Opal Aged Care Development – 56 Quarry Road, Bossley Park

DA Stage Acoustic Assessment

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DOCUMENT CONTROL REGISTER

Project Number	20180266.1
Project Name	Opal Aged Care Development - 56 Quarry Road, Bossley Park
Document Title	DA Acoustic Report
Document Reference	20180000.1/1603A/R8/TT
Issue Type	Email
Attention To	Opal

Revision	Date	Document Reference	Prepared By	Checked By	Approved By
0	16/3/2018	20180000.1/1603A/R0/TT	TT		
1	5/4/2018	20180000.1/1603A/R1/TT	TT		
2	3/5/2018	20180000.1/1603A/R2/TT	TT		
3	7/6/2018	20180000.1/1603A/R3/TT	TT		
4	7/6/2018	20180000.1/1603A/R4/TT	TT		
5	1/11/2019	20180000.1/1603A/R5/TT	TT		
6	20/1/2020	20180000.1/1603A/R6/TT	TT		
7	21/1/2020	20180000.1/1603A/R7/TT	TT		
8	23/1/2020	20180000.1/1603A/R8/TT	TT		

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1 INTRODUCTION

Acoustic Logic Consultancy (ALC) has been engaged to conduct an assessment of potential noise impacts associated with the redevelopment of the Opal Residential Aged Care Facility at 56 Quarry Road, Bossley Park.

This document addresses noise impacts associated with the following:

- External noise impacts on the site;
- Noise emissions from the site (primarily mechanical plant and vehicle noise);

This assessment has been conducted using the Jackson Teece architectural drawings, dated June 2018.

2 SITE DESCRIPTION

The site is located at 56 Quarry Road, Bossley Park.

It is proposed to demolish the existing 80 bed residential aged care facility on the site and construct a new 2-3 storey aged care development for 134 beds.

Although the street address is 56 Quarry Road, the site is located back from Quarry Road, behind a row of residential dwellings fronting the road. The site is accessed via a driveway running between the dwellings at 54 and 58 Quarry Road.

The site is bounded as follows:

- Residential development to the north, east and south of the site.
- The St Thomas Cathedral, to the west.

Although it is proposed to demolish the existing development and rebuild, the layout of the redeveloped site is similar to the existing:

- The re-developed site is generally still two storeys (with some three storey areas towards the eastern end of the site), approximately 134 beds in total.
- The northern portion of the site will continue to be used for vehicular access to Quarry Road and as a car park. However:
    - The existing port-cochere on the northern façade will be relocated east, moving it further away from the residential properties.
    - The driveway which currently runs along the northern boundary is replaced by parking spaces.

The lower floor level at the south-western corner of the site is below the ground level of the neighbouring properties to the west (St Thomas Cathedral) and to the south (residential dwellings).

With respect to acoustics, key differences between the existing and proposed development are:

- The parking area at the eastern end of the site will be replaced by the new building (an expanded foot print compared to existing).
- Noise from new plant and equipment.

The nearest noise sensitive properties are the residences to the north, east and south. Although the western boundary is adjoined by the St Thomas Cathedra;, it is a car park area that lies immediately adjacent to the common property boundary (which is not noise sensitive).

An aerial photo showing noise measurement positions and surrounding noise receivers is presented below.

Figure 2-1 – Aerial Site Map
Sourced from SixMaps NSW

3 ENVIRONMENTAL NOISE DESCRIPTORS

Environmental noise constantly varies. Accordingly, it is not possible to accurately determine prevailing environmental noise conditions by measuring a single, instantaneous noise level.

To accurately determine the environmental noise a 15 minute measurement interval is utilised. Over this period, noise levels are monitored on a continuous basis and statistical and integrating techniques are used to determine noise description parameters.

In analysing environmental noise, three-principle measurement parameters are used, namely L_{10}, L_{90} and L_{eq}.

The L_{10} and L_{90} measurement parameters are statistical levels that represent the average maximum and average minimum noise levels respectively, over the measurement intervals.

The L_{10} parameter is commonly used to measure noise produced by a particular intrusive noise source since it represents the average of the loudest noise levels produced by the source.

Conversely, the L_{90} level (which is commonly referred to as the background noise level) represents the noise level heard in the quieter periods during a measurement interval. The L_{90} parameter is used to set the allowable noise level for new, potentially intrusive noise sources since the disturbance caused by the new source will depend on how audible it is above the pre-existing noise environment, particularly during quiet periods, as represented by the L_{90} level.

The L_{eq} parameter represents the average noise energy during a measurement period. This parameter is derived by integrating the noise levels measured over the 15 minute period. L_{eq} is important in the assessment of environmental noise impact as it closely corresponds with human perception of a changing noise environment; such is the character of environmental noise.

4 AMBIENT NOISE SURVEY

External noise levels at the site were measured using a combination of attended and long term noise monitoring.

4.1 MEASUREMENT EQUIPMENT

Unattended noise monitoring was conducting using two Acoustic Research Laboratories Pty Ltd noise loggers. The loggers were programmed to store 15-minute statistical noise levels throughout the monitoring period. The equipment was calibrated at the beginning and the end of each measurement using a Rion NC-73 calibrator; no significant drift was detected. All measurements were taken on A-weighted fast response mode.

Attended short term measurements of traffic noise were undertaken to supplement the unattended noise monitoring. Measurements were conducted using a Norsonic 118 Sound Analyser. The analyser was set to fast response and calibrated before and after the measurements using a Norsonic Sound Calibrator type 1251. No significant drift was noted.

4.2 MEASUREMENT LOCATION

The long-term loggers were installed adjacent to the northern boundary and western boundaries of the site as shown in the aerial photograph in section 2.

Measurement locations were selected because:

- They are not located near pre-existing mechanical plant. This is evident on review of the L_{90} noise levels in the noise logging data in Appendices 1 and 2 – there are no sustained periods of consistent elevated L_{90} noise levels (an indicator of plant/equipment noise).

- Any periods of elevated noise levels are infrequent. Given the background (L_{90}) noise levels are based on the quietest 10% of the measurement period, intermittent activity on the site would not affect the L_{90}/background noise level.

- We also note that the noise levels measured at the two locations at the site were generally consistent, indicating that they have not been impacted by local noise sources.

The attended traffic noise measurement was made at 5m from the kerb of Quarry Road.

4.3 MEASUREMENT PERIOD

Unattended noise monitoring was conducted from 16 to 23 February 2018.

Attended noise measurements were undertaken between the hours of 10.00am and 11.00am on 7 March 2018.

4.4 RESULTS

Results of the noise measurements have been summarised below.

4.4.1 Measured Background Noise Levels

Background noise levels are established from the unattended noise monitoring conducted on site.

NSW EPA's rating background noise level assessment procedure requires determination of the background noise level for each day of the measurement period. The Rating Background Noise level is the median of the daily background noise levels measured for the entire monitoring period.

Appendix 1 provides the results of the unattended noise monitoring. Weather affected data was excluded from the assessment.

Summarised rating background noise levels are presented below.

Table 1 - Summarised Rating Background Noise Level

Location	Time of day	Rating Background Noise Level $dB(A)L_{90}$
Logger 1 (Northern Boundary)	Day (7am-6pm)	38
	Evening (6pm-10pm)	38
	Late Evening (10pm-11pm)	38
	Night (10pm-7am)	36
Logger 2 (South/Western Boundary)	Day (7am-6pm)	39
	Evening (6pm-10pm)	39
	Late Evening (10pm-11pm)	38
	Night (10pm-7am)	33

The following table presents the results of the attended noise monitoring.

Table 2 – Attended Traffic Noise Measurements

Location	Time of Measurement	Measured Noise Level
Quarry Road (5m from kerb)	10am-11am (7/3/2018)	$65dB(A)L_{eq(1hr)}$

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5 EXTERNAL NOISE INTRUSION ASSESSMENT

5.1 CRITERIA

We note that there are no specific noise goals for Residential Aged Care Developments in the Fairfield DCP.

The site does not lie on any major road or near any significant external noise source. As such, documents such NSW Department of Planning's '*Development Near Rail Corridors and Busy Roads (Interim Guideline)*' and SEPP Infrastructure are not applicable.

Given this, the building shell will be designed such that external noise impacts (distant traffic, school noise) will be attenuated to noise levels compliant with AS2107, as detailed below.

Table 3 – Summary of Internal Noise Level Criteria

Space	External Noise Intrusion Criteria
Bedroom	35dB(A)$L_{eq(1\ hour\ -\ night)}$
Living Areas	40dB(A)$L_{eq(1\ hour\ -\ day)}$

5.2 RECOMMENDED CONSTRUCTIONS

Recommended acoustic treatments to the building façade are detailed below.

5.2.1 Glazed Windows and Doors

The following constructions are recommended to comply with the project noise objectives.

Minimum glazing thicknesses and acoustic performance requirements for window/glass door systems are presented below. Thicker glazing may be required for structural, safety or other purposes. Where it is required to use thicker glazing than scheduled, this will also be acoustically acceptable.

Aluminium frames for any glass doors and windows must achieve the same R_w as the glass which is installed for that window/door.

All external windows and doors listed are required to be fitted with Q-lon type acoustic seals. (**Mohair Seals are unacceptable**).

The recommended constructions are listed in the table below.

Table 4 – Recommended Glazing Construction

Level	Facade	Space	Recommended Construction	Acoustic Seals
All	All	Living Rooms	6mm	Yes
		Bedrooms	6mm	Yes

It is recommended that only window systems having test results indicating compliance with the required ratings obtained in a certified laboratory be used where windows with acoustic seals have been recommended.

In addition to complying with the minimum scheduled glazing thickness, the R_w rating of the glazing fitted into open-able frames and fixed into the building opening should not be lower than the values listed in Table for all rooms. Where nominated, this will require the use of acoustic seals around the full perimeter of open-able frames and the frame will need to be sealed into the building opening using a flexible sealant.

Table 5 - Minimum R_w of Glazing (with Acoustic Seals)

Glazing Assembly	Minimum R_w of Installed Window
6mm	29

5.2.2 External Roof/Ceiling

Roof/ceiling construction will not require any upgrade for acoustic purposes.

5.2.3 External Walls

Concrete or masonry external wall construction will not require any upgrade for acoustic purposes.

In the event that light weight building elements are incorporated, minimum 75mm thick 11kg/m^3 glass wool insulation should be incorporated in any external wall cavity.

6 NOISE EMISSION ASSESSMENT

The noise emissions from the site are to comply with the following:

- Fairfield Council DCP 2013 and
- NSW Environmental Protection Agency document – *Noise Policy for Industry*.

6.1 NOISE EMISSION CRITERIA

6.1.1 Fairfield Council DCP 2013

Fairfield Council DCP does not contain any applicable noise emission criteria. In the absence of any applicable criteria the NSW EPA Noise Policy for Industry will be adopted.

6.1.2 NSW EPA Noise Policy for Industry

The NPfI provides guidelines for assessing noise impacts from developments. The recommended assessment objectives vary depending on the potentially affected receivers, the time of day, and the type of noise source. The INP has two requirements which both have to be complied with - the Amenity criteria and the Intrusiveness criteria.

6.1.2.1 Intrusiveness Criteria

The guideline is intended to limit the audibility of noise emissions at residential receivers and requires that noise emissions measured using the $L_{eq(15min)}$ descriptor not exceed the background noise level by more than 5dB(A).

Table 6 – EPA Intrusiveness Criteria

Receiver	Time of day	Background Noise Level dB(A)L_{90}	Intrusiveness Criteria (Background + 5dB(A)$L_{eq(15min)}$
Residential Receivers North of Site (Logger 1)	Day	38	43
	Evening	38	43
	Late Evening (10pm-11pm)	38	43
	Night	36	41
Residential Receivers South and East of Site (Logger 2)	Day	39	44
	Evening	39	44
	Late Evening (10pm-11pm)	38	43
	Night	33	38

6.1.2.2 Project Amenity Criterion

The guideline is intended to limit the absolute noise level from all noise sources to a level that is consistent with the general environment.

The Noise Policy for Industry sets out acceptable noise levels for various land uses. Table 2.1 on page 16 of the policy has four categories to distinguish different residential areas. They are rural, suburban, urban and urban/industrial interface.

For the purposes of a conservative assessment, ALC will assess noise emissions in accordance with the 'suburban' category.

Table 7 – EPA Project Amenity Criteria

Type of Receiver	Assessment Location	Time of day	Recommended Acceptable Noise Level dB(A)$L_{eq(15min)}$
Residential (suburban)	Property Boundary	Day	53
		Evening	43
		Night	38
St Thomas Cathedral	Inside	When in Use	40

6.2 SLEEP AROUSAL ASSESSMENT

Potential sleep arousal impacts should be considered for noise generated after 10pm.

Sleep arousal is a function of both the noise level and the duration of the noise.

As recommended in the NPfI, to assess potential sleep arousal impacts, a two-stage test is carried out:

- Step 1 – Section 2.5 *Maximum noise level event assessment* from the NPfI states the following:

  Where the subject development/premises night-time noise levels at a residential location exceed:

  - $L_{Aeq,15min}$ *40dB(A) or the prevailing RBL plus 5 dB, whichever is the greater, and/or*
  - L_{AFmax} *52 dB(A) or the prevailing RBL plus 15 dB, whichever is greater,*

  a detailed maximum noise level event assessment should be undertaken.

Based on the above the following noise objectives apply:

Table 8 – Sleep Arousal Criteria (*Average*/L_{eq} Noise Levels)

Location	Rating Background Level dB(A)L_{90}	Rating Background Level + 5dB(A)	Governing Criteria dB(A)$L_{eq(15mins)}$
Residential Receivers North of Site (Logger 1)	36 (38dB(A) – 10pm-11pm)	41 (43dB(A) – 10pm-11pm)	41 (43dB(A) – 10pm-11pm)
Residential Receivers South and East of Site (Logger 2)	33	38	40

Table 9 – Sleep Arousal Criteria (*Maximum*/L_{Max} Noise Events)

Location	Rating Background Level dB(A)L_{90}	Rating Background Level + 15dB(A)	Governing Criteria dB(A)$L_{(Max)}$
Residential Receivers North of Site (Logger 1)	36	51	52
Residential Receivers South and East of Site (Logger 2)	33	48	52

- Step 2 - If there are noise events that could exceed the average/maximum criteria detailed in the tables above, then an assessment of sleep arousal impact is required to be carried out taking into account the level and frequency of noise events during the night, existing noise sources, etc. This test takes into account the noise level and number of occurrences of each event with the potential to create a noise disturbance. As is recommended in the explanatory notes of the EPA Industrial Noise Policy, this more detailed sleep arousal test is conducted using the guidelines in the EPA Road Noise Policy. Most relevantly, the Road Noise Policy states:

  For the research on sleep disturbance to date it can be concluded that:

  - *Maximum internal noise levels below 50-55dB(A) are unlikely to awaken people from sleep.*
  - *One to two noise events per night with maximum internal noise levels of 65-70dB(A) are not likely to affect health and wellbeing significantly.*

6.3 NOISE EMISSION ASSESSMENT/RECOMMENDATIONS

The primary noise source associated with the site will be:

- Vehicle Noise.
- Mechanical plant.

