Appendix F

WestConnex

King Georges Road Interchange Upgrade

Construction and Operational Road Traffic

Noise and Vibration Impact Assessment

Report Number 610.14089-R1

1 October 2014

WestConnex Delivery Authority
Level 9, 101 Miller Street
NORTH SYDNEY NSW 2060

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WestConnex

King Georges Road Interchange Upgrade

Construction and Operational Road Traffic

Noise and Vibration Impact Assessment

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DOCUMENT CONTROL

Reference	Status	Date	Prepared	Checked	Authorised
610.14089-R1	Revision 1	1 October 2014	Robert Hall	Tom Cockings	Tom Cockings
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Executive Summary

PROJECT DESCRIPTION

The King Georges Road Interchange Upgrade project (KGRIU project) involves construction and operational changes associated with the upgrade of the existing M5 Motorway at the King Georges Road interchange. The main infrastructure changes which are pertinent to noise and vibration include reconfigured lanes, a full re-sheet of the M5 Motorway (within the project area) with a low noise pavement and modifications to the access ramp configurations.

A comparison between the Build and No Build options indicates that the KGRIU project is forecast to change the volume and mix of vehicles using the M5 Motorway when the full WestConnex scheme is considered. The 2017 timeframe (at opening) shows no change in traffic volumes. Generally, the overall number of vehicles forecast in the 2027 timeframe on the main carriageways of the M5 with the full WestConnex scheme is observed to decrease.

Within the KGRIU project area, the M5 Motorway is surrounded by various sections of dense residential areas. Other sensitive receivers include places of worship, educational facilities, child care centres, aged care facilities and open areas used for passive or active recreation.

The Secretary's Environmental Assessment Requirements (SEARs) were issued for the project EIS on 25 June 2014. These refer to the following (NSW) Environment Protection Agency (EPA) guidelines for the assessment of environmental noise and vibration impacts:

- The NSW *Road Noise Policy* (RNP) ((NSW) Environment Protection Agency (EPA), 2011) for operational noise impacts
- The *Interim Construction Noise Guideline* (ICNG) ((NSW) Department of Environment and Climate Change (DECC), 2009) for construction related noise impacts.
- *Assessing Vibration: A Technical Guideline* ((NSW) Department of Environment and Conservation (DEC), 2006) for construction related vibration impacts.

EXISTING ENVIRONMENT

Noise monitoring (both operator-attended and continuous unattended logging) was undertaken at seven locations within the project area during May 2014. The purpose of the noise monitoring is to assist in the validation of the operational noise model (which predicts noise to all identified buildings/receivers adjacent to the motorway), and as a basis for assessing potential noise impacts during construction. Locations were typically chosen close to the motorway (to minimise non-road related noise) where access to a suitable location was available. The number and locations for the noise monitoring were considered appropriate. The noise levels display a typical diurnal trend with lower noise levels during the night-time than the daytime and evening periods. This is characteristic of urban and suburban areas where the ambient noise environment is primarily influenced by road traffic.

Assessment overview

Noise levels associated with the project have been predicted using a three-dimensional noise model for the full length of the project area. The noise model allows for various parameters to be accurately simulated such as road geometry, traffic volume, mix, type of road surface, vehicle speed, reflections off building surfaces, physical noise barriers, etc.

The results for the validation model were found to correlate well (albeit slightly conservatively) with the monitoring data with average predictions 1.2 dB above the monitoring results during the daytime and 0.6 dB above during the night-time.

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As the KGRIU project is not forecast to change traffic volumes at project opening (2017), noise impacts are due to the change in road alignment, which moves the traffic closer to receivers and/or reduces the screening benefit from the existing ground topography and noise walls.

As the forecast traffic volumes as part of the full WestConnex scheme in 2027 are lower than they would be without the full WestConnex scheme, the total road traffic noise at receivers within the KGRIU assessment area is generally predicted to be lower as a result of the project in the 2027 scenario.

The predicted 'Build scenario' noise levels at receivers adjacent to the motorway are typically above the RNP noise goals at the majority of the adjacent receivers.

An increase in the number of maximum noise events is predicted in line with the increase in traffic volume.

Noise mitigation

Priority noise mitigation measures (road design/traffic management and quieter pavement surfaces) have been considered for all sensitive receivers where predicted noise levels in the Build scenarios are above the RNP noise goals. The use of a low noise pavement on the M5 Motorway and majority of the access ramps throughout the KGRIU project area are proposed as part of the design of the project in order to mitigate road traffic noise at source and therefore benefit receivers adjacent to the motorway.

Additional feasible and reasonable noise mitigation measures, including noise barriers and property treatments, have been considered for receivers which qualify on the basis of predicted residual noise levels and/or project related increases in noise.

Noise increases due to the project (comparing the No Build situation to the Build situation) are greater in the 2017 scenario than the 2027 scenario. This leads to the requirements for additional reasonable and feasible noise mitigation being controlled by the 2017 scenario. A total of 24 receivers (all residential) in the 2017 scenario are considered eligible while the 2027 scenario results in only two eligible receivers (both residential).

The majority of the eligible receivers (21 of the total 24 receivers) in the 2017 scenario are located in NCA08 (south of the motorway to the east of Cooloongatta Road). A noise barrier adjacent to these receivers has been considered in order to provide additional noise mitigation. The optimised height of this barrier was determined to be 3 metres, and was found to provide a reasonable noise benefit.

Further to the inclusion of the optimised project noise barrier a total of six residential receivers are predicted to be eligible for property treatment as part of the KGRIU project. This number comprises:

- Three residential receivers in NCA03 (north of the motorway to the west of King Georges Road)
- Three residential receivers in NCA08 (south of the motorway to the east of Cooloongatta Road)

This assessment has incorporated the proposed noise barrier design for the M5 Widening project (currently under construction). It is, therefore, recommended that the final extent of any proposed property treatments as part of the KGRIU project should be confirmed during detailed design, following a survey of 'as built' noise barrier heights to include the M5 Widening project noise barriers within the KGRIU project area.

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CONSTRUCTION NOISE AND VIBRATION

It is likely that construction works would be required outside of standard construction hours. The approach taken in this assessment has been to identify noise impacts of representative construction activities in all time periods, to inform scheduling of works to minimise impacts on sensitive receivers where practicable.

Consistent with the requirements of the ICNG, the construction noise impacts are based on a realistic worst-case assessment. For most activities, it is expected that the construction noise levels would be lower than have been predicted in this report.

Due to the proximity of residential and other noise sensitive receivers to noise generating construction works, some construction scenarios have the potential to result in high noise impacts. The linear movement of the construction works for the proposal means that, at most locations, the duration of the noisiest activities would be of limited duration.

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Glossary

Item	Description
AS	Australian Standard
BS	British Standard
CEMP	Construction Environmental Management Plan
CNVMP	Construction Noise And Vibration Management Plan
CORTN	Calculation of Road Traffic Noise
dBA	A-weighted decibels
DECC	Department of Environment and Climate Change NSW – Now EPA
DECCW	Department of Environment, Climate Change and Water NSW – Now EPA
DGA	Dense Graded Asphalt
DGRs	Director-General's Requirements
DIN	Deutsches Institute fur Normung
DP&E	(NSW) Department of Planning and Environment
ECRTN	Environmental Criteria for Road Traffic Noise (replaced by the RNP)
EIS	Environmental Impact Statement
ENMM	Environmental Noise Management Manual
EPA	(NSW) Environment Protection Authority
EPL	Environment Protection Licence
ICNG	Interim Construction Noise Guideline
KGRIU	King Georges Road Interchange Upgrade
LA90	The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.
LAeq(1hour)	The 'energy average noise level' evaluated for a specific one-hour period.
LAeq(9hour)	The 'energy average noise level' evaluated over the night-time period (10.00 pm to 7.00 am).
LAeq(15hour)	The 'energy average noise level' evaluated over the daytime period (7.00 am to 10.00 pm). The LAeq can be likened to a noise dose representing the cumulative effects of all the noise events occurring in the relevant time period.
LAmax	The maximum noise level from road traffic noise occurring at a particular location.
NATA	National Association of Testing Authorities
NCA	Noise Catchment Area
NML	Noise Management Level.
OEH	Office of Environment and Heritage – now EPA
OGA	Open Graded Asphalt
OOHW	Out of Hours Work
RBL	Rating Background Level
RMS	Root Mean Square
Roads and Maritime	(NSW) Roads and Maritime Services
SLR	SLR Consulting Australia
SPL	Sound Pressure Level
TNBA	The "total benefit per unit barrier area" (TNBA) is the "total noise benefit" (TNB) divided by the total area of the barrier in the road section being examined.

Glossary

Item	Description
MBV	The "marginal benefit value" (MBV) for a particular barrier height option is the increase in "total noise benefit" (TNB) divided by the increase in barrier height or area. (The methodology assumes barrier costs are proportional to barrier areas and are hence proportional to barrier heights, even though other factors such as barrier material will also have an influence on costs.)
SWL	Sound Power Level
VDV	Vibration Dose Value
WDA	WestConnex Delivery Authority

1 INTRODUCTION

1.1 Background

The King Georges Road Interchange Upgrade project (the KGRIU project) would tie into the completed M5 South West Motorway Widening project in the west. Some upgrading of the existing M5 dual carriageways would be required to retain two lanes in each direction and accommodate the possible future construction of WestConnex M5. The eastern end of the project would tie into the existing M5 East Motorway, near Kooemba Road, Beverly Hills.

To the west of King Georges Road, adjustment would be required to the eastbound off-ramp and the westbound on-ramp to make provision for the possible future construction of the WestConnex M5 project and link in with the completed M5 South West Motorway widening project respectively.

To the east of King Georges Road the eastbound on-ramp would be extended by about 160 metre to the east and a new bridge span would be constructed to the north of Cooloongatta Road overbridge. Similarly the westbound off-ramp will commence about 190 metre further east and a new bridge span would be constructed to the south of Cooloongatta Road overbridge. Additional vehicle capacity would be created by extending both ramps.

The NSW Government has established the WestConnex Delivery Authority (WDA) to deliver the WestConnex scheme. The Authority has been established as an independent subsidiary agency of the (NSW) Roads and Maritime Services (Roads and Maritime). For the purpose of the project planning for the KGRIU project, Roads and Maritime is the proponent.

1.2 Scope of this report

SLR Consulting Australia (SLR) has been engaged by WDA to assess the potential noise and vibration impacts associated with the construction and operation of the KGRIU project. This report has been prepared to comply with the assessment requirements of the Director General (refer **Section 3.1**), to inform the environmental assessment and be included in the Environmental Impact Statement (EIS) as a technical paper.

The assessment of noise and vibration includes:

- Ambient noise surveys to determine the existing noise environment within the project area (refer to **Section 4**).
- Identification of receivers along the alignment that are potentially sensitive to noise and vibration (refer to **Section 4**).
- Prediction of noise and vibration from the construction (refer to **Section 12** to **Section 15**) and operation (refer to **Section 6**) of the motorway, and assessment of the potential noise and vibration impacts in accordance with the relevant legislation and guidelines.
- The recommendation of management and mitigation measures to reduce and control potential impacts where noise and vibration levels are predicted to be above the assessment criteria (refer to **Section 8**).

1.3 Relevant guidelines

Noise from the operation of the proposal is required to be assessed in accordance with guidelines provided in the NSW *Road Noise Policy* (RNP) ((NSW) Environment Protection Agency (EPA), 2011) [i]. Guidance for assessing the potential for sleep disturbance from maximum noise events is taken from *Practice Note III* in the *Environmental Noise Management Manual* (ENMM) (Roads and Maritime, 2001)[ii].

Construction noise has been assessed in accordance with the *Interim Construction Noise Guideline* (ICNG) ((NSW) Department of Environment and Climate Change (DECC), 2009) [iii]. Construction road traffic noise has been assessed taking guidance from the noise assessment procedure contained in the RNP. Vibration from construction has been assessed in accordance with *Assessing Vibration: A Technical Guideline* ((NSW) Department of Environment and Conservation (DEC), 2006)[iv].

1.4 Terminology

The assessment has used specific acoustic terminology, and an explanation of common terms is included as **Appendix A**.

2 PROJECT DESCRIPTION

2.1 WestConnex scheme

The WestConnex scheme is a 33 kilometre long tolled motorway, linking Sydney's west and south west with Sydney Airport and the Port Botany precinct.

The WestConnex scheme aims to accommodate the growing transport needs of greater Sydney and strengthen access for industry to commercial centres, and improve growth opportunities for local businesses. It is also designed to enable urban renewal along the Parramatta Road corridor. The proposed alignment for the WestConnex scheme is indicated in **Figure 1**.

Figure 1 WestConnex scheme

Source: WestConnex Delivery Authority, 2014

WestConnex lies in a broad arc below, above and at surface level from the M4 Motorway near Parramatta, alongside Parramatta Road and Sydney Olympic Park, through the inner western suburbs, alongside Sydney Airport and Port Botany and connecting to the M5 East.

2.2 WestConnex – KGRIU project

As part of the KGRIU project, the King Georges Road interchange would be upgraded to provide additional storage on both the eastbound on-ramp (reducing queue lengths on King Georges Road) and the westbound off-ramp (reducing queuing back into the through motorway lanes). The KGRIU project would also make provision for the future WestConnex M5.

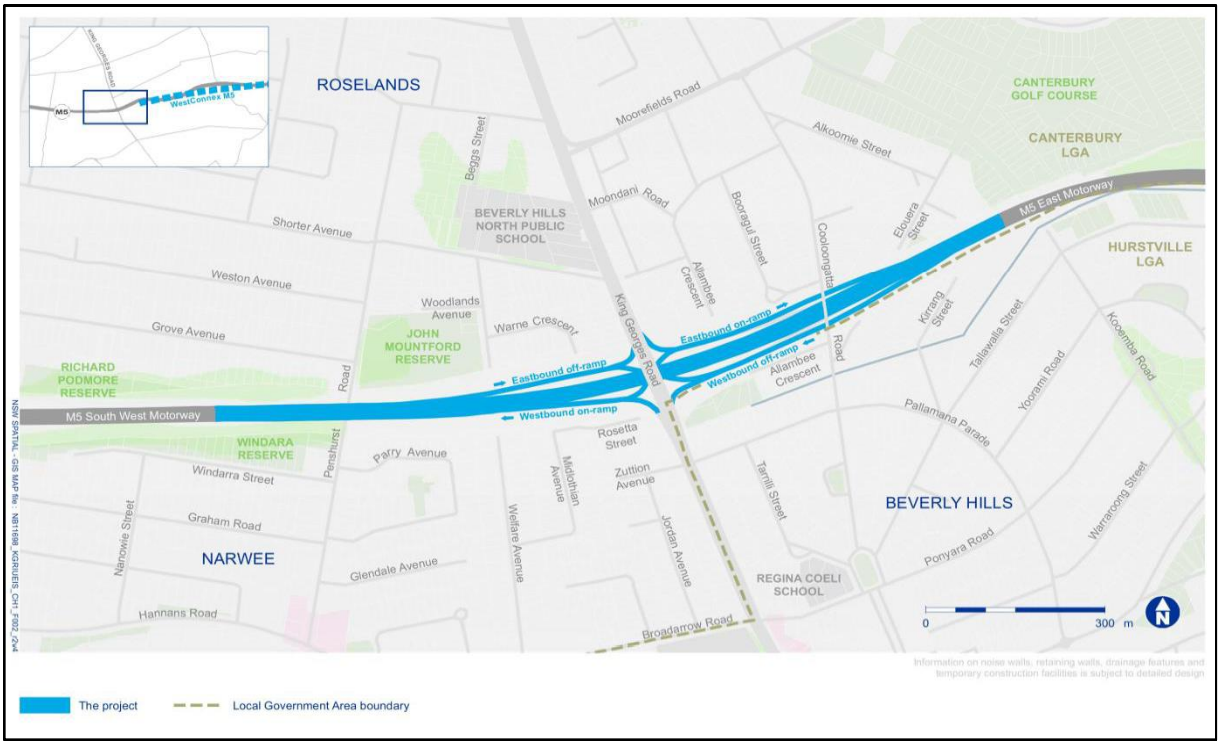
The KGRIU project would include the following key features:

- The eastbound off-ramp to King Georges Road would be lengthened. This would require widening of the eastbound carriageway from above 300 metres west of Penshurst Road. The nearside eastbound lane of the motorway would exit to King Georges Road and two remaining lanes would continue eastbound under King Georges Road
- The M5 South West Widening project provides for three lanes in each direction.

- WestConnex M5 would require an increase in the number of lanes passing underneath King Georges Road from two to three. Work to the westbound off-ramp and widening of the bridge over Penshurst Road is proposed as part of this project in order to accommodate all future WestConnex M5 configurations.
- The eastbound on-ramp from King Georges Road would be lengthened, connecting with the motorway about 160 metres further to the east. The on-ramp would be realigned and widened, merging to a single lane prior to passing below Cooloongatta Road overbridge via a new bridge span at its northern end.
- The length of the westbound off-ramp to King Georges Road would be increased by moving the off-load point about 190 metres further to the east. The off-ramp would be realigned passing below Cooloongatta Road overbridge via a new bridge span at its southern end.
- Widening of the existing bridge over Penshurst Road would be required to its north and south.
- Additional bridge spans would be required on both the northern and southern ends of the Cooloongatta Road overbridge to accommodate the east facing ramp configurations.
- Construction and installation of retaining walls, signage, drains, and noise barriers as required throughout the project area.

The project is located approximately 13 kilometres southwest of the Sydney central business district and generally follows the alignment of the existing M5 Motorway. The location of the KGRIU project area and key features is shown in **Figure 2**.

Figure 2 KGRIU project



Source: WestConnex Delivery Authority, 2014

The project traverses the suburbs of Beverly Hills and Narwee. The project spans two local government areas (LGAs) being Canterbury and Hurstville.

2.2.1 Description of existing M5 motorway

The existing lanes and posted speed limits for the eastbound and westbound directions of the M5 Motorway within the project area are shown in **Table 1** and **Table 2.**

Table 1 Existing eastbound M5 motorway speed zones

Section	Lanes	Posted Speed Limit (km/h)
West of King Georges Road	3[1]	110
Below King Georges Road	2[2]	90
East of King Georges Road	2[2]	90

Note 1: Current M5 South West project underway to widen to three lanes in each direction

Note 2: Plus shoulder

Table 2 Existing westbound M5 motorway speed zones

Section	Lanes	Posted Speed Limit (km/h)
West of King Georges Road	3[1]	110
Below King Georges Road	2	100
East of Cooloongatta Road	2	90

Note 1: Current M5 South West project underway to widen to three lanes in each direction

The prevailing pavement type on the existing M5 Motorway is understood to be Open Graded Asphalt (OGA).

