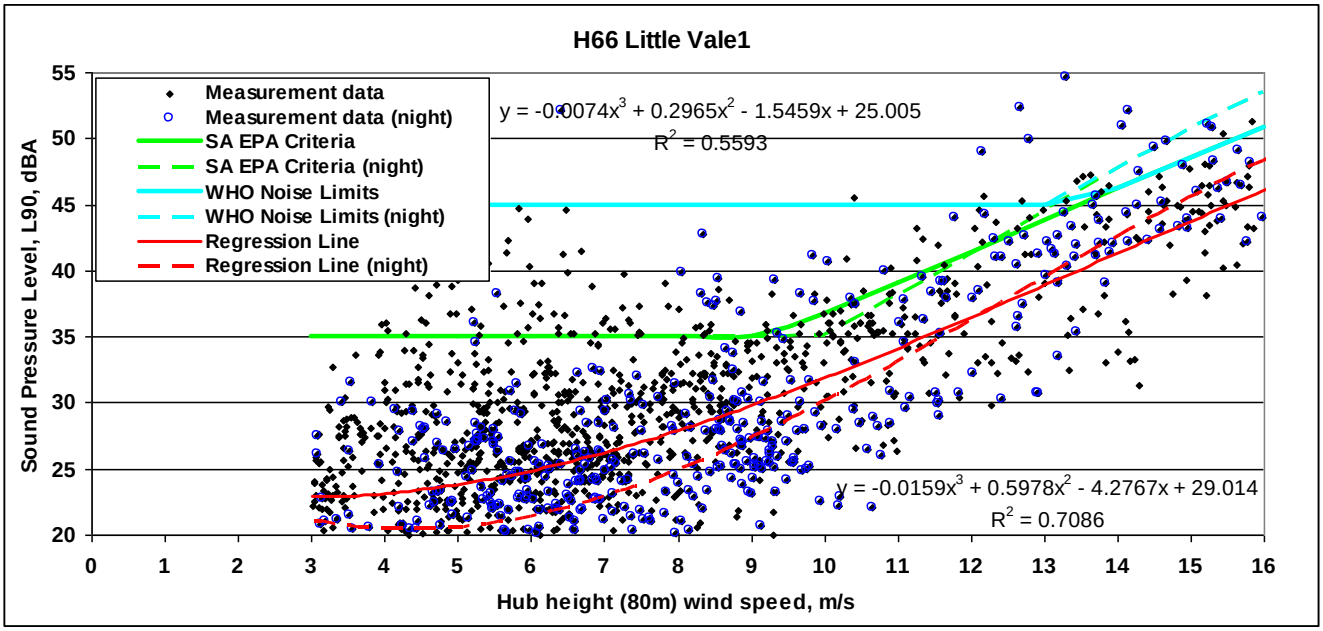
Figure 27 Measurement location Little Vale

The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 28**.

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 28 Background Noise Measurements and Noise Criteria Curve – Little Vale



7.11 H106 - Rosedale

The property of Rosedale is located to the north of the proposed Crookwell 3 East Wind Farm approximately 1.4 km from the nearest proposed WTG.

The residence is relatively protected from wind by large trees and an established garden. The location for the noise monitoring equipment was strictly determined by the landowner, being positioned in a stock proof enclosure in a paddock approximately 140 metres to the south of the building. The monitoring location was somewhat exposed to wind, however, approximately equidistant from a large stand of pine trees. The measurement location is shown in **Figure 29** below.

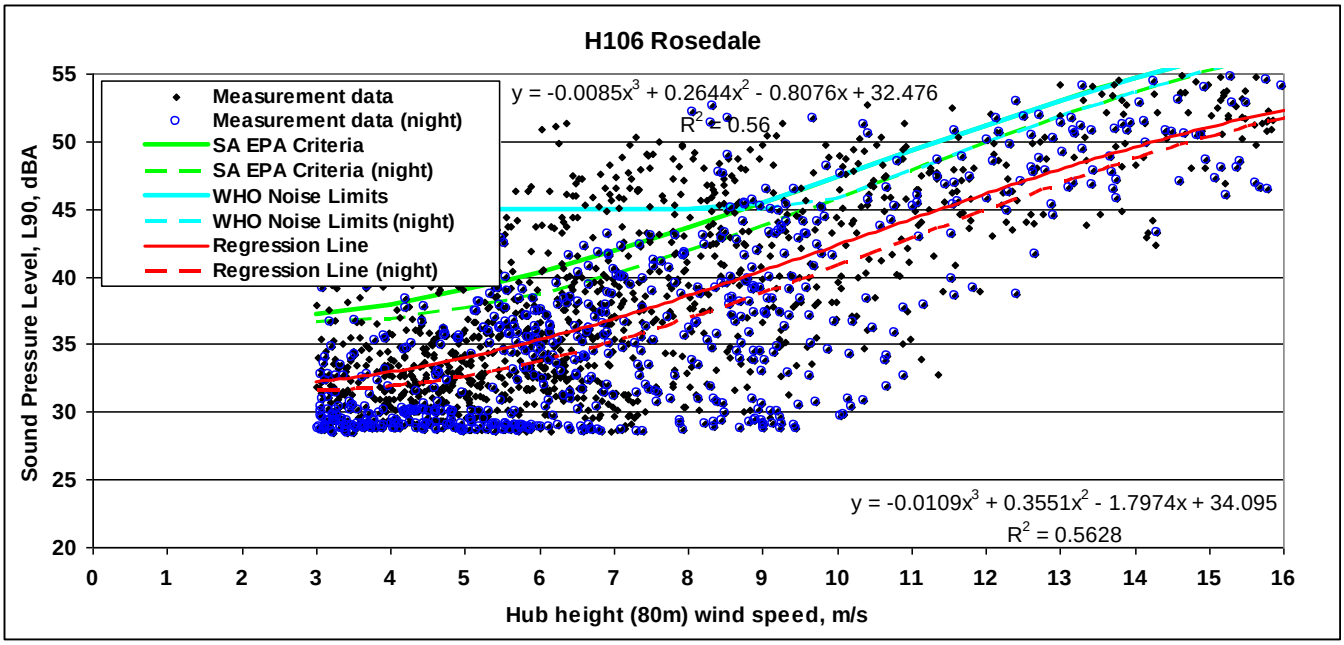
Figure 29 Measurement location Rosedale

The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 30**.

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 30 Background Noise Measurements and Noise Criteria Curve - Rosedale



7.12 H64 - Valdarnam Hill

The property of Valdarnam Hill is located to the west of the proposed Crookwell 3 East Wind Farm approximately 1.1 km from the nearest proposed WTG.

The residence is relatively unprotected from wind. The noise monitoring equipment was positioned on the fenceline to the south east of the house. A weather monitoring station was also deployed at this property. The measurement location is shown in **Figure 31** below.

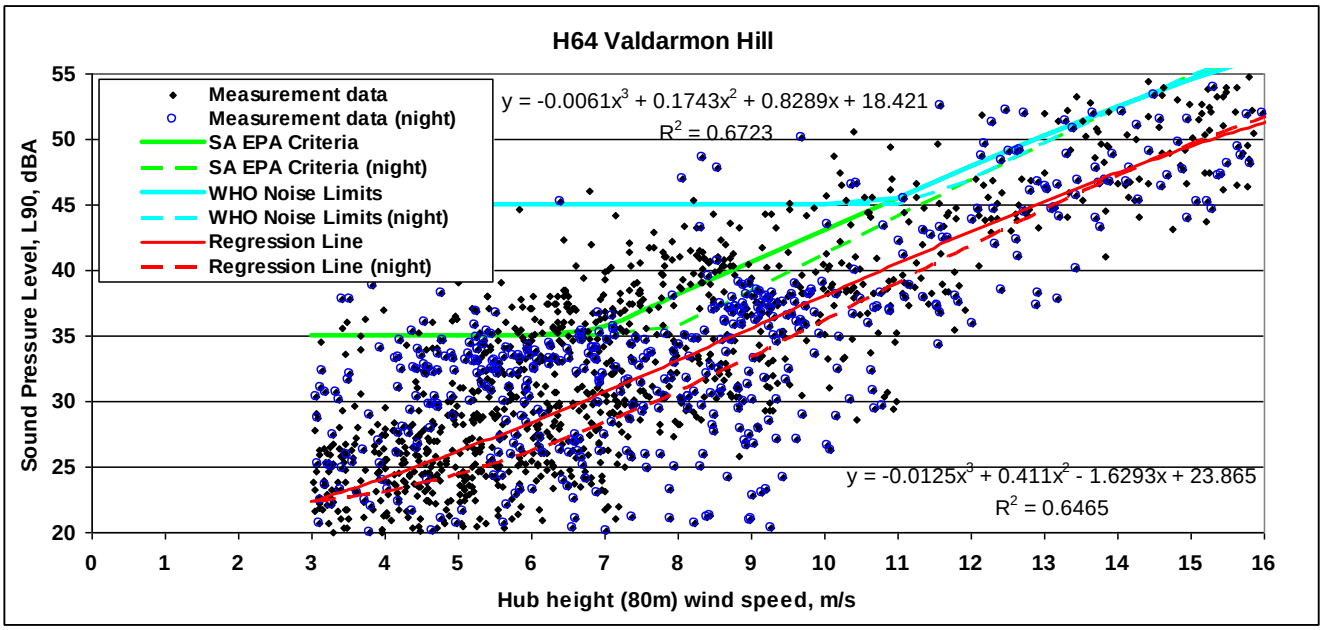
Figure 31 Measurement location Valdarnam Hill

The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 32**.

