Cyfoeth Naturiol Cymru
Natural Resources Wales

Low Frequency Sound Assessment – Darwen Drive, Penymynydd

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Rev No 1

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Contents

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1. Summary

1.1. Noise monitoring was performed between 18 and 24 November 2014. A sound level meter was placed in an occupied bedroom of residential property, [Address redacted].

1.2. A second meter was placed at Castle Cement, Padeswood to correlate any evidence of tonal noise captured in the home. The site was operational throughout the monitoring period.

1.3. A total of 5 noise events were recorded by the resident, 4 of which were analysed.

1.4. Two events were subjectively rated as almost intolerable (seven out of eight).

1.5. Breaches of the criteria curve were identified during the logged events but these were associated with the movement of the complainant in their home.

1.6. The analysis of frequencies measured at Castle Cement during the times of the logged events showed that the noise generated from the site was broadband and not tonal when compared to the low frequency assessment procedure outlined in NANR45.

2. Background

2.1. Natural Resources Wales and its predecessor has received complaints of a low frequency noise since 2009. The complainant considers the noise source to be Castle Cement, a large Cement manufacturing plant whose most easterly boundary is approximately [text redacted] to the South West of the property.

2.2. The complaint is of a constant low frequency noise that sounds similar to a “drone” and a “fan”. It occurs throughout the day and night.

2.3. As Castle Cement is regulated by Natural Resources Wales (NRW) under an environmental permit, NRW have a duty to investigate the complaint. NRW only has powers to regulate noise that comes from sites that need an environmental permit and if the noise source is found to be outside of a permitted area NRW is powerless to intervene regardless of the severity of any noise pollution.

2.4. In 2009 Environment Agency Wales completed a noise investigation which focussed on the operations at Castle Cement and the complainant of Darwen Drive. The investigation found “insufficient evidence of a causal link between the complaints and the activities at the works”.

2.5. An additional monitoring regime was carried out between May and July 2014 which consisted of 10 external night time noise monitoring episodes. Although the investigator found evidence of a tonal noise at 100Hz 1/3rd octave frequency band, this was attributed to [text redacted] electricity substation situated on Darwen drive [text redacted].

2.6. The findings of both the reports discussed above have been shared with the complainant.

3. Methodology

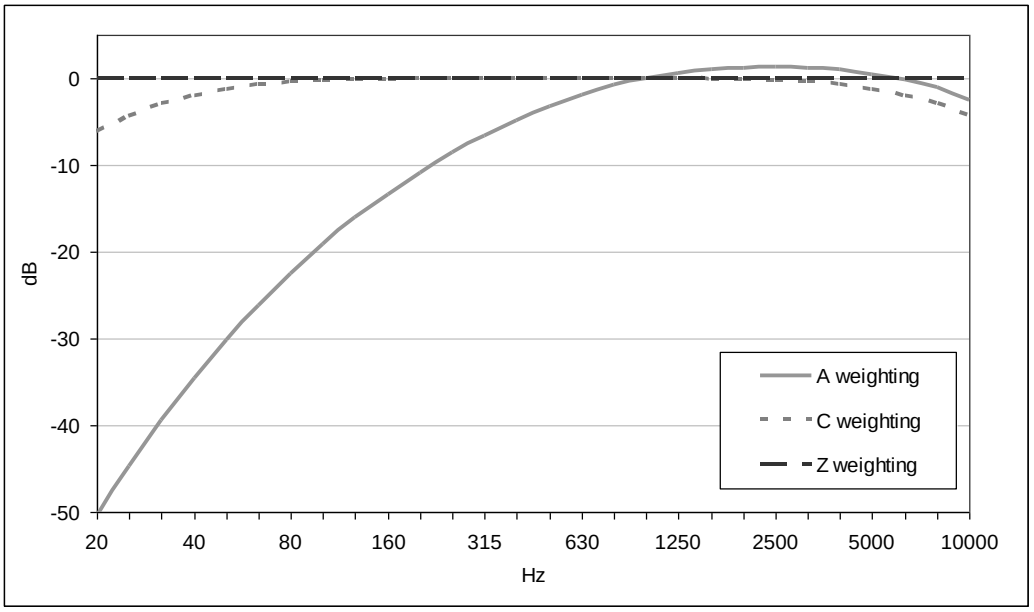
3.1. Noise monitoring was performed at a location between 18 and 24 November 2014.

3.2. The methodology that this investigation will follow is NANR45 'Proposed criteria for the assessment of low frequency noise disturbance'. This method was produced for DEFRA by the University of Salford in February 2005. It presents not only criteria for assessing the levels of low frequency noise, but also a methodology and a proforma for interviewing the complainant. This standard is available at:

http://archive.defra.gov.uk/environment/quality/noise/research/lowfrequency/documents/nanr45-procedure.pdf

3.3. In most noise assessments the frequencies assessed follow the same sensitivities as a 'normal' ear. We respond best to mid frequencies (between 200Hz and 2000Hz), less well at high frequencies above 2000Hz, and very poorly to low frequencies below 200Hz. Noise measurements can replicate this sensitivity by weighting the different frequencies differently, known as 'A' weighting (so many noise units include the letter 'A' to shows that this weighting has been applied – e.g. dB(A) or LAeq). This 'A' weighting is shown in Figure 1.

Figure 1: Frequency weightings



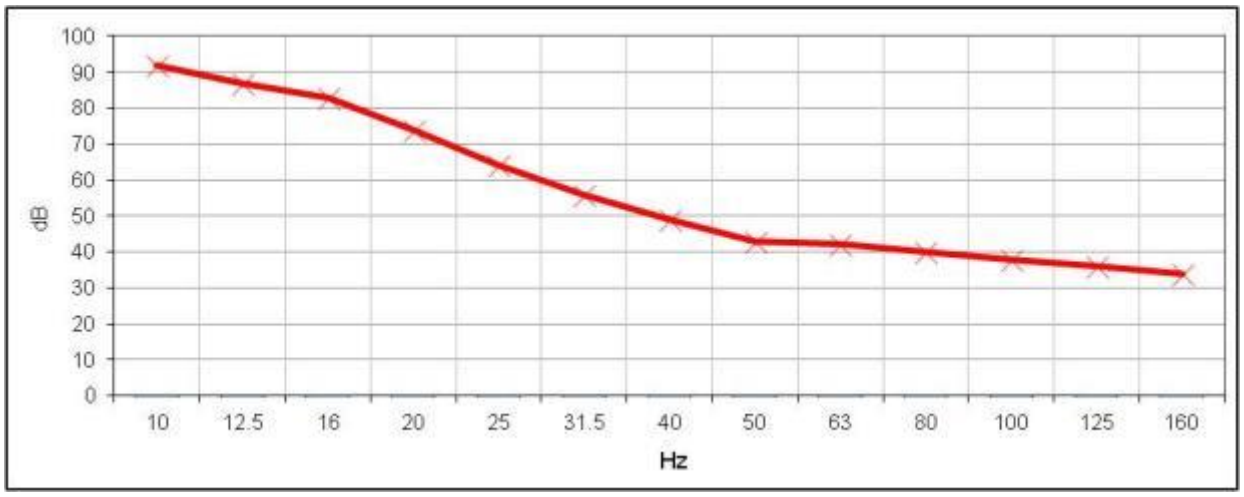
3.4. As the low frequencies are given less significance, 'A' weighted noise levels are unsuitable for any noise measurements that look to investigate low frequency noise.

3.5. The NANR45 criteria does not use any weighting, and instead looks at individual frequencies, each 1/3 of an octave wide. The criteria are given in Table 1, below, and graphically in Figure 2.

Table 1: NANR45 criteria

Frequency (Hz)	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160
Limit (dB)	92	87	83	74	64	56	49	43	42	40	38	36	34

Figure 2: NANR45 criteria



3.6. The Casella Stanger report entitled 'Low Frequency Noise, Technical Research Support for DEFRA Noise Programme' says:

"6.7 If no noise is heard or no particular low frequency noise can be measured there are several options. If it is believed that the measurements were made when the noise was not considered by the complainant to be at its worst, then a second visit would be advisable. However, consideration should be given to the possibility that the complainant is referring to a previous source that has now been abated.

6.8 If after a second visit the investigator is convinced that there is no noise, either heard or measured, that relates to the complaint, and no other family members or neighbours have heard the noise, then the complainant should be referred to an audiological specialist. This, of course, must be done in a sensitive manner, as a common criticism of low frequency noise investigation is that the problem is blamed immediately on tinnitus or some other related problem. The complainant should be told that the investigator has not been able to hear or measure the noise that they have described and that the sufferer should be examined by an audiological specialist as their hearing system may be part of the problem.

6.9 In fact low frequency tinnitus is reported to be very rare and is very difficult to confirm, however, a hearing test can be valuable in such cases."