3 ENVIRONMENTAL ASSESSMENT REQUIREMENTS

3.1 Secretary's environmental assessment requirements

Following receipt of the project application, Secretary's Environmental Assessment Requirements (SEARs) were issued for the project EIS on 25 June 2014. The SEARs specific to the assessment of noise and vibration from the proposal are provided in **Table 3**

Table 3 Secretary's environmental assessment requirements for the KGRIU project

Director-General Requirement	Where they are assessed in this Report
Key Noise and Vibration issues including:	
• An assessment of the noise impacts of the project during operation, consistent with the *Road Noise Policy* (Environment Protection Authority 2011). The assessment must include specific consideration of impacts to receivers (dwellings, child care centres, educational establishments, hospitals, motels, nursing homes, or places of worship), as relevant and identify reasonable and feasible mitigation measures.	**Section 5** to **Section 8**
• An assessment of construction noise and vibration impacts, consistent with the *Interim Construction Noise Guideline* (Department of Environment, Climate Change and Water 2009), and *Assessing Vibration: a technical guideline* (Department of Environment and Conservation 2006).	**Section 12** to **Section 15**
• Consideration of the nature and duration of construction noise and vibration impacts of the project, in terms of cumulative impacts of construction impacts from the M5 West widening Project on sensitive receivers in the vicinity of the project	**Section 12.6** and **Section 15.6**

4 DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1 Existing environmental noise

The existing ambient noise environment surrounding the project route is variable, with road traffic noise the primary contributor. The noise levels display a typical diurnal trend with noise levels during the night-time lower than the daytime and evening periods. This is characteristic of urban and suburban areas where the ambient noise environment is primarily influenced by road traffic.

The project area has been divided into multiple Noise Catchment Areas (NCAs). These NCAs reflect the changing land uses and ambient noise environments adjacent to the project and are detailed in **Table 4**.

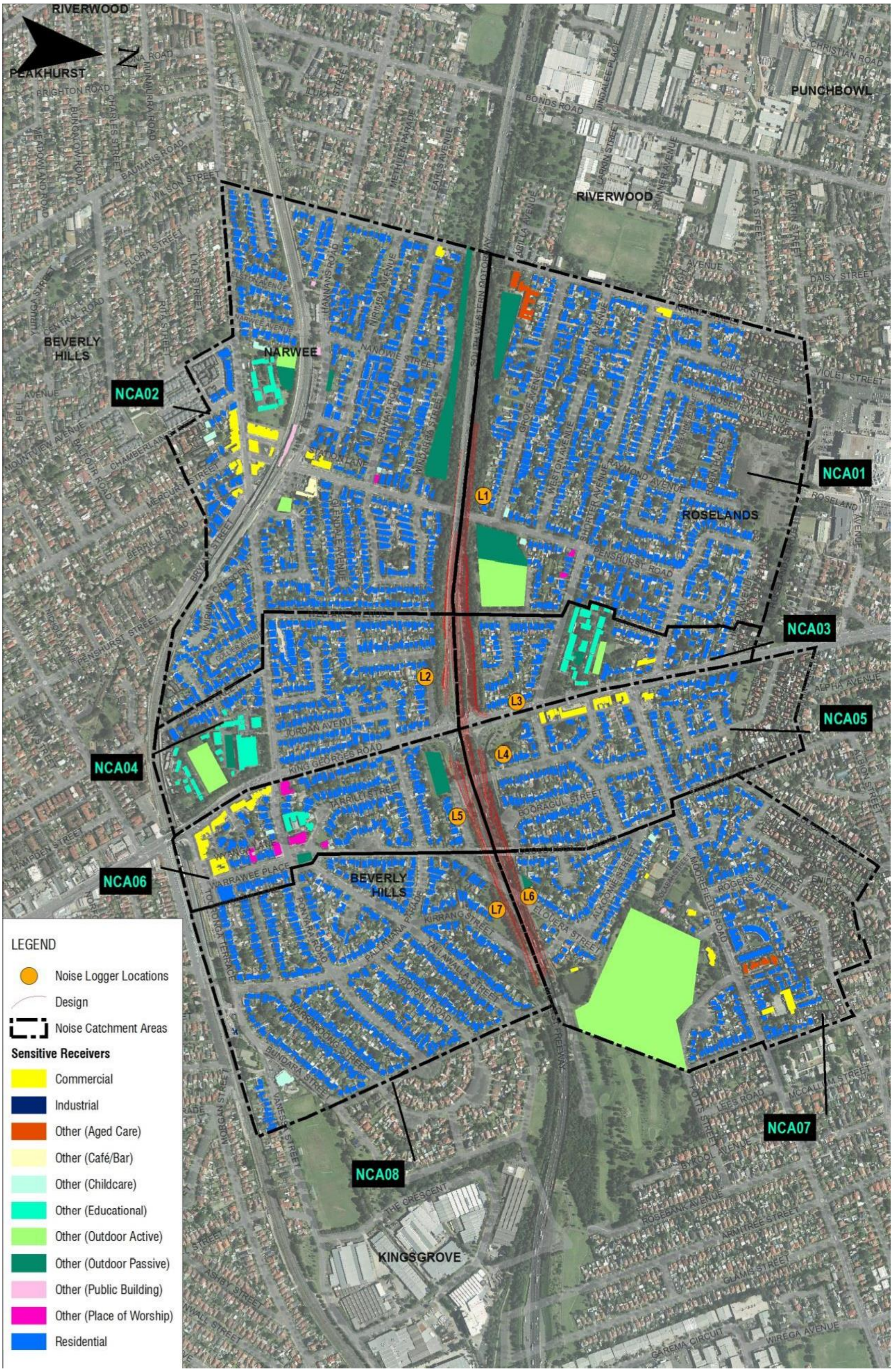
Table 4 Noise catchment areas and surrounding land uses

NCA	Minimum Distance (m)[1]	Description
NCA01	30	Receivers (predominantly residential and outdoor active) to the north of the M5 Motorway between Karne Street North, Narwee and Welfare Avenue, Narwee and Penshurst Road, Roselands.
NCA02	30	Receivers (predominantly residential) to the south of the M5 Motorway between Karne Street South, Narwee and Welfare Avenue South, Narwee.
NCA03	10	Receivers (predominantly residential and educational) to the north of the M5 Motorway between Welfare Avenue, Beverly Hills / Penshurst Road, Roselands and King Georges Road, Beverly Hills / Roselands
NCA04	25	Receivers (predominantly residential and educational) to the south of the M5 Motorway between Welfare Avenue South, Beverly Hills and King Georges Road, Beverly Hills
NCA05	20	Receivers (predominantly residential and commercial) to the north of the M5 Motorway between King Georges Road, Beverly Hills / Roselands and Cooloongatta Road, Beverly Hills / Stoddart Street, Roselands
NCA06	30	Receivers (mixed) to the south of the M5 Motorway between King Georges Road, Beverly Hills and Cooloongatta Road, Beverly Hills / Warilda Lane, Beverly Hills
NCA07	15	Receivers (predominantly residential and outdoor active) to the north of the M5 Motorway between Cooloongatta Road, Beverly Hills / Stoddart Street, Roselands and Doonkuna Street, Beverly Hills / Remly Street, Roselands
NCA08	20	Receivers (predominantly residential) to the south of the M5 Motorway between Cooloongatta Road, Beverly Hills / Warilda Lane, Beverly Hills and Kooemba Road, Beverly Hills

Note 1: Approximate minimum horizontal offset distance from the nearest receiver building facade (receiver of any type) to the centre of the nearest lane of the project.

The location of the various NCAs and sensitive receivers are indicated in **Figure 3** and are provided in detail in **Appendix B**.

Figure 3 Site plan, noise catchment areas and noise monitoring locations



4.2 Identification of noise and vibration sensitive receivers

The sensitivity of receivers to noise and vibration is dependent upon the occupancy type and the nature of the activities performed within the affected premises. Sensitivity to noise is a subjective response varying for different individuals and can depend on the existing noise environment.

For the purpose of this assessment, receivers potentially sensitive to noise and vibration have been categorised as:

- Residential.
- Education Institutions.
- Child-care Centres.
- Commercial.
- Hospitals (wards or other uses including medical centres).
- Places of Worship.
- Industrial.
- Other (such as cinemas, theatres, recreation areas).

This assessment considers all residences to be sensitive receivers during both construction and operation. All commercial receivers are considered to be sensitive to construction noise and vibration impacts.

Other receivers sensitive to noise and vibration (other than residential dwellings or commercial premises) are detailed in **Table 5**.

Table 5 Other noise and vibration sensitive receivers

NCA	Address	Description	Type	Distance (m)[1]
NCA01	59-63 Karne Street, Narwee	Bupa Narwee	Other (Aged Care)	115
NCA01	85 Penshurst Road, Narwee	Active Kids	Other (Childcare)	92
NCA01	Narwee	Richard Podmore Reserve	Other (Outdoor Passive)[2]	50
NCA01	Welfare Avenue, Narwee	John Mountford Reserve	Other (Outdoor Active)[2]	47
NCA01	36 Shorter Avenue, Narwee	St Matthew's Anglican Church	Other (Place of Worship)	251
NCA01	28 Shorter Avenue, Narwee	New Apostolic Church	Other (Place of Worship)	241
NCA02	116 Penshurst Road, Narwee	Narwee Hotel	Other (Café/Bar)	360
NCA02	71 Broad Arrow Road, Narwee	Goodstart Early Learning Narwee	Other (Childcare)	515
NCA02	34 Chamberlain Street, Narwee	Uniting Church in Australia	Other (Childcare)	595
NCA02	121 Penshurst Road, Narwee	The Salvation Army Narwee Corps (Church)	Other (Childcare)	193
NCA02	71 Broad Arrow Road, Narwee	Narwee Public School	Other (Educational)	490
NCA02	61-65 Broad Arrow Road, Narwee	Narwee Public School	Other (Outdoor Active)[2]	444
NCA02	42 Kardella Crescent, Narwee	Play Area	Other (Outdoor Active)[2]	401
NCA02	Broad Arrow Road, Narwee	Robert Gardner Reserve	Other (Outdoor Passive)[2]	50
NCA02	Windara Street , Narwee	Windara Reserve	Other (Outdoor Passive)[2]	57
NCA02	Hannans Road , Narwee	Frappell Reserve	Other (Outdoor Passive)[2]	346
NCA02	61-65 Broad Arrow Road, Narwee	Narwee Public School	Other (Outdoor Passive)[2]	472

NCA	Address	Description	Type	Distance (m)[1]
NCA02	105 Hannans Road, Narwee	Georges River Reflow Trading Centre	Other (Public Building)	415
NCA02	121 Penshurst Road, Narwee	The Salvation Army Narwee Corps (Church)	Other (Place of Worship)	197
NCA03	3 Shorter Avenue, Beverly Hills	Beverly Hills North Public School	Other (Educational)	245
NCA03	1-3 Shorter Avenue, Beverly Hills	Beverly Hills North Public School	Other (Outdoor Active)[2]	307
NCA03	1-7 Shorter Avenue, Beverly Hills	Beverly Hills North Public School	Other (Outdoor Passive)[2]	268
NCA06	77 Ponyara Road, Beverly Hills	Footsteps Early Learning Centre	Other (Childcare)	460
NCA06	70 Ponyara Road, Beverly Hills	Regina Coeli School	Other (Educational)	373
NCA06	Ponyara Road, Beverly Hills	Memorial Park	Other (Outdoor Passive)[2]	419
NCA06	82 Ponyara Road, Beverly Hills	Beverly Hills Uniting Church	Other (Place of Worship)	394
NCA06	2 Yarallah Place, Beverly Hills	Regina Coeli Memorial Church	Other (Place of Worship)	345
NCA06	9-11 Warrawee Place, Beverly Hills	Beverly Hills Baptist Church	Other (Place of Worship)	528
NCA07	9 Kerry Crescent, Roselands	RFBI Moorefields Masonic Village	Other (Aged Care)	470
NCA07	2 Alkoomie Street, Beverly Hills	Barfa Bear Child Care Centre	Other (Childcare)	344
NCA07	Moorefields Road , Beverly Hills	Canterbury Golf Course	Other (Outdoor Active)[2]	321

Note 1: Approximate horizontal offset distance from the nearest point of the receiver building to the centre of the nearest lane of the project.

Note 2: Assessment criteria are evaluated at the most affected point within the receiver boundary

4.3 Ambient noise surveys and monitoring locations

To quantify and characterise the existing ambient noise environment across the proposal area a baseline noise survey was undertaken from 22 May 2014 to 2 June 2014. The measured noise levels have been used to establish existing road traffic noise levels to allow for validation of the operational noise model, and as a basis for assessing potential noise impacts during construction.

The noise monitoring locations detailed in **Table 6** were selected to be representative of receivers and communities potentially affected by the construction and operation of the KGRIU project.

Noise monitoring equipment was deployed with consideration of other noise sources that may influence the measurements, accessibility and security, and with the consent of relevant land owners. The noise monitoring locations are indicated on the site plan drawings in **Figure 3** and **Appendix B**.

Table 6 Ambient noise survey locations

Noise Monitoring Location ID	NCA	Noise Monitoring Location Address	Equipment Serial Number
L01	NCA01	6 Grove Avenue, Narwee	SVAN 957 (SN: 20670)
L02	NCA03	15 Rosetta Street, Beverly Hills	SVAN 957 (SN: 20669)
L03	NCA04	311 King Georges Road, Beverly Hills	SVAN 957 (SN: 23293)
L04	NCA05	36 Allambee Crescent, Beverly Hills	SVAN 957 (SN: 27523)
L05	NCA06	6 Allambee Crescent, Beverly Hills	SVAN 957 (SN: 21857)
L06	NCA07	19 Elouera Street Beverly Hills	SVAN 957 (SN: 20668)
L07	NCA08	25 Kirrang Street, Beverly Hills	SVAN 957 (SN: 20670)

4.4 Methodology for unattended noise monitoring

The noise loggers continuously measured noise levels in 15 minute sampling periods to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime, evening and night-time periods.

The noise measurements were carried out with Svantek 957 Noise Loggers. The equipment was set up with microphones at 1.5 metres above the ground level. All microphones were fitted with wind shields.

All noise measurement instrumentation used in the surveys was designed to comply with the requirements of Australian Standard AS IEC 61672.1—2004 - *Electroacoustics—Sound level meters, Part 1: Specifications*[v] and carried appropriate and current National Association of Testing Authorities (NATA) calibration certificates. The calibration of the loggers was checked both before and after each measurement survey and the variation in calibration at all locations was found to be within acceptable limits at all times.

The results of the noise monitoring have been processed to exclude noise identified as extraneous and/or data affected by adverse weather conditions (ie strong wind or rain) so as to establish representative noise levels in the area at the residence.

4.5 Unattended noise monitoring results

The results of the unattended ambient noise surveys are summarised in **Table 7** as the Rating Background Level (RBL) noise levels for the ICNG daytime, evening and night-time periods, and the L_{Aeq} (energy averaged) noise levels for the RNP daytime and night-time periods. The 24 hour daily noise levels at each monitoring location are graphically presented in **Appendix C**.

The noise levels display a typical diurnal trend with lower noise levels during the night-time than the daytime and evening periods. This is characteristic of urban and suburban areas where the ambient noise environment is primarily influenced by road traffic.

This is consistent with observed traffic flows on the existing M5 Motorway which have a relatively small reduction in traffic volumes during the evening compared to the daytime period, and a more significant reduction in volumes during the night-time.

Table 7 Summary of unattended noise logging results

Noise Monitoring Location	Noise Level (dB)				
	ICNG Defined Time Periods			RNP Defined Time Periods	
	Daytime - RBL	Evening - RBL	Night-time - RBL	Daytime - $L_{Aeq(15hour)}$	Night-time - $L_{Aeq(9hour)}$
L01	52	51	39	57	53
L02	53	52	44	57	54
L03[3]	60	58	46	71	69
L04[4]	47	46	40	56	52
L05	51	50	44	55	52
L06	50	49	40	55	51
L07	49	49	42	54	51

Note 1: ICNG Governing Periods – Day: 7.00 am to 6.00 pm Monday to Saturday, 8.00 am to 6.00 pm Sunday; Evening: 6.00 pm to 10.00 pm; Night: 10.00 pm to 7.00 am Monday to Saturday, 10.00 pm to 8.00 am Sunday.

Note 2: RNP Assessment Time Periods – Day: 7.00 am to 10.00 pm; Night: 10.00 pm to 7.00 am.

Note 3: Monitoring location near to building facade. Measured noise levels considered to represent facade affected noise levels which are up to 2.5 dB higher than the equivalent free-field condition

Note 4: Monitoring data (refer to **Appendix C**) indicates significant extraneous noise from non-road sources.

4.6 Attended airborne noise measurements

Attended measurements of ambient noise were completed during the noise logging survey to determine the various noise sources that influence the existing noise environment. During each measurement the observer noted the various noise sources and the contributing noise level.

At each location the attended measurements were performed for 15 minutes using a calibrated Brüel and Kjær 2260 Precision Sound Level Meter. Wind speeds were less than 5 m/s at all times, and all measurements were performed at a height of 1.5 metres above ground level.

Calibration of the sound level meter was checked before and after each measurement and the variation in calibration at all locations was found to be within acceptable limits at all times.

The noise environment at each of the attended monitoring locations is summarised in

Table 8. Detailed observation notes are also provided in **Appendix C**.

Table 8 Summary of attended noise monitoring results

Measurement Details	Measured Noise Levels (dB)			Description of Ambient Noise Source – Typical LAmax Levels
	LA90	LAeq	LAmax	
L01 22/05/2014 13:25	54	58	69	M5 Light-vehicle road traffic: typically ~54-59 dB M5 Heavy-vehicle road traffic: 60-66 dB Neighbour activity: 55-58 dB
L02 22/05/2014 18:40	55	57	69	M5 Light-vehicle road traffic: typically ~56-58 dB, M5 Heavy-vehicle road traffic: 58-61 dB, Pedestrian activity: 55-69 dB
L03 02/06/2014 10:00	65	73	92	King Georges Rd Light-vehicles: typically ~65-79 dB, King Georges Rd Heavy-vehicle road traffic: 70-85 dB, Heavy vehicle pneumatic release: 75-89 dB, Motorbikes and sports cars: ~89-92
L04 22/05/2014 15:00	46	59	84	King Georges Rd and M5 road traffic: 50-60 dB, Birds: 55-72 dB , Dog barks: 70-84 dB
L05 22/05/2014 17:40	52	56	69	M5 road traffic: ~55-63 dB, Coolloongatta road traffic: 55-62 dB, King Georges road traffic: ~50-55 dB, Insects: 50-53 dB, Air traffic: ~59 dB.
L06 22/05/2014 16:40	50	54	72	M5 Light-vehicle road traffic: typically ~50-53 dB, M5 Heavy-vehicle road traffic: 55-59 dB, Local Road Traffic: 52-62 dB, Birds and Insects: 50-57 dB, Dog barking: 54-72 dB
L07 22/05/2014 15:50	46	51	67	M5 Light-vehicle road traffic: typically ~50-53 dB M5 Heavy-vehicle road traffic: 54-58 dB Motorbike: 59-65 dB Birds: 47-66 dB Dog barking: ~50 dB.

5 OPERATIONAL NOISE GOALS AND NOISE MITIGATION GUIDANCE

5.1 Introduction

The most common form of noise experienced by people is termed 'airborne' noise, indicating that it propagates between the source and receiver primarily through the air. This is the main form of noise that occurs adjacent to a road corridor or construction site.