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 32 Background Noise Measurements and Noise Criteria Curve - Valdarnam Hill

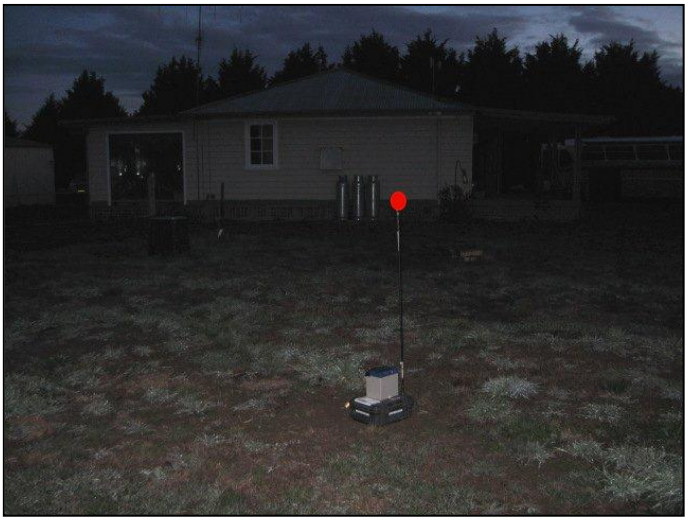


7.13 H58 - 650 Woodhouslee Road

The property of 650 Woodhouslee Road is located in the southern end of Woodhouslee to the south west of the proposed Crookwell 3 East Wind Farm approximately 1.3 km from the nearest proposed WTG.

The house is not so exposed to wind as it is situated in a north to south running valley and has a number of large trees and a well established garden around the house yard area. The measurement location was to the east of the house in the garden area and is shown in **Figure 33.**

Figure 33 650 Woodhouslee Road Measurement Location

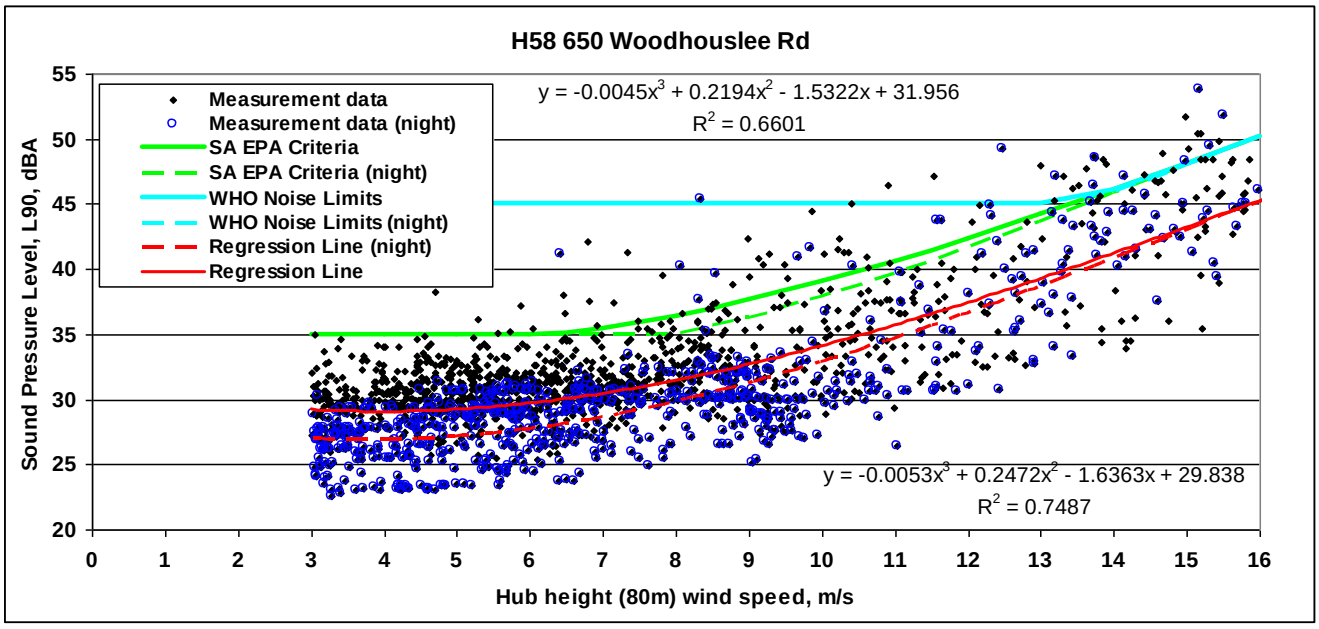


The results of the background noise monitoring taken in June-July 2010 showing the data points, line of best fit and the Noise Criteria Curve for the 'all data' and 'night' period are shown in are shown in **Figure 34**.

Graphically represented noise statistical indices, together with wind speed are presented in **Appendix D**. Higher noise levels at dawn were a feature of this location and likely a result of birds**.**

Results for the Rating Background Level (RBL) for all time periods is presented in **Table 13**.

Figure 34 Background Noise Measurements and Noise Criteria Curve – 650 Woodhouslee Road



8 ACOUSTIC ASSESSMENT OF CROOKWELL 1 AND PROPOSED CROOKWELL 3 WIND FARM NOISE

An assessment of the acceptability of combined noise levels from the Crookwell 1 wind farm and the proposed Crookwell 3 wind farm at all assessment receivers located within a distance of 6 km of the proposed wind farm was made in accordance with SA EPA Guideline criteria and the pre-existing background noise level regression analysis detailed in **Section 7**.

It should be noted that all predicted noise levels are generally considered to be conservative with the model assuming 'hard ground', average downwind propagation from all WTGs to each receiver and a well developed moderate ground based temperature inversion, a scenario which is not able to be re-created in reality.

8.1 Predicted Noise Levels – 30 WTG Layout, GE 2.5xl (2.5 MW)

The assessment figures contained in **Appendix A1** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 100m rotor diameter, GE 2.5xl, 2.5 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout six receivers listed in **Table 14** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

8.2 Predicted Noise Levels – 30 WTG Layout, Vestas V90 (2.0 MW)

The assessment figures contained in **Appendix A2** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 90m rotor diameter, Vestas V90, 2.0 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout two receivers listed in **Table 14** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

8.3 Predicted Noise Levels – 30 WTG Layout, Vestas V100 (1.8 MW)

The assessment figures contained in **Appendix A3** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 100m rotor diameter, Vestas V100, 1.8 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout two receivers listed in **Table 14** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

8.4 Predicted Noise Levels – 30 WTG Layout, RePower MM92 (2.0 MW)

The assessment figures contained in **Appendix A4** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 93m rotor diameter, Repower MM92, 2.0 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout ten receivers listed in **Table 14** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

Table 14 Receptors predicted to exceed based on Crookwell 1 and Crookwell 3 Wind Farms

GE 2.5xl		V90		V100		MM92	
House.	**Exceedance**	**House.**	**Exceedance**	**House**	**Exceedance**	**House**	**Exceedance**
House 8	1.1 dBA @ 8.2 m/s					House 8	2.4 dBA @ 8.2 m/s
House 19	1.0 dBA @ 8.2 m/s					House 19	2.4 dBA @ 8.2 m/s
						House 59	0.6 dBA @ 8.2 m/s
House 61	0.1 dBA @ 8.2 m/s					House 61	1.1 dBA @ 8.2 m/s
						House 62	1.2 dBA @ 8.2 m/s
						House 64	0.7 dBA @ 8.2 m/s
						House 65	0.6 dBA @ 8.2 m/s
House 66	6.3 dBA @ 9.6 m/s	House 66	3.0 dBA @ 9.6 m/s	House 66	3.3 dBA @ 9.6 m/s	House 66	6.5dBA @ 9.6 m/s
House 67	3.9 dBA @ 9.6 m/s	House 67	0.8 dBA @ 9.6 m/s	House 67	0.6 dBA @ 9.6 m/s	House 67	4.1 dBA @ 9.6 m/s
House 69	1.1 dBA @ 8.2 m/s					House 69	2.5 dBA @ 8.2 m/s
6 exceedances		2 exceedances		2 exceedances		10 exceedances	

9 ACOUSTIC ASSESSMENT OF CUMULATIVE WIND FARM NOISE (CROOKWELL 1, CROOKWELL 2 AND CROOKWELL 3 WIND FARM)

An assessment of the acceptability of cumulative wind farm noise levels from the existing Crookwell 1 Wind Farm, the approved Crookwell 2 Wind Farm and the proposed Crookwell 3 Wind Farm at all assessment receivers located within a distance of 6 km of the proposed wind farm was made in accordance with SA EPA Guideline criteria and the pre-existing background noise level regression analysis detailed in **Section 7**.

