COLLECTOR WIND FARM

NOISE IMPACT ASSESSMENT

4 June 2012

MARSHALL DAY Acoustics

4/46 Balfour St
Chippendale
NSW 2008
T: +612 9282 9422 Fax: +612 9281 3611
www.marshallday.com

Certified System ISO 9001

Project: **COLLECTOR WIND FARM**

Prepared for: **RATCH Australia c/o**

APP
PO Box 1573
North Sydney NSW 2059

Attention: **Mr. Chris Thompson**

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EXECUTIVE SUMMARY

An environmental noise impact assessment of the proposed Collector Wind Farm has been undertaken Marshall Day Acoustics Pty Ltd.

A turbine layout comprising sixty-eight (68) turbines has been assessed in accordance with the Director-General's Requirements (DGRs) provided by the NSW Government Department of Planning. Specifically, this assessment considers impacts relating to both construction and operation of the development and refers to relevant objective noise criteria detailed in the DGRs to determine the acceptability of the proposal.

Operational wind farm noise has been assessed using the South Australian EPA *Noise Guidelines for Wind Farms* (February 2003) as detailed in the DGRs relevant to this project. The 2003 SA Guideline noise criteria apply directly to dwellings that do not have an involvement in the project. To assess dwellings that do have an involvement in the project, reference has been made to advice contained in World Health Organization (WHO) guidelines and the document ETSU-R-97 *The Assessment and Rating of Noise from Wind Farms* (ETSU-R-97) to define suitable noise limits. This approach to involved dwellings is consistent with more recent advice from the South Australian EPA.

The assessment also accounts for the draft document *NSW Planning Guidelines: Wind Farms* issued by the NSW Department of Planning and Infrastructure in December 2011. In advance of any final guidelines, the noise assessment has taken account of the proposed noise criteria contained in the draft NSW guidelines.

Long-term background noise monitoring was conducted in two stages during 2010 at eight receivers. The collected data, where appropriate, was used to determine baseline conditions and establish indicative criteria for surrounding receivers at hub height wind speeds.

A three-dimensional digital noise model was used to predict noise emissions from the proposed 68 turbine layout to a total of thirty-four (34) noise sensitive receiver locations considered in this assessment. The noise predictions have been made for a range of candidate turbines which are being considered for the development

Based on the candidate turbines considered, it has been shown that the proposed 68 turbine layout could viably operate within the noise criteria at all relevant receiver locations, excluding the involved receiver N where separate arrangements have been made with the land owner. The predictions have however demonstrated that other candidate turbine options could necessitate reduced layouts comprising between sixty-four (64) and sixty-seven (67) turbines in order to maintain compliance with the criteria at all relevant assessment locations (accounting for the proposed arrangements with involved receiver N).

The 2003 SA Guideline requires that the predicted wind farm noise level should not exceed 35dBA or background noise by more than 5dBA, whichever is the greater, at all receivers not involved in the project, for the operating wind speed range of the wind farm from cut-in to rated power. The noise assessment has demonstrated that the Collector Wind Farm achieves compliance with the minimum noise limit of 35dBA applicable to all receivers not involved in the project. The minimum limit is independent of measured background noise levels. The assessment therefore does not rely on the benefit of higher background noise related limits. The measured background noise data, and any derived limits, are therefore only provided for reference purposes, and do not alter the assessment outcomes according to the 2003 SA Guideline noise criteria.

The predicted noise levels also comply with the proposed minimum noise limit nominated in the draft NSW guidelines. Additional information has also been provided where appropriate, in recognition of the proposed assessment requirements nominated in the draft NSW guidelines.

Cumulative noise impacts associated with the adjacent Cullerin Range Wind Farm have been assessed and found to comply with all relevant noise criteria assuming simultaneous downwind propagation from each turbine of the two developments.

Substation environmental noise levels have been assessed and found to comply with the NSW Industry Noise Policy, as referred to in the DGRs.

Transmission line Aeolian tones and corona noise effects have been considered, as per the DGR requirements. The Collector Wind Farm will be connecting to existing high voltage overhead lines in the area, and will not give rise to any additional noise of this nature.

Construction noise impacts have been assessed. Predicted noise emissions are expected to comply with the NSW *Interim Construction Noise Guideline* (CNG) noise limits at all receivers not involved with the project. The predicted construction noise levels at four of the involved receivers lie in the *noise affected* range according to the CNG, but are below the threshold defined as *highly affected*. As with operational noise from the wind farm, receivers with an involvement in the project are likely to accept higher levels of construction noise than non-involved receivers. Notwithstanding this consideration, a construction noise management plan will identify measures to be implemented to reduce the noise impacts during construction, including working practices and hours of construction.

Offsite construction traffic noise impacts have been assessed using the *Environmental Criteria for Road Traffic Noise* (ECRTN) as required in the DGRs and the *Road Noise Policy* (RNP) which has superseded ECRTN as of 1 July 2011. Predicted traffic noise levels at a range of locations along the construction traffic route have been shown to comply with the guideline limits defined by both ECRTN and RNP.

The commissioning of the scheme would include compliance noise monitoring to confirm that operational noise limits have been adhered to. In the unlikely event that noise levels were found to exceed the limits, an outline contingency strategy has been defined to reduce noise levels.

TABLE OF CONTENTS

1.0 INTRODUCTION

Marshall Day Acoustics Pty Ltd (MDA) has been engaged by RATCH-Australia (RATCH) to undertake a noise impact assessment for the proposed Collector Wind Farm.

This report details the methodology and findings of our assessment of noise associated with both construction and operation of the development.

Wind farm operational noise has been assessed in accordance with the South Australia Environmental Protection Authority (EPA) *Environmental Noise Guidelines: Wind Farms* (2003) (the 2003 SA Guideline), which is the current guideline for wind farm noise assessment in the state of New South Wales.

Dwellings that have been assessed in accordance with the 2003 SA Guideline are termed *receivers* within this report. Where landowners have entered into an agreement with the proponent their dwelling(s) are termed *involved receivers* within this report. For these dwellings the European Working Group on Noise from Wind Turbines document ETSU-R-97 and the World Health Organization's *Guidelines for Community Noise* have been referenced for guidance.

The assessment also accounts for the draft document *NSW Planning Guidelines: Wind Farms* issued by the NSW Department of Planning and Infrastructure in December 2011. The draft guidelines were released for consultation purposes and the public submission period remains open until 14 March 2012. In the interim, and in advance of any final guidelines, the noise assessment has taken account of the proposed noise criteria contained in the draft guidelines.

In addition to operational wind farm noise, an assessment of substation noise and various aspects of construction noise and vibration have been undertaken in accordance with the following guidelines:

- Electrical substation noise: *NSW Industrial Noise Policy* (NSW Environment Protection Authority 2000)
- Traffic noise: *Environmental criteria for road traffic noise* (NSW Environment Protection Authority 1999) *and the NSW Road Noise Policy* (NSW Department of Environment and Climate Change 2011)
- Site establishment and construction noise: *Interim Construction Noise Guideline* (NSW Department of Environment and Climate Change 2009)
- Construction vibration: *Assessing Vibration: A technical guideline* (Department of Environment and Conservation 2006)

Table 1 summarises the information that forms the basis of this assessment.

Table 1
Assessment reference data

Item	Date Received
Final turbine layout	Dec 2011
Final residences	March 2011
Collector mast data	July/Dec 2010
Wood Park mast data	July/Dec 2010
Terrain contours	Aug 2010
Candidate turbine data	March 2011

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

2.0 SITE DESCRIPTION

The proposed Collector Wind Farm site (the site) is located in NSW approximately 55km north-east of Canberra and 35km south west of Goulburn. The site is located centrally between the Hume Highway, Collector Road and Collector Creek. The south-east extent of the site is approximately 3km north-west of the township of Collector. The Upper Lachlan Shire Council is the relevant local authority.

Thirty-four (34) dwellings have been identified with the assistance of the proponent for inclusion in this assessment.

Refer to Appendix B for dwelling and turbine locations. Refer to Appendix D for site layout figures.

2.1 Proposed Wind Farm Layout

A maximum of sixty-eight (68) turbines has been considered for the layout of the Collector Wind Farm. The proposed 68 turbine maximum layout considered in this study is shown in Figure D1 of Appendix D.

The final turbine selection for the project would be made during the detailed design and procurement phase. It is therefore necessary for this assessment to consider the emissions of viable candidate turbine models which may be considered for the site. To this end, the proponent is seeking approval for a range of turbines, with varying hub heights, rotor diameters, generating capacity and noise emission levels.

The proponent has selected three (3) different makes of turbine which are representative of the range of turbines which could be considered for the site. All of the candidate turbines comprise three upwind rotor blades with variable blade pitch to control rotational speed, power generation and noise emissions. Table 2 summarises the relevant specifications of the 3 representative turbines. Appendix B provides the turbine layout coordinates and nomenclature.

Table 2
Representative turbine specification

Description	Candidate Turbines		
	Suzlon	REpower	Siemens
Model	S88-2.1MW, V3	3.4M 104	SWT-2.3-101
Rotor Diameter (m)	88	104	101
Hub Height (m)	79	80	80
Rotor speed range (rpm)	15-17.6	6.9–13.8	6-16
Cut-in Wind Speed (m/s)*	4	3.5	3-4
Rated Wind Speed (m/s)*	14	13.5	12-13
Cut-out Wind Speed (m/s)*	25	25	25
Maximum Sound Power L_{WA} (dB)**	104.3	105.0	107.0

* Hub height
** Maximum sound power from the range of wind speeds provided

Depending on the final model of turbine selected for the site, a combined generating capacity of up to 228 MW may be achieved.

The sound power levels presented in Table 2 have been derived from manufacturer test data which we understand is based on the methodology of IEC-61400-11:2006 *Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques* (IEC61400-11:2006). The data for the Suzlon and REpower turbines represent the maximum value of the A-weighted sound power level plus measurement uncertainty for all tested wind speeds. Measured test data was not available for the Siemens turbine so the maximum sound power level represents the manufacturer's guaranteed maximum A-weighted values.

Detailed sound power level data, including frequency characteristics, are provided in Appendix C. Test literature for the Suzlon and REpower turbines includes frequency information outside the normal reporting range, and extends from 20Hz upwards.

Table 2 indicates that there is a 1m variation in hub heights across the three turbine models. For simplicity, subsequent references to hub height in this report shall refer to 80m AGL (above ground level).

Modern wind turbine designs generally include specific design and construction measures for the control of noise associated with mechanical components such as gearboxes. These mechanical components can give rise to noise which is characterised by narrow frequency ranges, and may be perceived as tonal in nature. This type of noise is generally regarded as more intrusive than broad-band sound, and it is for this reason that modern turbine designs generally incorporate dedicated measures for the control of tonality. As a result, at separating distances typical of surrounding receiver locations, a correctly functioning modern wind farm is generally characterised by broader aerodynamic noise emissions associated with the passage of the blades through the air. Notwithstanding the reduced likelihood of tonality in modern turbine designs, the potential for it to occur must be controlled through the consent and design phases of the project. In recognition of this, we envisage that the procurement contract for the site would stipulate that the turbines must not produce emissions which would attract a penalty when assessed in accordance with the relevant noise criteria and any associated conditions of consent.

3.0 NOISE ASSESSMENT GUIDELINES

The NSW government (specifically, the NSW Office of Environment & Heritage - formerly DECCW) does not currently provide guidelines relating to the noise of operational wind farm developments. The NSW government has however acknowledged that the NSW Industrial Noise Policy (INP) is not appropriate for new wind farm developments.

In lieu of formal noise directives from the NSW government, there are a range of policy and guideline documents which should be considered when assessing noise from the construction and operation of the Collector Wind Farm. The following sections detail the project specific requirements including a set of Director-General's Requirements issued for the project by the NSW Department of Planning.

3.1 NSW Government Department of Planning

The NSW Department of Planning issued a set of Director-General's Requirements (DGRs) for the proposed Collector Wind Farm on 15 October 2010. The DGRs set out the issues, including noise and vibration considerations, which the environmental assessment of the proposal must address.

The *Key Assessment Requirements* noted by the Director-General include the following with respect to noise:

The EA must:

→ *Include a comprehensive noise assessment of all phases and components of the project taking into account cumulative impacts from surrounding approved or operational wind farms in the locality including: turbine operation, the operation of the transformer and electrical substation, corona and/or Aeolian noise from the transmission line, construction noise, traffic noise during construction and operation, and vibration generating activities during construction and/or operation. The assessment must identify noise/vibration sensitive location (including approved but not yet developed dwellings), baseline conditions based on monitoring results, the levels and character of noise (e.g. tonality, impulsiveness, low frequency etc) generated by noise sources, noise/vibration criteria, modelling assumptions and worst case and representative noise/vibration 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 van den Berg effect). 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 higher than 30 dB(A);*

→ *Identify any risks with respect to tonal, low frequency or infra-noise;*

→ *If any 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 and 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 (as or otherwise agreed with the DECCW):

→ *Wind Turbines – the South Australian Environment Protection Authority's Wind Farms – Environmental Noise Guidelines, 2003;*

→ *Electrical Substation – NSW Industrial Noise Policy (EPA, 2000);*

→ *Traffic Noise – Environmental Criteria for Road Traffic Noise (NSW EPA, 1999);*

→ *Site Establishment and Construction – Interim Construction Noise Guidelines (DECC 2009);*

→ *Blasting – Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration ANZECC 1990), and*

→ *Vibration – Assessing Vibration: A Technical Guideline (DECC, 2006).*

The criteria stipulated by the DGRs are discussed in further detail in the following sections, with the exception of blasting which we have been advised is not proposed as part of the construction of this project.

3.2 SA EPA Environmental Noise Guidelines: Wind Farms (2003)

In accordance with the DGRs, the South Australia EPA document *Environmental Noise Guidelines: Wind Farms* (2003) (the *2003 SA Guideline*) has been used to assess operational noise from the Collector Wind Farm. The 2003 SA Guideline noise criteria applicable to receivers not involved with the project are described as follows:

> *The predicted equivalent noise level ($L_{Aeq,10min}$), adjusted for tonality in accordance with these guidelines, should not exceed 35dBA, or the background noise ($L_{A90,\ 10\ min}$) by more than 5dBA, whichever is the greater, at all relevant receivers for each integer wind speed from cut-in to rated power of the WTG.*

Regarding involved receivers, Section 2.3 of the 2003 SA Guideline states:

> *The criteria have been developed to minimise the impact on the amenity of premises that do not have an agreement with wind farm developers.*

However, the Guideline notes that developers cannot absolve themselves of their obligations to protect the environment by entering into an agreement with a landowner. With this obligation in mind, involved receivers are included in this noise impact assessment report. The following documents have been referenced for guidance on setting limits at involved receivers:

- European Working Group on Noise from Wind Turbines document ETSU R-97 *The Assessment and Rating of Noise from Wind Farms* (ETSU R-97)
- World Health Organization (WHO) document *Guidelines for Community Noise*.

These documents are discussed further in the following section.

The 2003 SA Guideline noise criteria apply to noise levels occurring under free-field conditions which are not significantly influenced by reflections from vertical structures. Limits apply to the 24-hour period, seven days per week and do not differentiate between day, evening and night-time periods.

In recognition of current industry practice in Australia and internationally, this noise impact assessment uses hub height wind speeds rather than 10m above ground level (AGL) wind speeds as nominated in the 2003 SA Guideline. Further discussion of wind shear is provided in Appendix E.

The 2003 SA Guideline was developed in recognition of the inherent noise characteristics of a correctly functioning modern wind farm. These characteristics include aerodynamic noise from passing blades, referred to as “swish” and infrequent braking noise. In instances where a wind farm emits atypical noise characteristics such as tonality, the 2003 SA Guideline proposes a 5dBA penalty to account for characteristics of turbine operation that would be deemed annoying.

In relation to infrasound, the 2003 SA Guideline indicates that the EPA conducted an extensive literature search relating to the subject and was not able to identify any modern sites where significant levels of infrasound had been generated by a wind farm. The South Australian EPA have subsequently reiterated this view in Section 4.7 of their updated Guideline in 2009.

In accordance with the 2003 SA Guideline, measured background noise levels used for the purpose of deriving noise limits must not be significantly influenced by the contribution of existing operational wind farms. Specifically, Section 2.5 states:

> *…any additional wind farm that may impact on the same relevant receiver as an existing wind farm should meet the criteria using the background noise levels as they existed before the original wind farm site development.*

It is noted that the 2003 SA Guideline referenced in this study, as per the requirements of the DGRs, was superseded in South Australia by updated guidelines released in 2009. The document *Wind farms environmental noise guidelines* released by the South Australian EPA in July 2009 contains an assessment methodology similar in structure to the superseded document, but with revisions including additional survey requirements and the option of increased minimum noise limits for particular land zonings.

3.3 Draft NSW Planning Guidelines: Wind Farms

The NSW Department of Planning and Infrastructure released the draft *NSW Planning Guidelines: Wind Farms* (the *draft NSW guidelines*) in December 2011 to enable public consultation on a proposed regulatory framework for the development of wind farms in NSW. The consultation phase for the draft NSW guidelines extends to 14 March 2012. In the interim, and in advance of any final guidelines, the noise assessment has taken account of the proposed noise criteria contained in the draft NSW guidelines.

Appendix B of the draft NSW guidelines outlines a proposed noise assessment methodology for wind farms. The proposed methodology includes draft noise criteria for receivers not involved with the project and details of relevant noise prediction, background monitoring and compliance monitoring requirements. The noise criteria are:

> *For a new wind farm development the predicted (L_{eq}, 10 minute), adjusted for any excessive levels of tonality, amplitude modulation or low frequency, but including all other normal wind farm characteristics, should not exceed:*
>
> *35dB(A) or the background noise (L_{90}) by more than 5dB(A), whichever is greater, at all relevant receivers not associated with the wind farm, for wind speed from cut-in to rated power of the WTG at each integer wind speed in between. The noise criteria must be established on the basis of separate daytime (7am to 10pm) and night-time (10pm to 7am) periods.*

Appendix B of the draft NSW guidelines also provides a discussion of the basis for these criteria and notes the following:

> *To ensure that the amenity of an area is not compromised, criteria have been set to restrict noise generated by wind turbines to 5dB(A) below the lowest acceptable noise criteria for a suburban or rural amenity (which is 40dB(A) at night) unless the area experiences background noise levels higher than the average 30dB(A) in which case the noise criteria can be up to 5dB(A) above the L90 background noise level. These criteria apply to all periods of the day regardless of whether the acceptable amenity is higher during the day or night.*

Importantly, the minimum noise limit derived according to the proposed criteria in the draft NSW guidelines is 35dB(A), irrespective of the measured background noise level.

The draft NSW guidelines refer to negotiated agreements between wind farm proponents and owners of private land suitable for hosting wind turbines. In this context, the draft NSW guidelines specifically clarify that the proposed criteria are intended to minimise the impact on the amenity on neighbouring that do not have an agreement with the wind farm proponent. Whilst the draft NSW guidelines do not specifically define criteria applicable to involved land owners, it is implicit from this advice that the draft criteria provided for non-involved receivers should not be applied to involved receivers.

The draft NSW guidelines note that the proposed criteria for A-weighted noise levels have been specifically developed in recognition of the fundamental characteristics of the noise associated with a correctly functioning wind farm. In instances where the noise of a wind farm contains excessive levels of specific noise characteristics, the draft NSW guidelines propose relevant procedures in the section titled Data analysis within Appendix B.

Importantly, the procedures documented for these characteristics are documented as data analysis requirements which implicitly relate to post-construction compliance studies. However, Section 1.3(a) of the draft NSW Guidelines detail planning assessment requirements for specific situations where a wind farm proposal seeks to place turbines within 2km of existing residences. In these instances, the draft NSW guidelines indicate that the application should include the following where written consent has not been obtained from residences with 2km:

> *predicted levels of noise at any houses within the 2km zone (including low frequency noise)*

Section 1.3(a) of the draft NSW guidelines does not detail specific information requirements for low frequency noise. However, the proposed data analysis procedures of Appendix B suggest a threshold for external noise levels to trigger a detailed assessment of low frequency noise, stating the following:

> *If it is shown that the C-weighted noise (measured from 20Hz upwards) from a wind farm (excluding any wind induced or extraneous C-weighted noise) is repeatedly greater than 65dB(C) during the daytime or 60dB(C) during the night-time a more detailed low frequency noise assessment should be undertaken.*

Whilst the proposed trigger for detailed low frequency noise assessments is stated to apply to the measured noise levels of an operational wind farm, the proposed draft criteria provide a guide to the type of information required in specific situations where a proposed wind farm includes turbine positions within 2km of dwellings.

3.4 ETSU-R-97 and Word Health Organization

Reaction to environmental noise is dependent on a wide range of factors such as the level and character of the noise. Importantly, it is also influenced by an individual's attitude to the noise source in question, a factor which is particularly relevant when considering acceptable noise levels at dwellings which have some form of involvement in the project. Noise limits for involved receivers are nominated in ETSU-R-97, which recommends:

> *...that both day- and night-time lower fixed limits can be increased to 45dBA and that consideration should be given to increasing the permissible margin above background where the occupier of the property has some financial involvement in the wind farm.*

The ETSU-R-97 limit of 45dBA is consistent with the WHO criterion for the protection of amenity and avoidance of sleep disturbance, as published in the document *Guidelines for Community Noise* (1999).

For this noise impact assessment, a minimum guideline noise limit of 45dBA (free-field) is adopted for involved receivers. In combination with the background noise level dependent limits stipulated in the 2003 SA Guideline, the guideline criterion for involved receivers is as follows:

- 45dBA or background L_{A90} + 5dBA; whichever is the greater; for each integer wind speed from cut-in to rated power of the wind farm.

3.5 Construction Noise Guidelines

In July 2009 the DECCW issued interim construction noise guidelines to replace the *Environmental Noise Control Manual* (1994).

The *Interim Construction Noise Guideline* (CNG) is the applicable policy for assessing noise associated with construction activities. The CNG sets out *noise management levels* and defines two thresholds referred to as the *noise affected* level and the *highly noise affected* level.

The noise affected level applicable to residential dwellings is equal to the rating background level (RBL), as derived according to the methodology outlined in the Industrial Noise Policy, plus 10dB. The noise affected level is defined by the CNG as the point above which there may be community reaction.

In instances where the predicted or measured noise exceeds the noise affected level, the CNG recommends that the proponent should apply all feasible and reasonable work practices to meet the noise affected level. It also recommends that the proponent should inform all potentially impacted residents of the nature of the works to be carried out, the expected noise levels and their duration, as well as relevant site contact details.

The highly noise affected level applicable to residential dwellings is equal to a value of 75dBA, and represents the point above which there may be strong community reaction to noise. Where the noise is above this level, the CNG advises that the relevant authority may require respite periods by restricting the hours that the very noisy activities can occur, taking into account community attitudes to longer construction periods in exchange for restrictions on construction times.

In both cases, the noise management level relates to the $L_{Aeq, 15min}$ noise parameter.

The noise management levels are applicable during the standard hours of construction which are as follows:

- Monday to Friday, 0700-1800hrs
- Saturday, 0800-1300hrs
- No construction work to take place on Sundays or public holidays.

We understand that these working hours are consistent with the Upper Lachlan Shire Council recommended working hours.

The CNG acknowledges that there may be occasions when work needs to be carried out outside of the recommended standard hours. In this respect, the CNG makes references to works including the delivery of oversized plant or structures along public roads. The CNG also makes reference to emergency work, repair or maintenance works, public infrastructure works that shorted the length of the project, and works where the proponent justifies a need to operate outside standard hours.

3.6 Construction Vibration Guidelines

The DECC document *Assessing Vibration: A Technical Guideline* dated February 2006 (vibration guideline) presents preferred and maximum vibration criteria for use in assessing human response to vibration.

The acceptable values of human exposure to vibration are dependent on, amongst other things, the time of day. This assessment only considers the period in which construction is expected to normally occur (i.e. 0700-1800hrs Monday to Friday and 0800-1300hrs on Saturday).

The vibration criteria are separately specified for the following types of vibration characteristics:

- Continuous – vibration that continues uninterrupted for a defined period such as the duration of a day
- Impulsive – vibration that comprises a rapid build up to a peak followed by several cycles of progressively reducing vibration
- Intermittent – vibration that comprises interrupted periods of continuous (e.g. a drill) or repeated periods of impulsive vibration (e.g. a pile driver), or continuous vibration that varies significantly

The types of activities associated with the construction of a wind farm may include both continuous and impulsive vibration sources operating over interrupted periods of a working day. It is therefore expected that vibration would be typically classified as intermittent according to the vibration guideline, but may be continuous or impulsive on occasion.

Table 3 summarises the preferred and maximum values for acceptable human exposure to continuous and impulsive vibration. It is noted that the vibration guideline provides criteria for the assessment of continuous and impulsive vibration in the form of the weighted acceleration values. Given that empirical vibration data is more readily available in the form peak particle velocity (PPV) data, the criteria are reproduced here in the form of equivalent PPV values sourced from Appendix C of the vibration guideline.

Table 3
Preferred and maximum values for vibration during daytime (mm/s) 1-80Hz (PPV)

Location	Preferred Values	Maximum Values
Continuous		
Residences	0.28	0.56
Impulsive		
Residences	8.6	17

Table 4 summarises the preferred and maximum values for acceptable human exposure to intermittent vibration. The vibration guideline recommends the assessment of intermittent vibration on the basis of a more complex parameter referred to as the vibration dose value (VDV) which relates vibration magnitude to the duration of exposure.

Table 4
Vibration dose values for intermittent vibration during daytime ($m/s^{1.75}$) 1-80Hz

Location	Preferred Values	Maximum Values
Residences	0.2	0.4

The vibration guideline does not address vibration induced damage to buildings or structures. However, the thresholds for human exposure to vibration are generally well below accepted thresholds for minor cosmetic damage to lightweight structures. Accordingly, vibration which complies with the criteria for human exposure does not pose a risk in terms of structure damage.

3.7 Environmental Criteria for Road Traffic Noise (During Construction)

The DGRs refer to the NSW EPA's *Environmental Criteria for Road Traffic Noise* (ECRTN) for the assessment of traffic noise associated with the development.

The ECRTN guideline does not specifically preclude direct application to temporary changes in noise levels associated with construction traffic, however the document is predominantly focussed on longer term or permanent impacts associated with completed road projects. Table 5 presents the relevant traffic noise criteria for this development, however given these criteria could be equally applied to permanent changes associated with a completed development, they can be considered as very conservative when assessing the effects of temporary and intermittent traffic noise level changes associated with construction. The noise criteria apply to sensitive receptor locations such as residential dwellings or schools.

Table 5
Road traffic noise criteria

Type of Development	Criteria Day 0700-2200hrs
Land use developments with potential to create additional traffic on local roads	$L_{eq(1hr)}$ 55dBA
Land use developments with potential to create additional traffic on existing freeways/arterial roads	$L_{eq(15hr)}$ 60dBA

Source: Table 1 NSW EPA – Environmental Criteria for Road Traffic Noise

The ECRTN also states for situations where the criterion reproduced in Table 5 is already exceeded by existing traffic conditions, the traffic arising from the development should not increase existing noise levels by more than 2dBA $L_{eq(1hr)}$.

It should be noted that, on 1 July 2011, ECRTN will be superseded by the *NSW Road Noise Policy* (RNP) dated March 2011. The RNP noise criteria are similar to those presented in Table 5, and recommends that traffic noise levels should not increase by more than 12dBA. As per ECRTN, the RNP is not directly applicable to temporary increases in traffic volumes due to construction activities.

4.0 WIND FARM OPERATIONAL NOISE ASSESSMENT

4.1 Assessment Methodology for Operational Noise

4.1.1 Predictions and Receiver Assessment

Preliminary predictions of wind farm noise levels are calculated at each receiver using the method detailed in ISO9613-2: 1996- *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation* (ISO9613 2:1996). ISO9613-2:1996 is recognised as an appropriate method for use in calculating wind farm noise by several Australasian guidance documents[1]. Further discussion of ISO9613-2 and its application to this assessment is provided in section 4.4.1.

The preliminary predictions are used to identify potentially affected residential properties in the vicinity of the wind farm in accordance with Section 3.1 of the Guideline. Specifically, properties are identified where the predicted noise level exceeds the relevant base noise level of 35dBA at 10m/s (V_{10m}) or less. These are termed *relevant receivers*.

Background noise monitoring is required to be carried out at relevant receivers. Where a cluster of dwellings occurs, one receiver may be selected as being a worst-case representation of the cluster as a whole.

4.1.2 Background Noise Monitoring

Background noise monitoring is carried out in accordance with Section 3.1 of the 2003 SA Guideline at the identified relevant receivers. The data gathered from each site is analysed in accordance with Section 3.4 of the 2003 SA Guideline, together with wind speed data collected within the proposed site.

Wind shear is a factor which must be considered in the assessment of wind farm noise. Wind shear describes the variations in wind speed with height above ground level. In recognition of the influence of wind shear, current industry practice is to base wind farm noise assessments on hub-height wind speeds rather than the 10m AGL wind speeds nominated in the 2003 SA Guideline.

The use of hub-height wind speed data has been documented in more recent guidance from Australia[1] and New Zealand[1] as it is considered to better account for the influence of site-specific wind shear conditions in the noise assessment. Accordingly, hub height wind speeds are used for the Collector Wind Farm noise impact assessment.

[1] SA EPA Wind Farm Guidelines 2009, NZS6808:2010 *Acoustics – wind farm noise*, and AS4959:2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators*

4.1.3 Establishment of Noise Limits

Noise criteria for the development are determined in accordance with Sections 2.2 and 3.4 of the 2003 SA Guideline. Specifically, the 2003 SA Guideline requires that the predicted wind farm noise level should not exceed 35dBA or background noise $L_{A90,10\text{-}min}$ by more than 5dBA, whichever is the greater, at all receivers not involved in the project, for the operating wind speed range of the wind farm from cut-in to rated power.

As discussed in section 3.3, noise limits for all involved receivers are derived in a similar manner but the minimum noise limit increases from 35dBA to 45dBA.

The noise assessment presented in the following sections demonstrates that the Collector Wind Farm achieves compliance with the minimum noise limits applicable to all receivers not involved in the project. The minimum limits are independent of measured background noise levels. The assessment therefore does not rely on the benefit of higher background noise related limits. The measured background noise data, and any derived limits, are therefore only provided for reference purposes, and do not alter the assessment outcomes according to the 2003 SA Guideline noise criteria.

4.1.4 Assessment of Acceptability of Wind Farm Noise

Noise predictions for the proposed turbine layout are compared with the relevant noise limits for each receiver in order to establish acceptability of wind farm noise. As noted above in section 4.1.2, the assessment is to be based on a common wind speed height reference, equal to the hub-height of the turbines. The same wind speed height reference is therefore used when predicting variations in wind turbine noise levels with changing wind speed.

The predicted noise levels are then considered in combination with predicted noise levels from existing wind turbines in the area in order to assess any potential cumulative noise effects.

