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Jane Street and Mulgoa Road Infrastructure Upgrade

Review of Environmental Factors

Appendix J – Traffic and Construction Noise and Vibration Assessment Report

October 2016

Roads and Maritime Services

Jane Street and Mulgoa Road Infrastructure Upgrade

Operational Traffic and Construction Noise and Vibration Assessment Report

R00

Rev E | 31 October 2016

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 244597-00

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Contents

Appendices

Appendix A

Acoustic Terminology

Appendix B

Ambient Noise Survey Results

Appendix C

Noise Contour Plots for Predicted Scenarios

1 Introduction

Roads and Maritime Services (Roads and Maritime) has commissioned Arup to carry out an environmental noise and vibration assessment as part of a Review of Environmental Factors (REF) for the infrastructure upgrade road works to improve reduce congestion around the intersections of Jane Street, Mulgoa Road, Castlereagh Road and the Great Western Highway(High Street) in Penrith, NSW.

This chapter presents the construction and operational noise assessment for the Jane Street and Mulgoa Road infrastructure upgrade works.

A glossary of acoustic terminology used is provided in Appendix A.

1.1 Site Description

Jane Street, from Station Street to Castlereagh Road, is a four lane arterial road that forms part of the current Great Western Highway route in the Penrith City Centre. Jane Street connects to Castlereagh Road at a T- intersection. A short section of Castlereagh Road between Jane Street and High Street forms the next part of the route and connects to the Great Western Highway that approaches Victoria Bridge crossing the Nepean River.

Noise and vibration sensitive receivers that are currently located within the proposal area include:

- Residential receivers in the south-western and south-eastern corners of the proposal area
- Community and cultural receivers to the east of the proposal area, including the Penrith Civic Centre, Penrith City Library and the Joan Sutherland Performing Arts Centre
- Rowing and tennis clubs to the west of the proposal area (active recreation receivers)
- Woodriff Gardens park (passive recreation)

Additional receivers on the east and west of Mulgoa Road south of the proposal area may also be affected by changed noise levels associated with the proposal.

The land usage within the proposal area to the north of the Blue Mountains/Western railway line is predominantly industrial and is therefore not considered noise-sensitive for road traffic noise under the NSW Road Noise Policy. However, these receivers may be considered noise-sensitive for construction noise impacts from the proposed works.

This report only considers operational noise impacts on noise-sensitive receivers located to the south of the rail line.

Future residential development is also being discussed within the proposal area which could increase the number of sensitive receivers. These receivers would be located to the north-east of the proposal area along Castlereagh Road. However, these receivers would fall outside of the study area for the proposal, and no development approvals have yet been lodged for these receivers. As such, any impacts of the proposal on these receivers would be considered as part of the planning controls for the development and will not be discussed further.

Existing transport noise sources in the proposal area include:

- Road traffic noise along the Great Western Highway-High Street, Castlereagh Road and Mulgoa Road,
- Rail noise from the Western/Blue Mountains rail line.

Noise from road traffic is the dominant noise source at the residential receivers within the proposal area.

A map showing the locations of the existing noise sensitive receivers and main traffic noise sources is depicted in Figure 1:

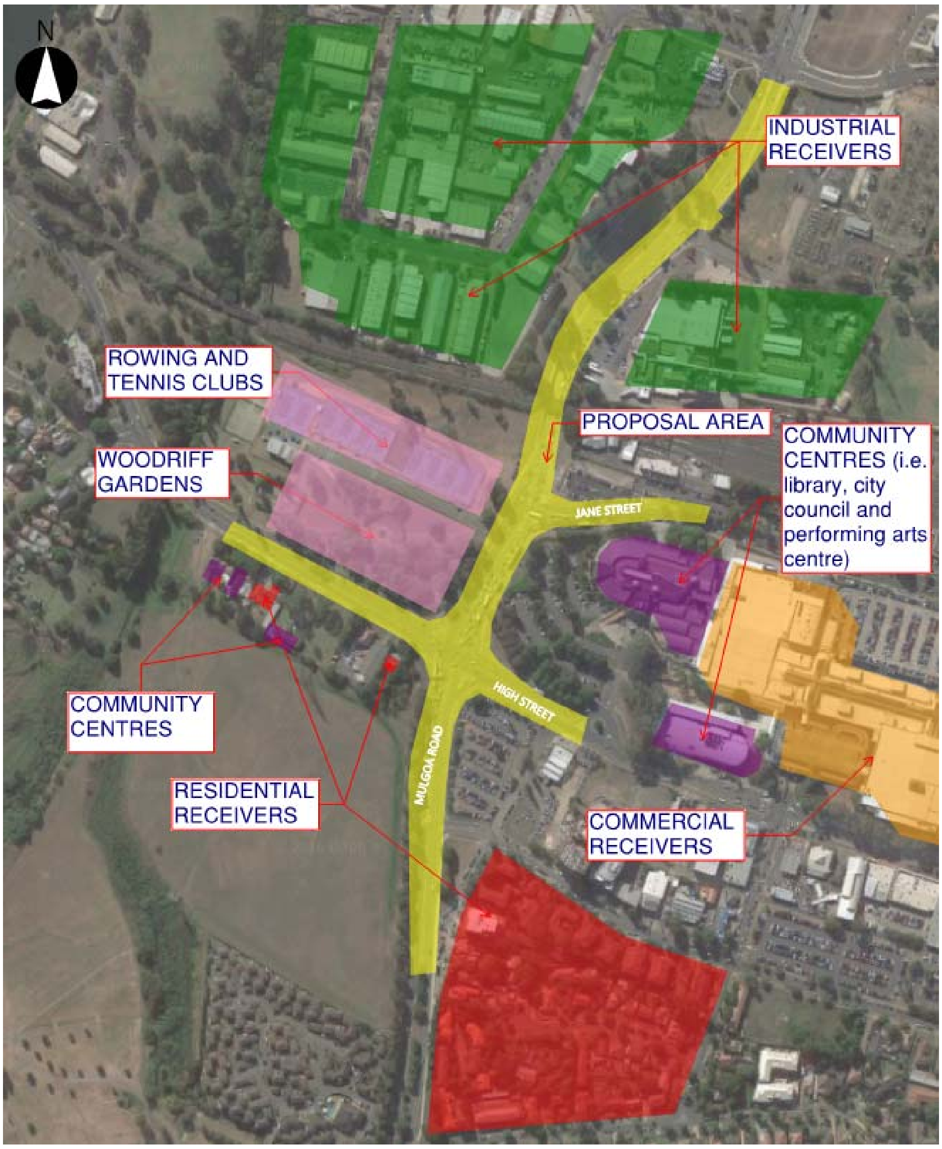


Figure 1: Locations of noise and vibration sensitive receivers and main noise sources around the Proposal area.

2 Project Description

2.1 Existing Road Features

The Jane Street / Mulgoa Road intersection provides access to the Penrith CBD. The intersection connects:

- Mulgoa Road – Castlereagh Road running north-south almost parallel to the Nepean River. It is a major arterial road with two through lanes in each direction connecting the existing residential areas.
- Jane Street, a four lane arterial road which runs east-west alongside the Western/Blue Mountains railway line (to the east of the Mulgoa Road) and turns into the Great Western Highway (to the west of Mulgoa Road).
- High Street also runs east-west to the south of Jane Street. It generally has four lanes and it runs for about 750 metres between Mulgoa Road and Station Street.
- Great Western Highway which runs to the south of Woodriff Gardens, approaches the Victoria Bridge, reduces to two lanes and crosses the Nepean River.

The road surface material consists of Dense Graded Asphalt (DGA). There are pedestrian paths on both sides of Castlereagh Road/ Mulgoa Road and Jane Street and a pedestrian path running along the westbound carriageway of the Great Western Highway/ High Street. The paths within the proposal area vary in width and provide access to a number of community, recreational and commercial premises.

2.2 Proposed Upgrade

The proposal includes the following key features:

- Widening the existing alignment on the western side of Mulgoa Road - Castlereagh Road between Union Road and a point south of Museum Drive to allow for six lanes of through traffic, a central median strip and auxiliary turning lanes at intersections
- Upgrade and widening of the Jane Street / Mulgoa Road - Castlereagh Road intersection and addition of a bus priority lane (‘queue-jump’) lane for buses turning right out of Jane Street onto Castlereagh Road
- Widening of the Great Western Highway to allow for four through lanes, a median strip and a longer left and additional right turning lane into Mulgoa Road – Castlereagh Road
- Upgrade and widening of the Mulgoa Road / High Street intersection to allow for an additional eastbound lane and right turn lane out of High Street onto Mulgoa Road
- Replacement of the existing railway bridge over Castlereagh Road with a new 39 m single span concrete bridge using a specialised method known as a ‘bridge slide’

- Installation of bridge protection beams on either side of Castlereagh Road as a safety mechanism for over-height vehicles on approach to the railway bridge
- Provision of a 4.5 m wide separated shared pedestrian and cycle pathway along the eastern side of Mulgoa Road - Castlereagh Road and safe crossings at the High Street and Jane Street intersections with Mulgoa Road - Castlereagh Road
- Relocation of underground utilities in the proposal area and improvement of local drainage
- Tree planting and landscaping to match the vision for the whole of the Mulgoa Road corridor
- Temporary establishment of up to three construction compound sites.

The proposed upgrade works are shown in Figure 2.

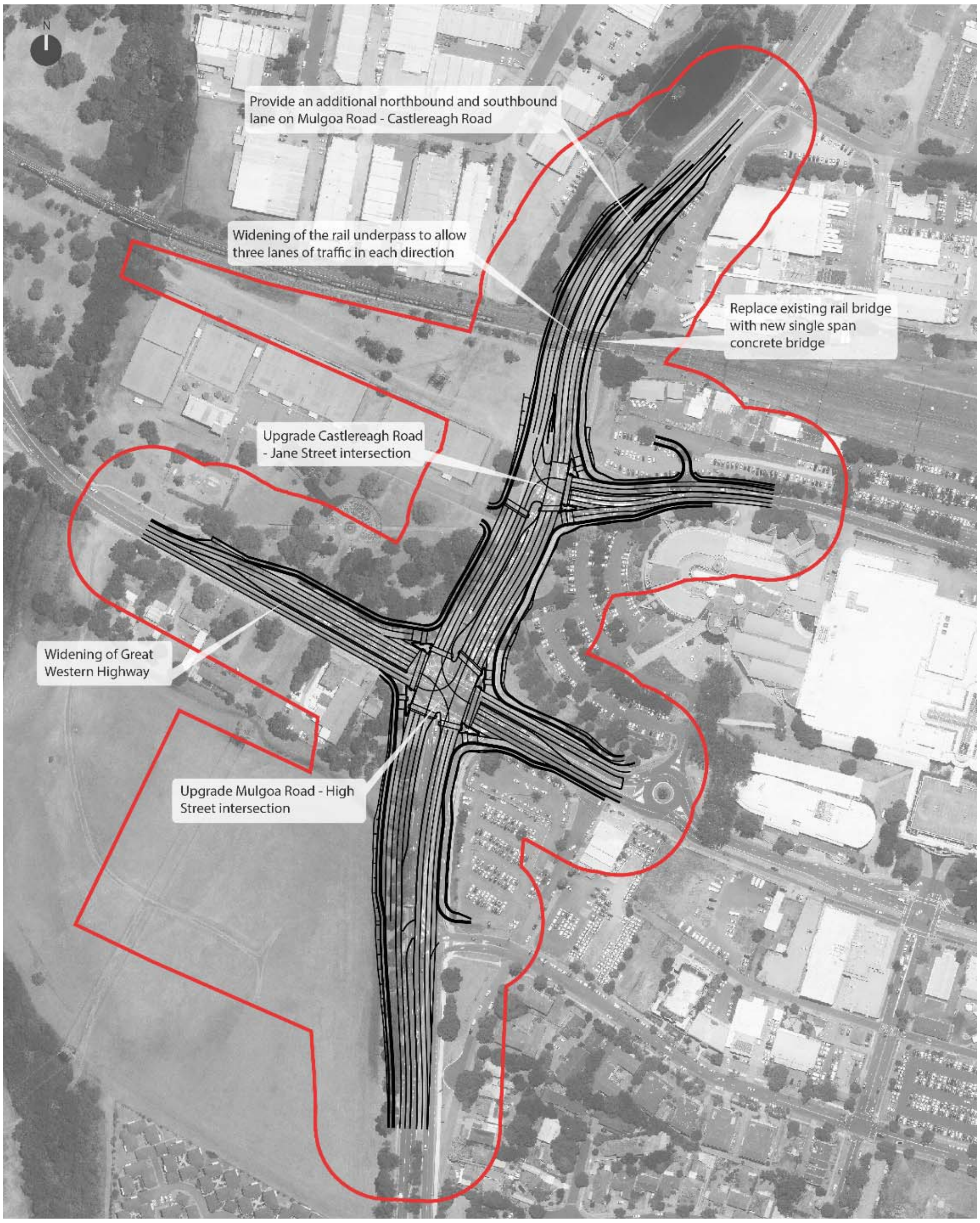


Figure 2: Proposed extent of works

These upgrade works will result in construction activities which may cause construction noise impacts. Refer to Section 7 for a description of construction activities associated with the project.

2.3 Assessment objectives

This assessment report has been prepared by Arup on behalf of Roads and Maritime Sydney West region. For the purposes of these works, Roads and Maritime is the proponent and the determining authority under Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The purpose of the assessment is to describe the proposal, to document the likely noise impacts of the proposal on the noise sensitive receivers, and to detail protective measures to be implemented.

3 Existing Ambient Noise Environment

3.1 Noise Sensitive Receivers

The proposal area is surrounded by a mix of residential, commercial, industrial and active recreation receivers. The worst-affected receivers for each receiver type are identified in Figure 1 and summarised in Table 1. These receivers are included in the project study area as defined in the RMS Noise Criteria Guideline (NCG).

Table 1: Noise sensitive receivers around the proposal area

Noise sensitive receiver location	Type of project/land use
2 De Vilnits Parade 3 De Vilnits Parade 4 De Vilnits Parade 5 De Vilnits Parade 6 De Vilnits Parade 666 High Street 680 High Street 682 High Street 4 John Tipping Grove 6-8 John Tipping Grove 10 John Tipping Grove 12 John Tipping Grove 14 John Tipping Grove 16 John Tipping Grove 60 Union Road 64 Union Road 68 Union Road 72-76 Union Road 78 Union Road 82 Union Road 83 Union Road 86 Union Road Mountain View Retreat Retirement Village (north-western receivers only)	Residential premises
Nepean District Tennis Association	Open space (active use[1])
Woodriff Gardens	Open space (passive use[2])
Penrith City Library	Community centre
Joan Sutherland Performing Arts Centre	Community centre

[1] Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion.

[2] Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, e.g. playing chess, reading.

3.2 Measurement Locations

An ambient noise survey was carried out for seven consecutive days of unattended road traffic noise monitoring from Thursday 26 November 2015 to Thursday 3 December 2015. Noise loggers were set up at:

- 682 Jane Street, Penrith, NSW
- 57 Mulgoa Road, Penrith, NSW (in front of Mountain View Retreat Retirement Village)

The noise loggers measured L_1, L_{10}, L_{eq} and L_{90} parameters over 15-minute intervals. The results of the unattended noise measurements are presented in Appendix B.

The noise logging locations were selected so that each site is only exposed to noise levels from one road segment, allowing each segment to be calibrated by itself and verified in the acoustic model.

The unattended noise measurements were supplemented by a 15-minute attended noise level measurement at each noise logger location at commencement and completion of the logging period for the purposes of verification.

Attended noise level measurements were also carried out at:

- Woodriff Gardens/Penrith Civic Centre (measuring contribution from segment between Jane Street and High Street)
- West of Mulgoa Road within the open area opposite John Tipping Grove (measuring segment south of High Street, for comparison with 57 Mulgoa Road logger data)
- Outside 666 High Street (nearest residential noise sensitive receiver).

The distance of each measurement location to the nearest road and nearest residential receiver is summarised in Table 2 and measurement locations are shown in Figure 3.

Table 2: Indicative distance of each noise monitoring location to the nearest road and nearest residential receiver.

ID	Location	Distance to Nearest Road Kerb	Distance to Nearest Residential Receiver	Attended or Unattended Measurement Location?
U1	682 Jane Street, Penrith	5 m	15 m	Unattended
U2	57 Mulgoa Road, Penrith	4 m	12 m	Unattended
A1	Woodriff Gardens	4 m	N/A	Attended
A2	Penrith Civic Centre	4 m, 8 m	N/A	Attended
A3	Open area opposite John Tipping Grove	7 m	N/A	Attended
A4	666 High Street, Penrith	6 m	16 m	Attended

Figure 3: Attended and unattended noise measurement locations.

3.3 Equipment

Table 3 outlines the measurement and calibration equipment used. All measurement and calibration equipment used in the noise survey holds current accredited laboratory calibration certification. All noise level measurement equipment was checked for calibration at the beginning and end of measurements, with no significant drift in calibration occurring over the duration of measurements.

Table 3: Measurement and calibration equipment details.

Type	Model	Serial Number
Noise logger	ARL Ngara with Type 1 Microphone	878107
Noise logger	ARL Ngara with Type 1 Microphone	8780D0
Sound level meter	Brüel & Kjaer Type 2270, Type 4189 Microphone	2754328
Sound level meter	Brüel & Kjaer Type 2250, Type 4189 Microphone	2449851
Calibrator	Brüel & Kjaer Type 4231 Sound Calibrator	2445716

3.4 Measured Noise Levels

3.4.1 Unattended Noise Survey

A summary of existing road traffic noise levels is provided in Table 4. Detailed results are provided in Appendix B.

Table 4: Existing average road traffic noise levels

ID	Location	Day (7am-10pm), dB		Night (10pm-7am), dB	
		$L_{Aeq,(15\ hour)}$	RBL[1]	$L_{Aeq,(9\ hour)}$	RBL
U1	682 Jane Street, Penrith	71	55	66	38
U2	57 Mulgoa Road, Penrith	70	47	66	33

[1] Rating Background Level. See NSW Industrial Noise Policy (INP) (NSW Department of Environment, Climate Change and Water, January 2000) for a detailed description.

3.4.1.1 Traffic Counts

Traffic counting was carried out concurrently with the noise survey at the intersection between High Street (East-West), Mulgoa Road (South) and Great Western Highway (North). The results of the traffic counts are summarised in Table 5.

Table 5: Traffic counting summary

Time Period	Vehicle Class	High Street West of the Intersection	Great Western Highway North of the Intersection	Mulgoa Road	High Street East of the Intersection
Daytime 7am-10pm	Light	29068	35979	29427	17158
	Heavy	1037	2943	2363	257
	Total	**30105**	**38922**	**31790**	**17416**
Night-time 10pm-7am	Light	3048	5322	4239	967
	Heavy	241	697	638	29
	Total	**3289**	**6019**	**4877**	**996**

3.4.2 Attended Noise Survey

Short term attended measurements of traffic noise were carried out at four locations around the study area where it was not practicable to carry out unattended noise measurements due to access or equipment security constraints. These measurements were performed upon setup and pickup of the noise loggers over a 15 minute daytime period. Third-octave band results were captured to characterise the typical noise frequency spectra at each location.

The results of this attended noise survey are summarised in Table 6 and Table 7.

Table 6: Simultaneous short term noise survey summary at opposite sides of road segment north of intersection between High Street and Mulgoa Road

ID	Location	Date/Time	$L_{Aeq,\ 30min}$	$L_{A90,\ 30min}$	$L_{A10,\ 30min}$	$L_{A1,\ 30min}$
A1	Woodriff Gardens	26-11-15 14:30	72	62	74	82
		03-12-15 11:00	71	61	74	80
A2	Penrith Civic Centre ~8m from road kerb	26-11-15 14:30	68	61	70	78
	Penrith Civic Centre ~4m from road kerb	03-12-15 11:00	72	60	73	81

Table 7: Short term noise survey summary at additional locations

ID	Location	Date/Time	$L_{Aeq,\ 15min}$	$L_{A90,\ 15min}$	$L_{A10,\ 15min}$	$L_{A1,\ 15min}$
A3	Open area opposite John Tipping Grove	26-11-15 15:00	71	62	73	79
		03-12-15 11:45	69	59	72	78
A4	666 High Street, Penrith	03-12-15 11:45	70	62	73	79

4 Applicable Policy and Guidelines

Arup's assessment has been carried out in accordance with:

ARCADIS. (November 2015). *Mulgoa Road/Castlereagh Road Corridor Upgrade Between Glenmore Parkway and Andrews Road, Volume 1 - Traffic/Transport Assessment and Economic Analysis Study.*

Australian Standard. (2010). *AS2436:2010 Guide to Noise and Vibration Control on Construction, Demolition and Maintenance Sites.*

British Standards. (2014). *BS5228-1:2009 + A1:2014 Code of Practice for Noise and Vibration Control on Construction and Open Sites - Part 1: Noise.*

British Standards. (June 2008). *BS 6472-1:2008 Guide to Evaluation of Human Exposure to Vibration in Buildings (Part 1: Vibration Sources Other Than Blasting).*

British Standards. (November 1993). *BS7385-2:1993 Evaluation and Measurement for Vibration in Buildings (Part 2: Guide to Damage Levels From Groundborne Vibration).*

German Standard. (February 1999). *DIN 4150-3 Structural Vibration - Effects of Vibration on Structures.*

Great Britain Department of Transport. (1988). *Calculation of Road Traffic Noise.* H.M.S.O.

NSW Department of Environment, Climate Change and Water. (January 2000). *Industrial Noise Policy.*

NSW Department of Environment, Climate Change and Water. (July 2009). *Interim Construction Noise Guideline.*

NSW Department of Environment, Climate Change and Water. (March 2011). *Road Noise Policy.*

NSW Environment Protection Authority. (February 2006). *Assessing Vibration: A Technical Guideline.*

NSW Roads and Maritime Services. (April 2015). *Noise Criteria Guideline.*

NSW Roads and Maritime Services. (April 2015). *Noise Mitigation Guideline.*

Saunders et. al. (1983). *An Evaluation of the U.K. DoE Traffic Noise Prediction Method.* Australian Road Research Board Research Report.

WG-AEN. (August 2007). *Position Paper - Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure (Version 2).*

5 Criteria

The noise criteria for residences is established using the NSW Government's Road Noise Policy (RNP) (NSW Department of Environment, Climate Change and Water, March 2011) and Roads and Maritime's Noise Criteria Guideline (NCG) (NSW Roads and Maritime Services, April 2015).

The aim of the proposal is to increase capacity, alleviate congestion and improve traffic flow on the road network in the area. As the pavement is not substantially realigned (as defined by the NCG), the project is best-characterised as a Redeveloped Road.

5.1 Study Area

The NCG defines a study area of up to 600 m from the road alignment on either side of the road project, over which the noise criteria should be evaluated. However, in cases where the contribution from other roads is higher than the contribution than the contribution from the road project, the study area distance may be reduced. The NCG defines this as the point where the road project causes an increase of no more than 2.0 dB(A) to the overall noise level – i.e. where the contribution from the project is less than 2.1 dB(A), the study area may be reduced in extent. However, the study area must extend to include any receivers where the project contribution is higher than 65 dB $L_{Aeq,15hr}$ or 60 dB $L_{Aeq,9hr}$, regardless of the relative contribution from the project.

For the Jane Street and Mulgoa Road upgrade works, the intersecting road network means that the 600 m buffer zones for Castlereagh Road/Mulgoa Road, Jane Street, and High Street/Great Western Highway would overlap. However, RMS have advised that the study area for this project should only be based on the project extent along Mulgoa Road.

Refer to Appendix C (Map F) for noise mapping showing the relative contribution of the project road segments. Only receivers located within the 2 dB(A) (or higher) noise contours have been included in the study area.

This results in the following noise-sensitive receivers being included in the study area:

- Receivers on High Street west of Mulgoa Road
- Receivers on Union Road between Mulgoa Road and Worth Street
- Receivers on John Tipping Grove
- Receivers west of Worth Street on the northern side of Vista Street and on De Vilnits Parade.
- Receivers at the north western corner of Mountain View Retreat Retirement Village

For other receivers within 600 m of the Mulgoa Road project alignment (e.g. receivers east of Worth Street, or receivers west of Peach Tree Creek), the project contribution is less than 2 dB(A) and hence these receivers have been excluded from the study area.

5.2 Applicable Criteria and Transition Zones

Once the study area has been defined, criteria are assigned for each residence (and, in some cases, for individual facades at a residence) based on the influence of the road project on the overall traffic noise level at the residence. In cases where multiple criteria apply the most stringent criteria are used at each façade.

For each road section associated with the project, the road upgrade results in an increase of less than 2.0 dB(A) on existing road segments, and the contribution from the redeveloped road segment is higher than the contribution from the existing road segments at the worst-affected receivers within the study area.

Indeed, for some receivers (particularly High Street west of Mulgoa Road), the proposal results in an (albeit insignificant) reduction in noise levels (for equal traffic flows) because the widened road shifts traffic on the eastbound carriageway further away from these receivers.

Refer to Appendix C (Map E) for noise mapping showing the relative increase in noise levels resulting from the project.

Accordingly, no transition zone criteria would apply and all receivers within the study area would be assessed against the redeveloped road criteria.

