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Department of **Environment Regulation**

REPORT

ALCOA Refinery Wagerup Noise Monitoring Report

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Environmental Noise Reporting Series

This technical bulletin forms part of a reporting series prepared by the Department of Environment Regulation. These Environmental Noise (EN) Reports provide guidance and advice on strategic issues relating to the assessment and management of environmental noise in Western Australia. Copies of EN Reports are available on request by contacting the Department of Environment Regulation on 6467 5000 or emailing info@der.wa.gov.au.

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1 Executive Summary

The Minister's approval of Alcoa's Regulation 17 application under the *Environmental Protection (Noise) Regulations 1997* was gazetted on 29 June 2012. The approval allows the emission of noise from the Wagerup refinery to vary from the prescribed standard. Following appeals, amendments to the approval were gazetted on 10 December 2013, with the approval having effect for a two-year period from this date.

Following the 2012 gazettal, the then Department of Environment and Conservation (DEC), now Department of Environment Regulation (DER) commenced a noise monitoring program in July 2012 to:

1. compare measured levels to those approved under Regulation 17
2. compare measured levels to Alcoa's noise model contours
3. ascertain whether there existed the possibility for noise-affected properties to be outside Area A, being the area identified by Alcoa for noise amelioration measures under its draft Wagerup Noise Amelioration Plan (Alcoa 2012).

The monitoring included short duration handheld noise measurements and extended period noise logging from July until September 2012.

Handheld measurements found there was potential for the noise levels to exceed those approved under Regulation 17 at two of the eight specified monitoring locations. Further study in the form of long term logged noise measurements is recommended to determine whether the short duration exceedences translate to exceedences over the three-hour assessment period referenced in the Regulation 17 approval. In this regard it is noted the amended approval of December 2013 requires Alcoa engage an independent acoustic consultant to undertake compliance monitoring on three occasions each year of the approval during the cooler months between 10pm and 7am with a view to capturing the highest refinery noise emissions received at the eight locations.

The exercise highlighted the difficulty of monitoring at eight locations and raised the question whether the protection of the community and prevention of noise emission increases could be achieved with fewer monitoring locations. It is suggested that this matter be the subject of further consideration by DER and Alcoa when the current approval expires.

Both handheld measurements and logged data indicate Alcoa's noise model is under-predicting the received noise levels. The measurements showed the under-prediction tended to increase with distance from the refinery whereby only slightly higher noise levels (2–3dB) were measured inside the 40dB(A) model contour, while a greater discrepancy (3–6dB) was observed beyond the 40dB(A) contour. The model's 35dB(A) contour has been used by Alcoa as the basis for determining the Area A boundary which lies outside the contour.

Primarily noise-affected properties are considered to be those receiving L_{A10} refinery noise emissions above 35dB(A). Measurements outside Area A found $L_{A10\ (3hr)}$ refinery noise emissions of 37dB(A) within the Hamel town site, north of the refinery. No noise-affected properties outside Area A were identified at other locations. Given the noise-affected properties appear to be limited to the area north of the refinery, as a viable alternative to incorporating those properties into the noise amelioration plan it may be practical to reduce the noise emissions from the refinery process areas that affect the northern noise emissions to the extent that the received levels fall to 35dB(A).

2 Background

In 2002, Alcoa of Australia Limited applied to the then Minister for the Environment under Regulation 17 of the *Environmental Protection (Noise) Regulations 1997* for approval to vary the allowable level of its Wagerup Refinery noise emissions from the prescribed standard. The Environmental Protection Authority (EPA) assessed the application as required under Regulation 17, conducting a detailed peer review of the technical aspects of Alcoa's application and comprehensive community consultation. Officers from the then Department of Environment assisted the EPA in the assessment. A recommended strategy (for Regulation 17) was developed, in conjunction with the revision of Alcoa's licence through the then Wagerup Tripartite Group.

The EPA provided its advice to the Minister for the Environment in Bulletin 1215 in January 2006 (EPA 2006), in conjunction with its advice (under Part IV of the Act) on the proposed Wagerup 3 expansion. In recommending approval under Regulation 17, the EPA's view was that practicable noise reductions, even if small, would be of benefit and should be pursued, particularly in the event that Wagerup 3 was not to proceed. In response, Alcoa requested time to conduct a detailed noise reduction study to consider potential noise reduction measures for all significant noise sources, along with costs and practicalities such as ongoing maintenance of the plant and the noise controls.

This work led to Alcoa's Noise Reduction Study of May 2008 (Alcoa 2008). As a result of a detailed review of the study, the EPA concluded that further significant noise reductions would not be practicable, and that the Regulation 17 strategy should revolve around exposure reduction, rather than emissions reduction.

On this basis, the EPA prepared a strategy paper which proposed a two-year Regulation 17 approval, with the emphasis on Alcoa using 'best endeavours' to purchase the remaining noise-affected properties in the area known as Area A. The EPA consulted on the Strategy in 2009 and finalised a draft approval on this basis. The EPA's supplementary advice was provided to the Minister in August 2010, (EPA 2010) and the Approval was subsequently gazetted on 29 June 2012. The appeals against the granting of the approval were determined and amendments to the approval were gazetted on 10 December 2013.

Following the Regulation 17 approval, DEC commenced a noise monitoring program in July 2012 to verify Alcoa's noise model and ascertain whether there existed the possibility for noise-affected properties to be outside Area A.

3 Measurements

DEC undertook noise monitoring of emissions from the Wagerup Refinery from 5 July 2012 until 28 September 2012. The monitoring took two forms: short duration handheld noise measurements and extended period noise logging. The programs ran concurrently.

The winter monitoring period was chosen as being the most likely to yield meteorological conditions that favour enhanced sound propagation.

3.1 Handheld measurements

The primary objective of the handheld monitoring program was to examine the possibility of refinery noise exceeding the Regulation 17 approved levels. Handheld, short duration (less than 20 minutes) spot measurements were conducted on five nights at the eight locations specified in the Regulation 17 approval.

Additionally, where the opportunity presented itself, spot measurements were undertaken at several other selected locations: three locations inside Area A to further examine Alcoa's noise model and three outside Area A to supplement the logging program and identify locations where longer duration logged measurements might be appropriate.

All handheld measurements were conducted between 11pm and 4am which provided for low background noise levels more conducive to measuring the refinery noise. Measurement days were selected on the basis of favourable weather forecasts (i.e. low wind speeds, no rain and high likelihood of a temperature inversion). Locations for measurement were chosen according to 'real-time' (updated every six minutes) wind direction data from the refinery meteorological station obtained from the Murdoch University–hosted website and field observations at the time, with the objective of capturing refinery noise under enhancing conditions, that is to say the 'worst case' circumstances at each location.

Sound pressure levels were obtained with a Brüel & Kjær Type 2250 sound level meter running BZ7225 enhanced logging software. The equipment was set to record full broadband, one-third octave spectral main and statistical parameters every second, as well as audio recording over the measurement period.

During the handheld measurements, officers were able to get an appreciation for the characteristics of the refinery noise that could later be applied to the analysis of the longer term logged data and audio recorded in the officer's absence.

3.2 Extended noise logging

Noise logging equipment consisted of DER 'yellow bricks', three in total, containing Brüel & Kjær Type 2250 sound level meters again running BZ7225 enhanced logging software. Similarly to the handheld measurements, the equipment was set to record full broadband and one-third octave spectral main and statistical parameters every second, continuously over several weeks, with timer triggers used to recorded audio between the hours of midnight and 4am daily. The equipment was deployed at properties where residents had previously advised they were affected by refinery noise.

Twenty-four hour logged data was collected so that a picture of the overall acoustic environment at each residence could be observed, while audio recording between midnight to 4am allowed for in-depth analysis of the refinery noise when extraneous noise levels were at their lowest.

The emphasis of the extended noise logging program was on properties outside Area A as a key objective of the study was to determine if there existed properties beyond Area A affected by refinery noise.

4 Measurement locations

4.1 Handheld measurements

4.1.1 Regulation 17 monitoring locations

The Regulation 17 approval specifies noise levels which are not to be exceeded at eight locations. Handheld measurements were undertaken at these locations all of which are within Area A and described as follows and shown in Figure 1 below:

Location 1 means any place at or adjacent to the north-eastern corner of Lot 16 on Plan 202652, near the intersection of Willowdale Road and South Western Highway, Wagerup.

Location 2 means any place at or adjacent to the south-eastern corner of Lot 145 on Plan 232779, near the intersection of Bancell Road and South Western Highway, Wagerup.

Location 3 means any place at or adjacent to the western boundary of Lot 1 on Diagram 51826, near South Western Highway, Wagerup.

Location 4 means any place at or adjacent to the south-western corner of Lot 500 on Plan 22014, near the water treatment plant on Boundary Road, Wagerup.

Location 5 means any place at or adjacent to the south-eastern corner of Lot 2606 on Plan 249779, near Boundary Road, Wagerup.

Location 6 means any place at or adjacent to the north-western corner of the intersection of Millar Street and Aitken Street, Wagerup.

Location 7 means any place at or adjacent to the intersection of Chapter Road and Aitken Street, Wagerup.

Location 8 means any place at or adjacent to the south-western corner of Lot 102 on Diagram 85596, near Waterous Road, Wagerup.

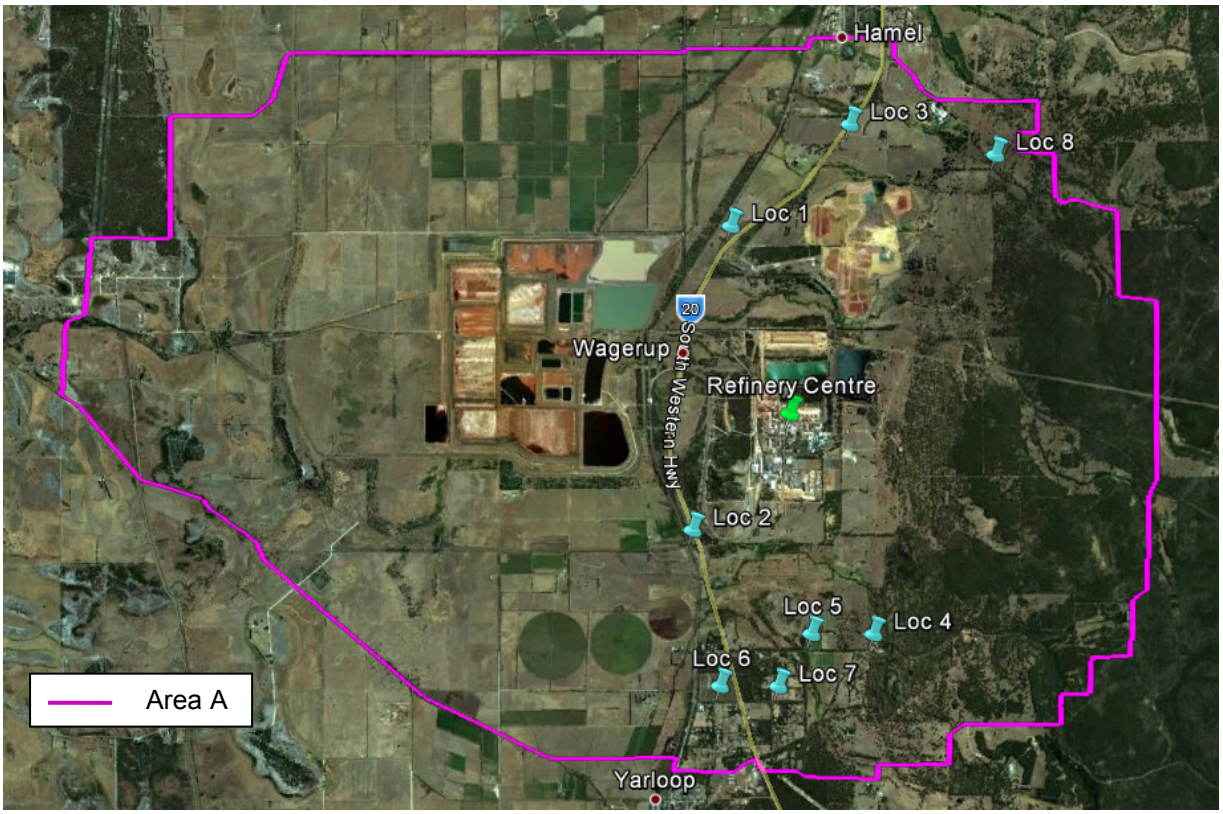

Figure 1: Handheld measurements: Regulation 17 monitoring locations (Google Earth 2013)

4.1.2 Other selected measurement sites

In addition to handheld measurements at the Regulation 17 locations, handheld measurements were undertaken at six selected sites for the purpose of providing further verification of Alcoa's noise model. Sites were determined at the time of measurement according to favourable meteorological conditions for the enhancement of the refinery noise and consisted of three sites inside and three sites outside of Area A. The sites are described below and shown in Figure 2.

Point 1 adjacent to Lot 2 on Plan 56397 on Johnston Road, Yarloop, near water treatment plant.

Point 2 adjacent to Lot 800 on Plan 300778 on Johnston Road, approximately 650 metres east of Brockman Road, Yarloop.

Point 3 adjacent to Lot 43 on Plan 223173 on Kaus Road approximately 40 metres west of South Western Highway Yarloop.

Point 4 adjacent to Lot 205 on Plan 34250 at the intersection of Kubank Road and Somers Road, Wagerup.

Point 5 adjacent to Lot 133 on Plan 222558 at the intersection of Allowrie Street and Cornucopia Street, Hamel.

Point 6 adjacent to Lot 700 on Plan 59305 at the intersection of South Western Highway and Marriot Road, Wagerup.