It should be noted that all predicted noise levels are generally considered to be conservative with the model assuming 'hard ground', average downwind propagation from all WTGs to each receiver and a well developed moderate ground based temperature inversion, a scenario which is not able to be re-created in reality.

9.1 Predicted Noise Levels – 30 WTG Layout, GE 2.5xl (2.5 MW)

The assessment figures contained in **Appendix B1** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 100m rotor diameter, GE 2.5xl, 2.5 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout twelve receivers listed in **Table 15** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

9.2 Predicted Noise Levels – 30 WTG Layout, Vestas V90 (2.0 MW)

The assessment figures contained in **Appendix B2** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 90m rotor diameter, Vestas V90, 2.0 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout seven receivers listed in **Table 15** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

9.3 Predicted Noise Levels – 30 WTG Layout, Vestas V100 (1.8 MW)

The assessment figures contained in **Appendix B3** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 100m rotor diameter, Vestas V100, 1.8 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout eight receivers listed in **Table 15** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

9.4 Predicted Noise Levels – 30 WTG Layout, RePower MM92 (2.0 MW)

The assessment figures contained in **Appendix B4** depict the predicted WTG noise level curves for the 30 WTG layout equipped with 93m rotor diameter, Repower MM92, 2.0 MW WTGs superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

For this layout fifteen receivers listed in **Table 15** were above the *'Background + 5 dBA'* intrusive criteria. All non Host Properties are predicted to be within the nominated World Health Organisation (WHO) guideline noise limits.

Table 15 Receptors predicted to exceed based on cumulative noise impacts (Crookwell 1, Crookwell 2 and Crookwell 3 Wind Farms)

GE 2.5xl		V90		V100		MM92	
House.	**Exceedance**	**House.**	**Exceedance**	**House**	**Exceedance**	**House**	**Exceedance**
House 8	2.6 dBA @ 8.2 m/s	House 8	1.3 dBA @ 8.2 m/s	House 8	1.5 dBA @ 8.2 m/s	House 8	3.6 dBA @ 8.2 m/s
House 17	0.6 dBA @ 8.2 m/s					House 17	1.5 dBA @ 8.2 m/s
House 19	2.5 dBA @ 8.2 m/s	House 19	1.1 dBA @ 8.2 m/s	House 19	1.2 dBA @ 8.2 m/s	House 19	3.5 dBA @ 8.2 m/s
House 20	2.9 dBA @ 8.2 m/s	House 20	2.4 dBA @ 8.2 m/s	House 20	2.2 dBA @ 8.2 m/s	House 20	3.2 dBA @ 8.2 m/s
						House 58	0.2 dBA @ 8.2 m/s
						House 59	0.9 dBA @ 8.2 m/s
House 61	0.1 dBA @ 8.2 m/s					House 61	1.4 dBA @ 8.2 m/s
						House 62	1.4 dBA @ 8.2 m/s
House 64	0.9 dBA @ 8.2 m/s					House 64	1.9 dBA @ 8.2 m/s
House 65	0.8 dBA @ 8.2 m/s					House 65	1.8 dBA @ 8.2 m/s
House 66	6.3 dBA @ 9.6 m/s	House 66	3.0 dBA @ 9.6 m/s	House 66	3.3 dBA @ 9.6 m/s	House 66	6.3 dBA @ 9.6 m/s
House 67	3.9 dBA @ 9.6 m/s	House 67	0.9 dBA @ 9.6 m/s	House 67	0.7 dBA @ 9.6 m/s	House 67	3.9 dBA @ 9.6 m/s
House 68	1.0 dBA @ 8.2 m/s					House 68	1.8 dBA @ 8.2 m/s
House 69	2.7 dBA @ 8.2 m/s	House 69	1.4 dBA @ 8.2 m/s	House 69	1.4 dBA @ 8.2 m/s	House 69	3.7 dBA @ 8.2 m/s
House 70	2.2 dBA @ 8.2 m/s	House 70	1.7 dBA @ 8.2 m/s	House 70	1.5 dBA @ 8.2 m/s	House 70	2.7 dBA @ 8.2 m/s
12 exceedances		7 exceedances		8 exceedances		15 exceedances	

10 ADDITTIONAL CONSIDERATIONS

10.1 Assessment of Tonality and Infrasound

WTG manufacturers are obliged to conduct independent tests in accordance with IEC 61400-11. A part of this assessment is to conduct a tonal audibility test. The tonal audibility ∆Lta is typically assessed using the methodology outlined in *Joint Nordic Method Version 2 – Objective Method for Assessing the Audibility of Tones in Noise*.

The warranted tonal audibility data ∆La,k values have been supplied by the WTG manufacturers as follows.

Table 16 Audible tonality assessment to IEC 61400-11

Wind speed m/s	**Manufacturer/WTG – ∆La,k value – audible tonality**			
	GE 2.5xl (2.5MW)	Vestas V90 (2 MW)	Vestas V100 (1.8 MW) *	RePower MM92 (2 MW)
3	≤-4			
4	≤-4			
5	≤-4			-13.73
6	≤-4	-3.74		-10.22
7	≤-4	-4.50		-11.72
8	≤-4	-9.44		-10.49
9	≤-4	-8.17		-9.58
10	≤-4			
11	≤-4			
12	≤-4			

* Data for the Vestas V100 (1.8 MW) is not available.

For the purposes of the assessment the tonality resulting from each of the 4 proposed turbine models was determined to be inaudible (∆La,k <-3) and hence no penalty has been applied. Infrasound is not tested as an obligatory part of IEC 61400-11. It is noted that, in general, modern upwind WTGs do not exhibit significant infrasound emissions.

10.2 Wind enhanced propagation

The noise modelling predictions for cumulative noise have been completed using the algorithms of ISO9613 which conservatively assume a long term downwind enhanced propagation from each source to each receptor. In the case of a number of receptors this assumption may be considered conservative as WTGs will be located multiple directional quadrants from the receptor and hence not all WTGs would be considered as propagating downwind.

The degree to which this assumption may be considered conservative has been tested by evaluating some alternative predictive results using the algorithms of CONCAWE, which allows evaluation of enhancement effects from specific wind directions as well as the conservative assumption of downwind enhanced propagation from each WTG to each receptor. Winds from the east and west were evaluated and the reduction in noise levels for each receptor compared to the conservative downwind enhanced propagation from all WTGs are shown in **Table 15**.

Table 17 Wind Enhanced Propagation Evaluation

Receptor	Noise Level difference "all downwind propagation" minus "westerly wind"	Noise Level difference "all downwind propagation" minus "easterly wind"
House 8	1.6 dB	4.2 dB
House 19	3.6 dB	1.7 dB
House 20	2.8 dB	2.5 dB
House 64	2.1 dB	2.2 dB
House 65	2.2 dB	2.1 dB
House 66	3.3 dB	1.4 dB
House 67	3.8 dB	1.1 dB
House 70	4.7 dB	0.8 dB

It can be seen that for the selected houses which are critical to compliance the predicted degree of conservatism due to assumption of downwind enhanced propagation from each WTG to each receptor is typically greater than predicted level of exceedance.

10.3 Temperature Inversions

The SA EPA Guidelines do not require or suggest that temperature inversions be included during wind farm noise assessments. The NSW INP states that temperature inversions be included in an assessment if they are deemed to be a prevalent feature of the environment, which generally requires they occur for greater than 30% of the total night-time during winter (approximately two nights per week between 6:00 pm and 7:00 am). Currently there is insufficient data available to accurately determine the prevalence of temperature inversions at the site.