5.3 Operational Noise

The RNP and NCG provide road traffic noise criteria for residential and non-residential land uses, as shown in Table 8. These traffic noise criteria apply for the year of opening (2019) and for a 10 year horizon following opening (2029, the Design Year). The relevant criteria categories for the project are summarised below:

Table 8: Road traffic noise assessment criteria for residential and non-residential land uses

Type of project/land use	Assessment Criteria – dB(A)	
	Day (7am-10pm)	Night (10pm-7am)
Existing residences affected by noise from redevelopment of existing freeways/arterial/sub-arterial roads	$L_{Aeq, (15 hour)}$ 60 (external)	$L_{Aeq, (9 hour)}$ 55 (external)
Open space (active use[1])	$L_{Aeq, (15 hour)}$ 60 (external) when in use	-
Open space (passive use[2])	$L_{Aeq, (15 hour)}$ 55 (external) when in use	-

[1] Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion.

[2] Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, e.g. playing chess, reading.

Explanations of modelling scenarios required under the RNP are provided in the following section, including model verification scenario, year of opening ‘build’ and ‘no build’ scenarios and design year ‘build’ and ‘no build’ scenarios.

5.4 Construction Noise

Construction noise is likely to cause annoyance to noise sensitive receivers in the vicinity of a construction site. The NSW Interim Construction Noise Guideline (ICNG) (NSW Department of Environment, Climate Change and Water, July 2009) provides guidance on construction management requirements based on management level criteria to determine the construction noise mitigation measures and control the noise amenity at residences, other sensitive land uses and, commercial and industrial premises.

Refer to Section 7 for a description of the construction works associated with the project.

5.4.1 Residences

The ICNG establishes "Noise affected" and a "Highly noise affected" management levels to determine the noise management requirements necessary to minimise the construction noise impact upon noise sensitive receivers. Table 9 summarizes the construction noise criteria.

Table 9: Construction noise management levels for residential receivers

Period	Management level $L_{Aeq, (15\ min)}$	Management requirements
Recommended standard hours: Monday to Friday (7am to 6pm) Saturday (8am to 1pm)	Noise affected RBL + 10 dB	- Apply all feasible and reasonable work practices to meet the affected level - Inform all potentially impacted residents of the nature of the works to be carried out, the expected noise levels, duration and contact details
	Highly noise affected 75 dB(A)	- The relevant authority may require respite periods by restricting the hours that very noisy activities can occur
Outside recommended standard hours	Noise affected RBL + 5 dB	- The relevant authority may request strong justification to carry out works outside of standard hours - Apply all feasible and reasonable work practices to meet the affected level - Negotiate with the community if the criteria is not met

5.4.2 Other Sensitive Land Uses

The ICNG also provides recommended noise management levels for sensitive land uses other than residential receivers. These recommended limits are reproduced in Table 10.

Table 10: ICNG Construction noise management levels for non-residential receivers

Sensitive Land Use	Management level, $L_{Aeq,15min}$ (applies when properties are being used)
Classrooms at schools and other educational institutions.	Internal noise level 45 dB(A)
Active recreation areas (characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dB(A)
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, for example, reading, meditation)	External noise level 60 dB(A)
Community centres	Internal noise levels 45 dB(A) (based on the Maximum internal noise level for Reading Areas in public libraries in AS2107)

Internal noise limits have been converted to external noise limits (for noise prediction) by assuming:

- For the Joan Sutherland Performing Arts Centre, an external noise criteria of 70 dB(A) derived from:
    - a satisfactory internal noise level of 25 dB(A),
    - a façade loss of 20 dB(A) and,
    - 25 dB(A) loss from sound propagating across the Foyer to the performance spaces.
- An external noise criteria of 75 dB(A) for the Penrith City Library building, derived from:
    - A maximum internal noise level of 45 dB(A) for reading areas
    - 30 dB(A) façade loss based on the observable building construction.

5.4.3 Commercial and Industrial Premises

The ICNG also gives recommended management measures for commercial (e.g. offices, retail outlets) and industrial premises:

- Commercial premises: external $L_{Aeq,15minute}$ 70 dB(A)
- Industrial premises: external $L_{Aeq,15minute}$ 75 dB(A)

There are no identified businesses within the study area that are considered particularly sensitive to noise. The Joan Sutherland Performing Arts Centre has been considered as a “community” receiver as discussed above.

5.5 Construction vibration

5.5.1 Human comfort and amenity

The NSW EPA's Assessing Vibration: A Technical Guideline (NSW Environment Protection Authority, February 2006) provides vibration criteria for maintaining human comfort within different space uses. The guideline recommends 'preferred' and 'maximum' weighted vibration levels for both continuous vibration sources, such as steady road traffic and continuous construction activity, and for impulsive vibration sources. The weighting curves are obtained from BS 6472 (British Standards, June 2008).

For intermittent sources (e.g. passing heavy vehicles, impact pile driving, intermittent construction), the guideline uses the vibration dose value (VDV) metric to assess human comfort effects of vibration. VDV takes into account both the magnitude of vibration events and the number of instances of the vibration event.

Intermittent events that occur less than 3 times in an assessment period (either day, 7 am to 10 pm, or night, 10 pm to 7 am) are counted as 'impulsive' sources for the purposes of assessment.

The recommended vibration limits for maintaining human comfort in residences and other relevant receiver types are given for continuous/impulsive and intermittent vibration in Table 11 and Table 12 respectively.

Table 11: Preferred and maximum weighted root-mean-square (rms) values for continuous and impulsive vibration acceleration (m/s^2) 1-80 Hz

Location	Assessment Period	Preferred Values		Maximum Values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
Continuous Vibration					
Residences	Daytime 0700-2200	0.010	0.0071	0.020	0.014
	Night-time 2200-0700	0.007	0.005	0.014	0.010
Impulsive Vibration					
Residences	Daytime 0700-2200	0.30	0.21	0.60	0.42
	Night-time 2200-0700	0.10	0.071	0.20	0.14

Table 12: Acceptable vibration dose values for intermittent vibration ($m/s^{1.75}$)

Location	Daytime 0700-2200		Night-time 2200-0700	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Residences	0.20	0.40	0.13	0.26

5.5.2 Building damage

With regards to the potential for vibration to cause structural damage to buildings, BS7385: Part 2: 1993 (British Standards, November 1993) was developed from an extensive review of UK data, relevant national and international documents and other published data, which yielded very few cases of vibration-induced damage. This standard contains the most up-to-date research on vibration damage in structures. Part 2 of the Standard gives specific guidance on the levels of vibration below which building structures are considered to be at minimal risk.

Limits on the foundations of the building as proposed in the Standard are listed in Table 13.

Table 13: Transient vibration guide values for cosmetic damage

Category	Peak component particle velocity in frequency range of predominant pulse	
	4 Hz to 15 Hz	15 Hz and above
2) Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s @ 4 Hz increasing to 20 mm/s @ 15 Hz	20 mm/s @ 15 Hz increasing to 50 mm/s @ 40 Hz and above

DIN 4150: Part 3: 1999 (German Standard, February 1999) also gives guidelines for short-term and steady state structural vibration for varying types of structure. The limits for short-term vibration in buildings of varying sensitivity are given in Table 14.

Table 14: Guideline Values of Vibration Velocity, v_i, for Evaluating the Effects of Short-term Vibration

	Vibration Velocity, v_i, in mm/s			
	Foundation			Plane of floor of uppermost full storey
Structural type	1 Hz to 10 Hz	10 to 50 Hz	50 to 100 Hz	Frequency mixture
Dwellings or Similar	5	5 to 15	15 to 20	15

The guidelines state that:

> *"Experience has shown that if these values are complied with, damage that reduces the serviceability of the building will not occur. If damage nevertheless occurs, it is to be assumed that other causes are responsible. Exceeding the values in table [17] does not necessarily lead to damage; should they be significantly exceeded, however, further investigations are necessary."*

The most stringent limit recommended in the German Standard is 3 mm/s. This criterion is applicable to particularly sensitive constructions such as heritage structures.

6 Operational Noise Assessment

Noise predictions for the nearest noise sensitive properties have been undertaken using the Calculation of Road Traffic Noise (CoRTN) (Great Britain Department of Transport, 1988) methodology, for verification of the model in the existing year (2015), year of opening (2019) 'build' and 'no build' scenarios and design year (2029) 'build' and 'no build' scenarios. The forecasted traffic volumes for the year of opening and design year are based on the expected traffic volume increment summarised in the Traffic Assessment provided by Arcadis (ARCADIS, November 2015). Details are provided in the following sub-sections.

6.1 Traffic Modelling Parameters

The forecasted traffic volumes at the intersection were based on the expected growth along the corridor in the section between Museum Drive and Union Road as it is the closest reference to the proposal area. The 'No Build' and 'Built' traffic volumes were assumed to be related to the Bureau of Transport Statistics (BTS) forecast (Scenario 1) and the Accelerated Growth forecast (Scenario 2) respectively for the study area.

The traffic volumes for each approach to the intersection were assumed to remain proportional to the total forecasted increase in traffic volumes for the study area and were scaled from the traffic counts carried out concurrently with the environmental noise survey.

Table 15 through Table 20 provide the traffic volumes used for each section of the roads in the study area.

Table 15: Traffic noise modelling parameters for Great Western Highway – Between Jane Street and High Street

Time Period	Vehicle Class	Year of Opening (2019) 'No Build' Scenario		Year of Opening (2019) 'Build' Scenario		Design Year (2029) 'No Build' Scenario		Design Year (2029) 'Build' Scenario	
		Volume	%	Volume	%	Volume	%	Volume	%
Daytime 7am-10pm	Light	35388	92	35528	92	38919	92	42396	91
	Heavy	2964	8	3205	8	3363	8	3984	9
	Total	**38352**	**100**	**38732**	**100**	**42281**	**100**	**46380**	**100**
Night-time 10pm-7am	Light	4971	88	4970	87	5457	87	5916	86
	Heavy	702	12	759	13	796	13	944	14
	Total	**5673**	**100**	**5729**	**100**	**6254**	**100**	**6860**	**100**

Table 16: Traffic noise modelling parameters for Mulgoa Road

Time Period	Vehicle Class	Year of Opening (2019) 'No Build' Scenario		Year of Opening (2019) 'Build' Scenario		Design Year (2029) 'No Build' Scenario		Design Year (2029) 'Build' Scenario	
		Volume	%	Volume	%	Volume	%	Volume	%
Daytime 7am-10pm	Light	28818	92	28945	92	32936	92	34798	91
	Heavy	2359	8	2573	8	2708	8	3390	9
	Total	**31177**	**100**	**31517**	**100**	**35644**	**100**	**38188**	**100**
Night-time 10pm-7am	Light	3855	86	3846	85	4404	86	4586	83
	Heavy	636	14	694	15	731	14	915	17
	Total	**4491**	**100**	**4540**	**100**	**5135**	**100**	**5501**	**100**

Table 17: Traffic noise modelling parameters for High Street West of intersection with Mulgoa Road

Time Period	Vehicle Class	Year of Opening (2019) 'No Build' Scenario		Year of Opening (2019) 'Build' Scenario		Design Year (2029) 'No Build' Scenario		Design Year (2029) 'Build' Scenario	
		Volume	%	Volume	%	Volume	%	Volume	%
Daytime 7am-10pm	Light	29447	96	29246	96	32517	97	32245	96
	Heavy	1138	4	1371	4	1140	3	1407	4
	Total	**30585**	**100**	**30616**	**100**	**33657**	**100**	**33651**	**100**
Night-time 10pm-7am	Light	2942	92	2891	90	3264	92	3201	91
	Heavy	265	8	319	10	265	8	327	9
	Total	**3207**	**100**	**3210**	**100**	**3529**	**100**	**3528**	**100**

Table 18: Traffic noise modelling parameters for High Street East of intersection with Mulgoa Road

Time Period	Vehicle Class	Year of Opening (2019) 'No Build' Scenario		Year of Opening (2019) 'Build' Scenario		Design Year (2029) 'No Build' Scenario		Design Year (2029) 'Build' Scenario	
		Volume	%	Volume	%	Volume	%	Volume	%
Daytime 7am-10pm	Light	17269	98	17237	98	18889	98	19400	98
	Heavy	302	2	287	2	381	2	381	2
	Total	**17571**	**100**	**17524**	**100**	**19270**	**100**	**19781**	**100**
Night-time 10pm-7am	Light	957	97	956	97	1044	96	1072	96
	Heavy	34	3	32	3	42	4	42	4
	Total	**990**	**100**	**988**	**100**	**1086**	**100**	**1115**	**100**

Table 19: Traffic noise modelling parameters for Castlereagh Street North of Jane Street

Time Period	Vehicle Class	Year of Opening (2019) 'No Build' Scenario		Year of Opening (2019) 'Build' Scenario		Design Year (2029) 'No Build' Scenario		Design Year (2029) 'Build' Scenario	
		Volume	%	Volume	%	Volume	%	Volume	%
Daytime 7am-10pm	Light	35965	92	36207	91	41518	92	44238	91
	Heavy	3243	8	3491	9	3686	8	4352	9
	Total	39208	100	39698	100	45204	100	48590	100
Night-time 10pm-7am	Light	5031	87	5045	86	5813	87	6156	86
	Heavy	768	13	827	14	873	13	1031	14
	Total	**5799**	**100**	**5872**	**100**	**6686**	**100**	**7187**	**100**

Table 20: Traffic noise modelling parameters for Jane Street

Time Period	Vehicle Class	Year of Opening (2019) 'No Build' Scenario		Year of Opening (2019) 'Build' Scenario		Design Year (2029) 'No Build' Scenario		Design Year (2029) 'Build' Scenario	
		Volume	%	Volume	%	Volume	%	Volume	%
Daytime 7am-10pm	Light	13138	94	13354	94	17110	95	17368	94
	Heavy	836	6	836	6	954	5	1036	6
	Total	**13974**	**100**	**14190**	**100**	**18064**	**100**	**18404**	**100**
Night-time 10pm-7am	Light	1271	87	1294	87	1672	88	1689	88
	Heavy	194	13	194	13	222	12	241	12
	Total	**1465**	**100**	**1488**	**100**	**1894**	**100**	**1930**	**100**

6.2 Modelling Methodology

The noise model is based upon the concept design alignment for the proposal, and may be updated and refined during the detailed design process.

Acoustic modelling has been undertaken in accordance with Roads and Maritime guidelines as well as international best practice. Predictions have been made using the CoRTN model within the SoundPLAN 7.4 software suite. Guidance on acoustic modelling best practice has been obtained from the Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure (WG-AEN, August 2007) as appropriate.

CoRTN predicts the L_{Aeq} noise level from road traffic, which is empirically corrected to an L_{A10} single number value (either $L_{A10,\ 1\ hour}$ or $L_{A10,\ 18\ hour}$) by means of a 3 dB correlation between L_{Aeq} and L_{A10} for free-flowing traffic, which is 'built-in' to the CoRTN algorithms. Hence, the L_{Aeq} traffic noise level may be readily obtained by subtracting 3 dB from the predicted CoRTN result.

L_{Aeq} noise levels are energy-average noise levels, and may be mathematically time corrected from one time period to another – e.g. the $L_{Aeq,15hr}$ noise level may be calculated using CoRTN by predicting a 1-hour L_{Aeq} noise level using the full 15-

hour traffic flow, and then time-correcting this 1-hour L_{Aeq} to a 15-hour L_{Aeq} noise level. Using this procedure, the $L_{Aeq,15hr}$ and $L_{Aeq,9hr}$ noise levels may be determined from the 15-hour and 9-hour traffic flows.

Point receiver calculations have been made at a height of 1.5 m above floor level of the worst affected storey on the most exposed facade of each receiver. Noise levels have been predicted at 1 m from the receiver façade and a +2.5 dB façade correction has been applied to take account of reflections of sound from the façade.

A summary of the modelling parameters is included below in Table 21.

Table 21: SoundPLAN input parameters

Input	Detail
Traffic speed	Design Speed (Posted): New bridge 60 km/hr All existing roads 50 km/hr
Source height (above ground level)	0.5 m
Road surface	Dense Graded Asphalt
Methodology	Department of Transport, Welsh Office, Calculation of Road Traffic Noise, 1988
CoRTN calibration for Australian conditions (Saunders et. al., 1983)	-1.7 dB, 1 m in front of building façade -0.7 dB, free field locations
Façade correction	+2.5 dB
Terrain data	3D road alignment, 1 m contours
Building heights	As per WG-AEN position paper.
Building footprints	Buildings from aerial photography
Noise receiver height	Ground floor receivers: 1.5 m above ground level First floor receivers: 4.5 m above ground level Other floors: 1.5 m above floor level
Traffic Volumes	Traffic volumes for 2015 (current traffic counts survey), 2019 (year of opening) and 2029 (design year) summarised in Section 6.1

6.3 Modelling Validation

The measured noise data presented in Table 4 has been used to validate the current SoundPLAN model for the project. Road traffic noise level calculations were performed based on the hourly traffic count data measured concurrently with the noise logging at the intersection between High Street and Mulgoa Road.

Table 22: Model validation results

Site ID	Location	$L_{Aeq,15hr}$, dB(A) Daytime 7am-10pm		Difference dB(A)	$L_{Aeq,9hr}$, dB(A) Night-time 10pm-7am		Difference dB(A)
		Measured	Modelled		Measured	Modelled	
U1	682 Jane Street, Penrith	71.3	71.8	+0.5	66.3	66.1	-0.2
U2	57 Mulgoa Road, Penrith	70.8	71.7	+0.9	66.4	67.2	+0.8

On the basis of the good agreement (within ± 1 dB, on average +0.5 dB) between modelled and measured levels for both the daytime and night time periods for noise impacts from the existing alignment, the SoundPLAN model generated is considered verified in accordance with Roads and Maritime guidelines.

6.4 Integrated Noise Reduction Measures

The NMG provides for a staged approach where all “feasible and reasonable” integrated noise reduction measures should be incorporated into the project during the design stage, with receivers with any residual exceedances of the criteria assessed for additional noise mitigation. Due to the relatively minor realignment works associated with the upgrade, it is not considered feasible or reasonable to incorporate any integrated noise reduction measures into the design of the Jane Street and Mulgoa Road upgrade project.

Accordingly, any residual exceedances of the NCG controlling criteria will be addressed at the individual-residence level, as discussed further in Section 6.7.

6.5 Predicted Noise Levels

Noise levels have been predicted at individual residential receivers and other sensitive land uses along the existing and proposed alignment. The noise level predictions were made both for daytime (7am - 10pm, 15hr) and night-time (10pm - 7am, 9hr) for two future scenarios; without the project (termed the ‘no-build’ scenario), and with the project (termed the ‘build’ scenario). The road traffic noise levels for both the ‘no-build’ and the ‘build’ scenario have been predicted for two future periods.

- Year of opening i.e. 2019
- 10 years after opening i.e. 2029.

Noise contour plots for these prediction scenarios are shown in noise contour maps in Appendix C. For multi-storey receivers (taller than double storey) point receiver results are included for all floors, but contours are only presented for ground floor and 1st floor for brevity.

Table 23: Traffic noise level contour plots, shown in Appendix C.

Map reference	Year	Description
A1	2019	‘No Build’ daytime ground floor noise level contours
A2	2019	‘No Build’ night-time ground floor noise level contours
A3	2019	‘No Build’ daytime 1st floor noise level contours
A4	2019	‘No Build’ night-time 1st floor noise level contours
B1	2019	‘Build’ daytime noise level contours
B2	2019	‘Build’ night-time ground floor noise level contours
B3	2019	‘Build’ daytime 1st floor noise level contours
B4	2019	‘Build’ night-time 1st floor noise level contours
C1	2029	‘No Build’ daytime ground floor ground floor noise level contours
C2	2029	‘No Build’ night-time ground floor noise level contours
C3	2029	‘No Build’ daytime 1st floor noise level contours
C4	2029	‘No Build’ night-time 1st floor noise level contours
D1	2029	‘Build’ daytime noise level contours
D2	2029	‘Build’ night-time ground floor noise level contours
D3	2029	‘Build’ daytime 1st floor noise level contours
D4	2029	‘Build’ night-time 1st floor noise level contours
E	2029	Change in noise level due to project (Build – No Build) contours
F	2029	Contribution of project road segments contours

The results for individual receivers are shown in Table 24. The applicable noise criteria have been determined for each property individually based on the requirements of the NCG. For some properties, due to their distance from the alignment or shielding by other properties, only the most-exposed façade has been assessed, as per the RNP which states "in straightforward situations… the residential façade most-affected by road traffic noise can be readily identified". These worst-affected façades are generally at or below the NCG controlling criteria, and hence the other façades of these properties would also comply with the NCG criteria. For receivers that are closer to the alignment where impacts to multiple façades of the receiver may be expected, noise levels have been predicted for all exposed façades.

Table 24: Predicted road traffic noise levels on the Year of Opening and Design Year, receivers in study area

Receiver	**Façade**	**Floor**	**Year of Opening**				**Design Year**				**NCG Criteria (dBA)**		**NCG Controlling Criteria Exceeded?**		**Change in Noise Level (dBA)**				**Exceeds Cumulative Limit?**		**Consider Mitigation?**
			No-Build (dBA)		Build (dBA)		No-Build (dBA)		Build (dBA)						Year of Opening		Design Year				
			Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
1 De Vilnits Parade	NW	G	54	50	55	50	55	50	55	51	**60**	**55**	NO	NO	0.2	0.2	0.5	0.7	NO	NO	NO
2 De Vilnits Parade	NW	G	55	51	55	51	56	51	56	52	**60**	**55**	NO	NO	0.2	0.2	0.6	0.7	NO	NO	NO
3 De Vilnits Parade	NW	G	56	51	56	51	56	52	57	52	**60**	**55**	NO	NO	0.2	0.2	0.5	0.7	NO	NO	NO
		1	58	53	58	53	58	54	59	54	**60**	**55**	NO	NO	0.1	0.2	0.6	0.7	NO	NO	NO
4 De Vilnits Parade	NW	G	52	46	52	47	52	47	53	48	**60**	**55**	NO	NO	0.1	0.1	0.4	0.6	NO	NO	NO
		1	54	49	54	49	54	49	55	50	**60**	**55**	NO	NO	0.1	0.1	0.4	0.6	NO	NO	NO
5 De Vilnits Parade	NW	G	51	47	52	47	52	47	52	48	**60**	**55**	NO	NO	0.1	0.2	0.5	0.6	NO	NO	NO
		1	53	49	54	49	54	49	54	50	**60**	**55**	NO	NO	0.1	0.1	0.5	0.6	NO	NO	NO
6 De Vilnits Parade	W	G	52	48	53	48	53	48	53	49	**60**	**55**	NO	NO	0.1	0.1	0.5	0.6	NO	NO	NO
		1	54	50	54	50	55	50	55	51	**60**	**55**	NO	NO	0.1	0.1	0.5	0.6	NO	NO	NO
4 John Tipping Grove	W	G	66	61	66	62	67	62	67	63	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.6	**YES**	**YES**	**YES**
		1	67	63	67	63	68	63	68	64	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.6	**YES**	**YES**	**YES**
	N	G	62	57	62	57	62	58	63	58	**60**	**55**	**YES**	**YES**	-0.1	-0.1	0.3	0.4	NO	NO	NO
		1	63	58	63	58	63	59	64	59	**60**	**55**	**YES**	**YES**	-0.1	-0.1	0.3	0.4	NO	NO	NO
	S	G	57	53	58	53	58	54	59	54	**60**	**55**	NO	NO	0.1	0.1	0.5	0.6	NO	NO	NO
		1	59	54	59	55	59	55	60	56	**60**	**55**	NO	**YES**	0.1	0.1	0.5	0.6	NO	NO	NO
6-8 John Tipping Grove	W	G	67	62	67	62	67	63	68	63	**60**	**55**	**YES**	**YES**	0.1	0.2	0.5	0.7	**YES**	**YES**	**YES***
		1	68	64	68	64	69	64	69	65	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.6	**YES**	**YES**	**YES***
		2	69	64	69	64	69	65	70	65	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.6	**YES**	**YES**	**YES***
		3	69	65	69	65	70	65	70	66	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.6	**YES**	**YES**	**YES***
		4	69	65	69	65	70	65	70	66	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.6	**YES**	**YES**	**YES***
		5	69	65	69	65	70	65	70	66	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.6	**YES**	**YES**	**YES***
	N	G	58	53	58	53	58	54	59	54	**60**	**55**	NO	NO	0.1	0.1	0.5	0.6	NO	NO	NO
		1	59	55	59	55	60	55	60	56	**60**	**55**	NO	**YES**	0.0	0.1	0.5	0.6	NO	NO	NO
		2	62	57	62	57	62	57	63	58	**60**	**55**	**YES**	**YES**	0.0	0.0	0.4	0.5	NO	NO	NO
		3	64	59	64	59	65	60	65	60	**60**	**55**	**YES**	**YES**	-0.1	0.0	0.3	0.5	**YES**	**YES**	**YES***

