

**To:** Hepburn Wind

**Attention:** Simon Holmes à Court

**Cc:** Tracy Anthony

**From:** Christophe Delaire

**Date:** 8 March 2011

**Page 1 of:** 28

**Subject:** HEPBURN WIND FARM – BACKGROUND NOISE MONITORING RESULTS

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Simon,

Pre-construction background noise monitoring was undertaken between 23 December 2010 and 15 February 2011 in the vicinity of the Hepburn Wind Farm. Table 1 lists the thirteen (13) sites selected for background noise monitoring.

**Table 1**  
**Background monitoring sites**

House	Monitoring period
H2	23 December 2010 – 6 January 2011
H5(rep)	23 December 2010 – 6 January 2011
H9	23 December 2010 – 6 January 2011
H10	23 December 2010 – 6 January 2011
H11(rep)	6 January – 11 February 2011
H12	23 December 2010 – 6 January 2011
H13(rep)	6 January – 11 February 2011
H14	23 December 2010 – 6 January 2011
H16	23 December 2010 – 6 January 2011
H17	6 January – 11 February 2011
H19	6 January – 15 February 2011
H31(rep)	6 January – 11 February 2011
H1872*	6 – 20 January 2011

HXX (rep) Noise monitoring at location deemed representative of the noise environment at House XX  
 \* 1872 Ballan-Daylesford Road

Background noise monitoring locations are presented in Figure 1.

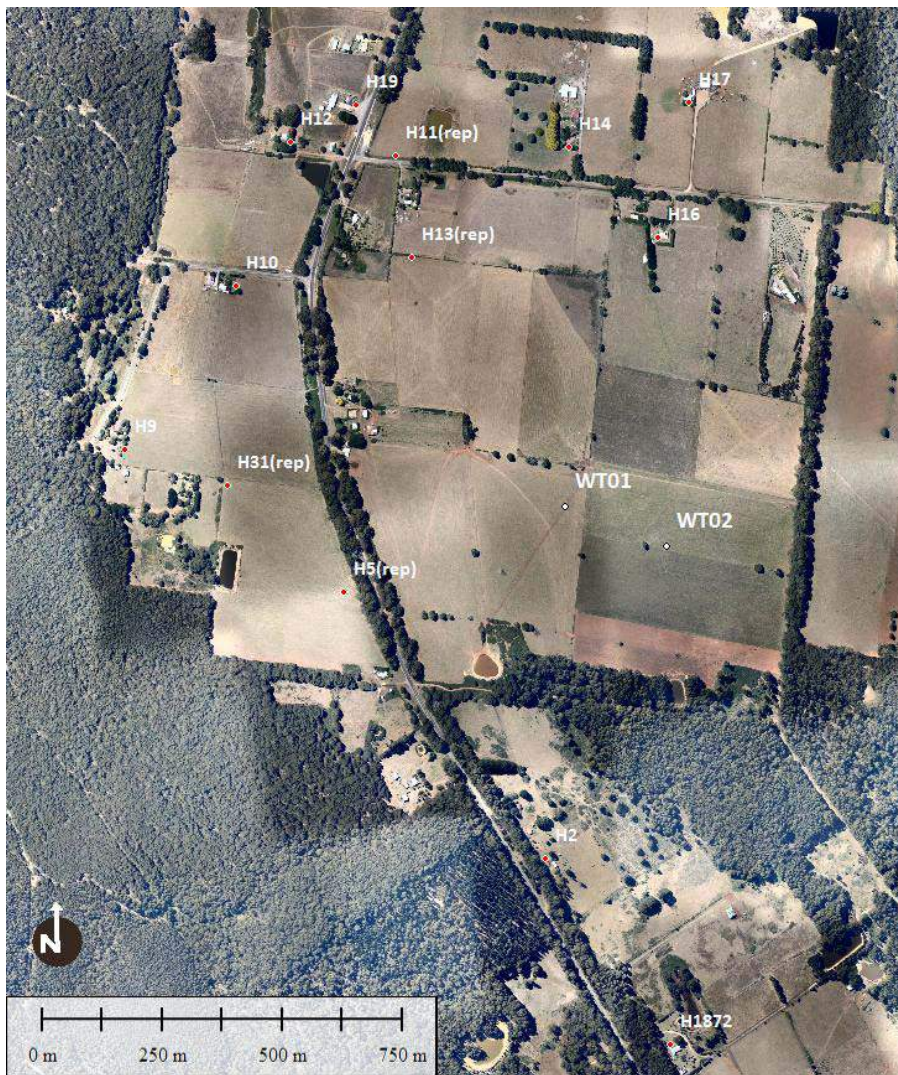


Figure 1: Background noise monitoring locations

Simultaneous wind speed monitoring was undertaken at a 10m high met mast within the wind farm site.

There were no construction activity at the wind farm site between 23 December 2010 and 9 January 2011, inclusive. From 10 January 2011, a diary of construction noise activities was kept by the REpower site manager. Pre-construction wind and noise level data collected when construction activities occurred have been removed from our analysis.

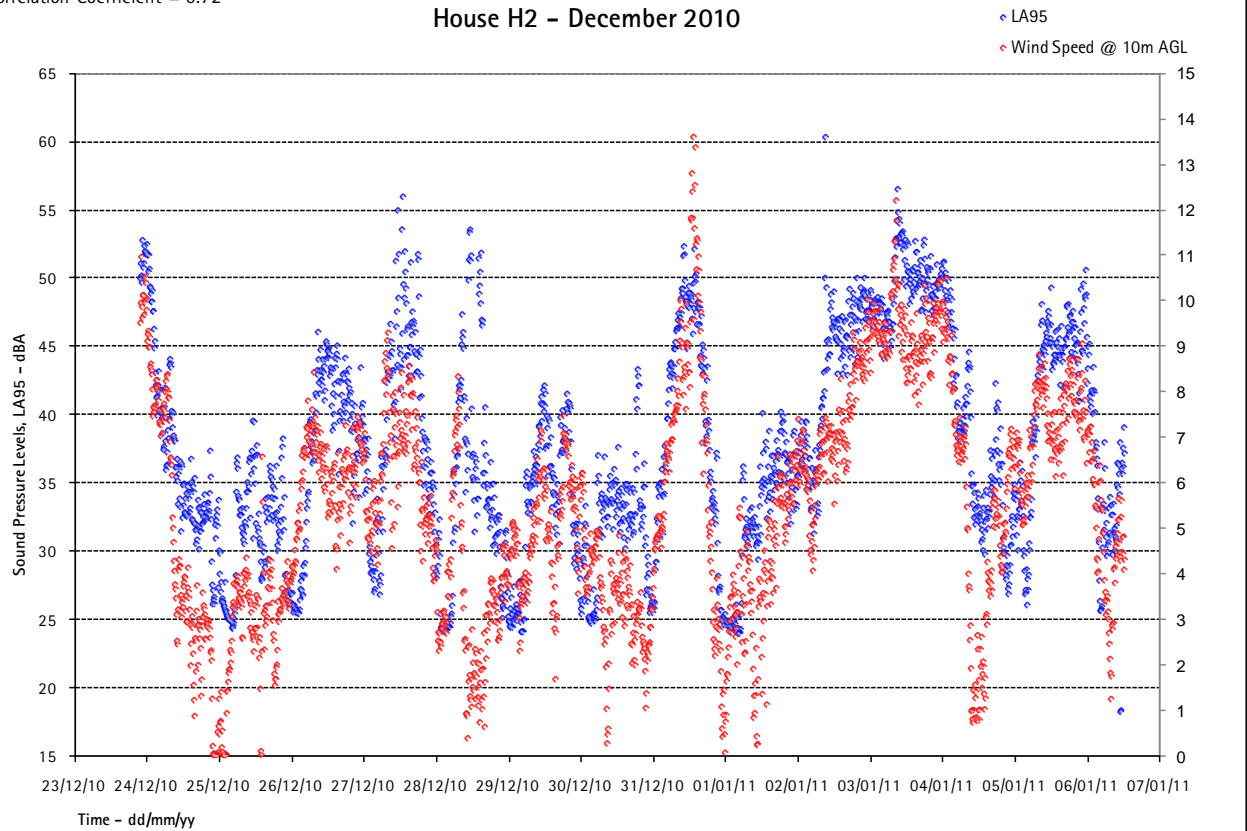
Also, based on rain data from the Bureau of Meteorology Ballarat weather station, pre-construction wind and noise level data has been removed where it is likely to have been affected by rain.

Both night-time and 24 hour noise limits have been derived by correlating pre-construction background noise data against 10m AGL wind speed for night-time periods (2200-0700hrs), as well as 24 hour periods, at all monitored positions, in accordance with New Zealand Standard 6808:1998 – *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS6808:1998).

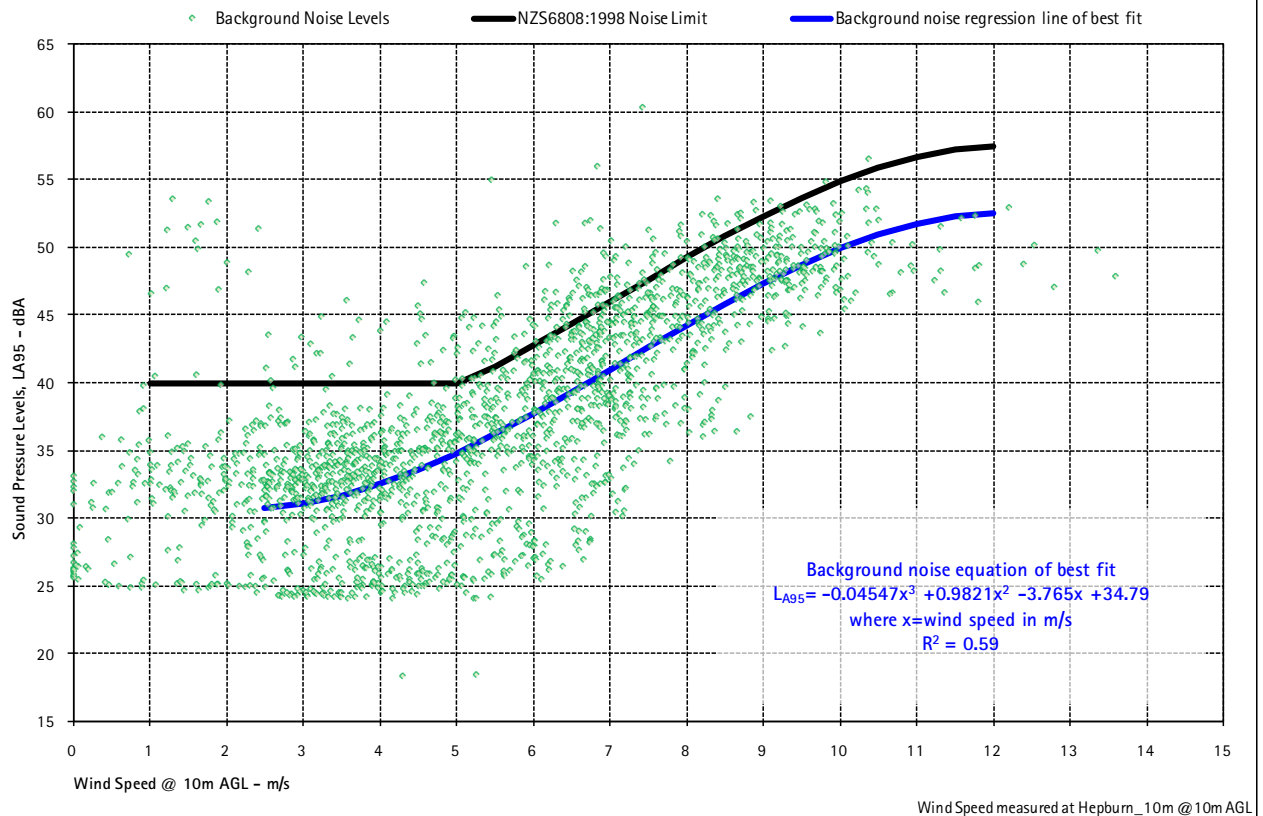
Presented below are the graphs used to derive the noise limits for each of the monitoring locations. The solid blue line represents the background noise line of best fit and the solid black line represents the noise limits derived in accordance with NZS6808:1998. The equation of the line of best fit is noted on each graph as is the correlation coefficient.

(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.72

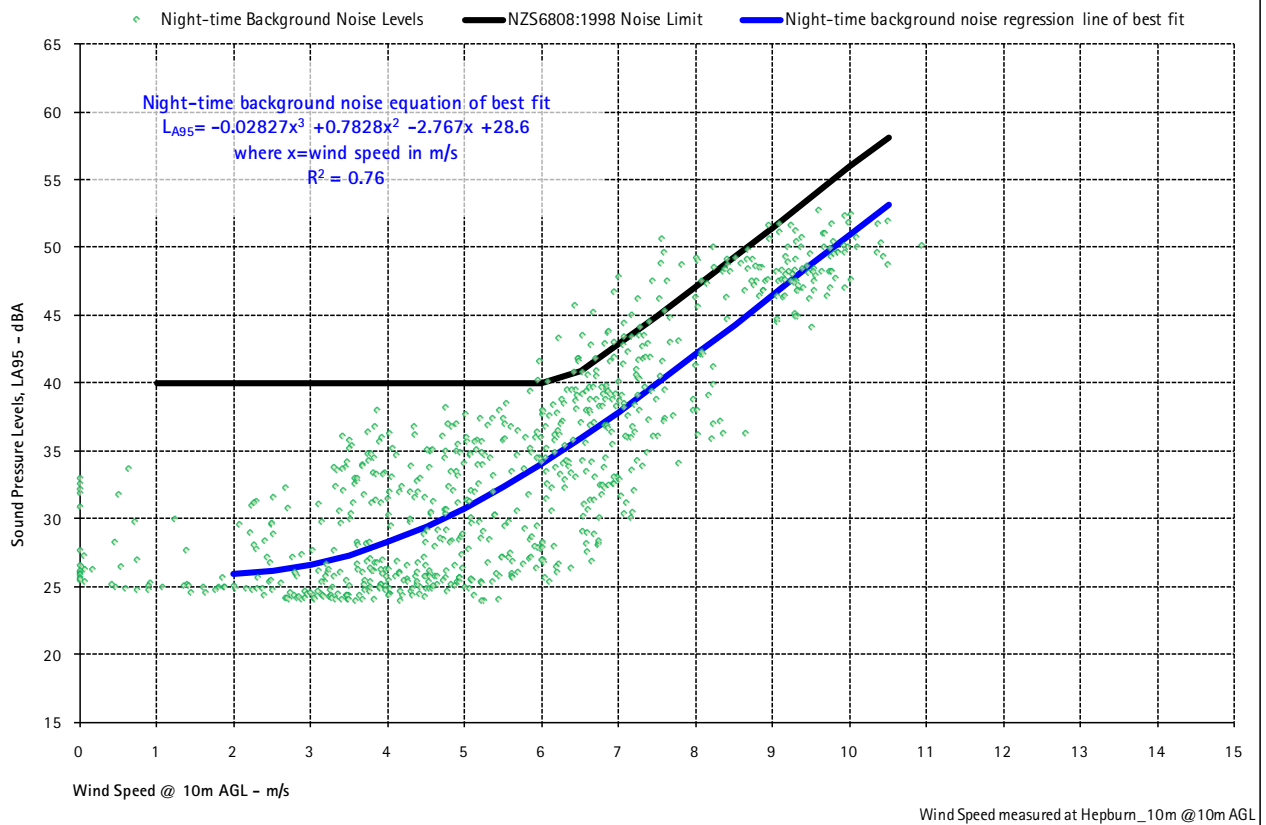
Background Noise Levels and Wind Speeds vs. Time  
House H2 - December 2010

(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H2 - December 2010

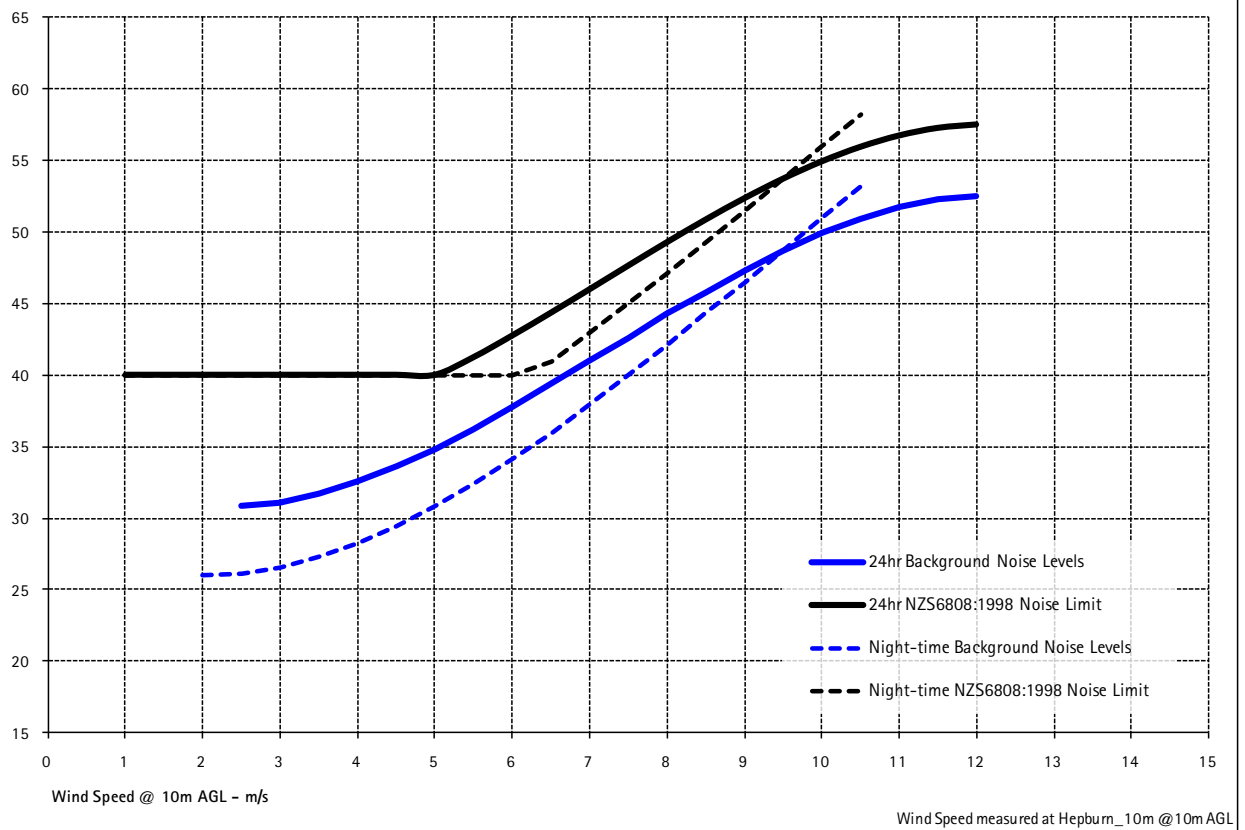
(23.12.2010 - 06.01.2011)

### Night-time Background Noise Levels vs. Wind Speeds House H2 - December 2010



(23.12.2010 - 06.01.2011)

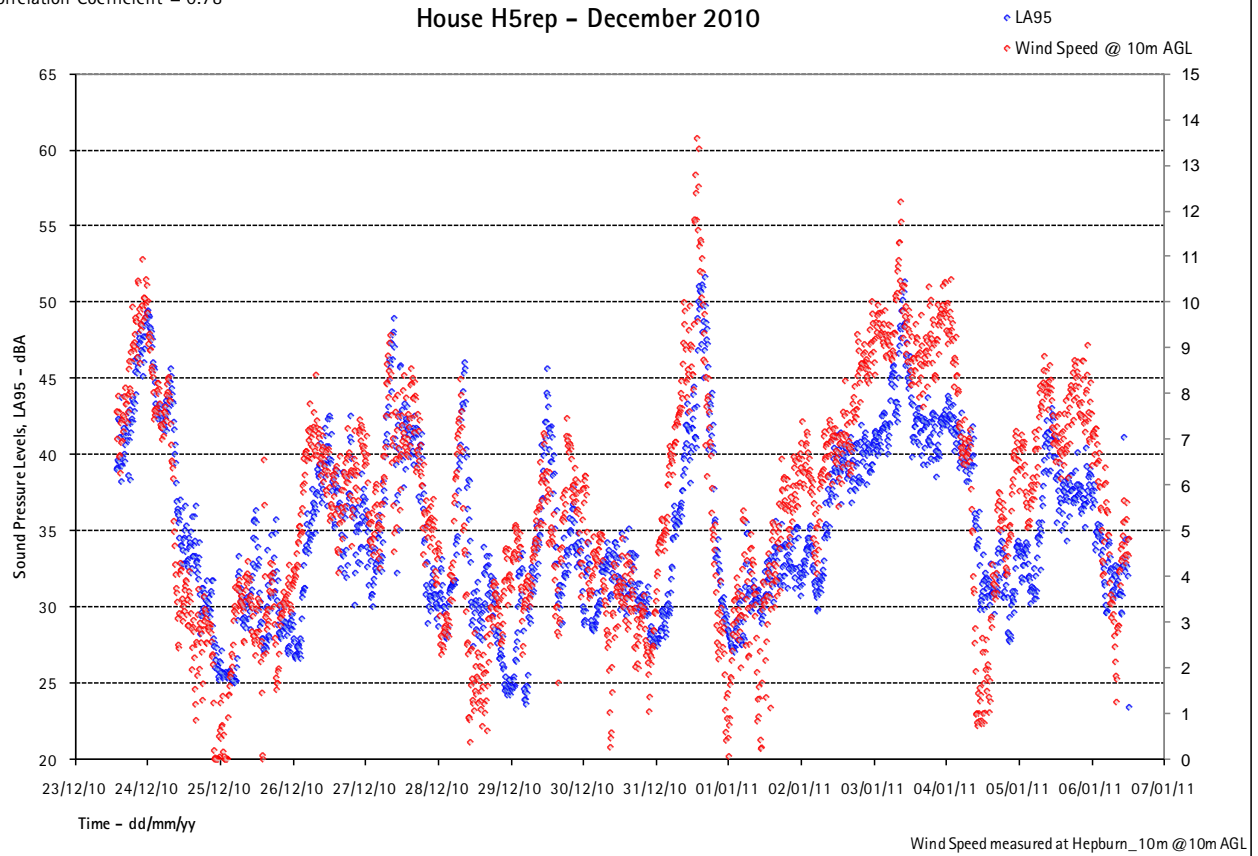
### Noise Limits House H2 - December 2010



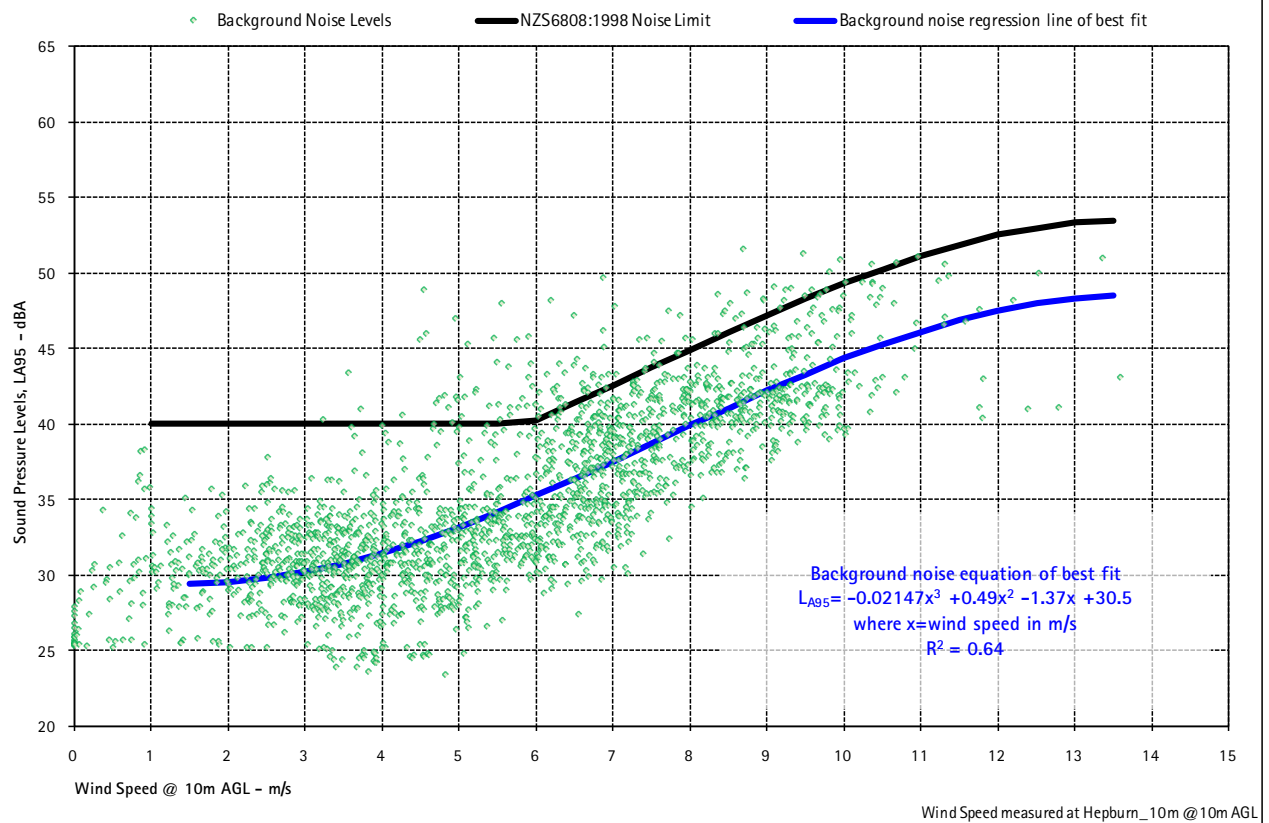


(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.78

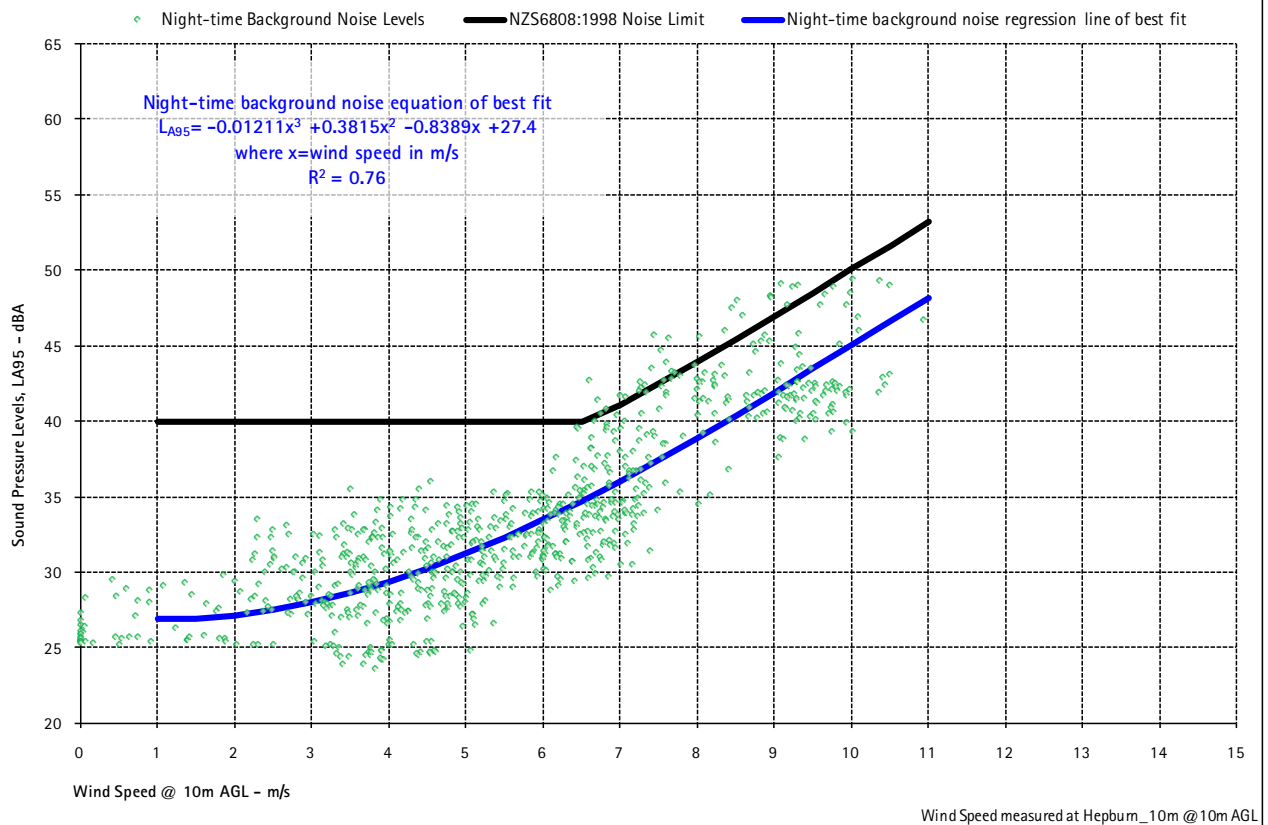
Background Noise Levels and Wind Speeds vs. Time  
House H5rep - December 2010

(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H5rep - December 2010

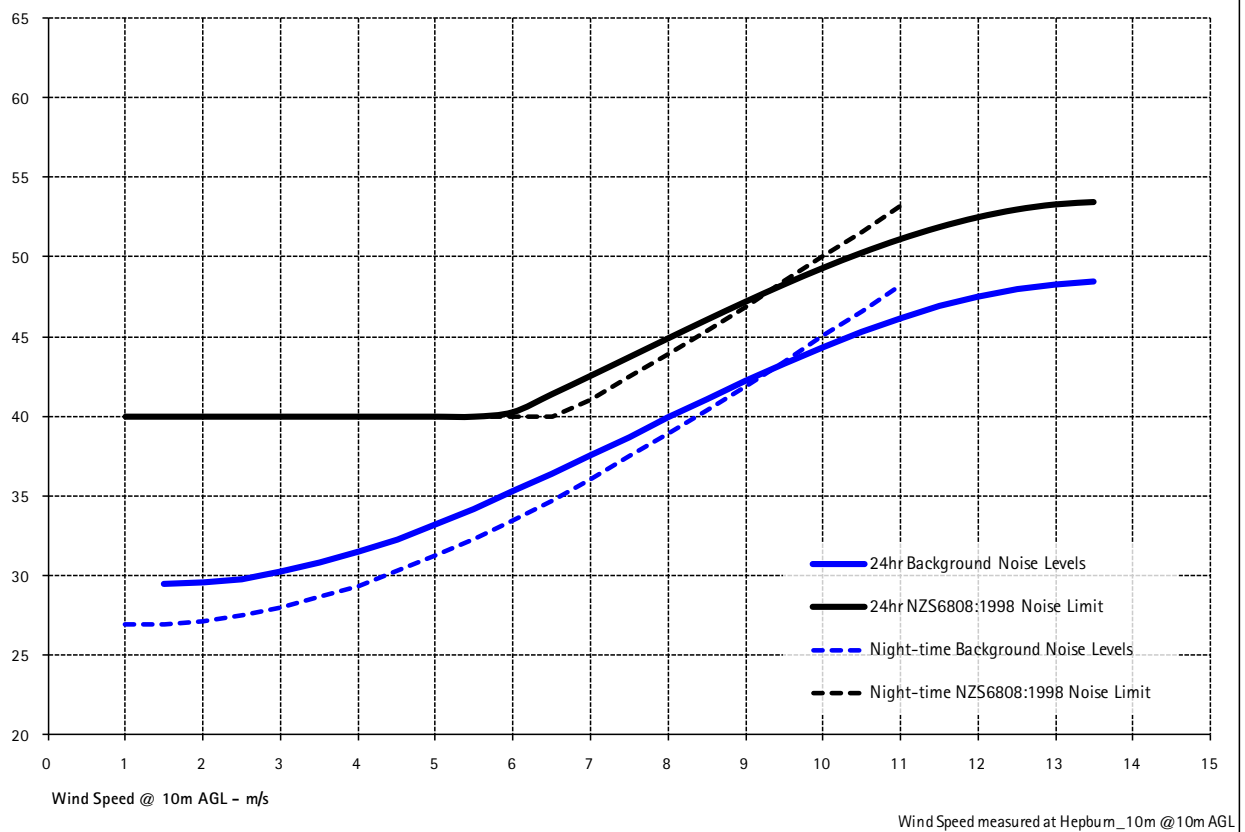
(23.12.2010 - 06.01.2011)

### Night-time Background Noise Levels vs. Wind Speed House H5rep - December 2010



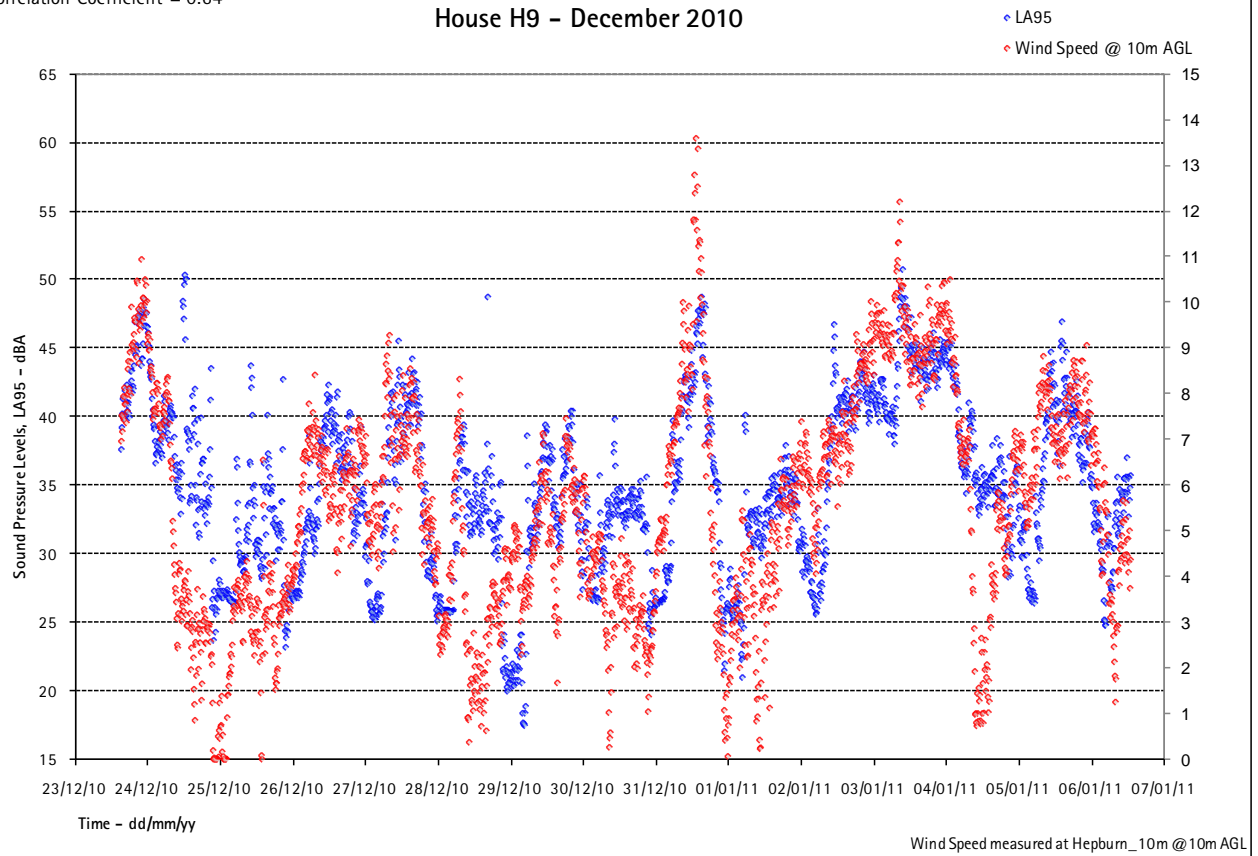
(23.12.2010 - 06.01.2011)

### Noise Limits House H5rep - December 2010

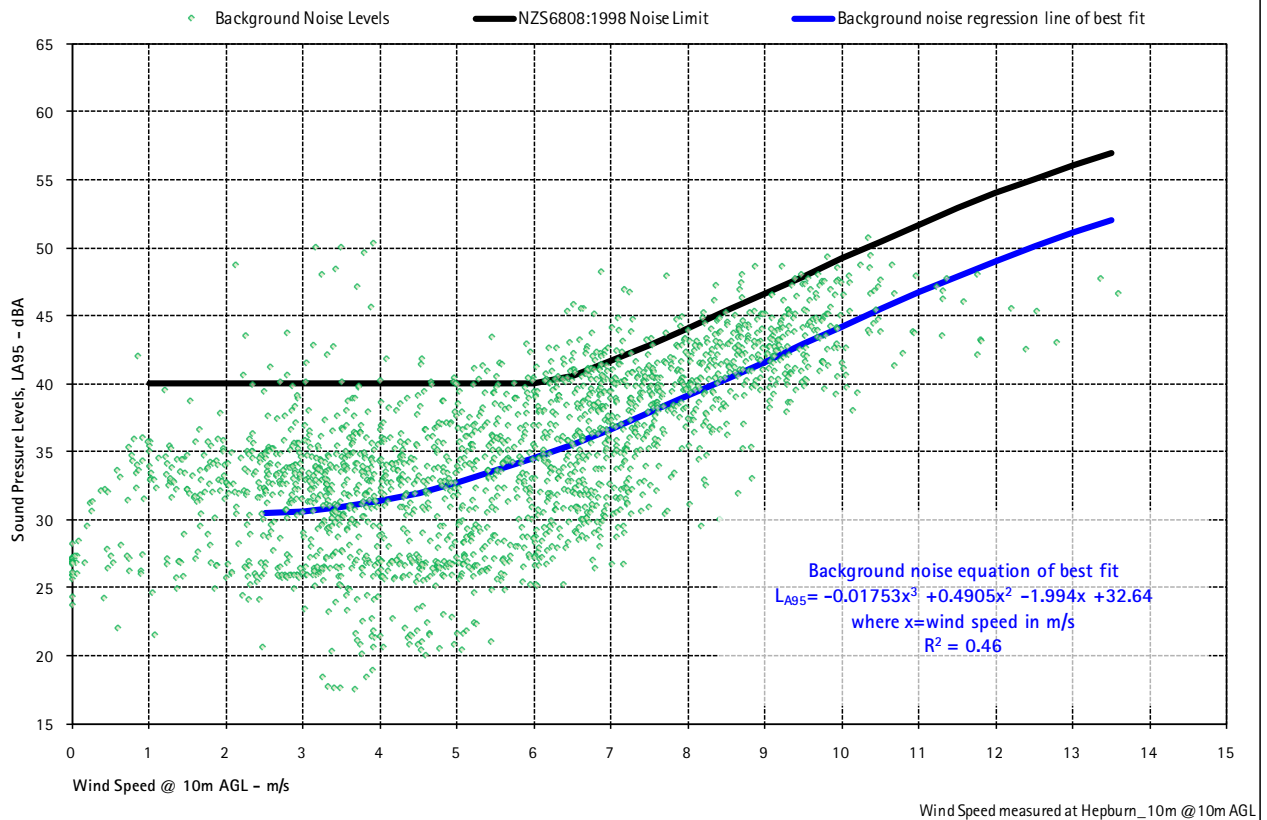


(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.64

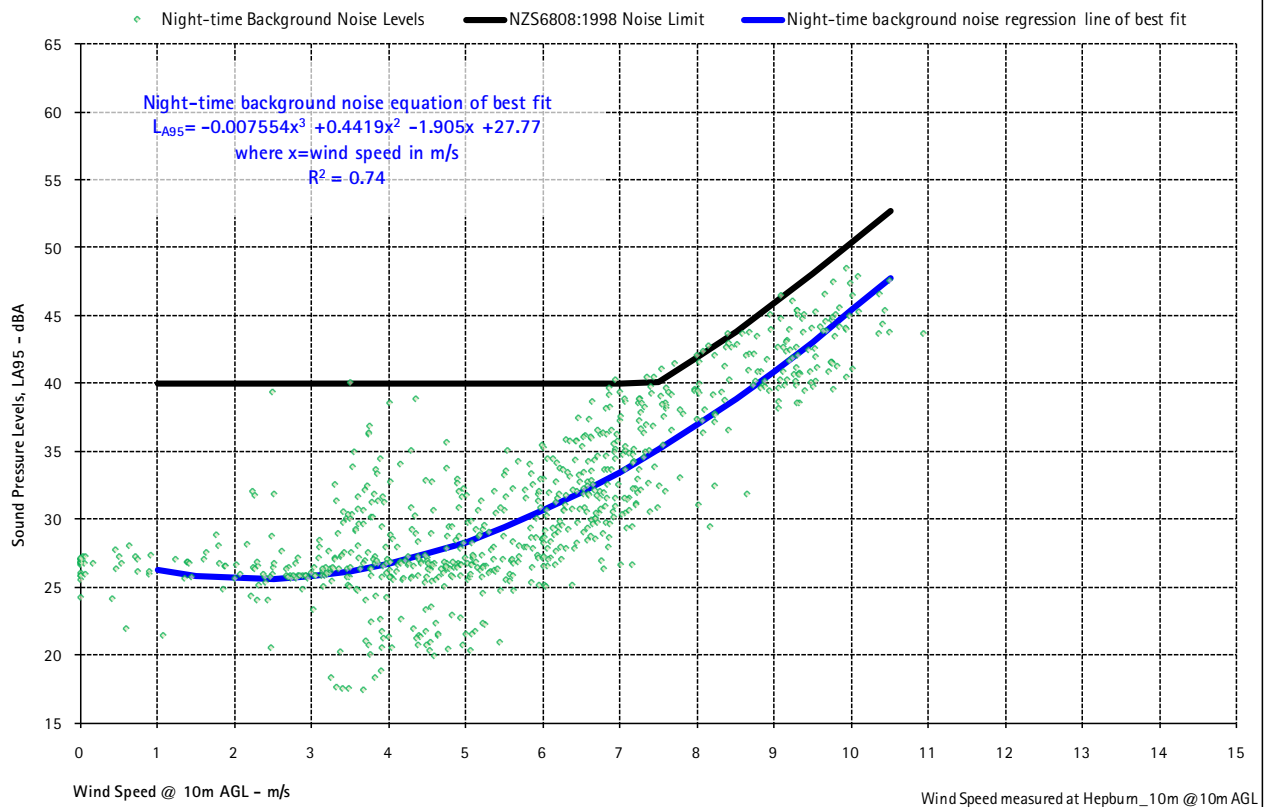
Background Noise Levels and Wind Speeds vs. Time  
House H9 - December 2010

(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H9 - December 2010

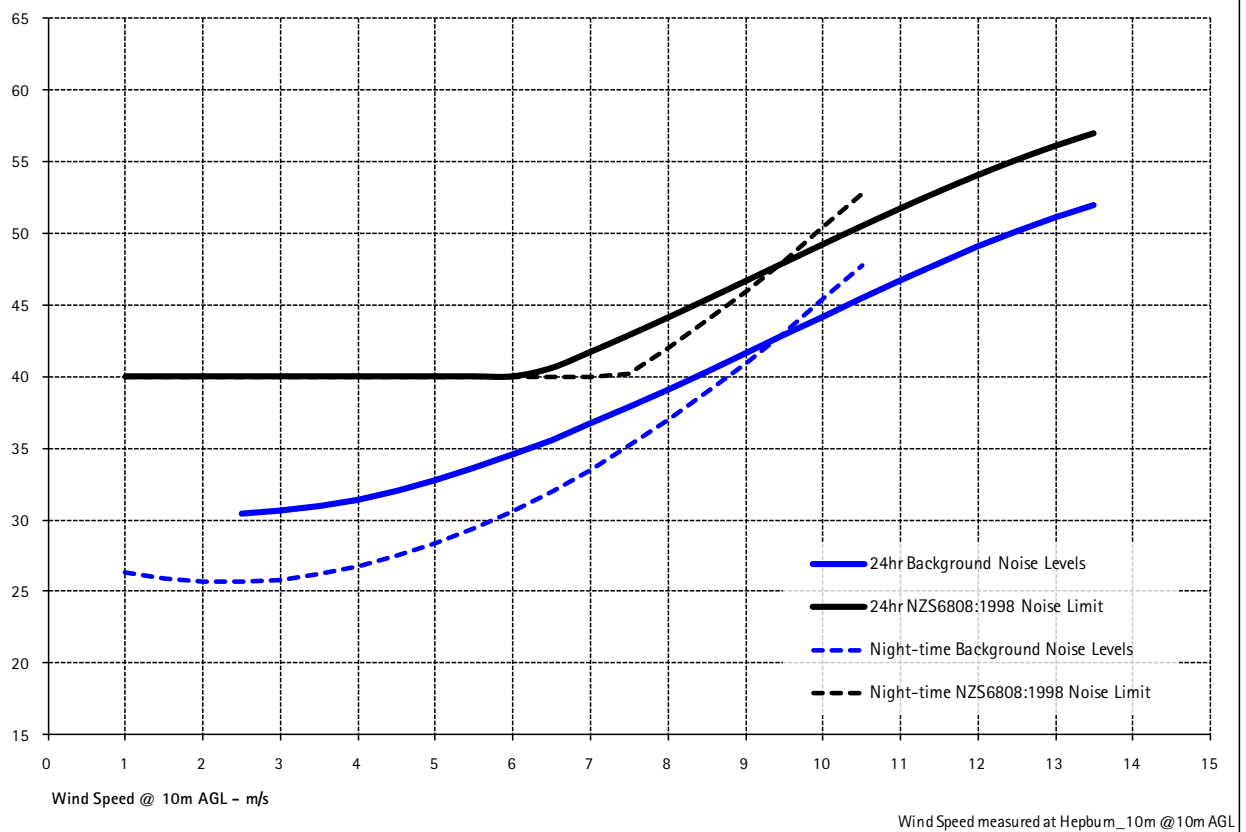
(23.12.2010 - 06.01.2011)

### Night-time Background Noise Levels vs. Wind Speeds House H9 - December 2010



(23.12.2010 - 06.01.2011)

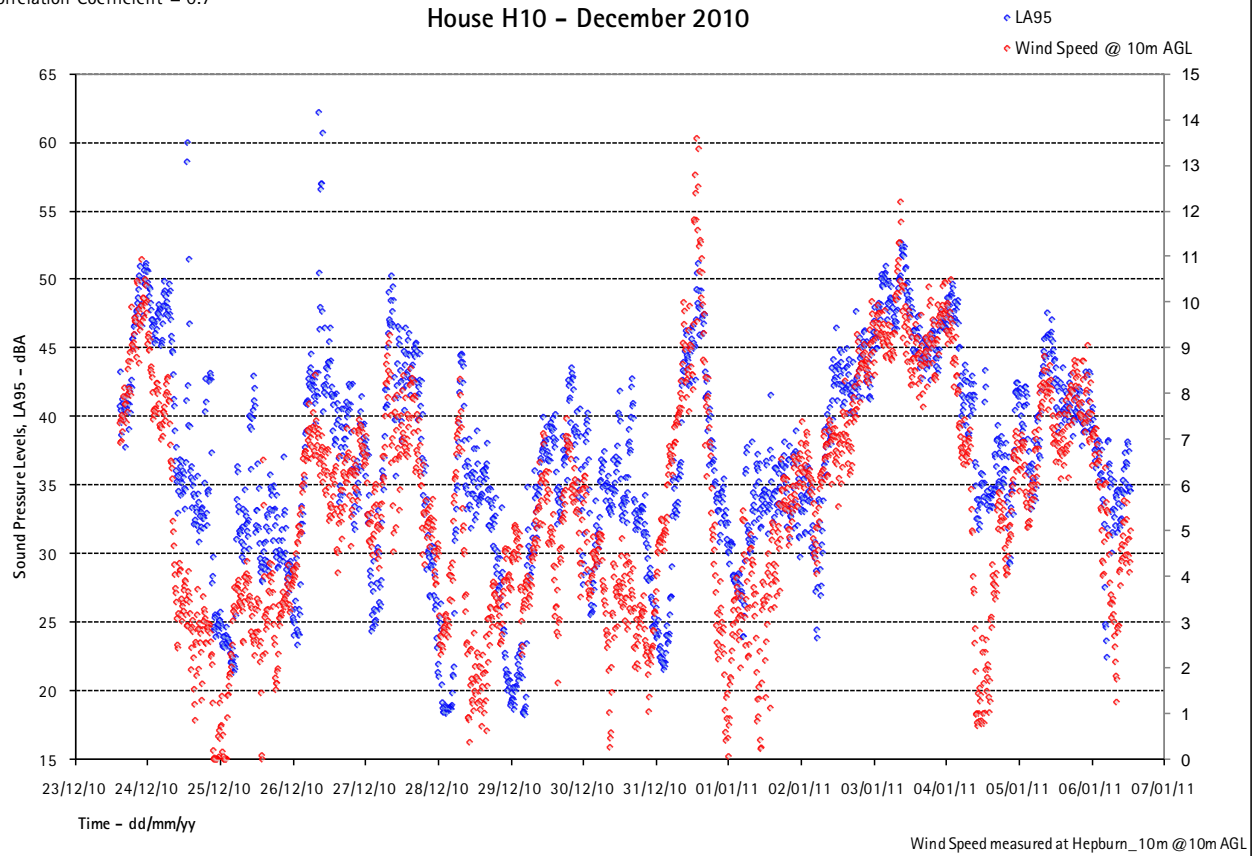
### Noise Limits House H9 - December 2010