3.7. The decision flow chart presented by this same report is presented in Appendix 1.

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4. Interview findings

4.1. [paragraph redacted]

4.2. [paragraph redacted]

4.3. The reported noise has been present since [text redacted] moved into the house around [text redacted] years ago but has been present and at a lower level. It was noted that the sound was reduced during an apparent reduction in demand at the cement site in 2008/09 but has been particularly bad over the last year.

4.4. The noise is thought to be present throughout the day, but most notable at night and there haven't been any occasions when it has stopped entirely. The noise is not present at other locations and when it is particularly intrusive it is reported as 'tonal drone' and similar to 'a fan'.

4.5. The noise does disturb the complainant during the night but it does not disrupt any of [text redacted] activities during the day. [Text redacted] has tried some coping strategies – including sleeping in a different room and using earplugs but finds that they only offer some reduction in sound levels.

4.6. [paragraph redacted]

4.7. The ambient noise within the house is low and [text redacted] advised that the traffic and other extraneous sounds do not bother [text redacted].

4.8. The interview provides evidence of a noise which is disturbing the complainant but could be exacerbated by the [text redacted].

5. Measurement locations

5.1. A sound level meter was located in the corner of the main bedroom of the house at head height when sleeping. This location was confirmed to be a position where it would be less intrusive but equally as loud. The measurement position and room dimensions are shown below.

Figure 3: Monitoring location (not to scale) and photographs of Sound Level Meter

[Photographs & drawing removed]

5.2. The room height was 2.4m and the floor was carpeted.

5.3. Subjectively there was no presence of the low frequency noise at the time of deployment and this was confirmed by the complainant.

5.4. The room width from wall to wall is 2.9m. This would amplify a frequency of 59Hz (63Hz 1/3rd octave). The room length of 3.38m would amplify a frequency of 51Hz (50Hz 1/3rd octave). The room height of 2.4m would amply a frequency of 71Hz (63Hz 1/3rd octave). There would also be likely to have strong modes at twice these frequencies (118Hz, 101Hz and 142Hz).

5.5. A second sound meter and an integrated weather station was placed within the Castle Cement installation boundary at grid reference SJ2911662143 with the intention of correlating sounds with the complainant's log. No sound recordings were made at this location (See figure 4).

Figure 4 – Photograph of SLM and weather station at Castle Cement

Figure 5: Complaint location and suspected noise source

[Aerial photograph removed]

5.6. Between the monitoring point and the suspected source is a mixture of residential areas and pasture fields. To the West of the complaint location is the A550 and to the North is the A5104 and the A55 approximately [text redacted] respectively.

5.7. The distance between complaint location and the eastern boundary of Castle cement is approximately [text redacted].

5.8. [paragraph redacted]

5.9. [paragraph redacted]

5.10. The sound level meter was set to record audio for the entire monitoring period. In addition, the reporter kept a noise diary.

6. Equipment & Meteorology

6.1. Noise measurements were made using 2 x Bruel & Kjaer 2250 sound level meters; one at the complaint location and an additional meter was placed at Castle Cement (NGR SJ2911662143) to correlate any changes in the sound level identified by the complainant. Before and after use, the noise meters ware calibrated and checked to 1kHz at 93.8dB and found to be accurate. The full details of the noise monitoring equipment, including serial numbers and calibration dates, are shown in Appendix 2.

6.2. The playback of recorded events was made possible by the use of two Fostex PM0.4n monitors and a Fostex PMsubN subwoofer.

6.3. An integrated six parameter weather station model MMM-0256-A was sited adjacent to the SLM position within the Castle Cement installation and was used to measure:

- Wind speed
- Wind direction
- Precipitation
- Atmospheric pressure
- Temperature
- Relative humidity

6.4. The wind direction was predominantly Easterly/South Easterly during the monitoring period. This could decrease the sound level experienced at the complaint location and therefore doesn't represent worst case scenario.

6.5. The weather data is presented in Appendix 3. This data is indicative of the wind direction and speed at the microphone position at Castle Cement. During the monitoring period the average wind speed was consistently below 5m/s.

7. Noise Analysis

7.1. The noise diary mentioned 5 noise events. Each of these events will be systematically assessed.

7.2. 1/3rd octave frequency bands from 10Hz to 1000Hz were analysed and graphed. Although NANR45 assessment specified low frequencies up to 160Hz, the analysis of events included the consideration of tones up to 1kHz.

7.3. As previously mentioned, 'A' weighted levels are not ideal for assessing low frequencies so the period of comment will also be assessed for any notable low frequencies and compared to the NANR45 criteria.

7.4. Any notable low frequencies will then be graphed as 1/3 octaves vs. time. This allows any changes in that frequency to be seen (such as a tone appearing or disappearing). Average 1/3rd octaves vs decibel levels during the events will also be graphed. The summary results of the assessment is shown in Table 2 below:

Table 2: Summary of low frequency noise assessments.

Event number	Time	Date	Rating by resident	Dominant Frequency	dB over criteria
1	04:30-06:00hrs	20/11/14	7	NA	NA
2	09:00-12:00hrs	20/11/14	5	NA	NA
3	03:55-06:40hrs	21/11/14	7	NA	NA
4	06:40-09:00hrs	22/11/14	6	Excluded	Excluded
5	22:50-04:20hrs	22/11/14	6	NA	NA

- Event 4 was excluded due to extraneous noise within the house.

Event 1

Table 3: Summary of Event 1

Event number	Time	Date	Rating by resident	Comments	Dominant Frequency	dB over criteria
1	04:30-06:00hrs	20/11/14	7	Tonal drone woke me at 04:30am. It started off intermittently then increased to a consistent drone at 04:45am onwards.	NA	NA

7.5. Figure 7 shows the $LA_{min(1\ second)}$ values during the event times and displays the minimum level consistently below 20dB, until around 06:00hrs where the levels rise as a sound source is introduced. This change in levels refers to the central heating system switching on.

7.6. There are a number of evident peaks in figure 6 at 04:32; 04:34; 04:41; 04:44 and 04:54hrs but by listening to these sections of the recordings, it was evident that these relate to movement of the complainant in their bed.

7.7. The peak in the 63Hz 1/3rd octave band in figure 6 was attributed to a vehicle passing at 05:34hrs and this raised the average Lzeq 63Hz level.

7.8. During the event there are no breaches of the criterion curve and it is the sound level in the 160Hz 1/3rd octave frequency which is the highest but is around 8dB below the criteria.

7.9. There is no evidence of a low frequency noise during the playback of the event.

7.10. What we would expect to see is where the complainant identifies that the noise source becomes audible, a change in the L_{min} values similar to what has been shown with the introduction of the central heating system in figure 7. There is no evidence of such a change in the logged event.