4.2 Selection of Relevant Receivers

In total, thirty-four (34) dwellings were identified as potential relevant receivers for inclusion in this assessment, comprising:

- five (5) involved receivers which are all located within 2km of a proposed turbine location
- twenty-nine (29) non-involved receivers, of which (3) are located within 2km of a proposed turbine

The identification of potential relevant receivers included a review by the proponent of sub-divisions and potential new developments to date. This review was based on local council data and visits to the area to confirm dwelling locations. Based on the site layout data available prior to commencement of the background noise surveys, a total eight (8) locations were identified for background noise monitoring, including four (4) receivers and four (4) involved receivers. A full list of receiver locations is contained in Appendix B. Table 6 provides details of the background noise monitoring locations in addition to all identified properties within 2km of a proposed turbine location.

Table 6
Background noise monitoring locations & dwellings with 2km

House	Involved receiver	Background monitoring	Easting (m)	Northing (m)	Closest turbine	
					Distance (km)	Designation
G	Yes	Yes	716686	6133417	1.2	CWTG60
M	Yes	Yes	715919	6137699	1.7	CWTG42
N	Yes	Yes	717810	6140502	0.3	CWTG10
S	Yes	No	716282	6138352	1.4	CWTG16
T	Yes	Yes	716186	6138745	1.0	CWTG16
L	No	Yes	714378	6135706	3.4	CWTG42
Q	No	Yes	713019	6140846	3.1	CWTG16
Z	No	Yes	715176	6138037	1.8	CWTG16
AA	No	Yes	722053	6137902	2.4	CWTG62
BB	No	No	723156	6141476	1.9	CWTG68
FF	No	No	721605	6139345	1.5	CWTG65

As noted previously, the findings of the noise assessment of the Collector Wind Farm presented in the following sections demonstrate compliance with the minimum noise limits. The measured background data, and any related derived limits, are therefore only provided for reference purposes, and do not alter the assessment outcomes according to the 2003 SA Guideline noise criteria. Further details of the background noise surveys carried out are contained in Appendix E to Appendix H.

4.3 Sound Power Level Data Adjustment

In order to conduct an assessment of turbine noise emissions referenced to hub-height wind speeds, it is necessary to convert the standardised manufacturers 10m AGL wind speed reference to the relevant hub-height wind speed, assuming the same shear profile factored in the manufacturers data. Specifically, using a reference roughness length factor (Z_0) of 0.05m in accordance with the sound power test procedure defined in IEC 61400-11:2006 *Wind turbine generator systems – Part 11: Acoustic noise measurement techniques*.

Accordingly, the following equation has been used to convert the 10m AGL wind speeds to corresponding hub-height wind speeds.

$$V_1 = V_2 \cdot \frac{\ln\left(\frac{h_1}{z_0}\right)}{\ln\left(\frac{h_2}{z_0}\right)}$$

Equation 2

Where:

V_1 = wind speed at height h_1 in m/s
V_2 = wind speed at height h_2 in m/s
Z_O = the surface roughness length

4.4 Wind Farm Noise Predictions

4.4.1 Noise Prediction Standard

Operational wind farm noise levels were predicted at all residential dwellings considered within this assessment using a three-dimensional noise model generated in SoundPLAN® version 7.0 software. Specifically, predictions have been carried out using the SoundPLAN implementation of ISO 9613-2: 1996 *Acoustics – Attenuation of sound during propagation outdoors Part 2: General method of calculation* to calculate noise propagation from the wind farm to each receiver location.

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

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

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

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

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

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

Wind farm noise propagation has been the subject of considerable research in recent years. These studies have provided support for the reliability of engineering methods such as ISO 9613-2 when a certain set of input parameters are chosen in combination. Specifically, the studies to date tend to support that the assignment of a ground absorption factor of G=0.5 for the source, middle and receiver ground regions between a wind farm and a calculation point tends to provide a reliable representation of the upper noise levels expected in practice, when modelled in combination with other key assumptions; specifically all turbines operating at identical wind speeds, emitting sound levels equal to the test measured levels plus a margin for uncertainty (or guaranteed values), at a temperature of 10 degrees and relative humidity of 70%. A limitation of 2dBA is applied to any calculated screening effects to account for the reduced effect of terrain shielding for elevated noise sources.

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

- A factor of G=0.5 is frequently applied in Australia for general environmental noise modelling purposes as a way of accounting for the potential mix of ground porosity which may occur in regions of dry/compacted soils or in regions where persistent damp conditions may be relevant

- NZS6808:2010 refers to ISO9613 as an appropriate prediction methodology for wind farm noise, and notes that soft ground conditions should be characterised by a ground factor of G=0.5

- In 1998, a comprehensive study, part funded by the European Commission, Development of a Wind Farm Noise Propagation Prediction Model[2] found that the ISO9613 model provided a robust representation of upper noise levels which may occur in practice, and provided a closer agreement between predicted and measured noise levels than alternative standards such as CONCAWE and ENM. Specifically, the report indicated the ISO 9613 method generally tends to marginally over predict noise levels expected in practice

- The UK Institute of Acoustics journal dated March/April 2009 published a joint agreement between practitioners in the field of wind farm noise assessment, including consultants routinely employed on behalf of both developers and community opposition groups, and indicated the ISO9613 method as the appropriate standard and specifically designated G=0.5 as the appropriate ground characterisation. It is noted that this publication specifically referred to predictions made to receiver heights of 4m in the interest of representing 2-storey dwellings which are more common in the UK. Predictions in Australia are generally based on a lower prediction height of 1.5m which tends to result

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

in higher ground attenuation factors for a given ground absorption factor, however conversely, predictions in Australia do not generally incorporate a -2dB factor (as applied in the UK) to represent the relationship between Leq and L90 noise levels. The result is that these differences tend to balance out to a comparable approach and thus supports the use of G=0.5 in the context of Australian prediction methodologies.

- A range of comparative measurement and prediction studies[3][4][5] for wind farms in which Marshall Day Acoustics' staff have been involved in have provided further support for the use of ISO9613 and G=0.5 as an appropriate representation of typical upper noise levels expected to occur in practice.

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

- the types of noise source heights associated with a modern wind farm, extending the scope of application of the method beyond the 30m maximum source heights considered in the original ISO 9613

- the types of environments in which wind farms are typically developed, and the range of atmospheric conditions and wind speeds typically observed around wind farm sites. Importantly, this supports the extended scope of application to wind speeds in excess of 5m/s.

ISO 9613 is primarily intended for the prediction of total A-weighted noise levels. The discussions presented above solely relate to the validation of ISO 9613 for the prediction of total A-weighted noise levels associated with the Collector Wind Farm.

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

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

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

In the absence of an international standard engineering prediction method specifically developed for the prediction of C-weighted noise levels, the ISO 9613 methodology has also been used to produce low frequency noise level predictions at non-involved receivers within 2km of a proposed turbine location. These predictions are provided to address the information requirements proposed in the draft NSW guidelines. It must however be recognised that ISO 9613 and other similar prediction methods are not specifically intended for this purpose, and involves applying the prediction methodology to frequencies outside the stated scope of the standard. As a result, the prediction of C-weighted noise levels is subject to a greater level of uncertainty. This is discussed further in subsequent sections where predicted noise levels are presented.

4.4.2 Wind Farm Layout

The sixty-eight (68) turbine layout has been found to comply with the minimum relevant noise criteria at all receivers not involved with the project, based on the emissions of the Suzlon candidate turbine. However, the noise predictions for the REpower and Siemens candidate turbines demonstrated that reduced layouts would be required to maintain compliance with the minimum noise criteria at all receivers not involved with the project.

Layout reductions were determined for the REpower and Siemens candidate turbines which are characterised by higher noise emissions. Specifically, reduced layouts comprising sixty-seven (67) and sixty-four (64) of the proposed turbine locations were found to be required for the REpower and Siemens candidate turbines respectively.

Table 7 details the layout reductions associated with the REpower and Siemens candidate turbines.

Table 7
Turbine layout reductions for the candidate turbine options

Candidate Turbine	Proposed Turbine Locations Removed to Achieve Compliance
REpower 3.4M 104	CWT65
Siemens SWT-2.3-101	CWT45, CWT65, CWT66 & CWT67

The reduced layouts, and the position of the turbines which have been removed from the predictions, are indicated in figures D1-D3 of Appendix D.

4.4.3 Predicted A-weighted Noise Levels

Table 8 presents the maximum predicted noise levels at each of the 34 assessment locations for the 3 candidate turbines considered in this assessment, accounting for the layout reductions noted above in Table 7 for each candidate turbine. Predicted noise levels below 20dBA cannot be practically measured in the conditions in which turbines operate, and therefore the numerical value of the predicted noise level at locations below 20dBA are not reported.

Table 8
Maximum A-weighted predicted receiver noise levels L_{eq} dBA

House	68 x Suzlon S88-2.1MW	67 x REpower 3.4M 104	64 x Siemens SWT-2.3-101	Minimum Noise Limit
A	<20	<20	<20	35
AA	31	31	32	35
B	<20	<20	<20	35
BB	31	31	31	35
C	<20	<20	<20	35
CC	26	27	27	35
D	21	21	21	35
DD	28	28	29	35
E	21	21	22	35
EE	25	25	25	35
F	25	25	26	35
FF	35	35	35	35
G	34	34	36	45*
GG	27	27	28	35
H	28	29	30	35
HH	29	30	30	35
I	26	26	27	35
J	30	30	32	35
K	30	31	32	35
L	30	30	31	35

House	68 x Suzlon S88-2.1MW	67 x REpower 3.4M 104	64 x Siemens SWT-2.3-101	Minimum Noise Limit
M	35	35	36	45*
N	46	47	49	45*
O	30	30	31	35
P	24	24	25	35
Q	27	27	28	35
R	28	28	29	35
S	37	38	39	45*
T	38	38	40	45*
U	22	22	23	35
V	30	30	31	35
W	27	27	28	35
X	27	27	27	35
Y	27	27	28	35
Z	33	34	35	35

* Involved receiver

The results presented in Table 8 demonstrate that, for all 3 candidate turbines, the maximum predicted noise levels are equal to or less than the minimum applicable limit under the 2003 SA Guideline, assuming no increase in limit due to background noise levels, at all locations except involved receiver N. Further, the predictions at non-involved receiver locations are within the minimum limit proposed in the draft NSW guidelines.

In relation to involved receiver N, it is noted that the proposed involved receiver limit is a guideline value only, and the 2003 SA Guideline does not stipulate noise limits to be applied to involved receivers. In addition, the arrangement of the turbines around involved receiver N is such that the prediction of noise on the basis of simultaneous downwind propagation from each turbine is likely to overestimate the noise which occurs in practice at involved receiver N. Notwithstanding these considerations, representatives of the proponent have advised the residents that predicted noise levels are above the 45dBA guideline value adopted for other involved receivers, and presented the option of modified turbine layouts to reduce the noise. We understand that the residents have chosen to waive the option of reduced turbine layouts, and instead seek to enter into a land holder agreement which retains the currently proposed layout and includes provisions to attenuate noise levels if required. The form of these attenuation measures are referred to in the discussion of contingency strategies presented in Section 7.0, and may include operational noise management strategies or a package of insulation measures provided for the dwelling.

Variations in predicted noise levels with wind speed for the candidate turbines are plotted on the reference noise limit curves in Appendix I. Sound power level data for the Siemens candidate turbine is only available for the wind speed at which the maximum emission occurs, and therefore Appendix I does not include the Siemens candidate turbine.

4.4.4 Predicted C-weighted Noise Levels

Table 9 presents the maximum predicted noise levels at each of the 3 non-involved receiver locations where a wind turbine is proposed to be located within 2km. The predicted noise levels presented in Table 9 are based on octave band noise level measured test data for frequencies upwards of 20Hz as presented in Appendix C, and correspond to the wind speeds where the maximum predicted noise levels presented in Section 4.4.3 occured.

In the case of the Siemens candidate turbine, the available test data is limited to 63Hz and above. The influence of noise emissions between 20Hz and 63Hz has been accounted for by applying the maximum calculated influence of these frequencies determined for the Suzlon and REpower candidate turbines.

Table 9
Maximum C-weighted predicted receiver noise levels L_{eq} dBC

House	68 x Suzlon S88-2.1MW	67 x REpower 3.4M 104	64 x Siemens SWT-2.3-101
Z	48	52	48
BB	44	50	48
FF	48	54	53

The predicted noise levels presented in Table 9 are below the 65dBC and 60dBC day and night respective levels nominated in the draft NSW guidelines as thresholds which could prompt a requirement for further detailed low frequency noise assessments.

The prediction of low frequency noise levels are however subject to increased margins of uncertainty. This uncertainty relates to the use of sound power level data below the normal frequency range reported by turbine manufacturers, combined with the application of engineering prediction methods specifically intended for the calculation of A-weighted noise levels. In relation to these uncertainties, the following considerations are noted:

- Quoted uncertainty values for the total C-weighted noise emissions of the turbines are not provided in the available manufacturers' literature. However, data for the Suzlon candidate turbine indicates uncertainty values ranging from +/-1dB up to approximately +/-6dB at frequencies below 63Hz. These uncertainty values are considered typical of the range likely to apply for other similar size turbines, depending on the specific circumstances in which the sound power test is carried out

- The prediction of environmental noise levels involves calculation of a number of atmospheric and environmental effects. In relation to key items, the following considerations are noted:

  - The ISO 9613 prediction method assumes an equal noise contribution from the reflected ground wave at 63Hz, and therefore applies no ground attenuation at this frequency irrespective of the selected ground absorption for the calculation. This effectively equates to a hard ground condition and therefore a hemi-spherical noise propagation pattern. In extending the application of ISO 9613 to C-weighted noise level calculations, frequencies below 63Hz are treated in a similar manner and therefore do not benefit from ground absorption

  - The ISO 9613 calculation method includes an attenuation factor related to atmospheric absorption. At low frequencies, this absorption is negligible, and the corresponding calculated attenuation equates to less than 0.1dB

Based on the above considerations, the ISO 9613 calculation of C-weighted noise levels can only be regarded as indicative predictions. The uncertainty associated with the C-weighted predicted noise levels is expected to be similar to, or greater than, than the uncertainty associated with the C-weighted sound power of the turbines.

Accounting for these uncertainties, and the margins between the predicted noise levels and the draft NSW guidelines' thresholds, indicates that wind turbine noise levels are likely to be below the lowest threshold value of 60dBC at the three (3) non-involved receivers located within 2km of the proposed turbine locations.

4.5 Infrasound, Low Frequency Noise, Vibration & Amplitude Modulation

The limits adopted for the assessment of operational noise from wind farms represent relatively low levels which have been specified in recognition of the quieter rural environments in which wind farms are normally located.

However, consistent with noise policies applied to other forms of development, the criteria are not intended to restrict wind farm noise to inaudible levels. Accordingly, a wind farm which achieves compliance with the criteria will still be audible at surrounding receiver locations on some occasions; this will depend on a range of factors such as the time of day, the speed and direction of the wind, the extent of vegetation around the dwelling, and the degree to which the dwelling is sheltered from prevailing wind conditions. Irrespective of the relatively low levels which operational wind farm noise is restricted to, an individual's judgement of the audible noise from a wind farm is highly subjective and will be influenced by a range of contextual factors.

The subject of the wind farm noise and its characteristics has attracted considerable attention in recent times. Specific attention has been directed to alleged matters relating to infrasound, low frequency sound and vibration. The definition of infrasound often varies in different jurisdictions, but is generally accepted to refer to frequencies of sound which lie below the frequency range of 20Hz and 20,000Hz which is often referred to as the audible frequency range. However, sounds below 20Hz are still actually audible, provided that the level of the sound is sufficiently high to exceed the threshold of audibility at the relevant frequencies. Low frequency sounds are then generally regarded as sounds above 20Hz and extending upwards into the range of 100-200Hz.

The issue of infrasound and low frequency noise emissions was a recognised consideration in the early design development of wind turbines. Older turbine technology was characterised by the blades being positioned on the downwind side of the tower. As the wind passed the tower of the turbines of these designs, a shadow region of low wind speed was created behind the tower. The movement of the blades into this interrupted region of airflow was found to generate significant low frequency sound which was perceived as a thumping sound. The re-positioning of the blades to the upwind side of the tower, as is the case in modern wind turbine designs, was found to avoid passage of the blades through the disrupted air region, and greatly reduced the level of noise produced by this mechanism.

Notwithstanding the above, and in common with many other sources of noise, wind turbines emit infrasound, low frequency sound and ground vibrations. However, what is often overlooked is that these types of sound and vibration are a feature of the everyday environment in which we live and arise from a wide range of natural sources such as the wind and the ocean to man-made sources such as domestic appliances, transportation and agricultural equipment. The important point in relation to wind turbines is that the levels of these types of emissions are low and therefore, in many cases, cannot be reliably measured amidst normal background levels.

An early study[6] of the subject in 1997 as part of a UK government funded investigation reported measured levels of infrasound, low frequency sound and vibration in the vicinity of modern wind farm. The results demonstrated noise and vibration levels complied with recommended residential criteria even on the wind turbine site itself, and the measured levels were below accepted levels of perception below 20Hz. It was found that the vibration levels at 100 m from the nearest turbine were lower than those recommended for human exposure in the most critical applications such as precision laboratories, and therefore well below the limits applied in less sensitive residential environments.

These types of emissions have been the subject of considerable misrepresentation in media commentary. Notably, the work of Dr Geoff Leventhall, a prominent UK consultant in the field of acoustics and vibration, and researcher in the field of low frequency noise is often cited in some documents which continue to claim concerns about infrasound and low frequency noise from wind turbines. However, Dr Leventhall has regularly made clear statements to assert that there is no significant infrasound from current designs of wind turbines and very little low frequency sound, neither of which are anywhere near the sorts of levels which would represent a direct health risk for neighbouring residents of modern wind farms. An example such publication, co-authored by Dr Leventhall, was published in the UK Institute of Acoustics Bulletin in March 2009[7]. This publication was prepared as an agreement between acoustic consultants regularly employed on behalf of wind farm developers, and conversely acoustic consultants regularly employed on behalf of community groups campaigning against wind farm developments. The intent of the article was to promote consistent assessment practices, and to assist in restricting wind farm noise disputes to legitimate matters of concern. On the subject of infrasound and low frequency noise, the article notes:

> *Infrasound is the term generally used to describe sound at frequencies below 20Hz. At separation distances from wind turbines which are typical of residential locations the levels of infrasound from wind turbines are well below the human perception level. Infrasound from wind turbines is often at levels below that of the noise generated by wind around buildings and other obstacles. Sounds at frequencies from about 20Hz to 200Hz are conventionally referred to as low-frequency sounds. A report for the DTI in 2006 by Hayes McKenzie concluded that neither infrasound nor low frequency noise was a significant factor at the separation distances at which people lived. This was confirmed by a peer review by a number of consultants working in this field. We concur with this view.*

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

[7] Institute of Acoustics Bulletin – Bowdler, Bullmore, Davis, Hayes, Jiggins, Leventhall, McKenzie - *Prediction and Assessment of Wind Turbine Noise* –March 2009

> *A Portuguese group has been researching 'Vibro-acoustic Disease' (VAD) for about 25 years. Their research initially focussed on aircraft technicians who were exposed to very high overall noise levels, typically over 120dB. A range of health problems has been described for the technicians, which the researchers linked to high levels of low frequency noise exposure. However other research has not confirmed this. Wind farms expose people to sound pressure levels orders of magnitude less than the noise levels to which the aircraft technicians were exposed. The Portuguese VAD group has not produced evidence to support their new hypothesis that infrasound and low frequency noise from wind turbines causes similar health effects to those experienced by the aircraft technicians.*

Another example of the misrepresentations made in relation to the environmental effects of wind turbines centred around work carried out by Keele University in the UK on ground vibration. Professor Peter Styles and his team at Keele University undertook a study of the effects of wind turbines on the seismic detection array at Eskdalemuir, Scotland. The results of this work were widely misinterpreted and resulted in a statement[8] from Professor Styles:

> *We are writing to clarify some misconceptions…. about wind farm noise. Whilst it is technically correct that 'vibrations can be picked up as far away as 10km', to give the impression that they can be felt at this distance is highly misleading. The levels of vibration from wind turbines are so small that only the most sophisticated instrumentation and data processing can reveal their presence, and they are almost impossible to detect. The Dunlaw study was designed to measure effects of extremely low level vibration on one of the quietest sites (Eskdalemuir) in the world, and one which houses one of the most sensitive seismic installations in the world. Vibrations at this level and in this frequency range will be available from all kinds of sources such as traffic and background noise - they are not confined to wind turbines. To put the level of vibration into context, they are ground vibrations with amplitudes of about one millionth of a millimetre. There is no possibility of humans sensing the vibration and absolutely no risk to human health. It is, however, an issue for the Eskdalemuir seismic array, as it can detect this level of vibration. It is designed to detect explosions and earthquakes of a low magnitude from all over the world. The infrasound generated by wind turbines can only be detected by the most sensitive equipment, and again this is at levels far below that at which humans will detect the low frequency sound. There is no scientific evidence to suggest that infrasound has an impact on human health.*

More recent measurements[9] have demonstrated that infrasound and low frequency sound produced by regularly encountered natural and man-made sources, such as the infrasound produced by the wind or distant traffic, is comparable to that of modern wind turbines. UK studies[10] have also indicated measured infrasound levels in the vicinity of modern multi-megawatt wind farms to be substantially lower than the threshold of hearing for even the most sensitive

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[8] Keele University Rejects Renewable Energy Foundation's Low Frequency Noise Research Claims. http://www.bwea.com/ref/lfn_keele.html.

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

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

members of the population. With respect to infrasonic noise levels below the hearing threshold, the World Health Organization has stated[11] that:

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

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

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

[...]

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

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

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

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

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

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

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

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

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

Other reported effects of modern wind farm noise relate to an effect known as enhanced amplitude modulation which relates to the rhythmic rise and fall in the level of noise associated with a wind farm, over and above the normal variation in noise associated with a wind farm. Despite considerable attention to this subject in recent years, little evidence currently exists to confirm the presence of this type of effect. This is largely due to the very limited numbers of sites where the effect has been reported, and at the sites where it has been reported, the limited and very specific atmospheric conditions required to result in the reported effect.

In recognition of the limited apparent extent of this reported matter, the subject of enhanced amplitude modulation has not altered the current approach in Australia. Specifically, current noise policies continue to represent a suitable basis for designing and assessing new wind farm developments.

4.6 Cumulative Effect of Adjacent Wind Farm Developments

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

There is currently one operational wind farm in the vicinity of the Collector Wind Farm, the Cullerin Range Wind Farm (Cullerin). We are not aware of any other proposed wind farm developments in the area which may impact on receivers around the Collector Wind Farm.

The presence of the Cullerin Wind Farm introduces the following considerations for the Collector Wind Farm noise assessment:

- the potential influence of Cullerin on measured background noise levels;
- the potential cumulative noise influence of Cullerin on receiver locations near the Collector wind farm; and
- conversely, the potential cumulative noise influence of the Collector Wind Farm on receiver locations near the Cullerin Wind Farm.

The figures contained in Appendix K indicate the position of the Cullerin turbines to the north of the Collector Wind Farm.

4.6.1 Influence on Background Noise Levels

Operation of the Cullerin Wind Farm is not considered to have influenced the measured background noise levels. Further detailed information is contained in Appendix E.

4.6.2 Possible Cumulative Impacts

To investigate the potential for cumulative impacts from the two wind farms, predicted operational noise levels from the Cullerin Wind Farm have been calculated using to the same ISO 9613-2:1996 methodology that has been applied to the Collector Wind Farm.

In particular, predictions assume simultaneous downwind propagation from each turbine of each wind farm. This results in a conservative assessment, since in many cases the receivers either cannot physically be downwind of all turbines or would only be downwind of all turbines for a narrow range of wind directions.

The Cullerin Wind Farm predictions are based on the site layout and sound power level data as detailed in Appendix J.

To assess the potential cumulative operational noise effects, the relative noise contributions of the Cullerin and Collector wind farms have been predicted.

Table 10 and Table 11 present the most affected receiver locations near the existing Cullerin and the proposed Collector wind farm respectively, and the corresponding predicted noise contributions of each. In the case of the Collector Wind Farm, the predicted noise levels presented in Table 10 and Table 11 are the highest of all three candidate turbines discussed in previous sections (and account for the reduced turbine numbers discussed for each candidate turbine).

Table 10
Key Cullerin wind farm receptor locations & predicted noise levels

House	Cullerin Wind Farm (L_{Aeq})	Collector Wind Farm (L_{Aeq})	Combined Total (L_{Aeq})	Comment
DD	33	29	35	Less than 2dBA predicted increase in received noise levels. Predicted levels from each site, as well as the combined total, achieve the minimum limit which could be derived according to the 2003 SA Guideline
EE	35	25	35	Less than 0.5dBA predicted increase in received noise level Predicted noise levels from each site are below the minimum limit which could be derived according to the 2003 SA Guideline

The worst case assessment for house DD indicates a marginal increase in noise level, and the predicted contributions of each site are below the minimum limit according to the 2003 SA Guideline. The worst case assessment for house EE indicates a negligible increase of less than 0.5dBA as a result of the contribution of the Collector Wind Farm.

All other receptors relevant to Cullerin are located at increased distance from the Collector Wind Farm, and would therefore experience reduced cumulative noise level effects. Based on these findings, the Collector Wind Farm is considered to represent a negligible influence on operational wind farm noise levels at houses relevant to the Cullerin Wind Farm.

Table 11
Key Collector wind farm receptor locations & predicted noise levels

House	Cullerin Wind Farm (L_{Aeq})	Collector Wind Farm (L_{Aeq})	Combined Total (L_{Aeq})	Comment
T*	17	40	40	Less than 0.2dBA predicted increase in received noise level due to the influence of Cullerin
G*	12	36	36	Less than 0.2dBA predicted increase in received noise level due to the influence of Cullerin
FF	20	35	35	Less than 0.2dBA predicted increase in received noise level due to the influence of Cullerin
CC	25	27	29	2dBA contribution from Cullerin to predicted noise levels Predicted levels from each site, as well as the combined total level, are more than 5dBA below the minimum limit which could be derived according to the 2003 SA Guideline

* Involved receivers

At all other houses around the Collector Wind Farm, the predicted increase in noise levels due to Cullerin is equal to 0.6dBA or less. The predicted contributions of Cullerin are well below the relevant minimum limits at each location. In addition, all combined predicted total noise levels are below the relevant minimum limits at each location.

Based on the above findings, the potential cumulative influence of Cullerin Wind Farm on noise levels around receivers surrounding the Collector Wind Farm proposal are considered negligible.

The predicted cumulative noise levels of the two wind farms are provided for all three candidate turbines in Appendix K.

4.7 Substation Transformer Noise Levels at Night-time

One substation has been proposed for the Collector Wind Farm. The substation will comprise dual 130MVA transformers which will be used to step-up the 33kV supply from the wind farm to match the 330kV requirement of the transmission line.

The position of the substation is indicated in the site layout figures contained in Appendix D.

Measured sound power level data for the transformers will not be available until a transformer type is finalised for the site. In lieu of measured data, Australian Standard AS2374-6:1994 *Power transformers – Determination of transformer and reactor sound levels* (AS2374-6:1994) provides a method for estimating transformer sound power levels. With reference to Figure AA1 from AS2374-6:1994, the estimated sound power level of each transformer as 103.5dBA.

It is noted that transformers typically display tonality at 100Hz, therefore we have applied a +5dBA correction to the predicted results.

Background noise levels for the night-time period have been determined in accordance with the procedure detailed in Table 3.1 *Methods for determining background noise* from the NSW INP. Termed the Rating Background Level (RBL), it is an overall single-figure background level representing the entire night-time period.

The RBL is the level used for assessment purposes. Background noise levels were measured to be less than 30dBA under calm wind conditions. In accordance with the INP, where background noise levels are less than 30dBA, the RBL is set to 30dBA.

Noise levels at the closest receivers, House DD and N, have been predicted using the ISO 9613-2:1996 methodology to determine the noise expected under conditions which favour the propagation of sound including a wind directed from the source to the receiver, or a moderate well developed ground based thermal inversion. Results are presented in Table 12 below.

Table 12
Predicted transformer noise level at the nearest affected receivers

Dwelling	Distance to Substation (km)	Predicted Transformer Level L_{eq}, dBA Including +5dBA Penalty for Tonality	Night-time RBL dBA	INP Intrusiveness Criteria (L_{90} + 5dB)	Comply?
DD	2.9	17	30	35	Y
N	3.2	16	30	35	Y

Table 12 demonstrates that predicted noise levels from the transformers are less than the RBL's and that they comply with INP noise limits under atmospheric conditions which enhance sound propagation.

4.8 Transmission Line Corona and Aeolian Noise

Corona and Aeolian noise can be generated by the interaction of high voltage overhead power lines with specific atmospheric conditions.

The Collector Wind Farm would connect to existing high voltage overhead lines in the area which extend generally in an east-west direction near the northern end of the site. This connection will occur at a distance of around 3km from the nearest existing residence, and is further from all residents than the existing overhead line.

The existing overhead power line may give rise to Corona and Aeolian noise at existing dwellings in the area. However, the introduction of the Collector Wind Farm will not alter the level or regularity of such emissions from the existing overhead line. Accordingly, the proposed Collector Wind Farm will not give rise to any noise impacts relating to Corona noise or Aeolian tones.

5.0 SITE CONSTRUCTION NOISE IMPACT ASSESSMENT

5.1 Construction Site Noise

Construction tasks associated with the project include the following:

- Access road construction
- Turbine tower foundation construction
- Trench digging to accommodate underground cabling
- Assembly of turbine tower, nacelle and rotor blades.

Equipment required to complete the tasks outlined above include:

- Bulldozers, graders, excavators, dump trucks, rollers, concrete trucks, front end loaders, cranes, pneumatic jack hammers etc
- All wheel drive vehicles and flat-bed delivery trucks.

Construction works may need to occur outside of standard working hours on some occasions. Examples of activities where this may be required include delivery of oversize plant or structures, including turbine nacelle, blades and tower in addition to erection of these structures based on weather constraints.

The construction phase of the project will be controlled by a construction management plan which will include details of working methods and times, including any requirements for work outside of standard hours.

The noise management levels for each receiver are defined as the RBL plus 10dBA. As defined in previous sections, the RBL in accordance with the NSW Industrial Noise Policy is 30dBA. Accordingly, the noise management level used to assess predicted construction noise is 40dBA $L_{eq\ 15minutes}$.

5.2 Predicted Construction Noise Levels

It is anticipated that a variety of demolition and construction equipment would be used for this project. Noise levels during construction have been predicted at the nearest noise sensitive locations during the construction phase. These noise levels have been predicted based on guidance and data sources including the CNG, AS2436:2010 *Guide to noise and vibration control on construction, demolition and maintenance sites* (AS2436:2010), and noise level data from previous projects of a similar nature. Table 13 summarises the noise emissions used to represent key items of plant associated with construction.

Table 13
Construction noise sources

Noise source	Sound Power Level, dBA, L_w
Excavator fitted with pneumatic breaker	118
Excavator (100 to 200kW)	107
Tracked loaders	115
Cranes	105
Delivery Trucks	107
Concrete trucks	108
Dump truck	117
Concrete pump	108
Generator	99
Grader	110
Bulldozer	108
Front end loader	113

To provide an indication of potential noise impacts associated with regular working areas, we have assessed predicted noise emissions from the closest turbine. Furthermore, we have assessed noise impact based on equipment being operational for the full 15-minute assessment period.