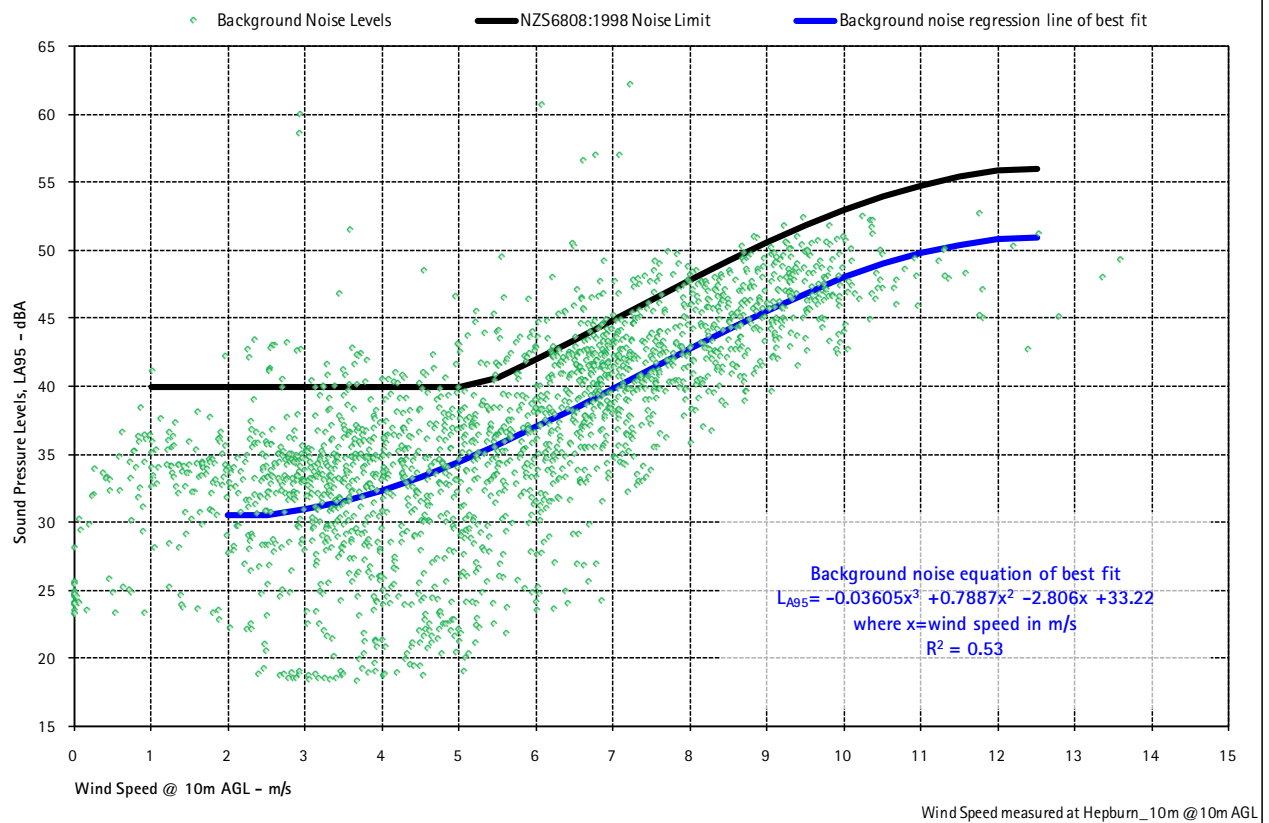


(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.7

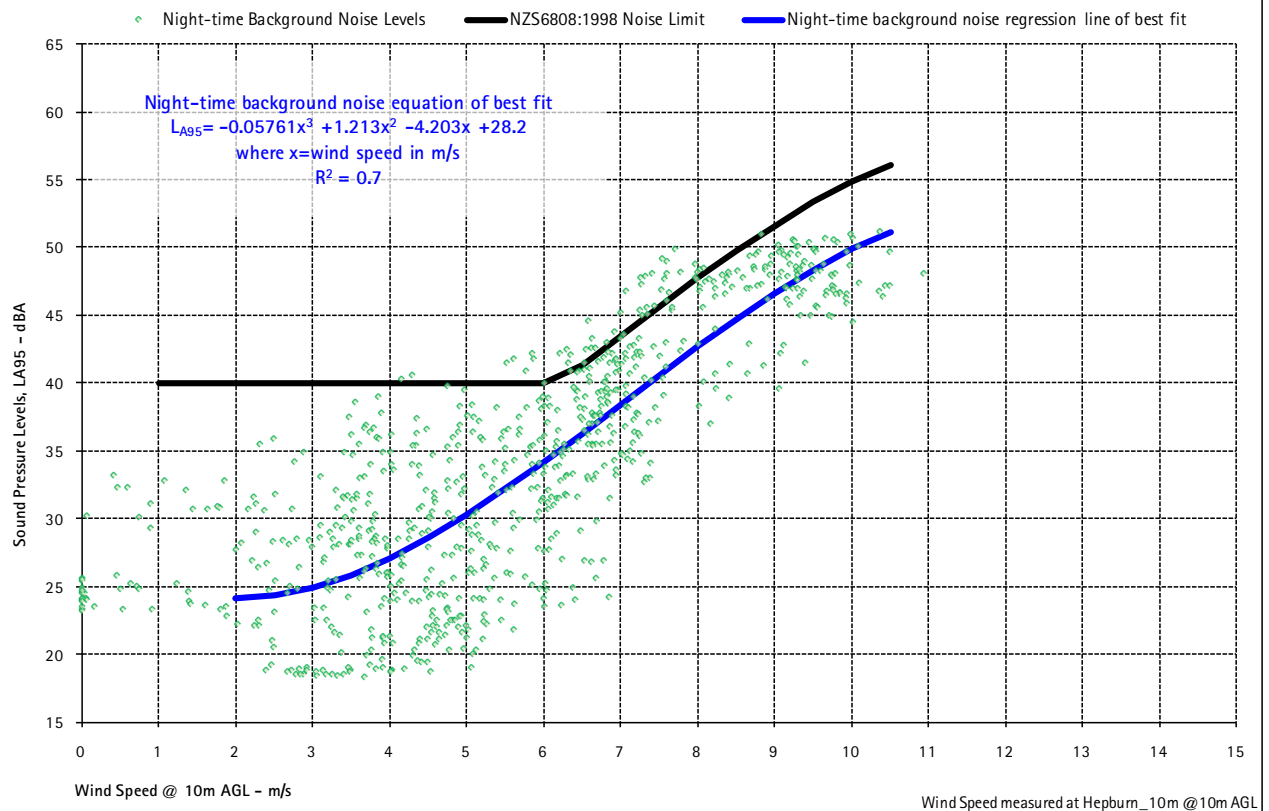
Background Noise Levels and Wind Speeds vs. Time  
House H10 - December 2010

(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H10 - December 2010

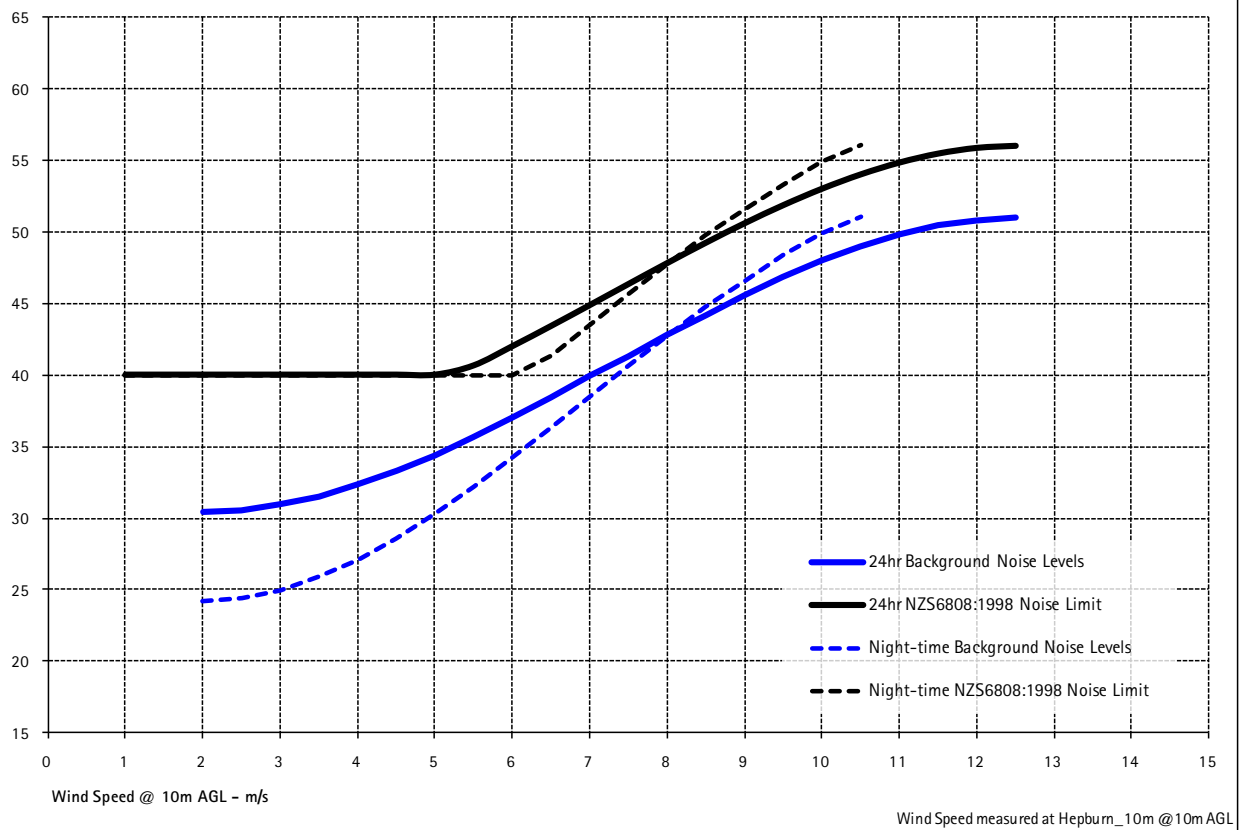
(23.12.2010 - 06.01.2011)

### Night-time Background Noise Levels vs. Wind Speed House H10 - December 2010



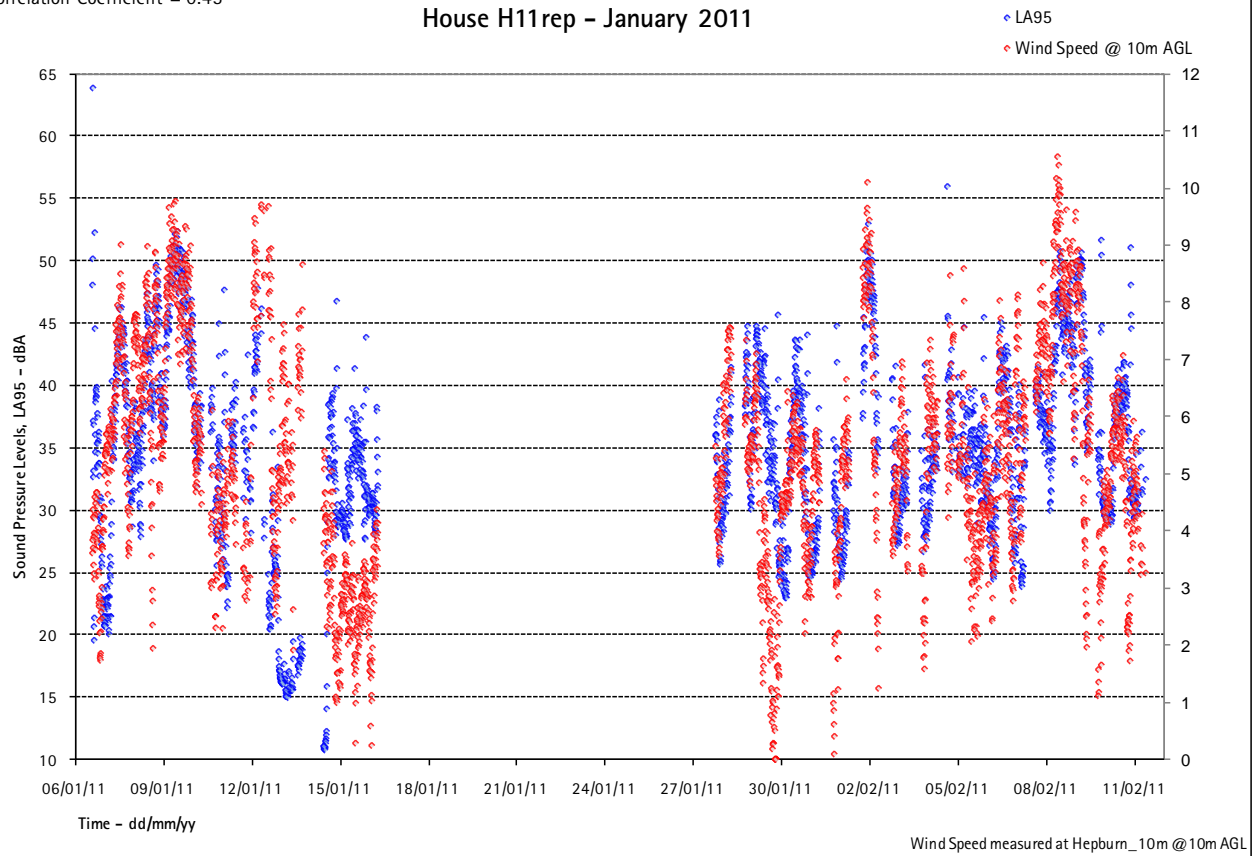
(23.12.2010 - 06.01.2011)

### Noise Limits House H10 - December 2010

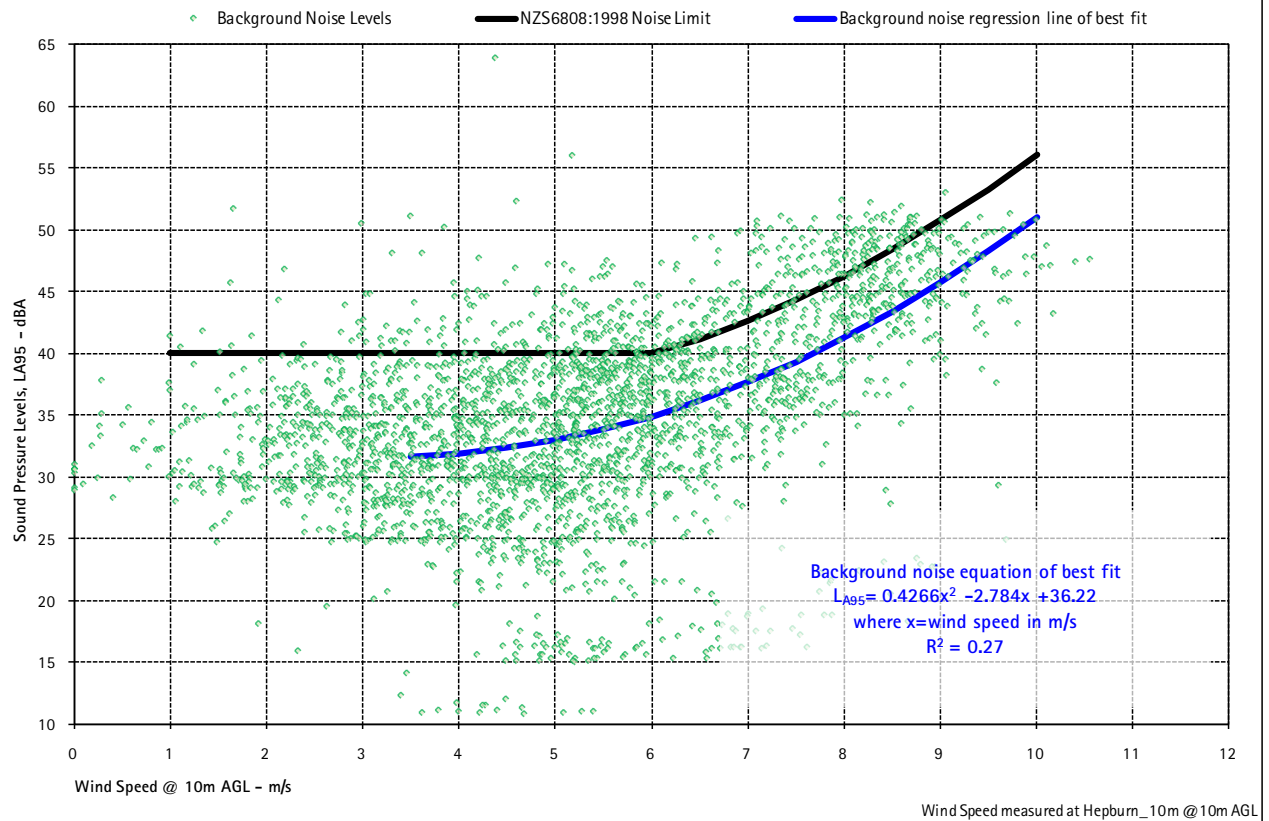


(06.01.2011 - 11.02.2011)

Correlation Coefficient = 0.45

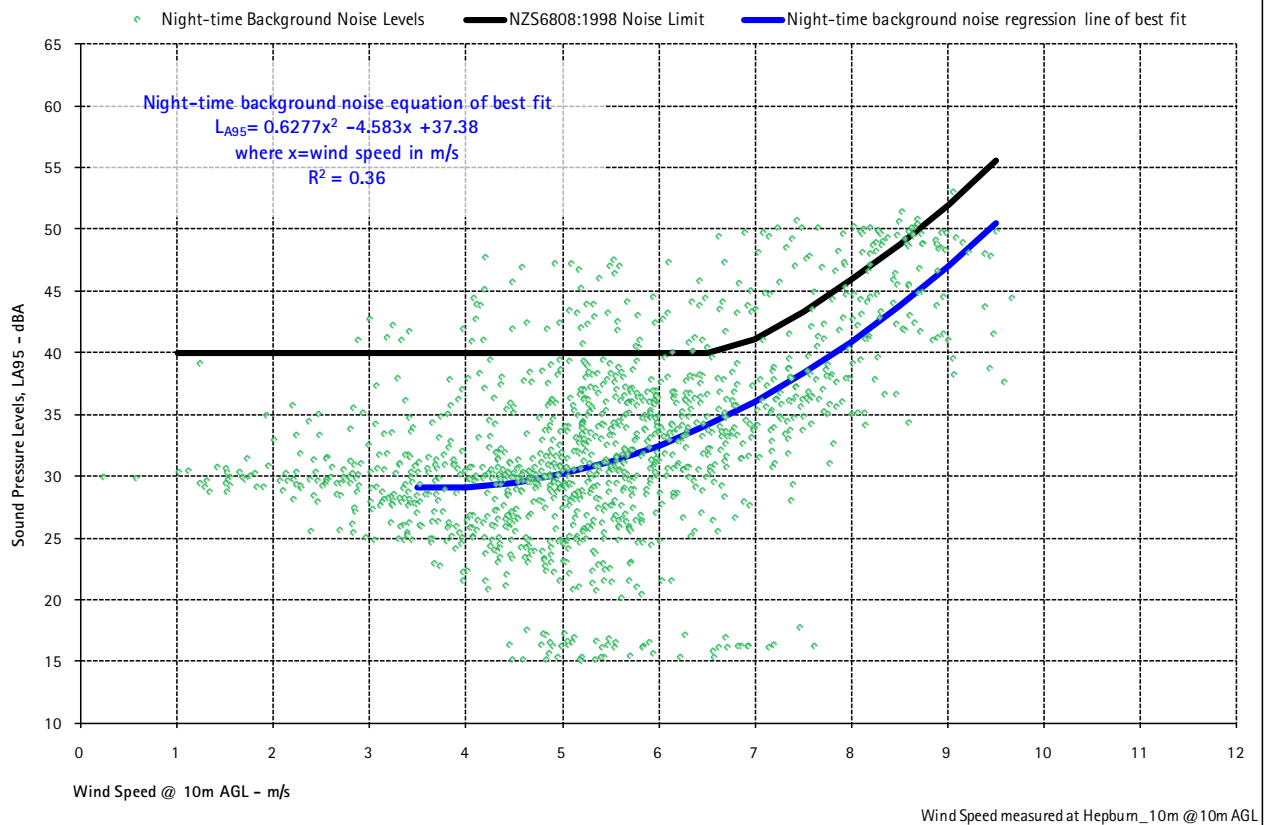
Background Noise Levels and Wind Speeds vs. Time  
House H11rep - January 2011

(06.01.2011 - 11.02.2011)

Background Noise Levels vs. Wind Speeds  
House H11rep - January 2011

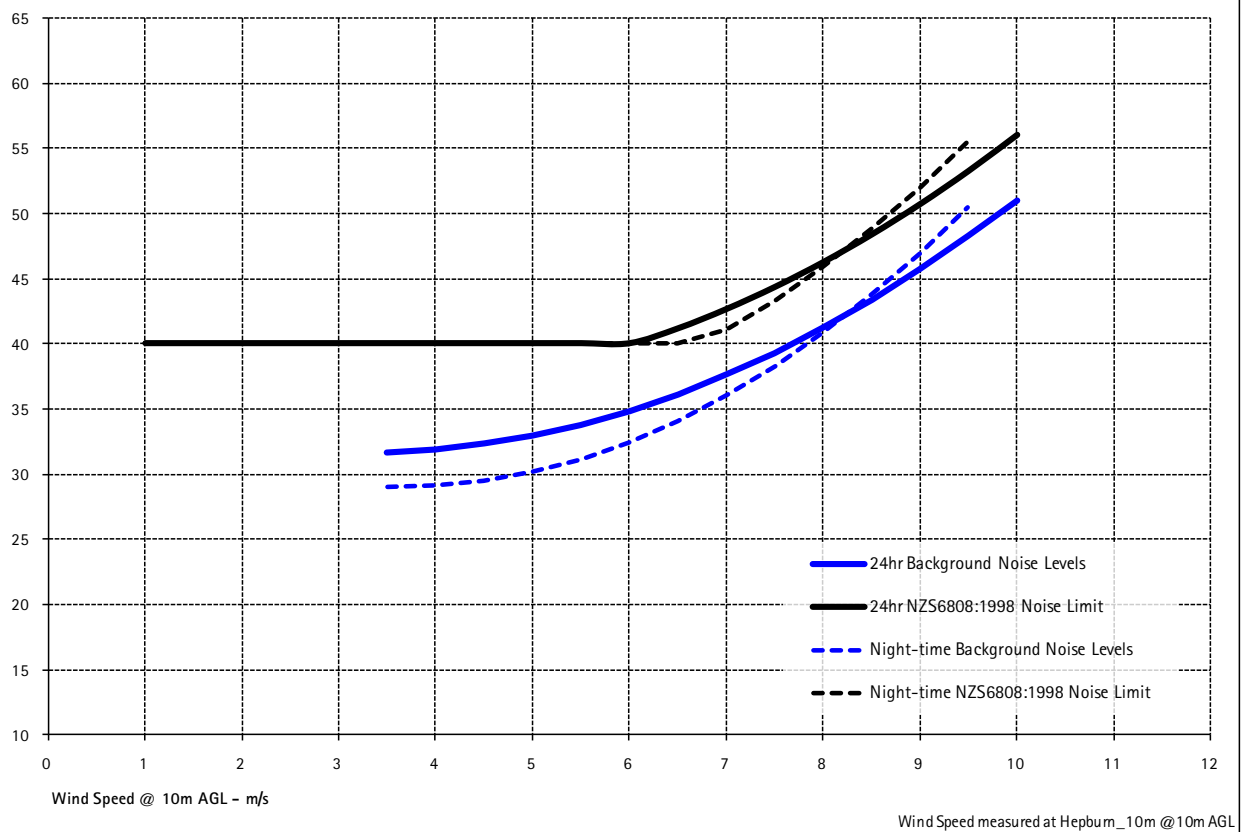
(06.01.2011 - 11.02.2011)

### Night-time Background Noise Levels vs. Wind Speed House H11rep - January 2011



(06.01.2011 - 11.02.2011)

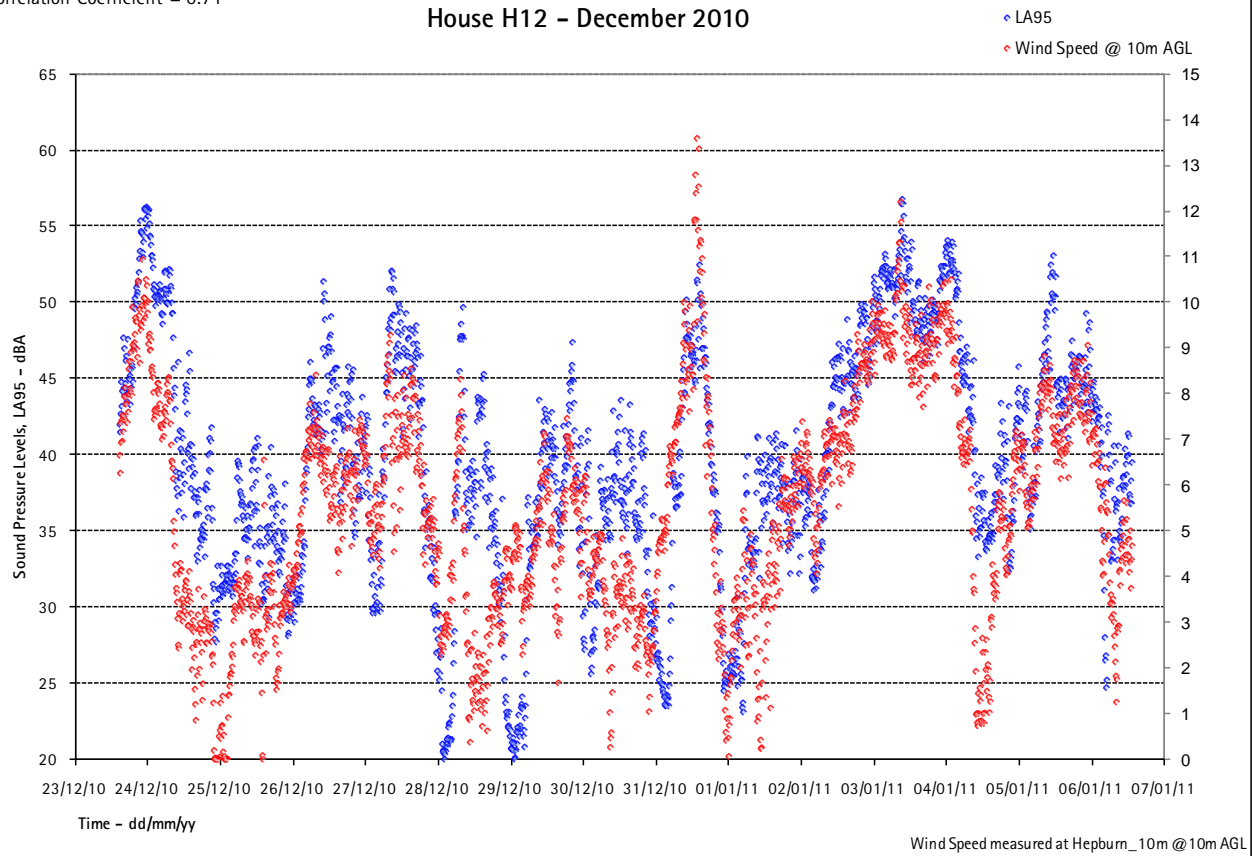
### Noise Limits House H11rep - January 2011



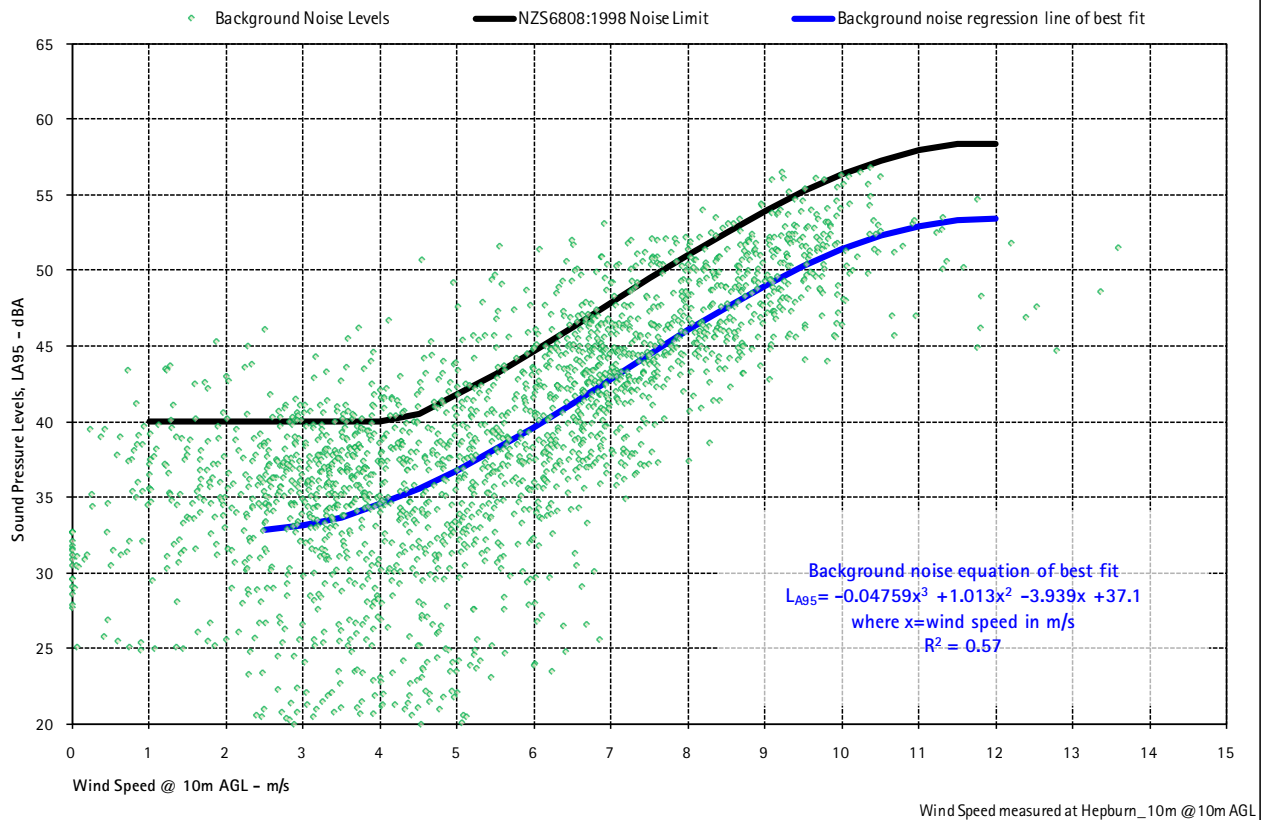


(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.71

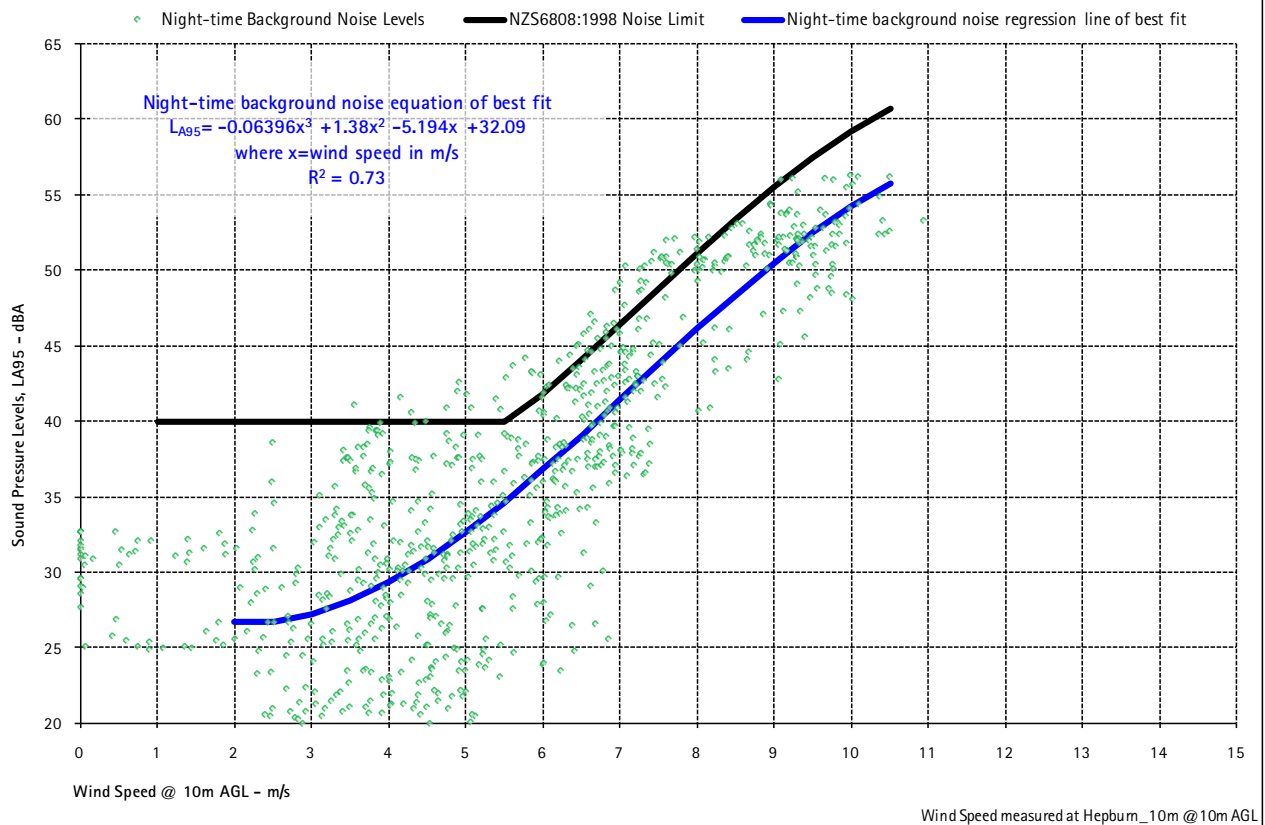
Background Noise Levels and Wind Speeds vs. Time  
House H12 - December 2010

(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H12 - December 2010

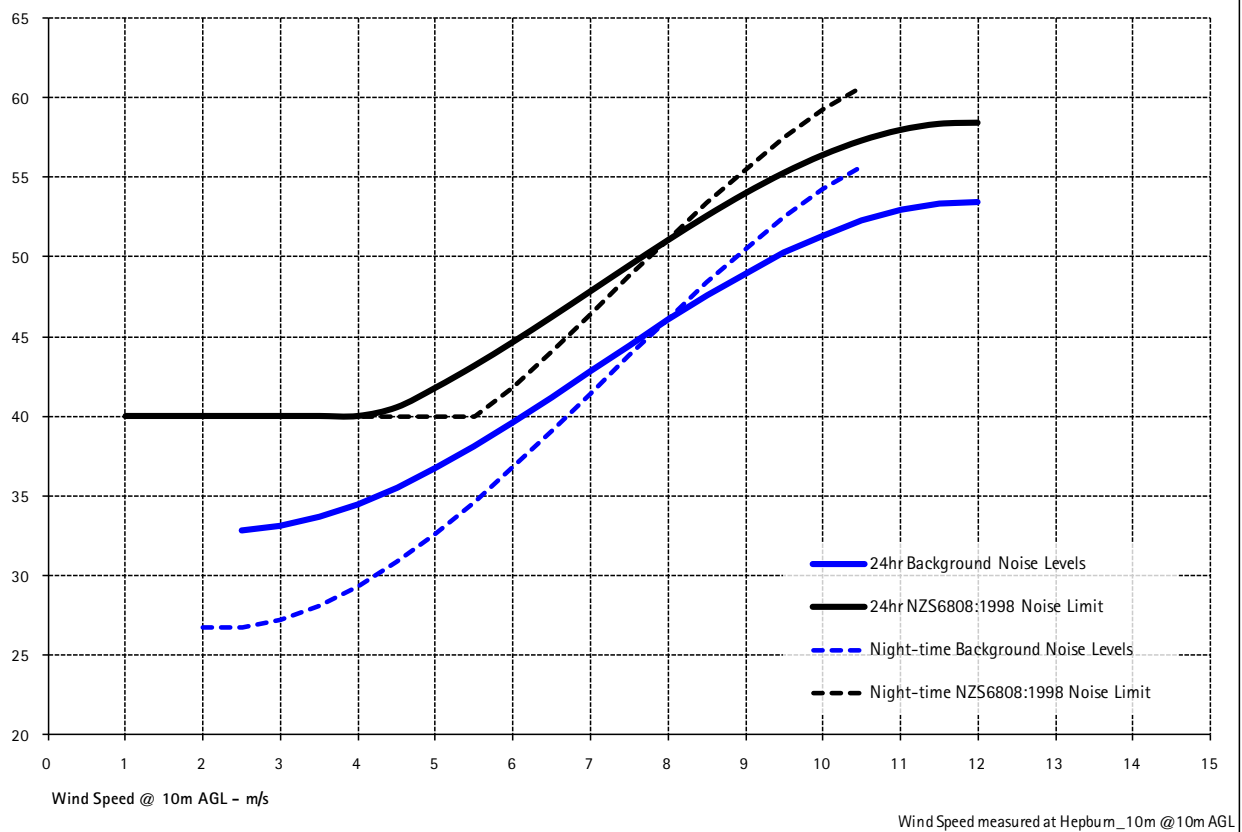
(23.12.2010 - 06.01.2011)

### Night-time Background Noise Levels vs. Wind Speed House H12 - December 2010



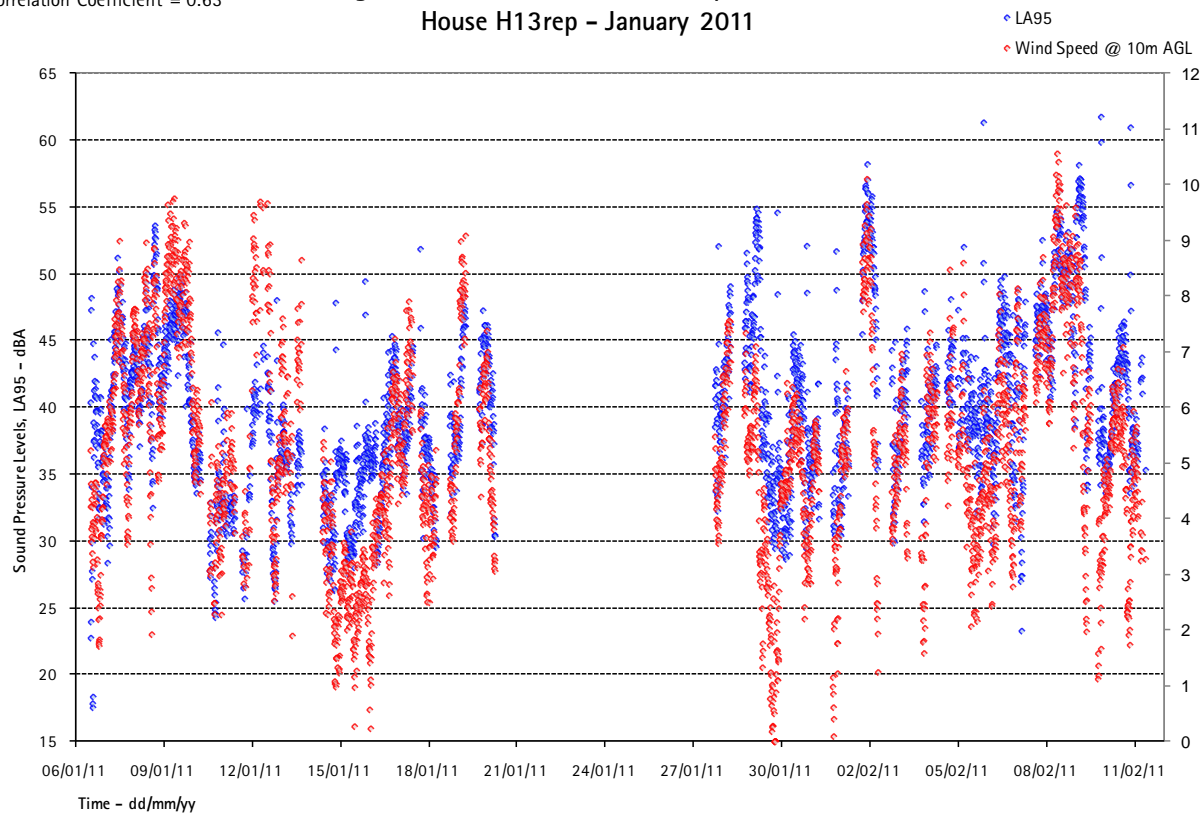
(23.12.2010 - 06.01.2011)

### Noise Limits House H12 - December 2010

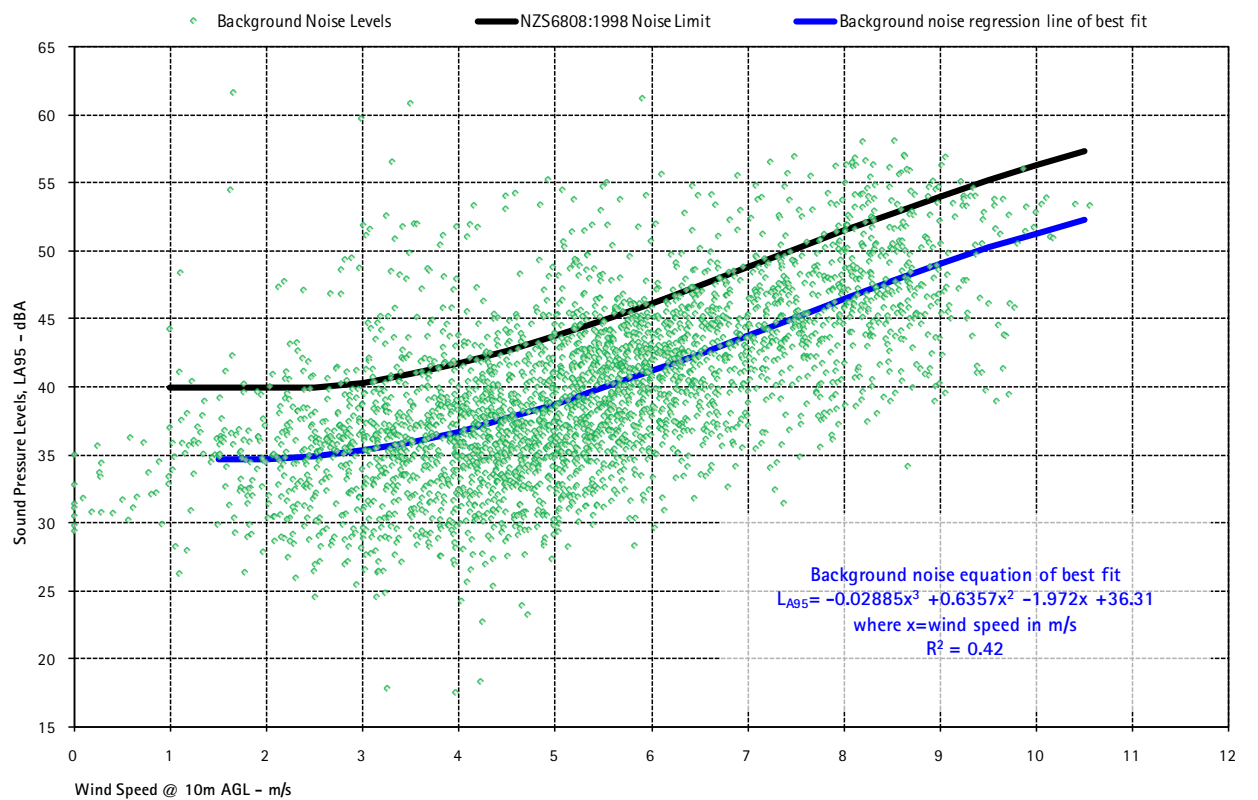


(06.01.2011 - 11.02.2011)

Correlation Coefficient = 0.63

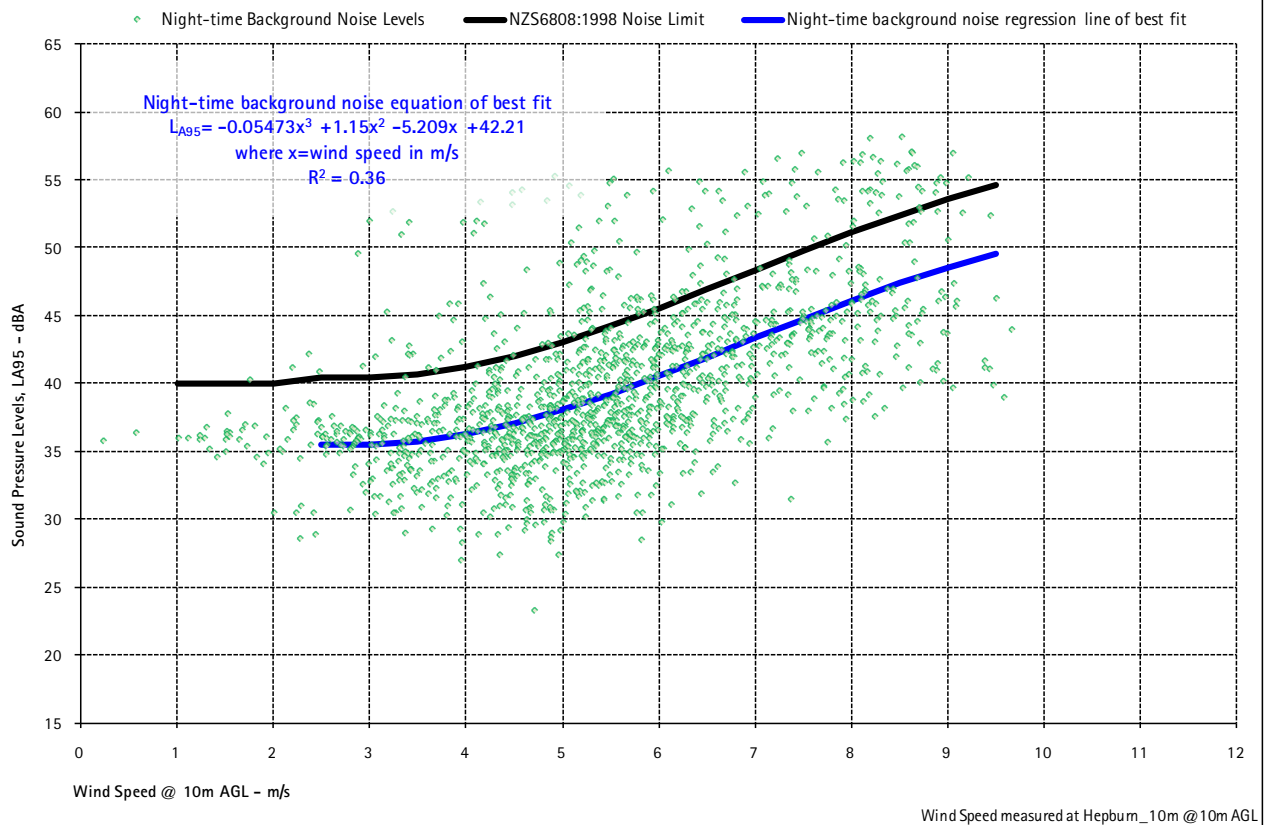
Background Noise Levels and Wind Speeds vs. Time  
House H13rep - January 2011

(06.01.2011 - 11.02.2011)

Background Noise Levels vs. Wind Speeds  
House H13rep - January 2011

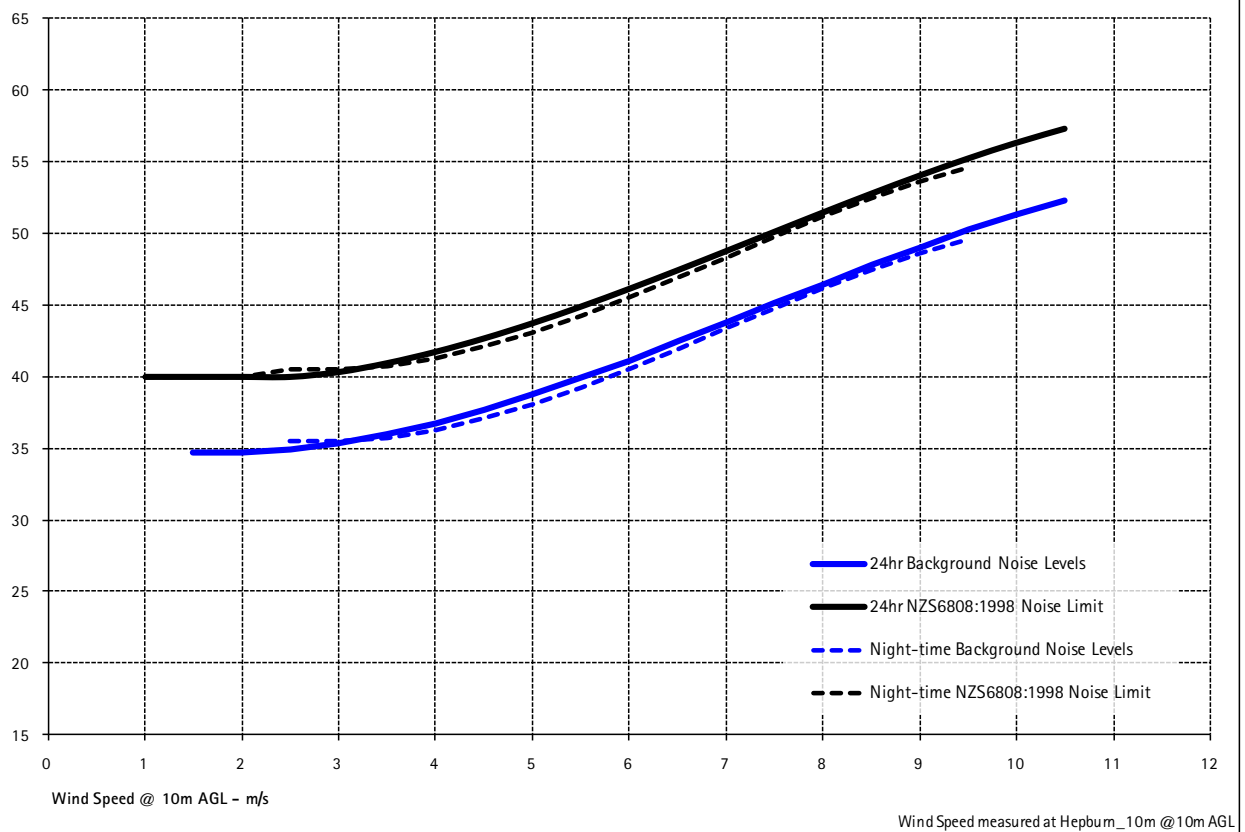
(06.01.2011 - 11.02.2011)

### Night-time Background Noise Levels vs. Wind Speeds House H13rep - January 2011



(06.01.2011 - 11.02.2011)

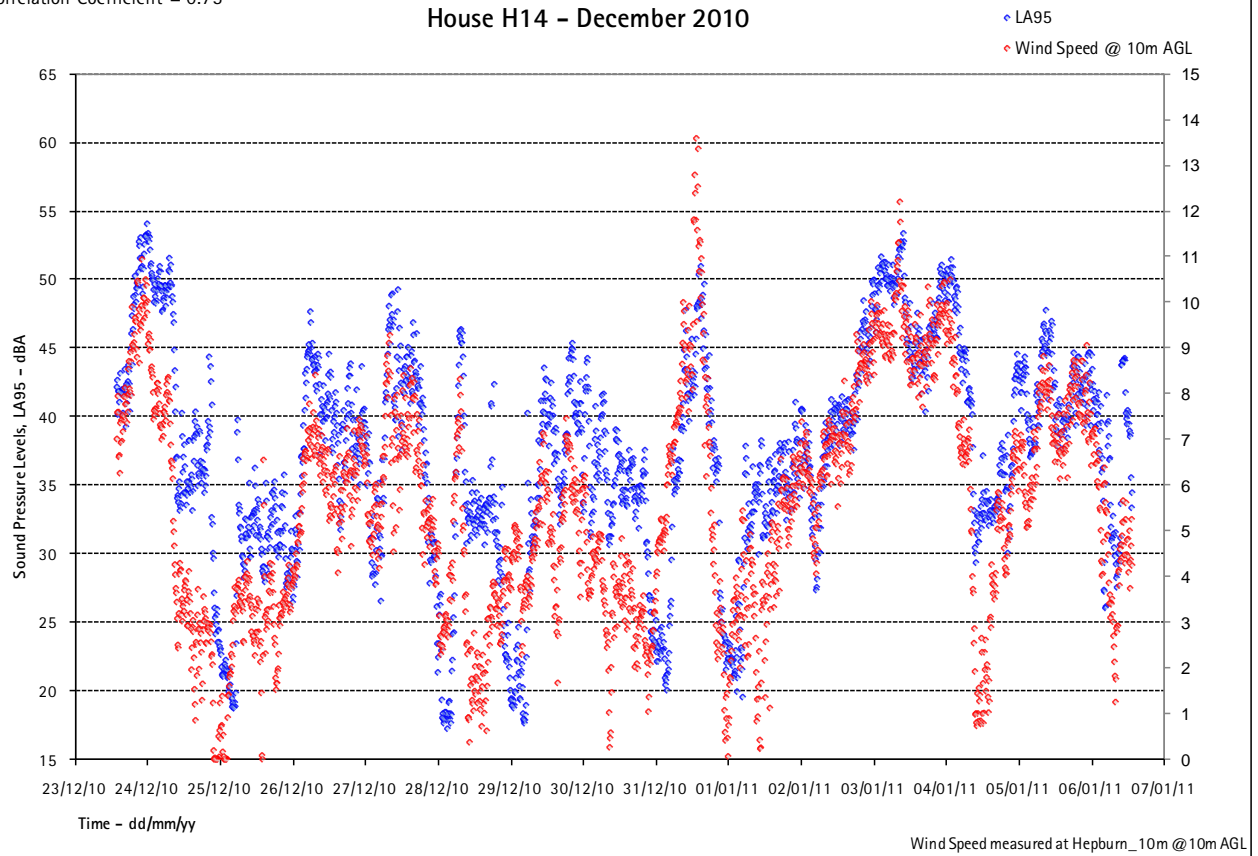
### Noise Limits House H13rep - January 2011