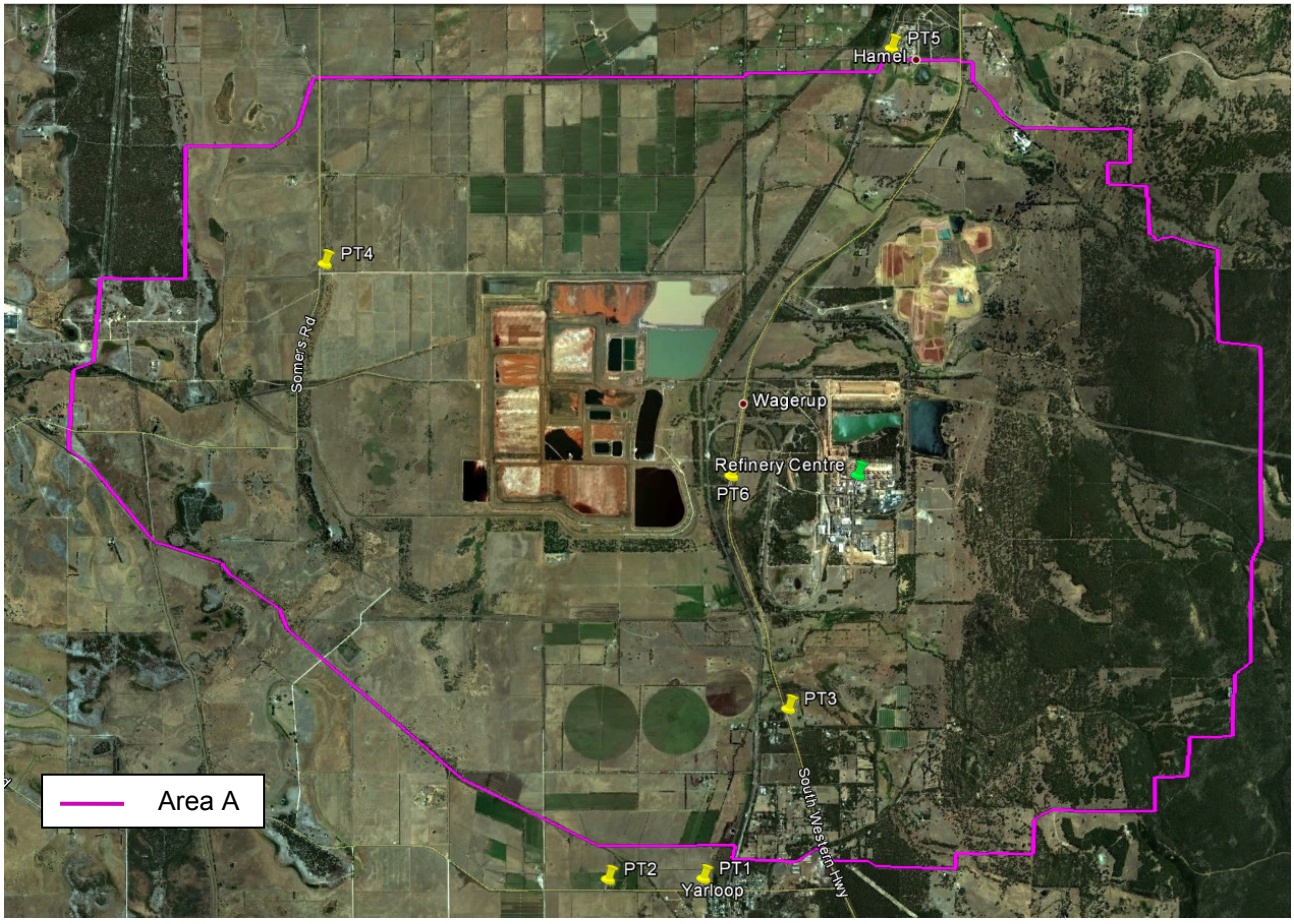

Figure 2: Handheld measurements: other selected measurement sites (Google Earth 2013)

4.2 Extended noise logging

Logging equipment was set up at four residences, three outside Area A and one inside Area A as describe below and shown in Figure 3. These locations where chosen specifically because the residents had advised of being impacted by refinery noise. In the case of the Logger 4 location the need for extended noise logging in the area became apparent after handheld measurements identified high refinery noise levels in the vicinity. The resident at this property subsequently came forward requesting to take part in the noise monitoring program.

Logger 1 Lot 351 on Plan 300453 known as 22 Francklyn Road, Yarloop.

Logger 2 Lot 101 on Plan 105027 known as 338 Brockman Road, Yarloop.

Logger 3 Lot 201 on Plan 301016 known as 247 Clifton Road, Yarloop.

Logger 4 Lot 133 on Plan 222558 known as 2 Allowrie Street, Hamel.

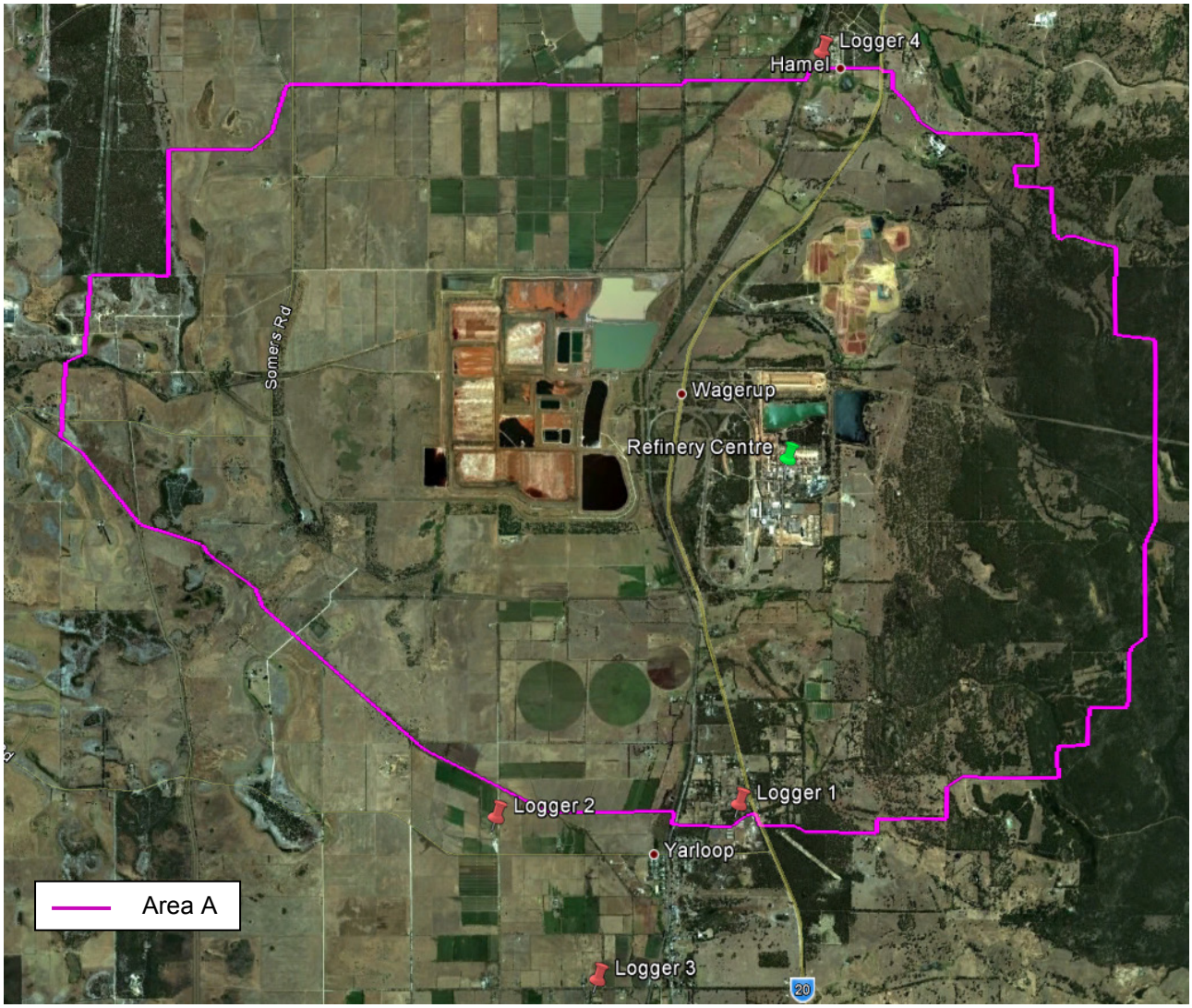

Figure 3: Extended noise logging locations (Google Earth 2013)

5 Methodology

Both handheld measurements and extended noise logging data was downloaded from the sound level meters with Brüel & Kjær BZ5503 utility software and analysed with Brüel & Kjær evaluator type 7820 software.

Detailed analysis was undertaken of each measurement associated with an audio recording, that is to say all handheld measurements and extended noise logging measurements between midnight and 4am. This analysis comprised listening to the audio recording, excluding logs in the time periods dominated by extraneous noise sources and examining the residual logged periods.

Where residual measurement periods were dominated by local high frequency noise from frogs, insects or birds, but otherwise unaffected, the high frequency one-third octave bands were excluded and the remaining bands summed to report the A-weighted refinery noise level (refer to Appendix A3: Detailed methodology for further information). The summed bands typically consisted of the 40Hz to 1000Hz bands. Figure A3 in the Appendix A2 shows a typical noise spectrum which includes refinery emissions and local high frequency noise (frogs/insects). Given affected measurement locations were further than two kilometres, (typically three to six kilometres), from the refinery centre and frequencies above 1000Hz are significantly attenuated by atmospheric absorption with distance, the component of refinery noise present above 1000Hz was likely to be insignificant compared to those in the lower frequencies, so the exclusion of those frequencies would have had a negligible influence on the A-weighted broadband emission level.

Where measurements are compared to Alcoa's noise model DER have attempted to use the most recent information available. Noise model contours have been obtained from reports provided to DER by Alcoa. In the case of the 35dB(A) and 40dB(A) contours these have been taken from Alcoa's report titled "Noise Regulation 17 Application: An Assessment of the Reasonableness and Practicability of Further Noise Reduction Opportunities at Wagerup Refinery" dated May 2008 (Alcoa 2008). DER does not have any recent information in relation to other noise contours, so 30dB(A), 45dB(A) and 50dB(A) contours have been taken from the report titled "Alcoa World Alumina Australia Wagerup Refinery Report Providing Technical Supporting Data for Alcoa's Wagerup Refinery Regulation 17 Application" prepared by Herring Storer Acoustics and dated February 2002 (HSA 2002a).

The noise contours and the Area A boundary shown in figures in this report have been transposed from other reports with care to maintain an appropriate degree of accuracy. They are included for the purpose of indicative assessment only and are not intended to be a precise point for point reproduction.

5.1 Handheld measurements

Handheld measurements were divided between those at Regulation 17 approved locations and those at other selected locations.

5.1.1 Regulation 17 approved monitoring locations

The Regulation 17 approval specifies L_{A1} and an L_{A10} approved levels at each monitoring location, where:

> ***L_{A1} approved level*** means an approved level which, measured as a $L_{A\ Slow}$ value, is not to be exceeded for more than one per cent of any period of three hours; and
>
> ***L_{A10} approved level*** means an approved level which, measured as a $L_{A\ Slow}$ value, is not to be exceeded for more than 10 per cent of any period of three hours.

For the purpose of analysis the L_{A1} and L_{A10} levels of the residual logged periods were calculated and compared to the night time (10pm on any day to 7am Monday to Saturday or to

9am Sunday and public holidays) approved levels. These are the lowest of the approved levels and correspond to those applicable at the time of measurement.

5.1.2 Other selected measurement sites

Inside Area A

Spot measurements inside Area A were undertaken for the purpose of comparison to Alcoa's noise model. To this end short duration L_{A10} measurements were assessed primarily against Alcoa's 35dB(A) and 40dB(A) noise contours, and in some instances to the 30dB(A), 45dB(A) and 50dB(A) contours where relevant to the specific site. Alcoa's model has been calibrated to provide the best agreement with short term L_{A10} measurements in the far field (HSA 2002b) making comparison of the handheld measurements to the model contours particularly relevant. The primary noise contours and the three measurement locations inside Area A are shown in Figure 4 below.

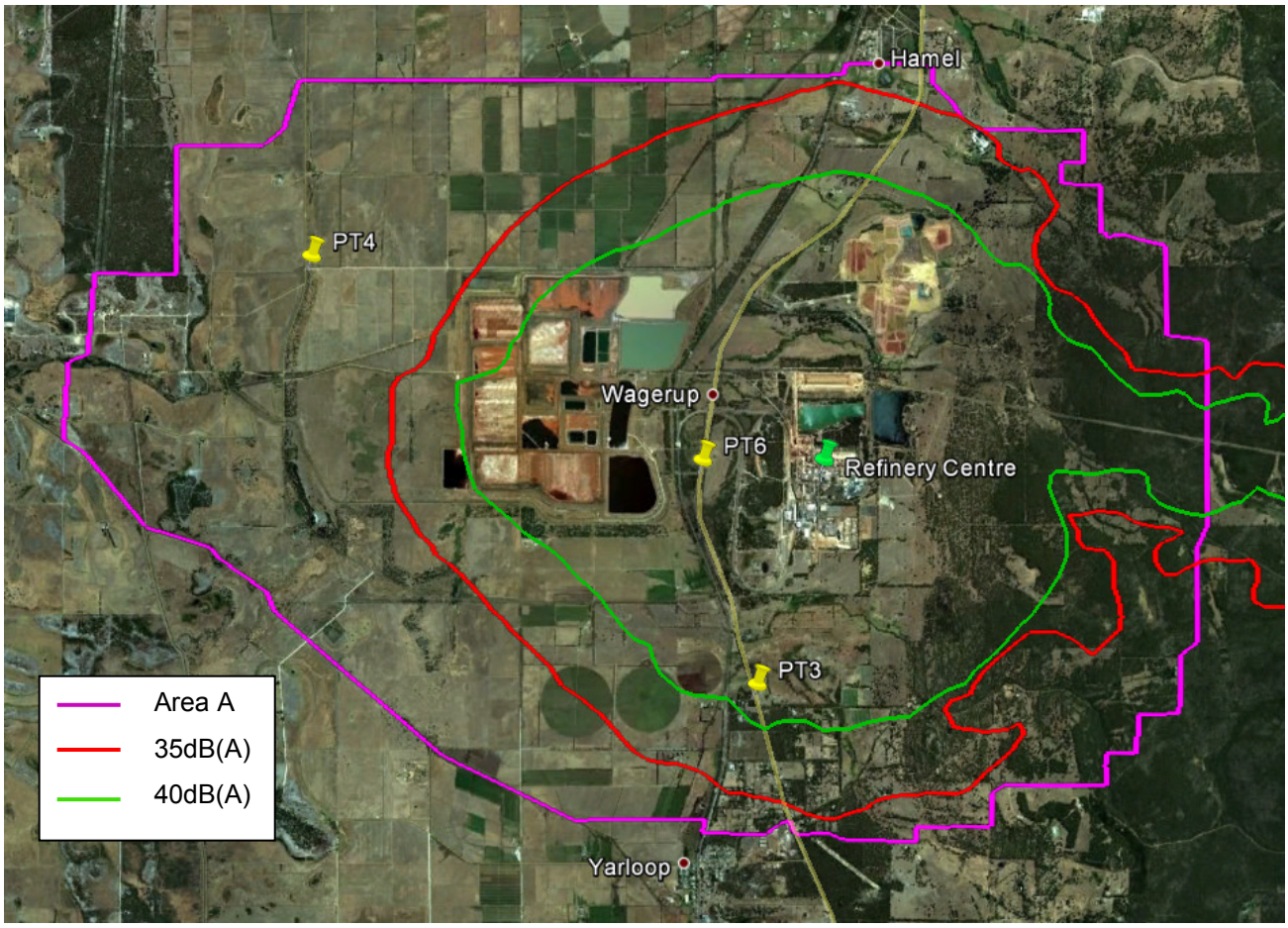

Figure 4: Handheld measurement locations inside Area A and modelled noise contours. (Google Earth 2013)

Outside Area A

The primary purpose of handheld measurements beyond Area A was to explore the possibility of noise-affected properties existing outside Area A thereby identifying locations which might warrant more detailed examination and inclusion in the extended noise logging program. The key criteria in this instance was the regulatory assigned levels, in particular the night time L_{A10} assigned level of 35dB(A). Measurements focused on the most populated regions being to the north and south of the refinery close to the Area A boundary as shown in Figure 5 below.