Our assessment of construction noise has been divided up into the five (5) main components during this phase of the development, namely:

- access road construction
- turbine foundation preparation
- concrete pouring
- cable trench digging
- turbine assembly.

It should be noted that predicted noise levels are for those receivers closest to the construction activities. Where a group of receivers is located in one area, one receiver is chosen as being a worst case representation of all receivers.

Table 14 details the predicted noise levels at a sample of key receptor locations based on the construction activities outlined above. Given that the precise equipment selections and methods of working would be determined during the development of a construction plan, and that the noise associated with construction plant and activity varies significantly, the predicted noise levels are provided as an indicative range of levels which may occur in practice.

Table 14
Indicative construction noise predictions L_{eq} dBA

Receiver	Management level $L_{eq, 15minutes}$	Access Road Construction	Turbine Foundation preparation	Cable Trench Digging	WTG Assembly	Concrete pouring	Compliance?
G*	40	**40-45**	**40-45**	**40-45**	<30	30-35	N
M*	40	35-40	35-40	35-40	<30	<30	Y
N*	40	**55-60**	**55-60**	**55-60**	**40-45**	**45-50**	N
T*	40	**45-50**	**45-50**	**40-45**	30-35	35-40	N
L	40	30-35	30-35	30-35	<30	<30	Y
Q	40	30-35	30-35	30-35	<30	<30	Y
Z	40	35-40	35-40	35-40	<30	<30	Y
FF	40	35-40	35-40	35-40	<30	<30	Y

* Involved receiver

From the results detailed in Table 14, it can be seen that predicted noise levels associated with the construction of the wind farm are expected to be below the noise affected levels, as defined by the CNG, at receiver locations not involved in the project.

At the involved receivers (excluding location N), the predicted noise levels are up to 20dBA greater than the noise affected level, but more than 10dBA below the threshold of highly affected levels defined by the CNG. The CNG however does not provide specific advice with respect to receptor locations with an involvement in the project. As discussed for operational wind farm noise, involved receivers are expected to have a higher tolerance to construction noise whilst the site is developed. Notwithstanding the involvement of these residences, the predictions indicate that noise levels are sufficient to warrant notification of working times and durations to the residents of these locations, as per the advice of the CNG.

In applying the management levels, the CNG requires that all feasible and reasonable work practices be employed. We understand that this would be addressed through an environmental management plan for construction. It is expected that this management plan will include measures to inform residents of key working hours and phases, and a requirement to notify affected residents of any proposed work outside of standard hours, such as turbine deliveries.

5.3 Construction Vibration Assessment

Ground vibration from construction activity is inherently variable, and is influenced by a range of factors related to the construction plant, ground conditions and the separating distance between the plant and the receptor location. Due to the complexity of the factors influencing ground vibration propagation, the prediction of ground vibration is subject to considerable uncertainty.

The NSW vibration guideline does not schedule empirical vibration data or advocate a specific method of vibration prediction. The vibration guideline does however make reference to example methods including the Transport Research Laboratory's (TRL) *Groundborne vibration caused by mechanised construction works* (Hiller & Crabb, 2000) which has been referenced for guidance. In addition, the superseded NSW Roads and Traffic Authority's *Environmental Noise Control Manual* (ENCM) dated 2001 provides indicative empirical vibration data for common types of construction plant.

The TRL document presents a detailed account of ground vibration sources and mechanisms and proposes a prediction method which is noted to be valid to distances of approximately 100m. It also notes that 100m encompasses the distances which ground vibration is likely to be perceptible at most sites, but notes that the effects of some larger items of plants and piling may be perceptible at greater distances. It further states that the use of the prediction method is not recommended beyond 100m, and the predictions at increased distances are likely to overestimate the level of vibration.

Given that the nearest receiver is approximately 300m from longer term areas of working, and the next nearest receiver is approximately 1000m away, ground vibration levels are expected to be low and detailed predictions are subject to considerable uncertainty. However, an estimated range of potential vibration levels has been determined on the basis of the indicative data and extrapolation method of the former NSW document ENCM.

Table 15 summarises empirical vibration data for common construction plant, the range of extrapolated values at 300 and 1000m, and the PPV criteria for continuous and impulsive vibration sourced from the NSW vibration guidelines. Note that the range of predicted values accounts for the range of vibration source values as well as the range of vibration propagation conditions (minimal propagation through to worst case propagation).

Table 15
Typical construction plant vibration levels

Equipment	Typical PPV (mm/s) at 10m	Indicative PPV (mm/s)		Vibration Limit (mm/s)	
		at 300m	at 1000m	Continuous	Impulsive
Piling	12-30	0.1-2.0	<0.1-0.8	n/a	8.6-17
Loader – breaking kerbs	6-8	<0.1-0.5	<0.2	n/a	8.6-17
15 tonne roller	7-8	<0.1-0.5	<0.2	0.28-0.56	n/a
7 tonne compactor	5-7	<0.1-0.5	<0.2	0.28-0.56	n/a
Roller	5-6	<0.1-0.4	<0.2	0.28-0.56	n/a
Pavement breaker	4.5-6	<0.1-0.4	<0.2	0.28-0.56	n/a
Bulldozer	2.5-4	<0.1-0.3	<0.1	0.28-0.56	n/a
Backhoe	1	<0.1	<0.1	0.28-0.56	n/a
Jackhammer	0.5	<0.1	<0.1	0.28-0.56	n/a

The results presented in Table 15 demonstrate that at the nearest location, involved receiver N, the majority of the range of predicted vibration levels are expected to fall within the preferred criteria, and all predictions are below the maximum limits even account for worst case source and propagation conditions. At the next nearest receiver at 1000m, all predicted vibration levels are well below the preferred values, again accounting for worst case source and propagation conditions.

In relation to intermittent vibration which comprises a combination of impulsive or periods of continuous vibration, the vibration guidelines recommend assessment on the basis of the VDV value. This parameter accounts for the frequency character of the vibration and the extent of variation in vibration over a working period. The VDV is a more complex parameter and there is limited empirical data to enable its reliable prediction. MDA has measured VDV values of less than $0.1m/s^{1.75}$ at a distance of 40-50m during the operation of a piling rig over the course of a typical day period for general construction.

Whilst VDV values can vary significantly as a result of actual local ground conditions, piling operations represent the most significant potential source of vibration associated with construction of a wind farm, and will be significantly lower at the increased distances of 300m and 1000m to the two nearest receivers. It is therefore unlikely that vibration levels from construction activities of a wind farm would exceed the acceptable vibration dose values for intermittent vibration ($0.2\text{-}0.4m/s^{1.75}$), as per the advice of the vibration guideline referred to in the DGRs.

5.4 Construction Traffic Noise

Traffic noise impacts of construction vehicles associated with the development using the road network surrounding the site have been assessed. Turbine components are likely to be transported from Port Kembla to the site via Picton Road and the Hume Freeway. It is proposed that access to the site will be gained via the Lerida Road South intersection with the Hume Highway. The surrounding road network is indicted in the figures contained in Appendix D.

The following table summarises the predicted peak combined volume of daily traffic entering and exiting the site during the peak construction period. These peak volumes are anticipated to occur during concrete pours for footings.

Table 16
Maximum anticipated daily construction traffic volume and composition

Description	Trips per day
Trucks	112
Light vehicles	220
Total:	332

Source: CWF Traffic & Transport Assessment, AECOM March 2011

The following table summarises the existing traffic conditions on the roads potentially impacted by construction traffic.

Table 17
Existing traffic volume and composition

Description	2007 AADT	Speed (km/h)	Heavy %
Hume Highway (W of Federal Highway)	7,431	110	40
Hume Highway (S of Illawarra Highway)	20,846	110	22
Picton Road	13,639*	90	18
Lerida Road South	~50	100	10**

Source: CWF Traffic & Transport Assessment, AECOM March 2011
** Estimated heavy vehicle %

Based on the information provided in Tables 16 and Table 17, we have predicted the existing and construction related traffic noise levels at dwellings most likely to be impacted by changes in traffic conditions. Specifically, we have assessed traffic noise levels at Receivers N & Z, adjacent to Lerida Road South, and Receiver CC, adjacent to the Hume Highway west of Federal Highway.

In addition, in the absence of a nearby receiver, we have assessed traffic noise levels for Picton Road at a nominal distance of 20m from the road. Similarly, we have assessed traffic noise levels at a nominal distance of 45m from the Hume highway south of Illawarra Highway.

It is noted that ECRTN and RNP, when strictly applied for the intended purpose of permanent changes in road traffic noise levels, consider the noise occurring over different periods of the day (e.g. changes over 15 hour and 1 hour periods). The application of these policies for the assessment of short term changes associated with construction traffic is for guidance purposes only, and the predictions are therefore solely based on changes in noise level occurring over the course of a day, during the peak traffic period of construction.

Table 18 details the predicted noise levels.

Table 18
Current and construction traffic noise levels*

Receiver	Distance to Road (m)	Current level	Construction level	ECRTN Criterion 7am-10pm ($L_{Aeq\ 1\text{-hour}}$)	Compliance?
N**	45	41	53	55 or less than 2dBA increase	Y
CC	700	49	50	60 or less than 2dBA increase	Y
Picton Road	20	66	67	60 or less than 2dBA increase	Y
Hume Highway (S of Illawarra Highway)	45	69	69	60 or less than 2dBA increase	Y
Z	625	28	40	55 or less than 2dBA increase	Y

* Rounded to nearest integer
** Involved receivers

The results presented in Table 18 indicate that the traffic noise level as a result of construction is predicted to comply with ECRTN criterion at all assessed receivers. All other receivers are located further from the identified traffic routes and will therefore also comply with the ECRTN criterion.

For receivers located along Picton Road and the Hume Highway, current predicted levels based at the stated nominal setback distances are already above the ECRTN criterion. Predicted construction traffic noise levels will not cause any significant increase in noise level on either road and will therefore also comply with ECRTN guidance.

It can be seen from Table 18 that predicted future traffic noise levels do not exceed the predicted current traffic noise levels by more than 12dBA. Therefore the RNP criteria are also achieved.

6.0 COMPLIANCE MONITORING

Following construction of the wind farm, noise monitoring would be carried out in accordance with the 2003 SA Guideline and any conditions of consent. The purpose of this monitoring would be to assess compliance with the noise criteria. Compliance monitoring would include an appraisal of noise levels at locations distributed around the wind farm, and would include monitoring to evaluate compliance across a representative range of wind speeds and directions.

7.0 CONTINGENCY STRATEGY

In addressing the issues set out in the DGRs, and assessing operational wind farm noise in accordance with the 2003 SA Guideline, it is expected that the project will satisfy the noise criteria. Notwithstanding this, consideration has been given to available contingency strategies to reduce noise levels if required.

The following summarises the 2 key measures available to reduce the noise:

- Procurement contract: the procurement contract for the supply of turbines to the site will typically include specifications concerning the allowable total noise emissions from the turbine, and the permissible characteristics of the turbine. In the event that turbine emissions are found to exceed the contracted values, the supplier will be required to implement measures to reduce the noise to the contracted value. This can include measures to rectify manufacturing defects or appropriate control settings.

- Noise reduction management strategy: modern wind farms include control systems which enable the operation of the turbines to be varied according to environmental constraints. Specifically, variable pitch turbines as proposed for this site include control functions which enable the noise emissions of the turbines to be selectively controlled; by adjusting the pitch of blade, the noise emissions of the turbine can be reduced. In addition, where required, the turbines can be selectively shut down under relevant wind speeds and directions. These types of control measures can be used separately, or in combination, to achieve noise reductions for predetermined wind speed ranges and directions.

In addition to the above general measures, the agreement for involved receiver N is intended to include additional contingency measures in recognition of the higher predicted noise levels expected to occur at this involved location. These additional measures would comprise options for landscaping measures around the dwelling to introduce additional sources of background masking noise (e.g. additional and taller foliage), and for a package of insulation measures designed to achieve suitable internal noise levels. The insulation measures would address ventilation treatments to enable windows to remain closed for a range of conditions, and potential upgrades to key facade elements such as windows.

8.0 CONCLUSION

Noise levels associated with the proposed Collector Wind Farm have been assessed to thirty-four (34) dwellings located within the Upper Lachlan Shire Council between the Hume Highway, Collector Road and Collector Creek.

Wind farm operational noise impacts have been assessed for a range of candidate turbines. A turbine layout comprising a maximum of sixty-eight (68) turbines was considered in this study.

Predicted operational noise levels from the 68 turbine layout comply with the 2003 SA Guideline criteria at all receivers not involved with the project. Significantly, compliance has been shown at these locations on the basis of the minimum limit at all assessed receivers, independent of background noise levels. The predictions have however demonstrated that other candidate turbine options could necessitate layout reductions to between sixty-four (64) and sixty-seven (67) turbines in order to maintain compliance with the minimum noise limit at all relevant assessment locations.

On the basis that the predicted operational noise levels at non-involved receivers have been shown to comply with the minimum noise limit applicable under the 2003 SA Guideline, the findings of this study also demonstrate compliance with the minimum possible operational noise limits which could be determined under the revised guidelines released in South Australia in 2009. In addition, the predicted noise levels also comply with the minimum A-weighted noise limits proposed in the draft NSW guidelines.

The assessment has also accounted for the proposed additional assessment requirements nominated in the draft NSW guidelines. Specifically, three (3) non-involved receivers have been identified within 2km of the proposed turbine locations. Accordingly, additional information has been prepared, comprising the prediction of low frequency noise levels. The prediction methodology for low frequency noise levels is not specified in the draft NSW guidelines. In the absence of ratified prediction methods for low frequency noise, indicative values have been provided. The results of these calculations, accounting for the inherent and increased uncertainty, indicates low frequency noise levels are likely to be below the thresholds proposed in the draft NSW as triggers for further detailed assessment of low frequency noise.

In relation to involved receivers, the predictions demonstrate compliance with relevant criteria derived on the basis of international references which are consistent with the revised guidelines released in South Australia in 2009. The exception to this is involved receiver N where a separate land owner agreement is proposed with additional optional measures to address environmental noise.

An assessment of potential cumulative noise effects associated with the combined operation of the existing Cullerin Range Wind Farm and the proposed Collector Wind Farm has been carried out. This assessment demonstrated compliance with the 2003 SA Guideline limits, accounting for the layout considerations noted above.

Noise associated with the operation of the substation and connecting infrastructure is predicted to be well below the relevant noise criterion defined by the NSW Industrial Noise Policy.

Construction noise impacts have been assessed and are predicted to comply with the NSW Interim Construction Noise Guideline at all receivers not involved with the project. Construction vibration has also been shown to be within preferred values of the NDW vibration guidelines at all receivers not involved with the project.

Construction traffic noise impacts have been assessed and are predicted to comply with guideline criteria provided by the NSW document *Environmental Criteria for Road Traffic Noise* and the recently released *NSW Road Noise Policy.*

APPENDIX A

ACOUSTIC TERMINOLOGY

Ambient	The ambient noise level is the noise level measured in the absence of the intrusive noise or the noise requiring control. Ambient noise levels are frequently measured to determine the situation prior to the addition of a new noise source.
dBA	Unit of overall noise level, in A-weighted decibels. The A-weighting approximates the average human response over the entire frequency range.
dBC	Unit of overall noise level, in C-weighted decibels. The C-weighting is proposed as an improved indication of human response to noise levels where increased low frequency noise may be present
L_w	Sound power level is the measure of acoustic power radiated by a sound source.
L_{10}	Non-continuous noise levels are described in terms of the level exceeded for 10% of the measurement period (L_{10}). This is commonly referred to as the typical maximum level and is generally measured in dBA.
L_{90}	Background noise levels are described in terms of the level exceeded for 90% of the measurement period (L_{90}). This is commonly referred to as the typical minimum level and is generally measured in dBA.
L_{eq}	Continuous or semi-continuous noise levels are described in terms of the equivalent continuous sound level (L_{eq}). This is the constant sound level over a stated time period which is equivalent in total sound energy to the time-varying sound level measured over the same time period. This is commonly referred to as the average noise level and is generally measured in dBA.
L_{Aeq}	The "A" weighted equivalent continuous sound level.
Octave band	The noise level at a range of individual frequencies can be determined by dividing the frequency range (usually 63Hz to 4kHz) into 7 frequency bands called octave bands, with centre frequencies of 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz and 4kHz.

APPENDIX B

HOUSE & TURBINE LOCATIONS

All coordinates in this report related to the WGS84-MGA94 Zone 55 system

Table B1
House locations

Location	Easting (m)	Northing (m)	Location	Easting (m)	Northing (m)
A	716166	6126500	R	713357	6142531
B	716366	6126247	S	716282	6138352
C	717211	6128373	T	716186	6138745
D	716571	6129490	U	719285	6130253
E	716897	6129714	V	715744	6133809
F	719761	6131405	W	722766	6134658
G	716686	6133417	X	723865	6136136
H	719839	6132819	Y	713396	6137919
I	721120	6132680	Z	715180	6138036
J	720081	6133755	AA	722062	6137959
K	714263	6137536	BB	723156	6141476
L	714476	6135604	CC	723831	6143954
M	715919	6137699	DD	717150	6146019
N	717810	6140502	EE	721052	6146502
O	715025	6134872	FF	721605	6139345
P	711956	6138527	GG	713009	6141552
Q	713019	6140846	HH	713908	6136554

Table B2
Turbine locations

Location	Easting (m)	Northing (m)	Location	Easting (m)	Northing (m)
CWT1	718433	6143522	CWT27	718632	6140529
CWT2	718303	6143229	CWT28	718527	6140218
CWT3	718143	6142944	CWT29	718256	6140030
CWT4	718016	6142661	CWT30	717952	6139751
CWT5	717920	6142333	CWT31	717751	6139480
CWT6	717869	6142028	CWT32	718184	6139157
CWT7	717778	6141753	CWT33	718539	6139389
CWT8	717667	6141456	CWT34	719192	6139375
CWT9	717737	6141127	CWT35	718149	6138894
CWT10	717665	6140808	CWT36	717986	6138660
CWT11	717307	6140667	CWT37	718135	6138349
CWT12	717140	6140259	CWT38	718725	6138734
CWT13	716368	6140791	CWT39	719054	6138902
CWT14	716269	6140490	CWT40	717678	6137581
CWT15	716134	6140091	CWT41	717952	6137867
CWT16	715885	6139665	CWT42	717564	6137136
CWT17	716574	6139788	CWT43	717954	6137251
CWT18	718978	6143004	CWT44	717848	6136663
CWT19	718891	6142467	CWT45	719633	6138534
CWT20	718960	6142121	CWT46	719531	6138241
CWT21	718935	6141776	CWT47	719325	6137942
CWT22	720164	6141628	CWT48	719170	6137671
CWT23	718878	6141471	CWT49	718708	6137467
CWT24	718785	6141111	CWT50	718574	6137092
CWT25	718721	6140828	CWT51	718443	6136785
CWT26	719303	6140601	CWT52	718448	6136312

Location	Easting (m)	Northing (m)	Location	Easting (m)	Northing (m)
CWT53	718277	6136058	CWT61	719646	6136708
CWT54	718233	6135757	CWT62	719793	6137054
CWT55	718042	6135504	CWT63	719612	6137380
CWT56	717976	6135216	CWT65	720847	6140638
CWT57	717905	6134890	CWT66	721081	6140856
CWT58	717877	6134568	CWT67	721100	6141132
CWT59	717815	6134260	CWT68	721245	6141392
CWT60	717758	6133946	CWT69	720925	6141697

APPENDIX C

CANDIDATE TURBINE SOUND POWER LEVEL DATA

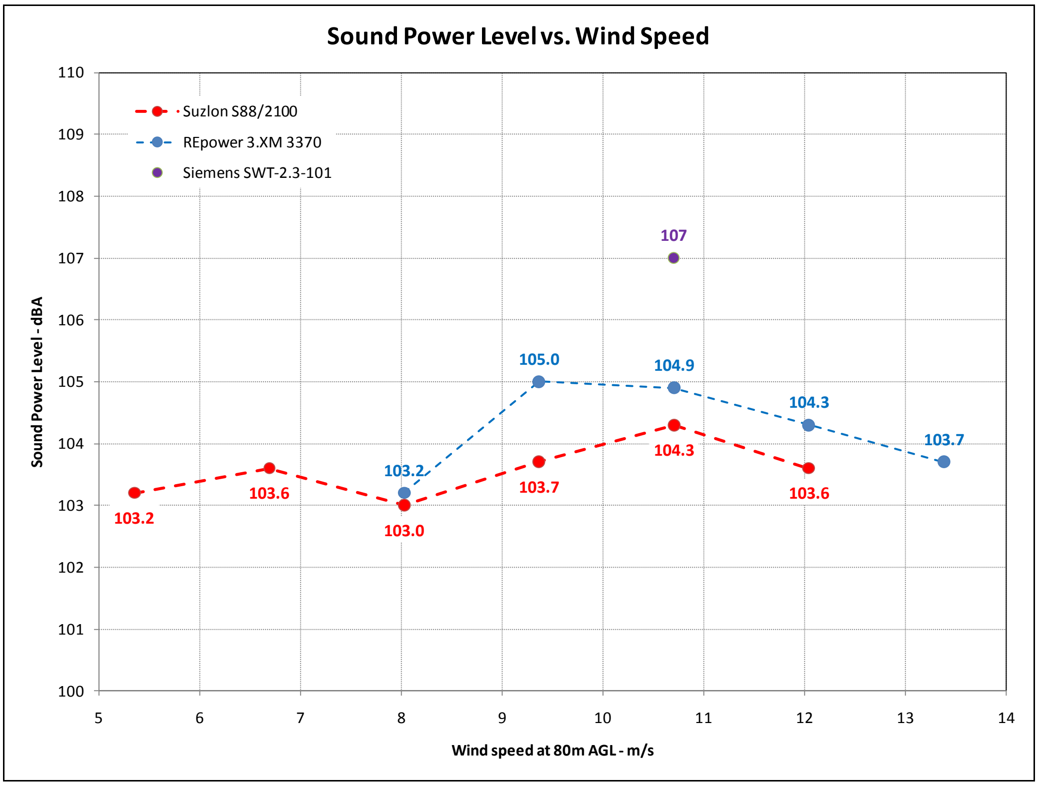

Figure C1: Broadband sound power level as a function of hub height wind speed

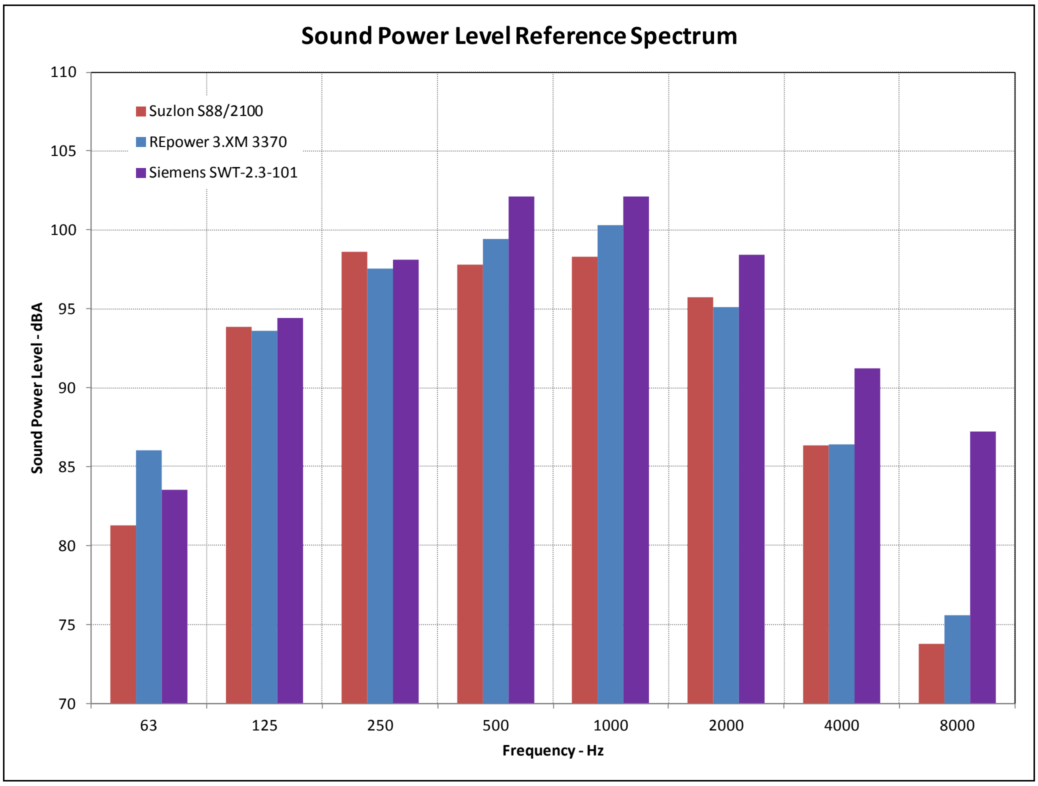

Figure C2: A-weighted sound power level spectrum

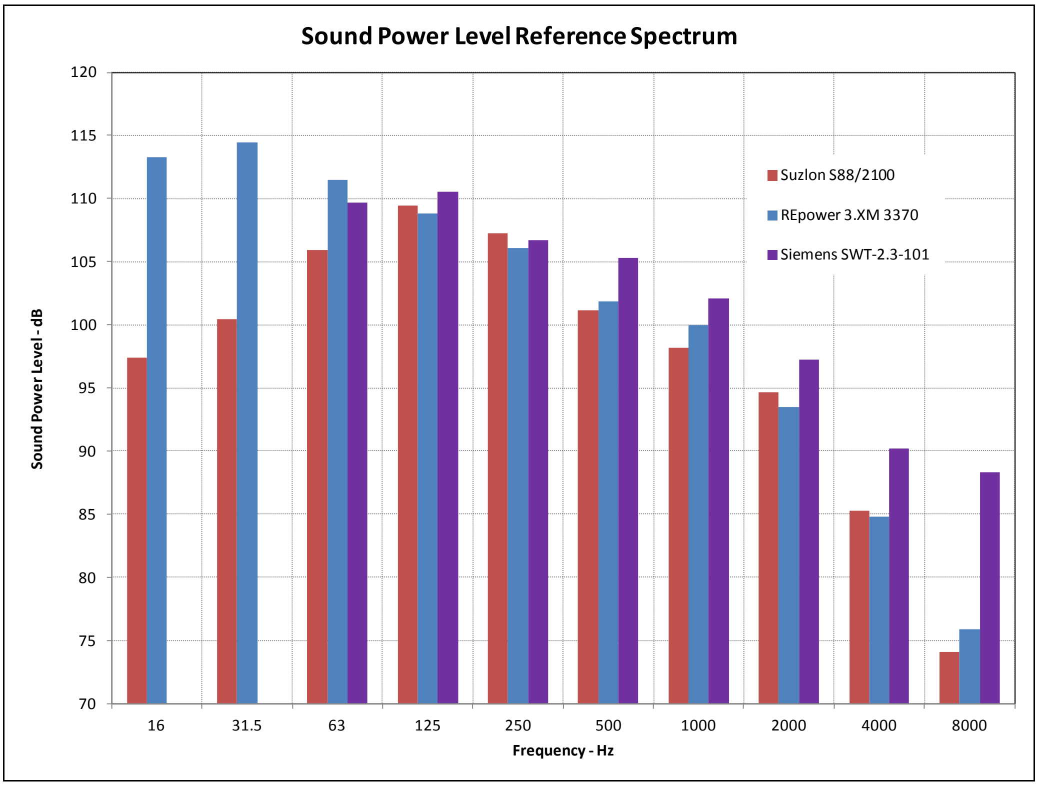

Figure C3: Linear sound power level spectrum for C-weighted predictions – 16Hz octave band contains contributions solely related to the 20Hz third octave band

APPENDIX D

PREDICTED OPERATIONAL WIND FARM NOISE CONTOURS

Figures D1 to D3 present the predicted noise contours for each of the three candidate turbines considered in the Collector Wind Farm noise assessment. In each case, the predicted contours relate to:

- Calculated noise levels assuming each calculation point is simultaneously downwind of each turbine.

- Calculated noise levels assuming each turbine simultaneously producing the highest noise emissions across the range of wind speeds in which the turbine operates.

Based on the above, the predicted contours are a worst case representation. Actual noise levels which occur under other wind speed conditions and other directions will therefore be lower than indicated by the noise contour values.