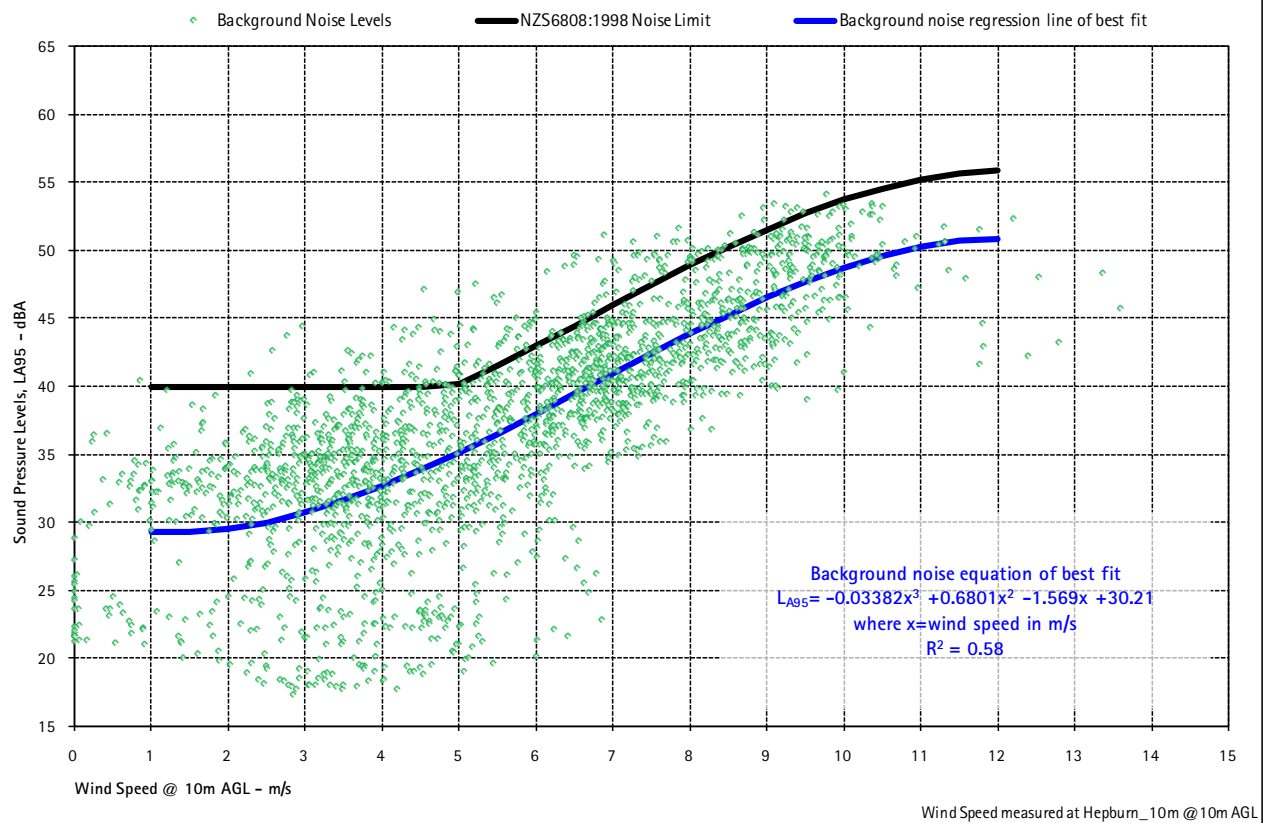


(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.75

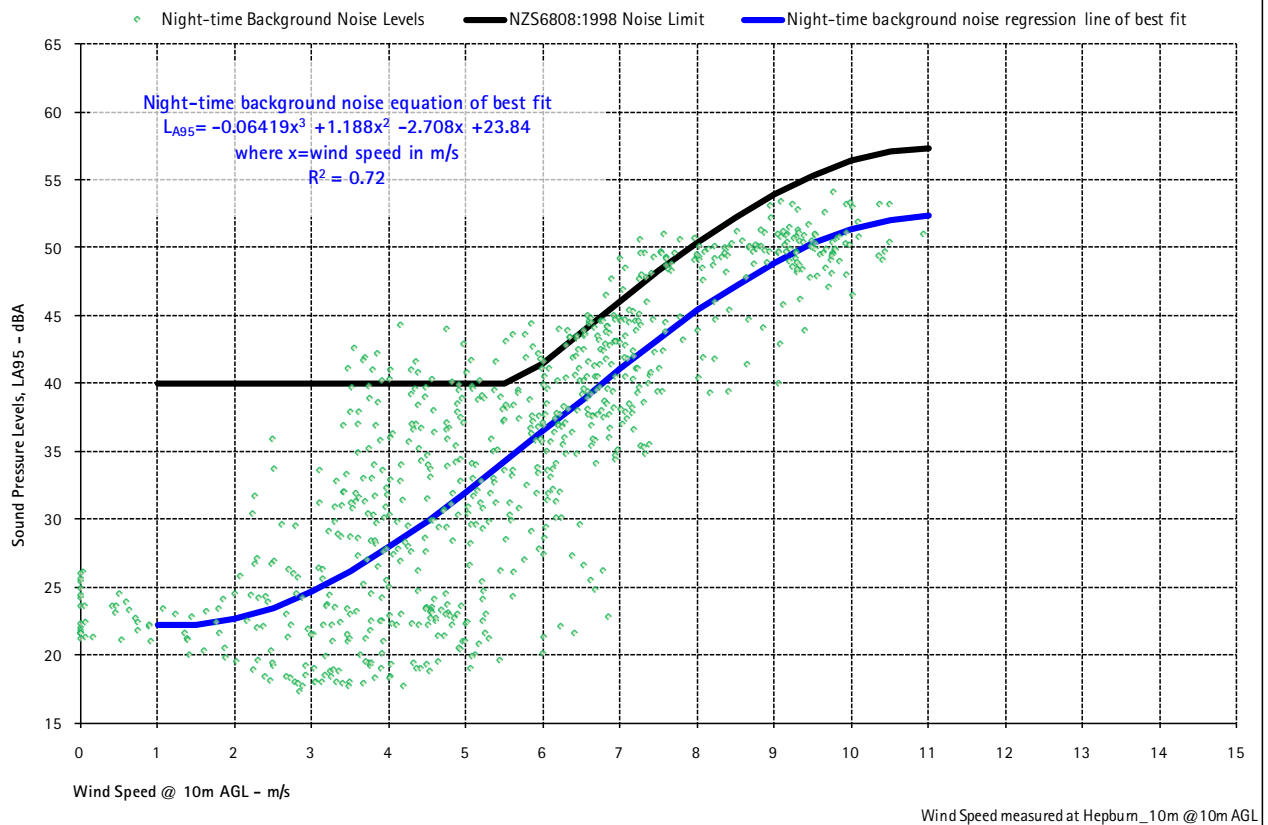
Background Noise Levels and Wind Speeds vs. Time  
House H14 - December 2010

(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H14 - December 2010

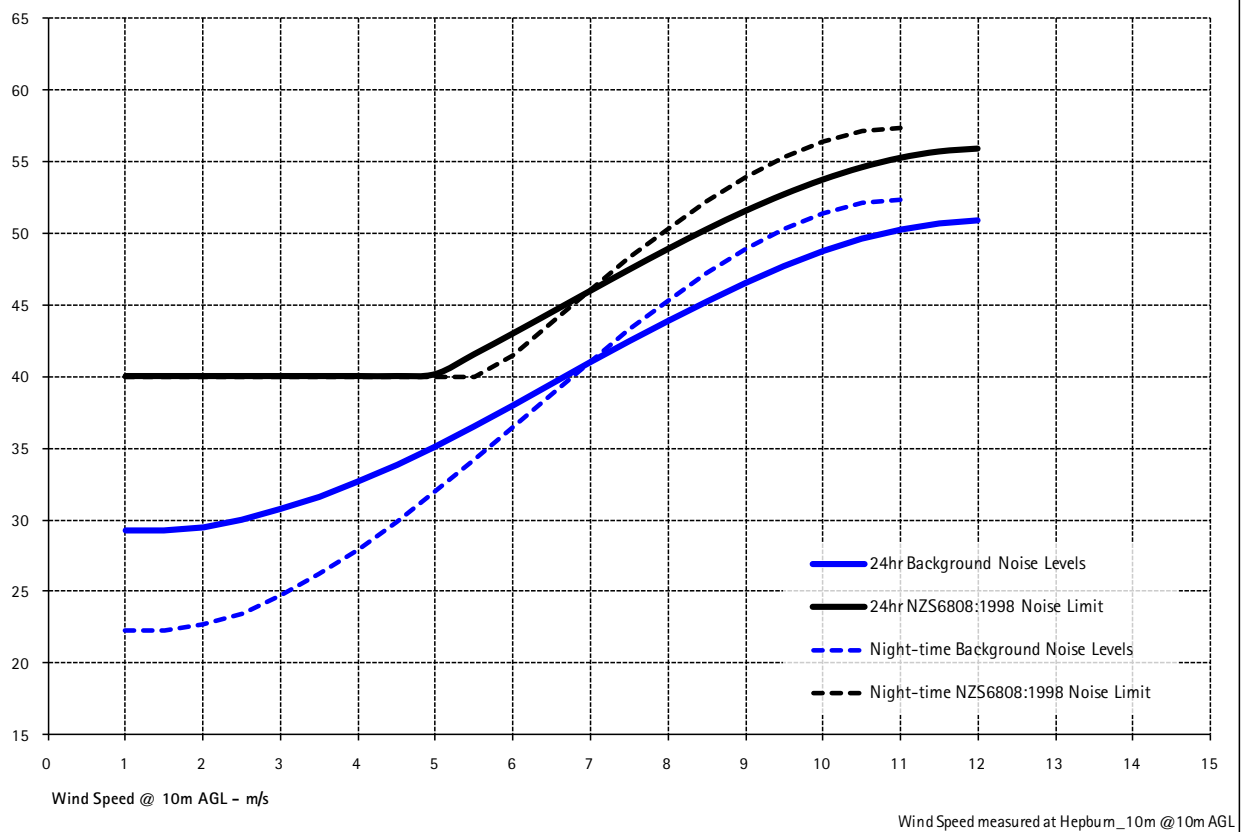
(23.12.2010 - 06.01.2011)

### Night-time Background Noise Levels vs. Wind Speeds House H14 - December 2010



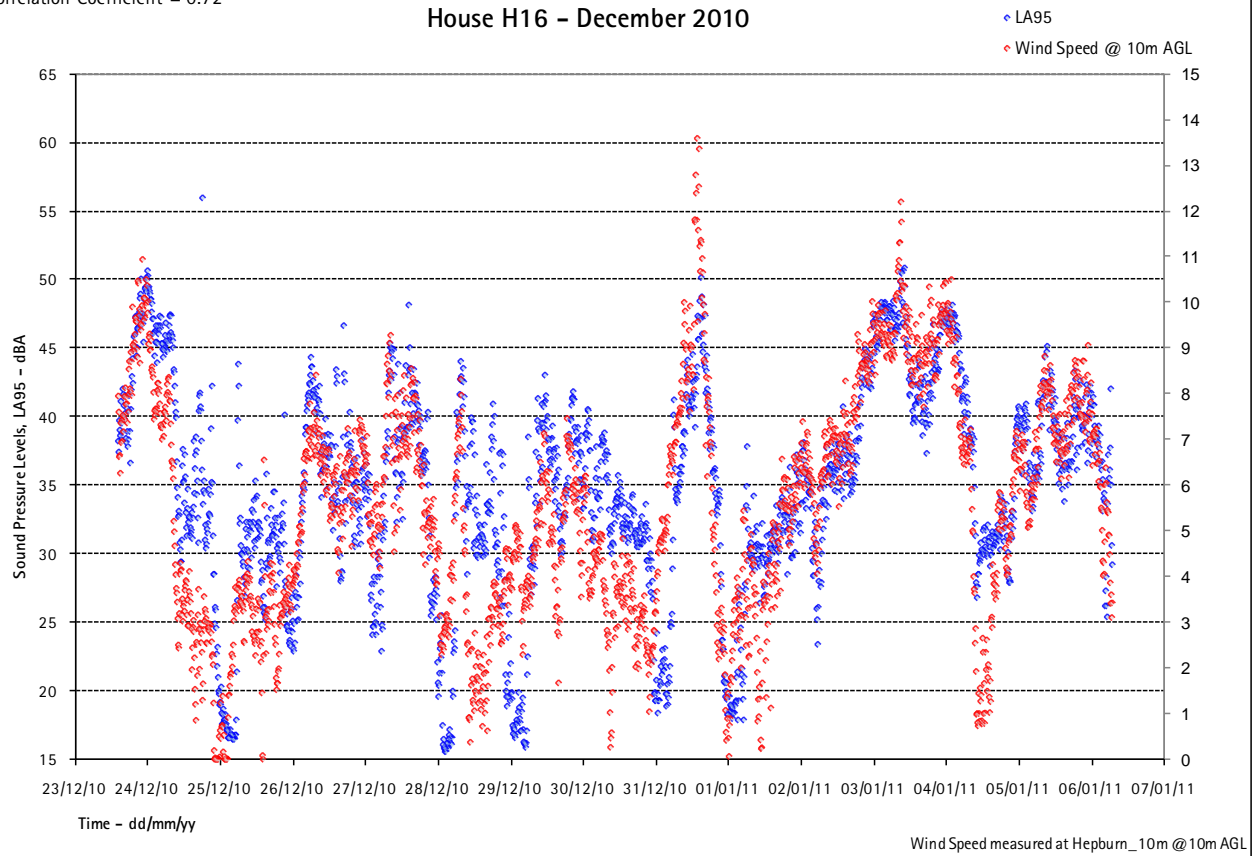
(23.12.2010 - 06.01.2011)

### Noise Limits House H14 - December 2010

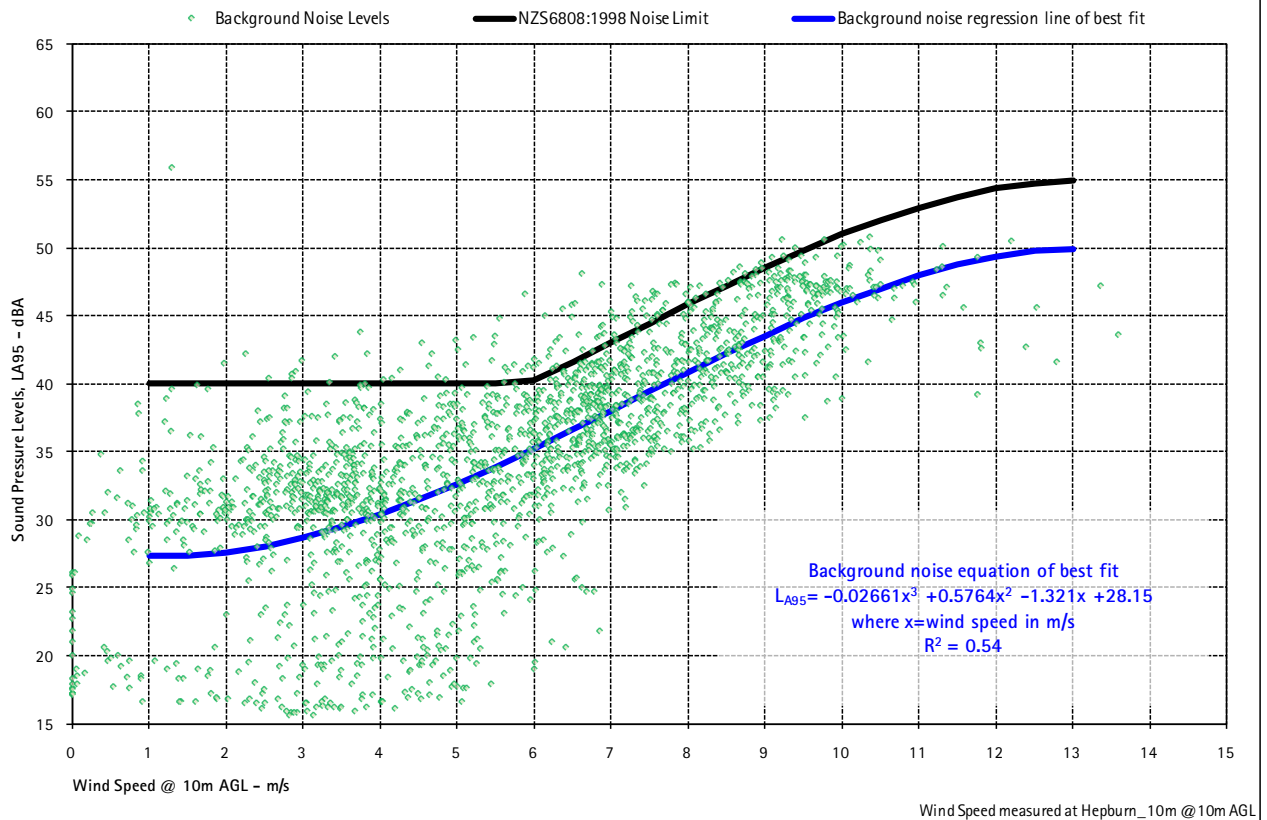


(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.72

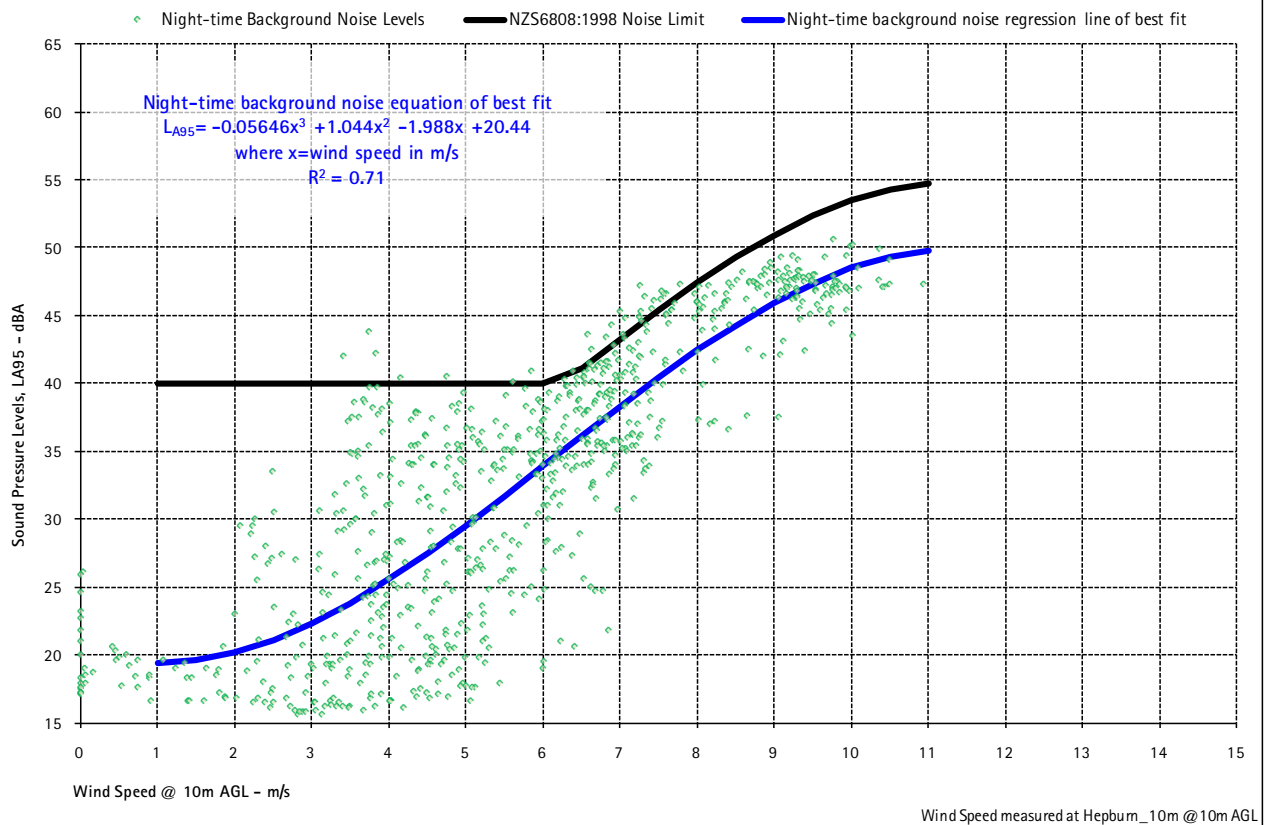
Background Noise Levels and Wind Speeds vs. Time  
House H16 - December 2010

(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H16 - December 2010

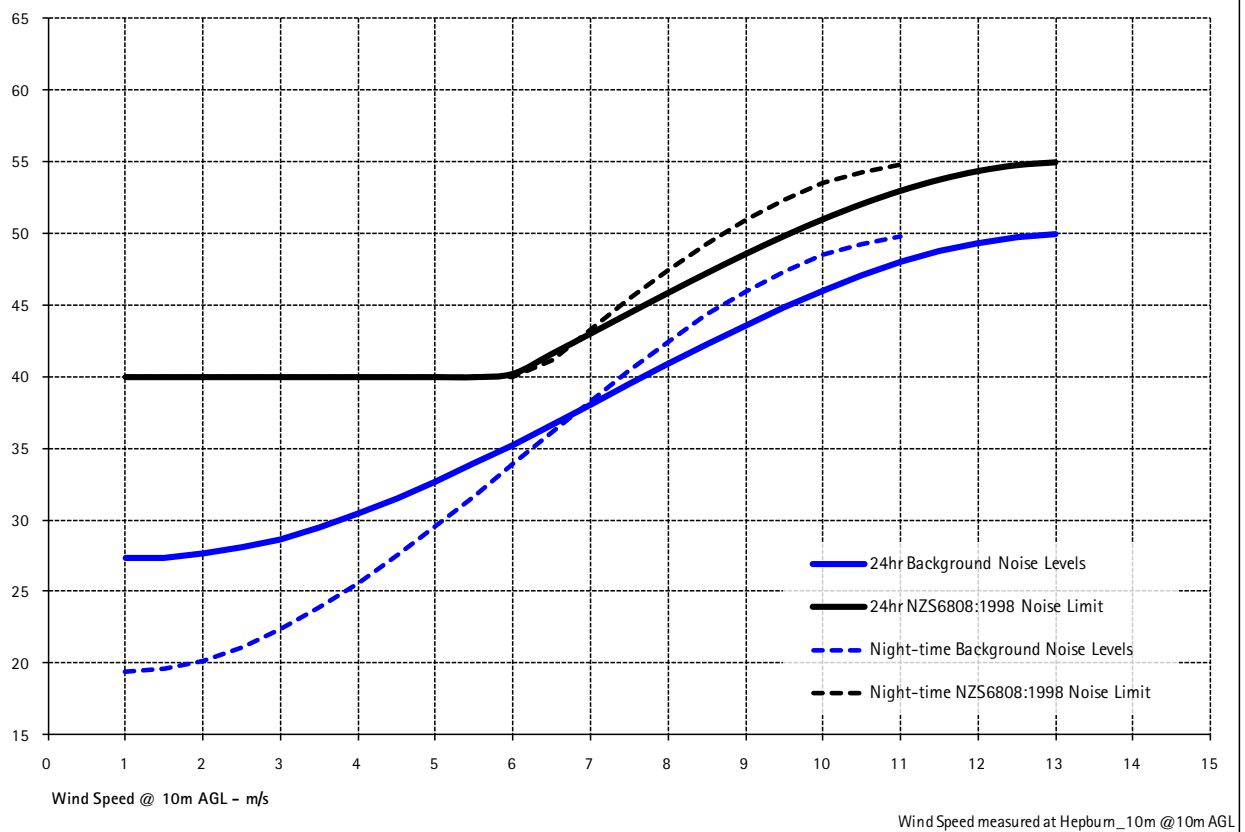
(23.12.2010 - 06.01.2011)

### Night-time Background Noise Levels vs. Wind Speed House H16 - December 2010



(23.12.2010 - 06.01.2011)

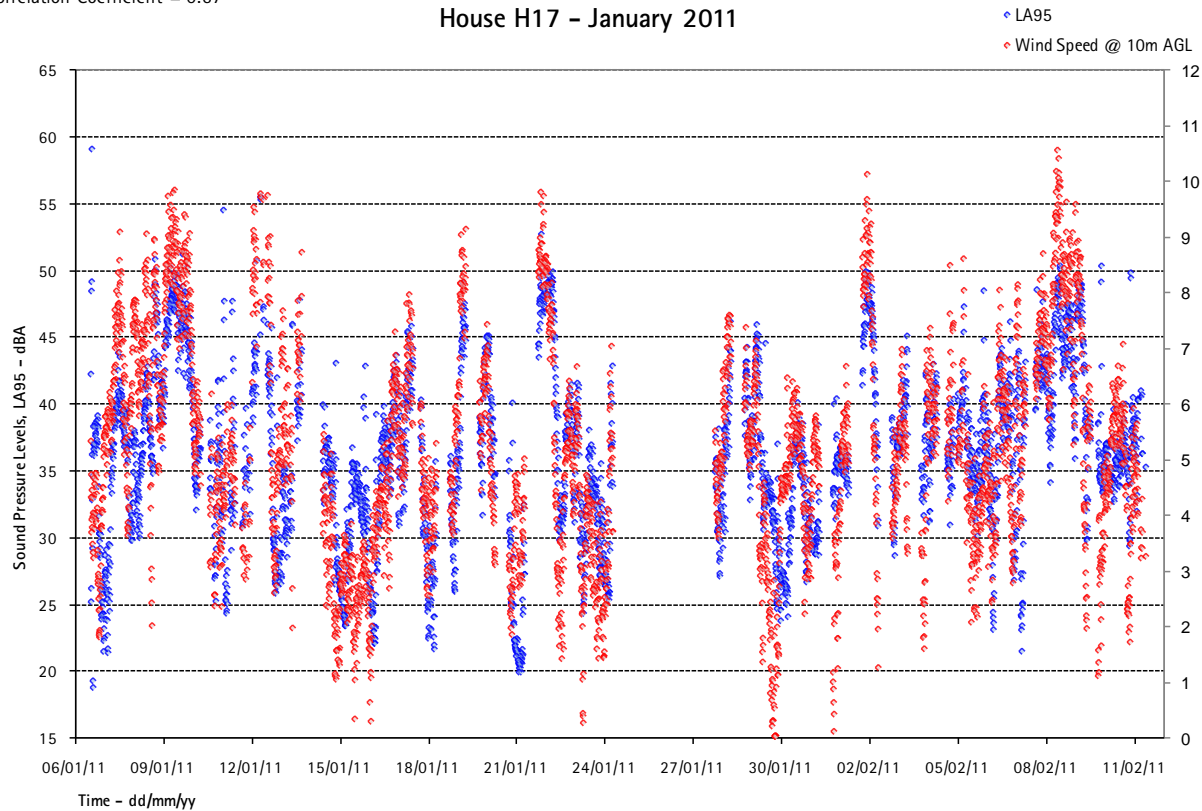
### Noise Limits House H16 - December 2010





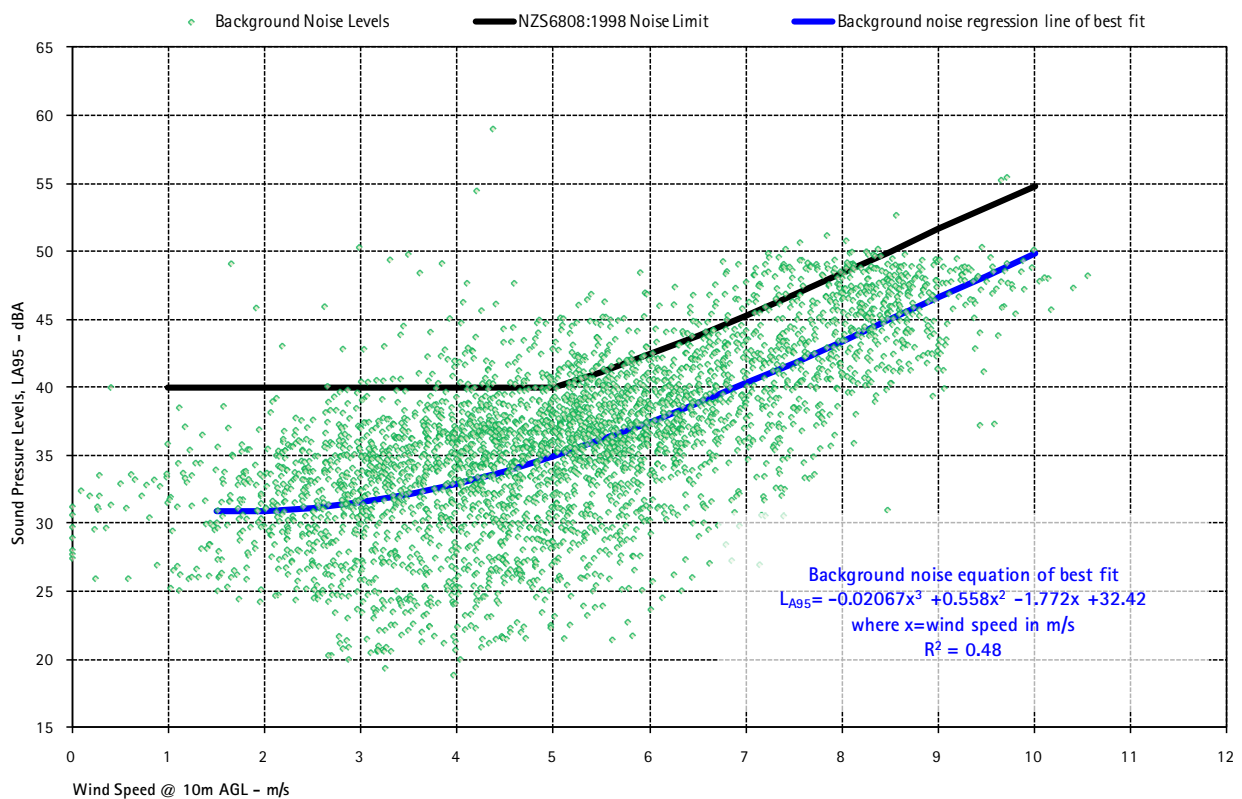
(06.01.2011 - 11.02.2011)

Correlation Coefficient = 0.67

Background Noise Levels and Wind Speeds vs. Time  
House H17 - January 2011

Wind Speed measured at Hepburn\_10m @ 10m AGL

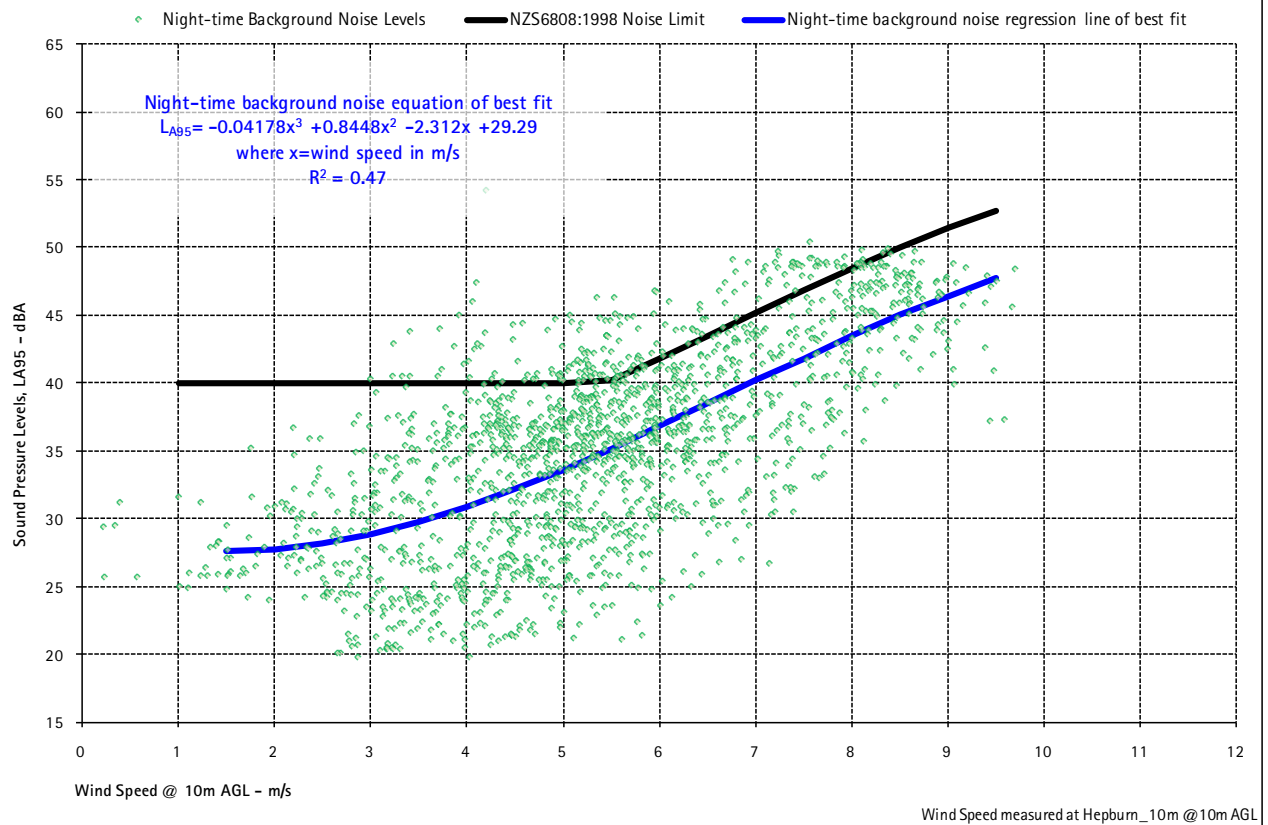
(06.01.2011 - 11.02.2011)

Background Noise Levels vs. Wind Speeds  
House H17 - January 2011

Wind Speed measured at Hepburn\_10m @ 10m AGL

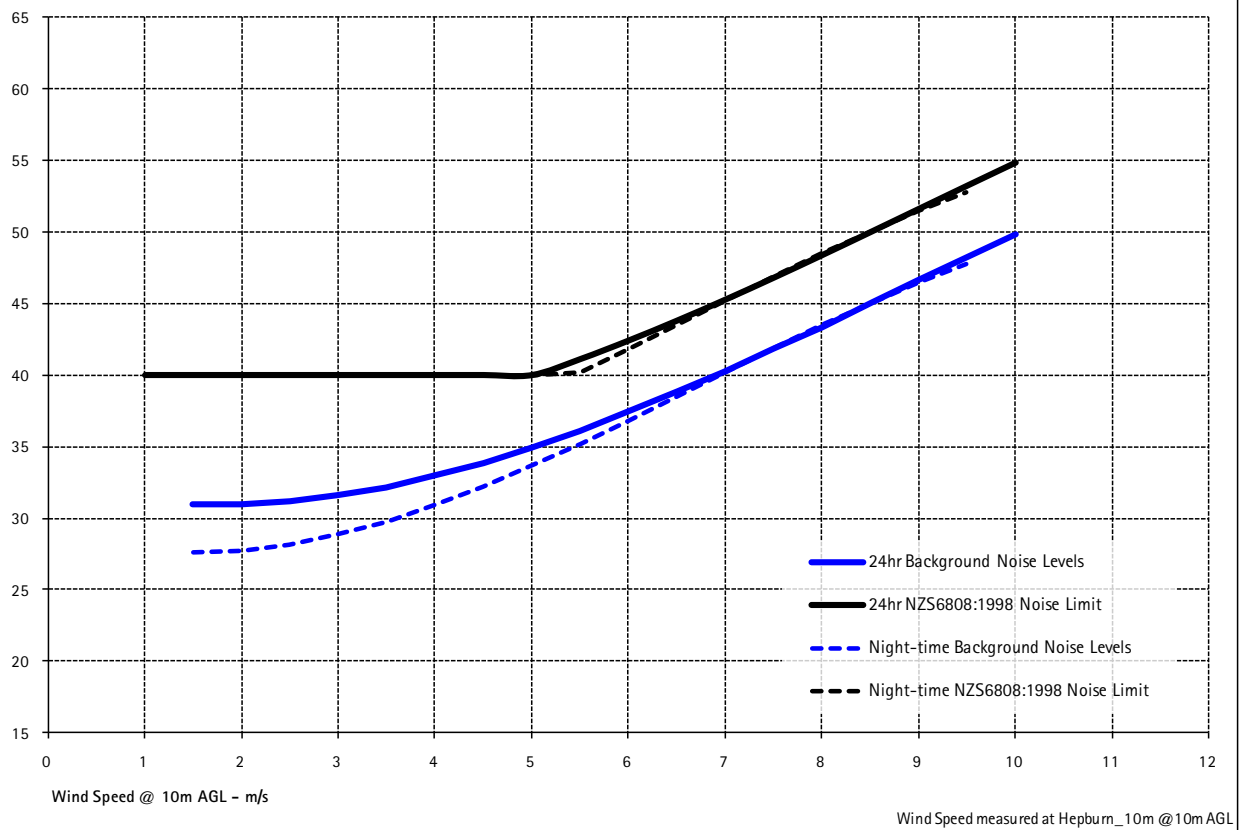
(06.01.2011 - 11.02.2011)

### Night-time Background Noise Levels vs. Wind Speeds House H17 - January 2011



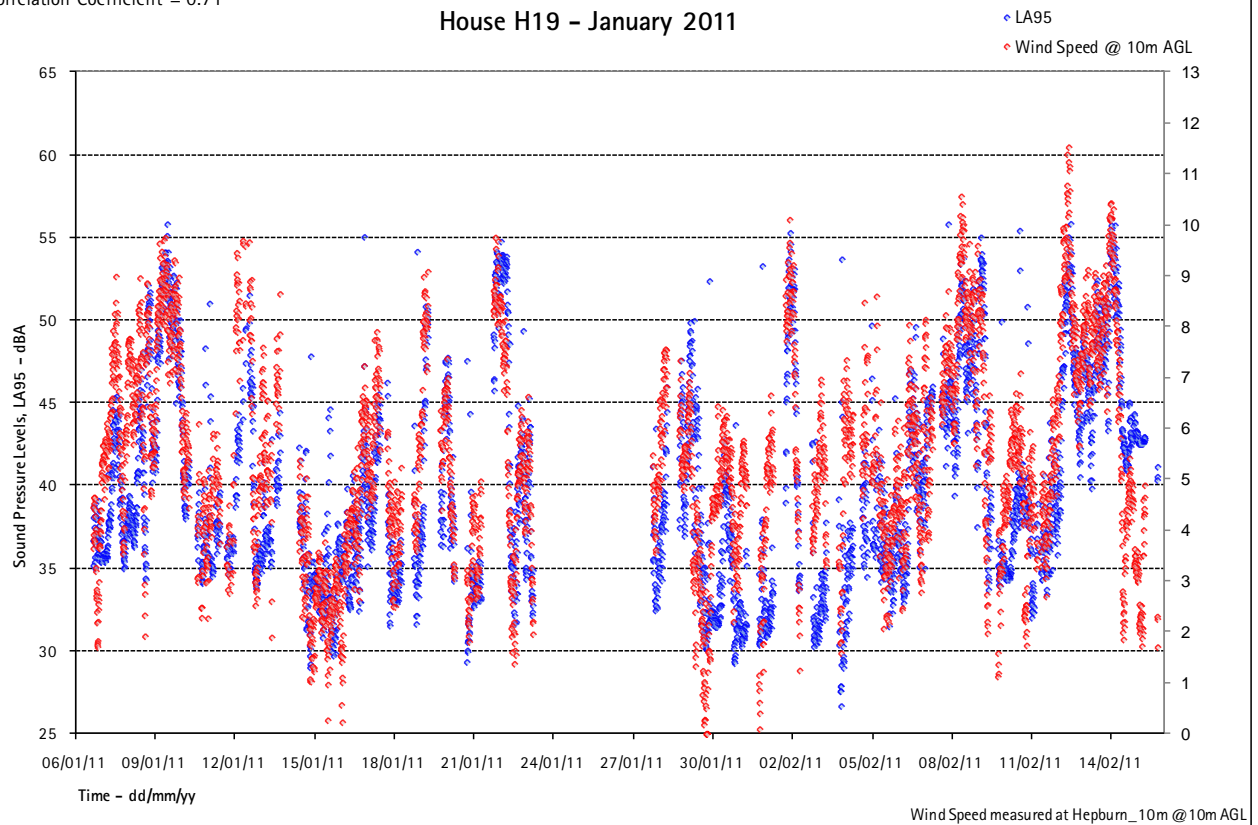
(06.01.2011 - 11.02.2011)

### Noise Limits House H17 - January 2011

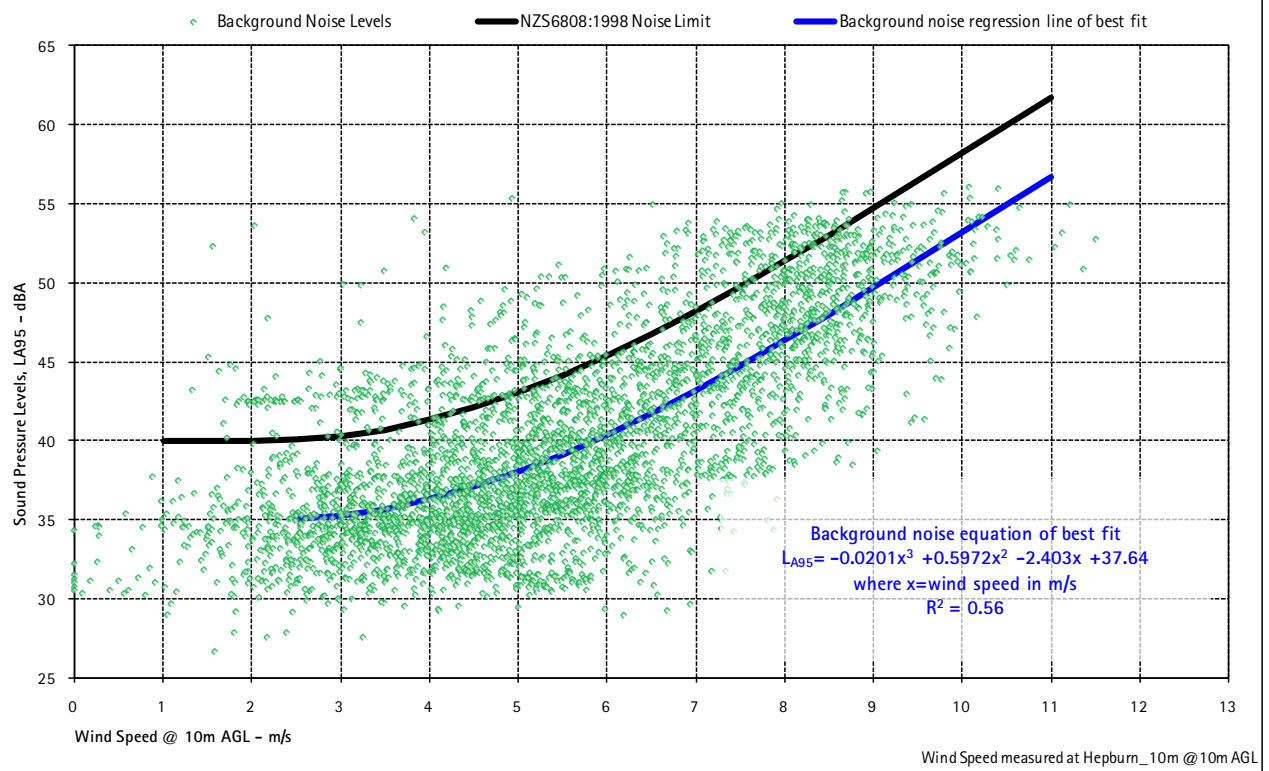


(06.01.2011 - 15.02.2011)

Correlation Coefficient = 0.71

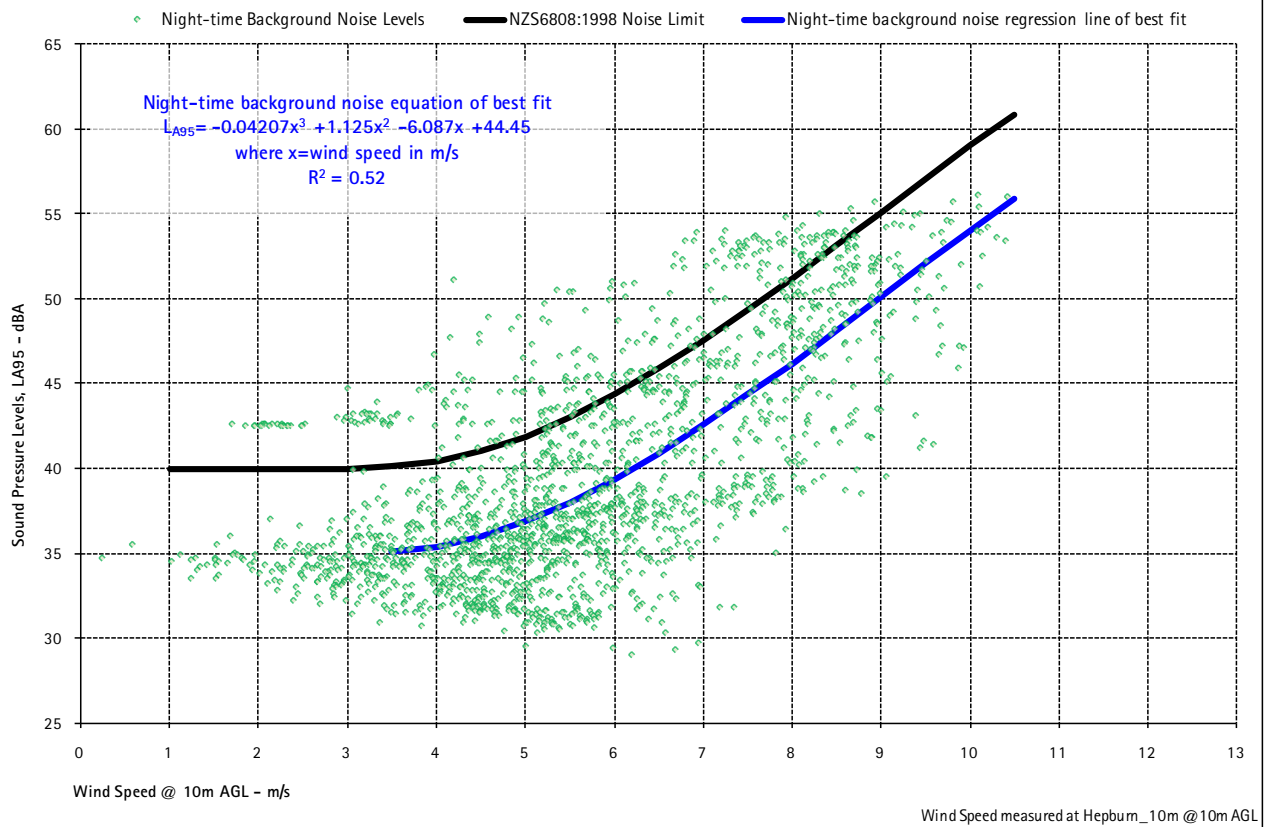
Background Noise Levels and Wind Speeds vs. Time  
House H19 - January 2011

(06.01.2011 - 15.02.2011)

Background Noise Levels vs. Wind Speeds  
House H19 - January 2011

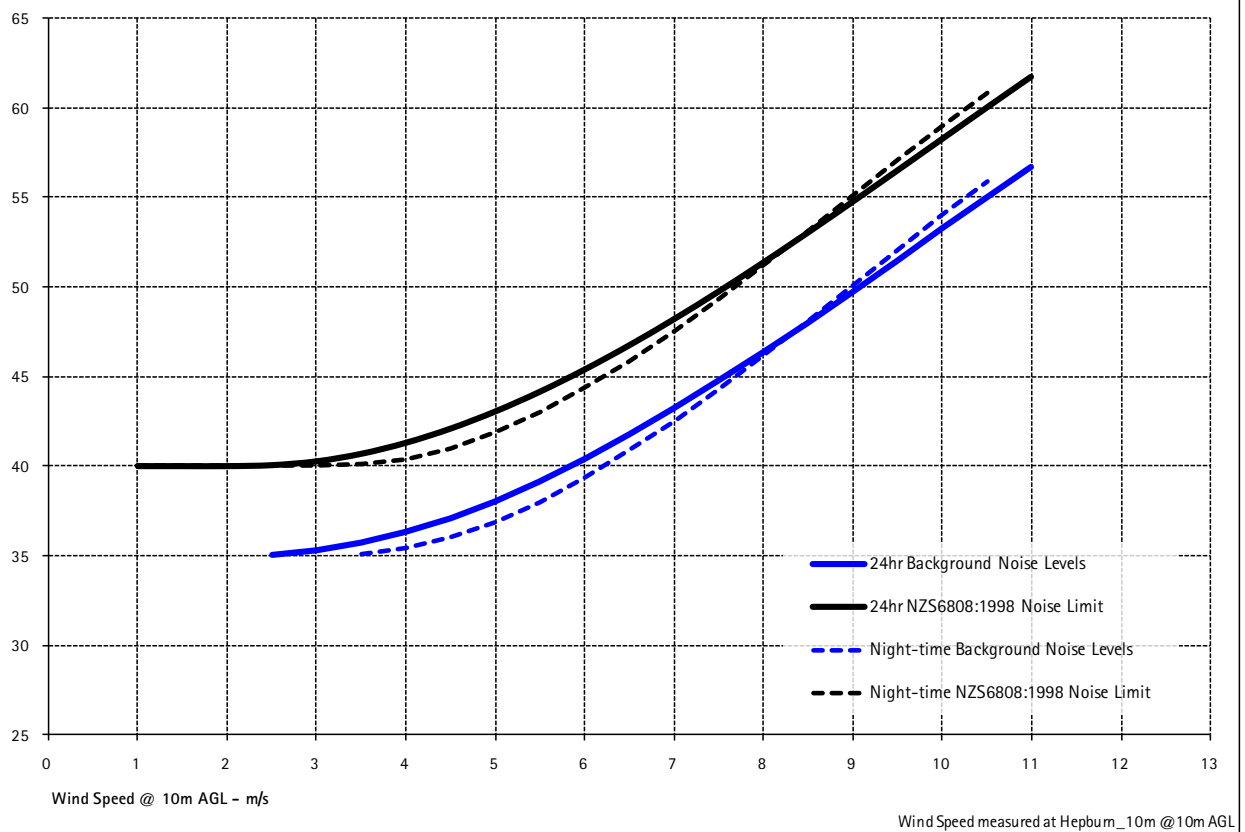
(06.01.2011 - 15.02.2011)