6.3.1 Vehicle/Car Park noise

With respect to vehicle noise, access to and from the site remains unchanged from the existing conditions (driveway to Quarry Road between 54 and 58 Quarry Road).

We note:

- The port-cochere/driveway currently on the northern boundary has been relocated so that it is now further away from the northern residential property boundary and the driveway on the northern boundary replaced with parking spaces. Overall, this would be expected to reduce vehicle noise compared to existing conditions, as the northern boundary will no longer be the access point to the port-cochere.

- Obviously there will no longer be noise generated by the eastern parking area, as this is to be removed (replaced with the new, expanded building).

Despite this, a detailed assessment is presented below.

Typically, it is the late night use of the car park /driveway and its potential impact on sleep disturbance that is the primary consideration in the assessment impacts on residential development.

The section below will address both Individual *Peak* noise events (door slam, and its sleep arousal impact) and *Average* noise events (late night periods – staff changeover).

6.3.1.1 *Peak* Noise Events (Intermittent/Short Duration Noise Events)

Peak noise emissions from the use of the car park/driveway is predicted based on the following assumptions:

- Engine noise from cars manoeuvring within the car park/driveway: 82dB(A)L_{eq} sound power.
- Engine noise from community bus manoeuvring within the car park/driveway: 87dB(A)L_{eq} sound power.
- Car door slam/engine start (night time peak noise event): 90dB(A)L_{max} sound power.
- The acoustic treatments detailed in section 6.4 are adopted.

Predicted noise levels at adjacent residences (Quarry Road, adjacent to the car park/driveway) are set out below. In the case of the residences adjacent to the driveway, the prediction is made at the first floor window (overlooking the boundary fencing), which is a worst case scenario.

As discussed in section 6.2, assessment of sleep disturbance is a two step process:

- Firstly, a "background+15" (BG+15) test is undertaken.
- Secondly, in the event that a '"Background+15 test is not satisfied, a more detailed assessment of sleep disturbance is undertaken (taking into account predicted internal noise levels within residences and the probability of awakening).

Table 10 – Car Park Noise– Noise Impact Assessment on Quarry Road Residences (Background+15 L_{max} Assessment)

Activity	Noise Source Location	Noise Receiver Location	Permitted Noise Level	Predicted Noise Level	Comment
Car Start/Door Slam	Car Parking Space – northern boundary.	Rear façade of residences adjacent to car park	52dB(A)$L_{(Max)}$	52dB(A)$L_{(Max)}$	Complies with BG+15 test.
Car Engine	Driveway (7m from residence)	Residences adjacent to driveway.	52dB(A)$L_{(Max)}$	62dB(A)$L_{(Max)}$	Exceeds BG+15 test. See additional analysis below.
Community Bus Engine	Driveway (7m from residence)	Residences adjacent to driveway.	52dB(A)$L_{(Max)}$	67dB(A)$L_{(Max)}$	

With respect to the potential sleep disturbance as a result of the use of the car park/driveway:

- As identified in section 6.2 of this report, if there is predicted to be an exceedance of the Sleep Arousal Criteria (Step 1 as detailed in section 6.2), the EPA *Noise Policy for Industry* guidelines recommended a more detailed acoustic assessment. In this case, there are two additional EPA documents which are useful in the assessment of sleep disturbance impact:

- Section 5.4 of the EPA document *Road Noise Policy (RNP)* presents a detailed method for the assessment of the probability of sleep awakening – extracted, Appendix 3.

- Tables of noise level versus probability of sleep disturbance in the EPA document *Environmental Criteria for Road Traffic Noise (ECRTN)* – extracted, Appendix 4.

With respect to the above, we note:

- In the event that a bedroom window to a residence is left open, it is typical that there is a 10dB(A) difference between the external noise level and the internal noise level.

- As noted in table 11:

    - The momentary noise level from a car on the driveway is predicted to be 62dB(A)L_{max} outside the window of the nearest residence. The corresponding noise level inside the room of the residence would 52dB(A)L_{max}. On review of the sleep disturbance probability tables in the EPA *ECRTN* (Appendix 4), the probability of an awakening as a result of this noise event is 0-1%) – Appendix 4, tables B3 and B4.

    - Further, the EPA *Road Noise Policy* also states:

      Maximum internal noise levels below 50-55dB(A) are unlikely to awaken people from sleep (Appendix 3, *Road Noise Policy* page 35).

    - With internal noise levels within residences from passenger vehicles predicted to be less than 52dB(A)L_{max}, predicted noise emissions are compliant with the EPA sleep disturbance guidelines.

- Community bus noise:

    - As the momentary noise level from a community bus on the driveway is predicted to be 67dB(A)L_{max} outside the window, the corresponding noise level inside the room of the residence would 57dB(A)L_{max}. On review of the sleep disturbance probability tables in the EPA document, the probability of an awakening as a result of this noise event is less than 2.5% (ECRTN Appendix 4, tale B3).

    - Further, the EPA *Road Noise Policy* document also states:

      One to two noise events per night with maximum internal noise levels of 65-70dB(A) are not likely to affect health and wellbeing significantly.

In light of the above, the proposed noise impact is considered reasonable. However as an additional abatement measured we recommend that the noise management controls outlined in section 6.4 are adopted.

6.3.1.2 Average/$L_{eq(15min)}$ Noise Events

Peak night time noisy periods occur during staff changeover. This occurs at 11pm, with typically 13 staff leaving, 13 arriving. This noise is assessed as a 15 minute average.

The 15 minute average (the $L_{eq(15min)}$) noise emission from the use of the car park/driveway is calculated based on the following assumptions:

- Engine noise from cars manoeuvring within the car park/driveway: 82dB(A)L_{eq}.
- Car door close: 87dB(A)SEL.
- It is assumed that there are 26 vehicle movements in a peak night time period (13 in, 13 out at the 11pm staff change over – the peak night time period). It is reasonable to assume that this occurs over a 30 minute period (13 vehicles arriving between 10.45-11.00pm, 13 leaving between 11:00pm-11:15pm).
- It takes approximately 20-30 seconds to drive from the parking space to the site exit.
- That the acoustic treatments detailed in section 6.4 are adopted.

Predicted noise levels at adjacent residences (Quarry Road, adjacent to the car park/driveway) are set out below. Predictions are made at the residences nearest to the car park/driveway. In the case of the residences adjacent to the driveway, the prediction is made at the first floor window (overlooking the boundary fencing), which is a worst case scenario.

Table 11 – Car Park Noise – Noise Impact Assessment on Quarry Road Residences (Average / $L_{eq(15min)}$ Noise Emissions)

Activity	Receiver Location	Noise Source Location	Permitted Noise Level	Predicted Noise Level	Comment
Cumulative noise – car engine, door close.	Quarry Residence – south façades	Parking Lot.	43dB(A)$L_{eq(15min)}$	38dB(A)$L_{eq(15min)}$)	Complies
	Quarry Residence – east/west façade (overlooking driveway)	Driveway (7m from residence)	43dB(A)$L_{eq(15min)}$	42dB(A)$L_{eq(15min)}$	Complies

In light of the above, the proposed noise impact is considered reasonable. However we recommend that the noise management controls outlined in section 6.4 are adopted.

6.3.2 Plant and Equipment Noise

Detailed acoustic review of plant and equipment noise has not been undertaken at this stage, as plant selections have not been determined. Detailed acoustic review should be undertaken at CC stage to determine the acoustic treatments necessary (if any) to control noise emissions to satisfactory levels.

Satisfactory levels will be achievable through appropriate plant selection and location and, if necessary, standard acoustic treatments such as duct lining, acoustic silencers and enclosures.

It is likely that a solid backing (6mm fc sheet or similar) will be required behind the louvred screens along the northern edge of the eastern, central and western roof top plant decks. The need for this will be depending on final equipment selections.

Similarly, a solid backing is likely to be reed to the louvered screen along the southern edge of the southern plant deck.

Noise emissions from all mechanical services to the closest residential and school receivers should comply with the requirements of section 6.1.2.

6.4 RECOMMENDATIONS

In order to ensure compliant noise emissions are nearby development:

- Boundary fencing – 1.8m solid boundary fencing is recommended to the northern boundary and along the main driveway from Quarry Road (similar to existing). In the case of the fencing along the northern boundary of the site adjacent to the car parking area, the 1.8m high fencing should be constructed on top of the retaining wall along the northern boundary of the car park.

- Detailed acoustic review of all plant and equipment should be conducted prior to the issuing of a Construction Certificate and treatments designed such that the acoustic requirements of the EPA Noise Policy for Industry are satisfied.

- In the event a community bus is used on site, the bus should not be left idling while waiting. There should be no more than one bus movement to/from the site after 10pm per day. There should be a sign erected on site to this effect (no idling) and a condition of consent created to impose this requirement.

- Staff Car parking areas are recommended to be designated adjacent to the RACF (to maximise the distance from the Quarry Street residences). Management are to ensure that staff entering/leaving the site between 10pm and 7am do not congregate/speak in external areas. There should be a sign erected on site to discourage vehicle idling and a condition of consent created to impose this requirement.

Provided that the above is adopted, noise emissions from new building elements will be compliant with EPA requirements and operational noise from vehicles is expected to reduce compared to current levels.

7 CONCLUSION

This report presents an acoustic assessment of noise impacts associated with the proposed redevelopment of the existing Residential Aged Care development at 56 Quarry Road, Bossley Park.

Provided that the treatments set out in section 5.2 of this report are adopted, internal noise levels (as a result of external noise impacts) will comply with AS2107.

External noise emissions criteria have been set out in this report to satisfy the requirements from:

- Fairfield Council DCP 2013 and
- The NSW EPA document *Noise Policy for Industry*

Provided that the recommendations set out in section 6.4 of the report are adopted, noise emission goals for the development will be achieved.

Please contact us should you have any further queries.