Receiver	Façade	Floor	Year of Opening				Design Year				NCG Criteria (dBA)		NCG Controlling Criteria Exceeded?		Change in Noise Level (dBA)				Exceeds Cumulative Limit?		Consider Mitigation?
			No-Build (dBA)		Build (dBA)		No-Build (dBA)		Build (dBA)						Year of Opening		Design Year				
			Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
		4	64	60	64	60	65	60	65	61	**60**	**55**	**YES**	**YES**	0.0	-0.1	0.3	0.4	**YES**	**YES**	**YES***
		5	65	60	65	60	65	60	66	61	**60**	**55**	**YES**	**YES**	-0.1	0.0	0.3	0.5	**YES**	**YES**	**YES***
	S	G	59	54	59	55	59	55	60	56	**60**	**55**	NO	**YES**	0.2	0.2	0.5	0.7	NO	NO	NO
		1	62	57	62	57	62	58	63	58	**60**	**55**	**YES**	**YES**	0.1	0.1	0.6	0.6	NO	NO	NO
		2	64	59	64	59	64	60	65	60	**60**	**55**	**YES**	**YES**	0.2	0.1	0.6	0.6	**YES**	**YES**	**YES***
		3	65	60	65	60	65	61	66	61	**60**	**55**	**YES**	**YES**	0.2	0.2	0.5	0.7	**YES**	**YES**	**YES***
		4	65	61	66	61	66	61	66	62	**60**	**55**	**YES**	**YES**	0.2	0.2	0.5	0.7	**YES**	**YES**	**YES***
		5	66	61	66	61	66	62	67	62	**60**	**55**	**YES**	**YES**	0.2	0.1	0.5	0.6	**YES**	**YES**	**YES***
10 John Tipping Grove	W	G	67	63	68	63	68	64	68	64	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.6	**YES**	**YES**	**YES**
	N	G	62	58	62	58	63	58	63	59	**60**	**55**	**YES**	**YES**	0.1	0.2	0.6	0.7	NO	NO	**YES**
	S	G	63	58	63	58	63	59	64	60	**60**	**55**	**YES**	**YES**	0.1	0.1	0.6	0.7	NO	**YES**	**YES**
12 John Tipping Grove	W	G	69	64	69	65	69	65	70	66	**60**	**55**	**YES**	**YES**	0.2	0.2	0.4	0.3	**YES**	**YES**	**YES**
		1	70	66	70	66	71	66	71	67	**60**	**55**	**YES**	**YES**	0.2	0.1	0.4	0.4	**YES**	**YES**	**YES**
	N	G	62	58	62	58	63	58	63	59	**60**	**55**	**YES**	**YES**	0.2	0.2	0.3	0.3	NO	NO	NO
		1	64	60	64	60	65	60	65	61	**60**	**55**	**YES**	**YES**	0.2	0.1	0.4	0.4	**YES**	**YES**	**YES**
	S	G	66	61	66	62	66	62	67	63	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.3	**YES**	**YES**	**YES**
		1	67	62	67	63	67	63	68	64	**60**	**55**	**YES**	**YES**	0.2	0.2	0.4	0.3	**YES**	**YES**	**YES**
14 John Tipping Grove	W	G	67	63	67	63	68	63	68	64	**60**	**55**	**YES**	**YES**	0.1	0.1	0.6	0.8	**YES**	**YES**	**YES**
	N	G	59	54	59	54	59	55	60	55	**60**	**55**	NO	NO	0.1	0.1	0.6	0.7	NO	NO	NO
	S	G	62	57	62	57	62	58	63	58	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.7	NO	NO	NO
16 John Tipping Grove	W	G	70	66	71	66	71	66	71	67	**60**	**55**	**YES**	**YES**	0.1	0.1	0.6	0.7	**YES**	**YES**	**YES**
	N	G	66	62	66	62	67	62	67	63	**60**	**55**	**YES**	**YES**	0.2	0.2	0.6	0.7	**YES**	**YES**	**YES**
	S	G	63	59	64	59	64	59	64	60	**60**	**55**	**YES**	**YES**	0.2	0.1	0.6	0.7	NO	**YES**	**YES**
60 Union Road	N	G	54	47	54	47	54	48	55	48	**60**	**55**	NO	NO	0.0	0.1	0.3	0.4	NO	NO	NO
		1	55	48	55	49	55	49	56	49	**60**	**55**	NO	NO	0.1	0.1	0.3	0.4	NO	NO	NO
64 Union Road	N	G	54	48	54	48	54	48	55	49	**60**	**55**	NO	NO	0.1	0.1	0.4	0.5	NO	NO	NO
68 Union Road (East Building)	N	G	54	47	54	48	54	48	55	48	**60**	**55**	NO	NO	0.1	0.1	0.3	0.5	NO	NO	NO
		1	55	49	55	49	56	49	56	50	**60**	**55**	NO	NO	0.0	0.1	0.3	0.4	NO	NO	NO
		2	56	49	56	50	56	50	57	50	**60**	**55**	NO	NO	0.0	0.1	0.3	0.4	NO	NO	NO
68 Union Road (West Building)	N	G	54	48	54	48	55	48	55	49	**60**	**55**	NO	NO	0.1	0.2	0.3	0.5	NO	NO	NO
		1	55	49	55	49	56	50	56	50	**60**	**55**	NO	NO	0.1	0.1	0.3	0.5	NO	NO	NO
		2	56	50	56	50	57	51	57	51	**60**	**55**	NO	NO	0.1	0.2	0.4	0.6	NO	NO	NO

Receiver	Façade	Floor	Year of Opening				Design Year				NCG Criteria (dBA)		NCG Controlling Criteria Exceeded?		Change in Noise Level (dBA)				Exceeds Cumulative Limit?		Consider Mitigation?
			No-Build (dBA)		Build (dBA)		No-Build (dBA)		Build (dBA)						Year of Opening		Design Year				
			Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
72-76 Union Road (West Building)	N	G	55	49	55	49	55	49	55	50	**60**	**55**	NO	NO	-0.1	-0.1	0.1	0.2	NO	NO	NO
		1	56	51	56	51	57	51	57	51	**60**	**55**	NO	NO	0.0	0.0	0.2	0.4	NO	NO	NO
		2	57	52	57	52	58	52	58	53	**60**	**55**	NO	NO	0.0	0.0	0.2	0.4	NO	NO	NO
72-76 Union Road (East Building)	N	G	55	48	55	48	55	49	55	50	**60**	**55**	NO	NO	-0.1	-0.1	0.1	0.2	NO	NO	NO
78 Union Road	N	G	56	51	56	50	56	51	57	51	**60**	**55**	NO	NO	-0.1	-0.2	0.2	0.3	NO	NO	NO
		1	58	53	58	53	59	53	59	53	**60**	**55**	NO	NO	-0.1	0.0	0.2	0.3	NO	NO	NO
		2	59	54	59	54	60	54	60	55	**60**	**55**	NO	NO	0.0	0.0	0.3	0.4	NO	NO	NO
82 Union Road (East Building)	N	G	57	52	57	52	58	53	58	53	**60**	**55**	NO	NO	0.0	0.1	0.3	0.5	NO	NO	NO
82 Union Road (South Building)	N	G	52	47	52	47	53	48	53	48	**60**	**55**	NO	NO	0.1	0.1	0.4	0.5	NO	NO	NO
82 Union Road (West Building)	N	G	59	53	59	53	59	54	59	54	**60**	**55**	NO	NO	-0.1	-0.1	0.2	0.3	NO	NO	NO
83-85 Union Road	W	G	61	56	61	56	62	56	62	57	**60**	**55**	**YES**	**YES**	0.1	0.2	0.4	0.6	NO	NO	NO
		1	62	57	62	57	63	58	63	58	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.5	NO	NO	NO
		2	63	57	63	58	63	58	64	59	**60**	**55**	**YES**	**YES**	0.2	0.2	0.5	0.6	NO	NO	NO
		3	63	58	63	58	64	58	64	59	**60**	**55**	**YES**	**YES**	0.2	0.2	0.4	0.6	NO	NO	NO
		4	63	58	64	58	64	59	64	59	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.6	NO	NO	NO
		5	64	58	64	59	64	59	65	59	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.5	**YES**	NO	**YES***
		6	64	59	64	59	65	59	65	60	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.6	**YES**	**YES**	**YES***
		7	64	59	64	59	65	60	65	60	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.6	**YES**	**YES**	**YES***
		8	65	59	65	59	65	60	65	60	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.6	**YES**	**YES**	**YES***
	S	G	54	49	54	49	54	50	55	50	**60**	**55**	NO	NO	0.1	0.2	0.5	0.7	NO	NO	NO
		1	54	50	55	50	55	51	56	51	**60**	**55**	NO	NO	0.1	0.1	0.5	0.6	NO	NO	NO
		2	55	51	55	51	56	51	56	52	**60**	**55**	NO	NO	0.1	0.1	0.6	0.7	NO	NO	NO
		3	56	51	56	52	56	52	57	53	**60**	**55**	NO	NO	0.1	0.1	0.5	0.6	NO	NO	NO
		4	57	52	57	52	57	53	58	53	**60**	**55**	NO	NO	0.2	0.1	0.5	0.6	NO	NO	NO
		5	57	53	57	53	58	53	58	54	**60**	**55**	NO	NO	0.2	0.1	0.5	0.6	NO	NO	NO
		6	58	53	58	54	59	54	59	55	**60**	**55**	NO	NO	0.2	0.2	0.5	0.7	NO	NO	NO
		7	59	54	59	54	59	55	60	55	**60**	**55**	NO	NO	0.1	0.1	0.6	0.7	NO	NO	NO
		8	59	55	59	55	60	55	60	56	**60**	**55**	NO	**YES**	0.1	0.1	0.5	0.6	NO	NO	NO
	N	G	61	54	61	54	62	55	62	56	**60**	**55**	**YES**	NO	0.0	0.0	0.2	0.3	NO	NO	NO

Receiver	Façade	Floor	Year of Opening				Design Year				NCG Criteria (dBA)		NCG Controlling Criteria Exceeded?		Change in Noise Level (dBA)				Exceeds Cumulative Limit?		Consider Mitigation?
			No-Build (dBA)		Build (dBA)		No-Build (dBA)		Build (dBA)						Year of Opening		Design Year				
			Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
		1	62	55	62	55	63	56	63	57	**60**	**55**	**YES**	**YES**	0.0	0.0	0.2	0.3	NO	NO	NO
		2	63	56	63	56	63	56	63	58	**60**	**55**	**YES**	**YES**	0.0	0.0	0.2	0.3	NO	NO	NO
		3	63	56	63	56	63	57	64	58	**60**	**55**	**YES**	**YES**	0.0	0.1	0.2	0.3	NO	NO	NO
		4	63	57	63	57	64	57	64	58	**60**	**55**	**YES**	**YES**	-0.1	0.0	0.2	0.3	NO	NO	NO
		5	63	57	63	57	64	57	64	58	**60**	**55**	**YES**	**YES**	0.0	0.0	0.2	0.2	NO	NO	NO
		6	64	57	64	57	64	58	64	58	**60**	**55**	**YES**	**YES**	0.0	0.0	0.2	0.3	NO	NO	NO
		7	64	57	64	57	64	58	64	58	**60**	**55**	**YES**	**YES**	-0.1	0.0	0.1	0.3	NO	NO	NO
		8	64	57	64	57	64	58	65	59	**60**	**55**	**YES**	**YES**	-0.1	-0.1	0.1	0.2	**YES**	NO	**YES***
86 Union Road	W	G	64	59	64	59	65	60	65	60	**60**	**55**	**YES**	**YES**	0.1	0.1	0.5	0.6	**YES**	**YES**	**YES**
		1	65	60	65	61	66	61	66	61	**60**	**55**	**YES**	**YES**	0.1	0.1	0.4	0.5	**YES**	**YES**	**YES**
		2	66	61	66	61	66	62	67	62	**60**	**55**	**YES**	**YES**	0.0	0.1	0.4	0.5	**YES**	**YES**	**YES**
	N	G	61	56	61	56	62	57	62	57	**60**	**55**	**YES**	**YES**	-0.1	-0.1	0.3	0.4	NO	NO	NO
		1	62	57	62	57	63	58	63	58	**60**	**55**	**YES**	**YES**	-0.1	0.0	0.2	0.4	NO	NO	NO
		2	63	58	63	58	63	58	63	58	**60**	**55**	**YES**	**YES**	-0.1	-0.1	0.2	0.4	NO	NO	NO
666 High Street	E	G	69	64	69	65	69	65	70	66	**60**	**55**	**YES**	**YES**	0.5	0.5	0.9	0.9	**YES**	**YES**	**YES**
	N	G	70	65	70	65	70	65	70	65	**60**	**55**	**YES**	**YES**	-0.1	0.0	0.1	0.2	**YES**	**YES**	**YES**
680 High Street	N	G	64	59	64	59	64	59	64	59	**60**	**55**	**YES**	**YES**	-0.2	-0.1	0.0	0.0	NO	NO	NO
		1	65	60	65	60	65	60	65	60	**60**	**55**	**YES**	**YES**	-0.2	0.0	-0.1	0.0	**YES**	**YES**	**YES**
682 High Street	N	G	70	66	70	65	71	65	70	65	**60**	**55**	**YES**	**YES**	-0.3	-0.4	-0.2	-0.2	**YES**	**YES**	**YES**
684 High Street	N	G	70	66	70	66	71	65	71	65	**60**	**55**	**YES**	**YES**	0.0	0.0	0.0	0.1	**YES**	**YES**	**YES**
686 High Street	N	G	70	65	70	65	70	65	70	65	**60**	**55**	**YES**	**YES**	0.2	0.2	0.2	0.2	**YES**	**YES**	**YES**
Mountain View Retreat – Northwest buildings only	N	G	57	52	58	53	58	53	58	54	**60**	**55**	NO	NO	0.1	0.2	0.5	0.7	NO	NO	NO

* 6-8 John Tipping Grove and 83 Union Street are recently-constructed (or under-construction) residential buildings. Refer below for a discussion of noise mitigation for these receivers.

6.6 Traffic Noise Level Assessment

According to Roads and Maritime's Noise Mitigation Guideline (NMG) (NSW Roads and Maritime Services, April 2015), the need for noise mitigation is required to be assessed once noise has been minimised by feasible and reasonable methods during the corridor planning and road design stages.

Residual exceedances of the NCG criteria would occur at the following properties:

- Receivers on High Street west of Mulgoa Road
- Receivers facing or exposed to Mulgoa Road, including 82 Union Street, 83 Union Street, 86 Union Street and receivers on John Tipping Grove

The NMG provides three triggers for determining whether a receiver should be considered for provision of noise mitigation:

1. If the predicted Build noise level exceeds the NCG controlling criteria and the project causes an increase of greater than 2 dB(A) [Build – No Build]
2. If the predicted Build noise level exceeds the cumulative limit (5 dB above the NCG controlling criteria), and the project significantly contributes to the overall noise level (a contribution of 2.1 dB(A) or greater to the overall noise level)
3. If the contribution from the project is "acute" (>65 dB $L_{Aeq,15hr}$ or >60 dB $L_{Aeq,9hr}$), even if the overall noise level at the receiver is dominated by a non-project road segment

Considering these triggers:

- Properties on High Street west of Mulgoa Road would qualify for noise mitigation because noise levels at the Year of Opening and Design Year exceed the cumulative noise limit, and the project road segments contribute at least 2.0 dB(A) to the overall noise level
- Properties on John Tipping Grove and at the western end of Union Road would qualify for noise mitigation because noise levels at the Year of Opening and Design Year exceed the cumulative noise limit, and the project road segments contribute at least 2.0 dB(A) to the overall noise level

6-8 John Tipping Grove and 83-85 Union Road, which are residential buildings either currently under construction or recently completed, would be predicted to experience an exceedance of the cumulative noise levels. However, given that the proposal would only result in a negligible (<1 dB) increase in noise levels at these receivers, it is reasonable to assume that the base build design for these receivers would have been based on the existing exceedance of the cumulative limit.

Search of Penrith City Council's DA register for these sites shows no specific clauses controlling noise intrusion from traffic noise, only a reference to the Penrith Development Control Plan, which does require an acoustic assessment to be conducted. However, no acoustic reports for these developments are publically available. Hence it is unclear if the façades of these buildings have been designed to control existing noise exposure.

Because the segment of Mulgoa Road that is the dominant noise emission segment for these roads has an AADT of fewer than 40,000 vehicles, these projects would not have been automatically required to comply with the recommendations of the Infrastructure State Environmental Planning Policy 2007 (ISEPP).

In these circumstances, provision of noise mitigation for these receivers may not be considered reasonable and these receivers have been marked as provisional for noise mitigation (with an asterisk in the list below).

It is the intention of the RNP to provide a feasible and reasonable noise mitigation approach to prevent noise sensitive receivers with an existing high noise level from remaining well above the criterion, including cases where the noise level did not significantly increase relative to the 'no-build' year.

It is only considered reasonable to provide noise mitigation measures in the form of quieter pavement surfaces, noise mounds or noise walls for cases where there are four or more closely spaced receivers.

For isolated receivers or small groups or receivers, at-property mitigation measures may be considered subject to feasible and reasonable assessment.

The only area with a group of four or more closely-spaced receivers qualifying for mitigation that are not accessed directly from a project road segment is John Tipping Grove. However, as discussed in more detail in Section 6.7, a noise barrier is not considered "feasible and reasonable" for the receivers on John Tipping Grove.

Under the provisions of the NMG, the following noise sensitive receivers would qualify for consideration of "feasible and reasonable" at-property noise mitigation measures as a result of the proposal:

- 680 High Street
- 682 High Street
- 686 High Street
- 688 High Street
- 4 John Tipping Grove
- 6-8 John Tipping Grove*
- 10 John Tipping Grove
- 12 John Tipping Grove
- 14 John Tipping Grove
- 83-85 Union Road*
- 86 Union Road

A summary of the recommended at-property noise mitigation measures are provided in Section 6.7.1 of this report.

6.7 Design of Additional Noise Mitigation Measures

Where a receiver qualifies for additional mitigation under the NMG, feasible and reasonable measures to meet the assessment criteria are required to protect against excessive decreases in amenity as the result of a project.

The NMG considers that quieter pavement, noise mounds or noise walls are a reasonable approach in cases where four or more receivers are closely spaces. However, at-property noise mitigation measures are preferred when isolated single residences or isolated groups of closely spaced residences are being assessed.

The NMG also recognises that there are factors which will result in some noise mitigation measures not being feasible for some receivers.

Quieter pavement is not considered a feasible mitigation measure, because the effectiveness of quieter pavement is reduced for lower average traffic speeds (below ~60-70 km/h as defined by various Australian transport authorities including the former RTA *Environmental Noise Management Manual* ENMM, and the QLD Department of Transport and Main Roads *Code of Practice for Road Traffic Noise Management*), which is the case for this project.

Similarly, many of the affected properties in the study area have direct access to a project road segment, which means noise barriers or noise mounds would not be a feasible mitigation measure. The effectiveness of noise mounds or noise barriers is significantly reduced where roads are non-access controlled – i.e. where properties have driveways to directly-access the road segment. In these cases, a continuous noise barrier is not feasible, and a noise barrier with openings for access would have negligible acoustic benefit. This is the case, for example, for receivers on High Street.

Although receivers on John Tipping Grove do not have direct access to Mulgoa Road, a noise barrier is not considered to be feasible to address noise impacts for all affected receivers on John Tipping Grove. This is because of insufficient space between Mulgoa Road and the cul-de-sac at the southern end of John Tipping Grove – at the narrowest point, the pedestrian/cycle path occupies the full width of the available space between Mulgoa Road and John Tipping Grove. This would restrict the effective length of the noise barrier to the point where it would not be effective at providing significant noise reduction to all properties at John Tipping Grove, and the benefit provided by the noise barrier would be affected by the limited length of the barrier. A noise barrier than only provides a significant noise reduction to one or two properties would not normally be considered reasonable under the NMG, although could potentially be considered during detailed design as part of a combination of property-based treatments and a noise barrier.

This means that at-property noise mitigation strategies are the only "feasible and reasonable" strategies relevant for the majority of affected receivers at the project. This could include both architectural treatment of the building façade and/or the provision of 'property fence' type localised noise barriers. A discussion of potential mitigation measures is summarised below.

6.7.1 At-Property Noise Mitigation Measures

The operational traffic noise assessment found that architectural treatment will be required at several residential properties which were found to be experiencing residual exceedances of the NCG noise levels. The number of properties requiring architectural treatment will be refined and confirmed after project approval and once the project detailed design is developed.

The form of the architectural treatment to be implemented on each property is to be agreed with the individual property owners, and will be undertaken in accordance with the NMG.

Architectural noise treatments may include one or a combination of the following:

- The installation of courtyard screen walls
- Fresh air ventilation systems that meet building code of Australia requirements with the windows and doors shut.
- Upgraded windows and glazing and solid core doors on exposed facades of substantial structures only (i.e. masonry or insulated weather board cladding with sealed underfloor)
- Upgrading window and doors seals and appropriately treating sub-floor ventilation
- The sealing of wall vents
- The sealing of the underfloor below the bearers
- The sealing of eaves.

The reduction in noise level that can be achieved by these treatments will depend on the structure type and condition of the existing building.

6.8 Maximum Noise Levels

The relationship between event maximum noise levels from road traffic and sleep disturbance is not currently well defined. The RNP and its predecessor, the Environmental Criteria for Road Traffic Noise (ECRTN) discuss sleep disturbance in relation to the number of noise events causing awakenings during the night-time period. As the relationship between noise and sleep disturbance is not fully understood, the RNP and ECRTN acknowledge sleep disturbance from road traffic and state that the continuation of research into its assessment is important.

The RNP and ECRTN identify that:

- Maximum internal noise levels below 50 – 55 dB(A) are unlikely to cause awakening reactions, and
- 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 RTA ENMM provides a protocol for assessing maximum noise levels in Practice Note III (PN-III). PN-III suggests that:

- At locations where road traffic is continuous rather than intermittent, the $L_{Aeq,9hr}$ (night-time) target noise levels should sufficiently account for sleep disturbance impacts.
- However, where the emergence of maximum levels L_{Amax} over the ambient L_{Aeq} is greater than 15 dB(A) (e.g. intermittent or interrupted flows), the $L_{Aeq,9hr}$ criteria may not sufficiently account for sleep disturbance impacts.

Therefore, an assessment of the impact of sleep disturbance on residents is made in terms of likely maximum noise levels from road traffic, the extent to which these maximum noise levels exceed the ambient level, and the expected number of noise events from road traffic during the night.

The logger data from 682 High Street (representative of noise sensitive receivers on High Street west of the intersection) and from 57 Mulgoa Road (representative of noise sensitive receivers on Mulgoa Road south of the intersection) has been analysed in 1-minute intervals to identify the number of existing Maximum Noise Level Events where the L_{max} noise level is ≥15 dB above the hourly L_{Aeq} ($L_{Aeq,1hr}$) from traffic noise, and where the L_{max} noise level exceeds 65 dB(A).

The data has been presented for each hour of each night of the survey in Table 25 and Table 26 below. In these tables, note that the date given is for the date of midnight during that night time period – i.e. Friday 27 November indicates data for the time period spanning Thursday 26 November 2200-2359 and Friday 27 November 0000-0659.

Table 25: Summary of Maximum Noise Level Events, 682 High Street

Day	**Number of Maximum Noise Level Events**									
	2200	**2300**	**0000**	**0100**	**0200**	**0300**	**0400**	**0500**	**0600**	**Total**
Friday 27 Nov 2015	0	5	7	7	10	7	14	5	2	**57**
Saturday 28 Nov 2015	0	3	4	3	4	7	8	3	3	**35**
Sunday 29 Nov 2015	1	0	0	2	2	7	4	3	2	**21**
Monday 30 Nov 2015	2	8	2	8	12	11	10	4	1	**58**
Tuesday 1 Dec 2015	2	5	5	7	8	8	10	4	2	**51**
Wednesday 2 Dec 2015	5	5	5	5	8	8	12	2	2	**52**
Thursday 3 Dec 2015	4	5	4	10	10	14	12	6	0	**65**
Average Weekday	**3**	**6**	**5**	**7**	**10**	**10**	**12**	**4**	**1**	**57**
Average Weekend	**1**	**2**	**2**	**3**	**3**	**7**	**6**	**3**	**3**	**28**
Average All Days	**2**	**4**	**4**	**6**	**8**	**9**	**10**	**4**	**2**	**48**

Table 26: Summary of Maximum Noise Level Events, 57 Mulgoa Road

Day	Number of Maximum Noise Level Events									
	2200	**2300**	**0000**	**0100**	**0200**	**0300**	**0400**	**0500**	**0600**	**Total**
Friday 27 Nov 2015	8	13	9	12	11	16	19	8	5	**101**
Saturday 28 Nov 2015	5	7	11	10	10	14	15	17	18	**107**
Sunday 29 Nov 2015	10	9	6	12	11	24	9	11	18	**110**
Monday 30 Nov 2015	13	12	11	11	10	13	11	19	11	**111**
Tuesday 1 Dec 2015	10	18	10	14	10	14	20	15	16	**127**
Wednesday 2 Dec 2015	13	14	15	13	14	17	22	14	8	**130**
Thursday 3 Dec 2015	11	14	13	14	15	14	21	20	12	**134**
Average Weekday	**11**	**14**	**12**	**13**	**12**	**15**	**19**	**15**	**10**	**121**
Average Weekend	**8**	**8**	**9**	**11**	**11**	**19**	**12**	**14**	**18**	**109**
Average All Days	**10**	**12**	**11**	**12**	**12**	**16**	**17**	**15**	**13**	**117**

The maximum noise levels summarised in Table 25 and Table 26 indicate that there is significant existing exposure of residents in the vicinity of the project to maximum noise levels from traffic, and that existing sleep disturbance impacts may be expected to occur.