### Night-time Background Noise Levels vs. Wind Speeds House H19 - January 2011



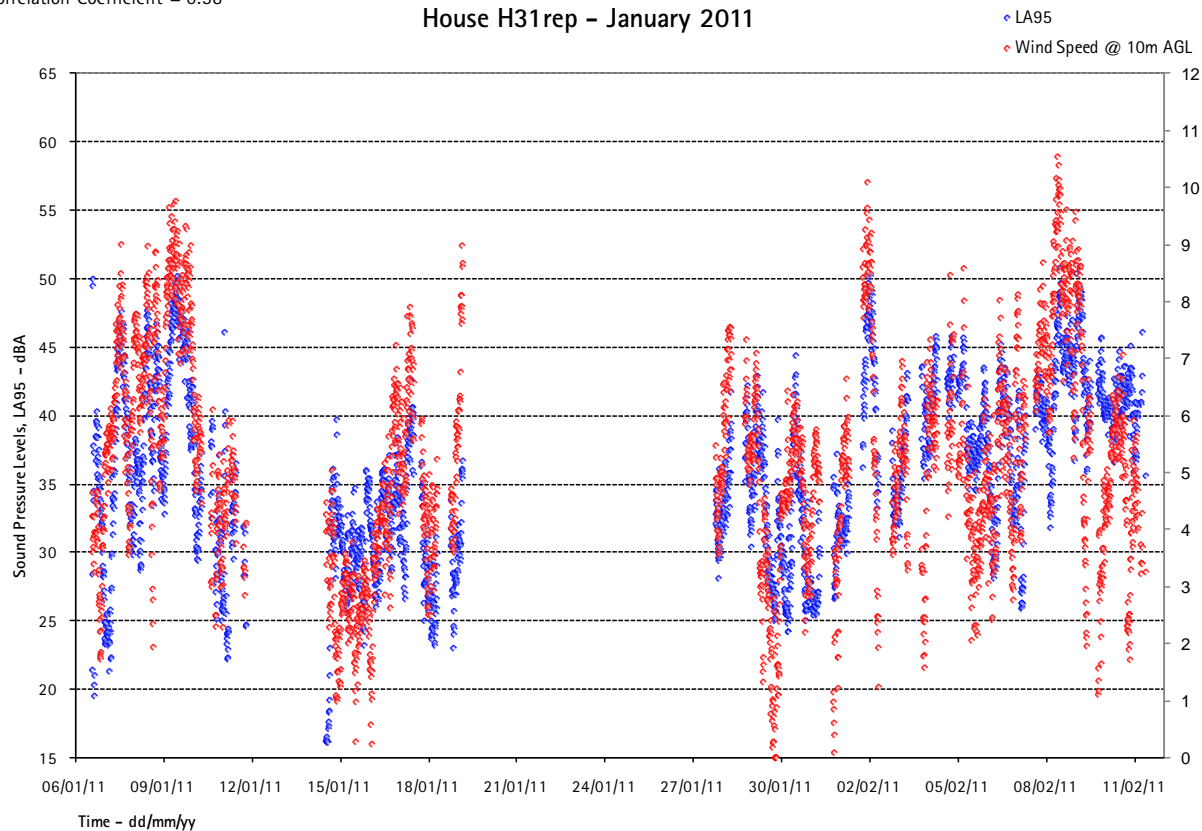
(06.01.2011 - 15.02.2011)

### Noise Limits House H19 - January 2011

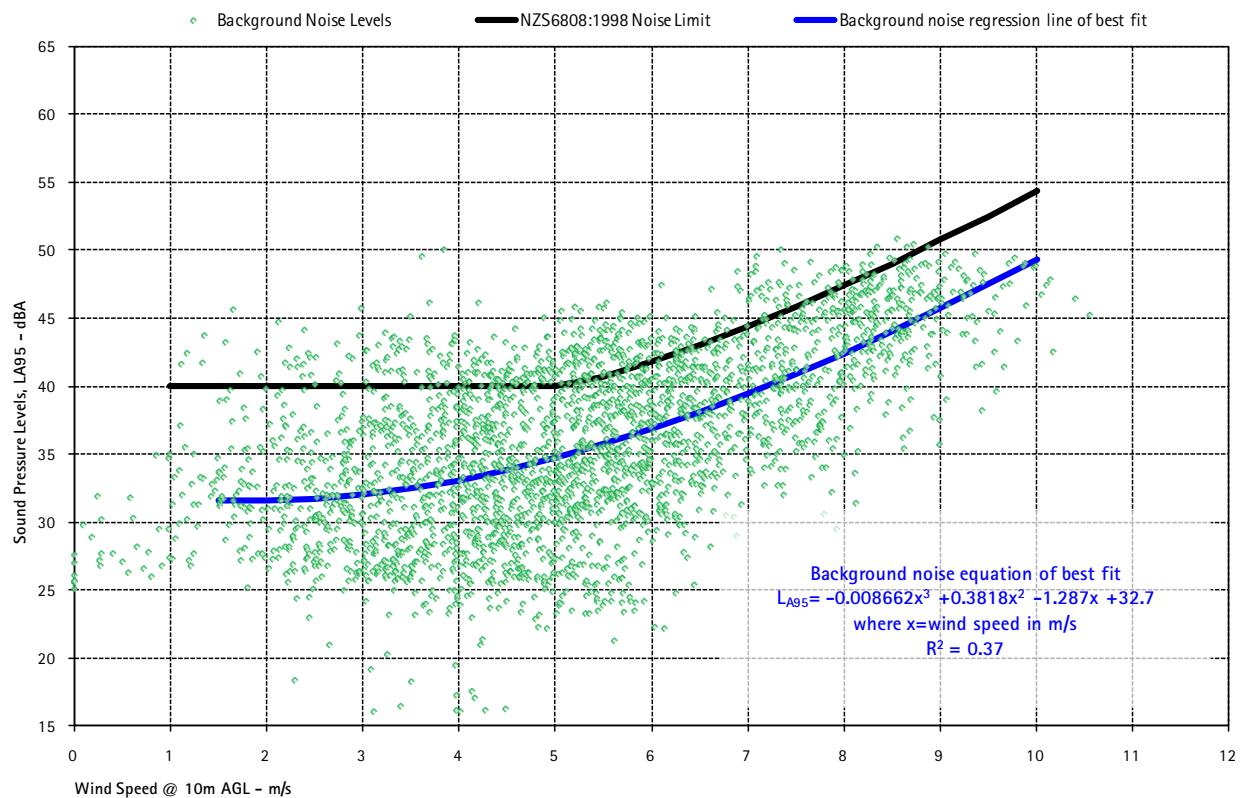


(06.01.2011 - 11.02.2011)

Correlation Coefficient = 0.58

Background Noise Levels and Wind Speeds vs. Time  
House H31rep - January 2011

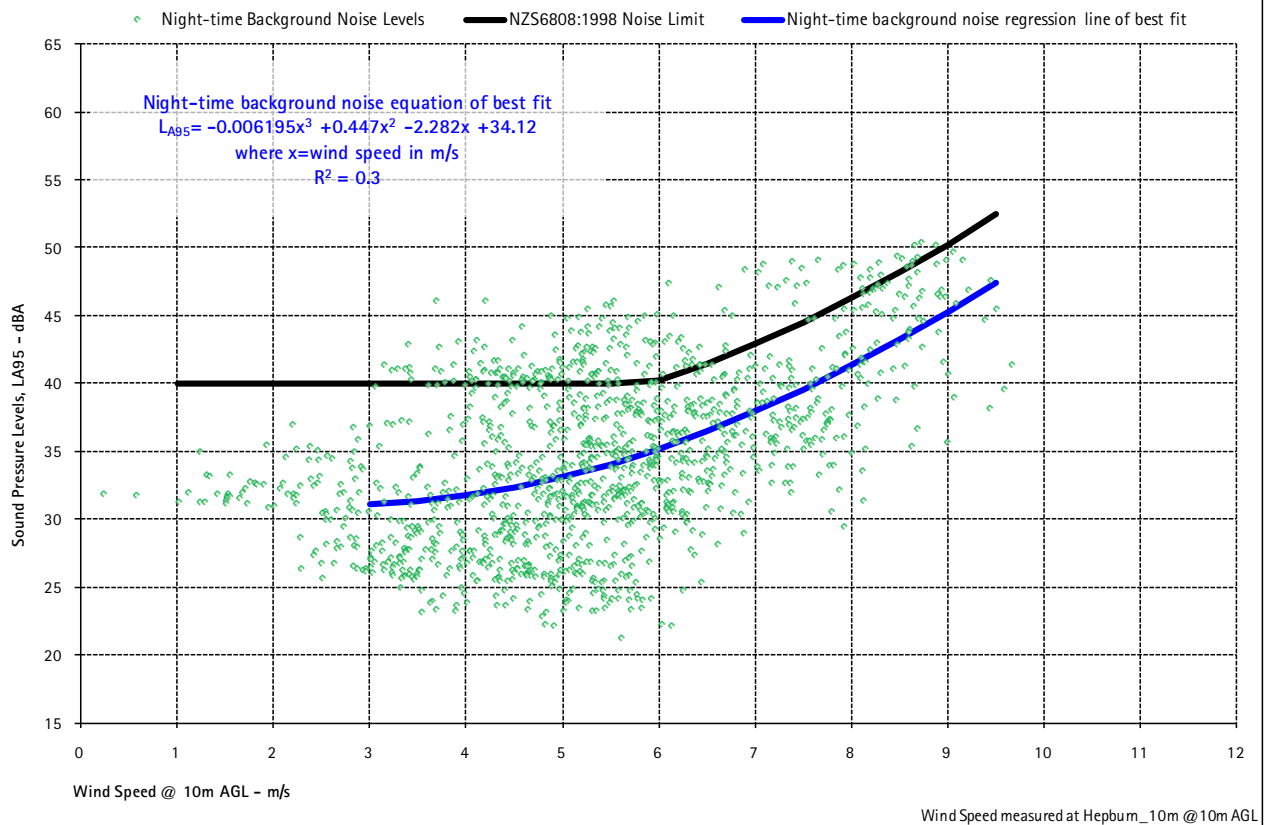
(06.01.2011 - 11.02.2011)

Background Noise Levels vs. Wind Speeds  
House H31rep - January 2011



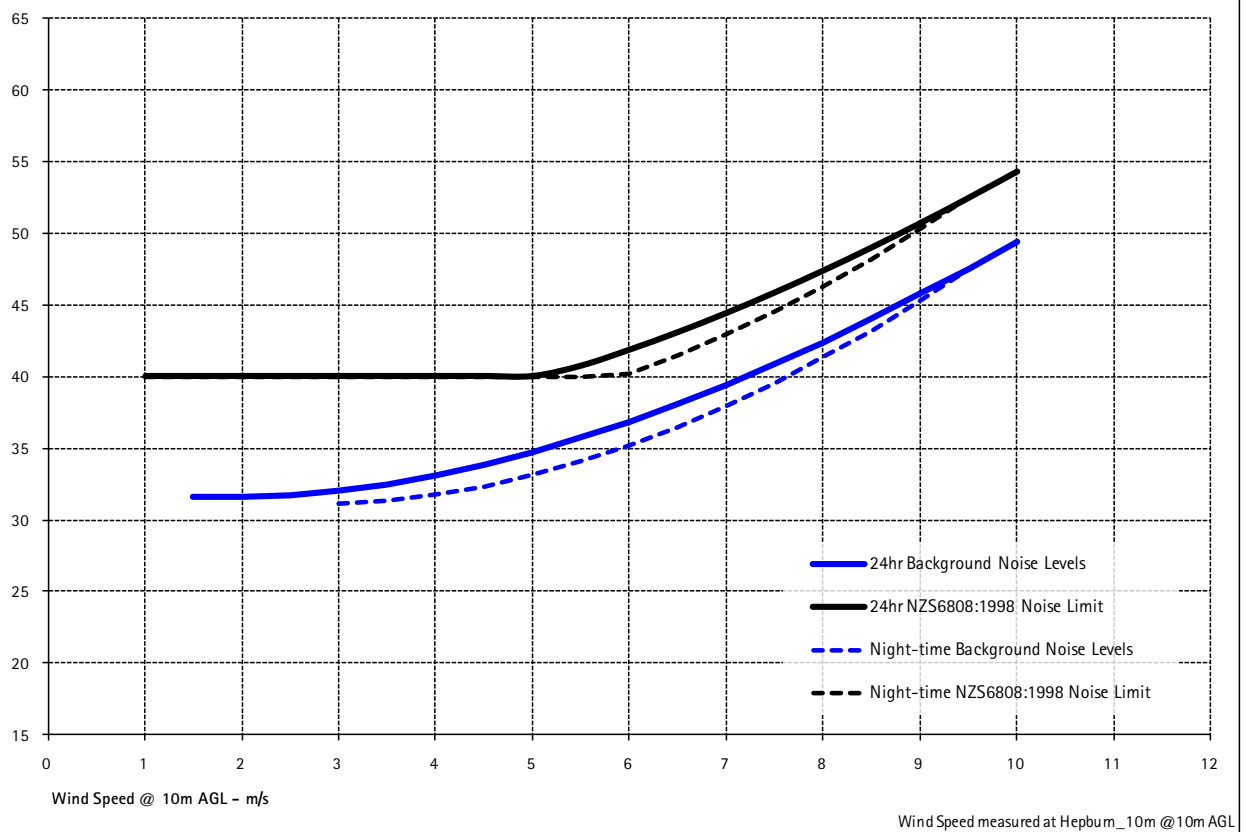
(06.01.2011 - 11.02.2011)

### Night-time Background Noise Levels vs. Wind Speed House H31rep - January 2011



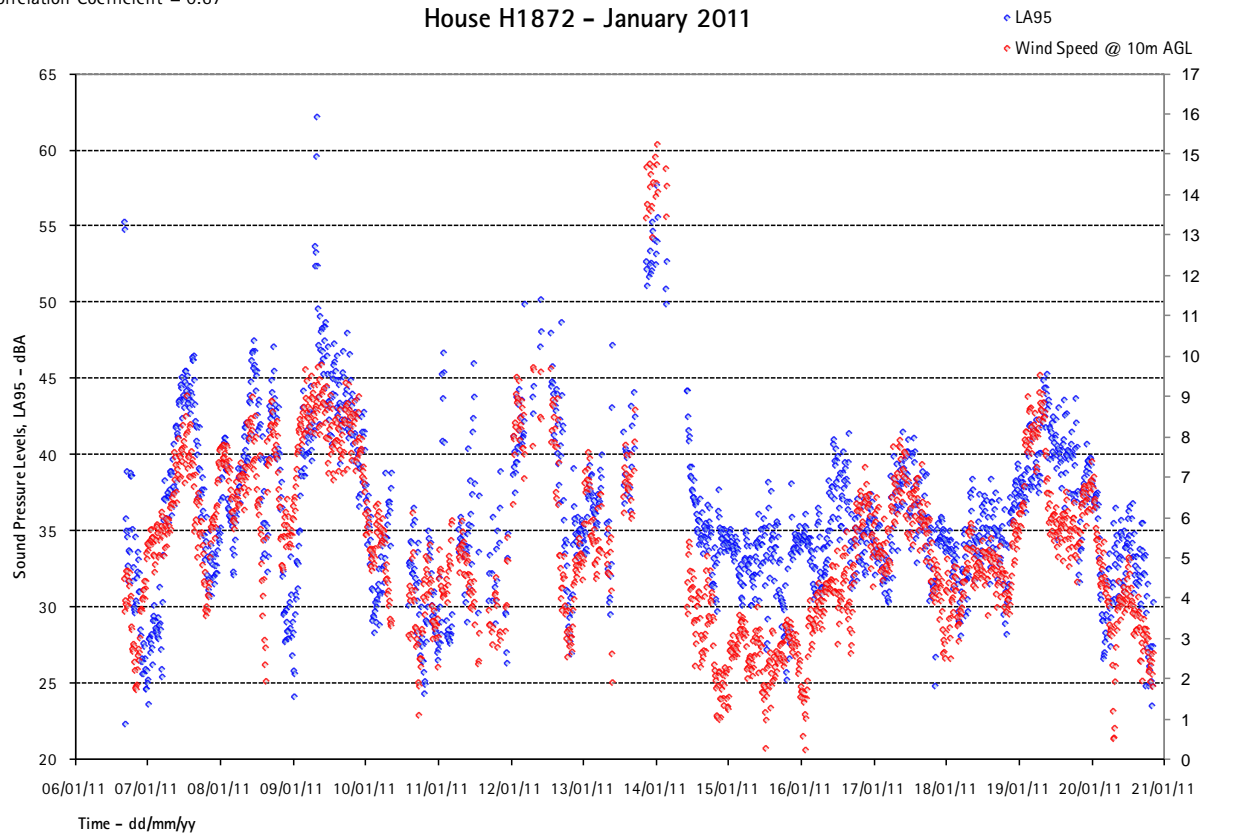
(06.01.2011 - 11.02.2011)

### Noise Limits House H31rep - January 2011

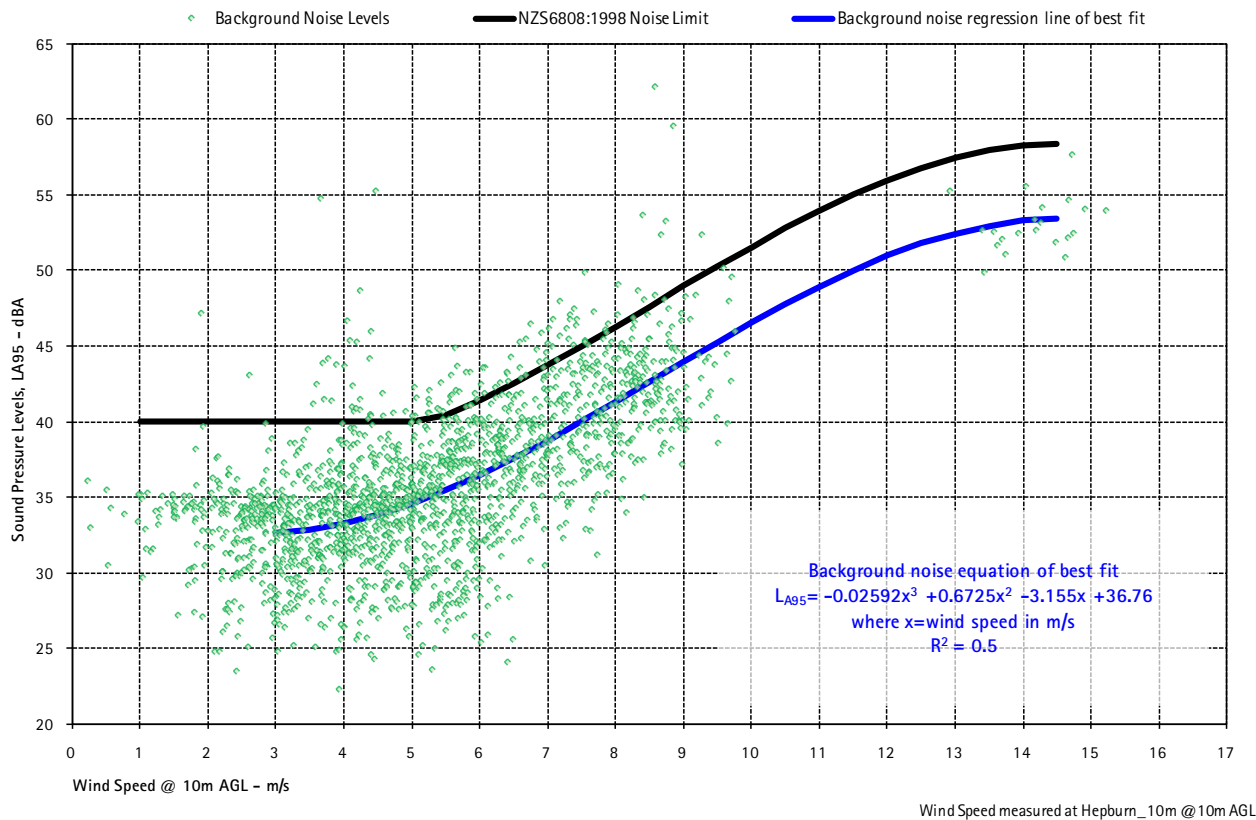


(06.01.2011 - 20.01.2011)

Correlation Coefficient = 0.67

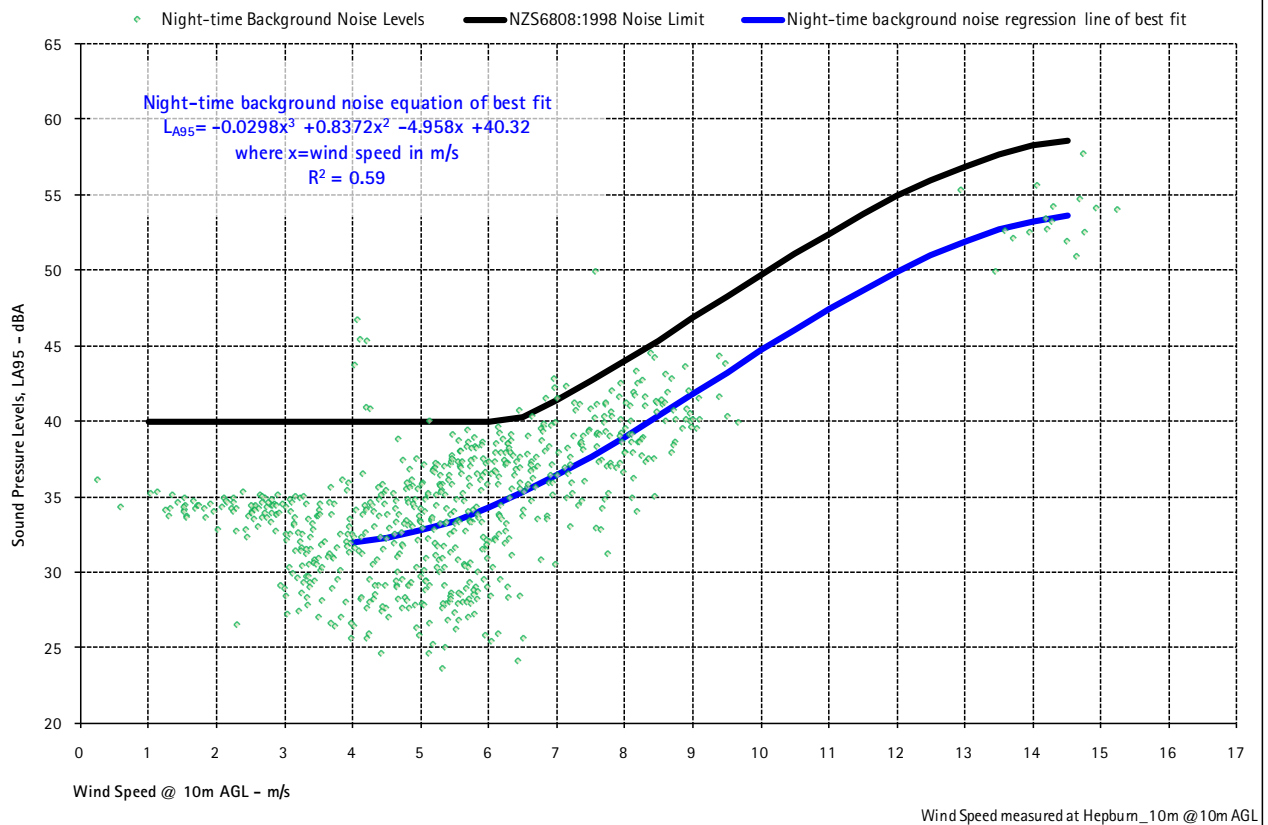
Background Noise Levels and Wind Speeds vs. Time  
House H1872 - January 2011

(06.01.2011 - 20.01.2011)

Background Noise Levels vs. Wind Speeds  
House H1872 - January 2011

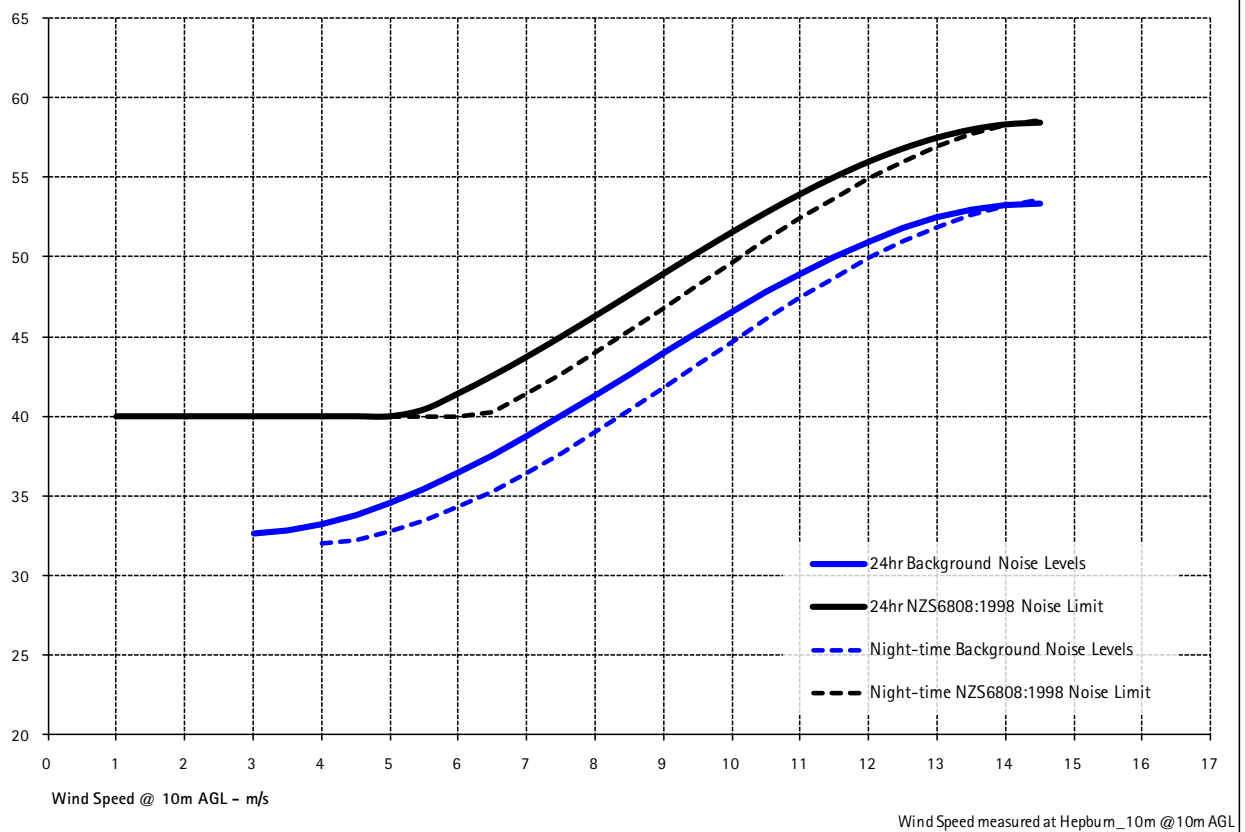
(06.01.2011 - 20.01.2011)

### Night-time Background Noise Levels vs. Wind Speeds House H1872 - January 2011



(06.01.2011 - 20.01.2011)

### Noise Limits House H1872 - January 2011



**HEPBURN WIND FARM**  
**Noise Compliance Testing Plan**  
**Rp001 R03 2011014ML**

**16 August 2011**



Project: **HEPBURN WIND FARM  
Noise Compliance Testing Plan**

Prepared for: **Hepburn Wind  
PO Box 225  
Daylesford VIC 3460**

Attention: **Tracy Anthony**

Report No.: **Rp001 R03 2011014ML**

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Status:	Issue:	Date:	Prepared by:	Reviewed by:
DRAFT	-	1 April 2011	CD	DG
DRAFT	R01	7 April 2011	CD	DG
FINAL	R02	8 April 2011	CD/JE	DG
FINAL	R03	16 August 2011	CD	DG



## TABLE OF CONTENTS

1.0	INTRODUCTION .....	4
2.0	PERMIT CONDITIONS .....	4
3.0	PRE-CONSTRUCTION NOISE MONITORING.....	5
3.1	Scope of monitoring.....	5
3.2	Methodology .....	6
4.0	NZS6808:1998 NOISE LIMITS.....	7
5.0	POST-CONSTRUCTION NOISE MONITORING .....	8
5.1	Monitoring methodology .....	8
5.1.1	Unattended monitoring.....	8
5.1.2	Attended monitoring (if required) .....	9
5.2	Testing schedule .....	9
5.3	Special audible characteristics.....	9
5.4	Reporting.....	10
6.0	COMPLAINTS RESPONSE.....	10
APPENDIX A	ACOUSTIC TERMINOLOGY .....	12
APPENDIX B	SITE LAYOUT .....	13
APPENDIX C	NOISE MONITORING LOCATIONS.....	14
APPENDIX D	NOISE LOGGER LOCATIONS .....	15
APPENDIX E	BACKGROUND NOISE AND WIND VS. TIME .....	16
APPENDIX F	NZS6808:1998 NOISE LIMITS .....	23

## 1.0 INTRODUCTION

The Hepburn Wind Farm is located south of Daylesford in Victoria. A noise impact assessment report for the wind farm, 2006293 001 R03 *Hepburn Community Wind Park – Noise Assessment* was issued by Marshall Day Acoustics Pty Ltd (MDA) on 4 June 2007 and formed part of the planning application for the project.

The wind farm received planning approval in July 2007. Planning Permit No. 2006/9231 was issued in conjunction with the planning approval requiring that noise emission from the wind farm satisfy the requirements of New Zealand Standard 6808:1998 *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS6808:1998). In particular, Condition 11 of the permit requires that a post-construction noise monitoring program be commissioned within two (2) months of the commencement of the wind farm.

The two (2) REpower MM82 wind turbines comprising the Hepburn Wind Farm have now been constructed and commissioning of the wind farm is expected to be completed in June 2011.

MDA has been engaged by Hepburn Wind to prepare a noise compliance testing plan detailing a methodology for undertaking the post-construction noise monitoring program and a process for responding to noise related complaints.

Acoustic terminology used throughout this report is provided in Appendix A. The wind farm layout is presented in Appendix B.

## 2.0 PERMIT CONDITIONS

Condition 10 of the planning permit requires that noise emissions from the wind farm comply with NZS6808:1998. This permit condition is reproduced below:

*The operation of the wind energy facility must comply with the New Zealand Standard 'Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators' (NZ 6806:1998) [sic] (the 'New Zealand Standard'), in relation to any dwelling existing at the date of approval of this permit, to the satisfaction of the Responsible Authority.*

Condition 11 of the permit, presented below, requires that a post-construction noise monitoring program be commissioned within two (2) months of the commencement of operation of any turbine. The program must be carried out in accordance with NZS6808:1998 at any dwelling within one kilometre radius of any turbine that is not in the same ownership as the subject land.

*Within two months of the commencement of operation of any turbine(s), an independent post-construction noise monitoring program must be undertaken by the proponent to the satisfaction of the Responsible Authority in accordance with the New Zealand Standard. The program must monitor noise levels at any dwelling within a one kilometre radius of any wind turbine that is not in the same ownership as the subject land.*

*A report summarising the results of the program, and the data collected, must be forwarded to the Responsible Authority within 30 days of the end of the monitoring period. The results must be written in plain English and formatted for reading by lay people.*

*Recommendations to address any non-compliance with NZS6808 must be included in the report and, on agreement by the Responsible Authority, measures to address non-compliance must be immediately implemented to the satisfaction of the Responsible Authority.*

### **3.0 PRE-CONSTRUCTION NOISE MONITORING**

#### **3.1 Scope of monitoring**

It is a requirement of Condition 10 of the planning permit for post-construction noise monitoring to be undertaken at all non-stakeholder residential properties within one kilometre of the wind farm. To determine the applicable NZS6808:1998 noise limits at these residential properties, pre-construction noise monitoring has been conducted at a number of these locations. This monitoring took place in both September 2006 and between 23 December 2010 and 15 February 2011.

Nineteen (19) residential properties were identified within one kilometre of the wind farm, including two (2) residential properties owned by stakeholders in the project (H6 and H7).

In September 2006, pre-construction noise monitoring was undertaken at two (2) residential properties (H7 and H18) in the vicinity of the Hepburn Wind Farm including one (1) property owned by a stakeholder in the project.

During December 2010 and January 2011, Hepburn Wind corresponded with all residents living within one kilometre of the wind farm requesting permission for pre-construction noise monitoring to be undertaken at their property, with the exception of the two (2) properties where monitoring was undertaken in 2006.

It is our understanding that approval was received to monitor at eight (8) residential properties. Non consent to conduct noise monitoring was provided by six (6) properties (H3 and H31 on behalf of itself and H4, H5, H11, and H13). No response was received from two (2) properties (H1 and H8) and the remaining property is owned by a stakeholder in the project (H6).

In order to determine the applicable NZS6808:1998 noise limits at the remaining residential properties, pre-construction noise monitoring has been undertaken at locations deemed representative of the noise environment at these properties.

Background noise measurements at eight (8) of the fourteen (14) monitored locations have been deemed representative of the background noise environment at other properties within close proximity as stated in Table 1.

The pre-construction noise monitoring locations are presented in Table 1 together with the monitoring periods and the additional properties for which the data is used, where applicable. A map showing the noise monitoring locations is presented in Appendix C.

**Table 1: Pre-construction noise monitoring locations**

Location	Additional houses represented by data	Noise monitoring period
2	1, 3, 4	23 December 2010 - 6 January 2011
7	6	5-20 September 2006
9	8	23 December 2010 - 6 January 2011
10		23 December 2010 - 6 January 2011
12		23 December 2010 - 6 January 2011
14		23 December 2010 - 6 January 2011
16		23 December 2010 - 6 January 2011
17		6 January - 11 February 2011
18		5-20 September 2006
19		6 January - 15 February 2011
A	5	23 December 2010 - 6 January 2011
B	11	6 - 20 January 2011
C	13	6 January - 11 February 2011
D	31	6 January - 11 February 2011

### 3.2 Methodology

Type 1 noise loggers Rion NL31 and ARL 316 were used to complete the background noise monitoring surveys.

Noise loggers were placed in accordance with NZS6808:1998, in positions that were representative of the general ambient noise environment of the dwelling.

Photographs of noise logger positions are presented in Appendix D.

The timing of the background noise monitoring campaign coincided, in part, with construction activities associated with the installation of the turbines. No construction activity took place at the wind farm site between 23 December 2010 and 9 January 2011, inclusive. Intermittent construction activity did occur from 10 January 2011, during which time a diary of construction noise activities was kept by the site manager. Periods of noisy activity were identified from the diary and associated pre-construction wind and noise level data was removed from the analysis.

Daily rainfall data collected by the Bureau of Meteorology at the Ballarat monitoring station were reviewed and where rainfall is likely to have occurred, these data points were removed from the analysis. Appendix E shows the trend of background noise and wind vs. time for each monitored locations together with the correlation coefficient.

#### **4.0 NZS6808:1998 NOISE LIMITS**

To determine the applicable noise limits in accordance with NZS6808:1998, a regression analysis of the background noise and wind speed is performed. 10m AGL (Above Ground Level) wind speed data is used. An investigation of a suitable regression analysis is carried out using linear, second order or third order polynomial curves. It has been found that either a second or third order polynomial provides the best representation of the background noise levels depending on the monitored site.

As detailed in Condition 10 of the planning permit, NZS6808:1998 states that the noise level from a wind turbine or wind farm at a residential site should not exceed the background noise level ( $L_{A95}$ ) by more than 5dBA or a level of 40dBA  $L_{A95}$ , whichever is greater.

The applicable noise limits for the Hepburn Wind Farm have been derived from the pre-construction background noise monitoring described in Section 3.0.

Noise limits determined for eight (8) of the fourteen (14) monitored locations have been deemed representative of the background noise environment at ten (10) other properties in close proximity.

The graphs used to derive the noise limits for each of the study sites are presented in Appendix F. The solid red line represents the background noise line of best fit and the solid black line represents the noise limits derived in accordance with NZS6808:1998. The equation of the line of best fit is noted on each graph as is the coefficient of determination.



## 5.0 POST-CONSTRUCTION NOISE MONITORING

### 5.1 Monitoring methodology

#### 5.1.1 Unattended monitoring

As required by Condition 11, unattended noise monitoring shall be carried out in accordance with NZS6808:1998. We recommend that it should concurrently satisfy the following criteria:

- Post-construction noise monitoring equipment should be located at the same location as for the pre-construction noise monitoring, as far as practical
- A target of capturing at least 1440 data pairs, consistent with the recommendations of NZS6808:1998. Typically, a minimum of two weeks of monitoring will be required to capture sufficient data.
- Use of wind speed and direction data collected at 10m AGL within the site

In Section A1.3, NZS6808:1998 states:

*Since the “operational” measurements will be combined wind farm and background levels, it may be necessary to adjust these measurements to determine the “wind farm only” levels.*

Accordingly, measured post-construction noise levels should be corrected for background noise. NZS6808:1998 does not provide explicit guidance on how this correction is to be applied, however this has been addressed in the 2010 version of the standard<sup>1</sup> which states:

*Post-installation measurements will capture both the wind farm sound and the background sound. In order to assess the wind farm sound level alone, the contribution of the background sound shall be removed from the regression curve drawn in 7.5.2 at each integer wind speed.*

*...While a simple energy subtraction of background and post-installation sound levels is not strictly mathematically correct for  $L_{90}$  centile levels, the difference may be taken as the  $L_{90}$  wind farm sound levels*

Measured post-construction data will be corrected according to the above methodology using the pre-construction noise levels presented in Appendix F.

Unattended noise compliance testing includes an inherent limitation in that it is possible to demonstrate compliance with noise limits but it is not possible to conclusively demonstrate non-compliance with noise limits. Specifically, where monitored noise levels are found to exceed a given noise limit, it may not be possible to determine the source of the excess as the measurements are unattended and specific sources of sound cannot generally be identified.

---

<sup>1</sup> New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010). NZS6808:2010 has recently been adopted as the relevant standard for assessment of new proposed wind farms in Victoria, as detailed in the *Policy and planning guidelines for development of wind energy facilities in Victoria* dated March 2011

In light of this limitation, attended monitoring may or may not be required. The following scenarios are possible.

**Table 2: Unattended monitoring outcomes**

Scenario	Outcome
Unattended compliance testing demonstrates compliance with the noise limits	Attended measurements are not required
Unattended compliance testing does not demonstrate compliance with the noise limits	Attended measurements may be required, as detailed below.

#### 5.1.2 Attended monitoring (if required)

NZS6808:1998 does not provide a methodology to undertake attended noise monitoring. If attended measurements are required, they will be carried out in general accordance with Section 7.7 from NZS6808:2010. The key features of this methodology are described in AS4959:2010 as follows:

- *Every measurement shall be expressed as the  $L_{90}$  sound level*
- *If the wind turbine/farm sound is steady then a measurement time interval of 2 minutes may be appropriate*
- *Measurements shall be conducted with the wind turbine/farm operational and then repeated immediately to measure the 'background' sound level with the wind turbine/farm shut off*
- *The background sound level with the wind turbine/farm off shall be energy subtracted from the 'post-installation' sound level with the wind turbine/farm operating*

In the case that attended measurements are required as part of compliance monitoring, a detailed test plan will be prepared by a suitably qualified acoustics expert and presented to the Relevant Authority for approval prior to carrying out any attended measurements.

## 5.2 Testing schedule

Condition 11 of the planning permit requires for the post-construction noise monitoring to start within two (2) months of the commencement of operation of any turbine.

It is our understanding that *commencement of operation of any turbine* refers to the time where any wind turbine is commissioned. The wind turbines were officially commissioned on 22 June 2011. However, at the time of preparing this document, restrictions have been imposed on the wind farm in terms of power output from the turbines. It is expected that this limitation will be lifted in the coming weeks.

In accordance with NZS6808:1998, the post-construction noise monitoring should be undertaken for a minimum of two weeks in order to collect at least 1440 valid data pairs.

## 5.3 Special audible characteristics

Listening tests should be carried out at each dwelling identified for post-construction monitoring and a subjective assessment made by a suitably qualified acoustics expert of whether any special audible characteristics are considered to be present in the wind farm noise emission.

The listening tests should be carried out at a range of wind speeds and directions which is sufficient to represent the range in wind farm noise emission that is likely between the cut-in wind speed and the wind speed of rated power. In particular, listening tests should at least be carried out for winds in the direction from the wind farm to the listening location.

In the case that the subjective assessment demonstrates the potential for one or more special audible characteristics to be present in the wind farm noise emission an objective assessment shall be carried out. Guidance for assessing potential special audible characteristics are presented in NZS6808:2010 and the EPHC *Draft National Wind Farm Development Guidelines* dated July 2010.

The assessment of special audible characteristics should include, but not be limited to, the following:

- Tonality
- Impulsiveness
- Amplitude modulation

In accordance with NZS6808:1998, if one or more special audible characteristics is found to be present in the wind farm noise emission at the dwelling being considered a penalty of 5dB shall be added to the post-construction wind farm noise levels (background corrected). Where two or more special audible characteristics are found to be present a total combined penalty of 5dB shall be added. The correction will only be applied at those wind speeds where the special audible characteristic has been found to be present.

#### **5.4 Reporting**

As required by Condition 11 of the planning permit, a noise report presenting the findings of the post-construction noise monitoring program must be submitted to the Responsible Authority within 30 days of the end of the monitoring period.

#### **6.0 COMPLAINTS RESPONSE**

When a formal complaint is lodged by a resident living in the vicinity of the wind farm, a pro-forma form will be provided to the resident by Hepburn Wind. This form will assist the resident in recording the following:

- Time when the wind farm caused disturbance
- Weather conditions at the time of the disturbance
- Character of the noise at the time of the disturbance

Once the information provided by the resident has been reviewed by Hepburn Wind and the complaint has been confirmed as genuine, a noise logger will be placed at the resident's property for a minimum period of two (2) weeks at a location in accordance with the requirements of NZS6808:1998.

To assist in identifying the source of disturbance, the noise logger will record the following:

- One third octave band noise levels
- Audio samples

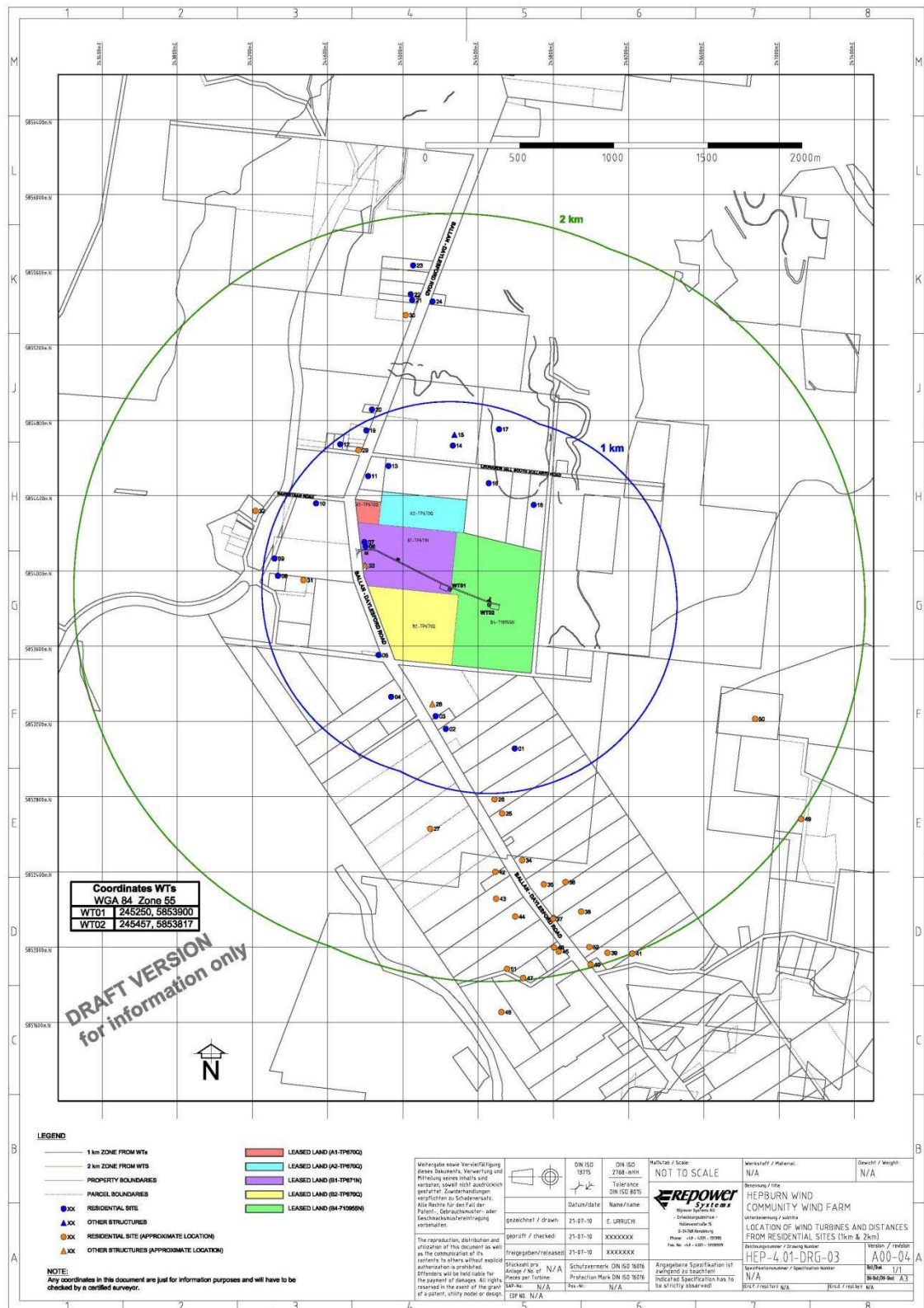
During the monitoring period, the resident should keep a diary of disturbances and provide it to Hepburn Wind once the survey is completed.

Results from the survey will be analysed by MDA and a short report presenting the findings of the survey will be provided to Hepburn Wind within four (4) weeks of the completion of the survey. Once Hepburn Wind has reviewed the findings of our report, feedback will be provided to the resident, the status of the complaint will be updated and further investigation will be undertaken if required.

## APPENDIX A ACOUSTIC TERMINOLOGY

<b>Frequency</b>	The number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz).
<b>Hertz (Hz)</b>	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
<b>Octave Band</b>	A range of frequencies where the highest frequency included is twice the lowest frequency. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.
<b>Sound Pressure Level (<math>L_p</math>)</b>	A logarithmic ratio of a sound pressure measured at distance, relative to the threshold of hearing (20 $\mu$ Pa RMS) and expressed in decibels.
<b>Sound Power Level (<math>L_w</math>)</b>	A logarithmic ratio of the acoustic power output of a source relative to $10^{-12}$ watts and expressed in decibels. Sound power level is calculated from measured sound pressure levels.
<b>dB</b>	Decibel – A measurement of sound level expressed as a logarithmic ratio of sound pressure P relative to a reference pressure of $P_r=20 \mu$ Pa i.e. $dB = 20 \times \log(P/P_r)$
<b>dBA</b>	A measurement of sound level which has its frequency characteristics modified by a filter (A-weighted) so as to more closely approximate the frequency bias of the human ear.
<b>A-weighting</b>	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear.  All noise levels are quoted relative to a sound pressure of $2 \times 10^{-5}$ Pa
<b><math>L_{Aeq}</math></b>	The equivalent continuous (time-averaged) A-weighted sound level. This is commonly referred to as the average noise level.
<b><math>L_{A90}</math></b>	The A-weighted noise level equalled or exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.