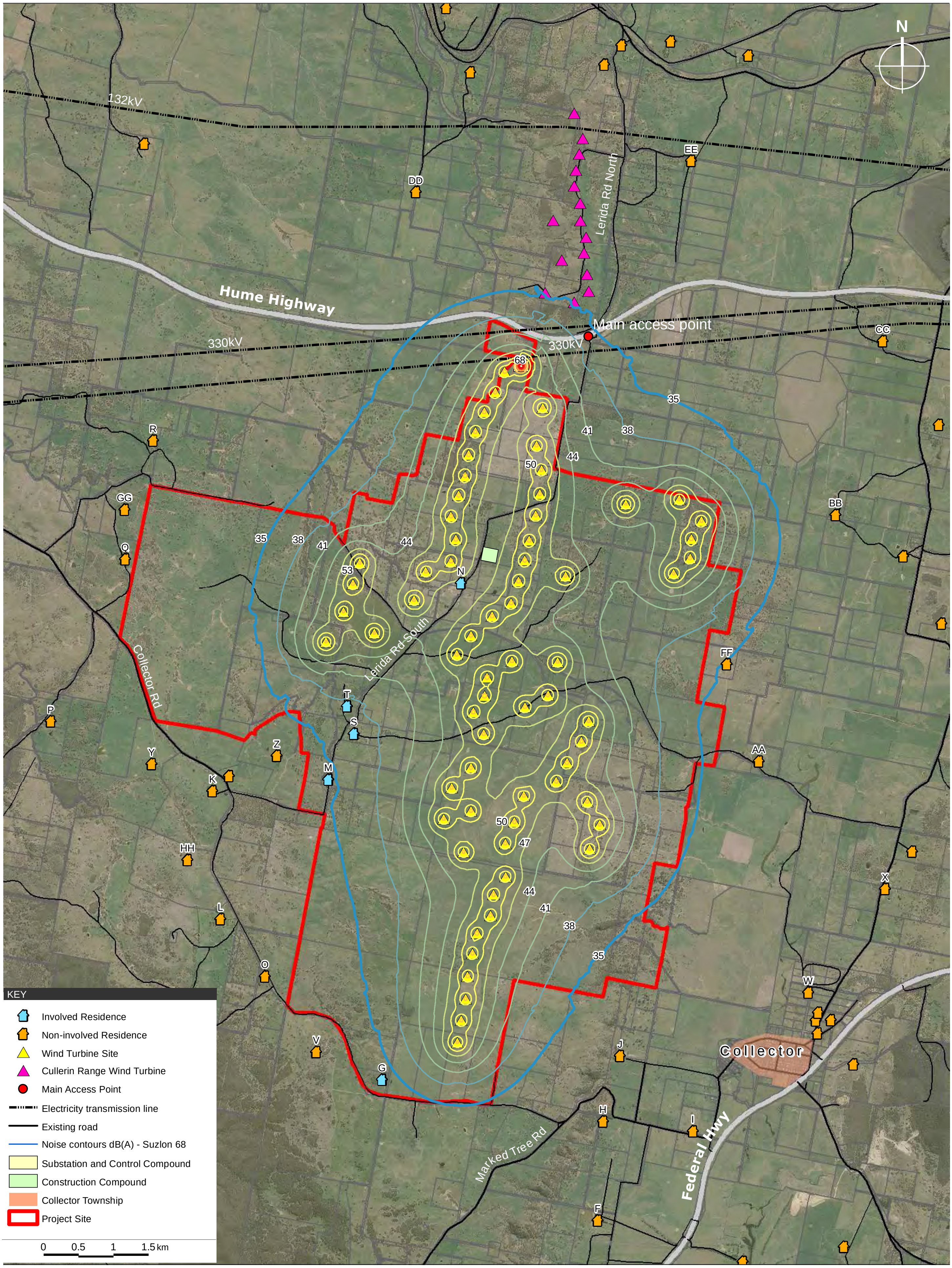

Figure D-1
Suzlon 68 Turbine Layout +
Substation Noise Levels

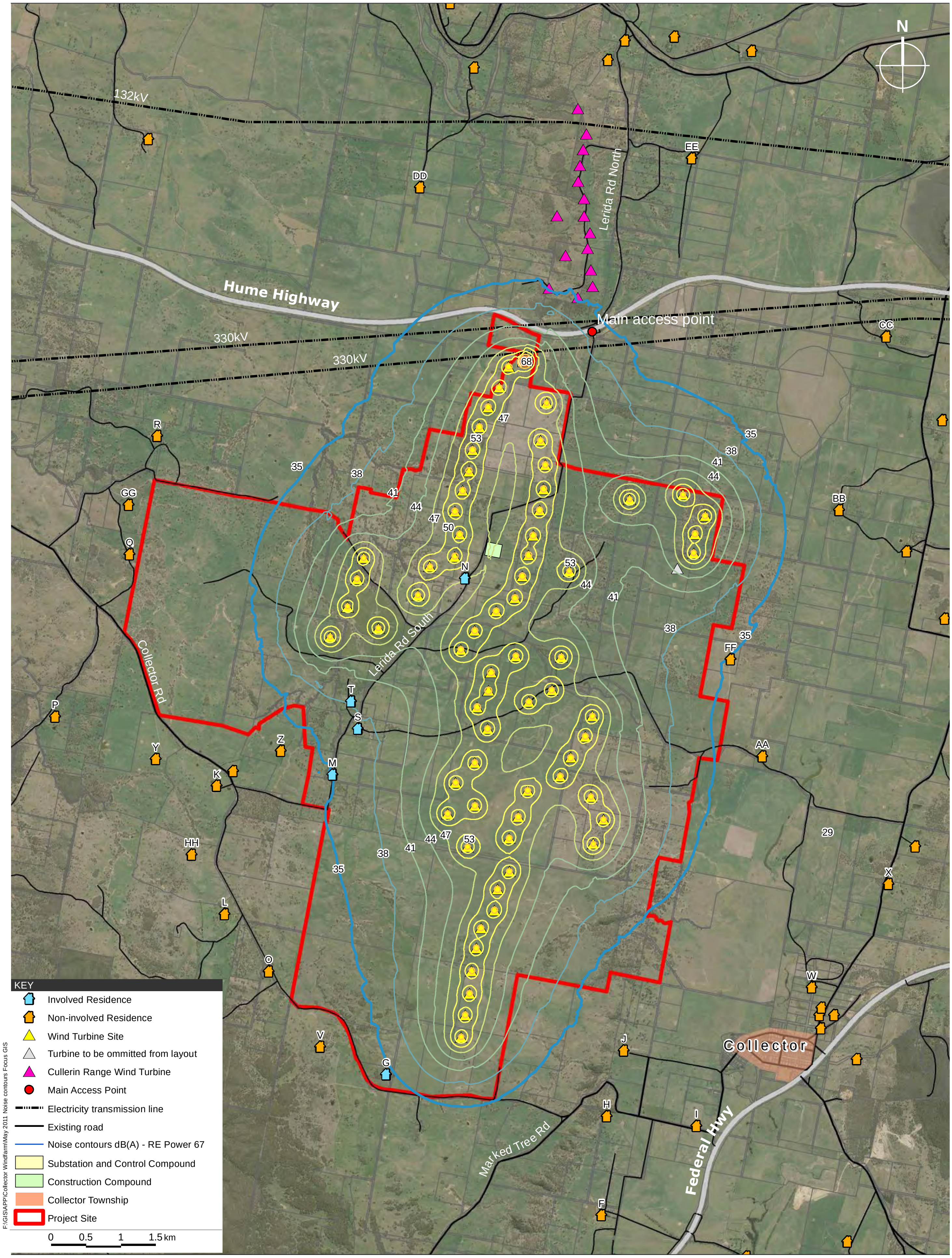

Figure D-2
REpower 67 Turbine Layout + Substation Noise Levels

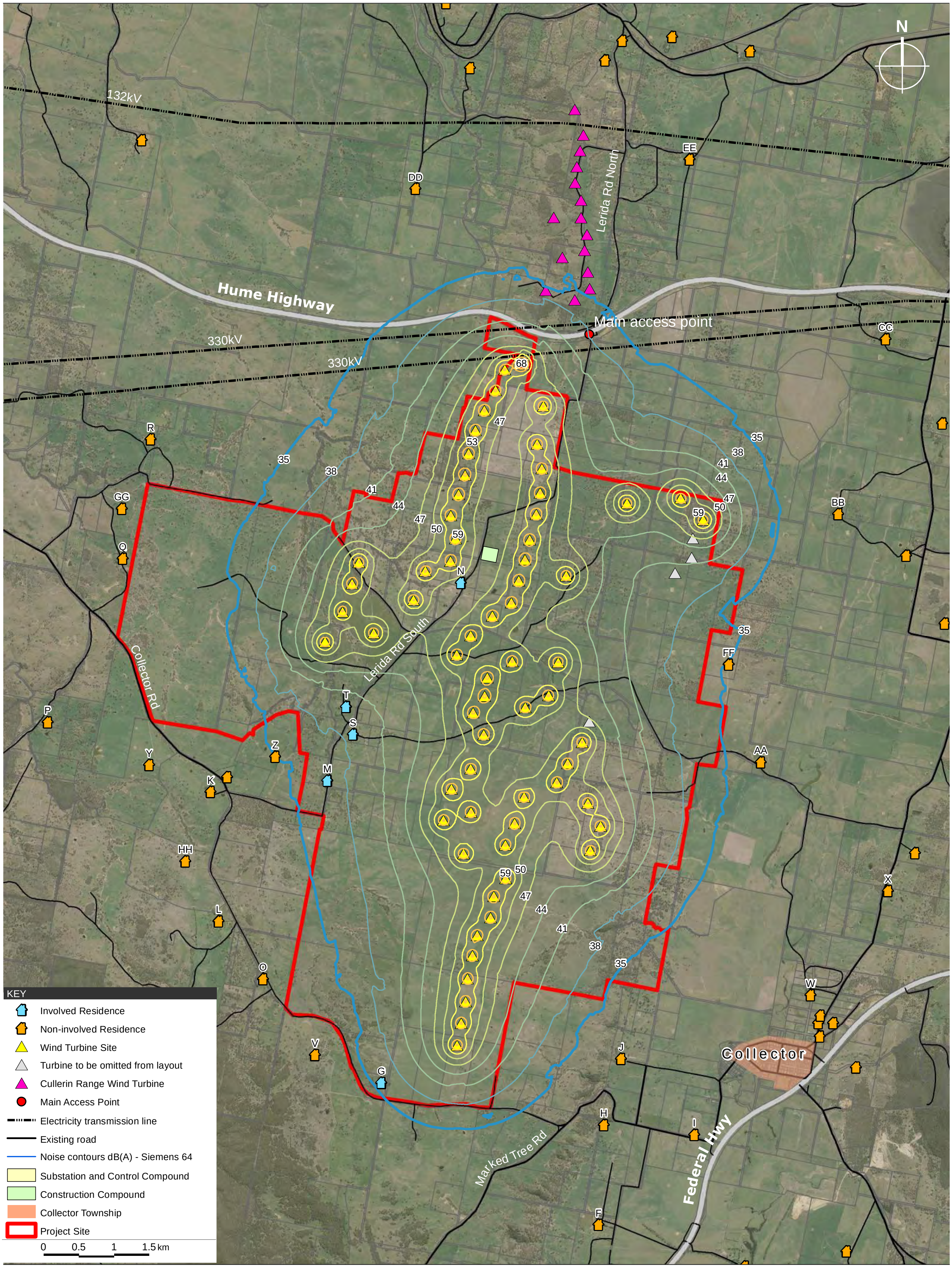

Figure D-3
Siemens 64 Turbine Layout +
Substation Noise Levels

APPENDIX E

BACKGROUND NOISE SURVEY DESCRIPTION

Background noise monitoring was undertaken during two separate periods:

- 27 April to 27 May 2010 inclusive, and;
- 5 to 29 November 2010 inclusive.

Automated Type 1 environmental noise loggers (Acoustic Research Laboratories EL-316) were used to conduct background noise level monitoring in 10-minute intervals.

Noise loggers were placed in general accordance with the requirements of Section 3.1 of the 2003 SA Guideline being: at least 5m from any reflective surface; within 20m of the nearest dwelling, and; in positions that were representative of the general background noise environment. Photos of the noise monitoring locations are available on request, subject to the permission of the residents.

Background Noise Survey Wind Data

Wind Data

Wind speeds were measured by the proponent in 10-minute intervals synchronised with the background noise measurements. The locations of the masts are detailed in Table E1.

Table E1
Anemometer mast locations

Location	Easting (m)	Northing (m)
Collector Mast	718728	6140923
Wood Park Mast	717010	6132314

Wind Shear

Wind shear describes the phenomenon of variations in wind speed with height above ground level. These variations occur for a range of reasons relating to ground surface factors, such as ground coverage and the complexity of the terrain profile, and atmospheric conditions.

Current industry practice is to base wind farm noise assessments on hub-height wind speeds rather than the 10m AGL wind speeds nominated in the 2003 SA Guideline. The use of hub-height wind speed data has been documented in more recent guidance from Australia[14] and New Zealand[15] as it is considered to better account for the influence of site-

[14] SA EPA Wind Farm Guideline 2009, AS4959: 2010 *Acoustics – Measurement, prediction and assessment of noise from wind turbine generators*
[15] NZS6808:2010 *Acoustics – Wind farm noise*

specific wind shear conditions in the noise assessment. Accordingly, hub height wind speeds are used for the Collector Wind Farm noise impact assessment.

The conventional method of assessment, as referenced in the 2003 SA Guideline, relied on a common 10m wind speed reference for both the measured background noise levels and the turbine noise emission data. In relation to background noise surveys, the 10m measurement height represented a practical requirement for the installation of temporary anemometry during the noise survey period. The 10m height wind speeds also generally tended to correspond more closely with wind conditions at surrounding receptor locations, enabling improved correlations between measured wind speeds and background noise levels.

In relation to turbine emission data however, the reliability of a 10m height wind was dependent on an assumed shear profile. Specifically, manufacturers' noise emission data referenced to 10m assumes a standard relationship between wind speeds at hub-height and 10m heights. This relationship is defined on the basis of the surface roughness length which is a measure of the extent to which the roughness of the ground influences the relationship between wind speed and height . This standardised conversion between hub-heights and 10m heights uses a reference surface roughness length (z0) of 0.05m which equates to a wind profile near ground level for relatively open farmland with limited tree coverage and mild undulating terrain. The benefit of this method is a standardised reference which enables the comparison of noise emissions from turbines with varying hub-heights.

The reliability of the 10m referenced turbine data is however reduced if actual wind shear conditions where the turbine is installed significantly differ from the assumed wind shear factored in the data. For example, if wind shear is lower than assumed, as may occur during the day at sites with very flat ground and little or no tree coverage, the turbine's noise emissions will occur at higher wind speeds than indicated by the 10m height standardised data, leading to potentially lower noise levels than expected for a given wind speed. Conversely, if wind shear is higher than assumed, the turbine's noise emissions will occur at lower wind speeds than indicated by the 10m standardised height, leading to potentially higher noise levels for a given wind speed.

Higher wind shear conditions than assumed in the turbine data can occur as a result of increasing terrain complexity and ground coverage, or importantly as a result of wind shear conditions being dominated by atmospheric stability effects rather than ground roughness effects. Stable atmospheric conditions may occur for a range of reasons such as the relative cooling of the air near ground level at night. The effect of stable atmospheric conditions and increased wind shear can therefore lead to situations where an assessment referenced to 10m wind speed heights will underestimate the level of turbine noise expected at surrounding locations for a given wind speed, a phenomenon reported in measurements published by Frits van den Berg , and since occasionally referred to as the "van den Berg effect". The influence of increased wind shear was particularly relevant for older types of turbine design which utilised stall based speed regulation systems which often produced persistent and significant increases in noise emission with increasing wind speeds. In contrast, modern pitch regulated machines tend to show an increase in noise emissions until reaching a typical maximum emission, above which noise levels do not generally increase with wind speed.

In light of the above considerations, the assessment of both background noise levels and wind turbine emissions has been based on hub-height wind speeds. This approach means that actual variations in site wind shear are reflected in the measured background noise data, and removes the potential for lower or higher than expected turbine emissions caused by site wind shear conditions differing from the standardised manufacturer values.

In order to reference the background noise survey to hub-height estimated wind speeds, the wind speeds were simultaneously measured by the proponent at 37m and 65m above ground level (AGL), for the duration of the background noise surveys. These results were then used to estimate the site specific wind shear exponent (a measure of the rate of increased in wind speed with increasing height) for each ten minute period. The calculated shear exponent was then used to estimate the wind speed expected at hub-height. In instances where a negative shear exponent was determined, the maximum of the 37m and 65m measured wind speeds was used as the hub-height wind speed in order to provide a conservative assessment.

These calculations were made according to the following Power Law equation used to convert wind speeds measured at a height of h1 to a height of h2 AGL:

$$V_1 = V_2 \cdot \left(\frac{h_1}{h_2}\right)^{\alpha}$$

Equation 1

Where:

V_1 = wind speed at height h_1 in m/s
V_2 = wind speed at height h_2 in m/s
α = measured wind shear

Noise Contributions from Existing Wind Farm Developments

Section 2.5 *Cumulative Development* of the 2003 SA Guideline requires that:

> *The noise generated by existing WTGs from another wind farm should not be considered as part of the background noise in determining criteria for subsequent development.*

There is currently one operational wind farm in the Collector area, the Cullerin Range Wind Farm (Cullerin), the southern extent of which is located approximately 4.2km north of the nearest identified Collector Wind Farm receiver.

For the purpose of establishing whether the selected background noise survey locations for the Collector Wind Farm are likely to be affected by the operation of Cullerin, it is necessary to consider the predicted levels of Cullerin noise at the selected locations.

The highest predicted noise levels (out of the range of wind speeds considered) associated with operation of Cullerin are less than 22dBA. Accordingly, operational noise from Cullerin is expected to be at least 25dBA less than the minimum/base noise limit of 45dBA which applies received involved N. On this basis, noise from Cullerin Wind Farm is not expected to have affected the reference noise limits derived from measured background noise levels at this location.

The highest predicted noise levels associated with operation of Cullerin are less than 16dBA at the nearest measurement location for a non-involved receiver, House AA. Accordingly, operational noise from Cullerin is expected to be less than the noise floor of the noise logging equipment used during the background noise monitoring campaign, and is not expected to have significantly influenced the measured noise levels.

Additional Survey Considerations

Rainfall Data

A Weather Pro® weather station was installed at a representative location central to the noise monitoring locations for each campaign of background noise monitoring. The monitoring station was installed at location N, Wood Park, for the duration of the first background noise monitoring campaign. The monitoring station was installed at location AA, Tamaroo, for the duration of the second background noise monitoring campaign.

The weather was monitored in 10-minute intervals synchronised with background noise and wind speed measurement intervals. Where it was identified that rainfall occurred, associated noise and wind speed data points were removed from the regression analysis, as per the requirements of the 2003 SA Guideline.

Cut-in and Cut-out Wind Speeds

Section 3.4 *Data analysis* of the 2003 SA Guideline requires that "data should be collected at wind speeds between the cut-in speed and the speed of rated power", implying that only wind speeds between cut-in and the wind speed of rated power should be included in the regression analysis.

However, Section 3.1 Background noise – Data of the 2003 SA Guideline notes the following.

> *Particular emphasis should be placed on collecting background noise data corresponding to the operating wind speed range of the WTGs.*

Concurrently, Section 3.2 of the 2003 SA Guideline requires the following.

> *Data should be provided for at least each integer wind speed from cut-in speed up to the speed of rated power.*

Consistent with these comments, monitored wind speeds above the speed of rated power have, where available, been included in the analysis. This approach is considered to better represent the background noise level trend at higher wind speeds.

Wind at the Microphone

The 2003 SA Guideline require monitoring of wind speeds at the microphone position. Where wind speed at the microphone location exceeds 5m/s during a given measurement interval, the noise data for that period should be removed from regression analysis.

A review of the data collected from the weather station located at Wood Park and Tamaroo dwellings indicated that wind speeds did not exceed 5m/s at any time whilst background noise monitoring occurred. Therefore, no data was removed from the analysis on the basis of excessive wind speed.

Data Analysis

The 2003 SA Guideline states that following completion of the data collection period, there should be a minimum of 2000 pairs of synchronised background noise data and wind speed measurements between the cut-in speed and the speed of rated power. The purpose of this number of data points is to obtain an indication of the range of noise levels occurring over the range of conditions in which the turbines would operate.

At least 2000 intervals (approximately 2 weeks in total) of measured background noise level ($_{LA90,\ 10min}$) data were collected at each noise monitoring location. A review of the data has been undertaken in order to determine data which fit the exclusion criteria.

Data has been excluded from each dataset where:

- any measurement coincided with recorded rainfall; and
- where measured wind speeds were below the cut-in speed of the turbine.

With all affected data excluded, the remaining valid data points are generally well in excess of 2000. The exceptions are involved receivers N and T where 1645 and 1919 data points are available for analysis respectively. Notwithstanding, the resulting analysis is considered sufficiently representative of the background noise environment at monitoring locations N & T. This is supported by similarity of the noise trends observed at other locations surveyed during the same time period.

The valid data has been plotted as an XY scatter as a function of the wind velocity at hub height. A regression analysis has been carried out for each data set in order to determine the background noise line of best fit. Table E2 summarises the data statistics for each location. The R^2 value, also called the coefficient of determination, describes the degree of variability of a set a data.

Table E2
Background noise logging statistics

House	Measurement Period	Logger Serial No.	Data points		Correlation R^2
			Total	Valid	
G	27/4/10 to 9/5/10 & 13/5/10 to 22/5/10	16-707-022	2946	2198	0.35
M	27/4/10 to 3/5/10 & 13/5/10 to 27/5/10	16-707-019	2955	2040	0.31
N	27/4/10 to 3/5/10 & 13/5/10 to 23/5/10	16-707-023	2310	1645	0.42
T	27/4/10 to 6/5/10 & 13/5/10 to 22/5/10	16-707-018	2673	1919	0.39
L	5/11/10 to 29/11/10	16-707-019	3275	2803	0.14
Q	5/11/10 to 29/11/10	16-207-027	2986	2576	0.05
Z	5/11/10 to 29/11/10	16-707-022	3439	2958	0.13
AA	5/11/10 to 29/11/10	16-707-018	3467	2968	0.13

Appendix F provides a summary of the weather data covering for the monitoring periods.

APPENDIX F

MEASURED WEATHER DATA

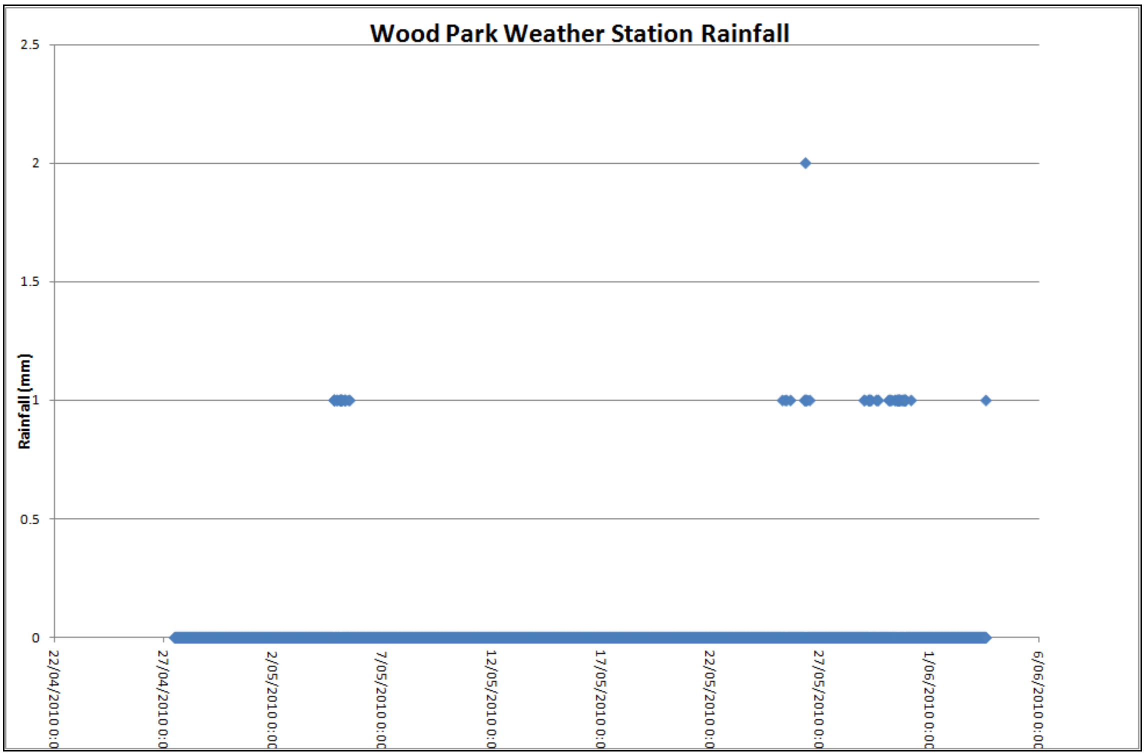

Figure F1: Rainfall at receiver Wood Park

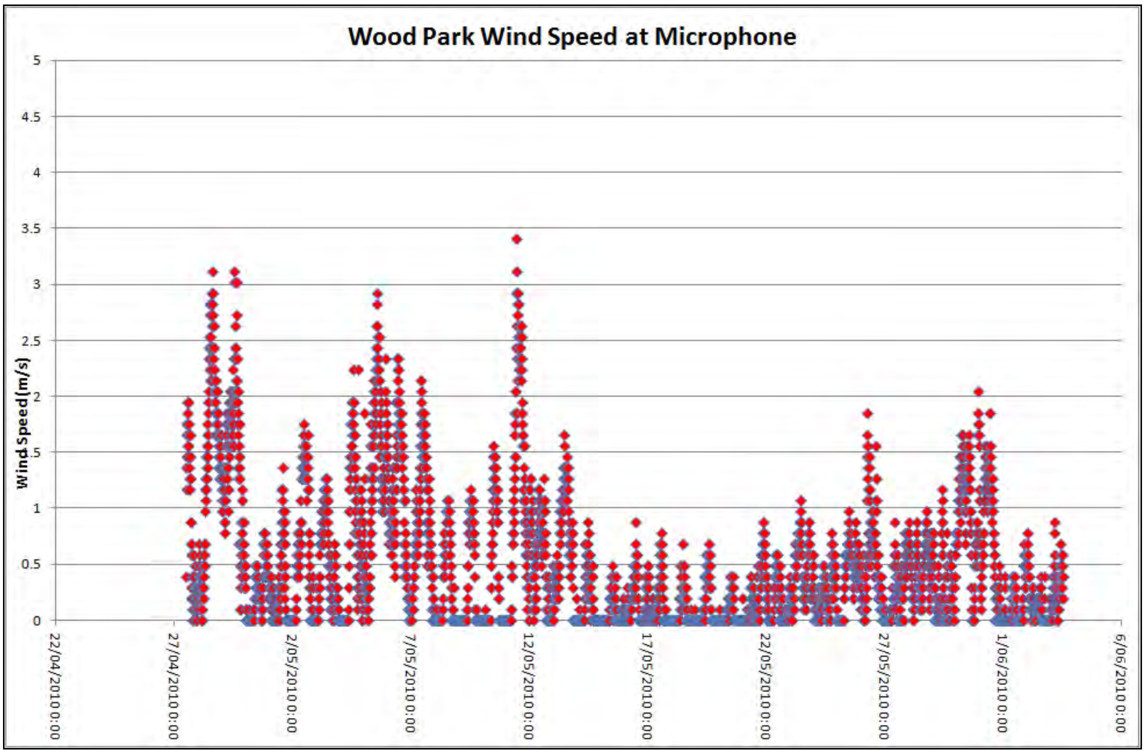

Figure F2: Wind speed at microphone at receiver Wood Park

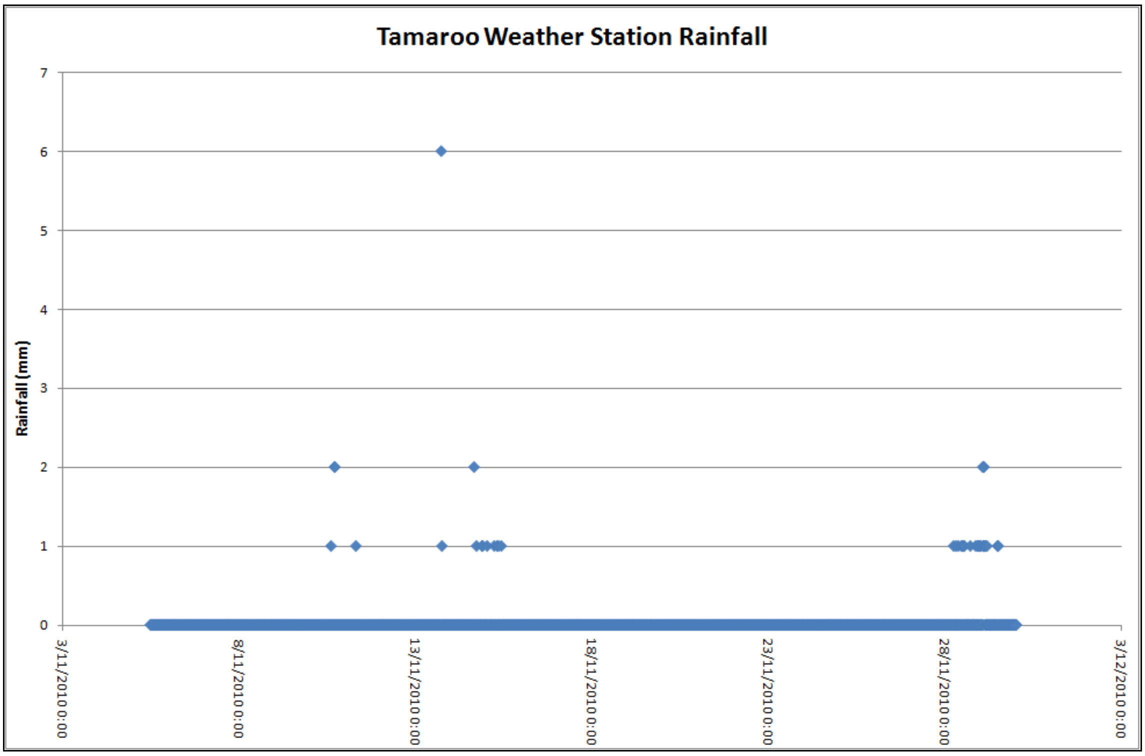

Figure F3: Rainfall at receiver Tamaroo

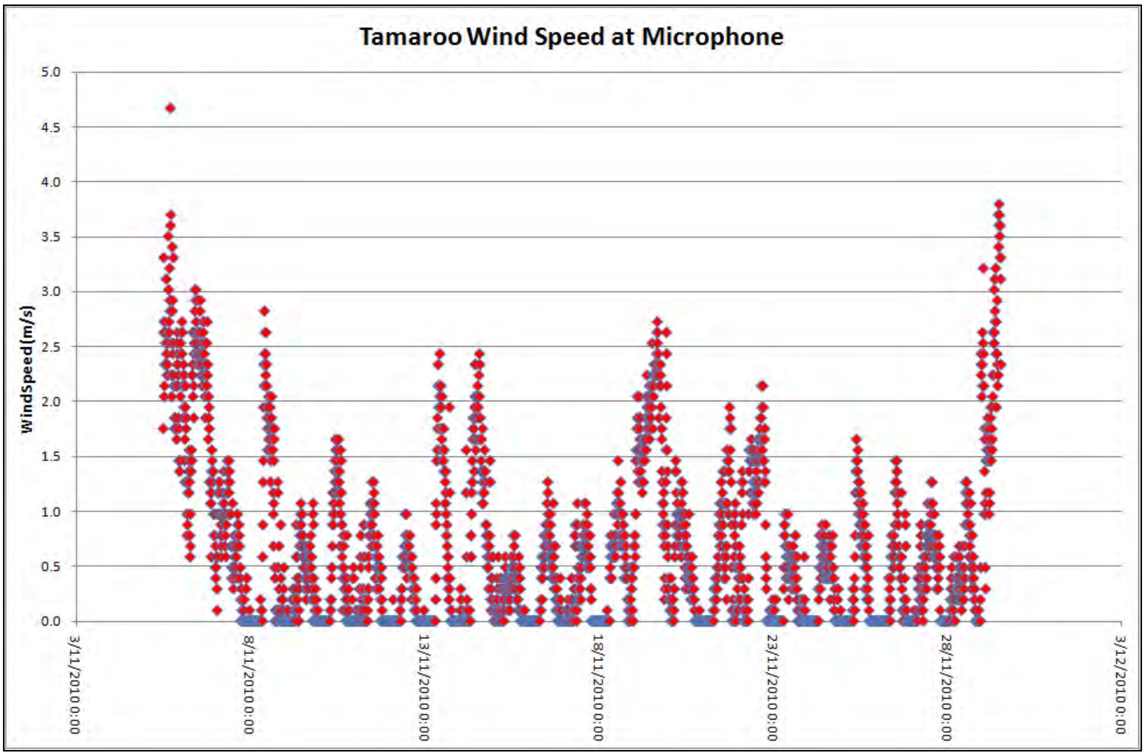

Figure F4: Wind speed at microphone at receiver Tamaroo

APPENDIX G

MEASURED BACKGROUND NOISE & WIND SPEED vs TIME

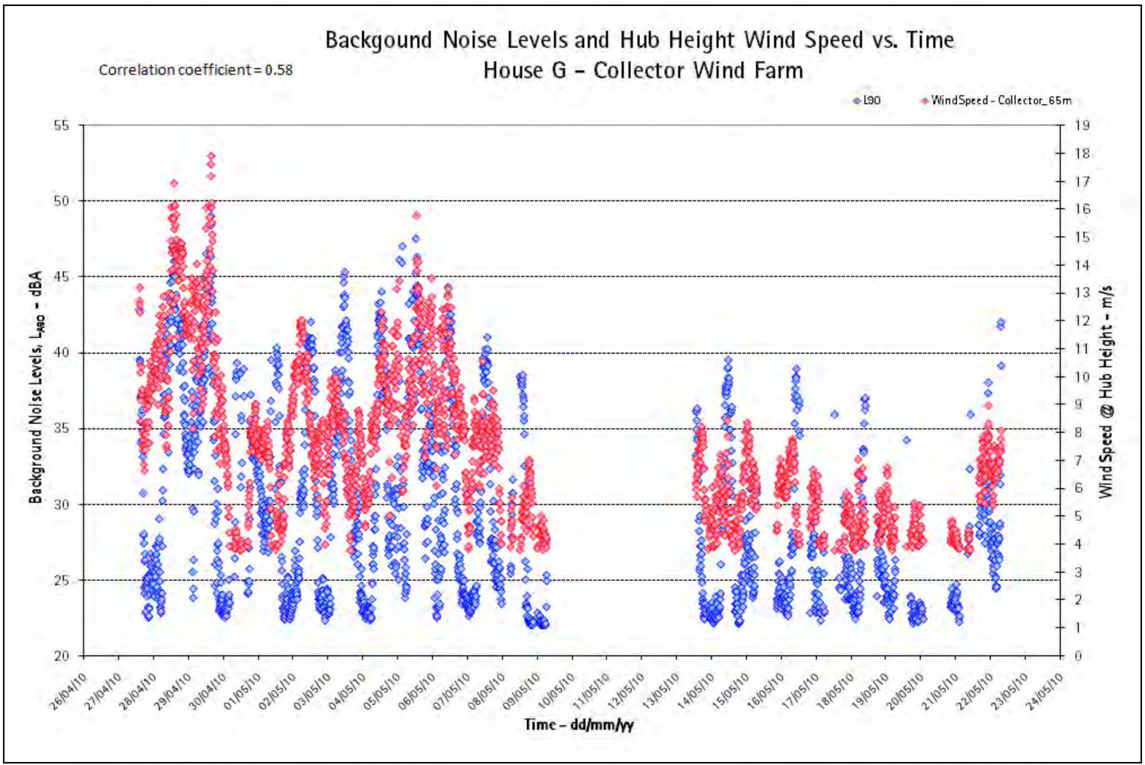

Figure G1: Correlation of background noise to hub height wind speed for receiver G