Temperature inversion is an atmospheric condition in which temperature increases with height above ground. Such conditions may increase noise levels by focussing sound wave propagation paths at a single point. Temperature inversions occurring within the lowest 50 m to 100 m of atmosphere can affect noise levels measured on the ground. Temperature inversions are most commonly caused by radiative cooling of the ground at night leading to cooling of the air in contact with the ground. Such conditions are especially prevalent on cloudless nights with little wind.

Conventional approaches to assessing noise propagation under temperature inversion conditions require knowledge of the temperature gradient and assume that the noise source is located below the temperature inversion, typically near to the ground. The effect of temperature inversions on noise propagation from WTGs is therefore not typical of other sources.

WTGs for the Crookwell 3 Wind Farm project are located on top of elevated ridges. The hub height (assumed acoustic centre of the WTG) is located typically on average 100-150m higher than the receiver locations on the surrounding area. It is therefore unlikely that conventional temperature inversion conditions, in the lower 100 m of the atmosphere, would affect noise propagation from such an elevated source.

A further consideration must be that temperature inversions require little to no wind in order to minimise atmospheric mixing and hence develop. During calm conditions the WTGs are unlikely to operate, as cut-in speed is 3 m/s.

Notwithstanding the above, an adaptive management approach could be implemented if undue noise impacts are identified during WTG operation that are related to temperature inversion effects.

10.4 Atmospheric stability and wind profile

The wind velocity at a location can be represented by a vertical profile (gradient) that generally is at a minimum at ground level and increases with altitude. The wind velocity profile is primarily determined by physical factors such as surface roughness and topographic (relief) effects, which are reasonably constant over time, however it can also be affected by more variable local atmospheric conditions including atmospheric stability and turbulence.

Atmospheric stability is determined by the total heat flux to the ground, primarily being the sum of incoming solar and outgoing thermal radiation and heat exchanged with the air. During clear summer days (incoming radiation dominates) air is heated from below and rises, causing significant thermal mixing, vertical air movements and turbulence. This process limits large variations in the vertical wind velocity profile.

During clear nights when outgoing radiation dominates, air is cooled from below, air density is greatest closer to the ground and minimal thermal mixing occurs. This leads to a stable atmosphere where horizontal layers of air are largely decoupled and allows for a higher wind velocity gradient.

A background noise data subset for night time (10:00 pm - 7:00 am) was analysed and the corresponding regression curves for night only are shown in **Section 7.** This represents the period when stable atmospheres are most likely.

Furthermore, one years worth of wind data collected from the site was analysed using recognised hourly stability classes determined using the Sigma Theta method from US Environmental Protection Agency, 2000 Meteorological Monitoring Guidance for Regulatory Modelling Applications, EPA-454/R-99-005 (USEPA, 2000). The Sigma Theta method (from Tables 6-9a and 6-9b of [NOTE: USEPA, 2000]) is a turbulence-based method which uses the standard deviation of the wind direction in combination with the scalar mean wind speed. An initial estimate of the stability class is determined using the sigma theta measurements, which is then refined using wind speed measurements, and time of day. Day time was assumed to be between the hours of 6am and 6pm. In total Stability Class E occurs for approximately 20% of the time.

The noise assessment methodology outlined in the SA EPA Guidelines, as do many other similar wind farm noise assessment methodologies, by necessity rely on the independently verified reference sound power data available for specific wind turbines measured at a manufacturer's test site. The measurement procedure has been standardised to require sound power data to be measured coincidentally with reference wind speed measurements at an altitude of 10 metres.

The SA EPA Guideline assessment procedure inherently assumes a fixed relationship between the 10 metre reference altitude and that at which the WTG operates, and that the relationship is the same during IEC 61400-11 test conditions. In practice, as discussed above, the wind velocity profile will vary as a result of ground roughness and atmospheric (stability) effects. The varying profile will likely result in variation in WTG noise emission levels, however, the extent to which levels will vary is difficult to quantify.

As discussed previously this assessment adopts a slightly modified procedure whereby the IEC 61400-11 sound power data extrapolated measured wind speed height datum used is the relevant hub height of the WTG. This is then applied at a specific site (e.g. at Crookwell 3) by using wind speed measured at 80 metres AGL (representative of hub height) to relate background noise levels to wind conditions present at the same time. The turbine noise power can then be applied and compared with background data at those same conditions of wind speed at hub height.

11 NOISE IMPACT MITIGATION STRATEGY

The exceedances of the SA EPA Guideline criteria listed in **Table 14** and **Table 15** arising from the predicted cumulative noise impacts of operational wind farms have been examined in detail and an appropriate noise impact mitigation strategy has been developed to address the cumulative noise impacts which includes;

- Developing a mitigated noise operation layout.
- Entering into agreements, in accordance with Section 2.3 of the SA EPA Guideline, with selected neighbouring landowners.
- Applying acoustic treatment to impacted dwellings.

11.1 Mitigated Noise Operation

A number of WTG models allow for operation in various 'low noise' modes. The control mechanism effectively modifies the blade angle to reduce rotor and inflow air speed and results in lower noise emissions at slightly reduced energy recovery.

The potential reduction in noise levels achievable through mitigated noise operation by selecting certain WTGs to operate in 'low noise' mode has been illustrated by evaluating a sample configuration.

11.1.1 Crookwell 1 and Crookwell 3 Wind Farm – Mitigated Operation

A scenario where Crookwell 3 Vestas V90 WTGs operating in Low Noise Mode 2 or are turned off during a limited range of wind speeds, refer to **Table 18** was modelled and the resulting assessment figures contained in **Appendix A5** depict the predicted WTG noise level curves superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

Table 18 Mitigated Noise Operation for Cumulative Noise Impacts (Crookwell 1 and Crookwell 3 Wind farms)

Crookwell 3 WTGs in Mode 2	Crookwell 3 WTGs Off
A5, A9, A10, A12, A13, A18	A15

The modelled mitigated noise operation example shows that compliance for cumulative noise impacts can be achieved at all receptors.

11.1.2 Crookwell 1, Crookwell 2 and Crookwell 3 Wind Farm – Mitigated Operation

A scenario where Vestas V90 WTGs operating in Low Noise Mode 2 or are turned off during a limited range of wind speeds, refer to **Table 19,** was modelled and the resulting assessment figures contained in **Appendix B5** depict the predicted WTG noise level curves superimposed over SA EPA Guideline Criteria and World Health Organisation based limits.

Table 19 Mitigated Noise Operation for Cumulative Noise Impacts (Crookwell 1 and Crookwell 2 and Crookwell 3 Wind farms)

Crookwell 2 WTGs in Mode 2	Crookwell 3 WTGs in Mode 2	Crookwell 3 WTGs Off
F16, F17, F18, F24, F25, F27, F33, F36, F37, F39, F44	A2, A6, A32, A33	A1

The modelled mitigated noise operation example shows that general compliance for cumulative noise impacts can be achieved at all receptors with marginal exceedances predicted at House 8 (1 dBA @ 8.2 m/s), House 20 (1.3 dBA @ 8.2 m/s), House 66 (3 dBA @ 9.6 m/s), House 67 (0.4dBA @ 9.6 m/s), House 70 (0.3 dBA @ 8.2 m/s).

It should be noted that the most effective method for mitigating the impact of cumulative noise of all wind farms would be a collaborative noise management approach. The proponent of the proposed Crookwell 3 Wind farm has committed to entering into an arrangement with the proponent of the approved Crookwell 2 Wind Farm to address cumulative noise impacts.

11.2 Agreements

Agreements with the landowners of House 8, House 20, House 66 and House 67 are proposed by the proponent. Should negotiations succeed and agreements be entered into then these properties would be treated in the same consideration as host properties. These properties are predicted to comply with World Health Organisation based limits.

If negotiations for agreements are unsuccessful then the following adaptive management approach is proposed:

- Verify actual WTG noise levels through comprehensive noise monitoring.
- Evaluate turning off WTGs during specific wind direction and speed that are identified as causing the exceedances and undue impact on the affected dwellings.
- Evaluate the acoustic design of the dwellings and provide acoustic upgrades (glazing, façade, masking noise etc) to the affected dwellings.
- Upon landowner initiated acquisition request, proceed with negotiations and give consideration to acquire the affected dwelling.
- If the above options are unsuccessful, the WTG(s) will be taken offline for further investigation and if impact is not able to be resolved then remove the WTG(s) causing the unresolved exceedances from the layout.