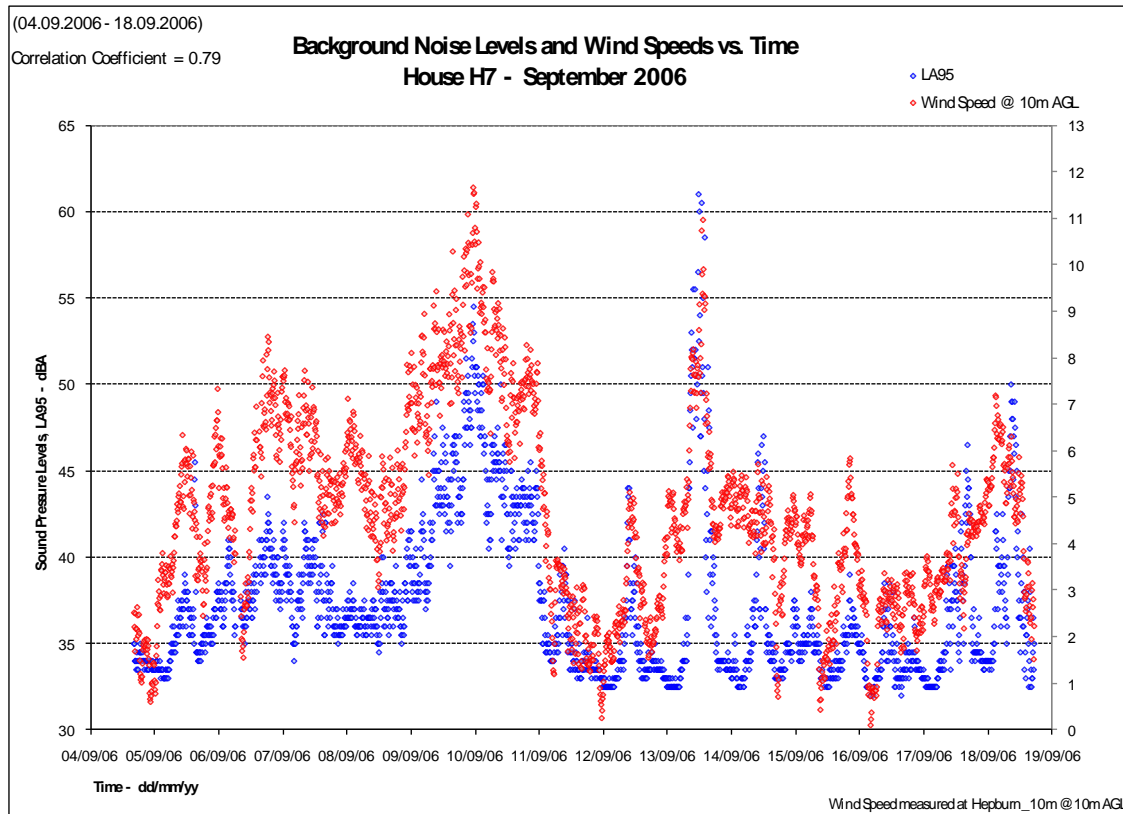
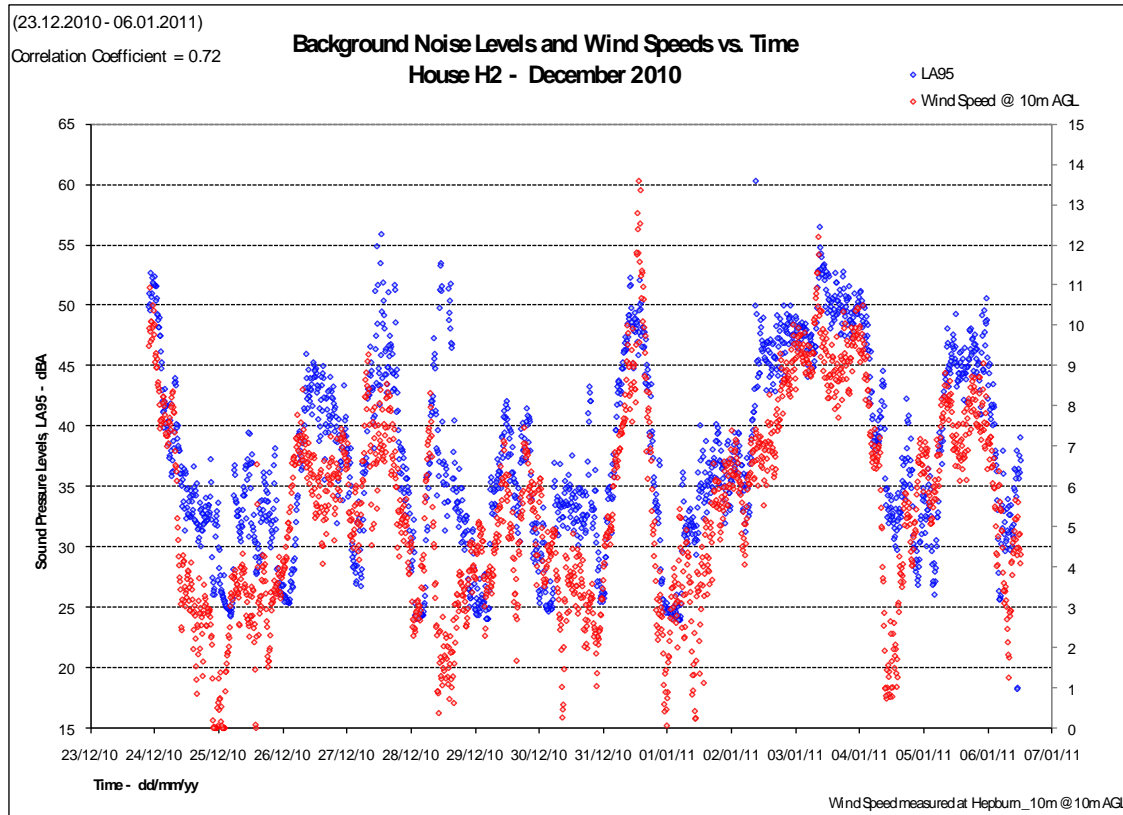
APPENDIX C NOISE MONITORING LOCATIONS



**APPENDIX D NOISE LOGGER LOCATIONS**



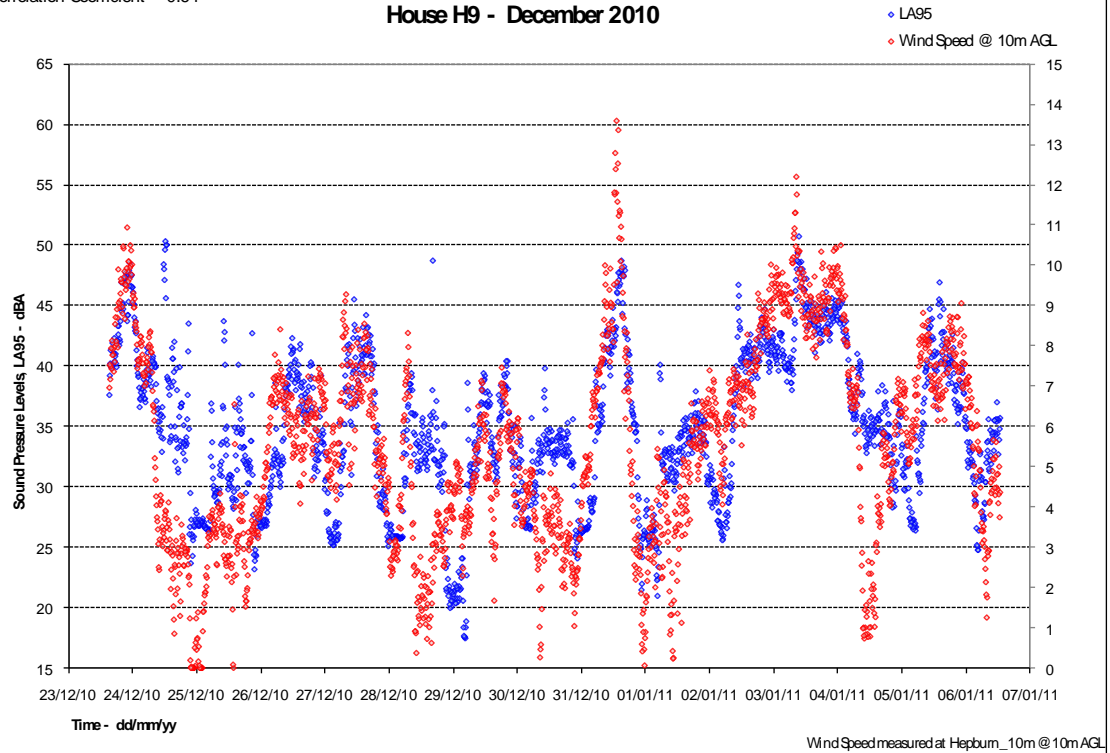
## APPENDIX E BACKGROUND NOISE AND WIND VS. TIME



(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.64

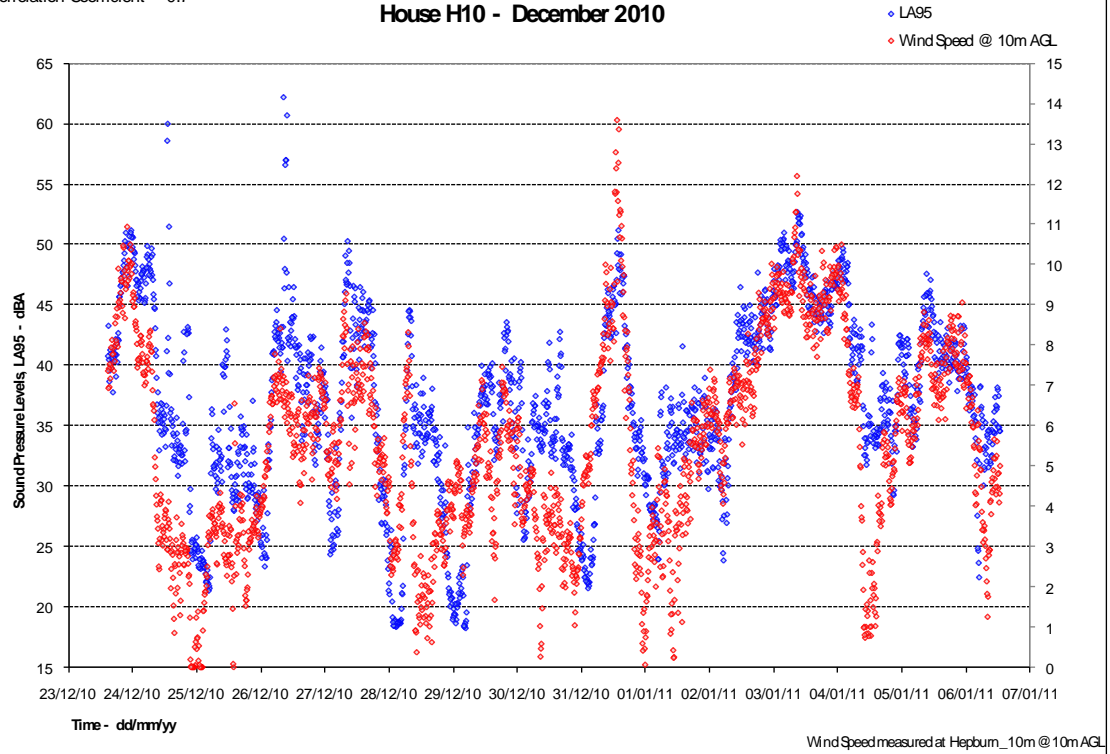
### Background Noise Levels and Wind Speeds vs. Time House H9 - December 2010



(23.12.2010 - 06.01.2011)

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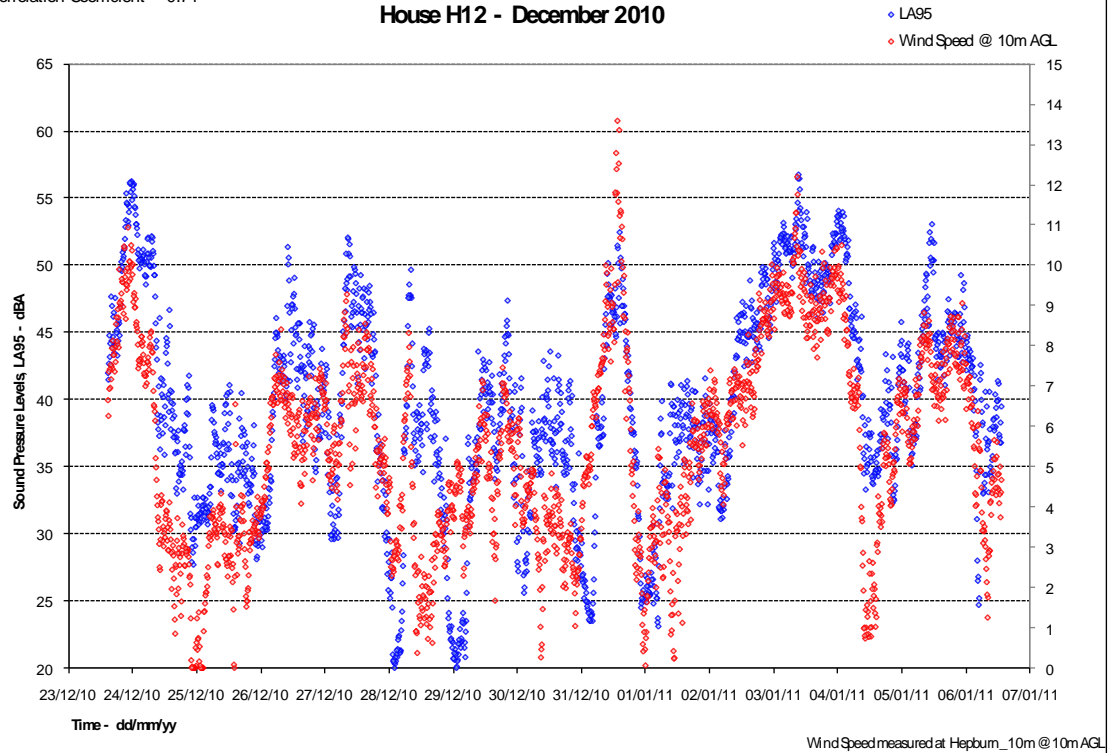
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(23.12.2010 - 06.01.2011)

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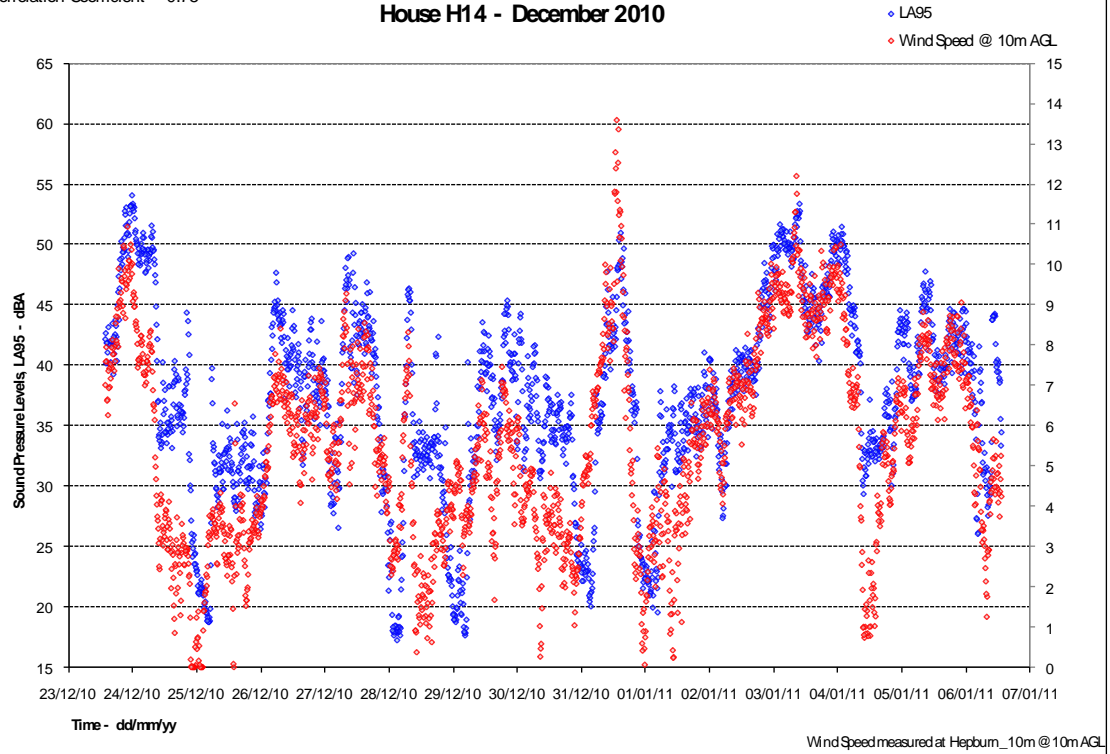
### Background Noise Levels and Wind Speeds vs. Time House H12 - December 2010



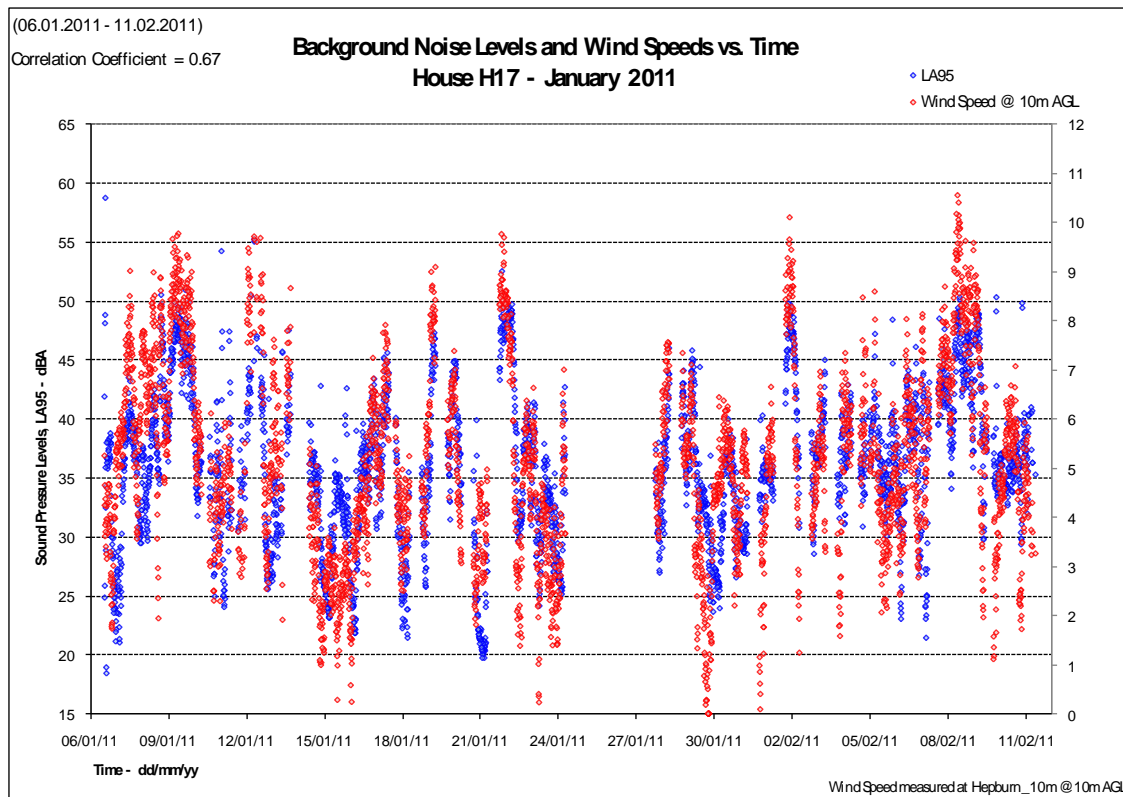
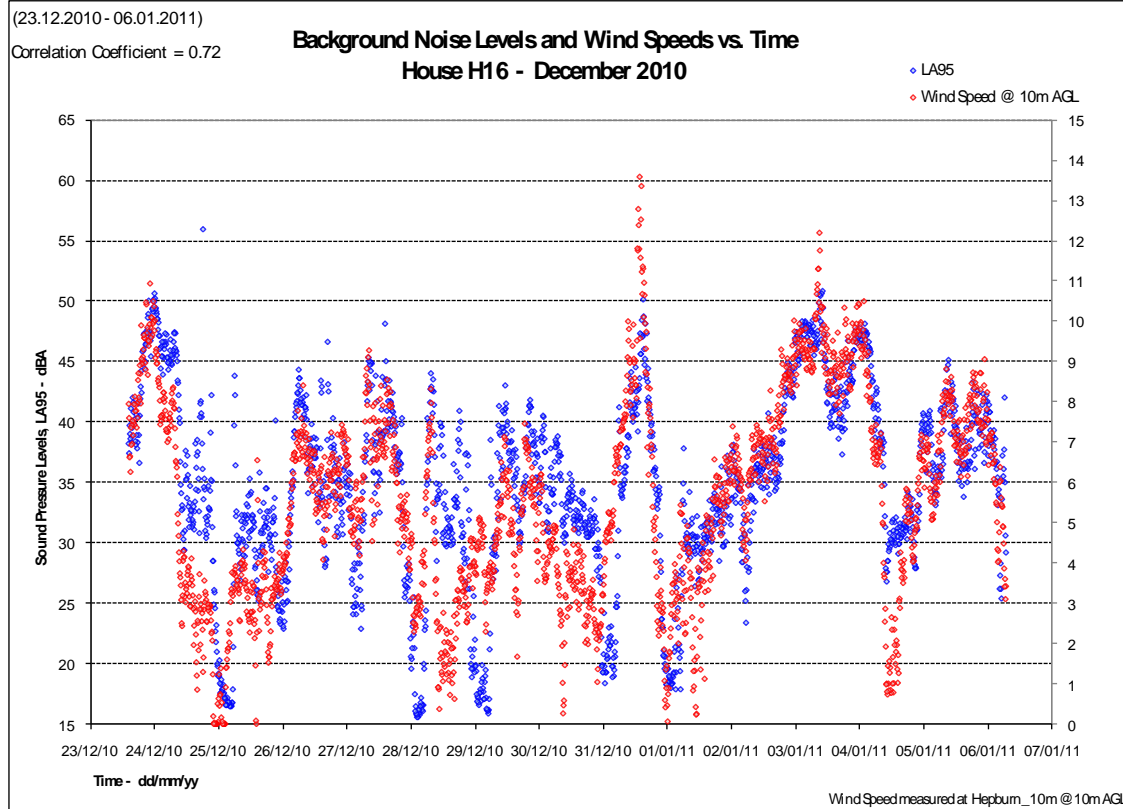
(23.12.2010 - 06.01.2011)

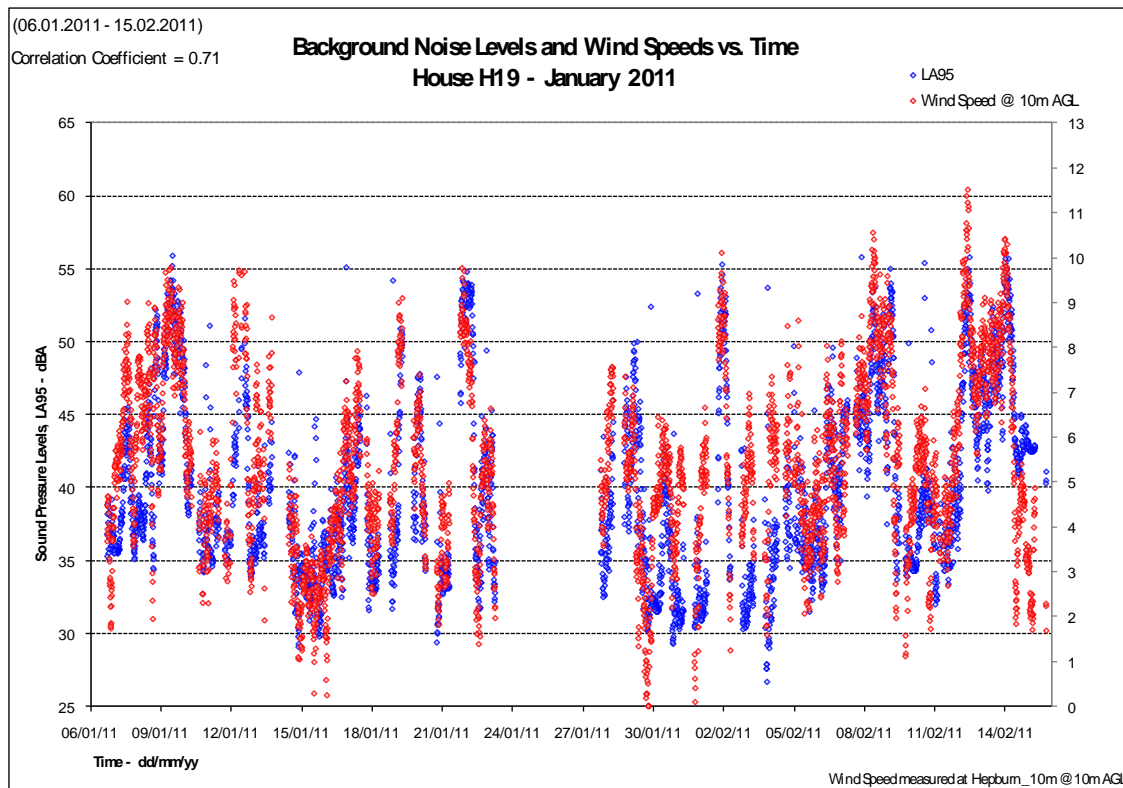
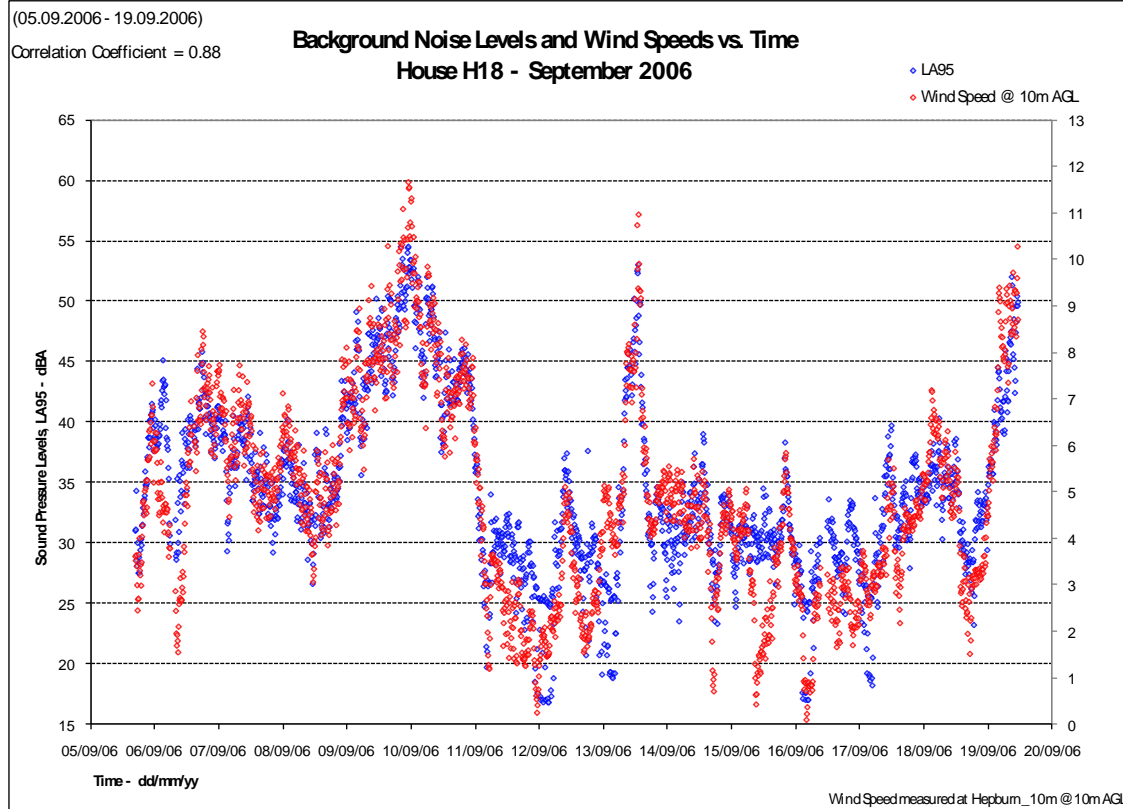
Correlation Coefficient = 0.75

### Background Noise Levels and Wind Speeds vs. Time House H14 - December 2010





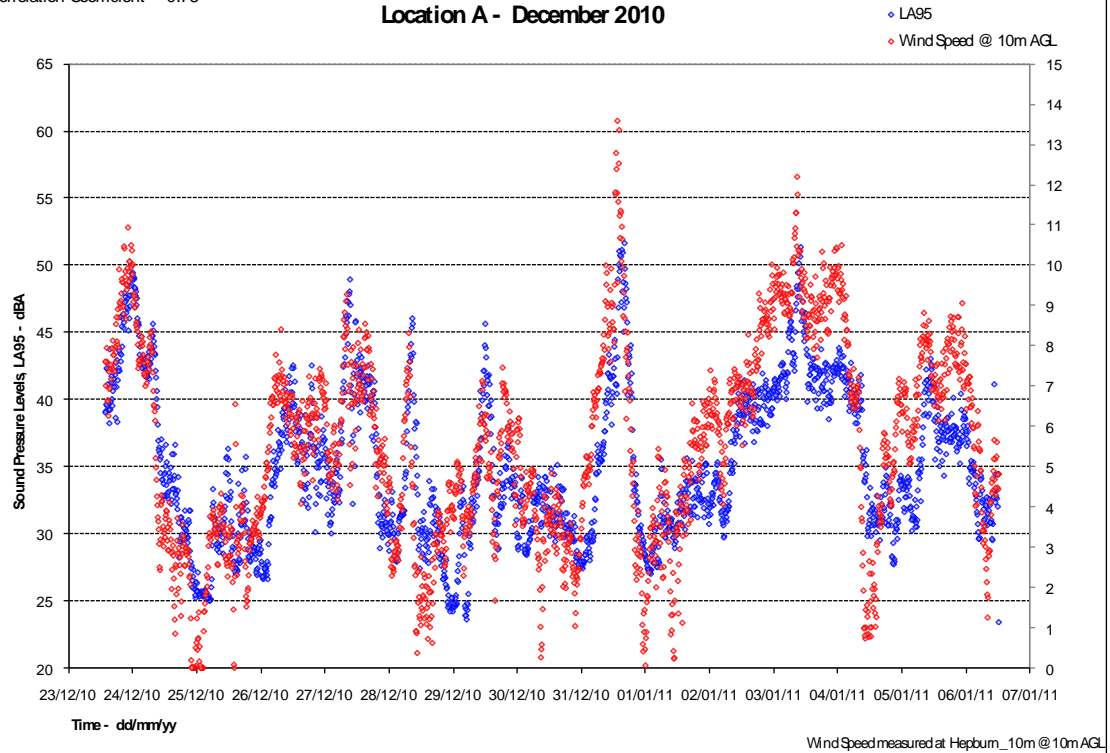




(23.12.2010 - 06.01.2011)

Correlation Coefficient = 0.78

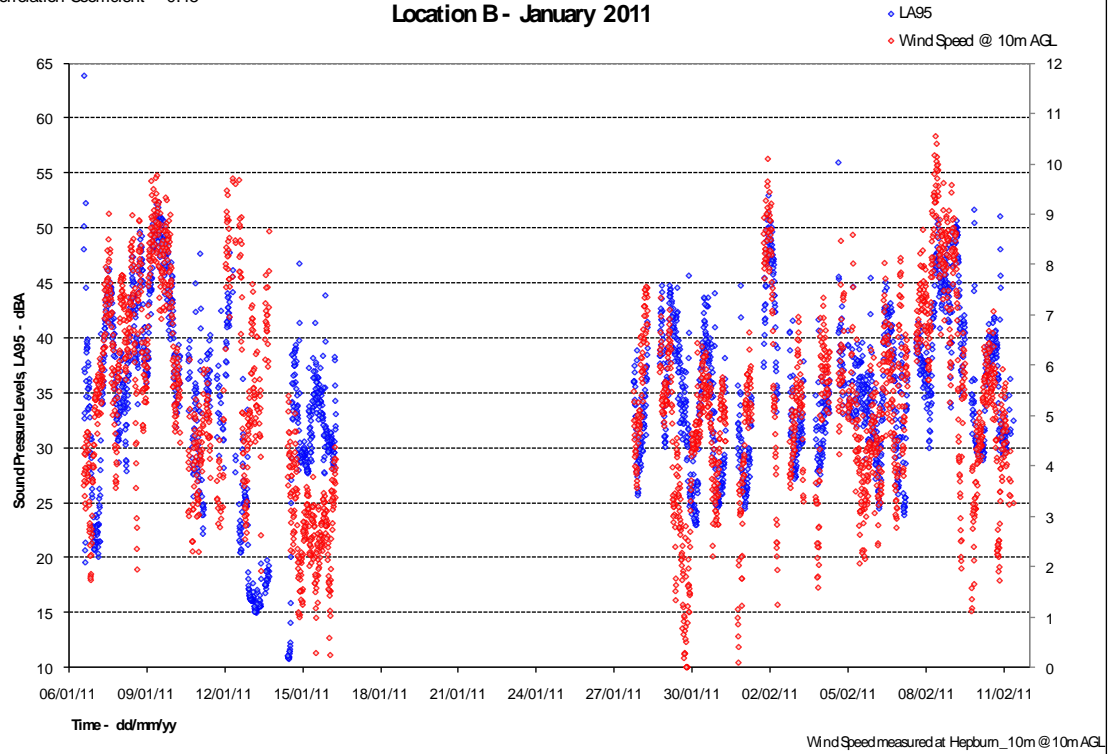
### Background Noise Levels and Wind Speeds vs. Time Location A - December 2010



(06.01.2011 - 11.02.2011)

Correlation Coefficient = 0.45

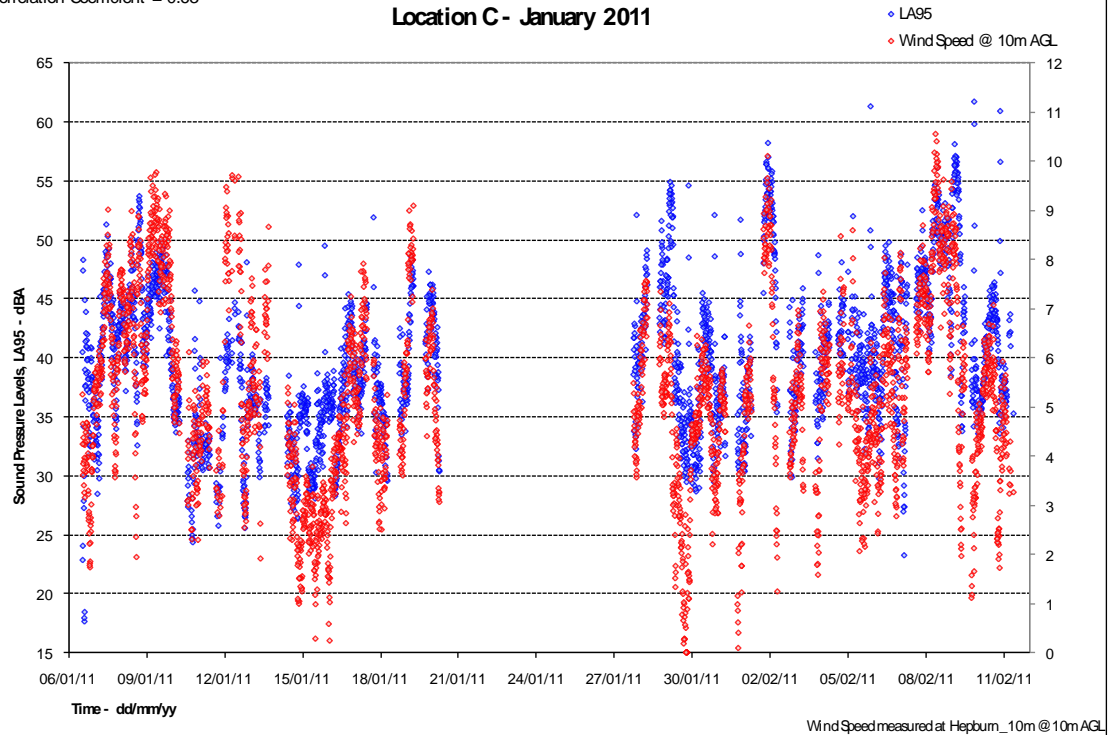
### Background Noise Levels and Wind Speeds vs. Time Location B - January 2011



(06.01.2011 - 11.02.2011)

Correlation Coefficient = 0.63

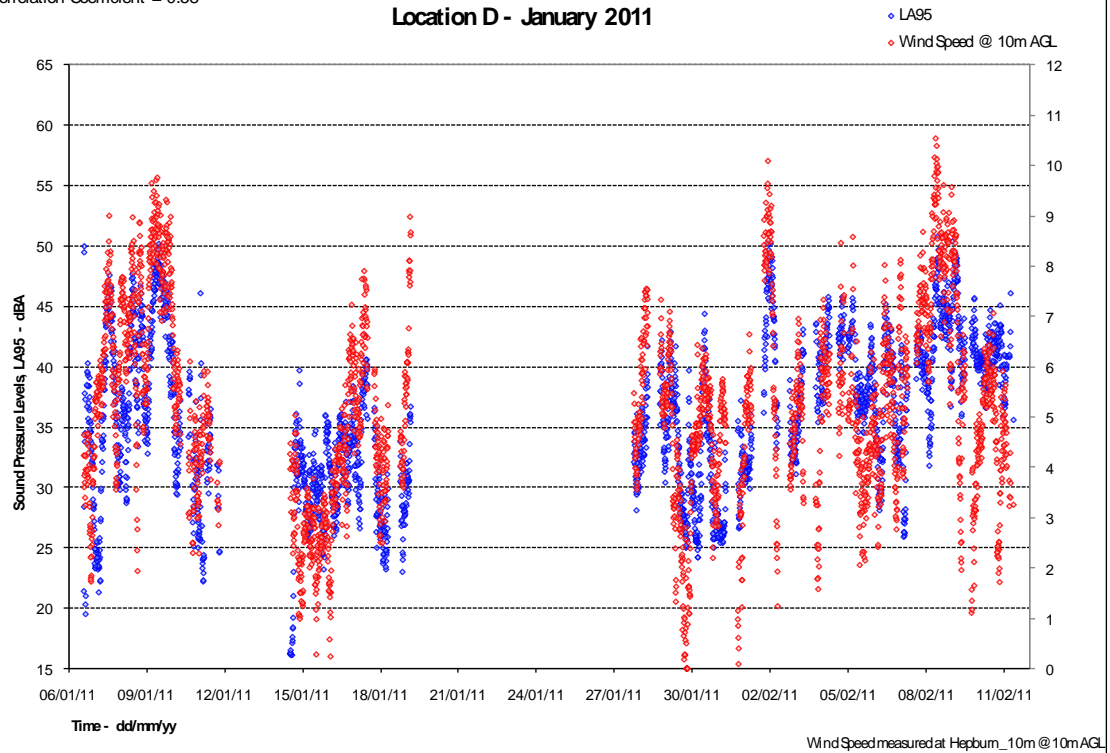
### Background Noise Levels and Wind Speeds vs. Time Location C - January 2011



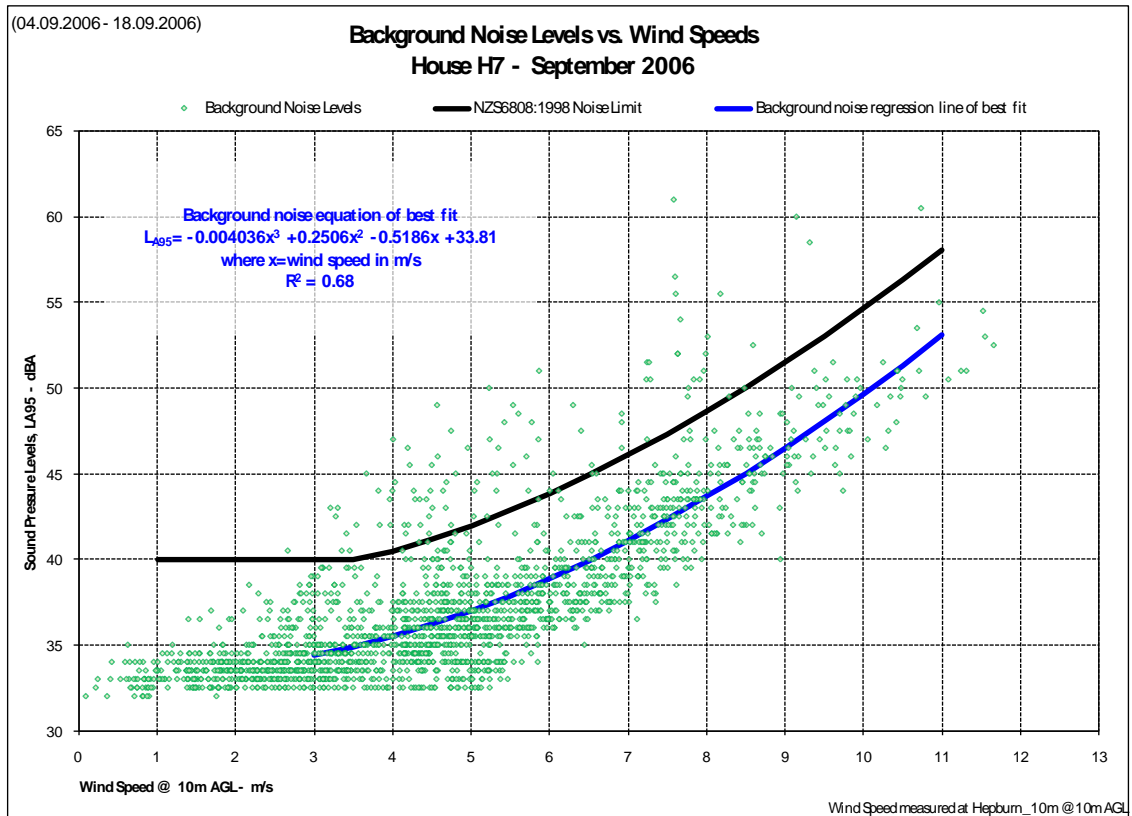
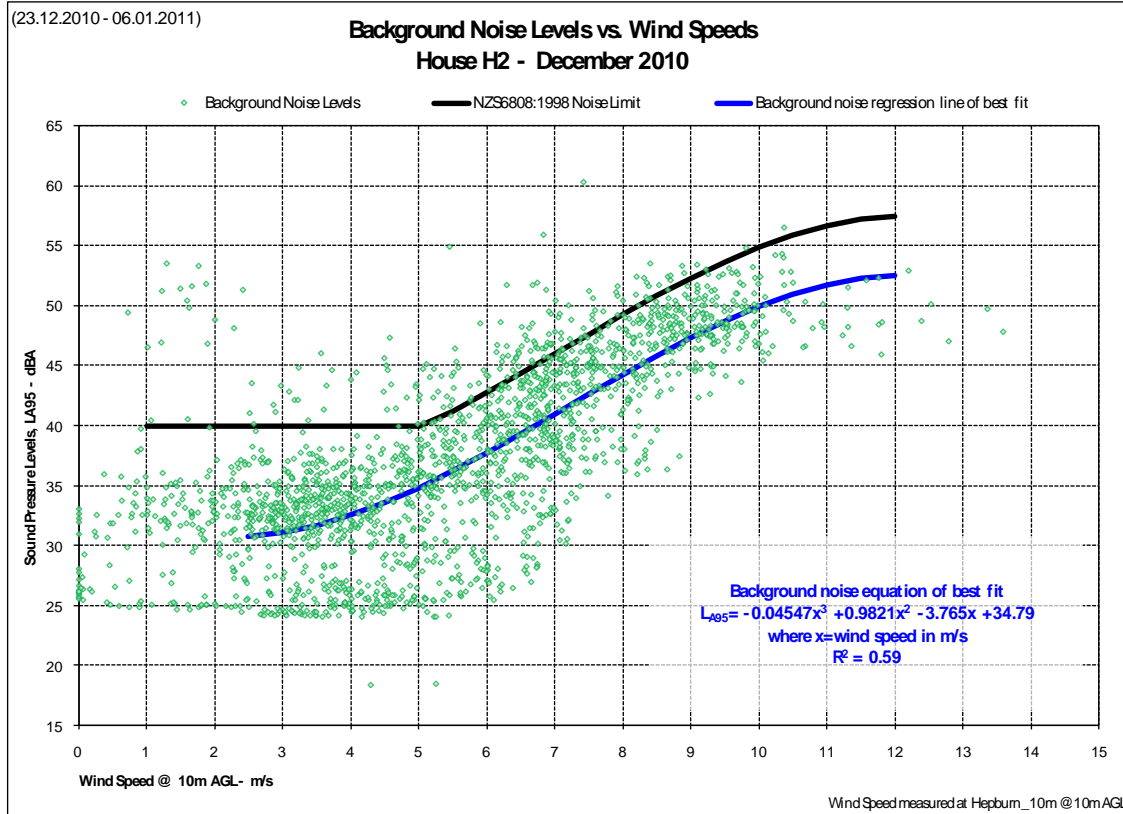
(06.01.2011 - 11.02.2011)

Correlation Coefficient = 0.58

### Background Noise Levels and Wind Speeds vs. Time Location D - January 2011



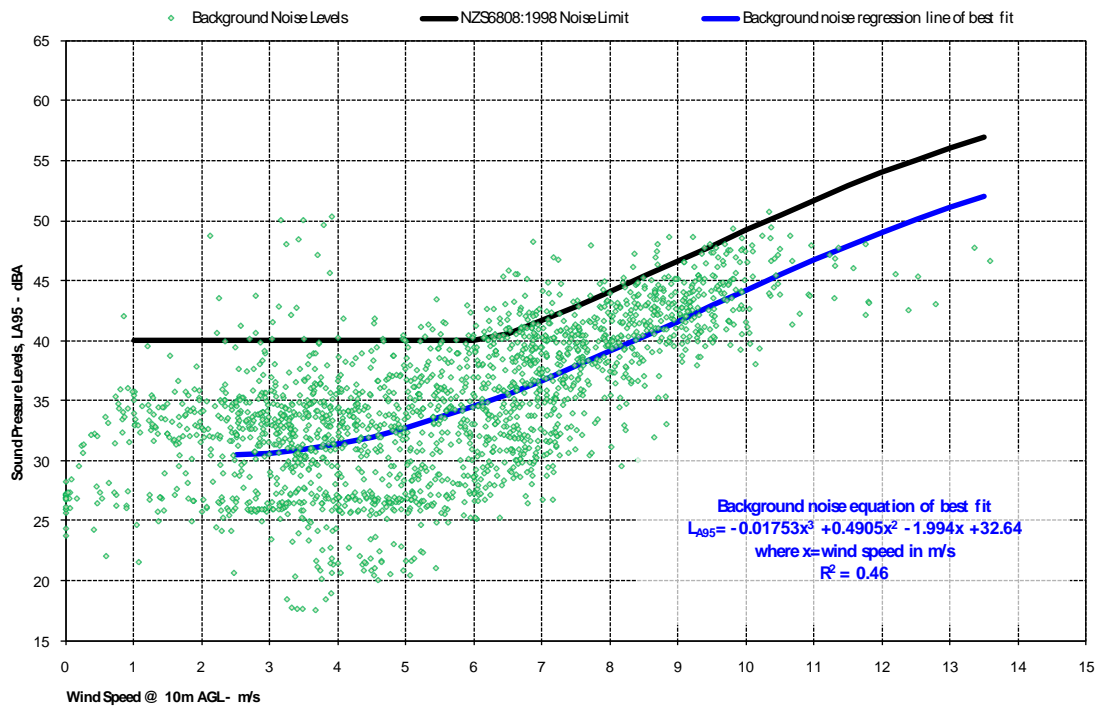
## APPENDIX F NZS6808:1998 NOISE LIMITS





(23.12.2010 - 06.01.2011)

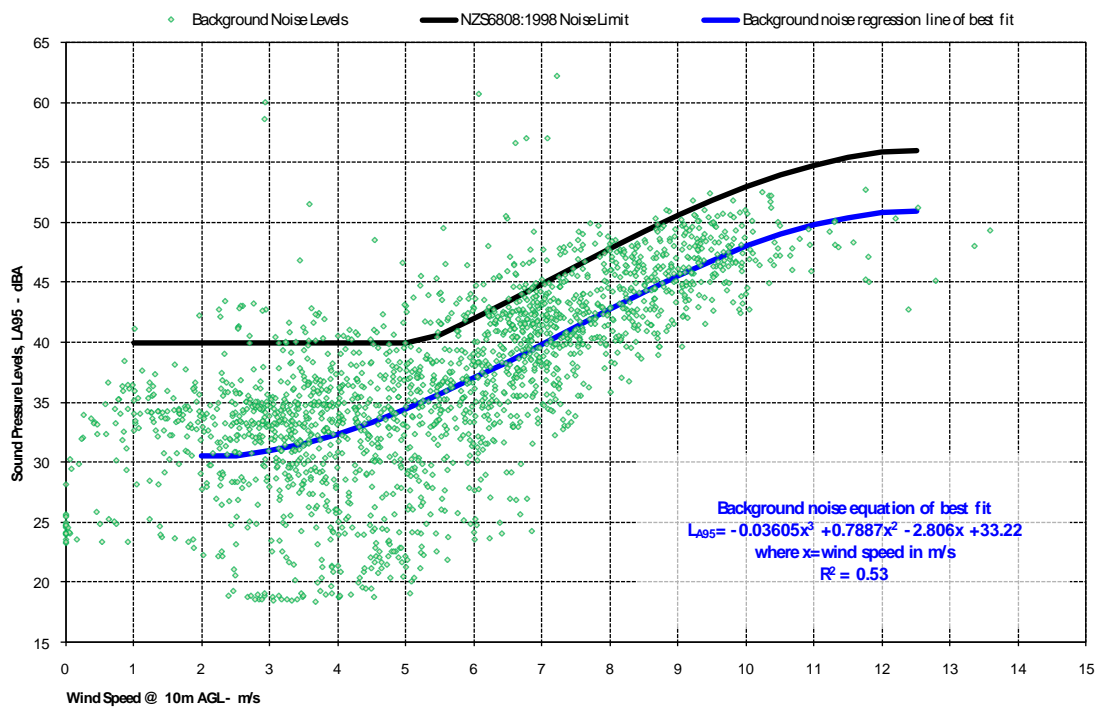
### Background Noise Levels vs. Wind Speeds House H9 - December 2010



Wind Speed measured at Hepburn\_10m @ 10m AGL

(23.12.2010 - 06.01.2011)

### Background Noise Levels vs. Wind Speeds House H10 - December 2010

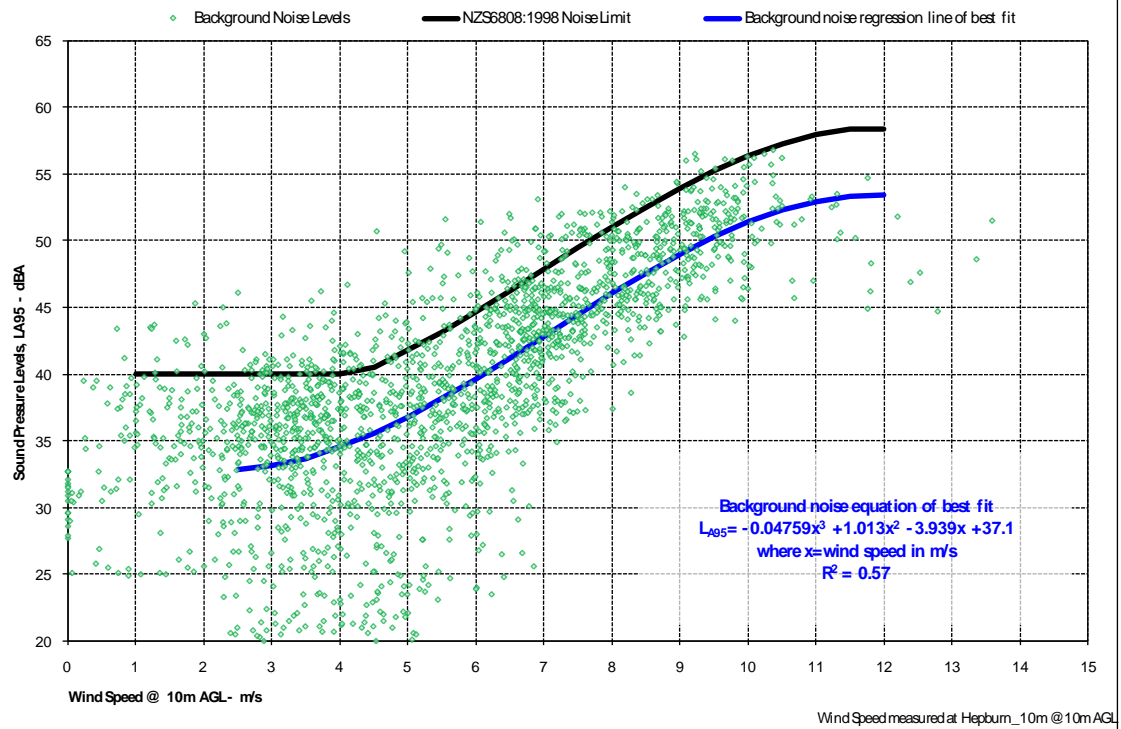


Wind Speed measured at Hepburn\_10m @ 10m AGL



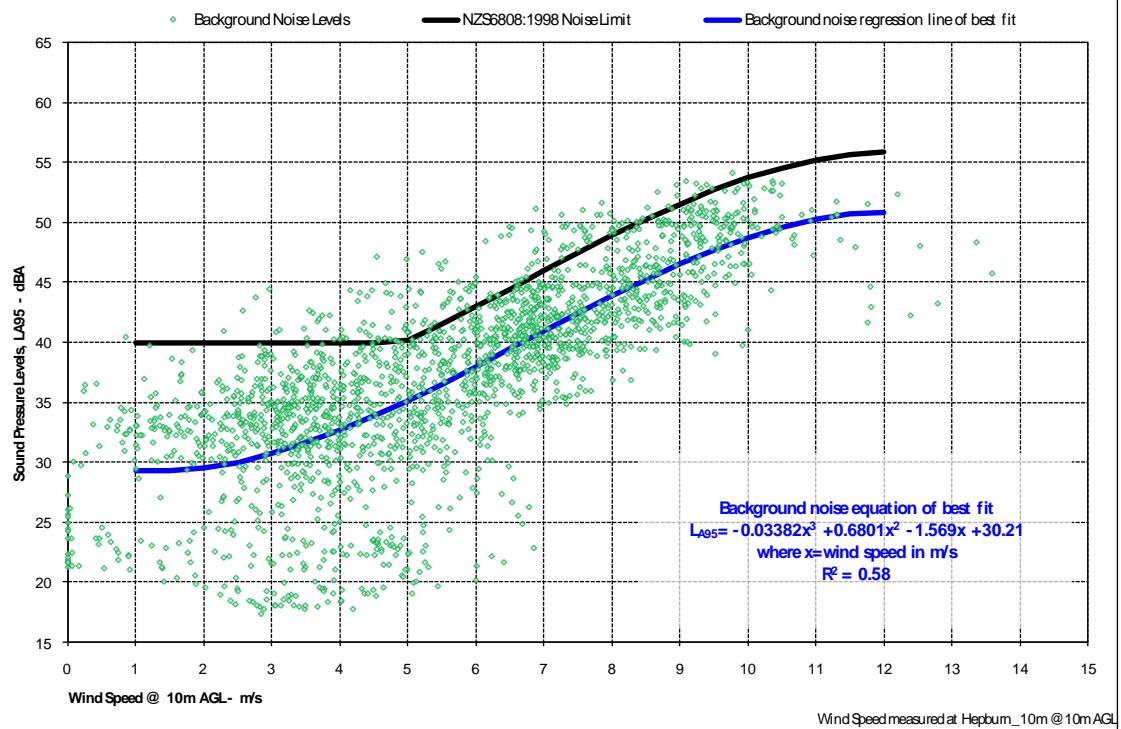
(23.12.2010 - 06.01.2011)