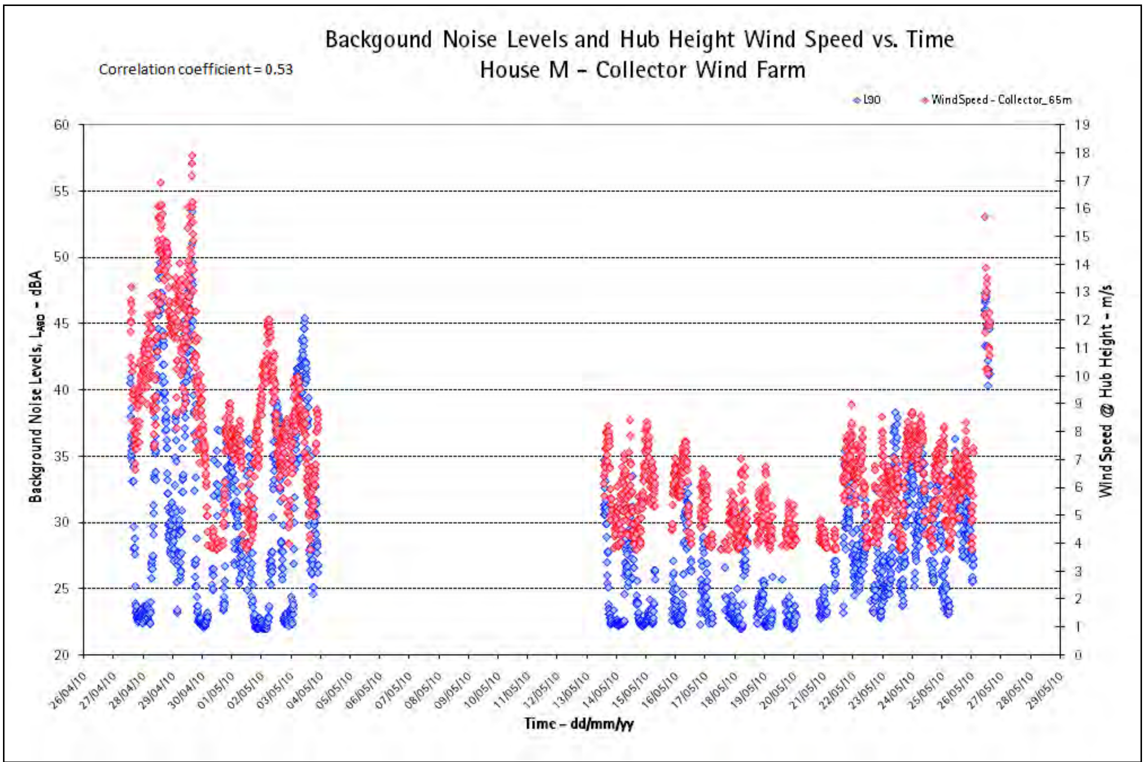

Figure G2: Correlation of background noise to hub height wind speed for receiver M

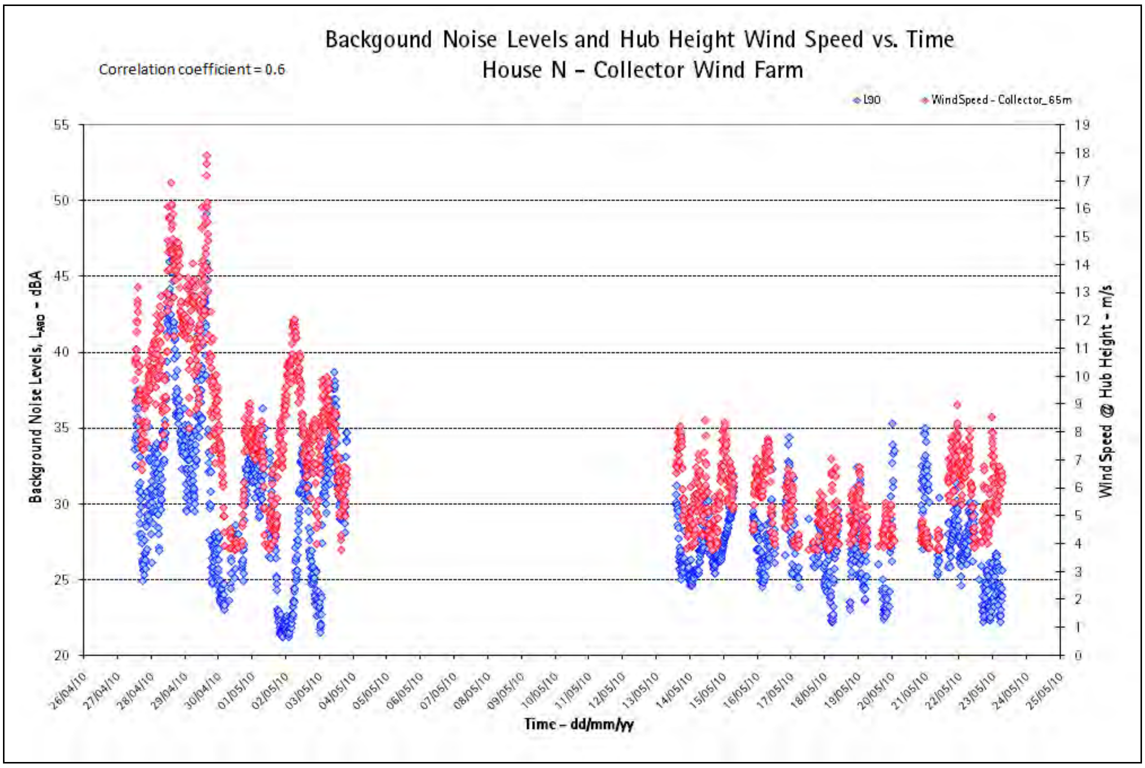

Figure G3: Correlation of background noise to hub height wind speed for receiver N

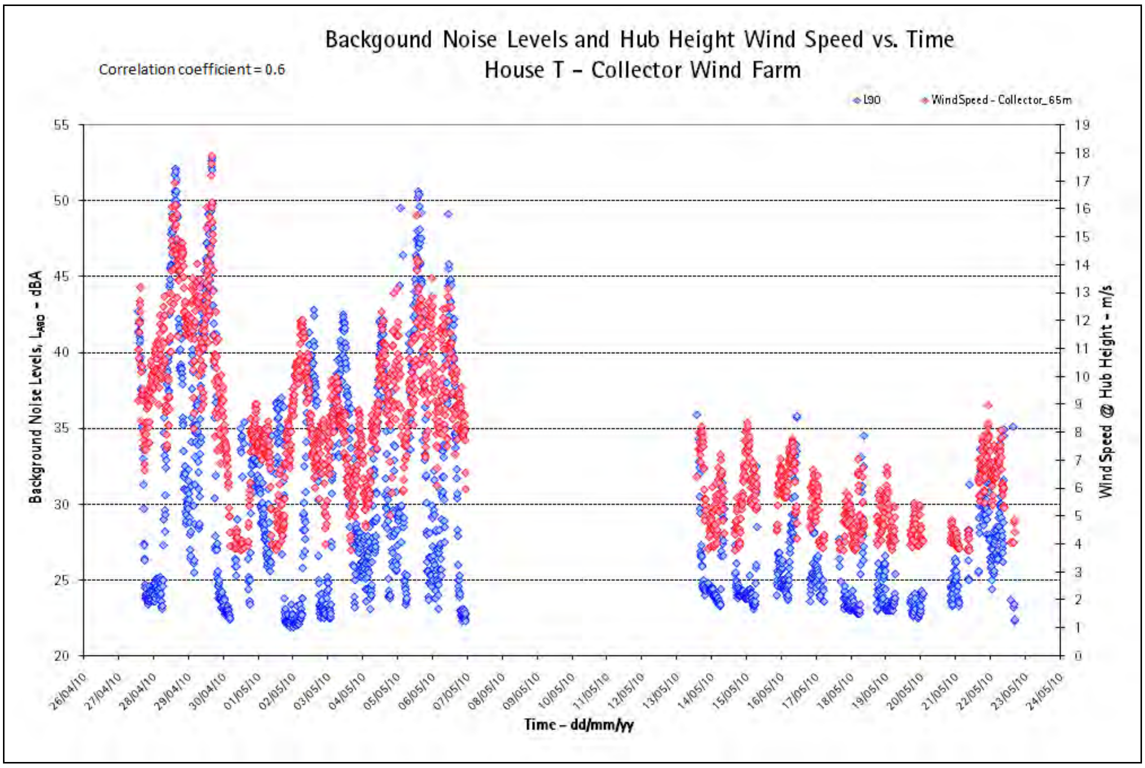

Figure G4: Correlation of background noise to hub height wind speed for receiver T

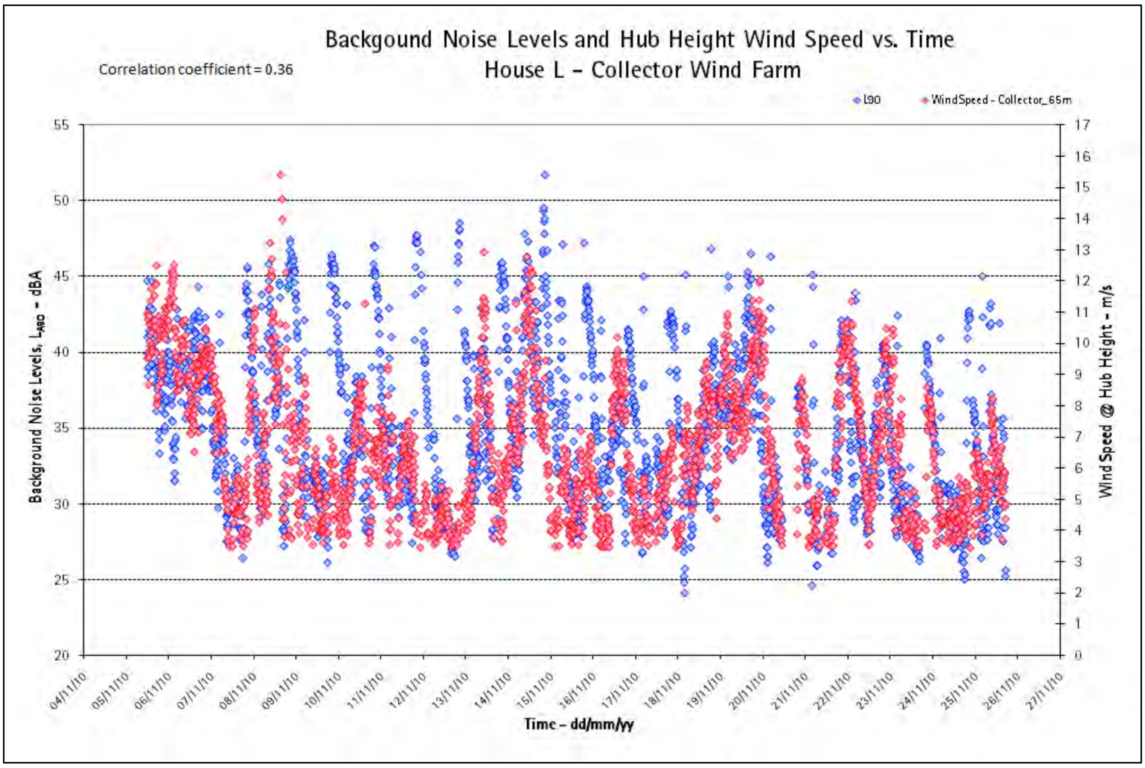

Figure G5: Correlation of background noise to hub height wind speed for receiver L

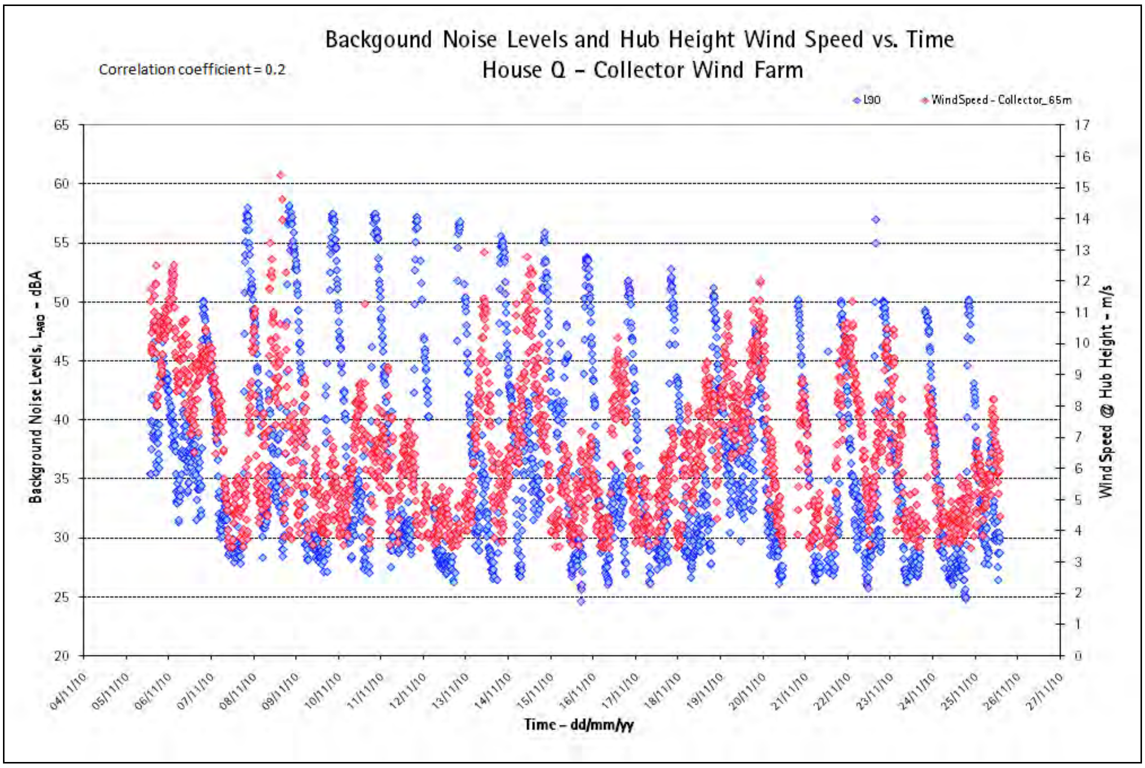

Figure G6: Correlation of background noise to hub height wind speed for receiver Q

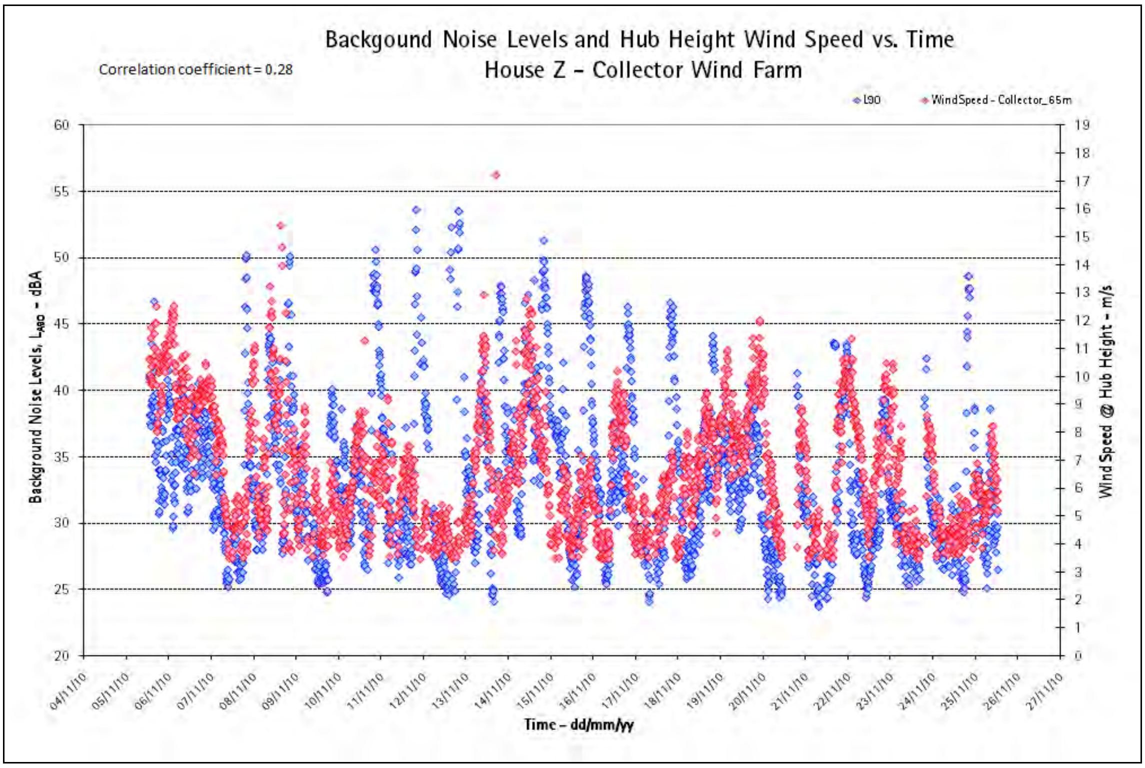

Figure G7: Correlation of background noise to hub height wind speed for receiver Z

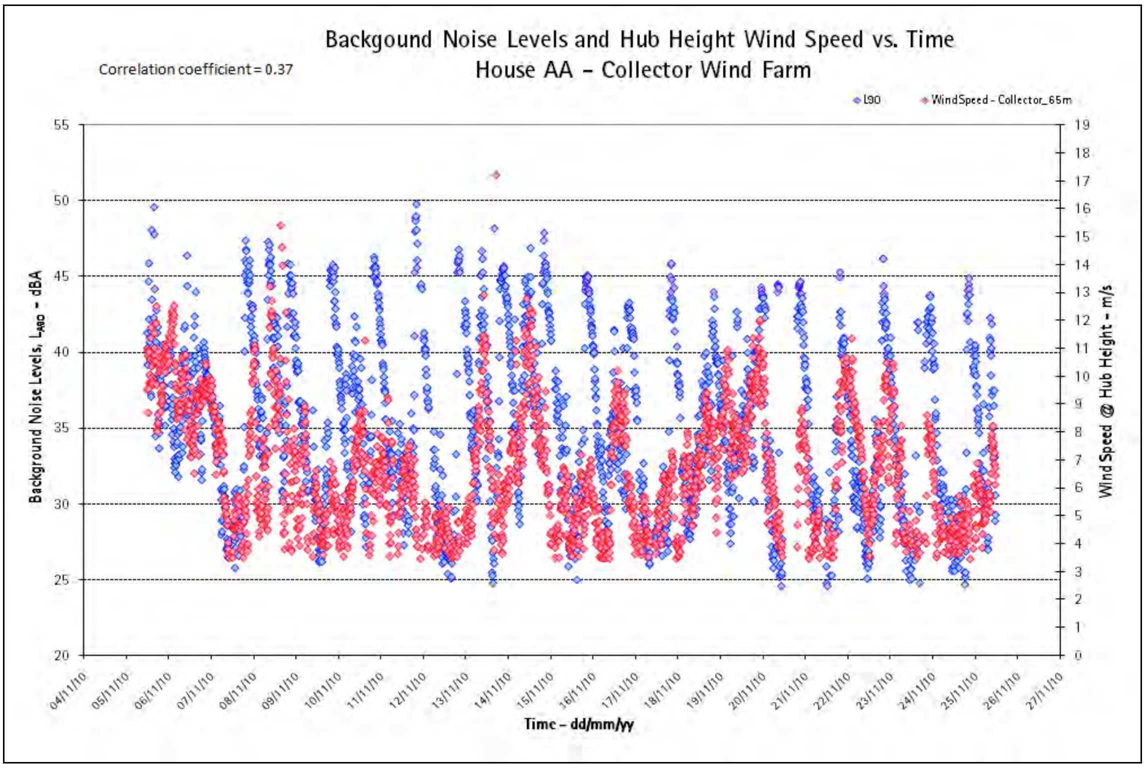

Figure G8: Correlation of background noise to hub height wind speed for receiver AA

APPENDIX H

MEASURED BACKGROUND NOISE & WIND SPEED CORRELATIONS

This section describes the environs each noise monitoring location and provides a graphic summary of the background noise and wind data, and where appropriate, the noise limits derived from the background data.

Involved Receiver G

Background noise monitoring was carried out at Stoney Creek Cottage, located at 1947 Collector Road, using ARL logger EL316 serial no. 16-707-022.

The dwelling is located at the southern end of the site, some 250m north of Collector Road.

The environment surrounding the measurement location consisted of an outcrop of trees to the west and south.

A total of 878 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H1 below, including the data scatter and regression line of best fit. In addition, the 2003 SA Guideline and involved receiver noise criteria are shown (reference purposes only).

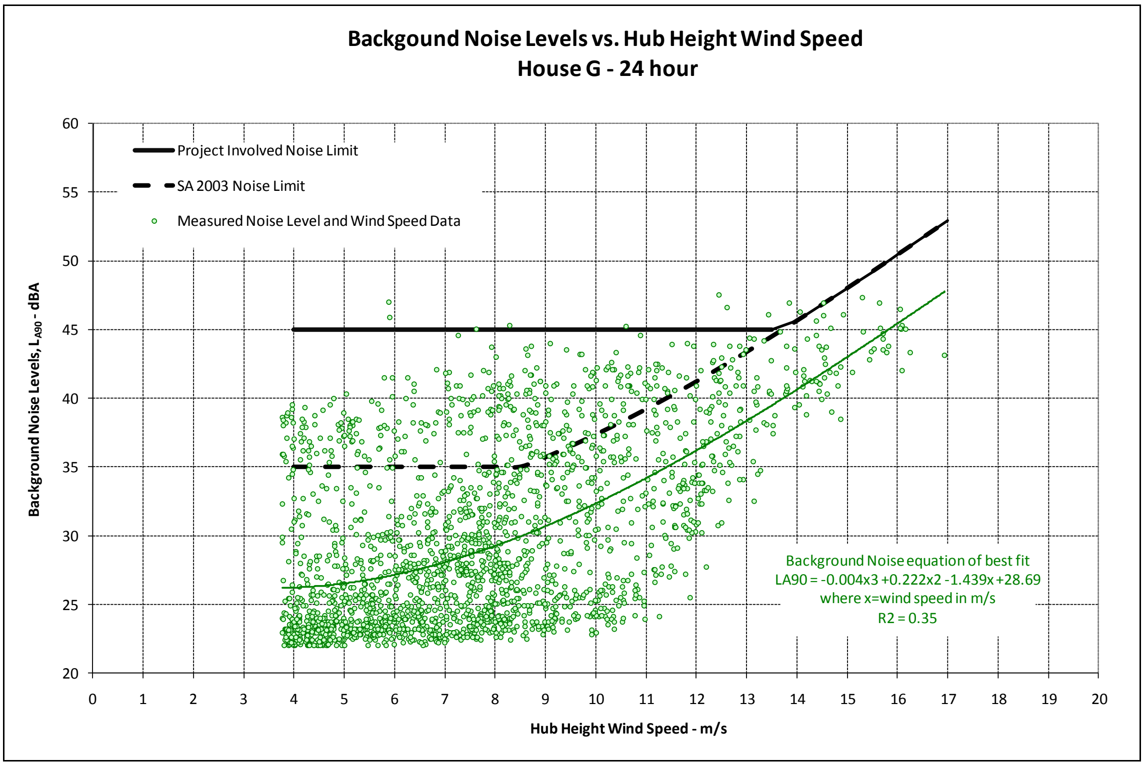

Figure H1: House G – 24 Hour Baseline Noise Data & Derived Criteria

Involved Receiver M

Background noise monitoring was carried out at 808 Lerida South Road, using ARL logger EL316 serial no. 16-707-019.

The dwelling is located towards the western side of the site, some 1.4km east of Collector Gunning Road. The measurement location was surrounded on all sides by trees at the property.

A total of 913 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H2 below, including the data scatter and regression line of best fit. In addition, the 2003 SA Guideline and involved receiver noise criteria are shown (reference purposes only).

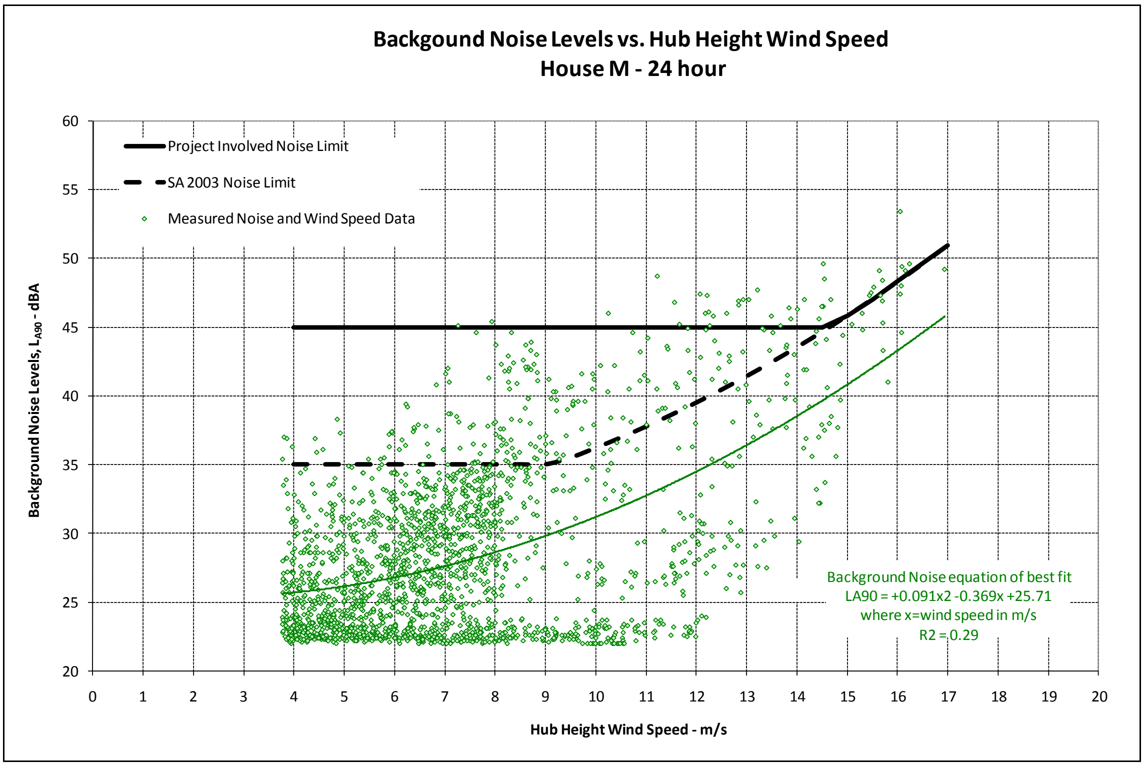

Figure H2: House M – 24 Hour Baseline Noise Data & Derived Criteria

Involved Receiver N

Background noise monitoring was carried out at Wood Park, located at 448 Lerida South Road, using ARL logger EL316 serial no. 16-707-023.

The dwelling is located toward the northern end of the site, some 3.5km south of the Hume Freeway. The measurement location was surrounded on all sides by trees at the property.

A total of 663 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H3 below, including the data scatter and regression line of best fit. In addition, the 2003 SA Guideline and involved receiver noise criteria are shown (reference purposes only).