The future L_{max} noise levels following the proposed upgrade can be estimated based on the existing L_{max} noise levels at receivers, noting the following factors:

- The existing flow environment is best characterised as “interrupted” due to the presence of existing traffic lights at the intersections within the study area.
- The proposed road upgrade is to improve capacity on the road network and may decrease road congestion, resulting in the traffic flows being more free-flowing following the upgrade. This may decrease L_{max} noise levels for individual passbys in cases where the L_{max} is due to noise from vehicle acceleration or deceleration (e.g. engine braking).
  This factor is likely to be more-pronounced away from the immediate vicinity of the intersection.
- Night time L_{max} noise levels in the immediate vicinity of the intersection are unlikely be significantly changed by the upgrade, since noise from vehicles accelerating away from the intersection will be present even after the upgrade.
- Increasing night-time traffic flows due to the increased traffic flow capacity allowed by the upgrade may raise the short-term ambient L_{Aeq} at some

receivers and may reduce the "emergence" of individual maximum noise events.

This means that individual vehicle pass-by L_{max} noise levels are not expected to increase following the upgrade (and indeed may decrease for some passbys due to the improved capacity and reduced congestion provided by the upgrade, as well as the emergence of individual pass-bys potentially reducing), but that the total number of pass-bys is likely to increase due to increased flow.

Hence, as a conservative estimate (assuming no decrease in noise level from individual pass-bys), the number of maximum noise level events following the upgrade may be estimated based on the existing and future traffic flows.

Hourly traffic flows were not available from the traffic survey data, and therefore the total number of measured 9-hour flows have been compared against the total number of maximum noise level events for each night. Table 27 and Table 28 compare the measured number of Maximum Noise Level Events to the traffic flows for each day of the survey period for the two logger locations:

Table 27 Comparison of Maximum Noise Level Events and Traffic Flows, 682 High Street

Day	Total Number of Maximum Noise Level Events	9-Hour Traffic Flows			Maximum Noise Level Events per		
		Light Vehicles	Heavy Vehicles	Total	Light Vehicle	Heavy Vehicle	Total Vehicles
Friday 27 Nov 2015	57	3,316	244	3560	1.7%	23.4%	1.6%
Saturday 28 Nov 2015	35	2,670	156	2,826	1.3%	22.4%	1.2%
Sunday 29 Nov 2015	21	1,752	33	1,785	1.2%	63.6%	1.2%
Monday 30 Nov 2015	58	2,681	240	2,921	2.2%	24.2%	2.0%
Tuesday 1 Dec 2015	51	2,970	250	3,220	1.7%	20.4%	1.6%
Wednesday 2 Dec 2015	52	3,103	3,342	3,342	1.7%	21.8%	1.6%
Thursday 3 Dec 2015	65	3,168	233	3,401	2.1%	27.9%	1.9%
Average Weekday	**57**	**3,048**	**241**	**3,289**	**1.9%**	**23.5%**	**1.7%**
Average Weekend	**28**	**2,211**	**95**	**2,306**	**1.3%**	**43.0%**	**1.2%**
Average All Days	**48**	**2,809**	**199**	**3,008**	**1.7%**	**29.1%**	**1.6%**

The relationship between number of maximum noise level events and number of heavy vehicles is most consistent; this is not unexpected as heavy vehicles are likely to represent the majority of maximum noise level events. Accordingly, for

High Street using the "average weekday" value of a maximum noise level event occurring for 23.5% of heavy vehicle movements is considered most appropriate (this is also essentially the same as the average for all days excluding Sunday, which appears to be an outlier).

Table 28 Comparison of Maximum Noise Level Events and Traffic Flows, 57 Mulgoa Road

Day	Total Number of Maximum Noise Level Events	9-Hour Traffic Flows			Maximum Noise Level Events per		
		Light Vehicles	Heavy Vehicles	Total	Light Vehicle	Heavy Vehicle	Total Vehicles
Friday 27 Nov 2015	101	4,684	244	3560	1.2%	16.3%	1.1%
Saturday 28 Nov 2015	107	3,800	359	4,159	0.9%	29.8%	0.8%
Sunday 29 Nov 2015	110	2,685	82	2,767	0.8%	134.1%	0.8%
Monday 30 Nov 2015	111	3,766	616	4,382	1.5%	18.0%	1.3%
Tuesday 1 Dec 2015	127	3,986	616	4,602	1.3%	20.6%	1.1%
Wednesday 2 Dec 2015	130	4,219	4,894	4,894	1.2%	19.3%	1.1%
Thursday 3 Dec 2015	134	4,540	661	5,201	1.4%	20.3%	1.2%
Average Weekday	**121**	**4,239**	**638**	**4,877**	**1.3%**	**18.9%**	**1.2%**
Average Weekend	**109**	**3,243**	**221**	**3,463**	**0.9%**	**49.2%**	**0.8%**
Average All Days	**117**	**3,954**	**518**	**4,473**	**1.2%**	**22.6%**	**1.1%**

The relationship between number of maximum noise level events and number of heavy vehicles is most consistent; this is not unexpected as heavy vehicles are likely to represent the majority of maximum noise level events. Accordingly, for Mulgoa Road using the "average weekday" value of a maximum noise level event occurring for 20% of heavy vehicle movements is considered most appropriate (this is also essentially the same as the average for all days excluding Sunday, which appears to be an outlier).

Using these correlations between heavy vehicle flow rates and the % incidence of maximum noise levels, the number of maximum noise level events for future years may be estimated using the traffic flows in Table 16 and Table 17, as summarised in Table 29.

Table 29: Estimated Numbers of Future Year Maximum Noise Level Events (Night)

Road Segment	Existing (2015) Measured, average weekday	Year of Opening (2019) 'No Build' Scenario	Year of Opening (2019) 'Build' Scenario	Design Year (2029) 'No Build' Scenario	Design Year (2029) 'Build' Scenario
High Street west of intersection	57 events	62 events	75 events	62 events	77 events
Mulgoa Road	121 events	127 events	139 events	146 events	183 events

The total number of maximum noise level events is predicted to increase following the upgrade; however the increase in events is largely due to the higher traffic flows that the upgrade allows.

Outside of peak times, the greater capacity may reduce the requirements for vehicles to accelerate or decelerate heavily and may result in a decrease in the % incidence of maximum noise level events compared to the assumptions used to produce Table 29.

As such, Table 29 should be viewed as a conservative estimate of future maximum noise levels, as it does not take into account the potential reduction in maximum noise emissions that may result from more free-flowing traffic following the upgrade, nor from the masking effect of the higher ambient L_{Aeq} from the higher traffic flows which may reduce the emergence of individual pass-bys for some road segments.

When considering the risk of additional sleep disturbance due to the upgrade, the following factors should be considered:

- The existing number of maximum noise level events at receivers and the presence of maximum noise level events as part of the existing noise environment
- An increase in the number of maximum noise level events would occur naturally due to increased traffic flows in the "No Build" case
- The level of individual pass-bys and/or the degree of emergence of individual pass-bys may reduce for some receivers following the upgrade

Considering these factors, there is considered to be a low risk of additional sleep disturbance due to the project.

Note also that the receivers that will be most-exposed for sleep disturbance impacts would already qualify for noise mitigation based on the $L_{Aeq,15hr}$ or $L_{Aeq,9hr}$ exceedances, and hence these mitigation measures would likely provide some benefit for sleep disturbance at these receivers. As per Practice Note III, sleep disturbance impacts should be considered when prioritising the implementation of noise mitigation for the project.

7 Construction Noise and Vibration Assessment

7.1 Construction Noise

This section provides an overview of the proposed construction timing, activities, ancillary facilities and working hours, and identifies where the key construction works will occur. It identifies the key construction activities which have the potential to result in noise and vibration impacts on the community. It provides a broad assessment of which areas may be impacted by construction noise levels above the construction noise criteria developed in Section 5.4, and what mitigation measures could be adopted to help control construction noise.

7.1.1 Construction Works Schedule

Refer to the *Final Concept Design Constructability Assessment Report* (244597-DC-CS-RPT-0001) and the *100% Concept Design Road User Delay Report* (244597-DC-CS-RPT-0002) for full details regarding the construction equipment and proposed staging of works.

The project program includes the following major activities (See Figure 4):

- Construction compounds
- Utility relocation
- Bridge construction works
- Road construction
- Finishing works

The detailed schedule shall be determined with the construction contractor as part of the planning of the construction sequence.

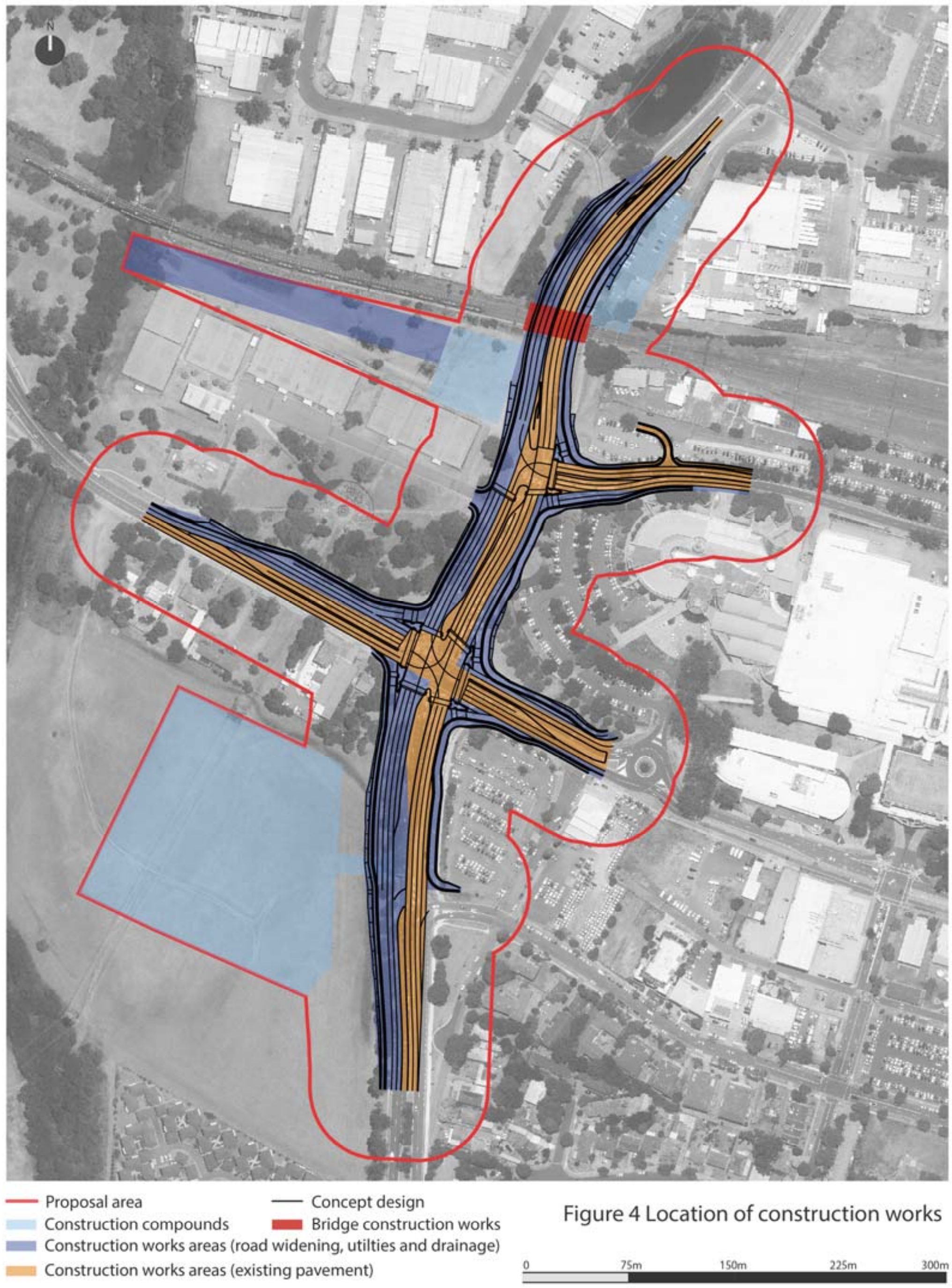


Figure 4: Location of Construction Works

7.1.2 Source Noise Levels

Indicative construction activity noise source levels have been assumed for the proposed construction works, based on previous construction noise assessments for road projects conducted by Arup and on the concept design construction methodology.

The following major construction activities have been modelled:

- Construction compounds (including stockpiling)
- Utility relocation
- Road construction (including removal of existing pavement, earthworks, and road surfacing)
- Bridgeworks (including piling)
- Finishing works

For each activity, typical construction equipment used for that activity has been combined into an overall source sound power level for the activity, accounting for the likely usage patterns of individual items of equipment over a typical 15-minute period (which is the assessment time frame for construction noise levels).

Sound levels for items of construction plant have been obtained from the databases in BS5228-1 (British Standards, 2014), AS2436 (Australian Standard, 2010) and the RMS Construction Noise and Vibration Guideline.

Items of plant that have particularly-annoying characteristics (e.g. impulsive or tonal noise characteristics, such as piling or drilling equipment) has had a +5 dB adjustment penalty applied to account for these characteristics, as required by the NSW ICNG.

Table 30 summarises the activity construction source level (including corrections for equipment usage and for annoying characteristics, as appropriate) and the major items of construction equipment modelled for each major construction activity:

Table 30: Activity Sound Power Level derived from the construction equipment typically used in each construction activity

Activity	Construction Equipment	Activity Sound Power Level, dB re 1pW
Site compounds	Generators / compressors Excavators (loading/unloading stockpiles) Waste collection On-site vehicle movements	$L_{eq,adj,15min}$ 113 dB(A)
Utility relocation	Excavators Trucks Jackhammers Concrete saws Generators Cranes Light vehicles	$L_{eq,adj,15min}$ 120 dB(A)
Removal of existing pavement	Bulldozers Scrapers Backhoes Trucks Breakers	$L_{eq,adj,15min}$ 124 dB(A)
Earthworks	Graders Bulldozers Backhoes Trucks Water carts Vibratory compactors Rollers	$L_{eq,adj,15min}$ 113 dB(A)
Pavement works	Pavement laying machine Asphalt truck Trucks Rollers Concrete pumps Concrete trucks	$L_{eq,adj,15min}$ 115 dB(A)
Bridge construction works	Piling rig (hammer) Mobile cranes Trucks Concrete pumps Concrete trucks Welding Generators/Compressors	$L_{eq,adj,15min}$ 122 dB(A)
Finishing works	Trucks Generators Light vehicles Mobile cranes	$L_{eq,adj,15min}$ 110 dB(A)

7.1.3 Methods of Construction

It should be noted that the construction contractor would refine construction methods to minimise the construction noise impact upon the noise sensitive receivers adjacent to the proposal area, and would be required to prepare a detailed Construction Noise and Vibration Management Plan as part of the construction process.

7.1.4 Predicted Construction Noise Levels

Indicative construction noise levels have been predicted for the sources given in Section 7.1.2 using the SoundPLAN noise described in section 6.2, implementing the CONCAWE environmental noise model.

The extent of works was summarised in the Constructability Assessment provided by Roads and Maritime and is presented in Figure 4.

The noise sources corresponding to each work activity were assessed at the worst case source location (i.e. at closest point of approach to each noise sensitive receiver catchment area) for each activity. Hence, predictions are not at specific receiver addresses, but represent the expected worst case impact for each receiver catchment. This is in keeping with the requirements of the ICNG, which states "the realistic worst-case or conservative noise (or blasting) levels from the source should be predicted for assessment locations representing the most noise-exposed residences or other sensitive land-uses".

This accounts for the highly-variable nature of construction noise, particular for road projects where the construction source location is "mobile" and will move relative to each receiver as the construction process progresses.

For each of these noise sources, Table 31 presents a summary showing the highest predicted noise level at each category of noise-sensitive receiver, and presents the ICNG construction screening criteria for comparison.

Table 31: Construction Noise Screening Calculations, dB re 20 µPa

Activity	**Receiver**	**Predicted Worst Case Construction Noise Level dB $L_{Aeq,adj,15min}$**	**Noise Management Level, dB(A)**		
			Day	**Evening**	**Night**
Site Compounds	Arts centre	56	70	-	-
	Library	58	75	-	-
	Gardens	61	60*	-	-
	Tennis club	68	65*	-	-
	Residential (High Street)	56	65	56	43
	Residential (Mulgoa Road)	57	57	50	38

Activity	Receiver	Predicted Worst Case Construction Noise Level dB $L_{Aeq,adj,15min}$	Noise Management Level, dB(A)		
			Day	Evening	Night
	Residential (Retirement Village)	60	57	50	38
Utility relocation	Arts centre	69	70	-	-
	Library	71	75	-	-
	Gardens	74	60*	-	-
	Tennis club	81	65*	-	-
	Residential (High Street)	73	65	56	43
	Residential (Mulgoa Road)	70	57	50	38
	Residential (Retirement Village)	66	57	50	38
Pavement Removal	Arts centre	79	70	-	-
	Library	85	75	-	-
	Gardens	82	60*	-	-
	Tennis club	77	65*	-	-
	Residential (High Street)	**88**	65	56	43
	Residential (Mulgoa Road)	74	57	50	38
	Residential (Retirement Village)	67	57	50	38
Earthworks	Arts centre	68	70	-	-
	Library	74	75	-	-
	Gardens	71	60*	-	-
	Tennis club	66	65*	-	-
	Residential (High Street)	**77**	65	56	43
	Residential (Mulgoa Road)	63	57	50	38
	Residential (Retirement Village)	58	57	50	38
Pavement Works	Arts centre	70	70	-	-
	Library	76	75	-	-
	Gardens	73	60*	-	-

Activity	Receiver	Predicted Worst Case Construction Noise Level dB $L_{Aeq,adj,15min}$	Noise Management Level, dB(A)		
			Day	Evening	Night
	Tennis club	68	65*	-	-
	Residential (High Street)	**79**	65	56	43
	Residential (Mulgoa Road)	65	57	50	38
	Residential (Retirement Village)	58	57	50	38
Bridgeworks (Hammer Piling)	Arts centre	63	70	-	-
	Library	70	75	-	-
	Gardens	67	60*	-	-
	Tennis club	74	65*	-	-
	Residential (High Street)	61	65	56	43
	Residential (Mulgoa Road)	59	57	50	38
	Residential (Retirement Village)	55	57	50	38
Finishing Works	Arts centre	65	70	-	-
	Library	71	75	-	-
	Gardens	68	60*	-	-
	Library	63	65*	-	-
	Residential (High Street)	74	65	56	43
	Residential (Mulgoa Road)	60	57	50	38
	Residential (Retirement Village)	55	57	50	38

* Noise limit applies when area is in use.

Time periods where construction noise for an activity would exceed the management level are shaded orange. Exceedances of the highly noise affected level at residences are identified in red bold text.

The initial construction noise predictions indicate that construction noise impacts are expected for the following activities:

- Bridge works outside of hours.
- Any daytime, evening or night works in the vicinity (within ~100 m) of residential premises

- Any works in the vicinity (within ~150 m) of the Jane Sutherland Performing Arts Centre.
- Any works in the vicinity (within ~100 m) of Woodriff Gardens.

For the loudest activities (e.g. pavement removal) the Highly Noise Affected Level will likely be exceeded when the source is in the immediate vicinity of residences (e.g. immediately in front of the residence). This would be expected to occur for High Street receivers when works are conducted on High Street west of the intersection. Noise levels at other times would be significantly reduced due to the increased source-receiver distance – e.g. when the source is located on Mulgoa Road, construction noise levels at most High Street receivers would reduce by ~15-20 dB(A).

As required by the ICNG, all "feasible and reasonable" noise mitigation measures should be implemented to reduce noise levels from these activities. A discussion of mitigation measures is given in Section 7.1.4.1.

7.1.4.1 Construction Traffic Noise

The peak expected construction traffic associated with the project is 200 light vehicle and 200 heavy vehicle movements per day, with construction vehicles accessing the main construction compound via Mulgoa Road between High Street and Jane Street.

Examination of the existing traffic flows (refer Table 5) shows that the addition of the construction traffic onto the surrounding road network will result in a negligible increase of 0.2 dB(A) to the $L_{Aeq,15hr}$ noise level.

Hence, impacts from additional construction traffic associated with the development will be negligible compared to the existing traffic flows on the surrounding road layout.

During bridgeworks, temporary diversions will be in place to redirect traffic from Castlereagh Road onto Jane Street/Great Western Highway, A9/Parker Street and either Coreen Avenue (light vehicles) or Andrews Road (heavy vehicles). These diversions will only occur during the three track possessions required for bridgeworks and would only occur for a timespan of up to five days; hence any traffic noise impacts on the diversion route would be short-term and no noise mitigation is considered reasonable.

Diversion works associated with the temporary closure (for approximately six weeks) of the right turn lanes from Mulgoa Road to Jane Street and from Jane Street to Castlereagh Road would result in additional vehicle movements on Castlereagh Road from turning traffic having to continue on Castlereagh Road to the Coreen Avenue roundabout and "double back" to turn left onto Jane Street. Traffic from Jane Street wishing to turn right onto Castlereagh Road would follow the same diversion as for bridgework traffic, via Parker Street and Coreen Avenue. The short-term traffic noise impacts associated with these diversions would be less than 1 dB(A) which is insignificant.

7.1.5 Construction Noise Mitigation Measures

Initial construction noise mitigation measures have been developed for each major activity of construction in order to reduce construction noise emission. These mitigation measures have been based on the guidance of the new RMS Construction Noise and Vibration Guideline.

These mitigation measures represent an initial estimate of all "feasible and reasonable" work practices suitable for consideration in the construction process. During detailed design of the construction process, a subsequent review of these mitigation measures should be conducted to determine whether these measures are still relevant to the developed construction process.

These mitigation measures consist of a combination of universal work practices that should be followed for all activities, as well as specific mitigation measures for individual construction activities.

7.1.5.1 Universal Work Practices

The following noise mitigation work practices are recommended to be adopted at all times on site:

- Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways to minimise noise.
- Ensure site managers periodically check the site and nearby residences for noise problems so that solutions can be quickly applied.
- Avoid the use of radios or stereos outdoors during night time works.
- Avoid the overuse of public address systems.
- Avoid shouting, and minimise talking loudly and slamming vehicle doors, especially during night time works.
- Turn off all vehicles, plant and equipment when not in use
- Ensure all doors/hatches are shut.
- Use non-"beeper" reversing/movement alarms such as broadband (non-tonal) alarms or ambient noise-sensing alarms.
- Ensure all plant and equipment used on site is compliant with the maximum noise levels in Table F1 of the RMS Construction Noise and Vibration Guideline

7.1.5.2 Site Establishment

- Turn off all vehicles, equipment/plant when not in use.
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc.
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.
- Avoid dropping materials from height.

- Provide resilient damping material on bin trucks or receptacles to minimise impact noise from materials loaded on truck.
- Avoid metal-to-metal contact on equipment wherever possible.
- Conduct work behind temporary hoardings/screens wherever possible, e.g. locate stockpiles behind site sheds/cabins. Site hoardings should be located as close to the noise source as possible, and should be as high as feasible considering the structural support of the hoarding.
  Site hoardings may not be effective at screening noise to upper floors of sensitive receivers, but can be an effective noise mitigation measure for receivers located on lower floors
- Plan construction compounds to minimise noise impacts on nearby sensitive receivers, e.g. placing temporary site buildings to provide shielding between stockpiles or stationary items of plant and receivers.
- Fit mufflers/silencers to pneumatic tools (e.g. breakers).
- Use residential-grade mufflers on plant.
- Use dampened bits on impulsive tools such as jackhammers to avoid "ringing" noise.

7.1.5.3 Utility Relocation

- Turn off all vehicles, equipment/plant when not in use.
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc.
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.
- Avoid dropping materials from height.
- Provide resilient damping material on bin trucks or receptacles to minimise impact noise from materials loaded on truck.
- Avoid metal-to-metal contact on equipment wherever possibleFit mufflers/silencers to pneumatic tools (e.g. breakers).
- Use residential-grade mufflers on plant.
- Use dampened bits on impulsive tools such as jackhammers to avoid "ringing" noise.

7.1.5.4 Road Construction

- Turn off all vehicles, equipment/plant when not in use
- Use residential-grade mufflers on all items of plant
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.

7.1.5.5 Bridgeworks

- Turn off all vehicles, equipment/plant when not in use.
- Use residential-grade mufflers on all items of plant.
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc.
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.
- Avoid dropping materials from height.
- Provide resilient damping material on bin trucks to minimise impact noise from materials loaded on truck.
- Avoid metal-to-metal contact on equipment wherever possible.
- Mitigation measures to reduce the impact of percussive piling activities include:
  - Using a resilient pad (dolly) between pile and hammer head
  - Enclosing the hammer head in a temporary acoustic shroud.
  - Alternatively, rotary bored or vibro-piling may be used where consistent with the type of pile used and restrictions on soil disturbance.

7.1.5.6 Finishing Works

The following noise mitigation work practices are recommended to be implemented to control noise impacts from internal works to internal noise-sensitive receivers:

- Turn off all vehicles, equipment/plant when not in use.
- Use residential-grade mufflers on all items of plant.
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc.
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.