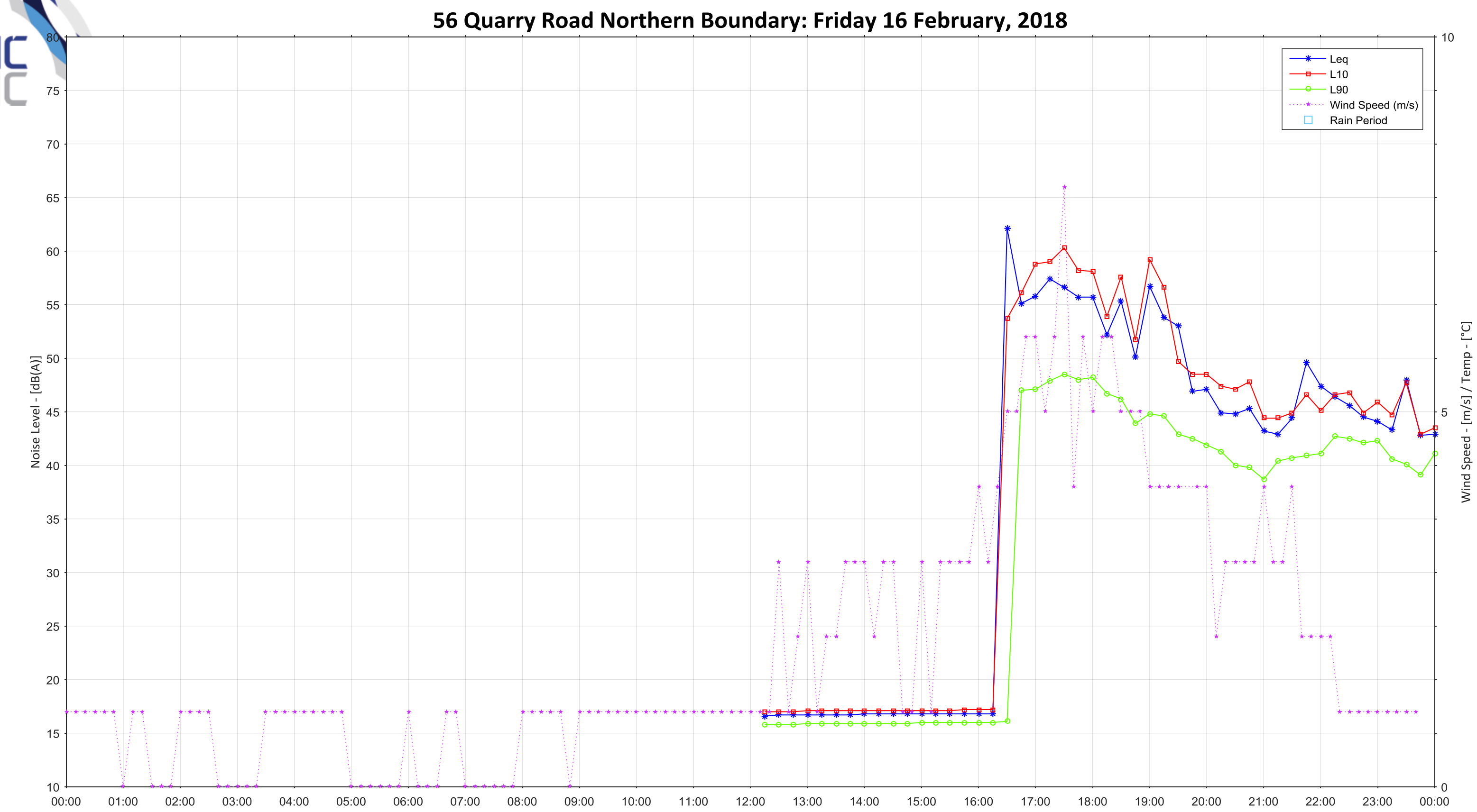
Yours faithfully,

Acoustic Logic Consultancy Pty Ltd
Thomas Taylor

APPENDIX ONE

UNATTENDED NOISE MONITORING DATA

– LOGGER 1



56 Quarry Road Northern Boundary: Friday 16 February, 2018
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
Leq
L10
L90
Wind Speed (m/s)
Rain Period
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
10
5
0
00:00
01:00
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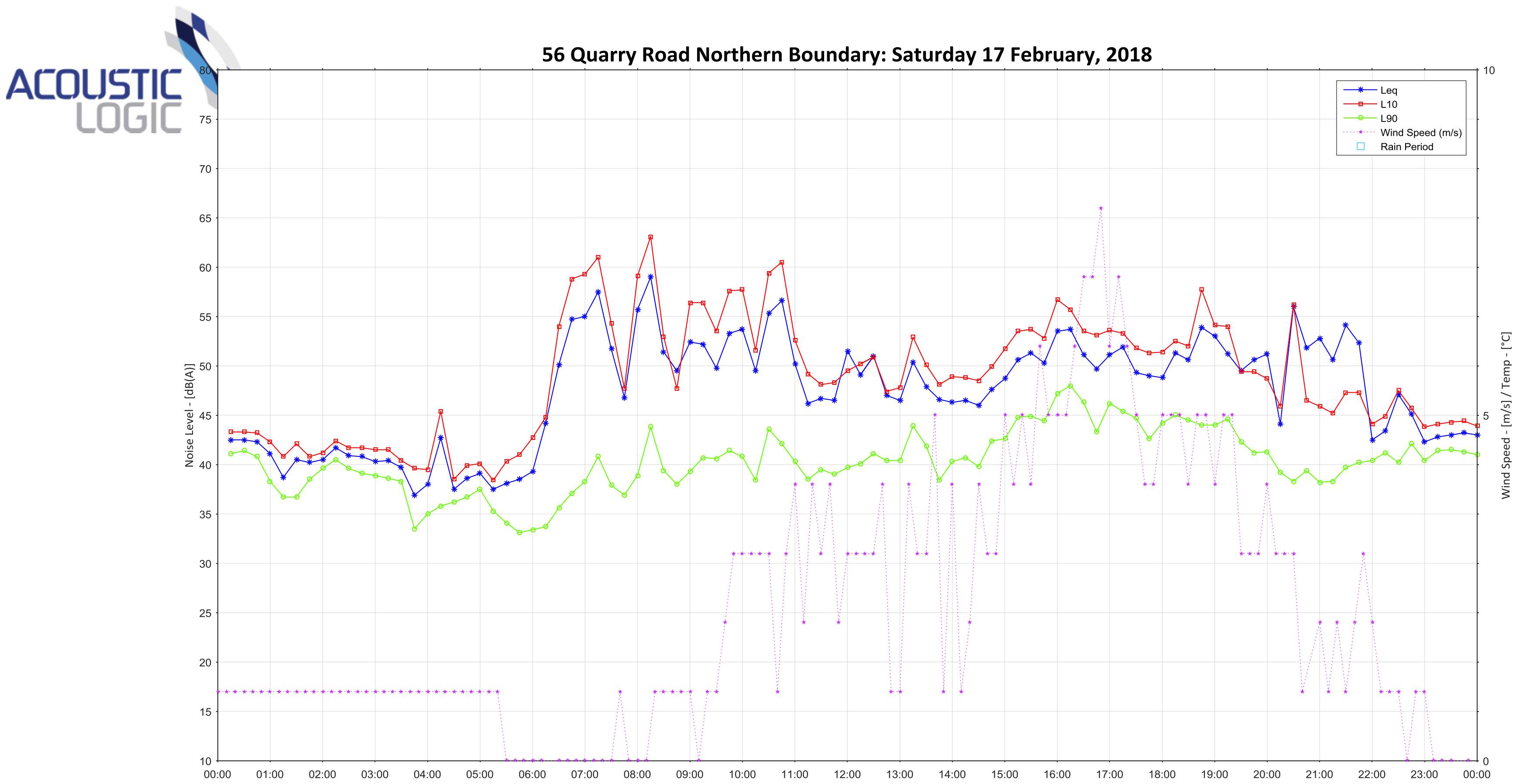

ACOUSTIC LOGIC
56 Quarry Road Northern Boundary: Saturday 17 February, 2018
Leq
L10
L90
Wind Speed (m/s)
Rain Period
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
10
5
0
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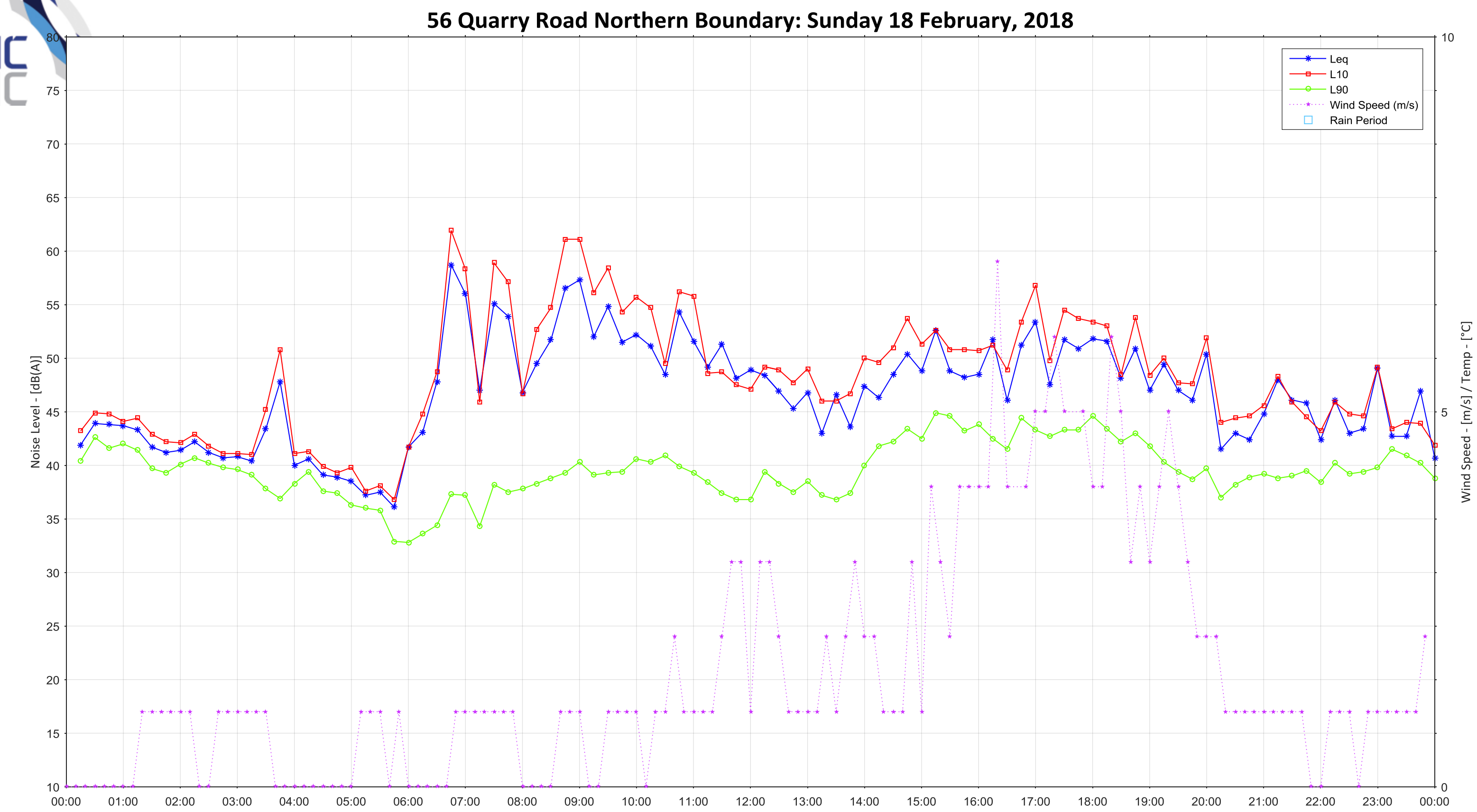

56 Quarry Road Northern Boundary: Sunday 18 February, 2018
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
Leq
L10
L90
Wind Speed (m/s)
Rain Period
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
10
5
0
00:00
01:00
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14:00
15:00
16:00
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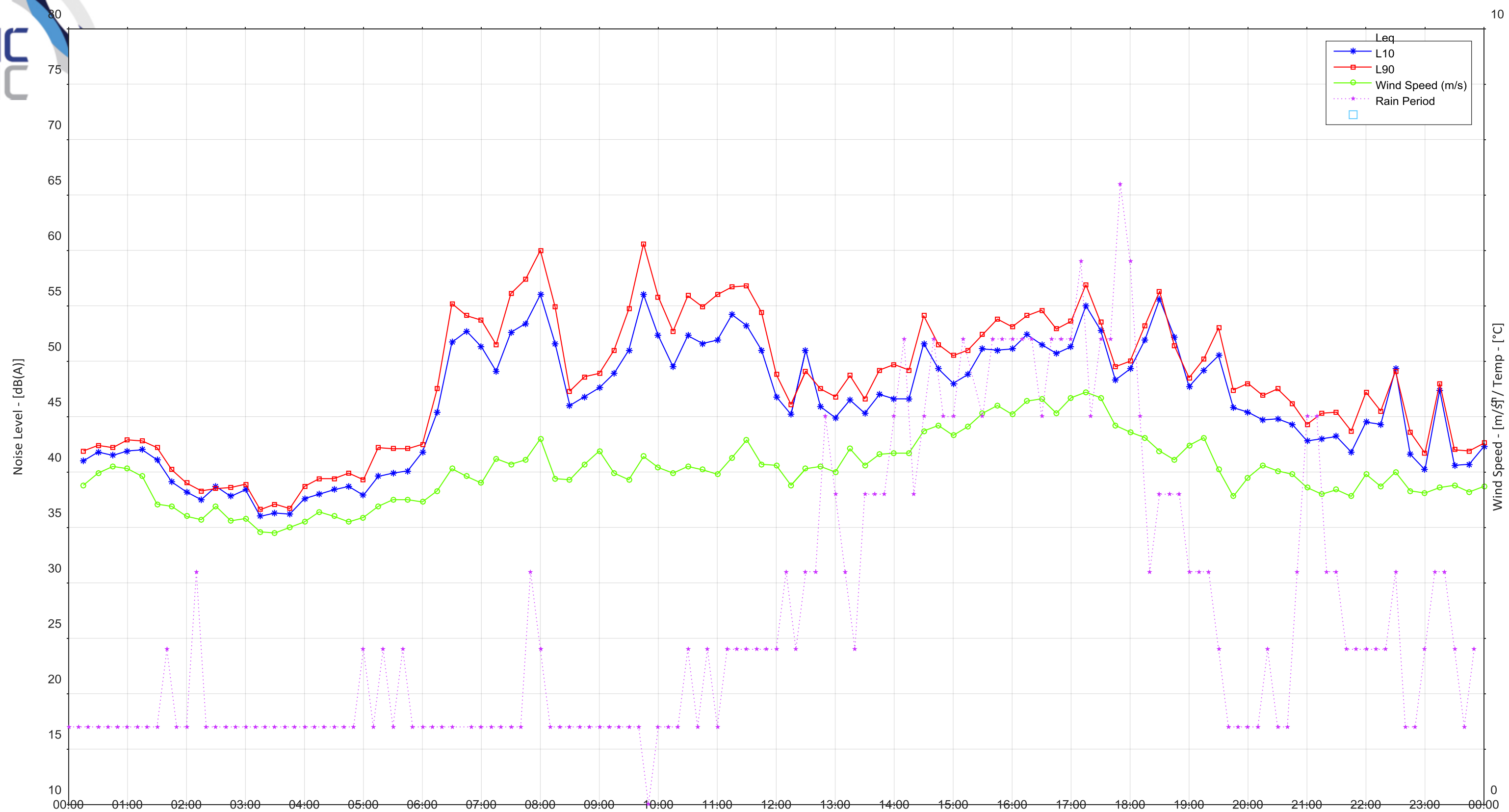
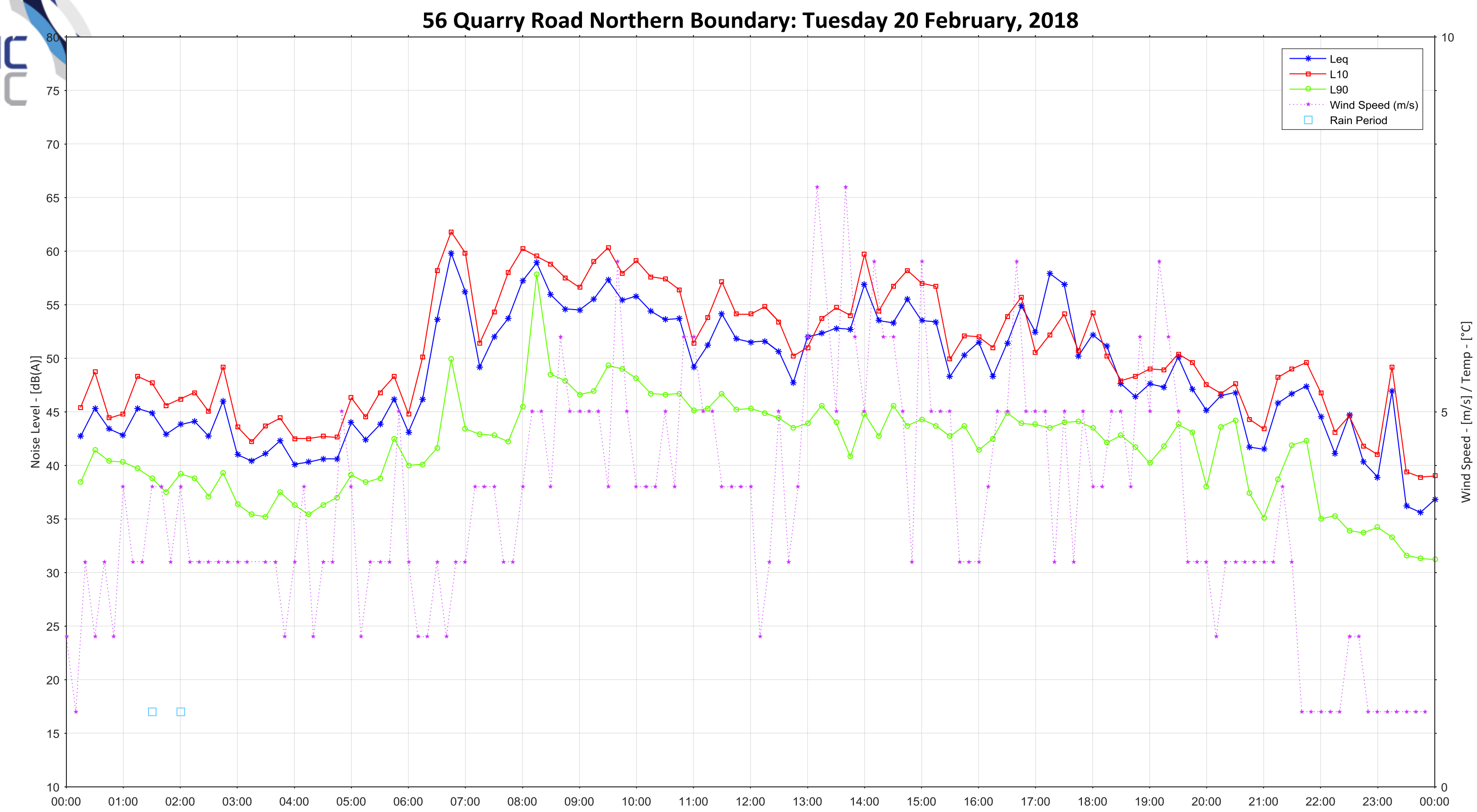
19:00
20:00
21:00
22:00
23:00
00:00