11.3 Building Acoustic Treatments

Where properties have been found to exceed the relevant SA EPA Guideline criteria the proponent will commit to, at the dwelling owner's request, undertaking a detailed acoustic assessment of the dwelling and designing and installing appropriate building acoustic treatments to reduce the impact of WTG noise.

The type of acoustic treatment required will depend upon the construction of dwelling and desired noise reduction, however, they could include;

- Provision for mechanical ventilation.
- Upgraded glazing and seals.
- Upgraded doors and seals.
- Provision for low level noise masking.

Improvement in the sound transmission loss of a typical dwelling of between 5-10 dBA would be possible.

11.4 Host Properties

The proponent, Crookwell Development Pty Ltd, proposes to enter into agreements in relation to noise limits with the Host Properties as well as the additional properties identified in **Section 11.2**., see the Statement of Commitments for details. Under the SA EPA Guidelines these residences are not required to comply to the 35 dBA or background + 5 dBA limits. However, it is necessary to ensure that the project does not result in an 'unreasonable interference' with the amenity of these Host Properties or cause any adverse health affects.

The World Health Organisation (WHO) publication '*Guidelines for Community Noise'* identifies the main health risks associated with noise and derives acceptable environmental noise limits for various activities and environments.

For the assessment of Host Properties the adopted external criteria of 45 dBA or the level given by the SA EPA Guideline criteria, where higher, will be adopted. Effectively this becomes 45 dBA or background + 5 dBA, whichever is the higher.

The predicted cumulative noise levels shown in **Table 9** and **Table 10** are predicted external noise levels which will be further mitigated by shielding effects of the building. Likewise, the anticipated internal levels will be reduced by the façade of the dwelling. Therefore, the WHO guidelines shown in **Section 2.4** are expected to be met for all receiver locations including the Host Properties.

Accordingly, while the proposed layouts are being assessed against the SA EPA Guidelines, some uncertainty remains as to the likely noise conditions that will result under specific atmospheric conditions over time. The SA EPA Guidelines noise limits are generally set within the requirements of the WHO Guidelines that relate to health impacts, and it is highly unlikely that the remaining uncertainty could lead to health impacts. However, it is possible that under certain conditions the amenity of existing dwellings could be reduced notwithstanding compliance with SA EPA Guidelines unless mitigation measures are implemented to avoid this. These conditions are likely to be variable and intermittent, and not result in a long-term loss in amenity.

11.5 Adaptive Management

If undue WTG noise impacts are identified during operations due to temperature inversion, atmospheric stability or excessive level then an 'adaptive management' approach can be implemented to mitigate or remove the impact. This process could include;

- Receiving and documenting noise impact complaint through 'hotline' or other means.
- Investigating the nature of the reported impact.
- Verifying actual WTG noise levels through comprehensive noise monitoring.
- Identifying exactly what conditions or times lead to undue impacts.
- Operating selected WTGs in a reduced 'noise optimised' mode during identified times and conditions (sector management).
- Evaluating the acoustic design of the dwellings and provide acoustic upgrades (glazing, façade, masking noise etc) to the affected dwellings.
- Turning off WTGs that are identified as causing the undue impact during identified times and conditions and if the impact is not able to be resolved then removing the WTG(s) causing the unresolved exceedances from the layout.

12 NSW DRAFT WIND FARM GUIDELINES

In December 2011 the NSW Department of Planning and Infrastructure released the *Draft NSW Planning Guidelines Wind Farms – Appendix B: NSW wind farm noise guidelines.*

Whilst the guidelines are yet to be finalised it has been requested by the Director General that during the interim period due consideration should be paid to a number of the additional requirements of the proposed draft guideline. These are presented below.

12.1 Daytime vs. Night-time Background Noise

The background noise data was reprocessed to define background noise curves for the daytime period (7.00 am to 10.00 pm) and night-time period (10.00 pm to 7.00 am) as defined by the draft guideline. The corresponding 3rd order regression curve and correlation coefficient are presented in **Table 20**.

Table 20 Background Noise Regression Curves and Correlation Coefficient

Location	Daytime	Daytime R^2	Night-time	Night-time R^2
H8 Narangi	-0.0178x^3 + 0.6425x^2 - 4.7373x + 35.598	R² = 0.7081	-0.0258x^3 + 0.9153x^2 - 7.2391x + 37.82	R² = 0.724
H18 Woolondilly2	-0.0117x^3 + 0.4492x^2 - 3.7292x + 39.208	R² = 0.5566	-0.0233x^3 + 0.8717x^2 - 7.7152x + 44.018	R² = 0.6668
H20 Normaroo	-0.0126x^3 + 0.4361x^2 - 2.7549x + 31.056	R² = 0.7852	-0.0166x^3 + 0.5896x^2 - 4.1646x + 30.403	R² = 0.8376
H58 650 Woodhouslee Rd	-0.0063x^3 + 0.2732x^2 - 2.1238x + 35.01	R² = 0.6708	-0.0054x^3 + 0.25x^2 - 1.6565x + 29.844	R² = 0.7554
H62 Cottonwood	-0.0108x^3 + 0.3272x^2 - 1.1223x + 26.145	R² = 0.6207	-0.0198x^3 + 0.6869x^2 - 5.0582x + 34.828	R² = 0.545
H64 Valdarmon Hill	-0.0029x^3 + 0.05x^2 + 2.1686x + 15.368	R² = 0.7192	-0.0124x^3 + 0.4067x^2 - 1.5764x + 23.669	R² = 0.6487
H66 Little Vale1	-0.005x^3 + 0.2054x^2 - 0.7457x + 24.797	R² = 0.5095	-0.0163x^3 + 0.6071x^2 - 4.345x + 29.066	R² = 0.7191
H70 Snowgums	-0.0243x^3 + 0.7873x^2 - 5.6462x + 38.638	R² = 0.6752	-0.0202x^3 + 0.6674x^2 - 3.9167x + 26.217	R² = 0.8367
H71 Lyncross	-0.0112x^3 + 0.3711x^2 - 1.685x + 29.241	R² = 0.6321	-0.018x^3 + 0.5724x^2 - 2.6978x + 23.324	R² = 0.7781
H79 Leeston	0.0034x^3 - 0.1331x^2 + 3.2435x + 17.824	R² = 0.5807	-0.0037x^3 + 0.1089x^2 + 0.9567x + 22.163	R² = 0.5508
H106 Rosdale	-0.0086x^3 + 0.2546x^2 - 0.6154x + 32.553	R² = 0.5819	-0.0106x^3 + 0.346x^2 - 1.6907x + 33.714	R² = 0.5649

The new background noise curves were used to update the noise limit curves for all receptors and all predicted results were assessed against these criteria. A full set of assessment graphs are presented in **Appendix F**. **Table 21** below shows the predicted exceedances for non-project involved locations for the daytime criteria.

Table 21 NSW Draft Wind Farm Guidelines Exceedances – Daytime Criteria

GE 2.5xl		V90		V100		MM92	
House.	**Exceedance**	**House.**	**Exceedance**	**House**	**Exceedance**	**House**	**Exceedance**
House 8	2.5 dBA @ 8.2 m/s	House 8	1.2 dBA @ 8.2 m/s	House 8	1.3 dBA @ 8.2 m/s	House 8	3.5 dBA @ 8.2 m/s
House 19	0.4 dBA @ 8.2 m/s					House 19	1.4 dBA @ 8.2 m/s

House 20	2.0 dBA @ 8.2 m/s	House 20	1.6 dBA @ 8.2 m/s	House 20	1.4 dBA @ 8.2 m/s	House 20	2.3 dBA @ 8.2 m/s
						House 59	0.1 dBA @ 8.2 m/s
						House 64	0.5 dBA @ 8.2 m/s
						House 65	0.4 dBA @ 8.2 m/s
House 66	4.9 dBA @ 8.2 m/s	House 66	2.9 dBA @ 8.2 m/s	House 66	3.3 dBA @ 8.2 m/s	House 66	6.3 dBA @ 8.2 m/s
House 67	2.5 dBA @ 8.2 m/s	House 67	0.7 dBA @ 8.2 m/s	House 67	0.6 dBA @ 8.2 m/s	House 67	3.9 dBA @ 8.2 m/s
						House 68	0.2 dBA @ 8.2 m/s
House 69	1.1 dBA @ 8.2 m/s					House 69	2.1 dBA @ 8.2 m/s
House 70	0.7 dBA @ 8.2 m/s	House 70	0.1 dBA @ 8.2 m/s			House 70	1.1 dBA @ 8.2 m/s
7 exceedances (5 less than previously)		5 exceedances (2 less than previously)		4 exceedances (4 less than previously)		11 exceedances (4 less than previously)	

Exceedances were all smaller in total and magnitude for all layouts. This is expected as the daytime only regression curve is higher than the original regression curve that was based on the 24 hour all data set.