Figure 6 – Event 1 average decibel 1/3rd octaves $LZ_{eq(5minute)}$

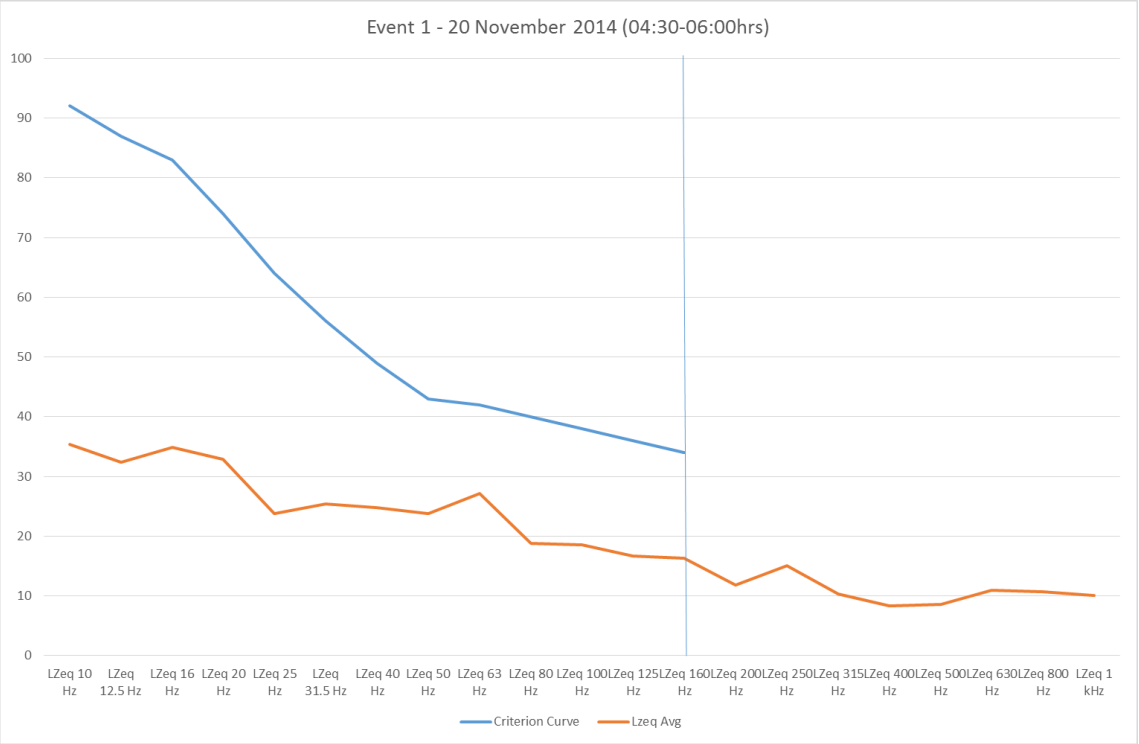
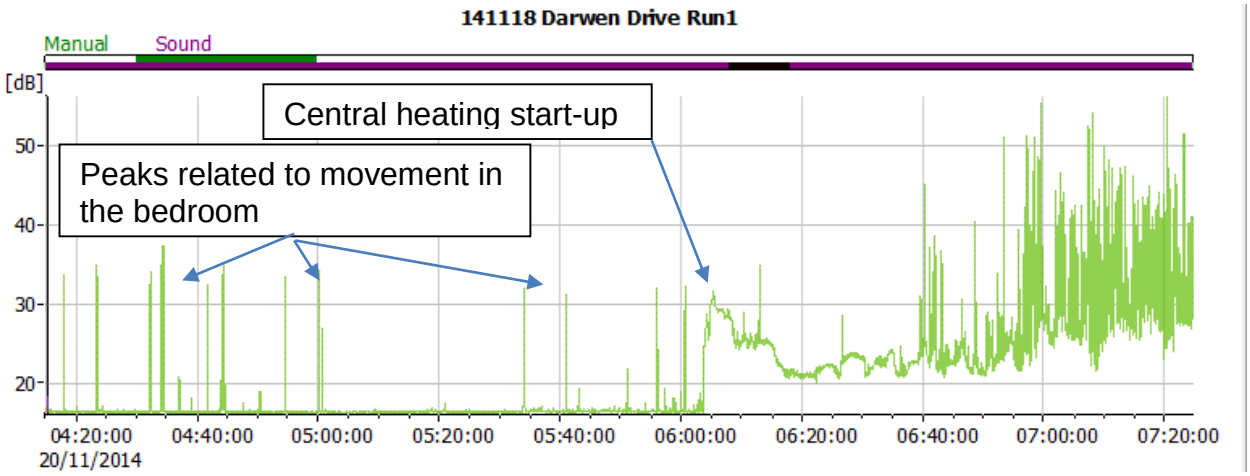


Figure 7 – Event 1 $LA_{min\ (1second)}$ plot over time



Event 2

Table 4: Summary of Event 2

Event number	Time	Date	Rating by resident	Comments	Dominant Frequency	dB over criteria
2	09:00-12:00hrs	20/11/14	5	I can hear the tonal drone in my house despite normal daily noise outside the house and appliance noise inside.	NA	NA

7.11. Recording starts off with the complainant in the bedroom. The event continues with regular movement in the house but with quiet periods in between. In these quiet periods there is no evidence of a low frequency noise that matches the description of the complaint.

7.12. Figure 8 shows the levels of the 1/3rd octave frequencies are close to the criteria curve (40-160Hz) but there are no breaches.

7.13. Figure 8 also shows higher levels of mid frequency sound (250-1000Hz) when compared to event 1. This can be attributed to the movement in the bedroom as the complainant makes the bed and appears to tidy the room, (9:08-09:19hrs), the extractor fan in the bathroom turning on (09:45hrs) the telephone ringing in the bedroom (11:14hrs); etc.

Figure 8– Event 2 average decibel 1/3rd octaves $LZ_{eq(5minute)}$

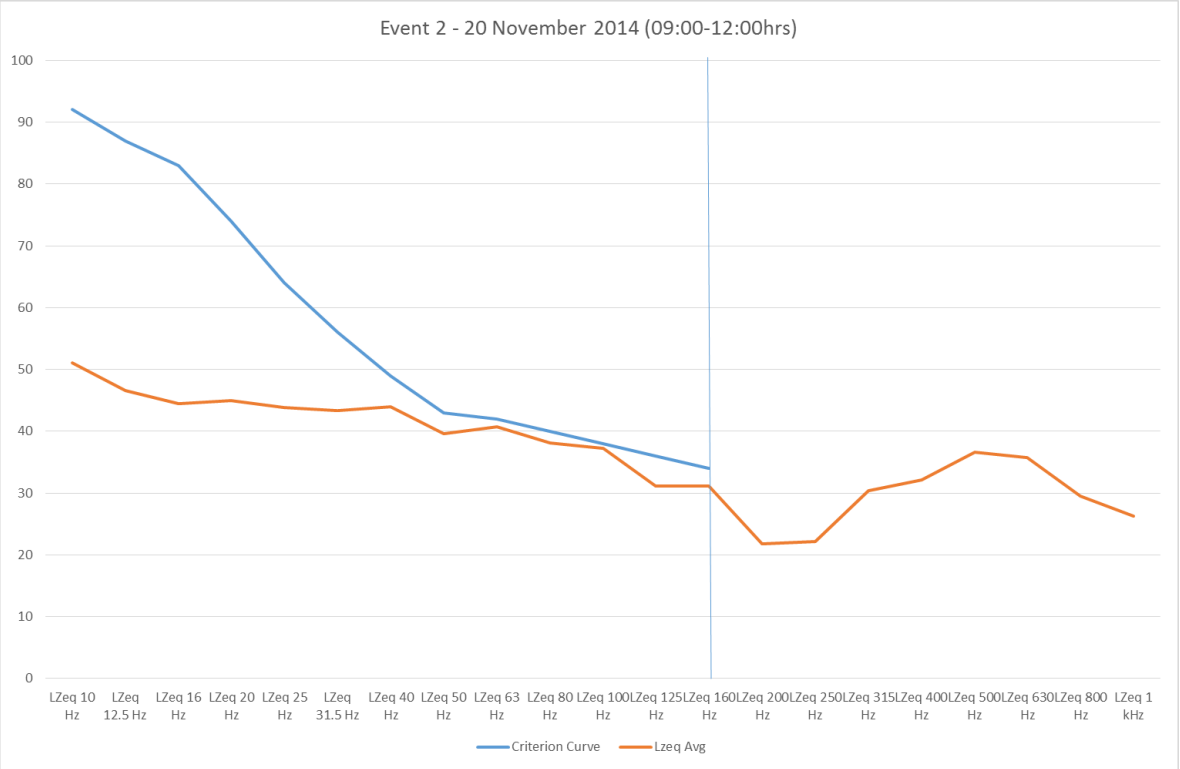


Figure 9 – Event 2 $LA_{min\ (1second)}$ plot over time

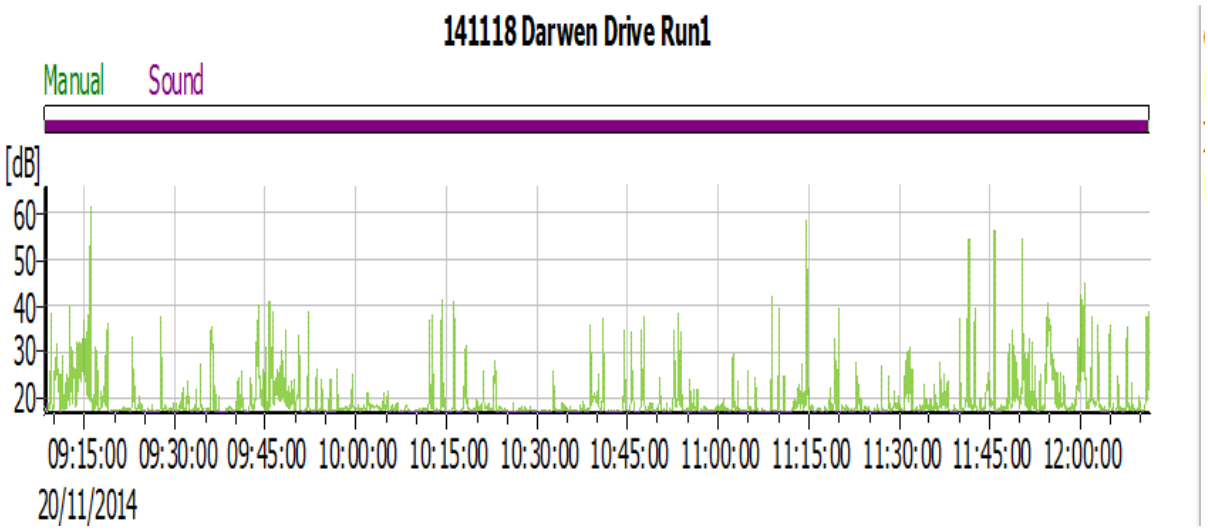
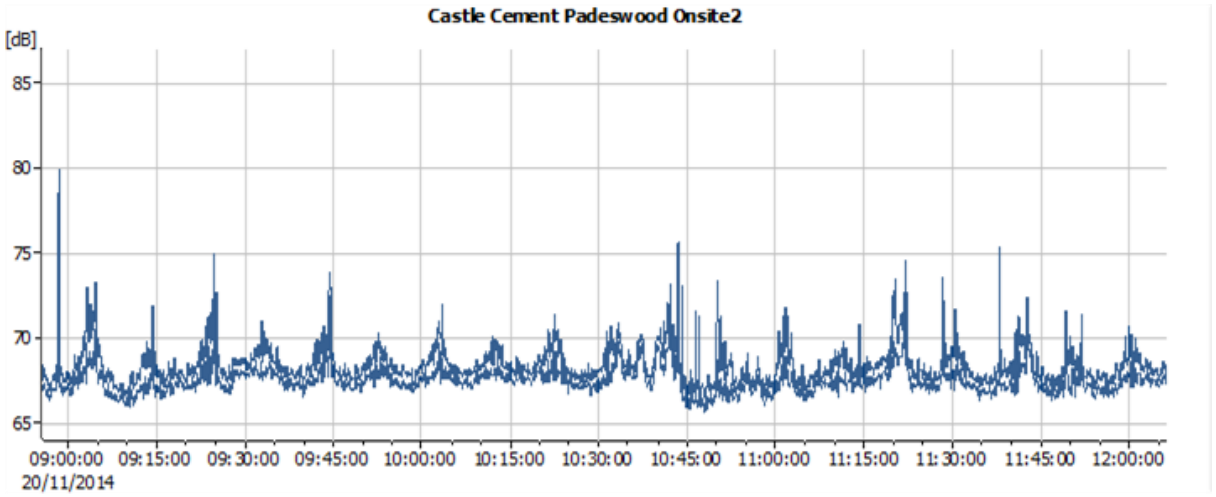