Background Noise Levels vs. Wind Speeds  
House H12 - December 2010



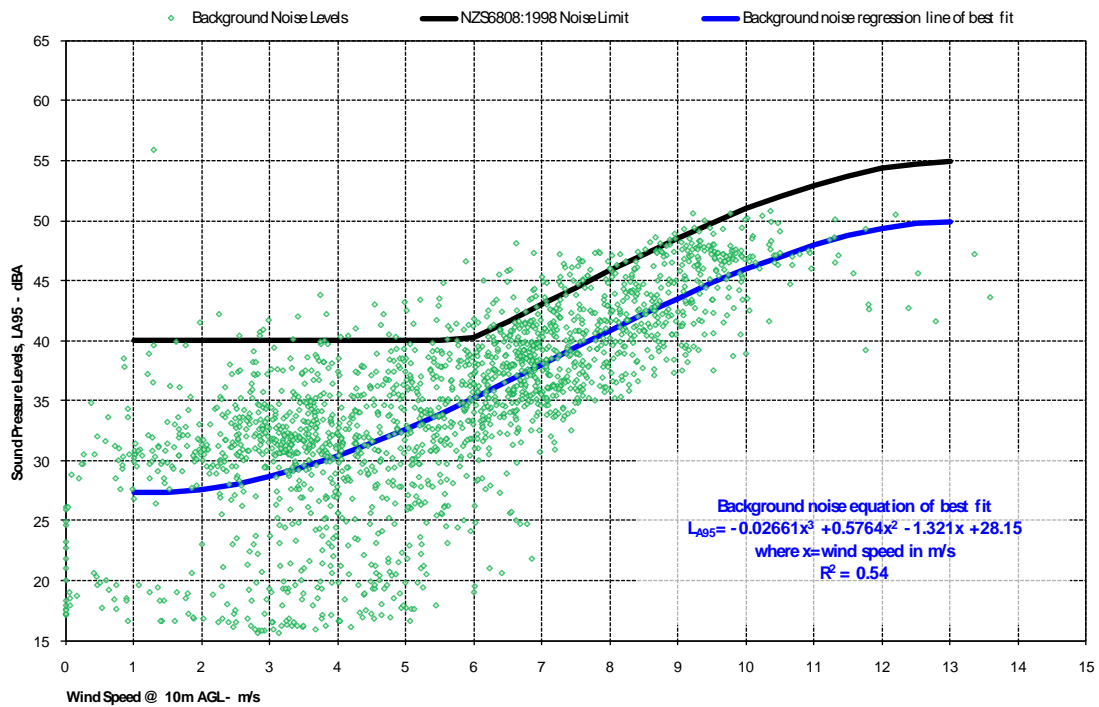
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Background Noise Levels vs. Wind Speeds  
House H14 - December 2010



(23.12.2010 - 06.01.2011)

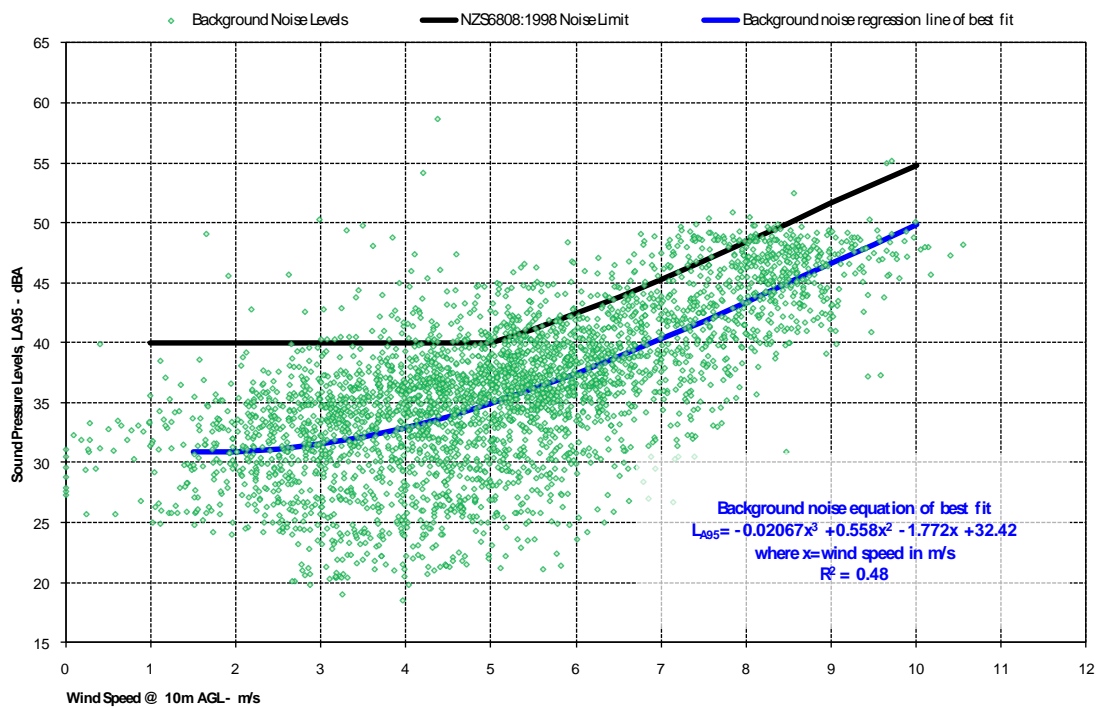
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Wind Speed measured at Hepburn\_10m @ 10m AGL

(06.01.2011 - 11.02.2011)

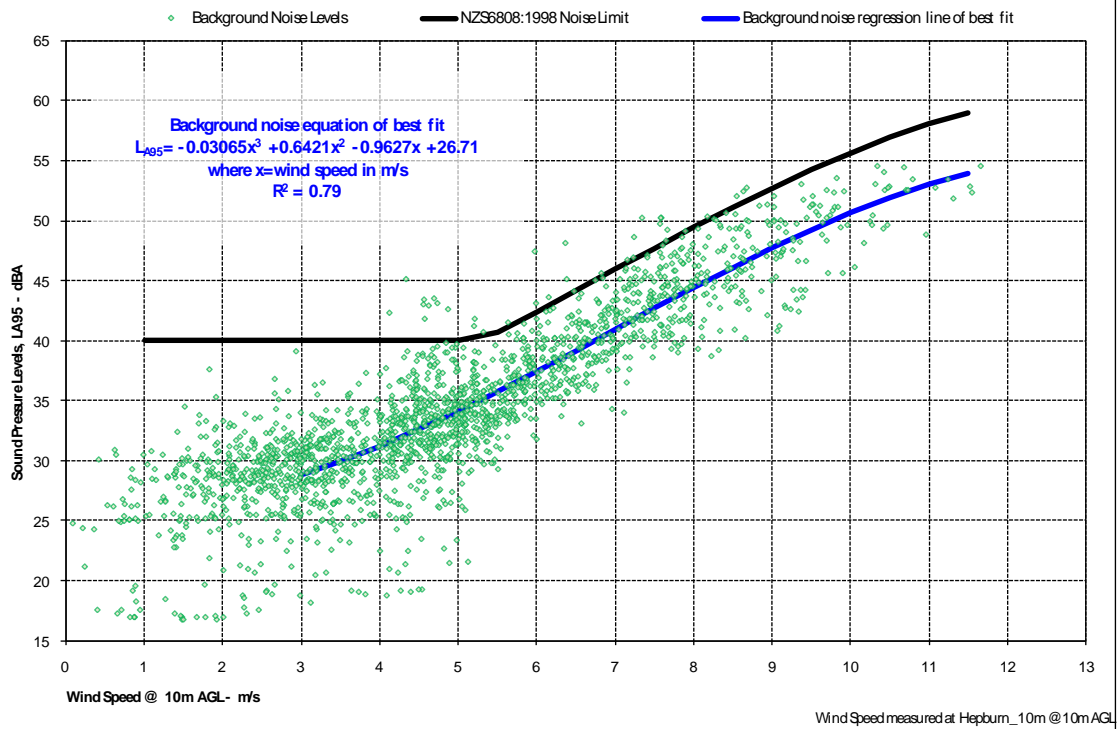
### Background Noise Levels vs. Wind Speeds House H17 - January 2011



Wind Speed measured at Hepburn\_10m @ 10m AGL

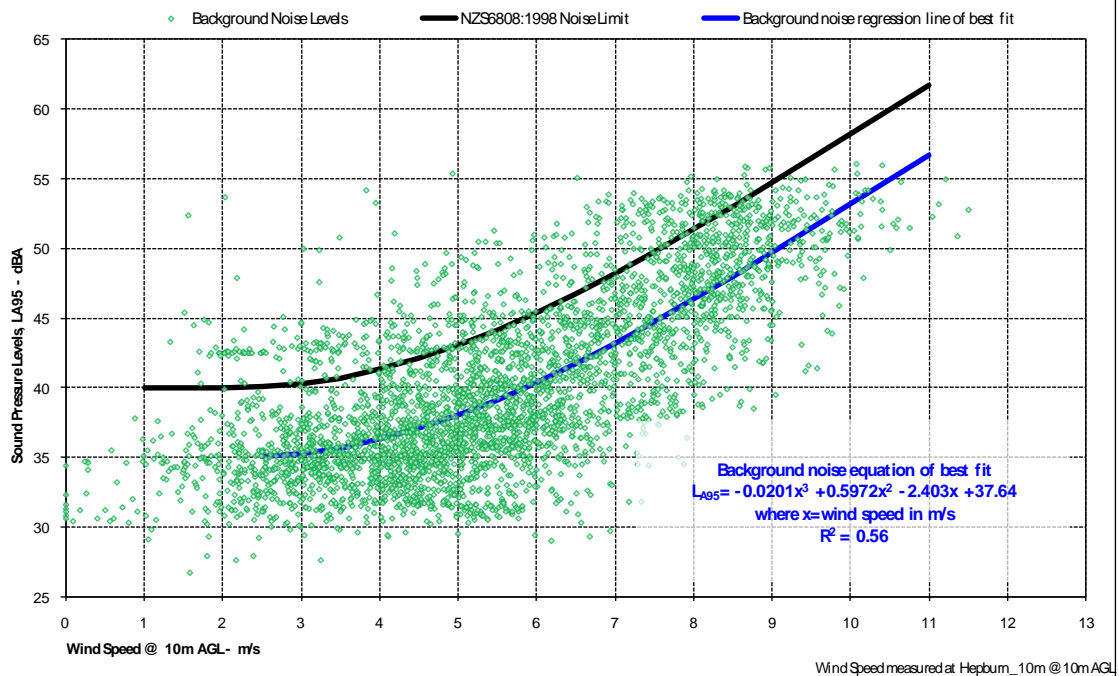
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### Background Noise Levels vs. Wind Speeds House H18 - September 2006



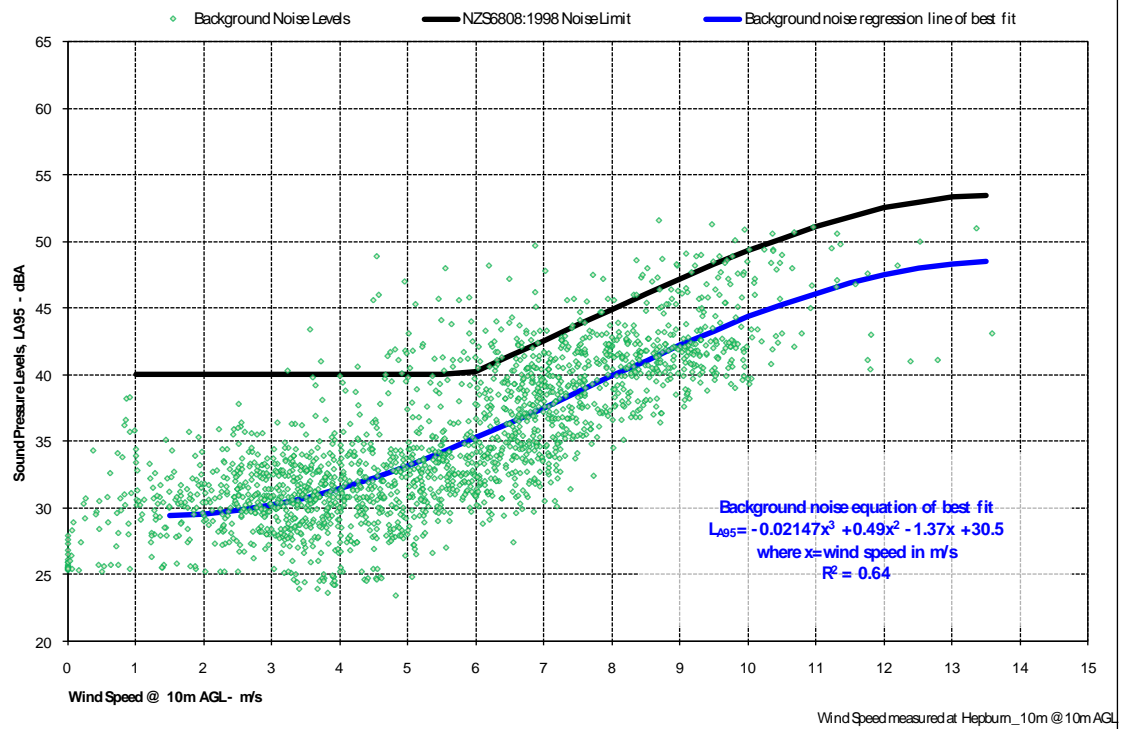
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### Background Noise Levels vs. Wind Speeds House H19 - January 2011



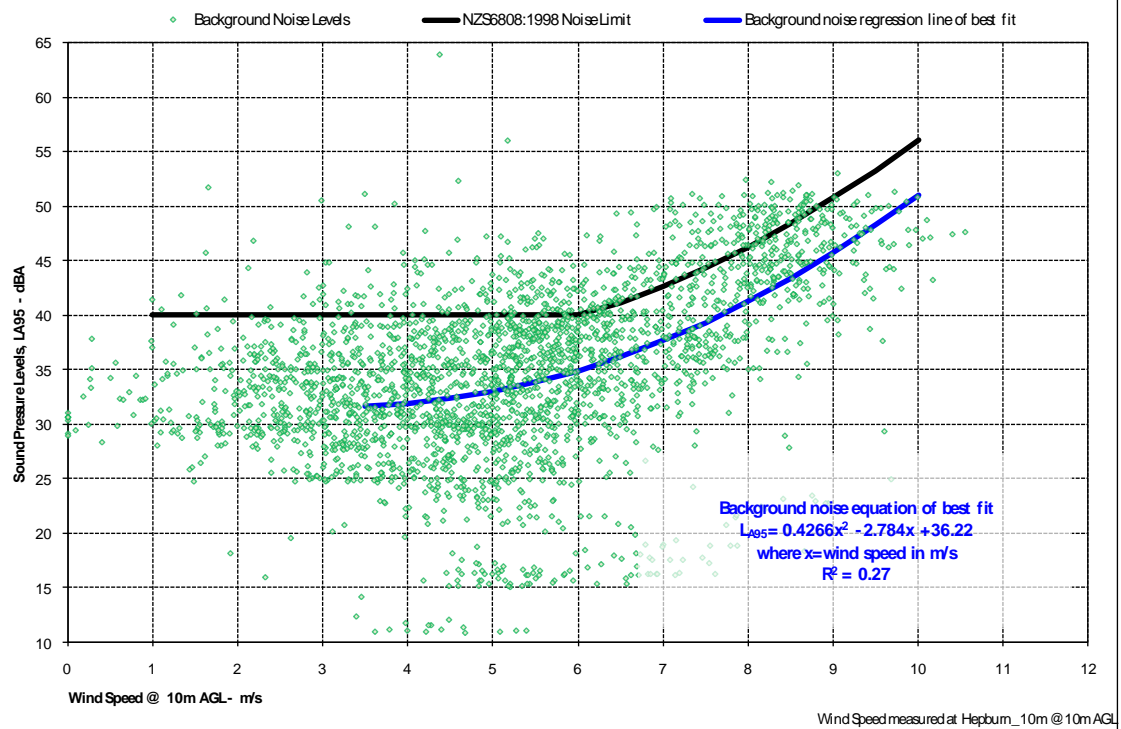
(23.12.2010 - 06.01.2011)

### Background Noise Levels vs. Wind Speeds Location A - December 2010



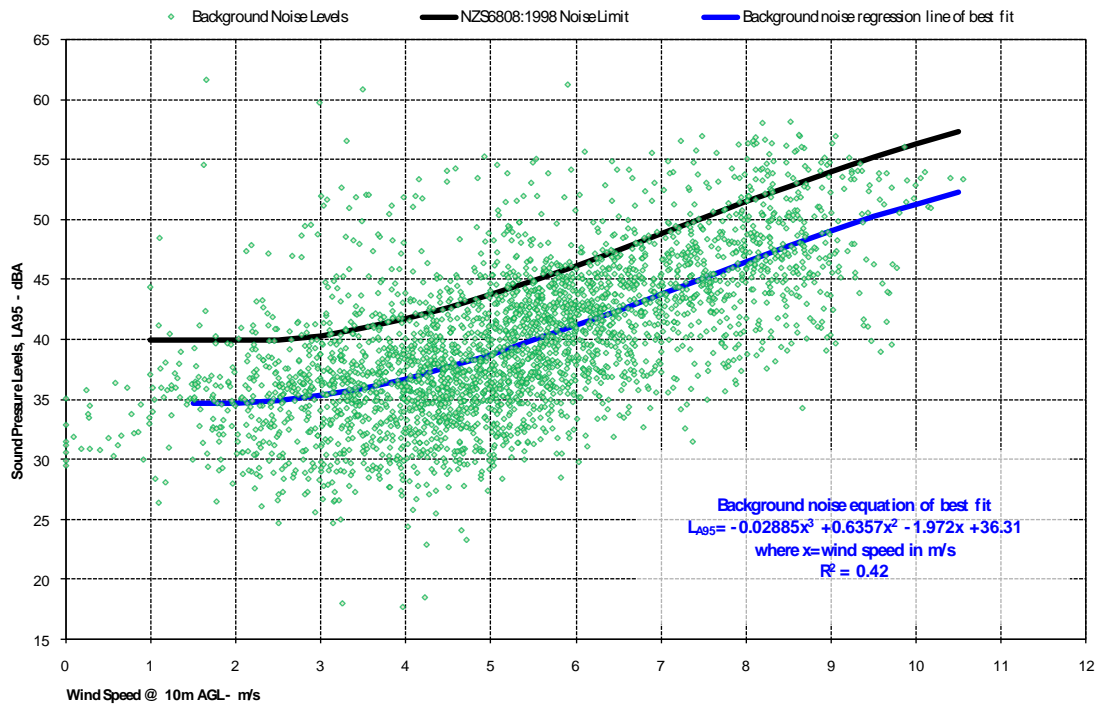
(06.01.2011 - 11.02.2011)

### Background Noise Levels vs. Wind Speeds Location B - January 2011



(06.01.2011 - 11.02.2011)

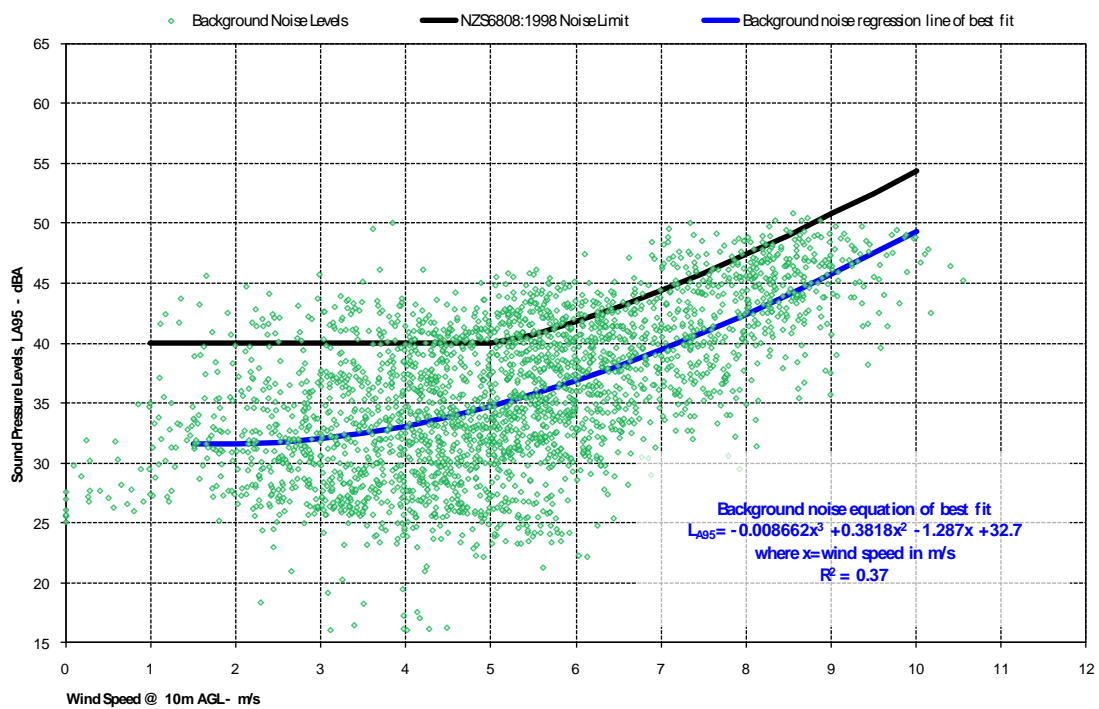
### Background Noise Levels vs. Wind Speeds Location C - January 2011



Wind Speed measured at Hepburn\_10m @ 10m AGL

(06.01.2011 - 11.02.2011)

### Background Noise Levels vs. Wind Speeds Location D - January 2011



Wind Speed measured at Hepburn\_10m @ 10m AGL



**HEPBURN COMMUNITY WIND FARM  
Preliminary Post-Construction Noise Compliance Assessment**

**Rp002 R01 2011014ML**

**1 December 2011**





Project: **HEPBURN COMMUNITY WIND FARM  
Preliminary Post-Construction Noise Compliance Assessment**

Prepared for: **Hepburn Wind  
PO Box 225  
Daylesford VIC 3460**

Attention: **Tracy Anthony**

Report No.: **Rp002 R01 2011014ML**

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Status:	Rev:	Comments	Date:	Author:	Reviewer:
Final	-	-	26/10/2011	CD	DG
Final	01	Changed erroneous photograph in Appendix D	1/12/2011	CD	-

## TABLE OF CONTENTS

1.0	INTRODUCTION .....	4
2.0	PERMIT CONDITIONS .....	5
3.0	METHODOLOGY .....	5
3.1	Outline.....	5
3.2	Pre-construction noise monitoring .....	6
3.3	Post-construction noise monitoring .....	7
3.4	Wind speed data .....	8
4.0	RESULTS.....	9
4.1	House 2 .....	11
4.2	House 7 .....	12
4.3	House 10 .....	13
4.4	House 14 .....	14
4.5	House 16 .....	15
4.6	Location A .....	16
4.7	Discussion .....	17
4.8	Special audible characteristics.....	17
4.8.1	Guidance documents .....	17
4.8.2	Subjective assessment .....	17
5.0	CONCLUSION .....	18
APPENDIX A	ACOUSTIC TERMINOLOGY.....	19
APPENDIX B	SITE LAYOUT .....	20
APPENDIX C	NOISE MONITORING LOCATIONS.....	21
APPENDIX D	NOISE LOGGER LOCATIONS .....	22

## 1.0 INTRODUCTION

The Hepburn Community Wind Farm is located at Leonards Hill, south of Daylesford in Victoria. Marshall Day Acoustics Pty Ltd (MDA) prepared a noise impact assessment report, 2006293 001 R02 *Hepburn Community Wind Park – Noise Assessment*, for the wind farm which was issued on 10 October 2006 and formed part of the planning application for the project.

The wind farm received planning approval in July 2007. Planning Permit No. 2006/9231 was issued in conjunction with the planning approval and required that noise emission from the wind farm satisfy the requirements of New Zealand Standard 6808:1998 *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS6808:1998). In particular, Condition 11 of the permit requires that a post-construction noise monitoring program be commissioned within two (2) months of the commencement of the wind farm.

Marshall Day Acoustics Pty Ltd was commissioned by Hepburn Wind to undertake preliminary post-commissioning noise monitoring at six (6) of the fourteen (14) assessable locations between 26 August and 9 September 2011.

The proposed methodology for undertaking the post-construction noise compliance assessment is presented in our report No. 001 R02 2011014ML entitled *Hepburn Wind Farm - Noise Compliance Testing Plan* dated 8 April 2011 (the NCTP). The NCTP also presents the applicable noise limits at the assessable residential properties in the vicinity of the wind farm.

Since the wind farm was commissioned, power output limitations have been imposed on the operators by Powercor. This means that, at the time of the monitoring, the wind turbines were not operating at full capacity. Due to this limitation, the results of the current assessment are preliminary only. Once the power output limitation has been lifted, it is recommended that further post-construction noise monitoring be offered to residents who have previously accepted monitoring.

Acoustic terminology used throughout this report is provided in Appendix A. The wind farm layout is presented in Appendix B.

## 2.0 PERMIT CONDITIONS

Condition 10 of the planning permit requires that noise emissions from the wind farm comply with NZS6808:1998:

*The operation of the wind energy facility must comply with the New Zealand Standard 'Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators' (NZ 6806:1998) [sic] (the 'New Zealand Standard'), in relation to any dwelling existing at the date of approval of this permit, to the satisfaction of the Responsible Authority.*

Condition 11 of the permit, presented below, requires that a post-construction noise monitoring program be commissioned within two (2) months of the commencement of operation of any turbine.

*Within two months of the commencement of operation of any turbine(s), an independent post-construction noise monitoring program must be undertaken by the proponent to the satisfaction of the Responsible Authority in accordance with the New Zealand Standard. The program must monitor noise levels at any dwelling within a one kilometre radius of any wind turbine that is not in the same ownership as the subject land.*

*A report summarising the results of the program, and the data collected, must be forwarded to the Responsible Authority within 30 days of the end of the monitoring period. The results must be written in plain English and formatted for reading by lay people.*

*Recommendations to address any non-compliance with NZS6808 must be included in the report and, on agreement by the Responsible Authority, measures to address non-compliance must be immediately implemented to the satisfaction of the Responsible Authority.*

## 3.0 METHODOLOGY

### 3.1 Outline

It is a requirement of Condition 10 of the planning permit that post-construction noise monitoring be undertaken at all non-stakeholder residential properties within one kilometre of the wind farm and that measured noise levels be assessed for compliance using NZS6808:1998.

To determine the applicable noise limits for the compliance assessment, NZS6808:1998 recommends that pre-construction noise monitoring be carried out, prior to the construction of the wind farm, to represent the ambient noise environment in the absence of noise from the wind farm.

### 3.2 Pre-construction noise monitoring

Nineteen (19) residential properties have previously been identified within one kilometre of the wind farm, including two (2) residential properties owned by stakeholders in the project, H6 and H7.

In September 2006, pre-construction noise monitoring was undertaken at two (2) residential properties, H7 and H18, in the vicinity of the Hepburn Community Wind Farm. One of these properties, H7, is owned by a stakeholder in the project.

During December 2010 and January 2011, Hepburn Wind corresponded with all residents living within one kilometre of the wind farm requesting permission to undertake pre-construction noise monitoring at their property, with the exception of the two (2) properties where monitoring was undertaken in 2006.

It is our understanding that approval was received to monitor at eight (8) residential properties. The owners of two (2) properties, H3, H31, have declined the request to conduct noise monitoring at their properties. The owner of H31 also declined the request to monitor on behalf of four (4) further properties (H4, H5, H11, and H13). No response was received from two (2) properties (H1 and H8). The remaining property (H6) is owned by a stakeholder in the project.

In order to establish suitable NZS6808:1998 noise limits at residential properties where background noise monitoring has not been carried out, pre-construction noise data collected at locations deemed representative of the noise environment at these properties has been used.

The noise monitoring locations are presented in Table 1 together with the monitoring periods and the additional properties for which the data is used, where applicable. A map showing the noise monitoring locations is presented in Appendix C.

**Table 1: Noise monitoring locations**

Location	Additional houses represented by data	Pre-construction noise monitoring period
2	1, 3, 4	23 December 2010 - 6 January 2011
7	6	5-20 September 2006
9	8	23 December 2010 - 6 January 2011
10		23 December 2010 - 6 January 2011
12		23 December 2010 - 6 January 2011
14		23 December 2010 - 6 January 2011
16		23 December 2010 - 6 January 2011
17		6 January - 11 February 2011
18		5-20 September 2006
19		6 January - 15 February 2011
A	5	23 December 2010 - 6 January 2011
B	11	6 - 20 January 2011
C	13	6 January - 11 February 2011
D	31	6 January - 11 February 2011

The applicable NZS6808:1998 noise limits are presented in Section 4.0 and Appendix F of the NCTP.

### 3.3 Post-construction noise monitoring

NZS6808:1998 requires that noise compliance monitoring be undertaken at the same positions and across a similar range of wind conditions for which the pre-construction background noise levels were previously collected. NZS6808:1998 recommends that the range of wind speeds monitored during the post-construction campaign span from the cut-in speed of the wind turbine to the wind speed of rated power.

Once post-construction data has been collected, a regression analysis is performed to describe the relationship between the monitored noise levels and wind speeds. This relationship can then be compared with the applicable noise limit to determine compliance. In particular, Section A1.3 of NZS6808:1998 notes:

*...the results of the 'operational' sound measurements should be compared with the background measurements...to determine compliance. Since the 'operational' measurements will be combined wind farm and background levels, it may be necessary to adjust these to determine 'wind farm only' levels.*



Accordingly, measured post-construction noise levels should be corrected for background noise. NZS6808:1998 does not provide explicit guidance on how this correction is to be applied, however this has been addressed in the 2010 version of the standard<sup>1</sup> which states:

*Post-installation measurements will capture both the wind farm sound and the background sound. In order to assess the wind farm sound level alone, the contribution of the background sound shall be removed from the regression curve drawn in 7.5.2 at each integer wind speed.*

*...While a simple energy subtraction of background and post-installation sound levels is not strictly mathematically correct for  $L_{90}$  centile levels, the difference may be taken as the  $L_{90}$  wind farm sound levels*

In accordance with NZS6808:1998, if one or more special audible characteristics is found to be present in the wind farm noise a penalty of 5dB shall be added to the wind farm noise levels at the dwelling being considered. The correction shall only be applied at those wind conditions where the special audible characteristic has been found to be present.

### 3.4 Wind speed data

In 2006, pre-construction 10m AGL wind speed data was extrapolated from wind data collected on site using a 50m high mast.

In 2010 and 2011, pre-construction wind speed data was collected from a 10m high mast located within the wind farm site. The same mast has been used to collect wind speed data during post-construction noise monitoring.

The range of wind speeds captured during any given monitoring period depends on the weather conditions during the period. To satisfy the intent of NZS6808:1998 ideally wind speeds between cut-in and rated power should be captured. For the REpower turbines used in this project, the cut-in wind speed is 3.5m/s at hub height. Using the roughness length of 0.2m (as detailed in Section 3.0 of the 2006 noise impact assessment report), this corresponds to a wind speed of approximately 2.3m/s at 10m above ground level (AGL). The rated power of the REpower turbines is approximately 10.5m/s at 10m AGL. Therefore, the target range of wind speeds for each post-construction monitoring period is 2.3-10.5m/s at 10m AGL. The rated wind speed of 10.5m/s is not an upper bound but rather a target such that the data collected may be considered representative of the operating range of wind speeds at the wind farm.

---

<sup>1</sup> New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010). NZS6808:2010 has recently been adopted as the relevant standard for assessment of new proposed wind farms in Victoria, as detailed in the *Policy and planning guidelines for development of wind energy facilities in Victoria* dated August 2011

## 4.0 RESULTS

The preliminary post-construction noise monitoring has been carried out at six (6) of the fourteen (14) assessable locations. Monitoring occurred between 26 August and 9 September 2011.

**Table 2: Post-construction noise monitoring locations**

Location	Additional houses represented by data	Post-construction noise monitoring period
2	1, 3, 4	26 August and 9 September 2011
7	6	26 August and 9 September 2011
9	8	To be commenced on 25 October 2011
10		26 August and 9 September 2011
12		To be commenced on 25 October 2011
14		26 August and 9 September 2011
16		26 August and 9 September 2011
17		-
18		To be commenced on 25 October 2011
19		To be commenced on 25 October 2011
A	5	26 August and 9 September 2011
B	11	-
C	13	-
D	31	-

Rion NL31 Class 1 noise loggers were used for the measurements. According to the manufacturer's information, the inherent internal noise (noise floor) of the Rion NL31 is below 20dBA and typically around 17dBA.

As required in Section 5.2.1 of NZS6808:1998, noise loggers were placed at approximately the same position as that used for the pre-construction noise monitoring. Photographs of the noise logger positions used during the post-construction surveys are attached in Appendix D.

NZS6808:1998 recommends that 1,440 valid data points be collected in order to carry out a regression analysis. Noise loggers were placed on site for a period of at least 14 days, measuring at 10 minute intervals, in order to acquire sufficient data for regression analysis.

Rainfall data collected on site were reviewed and where rainfall is likely to have occurred, these data points were removed from the analysis.

The collected data is filtered prior to the regression analysis in order to remove likely rain affected data as well as data points where the wind speed is below the turbine cut-in.

Monitoring periods, the number of data points collected and the number of data points included in the analysis are presented in the following sections together with the correlation coefficient, the coefficient of determination ( $R^2$ ) and the range of assessed wind speeds during each monitoring session.

For each study site the measured post-construction noise levels are shown in red with the regression line of best fit shown as a solid red line. Similarly, pre-construction background noise levels are shown in green with the regression line of best fit shown as a solid green line.

When the post-construction noise levels (solid red line) are lower than the noise limits (solid black line), the wind farm noise emissions are deemed to comply with NZS6808:1998. If the post-construction noise levels are higher than the noise limits, it is necessary to remove the potential effect of background noise and derive the “wind farm only” noise levels.

As detailed in Section 3.3, the “wind farm only” noise levels are obtained by logarithmically subtracting the pre-construction noise level from the post-construction noise level for each integer wind speed. The resulting noise levels are identified as the “derived wind farm noise levels” (solid blue line). When the derived wind farm noise levels are lower than the noise limits, the wind farm noise emissions are deemed to comply with NZS6808:1998.

#### 4.1 House 2

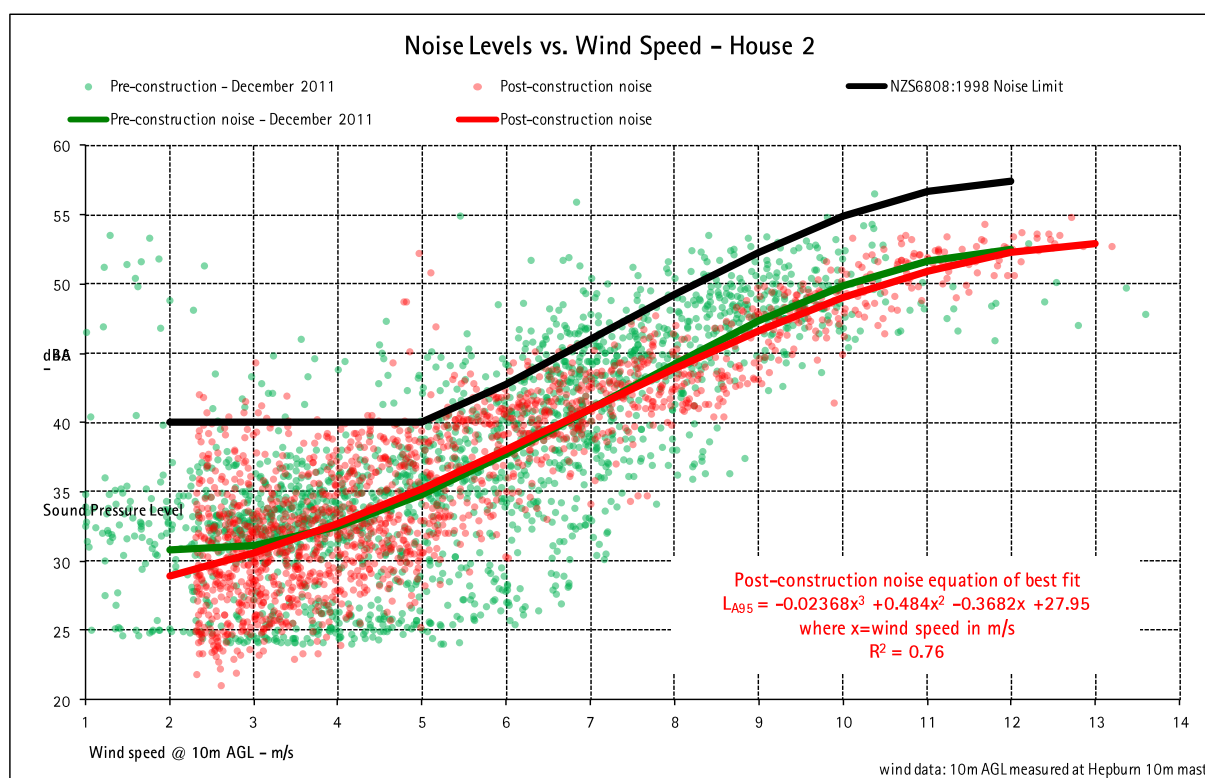
Noise level data measured between 26 August and 9 September 2011 at House 2 has been correlated with 10m AGL wind data collected on site. Results are summarised in Table 3 and Figure 1 below.

**Table 3: Summary of parameters – House 2**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,003
Number of data points removed*	320
Number of data points used for analysis	1,683
Post-construction correlation**	0.87
Post-construction regression line of best fit R <sup>2</sup>	0.76
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\*\* correlation between noise levels and wind speeds



**Figure 1: Post-construction noise levels vs. wind speed at House 2**

It can be seen from Figure 1 that the post-construction noise levels measured at House 2 are below the NZS6808:1998 noise limits at all assessed wind speeds.

## 4.2 House 7

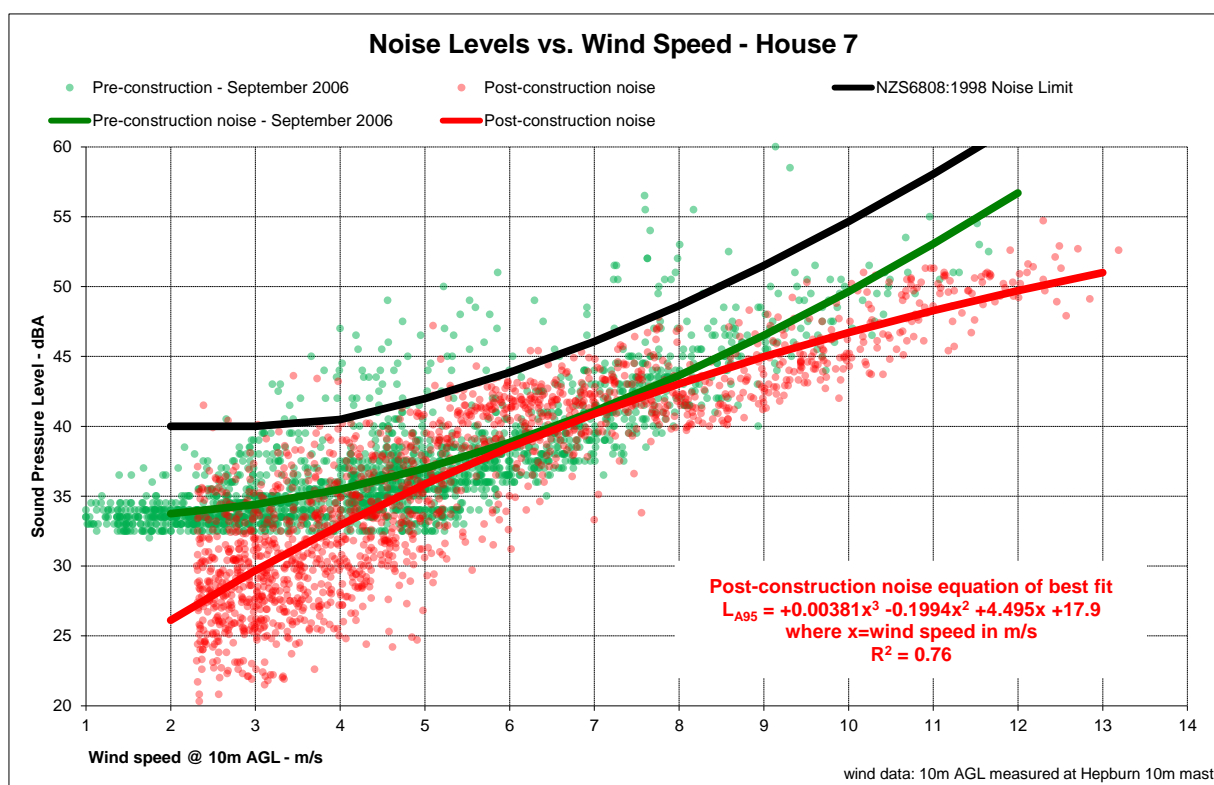
Noise level data measured between 26 August and 9 September 2011 at House 7 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 4 and Figure 2 below.

**Table 4: Summary of parameters – House 7**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	1,998
Number of data points removed*	320
Number of data points used for analysis	1,678
Post-construction correlation**	0.87
Post-construction regression line of best fit R <sup>2</sup>	0.76
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\*\* correlation between noise levels and wind speeds



**Figure 2: Post-construction noise levels vs. wind speed at House 7**

It can be seen from Figure 2 that the post-construction noise levels measured at House 7 are below the NZS6808:1998 noise limits at all assessed wind speeds.

### 4.3 House 10

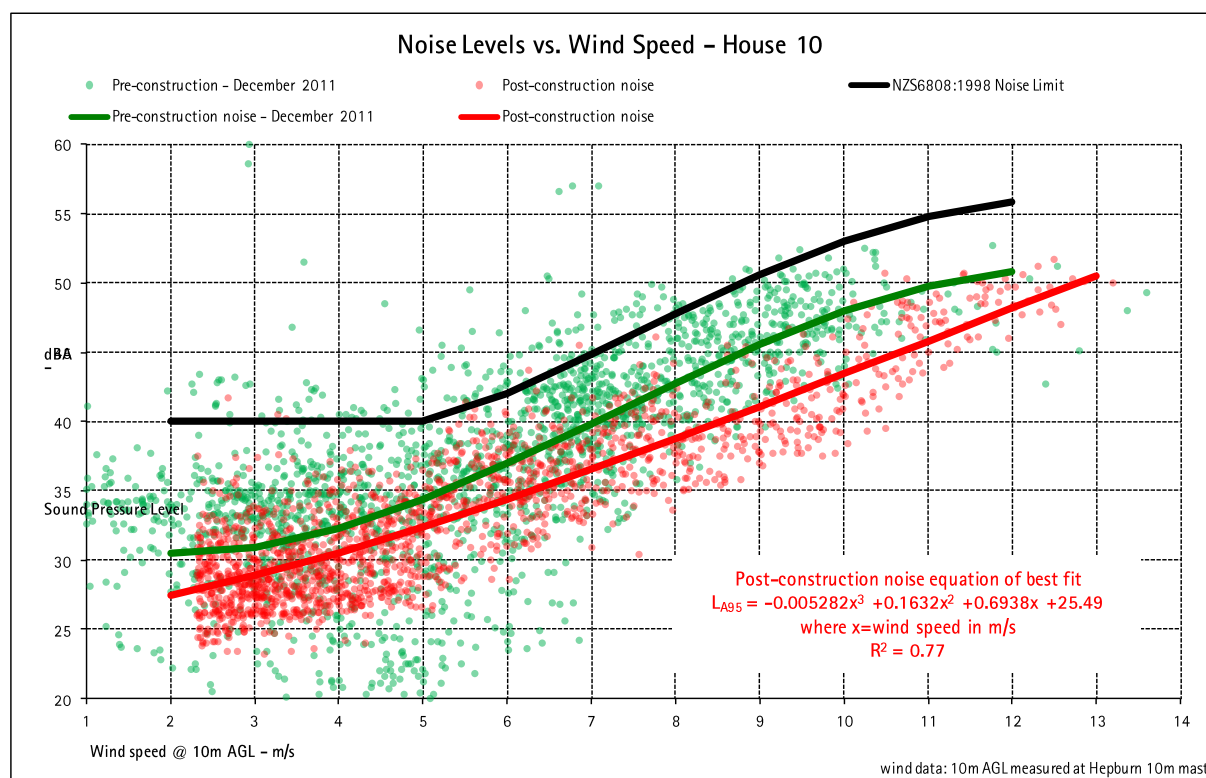
Noise level data measured between 26 August and 9 September 2011 at House 10 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 5 and Figure 3 below.

**Table 5: Summary of parameters – House 10**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,009
Number of data points removed*	324
Number of data points used for analysis	1,685
Post-construction correlation**	0.88
Post-construction regression line of best fit R <sup>2</sup>	0.77
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\*\* correlation between noise levels and wind speeds



**Figure 3: Post-construction noise levels vs. wind speed at House 10**

It can be seen from Figure 3 that the post-construction noise levels measured at House 10 are below the NZS6808:1998 noise limits at all assessed wind speeds.



#### 4.4 House 14

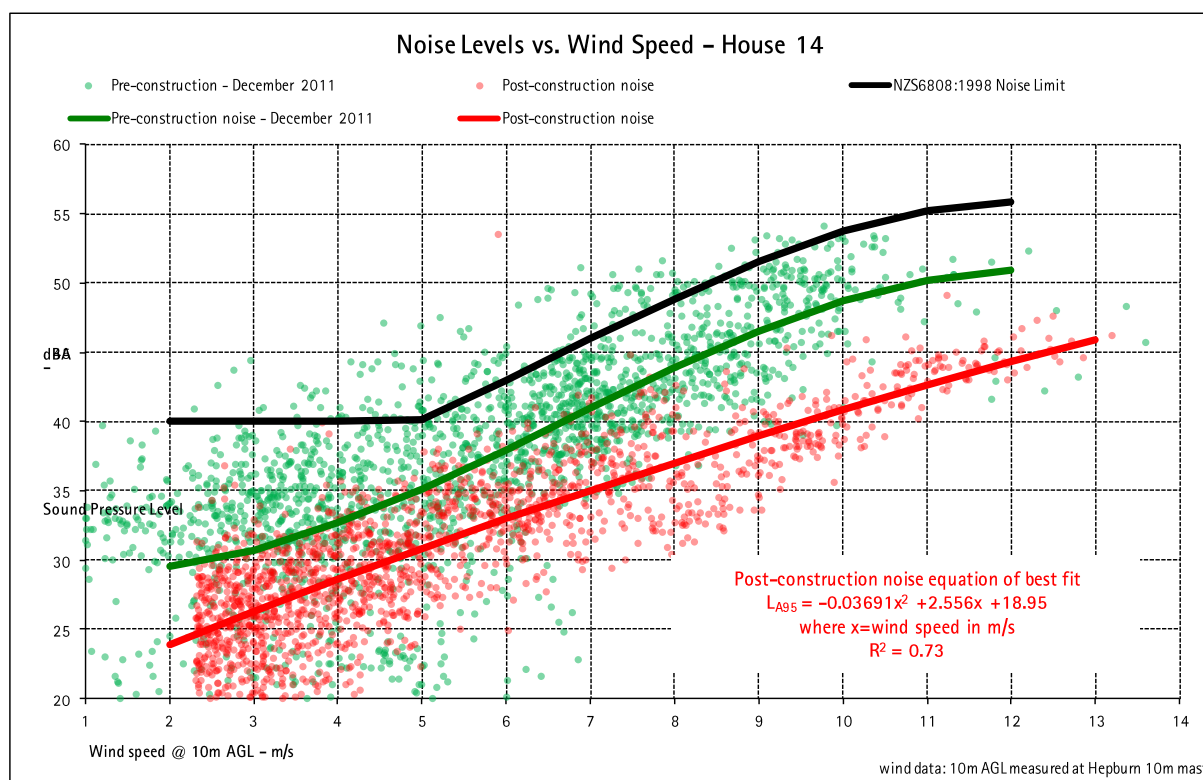
Noise level data measured between 26 August and 9 September 2011 at House 14 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 6 and Figure 4 below.

**Table 6: Summary of parameters – House 14**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,008
Number of data points removed*	324
Number of data points used for analysis	1,684
Post-construction correlation**	0.85
Post-construction regression line of best fit R <sup>2</sup>	0.73
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 4: Post-construction noise levels vs. wind speed at House 14**

It can be seen from Figure 4 that the post-construction noise levels measured at House 14 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.5 House 16

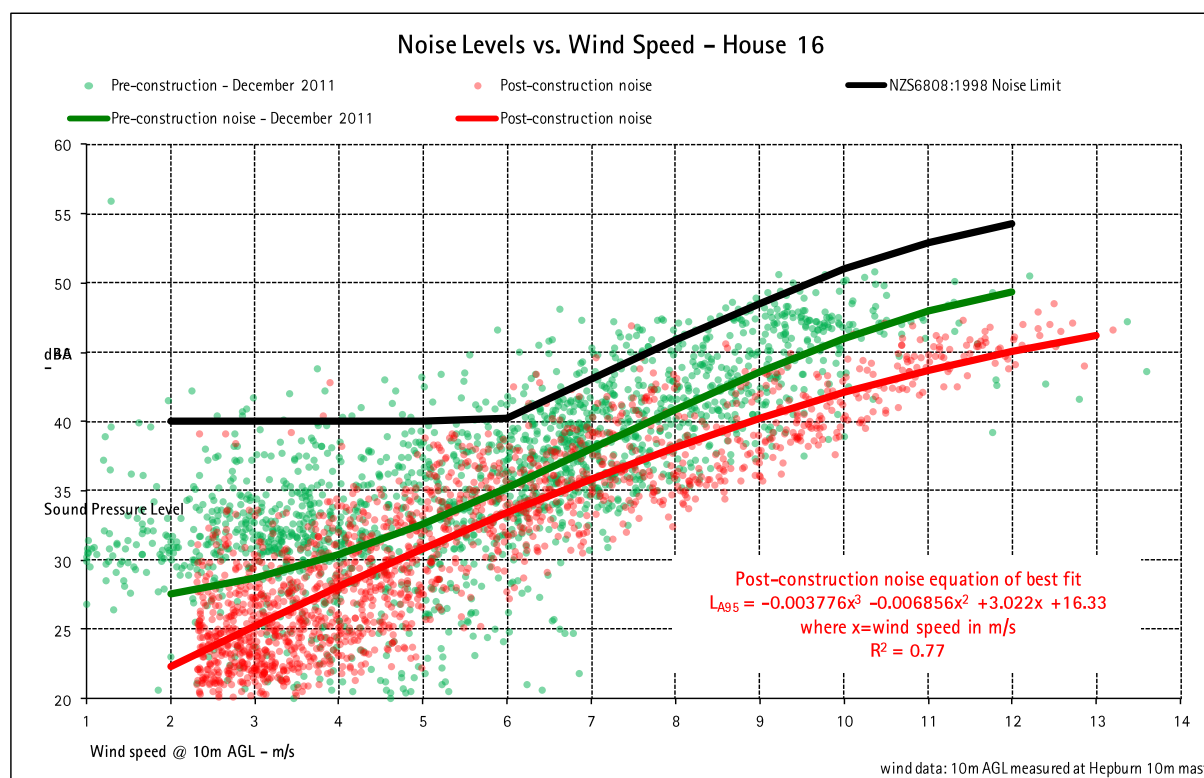
Noise level data measured between 26 August and 9 September 2011 at House 16 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 7 and Figure 5 below.

**Table 7: Summary of parameters – House 16**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,006
Number of data points removed*	321
Number of data points used for analysis	1,685
Post-construction correlation**	0.88
Post-construction regression line of best fit R <sup>2</sup>	0.77
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 5: Post-construction noise levels vs. wind speed at House 16**

It can be seen from Figure 5 that the post-construction noise levels measured at House 16 are below the NZS6808:1998 noise limits at all assessed wind speeds.