7.1.5.7 Assumed Noise Mitigation

Indicative noise mitigation for different noise mitigation measures have been obtained from the guidance of AS2436 and BS5228.1, as summarised below in Table 32

Table 32: Indicative Noise Reduction Provided by Noise Mitigation Measures

Construction Equipment	Noise Mitigation Measure	Indicative Noise Reduction	Source
Generators Cement mixers Hand-held tools Drilling rigs	Screening	5 dB(A)	Table C3 AS2436:2010

Construction Equipment	Noise Mitigation Measure	Indicative Noise Reduction	Source
Impulsive tools (jackhammers, breakers etc)	Damped bit / rubber silencer	5 dB(A)	Table C2 AS2436:2010
Piling	Resilient dolly Substitution of bored piling	10 dB(A)	Table C2 AS2436:2010 DEFRA
Excavators/loaders Trucks Mobile cranes Bored piling rig Graders Rollers	Residential-grade silencer	10 dB(A)	Table C2 AS2436:2010

Mitigated noise levels using these noise reduction values are presented in the following sections. Note that these noise reductions apply to individual items of plant and not to the entire construction activity, and hence the full benefit of the mitigation measures may not be achieved in cases where another noise source (for which mitigation is not practical) begins to dominate the construction noise level.

An example of this would be using excavators for loading/unloading of material – while residential-grade silencers and increased sound-insulation of the excavator casing can reduce the mechanical noise emission of the excavator, any “activity” noise (e.g. noise from unloading rubble) would not be affected by the noise mitigation measures. The overall noise reduction would be of the order of 1 dB(A) when unloading, but 10 dB(A) when idling.

Detailed construction noise predictions (to be conducted during the detailed design of the construction sequence by the appointed contractor) will consider potential noise mitigation measures in greater detail than is possible (or appropriate) at REF stage before a contractor is appointed.

7.1.6 Predicted Construction Noise Levels With Mitigation

Table 33: Construction Noise Screening Calculations with Mitigation, dB re 20 µPa

Activity	Receiver	Predicted Worst Case Construction Noise Level dB $L_{Aeq,adj,15min}$	Noise Management Level, dB(A)		
			Day	Evening	Night
Site Compounds	Arts centre	49	70	-	-
	Library	51	75	-	-
	Gardens	54	60*	-	-
	Tennis club	61	65*	-	-
	Residential (High Street)	49	65	56	43
	Residential (Mulgoa Road)	50	57	50	38
	Residential (Retirement Village)	53	57	50	38
Utility relocation	Arts centre	67	70	-	-
	Library	69	75	-	-
	Gardens	72	60*	-	-
	Tennis club	79	65*	-	-
	Residential (High Street)	71	65	56	43
	Residential (Mulgoa Road)	68	57	50	38
	Residential (Retirement Village)	64	57	50	38
Pavement Removal	Arts centre	74	70	-	-
	Library	80	75	-	-
	Gardens	77	60*	-	-
	Tennis club	72	65*	-	-
	Residential (High Street)	**83**	65	56	43
	Residential (Mulgoa Road)	69	57	50	38
	Residential (Retirement Village)	62	57	50	38
Earthworks	Arts centre	60	70	-	-
	Library	66	75	-	-
	Gardens	63	60*	-	-

Activity	Receiver	Predicted Worst Case Construction Noise Level dB $L_{Aeq,adj,15min}$	Noise Management Level, dB(A)		
			Day	Evening	Night
	Tennis club	58	65*	-	-
	Residential (High Street)	69	65	56	43
	Residential (Mulgoa Road)	55	57	50	38
	Residential (Retirement Village)	50	57	50	38
Pavement Works	Arts centre	63	70	-	-
	Library	69	75	-	-
	Gardens	66	60*	-	-
	Tennis club	61	65*	-	-
	Residential (High Street)	73	65	56	43
	Residential (Mulgoa Road)	58	57	50	38
	Residential (Retirement Village)	51	57	50	38
Bridgeworks (Bored Piling)	Arts centre	50	70	-	-
	Library	57	75	-	-
	Gardens	54	60*	-	-
	Tennis club	61	65*	-	-
	Residential (High Street)	48	65	56	43
	Residential (Mulgoa Road)	46	57	50	38
	Residential (Retirement Village)	42	57	50	38
Finishing Works	Arts centre	55	70	-	-
	Library	61	75	-	-
	Gardens	58	60*	-	-
	Library	53	65*	-	-
	Residential (High Street)	64	65	56	43
	Residential (Mulgoa Road)	50	57	50	38

Activity	Receiver	Predicted Worst Case Construction Noise Level dB $L_{Aeq,adj,15min}$	Noise Management Level, dB(A)		
			Day	Evening	Night
	Residential (Retirement Village)	45	57	50	38

* Noise limit applies when area is in use.

The predictions indicate that even with all "practicable and reasonable" mitigation measures in place, some residual exceedances of the noise limits are predicted to occur as shaded in the table above at the follow locations/activities:

- Pavement removal
- Bridgeworks (at night)
- Evening or night-time roadworks in the vicinity (within ~150 m) of residential receivers.
- Daytime roadworks in the immediate vicinity (within ~30-70 m) of residential receivers.
- Daytime roadworks in the vicinity (within ~50 m) of Woodriff Gardens.

7.1.7 Construction Working Hours

The proposed working hours for the project are the standard approved working hours for construction projects, namely:

- Weekdays: 7am to 6pm
- Saturdays: 8am to 1pm
- Sundays and public holidays: no work.

The majority of construction activities would be carried out during the proposed working hours. There would be certain activities that would need to be carried out outside of these standard working hours.

7.1.7.1 Outside Recommended Standard Hours

The ICNG encourages construction works to be conducted during recommended standard hours wherever possible, stating that "*all efforts should be made to avoid conducting construction activities outside of non-standard hours*"; however it is recognised that sometimes it is are unavoidable.

A single construction noise management level (RBL+5) is defined based on the RBL ambient noise level for each receiver as shown in Table 9.

If noise levels are predicted to exceed the noise management level for work outside of recommended standard hours, all "practicable and reasonable" mitigation measures should be implemented. This would be subject to additional assessment conducted by the contractor in the form of a Construction Noise

Impact Assessment (CNIA) for individual activities, if out of hours works are required.

The ICNG states that "*where night work is required in the vicinity of residential or other sensitive sites, careful planning is required and a higher level of control is recommended, to mitigate potential complaints of sleep disturbance*".

A detailed sleep disturbance assessment would also be required to be conducted (by the contractor) for any planned out of hours work. Based on the indicative predictions conducted at this stage, it is expected that the following activities may cause sleep disturbance impacts and would require more-detailed assessment:

- Utility relocation (in the vicinity of residential receivers)
- Road construction (in the vicinity of residential receivers)
- Finishing works (in the vicinity of residential receivers)

Bridgeworks are located sufficiently far (>300 m) from residential receivers that sleep disturbance impacts are unlikely; however a screening assessment should be conducted once additional details of the proposed construction methodology and equipment are available during detailed design.

The detailed sleep disturbance assessment should include consideration of the absolute level of the activity, the degree of emergence above the ambient noise level, and the number of individual noisy events likely to occur per night. This level of detail is not yet available and hence a detailed sleep disturbance assessment is not possible at this stage.

If, after all "practicable and reasonable" mitigation measures have been applied, noise levels still exceed the limiting criteria, further administrative management measures are required, to be determined via consultation with affected receivers.

Where residual impacts occur, the ICNG requires additional noise management measures to be determined in consultation with affected receivers (i.e. residential receivers west of the intersection of High Street and Mulgoa Road, or on Mulgoa Road north of Rodley Avenue) providing designated times where no works occur (e.g. agreeing with residents a schedule of nights when construction will and will not occur). Refer to Section 0 for details of additional mitigation measures.

7.1.8 Community Consultation and Additional Mitigation Measures

Table C1 of the RMS Construction Noise and Vibration Guideline includes details of additional mitigation measures to be implemented based on the level of exceedance of the Noise Management Level. Table C1 is reproduced below in simplified form as Table 34.

Table 34 RMS Construction Noise and Vibration Guideline Additional Mitigation Categories

Time Period	Category	Predicted $L_{Aeq,adj,15min}$	Additional Mitigation
All Times	Exceeds Highly-Affected Noise Level	$L_{Aeq,15min}$ > 75 dB(A)	Letter Box Drop Verification Phone Calls Respite Offers
Standard Hours	Noticeable	$L_{Aeq,15min}$ < NML	Nil
	Clearly Audible	NML ≤ $L_{Aeq,15min}$ < NML+10	Nil
	Moderately Intrusive	NML+10 ≤ $L_{Aeq,15min}$ ≤ NML+20	Letter Box Drop Verification
	Highly Intrusive	$L_{Aeq,15min}$ > NML+20	Letter Box Drop Verification

Time Period	Category	Predicted $L_{Aeq,adj,15min}$	Additional Mitigation
OOHW Period 1*	Noticeable	$L_{Aeq,15min} < NML + 5$	Nil
	Clearly Audible	$NML + 5 \leq L_{Aeq,15min} < NML+15$	Letter Box Drop Respite Period (Type 1) Duration Respite
	Moderately Intrusive	$NML+15 \leq L_{Aeq,15min} \leq NML+25$	Letter Box Drop Verification Respite Period (Type 1) Duration Respite
	Highly Intrusive	$L_{Aeq,15min} > NML+25$	Letter Box Drop Verification Individual Briefings Phone Calls Specific Notifications Respite Period (Type 1) Duration Respite

*Out of Hours Work Period 1:

- Monday - Friday 1800-2200
- Saturday 0700-0800 and 1300-2200
- Sunday/Public Holiday 0800-1800

Time Period	Category	Predicted $L_{Aeq,adj,15min}$	Additional Mitigation
OOHW Period 2**	Noticeable	$L_{Aeq,15min}$ < NML + 5	Letter Box Drop
	Clearly Audible	NML + 5 ≤ $L_{Aeq,15min}$ < NML+15	Letter Box Drop Verification Respite Period (Type 2) Duration Respite
	Moderately Intrusive	NML+15 ≤ $L_{Aeq,15min}$ ≤ NML+25	Letter Box Drop Verification Individual Briefings Phone Calls Specific Notifications Respite Period (Type 2) Duration Respite
	Highly Intrusive	$L_{Aeq,15min}$ > NML+25	Letter Box Drop Verification Individual Briefings Phone Calls Specific Notifications Respite Period (Type 2) Duration Respite Alternative Accommodation

**Out of Hours Work Period 2:

- Monday-Friday 2200-0700
- Saturday 2200-0800
- Sunday/Public Holiday 1800-0700

7.1.8.1 Notification

General notification (letter box drops or equivalent) to all potentially affected receivers should detail the expected type of work activities to be conducted, the timing and duration of the proposed activities, the likely impacts of the work activities and details of any mitigation measures implemented. General notification should occur a minimum of five working days prior to the works.

Additional notification would be conducted for particular highly-affected receivers, including:

- **Specific notification**, which is more-targeted notifications delivered to individual stakeholders a minimum of seven calendar days prior to commencement of works. Specific notification provides additional information for particular highly-affected receivers.
- **Phone calls** made to individual highly-affected receivers made within seven calendar days of the proposed works. Phone calls should allow for personalised contact with affected stakeholders and will provide more-tailored advice, and provide stakeholders with the opportunity to comment on the proposed works.
- **Individual briefings** are conducted with particularly highly-affected stakeholders within 48 hours of the commencement of works, and consist of a visit to the stakeholder by a project representative.

7.1.8.2 Verification

Where construction noise levels are predicted to trigger additional mitigation measures, attended measurements should be conducted within 14 days from commencement of construction in order to check the actual construction noise levels and to verify that the proposed additional mitigation measures are appropriate.

7.1.8.3 Respite Periods

Where noise or vibration generating activities in the vicinity of receivers exceed the Highly Noise Affected Level, **respite offers** should be made to affected residences. Respite offers consist of providing minimum respite periods between “blocks” of work (e.g. a minimum 1 hour break in between maximum 3 hour periods of work), to be negotiated on a project-by-project basis.

For out of hours work, there are two respite categories, which aim to restrict the total number of days over which impacts occur.

During OOHW Period 1, **respite period type 1** restricts out-of-hours construction work as follows (unless otherwise negotiated with the community as part of a Duration Respite):

- Noise must not occur for more than three consecutive evenings per week.

- Each "period" of evening work must be separated by at least one week from any other period of evening work
- Work must not occur for more than six evenings per month.

During OOHW Period 2, **respite period type 2** restricts out-of-hours construction work as follows (unless otherwise negotiated with the community as part of a Duration Respite):

- Noise must not occur for more than two consecutive nights per week.
- Each "period" of night work must be separated by at least one week from any other period of night work
- Work must not occur for more than six nights per month.
- Where possible, high noise-generating works must be completed by 11 pm

For longer duration projects, provision of Respite Periods may prolong the overall noise impact by restricting the ability of the project to conduct OOHW. In these instances, provided that support from the affected community can be demonstrated, **Duration Respite** can be offered, in which OOHW is conducted over additional nights in order to complete the overall construction program more-rapidly. The community consultation should include meeting with individual receivers where reasonable given the community engagement resources available to the project.

7.1.8.4 Alternative Accommodation

In cases where residents would be exposed to highly-intrusive noise levels, alternative accommodation should be considered to be offered on a project-by-project basis. Factors to include in deciding whether to offer alternative accommodation include whether the activities causing the highly-intrusive noise levels would occur after midnight.

7.1.9 Indicative Areas of Impacts

To assist in identifying potentially-affected receivers, indicative maps of the expected maximum areas of construction noise impacts for the project are presented in Appendix C for four source locations:

- The southernmost area of works along Mulgoa Road south of the intersection
- The westernmost area of works along High Street west of the intersection
- The easternmost area of works along High Street east of the intersection
- The easternmost area of works along Jane Street east of the intersection

Taken together, these four locations would be indicative of the maximum expected geographical extent of noise impacts at sensitive receivers from construction works.

Contours of the Highly Noise Affected Level and the subjective impact categories in Table 34 are presented for works during standard hours and for works outside of standard hours to show the indicative zones of construction noise impacts.

The sound power level used to derive these contours is 124 dB(A), which is the sound power of the loudest activity modelled in the construction noise assessment (pavement removal). Noise levels from other activities (and for locations further away than the assumed locations) will be lower than the “worst case” levels and source locations used to produce these maps, and hence the zone of impacts will reduce for other, quieter, activities.

Additionally, the assumed sound power level is deliberately conservative because there is no contractor yet appointed, and the exact equipment to be used on site will not be known until later in the project when a contractor is appointed. Therefore, these maps do not include “feasible and reasonable” mitigation measures (such as selecting quieter plant/equipment) that will be considered by the contractor as part of the detailed planning of the construction process.

The following indicative background noise levels have been used to determine the zones of impacts:

- During standard hours 45 dB(A)
- Outside standard hours 35 dB(A)

These background noise levels are based on measured background noise levels measured from this project (Table 4), and also from the Appendix A of Australian Standard AS1055.2 (1997) *Acoustics – Description and measurement of environmental noise. Part 2: Application to specific situations*, which contains “estimated average” background noise levels for typical noise area categories. Based on the measured background noise levels on site, the surrounding receivers are intermediate between receiver categories R2 “Areas with low-density transportation” and R3 “Areas with medium-density transportation”.

As a conservative assumption, all receivers have been assumed to have the same background noise levels as “R2” receivers. In practice, some receivers (particularly those closest to major roads) will have higher background noise levels which would decrease the degree of impact at these receivers; however using the assumed background noise levels allows an estimate of the area of impacts for receivers on local roads away from the project to be made.

It must be stressed that the predicted zones of impact for construction noise in the impact maps in Appendix C are deliberately very conservative, and are aimed at identifying receivers where noise impacts during construction *may* occur.

Once a contractor is appointed and a more-detailed assessment is conducted as part of the Construction Noise Impact Assessment, this will allow the expected zones of impact to be established more-accurately based on the detailed knowledge of plant/equipment and work practices to be followed for the project. The areas of impact are likely to reduce significantly with this more-detailed mapping.

7.2 Construction Vibration

The main sources of construction vibration will be as follows

- Excavation
- Grading of existing roadways
- Vibratory compacting of new road surfaces

A screening calculation has been carried out for vibration impact at the performance spaces at the Joan Sutherland Performing Arts Centre which is considered the most vibration-sensitive receiver. The screening calculation predicted no significant ground borne noise impacts to the performance space.

7.2.1 Safe Working Distance

The Transport for NSW guidance also provides recommended safe working distances for vibration intensive plant. These are based on international standards and guidance and have also been adopted in the RMS Construction Noise and Vibration Guideline. These safe working distances are reproduced in Table 35. There are no identified heritage or particularly vibration-sensitive structures within the project area and hence the standard Safe Working Distances provided here are appropriate. No dilapidation surveys are considered necessary based on the identified vibration-sensitive receivers.

Table 35: TfNSW recommended safe working distances for vibration intensive plant

Plant Item	Rating / Description	Safe Working Distance	
		Cosmetic Damage (BS 7385)	Human Response (DECCW Vibration Guideline)
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4 tonnes)	6 m	20 m
	< 200 kN (Typically 4-6 tonnes)	12 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	100 m
	> 300 kN (> 18 tonnes)	25 m	100 m
Small Hydraulic Hammer	(300 kg - 5 to 12t excavator)	2 m	7 m
Medium Hydraulic Hammer	(900 kg – 12 to 18t excavator)	7 m	23 m
Large Hydraulic Hammer	(1600 kg – 18 to 34t excavator)	22 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2 m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

Mitigation (or alternative work practices) will therefore need to be considered where sensitive receivers are located closer to the construction work zone than these ‘safe working distances’.

Maps H1 and H2 in Appendix C present these impact distances overlaid on the extent of works to assist in identifying sensitive that may lie within vibration impact distances. Note that Pile Boring and Jackhammer are not shown because the impact distances are so small as to not show at the scale of the maps.

7.3 Construction Noise Mapping

Table 36 summarises the indicative construction noise and vibration impact maps produced for the project:

Table 36: Indicative construction noise and vibration impact plots in Appendix C.

Map reference	Description
G1	Indicative noise impact extents - Mulgoa Road (South) – Standard Hours
G2	Indicative noise impact extents - Mulgoa Road (South) – OOHW
G3	Indicative noise impact extents - High Street (West) – Standard Hours
G4	Indicative noise impact extents - High Street (West) – OOHW
G5	Indicative noise impact extents - High Street (East) – Standard Hours
G6	Indicative noise impact extents - High Street (East) – OOHW
G7	Indicative noise impact extents - Jane Street (East) – Standard Hours
G8	Indicative noise impact extents - Jane Street (East) – OOHW
H1	Indicative vibration impact extents – Human comfort
H2	Indicative vibration impact extents – Building damage

8 Conclusion

Noise and vibration from the construction and operation of the proposed infrastructure upgrade of Jane Street and Mulgoa Road has been assessed in accordance with the Road and Maritime requirements.

The construction noise and vibration assessment indicates that noise from the general construction works may impact on residential sensitive receivers that are close to the construction works zone, particularly for any evening or night-time works that may occur. Out of hours work, if required, would be subject to additional assessment by the contractor to investigate sleep disturbance impacts from the works.

Commercial, industrial and other sensitive receivers (i.e. Performing Arts Centre) are likely to have much less impact, since they are further away from the works area.

Vibration from the construction work is not likely to adversely impact on sensitive receivers, provided that safe working distance recommendations are followed. For cases where vibration-generating works are required to occur within the safe working distances close to sensitive receivers, impacts may occur and more-detailed assessment should be conducted by the construction contractor as part of the planning of the construction sequence.

The noise modelling and on site measurements indicate that noise sensitive receivers along High Street west of the intersection with Mulgoa Road, on Mulgoa Road north of Rodley Avenue, as well as the active and passive recreation areas adjacent to the proposal area (i.e. Woodriff Gardens and Nepean District Tennis Association) are already experiencing an exceedance of the NCG noise criteria for road redevelopments.

Although no significant increase in noise levels is predicted to occur as part of the project, these receivers are predicted to exceed the cumulative noise limit, with noise levels from project road segments being the dominant noise sources.

Under the provisions of the NMG, these receivers would qualify for consideration of at-property noise mitigation as a result of the proposal. Mitigation via low-noise pavements or noise barriers/mounds is not considered feasible for these receivers. Mitigation measures will be considered further upon approval of the project and during detailed design stages.

Appendix A

Acoustic Terminology

A1 Acoustic Terminology

Ambient Noise Level

The ambient noise level is the overall noise level measured at a location from multiple noise sources. When assessing noise from a particular development, the ambient noise level is defined as the remaining noise level in the absence of the specific noise source being investigated. For example, if a fan located on a city building is being investigated, the ambient noise level is the noise level from all other sources without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans on other buildings.

Background Noise Level

The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects.

Assessment Background Level (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background L_{A90} noise levels – i.e. the measured background noise is above the ABL 90% of the time.

Rating Background Level (RBL / min$L_{A90,1hour}$)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey. This parameter is denoted RBL in NSW, and min$L_{A90,1hour}$ in QLD.

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressure levels, which would be unwieldy if presented on a linear scale. Therefore a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.

dB(A)

dB(A) denotes a single-number sound pressure level that includes a frequency weighting ("A-weighting") to reflect the subjective loudness of the sound level.

The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, and so the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A).

Some typical dB(A) levels are shown below.

Sound Pressure Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

L_1

The L_1 statistical level is often used to represent the maximum level of a sound level that varies with time.

Mathematically, the L_1 level is the sound level exceeded for 1% of the measurement duration. As an example, 87 dB $L_{A1,15min}$ is a sound level of 87 dB(A) or higher for 1% of the 15 minute measurement period.

L_{10}

The L_{10} statistical level is often used as the "average maximum" level of a sound level that varies with time.

Mathematically, the L_{10} level is the sound level exceeded for 10% of the measurement duration. L_{10} is often used for road traffic noise assessment. As an example, 63 dB $L_{A10,18hr}$ is a sound level of 63 dB(A) or higher for 10% of the 18 hour measurement period.

L_{90}

The L_{90} statistical level is often used as the "average minimum" or "background" level of a sound level that varies with time.

Mathematically, L_{90} is the sound level exceeded for 90% of the measurement duration. As an example, 45 dB $L_{A90,15min}$ is a sound level of 45 dB(A) or higher for 90% of the 15 minute measurement period.

L_{eq}

The 'equivalent continuous sound level', L_{eq}, is used to describe the level of a time-varying sound or vibration measurement.

L_{eq} is often used as the "average" level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period of time (i.e. the constant sound level that contains the same sound energy as the measured level). When the dB(A) weighting is applied, the level is denoted dB $L_{Aeq.}$ Often the measurement duration is quoted, thus $L_{Aeq,15\ min}$ represents the dB(A) weighted energy-average level of a 15 minute measurement.

L_{max}

The L_{max} statistical level can be used to describe the "absolute maximum" level of a sound or vibration level that varies with time.

Mathematically, L_{max} is the highest value recorded during the measurement period. As an example, 94 dB L_{Amax} is a highest value of 94 dB(A) during the measurement period.

Since L_{max} is often caused by an instantaneous event, L_{max} levels often vary significantly between measurements.

Frequency

Frequency is the number of cycles per second of a sound or vibration wave. In musical terms, frequency is described as "pitch". Sounds towards the lower end of the human hearing frequency range are perceived as "bass" or "low-pitched" and sounds with a higher frequency are perceived as "treble" or "high pitched".