The primary source of airborne noise from road traffic sources originates from the engine at low speed and from the interaction of the tyre and road at higher speeds. Heavy vehicle (trucks) exhausts are also a significant source of airborne noise during heavy acceleration or engine braking events.

The key influences on road traffic airborne noise are the speed of the passing vehicles, the condition of the pavement surface, the volume of traffic on the road and the number of heavy vehicles. The level of airborne noise experienced at a receiver is also dependent upon the distance to the road corridor and the presence of any natural or man-made barriers between the corridor and the receiver which can impede the propagation of noise.

5.2 Operational noise metrics

The noise metrics applied in the modelling and assessment of airborne noise from road traffic are:

$L_{Aeq(15hour)}$ the 'energy average noise level' evaluated over the daytime period (7.00 am to 10.00 pm). The L_{Aeq} can be likened to a noise dose representing the cumulative effects of all the noise events occurring in the relevant time period.

$L_{Aeq(9hour)}$ the 'energy average noise level' evaluated over the night-time period (10.00 am to 7.00 am).

$L_{Aeq(1hour)}$ the 'energy average noise level' evaluated for a specific one-hour period.

L_{Amax} The maximum noise level from road traffic noise occurring at a particular location.

The subscript 'A' indicates that the noise levels are filtered to match normal human hearing characteristics (ie A-weighted).

5.1 Noise criteria – NSW Road Noise Policy

The RNP provides guidance for assessing traffic noise impacts through setting design objectives for a range of development types. The document identifies strategies that address the issue of road traffic noise at adjacent potentially sensitive receivers. Road traffic noise is assessed for the following scenarios:

- Existing roads.
- New road projects.
- Road redevelopment projects.
- New traffic-generating developments.

The RNP noise criteria aim to protect amenity inside and immediately around permanent residences, schools, hospitals and other sensitive land uses, rather than at all points in a given locality, which would not be practical or possible.

Although it is not mandatory to achieve the noise assessment criteria in the RNP, project proponents need to provide justification if it is not considered feasible or reasonable to achieve them.

The guideline recognises that there are generally more opportunities to minimise noise impacts from new roads and road corridors, especially those in greenfield locations, through judicious road design and land use planning. The scope to reduce noise impacts from existing roads and corridors is typically more limited. The RNP criteria are applicable both at the time of project opening and also in a future design year, typically taken to be ten years after project completion.

Where multi-level residential buildings are apparent next to road infrastructure projects, the RNP requires that the two most affected floors of each building be considered for reference.

5.1.1 Noise assessment criteria

The KGRIU project area is considered an existing freeway. As per the guidance provided in *Practice Note I* of the ENMM, the KGRIU project is considered a redevelopment project. The RNP assessment criteria for residences adjacent to such projects are summarised in **Table 9**.

Table 9 RNP criteria – residential

Road Category	Type of Project/Land Use	Assessment Criteria (dB)	
		Daytime (7 am – 10 pm)	Night-time (10 pm – 7 am)
Freeway/ arterial/ sub-arterial roads	2. Existing residences affected by noise from **redevelopment** of existing freeway/arterial/sub-arterial roads 3. Existing residences affected by **additional traffic** on existing freeways/arterial/sub-arterial roads generated by land use developments	$L_{Aeq(15hour)}$ 60 (external)	$L_{Aeq(9hour)}$ 55 (external)

The project has the potential to impact on a number of other sensitive receivers that are situated within the project area. These are detailed in **Table 10**. Further information on the other sensitive land use receivers are provided in **Section 4.2**.

Table 10 RNP criteria – other sensitive land uses

Existing Sensitive Land Use	Assessment Criteria (dB)		Additional Considerations
	Daytime (7 am – 10 pm)	Night-time (10 pm – 7 am)	
School Classrooms	$L_{Aeq(1hour)}$ 40 (internal)	-	In the case of buildings used for education or health care, noise level criteria for spaces other than classrooms and wards may be obtained by interpolation from the 'maximum' levels shown in Australian Standard 2107:2000 (Standards Australia 2000).
Places of Worship	$L_{Aeq(1hour)}$ 40 (internal)	$L_{Aeq(1hour)}$ 40 (internal)	The criteria are internal, ie the inside of a church. Areas outside the place of worship, such as a churchyard or cemetery, may also be a place of worship. Therefore, in determining appropriate criteria for such external areas, it should be established which activities in these areas may be affected by road traffic noise.
Open Space (Active Use)	$L_{Aeq(15hour)}$ 60 (external) when in use	-	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.
Open Space (Passive Use)	$L_{Aeq(15hour)}$ 55 (external) when in use	-	Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, eg playing chess, reading.

Existing Sensitive Land Use	Assessment Criteria (dB)		Additional Considerations
	Daytime (7 am – 10 pm)	Night-time (10 pm – 7 am)	
Childcare facilities	Sleeping rooms LAeq(1hour) 35 (internal) Indoor play areas LAeq(1hour) 40 (internal) Outdoor play areas LAeq(1hour) 55 (external)	-	Multi-purpose spaces, e.g. shared indoor play/sleeping rooms should meet the lower of the respective criteria. Measurements for sleeping rooms should be taken during designated sleeping times for the facility, or if these are not known, during the highest hourly traffic noise level during the opening hours of the facility.
Aged care facilities	-	-	Residential land use noise assessment criteria should be applied to these facilities.

For sensitive receivers such as schools, places of worship and childcare facilities, the RNP criteria presented in **Table 10** are based on internal noise levels. A minimum (conservative) outside-to-inside attenuation of 10 dB, on the basis of openable windows, has been assumed to determine external noise criteria for such receivers.

In addition to the noise criteria in **Table 9** and **Table 10**, the RNP describes a 'Relative Increase Criteria' of 12 dB above existing traffic noise. This criterion is primarily intended to protect existing quiet areas from excessive changes in amenity. For a road in the same location, and with the same mix in traffic, a 12 dB increase in road traffic noise levels would require a 16-fold increase in traffic.

5.1.2 Potential road traffic noise impacts on the surrounding road network

With regard to potential increases in the traffic volumes on the surrounding road network in locations which are not directly affected by the WestConnex project through design or engineering changes, RMS has advised that the WestConnex proposal should be considered as a traffic generating development.

The RNP applies a 2 dB increase limit to existing residences and other sensitive land uses affected by additional traffic on existing roads due to land use developments. The 2 dB increase limit is applied to the difference between the total traffic noise level of the Build and No-Build scenarios.

The scope of this assessment considers potential increases in in the traffic volumes on the surrounding road network within the KGRIU project area.

5.1.3 Sleep disturbance

Guidance for the assessment of sleep disturbance given in the RNP is reproduced as follows:

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

The protocol for assessing the potential for sleep disturbance, detailed within *Practice Note III* of the ENMM, is determined by performing an $L_{AFmax} – L_{Aeq(1hr)}$ calculation on individual vehicle passby noise measurements. A maximum noise level event is then defined as a passby for which the night-time $L_{AFmax} – L_{Aeq(1hr)}$ difference is greater than 15 dB.

With regard to reaction to potential sleep disturbance events, the RNP gives the following guidance:

> *From the research on sleep disturbance to date it can be concluded that:*
>
> - *maximum internal noise levels below 50–55 dB are unlikely to awaken people from sleep*
> - *one or two noise events per night, with maximum internal noise levels of 65–70 dB, are not likely to affect health and wellbeing significantly.*

It is generally accepted that internal noise levels in a dwelling with the windows open are 10 dB lower than external noise levels. Based on this conservative minimum attenuation of 10 dB, the first conclusion above suggests that short term external noises of 60 dB to 65 dB L_{AFmax} are unlikely to cause awakening reactions.

The second conclusion suggests that one or two noise events per night with maximum external noise levels of 75 dB to 80 dB L_{AFmax} are not likely to affect health and wellbeing significantly.

5.2 Environmental Noise Management Manual (ENNM)

The ENMM was issued in December 2001 and provides guidance in managing and controlling road traffic generated noise.

The ENMM recognises that the base criteria recommended by the RNP are not always practicable and that it is not always feasible or reasonable to expect that they should be achieved.

The ENMM notes that the most effective way of minimising noise from vehicles and traffic is to control vehicle noise at the source. Where source measures are not practical, or do not provide sufficient noise reduction, additional methods are required to reduce levels to within acceptable margins. Such additional methods may include the use of noise barriers and/or consideration for architectural treatment of residences.

The ENMM introduces the term 'acute'. This refers to receivers which are exposed to higher levels of road traffic generated noise (specifically at least 65 dB $L_{Aeq(15hour)}$ or 60 dB $L_{Aeq(9hour)}$). In operational road traffic noise assessments, consideration for noise mitigation treatment is typically given to properties that experience acute levels of noise at the project design year even when there is no change in noise level due to the project.

5.3 KGRIU project criteria for consideration of additional noise mitigation

Roads and Maritime consider it reasonable to consider additional noise mitigation (beyond the adoption of road design and traffic management measures) where:

Scenario 1

- The predicted Build noise level exceeds the RNP base criteria for redeveloped roads and the noise level increase due to the project (ie the noise predictions for the Build minus the No Build) is greater than 2 dB.

or:

Scenario 2

- The predicted Build noise levels are acute (≥65 dB $L_{Aeq(15hour)}$ or ≥60 dB $L_{Aeq(9hour)}$) regardless of the incremental impact of the project.

The above criteria are consistent with the ENMM.

6 PREDICTION OF AIRBORNE NOISE DURING OPERATION

6.1 Assessment procedure

The RNP requires that road traffic noise levels from road infrastructure projects are evaluated at two specific timeframes:

- Within one year of changed traffic conditions:

  For the KGRIU project this is **2017**.
  This timeframe includes traffic data for the KGRIU project.

- For a future design year (typically ten years) after changed traffic conditions:

  For the KGRIU project this is **2027**.
  This timeframe includes traffic data for the full WestConnex scheme (ie Stages 1, 2 and 3).

For each for the above timeframes, a comparison is to be made between the following two scenarios:

- The road traffic noise levels if the project proceeds (termed the Build option).
- The corresponding road traffic noise levels due to general traffic growth that would have occurred if the project had not proceeded (termed the No Build option).

RNP assessment scenarios

Based on the discussion above the following four scenarios were modelled for this assessment:

- **2017 No Build**
  Base 'do minimum' (2017) – the forecast road traffic volumes without the KGRIU project.
- **2017 Build**
  KGRIU (2017) – the forecast 'at opening' road traffic volumes with the KGRIU, without any other stages of the WestConnex scheme.
- **2027 No Build**
  Future 'do minimum' (2027) – the forecast road traffic volumes in 10 years due to general traffic growth that would have occurred without the KGRIU or the WestConnex scheme.
- **2027 Build**
  Full WestConnex (2027) – the forecast '10 years after opening' road traffic volumes if the project proceeds based on worst-case traffic assuming the entire WestConnex scheme is operational.

The comparison for 2017 will indicate the potential for any noise issues at the commencement of the project, such as community reaction to significant changes in noise levels. The comparison for 2027 will indicate the potential for noise impacts in the longer term once the project is well established and the surrounding road network has stabilised.

6.2 Road noise prediction algorithms

Noise modelling of the project area was carried out using the *Calculation of Road Traffic Noise* (CORTN) (UK Department of Transport, 1988)[vi] algorithms incorporated in SoundPLAN V7.1. The modelling allows for traffic volume and mix, type of road surface, vehicle speed, road gradient, reflections off building surfaces, ground absorption and shielding from ground topography and physical noise barriers.

The algorithm output of CORTN (fundamentally an L_{A10} predictor) has been modified to calculate the relevant daytime $L_{Aeq(15hour)}$ and night-time $L_{Aeq(9hour)}$ road traffic noise emission levels at noise sensitive receivers, as required by the RNP.

The SoundPLAN traffic noise source 'strings' used in the CORTN algorithm have also been modified to incorporate four effective noise sources (and associated heights) for each carriageway. These comprise a *'CAR'* source with height of 0.5 metres above pavement and three *'TRUCK'* sources at three separate heights representing the noise emission from truck tyres (0.5 metres), truck engines (1.5 metres) and truck exhausts (3.5 metres).

The SoundPLAN noise models were set-up to calculate noise levels at receiver points for all facades of each noise sensitive receiver identified within the project area.

6.3 Modelling of the road alignment

The noise model was constructed from a combination of survey road corridor ground topography, aerial photography and Light Detection and Ranging (LIDAR) information. All design information (altered road corridor, carriageway levels, modified ramps, etc) in areas where upgrade works are proposed within the project area was supplied by the WDA project team.

No Build scenarios

The predictions for the No Build scenarios make use of the existing road alignment geometry of the M5 Motorway and surrounding road network. No Build noise barriers (including those in the M5 Widening project design currently in construction) and features within the road corridor are also included in the No Build noise modelling scenarios.

Build scenarios

The Build scenarios make use the proposed design of the project which includes all proposed widening works of the motorway, modifications to the access ramps, modified noise wall locations and changes to existing cuttings / embankments etc.

6.4 Modelling of pavement surfaces

Existing surface

The existing M5 Motorway pavement surface is understood to be OGA. For the purpose of this assessment, OGA (-2 dB surface correction) has been assumed on the existing motorway.

Future surface

The KGRIU project includes a full re-sheeting of the motorway pavements within the KGRIU project area and majority of the King Georges Road ramps with a low noise OGA surface (-2 dB surface correction). Small sections of the ramps (up to around 50 metres) adjoining King Georges Road would remain as DGA (0 dB surface correction). This re-sheeting is accounted for in the Build noise modelling scenarios for both 2017 and 2027.

6.5 Modelling of traffic data

RNP assessment scenarios

Traffic data for the RNP Build and No Build assessment scenarios for both project opening and the future design year was provided by the WDA project team and is contained in **Appendix D-2**.

6.6 Modelling of noise barriers

Existing

Existing noise barrier locations and heights were provided by the WDA project team. This was supplemented by visual site inspection, where necessary, to determine the appropriateness of any barriers to be included in the model.

No Build

No Build noise barrier locations and heights were provided by the WDA project team. These include the existing noise barriers to the east of King Georges Road and the M5 Widening project noise barriers (in construction) to the west of King Georges Road (taken as the supplied design height).

Build

The construction of the project results in a number of locations where the Existing / No Build noise barriers are required to be replaced to allow for the widened alignment of the road. This is apparent at the following locations:

- Adjacent to the proposed maintenance bay (western end of Windarra Street, westbound) – refer to **Figure 4**.
- Adjacent to Penshurst Road bridge (both sides of the carriageway) – refer to **Figure 4**.
- Adjacent to Cooloongatta Road bridge (both sides of the carriageway) – refer to **Figure 5**.

Figure 4 Existing noise barriers to be replaced (near Penshurst Road Bridge)

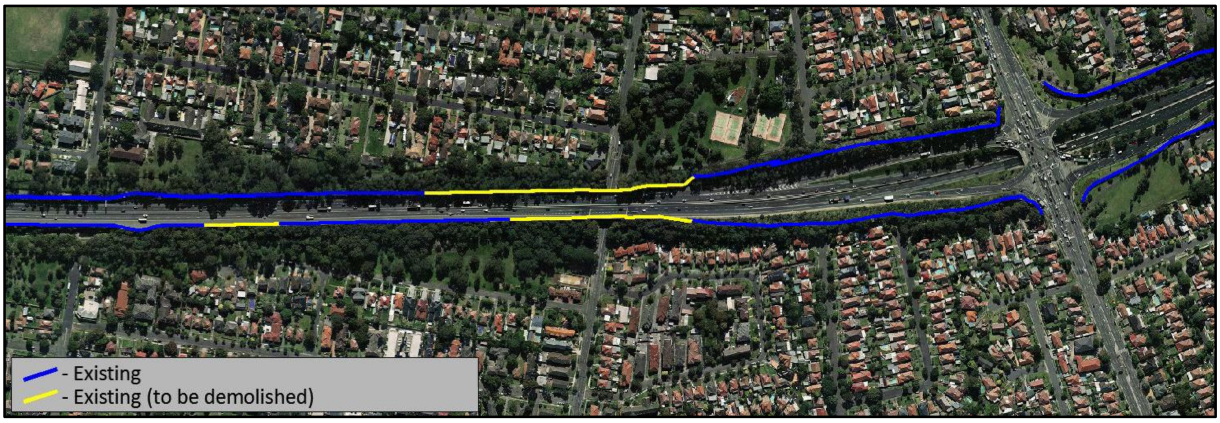


Figure 5 Existing noise barriers to be replaced (near Cooloongatta Road Bridge)

The modelled Build scenario noise barriers in the above locations have taken the existing barriers and 'displaced' them to a feasible location maintaining the same absolute top of barrier height as the existing barrier.

6.7 Summary of noise modelling parameters

A summary of the modelling parameters is provided in **Table 11**.

Table 11 Summary of noise model inputs and parameters

Input Parameter	Source of Data	
Ground topography	Combination of surveyed road corridor data and LIDAR point cloud survey	
Receiver Locations	Aerial photography and LIDAR point cloud	
Vehicle Speed (Model Validation Situation)	Main carriageway Access ramps Secondary	As measured during traffic survey
Vehicle Speed (2017 and 2027 Build and No Build)	Main carriageway Access ramps Secondary	Posted speed 80 to 30 km/h 60 km/h
Source Heights	Car exhaust Truck tyres Truck engines Truck exhausts	0.5 m 0.5 m 1.5 m 3.5 m
Road Surface Corrections	Dense Grade Asphalt Open Grade Asphalt	0 dB -2 dB[1]
Surface Types	Main carriageway – No Build Main carriageway – Build Access ramps Secondary	OGA OGA OGA DGA
Receiver Location (@ 1m from Facade)	Ground floor[2] First floor[2]	1.5m 4.5m
Facade Correction	+2.5 dB	
ARRB	-1.7 dB for facade conditions	
L_{A10} to L_{Aeq}	-3 dB	
Governing Time frame	2027	
Governing Assessment Period	Night-time $L_{Aeq(9hour)}$	

Note 1: This is the standard correction for OGA.

Note 2: These are typical heights above ground level, the height of some receivers were adjusted according to site survey information.

6.8 Noise model validation

Traffic counting equipment was deployed on the main carriageway and on King Georges Road during the period of unattended noise logging, discussed in **Section 4**. The measured traffic data for the model validation situation is summarised in **Appendix D-1**.

The measured traffic data was used within the noise model to predict operational noise levels for the 2014 existing scenario have been compared to the noise levels measured during the ambient noise survey, discussed in **Section 4**, for the purpose of noise model validation.

Small variations between measured and predicted values are to be expected within any noise model. This can be due to many factors, including, the dependence of measured noise levels on road surface characteristics near the specific measurement sites, the incidence of vehicles changing gears near the site, the use of brakes in downhill sections, the bias in use of multiple lanes during different periods of the day, the effects of local screening (eg fences, sheds), etc.

Comparison of measured and predicted levels has been performed by undertaking single point receiver calculations at noise model locations coinciding with the ambient monitoring locations. The results from this are shown in **Table 12**.