Table 22 below shows the exceedances for non-project involved locations for the night-time criteria.

Table 22 NSW Draft Wind Farm Guidelines Exceedances – Night-time criteria

GE 2.5xl		V90		V100		MM92	
House.	**Exceedance**	**House.**	**Exceedance**	**House**	**Exceedance**	**House**	**Exceedance**
House 8	4.3 dBA @ 9.6 m/s	House 8	2.1 dBA @ 9.6 m/s	House 8	2.2 dBA @ 9.6 m/s	House 8	4.5 dBA @ 9.6 m/s
House 19	4.5 dBA @ 9.6 m/s	House 19	2.1 dBA @ 9.6 m/s			House 19	1.4 dBA @ 8.2 m/s
House 20	4.0 dBA @ 9.6 m/s	House 20	3.3 dBA @ 9.6 m/s	House 20	3.1 dBA @ 9.6 m/s	House 20	4.1 dBA @ 9.6 m/s
House 58	0.4 dBA @ 8.2 m/s					House 58	1.8 dBA @ 8.2 m/s
House 59	1.2 dBA @ 8.2 m/s					House 59	2.5 dBA @ 8.2 m/s
						House 60	0.1 dBA @ 8.2 m/s
						House 61	2.7 dBA @ 8.2 m/s
House 62	1.4 dBA @ 8.2 m/s					House 62	2.7 dBA @ 8.2 m/s
						House 63	0.8 dBA

							@ 8.2 m/s
House 64	3.1 dBA @ 8.2 m/s	House 64	1.7 dBA @ 8.2 m/s	House 64	1.9 dBA @ 8.2 m/s	House 64	4.2 dBA @ 8.2 m/s
House 65	3.0 dBA @ 8.2 m/s	House 65	1.7 dBA @ 8.2 m/s	House 65	1.8 dBA @8.2	House 65	4.1 dBA @ 8.2 m/s
House 66	6.9 dBA @ 9.6 m/s	House 66	3.6 dBA @ 9.6 m/s	House 66	3.9 dBA @ 9.6 m/s	House 66	7.1 dBA @ 9.6 m/s
House 67	4.5 dBA @ 9.6 m/s	House 67	1.4 dBA @ 9.6 m/s	House 67	1.2 dBA @ 9.6 m/s	House 67	4.7 dBA @ 9.6 m/s
House 68	1.2 dBA @ 8.6 m/s					House 68	2.1 dBA @ 8.2 m/s
House 69	3.0 dBA @ 8.2 m/s	House 69	1.7 dBA @ 8.2 m/s	House 69	1.7 dBA @ 8.2 m/s	House 69	4.0 dBA @ 8.2 m/s
House 70	2.5 dBA @ 8.2 m/s	House 70	2.0 dBA @ 8.2 m/s	House 70	1.8 dBA @ 8.2 m/s	House 70	3.0 dBA @ 8.2 m/s
13 exceedances (1 more than previously)		9 exceedances (2 more than previously)		8 exceedances (same as previously)		16 exceedances (1 more than previously)	

Exceedances for the night-time criteria curve were greater in total and magnitude for all layouts. This is due to the lower night-time background noise at the critical lower wind speeds, 6 - 7 m/s compared to the 24 hour all data set.

The results for the daytime and night-time criteria are presented as a means of comparison only. The DGR's for the project remain those defined by the SA EPA Guidelines.

It should be noted that the predictions are based on the cumulative noise total of Crookwell 1 Wind Farm and Crookwell 2 Wind Farm and Crookwell 3 Wind Farm and represent a direct comparison to **Table 15** i.e. no mitigated low noise operation.

12.2 Special Audible Characteristics

The Draft NSW Guidelines have been developed with the fundamental characteristics of wind turbine noise taken into consideration including reasonable levels of swish, modulation, discrete tones and low frequency noise.

The Draft NSW Guidelines introduce recommendations for procedures to assess excessive levels of special audible character and these procedures (if adopted) are to be used to evaluate noise character from an operational wind farm. Notwithstanding the above, the proposed procedures have been adopted to evaluate the predicted likelihood of excessive levels of special audible character.

12.2.1 Low Frequency Noise

An assessment of the potential for low frequency noise was completed with C-weighted noise levels predicted for the 4 different WTG options considered for Crookwell 3, combined with the cumulative noise from combined Crookwell 1 and Crookwell 2 wind farms.

A criteria of 65 dBC daytime and 60 dBC night-time as proposed by the Draft NSW Guidelines was used to determine if further investigation into low frequency noise was warranted.

The results from the SoundPlan model predict that wind turbine noise would not exceed 60 dBC for any receiver location. A full set of C-weighted noise predictions for each receptor location are shown in **Appendix G.**

12.2.2 Tonality

The simplified 1/3 octave band method for assessing tonality as proposed by the Draft NSW Guidelines was completed for the Vestas V90, Vestas V100 and RePower MM92 layouts. The GE 2.5xl turbine reference sound power data was in octave bands, rather than one third octave bands and as such no tonality test was possible for this layout. Should this turbine option be considered for the final layout, the manufacturer should provide one third octave band data for the purposes of the tonality assessment.

This method determines if a single one-third octave band exceeds the level of the adjacent bands by;

- **5 dB or more** if the centre frequency of the band containing the tone is above 400Hz
- **8 dB or more** if the centre frequency of the band containing the tone is 160 to 400Hz inclusive
- **15 dB or more** if the centre frequency of the band containing the tone is below 160Hz

The tonality tests showed no presence of tonality in the predicted results. The tonality test for each receptor location is shown in **Appendix G.**

12.2.3 Amplitude Modulation

Amplitude modulation (AM) refers to the cyclical modulation of audible aerodynamic noise from WTGs. The modulation typically occurs at rate corresponding to blade passing frequency which is approximately once per second (i.e. ~1 Hz). This is not to be confused with infrasound, that is, sound waves at frequencies below the range of human hearing; rather it refers to the fluctuation of noise level in the audible range.

Noise from a wind turbine typically includes an inherent level of amplitude modulation, often referred to as ‘swish’ and the criteria in the Draft NSW Guidelines have been determined with the inherent characteristics of wind turbine noise – including reasonable levels of amplitude modulation – taken into consideration. The Draft NSW Guidelines propose an excessive level of modulation is taken to be a variation of greater than 4 dBA at the blade passing.

The issue of AM of WTG noise is now the subject of considerable research and investigation and whilst ‘normal’ amplitude modulation (swish) is generally well characterised and the source mechanism better understood, the hypothesised potential causes of excessive (Other) AM are somewhat more complex and not well understood.

Research into AM undertaken by Salford University in 2007, found that out of the total number of operational wind farms in the investigated (133) in the UK approximately 20% at some point had registered a noise complaint(s); but AM was considered to be a factor in noise complaints at only 3% of the sites and a possible factor at 6% of the sites. Furthermore, the periods when AM complaints were registered at four wind farms determined that the necessary conditions were relatively infrequent. From this it appears that whatever the actual number of occurrences of potential excessive AM, it only occurs at a minority of wind farm sites for a small amount of the time.

There currently is no means to predict the eventuality, severity or frequency of occurrence of excessive AM and the proposed Draft NSW Guideline methodology is limited to the assessment of operational wind farms. Research evidence would suggest that excessive AM has only been confirmed at a small number of wind farm sites and when it occurs it is relatively infrequent.

Nevertheless, should excessive AM be found to be a problem with the wind farm, it would be possible to limit the impact on the residents through adaptive management techniques (see also **Section 11.5 - Adaptive Management**).

13 ASSESSMENT OF CONSTRUCTION NOISE LEVELS

13.1 Construction Noise

Construction activities include:

- construction of access roads;
- establishment of turbine tower foundations and electrical substation;
- digging of trenches to accommodate underground power cables; and
- erection of turbine towers and assembly of WTGs.

The equipment required to complete the above tasks will typically include:

- excavator/grader, bulldozer, dump trucks, roller;
- bucket loader, rock breaker, drill rig, excavator/grader, bulldozer, trucks (dump, flat beds, concrete);
- excavator, flat bed trucks; and
- cranes, fork lift, and various 4WD and service vehicles.