Figure 10 – Event 2 $LA_{eq(1second)}$ plot over time at Castle Cement



7.14. Figure 10 above is the sound level ($LA_{eq(1second)}$) measured at Castle Cement during event 2. What is evident is the cyclic pattern of sound throughout the event with levels rising and falling between the range of 67dB and 75dB.

Event 3

Table 4: Summary of Event 3

Event number	Time	Date	Rating by resident	Comments	Dominant Frequency	dB over criteria
3	03:55-06:40hrs	21/11/14	7	Constant drone started at 03:55am and was ongoing until 6am	NA	NA

7.15. Figure 12 shows the LA_{min} values. The spikes in the graph are very transient and relate to movement in the bedroom as the complainant turns in bed.

7.16. The largest peak at around 05:20hrs is from a cough and results in a breach of two 1/3rd octave bands (125 and 160Hz) and pushed the average Lzeq figures close to the criteria curve (Figure 11).

7.17. The increase in minimum sound levels in figure 12 at 06:03hrs is associated with the heating system switching on and a dominant tone is evident at 100Hz. This rise in LA_{min} values is what we would expect to see with the introduction of a noise source but there is no evidence of such a change that correlates to the complainant's description.

7.18. Analysis of the data identifies two breaches of NANR45 criteria during this event at around 05:20hrs (as discussed above).

Figure 11 – Event 3 average decibel 1/3rd octaves $LZ_{eq(5minute)}$

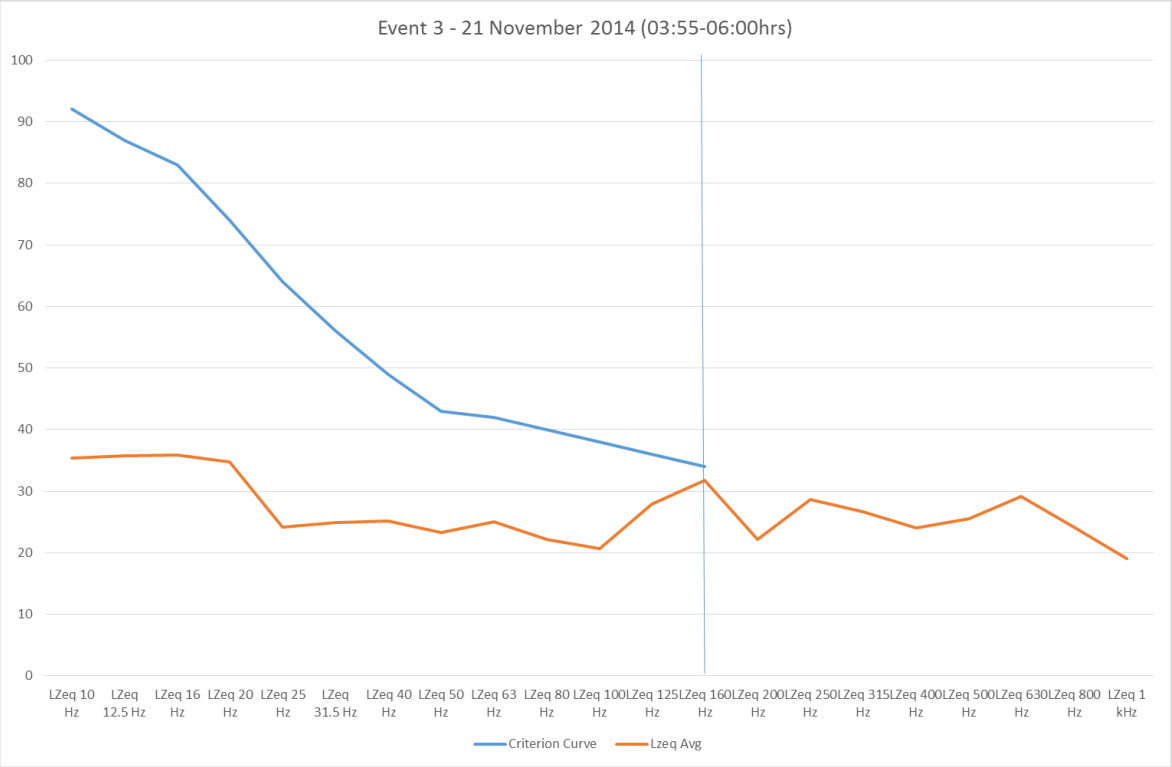
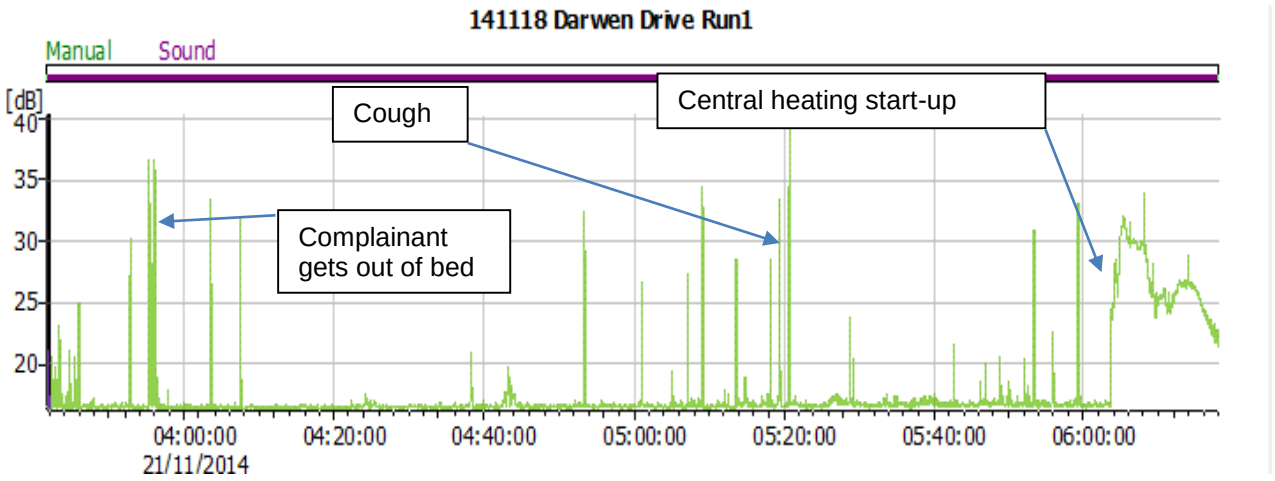
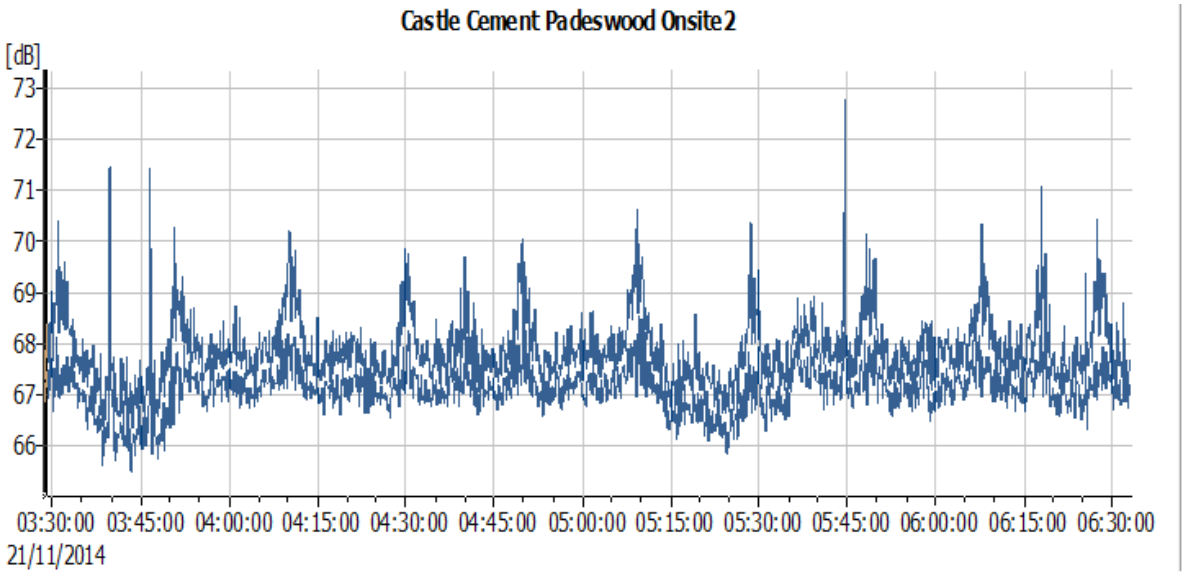