56 Quarry Road Northern Boundary: Monday 19 February, 2018





56 Quarry Road Northern Boundary: Tuesday 20 February, 2018
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
Leq
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Wind Speed (m/s)
Rain Period
00:00
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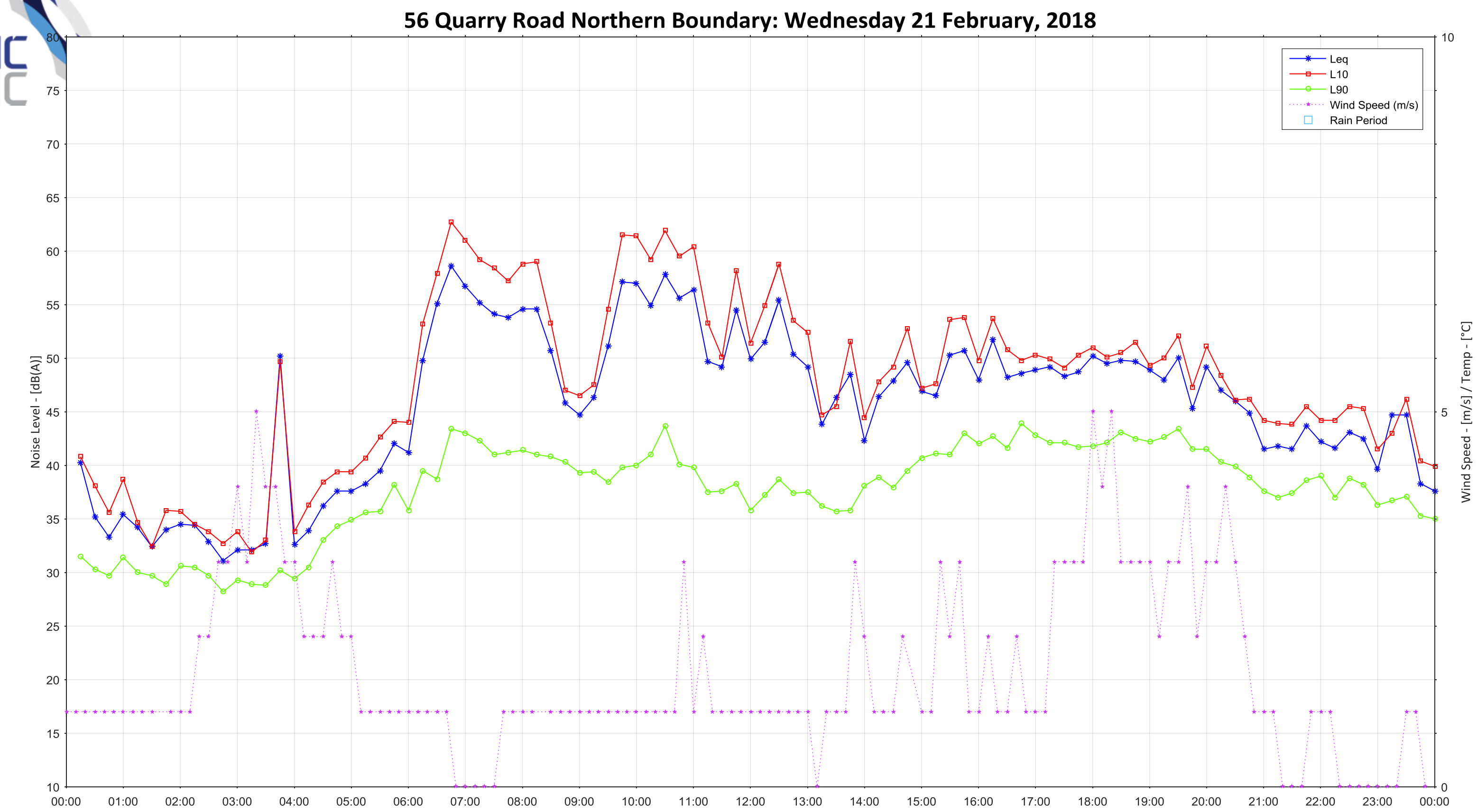

56 Quarry Road Northern Boundary: Wednesday 21 February, 2018
Leq
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Wind Speed (m/s)
Rain Period
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
80
75
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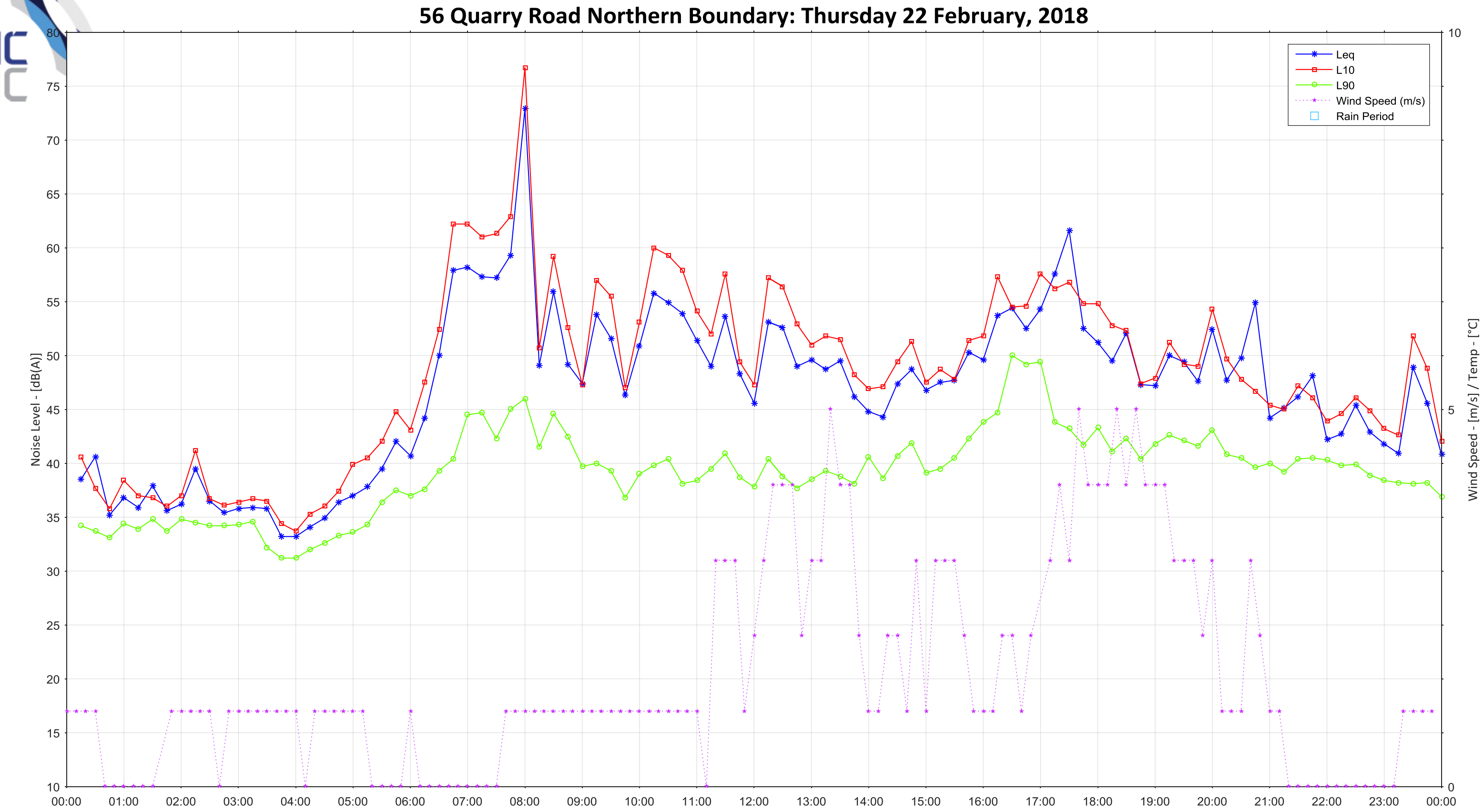
56 Quarry Road Northern Boundary: Thursday 22 February, 2018
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L90
Wind Speed (m/s)
Rain Period
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
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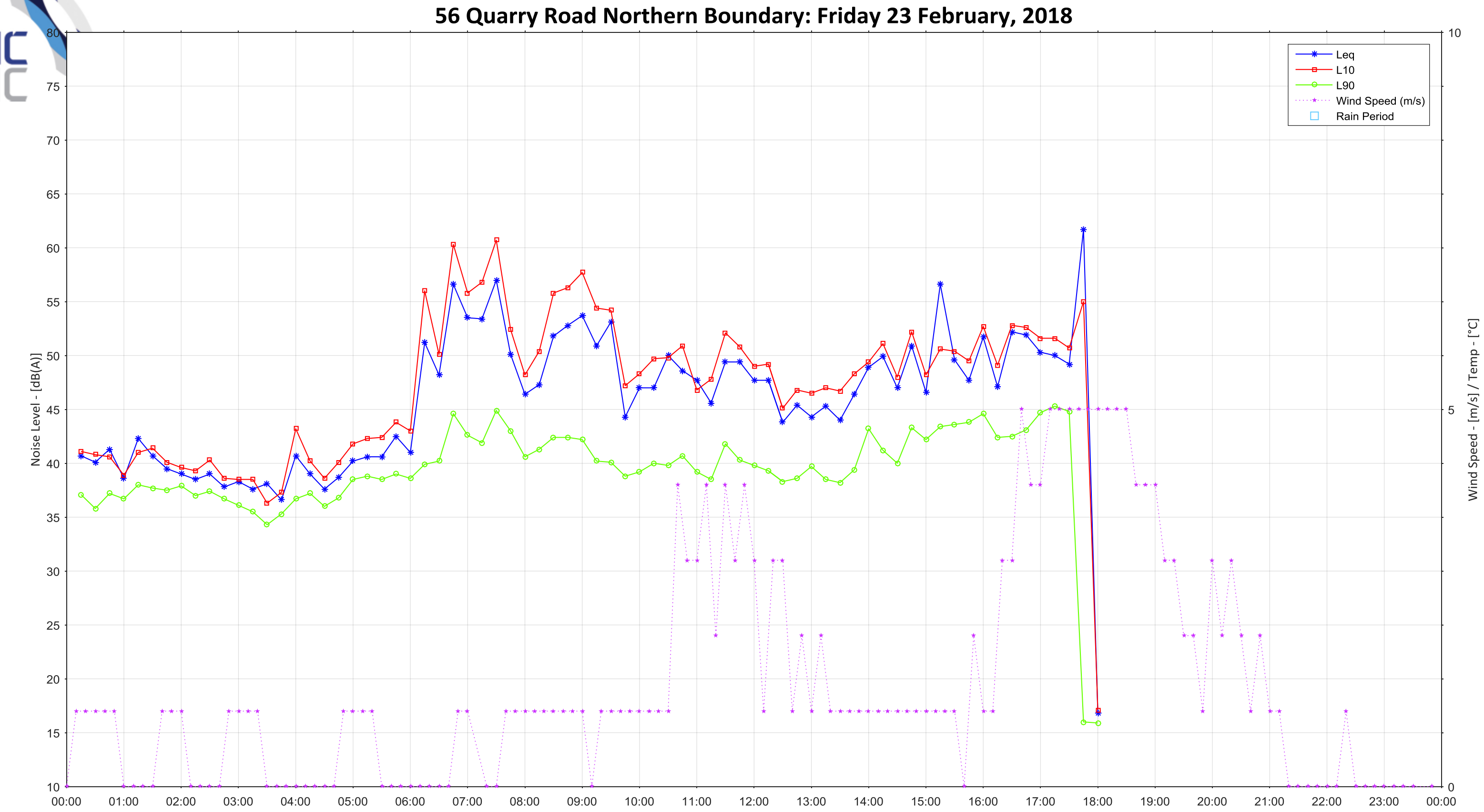
56 Quarry Road Northern Boundary: Friday 23 February, 2018
Leq
L10
L90
Wind Speed (m/s)
Rain Period
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
80
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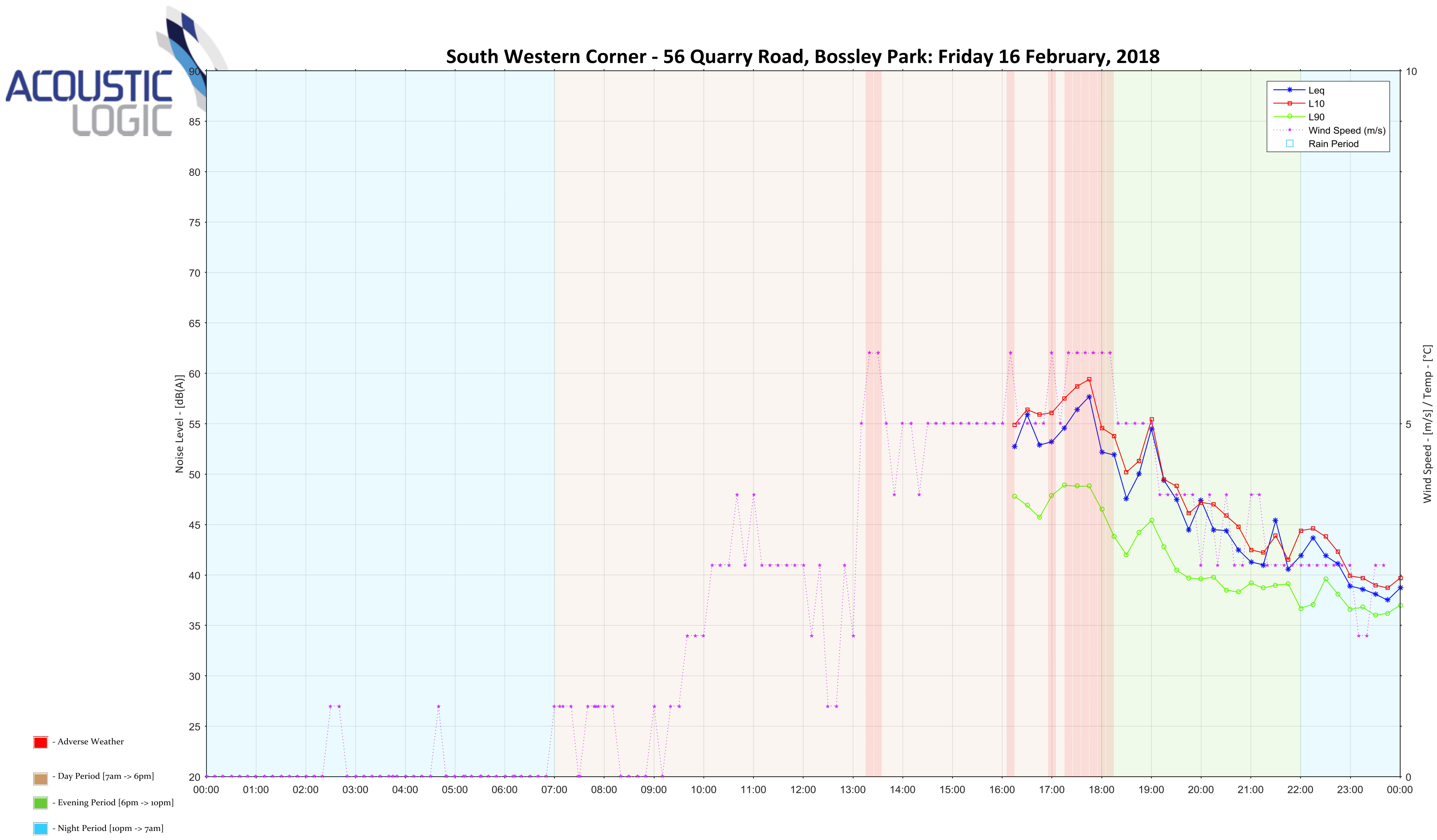
APPENDIX TWO