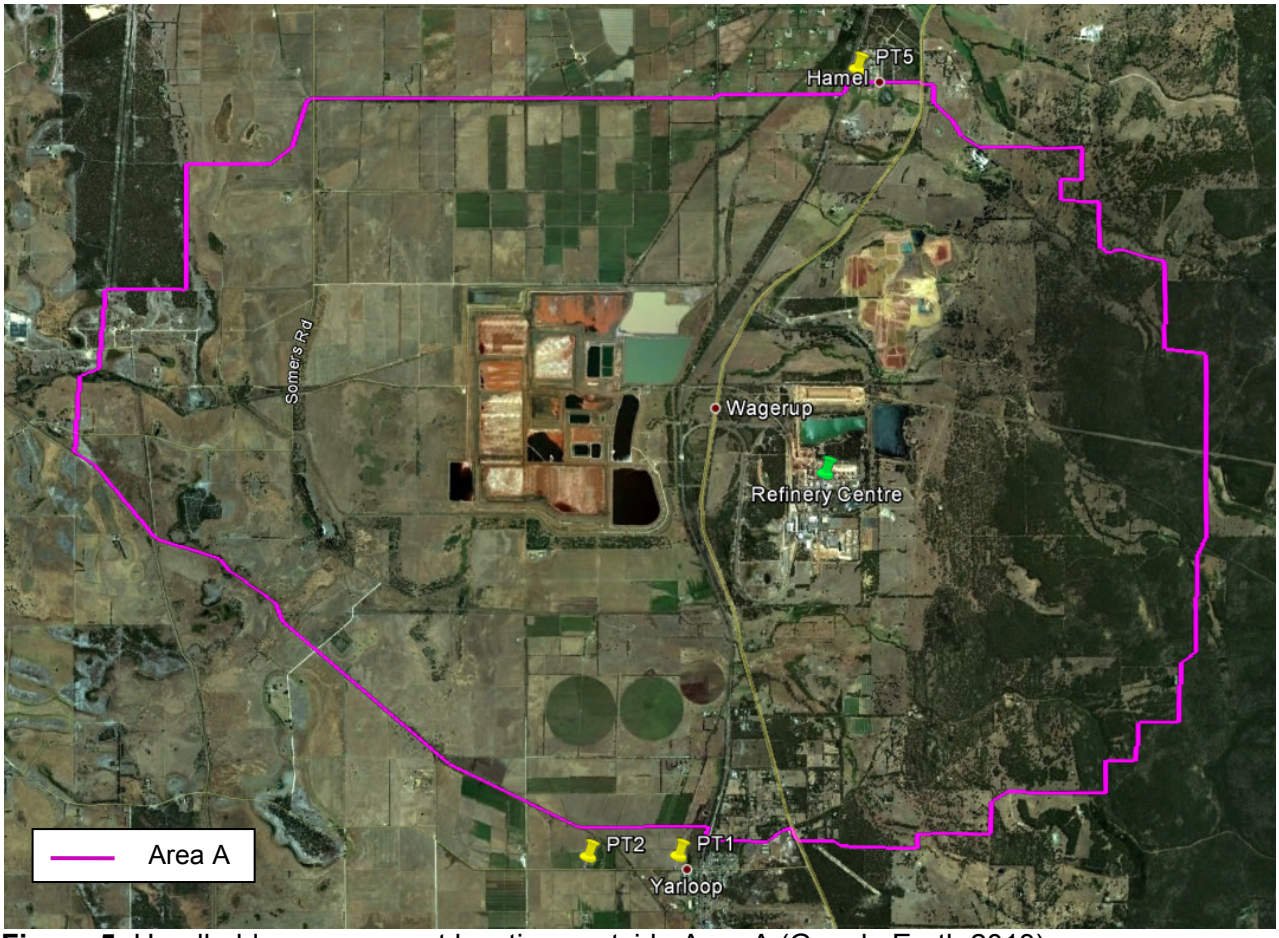

Figure 5: Handheld measurement locations outside Area A (Google Earth 2013)

5.2 Extended noise logging

Analysis of the extended noise logging data focused on the period of audio recording between midnight and 4am. The long measurement period meant L_{A1} and L_{A10} levels could be assessed over a three-hour period and so compared directly to either the assigned levels or the modelled noise contours. The regulations allow for a representative assessment period of between 15 minutes and four hours. The Regulation 17 approval refers to a three-hour assessment period, so the same assessment period has been chosen for this analysis.

5.2.1 Inside Area A

Inside Area A logged measurements were only undertaken at one location, Logger 1. Being within Area A, this location is already identified by Alcoa as noise-affected even though it lies outside the predicted 35dB(A) contour, see Figure 6. Consequently, analysis focused on verifying if L_{A10} measured noise levels were consistent with the modelling and fall between 30 and 35dB(A).

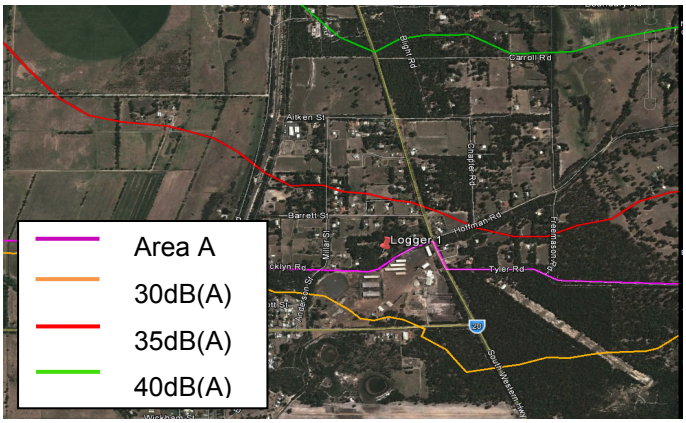

Figure 6: Extended logging inside Area A (Logger 1) (Google Earth 2013)

5.2.2 Outside Area A

The purpose of measurements outside Area A was to determine whether noise-affected properties existed beyond Area A. Noise-affected properties in these locations are considered to be those receiving levels above the assigned levels. The most relevant assigned levels are the night time L_{A1} and L_{A10} levels. The assigned levels for the three logging location outside Area A are not affected by any influencing factors so the night time assigned levels applicable are:

L_{A1} = 45dB (A); and
L_{A10} = 35dB(A).

The analysis compared the measured L_{A1} and L_{A10} levels to the assigned levels in order to determine if the location was noise-affected.

6 Results

6.1 Handheld measurements

6.1.1 Regulation 17 approved monitoring locations

Table 1 below presents the results of the handheld monitoring at the Regulation 17 approved locations. Measurements exceeding the approved levels are highlighted in red. As the residual logged periods are much shorter (approx. 20 seconds to 14 minutes) than the three-hour period referred to in the approval and the L_{A1} and L_{A10} levels presented are only indications of the potential for the levels to be exceeded over the three hours. Where measurements are above the approved levels this cannot be regarded as non-compliance, but what they suggest is that if the measurement period is typical of the refinery noise over a longer period the potential exists for the approved levels to be exceeded.

Table 1: Regulation 17 approved locations: L_{A1} and L_{A10} handheld measurement results

Location:	**Loc 1**		**Loc 2**		**Loc 3**		**Loc 4**		**Loc 5**		**Loc 6**		**Loc 7**		**Loc 8**	
Criteria:	L_{A1}	L_{A10}	L_{A1}	L_{A10}	L_{A1}	L_{A10}	L_{A1}	L_{A10}	L_{A1}	L_{A10}	L_{A1}	L_{A10}	L_{A1}	L_{A10}	L_{A1}	L_{A10}
Approved Level dB	49	47	48	46	47	45	45	41	45	41	45	37	45	37	45	36
Date	Measured levels dB(A)															
05/07/12	33	31	48 47	48 46							41	40				
12/07/12	43 44	41 43			35* 36* 41	34* 36* 40			29*	28*					35*	34*
13/07/12	43	41	45	43	41	40	31*	30*	38	38	22* 32	21* 32			37*	35*
19/07/12	43 46	42 43	43 44	43 43	34*	33*			33*	33*						
20/07/12			43 43 50	43 42 48					37*	37*	33 36 34	33 35 33	37	37		

Notes: Measurements impacted by extraneous noise to an extent that prevented meaningful analysis have been removed.

* Level derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.

The potential for noise levels above the approved levels was demonstrated at two of the approved monitoring locations, Location 2 and Location 6. Exceedences at Location 2 were measured on two separate occasions but were only a marginal 2dB above the approved levels. At Location 6 the exceedence was slightly greater at 3dB over the approved level, observed for one measurement on 5 July. Favourable conditions for high refinery noise levels at Location 6 were present on 20 July, but did not yield any exceedences at the time of measurement. On the same day Location 7, which is a similar direction and distance from the refinery as Location 6, recorded a level equal to its L_{A10} approved level.

Only one result each is presented for Location 4 and 7, this is largely due to the difficulty with obtaining meaningful measurements of refinery noise at these locations. The sites are surrounded by trees in close proximity so the slightest breeze rustles the leaves making accurate measurement difficult.

The levels recorded in the table above were measured over short periods so the L_{A10} and L_{A1} exceedences occurred for proportionally short periods (10 per cent and 1 per cent of the residual measurement period). The length of the residual measurement period and corresponding length of time the levels were above the L_{A10} and L_{A1} approved level are shown in Table 2 below. For comparison, in order to demonstrate non-compliance with the Regulation 17 approval the L_{A10} and L_{A1} levels would need to be exceeded for 18 minutes and 1.8 minutes respectively.

Table 2: Duration of exceedences at Locations 2 and 6

Location	Date	Residual measurement period (min:sec)	Length of time L_{A10} exceeded (min:sec)	Length of time L_{A1} exceeded (min:sec)
Loc 2	05/07/12	7:27	0:45	0:00
Loc 2	20/07/12	13:20	1:20	0:08
Loc 6	05/07/12	5:00	0:30	0:00

Comparing the highest L_{A10} measured levels at each location to the model contours (Figure 7 below) shows that higher than predicted levels were measured at Locations 2, 3 and 6 with the most significant being measured at Location 6 where 40dB(A) was recorded. Lying between the 35dB(A) and 40dB(A) contours this level is about 3dB above what would be expected from the model at this site.

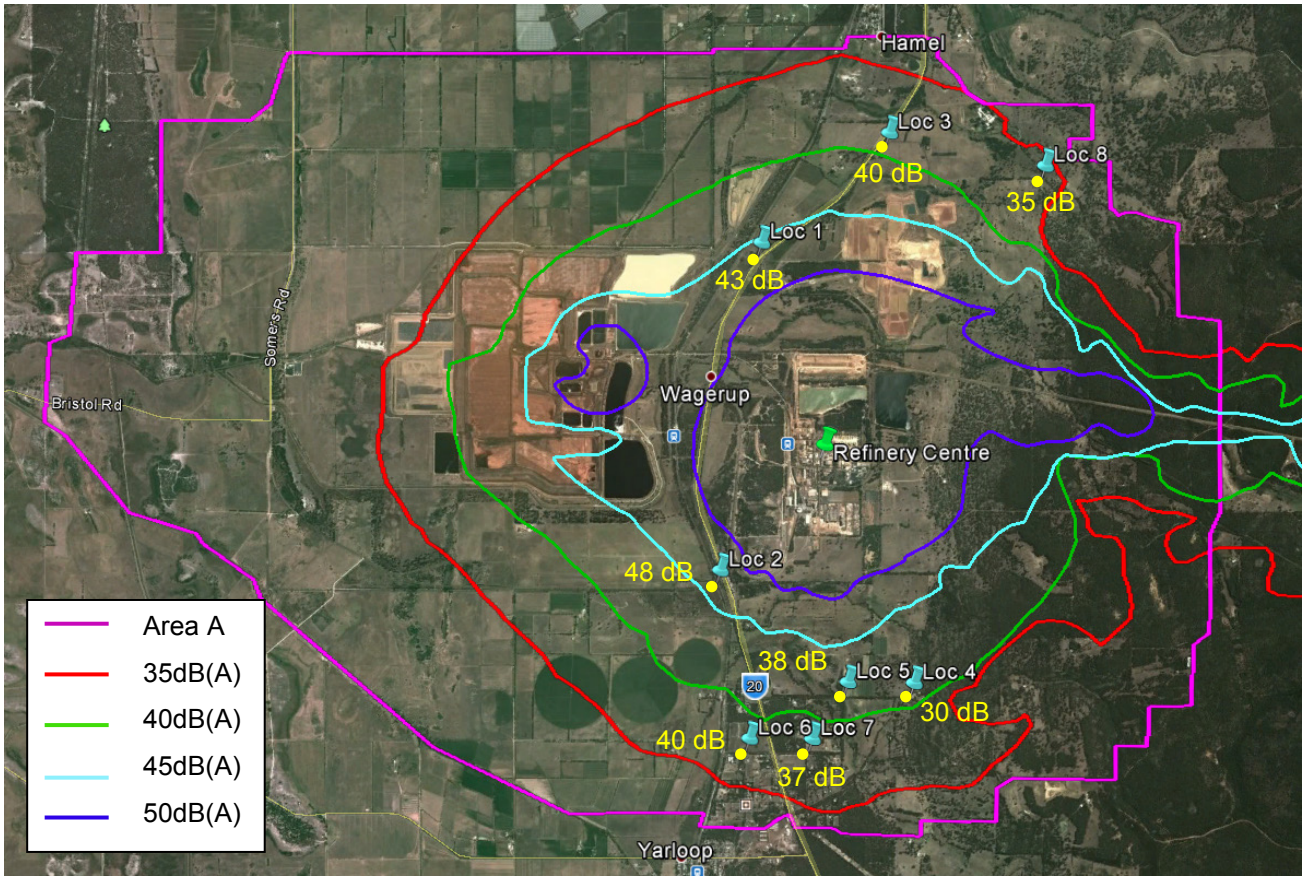

Figure 7: Regulation 17 locations – highest L_{A10} measurements compared to model contours (Google Earth 2013)

6.1.2 Other selected monitoring locations

Inside Area A

With the focus of the handheld measurement program on the Regulation 17 approved locations there was limited opportunity for other monitoring within Area A, and only four measurements at three locations were undertaken. The results of these measurements are presented in Table 3 and Figure 8 below.

The levels measured at Points 3 and 6 did not represent any significant departure from the model predictions. Point 3 recorded an L_{A10} high of 42dB(A) which was consistent with its position between the 40dB(A) and 45dB(A) contours. Similarly at Point 6 an L_{A10} level of 51dB(A) was consistent with its position approximately 1.5 kilometres west of the refinery centre, just inside the 50dB(A) contour.

The result at Point 4 departed from the model prediction. Lying approximately 1.5 kilometres outside the 35dB(A) contour (6.2 kilometres from the refinery centre) an L_{A10} level of 34 dB(A) was measured. To be consistent with the model a level below 30dB(A) would be expected. Consistency with the model at Point 6, but higher than expected measured levels at Point 4, suggests that the model may be tending to under predict with distance from the refinery in the westerly direction. This observation is given weight by SVT Engineering Consultant's (SVT) comments when they reviewed the February 2002 model (SVT 2003) and noted that calibration of the model had been principally based on measured levels at two locations: Boundary Road and Bancell Road, which both lie south of the refinery less than 2.6 kilometres (approximately) from the refinery centre. Further, no details of model calibration to the east and west of the refinery had been presented. Whether this was rectified in more recent incarnations of the noise model is not known, but variations in the 35dB(A) and 40dB(A) contours are noted between 2002 and 2008 indicating some adjustment has been made to the model over this period.

Table 3: Handheld L_{A10} measurements inside Area A

Location:	**Pt 3**	**Pt 4**	**Pt 6**
Model levels (approx.) dB(A):	42	25 - 28	51
Date	Measured levels dB(A)		
05/07/12	42		
12/07/12		34[*1]	
19/07/12			51
20/07/12	31[*]		

Notes: 1. Measurement affected by train noise, level quoted is a conservative estimate based upon spectral data and typical refinery noise spectral profile.

* Level derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.