Table 12 Model validation – comparison of predicted noise levels to measured noise levels

Ref.	Noise Logging Address	Noise Level (dB)					
		Measured Existing		Predicted Existing		Difference – Predicted Minus Measured	
		Daytime LAeq(15hour)	Night-time LAeq(9hour)	Daytime LAeq(15hour)	Night-time LAeq(9hour)	Daytime LAeq(15hour)	Night-time LAeq(9hour)
L01	6 Grove Avenue, Narwee	57	53	58	54	1	1
L02	15 Rosetta Street, Beverly Hills	57	54	58	54	1	0
L03	311 King Georges Road, Beverly Hills	71	69	72	69	1	0
L05	6 Alambee Crescent, Beverly Hills	55	52	57	53	2	1
L06	19 Elouera Street, Beverly Hills	55	51	56	52	1	1
L07	25 Kirrang Street, Beverly Hills	54	51	56	52	2	1
				Average Difference		**1.2**	**0.6**
				Standard Deviation		**0.5**	**0.2**

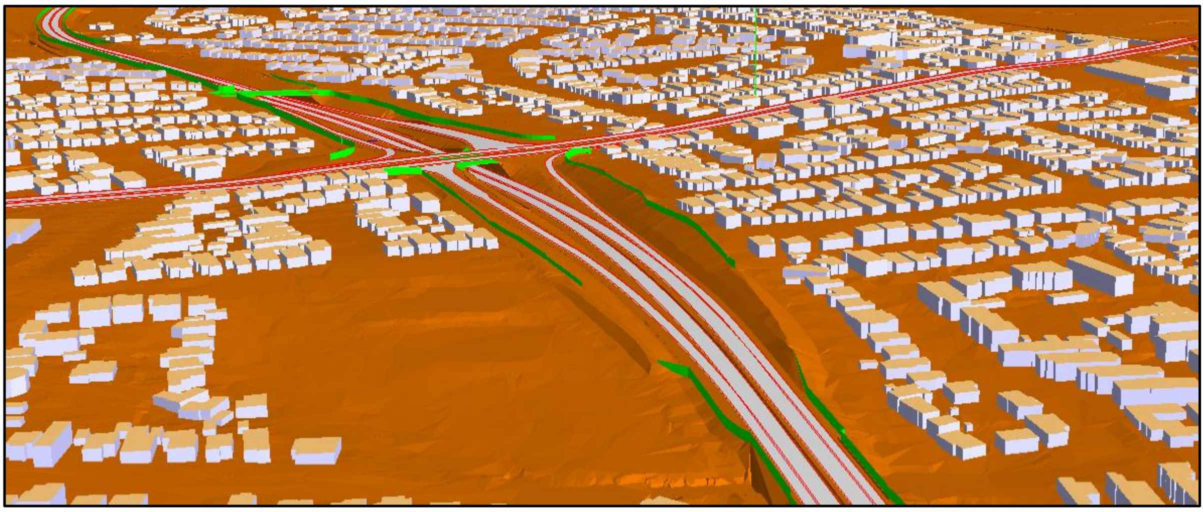
The information contained in **Table 12** shows a good correlation between the predicted and measured data sets along the project area, with the noise model demonstrating slight conservatism.

The ENMM notes that *"it should be recognised that noise prediction modelling has some accuracy limitations and will commonly produce acceptable errors of around 2 dBA"*. On the basis of the comparison of the noise model predictions with the baseline measurement results, it is concluded that the noise model provides results which enable a reliable assessment of the project.

No further model corrections have been applied in this case as the average difference between predicted and measured noise levels is positive and greater than one standard deviation of the dataset (refer to **Table 12**). This approach is considered conservative.

An example screenshot from the validation noise modelling situation is provided in **Figure 6**.

Figure 6 Example KGRIU Noise Model Screenshot



6.9 Receivers included for assessment

In accordance with Roads and Maritime guidance, receiver noise levels are not required to be assessed where the project related roads are not predicted to contribute significantly to the total road traffic noise. This means that in certain locations where secondary roads are seen to be dominant, and the noise level contribution from the project is not significant, the receiver should be excluded from the assessment.

Notwithstanding the above, in locations adjacent to secondary roads, noise levels are required to be assessed where the project generates an increase in total road traffic noise (ie from No Build to Build) of greater than 2 dB, or where the noise levels due to the project road results in 'acute' noise levels.

7 OPERATIONAL NOISE ASSESSMENT WITH EXISTING NOISE BARRIERS

Operational road traffic noise predictions at all assessed receiver locations are shown in **Appendix E**. The table in **Appendix E** shows the RNP noise assessment predictions for both the 2017 at-opening and 2027 future design year.

Predicted noise level maps showing individual noise levels at all assessed ground and first floor residential receivers are provided in **Appendix F** for the following assessment scenarios:

- **Appendix F1-1** – 2017, No Build
- **Appendix F1-2** – 2017, Build (KGRIU)
- **Appendix F1-3** – 2027, No Build
- **Appendix F1-4** – 2027, Build (Full WestConnex scheme)

7.1 Summary of noise impacts with existing noise barriers

A summary of the operational traffic noise assessment is provided in **Table 13** and **Table 14**. The tables show the predicted number of receivers with 'acute' noise levels and those above the RNP noise goals, respectively.

It is noted that the assessment counts each floor of properties as individual 'receivers'. It is not practicable at this stage in the assessment to inspect all properties within the assessment area in order to establish the number of households within each building.

Table 13 Baseline operational noise predictions – 'acute' receivers

NCA	Receiver Type	Floor	2017 No Build		2017 Build		2027 No Build		2027 Build	
			Day[1]	Night[1]	Day[1]	Night[1]	Day[1]	Night[1]	Day[1]	Night[1]
NCA01	Residential	All	0	0	0	0	0	2	0	0
NCA02	Residential	All	0	0	1	1	1	5	1	1
NCA03	Residential	All	1	3	1	3	1	1	1	1
NCA04	Residential	All	0	0	0	0	1	1	0	0
NCA05	Residential	All	0	0	0	0	0	0	0	0
NCA06	Residential	All	0	0	0	0	0	2	0	0
NCA07	Residential	All	0	0	0	0	0	0	0	0
NCA08	Residential	All	0	0	2	5	0	1	1	1
All	**Residential**	**All**	1	3	4	9	3	12	3	3
All	**Other**	**All**	0	0	0	0	0	0	0	0

Note 1: Sensitive receivers (residences, schools, places of worship or health care centres) are considered as 'acute' under the ENMM for LAeq(15hour) daytime road traffic noise levels of 65 dBA and above, or for LAeq(9hour) night-time road traffic noise levels of 60 dBA and above.

Table 14 Baseline operational noise predictions – receivers over the RNP noise goal

NCA	Receiver Type	Floor	2017 No Build		2017 Build		2027 No Build		2027 Build	
			Day	Night	Day	Night	Day	Night	Day	Night
NCA01	Residential	All	17	15	19	17	34	40	23	29
NCA02	Residential	All	51	40	51	48	78	88	69	71
NCA03	Residential	All	8	10	8	10	9	11	8	7
NCA04	Residential	All	9	12	8	12	13	19	5	4
NCA05	Residential	All	8	13	8	13	9	15	2	4
NCA06	Residential	All	11	19	11	18	12	16	3	3
NCA07	Residential	All	10	15	6	12	15	26	1	0
NCA08	Residential	All	6	18	27	40	13	37	17	13
All	**Residential**	**All**	**120**	**142**	**138**	**170**	**183**	**252**	**128**	**131**
All	**Other**	**All**	**75**	**16**	**75**	**16**	**71**	**17**	**69**	**16**

The information presented in **Table 13** and **Table 14** indicates the following:

Acute exceedances

- The KGRUI project is predicted to result in a relatively small increase in the number of night-time 'acute' receivers from three to nine in the 2017 No Build to Build scenarios.
- A reduction in night-time 'acute' receivers from twelve to three receivers is predicted in the 2027 No Build to Build scenarios.

RNP noise goal exceedances

- Both the 2017 and 2027 scenarios are controlled by the night-time period.
- Noise levels for the No Build scenarios (ie without the project) are predicted to be above the RNP noise goals for a significant number of receivers within the KGRIU project area.
  - In the 2017 scenario, the KGRUI project is predicted to increase the number of residential receivers with night-time noise levels above the RNP noise goals from 142 to 170.
  - For the 2027 scenario; however, a reduction in the number of residential receivers being above the RNP goals is predicted to almost half, from 252 to 131.
- The KGRUI project is predicted to result in a negligible change in the number of other sensitive receivers with noise levels above the RNP noise goals.

As the KGRIU project is not forecast to change traffic volumes at project opening (2017), noise impacts in this scenario are due to the change in road alignment alone, which moves the traffic closer to receivers and/or reduces the screening benefit from the existing ground topography and noise walls.

Due to the 2027 forecast traffic volumes (within the KGRUI assessment area) with the full WestConnex scheme being generally lower on the M5 Motorway than they would be without the scheme, the noise impacts in this scenario are generally predicted to be reduced as a result of the project.

All traffic data used in the prediction of operational road traffic noise impacts has been provided by the WDA and is based on outputs from the WestConnex Road Traffic Model. Reference should be made to the corresponding traffic and transport working paper for further details relating to the methodology and potential limitations of the data.

7.2 Summary of receivers for consideration of additional noise mitigation

Predicted noise levels at receivers which are above the RNP noise goals do not necessarily result in exceedances of the adopted project criteria. As per the discussion in **Section 5.3**, further criteria are used to decide which of those receivers are eligible for additional noise mitigation measures.

Table 15 shows the number of receivers which have been identified for consideration of additional noise mitigation. The locations of these receivers are shown graphically in in **Appendix F2-1** and **Appendix F2-2**.

Table 15 Number of receivers considered for additional noise mitigation (as per ENNM)

NCA	Receiver Type	2017 Baseline Build			2027 Baseline Build		
		Day	Night	Combined	Day	Night	Combined
NCA01	Residential	0	0	0	0	0	0
NCA02	Residential	0	0	0	0	0	0
NCA03	Residential	1	3	3	1	1	1
NCA04	Residential	0	0	0	0	0	0
NCA05	Residential	0	0	0	0	0	0
NCA06	Residential	0	0	0	0	0	0
NCA07	Residential	0	0	0	0	0	0
NCA08	Residential	21	21	21	1	1	1
All	**Residential**	**22**	**24**	**24**	**2**	**2**	**2**
All	Other (Educational)	0	0	0	0	0	0
All	Other (Place of Worship)	0	0	0	0	0	0
All	Other (Child Care)	0	0	0	0	0	0
All	Other (Aged Care)	0	0	0	0	0	0
All	Other (Outdoor Active)	0	0	0	0	0	0
All	Other (Outdoor Passive)	0	0	0	0	0	0
All	**Total**	**22**	**24**	**24**	**2**	**2**	**2**

The information presented in **Table 15** indicates that the night-time 2017 scenario results in the highest number of receivers being identified as being eligible for consideration of additional noise mitigation. These receivers are all residential. The 2017 scenario is therefore controlling and is due to the higher increases in road traffic noise due the project in the 2017 scenario when compared to 2027.

A total of 24 receivers (all residential) in the 2017 scenario are considered eligible while the 2027 scenario results in only two eligible receivers (again both residential).

The majority of the eligible receivers (21 of the total 24 receivers) in the 2017 scenario are located in NCA08 (south of the motorway to the east of Cooloongatta Road).

Whilst a number of other sensitive receivers are predicted to be exposed to noise levels above their respective RNP noise goal (refer to **Table 14**), the majority of these receivers are considered in use during the daytime period only (eg educational facilities and outdoor areas). As the project is generally not predicted to result in daytime noise increases of more than the 2 dB at these locations, or result in noise levels which are acute, these receivers are therefore not be eligible for consideration of additional noise mitigation.

The consideration of additional feasible and reasonable noise mitigation measures for the eligible receivers is discussed in detail in the following sections.

8 ASSESSMENT OF REASONABLE AND FEASIBLE MITIGATION MEASURES

8.1 Procedure overview

As highlighted in the RNP, the redevelopment of existing road corridors offers a limited range of noise control measures because of the inherent limitations to using corridor route adjustment, the proximity of existing residents to the road and limited road redesign options.

Where existing noise levels already exceed the criteria, the RNP gives the following guidance:

> *Where existing traffic noise levels are above the noise assessment criteria, the primary objective is to reduce these through feasible and reasonable measures to meet the assessment criteria. A secondary objective is to protect against excessive decreases in amenity as the result of a project by applying the relative increase criteria.*
>
> *In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.*

Where exceedances of the noise criteria are identified, the RNP describes noise mitigation measures to be considered in order of priority:

1 Road design and traffic management.

2 Quieter pavement surfaces.

3 In-corridor noise barriers/mounds.

4 At-property treatments or localised barriers/mounds.

The priority of mitigation measures recognises that noise control at the source is preferable over noise path control and noise mitigation at the receiver.

The RNP notes that it is not mandatory to achieve the noise assessment criteria, and that noise mitigation measures should be both feasible and reasonable.

Selecting reasonable measures from those that are feasible involves judging whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the abatement measure. To make such a judgement, consideration may be given to noise impacts, noise mitigation benefits, the cost effectiveness of noise mitigation and community views.

8.2 ENNM – feasible and reasonable

Where the noise goals in the Build scenarios are found to be exceeded as a result of a project, the project is required to adopt all feasible and reasonable mitigation measures to meet the targets.

Practice Note IV of the ENMM defines what feasible and reasonable factors may be considered when investigating noise mitigation measures.

'Feasibility' relates to engineering considerations (what can be practically built) and may include:

- The inherent limitations of different techniques to reduce noise emissions from road traffic noise sources.
- Safety issues, such as restrictions on road vision.
- Road corridor site constraints such as space limitations.
- Floodway and stormwater flow obstruction.
- Access requirements.

- Maintenance requirements.

'Reasonableness' relates to the application of wider judgements. The factors to be considered are:

- The noise reduction provided and the number of people protected.
- The cost of mitigation, including the total cost and cost variations with different benefits provided.
- Community views and wishes.
- Visual impacts.
- Existing and future noise levels, including changes in noise levels.
- The benefits arising from the proposed road or road development.

8.3 Road design and traffic management

There are limited opportunities to acoustically optimise the design of the KGRIU project given that the M5 Motorway is an existing motorway surrounded in most places by existing communities.

Similarly, traffic management strategies are not considered to be a feasible option for the project given the high daily volumes of traffic that use the motorway in both the existing and future scenarios.

8.4 Low noise pavement surfaces

As noted previously, the proposal includes a full re-sheet of the existing M5 Motorway surface (within the project area) with a low noise OGA pavement surface. This measure provides mitigation of road traffic noise at source and will be a benefit to all sensitive receivers which are surrounding the M5 Motorway compared to higher noise pavement type.

8.5 Noise barriers and architectural treatments

Where the optimisation of the roadway design is insufficient to meet the target noise levels in the Build assessment scenarios, a project is required to apply all feasible and reasonable additional noise control methods (ie noise barriers and architectural treatments) in an attempt to meet the goals.

Where additional mitigation measures are identified as being required, preference is to be given to the use of 'built' wayside noise barriers, as all dwellings (and associated external/outdoor areas) behind the barriers benefit from the resulting reduction in noise.

The following sections discuss the design and optimisation of the project noise barriers and the resulting residual architectural treatments.

9 NOISE WALL DESIGN AND OPTIMISATION

9.1 Assessment overview

In sensitive receiver locations where exceedances of the operational noise criteria are predicted, new or increased height noise barriers have been considered where more than three exceeding properties are found to be closely spaced. Where the number of exceeding receivers is found to be three or less, the specification of noise barriers is not considered to be a reasonable or cost-effective approach and architectural treatment of these receivers should be considered. This approach is consistent with the ENMM.

Noise barriers are typically most efficient when the receivers that it is protecting are located at ground floor level. As the height above ground of a receiver increases, the noise reduction due to the barrier is usually seen to reduce due to the increased line-of-sight over the top of the barrier to the road corridor (ie reduced path length difference).

It is not uncommon for upper floors of multi-storey buildings to see little to no reduction in noise levels from nearby barriers because of their elevation. The process of determining reasonable barrier heights would therefore generally be less likely to result in noise barriers being considered a reasonable option where the most affected receiver is located on the higher floors. With consideration of this, the following assessment and optimisation of noise barriers for the project makes use of noise predictions at ground and first floor only.

9.2 Practice Note IV of the ENMM – requirements

Practice Note IV(a) of the ENMM states that where noise barriers are considered to be a potentially acceptable mitigation option, it is first necessary to determine the barrier height that will reduce the future noise levels at the most affected receiver to the appropriate RNP target levels. The height of barrier is called the **Target Barrier**.

If the Target Barrier does not achieve the goals or it cannot be adopted because of feasibility and reasonableness issues then the **Assessed Barrier** height is to be determined by investigating the effectiveness of the barrier in question at varying heights. The Assessed Barrier is then the height of barrier selected when considering the following parameters:

- The 'total noise benefit' (TNB) for each barrier height. This is the sum of the dB reductions achieved at all residences and other noise-sensitive receptors within each segment.
- The 'marginal benefit value' (MBV) for a particular barrier height. This is the increase in 'total noise benefit' (TNB) divided by the increase in barrier height or area.
- The 'total benefit per unit barrier area' (TNBA). This is the 'total noise benefit' (TNB) divided by the total area of the barrier in the road section being examined.

ENMM Noise Barrier Requirements

Practice Note IV of the ENMM also contains a number of requirements with regard to the attenuation that noise barriers of different heights should generally give. These are detailed below.

> *"In order to be considered cost-effective and therefore warrant consideration as a viable noise treatment option, noise barriers must provide an "insertion loss" – the actual noise reduction, taking account of the barrier's reduction of noise from the proposal and noise from all other road traffic noise sources – of at least 5 dB(A) at the most affected residence. An exception to this may be reasonable, however, in the case of small barriers that are relatively cheap to install (such as "New Jersey"-style kerbs), at locations where even small noise reductions are important.*

- *For noise barriers more than 3 m high, the insertion loss must be more than 5 dB(A) at the most affected residence.*
- *For barriers which are 5 m high or higher, the insertion loss must be at least 10 dB(A) at the most affected residence.*
- *Noise barriers more than 8 m high are generally considered visually unacceptable."*

In certain situations the requirements for the Assessed or the Target barrier cannot always be met. In this case further feasible and reasonable considerations are undertaken with guidance from the RMS.

9.3 Selection of barriers for optimisation

A total of 24 receivers (all residential) in the 2017 scenario are eligible for consideration of additional noise mitigation (refer to **Section 7.2**) while the 2027 scenario results in only two eligible receivers (again, both residential).

The majority of the eligible receivers (21 of the total 24 receivers) in the 2017 scenario are located in NCA08, which is to south of the motorway and to the east of Cooloongatta Road. The noise barrier adjacent to these receivers has been selected for optimisation – this barrier is labelled NW.WB01.