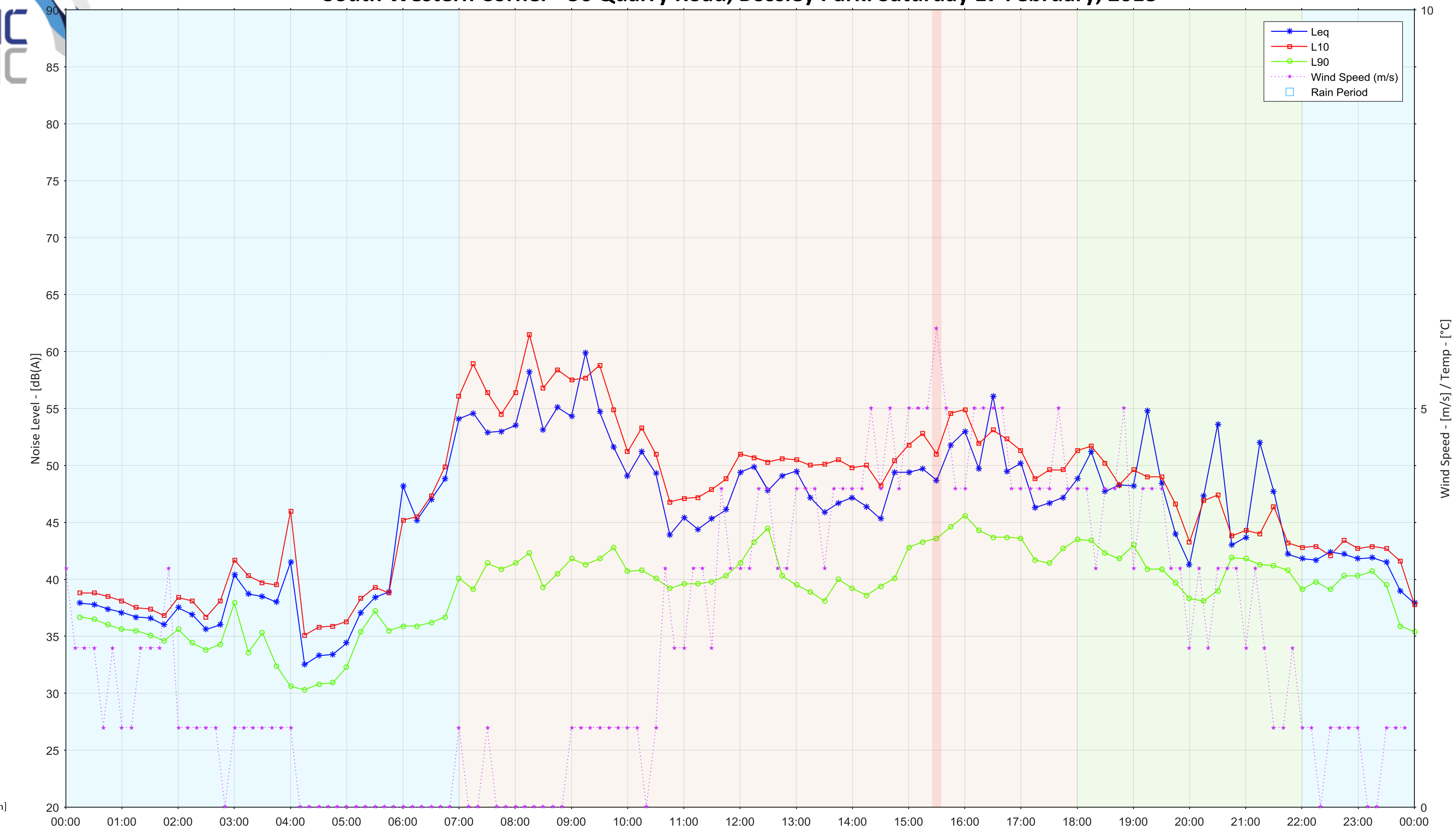
UNATTENDED NOISE MONITORING DATA

– LOGGER 2



South Western Corner - 56 Quarry Road, Bossley Park: Friday 16 February, 2018
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
Leq
L10
L90
Wind Speed (m/s)
Rain Period
- Adverse Weather
- Day Period [7am -> 6pm]
- Evening Period [6pm -> 10pm]
- Night Period [10pm -> 7am]

South Western Corner - 56 Quarry Road, Bossley Park: Saturday 17 February, 2018



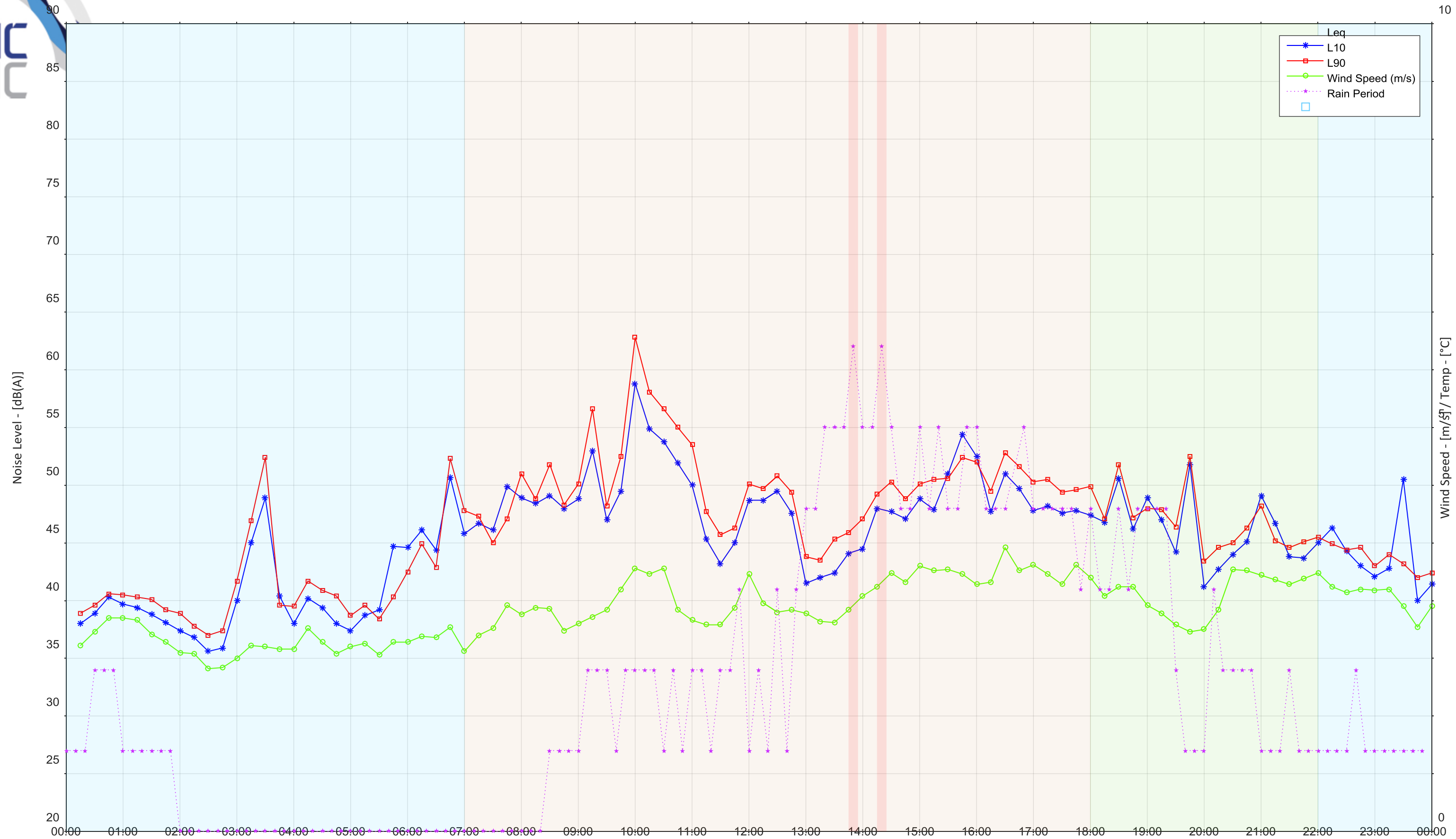
- Adverse Weather

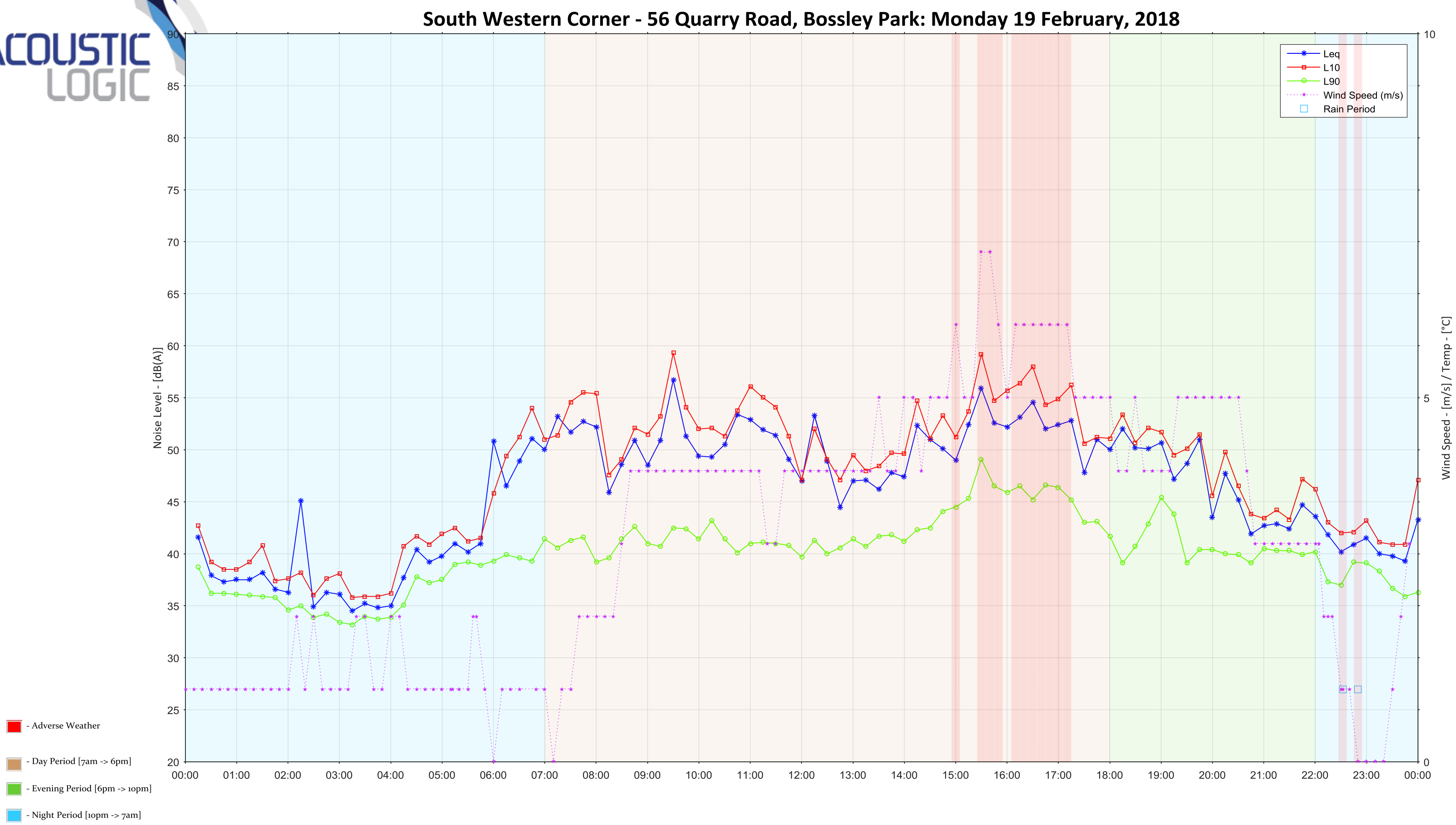
- Day Period [7am -> 6pm]