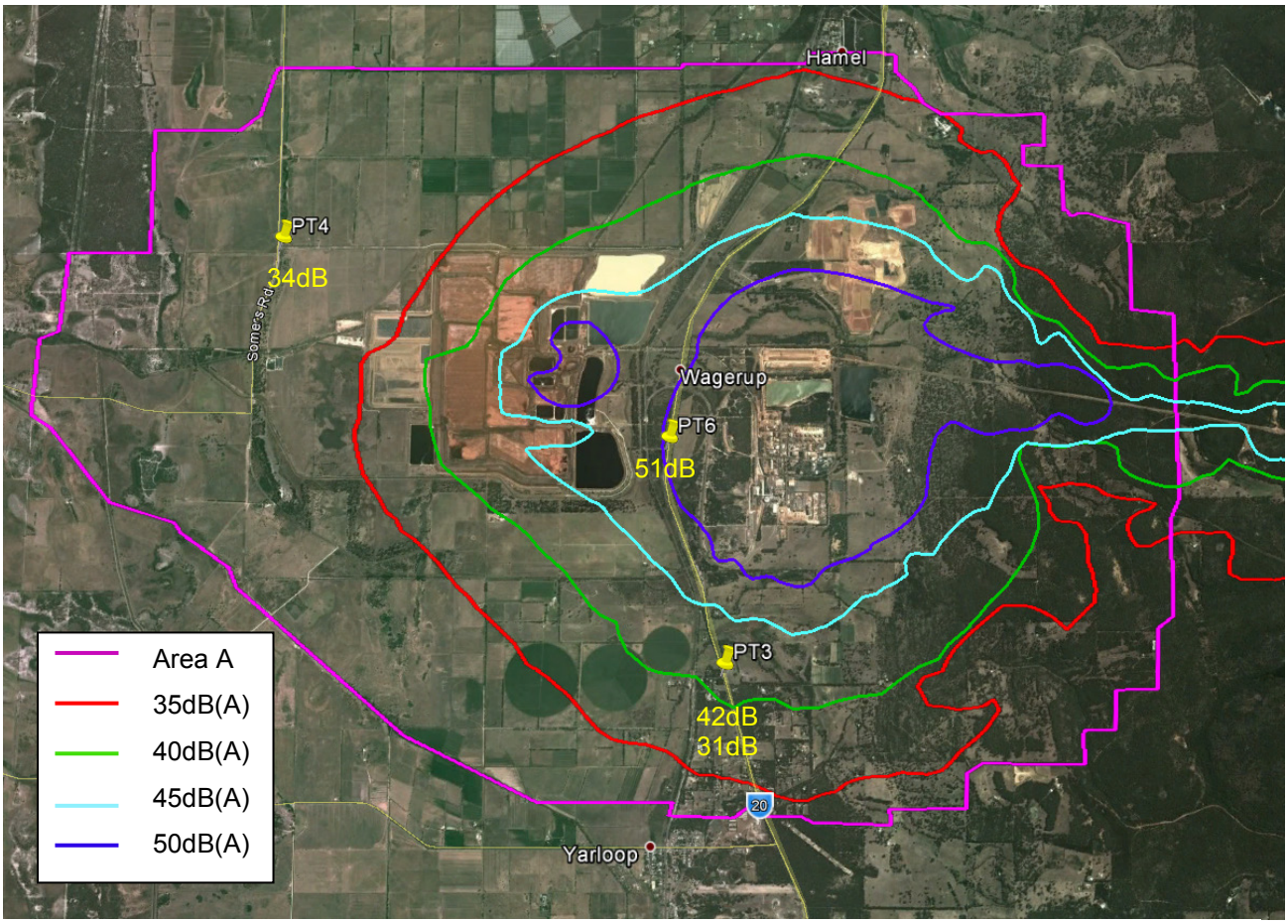

Figure 8: Handheld L_{A10} measurements inside Area A compared to noise contours (Google Earth 2013)

Outside Area A

Similar to the measurements inside Area A, there was only limited opportunity for measurements outside Area A, and only four measurements at three locations were undertaken. The results are presented in Table 4 and Figure 9 below.

One measurement, at Point 5 within the Hamel town site, exceeded the assigned level of 35dB(A) and as such demonstrated the possibility for noise-affected properties to exist outside Area A. Subsequently, extended logging noise monitoring was undertaken at 2 Allowrie Street Hamel (Logger 4) immediately adjacent to the Point 5 handheld measurement site. Results of the extended logging at this location are presented in section 6.2.2 below.

To the south of the refinery neither of the handheld measurements exceeded 35dB(A), nonetheless three loggers in the area were used to explore the existence of noise-affected properties further. Results of extended logging at these three southern locations are also presented in section 6.2 below.

Table 4: Handheld L_{A10} measurements outside Area A

Location:	Pt 1	Pt 2	Pt 5
Assigned level dB(A)	35		
Date:	Measured levels dB(A)		
05/07/12	34*	32*	
13/07/12			38*
19/07/12			28*

Notes: * Level derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.

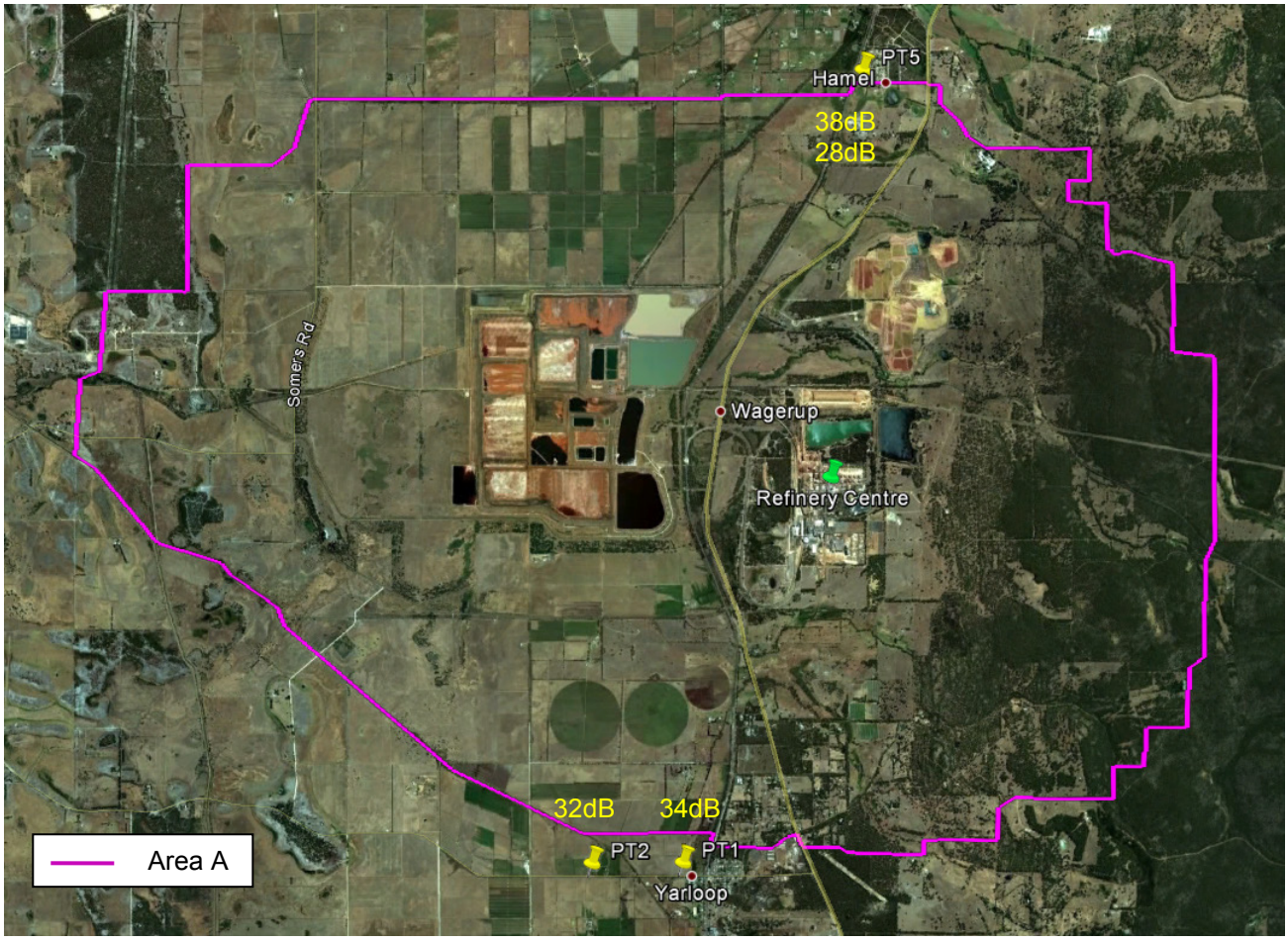

Figure 9: Handheld L_{A10} measurements outside Area A (Google Earth 2013)

The two southern measurements were compared to the model contours. Figure 10 shows the Point 1 and Point 2 measurements south of the 30dB(A) contour. The modelling would be expected to return levels below 30dB(A) in this region, while handheld measurements recorded levels in excess of 30dB(A). Consistency with the model at Point 3 (inside Area A) which is also south of the refinery suggests that, like the result to the west, the model may also be under predicting to an increasing degree with distance from the refinery to the south.

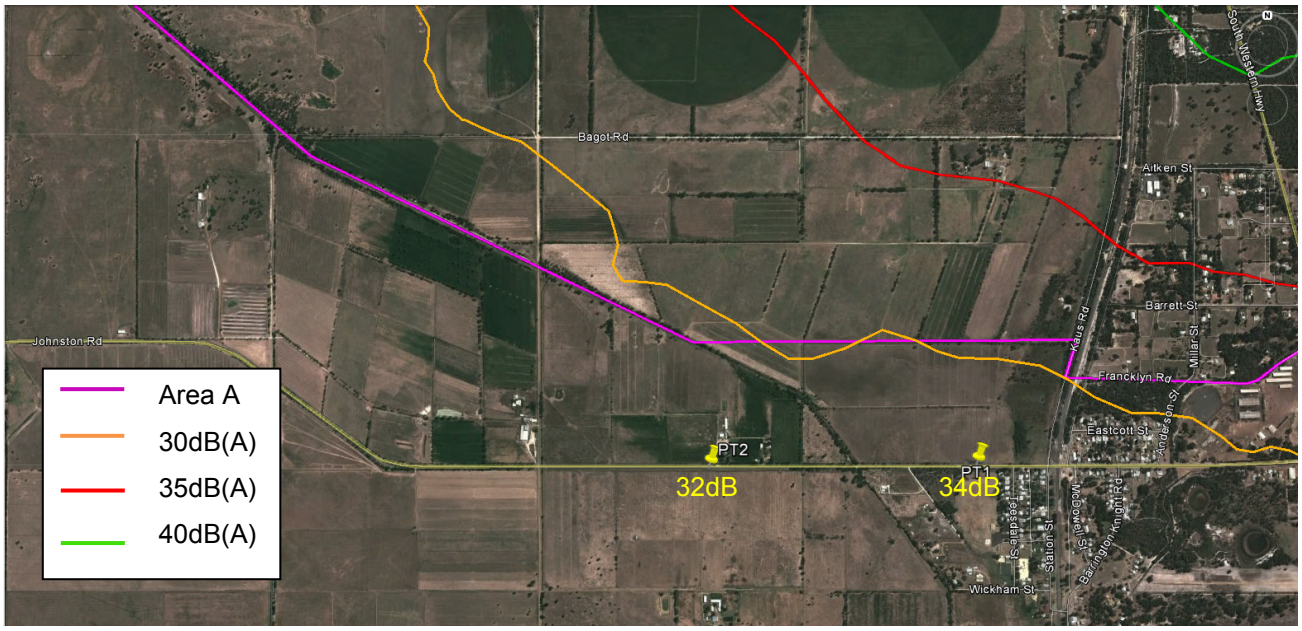

Figure 10: Noise contours and handheld L_{A10} measurements outside Area A – south of refinery (Google Earth 2013)

6.2 Extended noise logging

6.2.1 Inside Area A

Logged measurements inside Area A were conducted at one location (Logger 1), south of the refinery and close to the Area A boundary. Extended noise logging was undertaken from 5 July 2012 until 17 August 2012 and the results are presented in Table 5 below.

Table 5: Extended logging $L_{A10\ (3hr)}$ level at Logger 1 inside Area A

Date	L_{A10} dB	Date	L_{A10} dB	Date	L_{A10} dB
05/07/2012	inaudible	20/07/2012	28	04/08/2012	32
06/07/2012	35	21/07/2012	31*	05/08/2012	inaudible
07/07/2012	28	22/07/2012	32	06/08/2012	34
08/07/2012	inaudible	23/07/2012	24	07/08/2012	inaudible
09/07/2012	30	24/07/2012	inaudible	08/08/2012	31
10/07/2012	masked	25/07/2012	21	09/08/2012	inaudible
11/07/2012	inaudible	26/07/2012	inaudible	10/08/2012	corrupted
12/07/2012	23	27/07/2012	inaudible	11/08/2012	35*
13/07/2012	inaudible	28/07/2012	inaudible	12/08/2012	inaudible
14/07/2012	corrupted	29/07/2012	31	13/08/2012	inaudible
15/07/2012	29	30/07/2012	inaudible	14/08/2012	28
16/07/2012	corrupted	31/07/2012	masked	15/08/2012	inaudible
17/07/2012	inaudible	01/08/2012	corrupted	16/08/2012	inaudible
18/07/2012	corrupted	02/08/2012	32	17/08/2012	34*
19/07/2012	24	03/08/2012	inaudible		

Notes: * Level derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.

'inaudible' indicates the refinery could not be heard in the audio recording even when the playback levels were significantly amplified.

'corrupted' indicates the recorded data was corrupted and unable to be analysed.

'masked' indicates the refinery noise was audible but masked by extraneous sources (e.g. wind, rain, trains, traffic etc) to a significant extent preventing calculation of reliable statistical levels.

The maximum L_{A10} level observed at Logger 1 location was 35dB(A) on 2 occasions, 6 July 2012 and 11 August 2012. Measurements at this location were often impacted by one or more nearby but unidentified industrial noise sources (possibly a cold storage facility) with similar frequency content as the refinery noise. As such the sources were indistinguishable and the noise levels stated are best thought of as an upper limit level of refinery noise. With this in mind even though Logger 1 lies between the 30dB(A) and 35dB(A) contours (see Figure 11 opposite) it is difficult to conclude that an L_{A10} measurement of 35dB(A) is evidence of model under-prediction. However, when considered in the context of the higher than expected hand-held measurements at Point 1 and Point 2, which also lie south of the refinery, the case for under-prediction in the area to the south of the refinery is strengthened.

It is worth noting for 18 of the 44 nights (41 per cent) the monitoring equipment was in place the refinery was inaudible at the Logger 1 location.

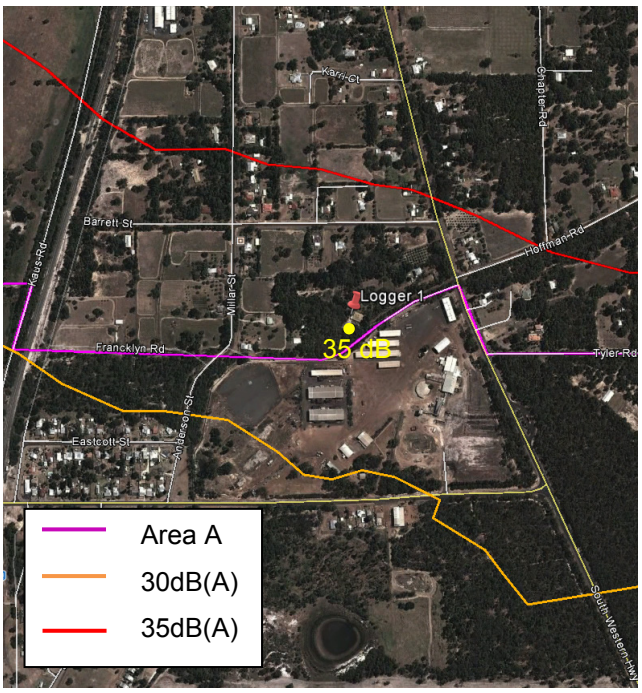

Figure 11: Logger 1 – highest L_{A10} measurement relative to Area A and the model contours (Google Earth 2013)

Five entries in the table above refer to corrupted data due to equipment failure; no meaningful analysis of noise levels on these nights was possible. The cause has been investigated and is believed to be the result of moisture either entering the microphone cable joints or entering through a perforation in the cable itself.