Figure 12 – Event 3 $LA_{min\ (1second)}$ plot over time



7.19. The sound level ($LA_{eq(1\ second)}$ from Castle Cement is graphed below. Once again the cyclic pattern is evident. It is also apparent that the levels (LAeq) are generally in the range of 66dB to 70 dB with three peaks at 03:40; 03:47 and 05:45hrs.

Figure 13 – Event 3 LAeq(1second) plot over time at Castle Cement



Event 4

Table 5: Summary of Event 4

Event number	Time	Date	Rating by resident	Comments	Dominant Frequency	dB over criteria
4	06:40 - 09:00 hrs	22/11/14	6	Continual drone present before it was drowned out [text redacted] and central heating	Excluded	Excluded

7.20. The event starts off very quiet at 06:40hrs as the complainant is asleep. At 06:40:49 a vehicle passes and the complainant stirs. A ticking clock can be heard but it is very faint and no other low frequency noise is apparent. [Text redacted]. Movement in the house continues until 06:51:15hrs when it sounds like the heating is on and turns off over the event.

7.21. This event is excluded as there is too much noise in the house. This is in line with the NANR45 procedure.

Figure 14 – Event 4 (Excluded due to noise within the house during the event)

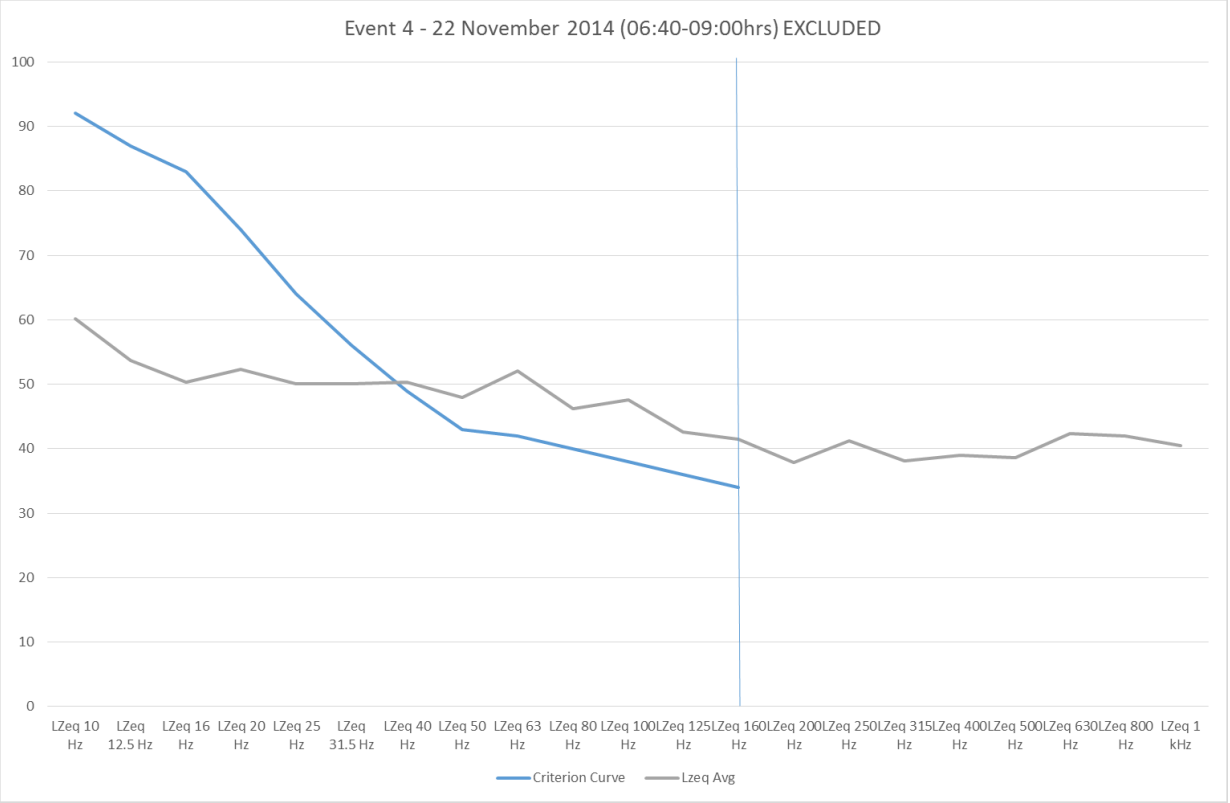
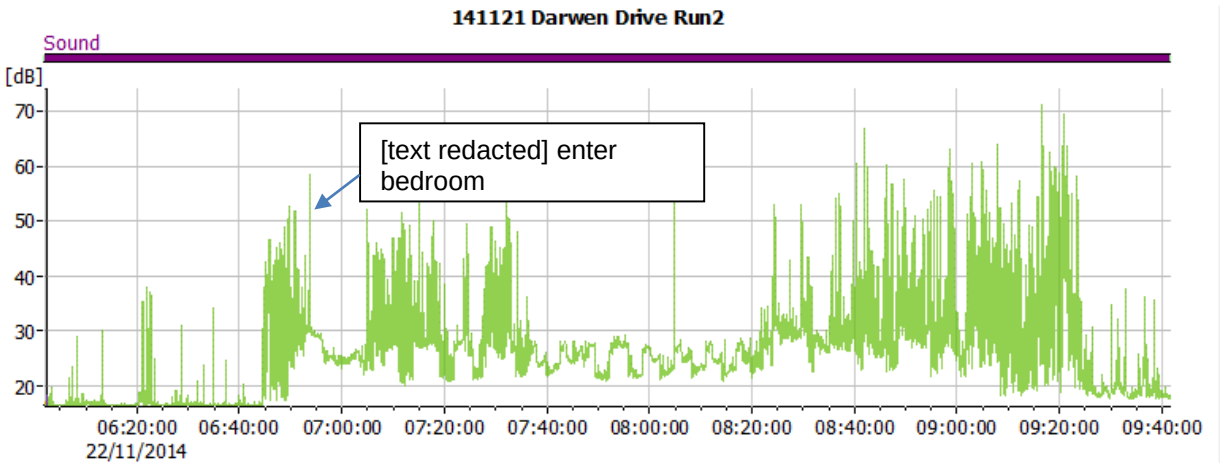


Figure 15 – Event 4 $LA_{min\ (1second)}$ plot over time



Event 5

Table 6: Summary of Event 5

Event number	Time	Date	Rating by resident	Comments	Dominant Frequency	dB over criteria
5	22:50 - 04:20 hrs	22-23/11/14	6	Continuous tonal drone present when I went to bed. Continuous throughout the night until 04:20 when it went to intermittent and stopped.	NA	NA

7.22. This event is the longest measured event and lasts approximately five and a half hours.

7.23. During this event there is one breach of the criteria curve over this period and this occurs in the first 5 minute of the event (22:50hrs) while the complainant prepares for bed.