The anticipated construction period is expected to be about 12 to 15 months, with civil works expected to span approximately 9 to 10 months. Due to the large area of the wind farm site, intensive works will be located within a distance of potential impact for each surrounding residential receiver for only very short and intermittent periods of time. It is anticipated that most construction will occur during standard construction hours and it is therefore considered appropriate that construction noise levels up to 10 dBA above the RBLs would be acceptable. Construction noise levels greater than 10 dBA above RBL could be considered as noise affected. At levels greater than 75 dBA receptors would be considered highly noise affected by construction noise.

Computer noise models of typical construction scenarios were developed which included all anticipated mobile equipment for the activity operating simultaneously at full load. A de-rating factor of 5 dBA was selected to convert modelled full load simultaneous operation to typical operations of multiple mobile construction vehicles.

To look at the possible worst case construction scenario for all nearby receivers, all four different construction activities were modelled at each turbine location and the highest noise levels for each receiver predicted.

The resulting predicted construction noise level for the relevant ‘worst case’ scenario is detailed in **Table 23** together with the Rating Background Level (RBL) obtained during the background noise monitoring campaign.

Table 23 Worst case Construction L_{Aeq} Noise Levels (dBA)

Receiver Location	Rating Background Level (RBL), dBA	Highest Construction Noise anticipated at WTG#	Access Road	Trench excavation	Turbine foundation establishment	WTG erection
1	24.7	A26	32.9	24.9	43.9	24.9
2	24.7	A26	35.4	27.4	46.4	27.4
3	24.7	A26	24.5	16.5	35.5	16.5
4	24.7	A26	31.8	23.8	42.8	23.8
5	24.7	A26	22.1	14.1	33.1	14.1
6	24.7	A28	32.6	24.6	43.6	24.6
7	24.7	A28	32.9	24.9	43.9	24.9
8	24.7	A31	35.9	27.9	46.9	27.9
17	28.3	A33	42.9	34.9	53.9	34.9
18	28.3	A33	35.5	27.5	46.5	27.5
19	28.3	A32	44.6	36.6	55.6	36.6
20	32.1	A29	34.3	26.3	45.3	26.3
33	30.2	A23	26	18	37	18
34	30.2	A33	27.8	19.8	38.8	19.8
35	30.2	A23	26.5	18.5	37.5	18.5
36	30.2	A23	28.8	20.8	39.8	20.8
37	30.2	A33	21.5	13.5	32.5	13.5
38	30.2	A33	35.3	27.3	46.3	27.3
39	30.2	A33	35.9	27.9	46.9	27.9
40	30.2	A23	28.7	20.7	39.7	20.7
53	30.2	A23	30	22	41	22
54	30.2	A23	31.8	23.8	42.8	23.8
55	30.2	A23	32.6	24.6	43.6	24.6
56	30.2	A23	31	23	42	23
57	30.2	A20	30.7	22.7	41.7	22.7
58	30.2	A25	36.6	28.6	47.6	28.6
59	30.2	A12	36.6	28.6	47.6	28.6
60	25.5	A23	35.5	27.5	46.5	27.5
61	25.5	A20	39.3	31.3	50.3	31.3
62	25.5	A20	39.2	31.2	50.2	31.2
63	25.8	A10	44.8	36.8	55.8	36.8
64	23.2	A2	42.4	34.4	53.4	34.4
65	23.2	A12	34.1	26.1	45.1	26.1
66	21	A12	43.4	35.4	54.4	35.4
67	21	A12	40.2	32.2	51.2	32.2
68	24.9	A1	42.2	34.2	53.2	34.2

Receiver Location	Rating Background Level (RBL), dBA	Highest Construction Noise anticipated at WTG#	Access Road	Trench excavation	Turbine foundation establishment	WTG erection
69	24.9	A1	45.5	37.5	56.5	37.5
70	24.9	A1	39.4	31.4	50.4	31.4
71	26.9	A1	24.6	16.6	35.6	16.6
72	26.9	A1	23	15	34	15
73	26.9	A4	27.5	19.5	38.5	19.5
74	26.9	A1	17.2	9.2	28.2	9.2
75	26.9	A1	16.6	8.6	27.6	8.6
76	26.9	A1	17	9	28	9
79	25.8	A8	32.7	24.7	43.7	24.7
80	25.8	A16	40.2	32.2	51.2	32.2
81	26.9	A1	17.5	9.5	28.5	9.5
82	26.9	A1	18.8	10.8	29.8	10.8
103	31.5	A5	15.9	7.9	26.9	7.9
104	31.5	A5	23.4	15.4	34.4	15.4
106	31.5	A18	17.4	9.4	28.4	9.4
107	31.5	A5	19.3	11.3	30.3	11.3
108	31.5	A4	18.6	10.6	29.6	10.6
109	26.9	A1	18	10	29	10
110	26.9	A1	16.8	8.8	27.8	8.8
112	26.9	A1	16.9	8.9	27.9	8.9
113	31.5	A4	18.5	10.5	29.5	10.5
114	31.5	A4	20.6	12.6	31.6	12.6
115	26.9	A1	16.7	8.7	27.7	8.7
116	26.9	A1	16.4	8.4	27.4	8.4

Note	
40.2	Shading indicates receptor might be noise affected during construction
32.2	Shading indicates construction noise at receptor will be acceptable

The predicted 'worst case' construction noise impacts (shaded in green) are, for most receiver locations, below management level and indeed below the existing typical daytime rating background level and so are unlikely to result in adverse reaction.

Some nearby receivers may receive elevated construction noise levels (shaded in orange) when civil works are located nearby. The highest noise levels are a result of the operation of a rock-breaker during turbine foundation establishment. This is dependent upon the geotechnical conditions of the foundation site and would be operated intermittently at most. Consideration for mitigative measures such as localised shrouding may be needed if adverse conditions are experienced if and when operating the rock-breaker at the most exposed positions.

No receptors are predicted exceed 75 dBA or in the category of highly noise affected.

13.2 Blasting

13.2.1 Applicable Criteria

The ground vibration and airblast levels which cause concern or discomfort to residents are generally lower than the relevant building damage limits.

The DECC advocates the use of the Australian and New Zealand Environment Conservation Council (ANZECC) guideline *"Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration"* for assessing potential residential disturbance arising from blast emissions. The ANZECC guidelines for control of blasting impact at residences are as follows:

- The recommended maximum level for airblast is 115 dB Linear. The level of 115 dB Linear may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 120 dB Linear at any time.
- The recommended maximum for ground vibration is 5 mm/s, Peak Vector Sum (**PVS**) vibration velocity. It is recommended however, that 2 mm/s PVS be considered as the long term regulatory goal for the control of ground vibration. The PVS level of 5 mm/s may be exceeded on up to 5% of the total number of blasts over a period of 12 months. The level should not exceed 10 mm/s at any time.
- Blasting should generally only be permitted during the hours of 9:00 am to 5:00 pm Monday to Saturday. Blasting should not take place on Sundays and public holidays.
- Blasting should generally take place no more than once per day.

The Australian Standard 2187.2-1993 "*Explosives - Storage, Transport and Use. Part 2: Use of Explosives*" does not present human comfort criteria for ground vibration from blasting. It does however make mention of human comfort level for airblast in saying "a limit of 120 dB for human comfort is commonly used". This is consistent with the ANZECC guidelines.

AS 2187.2-1993 nominates building damage assessment criteria as presented in **Table 24**.

Table 24 Blast Emission Building Damage Assessment Criteria (AS 2187)

Building Type	Vibration Level	Airblast Level (dB re 20 µPa)
Sensitive (and Heritage)	PVS 5 mm/s	133 dB(Linear) Peak
Residential	PVS 10 mm/s	133 dB(Linear) Peak
Commercial/Industrial	PVS 25 mm/s	133 dB(Linear) Peak

13.2.2 Blasting Assessment

As part of the civil works it is expected that infrequent blasting will be required to clear obstacles and prepare WTG foundations.

Blasting may be required in some areas to clear large rock outcrops to prepare turbine foundations.

The proposed wind farm site is a green field site where no previous blasting or blast monitoring has been conducted and therefore no site specific propagation decay laws exist. We have therefore adopted a site law derived from measurement data at a different site to give an indicative result.

The 5% site laws for ground vibration and airblast are:

Ground Vibration $PVS\ (5\%) = 16202\ (SD_1)^{-2.03}$

Airblast $SPL(5\%) = 189.3 - 31.8 \log (SD_2)$

where PVS (5%) and SPL (5%) are the levels of ground vibration (Peak Vector Sum - mm/s) and airblast (dB Linear) respectively, above which 5% of the total population (of data points) will lie, assuming that the population has the same statistical distribution as the underlying measured sample.