## 4.6 Location A

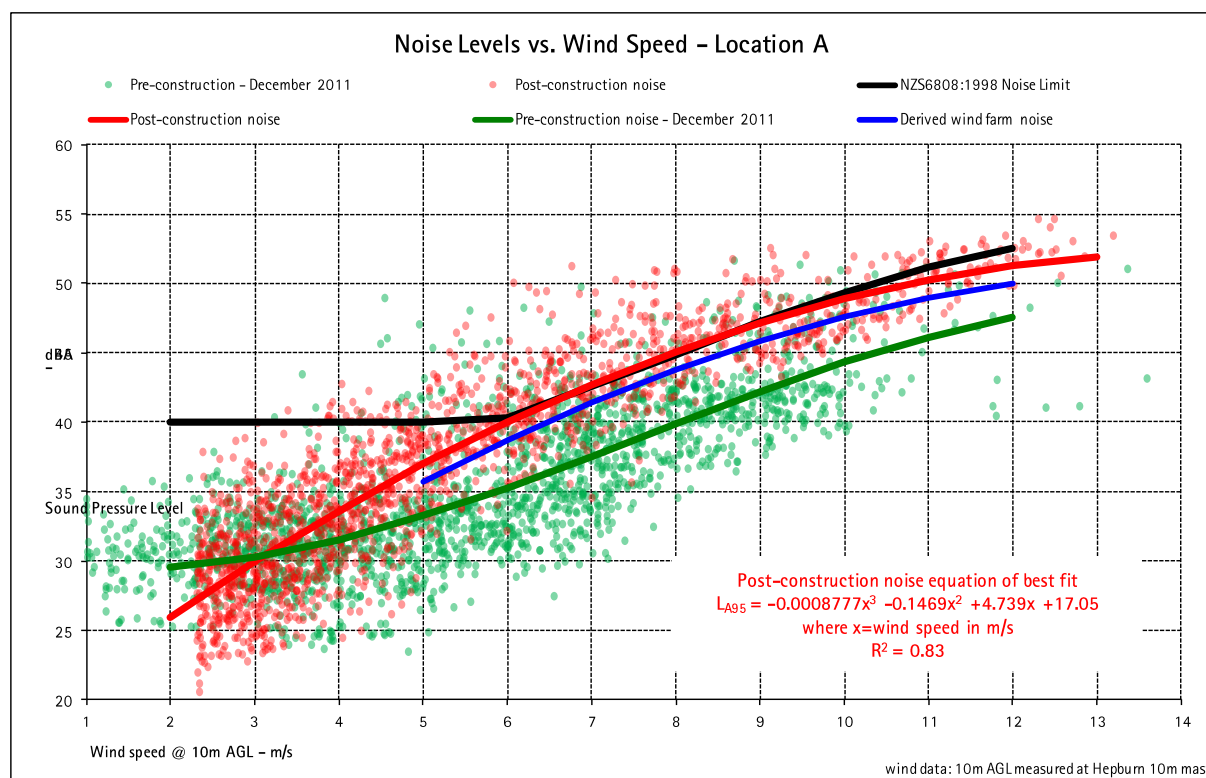
Noise level data measured between 26 August and 9 September 2011 at Location A has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 8 and Figure 6 below.

**Table 8: Summary of parameters – Location A**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,008
Number of data points removed*	323
Number of data points used for analysis	1,685
Post-construction correlation**	0.90
Post-construction regression line of best fit R <sup>2</sup>	0.83
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\*\* correlation between noise levels and wind speeds



**Figure 6: Post-construction noise levels vs. wind speed at Location A**

It can be seen from Figure 6 that the derived wind farm noise levels at Location A are below the NZS6808:1998 noise limits at all assessed wind speeds.

## 4.7 Discussion

In several of the figures presented above it can be seen that the post-construction noise regression line is generally lower than the pre-construction noise regression line. This indicates that over the post-construction noise monitoring period, noise levels were generally lower than those measured during the pre-construction noise monitoring period.

These differences may be attributable to regularly occurring variations in noise levels across different monitoring periods<sup>2</sup>. In particular, variations in the ambient noise level, that is in the absence of wind farm noise, may be significant here. Results from future monitoring periods will assist in identifying whether this is the case.

## 4.8 Special audible characteristics

### 4.8.1 Guidance documents

NZS6808:1998 provides only limited guidance regarding the assessment of special audible characteristics:

*At present, there is no simple objective procedure available to quantify special audible characteristics, and subjective assessment is therefore necessary, supported by objective evidence (eg. frequency analysis) where appropriate.*

These comments are complimented by comment CB3.1 from the more recent version of the standard, NZS6808:2010<sup>3</sup>, which states the following:

*By the very nature of wind turbine blades passing in front of a support tower, some amplitude modulation will always be present in the sound of a rotating wind turbine although this will not always be audible at distances from the wind farm. Amplitude modulation special audible characteristics occur when there is significant amplitude modulation of the aerodynamic sound from one of more wind turbines such that there is a greater than normal degree of fluctuation as a function of the blade passing frequency (typically about once per second for larger turbines).*

### 4.8.2 Subjective assessment

As required by NZS6808:1998, MDA has carried out a subjective assessment of special audible characteristics.

Specifically, listening tests have been carried out during site visits at properties and locations neighbouring the wind farm. In addition, audio samples have been recorded and further listening tests have been carried out, away from site, using the audio samples.

---

<sup>2</sup> As discussed by Delaire in two papers presented at the International Wind Turbine Noise conferences: *A comparison of background noise levels collected at the Portland Wind Energy Project in Victoria, Australia* (2009), and; *Review of noise conditions from planning permits recently approved in Victoria, Australia* (2011).

<sup>3</sup> New Zealand Standard 6808:2010 Acoustics – Wind farm noise

For the wind farm noise assessed during the listening tests, we consider the following:

- No tones were audible
- The wind farm was not impulsive in character
- Only amplitude modulation typical from a normally operation wind turbine was audible

During the listening tests the Hepburn Community Wind Farm has shown audible characteristics typical of normally operating wind turbines. On this basis, we consider that no penalty for special audible characteristics is required.

## **5.0 CONCLUSION**

As required by Condition 11 of the Hepburn Community Wind Farm planning permit, post-construction noise monitoring has been undertaken at properties neighbouring the wind farm between 26 August and 9 September 2011 in accordance with NZS6808:1998.

To date, post-construction noise monitoring has been undertaken at six (6) of the fourteen (14) assessable locations. Due to power output limitations imposed on the operator by Powercor, the results of this assessment can only be considered as preliminary.

The preliminary results indicate that compliance with the NZS6808:1998 noise limits is achieved at all assessed properties for the required wind speed range.

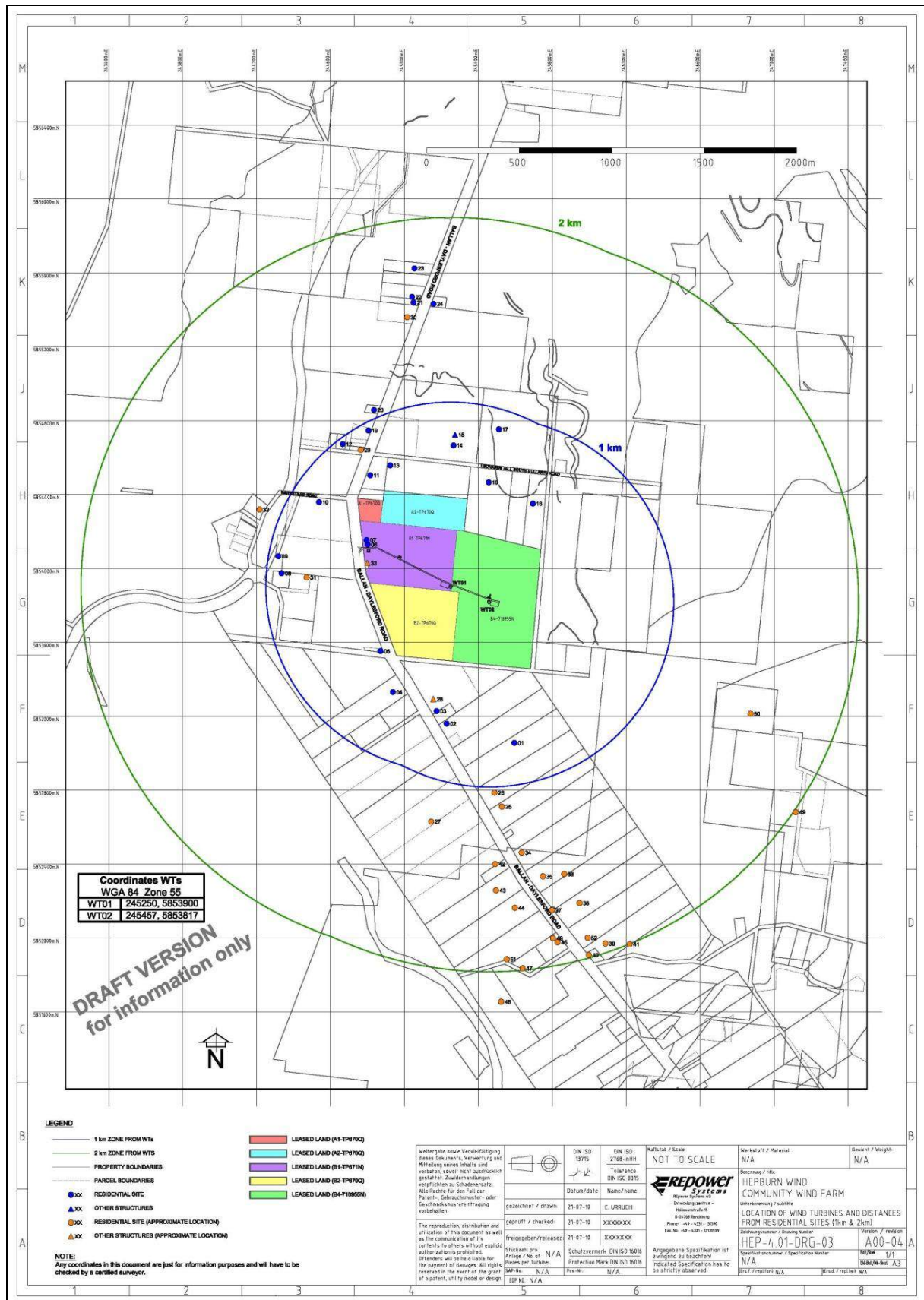
Further post-construction noise monitoring should be undertaken when the power output limitation has been lifted by Powercor.

## APPENDIX A ACOUSTIC TERMINOLOGY

<b>Frequency</b>	The number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz).
<b>Hertz (Hz)</b>	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
<b>Octave Band</b>	A range of frequencies where the highest frequency included is twice the lowest frequency. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.
<b>Sound Pressure Level (<math>L_p</math>)</b>	A logarithmic ratio of a sound pressure measured at distance, relative to the threshold of hearing (20 $\mu$ Pa RMS) and expressed in decibels.
<b>Sound Power Level (<math>L_w</math>)</b>	A logarithmic ratio of the acoustic power output of a source relative to $10^{-12}$ watts and expressed in decibels. Sound power level is calculated from measured sound pressure levels.
<b>dB</b>	Decibel – A measurement of sound level expressed as a logarithmic ratio of sound pressure P relative to a reference pressure of $P_r=20 \mu$ Pa i.e. $dB = 20 \times \log(P/P_r)$
<b>dBA</b>	A measurement of sound level which has its frequency characteristics modified by a filter (A-weighted) so as to more closely approximate the frequency bias of the human ear.
<b>A-weighting</b>	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear.  All noise levels are quoted relative to a sound pressure of $2 \times 10^{-5}$ Pa
<b><math>L_{Aeq}</math></b>	The equivalent continuous (time-averaged) A-weighted sound level. This is commonly referred to as the average noise level.
<b><math>L_{A90}</math></b>	The A-weighted noise level equalled or exceeded for 90% of the measurement period. This is commonly referred to as the background noise level.



## APPENDIX B SITE LAYOUT



## APPENDIX C NOISE MONITORING LOCATIONS



## APPENDIX D NOISE LOGGER LOCATIONS



**D1 House 2**



**D2 House 7**





**D3 House 10**



**D4 House 14**





D5 House 16



D6 Location A





**HEPBURN COMMUNITY WIND FARM  
Post-Construction Noise Compliance Assessment  
Rp003 R01 2011014ML**

**1 June 2012**



Project: **HEPBURN COMMUNITY WIND FARM  
Post-Construction Noise Compliance Assessment**

Prepared for: **Hepburn Wind  
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Report No.: **Rp003 R01 2011014ML**

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Status:	Rev:	Comments	Date:	Author:	Reviewer:
Final	-	-	30/05/2012	CD	DG
Final	01	Typographical corrections	1/06/2012	CD	DG

## TABLE OF CONTENTS

1.0	INTRODUCTION .....	5
2.0	PERMIT CONDITIONS .....	6
3.0	METHODOLOGY .....	7
3.1	Outline.....	7
3.2	Pre-construction noise monitoring .....	7
3.3	Post-construction noise monitoring .....	8
3.3.1	Phase 1 monitoring .....	9
3.3.2	Phase 2 monitoring .....	9
3.4	Wind speed data .....	9
4.0	RESULTS.....	10
4.1	House 1 (Phase 1).....	13
4.2	House 2 .....	14
4.2.1	Phase 1 noise monitoring .....	14
4.2.2	Phase 2 noise monitoring .....	15
4.3	House 7 .....	16
4.3.1	Phase 1 noise monitoring .....	16
4.3.2	Phase 2 noise monitoring .....	17
4.4	House 9 (Phase 1).....	18
4.5	House 10 .....	19
4.5.1	Phase 1 noise monitoring .....	19
4.5.2	Phase 2 noise monitoring .....	20
4.6	House 12 (Phase 1).....	21
4.7	House 14 (Phase 1).....	22
4.8	House 16 .....	23
4.8.1	Phase 1 noise monitoring .....	23
4.8.2	Phase 2 noise monitoring .....	24
4.9	House 18 .....	25
4.9.1	Phase 1 noise monitoring .....	25
4.9.2	Phase 2 noise monitoring .....	26
4.10	House 19 (Phase 1).....	27
4.11	Location A (Phase 1).....	28
4.12	Discussion .....	29
4.12.1	Comparison of Phase 1 and Phase 2 monitoring .....	29
4.12.2	Regression lines .....	29
4.13	Special audible characteristics.....	29
4.13.1	Criteria.....	29
4.13.2	Subjective assessment .....	30
5.0	CONCLUSION .....	31

APPENDIX A      ACOUSTIC TERMINOLOGY..... 32

APPENDIX B      SITE LAYOUT ..... 33

APPENDIX C      NOISE MONITORING LOCATIONS..... 34

APPENDIX D      ANALYSIS OF EXTRANEIOUS NOISE ..... 35

APPENDIX E      NOISE LOGGER LOCATIONS ..... 37

## 1.0 INTRODUCTION

The Hepburn Community Wind Farm is located at Leonards Hill, south of Daylesford in Victoria and consists of two (2) REpower MM82 wind turbines.

Marshall Day Acoustics Pty Ltd (MDA) prepared a noise impact assessment report, 2006293 001 R02 *Hepburn Community Wind Park – Noise Assessment*, for the wind farm which was issued on 10 October 2006 and formed part of the planning application for the project.

The wind farm received planning approval in July 2007. Planning Permit No. 2006/9231 was issued in conjunction with the planning approval and required that noise emission from the wind farm satisfy the requirements of New Zealand Standard 6808:1998 *Acoustics – The assessment and measurement of sound from wind turbine generators* (NZS6808:1998). In particular, Condition 11 of the permit requires that a post-construction noise monitoring program be commissioned within two (2) months of the commencement of the wind farm.

The wind farm was commissioned in June 2011. However, until February 2012, power output limitations were imposed on the wind farm by Powercor. During this period the generating capacity of the facility was constrained to 2.6MW, compared to a maximum capacity of 4.1MW.

REpower, the turbine manufacturer, has advised that the constraints on the generating capacity are not likely to have significantly affected noise levels from the wind farm. Nonetheless, a post-construction noise monitoring survey has been carried out in two phases:

- Phase 1: A noise monitoring survey which commenced within two months of the wind farm being commissioned. This monitoring occurred during the period of limited generating capacity.
- Phase 2: A noise monitoring survey carried out following the end of the limited generating capacity period.

MDA has been commissioned by Hepburn Wind to undertake a post-construction noise monitoring survey to satisfy the planning permit requirements. The proposed methodology for undertaking the post-construction monitoring is presented in our report No. 001 R03 2011014ML entitled *Hepburn Wind Farm - Noise Compliance Testing Plan* dated 16 August 2011 (the NCTP). The NCTP also presents the applicable noise limits at the assessable residential properties in the vicinity of the wind farm.

Phase 1 noise monitoring has been carried out at eleven (11) properties, including ten (10) of the fourteen (14) assessable locations, as defined in the NCTP.

Preliminary results from the Phase 1 monitoring survey are presented in our report No. 002 R02 2011014ML entitled *Hepburn Wind Farm – Preliminary post-construction noise assessment* which was issued on 23 December 2011. The Phase 1 monitoring results demonstrated that the Hepburn Community Wind Farm complied with the relevant noise limits at all assessed residential properties.

After the power output limitation was lifted, Phase 2 noise monitoring survey has been undertaken at five (5) of the eleven (11) properties monitored during Phase 1 to assess whether the outcome of the Phase 1 monitoring is still applicable.

We present herein a consolidated summary of the post-construction monitoring surveys, including both Phases of monitoring.

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

The wind farm layout is presented in Appendix B.

## 2.0 PERMIT CONDITIONS

Condition 10 of the planning permit requires that noise emissions from the wind farm comply with NZS6808:1998:

*The operation of the wind energy facility must comply with the New Zealand Standard 'Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators' (NZ 6806:1998) [sic] (the 'New Zealand Standard'), in relation to any dwelling existing at the date of approval of this permit, to the satisfaction of the Responsible Authority.*

Condition 11 of the permit, presented below, requires that a post-construction noise monitoring program be commissioned within two (2) months of the commencement of operation of any turbine.

*Within two months of the commencement of operation of any turbine(s), an independent post-construction noise monitoring program must be undertaken by the proponent to the satisfaction of the Responsible Authority in accordance with the New Zealand Standard. The program must monitor noise levels at any dwelling within a one kilometre radius of any wind turbine that is not in the same ownership as the subject land.*

*A report summarising the results of the program, and the data collected, must be forwarded to the Responsible Authority within 30 days of the end of the monitoring period. The results must be written in plain English and formatted for reading by lay people.*

*Recommendations to address any non-compliance with NZS6808 must be included in the report and, on agreement by the Responsible Authority, measures to address non-compliance must be immediately implemented to the satisfaction of the Responsible Authority.*



### **3.0 METHODOLOGY**

#### **3.1 Outline**

It is a requirement of Condition 10 of the planning permit that post-construction noise monitoring be undertaken at all non-stakeholder residential properties within one kilometre of the wind farm and that measured noise levels be assessed for compliance using NZS6808:1998.

To determine the applicable noise limits for the compliance assessment, NZS6808:1998 recommends that pre-construction noise monitoring be carried out, prior to the construction of the wind farm, to represent the ambient noise environment in the absence of noise from the wind farm.

#### **3.2 Pre-construction noise monitoring**

Nineteen (19) residential properties have previously been identified within one kilometre of the wind farm, including two (2) residential properties owned by stakeholders in the project, H6 and H7.

In September 2006, pre-construction noise monitoring was undertaken at two (2) residential properties, H7 and H18, in the vicinity of the Hepburn Community Wind Farm. One of these properties, H7, is owned by a stakeholder in the project.

During December 2010 and January 2011, Hepburn Wind corresponded with all residents living within one kilometre of the wind farm requesting permission to undertake pre-construction noise monitoring at their property, with the exception of the two (2) properties where monitoring was undertaken in 2006.

It is our understanding that approval was received to monitor at eight (8) residential properties.

The request to monitor was declined by two (2) property owners, H3 and H31. In addition, the owner of H31 also declined the request to monitor on behalf of four (4) further properties: H4, H5, H11 and H13.

No response was received from two (2) properties, H1 and H8. The remaining property, H6, is owned by a stakeholder in the project.

In order to establish suitable NZS6808:1998 noise limits at residential properties where background noise monitoring has not been carried out, pre-construction noise data collected at locations deemed representative of the noise environment at these properties has been used.

The pre-construction noise monitoring locations are presented in Table 1 together with the monitoring periods and the additional properties for which the data is used, where applicable. A map showing the noise monitoring locations is presented in Appendix C.

**Table 1: Pre-construction noise monitoring locations**

Location	Additional houses represented by data	Pre-construction noise monitoring period	Noise logger model
2	1, 3, 4	23 December 2010 - 6 January 2011	ARL 316
7	6	5-20 September 2006	Rion NL31
9	8	23 December 2010 - 6 January 2011	Rion NL31
10		23 December 2010 - 6 January 2011	Rion NL31
12		23 December 2010 - 6 January 2011	Rion NL31
14		23 December 2010 - 6 January 2011	Rion NL31
16		23 December 2010 - 6 January 2011	Rion NL31
17		6 January - 11 February 2011	Rion NL31
18		5-20 September 2006	Rion NL31
19		6 January - 15 February 2011	ARL 316
A	5	23 December 2010 - 6 January 2011	ARL 316
B	31	6 - 20 January 2011	Rion NL31
C	11	6 January - 11 February 2011	Rion NL31
D	13	6 January - 11 February 2011	Rion NL31

The applicable NZS6808:1998 noise limits are presented in Section 4.0 and Appendix F of the NCTP.

### 3.3 Post-construction noise monitoring

NZS6808:1998 requires that noise compliance monitoring be undertaken at the same positions and across a similar range of wind conditions for which the pre-construction background noise levels were previously collected. NZS6808:1998 recommends that the range of wind speeds monitored during the post-construction noise survey span from the cut-in speed of the wind turbine to the wind speed of rated power.

Once post-construction data has been collected, a regression analysis is performed to describe the relationship between the monitored noise levels and wind speeds. This relationship can then be compared with the applicable noise limit to determine compliance. In particular, Section A1.3 of NZS6808:1998 notes:

*...the results of the 'operational' sound measurements should be compared with the background measurements...to determine compliance. Since the 'operational' measurements will be combined wind farm and background levels, it may be necessary to adjust these to determine 'wind farm only' levels.*

Accordingly, measured post-construction noise levels should be corrected for background noise. NZS6808:1998 does not provide explicit guidance on how this correction is to be applied, however this has been addressed in Section 7.5.3 of the 2010 version of the standard<sup>1</sup> which states:

*Post-installation measurements will capture both the wind farm sound and the background sound. In order to assess the wind farm sound level alone, the contribution of the background sound shall be removed from the regression curve drawn in 7.5.2 at each integer wind speed.*

*...While a simple energy subtraction of background and post-installation sound levels is not strictly mathematically correct for  $L_{90}$  centile levels, the difference may be taken as the  $L_{90}$  wind farm sound levels*

In accordance with NZS6808:1998, if one or more special audible characteristics is found to be present in the wind farm noise a penalty of 5dB shall be added to the wind farm noise levels at the dwelling being considered. The correction shall only be applied at those wind conditions where the special audible characteristic has been found to be present.

#### 3.3.1 Phase 1 monitoring

An initial noise monitoring survey has been carried out, commencing within two months from the start of operations at the wind farm, between August and November 2011.

The objective of this phase of monitoring is to provide a base line dataset for noise emission from the wind farm for compliance assessment.

#### 3.3.2 Phase 2 monitoring

A second noise monitoring survey has been carried out following the end of the limitations to generating capacity of the turbines.

The objective of the Phase 2 noise monitoring survey is to confirm the advice from the turbine manufacturer that noise emission from the wind farm is not expected to be significantly different after the removal of the 2.6 MW generation constraint. In particular, it is expected that, with the removal of the constraint, monitoring results will demonstrate the same compliance outcome as observed for the Phase 1 monitoring.

### 3.4 Wind speed data

In 2006, pre-construction 10m AGL wind speed data was extrapolated from wind data collected on site using a 50m high mast.

In 2010 and 2011, pre-construction wind speed data was collected from a 10m high mast located within the wind farm site. The same mast has been used to collect wind speed data during post-construction noise monitoring.

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<sup>1</sup> New Zealand Standard 6808:2010 *Acoustics – Wind farm noise* (NZS6808:2010). NZS6808:2010 has recently been adopted as the relevant standard for assessment of new proposed wind farms in Victoria, as detailed in the *Policy and planning guidelines for development of wind energy facilities in Victoria* dated August 2011

The range of wind speeds captured during any given monitoring period depends on the weather conditions during the period. To satisfy the intent of NZS6808:1998 ideally wind speeds between cut-in and rated power should be captured. For the REpower turbines used in this project, the cut-in wind speed is 3.5m/s at hub height. Using the roughness length of 0.2m (as detailed in Section 3.0 of the 2006 noise impact assessment report), this corresponds to a wind speed of approximately 2.3m/s at 10m above ground level (AGL). The rated power of the REpower turbines is approximately 10.5m/s at 10m AGL. Therefore, the target range of wind speeds for each post-construction monitoring period is 2.3-10.5m/s at 10m AGL. The rated wind speed of 10.5m/s is not an upper bound but rather a target such that the data collected may be considered representative of the operating range of wind speeds at the wind farm.

#### 4.0 RESULTS

The Phase 1 post-construction noise monitoring has been carried out at eleven (11) properties, including ten (10) of the fourteen (14) assessable locations. Monitoring occurred between August and November 2011.

**Table 2: Post-construction noise monitoring locations**

Location	Additional houses represented by data	Post-construction noise monitoring period
1		11 to 25 November 2011
2	3, 4	26 August to 9 September 2011
7	6	26 August to 9 September 2011
9	8	25 October to 11 November 2011
10		26 August to 9 September 2011
12		25 October to 11 November 2011
14		26 August to 9 September 2011
16		26 August to 9 September 2011
17		No monitoring undertaken (see below)
18		25 October to 11 November 2011
19		25 October to 11 November 2011
A	5	26 August to 9 September 2011
B	31	No monitoring undertaken (see below)
C	11	No monitoring undertaken (see below)
D	13	No monitoring undertaken (see below)

For the post-construction noise monitoring survey, the owners of three (3) properties (H3, H4 and H5) declined the request to conduct measurements at their properties. No response was received from four (4) properties (H8, H11, H13 and H31). One property (H6) is owned by a stakeholder in the project and is not occupied. The remaining property (H17) is in the same ownership as House 14 (located approximately 250m west) and is occupied by the CEO of Hepburn Wind.

To provide indication of noise compliance at properties located to the east of the wind farm, post-construction noise monitoring was undertaken at Location A. This position was identified as representative of the noise environment of House 5 during the pre-construction noise monitoring period.

Pre-construction noise data is available at all post-construction noise monitoring locations, with the exception of House 1 which did not respond to the initial request by Hepburn wind. As pre-construction noise monitoring was not undertaken at House 1, background related noise limits are not directly available for this property. House 2 is the nearest property where pre-construction noise monitoring has been undertaken and therefore noise limits determined at this property have been used to assess compliance at House 1.

For the Phase 2 monitoring, following the end of limitations of generating capacity, post-construction noise monitoring has been repeated at the five (5) locations presented in Table 3. The properties selected for Phase 2 monitoring are the nearest to the wind farm of those monitored during Phase 1. Monitoring occurred between March and May 2012.

**Table 3: Repeat post-construction noise monitoring locations**

Location	Additional houses represented by data	Post-construction noise monitoring period
2	3, 4	7-18 March 2012 <sup>1, 2</sup>
7	6	7-22 March 2012
10		7-22 March 2012 <sup>2</sup> 30 March – 13 April 2012 <sup>2</sup> 13-27 April 2012 <sup>2</sup>
16		7-22 March 2012
18		7-22 March 2012 <sup>3</sup> 30 March – 13 April 2012 <sup>2</sup> 13-27 April 2012 <sup>3</sup> 27 April – 11 May 2012

<sup>1</sup> noise logger stopped before collecting 14 days of data due to battery failure

<sup>2</sup> data affected by extraneous noise (insects)

<sup>3</sup> equipment failure

Rion NL31 Class 1 noise loggers were used for these measurements. According to the manufacturer's information, the A-weighted inherent internal noise (noise floor) of the Rion NL31 is below 20dB and typically around 17dB.

As required in Section 5.2.1 of NZS6808:1998, noise loggers were placed at approximately the same position as that used for the pre-construction noise monitoring. Photographs of the noise logger positions used during the post-construction surveys are attached in Appendix E.

NZS6808:1998 recommends that 1,440 valid data points be collected in order to carry out a regression analysis. Noise loggers were placed on site for a period of at least 14 days, measuring at 10 minute intervals, in order to acquire sufficient data for regression analysis.

Rainfall data collected on site were reviewed and where rainfall is likely to have occurred, these data points were removed from the analysis.

The collected data is filtered prior to the regression analysis in order to remove likely rain affected data as well as data points where the wind speed is below the turbine cut-in.

Monitoring periods, the number of data points collected and the number of data points included in the analysis are presented in the following sections together with the correlation coefficient, the coefficient of determination ( $R^2$ ) and the range of assessed wind speeds during each monitoring session.

For each study site the measured post-construction noise levels are shown in red with the regression line of best fit shown as a solid red line. Similarly, pre-construction background noise levels are shown in green with the regression line of best fit shown as a solid green line.

When the post-construction noise levels (solid red line) are lower than the noise limits (solid black line), the wind farm noise emissions are deemed to comply with NZS6808:1998. If the post-construction noise levels are higher than the noise limits, it is necessary to remove the potential effect of background noise and derive the “wind farm only” noise levels.

As detailed in Section 3.3, the “wind farm only” noise levels are obtained by logarithmically subtracting the pre-construction noise level from the post-construction noise level for each integer wind speed. The resulting noise levels are identified as the “derived wind farm noise levels” (solid blue line). When the derived wind farm noise levels are lower than the noise limits, the wind farm noise emissions are deemed to comply with NZS6808:1998.

Data collected during several monitoring periods appear to have been affected by extraneous noise. Where possible, two noise loggers were installed in tandem at affected locations. To try and identify the source of extraneous noise, the second noise logger monitored frequency spectra in addition to A-weighted levels. Our analysis of this additional data shows significant, diurnal high frequency noise levels, independent of wind speed. Insect noise is the likely cause of these high noise levels, which is consistent with site observations. Further discussion is provided in Appendix D.



#### 4.1 House 1 (Phase 1)

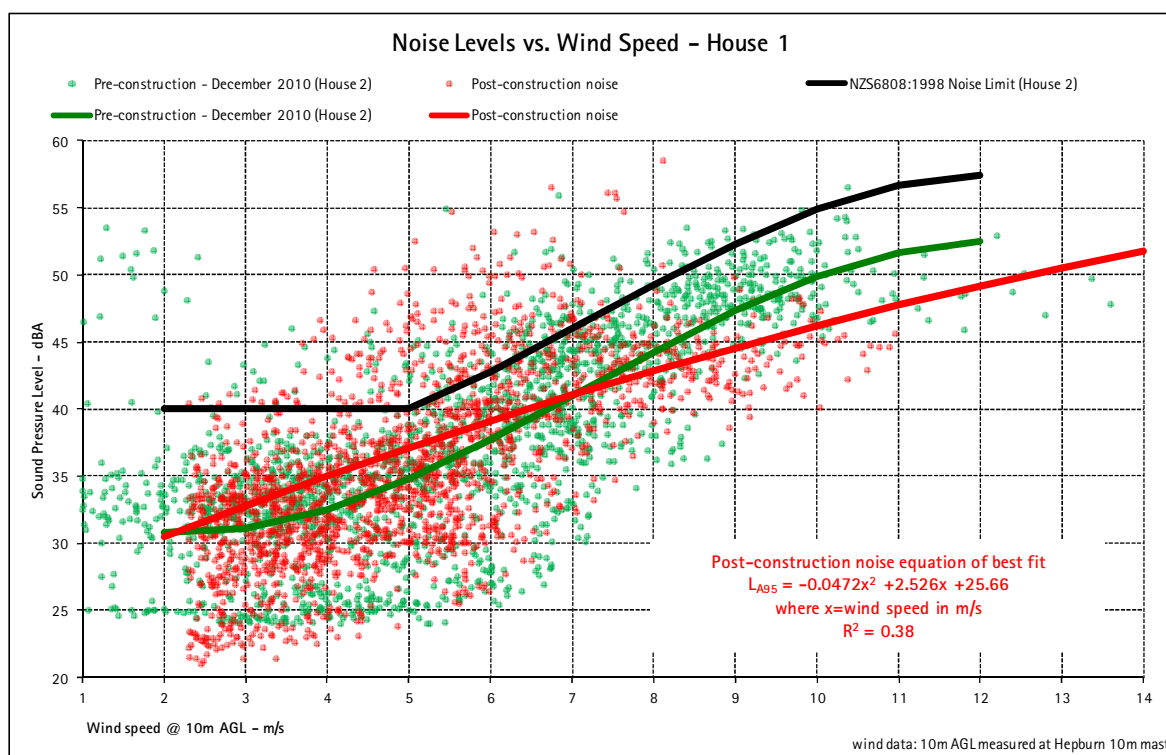
Noise level data measured between 11 and 25 November 2011 at House 1 has been correlated with 10m AGL wind data collected on site. Results are summarised in Table 4 and Figure 1 below.

**Table 4: Summary of parameters – House 1**

Monitoring period	11.11.11 to 25.11.11
Total number of valid data points collected	2,137
Number of data points removed*	285
Number of data points used for analysis	1,852
Post-construction correlation**	0.62
Post-construction regression line of best fit $R^2$	0.38
Wind speed range used for analysis (10m AGL)	2.3 to 11.0m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 1: Post-construction noise levels vs. wind speed at House 1**

It can be seen from Figure 1 that the post-construction noise regression derived at House 1 is below the NZS6808:1998 noise limits, derived using pre-construction noise monitoring at House 2, at all assessed wind speeds.

## 4.2 House 2

### 4.2.1 Phase 1 noise monitoring

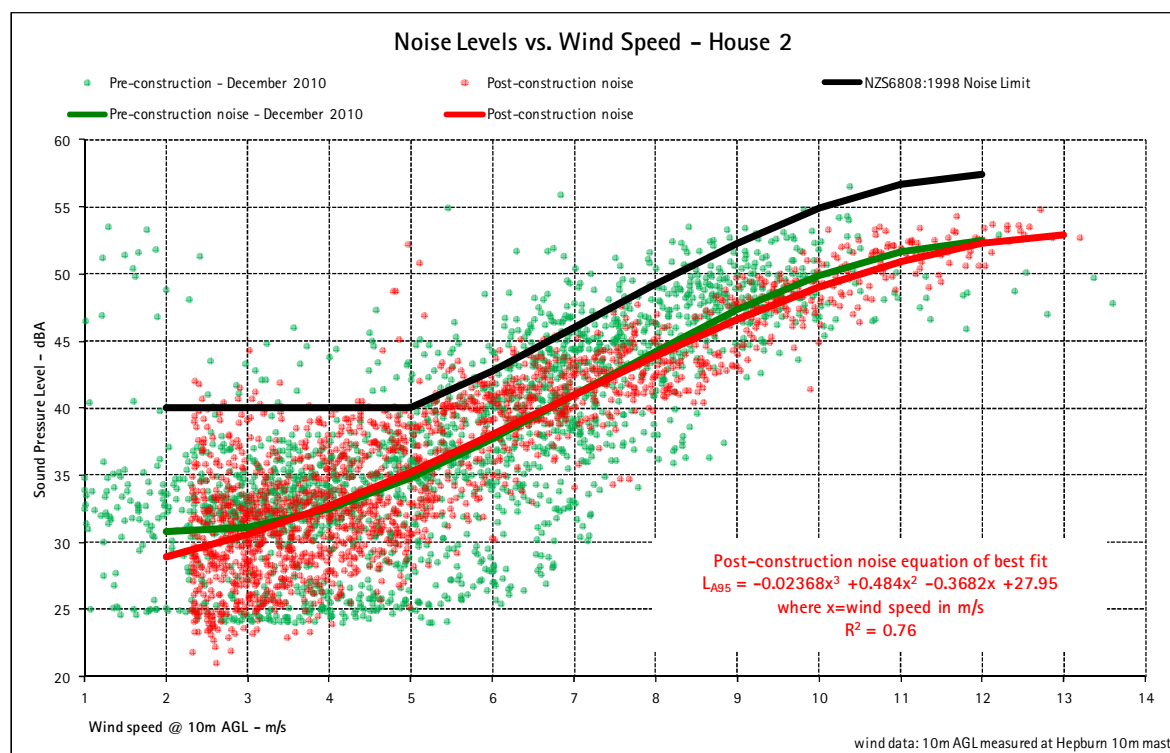
Noise level data measured between 26 August and 9 September 2011 at House 2 has been correlated with 10m AGL wind data collected on site. Results are summarised in Table 5 and Figure 2 below.

**Table 5: Summary of parameters – House 2 (August 2011)**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,003
Number of data points removed*	320
Number of data points used for analysis	1,683
Post-construction correlation**	0.87
Post-construction regression line of best fit $R^2$	0.76
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 2: Post-construction noise levels vs. wind speed at House 2 (August 2011)**

It can be seen from Figure 2 that the post-construction noise levels measured at House 2 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.2.2 Phase 2 noise monitoring

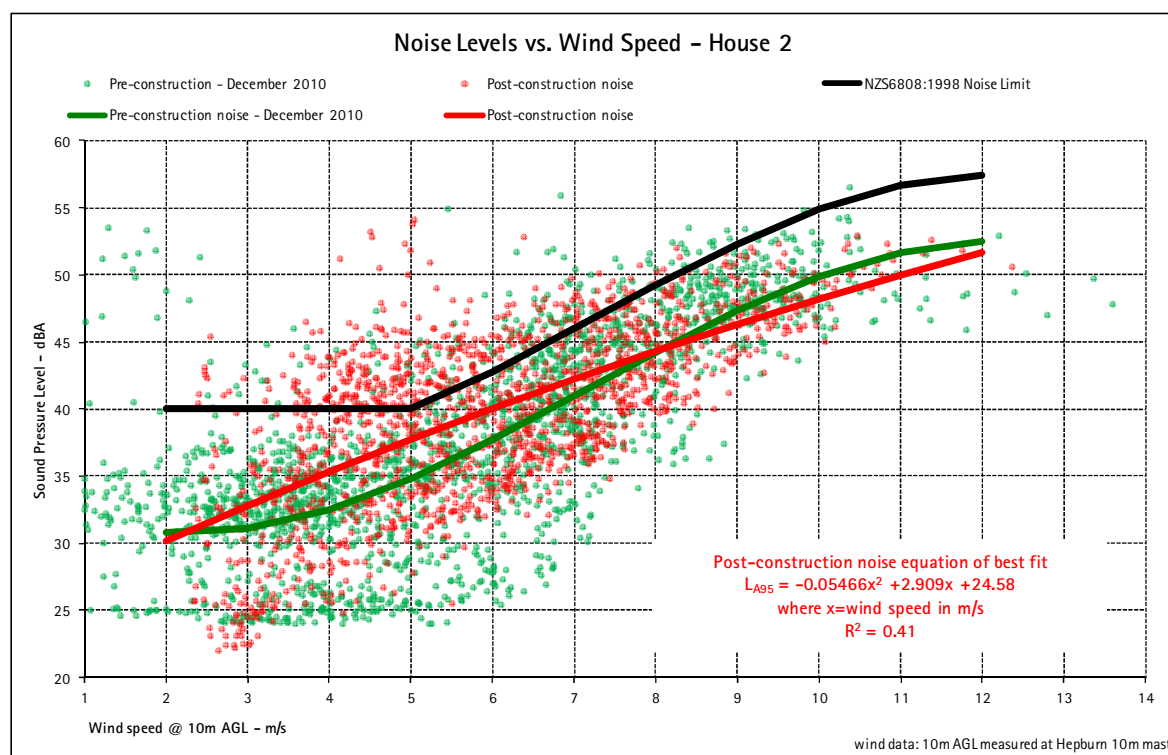
Noise level data measured between 7 and 19 March 2012 at House 2 has been correlated with 10m AGL wind data collected on site. Results are summarised in Table 6 and Figure 3 below.

**Table 6: Summary of parameters – House 2 (March 2012)**

Monitoring period	7.03.12 to 18.03.12
Total number of valid data points collected	1621
Number of data points removed*	109
Number of data points used for analysis	1512
Post-construction correlation**	0.66
Post-construction regression line of best fit $R^2$	0.41
Wind speed range used for analysis (10m AGL)	2.3 to 12.4m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 3: Post-construction noise levels vs. wind speed at House 2 (March 2012)**

It can be seen from Figure 3 that the post-construction noise levels measured at House 2 are below the NZS6808:1998 noise limits at all assessed wind speeds.

### 4.3 House 7

#### 4.3.1 Phase 1 noise monitoring

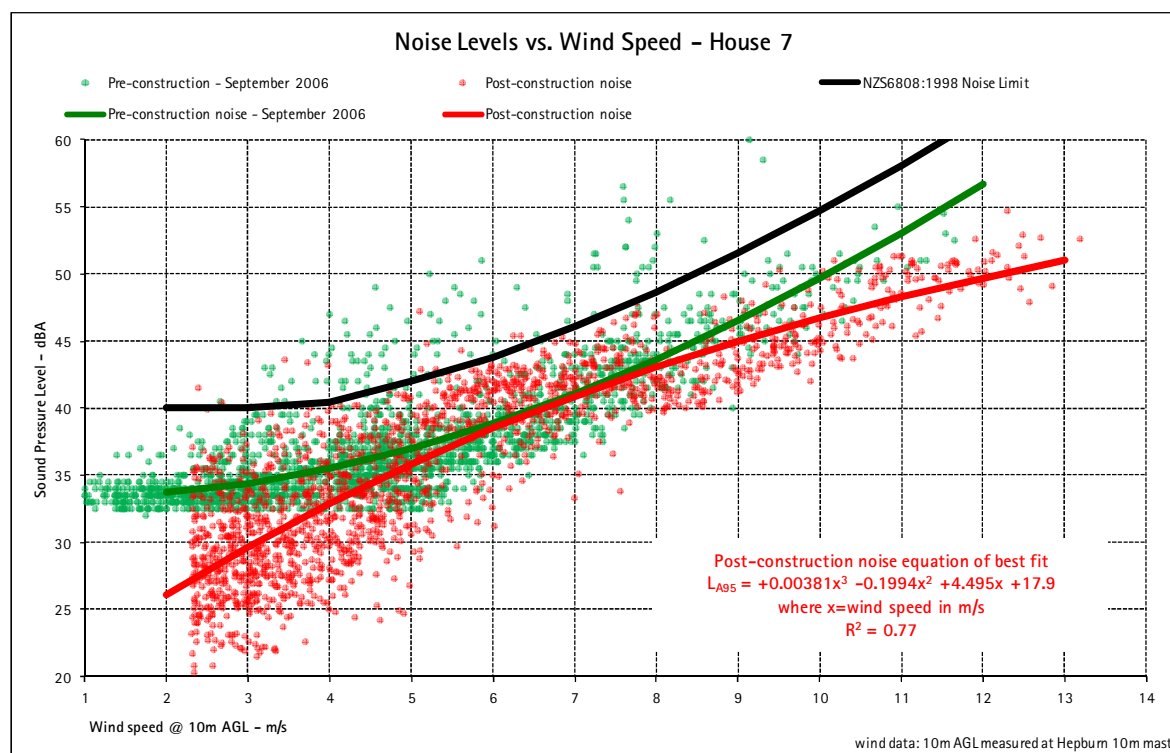
Noise level data measured between 26 August and 9 September 2011 at House 7 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 7 and Figure 4 below.

**Table 7: Summary of parameters – House 7 (August 2011)**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	1,998
Number of data points removed*	320
Number of data points used for analysis	1,678
Post-construction correlation**	0.87
Post-construction regression line of best fit $R^2$	0.77
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 4: Post-construction noise levels vs. wind speed at House 7 (August 2011)**

It can be seen from Figure 4 that the post-construction noise levels measured at House 7 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.3.2 Phase 2 noise monitoring

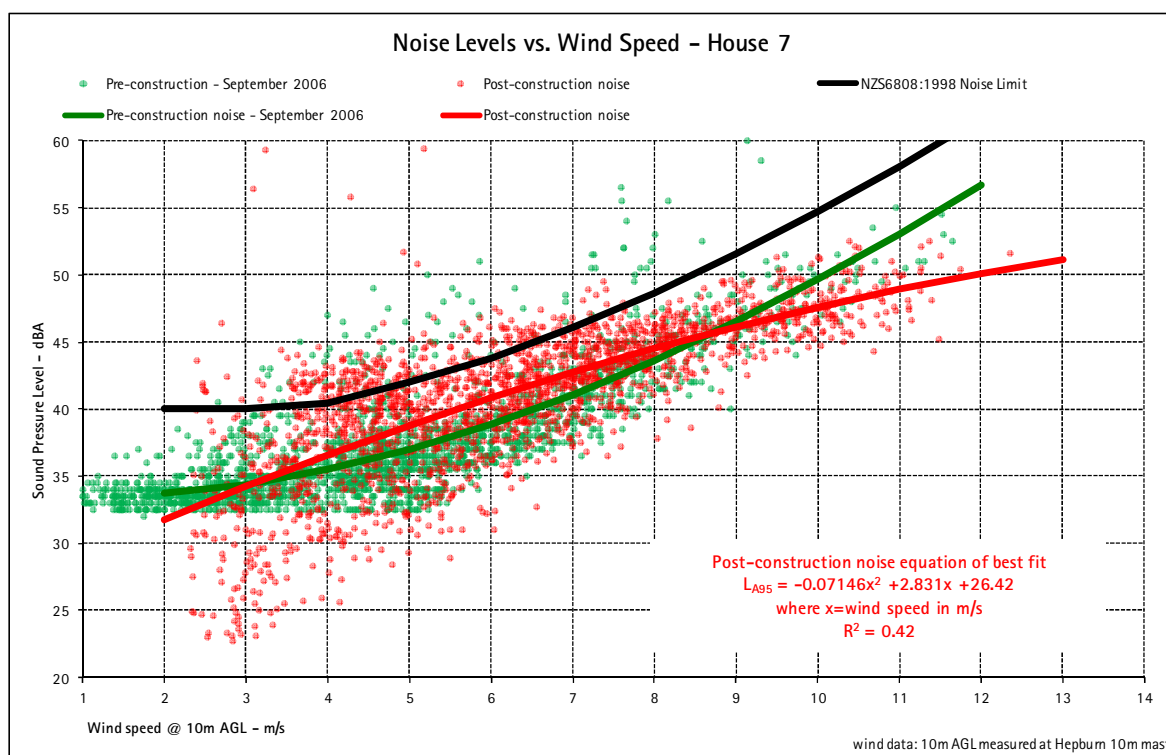
Noise level data measured between 7 and 21 March 2012 at House 7 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 8 and Figure 5 below.

**Table 8: Summary of parameters – House 7 (March 2012)**

Monitoring period	7.03.12 to 21.03.12
Total number of valid data points collected	2,035
Number of data points removed*	115
Number of data points used for analysis	1,920
Post-construction correlation**	0.72
Post-construction regression line of best fit $R^2$	0.42
Wind speed range used for analysis (10m AGL)	2.3 to 12.4m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 5: Post-construction noise levels vs. wind speed at House 7 (March 2012)**

It can be seen from Figure 5 that the post-construction noise levels measured at House 7 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.4 House 9 (Phase 1)

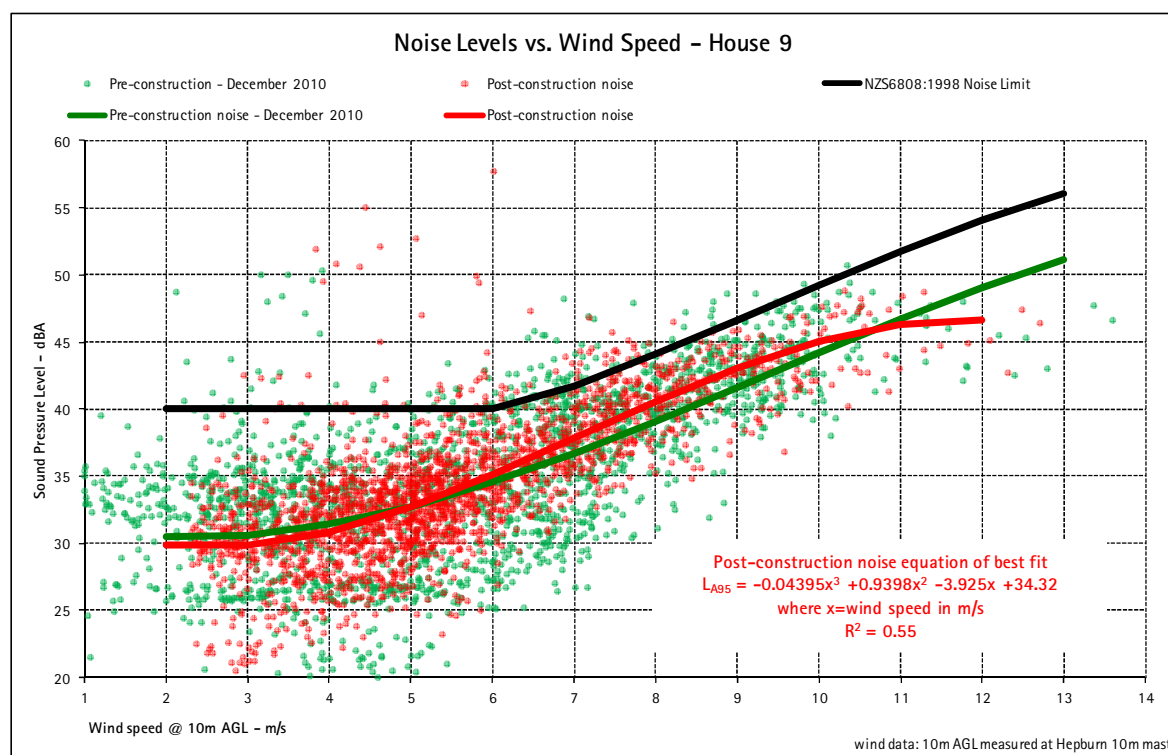
Noise level data measured between 25 October and 11 November 2011 at House 9 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 9 and Figure 6 below.

**Table 9: Summary of parameters – House 9**

Monitoring period	25.10.11 to 11.11.11
Total number of valid data points collected	2,297
Number of data points removed*	236
Number of data points used for analysis	2,061
Post-construction correlation**	0.73
Post-construction regression line of best fit R <sup>2</sup>	0.55
Wind speed range used for analysis (10m AGL)	2.3 to 12.7m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 6: Post-construction noise levels vs. wind speed at House 9**

It can be seen from Figure 6 that the post-construction noise levels measured at House 9 are below the NZS6808:1998 noise limits at all assessed wind speeds.