6.2.2 Outside Area A

Logger 2 location
Noise logging equipment was installed at Logger 2 location from 5 July 2012 until 28 September 2012. The measurement results are presented in Table 6 below.

Table 6: Extended logging $L_{A10\ (3hr)}$ & $L_{A1\ (3hr)}$ levels at Logger 2 outside Area A

Date	L_{A10} dB	L_{A1} dB	Date	L_{A10} dB	L_{A1} dB	Date	L_{A10} dB	L_{A1} dB
05/07/2012	32*	33*	27/08/2012	masked	masked	01/09/2012	inaudible	inaudible
06/07/2012	30*	31*	30/08/2012	masked	masked	25/09/2012	masked	masked
07/07/2012	30*	33*	31/08/2012	masked	masked	26/09/2012	inaudible	inaudible

Notes: *All levels derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.
'inaudible' indicates the refinery could not be heard in the audio recording even when the playback levels were significantly amplified.
'masked' indicates the refinery noise was audible but masked by extraneous sources (e.g. wind, rain, trains, traffic etc) to a significant extent preventing calculation of reliable statistical levels.

Despite having equipment at the Logger 2 location for almost three months data was only collected on nine nights. This was due to on-going problems with the equipment which failed to record as anticipated. The equipment failure has been investigated and discussed with the manufacturer. The most likely cause is a compatibility issue between the sound level meter and the SD memory card used to record the data. All of the logging equipment utilised identical memory cards, however, DER understands that even 'identical' cards of the same model, produced by the same company, can have different performance and this may have caused the equipment to be inconsistent in writing the data to the memory card.

Notwithstanding these difficulties the successful measurements between 5 to 7 July 2012 are considered to be representative. Meteorological conditions (wind direction and thermal inversion) were favourable for enhancement of refinery noise at this location over these dates. On 5 July and 7 July close to ideal 'worst case' conditions were present for a period resulting in an L_{A1} measurement of 33dB(A). This is believed to be typical of the highest refinery noise level likely to be experienced at this location. As even the L_{A1} measured level falls below the L_{A10} assigned level (35dB(A)), Logger 2 location is not considered to be noise-affected.

Logger 2 lies south west of the refinery and outside the 30dB(A) contour (see Figure 12), so an L_{A10} measurement of 32dB(A) is further indication that the model is under-predicting south of the refinery by up to 4dB, which is consistent with other findings of this monitoring program.

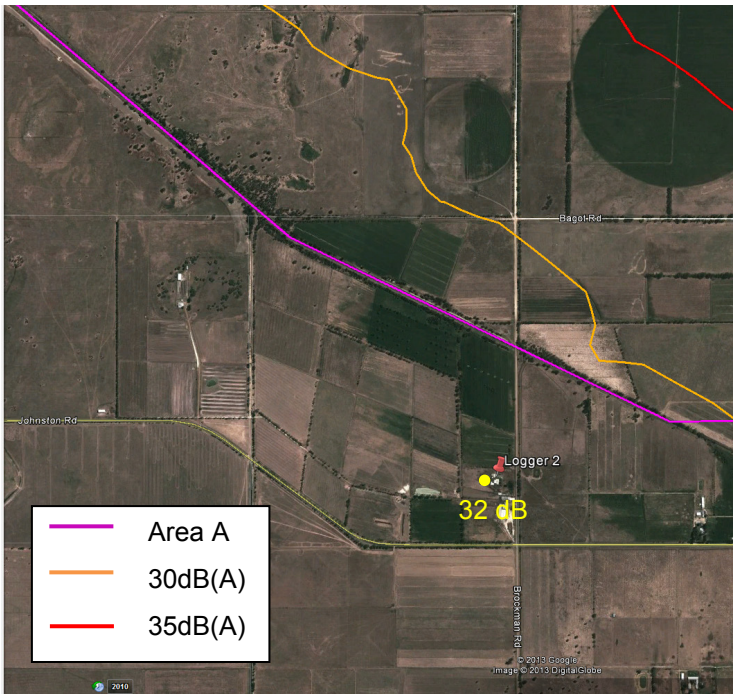

Figure 12: Logger 2 – highest L_{A10} measurement relative to Area A and model contours (Google Earth 2013)

Logger 3 location

Measurements were undertaken at Logger 3 location from 18 July 2012 to 12 August 2012, and the results are presented in Table 7 below.

Table 7: Extended logging $L_{A10\ (3hr)}$ & $L_{A1\ (3hr)}$ levels at Logger 3 outside Area A

Date	L_{A10} dB	L_{A1} dB	Date	L_{A10} dB	L_{A1} dB	Date	L_{A10} dB	L_{A1} dB
18/07/2012	25*	27*	31/07/2012	26*	28*	07/08/2012	inaudible	inaudible
19/07/2012	inaudible	inaudible	01/08/2012	inaudible	inaudible	08/08/2012	masked	masked
20/07/2012	25*	27*	02/08/2012	24*	27*	09/08/2012	28*	30*
21/07/2012	23*	26*	03/08/2012	inaudible	inaudible	10/08/2012	26*	28*
28/07/2012	inaudible	inaudible	04/08/2012	20*	23*	11/08/2012	26*	28*
29/07/2012	28*	31*	05/08/2012	masked	masked	12/08/2012	inaudible	inaudible
30/07/2012	masked	masked	06/08/2012	masked	masked			

Notes: *All levels derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.
'inaudible' indicates the refinery could not be heard in the audio recording even when the playback levels were significantly amplified.
'masked' indicates the refinery noise was audible but masked by extraneous sources (e.g. wind, rain, trains, traffic etc) to a significant extent preventing calculation of reliable statistical levels.

No measurements exceeded the assigned levels at Logger 3. The highest L_{A10} and L_{A1} measured levels were 28dB(A) and 31dB(A) respectively, some 7dB and 14dB below the assigned levels. These levels were recorded on 29 July 2012 when metrological conditions favouring refinery noise enhancement were present. This is believed to be the typical 'worst-case' noise level, and so the location is not considered to be noise-affected.

For 50 per cent of the 20 measurements refinery noise was noted as 'inaudible' or 'masked', attributed mostly to the influence of meteorological conditions at this location which is approximately 6.2 kilometres from the refinery centre.

Logger 3 is the most distant extended logging location used in this monitoring program lying approximately two kilometres south of Area A and the 30dB(A) contour (see Figure 13 opposite). As noted at other southern locations, L_{A10} measurements above those expected by the model show the tendency of the model to under-predict with increasing distance from the refinery.

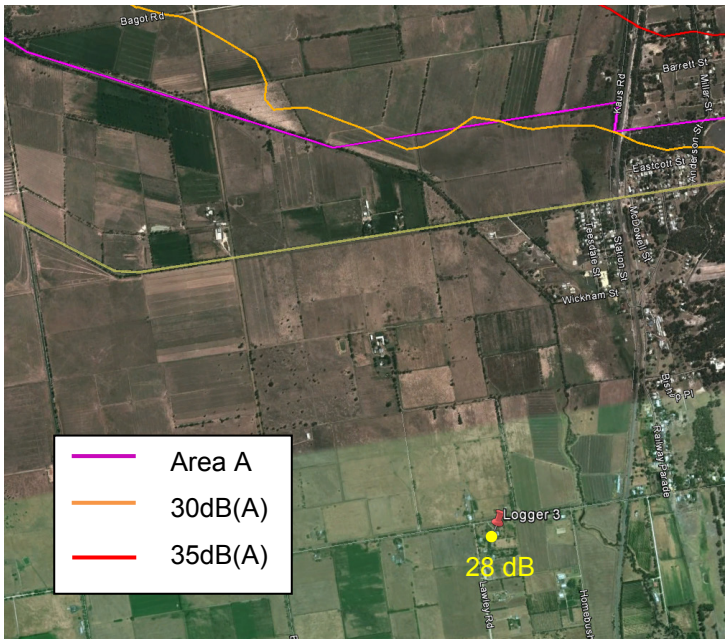

Figure 13: Logger 3 – highest L_{A10} measurement relative to Area A and model contours (Google Earth 2013)

Logger 4 location

One handheld measurement at Point 5 identified a short term level above 35dB(A); this was further investigated with extended logging at the Logger 4 location. Measurements were made from 25 August until 21 September 2012 and the results are presented in Table 8 below.

Table 8: Extended logging $L_{A10\ (3hr)}$ & $L_{A1\ (3hr)}$ levels at Logger 4 outside Area A

Date	L_{A10} dB	L_{A1} dB	Date	L_{A10} dB	L_{A1} dB	Date	L_{A10} dB	L_{A1} dB
25/08/2012	masked	masked	04/09/2012	inaudible	inaudible	14/09/2012	32*	34*
26/08/2012	corrupted	corrupted	05/09/2012	36*	38*	15/09/2012	31*	33*
27/08/2012	31*	34*	06/09/2012	37*	40*	16/09/2012	masked	masked
28/08/2012	35*	37*	07/09/2012	32*	37*	17/09/2012	inaudible	inaudible
29/08/2012	corrupted	corrupted	08/09/2012	masked	masked	18/09/2012	inaudible	inaudible
30/08/2012	33*	35*	09/09/2012	masked	masked	19/09/2012	28*	32*
31/08/2012	24*	28*	10/09/2012	inaudible	inaudible	20/09/2012	27*	29*
01/09/2012	masked	masked	11/09/2012	29*	32*	21/09/2012	24*	26*
02/09/2012	corrupted	corrupted	12/09/2012	34*	36*			
03/09/2012	inaudible	inaudible	13/09/2012	masked	masked			

Notes: * All levels derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.
'inaudible' indicates the refinery could not be heard in the audio recording even when the playback levels were significantly amplified.
'corrupted' indicates the recorded data was corrupted and unable to be analysed.
'masked' indicates the refinery noise was audible but masked by extraneous sources (e.g. wind, rain, trains, traffic etc) to a significant extent preventing calculation of reliable statistical levels.

The Logger 4 location is significant, being in the south-west corner of the Hamel town site; noise levels measured here are likely to be indicative of those that affect most of the town.

Two three-hour measurements on 5 and 6 September 2012 showed a marginal exceedence of 1 to 2dB above the L_{A10} assigned level, demonstrating that noise-affected properties do exist within Hamel. Additional detail of the analysis of these two measurements is presented in Appendix A4.

Three L_{A10} measurements were equal or greater than 35dB(A). Given that the location lies outside the 35dB(A) contour the L_{A10} results show the model is under-predicting in this area north of the refinery (see Figure 14 opposite).

Measurements were masked on six of the 28 measurement nights (21 per cent) most significantly due the close proximity of trees to the measurement site, so nights with more than slight winds resulted in foliage noise masking the refinery noise. There were a further five nights when refinery noise was inaudible. On three occasions the measurement data is reported as corrupted. The measurement equipment used at this location was relocated from the Logger 1 location and the issue is consistent with that previously noted at section 6.2.1.

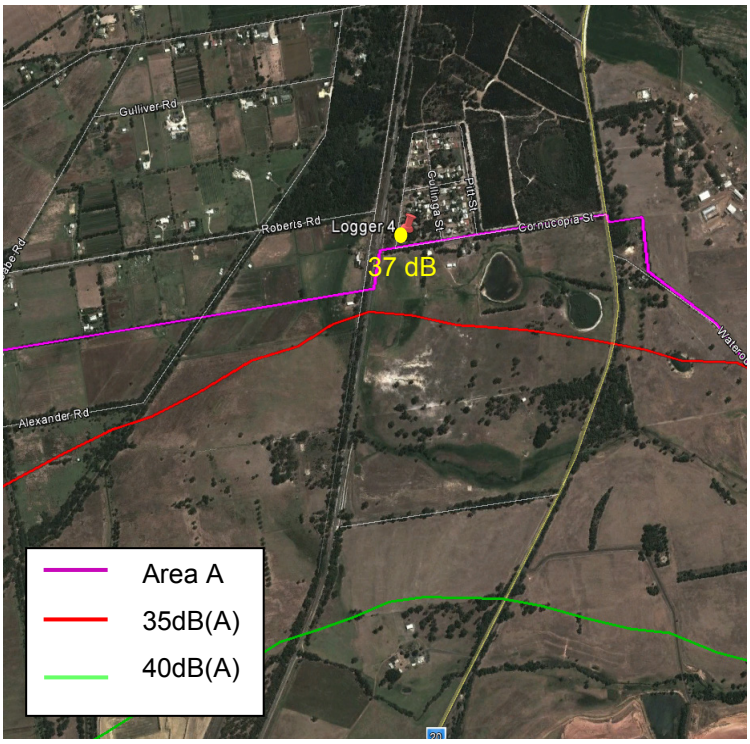

Figure 14: Logger 4 – highest LA10 measurements relative to Area A and model contours (Google Earth 2013)

7 Discussion

7.1 Regulation 17 monitoring locations

The handheld measurement program showed there was potential for exceedence of the approved levels at two of the Regulation 17 locations: Location 2 and Location 6. Whether this translates to an actual exceedence of the Regulation 17 approval will depend on the consistency of 'worst case' conditions at the time of assessment. At each location conditions resulting in an exceedence will need to be present for 18 minutes in the case of an L_{A10} exceedence and 1.8 minutes for an L_{A1} exceedence in a three-hour period, which is not inconceivable.

Given the limited scope of the handheld measurement program, it is recommended that a more extensive winter noise monitoring program be undertaken at the Regulation 17 locations. Ideally, further study would include longer term logging with a view to gaining a better understanding of whether exceedences do eventuate over a three-hour assessment period and if so, what is the prevalence and extent of those exceedences. In this regard it is noted the amended approval of December 2013 requires Alcoa to engage an independent acoustic consultant to undertake compliance monitoring on three occasions each year of the approval during the cooler months between 10pm and 7am with a view to capturing the highest refinery noise emission received at the eight locations.

The monitoring program highlighted the difficulty and labour-intensive nature of monitoring at eight locations. The locations were selected to protect the community and prevent any increase in noise emissions from the refinery. The question is whether these objectives could still be achieved with approved noise levels at fewer locations.

In some instances the current locations were chosen because of proximity to a single residence. It is understood that the status of some of these residences may have changed, either by being purchased by Alcoa or no longer occupied. Furthermore, as identified at Locations 4 and 7, some sites do not lend themselves to noise monitoring due to the closeness of local vegetation such as trees and bushes. One approach may be a move to a smaller number of permanent monitoring locations amenable to collection of data over the long term, and importantly showing trends over an extended timeframe. In this regard it is noted that the amended approval requires continuous monitoring at two sites close to the refinery to enable comparison of noise emission levels over time. Furthermore, the requirement for campaign monitoring at sites further away would provide valuable insight into the meteorological influence which characterises the noise in the most populated areas north and south of the refinery, while also directly monitoring the noise impacts on a significant portion of the community. It is suggested that this matter be the subject of further consideration by DER and Alcoa when the current approval expires.

7.2 Modelling and noise-affected properties

Both the handheld measurements and logged data indicated a tendency for the model to under-predict. Only a slight under-prediction is apparent within the model's 40dB(A) contour; however, as distance from the refinery increases so too does the discrepancy between the measured levels and the predicted levels. To some extent the tendency for the model's accuracy to deteriorate with distance from the source is not unexpected. The model is at best an approximation of the 'real-world' situation; it relies upon an idealised algorithm, a component of which is displacement dependent, so that with increasing displacement there is an amplification of the inherent errors, resulting in a decrease in accuracy.

In relation to the 2002 model SVT concluded that generally the model was accurate to ± 5dB, while in the area south of the refinery in the vicinity of Bancell and Boundary Roads, the model is more accurate and in the order of ± 3dB (SVT 2003).