- Evening Period [6pm -> 10pm]

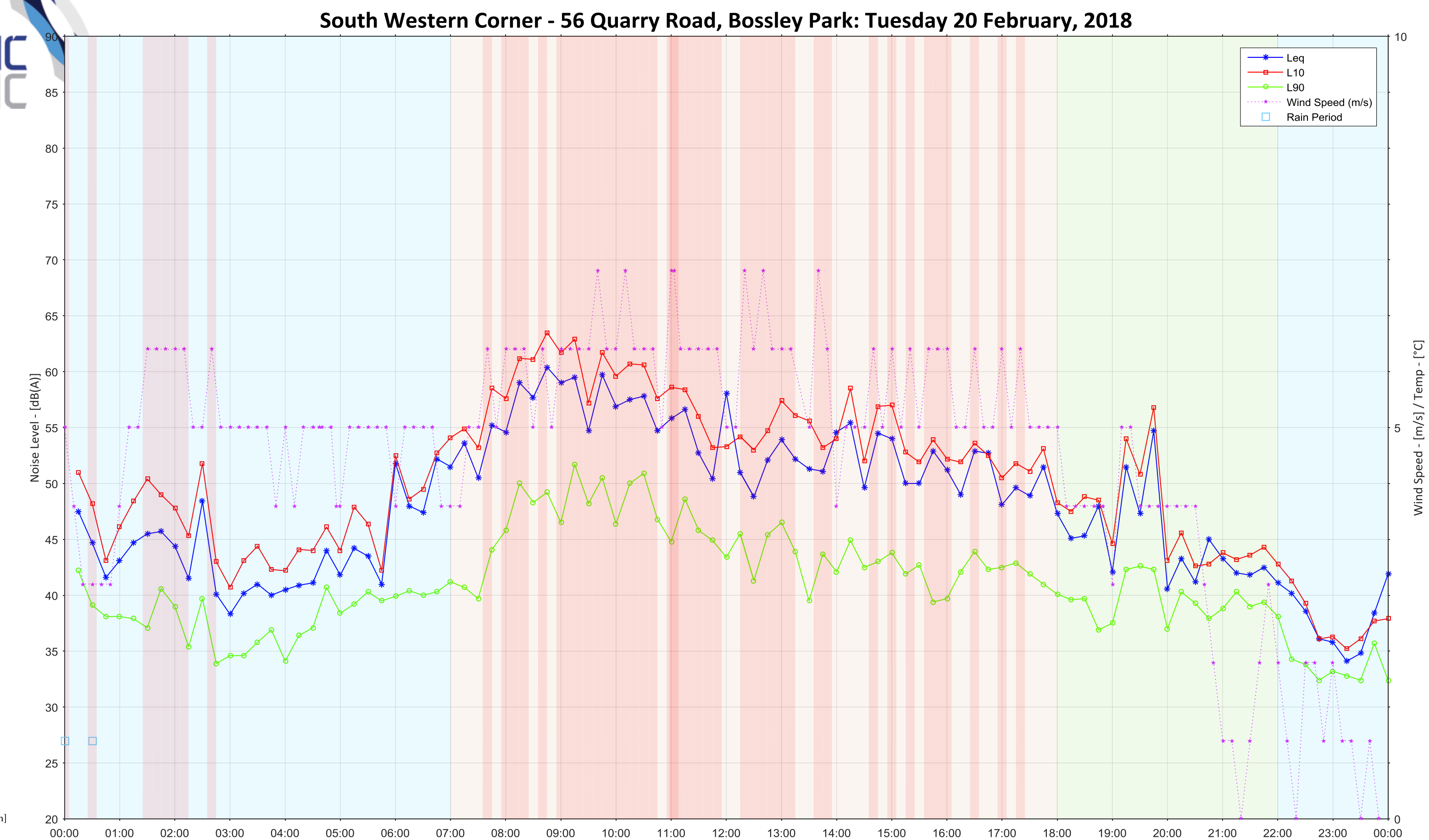
- Night Period [10pm -> 7am]

South Western Corner - 56 Quarry Road, Bossley Park: Sunday 18 February, 2018





South Western Corner - 56 Quarry Road, Bossley Park: Monday 19 February, 2018
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
Leq
L10
L90
Wind Speed (m/s)
Rain Period
00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
0 5 10
- Adverse Weather
- Day Period [7am -> 6pm]
- Evening Period [6pm -> 10pm]
- Night Period [10pm -> 7am]

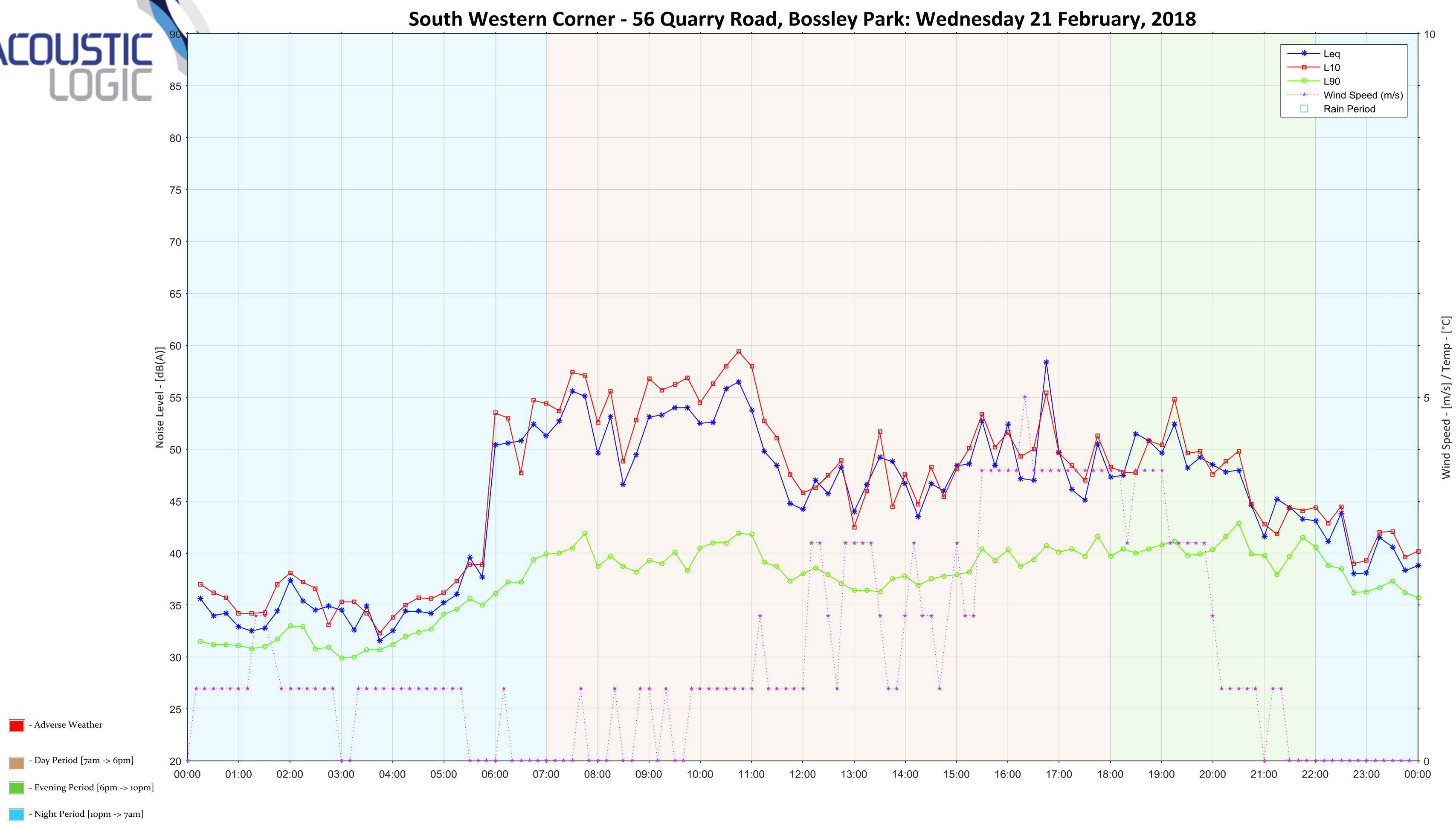


- Adverse Weather

- Day Period [7am -> 6pm]

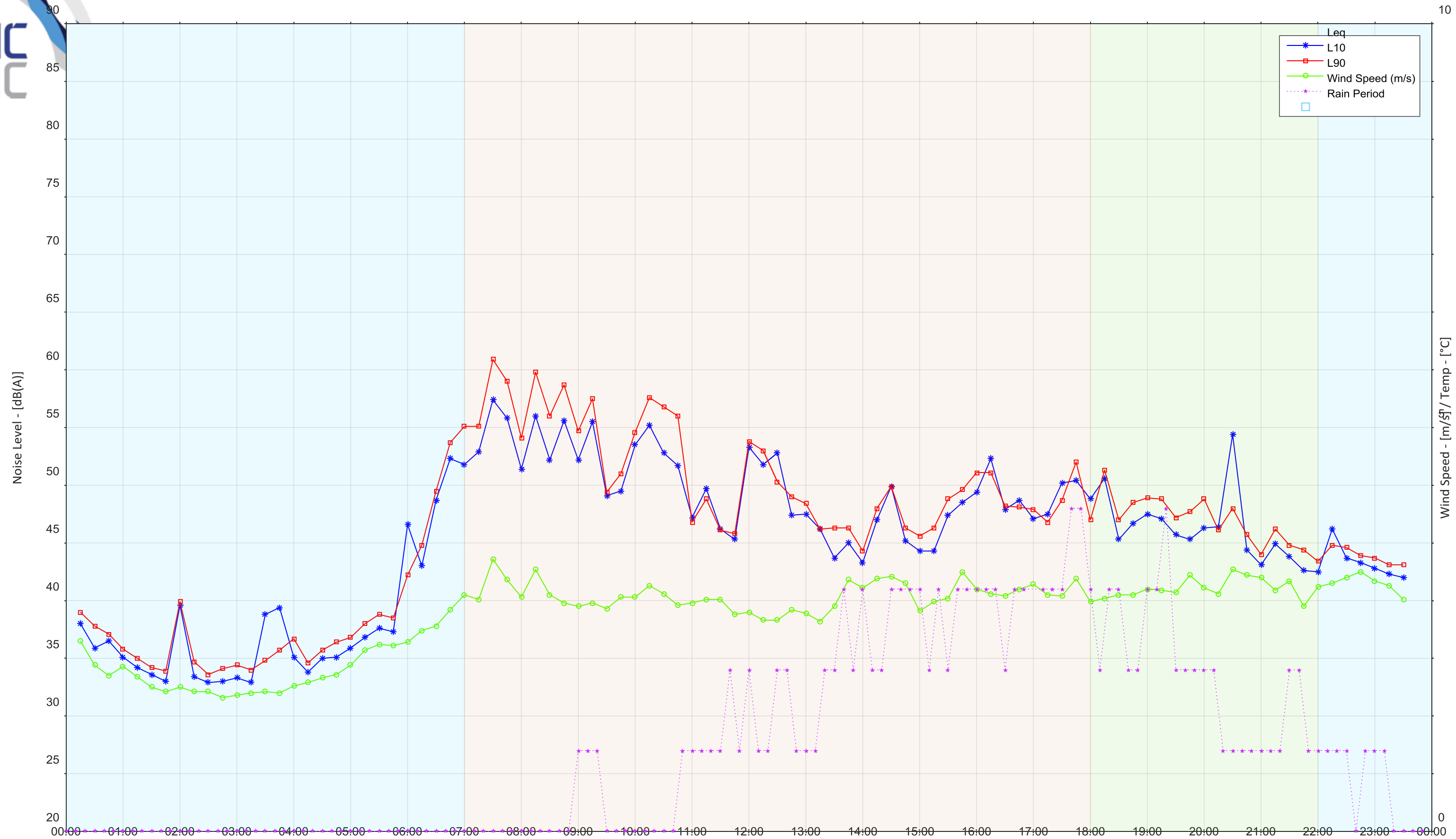
- Evening Period [6pm -> 10pm]

- Night Period [10pm -> 7am]



South Western Corner - 56 Quarry Road, Bossley Park: Wednesday 21 February, 2018
Noise Level - [dB(A)]
Wind Speed - [m/s] / Temp - [°C]
Leq
L10
L90
Wind Speed (m/s)
Rain Period
- Adverse Weather
- Day Period [7am -> 6pm]
- Evening Period [6pm -> 10pm]
- Night Period [10pm -> 7am]

South Western Corner - 56 Quarry Road, Bossley Park: Thursday 22 February, 2018



APPENDIX THREE

EPA ROAD NOISE POLICY NOISE EXTRACT (SLEEP DISTURBANCE)

NSW GOVERNMENT

Environment, Climate Change & Water

NSW Road Noise Policy

All cover photographs by DECCW.

Published by:
Department of Environment, Climate Change and Water NSW
59–61 Goulburn Street
Sydney
PO Box A290
Sydney South 1232

Report pollution and environmental incidents
Environment Line: 131 555 (NSW only) or info@environment.nsw.gov.au
See also www.environment.nsw.gov.au

Phone: 131 555 (NSW only – publications and information requests)
Phone: (02) 9995 5000 (switchboard)
Fax: (02) 9995 5999
TTY: (02) 9211 4723
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

DECCW 2011/236
ISBN 978 1 74293 212 5
March 2011

An Australian study (Brown 1987) considered reactions to a sudden increase in road traffic noise levels. It was found that while the reported reaction to traffic noise was consistent with other studies before the change in exposure, after the change it was higher than would have been predicted from studies performed under conditions of constant exposure. The difference was equivalent to a difference of between 3 and 15 dB in noise exposure. This variation reflects the uncertainty in predicting reactions to a given exposure under steady conditions.

In addition, one study (Geoplan Resource Planning 1992) investigated reactions to traffic noise in residents living near the newly opened F3 freeway. The level of reaction was compared to that of residents living near the Pacific Highway, before the opening of the freeway, who were exposed to similar noise levels. The reaction of residents near the F3 freeway was found to be higher than that of residents near the Pacific Highway for the same noise level, the difference being equivalent to a difference of approximately 9 dB in noise level.

The results of these studies are consistent and indicate that where noise exposure is suddenly and substantially increased, reaction is higher than would be predicted from studies of steady conditions. It is for this reason that the relative increase criteria have been introduced into this policy.