Sound Power and Sound Pressure

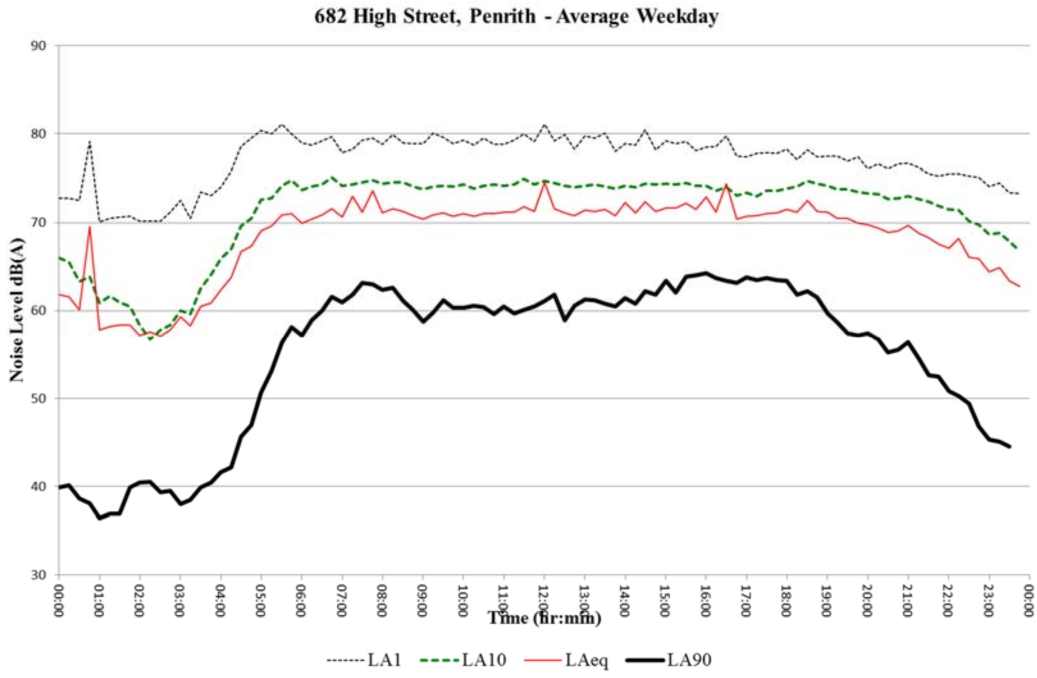
The sound power level (L_w) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (L_p) varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located

Appendix B

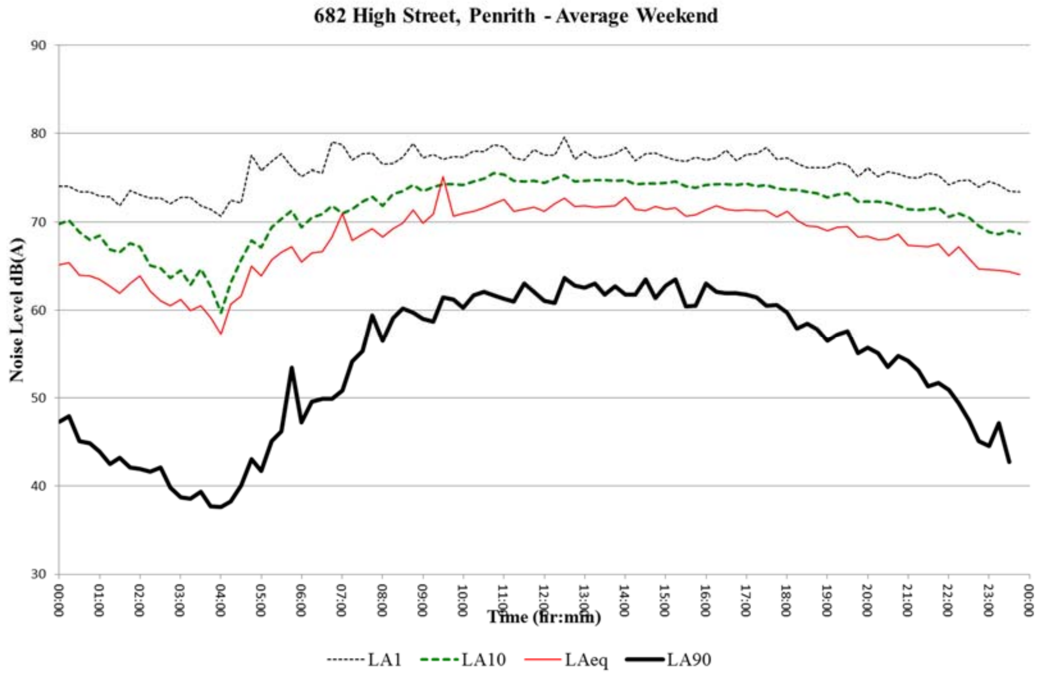
Ambient Noise Survey Results

B1 Location 1 – 682 High Street, Penrith

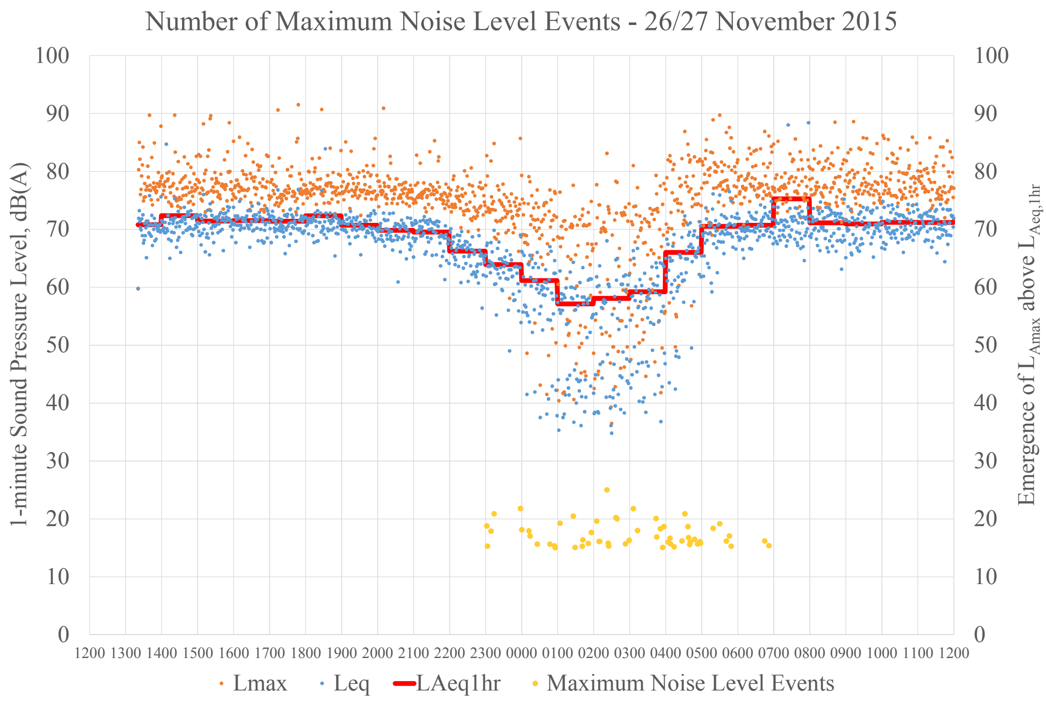
B1.1 Average Weekday

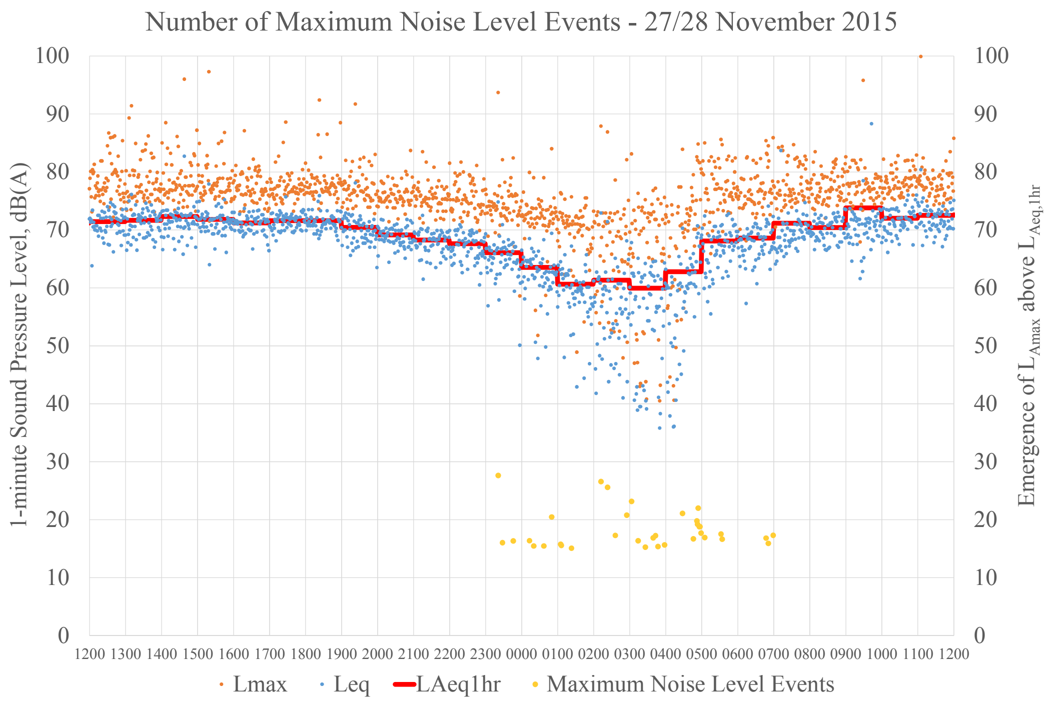


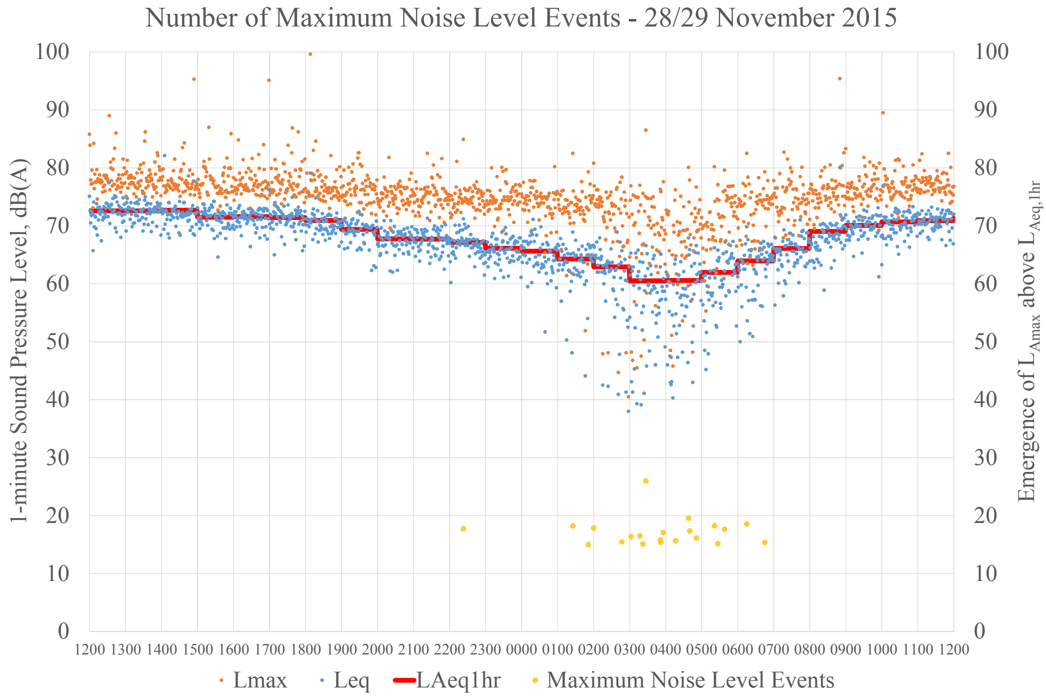
B1.2 Average Weekend

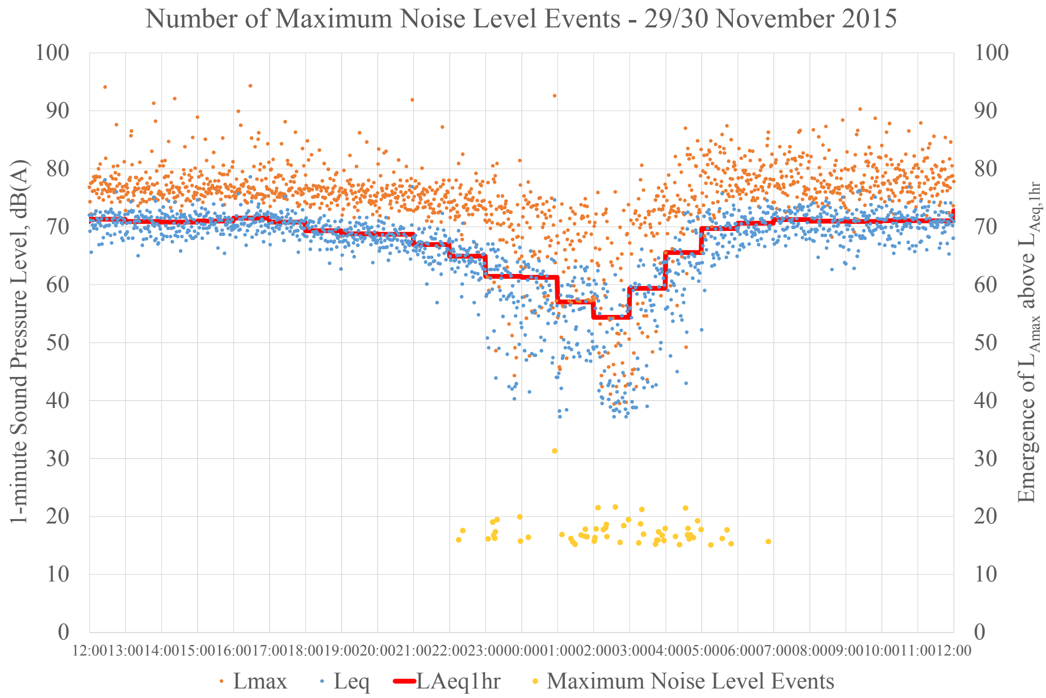


B1.3 Maximum Noise Level Monitoring






Number of Maximum Noise Level Events - 28/29 November 2015
1-minute Sound Pressure Level, dB(A)
Emergence of LAmax above LAeq,1hr
0
10
20
30
40
50
60
70
80
90
100
1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200
Lmax
Leq
LAeq1hr
Maximum Noise Level Events


Number of Maximum Noise Level Events - 29/30 November 2015
1-minute Sound Pressure Level, dB(A)
Emergence of LAmax above LAeq,1hr
0
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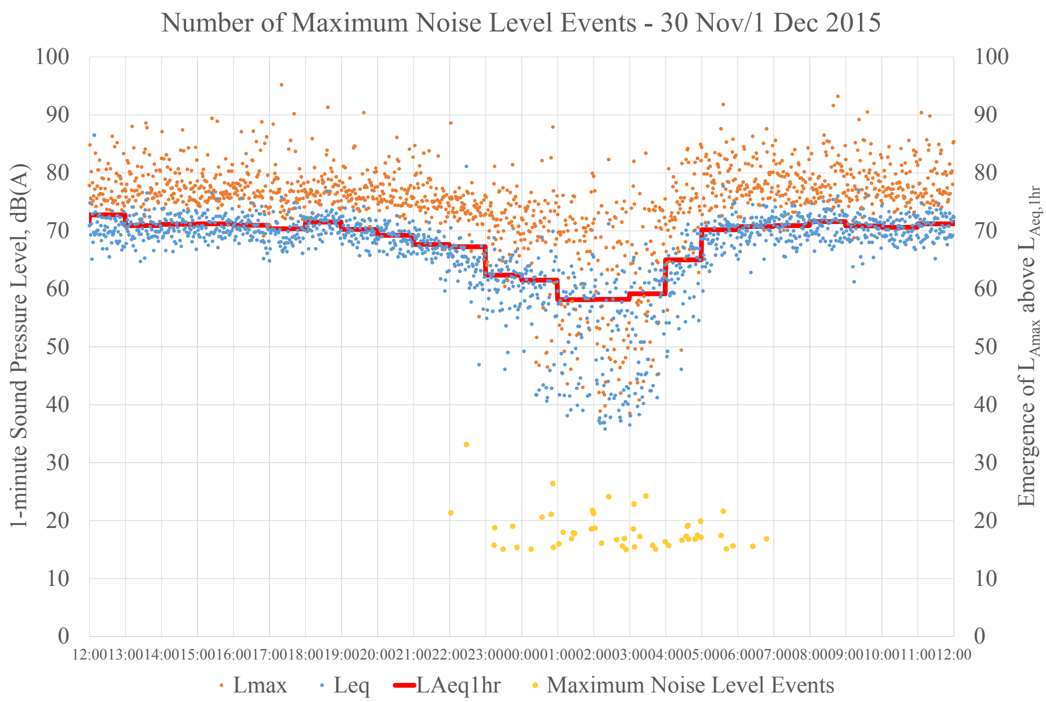
30
40
50
60
70
80
90
100
12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 00:00 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00
Lmax
Leq
LAeq1hr
Maximum Noise Level Events


Number of Maximum Noise Level Events - 30 Nov/1 Dec 2015
1-minute Sound Pressure Level, dB(A)
Emergence of LAmax above LAeq,1hr
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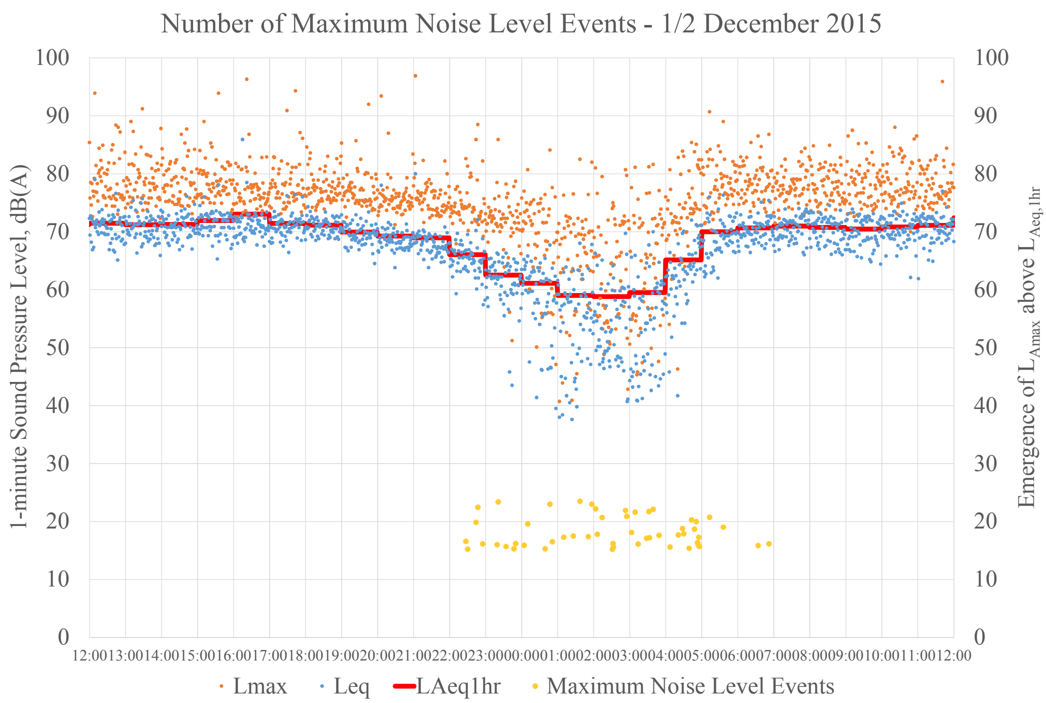
Lmax
Leq
LAeq1hr
Maximum Noise Level Events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1-minute Sound Pressure Level, dB(A)
Emergence of LAmax above LAeq,1hr
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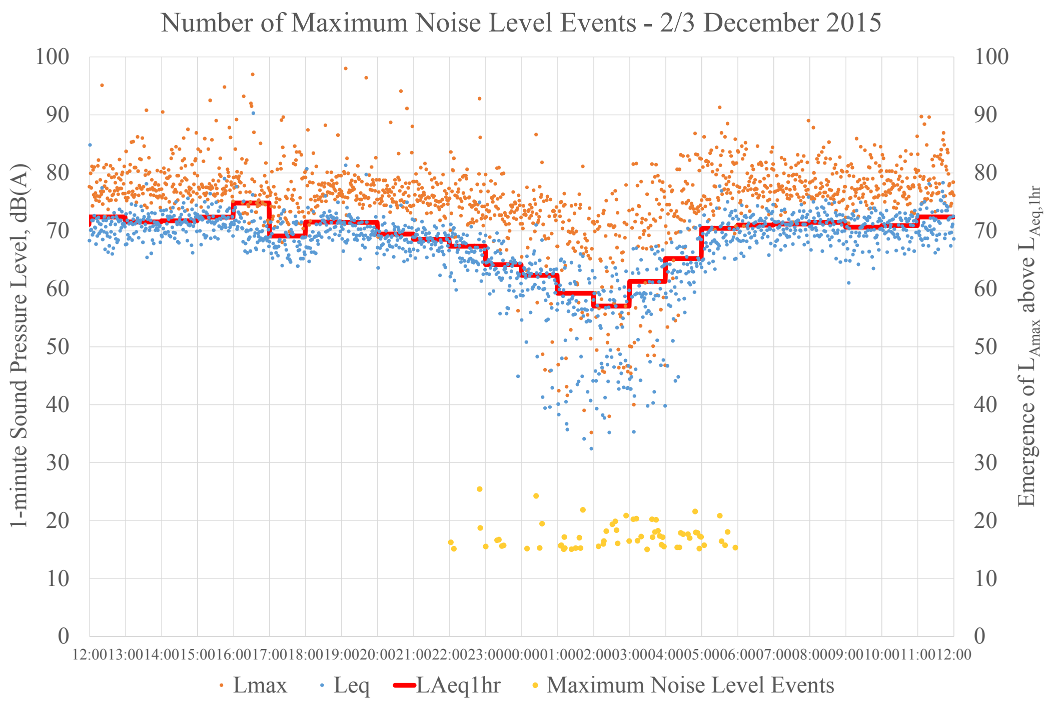
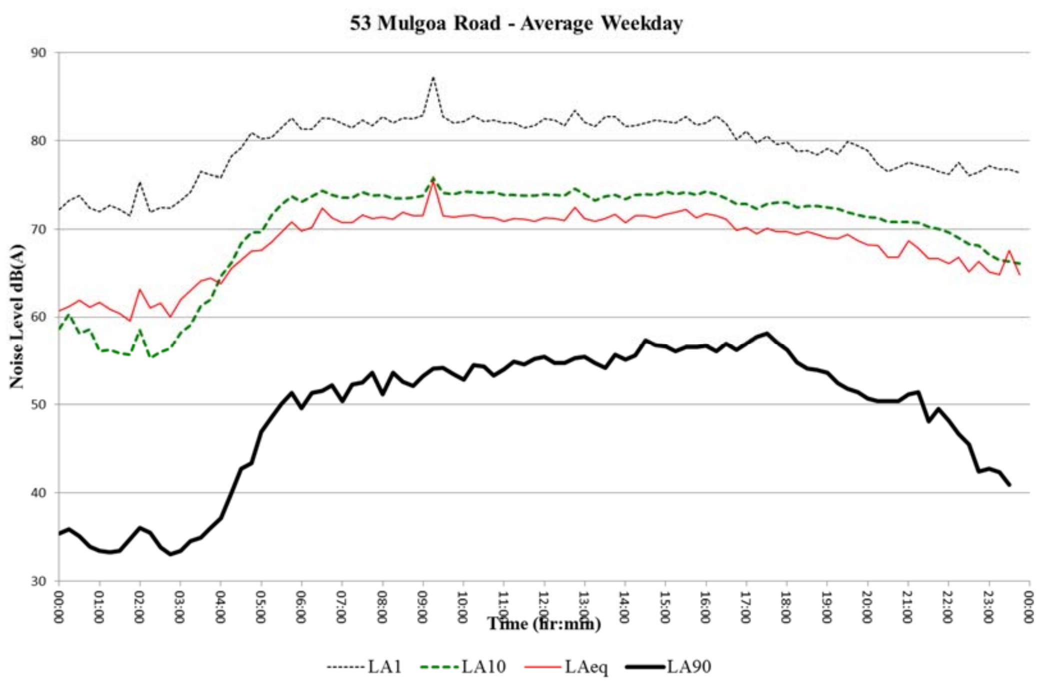
Lmax
Leq
LAeq1hr
Maximum Noise Level Events