Further consideration of noise barriers in other locations is not required on the basis that exceedances are not clustered behind these locations (refer to **Appendix F2-1** and **Appendix F2-2**). 'Clustered' is noted as being defined as more than three closely spaced properties which are identified as being eligible for consideration of additional noise mitigation.

9.4 Optimisation – recommended project noise barriers

The only noise barrier considered for optimisation is barrier NW.WB01. This barrier has been optimised using the process outlined in Practise Note IV(a) of the ENMM. The results of the optimisation are detailed in **Table 16** and illustrated in **Figure 7**. Reference should also be made to **Appendix G** for further information on the noise barrier optimisation process.

The Target Barrier was found to be 8.0 m in height. A barrier of this size is not considered to be feasible to build, therefore the feasibility and reasonableness of the Assessed Barrier has been considered at this location.

The final recommended noise barrier is the Assessed Barrier unless the ENMM process yields a result which is neither cost effective nor acoustically effective. In this case further selection is based on additional feasible and reasonable considerations as determined by RMS.

Table 16 Optimisation – recommended project noise barriers

Barrier Reference[1]	Barrier Length (m)	Barrier Height (m)				Notes
		Existing	Target	Assessed	Recommended	
NW.WB01	428 (full length of potential wall)	2.5 (partial, approx. 30 meters, displaced as part of the widening)	8.0	4.5	3.0	The Assessed and the Target barriers failed to satisfy all of the requirements in the ENMM Practice Note IV(a). Consideration of how many receivers satisfy the RNP criteria (of those considered for treatment by the ENMM) shows that a 3.0 m noise wall allows 72% of these receivers to satisfy the RNP criteria. In this case, the Assessed barrier only allows four (4) additional receivers to satisfy the RNP criteria. The marginal improvement of RNP receivers between the 3.0 and 4.5 m barrier means that the 3.0 m barrier has been recommended. Any receivers that remain above the RNP criteria will be eligible for architectural property treatment.

Note 1: Noise barrier reference – for example 'NW.WB01' is barrier 01 in the West Bound direction within the KGRIU noise assessment area.

Note 2: Existing height is the height of the existing or the 'displaced' noise wall used in the Build scenario noise predictions.

We note that the western edge of the noise barrier NW.WB01 is an existing barrier which is displaced as part of the widening works. The RL of the displaced section of the noise barrier should be maintained unless the recommended barrier height is greater.

The final extent of any proposed increase in noise barrier height as part of the KGRIU project should be confirmed during detailed design, following a survey of 'as built' noise barrier heights to include the M5 Widening project noise barriers (currently in construction) within the KGRIU project area.

Figure 7 Recommended noise barriers

Note: The 'new/replaced' sections of barrier not labelled as NW.WB01 are the 'displaced' barriers discussed in **Section** Error! Reference source not found.

10 ARCHITECTURAL PROPERTY TREATMENTS

At some locations where the noise criteria are exceeded as a result of the project, the feasibility and reasonableness considerations discussed previously have concluded that the construction or modification of noise barriers is not feasible, reasonable or cost-effective.

At locations, where residual impacts remain after all feasible and reasonable approaches have been exhausted, noise mitigation in the form of acoustic treatment of existing individual dwellings is to be considered.

At-property architectural acoustic treatments should aim to achieve internal noise levels in habitable rooms 10 dB below the external noise level criteria. In some cases this will be limited by the existing construction and condition of the residence.

Building element treatments are more effective when they are applied to masonry structures than lightly clad timber frame structures. Caution should be exercised before providing treatments for buildings in a poor state of repair, as they will be less effective and may not provide any appreciable noise reduction benefit.

The acoustic treatments provided by Roads and Maritime are typically limited to:

- Fresh air ventilation systems that meet the Building Code of Australia requirements with the windows and doors closed (in certain circumstances air conditioning that includes fresh air intake may also be considered, particularly where adverse climate conditions prevail).
- Upgraded windows and glazing and solid core doors on the exposed facades of the substantial structures only (eg masonry or insulated weather board cladding with sealed underfloor). These techniques would be unlikely to produce any noticeable benefit for light frame structures with no acoustic insulation in the walls.
- Upgrading window or door seals and appropriately treating sub-floor ventilation.
- The sealing of wall vents.
- The sealing of the underfloor below the bearers.
- The sealing of eaves.

In accordance with the RNP, where facade treatment is undertaken, there is no guarantee that remedial works will achieve any specific noise levels.

Where multi-level residential buildings are apparent, Roads and Maritime policy is to only consider architectural treatment options at the ground and first floor levels.

For the KGRIU project, the recommended residual noise impact mitigation package for all habitable rooms of eligible locations is as follows:

Architectural treatment of exceeding dwellings <10 dB over RNP target

- Where external noise levels are less than 10 dB above the RNP base criteria, acceptable internal noise levels may be achieved with windows closed on exposed facades.
- A light framed building with single glazed (closed) windows with sealed wall vents will typically provide an external to internal noise reduction of 20 dB. Where the RNP internal base criteria in habitable rooms can only be achieved with windows and vents closed, then mechanical ventilation should be provided (subject to individual consultation with dwelling owners) to ensure sufficient airflow inside the dwelling, so as to meet the requirements of the Building Code of Australia.

Architectural treatment of exceeding dwellings >=10 dB over RNP target

Where the external levels are 10 dB or higher than the RNP base criteria, then upgraded windows, doors and/or seals (depending on individual assessment and generally only suitable for masonry type buildings) is necessary, in addition to the above.

11 OPERATIONAL NOISE IMPACTS WITH RECOMMENDED NOISE BARRIERS

The final design of the recommended noise barriers as shown in **Table 16** and **Figure 7** has been included in the modelling of the Final Build scenarios. This scenario predicts the noise impacts remaining after the additional noise mitigation of a low noise pavement (OGA) and optimised barrier heights have been included.

Predicted noise level maps showing individual noise levels at all residential receivers for the Final Build scenario are provided in **Appendix H**. The following tables summarise the Final Build scenario operational noise impacts.

11.1 Summary of the acute impacts

The summary of the acute impacts is as follows:

- **Overall:** The number of acute receivers in any timeframe or scenario is very low. The project is seen to reduce the number of acute receivers in the 2027 timeframe. The change between the No Build 2017 and Build 2027 scenarios is minimal.
- **NCA01:** The change in acute receivers is zero between the No Build 2017 and Build 2027 scenarios for both the day and night-time periods. The project has zero acute noise impact as a result.
- **NCA02:** The increase in acute receivers is one between the No Build 2017 and Build 2027 scenarios for both the day and night-time periods. The project has a minimal acute noise impact as a result.
- **NCA03:** There is no change between the No Build and Build scenarios for both the 2017 and 2027 timeframes. The project has zero acute noise impact as a result.
- **NCA04:** The change in acute receivers is zero between the No Build 2017 and Build 2027 scenarios for both the day and night-time periods. The project has zero acute noise impact as a result.
- **NCA05:** The project has zero acute impact for these receivers.
- **NCA06:** The change in acute receivers is zero between the No Build 2017 and Build 2027 scenarios for both the day and night-time periods. The project has zero acute noise impact as a result.
- **NCA07:** The change in acute receivers is zero between the No Build 2017 and Build 2027 scenarios for both the day and night-time periods. The project has zero acute noise impact as a result.
- **NCA08:** The change in acute receivers is zero between the No Build 2017 and Build 2027 scenarios for both the day and night-time periods. The project has zero acute noise impact as a result.

Table 17 provides the final operational noise predictions for those receivers which are still 'acute'. A comparison between the No Build and Final Build scenarios is also provided.

Table 17 Final operational noise predictions – 'acute' receivers

NCA	Receiver Type	Floor	2017 No Build		2017 Final Build		2027 No Build		2027 Final Build	
			Day[1]	Night[1]	Day[1]	Night[1]	Day[1]	Night[1]	Day[1]	Night[1]
NCA01	Residential	All	0	0	0	0	0	2	0	0
NCA02	Residential	All	0	0	1	1	1	5	1	1
NCA03	Residential	All	1	3	1	3	1	1	1	1
NCA04	Residential	All	0	0	0	0	1	1	0	0
NCA05	Residential	All	0	0	0	0	0	0	0	0
NCA06	Residential	All	0	0	0	0	0	2	0	0
NCA07	Residential	All	0	0	0	0	0	0	0	0
NCA08	Residential	All	0	0	0	0	0	1	0	0
All	**Residential**	**All**	**1**	**3**	**2**	**4**	**3**	**12**	**2**	**2**
All	**Other**	**All**	0	0	0	0	0	0	0	0

Note 1: Residential receivers are defined as 'acute' under the ENMM for LAeq(15hour) daytime road traffic noise levels of 65 dBA and above, or for LAeq(9hour) night-time road traffic noise levels of 60 dBA and above.

11.2 Summary of RNP exceedances

The summary of the RNP exceedances is as follows:

- **Overall:** The No Build Scenarios in both the 2017 and 2027 timeframe have a larger number of RNP exceedances compared to the Build Scenarios. Therefore, building the project gives a reduction in the number of RNP exceedances.
- **NCA01:** During the day and night-time a small increase in RNP exceedances is observed between the No Build and Build options during the 2017 timeframe. The increase is 2 additional receivers in both the day and night-time.
  The same comparison in the 2027 timeframe shows a reduction in the RNP exceedances for both the day and night-time periods. Overall, building the project will reduce the RNP impacts for this catchment.
- **NCA02:** During the night-time a small increase in RNP exceedances is seen between the No Build and Build options during the 2017 timeframe. The increase is 8 additional receivers during the night-time.
  The same comparison in the 2027 timeframe shows a reduction in the RNP exceedances for both the day and night-time periods. Overall, building the project will reduce the RNP impacts for this catchment.
- **NCA03:** There is a reduction in the number of RNP exceedances between the Build 2017 and 2027 scenarios. There is also a reduction (or zero change) between the Build and No Build options in each timeframe. Therefore, building the project is seen to reduce the overall number of exceedances of the RNP criteria in this catchment.
- **NCA04:** There is a reduction in the number of RNP exceedances between the Build 2017 and 2027 scenarios. There is also a reduction between the Build and No Build options in each timeframe. Therefore, building the project is seen to reduce the overall number of exceedances of the RNP criteria in this catchment.

- **NCA05:** There is a reduction in the number of RNP exceedances between the Build 2017 and 2027 scenarios. There is also a reduction between the Build and No Build options in each timeframe. Therefore, building the project is seen to reduce the overall number of exceedances of the RNP criteria in this catchment.
- **NCA06:** There is a reduction in the number of RNP exceedances between the Build 2017 and 2027 scenarios. There is also a reduction between the Build and No Build options in each timeframe. Therefore, building the project is seen to reduce the overall number of exceedances of the RNP criteria in this catchment.
- **NCA07:** There is a reduction in the number of RNP exceedances between the Build 2017 and 2027 scenarios. There is also a reduction between the Build and No Build options in each timeframe. Therefore, building the project is seen to reduce the overall number of exceedances of the RNP criteria in this catchment.
- **NCA08:** There is a reduction in the number of RNP exceedances between the Build 2017 and 2027 scenarios. There is also a reduction between the Build and No Build options in each timeframe. Therefore, building the project is seen to reduce the overall number of exceedances of the RNP criteria in this catchment.

Table 18 provides the final operational noise predictions for all receivers which still exceed the RNP noise goals in the Final Build scenario.

Table 18 Final operational noise predictions – receivers over the RNP noise goal

NCA	Receiver Type	Floor	2017 No Build		2017 Final Build		2027 No Build		2027 Final Build	
			Day	Night	Day	Night	Day	Night	Day	Night
NCA01	Residential	All	17	15	19	17	34	40	23	29
NCA02	Residential	All	51	40	51	48	78	88	69	71
NCA03	Residential	All	8	10	8	10	9	11	8	7
NCA04	Residential	All	9	12	7	12	13	19	5	4
NCA05	Residential	All	8	13	8	12	9	15	2	4
NCA06	Residential	All	11	19	10	16	12	16	3	3
NCA07	Residential	All	10	15	5	10	15	26	1	0
NCA08	Residential	All	6	18	4	7	13	37	0	0
All	**Residential**	**All**	**120**	**142**	**112**	**132**	**183**	**252**	**111**	**118**
All	**Other**	**All**	**75**	**16**	**75**	**16**	**71**	**17**	**69**	**16**

11.3 Summary of receivers eligible for property treatment

The summary of eligible property treatment impacts is as follows:

- **Overall:** The total number of properties eligible for architectural treatment is six - due to both the 2017 and 2027 timeframe. Only NCA03 and NCA08 have any receivers eligible for treatments. The impacts of the project with respect to property treatments are therefore considered to be very low.
  All treatments are required for residential receivers, with no impacts observed for other sensitive receivers.
- **NCA01:** No treatments required.
- **NCA02:** No treatments required.

- **NCA03:** Three treatments required due to the 2017 timeframe noise impacts with only one treatment required due to the 2027 timeframe noise impacts.
- **NCA04:** No treatments required.
- **NCA05:** No treatments required.
- **NCA06:** No treatments required.
- **NCA07:** No treatments required.
- **NCA08:** Three treatments required due to the 2017 timeframe noise impacts.

Table 19 shows the number of receivers which have been identified as eligible for property treatments in the Final Build scenario.

Table 19 Final number of receivers eligible for property treatment (as per ENNM)

NCA	Receiver Type	2017 Final Build			2027 Final Build		
		Day	Night	Combined	Day	Night	Combined
NCA01	Residential	-	-	-	-	-	-
NCA02	Residential	-	-	-	-	-	-
NCA03	Residential	1	3	3	1	1	1
NCA04	Residential	-	-	-	-	-	-
NCA05	Residential	-	-	-	-	-	-
NCA06	Residential	-	-	-	-	-	-
NCA07	Residential	-	-	-	-	-	-
NCA08	Residential	2	3	3	-	-	-
All	**Residential**	**3**	**6**	**6**	**1**	**1**	**1**
All	Other (Educational)	-	-	-	-	-	-
All	Other (Place of Worship)	-	-	-	-	-	-
All	Other (Child Care)	-	-	-	-	-	-
All	Other (Aged Care)	-	-	-	-	-	-
All	Other (Outdoor Active)	-	-	-	-	-	-
All	Other (Outdoor Passive)	-	-	-	-	-	-
All	**Total**	**3**	**6**	**6**	**1**	**1**	**1**

Table 20 provides a detailed list of all of the sensitive receivers that are eligible for additional property treatments as part of the KGRUI project. The full assessment table for all identified sensitive receivers is provided in **Appendix I**.

Table 20 Summary of impacts at receivers qualifying for property treatment

Count	Receiver Details							Receiver Assessment Period	RNP Criteria		Predicted Noise Level (dBA)			
											Most Affected Facade			
	Address (approximate within 50 metres)				Centroid Coordinates		Type				2017		2027	
											Final Design		Final Design	
	Floor	Street No.	Street	Suburb	Easting	Northing			Day	Night	Day	Night	Day	Night
1	2	13	WARNE CRESCENT	BEVERLY HILLS	322132	6242512	Residential	Period	60	55	65	60	65	60
2	2	321	KING GEORGES ROAD	BEVERLY HILLS	322226	6242544	Residential	Period	60	55	-[1]	73[2]	-[1]	-[1]
3	1	323	KING GEORGES ROAD	BEVERLY HILLS	322231	6242533	Residential	Period	60	55	58	73[2]	58	54
4	1	28	KIRRANG STREET	BEVERLY HILLS	322835	6242651	Residential	Period	60	55	60	56	58	53
5	2	28	KIRRANG STREET	BEVERLY HILLS	322835	6242651	Residential	Period	60	55	62	58	60	55
6	2	54	TALLAWALLA STREET	BEVERLY HILLS	322902	6242632	Residential	Period	60	55	61	56	59	54

Note 1: Predicted overall road traffic noise level is dominated by non-project road noise (King Georges Road), increase due to the project is not greater than 2 dB and project road noise is not 'acute'.

Note 2: Predicted overall road traffic noise level is dominated by non-project road noise (King Georges Road) however facade is included in the assessment on the basis that the predicted project road noise contribution is 'acute'

11.4 Discussion of required treatments

Further to the inclusion of the optimised project noise barrier a total of six residential receivers are predicted to be eligible for property treatment as part of the KGRIU project. This number comprises:

- Three residential receivers in NCA03 (north of the motorway to the west of King Georges Road)
- Three residential receivers in NCA08 (south of the motorway to the east of Cooloongatta Road)

For individual residential receivers Roads and Maritime does not consider it reasonable to consider noise mitigation above the ground and first floor.

A number of residential receivers that have been identified exceeding the RNP criteria are multi-storey apartment buildings. A further feasible and reasonable review of architectural treatments at multi-storey apartments should be completed during the detail design.

Furthermore, the above numbers count single floors of properties as individual 'receivers'. This means that where, for example, a property is predicted to have exceedances of the criteria at both the ground and first floor levels, that property would then be counted as two separate 'receivers' in the summary counts. This is apparent at one property (28 Kirrang Street) for this project.

11.5 Change in noise levels

The change in operational noise levels for residential receivers in 2027 as a result of the KRGUI are illustrated in **Figure 8**. Overall the figure indicates the following:

Overall

- A general trend of lower noise levels between the Build and No Build options for the 2027 timeframe is demonstrated in the assessment data.

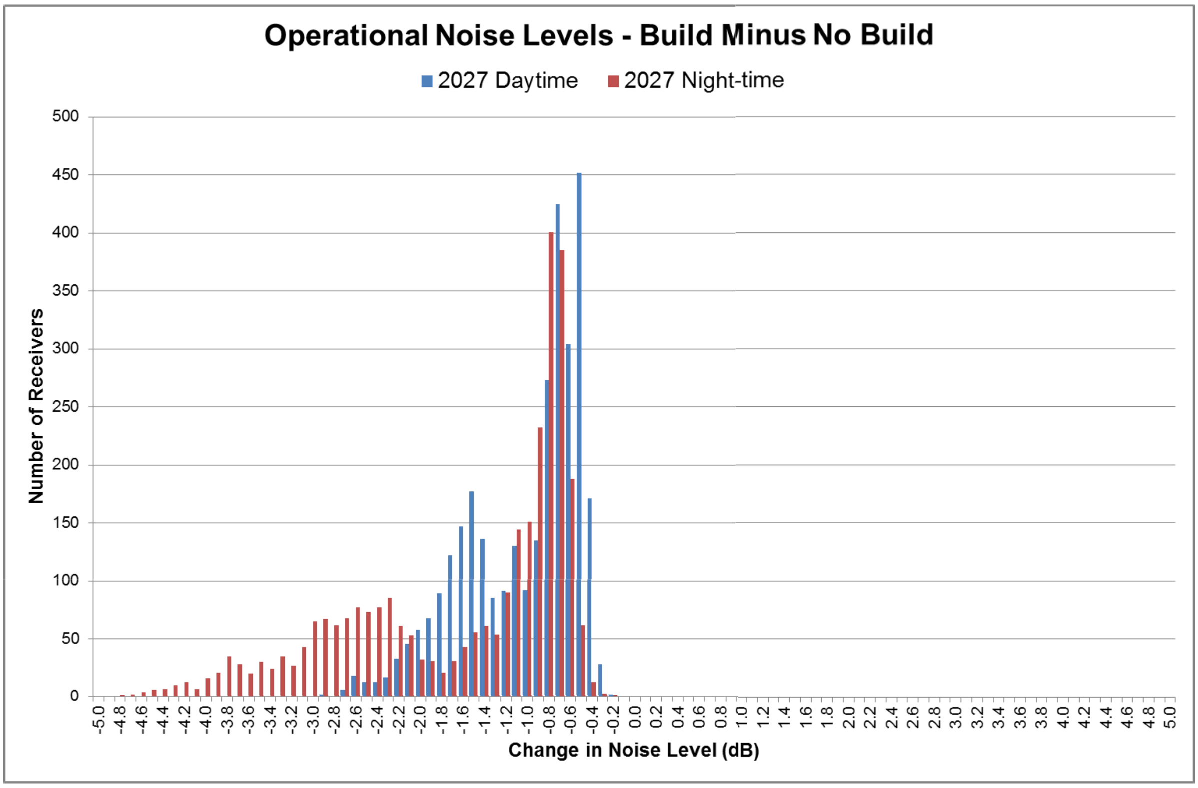
Daytime

- The median decrease in noise levels across the project is 0.8 dB.
- No receivers have an increase of more than 0.5 dB.