Converse findings have been reported for reactions to a sudden decrease in exposure, that is, the reaction to the altered situation is less than would have been predicted from the reaction to steady conditions.

5.4 Sleep disturbance

The disruption of a person's normal sleep patterns, or sleep disturbance, due to road traffic noise, has been the subject of numerous research studies conducted over the last 30 years. Despite intensive research, the triggers for and effects of sleep disturbance have not yet been conclusively determined. Sleep disturbance occurs through changes in sleep state and awakenings. Awakenings are better correlated to subjective assessments of sleep quality than are changes in sleep state, which generally require objective measurement.

Both subjective and measured physiological responses have been observed following exposure to road traffic noise and low frequency noise during sleep. Subjective responses include a negative mood, reduced task performance, irritation, tiredness, less social orientation, anxiety and tension (Waye 2004). Measured differences include an increased length of time to accomplish the transition from full wakefulness to sleep, reduced duration of deep (slow-wave) sleep, corresponding increases in rapid eye movement sleep and nocturnal awakening, and a variation in cortisol levels during sleep and after awakening in the morning, indicating a potential disruption of the body's circadian rhythm (Waye et al 2002, 2004; Waye 2004).

Individuals describing themselves as sensitive to noise tend to be more affected by it. The potential for sleep disturbance of shift workers who typically sleep during day-time periods was just as great as for night-time sleepers. It is also apparent that sleep disturbance due to noise is not diminished over time and some cumulative negative effects may occur (Ohrstrom et al 1988).

A summary of the current literature concerning sleep disturbance due to noise indicates that the main noise characteristics that influence sleep disturbance are the number of noisy events heard distinctly above the background level, the emergence of these events and the highest noise level.

The L_{Aeq}, which is the energy average level of the noise signal, accounts for the number and level of the louder events in a signal, due to the high amount of energy such events carry. However, the consensus is that L_{Aeq} by itself is an inadequate predictor of the potential of a varying noise to disturb sleep. For continuous traffic flow, L_{Aeq} appears to be acceptably correlated with sleep disturbance, since under these conditions there are few emergent noise events above the main hum of the traffic. However, for intermittent traffic flow, which often occurs at night, some other measure that takes into account the emergence, described by measures such as (L_{AFmax}–L_{Aeq}) or (L_{AFmax}–L_{AF90}), the highest level of noise and the number events may be needed to obtain a better correlation with sleep disturbance.

The World Health Organisation guidelines (World Health Organisation 1999) recommended that:

> 'where noise is continuous, the equivalent sound pressure level should not exceed 30 dB(A) indoors, if negative effects on sleep are to be avoided'.

Further studies by the enHealth Council (2004) and the guidelines published by the World Health Organisation (1999) were reviewed and analysed in terms of the guidance on noise exposure and sleep disturbance. The enHealth report states that:

> 'as a rule for planning for short-term or transient noise events, for good sleep over 8 hours the indoor sound pressure level measured as a maximum instantaneous value should not exceed approximately 45 dB(A) $L_{A,\ (Max)}$ more than 10 or 15 times per night'.

The *Night noise guidelines for Europe* (World Health Organisation 2009) comprehensively reviewed policy and research on:

- methods and criteria for measuring night-time noise
- the relationship between sleep and health
- the effects of night-time noise on sleep
- the effects of night-time noise on health and wellbeing.

Long-term effects, such as cardiovascular disorders, are more correlated with noise indicators summarising the situation over a long period, such as $L_{Anight,outside}$ whereas instantaneous effects such as sleep disturbance are better linked to the maximum noise level per event (L_{Amax}).

The NSW Roads and Traffic Authority is tackling the issue of engine brake noise. Photo: DECCW

The World Health Organisation report (2009) uses $L_{Anight,outside}$ as a primary measure of night-time noise. This is the yearly average of outside façade noise levels during the night-time period, and roughly equivalent to the $L_{Aeq9hour}$ night-time descriptor.

Groups vulnerable to night noise exposure include the elderly and shift workers; children tend to be less sensitive. The report concluded that, although individual responses may vary:

- at $L_{Anight,outside}$ levels of <30 dB(A), no substantial biological effects are observed
- at $L_{Anight,outside}$ levels between 30 dB(A) and 40 dB(A), a number of effects are observed, but their impact is modest
- at $L_{Anight,outside}$ levels between 40 dB(A) and 55 dB(A), adverse health effects are observed, with many people needing to adapt their lives to cope; vulnerable groups are more severely affected
- at $L_{Anight,outside}$ levels above 55 dB(A), adverse health effects occur frequently, and a sizeable proportion of the population is highly annoyed and sleep disturbed. Cardiovascular disease risk rises, and public health is also threatened.

The report recommends a long-term $L_{Anight,outside}$ noise guideline level of 40 dB(A), with an interim $L_{Anight,outside}$ target level of 55 dB(A). The interim target is only intended as an intermediate step in localised situations as health impacts, particularly on vulnerable groups, are apparent at this noise level.

From the research on sleep disturbance to date it can be concluded that:

- maximum internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep
- one or two noise events per night, with maximum internal noise levels of 65–70 dB(A), are not likely to affect health and wellbeing significantly.

The *Environmental criteria for road traffic noise* (Environment Protection Authority NSW 1999) discussed a guideline aimed at limiting the level of sleep disturbance due to environmental noise – that the $L_{AF1,\ 1\ minute}$ level of any noise should not exceed the ambient L_{AF90} noise level by more than 15 dB. This guideline takes into account the emergence of noise events, but does not directly limit the number of such events or their highest level, which are also found to affect sleep disturbance.

Triggers for, and effects of sleep disturbance from, exposure to intermittent noise such as noise from road traffic are still being studied. There appears to be insufficient evidence to set new indicators for potential sleep disturbance due to road traffic noise. The NSW Roads and Traffic Authority's Practice Note 3 (NSW Roads and Traffic Authority 2008a) outlines a protocol for assessing and reporting on maximum noise levels and the potential for sleep disturbance.

DECCW will continue to review research on sleep disturbance as it becomes available.

5.5 Health effects

Recent research literature (Bluhm et al 2007, Grazuleviciene et al 2004, Muzet 2007, van Kempen et al 2002) has supported earlier research findings (Carter 1996, Ohrstrom & Bjorkman 1988) that the shorter-term health effects of sleep disturbance due to excessive noise exposure can affect quality of life during the subsequent waking hours. Symptoms include fatigue, moodiness, irritability, headaches, stomach upsets, lack of concentration and reduced work ability. These shorter-term effects do not appear to be reduced through repeated exposure.

Longer-term effects on health are more difficult to quantify, although tentative links have been drawn between noise exposure and heart rate, immune response, hypertension, blood pressure, occurrence of ischaemic heart disease, cardiovascular disease and myocardial

APPENDIX FOUR

EPA ENVIRONMENTAL CRITERIA FOR ROAD TRAFFIC NOISE EXTRACT (SLEEP DISTURBANCE)

Environmental criteria for road traffic noise

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Environmental Policy Branch
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Published by:

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Web: www.epa.nsw.gov.au

ISBN 0 7313 0203 6
EPA 99/3

May 1999
Printed on recycled paper

point at which 10 % of residents are highly annoyed.

This would indicate that, for road traffic noise, such objectives should be set at approximately 55 dB(A) L_{eq} for daytime noise exposure. However, other factors also influence the choice of a criterion, including the practicality of achieving the criterion in high-noise areas and the additional impact of the introduction of a new noise source to a relatively quiet environment. The latter factor is discussed in Section B4.

B3 Sleep disturbance due to traffic noise—results of recent research

In addition to causing annoyance, traffic noise can also significantly disturb specific activities within residences. Among these are:

- conversation, either in person or on the telephone
- watching and listening to television
- sleeping
- relaxing, listening to music, reading and other passive indoor activities.

In general, studies of reaction to environmental noise indicate that the activity that most people would like to have free from noise disturbance is watching television. However, if only those people who are seriously affected by the noise are considered, the most important disturbance for these people is to sleeping.

Disturbance to sleep as a result of environmental noise is a particularly emotive issue, raising the possibility of effects on health, and other effects of which a resident may not be fully aware. For this reason, most researchers have preferred experimental methodologies to study the degree of sleep disturbance caused by noise, rather than social surveys. The sleep disturbance can be assessed by subjectively-reported sleep quality, number of awakenings during the night (either self-reported or as assessed with an electroencephalograph) or number of changes in sleep state.

The present review of results from this research includes studies of single noise events other than motor vehicle passbys, such as individual train and aircraft passbys. The effects of these various noises on sleep are assumed to be similar, for the same noise level, so that results from the various studies can be compared.

A number of experimental studies have concluded that the use of the L_{eq} noise level alone does not provide an adequate measure of the sleep disturbance produced by noise, and that a better measure would be one that also takes account of the level and number of individual noise events, or noise 'peaks'. For example, Brown and Rutherford (1991), in their assessment of several published studies of the effects of noise on sleep, conclude that, for continuous traffic noise conditions, L_{eq} appears to provide an appropriate measure of sleep disturbance, but that in cases where traffic noise is intermittent (which is often the case at night) sleep disturbance is affected more by the number of individual noise events exceeding a particular level. They point out that various studies indicate that it is the emergence of a noise event above the background that tends to lead to sleep disturbance, rather than the actual peak noise level of the event.

Eberhardt (1988) and Eberhardt et al. (1987) state that the results of their studies indicate that in cases of intermittent traffic flow L_{eq} is an inadequate descriptor of sleep disturbance, and needs to be complemented with some measure of noise peaks. Eberhardt states that the emergence of noise events from the background—rather than the absolute noise level of such events—determines the frequency of sleep disturbance. Eberhardt also states that high continuous traffic noise levels have an undesirable effect on REM sleep.

Vallet et al. (1983) conclude that it is possible to use L_{eq} as a single noise index to measure sleep disturbance due to continuous traffic flow. Vallet states that both L_{eq} and L_{max} are important in assessing sleep disturbance, but that for continuous traffic flow these two levels are correlated; therefore L_{eq} alone can be used as an index. On the other hand, for intermittent traffic flow where the emergence of a noise event, the number of noise events and the intervals between them become important, the use of L_{eq} is not considered adequate, although Vallet does postulate an approach whereby the L_{eq} levels of individual noise events are used to characterise intermittent traffic noise. It is difficult to see how this could be done in practice for road traffic noise.

Vernet (1979) finds that sleep disturbance is related to both L_{eq} and L_{max}, as well as to signal emergence. However, because in his results the L_{max} and emergence were strongly correlated, he comments that it is difficult to discriminate between their effects. Vernet (1983) also finds that in quiet areas it is emergence that is most closely related to sleep disturbance, but that in noisier areas it is the noise duration and peak level that are the more dominant factors.

Griefahn and Muzet (1978) find that the greater the difference between the peak level of noise and the ambient noise (that is, the greater the emergence of a noise event) the greater the level of sleep disturbance. Griefahn (1992) also finds that people are generally more disturbed by intermittent than by continuous noises, and he suggests that this indicates that L_{eq} alone is not generally suitable for the prediction of sleep disturbance.

Ohrstrom and Bjorkman (1988), and Ohrstrom and Rylander (1982), state that intermittent noise was found to have a significantly more noticeable effect on sleep quality than continuous noise at the same L_{eq} level; they suggest that these results imply that peak noise levels should be taken into account when setting criteria for nocturnal noise. In one set of studies, Ohrstrom concludes that the L_{eq} noise level was totally unrelated to sleep disturbance effects.

Horonjeff et al. (1982) conclude that the maximum level, duration and signal-to-noise ratio of a noise event are all closely related to the probability of awakening. They suggest that awakening may be more closely related to signal detectability (emergence) than to absolute level.

Griefahn and Muzet (1978) note that although the number of awakenings increases with the number of noise events, this relationship is not a linear one, with less awakenings per event occurring as the number of events increases. Similarly, Ohrstrom and Rylander (1990) indicate that the number of awakenings from 64 events per night was four times the number from eight events, rather than eight times as expected. However, Vernet (1979) concludes that the number of noise events is closely related to the number of disturbances to sleep.

In summary, the current literature concerning sleep disturbance due to noise indicates that the main noise characteristics that influence sleep disturbance are the number of noisy events heard distinctly above the background level, and the peak level and emergence of these events. The L_{eq}, which is the energy average level of the noise signal, takes some account of the number and level of the louder events in a signal, due to the high amount of energy such events carry. However, the consensus is that L_{eq} by itself is an inadequate predictor of the potential of a noise signal to disturb sleep. For continuous traffic flow, L_{eq} appears to be acceptably correlated with sleep disturbance, since under these conditions there are few emergent noise events above the main hum of the traffic. However, for intermittent traffic flow, which often occurs at night, some other measure that takes into account the emergence, peak level and number of noise events is required.

B4 Response to a change in noise level

The data presented above are based on the responses of people living in residences that have been exposed to road traffic noise for some time. However, the level of reaction to a newly introduced noise may not be directly predictable from these results. In simple terms, while people may express a certain level of acceptance of their existing noise environment, they may feel strongly about any increase in noise.

There is evidence to suggest that reaction to a newly introduced noise source is considerably higher than reaction to a source that has been present for some time. One study (reported in Schultz 1979), conducted in Japan, compared the reaction to noise near a newly-opened Shinkansen (fast train) line with the reaction near a line that had been open for eight years. For the same noise level, reaction was higher near the newly opened line. The difference in reported annoyance was equivalent to a difference of approximately 8 dB in noise exposure (L_{eq}). The difference in reported awakenings from sleep was equivalent to a difference of 7dB in maximum noise levels.

An Australian study (Brown 1987) considered reaction to a sudden increase in road traffic noise levels. It was found that while reported reaction to traffic noise was consistent with other studies before the change in exposure, after the change it was higher than would have been predicted from studies performed under conditions of constant exposure. The difference was equivalent to a difference of between 3 and 15 dB in noise exposure, this variation reflecting the uncertainty in predicting reaction for a given exposure under steady conditions.

In addition, one study (Geoplan Resource Planning 1992) investigated reaction to traffic noise in residents living near the newly opened F3 freeway. The level of reaction was compared with that of residents living near the Pacific Highway, before the opening of the freeway, who were exposed to similar noise levels. The reaction of residents near the F3 freeway was found to be higher than that of residents near the Pacific Highway for the same noise level, the difference being equivalent to a difference of approximately 9 dB in noise level.

The results of these studies are consistent, and indicate that where noise exposure is suddenly and substantially increased, reaction is higher than would be predicted from studies of steady conditions. Converse findings have been reported for the case of reaction to a sudden decrease in exposure, that is, the reaction to the altered situation is lower than would have been predicted from the reaction to steady conditions.