SD_1 and SD_2 are the ground vibration and airblast scaled distances, where:

$$SD_1 = \frac{\text{Distance}}{\sqrt{\text{MIC}}} \quad (m.kg^{-0.5})$$

and,

$$SD_2 = \frac{\text{Distance}}{\sqrt[3]{\text{MIC}}} \quad (m.kg^{-0.33})$$

Based on the adopted blast emissions site laws, calculations were also conducted to indicate the allowable MIC's for compliance with the general EPA Human Comfort criteria of 115 dB Linear (airblast) and 5 mm/s (ground vibration).

The closest anticipated distance between blasting and residences would be approximately 600 metres (Leeston). At this distance the predicted maximum MIC of up to 21 kg is likely to produce an airblast overpressure below the acceptable level of 115 dB Linear. An MIC of 21kg is expected to result in a vibration level (Peak Vector Sum) of 0.81 mm/s well within the recommended maximum level of 5 mm/s in the ANZECC Guidelines.

It is evident that the anticipated blasting is likely to meet all human comfort limits and building damage assessment criteria are easily met. All other sources of vibration would be less than that assumed above.

13.3 Traffic Noise

Traffic generated by the project during its construction phase has been separately evaluated as part of the EA. Traffic generated by the project during its operational phase will be insignificant.

Project construction traffic for the Crookwell 3 wind farm will primarily utilise the local roads of Woodhouselee Road and the Crookwell-Goulburn Road. Beyond the project area, construction traffic will use the Hume Highway.

The projected maximum construction traffic on proposed access roads represent, in some cases, a significant increase in traffic movements. This results in an increase in existing traffic noise levels as shown in **Table 25.**

The projected increase in road traffic noise levels on all local roads is expected to be greater than 2 dBA during peak construction periods, however, road traffic noise levels are anticipated to meet the Roads and Traffic Authority of NSW (RTA) *Environmental Criteria for Road Traffic Noise (ECRTN) 1999* target for a local road of daytime $L_{Aeq(1\ hour)}$ = 55 dBA at modest setback distances. As the areas surrounding the site consist of a rural farming community that most receptors are at much greater setback distances from the road frontage and therefore will easily meet the ECRTN requirement.

Table 25 Construction Traffic Noise

Proposed Access Road	VPD Current	VPD Projected Maximum Construction Traffic	Projected increase in existing road traffic noise level	ECRTN classification	ECRTN requirement	Approximate distance at which ECRTN requirement is achieved
Hume Highway				Freeway / Arterial	$L_{eq(15hr)}$ 60 dBA	
Woodhouselee Road	< 30	Less than 100	6 dBA	Local	$L_{eq(1hr)}$ 55 dBA	
Crookwell-Goulburn Road	< 30	Less than 100	6 dBA	Local	$L_{eq(1hr)}$ 55 dBA	

13.3.1 Night-time deliveries

There could potentially be deliveries of equipment scheduled for out of hours, necessitated by traffic congestion considerations and safe passage of heavy vehicle convoys or especially long loads. Night-time traffic has the potential to cause sleep disturbance to residential receivers along the route.

Preliminary calculations indicate that maximum noise levels at a residence approximately 10 metres from the road as a result of a heavy vehicle pass-by would be in the range 45-80 dBA. We would anticipate that night-time background noise levels along affected routes could be as low as 30 dBA and as such maximum noise levels from pass-bys may have the potential for sleep disturbance

To minimise potential noise impacts associated with night-time deliveries some potential measures to be considered are;

- Prior notification of affected public where night-time convoys are scheduled
- Restricted use of exhaust/engine brakes in built up areas

14 CONCLUSION

WTG noise has been predicted and assessed against relevant criteria prescribed by the SA EPA Guideline and World Health Organisation (WHO) goals where appropriate.

Predictions for cumulative WTG noise levels have been completed for two alternative possibilities;

- Existing Crookwell 1 Wind Farm and proposed Crookwell 3 Wind Farm
- Existing Crookwell 1 Wind Farm, approved Crookwell 2 Wind Farm and proposed Crookwell 3 Wind Farm

Four alternative WTG model were considered for the proposed Crookwell. 3 Wind farm;

- GE 2.5xl, 100m rotor diameter, 100m hub height, 2.5 MW
- Vestas V90, 90m rotor diameter, 105m hub height, 2.0 MW
- Vestas V100, 100m rotor diameter,95m hub height, 1.8 MW
- Repower MM92, 93m rotor diameter, 100m hub height, 2.0 MW

Cumulative WTG noise from existing Crookwell 1 and proposed Crookwell 3 Wind farms was predicted and assessed. Exceedances of the SA EPA Guideline limit were predicted for all four investigated WTGs, with the Vestas V90 WTG layout resulting in 2 exceedances. A mitigated operation scenario was considered where one WTG is turned off and a select few WTG's are operated in a 'low noise' mode for a limited range of wind speeds. The predicted reduction in noise levels resulted in no exceedances of the SA EPA Guideline limit.

Cumulative WTG noise from the existing Crookwell 1, approved Crookwell 2 and proposed Crookwell 3 Wind farms was predicted and assessed. Exceedances of the SA EPA Guideline limit were predicted for all four investigated WTGs, with the Vestas V90 WTG layout resulting in 7 exceedances.

The proponent proposes to negotiate noise agreements with House 8, House 20, House 66 and House 67 as well with as the host properties.

A mitigated operation scenario was considered where a select few WTGs (Vestas V90) from both the approved Crookwell 2 Wind Farm and the proposed Crookwell 3 Wind Farm are operated in a 'low noise' mode. The resulting reduction in cumulative noise levels at potentially affected receptors was sufficient to reduce the total number of cumulative noise exceedances to 1 (House 70 exceedance of 0.3 dBA at 8.2 m/s) which would be considered only marginal.

It should be noted that the noise modelling procedure relies on a number of conservative assumptions, the foremost being that noise propagates downwind from each source. This will overestimate the predicted noise level where receptors have WTGs located around them in more than a singular direction or quadrant as wind is not able to blow in more than one directional quadrant simultaneously. This exact scenario describes the relative positioning the receptors identified as exceeding SA EPA Guideline levels have with respect to WTGs form Crookwell 2 and Crookwell 3. The degree to which this conservative assumption potentially over-estimates noise levels has been evaluated by predicting noise at compliance critical receptors using alternative algorithms and specific wind directions of easterly and westerly versus all downwind. The predicted degree of conservatism of the all downwind assumption is expected to be greater than the predicted exceedances.

During commissioning of the proposed Crookwell 3 Wind Farm the actual received WTG noise level will need to be verified and determined through extensive monitoring. In addition, an adaptive noise management plan will need to be developed and implemented whereby WTGs will be turned down to 'low noise' mode or alternatively turned off during conditions where actual exceedances are identified. The most effective approach to developing an adaptive noise management plan where multiple wind farms contribute to the cumulative noise impact is to assess received WTG noise levels through the collaborative and coordinated WTG "on-off" testing which removes much of the variability of non wind farm influences. Directional noise monitoring might also be a feasible means of monitoring noise from multiple projects and determining the most effective mitigation strategy.

To ensure the reliable long term operation of the wind farm with respect to minimising impacts the proponent will commit to routine noise monitoring, assessment and reporting at compliance critical locations to ensure that the ongoing operation of the proposed Crookwell 3 Wind Farm remains vigilant in minimising noise impacts.

Construction noise impact has been assessed and the 'worst case' scenarios modelled were found to be generally acceptable.

Blasting impact has been assessed and found to be acceptable. With a maximum instantaneous charge (MIC) of up to 21 kg, the airblast overpressure is anticipated to be below the acceptable level of 115 dB Linear for all existing residences.

Construction traffic noise impact has been assessed and the 'worst case' maximum construction traffic generated scenario modelled would increase existing traffic noise levels when measured along local roads by up to 3-7 dBA. However, due to the typically large setback of dwellings from the road network in the area, it is considered that the construction traffic noise would result in noise level that would be considered acceptable under the NSW DECCW *Environmental criteria for Road Traffic Noise* (ECRTN).

Subsequent to a request by the Director General due consideration has been paid to a number of the additional requirements of the proposed *Draft NSW Planning Guidelines Wind Farms – Appendix B: NSW wind farm noise guidelines* released by the NSW Department of Planning and Infrastructure in December 2011. These include consideration to separate daytime and night-time periods and alternative methods of evaluation for Special Audible Character.

15 CLOSURE

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

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