Night-time

- The median decrease in noise levels across the project is 1.1 dB.
- No receivers have an increase of more than 0.5 dB.

Figure 8 Changes in operational noise levels between build and no build scenarios



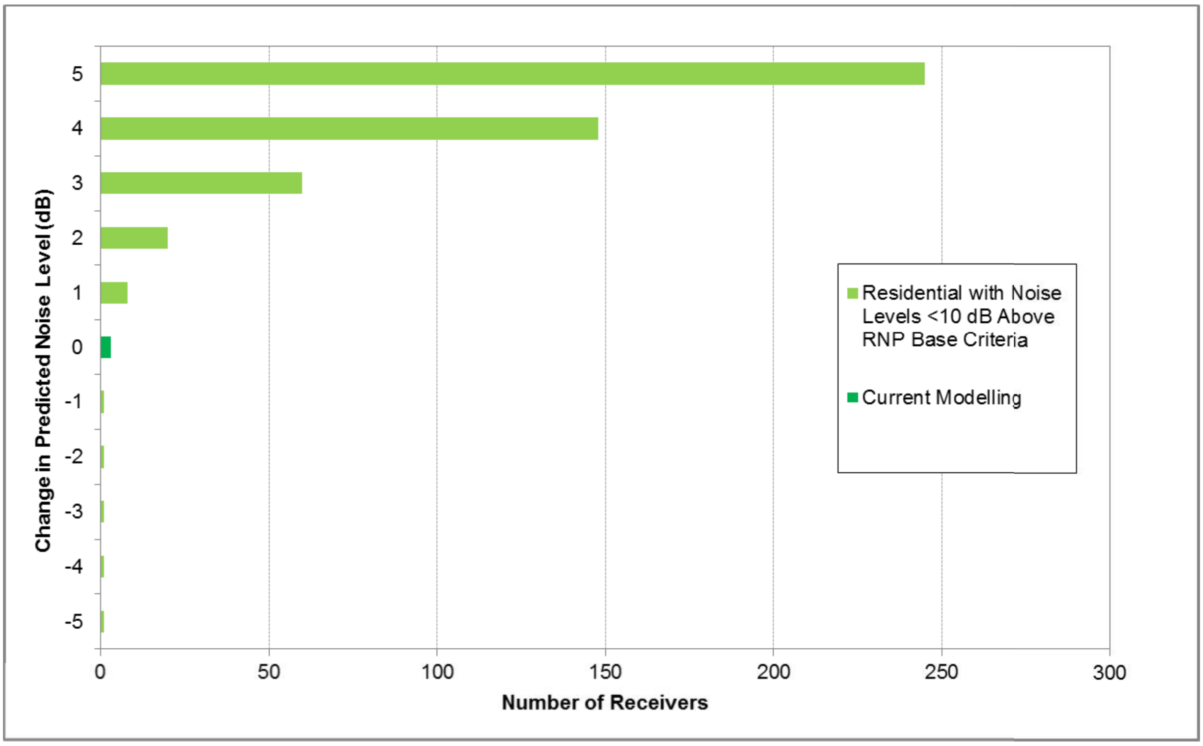
11.6 Sensitivity analysis

A sensitivity analysis of the operational road traffic noise assessment and noise modelling methodology has been undertaken.

The likely change in the predicted number of receivers that are considered eligible for consideration of property treatment has been determined by applying a nominal correction factor to the 2027 Final Build noise model predictions in 1 dB increments. This exercise is summarised in **Figure 5**.

The 6 residential receivers that are currently predicted in the modelling to require additional property treatments are shown by the dark green bar.

Figure 5 ENMM sensitivity analysis – number of property treatments



Reference to the above indicates that an additional 10 receivers would be eligible for consideration of property treatment if a +1 dB correction were to be added to the noise model predictions. A reduction of 4 receivers would be apparent if 1 dB was to be subtracted from the noise model predictions.

11.7 Maximum noise levels

A maximum noise level assessment has been conducted in accordance with the procedure *Preparing an Operational Noise and Vibration Assessment* (Roads and Maritime, 2011).

It is noted that the RNP and ENMM both state that whilst a maximum noise level assessment is required to be undertaken for new and upgraded road infrastructure projects, it should only be used as a tool to help prioritise and rank mitigation strategies, and should not be applied as a decisive criterion in itself.

The objective of the maximum noise level assessment is to determine whether maximum noise levels are likely to increase or decrease as a result of the project.

11.7.1 Maximum noise level measurements

Maximum noise level events were measured as part of the ambient noise study undertaken at noise monitoring locations L01 to L07 from 22 May 2014 to 2 June 2014. Noise monitoring locations and measurement methodologies are described in detail in **Section 4**.

The maximum noise level assessment includes an evaluation of the number and distribution of night-time passby events in accordance with the ENMM. A maximum noise level event is defined within the ENMM as being any pass by where:

- The maximum noise level of the event is greater than 65 dBA, and
- The L_{AFmax} – $L_{Aeq(1hour)}$ is greater than or equal to 15 dB.

The results of the maximum noise level assessments are provided in **Appendix J** and include the maximum noise level range for the passby events. A summary of the maximum noise level assessments is presented in **Table 21**.

Table 21 Maximum Noise Level Events

Monitoring Location	Monitoring Dates	Total Night-time Events within the Monitoring Period	Measured Maximum Noise Level (dBA)	
			Range	Average
L01	22/05/14-2/06/14	31	67-74	70
L02	22/05/14-2/06/14	46	65-78	70
L03[1]	22/05/14-2/06/14	321	80-92	84
L04[2]	22/05/14-2/06/14	133	65-79	71
L05	22/05/14-2/06/14	43	65-78	70
L06	22/05/14-2/06/14	55	65-74	68
L07	22/05/14-2/06/14	50	65-74	68

Note 1: Location immediately adjacent to King Georges Road with negligible influence from M5 traffic noise.

Note 2: This location was affected by extraneous noise (birds and dog noise) and should be regarded as indicative only

From the results presented within **Table 21**, it can be seen that average maximum noise level events typically range from 65 dBA to 80 dBA at monitoring locations affected by road traffic noise from the M5 carriageway and ramps.

11.7.2 Change in Maximum Noise Levels

The results of the maximum noise assessment indicate that there is potential for a decrease in the maximum noise environment for several clusters of receivers adjacent to the M5 Motorway. These clusters are typically situated in locations where new or increased height noise barriers are apparent in the final design of the project. The new or increased height barriers provide additional screening of the motorway and therefore reduce maximum noise levels accordingly.

No significant increases in the magnitude of maximum noise events is predicted on the basis that all design noise barriers across the project area are either proposed to remain at the existing height, to be increased in height or for a new noise barrier to be installed, and do not significantly increase the angle of view to the adjacent receivers.

While no increase in the magnitude of maximum noise events is expected, the number of maximum noise events would be expected to vary in line with the changes in traffic volumes.

Notwithstanding the potential for the increase in the number of maximum noise level events at the nearest residences where traffic volumes increase, it should be noted that strategies are currently being implemented to reduce road traffic noise across the state's road network which may reduce the number of maximum noise levels events over the longer term.

These strategies include local council requirements to include noise mitigation in new dwellings, metropolitan plans to increase the use of public transport, state wide plans for upgrades of major transport routes, and national initiatives to reduce heavy vehicle engine brake noise and road freight haulage.

In addition, state wide strategies for sharing freight with rail modes are expected to result in reduced noise from heavy vehicle freight on roads in many areas and a corresponding reduction in high noise level events from road traffic.[Intentionally left blank]

12 ASSESSMENT OF CONSTRUCTION NOISE – ON SITE WORKS

People are usually more tolerant to noise and vibration during the construction phase of proposals than during normal operation. This response results from recognition that the construction emissions are of a temporary nature – especially if the most noise-intensive construction impacts occur during the less sensitive daytime period. For these reasons, acceptable noise and vibration levels are normally higher during construction than during operations.

Construction often requires the use of heavy machinery which can generate high noise and vibration levels at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts should be minimised by using feasible and reasonable management techniques.

At any particular location, the potential impacts can vary greatly depending on factors such as the relative proximity of sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration levels, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

The following section details the assessment of potential airborne noise impacts associated with the construction of the proposal. Construction noise goals have been determined based on the relevant government guidelines and industry standards. Potential noise levels have been predicted at sensitive receivers for expected activities and where levels are above the goals, feasible and reasonable impact mitigation measures are considered.

12.1 Proposed Construction Activities

12.1.1 Proposed Works

This report provides an assessment of the potential noise and vibration impacts associated with the proposed activities required to construct the proposal, including earthworks, excavations and construction of operational infrastructure.

The construction noise and vibration assessment has considered the following construction activities:

- General excavation activities along the alignment, expected to involve conventional road excavation equipment including road saws, rock breakers, jackhammers, chainsaws, road profilers, excavators and trucks.
- Pavement works along the alignment including removal and laying concrete and asphaltic surfaces, expected to involve rock breakers, milling machines, concrete trucks, concrete pumps, rollers and paving machines.
- Slope stability works and landscaping along the alignment, expected to involve diamond rock saws, concrete/grout pumps and conventional heavy earth moving equipment including bulldozers, excavators, rollers and graders.
- Installation of street lighting, signs, safety barriers and linemarking along the alignment, expected to involve handtools, road saws, mobile cranes, excavators, piling rigs, plate compactors and line marking plant.
- Establishment and use of site compounds.
- Structural works on bridges, expected to involve rollers, mobile cranes, piling rigs and concreting plant.
- Removal of noise barriers, expected to involve elevated working platforms, cranes, excavator breakers, dozers and hand tools.

12.1.2 Construction Hours

Where possible, works would be completed during the standard day time construction hours of Monday to Friday 7.00 am to 6.00 pm and Saturdays 8.00 am to 1.00 pm. However, the nature of the project means evening and night work would also be required, particularly where safety considerations require lane closures to undertake the work.

Out of Hours Works (OOHWs) are included in the assessment for all proposed works at all locations in order to inform the scheduling of construction activity and management of noise during the detailed design phase. It is anticipated that the finalised requirements for OOHWs would be determined at a later design stage. It is understood that any OOHW would be subject to a separate approval on a case-by-case basis and would likely require approval under the King Georges Road Interchange Upgrade project's Environmental Protection Licence (EPL).

12.2 Construction Noise Metrics

The three primary noise metrics used to describe construction noise emissions in the modelling and assessments are:

$L_{A1(1minute)}$ The typical 'maximum noise level for an event', used in the assessment of potential sleep disturbance during night-time periods. Alternatively, assessment may be conducted using the L_{Amax} or maximum noise level

$L_{Aeq(15minute)}$ The 'energy average noise level' evaluated over a 15-minute period. This parameter is used to assess the potential construction noise impacts.

L_{A90} The 'background noise level' in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively. The $L_{Aeq(15minute)}$ construction noise management levels are based on the L_{A90} background noise levels.

The subscript 'A' indicates that the noise levels are filtered to match normal hearing characteristics (A-weighted).

12.3 Noise Management Levels for Construction Activity

The ICNG requires proposal specific Noise Management Levels (NMLs) to be established for noise affected receivers. In the event construction noise levels are predicted to be above the NMLs, all feasible and reasonable work practices are investigated to minimise noise emissions.

Having investigated all feasible and reasonable work practices, if construction noise levels are still predicted to exceed the NMLs then the potential noise impacts would be managed via site specific construction noise management plans, to be prepared in the detailed design phase.

12.3.1 Residential Receivers

The ICNG provides an approach for determining $L_{Aeq(15minute)}$ NMLs at residential receivers along the alignment applying the measured $L_{A90(15minute)}$ background noise levels, as described in **Table 22**.

Table 22 Determination of NMLs for Residential Receivers

Time of Day	NML LAeq(15minute)	How to Apply
Standard hours Monday to Friday 7:00 am to 6:00 pm Saturday 8:00 am to 1:00 pm No work on Sundays or public holidays	RBL + 10 dBA	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured LAeq(15minute) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practises to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restructuring the hours that the very noisy activities can occur, taking into account: • Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools or mid-morning or mid-afternoon for works near residences. • If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	RBL + 5 dBA	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practise have been applied and noise is more than 5 dB above the noise affected level, the proponent should negotiate with the community.

Note 1 Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Note 2 The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours). The term RBL is described in detail in the NSW Industrial Noise Policy.

Adopting the measured background noise levels in **Table 7** the NMLs derived for the proposal are detailed in **Table 23**.

Table 23 Residential Receiver NMLs for Construction

NCA-receiver type	Location ID	Receiver Type	Standard Construction (RBL +10dB)	Out of Hours (RBL +5dB)			Sleep Disturbance Screening (RBL+15)
			Daytime	Daytime	Evening	Night-time	
NCA01.RES	L01	Residential	62	57	56	44	54
NCA02.RES	L01	Residential	62	57	56	44	54
NCA03.RES	L02	Residential	63	58	57	49	59
NCA04.RES	L02	Residential	63	58	57	49	59
NCA05.RES	L04	Residential	57	52	51	45	55
NCA06.RES	L05	Residential	61	56	55	49	59
NCA07.RES	L06	Residential	60	55	54	45	55
NCA08.RES	L07	Residential	59	54	54	47	57

NCA-receiver type	Location ID	Receiver Type	Standard Construction (RBL +10dB)	Out of Hours (RBL +5dB)			Sleep Disturbance Screening (RBL+15)
			Daytime	Daytime	Evening	Night-time	
West of project area	L01	Residential	62	57	56	44	54
East of project area	L07	Residential	59	54	54	47	57

Where construction would be undertaken during the night-time period the potential for sleep disturbance should be assessed. The current approach to identifying potential sleep disturbance impacts is to set a screening criterion 15 dB above the RBL during the night-time period (10.00 pm to 7.00 am).

The term 'screening criterion' indicates a noise level that is intended as a guide to identify the likelihood of sleep disturbance. It is not a firm criteria to be met, however where the criterion is met sleep disturbance is not likely. When the screening criterion is not met, a more detailed analysis is required.

The detailed analysis should assess the maximum noise level or $L_{A1(1minute)}$, the extent that the maximum noise level exceeds the background noise level and the number of times any exceedance occurs during the night-time period.

The RNP contains a section on sleep disturbance that includes a summary of current literature; concluding that:

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

12.3.2 Other Sensitive Land Uses

The proposal specific $L_{Aeq(15minute)}$ NMLs for other non-residential noise sensitive receivers from the ICNG are provided in **Table 24**.

Table 24 Noise Management Levels for Other Sensitive Receivers

Land Use	NML $L_{Aeq(15minute)}$ (Applied when the property is in use)
Classrooms at schools and other education institutions	Internal noise level 45 dB
Hospital wards and operating theatres	Internal noise level 45 dB
Places of Worship	Internal noise level 45 dB
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
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, e.g. reading, meditation)	External noise level 60 dB
Community centres	Depends on the intended use of the centre. Refer to the recommended 'maximum' internal levels in AS 2107 for specific uses.

For sensitive receivers such as schools and places of worship, the NMLs presented in **Table 24** are based on internal noise levels. For the purpose of this assessment, it is conservatively assumed that all schools and places of worship have open-able windows. On the basis that external noise levels are typically 10 dB higher than internal noise levels when windows are open, an external $L_{Aeq(15minute)}$ NML of 55 dB has been adopted.

Other noise-sensitive businesses require separate proposal specific noise goals and it is suggested in the ICNG that the internal construction noise levels at these premises are to be referenced to the 'maximum' internal levels presented in AS 2107 Acoustics – *Recommended design sound levels and reverberation times for building interiors*. The ICNG and AS2107 do not provide specific guideline noise levels for childcare centres. Childcare centres generally have internal play areas and sleep areas. For internal play areas an internal NML of $L_{Aeq(15minute)}$ 55 dB has been adopted and for sleeping areas, an internal NML of $L_{Aeq(15minute)}$ 40 dB (when in use) has been adopted.

On the assumption that windows and doors of childcare centres may be opened, an external NML of $L_{Aeq(15minute)}$ 65 dB for play areas has been applied at the facade and would also be applicable to external play areas. For sleeping areas on the assumption that windows are open, the external NML is $L_{Aeq(15minute)}$ 50 dB.

12.3.3 Commercial and Industrial Premises

For commercial premises, including offices, retail outlets and small commercial premises an external NML of $L_{Aeq(15minute)}$ 70 dB has been adopted. An external NML of $L_{Aeq(15minute)}$ 75 dB has been adopted for industrial premises. In both land uses, the external noise levels should be assessed at the most affected occupied point on the premises.

12.3.4 Construction Traffic Noise

When trucks and other vehicles are operating within the boundaries of the various construction sites, road vehicle noise contributions are included in the overall predicted $L_{Aeq(15minute)}$ construction site noise emissions. When construction related traffic moves onto the public road network a different noise assessment methodology is appropriate, as vehicle movements would be regarded as 'additional road traffic' rather than as part of the construction site. Construction traffic noise impacts on public roads are assessed in **Section 13**.

12.4 Overview of Construction Noise Modelling

To quantify noise levels from the construction activities a noise prediction model was developed using SoundPLAN Version 7.1 noise propagation software. The concept designs of the proposal, local terrain, receiver buildings and structures have been digitised in the noise model to develop a three-dimensional representation of the construction sites and surrounding environment.

Maximum sound power levels for the typical operation of construction equipment applied in the modelling are listed in **Table 25**. To assess construction noise levels against the NMLs, the maximum noise levels have been converted to equivalent $L_{Aeq(15minute)}$ noise emissions. Based on SLR's experience on large construction proposals suitable adjustments of between 2 dB to 5 dB have been applied to convert the L_{Amax} noise levels in to L_{Aeq} noise levels for assessment with the NMLs.