7.24. Once again the peaks in figure 17 represent movement or noise in the bed room generated by the complainant.

7.25. The rise in sound levels at around 02:00hrs are related to the complainant's raised breathing.

7.26. No tones were evident in this recording.

Figure 16 – Event 5 average decibel 1/3rd octaves $LZ_{eq(5minute)}$

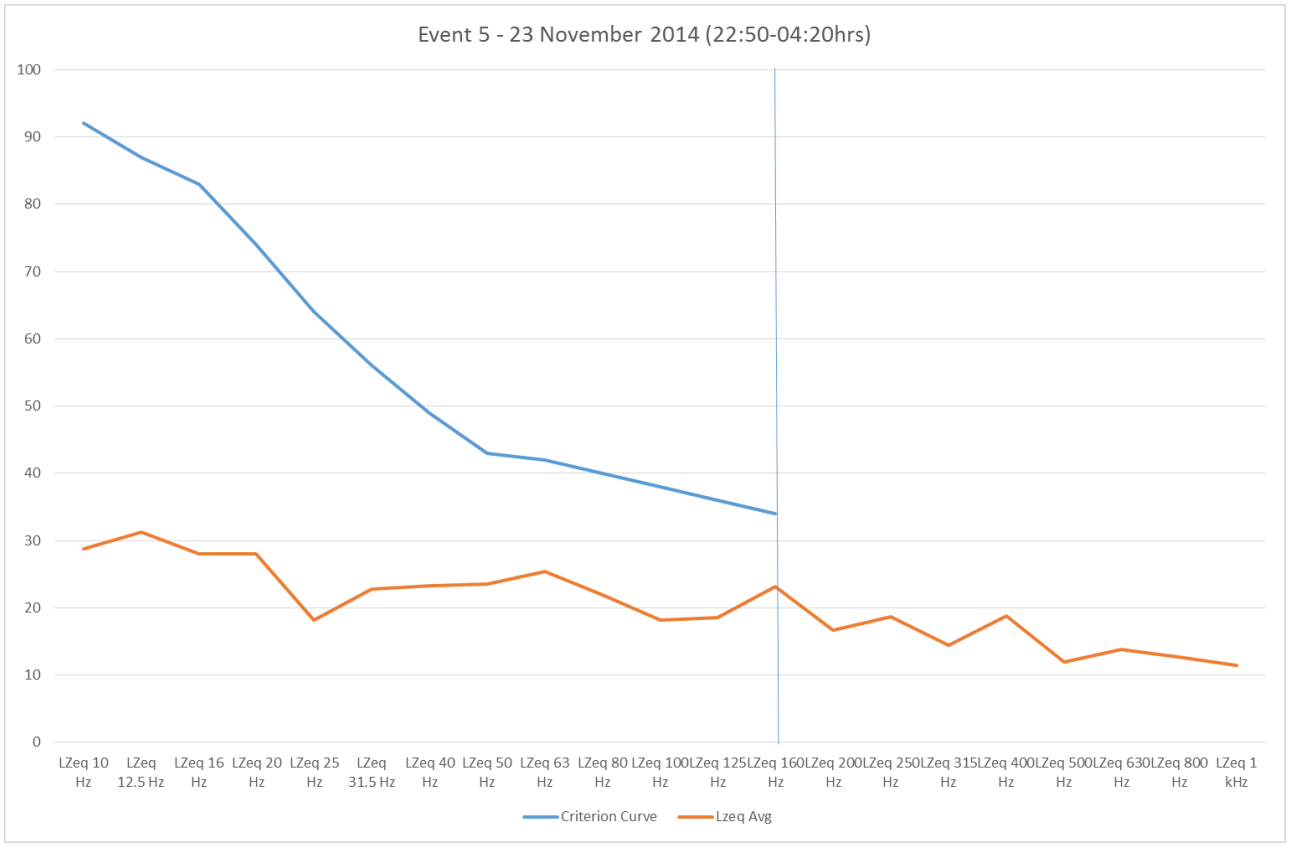


Figure 17 – Event 5 $LA_{min\ (1second)}$ plot over time

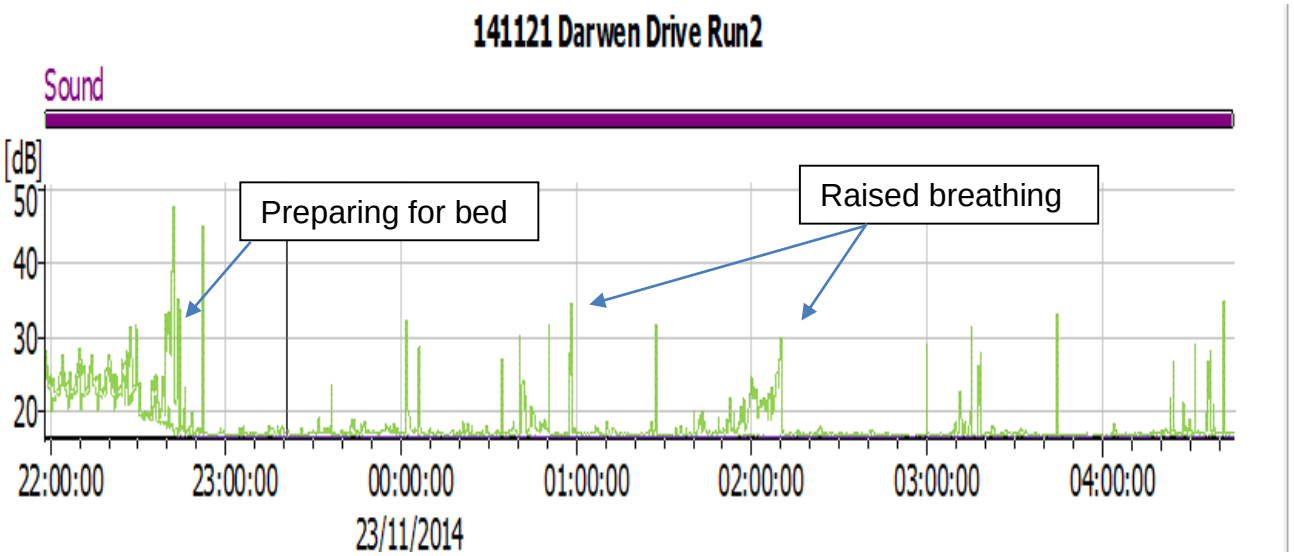
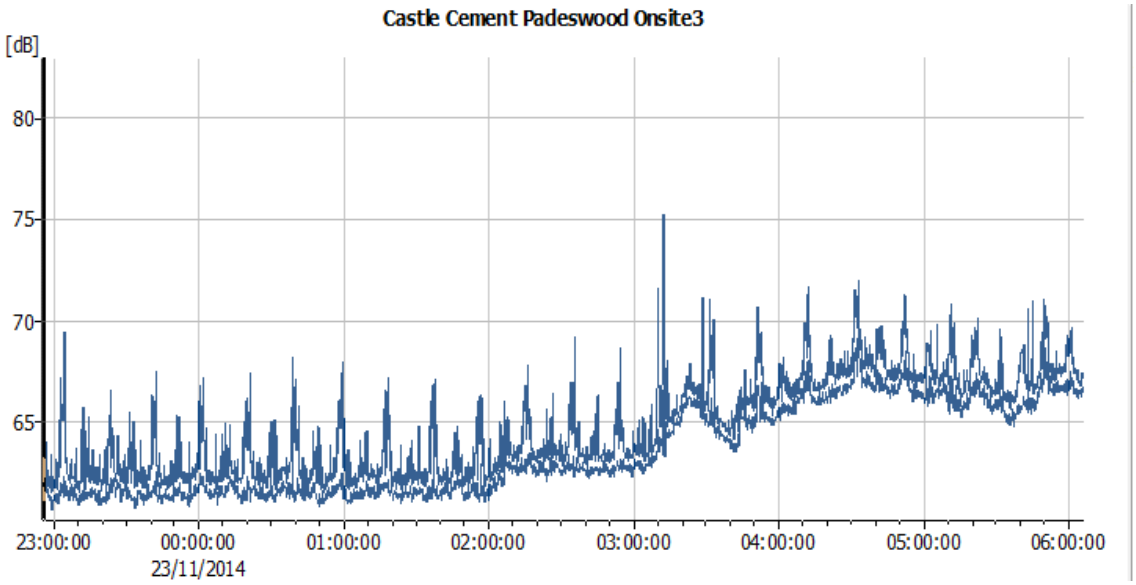


Figure 18 – Event 5 LAeq levels – Castle Cement



7.27. Figure 18 above shows the cyclic pattern of onsite sound as it rises and falls. What is evident is the slight increase of sound level around 02:00hrs which continues to rise until around 04:30hrs where there is a continuation of the cyclic pattern. The higher sound levels continue for the rest of the monitoring period.