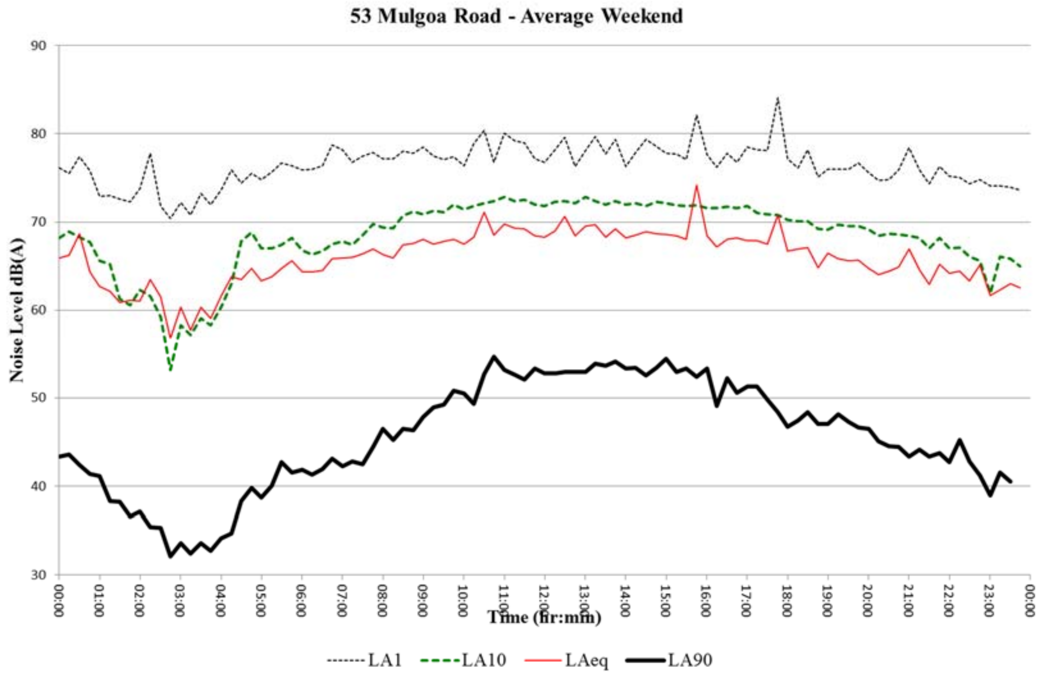


B2 Location 2 – 53 Mulgoa Road, Penrith

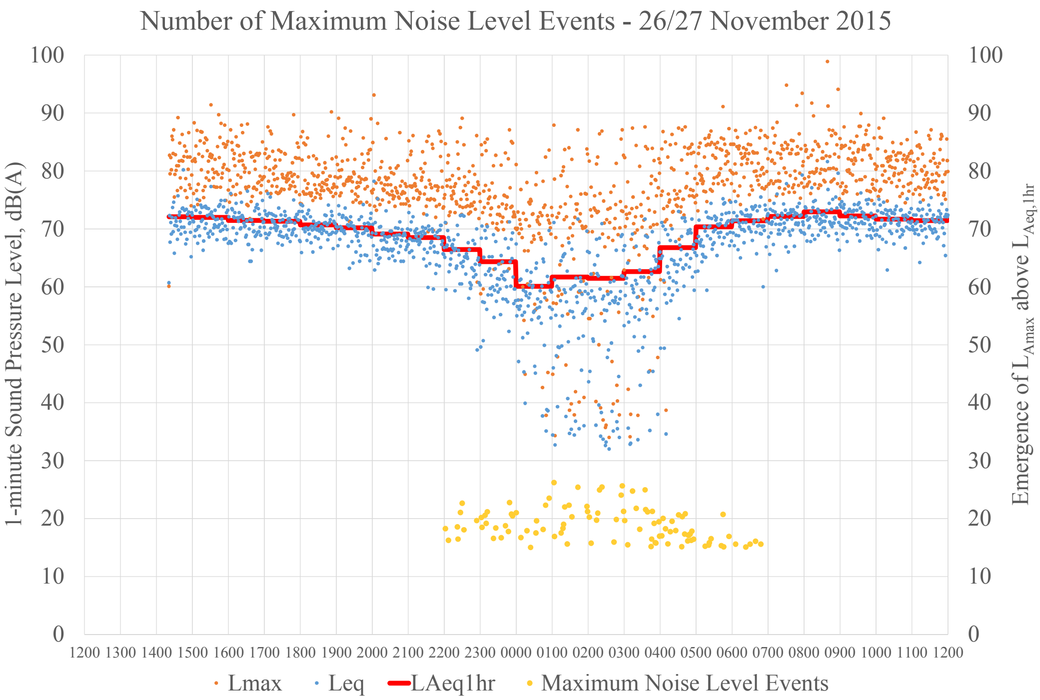
B2.1 Average Weekday

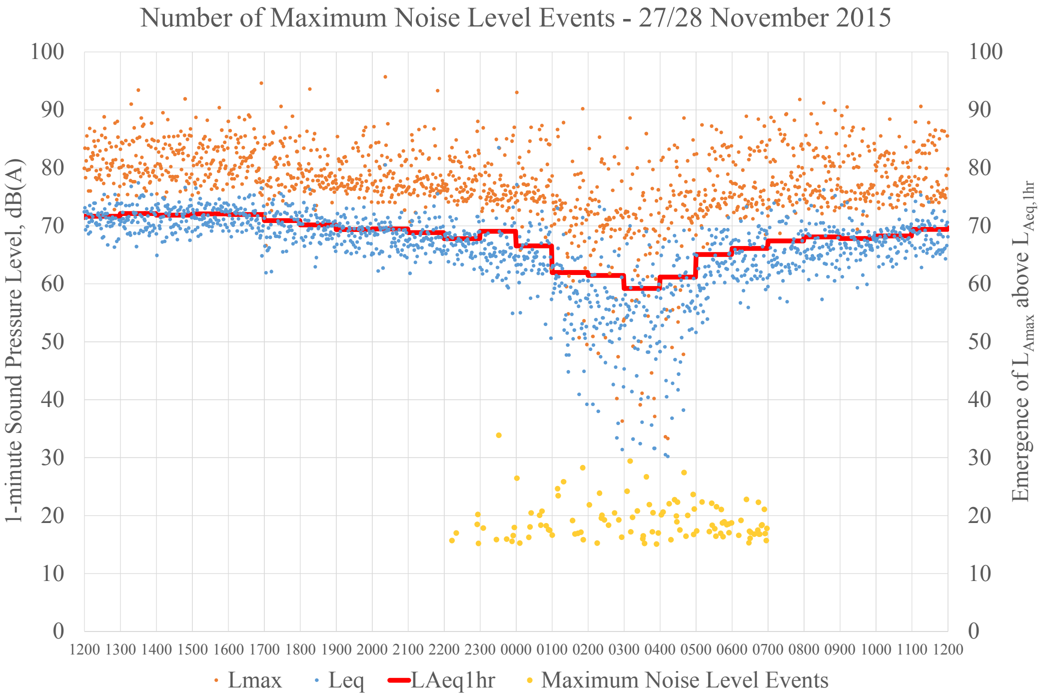


B2.2 Average Weekend



B2.3 Maximum Noise Level Monitoring

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10
20
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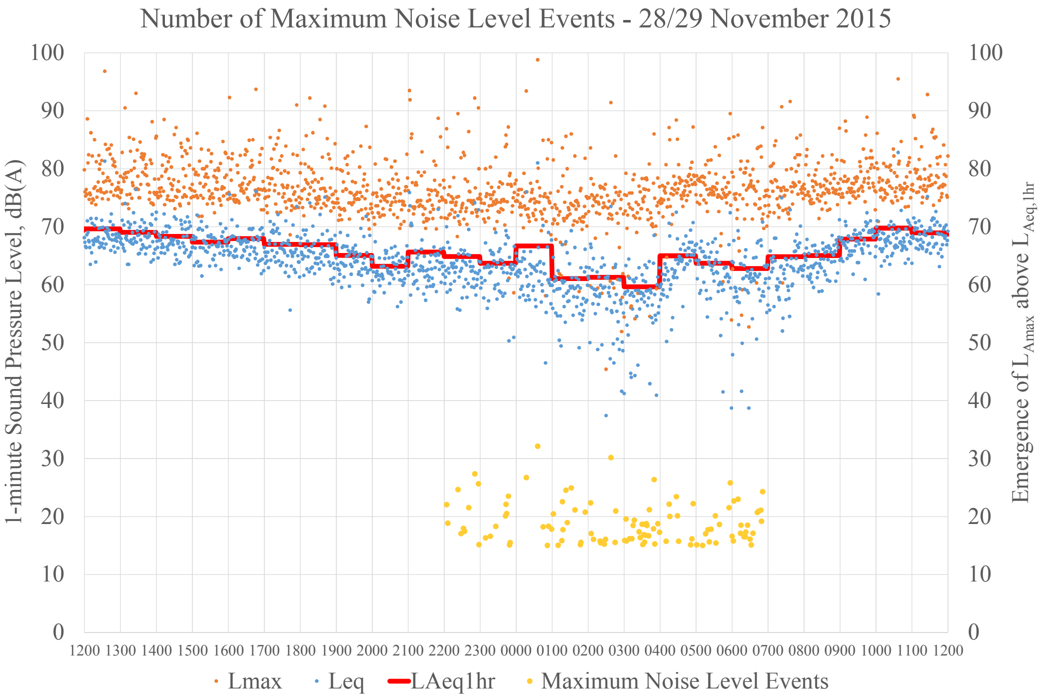
80
90
100
1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200
Lmax
Leq
LAeq1hr
Maximum Noise Level Events


Number of Maximum Noise Level Events - 28/29 November 2015
1-minute Sound Pressure Level, dB(A)
Emergence of L_{Amax} above $L_{Aeq,1hr}$
0
10
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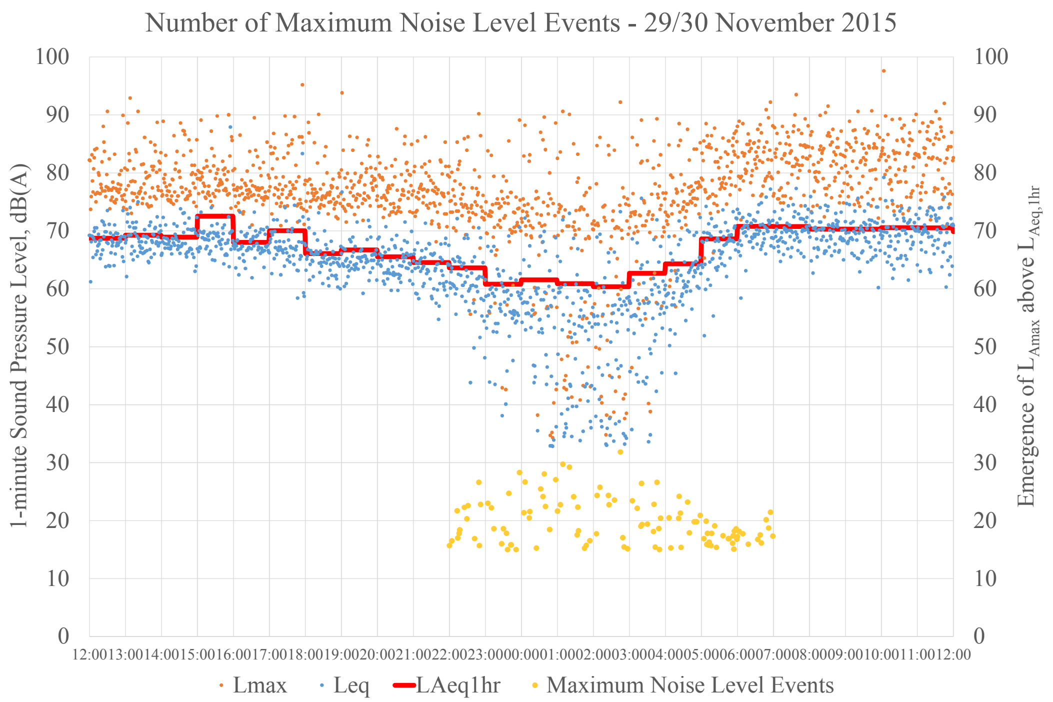
80
90
100
1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200
Lmax
Leq
LAeq1hr
Maximum Noise Level Events


Number of Maximum Noise Level Events - 29/30 November 2015
1-minute Sound Pressure Level, dB(A)
Emergence of LAmax above LAeq,1hr
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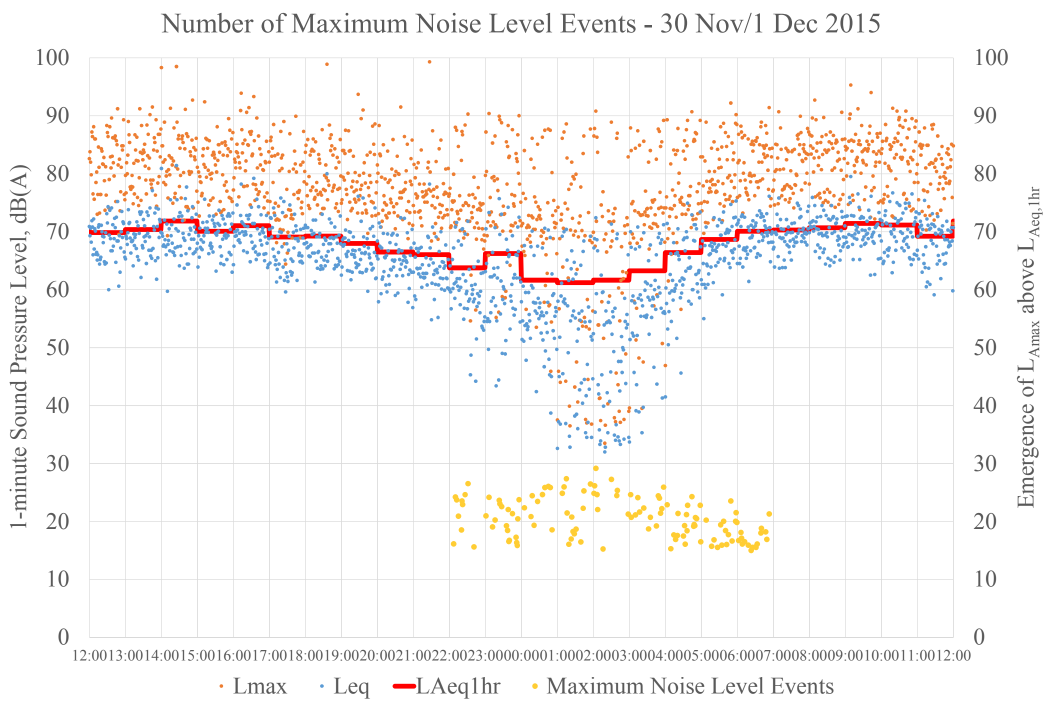
Lmax
Leq
LAeq1hr
Maximum Noise Level Events


Number of Maximum Noise Level Events - 30 Nov/1 Dec 2015
1-minute Sound Pressure Level, dB(A)
Emergence of LAmax above LAeq,1hr
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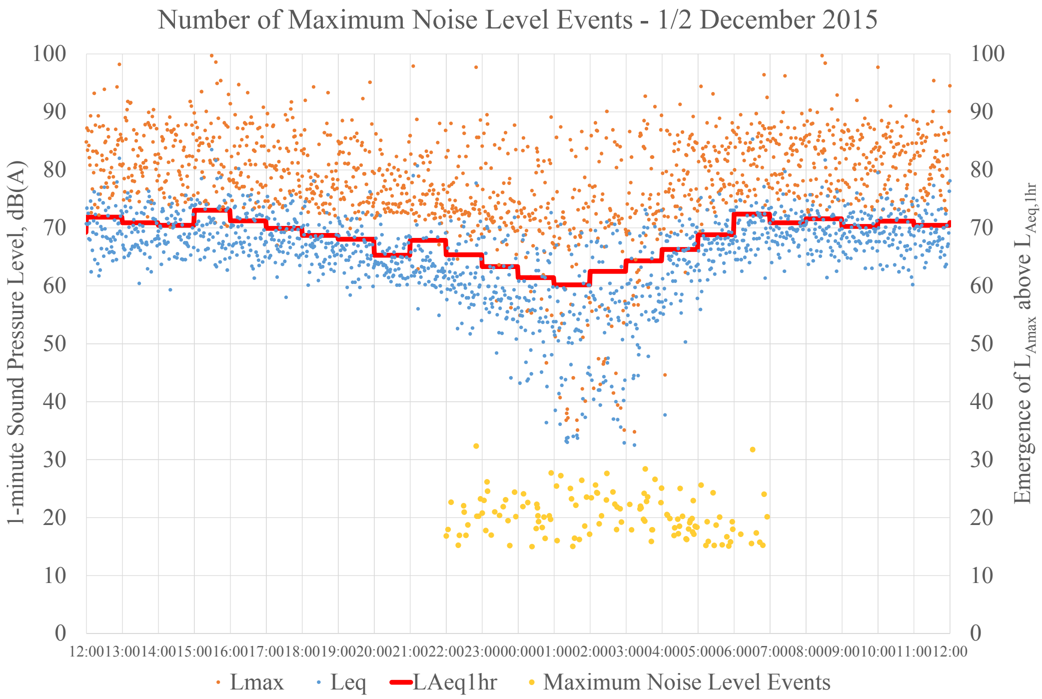
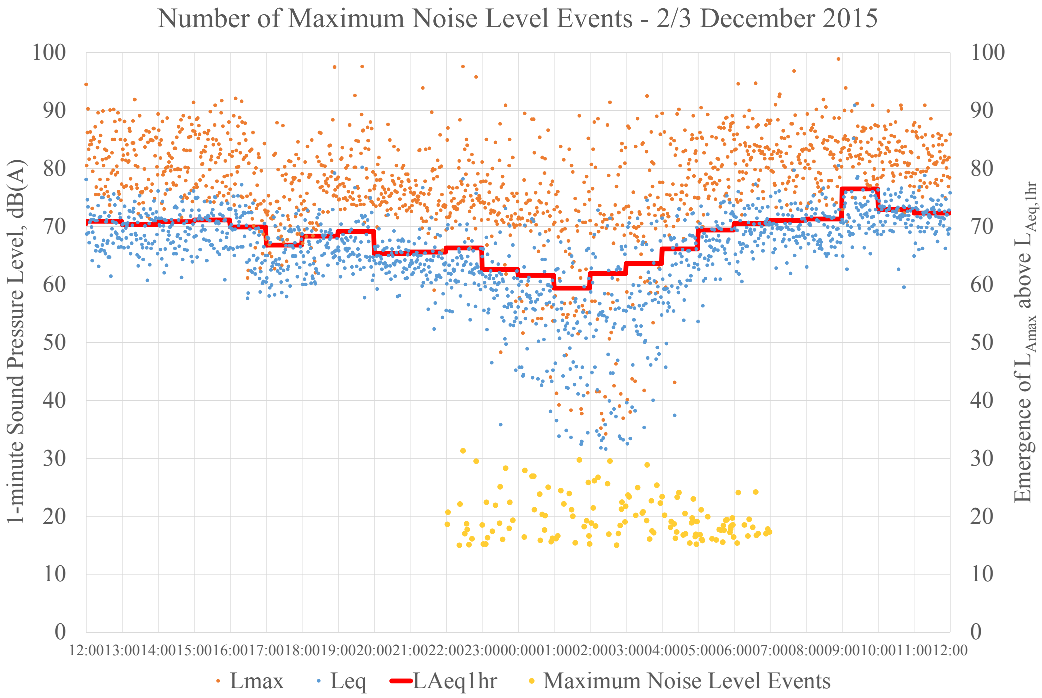
Lmax
Leq
LAeq1hr
Maximum Noise Level Events


Number of Maximum Noise Level Events - 1/2 December 2015
1-minute Sound Pressure Level, dB(A)
Emergence of L_{Amax} above $L_{Aeq,1hr}$
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 01:00 02:00 03:00 04:00 05:00 06:00 07:00 08:00 09:00 10:00 11:00 12:00
Lmax
Leq
LAeq1hr
Maximum Noise Level Events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1-minute Sound Pressure Level, dB(A)
Emergence of L_{Amax} above $L_{Aeq,1hr}$
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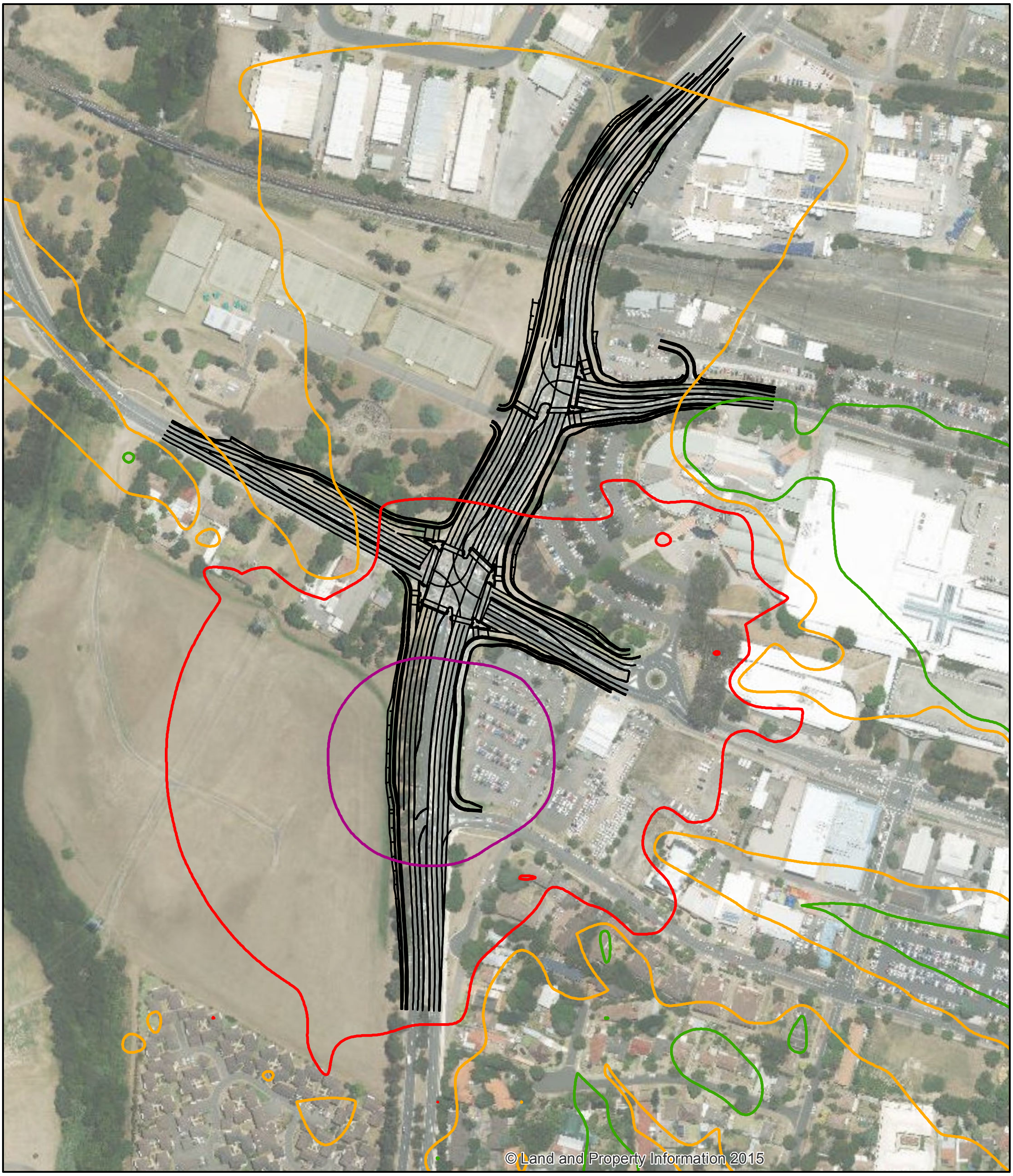
Lmax
Leq
LAeq1hr
Maximum Noise Level Events