Table 25 Sound Power Levels for Construction Equipment

Scenario Name	Activity (ie Equipment Split)	Equipment (realistic worst-case)	Operating minutes in 15-min period	No of items in same location	Sound Power Level (dBA) Maximum LAeq Item	Maximum LAeq Activity	LAmax Activity
Main Corridor / Ramp Works	Clearing, Grubbing and Earthworks	Grader	15.0	1	108	117	123
		Road Profiler	15.0	1	107		
		Water Tanker (8000 litre)	15.0	1	98		
		Concrete Saw[1]	5.0	1	115		
		Truck (10 tonne)	15.0	1	98		
		Vibratory Roller (10 - 12 tonne)[1]	15.0	1	109		
		Excavator (20 tonne)	15.0	1	99		
		Compactor	15.0	1	108		
		Dozer	15.0	1	110		
	Drainage Works - Excavation of trenches and pits, delivery and placement of precast pipes and pits, filling and compacting	Excavator (15 tonne)	15.0	1	96	111	118
		Tipper Truck	15.0	1	97		
		Plate compactor	5.0	1	108		
		Jackhammer[1]	5.0	1	108		
		Piling Rig (Bored)	7.5	1	108		
		Vibratory Roller (Light)[1]	15.0	1	105		
	Drainage Works - Modification to existing water quality basins and associated concrete and drainage work	Welding Equipment	15.0	1	97	105	109
		Concrete Pump	7.5	1	106		
		Crane Truck	15.0	1	100		
	Ripping and re-compacting of subgrade	Dozer	15.0	1	110	111	118
		Excavator (20 tonne)	15.0	1	99		
		Plate compactor	5.0	1	108		
		Tipper Truck	15.0	1	97		
	Construction of pavement, kerbing and barriers	Concrete Truck / Agitator	7.5	1	106	118	124
		Smooth Drum Roller[1]	15.0	1	109		
		Water Tanker (8000 litre)	15.0	1	98		
		Excavator (Breaker)[1]	3.0	1	121		
		Concrete Saw[1]	5.0	1	115		
		Truck (10 tonne)	15.0	1	98		
		Vibratory Roller (10 - 12 tonne)[1]	15.0		109		
		Excavator (20 tonne)	15.0		99		
		Paving Machine	15.0		104		
		Slip Form Machine	15.0		102		
	Milling and re-sheeting of pavement surfaces	Asphalt Milling Machine[1]	15.0	1	111	114	119
		Truck (10 tonne)	15.0	1	98		
		Vibratory Roller (10 - 12 tonne)[1]	15.0	1	109		
		Compactor	15.0		108		

Scenario Name	Activity (ie Equipment Split)	Equipment (realistic worst-case)	Operating minutes in 15-min period	No of items in same location	Sound Power Level (dBA) Maximum LAeq Item	Sound Power Level (dBA) Maximum LAeq Activity	Sound Power Level (dBA) LAmax Activity
	Asphalt paving, saw cutting	Truck (10 tonne)	15.0	1	98	116	123
		Compactor	15.0	1	108		
		Concrete Saw[1]	5.0	1	115		
		Concrete Truck / Agitator	7.5	1	106		
		Concrete Pump	7.5	1	106		
		Smooth Drum Roller[1]	15.0	1	109		
		Vibratory Roller (10 - 12 tonne)[1]	15.0	1	109		
		Paving Machine	15.0	1	104		
		Crane (small)	15.0	1	98		
	Line Marking	Generator	7.5	1	101	102	106
		Line Marking Plant	15.0	1	98		
		Hand Tools	15.0	1	94		
	Operational Management Control System and Finishing works - Installation of signs, safety barriers and lighting	Mobile Crane (50 tonne)	15.0	1	100	111	118
		Concrete Pump	7.5	1	106		
		Concrete Truck / Agitator	7.5	1	106		
		Dumper (5 tonne)	15.0	1	95		
		Generator	7.5	1	101		
		Excavator (20 tonne)	15.0	1	99		
		Piling Rig (Bored)	7.5	1	108		
		Plate compactor	5.0	1	108		
	Finishing works - Landscaping and vegetation works	Truck (10 tonne)	15.0	1	98	105	110
		bobcat	15.0	1	104		
		Hand Tools	15.0	1	94		
	Slope Stability and Retaining Wall Works	Dozer	15.0	1	110	112	118
		Back Hoe (7.5 tonne JCB)	15.0	1	102		
		Grout Mixer & Pump	15.0	1	97		
		Excavator (Diamond Rock Saw)[1]	7.5	1	106		
		Elevated Working Platform	15.0	1	97		

Scenario Name	Activity (ie Equipment Split)	Equipment (realistic worst-case)	Operating minutes in 15-min period	No of items in same location	Sound Power Level (dBA)		
					Maximum LAeq		LAmax
					Item	Activity	Activity
Site Compounds	Enabling works - Establishment of construction site compounds including offices and storage areas	Truck (HIAB)	15.0	1	98	106	109
		Crane Truck	15.0	1	100		
		Generator	7.5	1	101		
		Hand Tools	15.0	1	94		
		Vehicle (Light coommercial e.g. 4WD)	15.0	1	101		
	Deliveries of demountable office faciliites	Semi Trailer	5.0	1	106	105	112
		Mobile Crane (100 tonne)	15.0	1	101		
		Hand Tools	15.0	1	94		
	Installation of temporary boundary fencing	Truck (10 tonne)	15.0	1	98	99	103
		Hand Tools	15.0	1	94		
	Stockpiling and materials storage areas within the sites, and the movement of construction plant and equipment	Semi Trailer	5.0	1	106	110	113
		Franna Crane	15.0	1	99		
		Grader	15.0	1	108		
		Concrete Truck / Agitator	7.5	1	106		
		Excavator (12 tonne)	15.0	1	94		
Structures - Bridge & Viaduct Construction	Excavation of soil	Excavator (12 tonne)	15.0	1	94	99	107
		Tipper Truck	15.0	1	97		
	Unloading/Forming Steel Reinforcements	Mobile Crane (100 tonne)	15.0	1	101	102	107
		Hand Tools	15.0	1	94		
	Piling (Vibratory)	Piling Rig (Vibratory)[1]	7.5	1	116	113	121
	Piling (Bored)	Piling Rig (Bored)	7.5	1	108	105	118
	Abutments	Mobile Crane (100 tonne)	15.0	1	101	107	112
		Concrete Truck / Agitator	7.5	1	106		
		Concrete Pump	7.5	1	106		
		Hand Tools	15.0	1	94		
	Erection of bridge truss, Erection/dismantling of scaffolding & Erection of bridge decking	Mobile Crane (300 tonne)	15.0	1	104	104	110
Noise Wall Removal	Demolition of old noise walls	Elevated Working Platform	15.0	1	97	116	120
		Crane Truck	15.0	1	100		
		Excavator (Breaker - Small)[1]	7.5	1	117		
		Dozer	15.0	1	110		
		Hand Tools	15.0	1	94		

Note 1: In accordance with the EPA ICNG for activities identified as particularly annoying (such as jackhammering, rock breaking and power saw operation), a 5 dB 'penalty' is added to the source sound power level when predicting noise using the quantitative method.

Consistent with the requirements of the ICNG, and to inform the scheduling of construction activity and management of noise during the detailed design phase, the construction noise impacts are based on a worst-case assessment. The ICNG recommends that the realistic worst-case or conservative noise levels from the source should be predicted for assessment locations representing the most noise-exposed residences or other sensitive land uses. For each receiver area the noise levels are predicted at the most noise-exposed location, which would usually be the closest receiver.

For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst-case assessment.

Furthermore, other receivers within each receiver area would generally experience lower noise levels compared to the most noise-exposed location as construction work is undertaken at greater separation distance from receivers. To provide an indication of the likely reduction in construction noise levels, the following can be assumed:

- A doubling of the distance between the source and receiver would provide an approximate 6 dB reduction in noise level. For example the sound pressure levels from most items of plant would decrease by around 6 dB as the distance increases from 15 metres to 30 metres.
- Buildings and other solid structures located between the construction noise source and sensitive receivers would act as barriers and would typically reduce noise levels by up to 15 dB. For example, in a residential area adjoining a construction site the first row of houses would provide an effective shield to the second and subsequent rows with resulting noise levels up to 10 dB lower than would otherwise be experienced in the absence of the first row.

12.5 Noise Assessment at the Nearest Noise Sensitive Receivers

12.5.1 Predicted Construction Noise Levels

In each of the NCAs, the noise impacts have been quantitatively assessed for several construction activity groups and scenarios. The scenarios considered are described in **Table 26**.

The noise sensitive receivers in each area are identified in **Section 4.2**.

Table 26 Summary of Airborne Construction Noise Scenarios Assessed

Construction Activity	Locations	Scenarios	Scenario Sound Power Level (dB)	Approximate duration of works at any locality[1]
Main Corridor / Ramp Works	General carriageway and ramp footprint (concept design)	Clearing, Grubbing and Earthworks	117	2-4 weeks
		Drainage Works - Excavation of trenches and pits, delivery and placement of precast pipes and pits, filling and compacting	111	2-4 weeks
		Drainage Works - Modification to existing water quality basins and associated concrete and drainage work	105	2-4 weeks
		Ripping and re-compacting of subgrade	111	2-4 weeks
		Construction of pavement, kerbing and barriers	118	2-4 weeks
		Milling and re-sheeting of pavement surfaces	114	2-4 weeks
		Asphalt paving, saw cutting	116	2-4 weeks
		Line Marking	102	1-2 weeks
		Operational Management Control System and Finishing works - Installation of signs, safety barriers and lighting	111	2 weeks
		Finishing works - Landscaping and vegetation works	105	2-4 weeks
		Slope Stability and Retaining Wall Works	112	2-4 weeks
Site Compounds	General footprint of compound	Enabling works - Establishment of construction site compounds including offices and storage areas	106	Intermittent activity, up to 2 years at some locations
		Deliveries of demountable office facilities	105	
		Installation of temporary boundary fencing	99	
		Stockpiling and materials storage areas within the sites, and the movement of construction plant and equipment	110	

Construction Activity	Locations	Scenarios	Scenario Sound Power Level (dB)	Approximate duration of works at any locality[1]
Structures - Bridge Construction	Penshurst Road, Cooloongatta Road	Excavation of soil	99	2-4 weeks
		Unloading/Forming Steel Reinforcements	102	2-4 weeks
		Piling (Vibratory)	113	2-4 weeks
		Piling (Bored)	105	2-4 weeks
		Abutments	107	2-3 weeks
		Erection of bridge truss, Erection/dismantling of scaffolding & Erection of bridge decking	104	2-4 weeks
Noise Barrier Removal	Adjacent to Windarra Street, Penshurst Road and Cooloongatta Road/Elouera Street	Demolition of old noise barriers	116	1-2 weeks

Note 1: Limited information is available on the approximate durations of the activities at this phase of the proposal, and hence, the key activities determined have only had high level assumptions made with respect to proposed duration, based on previous similar activity type.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at the worst-affected floor level) are provided in **Appendix K** for each of the construction activity groups and are representative of the 'noisiest' construction periods allowing for the simultaneous operation of noise intensive construction plant in proximity to adjacent receivers. In **Appendix K**, the quantitative assessment results are presented as a range with the lower end of the range corresponding to the least noise-intensive scenario in each activity group and the upper end of the range corresponding to the most noise-intensive scenario.

The results of the quantitative noise impact assessment for construction of the proposal are summarised across all activity groups and scenarios by precinct in **Table 27**. The range of predicted NML exceedances represents the range of exceedances for different construction scenarios, with some scenarios being considerably more noise intensive than others. For assessment purposes, it has been assumed that all construction activities and scenarios may occur during any time period – daytime, evening or night-time.

Table 27 Summary of Airborne Construction NML Exceedances

NCA	RBL			NML				Noise Level – LAeq(15minute) (dBA) (least noise intensive scenario – most noise intensive scenario)				
								Worst-case Predicted at Nearby Receivers	NML Exceedance			
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night
Main Corridor / Ramp Works												
NCA01.RES	52	51	39	62	57	56	44	63-79	1 - 17	6 - 22	7 - 23	19 - 35
NCA02.RES	52	51	39	62	57	56	44	66-82	4 - 20	9 - 25	10 - 26	22 - 38
NCA03.RES	53	52	44	63	58	57	49	61-77	up to 14	3 - 19	4 - 20	12 - 28
NCA04.RES	53	52	44	63	58	57	49	49-65	up to 2	up to 7	up to 8	up to 16
NCA05.RES	47	46	40	57	52	51	45	49-65	up to 8	up to 13	up to 14	4 - 20
NCA06.RES	51	50	44	61	56	55	49	50-66	up to 5	up to 10	up to 11	1 - 17
NCA07.RES	50	49	40	60	55	54	45	66-82	6 - 22	11 - 27	12 - 28	21 - 37
NCA08.RES	49	49	42	59	54	54	47	44-60	up to 1	up to 6	up to 6	up to 13
West of Project Area	52	51	39	62	57	56	44	40-56	-	-	-	up to 12
East of Project Area	49	49	42	59	54	54	47	40-56	-	up to 2	up to 2	up to 9
Site Compounds												
NCA01.RES	52	51	39	62	57	56	44	42-53	-	-	-	up to 9
NCA02.RES	52	51	39	62	57	56	44	87-98	25 - 36	30 - 41	31 - 42	43 - 54
NCA03.RES	53	52	44	63	58	57	49	61-72	up to 9	3 - 14	4 - 15	12 - 23
NCA04.RES	53	52	44	63	58	57	49	61-72	up to 9	3 - 14	4 - 15	12 - 23
NCA05.RES	47	46	40	57	52	51	45	67-78	10 - 21	15 - 26	16 - 27	22 - 33
NCA06.RES	51	50	44	61	56	55	49	83-94	22 - 33	27 - 38	28 - 39	34 - 45
NCA07.RES	50	49	40	60	55	54	45	80-91	20 - 31	25 - 36	26 - 37	35 - 46
NCA08.RES	49	49	42	59	54	54	47	79-90	20 - 31	25 - 36	25 - 36	32 - 43
West of Project Area	52	51	39	62	57	56	44	up to 40	-	-	-	-
East of Project Area	49	49	42	59	54	54	47	34-45	-	-	-	-
Structures – Bridge Construction												
NCA01.RES	52	51	39	62	57	56	44	62-76	up to 14	5 - 19	6 - 20	18 - 32
NCA02.RES	52	51	39	62	57	56	44	63-77	1 - 15	6 - 20	7 - 21	19 - 33
NCA03.RES	53	52	44	63	58	57	49	35-49	-	-	-	-
NCA04.RES	53	52	44	63	58	57	49	38-52	-	-	-	up to 3
NCA05.RES	47	46	40	57	52	51	45	63-77	6 - 20	11 - 25	12 - 26	18 - 32
NCA06.RES	51	50	44	61	56	55	49	59-73	up to 12	3 - 17	4 - 18	10 - 24
NCA07.RES	50	49	40	60	55	54	45	68-82	8 - 22	13 - 27	14 - 28	23 - 37
NCA08.RES	49	49	42	59	54	54	47	53-67	up to 8	up to 13	up to 13	6 - 20
West of Project Area	52	51	39	62	57	56	44	up to 42	-	-	-	-
East of Project Area	49	49	42	59	54	54	47	34-48	-	-	-	up to 1

NCA	RBL			NML				Noise Level – LAeq(15minute) (dBA) (least noise intensive scenario – most noise intensive scenario)				
								Worst-case Predicted at Nearby Receivers	NML Exceedance			
	Day	Eve	Night	Day	Day OOH	Eve	Night		Day	Day OOH	Eve	Night
Noise Wall Removal												
NCA01.RES	52	51	39	62	57	56	44	up to 78	up to 16	up to 21	up to 22	up to 34
NCA02.RES	52	51	39	62	57	56	44	up to 81	up to 19	up to 24	up to 25	up to 37
NCA03.RES	53	52	44	63	58	57	49	up to 53	-	-	-	up to 4
NCA04.RES	53	52	44	63	58	57	49	up to 55	-	-	-	up to 6
NCA05.RES	47	46	40	57	52	51	45	up to 79	up to 22	up to 27	up to 28	up to 34
NCA06.RES	51	50	44	61	56	55	49	up to 79	up to 18	up to 23	up to 24	up to 30
NCA07.RES	50	49	40	60	55	54	45	up to 90	up to 30	up to 35	up to 36	up to 45
NCA08.RES	49	49	42	59	54	54	47	up to 83	up to 24	up to 29	up to 29	up to 36
West of Project Area	52	51	39	62	57	56	44	up to 57	-	-	up to 1	up to 13
East of Project Area	49	49	42	59	54	54	47	up to 53	-	-	-	up to 6

12.5.2 Discussion of Predicted Construction Noise Impacts - Main Corridor / Ramp Works

Activities associated with Main Corridor / Ramp Works are anticipated to be undertaken throughout the project area as these activities consist of general road works which are not limited to a specific area. For works during standard daytime hours, minor worst-case NML exceedances of less than 10 dB are predicted at residential receivers in NCA04, NCA05, NCA06 and NCA08 where a combination of existing noise walls and offset distance to the works help to mitigate impacts. In NCA01, NCA02, NCA03 and NCA07, predicted worst-case noise impacts are significant with predicted NML exceedances during standard daytime hours of up to 22 dB. In these locations, elevated receiver positions and noise via demolished noise wall sections result in higher noise impacts. Noise mitigation measures, including construction of the design noise walls (for mitigating operational noise impacts) at an early stage in the construction are discussed in **Section 12.7**.

Out of hours works would be expected to result in higher noise impacts than works during standard daytime hours at all locations. Predicted construction noise levels at the most affected residential receivers in each NCA would typically be greater than 10 dB. The most affected receivers are predicted to be those in NCA01, NCA02 and NCA07. The predicted worst-case NML exceedances are greater than 20 dB during noise intensive periods where works are located immediately adjacent to these receivers.

Other sensitive receivers are predicted to be subject to moderate NML exceedances of up to 15 dB (refer to **Appendix L**).

The most noise intensive works are 'site clearing and pavement works' which may require use of a rockbreaker. With reference to **Table 26**, impacts from each of these activities are expected to last for about two weeks in total at any single receiver during the Main Corridor / Ramp works (works taking place along the length of the alignment).

12.5.3 Discussion of Predicted Construction Noise Impacts - Site Compounds

The quantitative noise predictions for construction compounds presented in **Appendix L** relate to the nearest construction compound to the most affected sensitive receiver in each NCA (refer to **Table 28**).

Table 28 Construction Compound Location by NCA

NCA	Compound(s)
NCA01	n/a (nearest compound - Penshurst Road)
NCA02	Penshurst Road
NCA03	n/a (nearest compound – King Georges Road north)
NCA03	n/a (nearest compound – King Georges Road south)
NCA05	King Georges Road north
NCA06	King Georges Road south
NCA07	Elouera Street compounds
NCA08	Kirrang Street

The information presented in **Table 27** indicates that noise impacts due to establishment and use of the site compounds results in the highest noise impacts in immediately adjacent NCAs. Noise impacts in NCA02 (adjacent to the Penshurst Road compound), NCA05 (adjacent to the King Georges Road north compound), NCA06 (adjacent to the King Georges Road south compound), NCA07 (adjacent to the Elouera Street compounds) and NCA08 (adjacent to the Kirrang Street compounds) are predicted to be significant with NML exceedances of over 25 dB during both standard daytime and out of hours work periods.