The model has been used by Alcoa as the basis for determining the properties which are within the 35dB(A) contour and so therefore determined to be noise-affected. The Regulation 17 approval requires Alcoa to develop a noise amelioration plan with two aspects to it:

(a) an acoustic amelioration programme setting out procedures for the provision by Alcoa of noise insulation for noise-sensitive buildings, on noise-affected land

(b) a land management plan setting out the procedures for the purchase by Alcoa of noise-affected land.

To date Alcoa's approach has been to endeavour to purchase properties in Area A or, in instances where residents do not wish to move, to offer to provide noise insulation packages to dwellings.

This study has identified that noise-affected properties exist within the Hamel town site which is located outside Area A. These properties are not within the scope of Alcoa's current amelioration plan but are nonetheless required to be addressed under the Regulation 17 approval.

The Area A boundary lies outside the model's 35dB(A) contour and is intended to capture all properties receiving an L_{A10} level above 35dB(A). The distance between the Area A boundary and the 35dB(A) contour varies considerably. To the north and south the boundary is close to the 35dB(A) contour. However, the western side of Area A goes well beyond the 35dB(A) contour, past the refinery residue areas. On the eastern side, north and south of the refinery's overland conveyor, the boundary also extends beyond the 35dB(A) contour.

SVT (SVT 2003) noted that the model is most accurate to the south and less accurate to the west and north. This seems to be substantiated by the current noise monitoring program. To the north and south lie the population centres of Hamel and Yarloop, making these regions of particular interest. To the south, better model accuracy may explain why no noise-affected properties were detected beyond Area A. In the north however, while Area A is similarly close to the 35dB(A) contour, the model is less accurate and so the detection of noise-affected properties beyond Area A is more likely, possibly explaining the findings in this case.

Noise-affected properties outside Area A may be addressed by Alcoa in one of two ways. Firstly, the properties could be included in the noise amelioration plan required to be developed under the Regulation 17 approval. Alternatively, Alcoa may wish to consider noise reduction measures aimed specifically at reducing the noise received north of the refinery. Noise emitted from the stockyard and milling areas have been identified as significantly contributing to levels received at northern residences (Alcoa 2008). Acoustic treatments to these areas alone may reduce the received noise levels sufficiently so that properties north of the Area A boundary would no longer be considered noise-affected.

8 Glossary

Alcoa	Alcoa World Alumina Australia
Approved levels	Noise levels approved under Regulation 17 which are not to be exceeded at approved locations
Approved locations	Locations identified by the Regulation 17 approval at which noise level must not exceed approved levels
Assigned levels	A prescribed standard under the *Environmental Protection Act 1986* specified by the *Environmental Protection (Noise) Regulations 1997* as noise levels which must not to be exceeded
DER	Department of Environment Regulation
EPA	Environmental Protection Authority
Minister	Minister for Environment
Noise-affected	Noise-sensitive locations that receive refinery noise at a level which exceeds the assigned levels
Noise Regulation	Noise Regulation of Department of Environment Regulation
Regulation 17	Regulation 17 of the *Environmental Protection (Noise) Regulations 1997* which provides a pathway by which approval can be sought to allow a noise emission to exceed or vary from a prescribe standard
Regulations	*Environmental Protection (Noise) Regulations 1997*
Residual logged periods	Noise measurement periods which remain after the one second noise measurement logs dominated by transient extraneous noise sources (non-refinery noise from foliage, traffic, trains etc) have been excluded

9 References

Alcoa World Alumina Australia (Alcoa) 2008, Alcoa Noise Regulation 17 Application An Assessment of the Reasonableness and Practicability of Further Noise Reduction Opportunities at Wagerup Refinery, Alcoa, WA.

Alcoa World Alumina Australia (Alcoa) 2012, *Wagerup Noise Management Plan – Draft for Comment*, Alcoa, WA.

Environmental Protection Authority (EPA) 2006, Wagerup Alumina Refinery – Increase in Production to 4.7 Mtpa; and Wagerup Cogeneration Plant Alcoa World Alumina Australia Report and Recommendations of the Environmental Protection Authority, EPA, Bulletin 1215, Perth, WA.

Environmental Protection Authority (EPA) 2010, Wagerup Alumina Refinery Noise Regulation 17 Variation – Supplementary Advice Alcoa of Australia Ltd Report and Recommendations of the Environmental Protection Authority, EPA, Report 1365, Perth, WA.

Google Earth 7.1 2013, Imagery Date: 23 January /2013 , lat:-32.87^{o} to -32.97^{o}, lon 115.82^{o} to 116^{o}, Layers: Boarders and Labels, Place, Roads.

Herring Storer Acoustics (HSA) 2002a, Alcoa World Alumina Australia Wagerup Refinery Report Providing Technical Supporting Data for Alcoa's Wagerup Refinery Regulation 17 Application, Alcoa, WA.

Herring Storer Acoustics (HSA) 2002b, Alcoa World Alumina Australia Wagerup Refinery Noise Emission Modelling and Source Ranking, Alcoa, WA.

SVT Engineering Consultants (SVT) 2003, Review of Environmental Noise Emissions from Alcoa Wagerup Refinery for Department of Environmental Protection, SVT, Perth, WA.

Appendices – Additional figures and information

A1. Measurement locations and model contours

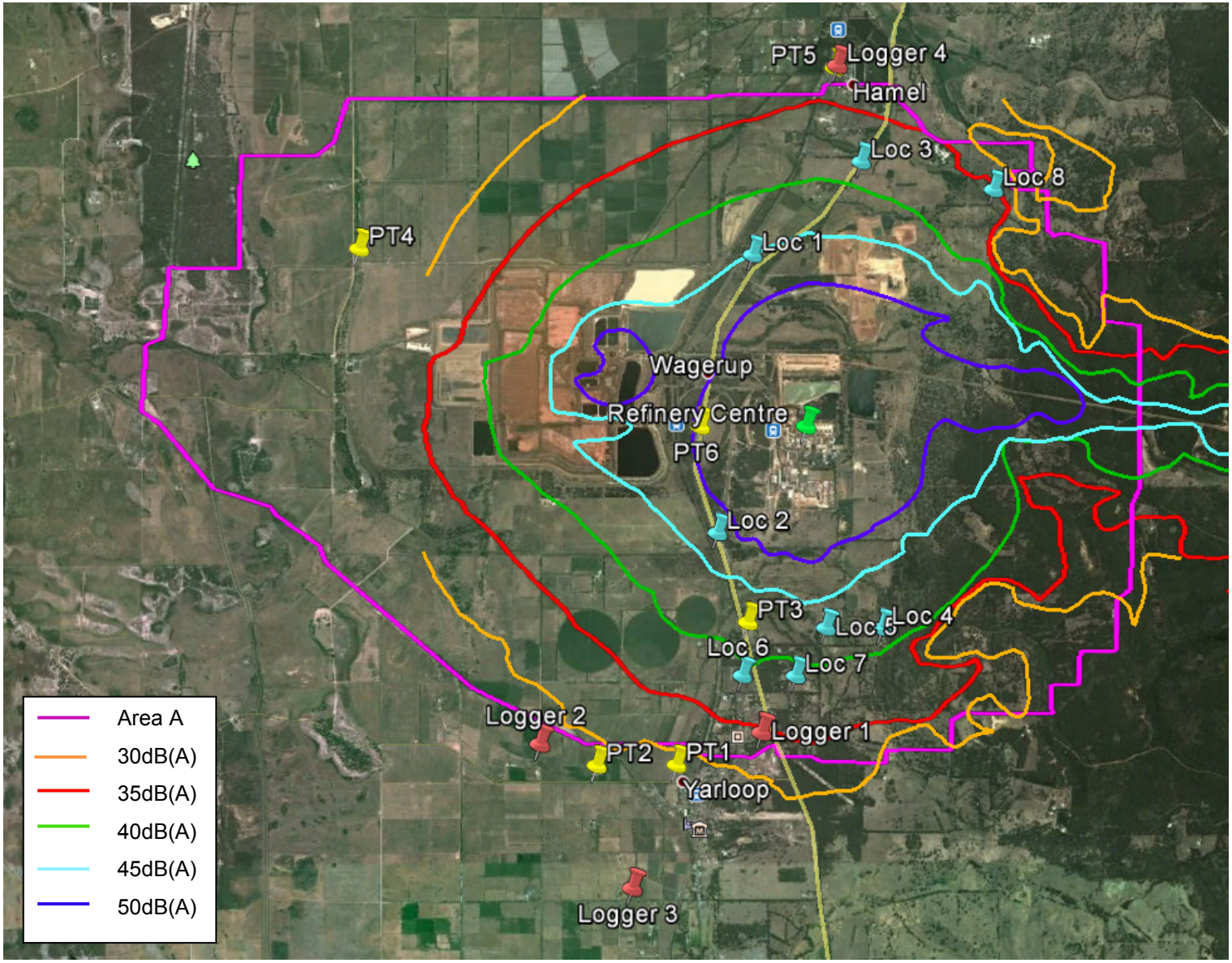

Figure A1: Measurement locations and model contours (Google Earth 2013)

A2. Typical refinery spectral profiles

Figures A2 and A3 (below) show the typical refinery noise spectrum near to the refinery (A2) and distant from the refinery (A3). Both profiles show the typical double hump between 40–1000 Hz which characterise the refinery noise emissions.

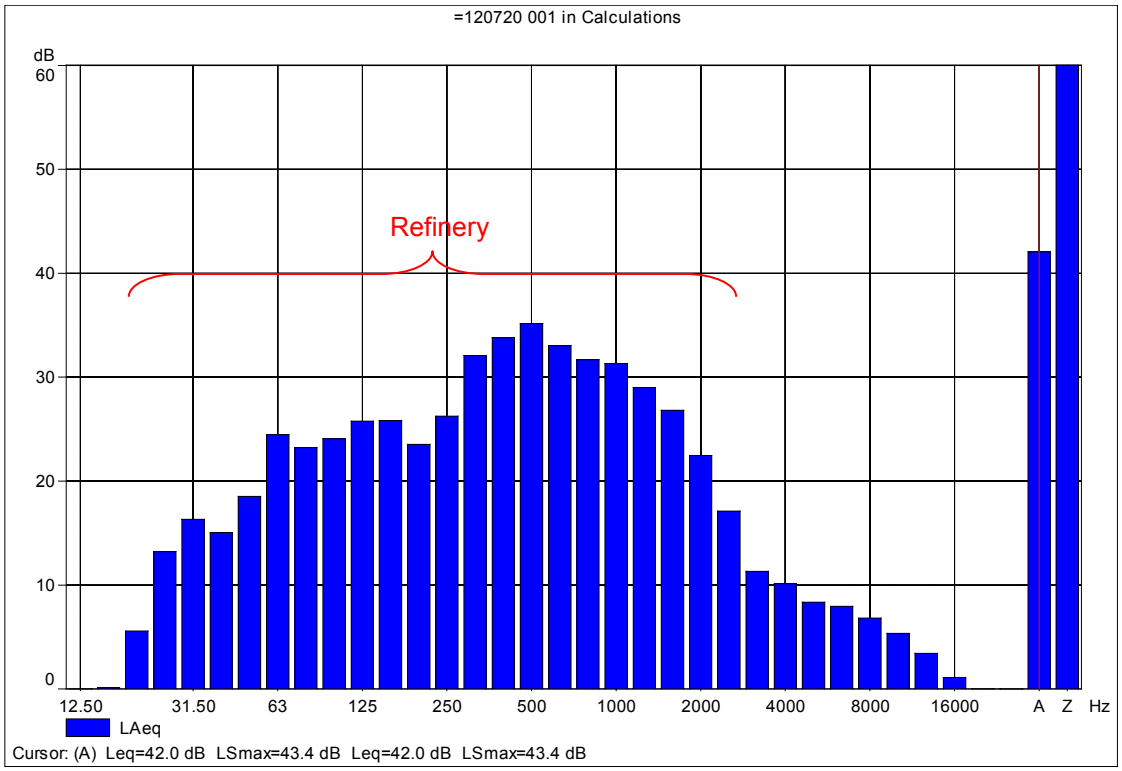

Figure A2: Location 2; 1.8km (approx.) from refinery centre: typical spectrum after removal of the influence of transient extraneous noise sources.

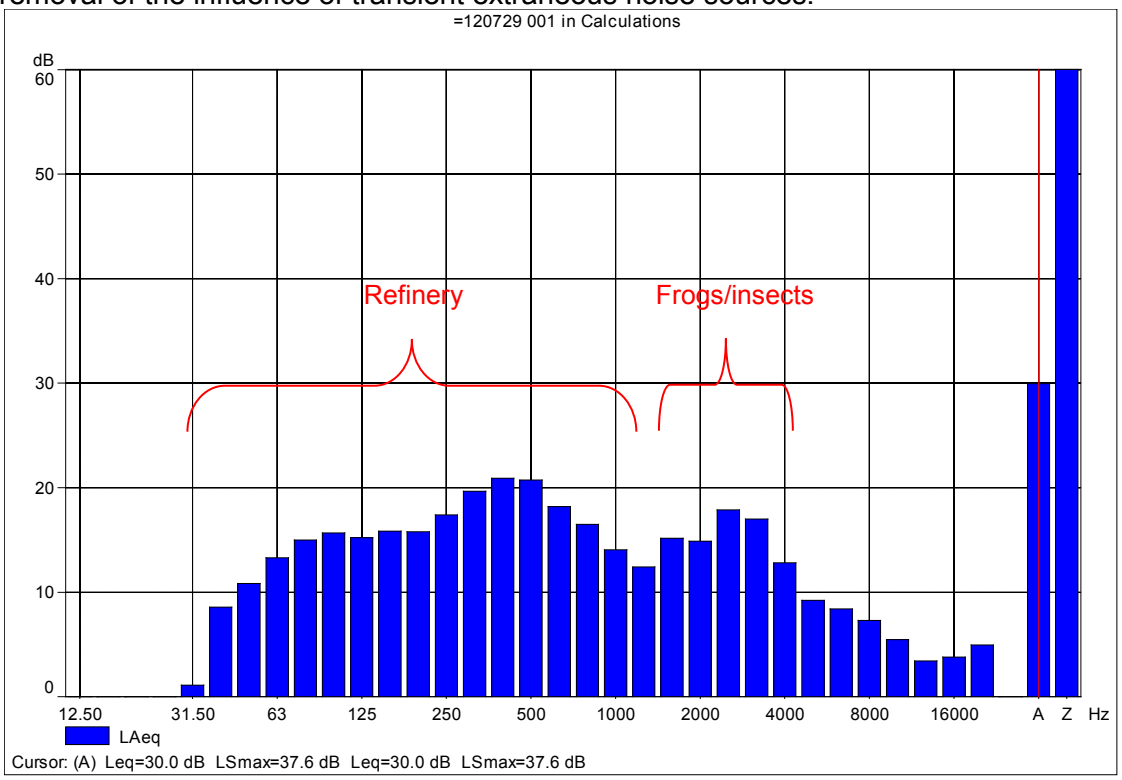

Figure A3: Logger 3; 6.3km (approx.) from refinery centre: spectrum after removal of the influence of transient extraneous noise sources; the influence of non-transient high frequency sources (frogs/insects) is still present. Note that frequencies above 1kHz reduce more quickly with distance from the source.

A3. Detailed methodology

Where residual measurement periods were dominated by local high frequency noise from frogs, insects or birds and alike, but otherwise unaffected, the high frequency one-third octave bands were excluded and the remaining bands summed to report the A-weighted refinery noise level. The summed bands typically consisted of the 40Hz to 1000Hz bands.