Appendix C

Noise Contour Plots for Predicted Scenarios



G1: Indicative Noise Impact Extents Mulgoa Road (South) - Standard Hours

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

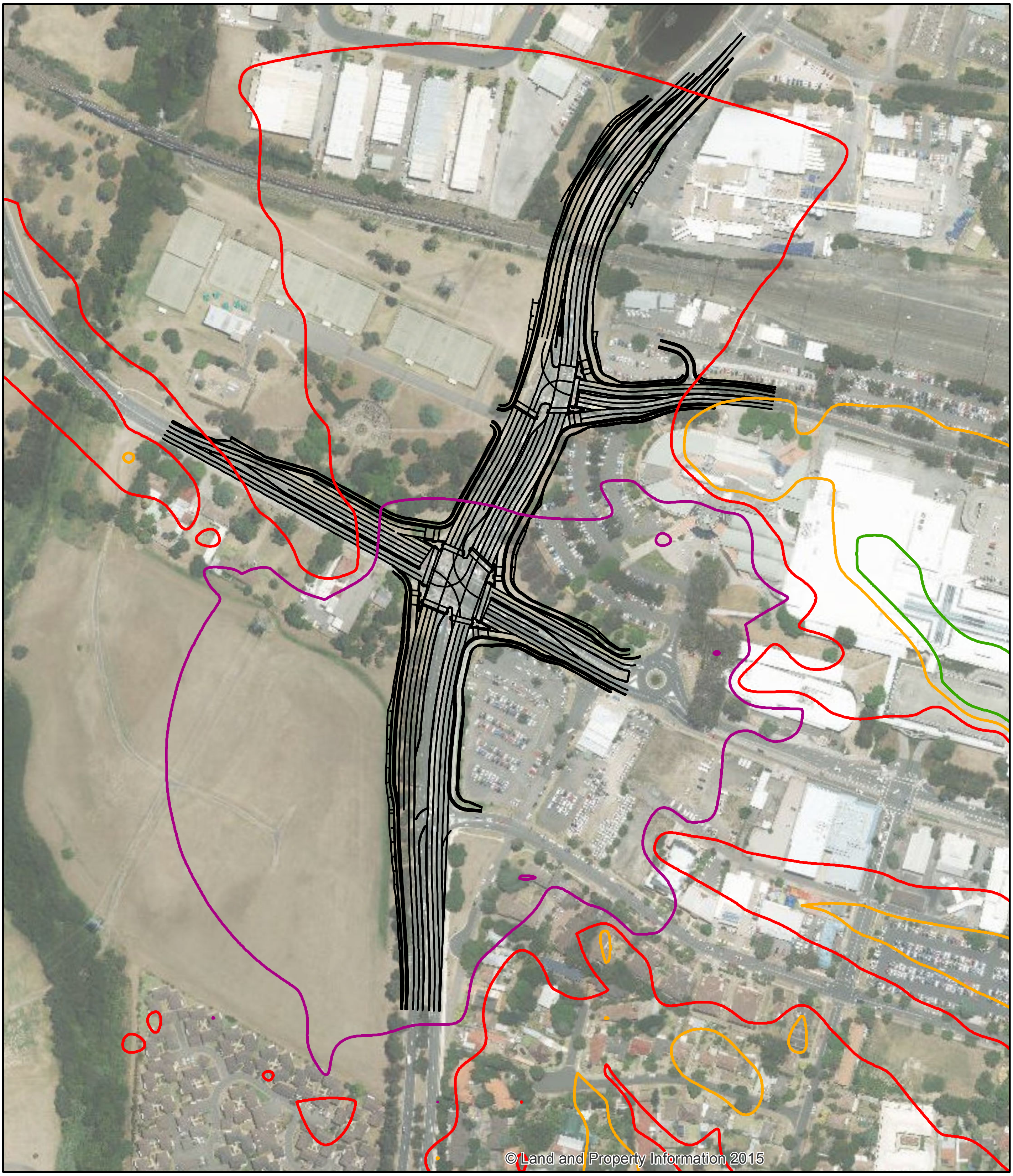
Moderately Intrusive

Highly Noise-Affected

N

0 75 150 300

Metres



G2: Indicative Noise Impact Extents
Mulgoa Road (South) - OOHW

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

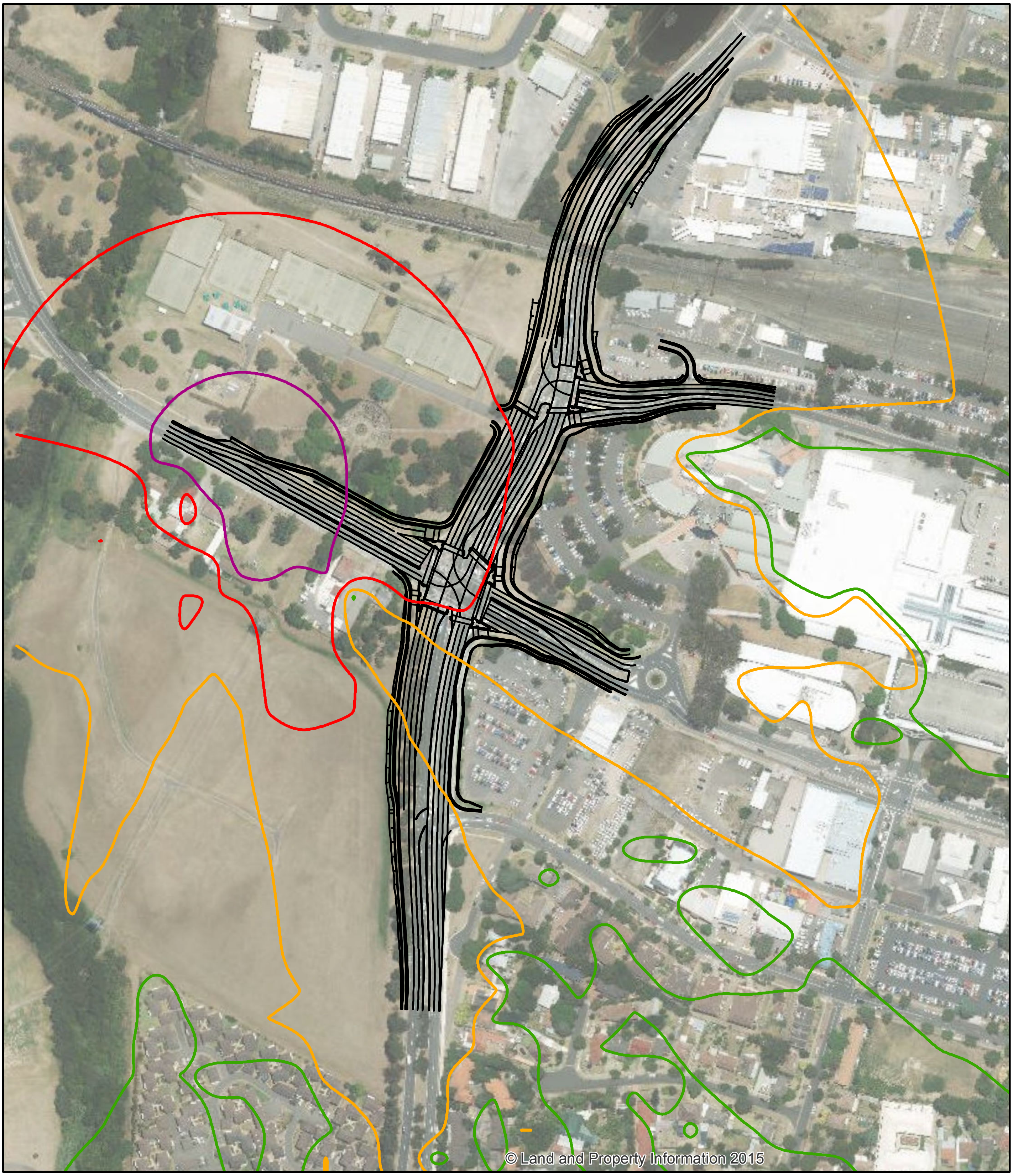
Moderately Intrusive

Highly Intrusive

N

0 75 150 300

Metres



G3: Indicative Noise Impact Extents High Street (West) - Standard Hours

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

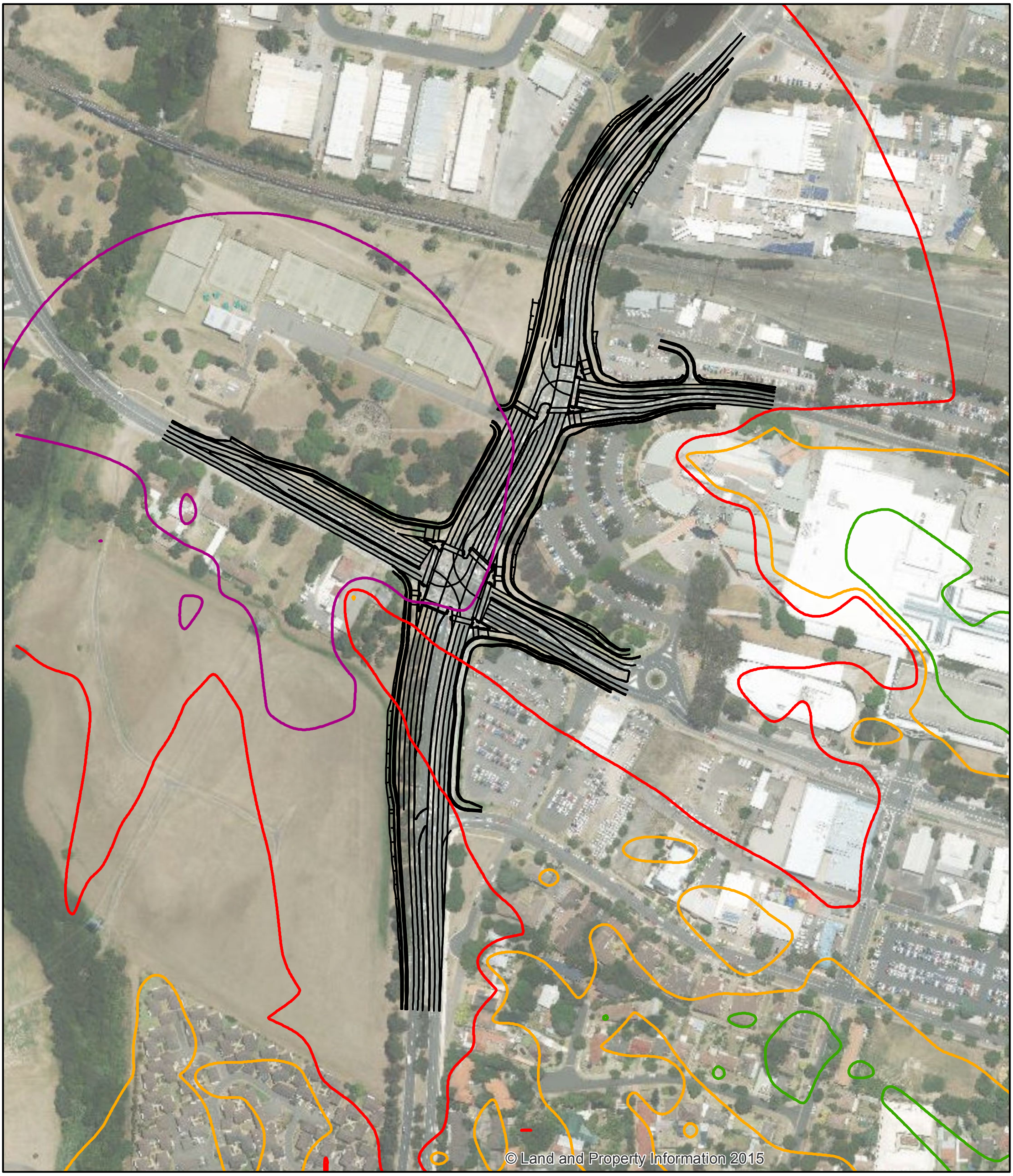
Moderately Intrusive

Highly Noise-Affected

N

0 75 150 300

Metres



G4: Indicative Noise Impact Extents High Street (West) - OOHW

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

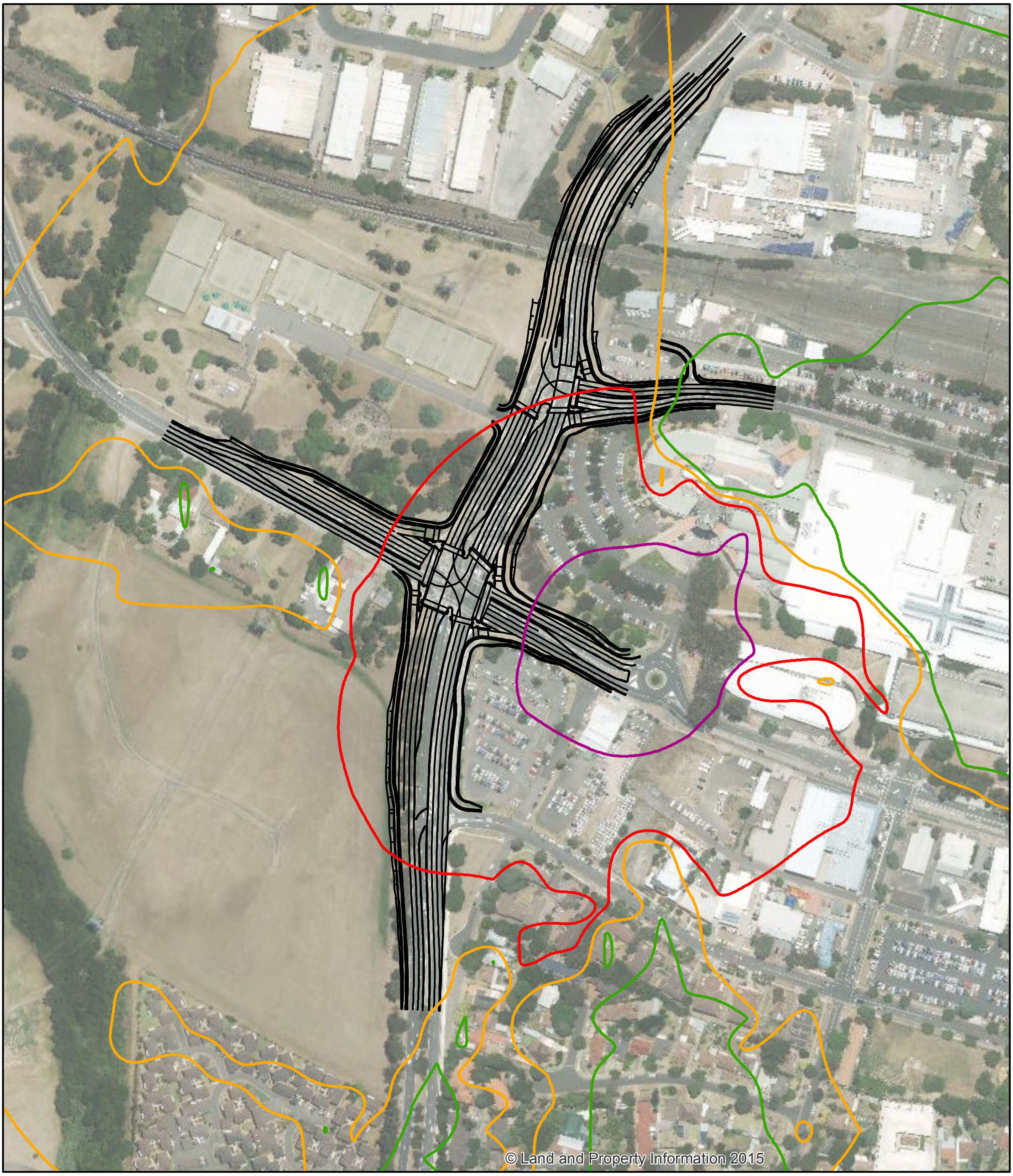
Moderately Intrusive

Highly Intrusive

N

0 75 150 300

Metres



G5: Indicative Noise Impact Extents High Street (East) - Standard Hours

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

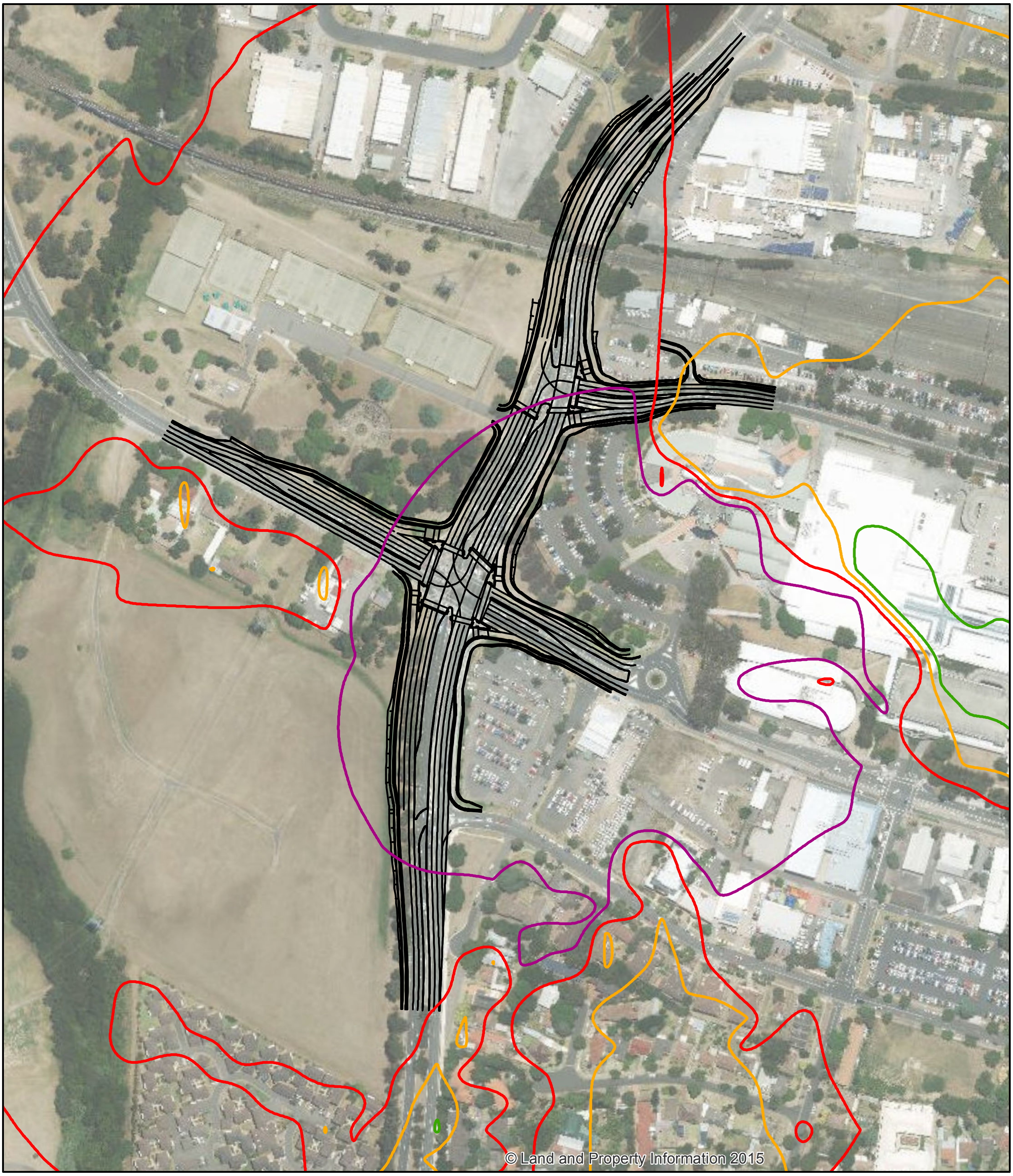
Moderately Intrusive

Highly Noise-Affected

N

0 75 150 300

Metres



G6: Indicative Noise Impact Extents High Street (East) - OOHW

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

Moderately Intrusive

Highly Intrusive

N

0 75 150 300

Metres

G7: Indicative Noise Impact Extents Jane Street (East) - Standard Hours

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

Moderately Intrusive

Highly Noise-Affected

N

0 75 150 300

Metres

G8: Indicative Noise Impact Extents Jane Street (East) - OOHW

Legend

Road Upgrade Works

Noise Level

Noticeable

Clearly Audible

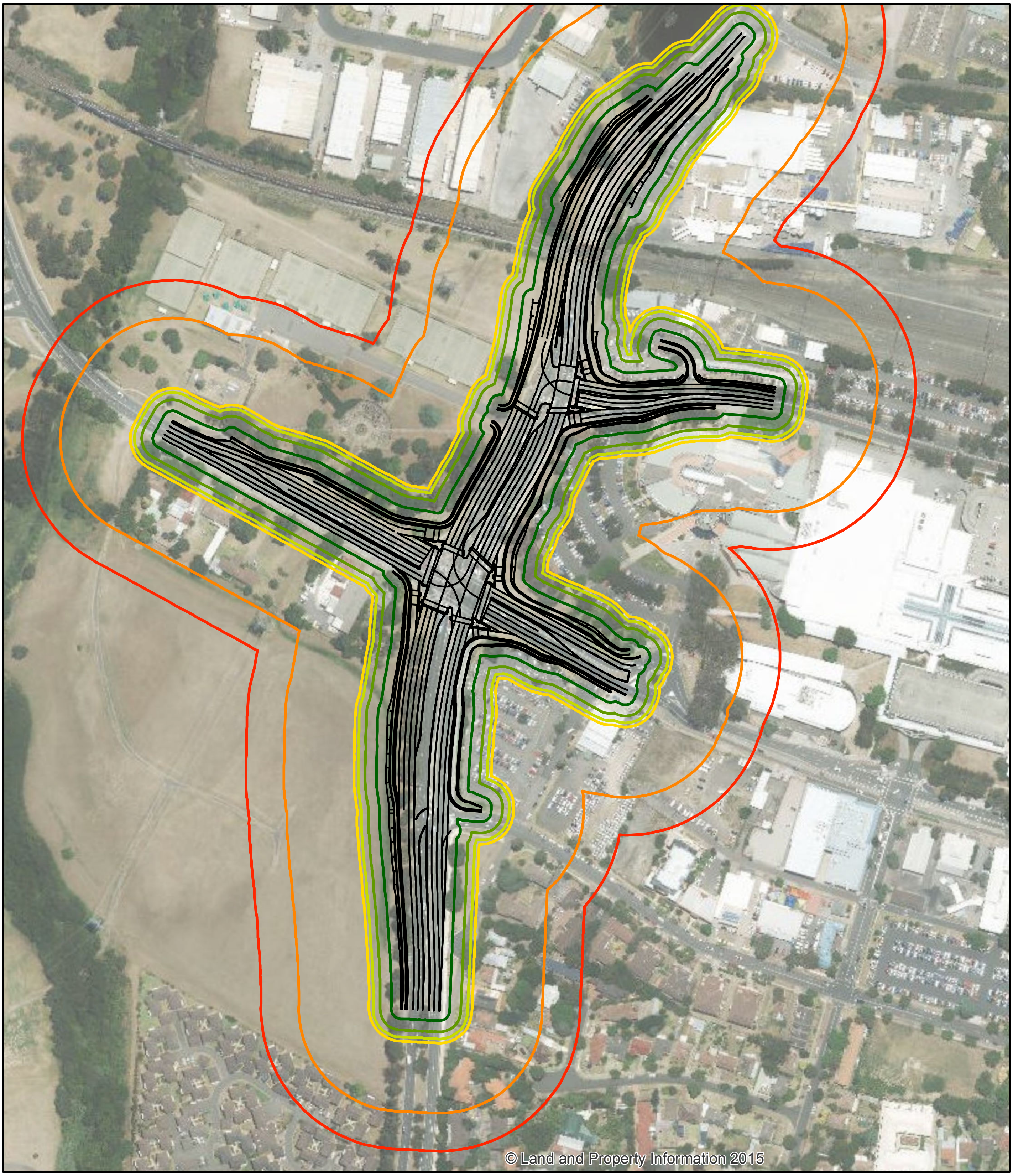
Moderately Intrusive

Highly Intrusive

N

0 75 150 300

Metres



Legend

Road Upgrade Works

Plant Item

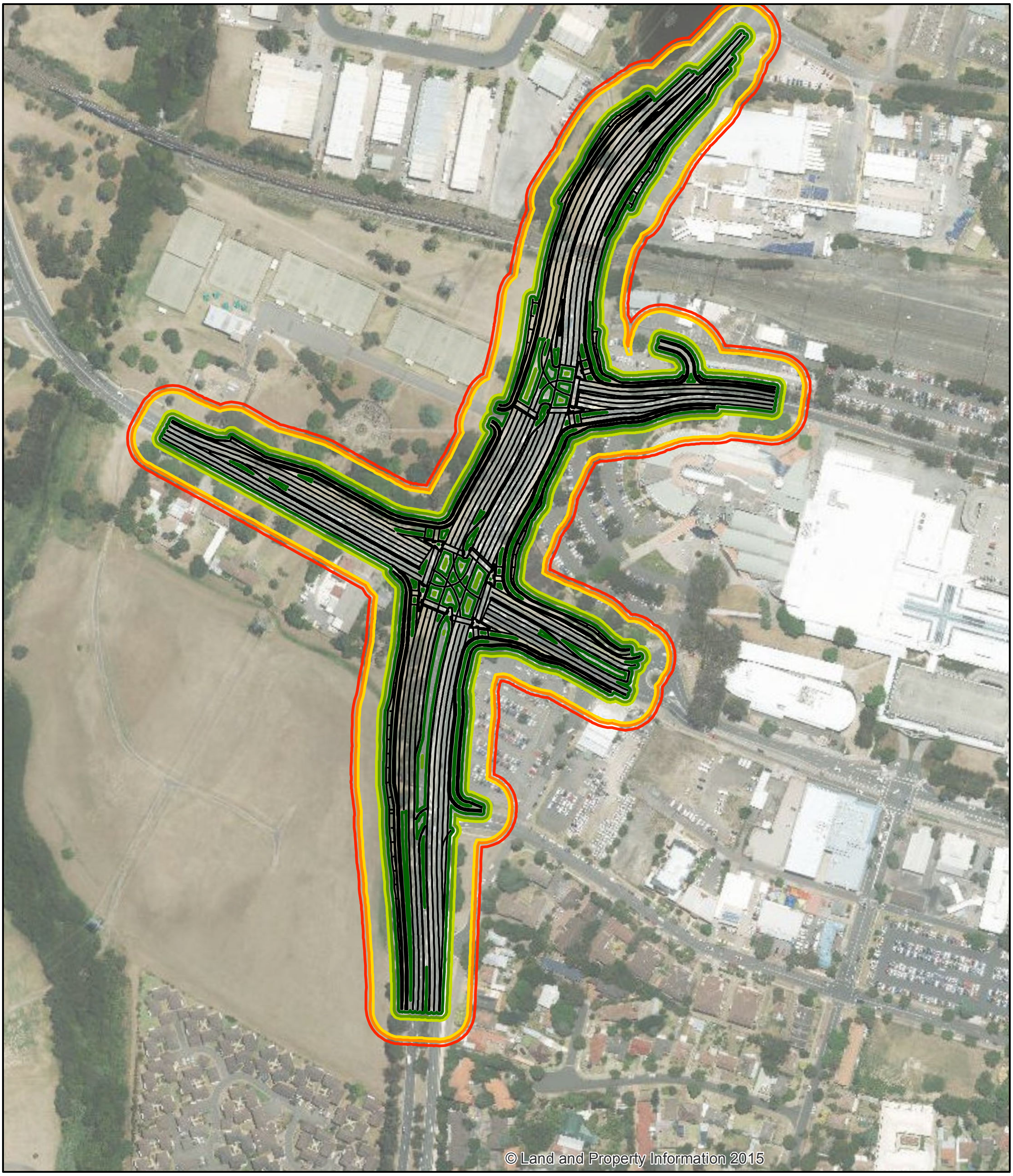
- Small Hydraulic Hammer
- Small Vibratory Roller
- Vibratory Pile Driver
- Medium Hydraulic Hammer
- Large Hydraulic Hammer
- Large Vibratory Roller

H1: Indicative Vibration Impact Extents Human Comfort

N

0 75 150 300

Metres



Legend

Road Upgrade Works

Plant Item

- Small Hydraulic Hammer
- Small Vibratory Roller
- Medium Hydraulic Hammer
- Vibratory Pile Driver
- Large Hydraulic Hammer
- Large Vibratory Roller

H2: Indicative Vibration Impact Extents Building Damage

N

0 75 150 300

Metres

www.rms.nsw.gov.au/JaneStreetMulgoaRoad

1800 733 084

Jane Street and Mulgoa Road Upgrade
Roads and Maritime Services
PO Box 973
Parramatta CBD NSW 2124

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