## 4.5 House 10

### 4.5.1 Phase 1 noise monitoring

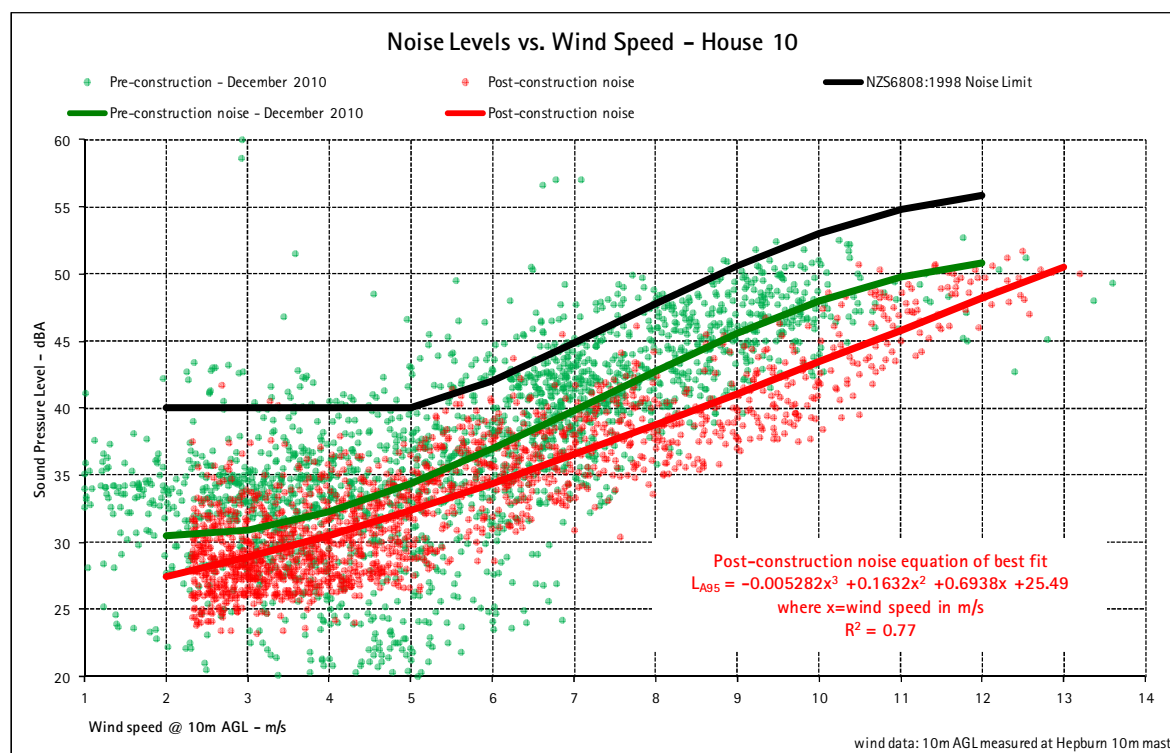
Noise level data measured between 26 August and 9 September 2011 at House 10 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 10 and Figure 7 below.

**Table 10: Summary of parameters – House 10 (August 2011)**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,009
Number of data points removed*	324
Number of data points used for analysis	1,685
Post-construction correlation**	0.88
Post-construction regression line of best fit $R^2$	0.77
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 7: Post-construction noise levels vs. wind speed at House 10 (August 2011)**

It can be seen from Figure 7 that the post-construction noise levels measured at House 10 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.5.2 Phase 2 noise monitoring

Noise level data measured between 7 March and 27 April 2012 at House 10 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 11 and Figure 8 below.

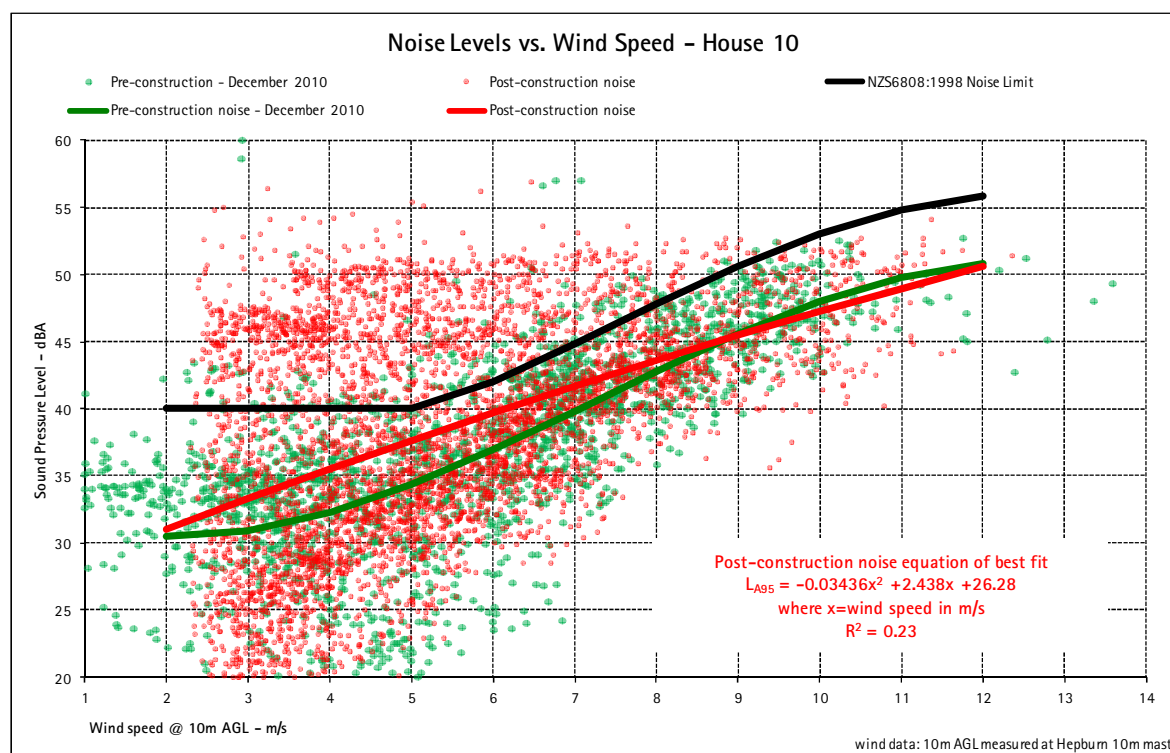
**Table 11: Summary of parameters – House 10 (March 2011)**

Monitoring periods	7.03.12 to 22.03.12 <sup>+</sup> 30.03.12 to 13.04.12 <sup>+</sup> 13.04.12 to 27.04.12 <sup>+</sup>
Total number of valid data points collected	5,285
Number of data points removed*	424
Number of data points used for analysis	4,861
Post-construction correlation**	0.48
Post-construction regression line of best fit R <sup>2</sup>	0.23
Wind speed range used for analysis (10m AGL)	2.3 to 12.4m/s

<sup>+</sup> data affected by extraneous noise (insects) – See Appendix D

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 8: Post-construction noise levels vs. wind speed at House 10 (August 2011)**

It can be seen from Figure 8 that the post-construction noise levels measured at House 10 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.6 House 12 (Phase 1)

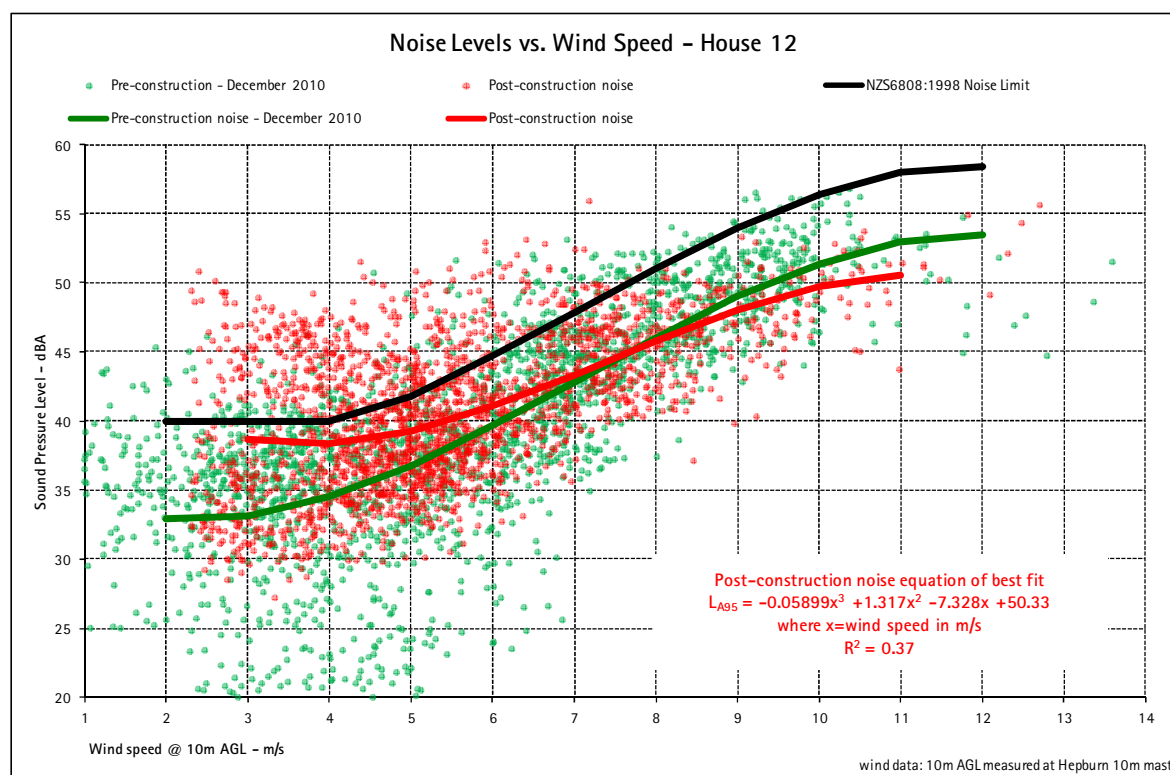
Noise level data measured between 25 October and 11 November 2011 at House 12 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 12 and Figure 9 below.

**Table 12: Summary of parameters – House 12**

Monitoring period	25.10.11 to 11.11.11
Total number of valid data points collected	2,302
Number of data points removed*	236
Number of data points used for analysis	2,066
Post-construction correlation**	0.56
Post-construction regression line of best fit $R^2$	0.37
Wind speed range used for analysis (10m AGL)	2.3 to 12.7m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 9: Post-construction noise levels vs. wind speed at House 12**

It can be seen from Figure 9 that the post-construction noise levels measured at House 12 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.7 House 14 (Phase 1)

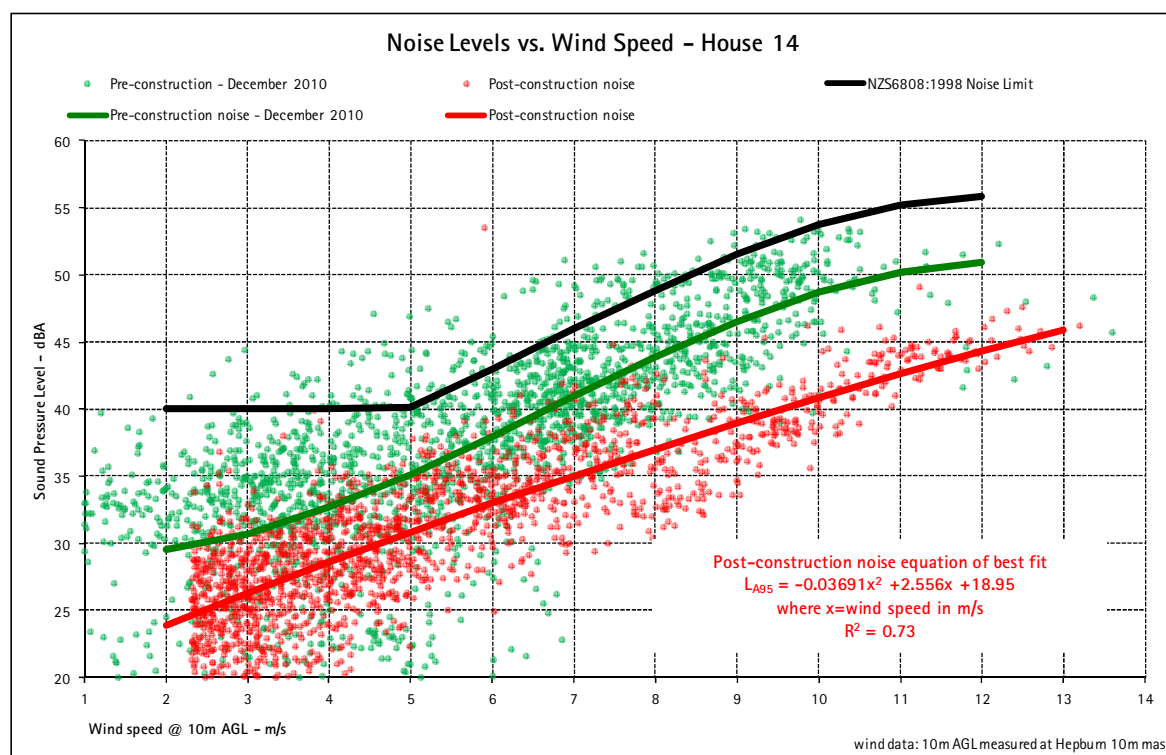
Noise level data measured between 26 August and 9 September 2011 at House 14 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 13 and Figure 10 below.

**Table 13: Summary of parameters – House 14**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,008
Number of data points removed*	324
Number of data points used for analysis	1,684
Post-construction correlation**	0.85
Post-construction regression line of best fit $R^2$	0.73
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 10: Post-construction noise levels vs. wind speed at House 14**

It can be seen from Figure 10 that the post-construction noise levels measured at House 14 are below the NZS6808:1998 noise limits at all assessed wind speeds.

It can be seen from Figure 10 that post-construction noise levels are generally lower than the pre-construction noise levels. At this property, the difference is believed to be due to seasonal variations and may relate to factors such as the extent of foliage on deciduous trees in proximity of the noise monitoring location.

## 4.8 House 16

### 4.8.1 Phase 1 noise monitoring

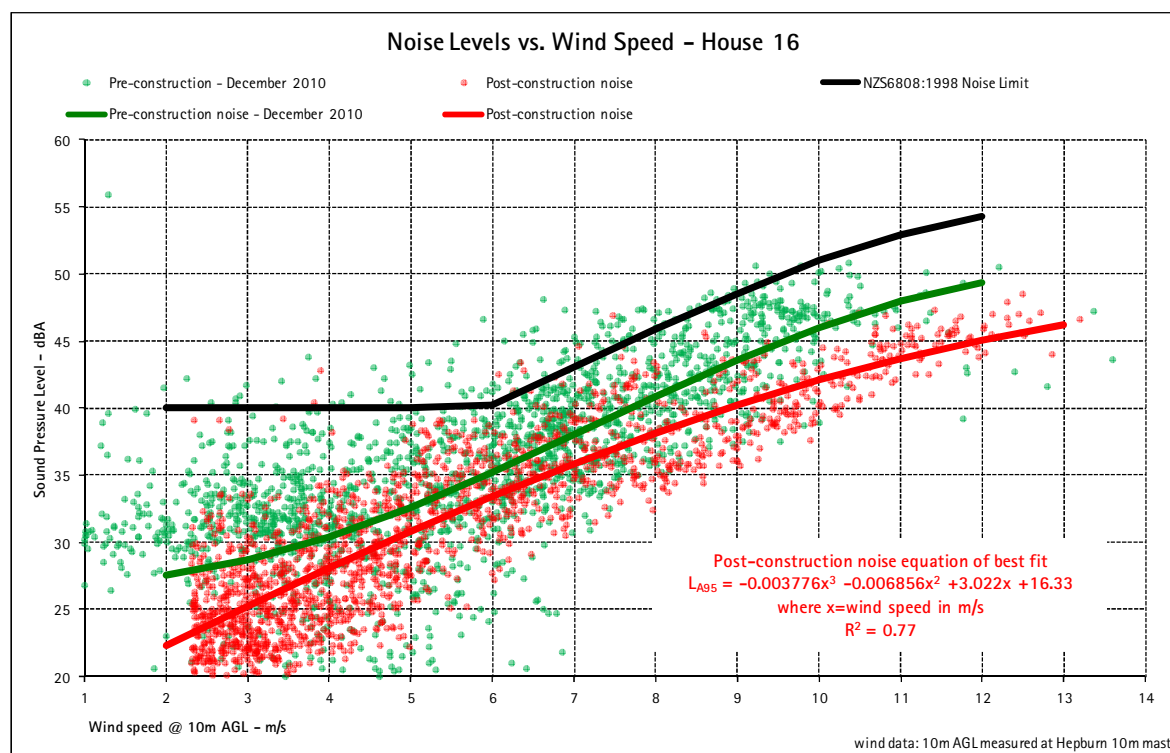
Noise level data measured between 26 August and 9 September 2011 at House 16 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 14 and Figure 11 below.

**Table 14: Summary of parameters – House 16 (August 2011)**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,006
Number of data points removed*	321
Number of data points used for analysis	1,685
Post-construction correlation**	0.88
Post-construction regression line of best fit $R^2$	0.77
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 11: Post-construction noise levels vs. wind speed at House 16 (August 2011)**

It can be seen from Figure 11 that the post-construction noise levels measured at House 16 are below the NZS6808:1998 noise limits at all assessed wind speeds.



#### 4.8.2 Phase 2 noise monitoring

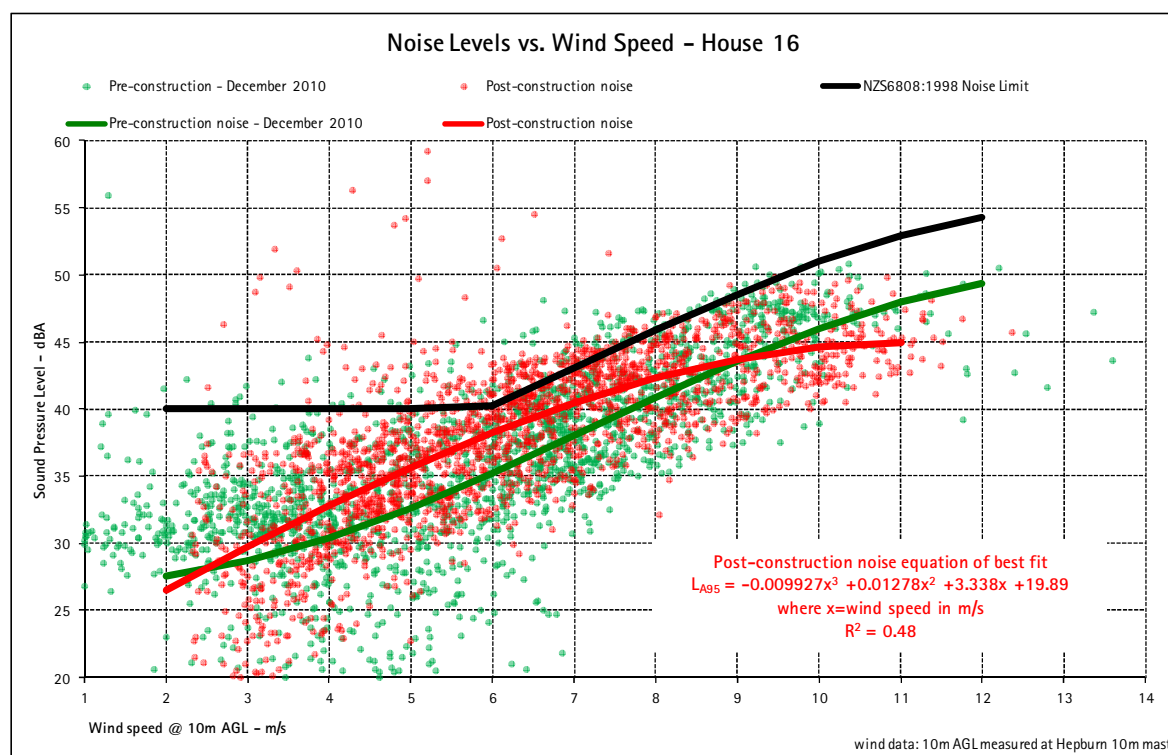
Noise level data measured between 7 and 21 March 2012 at House 16 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 14 and Figure 11 below.

**Table 15: Summary of parameters – House 16 (March 2012)**

Monitoring period	7.03.12 to 21.03.12
Total number of valid data points collected	2,040
Number of data points removed*	151
Number of data points used for analysis	1,889
Post-construction correlation**	0.70
Post-construction regression line of best fit $R^2$	0.48
Wind speed range used for analysis (10m AGL)	2.3 to 12.4m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 12: Post-construction noise levels vs. wind speed at House 16 (August 2011)**

It can be seen from Figure 11 that the post-construction noise levels measured at House 16 are below the NZS6808:1998 noise limits at all assessed wind speeds.

## 4.9 House 18

### 4.9.1 Phase 1 noise monitoring

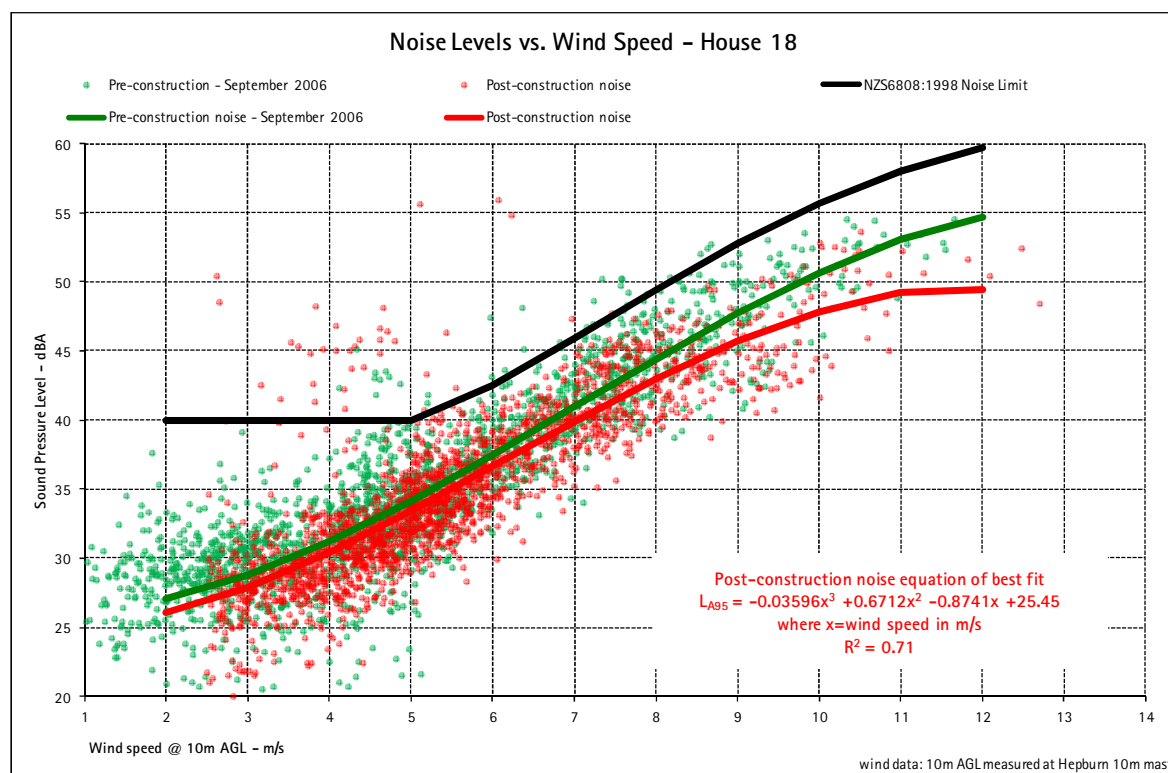
Noise level data measured between 25 October and 11 November 2011 at House 18 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 16 and Figure 13 below.

**Table 16: Summary of parameters – House 18**

Monitoring period	25.10.11 to 11.11.11
Total number of valid data points collected	2,170
Number of data points removed*	221
Number of data points used for analysis	1,949
Post-construction correlation**	0.85
Post-construction regression line of best fit $R^2$	0.71
Wind speed range used for analysis (10m AGL)	2.3 to 12.7m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 13: Post-construction noise levels vs. wind speed at House 18**

It can be seen from Figure 13 that the post-construction noise levels measured at House 18 are below the NZS6808:1998 noise limits at all assessed wind speeds.

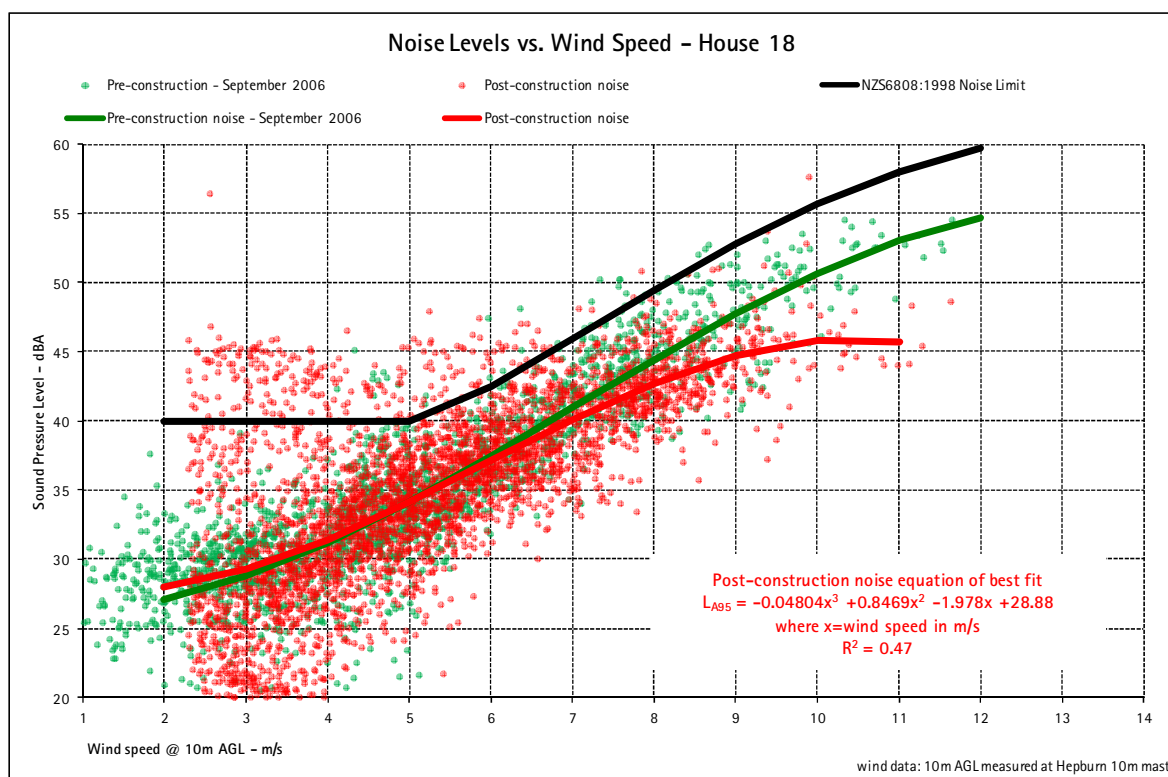
#### 4.9.2 Phase 2 noise monitoring

Noise level data measured between 7 March and 11 May 2012 at House 18 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 17 and Figure 14 below.

**Table 17: Summary of parameters – House 18 (March 2012)**

Monitoring period	7.03.12 to 22.03.12 <sup>++</sup> 30.03.12 to 13.04.12 <sup>+</sup> 13.04.12 to 27.04.12 <sup>++</sup> 27.04.12 to 11.05.12
Total number of valid data points collected	3,477
Number of data points removed*	149
Number of data points used for analysis	3,328
Post-construction correlation**	0.68
Post-construction regression line of best fit R <sup>2</sup>	0.47
Wind speed range used for analysis (10m AGL)	2.3 to 11.6m/s

<sup>+</sup> data affected by extraneous noise (insects) – See Appendix D  
<sup>++</sup> equipment failure – data collected was not valid and therefore not analysed  
<sup>\*</sup> removed due to periods of rain and wind speed below cut-in  
<sup>\*\*</sup> correlation between noise levels and wind speeds



**Figure 14: Post-construction noise levels vs. wind speed at House 18 (March 2012)**

It can be seen from Figure 14 that the post-construction noise levels measured at House 18 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.10 House 19 (Phase 1)

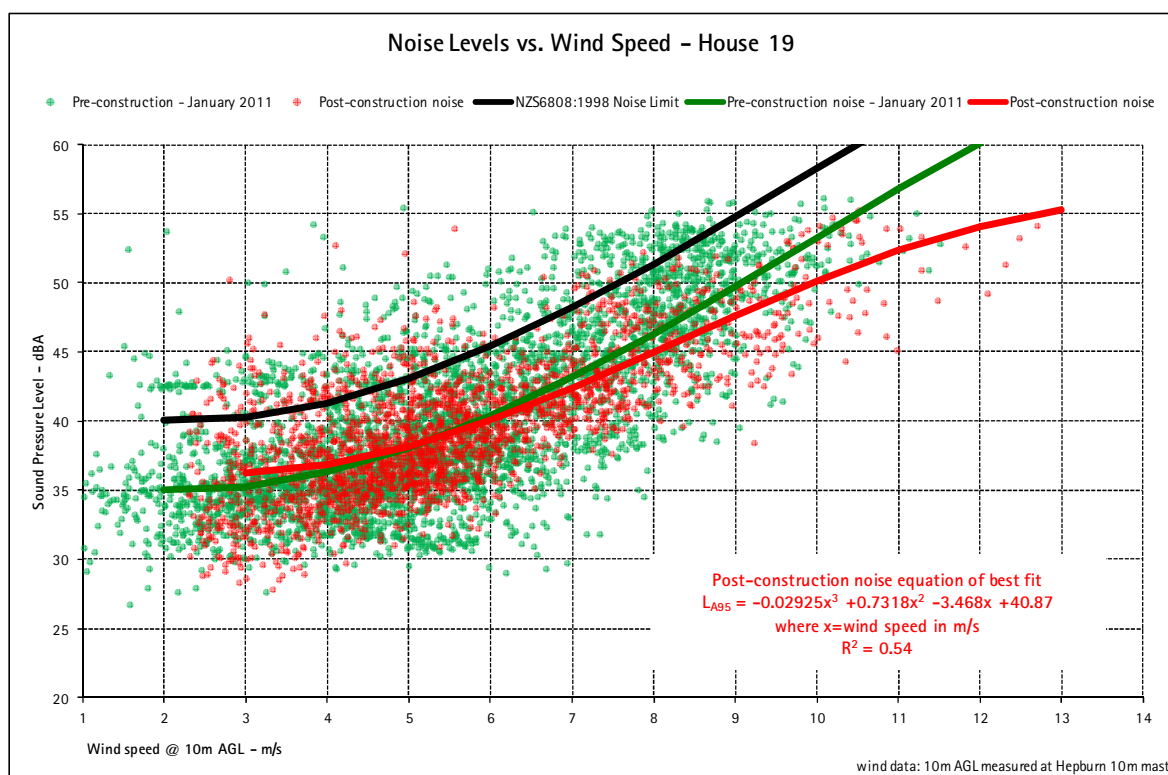
Noise level data measured between 25 October and 11 November 2011 at House 19 has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 18 and Figure 15 below.

**Table 18: Summary of parameters – House 19**

Monitoring period	25.10.11 to 11.11.11
Total number of valid data points collected	2,303
Number of data points removed*	236
Number of data points used for analysis	2,067
Post-construction correlation**	0.70
Post-construction regression line of best fit $R^2$	0.54
Wind speed range used for analysis (10m AGL)	2.3 to 12.7m/s

\* removed due to periods of rain and wind speed below cut-in

\*\* correlation between noise levels and wind speeds



**Figure 15: Post-construction noise levels vs. wind speed at House 19**

It can be seen from Figure 15 that the post-construction noise levels measured at House 19 are below the NZS6808:1998 noise limits at all assessed wind speeds.

#### 4.11 Location A (Phase 1)

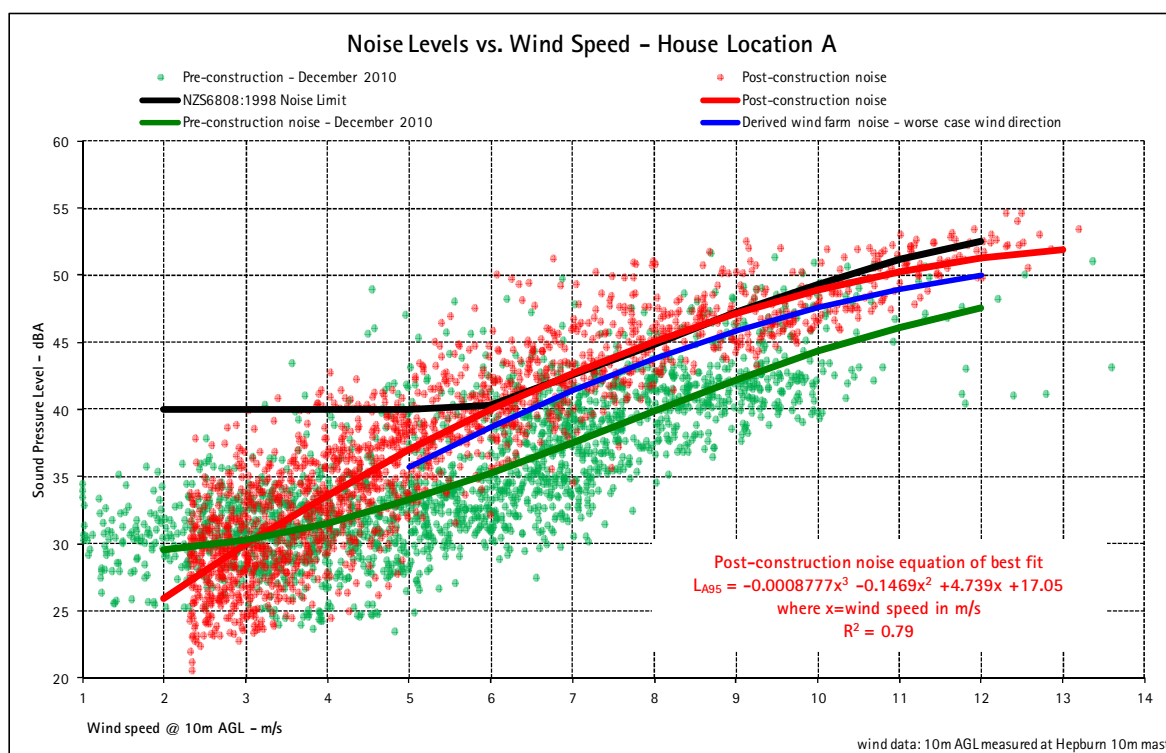
Noise level data measured between 26 August and 9 September 2011 at Location A has been correlated with the 10m AGL wind data collected on site. Results are summarised in Table 19 and Figure 16 below.

**Table 19: Summary of parameters – Location A**

Monitoring period	26.08.11 to 9.09.11
Total number of valid data points collected	2,008
Number of data points removed*	323
Number of data points used for analysis	1,685
Post-construction correlation**	0.90
Post-construction regression line of best fit R <sup>2</sup>	0.79
Wind speed range used for analysis (10m AGL)	2.3 to 13.2m/s

\* removed due to periods of rain and wind speed below cut-in

\*\*\* correlation between noise levels and wind speeds



**Figure 16: Post-construction noise levels vs. wind speed at Location A**

It can be seen from Figure 16 that the derived wind farm noise levels at Location A are below the NZS6808:1998 noise limits at all assessed wind speeds.



## 4.12 Discussion

### 4.12.1 Comparison of Phase 1 and Phase 2 monitoring

The objective of the Phase 2 noise monitoring survey is to confirm the advice from the turbine manufacturer that noise emission from the wind farm is not expected to be significantly different after the removal of the 2.6 MW generation constraint. It is for this reason that the Phase 2 monitoring comprised a targeted survey of the five (5) dwellings located nearest to the turbines.

From the results presented above, noise emission from the wind farm demonstrates compliance with the applicable noise limits at all assessed locations during both phases of monitoring. This result is consistent with the advice provided from the turbine manufacturer.

### 4.12.2 Regression lines

In several of the figures presented above it can be seen that the post-construction noise regression line is generally lower than the pre-construction noise regression line. This indicates that over the post-construction noise monitoring period, noise levels were generally lower than those measured during the pre-construction noise monitoring period.

These differences may be attributable to variations in background noise levels across different monitoring periods<sup>2</sup>. In particular, variations of non wind farm related ambient noise levels (e.g. farming activities, vegetation, etc) may affect the measured post-construction noise levels.

A discussion of likely insect affected data sets is provided in Appendix D.

## 4.13 Special audible characteristics

### 4.13.1 Criteria

Section 5.3.1 of NZS6808:1998 states the following regarding assessment of special audible characteristics:

*Sound from a WTG (Wind Turbine Generator) that has special audible characteristics (clearly audible tones, impulses or modulation of sound levels) is likely to arouse adverse community response at lower levels of sound than sound without such characteristics. At present, there is no simple objective procedure available to quantify special audible characteristics, and subjective assessment is therefore necessary, supported by objective evidence (e.g. frequency analysis) where appropriate.*

The standard goes on to note that if a special audible characteristic has been identified through a subjective assessment and verified using an objective assessment, a 5dB penalty should be applied to the wind farm noise level at the time when the special audible characteristics occurred.

---

<sup>2</sup> As discussed by Delaire in a paper presented at the 2009 International Wind Turbine Noise conference:  
*A comparison of background noise levels collected at the Portland Wind Energy Project in Victoria, Australia*

These comments are complimented by comment CB3.1 from the more recent version of the standard, NZS6808:2010<sup>3</sup>, which states the following:

*By the very nature of wind turbine blades passing in front of a support tower, some amplitude modulation will always be present in the sound of a rotating wind turbine although this will not always be audible at distances from the wind farm. Amplitude modulation special audible characteristics occur when there is significant amplitude modulation of the aerodynamic sound from one of more wind turbines such that there is a greater than normal degree of fluctuation as a function of the blade passing frequency (typically about once per second for larger turbines).*

#### 4.13.2 Subjective assessment

As required by NZS6808:1998, MDA has carried out a subjective assessment of the wind farm noise to investigate the presence of special audible characteristics.

Specifically, listening tests have been carried out during site visits at properties and locations neighbouring the wind farm, including positions downwind from the turbines. Details of our site visits are presented in Table 20.

**Table 20: Site visits**

Date	Time period	Wind speed range	Wind direction range
8 July 2011	1200-1700hrs	4.2-6.5 m/s	NW-NNW
20 July 2011	1330-1600hrs	9.2-11.3 m/s	SSE
26 August 2011	1300-1700hrs	2-4 m/s	SW-NW
9 September 2011	1300-1500hrs	5.8-10.2 m/s	S-SSW
25 October 2011	1200-1500hrs	7.5-9.9 m/s	SE-SSE
11 November 2011	1200-1400hrs	3.5-4.4 m/s	NW-N
7 March 2012	1100-1400hrs	6.9-9.9 m/s	SE-SSE
13 April 2012	1200-1400hrs	5.2-6.3 m/s	NW-NNW
27 April 2012	1100-1300hrs	3.5-4.5 m/s	S-SSW
11 May 2012	1100-1200hrs	5.9-7.5 m/s	SW-WSW

In addition, audio samples have been recorded and further listening tests have been carried out, away from site, using the audio samples.

For the wind farm noise assessed during the site visits and listening tests, we consider the following:

- No tones were audible
- The wind farm was not impulsive in character
- Only amplitude modulation (swish) typical from a normally operating wind turbine was audible

<sup>3</sup> New Zealand Standard 6808:2010 *Acoustics – Wind farm noise*

During the listening tests the Hepburn Community Wind Farm has shown audible characteristics typical of normally operating wind turbines. On this basis, we consider that objective assessment is not required and no penalty for special audible characteristics is deemed applicable.

## **5.0 CONCLUSION**

As required by Condition 11 of the Hepburn Community Wind Farm planning permit, post-construction noise monitoring has been undertaken at properties neighbouring the wind farm. Monitoring has been carried out in two phases, during periods of different maximum generation capacities of the wind farm.

All monitoring has been carried out in accordance with NZS6808:1998.

Phase 1 monitoring was carried out between August and November 2011 at eleven (11) properties, including ten (10) of the fourteen (14) assessable locations. Phase 2 monitoring was carried out between March and May 2012 at five (5) properties.

As advised by the turbine manufacturer, after the removal of the constraint, Phase 2 noise monitoring results demonstrate the same compliance outcome as observed for the Phase 1 noise monitoring.

The results of the post-construction noise monitoring surveys, across both Phase 1 and 2, demonstrate compliance with the NZS6808:1998 noise limits at all monitored properties.

## APPENDIX A ACOUSTIC TERMINOLOGY

<b>Frequency</b>	The number of pressure fluctuation cycles per second of a sound wave. Measured in units of Hertz (Hz).
<b>Hertz (Hz)</b>	Hertz is the unit of frequency. One hertz is one cycle per second. One thousand hertz is a kilohertz (kHz).
<b>Octave Band</b>	A range of frequencies where the highest frequency included is twice the lowest frequency. Octave bands are referred to by their logarithmic centre frequencies, these being 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz for the audible range of sound.
<b>Sound Pressure Level (<math>L_p</math>)</b>	A logarithmic ratio of a sound pressure measured at distance, relative to the threshold of hearing (20 $\mu$ Pa RMS) and expressed in decibels.
<b>Sound Power Level (<math>L_w</math>)</b>	A logarithmic ratio of the acoustic power output of a source relative to $10^{-12}$ watts and expressed in decibels. Sound power level is calculated from measured sound pressure levels.
<b>dB</b>	Decibel – A measurement of sound level expressed as a logarithmic ratio of sound pressure P relative to a reference pressure of $P_r=20 \mu\text{Pa}$ i.e. $\text{dB} = 20 \times \log(P/P_r)$
<b>A-weighting</b>	The process by which noise levels are corrected to account for the non-linear frequency response of the human ear.  All noise levels are quoted relative to a sound pressure of $2 \times 10^{-5} \text{Pa}$
<b><math>L_{Aeq}</math></b>	The equivalent continuous (time-averaged) A-weighted sound level. This is commonly referred to as the average noise level.
<b><math>L_{A95}</math></b>	The A-weighted noise level equalled or exceeded for 95% of the measurement period. This is commonly referred to as the background noise level.





## APPENDIX C NOISE MONITORING LOCATIONS



### Legend:

<b>Red house</b>	Residential property where background noise levels were monitored
<b>Red star</b>	Noise monitoring location deemed representative of a neighbouring residential property
<b>Yellow house</b>	Residential property
<b>Yellow circle</b>	Non residential property or derelict residential property

## APPENDIX D ANALYSIS OF EXTRANEOUS NOISE

As shown in the monitoring results for House 10 and House 18, Figure 8 and Figure 14 respectively, measured post construction noise levels appear to have been significantly influenced by extraneous noise.

In particular, analysis of the data collected at House 10 during the first Phase 2 monitoring period shows a high amount of extraneous noise, unrelated to wind speeds.

To investigate this extraneous noise further, two noise loggers were installed in tandem at Houses 10 and 18 during a two (2) week period. In each case, the second noise logger recorded one third octave band frequency data.

Review of the collected frequency data indicates a high level of high frequency noise centred on the 6.3kHz and 8kHz one-third octave bands. This spectral content is typical of insect noise.

A further sensitivity analysis has been undertaken on the spectral data to estimate the extent to which the identified high frequency noise levels may have affected results of the primary noise logger at each location. A “filtered  $L_{95}$ ” noise level has been calculated from the frequency data set by removing all one-third octave bands above 6.3kHz, as these high frequencies do not generally significantly influence the overall A-weighted noise levels without insect noise.

A comparison of the measured (blue) and filtered (red)  $L_{A95}$  noise levels are plotted in Figure 17 and Figure 18 against 10m AGL wind speeds together with the respective regression lines and coefficient of determination ( $R^2$ ).

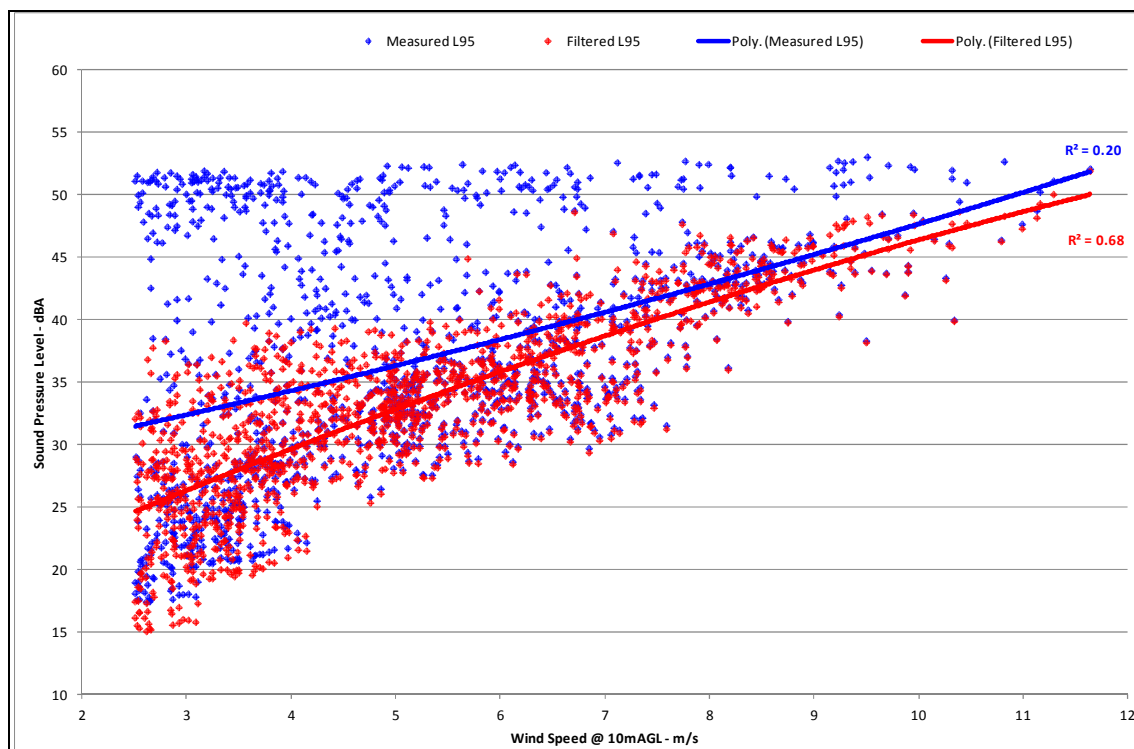
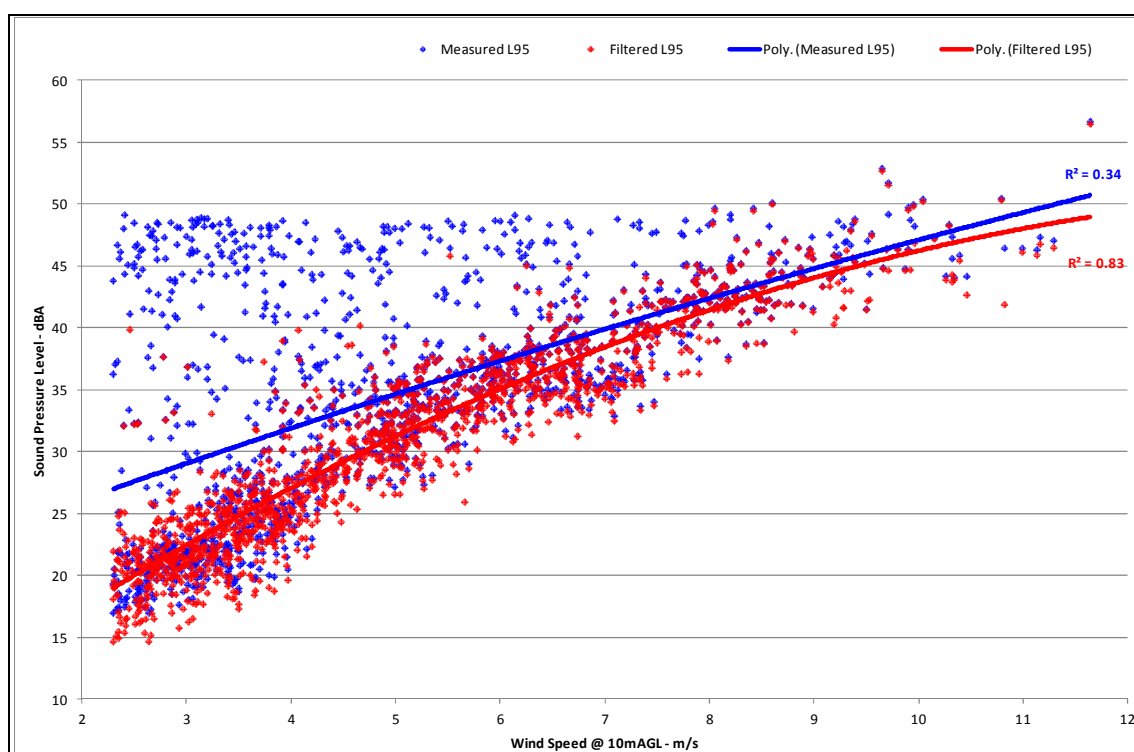


Figure 17: Sensitivity analysis at House 10





**Figure 18: Sensitivity analysis at House 18**

It can be seen from Figure 17 and Figure 18 that the correlation between noise levels and wind speeds increase significantly when the high frequency content is removed.

We consider it likely that insects are the source of the high frequency noise at monitoring locations H10 and H18 and that the resulting high noise levels measured by the primary noise logger are not representative of the noise emission from the wind farm. Notwithstanding this, all available data has been included in the assessment provided above and compliance is demonstrated with the applicable noise limits. We consider that not removing data affected by insects presents a conservative compliance assessment.

APPENDIX E NOISE LOGGER LOCATIONS

E1 House 1



E2 House 2





E3 House 7



E4 House 9





E5 House 10



E6 House 12





E7 House 14



E8 House 16



E9 House 18



E10 House 19





E11 Location A





File: 103800P

26 September 2012

Tracy Anthony  
Hepburn Wind  
13 Knox St.  
Daylesford 3460

Dear Sir/Madam,

**Re: Planning Permit 2006 9231 - 2040 Ballan-Daylesford Road, Leonards Hill**

I refer to the above matter.

Hepburn Shire, as the Responsible Authority, has been actively involved with all parties involved in this matter. Council's Planning Enforcement Officer has spent considerable time investigating and assessing issues which have been raised. These investigations have been conducted over a long period of time.

The most recent area of investigation is based around the programmed noise monitoring. The results of the testing have been forwarded to EPA for their comment. In response, EPA has advised that they are satisfied with the acoustic reporting. I attach a copy of the EPA response for your information.

Hepburn Shire Council is confident that the facility is operating in compliance with the conditions attached to Planning Permit 2006/9231. Council will continue to monitor the operation of the facility to ensure ongoing compliance.

If you require further information regarding this matter, please contact Geoff Newton Senior Planning Compliance Officer on 5321 6426.

Yours sincerely

A handwritten signature in blue ink, appearing to read "Geoff Newton", is written over the typed name.

**GEOFF NEWTON  
SENIOR PLANNING COMPLIANCE OFFICER**

24 August 2012

Geoff Newton  
Planning Compliance Officer  
**Hepburn Shire Council**  
76 Vincent Street  
DAYLESFORD VIC 3460

Our Ref: 25498

Dear Mr Newton,

**HEPBURN WIND - LEONARDS HILL WIND FARM**

Thank you for asking EPA to review the acoustic report undertaken by Marshall Day Acoustics for the Leonards Hill Wind Farm.


EPA has reviewed the report and is satisfied that the report has been prepared in accordance with the New Zealand Standard (NZS6808:1998) as required in the planning permit.

EPA is satisfied that Marshall Day Acoustics has addressed those deficiencies previously identified by EPA's review of the preliminary report.

EPA's role in providing comment on this report is in extending a courtesy to council in the form of technical support to assist Council as the responsible planning authority. The planning framework provides the statutory mechanism to manage compliance with wind turbine noise standards in Victoria.

If you require further information in relation to this matter, please contact me on 1300 372 842.

Yours sincerely



**James Courtman**  
Environment Protection Officer  
North West | Bendigo  
EPA Victoria

**HEPBURN SHIRE COUNCIL**

File No: 103800 P

4/0360/02700/P

Rec'd Date: 28 AUG 2012

Rec'd By: RJH

Action By: G. Newton

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