Specifically the one second L_{Aeq} one-third octave band data was exported to Excel and filtered for extraneous noise identified and marked during audio playback. The one-third octave bands between 40 and 1000 Hz of the residual one second data were logarithmically summed according to the general equation:

$$\mathrm{L} = \log_{10}\left(\sum_{i=1}^{N} 10^{\left(\frac{L_i}{10}\right)}\right)$$

or specifically …

$$L_{Aeq(40Hz-1kHz)} = 10\log_{10}\left(10^{L_{Aeq(40Hz)}/10} + 10^{L_{Aeq(50Hz)}/10} + 10^{L_{Aeq(63Hz)}/10} \ldots + 10^{L_{Aeq(1kHz)}/10}\right)$$

For the short duration measurements the L_{A10} level was determined as the 90th percentile and the L_{A1} as the 99th percentile of the one second $L_{Aeq(40Hz\text{-}1kHz)}$ measurements; that is, the level below which 90 per cent and 99 per cent of the measurements fall, or the corollary being the level which 10 per cent and one per cent of the measurements exceeded.

For extended logged measurements the $L_{A10(3hr)}$ and $L_{A1(3hr)}$ level was determined as the percentile of the one second $L_{Aeq(40Hz\text{-}1kHz)}$ measurements which corresponded to a level exceeded for 10 per cent and one per cent of three hours respectively. Or another way of looking at it is the level which the highest 1080 and 108 one second $L_{Aeq(40Hz\text{-}1kHz)}$ measurements exceeded, which corresponds 10 per cent and one per cent of three hours.

DER notes that the use of L_{Aeq} measurements to determine L_{A10} is not strictly in accordance with the *Environmental Protection (Noise) Regulations 1997* which require L_{A10} to be determined from L_{ASlow} measurements. However full spectrum comparisons for L_{A1} and L_{A10} values derived from broadband L_{AS} and L_{Aeq} conducted by DER in relation to the refinery noise emissions noted minimal variation between the two methods and of the order of 0–0.1dB for L_{A10} and 0–0.3dB for L_{A1}. Further, DER compared the broadband L_{Aeq} levels measured directly by the sound level meter and the broadband L_{Aeq} levels derived from the logarithmic addition of one-third octave band L_{Aeq} levels finding both broadband L_{Aeq} levels were equivalent. The findings above are likely to be a consequence of the refinery noise being a relatively constant source with slow changes in noise levels due mostly to atmospheric variation, a different source with faster fluctuations in level may not result in the same finding and this method would not be applicable.

A4. Detailed assessment of L_{A10} assigned level exceedences in Hamel (Logger 4)

$L_{A10(3hr)}$ measurements in excess of 35dB(A) were recorded at Logger 4 location on two nights during the monitoring program. These measurements represent an exceedence of what would ordinarily be the 35dB assigned level if a regulation 17 approval was not in place. Consequently, the measurements also identify the location as 'noise affected land' under the *Environmental Protection (Wagerup Alumina Refinery Noise Emissions) Approval 2012*.

5 September 2012

Table A1 below presents a summary of detailed information for the measurement at Logger 4 on 5 September 2012.

Table A1: Logger, 5 September 2012: Summary of detailed information

Location	Logger 4 (Hamel)
Date	5 September 2012
Assessment period (3hr)	00:00 to 03:00 hrs
Measurement period (after exclusion of extraneous noise)	0h 49m 42s
$L_{A10(3hr)}$ over a 3-hour period (quoted level)	36dB
L_{A10} of measurement period	37dB
Time above 35.0dB(A)	0h 35m 31s
Percentage of measurement period above 35.0dB(A)	72%
Percentage of 3 hour period above 35.0dB(A)	19.7%
Time above or equal to 35.5dB(A)	0h 26m 7s
Percentage of measurement period ≥ 35.5dB(A)	52.9%
Percentage of 3 hour period ≥ 35.5dB(A)	14.5%

Note: All levels derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.

It can be seen from Table A1 that of the 3 hour assessment period only 49 minutes and 42 seconds (measurement period) was able to be used for the purpose of refinery noise measurement as the remaining portions of the assessment period were affected by extraneous noise present within the refinery noise frequency spectrum (40Hz – 1kHz). Figure A4 shows in detail the excluded and included periods. Throughout the excluded periods, except those dominated by very high level extraneous noises, the refinery noise was still audible at subjectively similar levels to those during the unaffected periods (measurement period).

The measurement period was used to determine the $L_{A10(3hr)}$ level (the level exceeded for 18 minutes of the measurement period) which is reported as the 36dB measured level in this report. In addition, Table A1 shows the L_{A10} for the measurement period as 37dB (i.e. the level exceeded for 10% of the measurement period only), being 1dB higher than the $L_{A10(3hr)}$ level. Arguably, the L_{A10} level over the measurement period may be closer to the true level of the refinery which might be measured if it was possible to continuously measure the refinery noise over the excluded periods.

Further analysis presented in Table A1 found the refinery noise was above 35.0dB(A) for 72% of the measurement period and above 35.5dB(A) for 52.9%, highlighting the consistency with which the refinery noise exceeded the normally applicable assigned level during the measurement period. Noting that subjectively the refinery noise level is similar for both periods, it would not be unreasonable to assume that the refinery noise during the excluded periods was consistent with that during the measurement period and so the refinery noise may be above 35dB(A) for the majority of the assessment period. Figure A4 below displaying the time history over the whole assessment period supports this notion, where it can be seem that the $L_{Aeq(40Hz-1kHz)}$ level only occasionally falls below 35dB(A). Figure A5 presents a 10 minute portion of the assessment period in more detail. It can be seen that generally the difference between the broadband (L_{Aeq}) and the lower frequency ($L_{Aeq(40Hz-1kHz))}$ level is less than 2dB over this portion. At times it is apparent the refinery noise (40Hz-1kHz) is driving the broadband levels

.

The sample spectrum presented in Figure A6 provides more information. It represents a “slice” in time for the period 02:31:09 – 02:31:10 shown as the vertical blue line in Figure A5. Refinery noise is seen to hit a high point at this time (L_{Aeq} = 39dB). Figure A6 shows the characteristic “double hump” of the refinery noise between 40Hz and 1kHz which is dominant over the other higher frequency sources. Particularly pronounced at this time are the levels in the 400Hz and 500Hz one-third octave bands which correspond to a slight tone in the audio recording. The third “hump” in Figure A6 comprising the 2kHz to 3.15kHz one-third octave bands is caused by frog and insect noise which at times increases, pushing the broadband levels higher above the low frequency refinery noise.

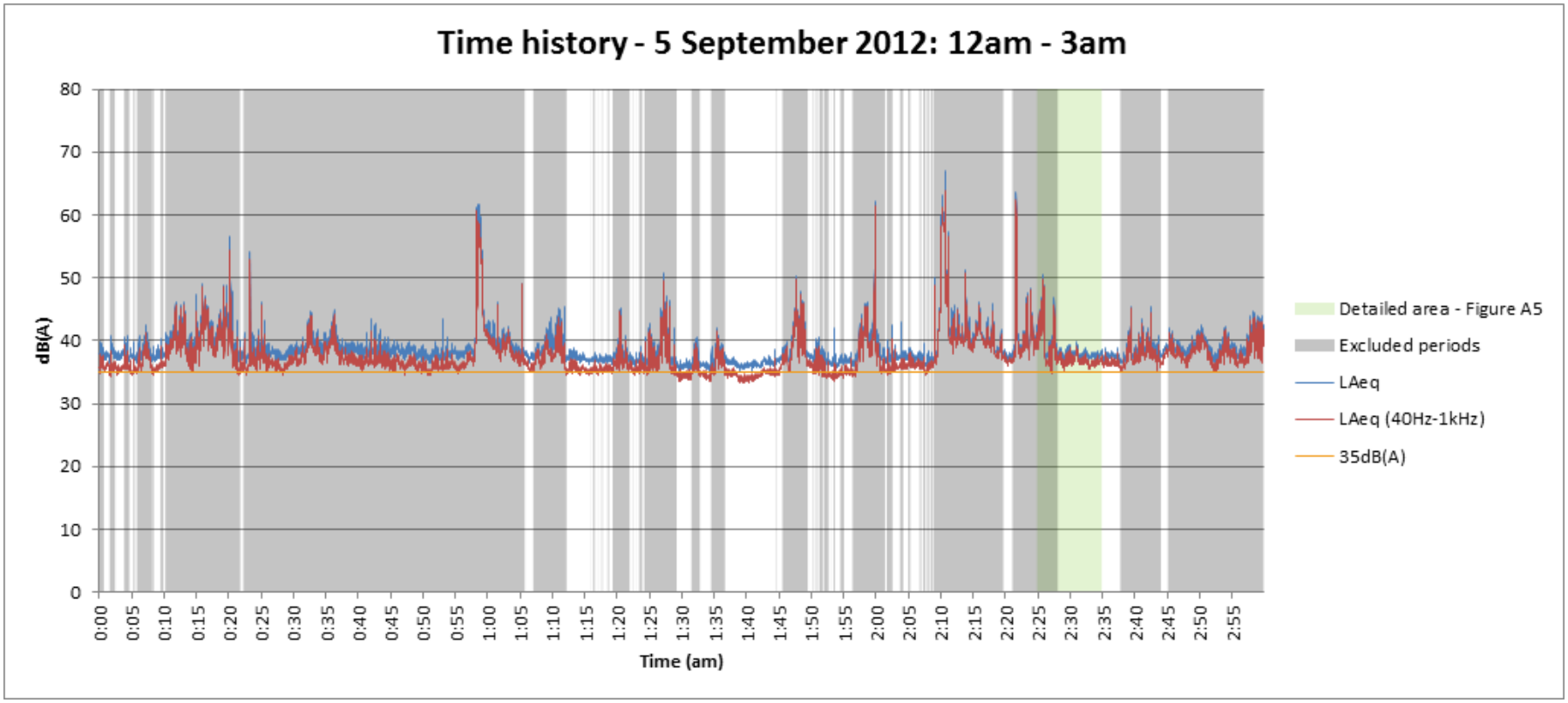

Figure A4: Logger 4 location: time history of broadband (L_{Aeq}) and refinery frequency ($L_{Aeq(40Hz-1kHz)}$) levels. Areas shaded grey are periods excluded from the measurement period because they are affected by extraneous noise such as wind, passing traffic, trains, animal noise etc. The pale green area is a 10 minute period chosen to provide a more detailed view of a portion of the measurement in Figure A5.

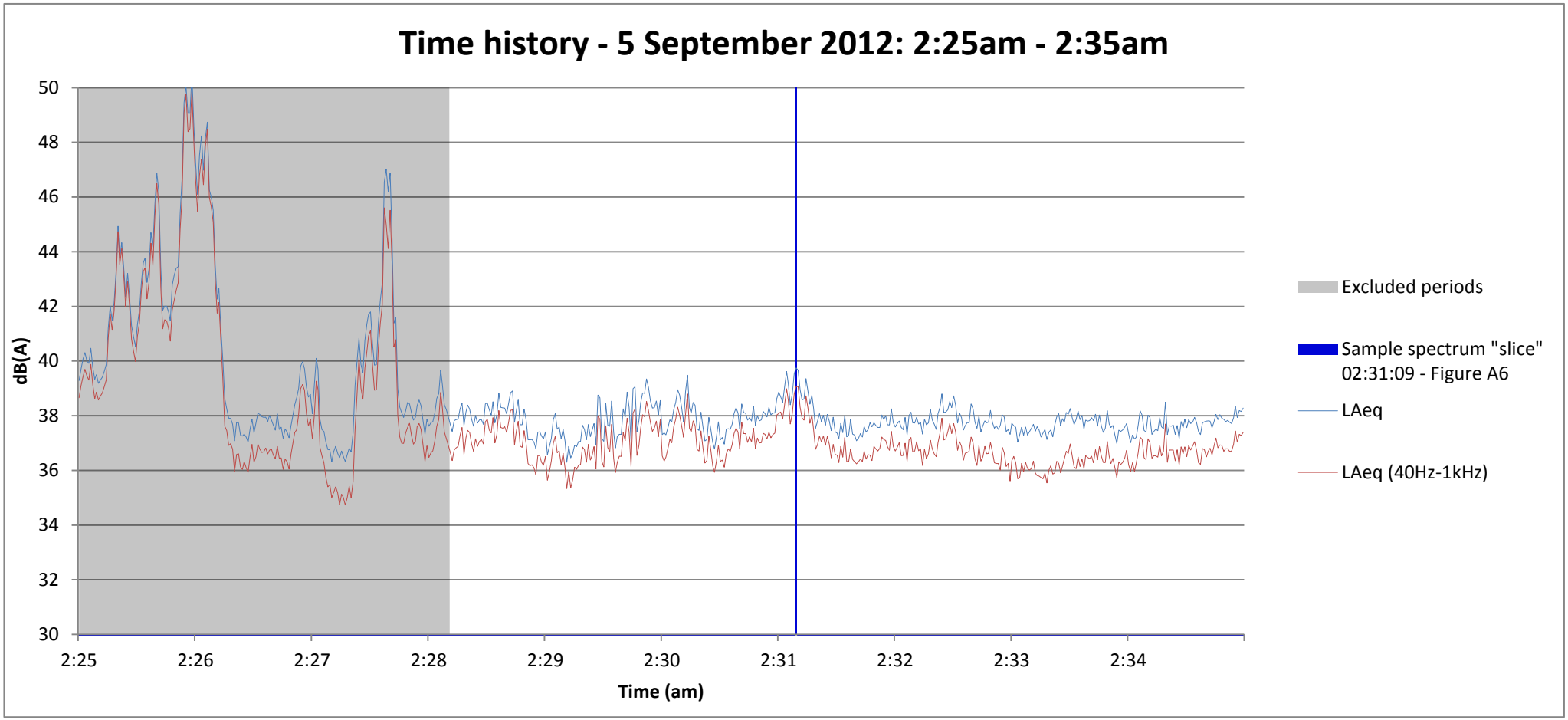

Figure A5: Logger 4 location: time history of broadband (L_{Aeq}) and refinery frequency ($L_{Aeq(40Hz-1kHz)}$) levels. Area shaded grey is the period excluded from the measurement period because it is affected by extraneous noise, in this case passing traffic. The vertical blue line is a one second slice in time for which Figure A6 shows the L_{Aeq} one-third octave spectrum.