On the other hand, very small increases (or decreases) in noise exposure can be assumed to result in only minor changes in noise reaction. The minimum detectable change in a constant noise level is approximately 1 dB under ideal conditions, or 2 dB under field conditions. Given the fact that a change of this magnitude is likely not to be noticed by residents experiencing it, it can be assumed that the significant increase in noise reaction described above would not apply to changes in noise exposure of 2 dB or less.

B5 Potential noise level descriptors for assessing the impact of road traffic noise on sleep

The first step in determining a practical noise level goal for limiting sleep disturbance due to road traffic noise is to determine the units in which the goal is to be expressed.

From the discussion in Appendix B3, the characteristics of a noise signal that are most strongly related to sleep disturbance are:

- the peak level of noise events, described by L_{max}
- the emergence of noise events above the general noise level, described by measures such as ($L_{max} – L_{eq}$) or ($L_{max} – L_{90}$)
- the number of such noise events occurring during the sleeping period.

Ideally, any night-time noise assessment methodology should take each of these factors into account if it is to provide effective protection against sleep disturbance. The use of single level indicators, such as L_{eq}, which is widely used to define night-time noise criteria, does not take full account of all these factors.

In the light of studies such as Horonjeff et al. (1982), the SPCC incorporated a guideline in its *Environmental Noise Control Manual* (1985) aimed at limiting the level of sleep disturbance due to environmental noise—namely that the L_1 level of any noise should not exceed the ambient L_{90} noise level by more than 15 dB. This criterion takes into account the emergence of noise events, but does not directly limit the number of such events or their peak level, which are also found to affect sleep disturbance.

The use of an indicator such as L_1 may appear favourable, in that it represents the higher noise levels experienced, and also takes some account of the number of events. However, L_1 also depends on other characteristics of the noise (notably the duration of events) that are not strongly correlated with sleep disturbance. In addition, the value of this index is very difficult to predict using standard traffic noise prediction methodologies.

Ultimately, a descriptor used to assess the impact of road traffic noise on sleep should be able to predict the level of sleep disturbance directly, as is possible for annoyance using the daytime L_{eq} level (Figure B1). This would necessarily involve a relatively complex methodology, taking into account the distribution of numbers of noise events by noise level, as well as the emergence of noise events. Such a methodology has not yet been adequately demonstrated or tested.

There is a large difference in the level of effects of noise on sleep between studies conducted in the

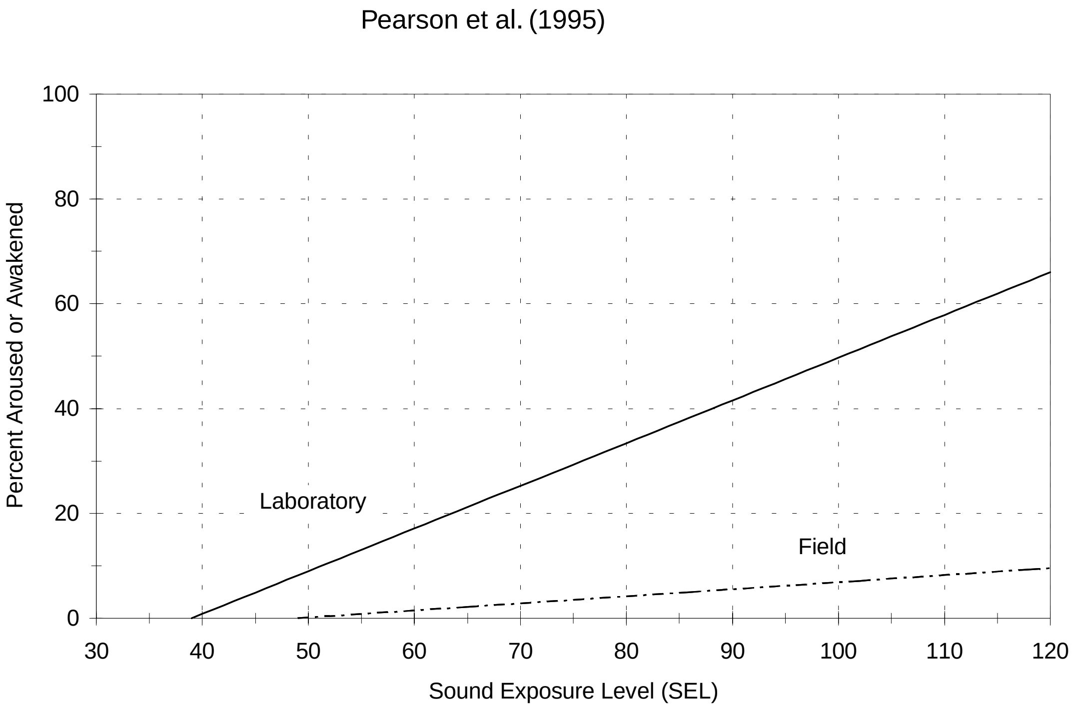


Figure B2 Example of the different effects of noise on sleep in the laboratory and in the field (Pearson et al. 1995)

laboratory and those conducted in the field. Laboratory studies usually show much greater levels of sleep disturbance than for field studies at a given noise level. The reason for such large variations has not been fully explained, but is probably due to the difference in sleeping environments between the field and laboratory studies.

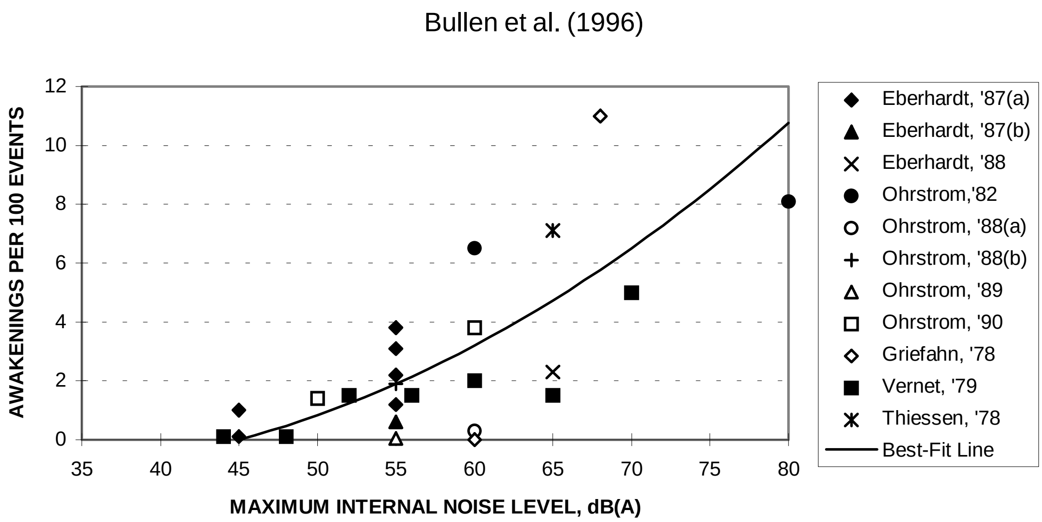
Figure B2, extracted from Pearson et al. (1995), demonstrates the difference between laboratory and field studies.

A number of researchers have produced results designed to allow an assessment of noisy events on sleep. The following examples provide a perspective of the approaches and their results.

Figure B3, produced by Bullen et al. 1996, synthesises a number of studies that have been conducted into sleep disturbance due to noise.

This graph demonstrates the problems in using the current level of understanding of the effects of

Figure B3 Awakenings due to noise (compiled from various studies)



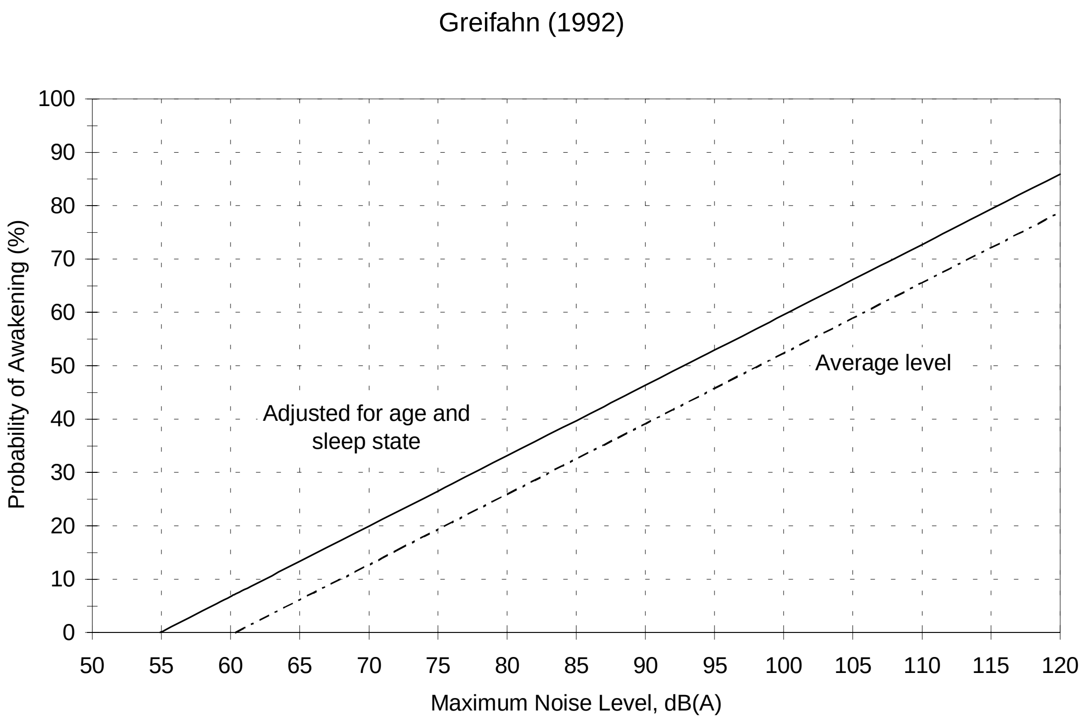


Figure B4 Probability of awakening related to age and sleep state (Griefahn 1992)

noise on sleep to predict awakenings. For instance, the same probability of sleep disturbance is given for one event of 70 dB(A), ten events of 49 dB(A) and thirty events of 46 dB(A). However, it is unlikely that even a relatively high number of noise events at a low noise level would cause awakening reactions.

Figure B4 is adapted from Griefahn (1992). It shows two lines: one derived from survey results, and a second line adjusted to incorporate the increased reaction to noise with age and adjusted to show awakening reaction in the most sensitive sleep state.

Griefahn's results show a very different level of awakening reaction from that in Bullen's figure B3.

Figure B5 is from Finegold et al. (1994), and presents percentage awakenings compared with noise events expressed in ASEL (A-weighted sound exposure level). The authors acknowledge the problem with differences between laboratory and field data and the need for further research. They present their graph as a possible interim means of evaluating awakening reactions from general transportation.

Again, the results presented in this graph bear little relationship to those in the previous two graphs. To allow for a rough comparison, if it can be assumed that the ASEL levels presented in figure B5 correspond to maximum noise levels of about 10 dB lower, then it is clear that Finegold's results indicate a much higher level of reaction than the synthesis presented by either Bullen or Griefahn.

Considering all of the foregoing information the following conclusions can be drawn:

- Maximum internal noise levels below 50–55 dBA are unlikely to cause awakening reactions.
- One or two noise events per night, with maximum internal noise levels of 65–70 dBA, are not likely to affect health and wellbeing significantly.

More work is required to answer two essential questions:

- What is the cause–effect relationship between noisy events and awakening reactions in the home?

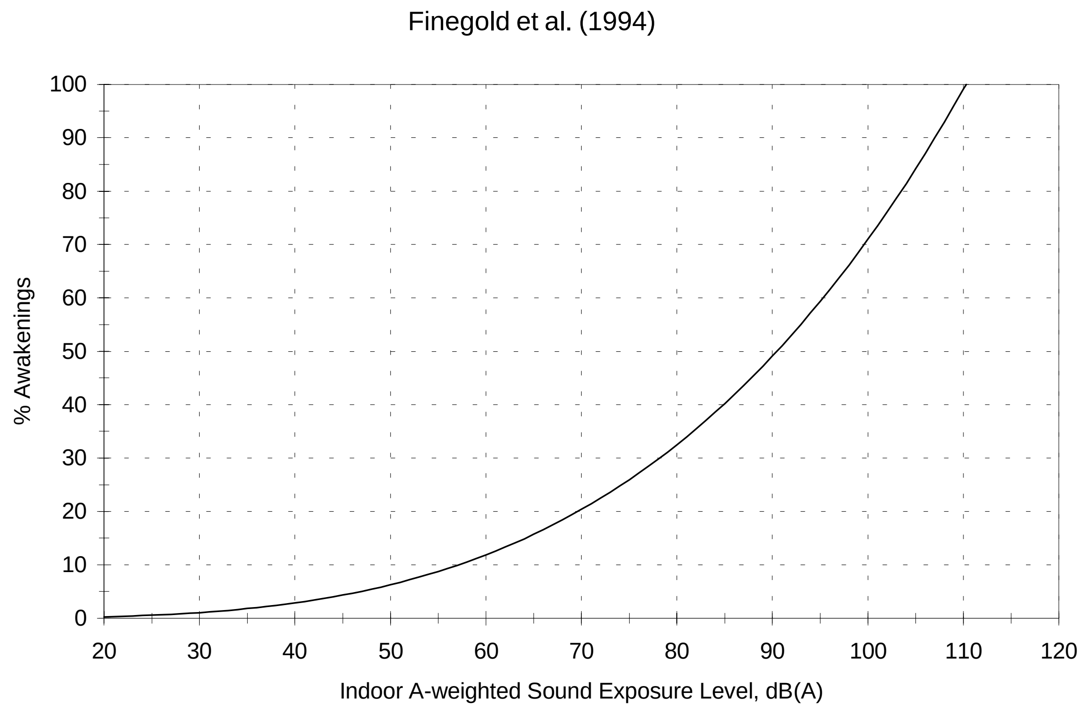


Figure B5 Percentage awakenings from noise events expressed as ASEL (Finegold et al. 1994)

- At what level do awakenings affect our health and wellbeing?

Until more definitive information becomes available, it will not be possible to develop noise level criteria for sleep disturbance that would have the equivalent level of confidence as those noise criteria used for annoyance reactions.

The EPA will continue to review research on sleep disturbance as it becomes available. A more complete review exploring the two essential issues raised above is planned.