Breaches of Lzeq 5 minute 1/3rd octave frequencies during the monitoring period

7.28. The sound level meter placed in the front bedroom of the complainants home recorded continuously throughout the monitoring period and logged sound levels in every frequency between 10 and 1000Hz, every second

7.29. As part of the assessment the 1 second values for each 1/3rd octave bands were averaged over a 5 minute period.

7.30. The resultant 5 minute values were then used to plot against the NANR45 criteria for the associated 1/3rd octaves. The number of breaches in each of the 1/3rd octaves over the monitoring days are provided in the table below:

Table 7 – Number of breaches of criterion curve in 1/3rd octave bands (10-160Hz) during the monitoring period

	LZeq 10 Hz	LZeq 12.5	LZeq 16 Hz	LZeq 20 Hz	LZeq 25 Hz	LZeq 31.5	LZeq 40 Hz	LZeq 50 Hz	LZeq 63 Hz	LZeq 80 Hz	LZeq 100 Hz	LZeq 125 Hz	LZeq 160 Hz
18/11/2014	0	0	0	0	0	0	3	9	22	19	65	7	11
19/11/2014	0	0	0	0	1	2	9	23	33	28	103	18	24
20/11/2014	0	0	0	0	0	2	11	23	39	29	116	19	27
21/11/2014	0	0	0	0	0	0	12	15	36	24	113	12	21
22/11/2014	0	0	0	0	0	4	13	24	30	26	113	19	28
23/11/2014	0	0	0	0	0	5	18	25	39	32	103	16	22
24/11/2014	0	0	0	0	0	3	7	12	15	14	29	12	14
TOTAL	0	0	0	0	1	16	73	131	214	172	642	103	147

7.31. The most notable number of breaches occur in the 100Hz 1/3rd octave frequency band where 642 breaches occur over the monitoring period.

7.32. What is also apparent is the similarity in the number of breaches each day within the 100Hz frequency.

7.33. By listening to the recordings during the breaches and plotting the change in the 100Hz frequency it was apparent that the sound was generated by the internal central heating system and figure 19 and 20 below show the pattern of the heating system coming on and switching off in the morning and the afternoon.

Figure 19 – 100Hz 1/3rd octave plot over time (19-21/11/14)

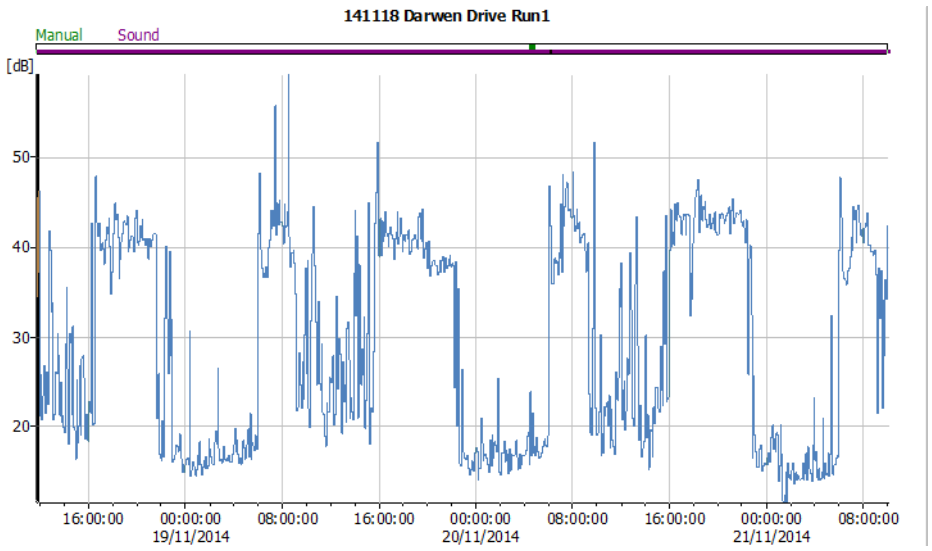
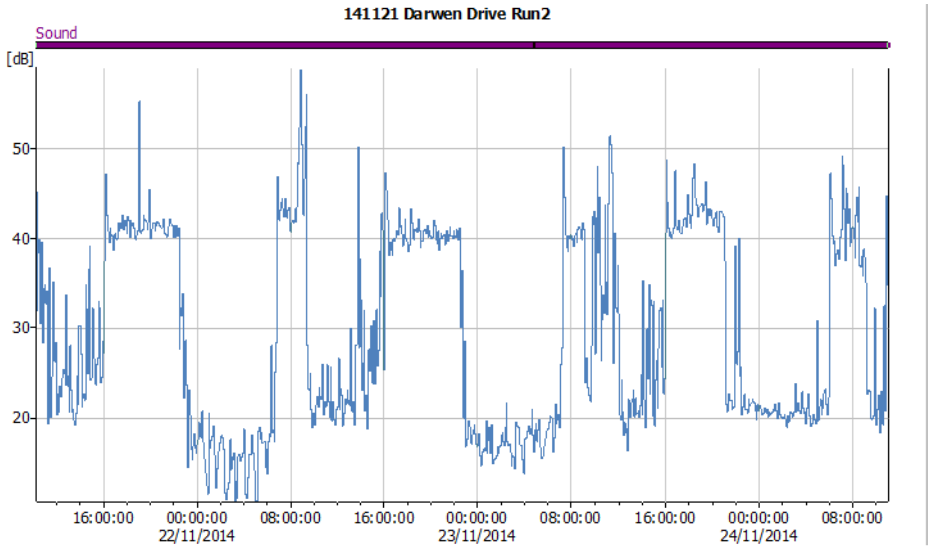


Figure 20 – 100Hz 1/3rd octave plot over time (21-24/11/14)



7.34. All of the remaining breaches across the monitoring period occurred either during movement in the house or transient noises from outside the home e.g. cars passing.

Operational noise at Castle Cement

7.35. The following three graphs are the plot of $LAeq_{(1\ second)}$ values during the monitoring at Castle Cement.

7.36. Castle Cement was operational during the entire period of monitoring at the complaint location and the graphs suggest that this is the case.

7.37. Operational noise was relatively consistent over the monitoring period.

7.38. The complainant identified in their log that “no noise other than fridge and fish tank, very quiet” and “no noise audible” but the operational sound level would suggest that the process hadn’t changed.