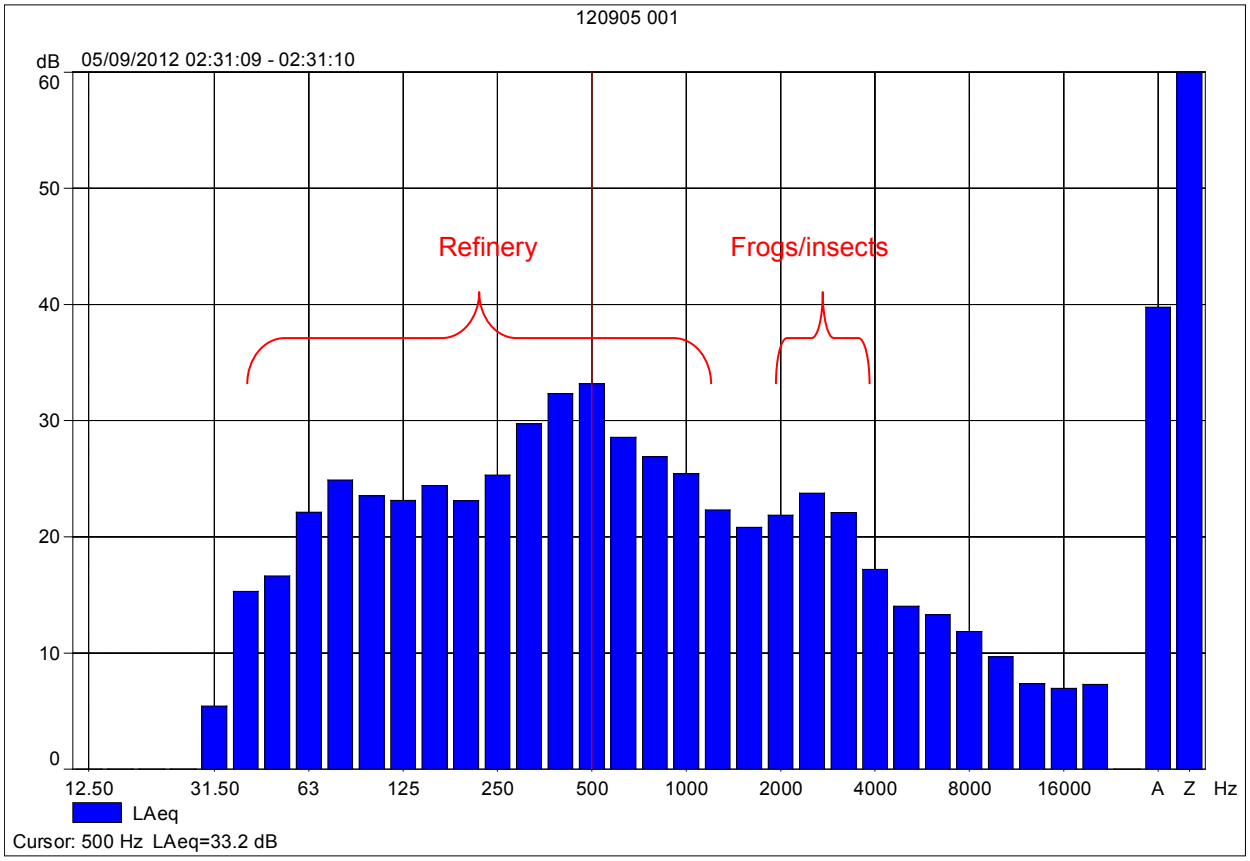

Figure A6: Logger 4 location: 5 September 2012, L_{Aeq} spectrum at 02:31:09 hrs

6 September 2012

Table A2 below presents a summary of detailed information for the measurement at Logger 4 on 6 September 2012.

Table A2: Logger 4, 6 September 2012: Summary of detailed information

Location	Logger 4 (Hamel)
Date	6 September 2012
Assessment period (3hr)	00:00 to 03:00 hrs
Measurement period (after exclusion of extraneous noise)	0h 46m 18s
$L_{A10(3hr)}$ over a 3-hour period (quoted level)	37dB
L_{A10} of measurement period	39dB
Time above 35.0dB(A)	0h 39m 06s
Percentage of measurement period above 35.0dB(A)	84.4%
Percentage of 3 hour period above 35.0dB(A)	21.7%
Time above or equal to 35.5dB(A)	0h 34m 58s
Percentage of measurement period ≥ 35.5dB(A)	75.5%
Percentage of 3 hour period ≥ 35.5dB(A)	19.4%

Note: All levels derived from the sum of low frequency one-third octave bands, refer to section 5 Methodology for further information.

In a similar result to the 5 September measurement the 3 hour assessment period only yielded 46 minutes and 18 seconds of measurement unaffected by extraneous noise. Figure A7 shows the excluded and included periods and again, for most of the excluded periods the refinery noise is clearly audible at subjectively similar levels to those of the adjacent included periods.

The reported measured level on this occasion was 37dB, being the $L_{A10(3hr)}$ level obtained from the measurement period. Once more, an L_{A10} level for measurement period of 39dB was higher than the $L_{A10(3hr)}$ level, and may conceivably be closer than the reported level to the true refinery noise level on this occasion.

The generally higher refinery noise levels on 6 September compared to 5 September 2012 are also reflected in the proportion of the measurement period the measured level is above 35.0dB and 35.5dB, being 84.4% and 75.5% of the measurement period respectively. Again this is reflected in the time history (Figure A7), where the refinery noise frequencies are above 35dB(A) for the majority of the assessment period.
The period 01:10hrs to 01:20hrs in Figure A7 shows a distinct rise in the refinery noise at approximately 01:16hrs, so the time period is presented in more detail below in Figure A8.

A similar pattern can be seen in Figure A8 to that seen in Figure A5, where the refinery frequencies generally sit less and 2dB below the broadband levels, but there are also periods where the refinery noise completely dominates. One such period is between 01:15:30hrs and 01:16:45hrs. During this period strong mid-frequency tones can be heard in the refinery noise. At 01:16:18hrs the refinery noise level peaks (L_{Aeq} = 41dB) and the L_{Aeq} spectrum for this point in time is presented in Figure A9.

Figure A9 shows the strong tone in the 400Hz one-third octave band which is readily audible. Again, it is clear the refinery noise is dominating over the background frog and insect noise.

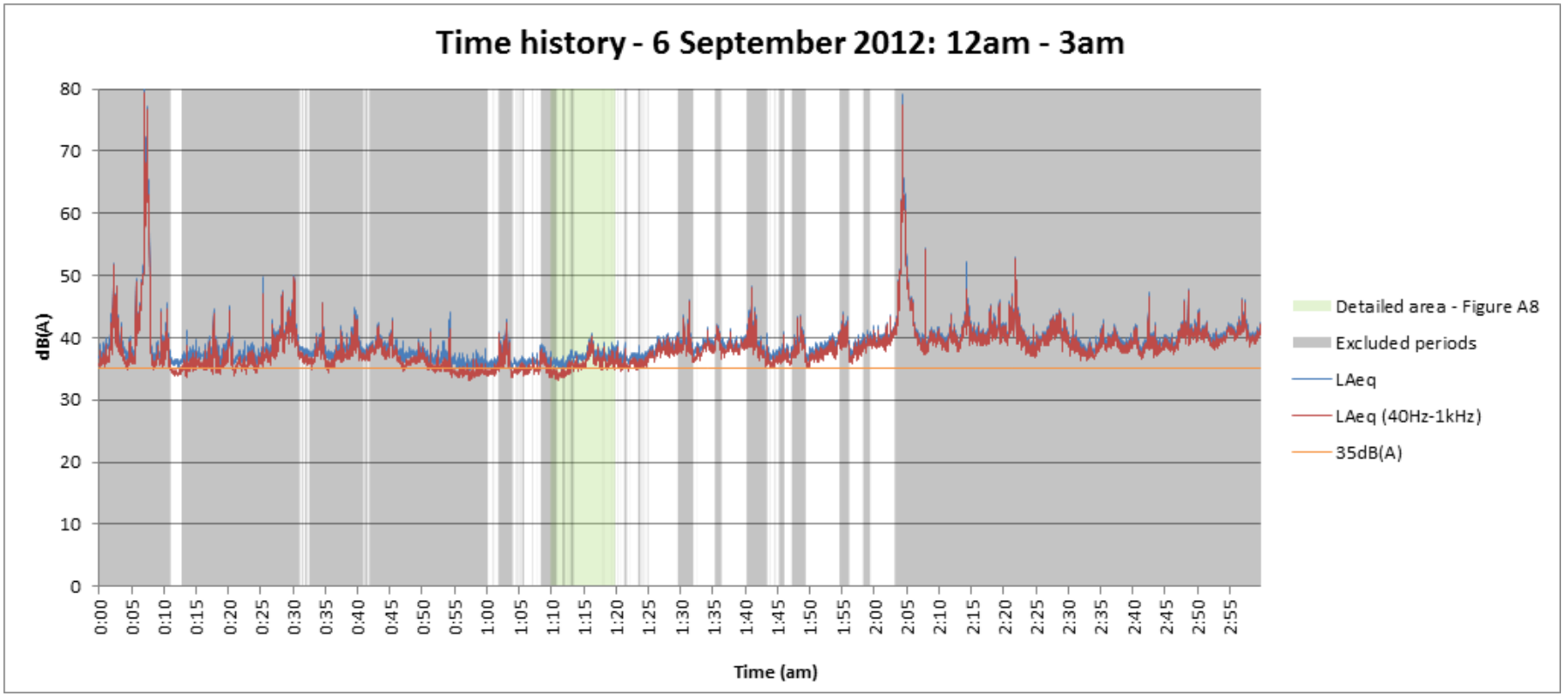

Figure A7: Logger 4 location: time history of broadband (L_{Aeq}) and refinery frequency ($L_{Aeq(40Hz-1kHz)}$) levels. Areas shaded grey are periods excluded from the measurement period because they are affected by extraneous noise such as wind, passing traffic, trains, animal noise etc. The pale green area is 10 minute period chosen to provide a more detailed view of a portion of the measurement in Figure A8.

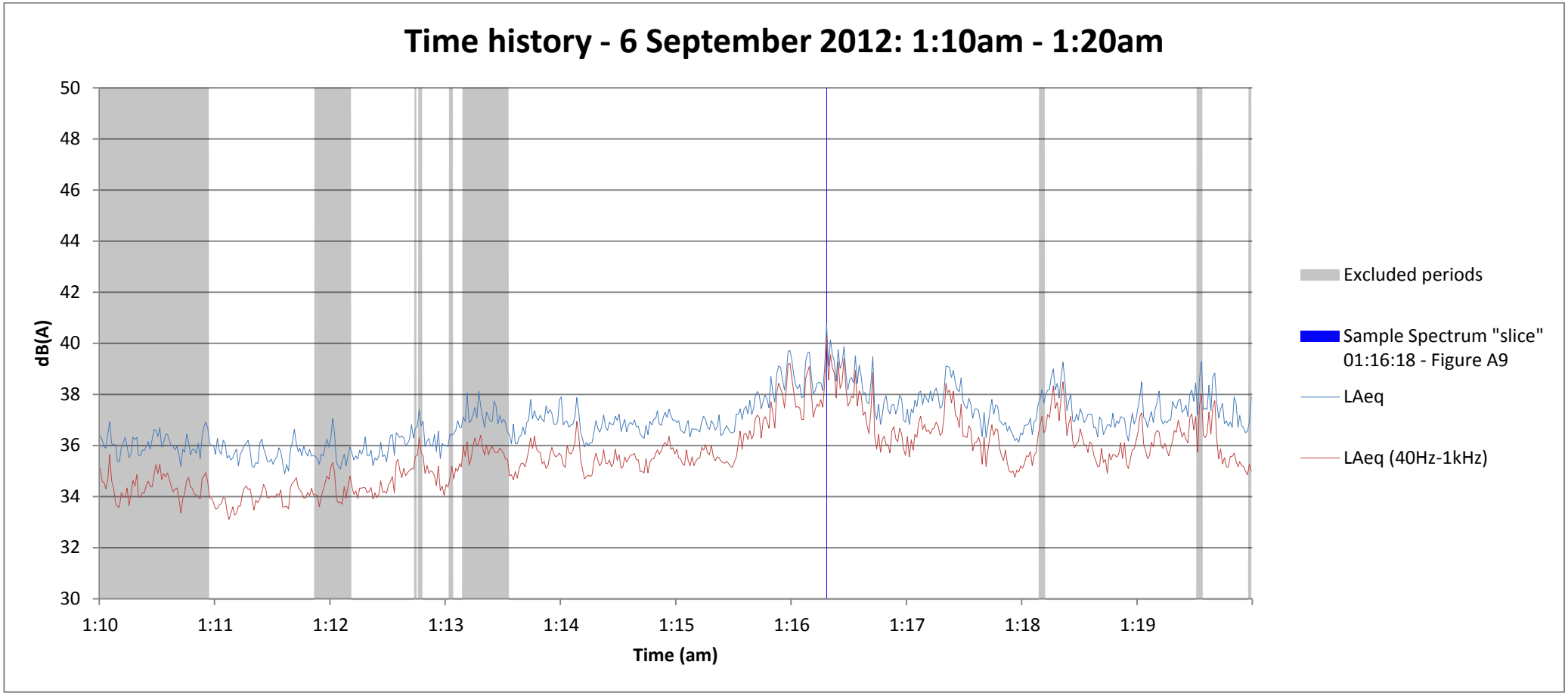

Figure A8: Logger 4 location: time history of broadband (L_{Aeq}) and refinery frequency ($L_{Aeq(40Hz-1kHz)}$) levels. Area shaded grey is the period excluded from the measurement period because it is affected by extraneous noise, in this case passing traffic. The vertical blue line is a one second slice in time for which Figure A9 shows the L_{Aeq} one-third octave spectrum.

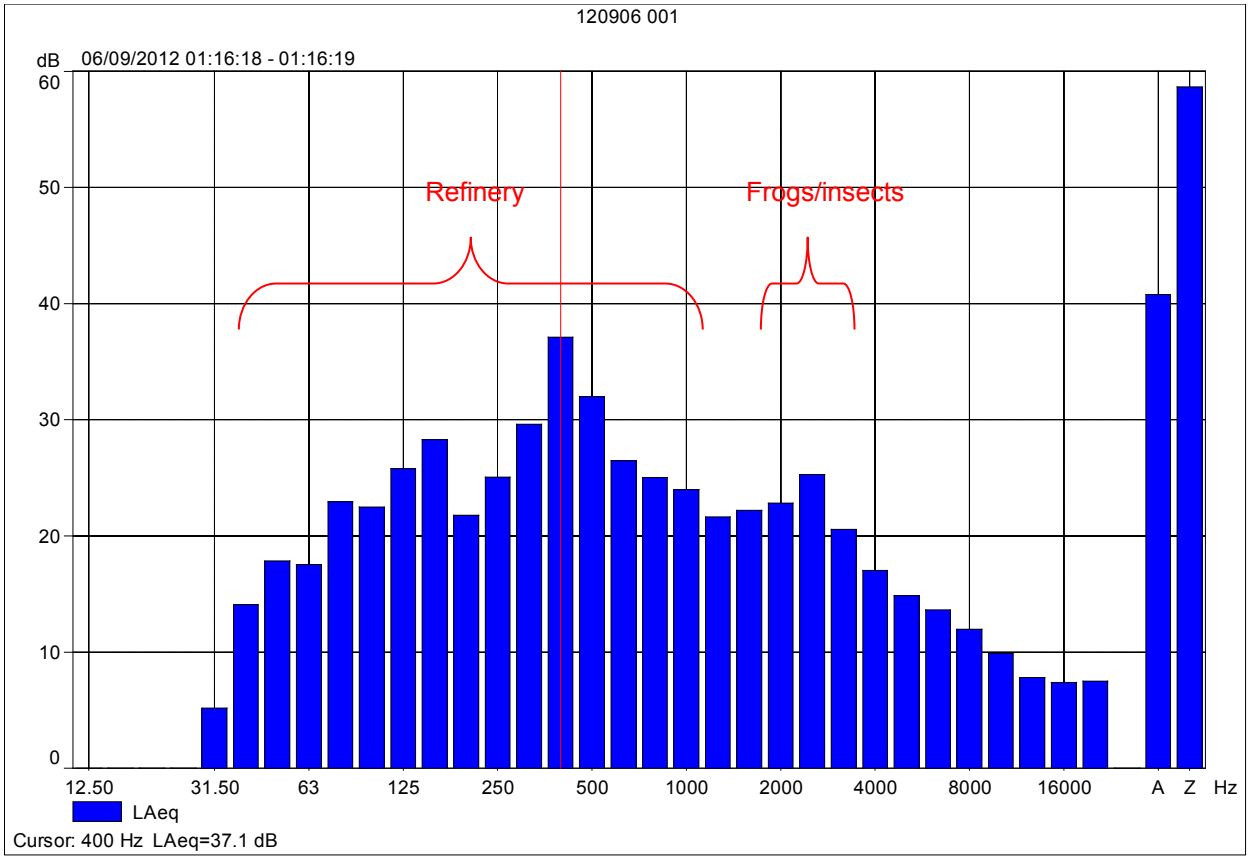

Figure A9: Logger 4 location: 6 September 2012, L_{Aeq} spectrum at 01:16:18 hrs