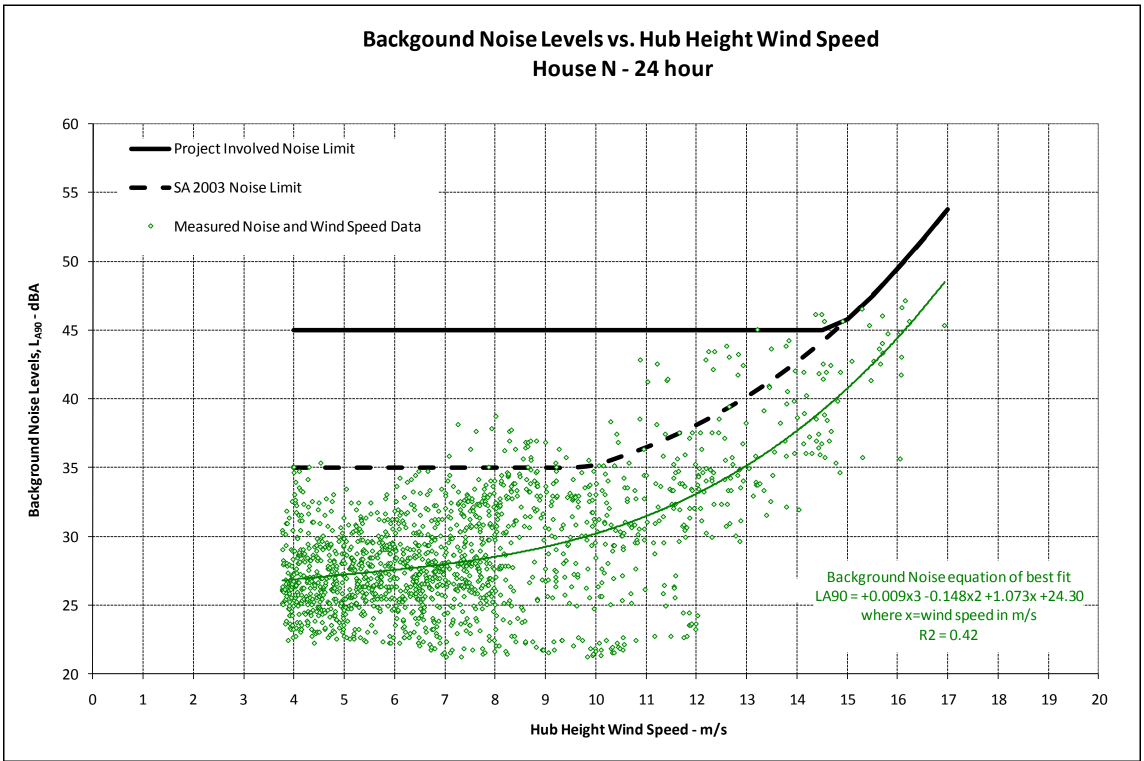

Figure H3: House N – 24 Hour Baseline Noise Data & Derived Criteria

Involved Receiver T

Background noise monitoring was carried out at Cottage No. 1, using ARL logger EL316 serial no. 16-707-018.

The dwelling is located on the western side of the site, some 2.2km north-east of Collector Gunning Road. The measurement location was relatively exposed, with only a small outcrop of trees to the north-west.

A total of 752 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H4 below, including the data scatter and regression line of best fit. In addition, the 2003 SA Guideline and involved receiver noise criteria are shown (reference purposes only).

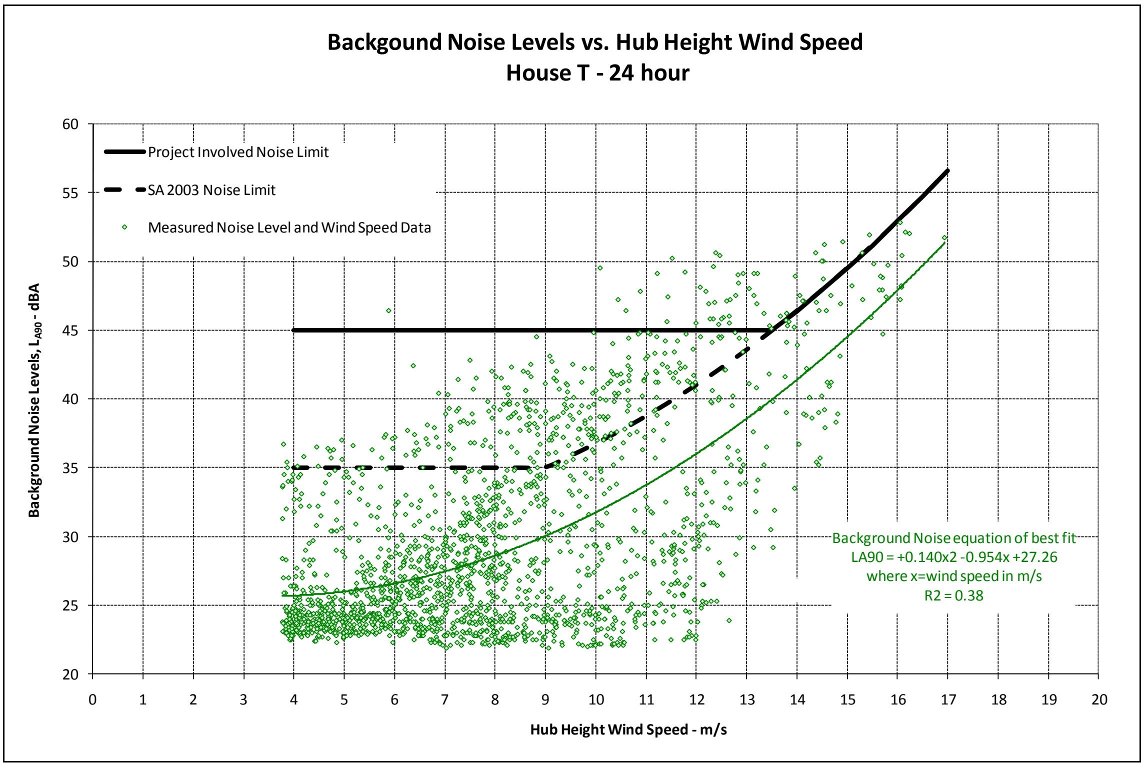

Figure H4: House T – 24 Hour Baseline Noise Data & Derived Criteria

Receiver L

Background noise monitoring was carried out at The Towers, using ARL logger EL316 serial no. 16-707-019.

The dwelling is located at the south-west end of the site, some 300m south-west of Collector Road. The noise logger was located on a small rise, to the south of the dwelling and approximately 20m north-east of the nearby shed.

A total of 472 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H5 below, including the data scatter and regression line of best fit.

The data is noted to include a concentration of elevated noise levels at lower wind speeds. As a result of this influence, a cautious approach has been applied and the baseline noise data obtained at this location has not been used to derive operational wind farm noise limits. This is discussed in more detail in subsequent sections.

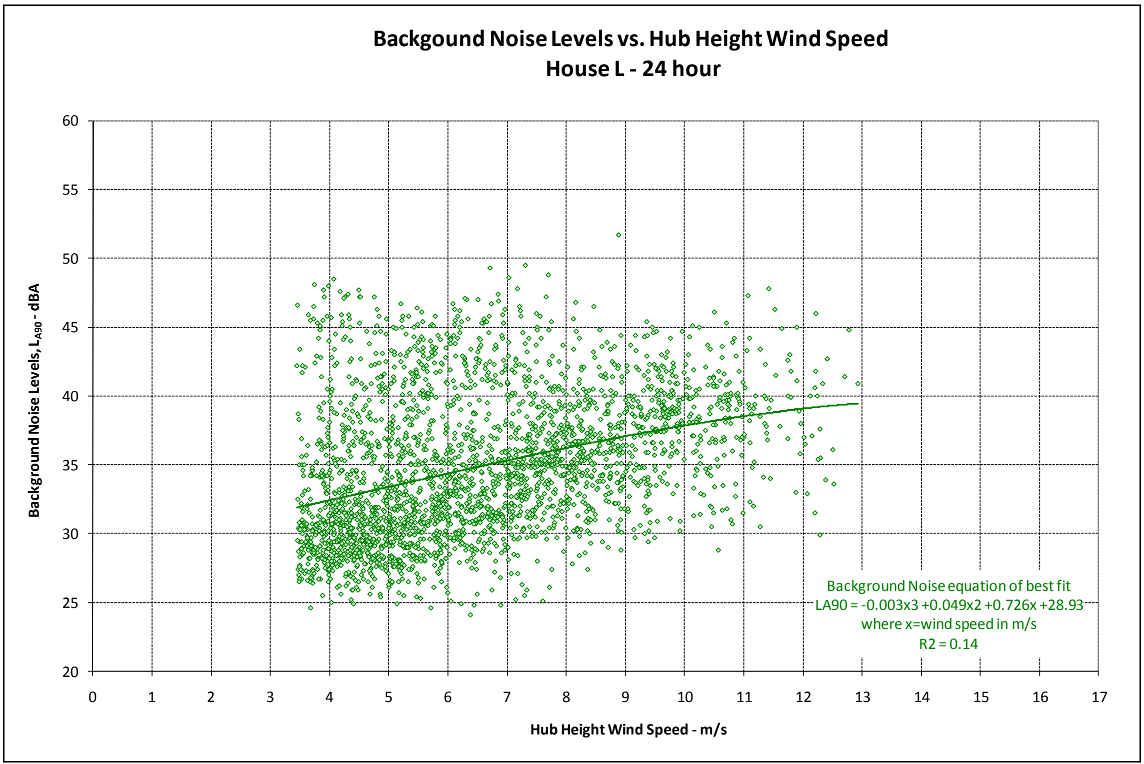

Figure H5: House L – 24 Hour Baseline Noise Data

Receiver Q

Background noise monitoring was carried out at Allendale, using ARL logger EL316 serial no. 16-707-027.

The dwelling is located on the western side of the site, some 850m north-east of Collector Gunning Road. The noise logger was located on the southern façade of dwelling, approximately 14m due south.

A total of 410 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H6 below, including the data scatter and regression line of best fit.

The data is noted to include a concentration of elevated noise levels at lower wind speeds. As per location L, the survey data has not been used to define increased noise limits. Further discussion is provided subsequent sections.

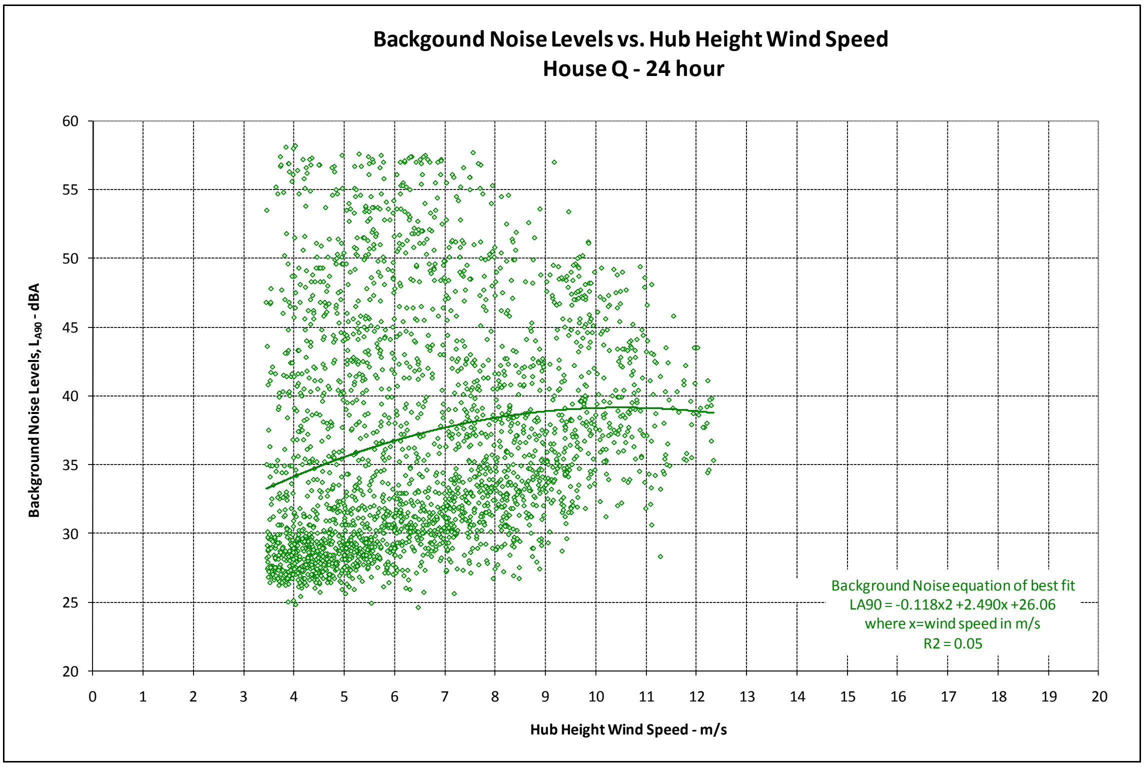

Figure H6: House Q – 24 Hour Baseline Noise Data

Receiver Z

Background noise monitoring was carried out at 1373 Collector Gunning Road, using ARL logger EL316 serial no. 16-707-022.

The dwelling is located on the western side of the site, some 800m north-east of Collector Gunning Road. The noise logger was located on the western façade of the dwelling, approximately 15m away.

A total of 481 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H7 below, including the data scatter and regression line of best fit.

The data is noted to include a concentration of elevated noise levels at lower wind speeds. As per locations L & Q, the survey data has not been used to define increased noise limits. Further discussion is provided in subsequent sections.

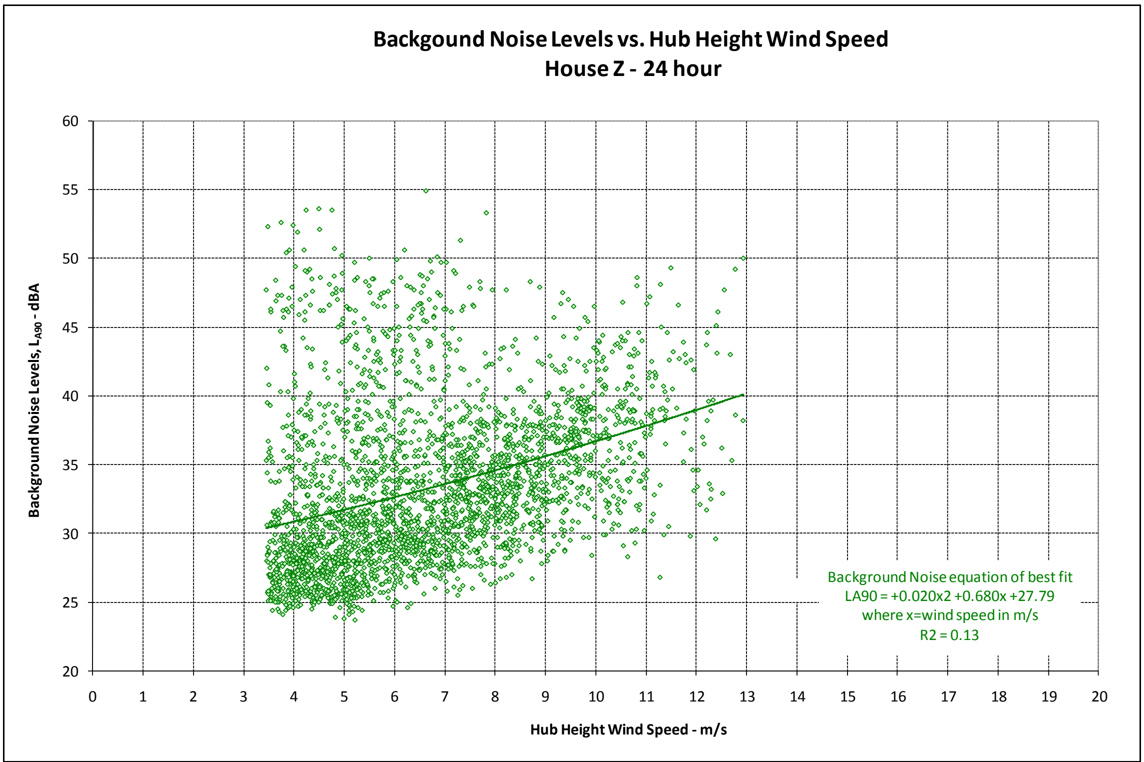

Figure H7: House Z – 24 Hour Baseline Noise Data

Receiver AA

Background noise monitoring was carried out at Tamaroo, using ARL logger EL316 serial no. 16-707-018.

The dwelling is located on the eastern side of the site, some 2.1m west of Collector Road. The noise logger was located on the western façade of the dwelling, approximately 15m away.

A total of 499 data points were excluded from the analysis due to weather, extraneous noise and turbine cut-in point restrictions. The results of baseline noise monitoring ($L_{A90,10min}$) are shown in Figure H8 below, including the data scatter and regression line of best fit. In addition, Guideline noise criteria for non-involved receivers are shown.

The data is noted to include a concentration of elevated noise levels at lower wind speeds. As per locations L ,Q, & AA the survey data has not been used to define increased noise limits. Further discussion is provided in subsequent sections.

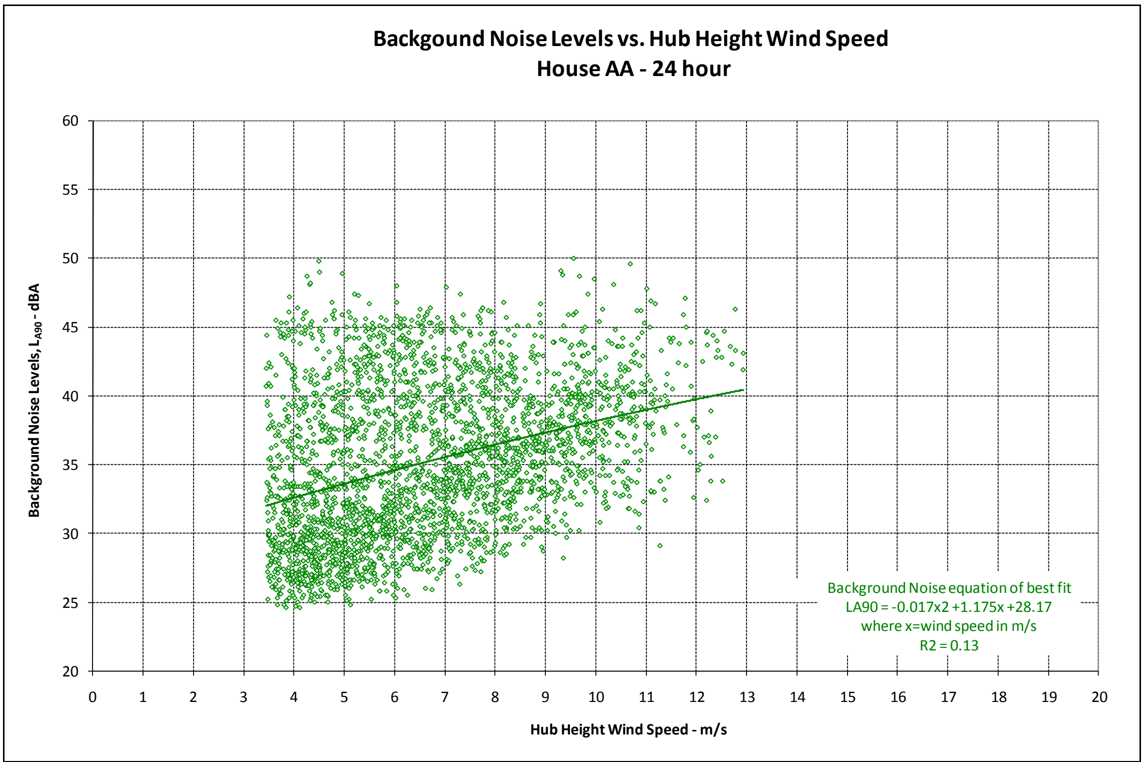

Figure H8: House AA – 24 Hour Baseline Noise Data

Background Noise Data Evaluation - Possible Seasonal/Temporal Effects

The 2003 SA Guideline acknowledges that background noise levels are inherently, and state that noise varies naturally through the year, with different prevailing wind directions, foliage on trees, atmospheric conditions and the like. The 2003 SA Guideline does not require measurements at every time of the year. Rather, the requirement is that any measured noise data used to derive operational wind farm noise limits should be representative of the location and area under investigation. The 2003 SA Guideline does however indicate that an account must be made of different periods of the year where valid concerns exist, for example in relation to significant seasonal factors.

The charts presented in figures H5 to H8 has identified that the measurement data collected at all locations during the second noise monitoring campaign exhibit a consistent pattern of elevated noise levels at lower wind speeds. To illustrate the pattern, Figure 9 shows the lines of best-fit previously presented in Figures H1 to H8 in order to enable comparison of the trends between the 2 different monitoring campaigns.

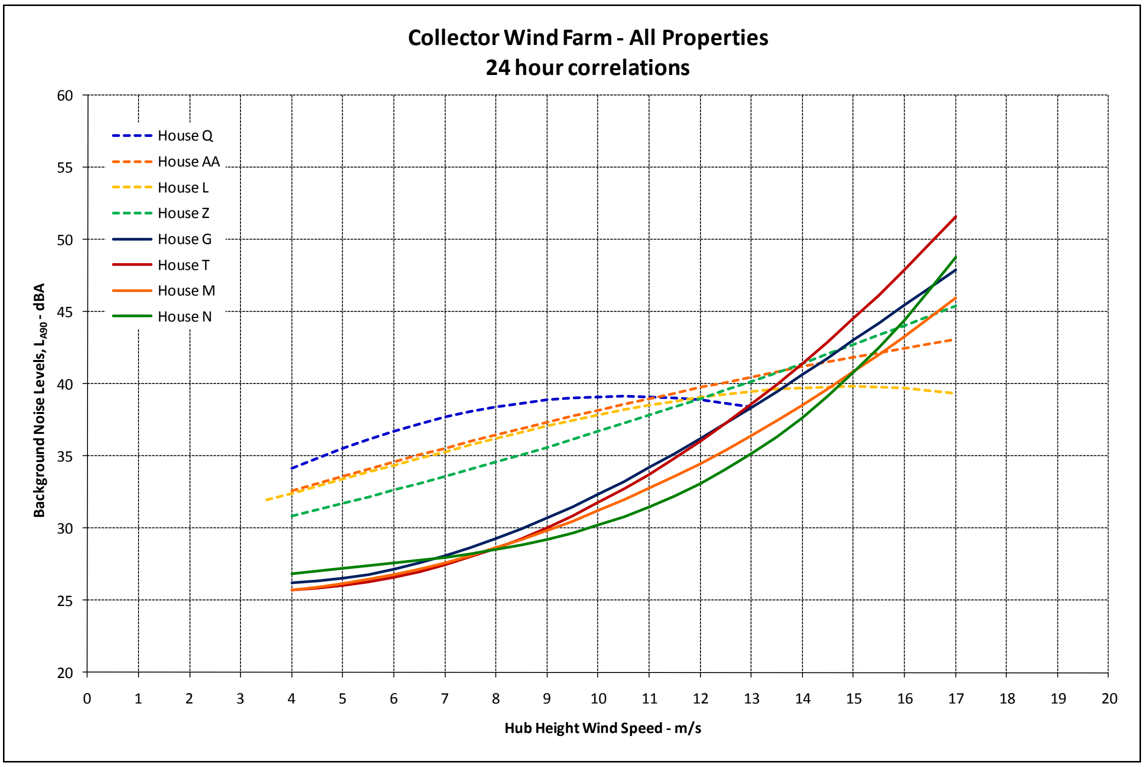

Figure H9: All Survey Locations – 24 Hour Baseline Noise Data Correlations

The data trends for Houses G, M, N and T, which were monitored during the first campaign, show relatively close agreement, particularly given the natural level of variation expected across different locations. The regression curve trends at these locations are consistent with expectations for the type of rural environment at the site. Notably, average noise levels at low wind speeds are less than 30dBA. Average noise levels do not increase above 30dBA until hub-height wind speeds of 8-10m/s are reached, after which the regression noise levels increase clearly with increasing wind speed.

Inspection of the time-history records for the second measurement campaign indicated a persistent and recurring increase in noise levels during the evening at each location. The nature of the increase suggested a potential temporary or seasonal phenomenon such as frog or insect noise.

Consistent with the 2003 SA Guideline, and in recognition of the concern that these increased noise levels may not be representative of other times of year, the data has not been used to defined increased background-related noise limits for the site. In lieu of noise limits based on monitored background noise levels, we have established noise limits at Houses L, Q, Z and AA based on the applicable minimum or base limits. Specifically, as all four locations are non-involved receivers, a limit equal to the minimum value of 35dBA has been applied.

Diurnal Noise Trends of Representative Datasets

In accordance with the DGRs, the valid 24 hour survey data collected at Houses G, M, N and T has been reviewed to investigate the relationship between day and night-time noise levels. Figures H10 to H17 provide the noise versus wind speed correlations for the separate day (07:00 to 22:00 hours) and night periods (22:00 to 07:00 hours).

The extent of conclusions which can be reached by comparison of the two sets of trends is limited by the reduced datasets available for each correlation. Notwithstanding this, all locations show a clear trend of reduced noise levels during the night time period. Specifically, the average data trends at night indicate levels which are 5-10dBA lower than the daytime data.

The pattern of reduced noise levels at night in this type of rural setting may be attributable to a range of factors such as reduced man-made noise during the night (e.g. distant agricultural activity or traffic), increased bird noise during the day and variable wind shear effects between day and night.