Figure 20 – $LA_{eq(1second)}$ plot 18-19 November 2014 at Castle Cement

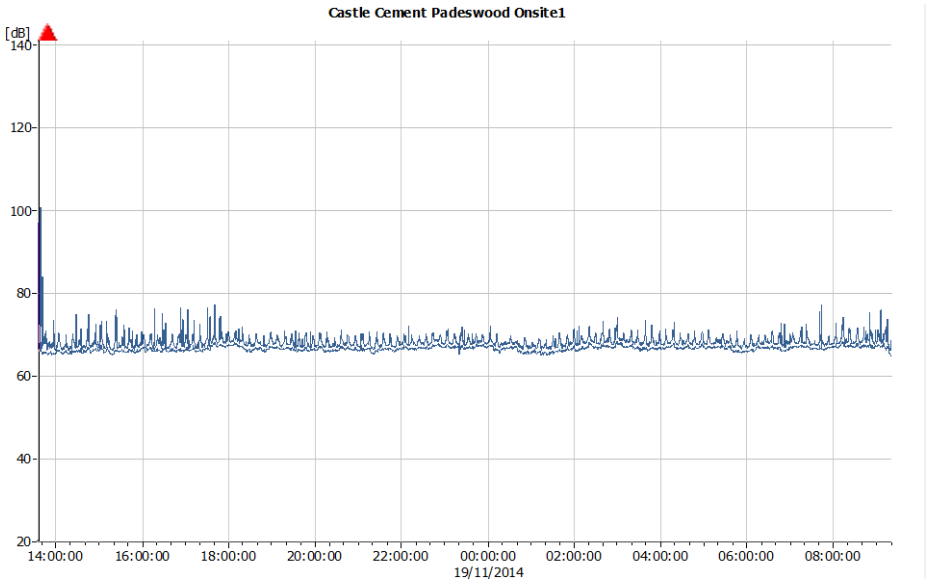


Figure 21 - $LA_{eq(1second)}$ plot 19-21 November 2014 at Castle Cement

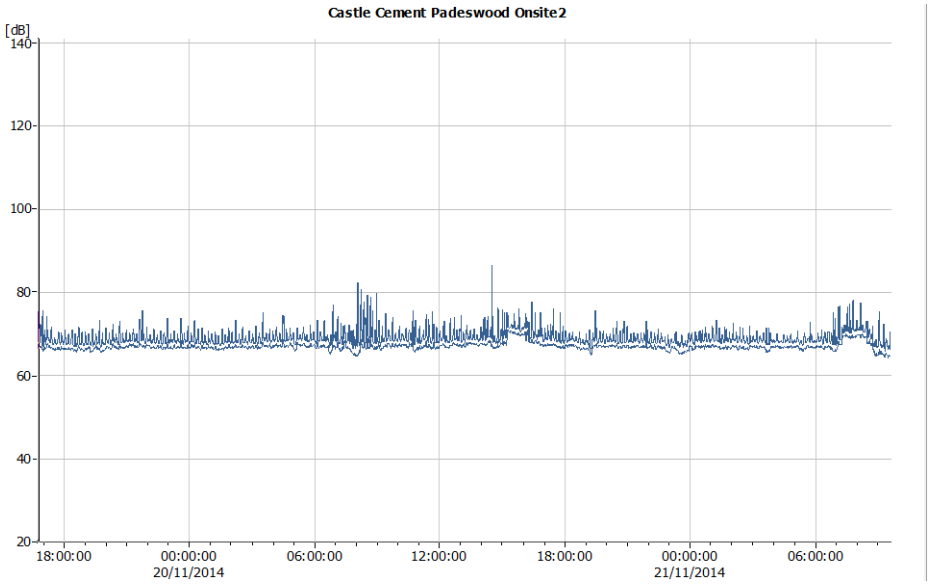
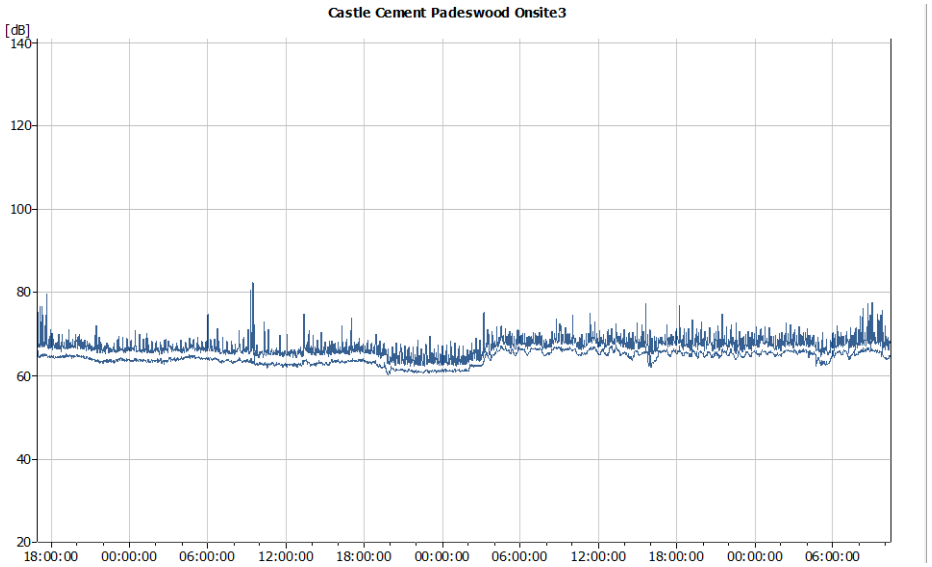


Figure 22 - $LA_{eq(1second)}$ plot 21-24 November 2014



8. Interpretation

8.1. Of the 5 logged events, it was not possible to find evidence of a low frequency tone within the home of the complainant that related to their description of the noise and the associated rating level.

8.2. Short term breaches of the curve occurred during logged events and related to internal noise within the home i.e. central heating system and [text redacted] movements.

8.3. The complainant's rating of two of the noise events was almost intolerable but the 'drone' was not identified in the playback of the event nor was it evident in the analysis.

8.4. Analysis of the monitoring data at Castle Cement during the logged events did not show any tones, instead the sound was considered to be broadband and the level was very stable through the monitoring period.

8.5. There did not appear to be any correlation between the complainant's descriptions of the noise being present and absent with operations at Castle Cement.

8.6. The Casella report suggests that where noise is not audible to the investigator nor is it measurable but is still audible by the complainant then re-measure. It is the investigator's suggestion that this option would be considered if the tolerance level had been lower i.e. around 2-3 out of 8. Instead the noise was thought to be present

and was at an almost intolerable level therefore to re-measure would be not be sensible.

8.7. The Casella report also suggests that in the same scenario as described above, the complainant could be subject to [text redacted]. This may not account for the sound being present and absent during the monitoring period.

8.8. Previous reports carried out by Environment Agency Wales and NRW have identified that there is no correlation between the operational noise at Castle Cement and the complaint location and that a 100Hz 1/3rd octave frequency tone is generated from [text redacted] electricity substation and not from Castle Cement. The monitoring undertaken during the internal assessment did not identify the 100Hz tone though to be from the substation. Instead the 100Hz tones was specific to the home's central heating system.

9. Next steps

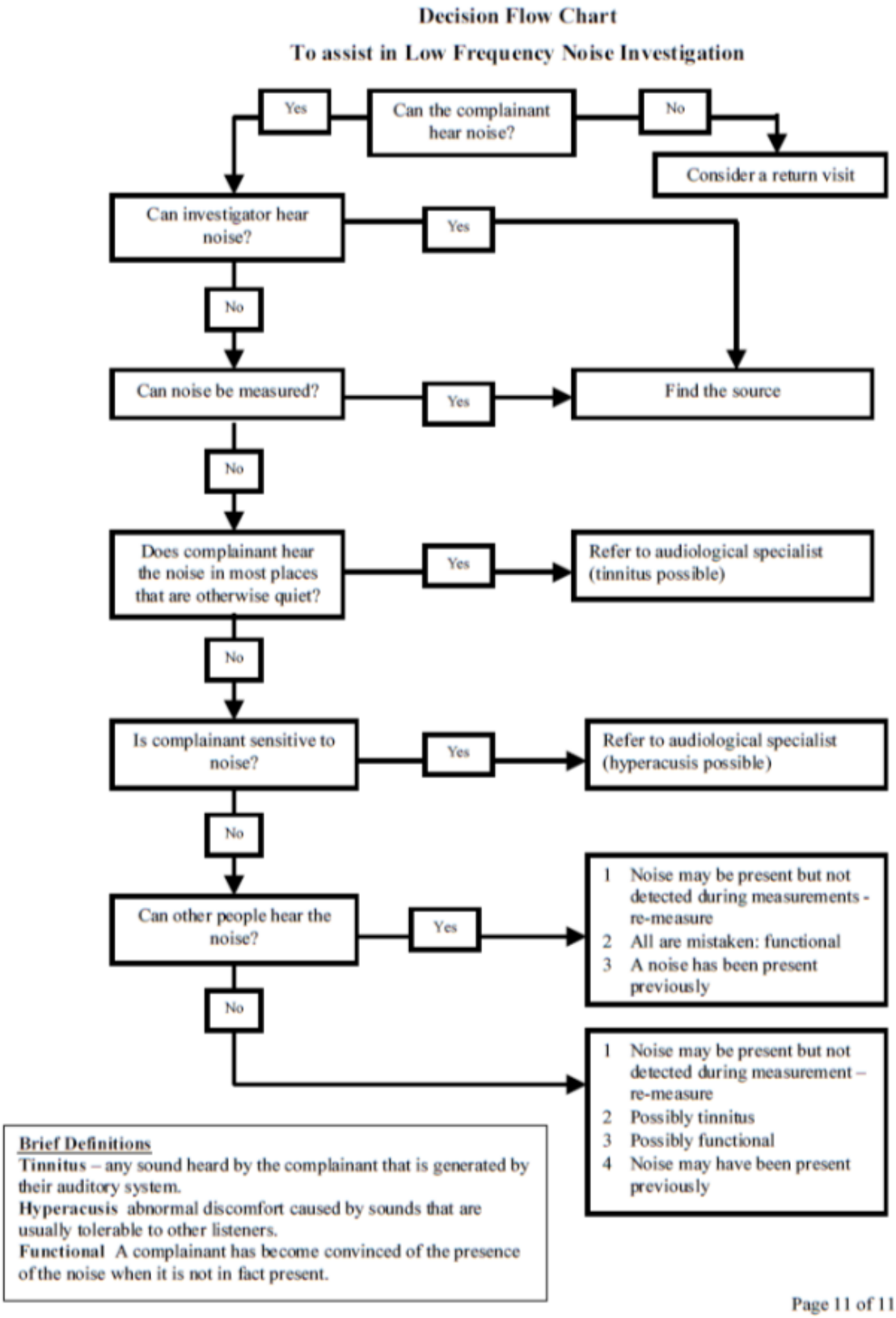
9.1. The monitoring shows that there is not a low frequency noise which can be measured or is audible to the investigator within the bedroom of the complainant that would be considered disturbing in line with NANR45.

9.2. It is recommended that Natural Resources Wales share the findings of the report with the complainant and advise [text redacted] that we will not be taking any further action to investigate the complaint of low frequency noise in [text redacted] home.

9.3. I would also recommend that the findings of the report are shared with Castle Cement subsequent to the discussion with the complainant.

Cyfoeth Naturiol Cymru
Natural Resources Wales

Appendix 1: Decision Flow Chart



Appendix 2: Equipment and calibration details

Meter 1:

Equipment	Serial number	Calibration date	Calibration due
Bruel & Kjaer 2250 sound level meter	2626161	January 2014	January 2016
Bruel & Kjaer 4189 microphone	2621156	January 2014	January 2016
Bruel & Kjaer acoustic calibrator	2615248	January 2014	January 2015

Meter 2:

Equipment	Serial number	Calibration date	Calibration due
Bruel & Kjaer 2250 sound level meter	2661288	April 2014	April 2016
Bruel & Kjaer 4189 microphone	2656052	April 2014	April 2016
Bruel & Kjaer acoustic calibrator	2605867	April 2014	April 2015

Appendix 3: Wind data 18 - 24 November 2014 (Taken from onsite weather station at Castle Cement)