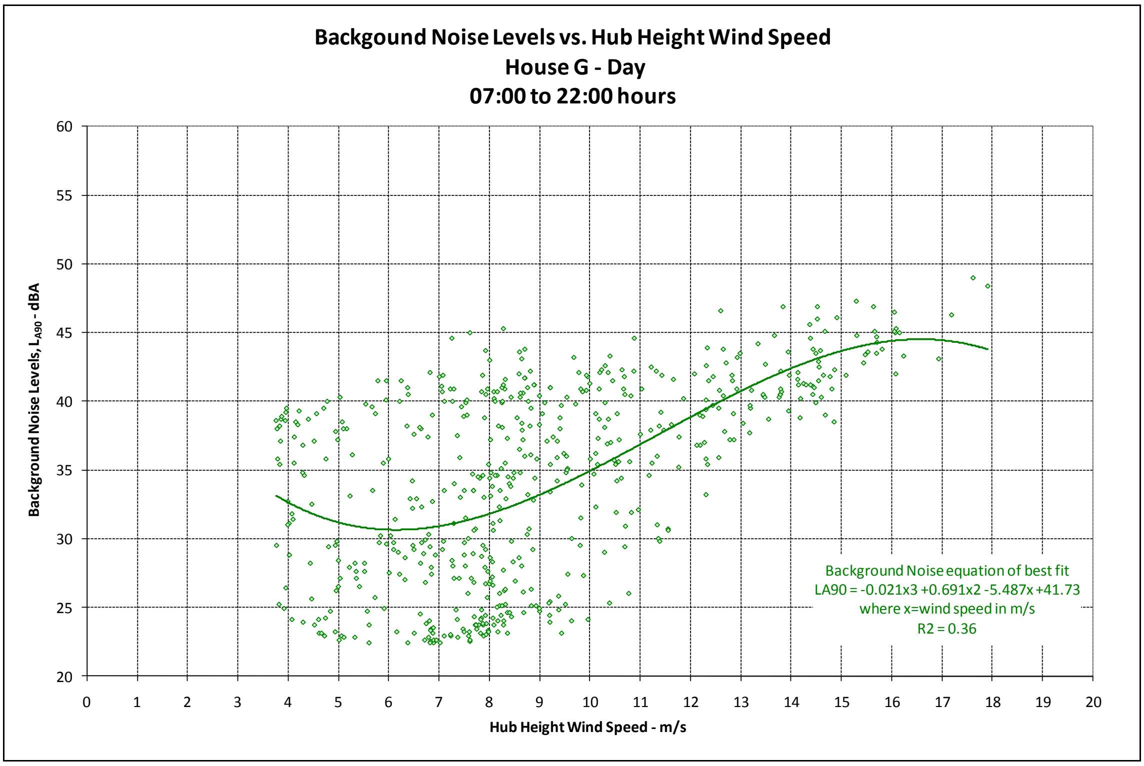

Figure H10: House G – Daytime Baseline Noise Data

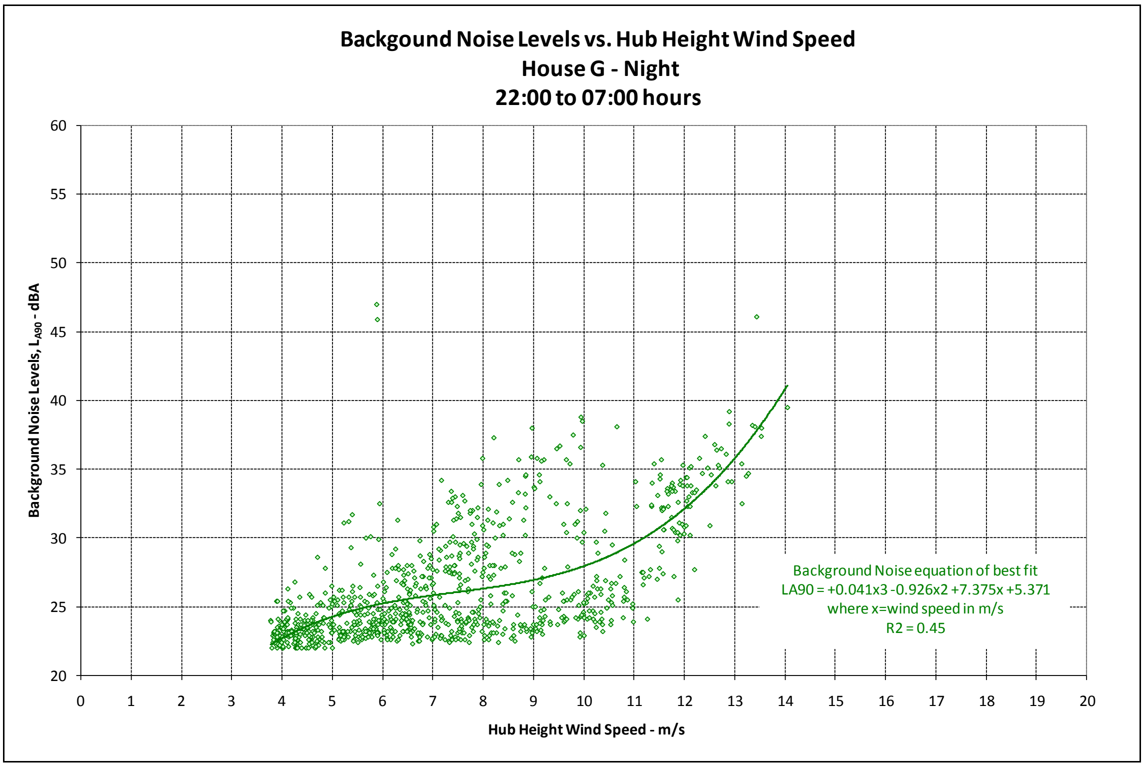

Figure H11: House G – Night-time Baseline Noise Data

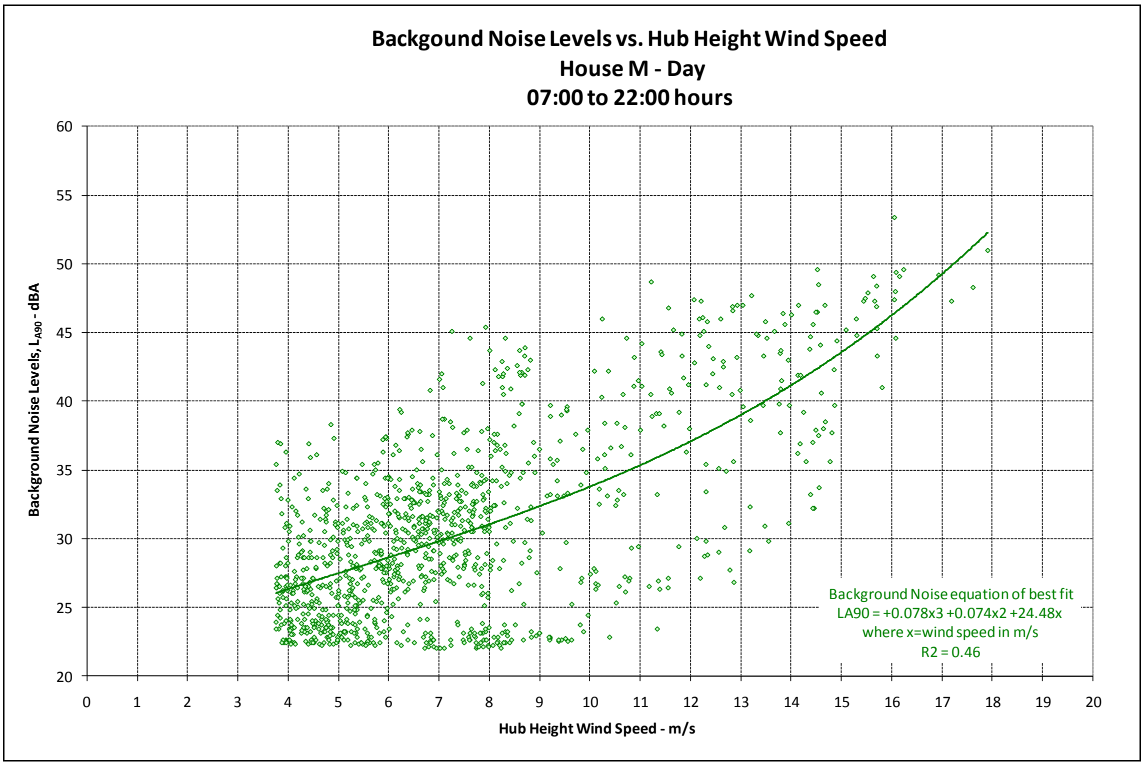

Figure H12: House M – Daytime Baseline Noise Data

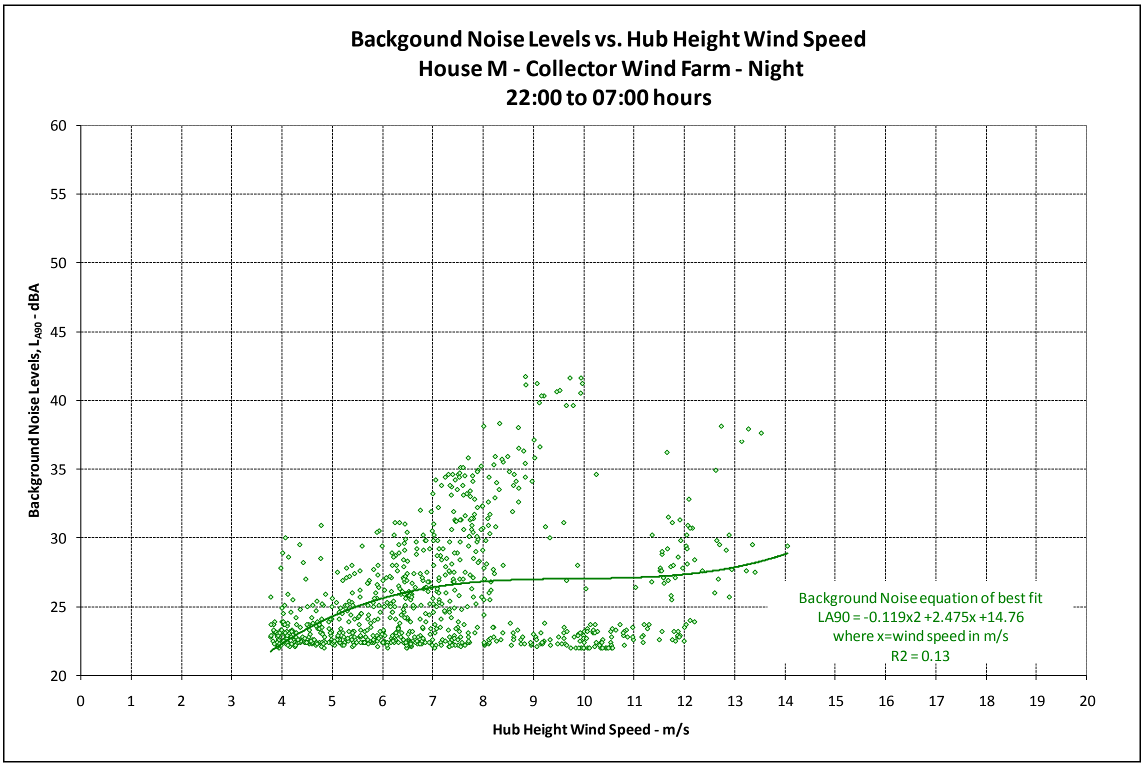

Figure H13: House M – Night-time Baseline Noise Data

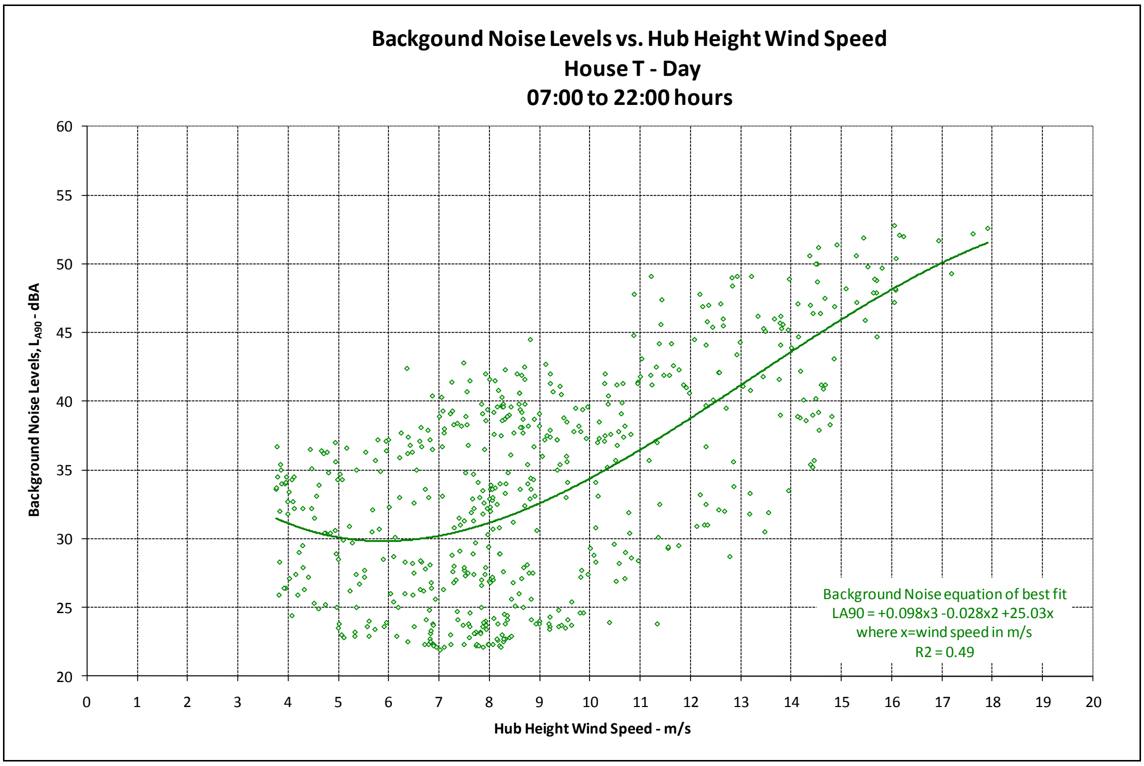

Figure H14: House T – Daytime Baseline Noise Data

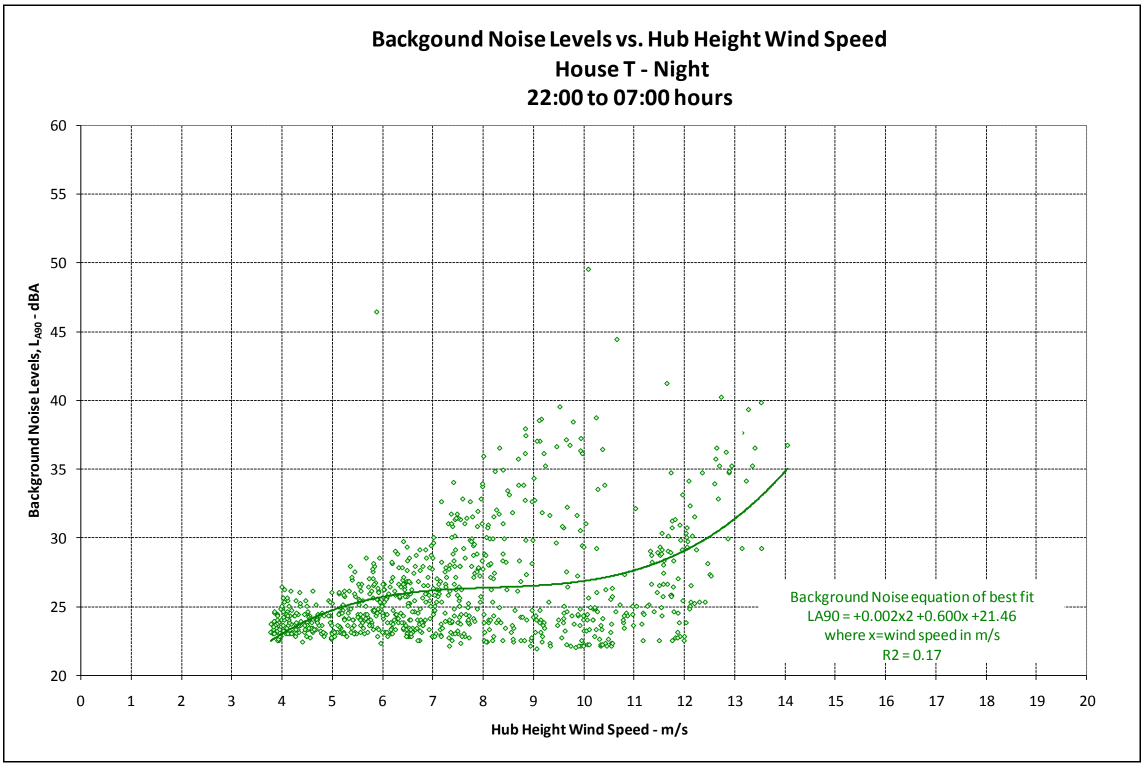

Figure H15: House T – Night-time Baseline Noise Data

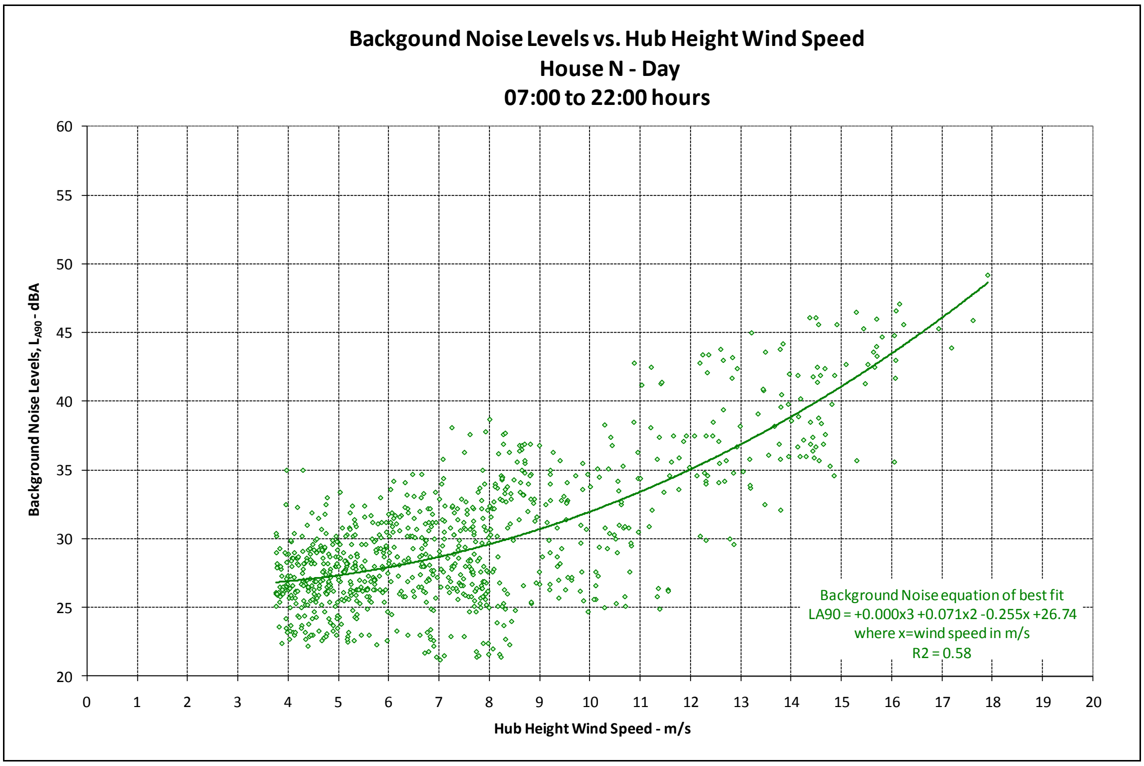

Figure H16: House N – Daytime Baseline Noise Data

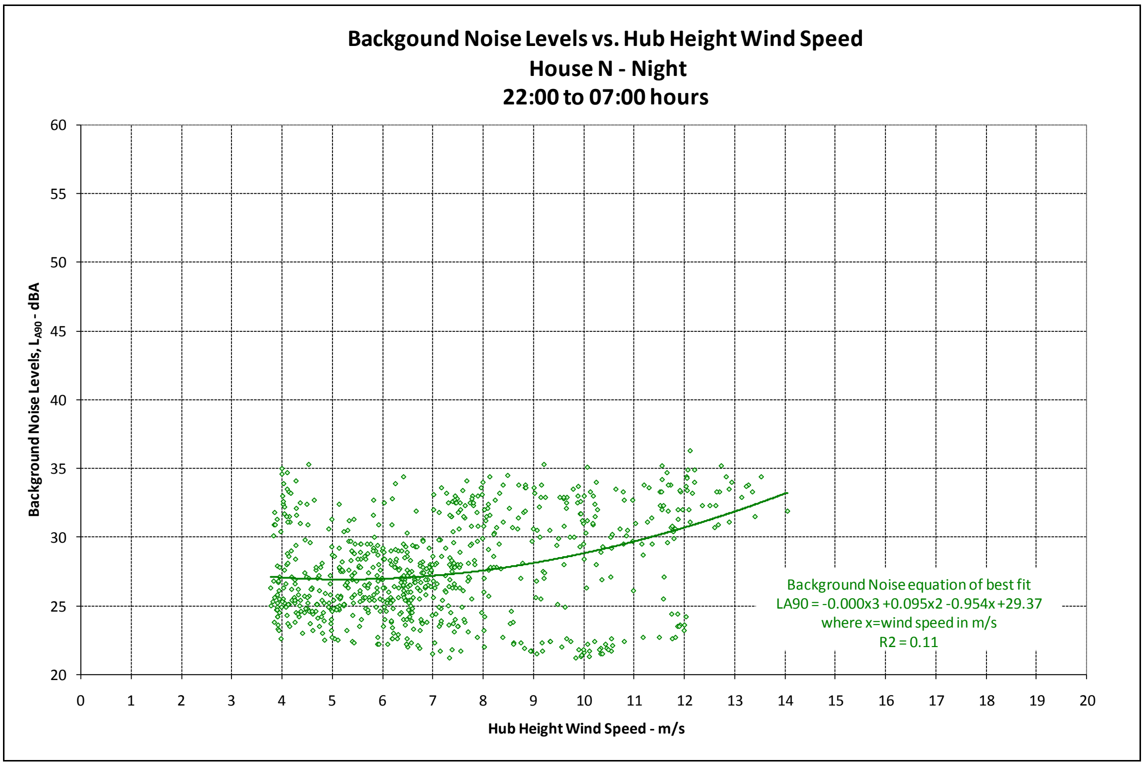

Figure H17: House N – Night-time Baseline Noise Data

APPENDIX I

WIND FARM PREDICTED NOISE LEVELS VS NOISE LIMITS

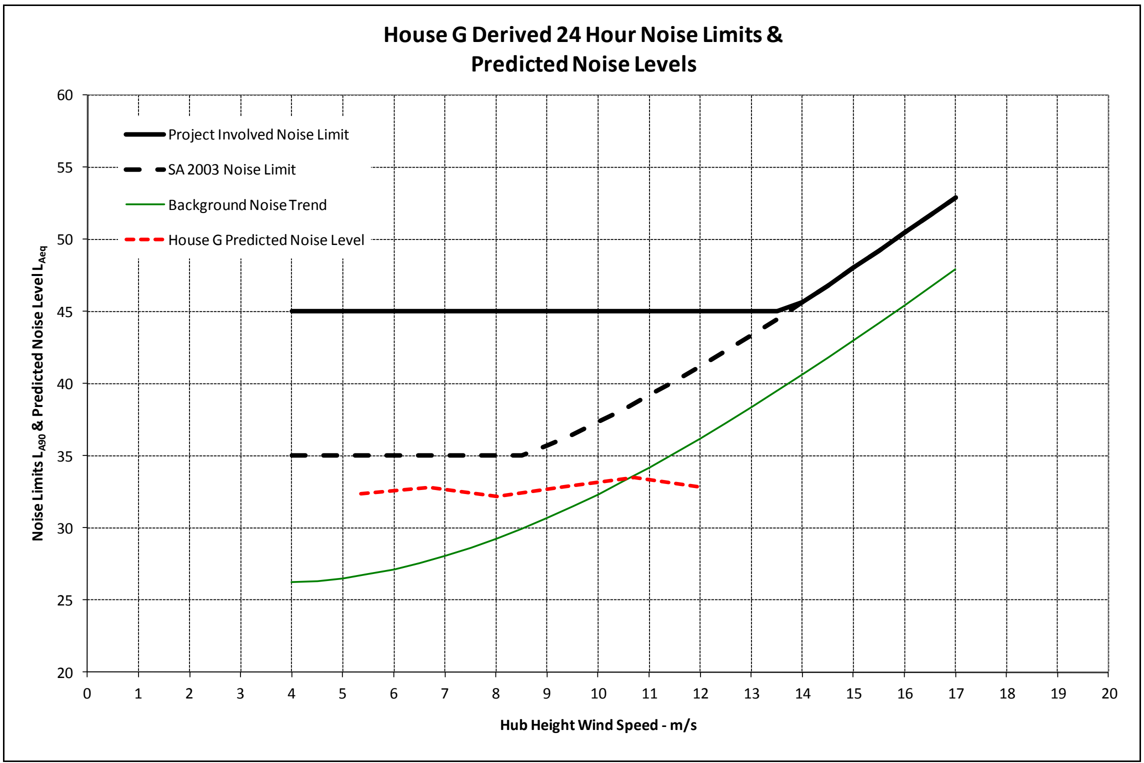

Figure I1: House G Limits & Suzlon S88 Predicted Noise Levels - 68 Turbines

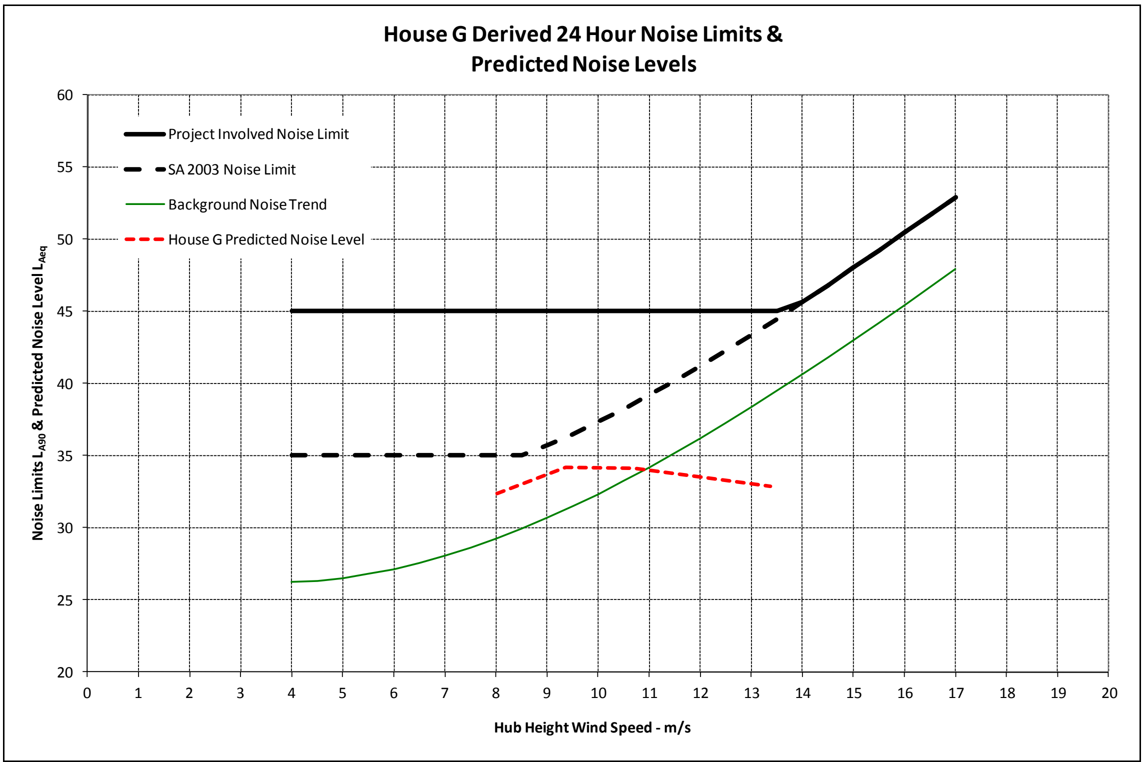

Figure I2: House G Limits & REpower 3.4M 104 Predicted Noise Levels - 67 Turbines

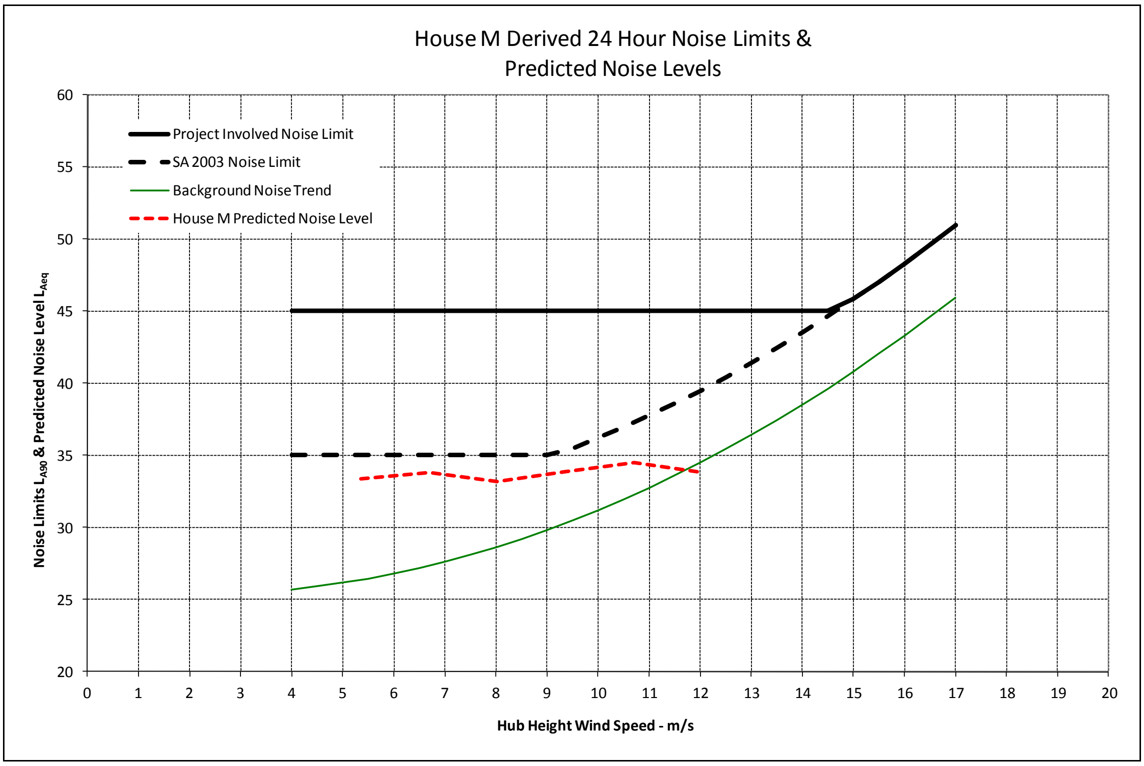

Figure I3: House M Noise Limits & Suzlon S88 Predicted Noise Levels - 68 Turbines

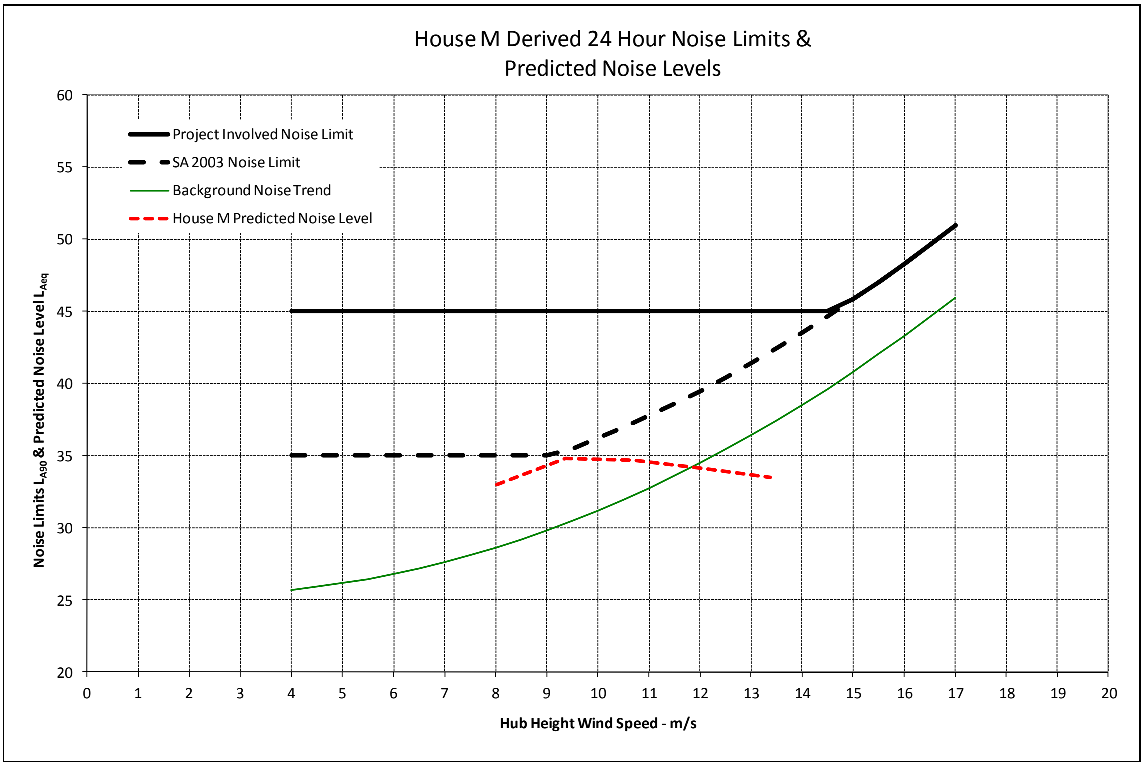

Figure I4: House M Limits & REpower 3.4M 104 Predicted Noise Levels - 67 Turbines

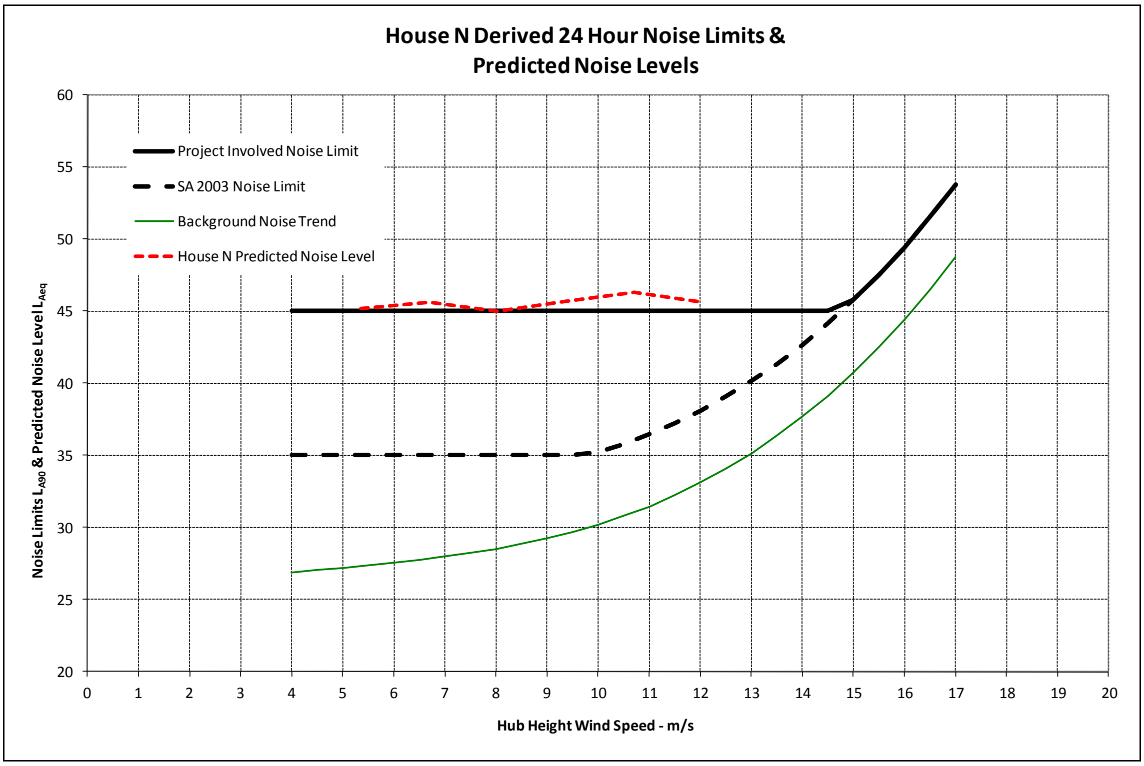

Figure I5: House N Limits & Suzlon S88 Predicted Noise Levels - 68 Turbines

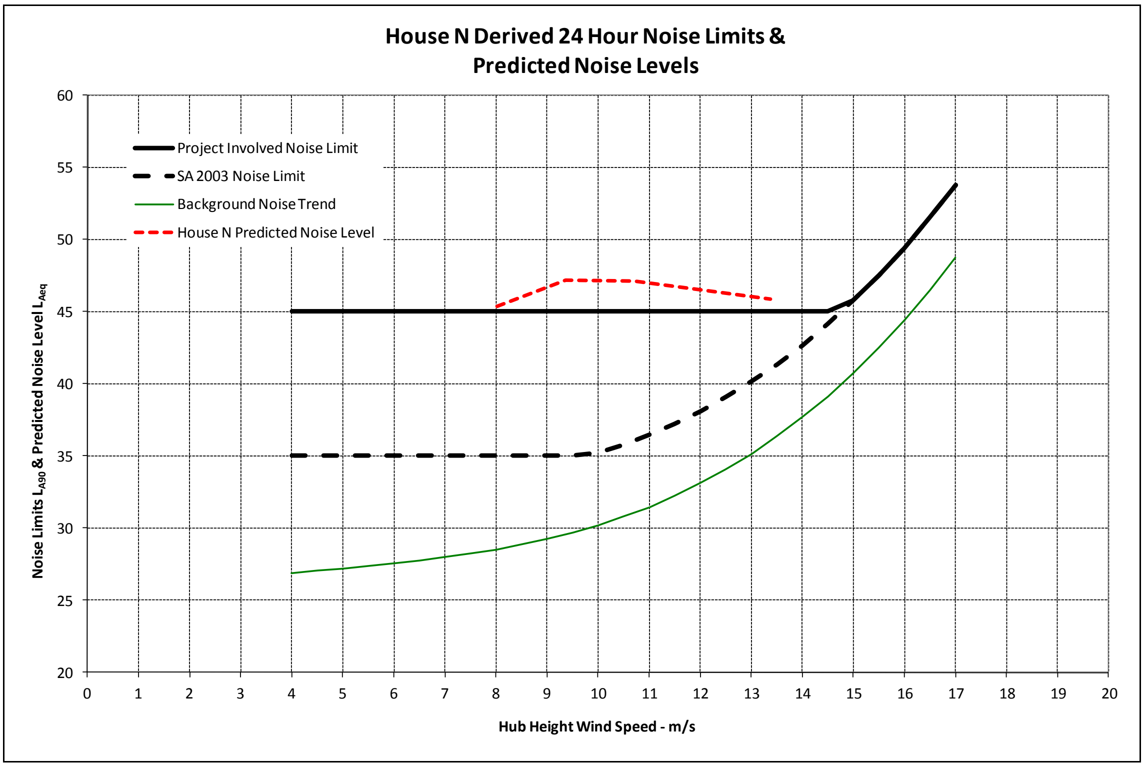

Figure I6: House N Limits & REpower 3.4M 104 Predicted Noise Levels - 67 Turbines

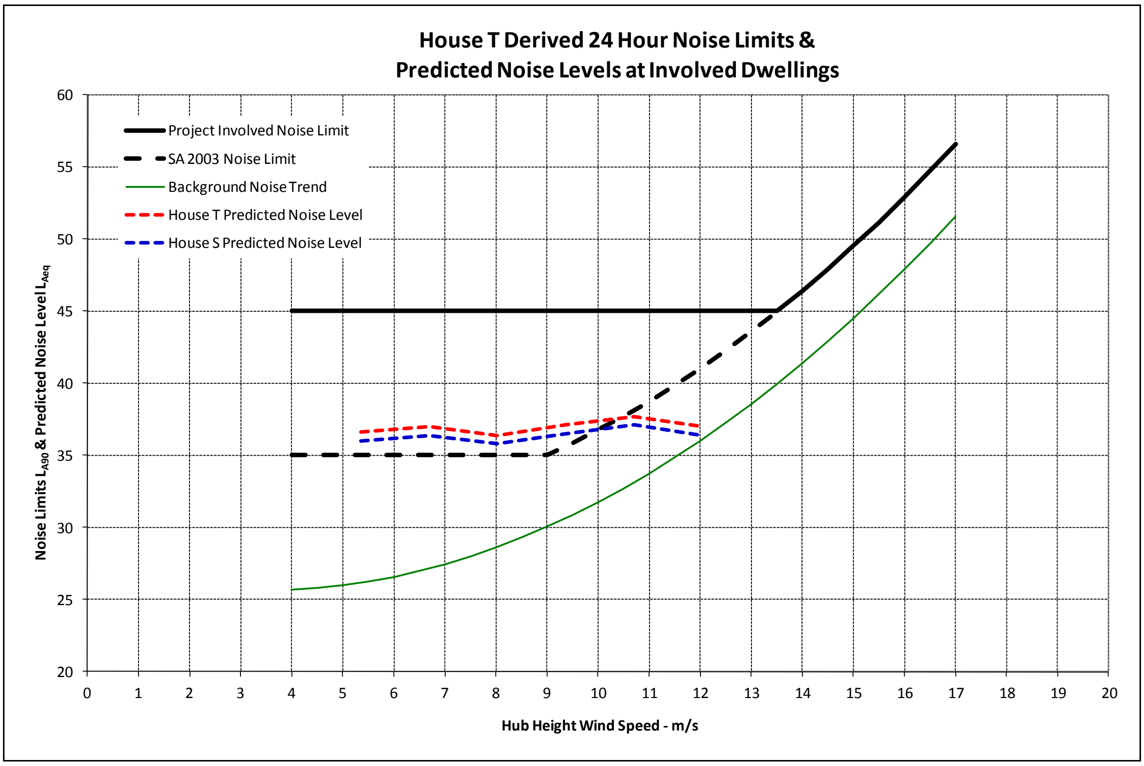

Figure I7: House T Limits & Suzlon S88 Predicted Noise Levels - 68 Turbines

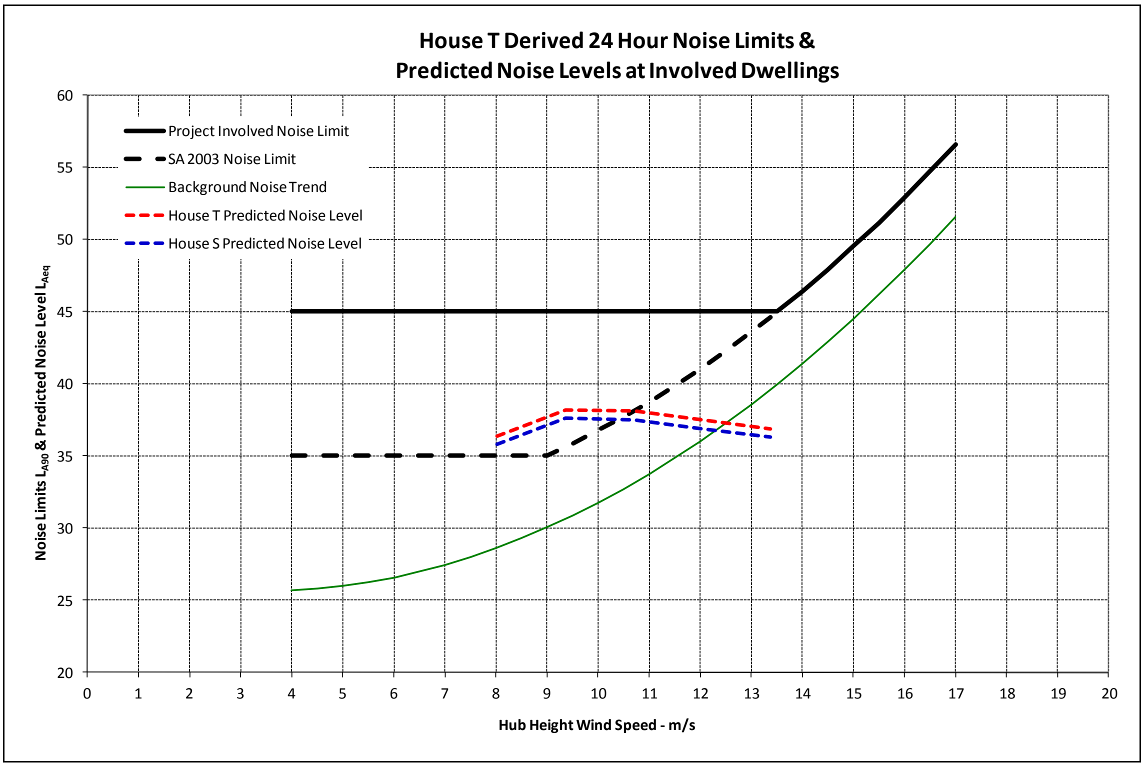

Figure I8: House T Limits & REpower 3.4M 104 Predicted Noise Levels - 67 Turbines

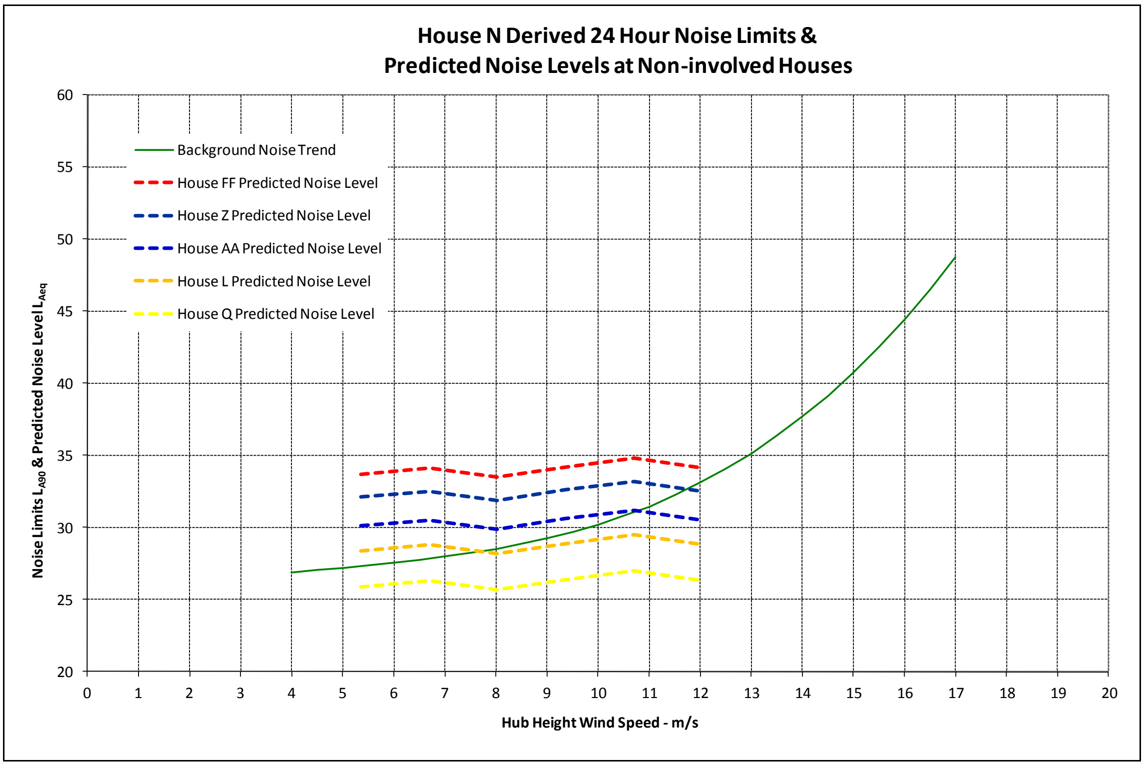

Figure I9: House N Derived Limits & Suzlon S88 Predicted Noise Levels at Sample Non-involved Houses - 68 Turbines

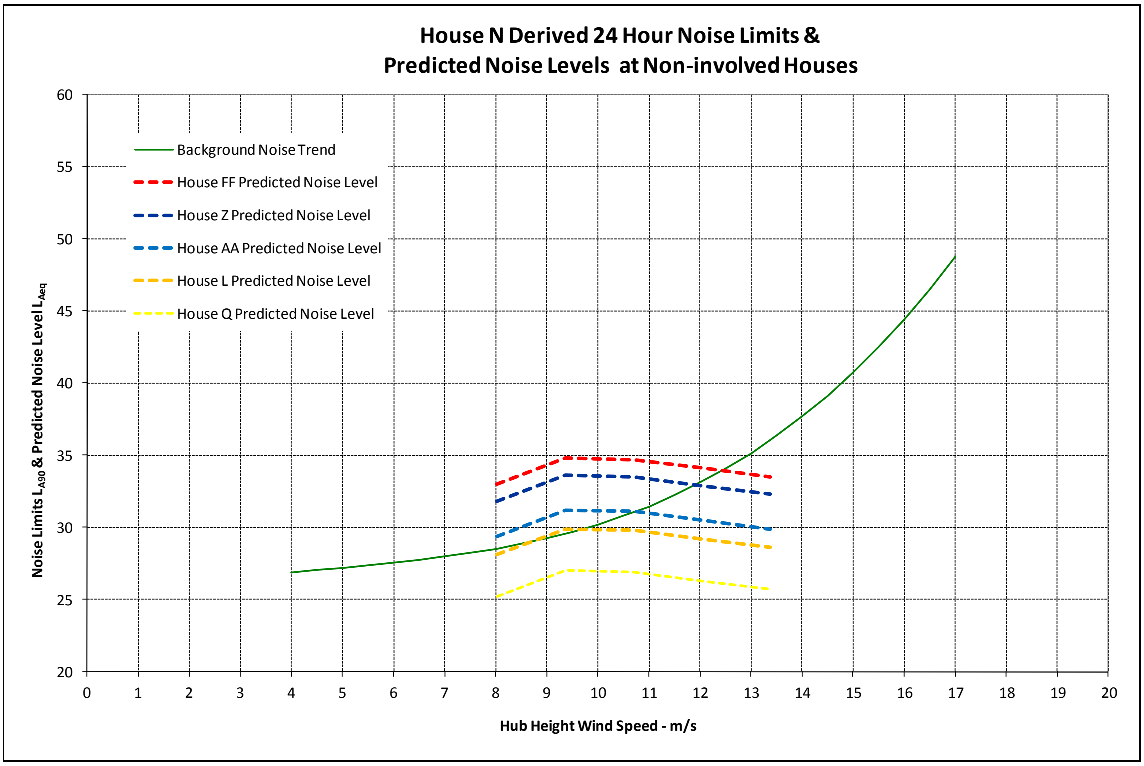

Figure I10: House N Derived Limits & REpower 3.4M 104 Predicted Noise Levels at Sample Non-involved Houses - 67 Turbines

APPENDIX J

CULLERIN RANGE WIND FARM DATA

Table J1
Turbine locations

Location	Easting (m)	Northing (m)	REpower model
R1a	719426	6147208	MM92
R2a	719013	6144645	MM92
R3	719548	6146849	MM92
R4	719501	6146626	MM92
R5	719453	6146397	MM82
R6	719428	6146170	MM82
R7	719512	6145924	MM92
R8	719515	6145674	MM82
R9	719128	6145680	MM82
R11	719565	6145212	MM82
R10	719596	6145437	MM82
R12	719248	6145112	MM82
R13	719611	6144907	MM82
R14	719636	6144668	MM92
R15	719426	6144510	MM92

* Source: Proponent 18 June 2010

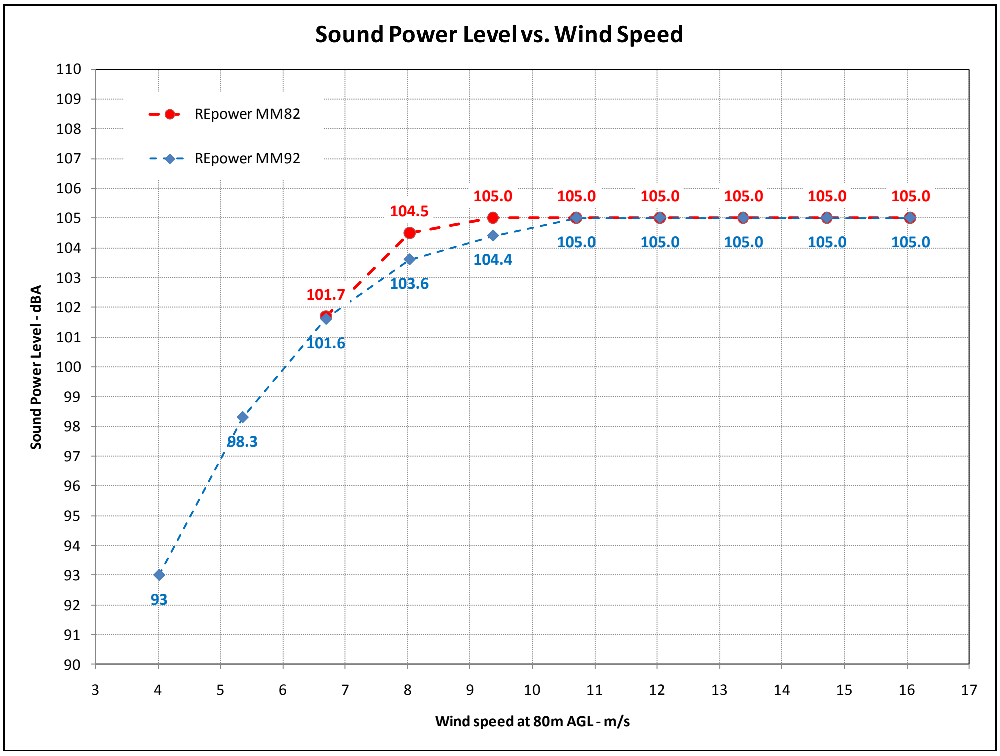

Figure J1: A-weighted sound power level spectrum REpower MM82[16] and MM92[17]

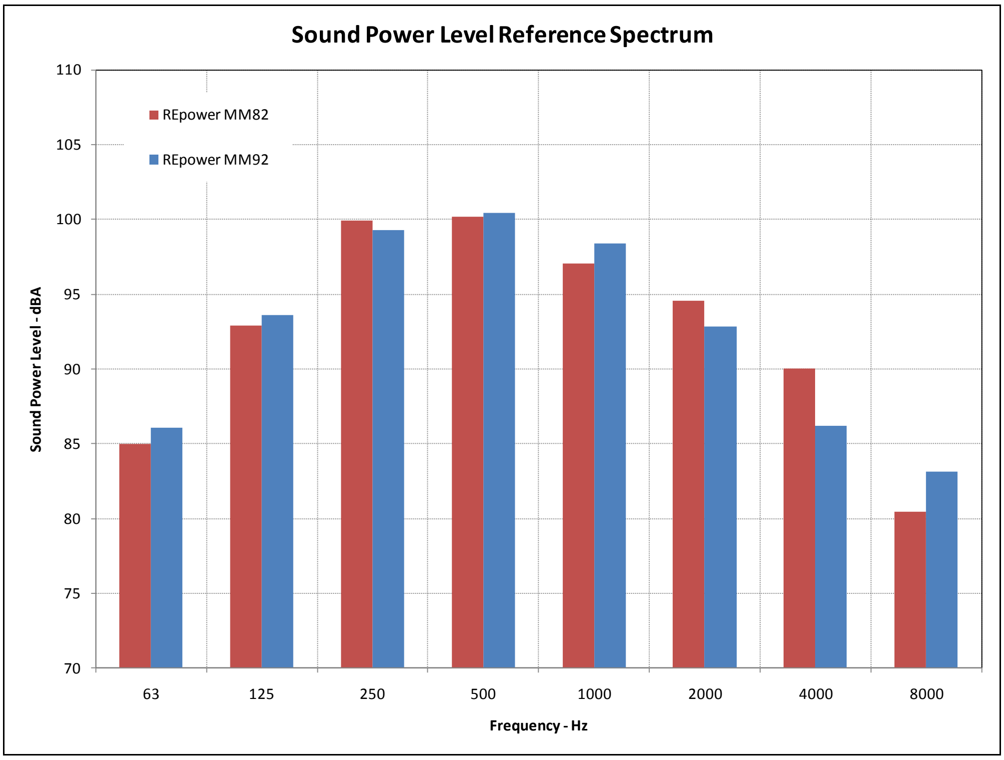

Figure J2: A-weighted sound power level spectrum REpower MM82 & MM92[18]

[16] Derived from document Wind Test WT 5482/06
[17] Reference document from REpower Systems SD-2.2-WT.SL-1-1C-EN
[18] Derived from Wind Test document SE06010B2

APPENDIX K

PREDICTED CUMULATIVE OPERATIONAL WIND FARM NOISE CONTOURS

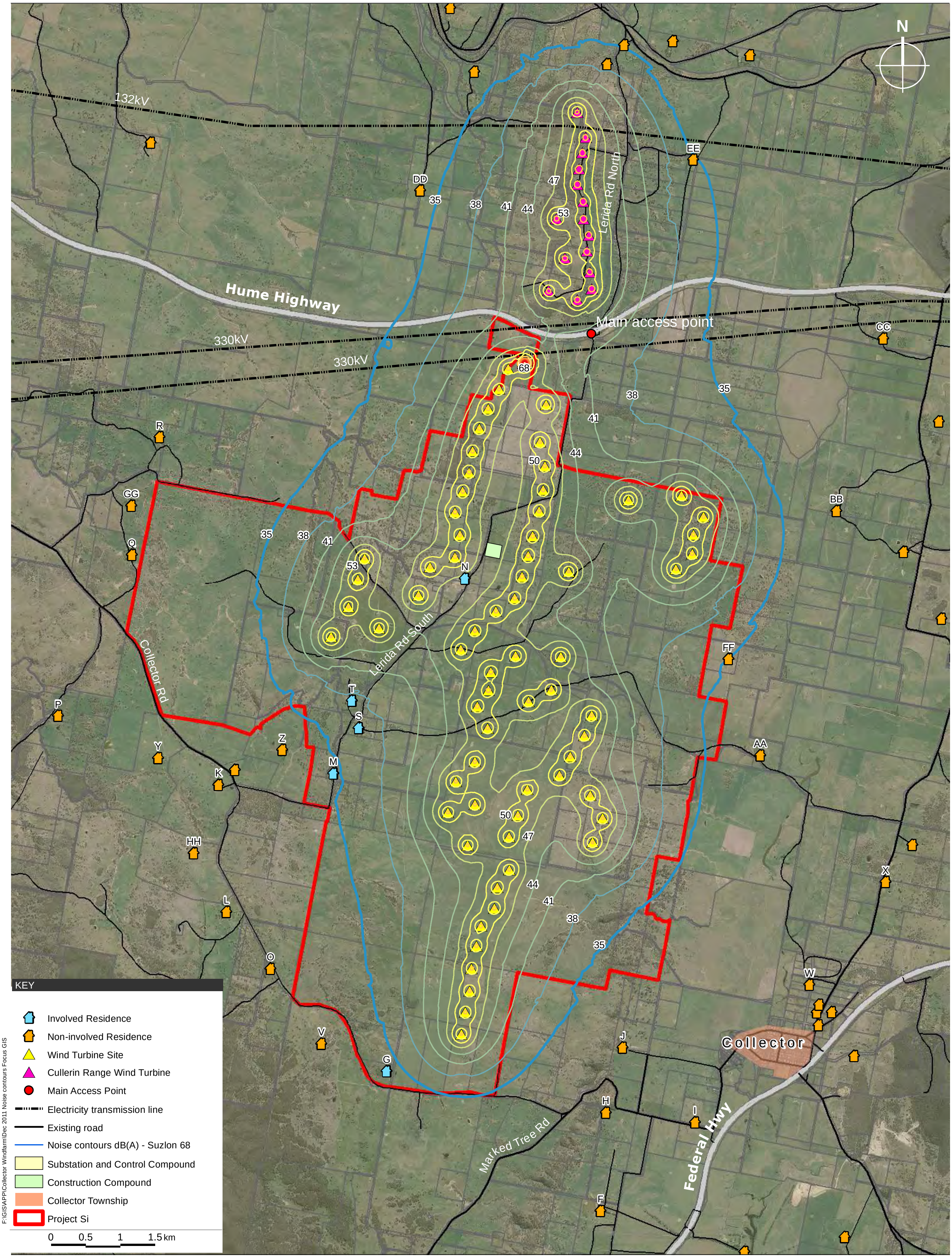

Figure K-1
Suzlon 68 Turbine Layout +
Substation Noise Levels +
Cullerin Range Wind Farm

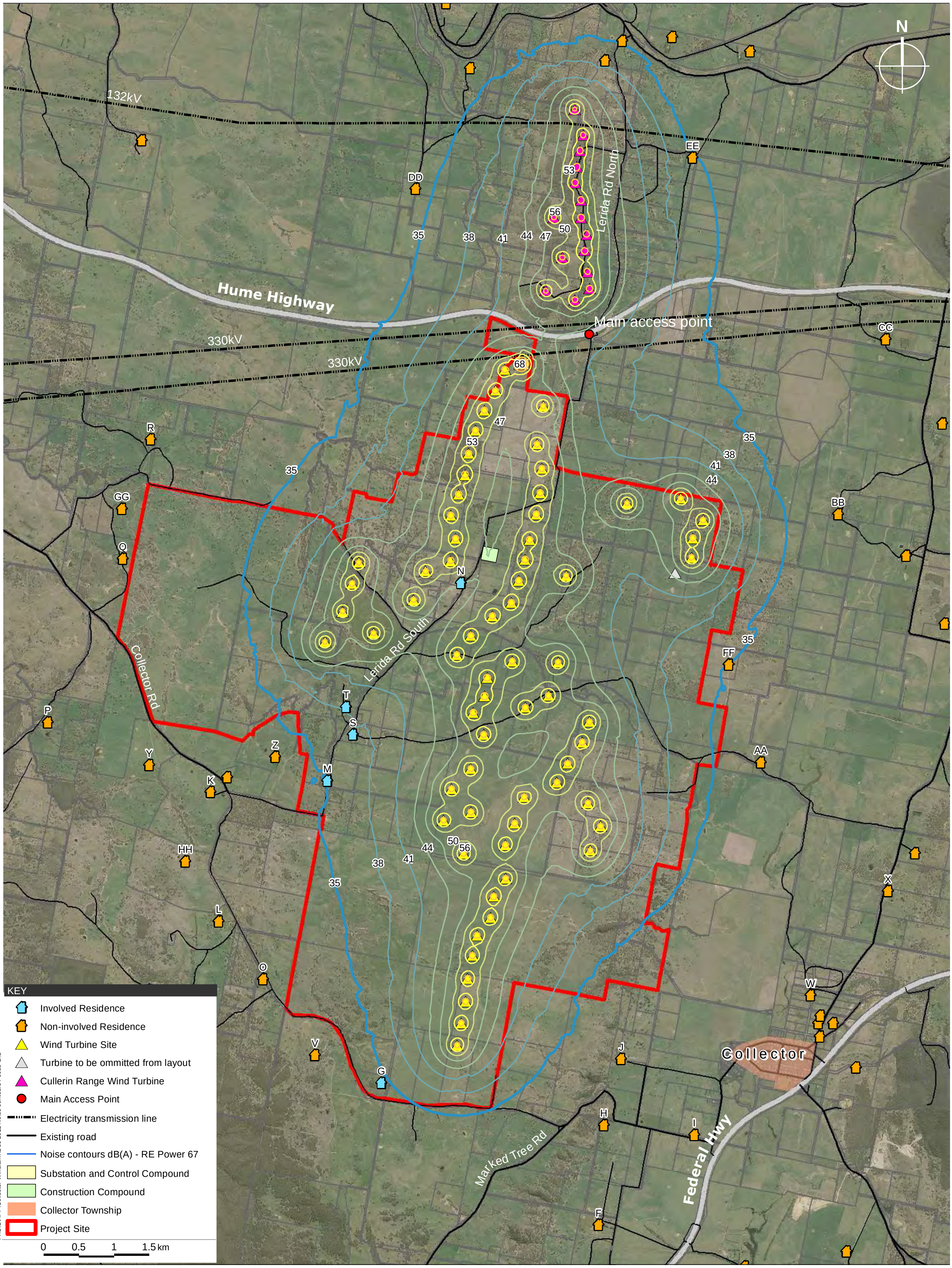

Figure K-2
RE Power 67 Turbine Layout +
Substation Noise Levels +
Cullerin Range Wind Farm

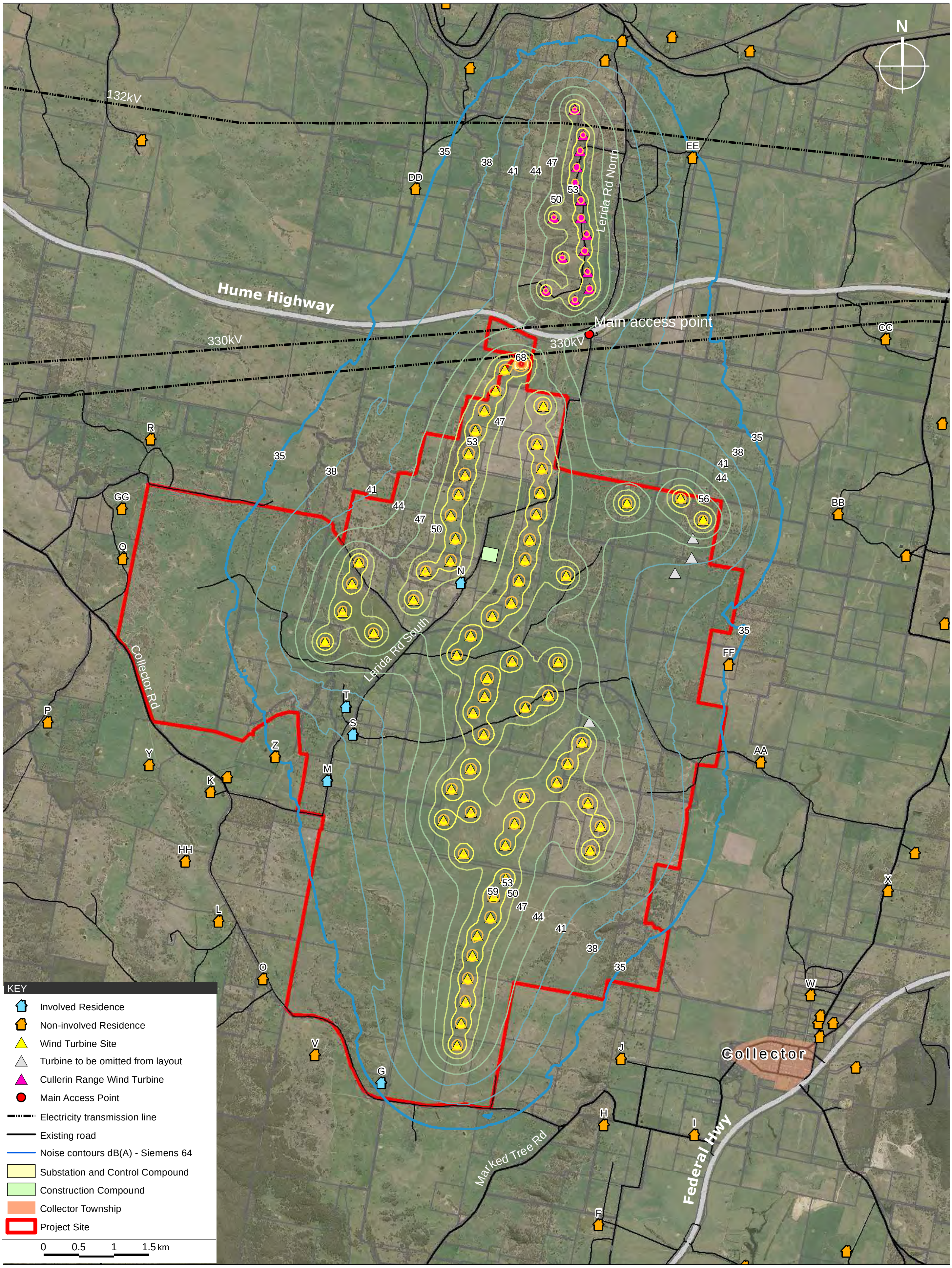

Figure K-3
Siemes 64 Turbine Layout +
Substation Noise Levels +
Cullerin Range Wind Farm