The most noise intensive works are 'stockpiling and materials storage areas within the sites, and the movement of construction plant and equipment' which may require use of semi-trailers, trucks and graders. This scenario is considered to be representative of both establishment and operation of the compounds (as a worst-case). A graphical summary of the worst-case predicted NML exceedances at all receiver types during these works is presented in **Appendix L1** for daytime impacts and **Appendix L2** for night-time impacts. At this stage in the project, all potential compounds are considered in the assessment in order to inform the detailed planning of works at a later design stage.

With reference to **Table 26**, impacts from each of these activities are expected to be intermittent but may last for up to two years during construction. As the compound works are at fixed locations, it is likely that mitigation measures such as temporary noise walls, in combination with judicious selection of works areas within the site compound would assist in reducing impacts. These are discussed further in **Section 12.7**.

12.5.4 Discussion of Predicted Construction Noise Impacts – Bridge Construction

The information presented in **Table 27** indicates that noise impacts due bridge construction works are effectively limited to the NCAs adjacent to the works. Significant noise impacts of over 10 dB are predicted in NCA01 and NCA02 (adjacent to the Penshurst bridge works) during standard daytime construction hours. Significant NML exceedances of over 10 dB are also predicted in NCA05, NCA06 and NCA07 (adjacent to the Cooloongatta bridge works) during standard daytime construction hours.

Worst-case out of hours NML exceedances are generally predicted to be over 20 dB during bridge construction works at the immediately adjacent receivers.

The most noise intensive works are 'piling (vibratory)'. With reference to **Table 26**, impacts from each of these activities are expected to be intermittent but may last for two to four weeks. It is noted that bored piling is predicted to be less noisy than vibratory piling and would result in reduced noise impacts for these works if practicable. Mitigation measures are discussed further in **Section 12.7**.

The most noise intensive works during the 'demolition of old noise walls' involve the use of a rockbreaker (small) and dozer. With reference to **Table 26**, impacts from each of these activities are expected to last for two to four weeks. It is noted that bored piling is predicted to be less noisy than vibratory piling and would result in reduced noise impacts for these works if practicable. Mitigation measures are discussed further in **Section 12.7**.

12.5.5 Discussion of Predicted Construction Noise Impacts – Noise Wall Removal

Due to the close vicinity of the noise wall removal works to the receivers, and by eliminating the screening benefit provided by the existing noise walls, high noise impacts are predicted during these works. These high noise impacts are limited to the NCAs immediately adjacent to the works. Worst-case NML exceedances are typically predicted to be over 15 dB during these works. The most noise impacted receivers in NCA07 are predicted to be subjected to NML exceedances of up to 30 dB during standard hours, and up to 45 dB for works during the night-time. This is due to these receivers being located very close to the existing noise wall to be removed.

The most noise intensive works during the 'demolition of old noise walls' involve the use of a rockbreaker (small) and dozer. With reference to **Table 26**, impacts from each of these activities are expected to last for one to two weeks at any one receiver. Mitigation measures are discussed further in **Section 12.7** and would likely consist of scheduling noise intensive works to less sensitive periods as far as reasonably practicable.

12.5.6 Predicted Construction Noise Levels – Qualitative Interpretation

The following sections discuss the predicted noise impacts in each NCA, with reference to a qualitative description of the impacts of each activity relative to the background noise in that area in the relevant time period. For assessment purposes, it has been assumed that all construction activities and scenarios may occur during any time period – daytime, evening or night-time.

This qualitative representation of the results of the assessment is provided to clarify interpretation of the quantitative results above and in **Appendix L**, and to facilitate understanding of the level of worst-case impact for each of the works. The qualitative descriptions are related to the quantitative predicted noise levels as follows:

- Below RBL — $L_{Aeq(15minute)}$ noise levels below the background.
- Noticeable — $L_{Aeq(15minute)}$ noise levels within 10 dB of the background.
- Clearly audible — $L_{Aeq(15minute)}$ noise levels 10 dB to 20 dB above the background.
- Moderately intrusive — $L_{Aeq(15minute)}$ noise levels 20 dB to 30 dB above the background.
- Highly intrusive — $L_{Aeq(15minute)}$ noise levels more than 30 dB above the background.

A qualitative assessment of the noise predictions, based on the worst-case noise impacts at the nearest residential receivers to each of the proposed works is shown in **Table 29**.

Table 29 Qualitative Construction Noise Assessment

Scenario	NCA	Type	Qualitative[1] Assessment of Worst-case Noise Levels		
			Day	Eve	Night
Main Corridor / Ramp Works	NCA01.OAC	Other (Aged Care)	<RBL	<RBL	Clearly Audible
	NCA01.RES	Residential	Moderately Intrusive	Moderately Intrusive	Highly Intrusive
	NCA02.RES	Residential	Moderately Intrusive	Highly Intrusive	Highly Intrusive
	NCA03.RES	Residential	Moderately Intrusive	Moderately Intrusive	Highly Intrusive
	NCA04.RES	Residential	Clearly Audible	Clearly Audible	Moderately Intrusive
	NCA05.RES	Residential	Clearly Audible	Clearly Audible	Moderately Intrusive
	NCA06.RES	Residential	Clearly Audible	Clearly Audible	Moderately Intrusive
	NCA07.OAC	Other (Aged Care)	<RBL	<RBL	Noticeable
	NCA07.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA08.RES	Residential	Clearly Audible	Clearly Audible	Clearly Audible
	East of Project Area	Residential	Noticeable	Noticeable	Clearly Audible
	West of Project Area	Residential	Noticeable	Noticeable	Clearly Audible
Site Compounds	NCA01.OAC	Other (Aged Care)	<RBL	<RBL	Noticeable
	NCA01.RES	Residential	Noticeable	Noticeable	Clearly Audible
	NCA02.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA03.RES	Residential	Clearly Audible	Clearly Audible	Moderately Intrusive
	NCA04.RES	Residential	Clearly Audible	Clearly Audible	Moderately Intrusive
	NCA05.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA06.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA07.OAC	Other (Aged Care)	<RBL	<RBL	<RBL
	NCA07.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA08.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	East of Project Area	Residential	<RBL	<RBL	Noticeable
	West of Project Area	Residential	<RBL	<RBL	Noticeable
Structures - Bridge Construction	NCA01.OAC	Other (Aged Care)	<RBL	<RBL	Noticeable
	NCA01.RES	Residential	Moderately Intrusive	Moderately Intrusive	Highly Intrusive
	NCA02.RES	Residential	Moderately Intrusive	Moderately Intrusive	Highly Intrusive
	NCA03.RES	Residential	<RBL	<RBL	Noticeable
	NCA04.RES	Residential	<RBL	<RBL	Noticeable
	NCA05.RES	Residential	Moderately Intrusive	Highly Intrusive	Highly Intrusive
	NCA06.RES	Residential	Moderately Intrusive	Moderately Intrusive	Moderately Intrusive
	NCA07.OAC	Other (Aged Care)	<RBL	<RBL	<RBL
	NCA07.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA08.RES	Residential	Clearly Audible	Clearly Audible	Moderately Intrusive
	East of Project Area	Residential	<RBL	<RBL	Noticeable
	West of Project Area	Residential	<RBL	<RBL	Noticeable

Scenario	NCA	Type	Qualitative[1] Assessment of Worst-case Noise Levels		
			Day	Eve	Night
Noise Barrier Removal	NCA01.OAC	Other (Aged Care)	Noticeable	Noticeable	Clearly Audible
	NCA01.RES	Residential	Moderately Intrusive	Moderately Intrusive	Highly Intrusive
	NCA02.RES	Residential	Moderately Intrusive	Moderately Intrusive	Highly Intrusive
	NCA03.RES	Residential	<RBL	Noticeable	Noticeable
	NCA04.RES	Residential	Noticeable	Noticeable	Clearly Audible
	NCA05.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA06.RES	Residential	Moderately Intrusive	Moderately Intrusive	Highly Intrusive
	NCA07.OAC	Other (Aged Care)	<RBL	<RBL	Noticeable
	NCA07.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	NCA08.RES	Residential	Highly Intrusive	Highly Intrusive	Highly Intrusive
	East of Project Area	Residential	Noticeable	Noticeable	Clearly Audible
	West of Project Area	Residential	Noticeable	Noticeable	Clearly Audible

Note 1: See **Appendix H** for quantitative assessment results

Note 2: Bridge works not proposed in these areas

12.5.7 Sleep Disturbance

Review of the predicted $L_{A1(1minute)}$ noise levels at the nearest noise sensitive receivers provided in **Appendix K** indicate that the sleep disturbance screening criterion is likely to be exceeded when night works are occurring adjacent to residential receivers for the majority of works scenarios. This level of noise is typical for construction works using noise intensive equipment in built up areas.

At this early stage in the approval process, the assessment has included predictions of maximum noise impacts for assessment of potential sleep disturbance; however, it is noted that the ICNG only requires the proposal to consider maximum noise levels where construction works are planned to extend over more than two consecutive nights.

It is anticipated that the finalised requirements for OOHWs would be determined at a later design stage.

12.6 Cumulative Noise Impacts

It is understood that the construction period relating to the M5 West Widening project may overlap with the KGRIU works. Works for both projects may therefore occur in close proximity within the works area to the west of King Georges Road (ie NCA01 to NCA 04).

The prediction of cumulative noise levels from more than one construction scenario operating close to another scenario within the project area is a complex matter given the number of sources and possible locations of a particular combination of construction works.

In practice, it is not always possible to specify the precise location of more than one works for the same 15-minute period and the assessment becomes overly conservative to calculate the cumulative impacts based on all nearby works operating on a worst-case basis at the same time.

Since the works are anticipated to be of a similar nature, the effect of concurrent construction works is likely only to increase the number of 15-minute periods during construction where the predicted worst-case noise impacts are apparent. In practice, the noise levels will vary due to the fact that plant and equipment will move about the worksites and will not all be operating concurrently at the worst-case scenario used in the assessment (ie there are times where equipment is not operating).

It is understood that the project SEARs require consideration of cumulative impacts where these are likely and, to satisfy this requirement, an approach is outlined below which is based on increasing the 'exceedance category' where two works with similar noise impacts are apparent.

In order to manage potential cumulative noise impacts, it is suggested that an exceedance category system be employed in steps of 5 dB as follows:

- NML Exceedance Category 1 : >0 to 5 dB exceedance of NML
- NML Exceedance Category 2 : >5 to 10 dB exceedance of NML
- NML Exceedance Category 3 : >10 to 15 dB exceedance of NML
- NML Exceedance Category 4 : >15 to 20 dB exceedance of NML
- NML Exceedance Category 5 : >20 to 25 dB exceedance of NML
- NML Exceedance Category 5 : >25 dB exceedance of NML

For the subject works and separation distances involved, the following approach can be used to estimate the likely effect of cumulative impacts and to identify scenarios where such impacts may be significant:

- Where the predicted exceedances of the NML <u>at the same receiver</u> for a number of proposed activities fall within different exceedance categories (eg one in 6-10 dB category and one in the 11-20 dB exceedance category) the works corresponding to the higher of the exceedance categories should be considered dominant (without further considering cumulative impacts).
- Where the predicted exceedances of the NML <u>at the same receiver</u> for a number of proposed activities fall within the same exceedance category, the cumulative impact would be likely to increase the predicted level by up to 3 dB for two activities and up to 6 dB for four activities.

12.7 Construction Noise Mitigation

The ICNG describes strategies for construction noise mitigation and control that are applicable to this proposal. The strategies are designed to minimise, to the fullest extent practicable, noise during construction.

12.7.1 Restriction of Construction Hours

Where reasonable and feasible, preference would be given to scheduling construction works within the standard construction hours of:

- Monday to Friday 7.00 am to 6.00 pm.
- Saturday 8.00 am to 1.00 pm.

The nature of the project means evening and night work would also be required. Construction works would be required outside of standard hours where:

- Temporary road closures and other measures are required by the Police and other regulatory authorities for the safe delivery of material/ equipment.
- Works have the potential to disrupt commuter services and road networks.
- Works are required to be completed to maintain health and safety, avoid loss of life or injury and to prevent environmental damage.

Working 24 hours would allow contractors to spread the workload from peak to non-peak periods where there are less traffic impacts. It would allow the works to be less constrained which would reduce the impacts to businesses and residents in that the overall duration of the works would be reduced.

Where works are proposed during the night-time period (10:00 pm to 7:00 am) site specific Construction Noise and Vibration Management Plans (CNVMPs) would be developed in the detailed design phase. The CNVMPs would provide a detailed assessment of potential noise levels and site specific measures to control potential noise impacts and minimise the potential for disturbance at affected receivers. It is understood that any OOHW would be subject to a separate approval on a case-by-case basis and would likely require approval under the King Georges Road Interchange Upgrade project's EPL. A range of feasible and reasonable construction noise mitigation measures is provided in **Section 12.7.3**.

12.7.2 Restriction of Construction Noise Levels

The ICNG acknowledges that due to the nature of construction activities it is inevitable there would be some noise from construction sites. The NMLs identified in this report have been applied to prescribe measures for the control of potential construction noise impacts at sensitive receivers. Where exceedances of the NMLs have been predicted during the daytime (standard construction hours), receivers are considered to be noise affected.

The proponent should apply all feasible and reasonable work practices to meet the NMLs and inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels, duration of noise generating construction works, and the contact details for the proposal.

Receivers are considered to be highly noise affected if noise levels from construction exceed 75 dBA L_{Aeq}. This relates to daytime works only. **Table 30** presents a worst-case summary of highly noise affected receivers.

Table 30 Summary of Highly Noise Affected Receivers

Scenario	NCA	Type	Number of worst-case highly noise affected residential receivers[1]
Main Corridor / Ramp Works	NCA01.OAC	Other (Aged Care)	0
	NCA01.RES	Residential	1
	NCA02.RES	Residential	3
	NCA03.RES	Residential	2
	NCA04.RES	Residential	0
	NCA05.RES	Residential	0
	NCA06.RES	Residential	0
	NCA07.OAC	Other (Aged Care)	0
	NCA07.RES	Residential	5
	NCA08.RES	Residential	0
	East of Project Area	Residential	0
	West of Project Area	Residential	0

Scenario	NCA	Type	Number of worst-case highly noise affected residential receivers[1]
Site Compounds	NCA01.OAC	Other (Aged Care)	0
	NCA01.RES	Residential	0
	NCA02.RES	Residential	9
	NCA03.RES	Residential	0
	NCA04.RES	Residential	0
	NCA05.RES	Residential	4
	NCA06.RES	Residential	6
	NCA07.OAC	Other (Aged Care)	0
	NCA07.RES	Residential	5
	NCA08.RES	Residential	7
	East of Project Area	Residential	0
	West of Project Area	Residential	0
Structures - Bridge Construction	NCA01.OAC	Other (Aged Care)	0
	NCA01.RES	Residential	1
	NCA02.RES	Residential	2
	NCA03.RES	Residential	0
	NCA04.RES	Residential	0
	NCA05.RES	Residential	1
	NCA06.RES	Residential	0
	NCA07.OAC	Other (Aged Care)	0
	NCA07.RES	Residential	2
	NCA08.RES	Residential	0
	East of Project Area	Residential	0
	West of Project Area	Residential	0
Noise Barrier Removal	NCA01.OAC	Other (Aged Care)	0
	NCA01.RES	Residential	1
	NCA02.RES	Residential	5
	NCA03.RES	Residential	0
	NCA04.RES	Residential	0
	NCA05.RES	Residential	2
	NCA06.RES	Residential	1
	NCA07.OAC	Other (Aged Care)	0
	NCA07.RES	Residential	9
	NCA08.RES	Residential	3
	East of Project Area	Residential	0
	West of Project Area	Residential	0

Note 1: Count is based on the total number of receiver buildings predicted to be subject to worst-case daytime construction noise levels above the highly noise affected level (75 dBA) at any time in the entire construction schedule. This is generally limited to periods when noise intensive activities are located immediately adjacent to residences. It is therefore expected that the number of noise affected receivers on a typical day to day basis would be considerably less than presented in this table.

The information presented in **Table 30** indicates that, due to the close vicinity of the works, worst case construction works may result in daytime noise levels above 75 dBA during noise intensive activities at immediately adjacent residences during the following scenarios:

- Main Corridor / Ramp Works within NCA01, NCA02, NCA03 and NCA07.
- Site Compounds within NCA02, NCA05, NCA06, NCA07 and NCA08.
- Structures - Bridge Construction within NCA01, NCA02, NCA05 and NCA07
- Noise Barrier removal within NCA01, NCA02, NCA05, NCA06, NCA07 and NCA08.

Consequently, site-specific CNVMPs should be developed in the detailed design phase when more information is available on the schedule for the works and the equipment to be used. The proponent and construction contractor(s) should schedule work to provide respite periods from the noisiest activities, and communicate with the impacted residents by clearly explaining the duration and noise level of the works. A potential approach would be to schedule a respite period of one hour for every three hours of continuous construction activity, or scheduling high noise generating works to less sensitive times of 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm.

Where OOHWs are required, these would be predicted to result in significant exceedances of the NMLs (refer to **Section 12.5.1**). The proponent should identify all feasible and reasonable work practices in the CNVMPs to reduce potential noise impacts. Where all feasible and reasonable practices have been applied and noise would be more than 5 dB above the noise affected level, the proponent should negotiate with the community to determine the schedule for the works or provide respite to occupants where sleep disturbance is likely to occur.

12.7.3 Construction Noise Mitigation Measures

Based on the assessment of construction noise impacts in this report a range of noise mitigation measures have been recommended to reduce and control potential construction noise impacts. The construction noise mitigation measures are recommended to, where feasible and reasonable, minimise potential for disturbance at receivers, preserve the acoustic amenity of the surrounding environment and aim to control noise levels within the construction NMLs.

The reasonableness of the identified feasible mitigation measures would be considered during the construction planning and site establishment phases of the proposal, and in the development of CNVMPs. In general, mitigation measures that should be considered are summarised as follows:

- For construction concentrated in a single area, such as at the compounds and bridge sites, temporary acoustic fencing/barriers around the site perimeter should be considered where feasible and reasonable to mitigate off-site noise levels. Noise barriers are effective for receivers at or near ground level and not effective for receivers overlooking the sites.
- Construct the noise barriers proposed to mitigate operational noise impacts of the project (refer to **Section 9**) at the earliest practicable stage in the construction period in order to provide noise screening to adjacent receivers during the subsequent construction activities.
- Given the potentially high noise levels at residential receivers, adherence to daytime construction hours is recommended for excavation, demolition or rock breaking activities, and for activities concentrated in a single area (ie activities that do not move along the alignment, and do not require out of hours activities for safety reasons or to minimise disruption to road networks).
- Night works should be programmed to minimise the number of consecutive nights work impacting the same receivers.
- When working adjacent to schools, particularly noisy activities should be scheduled outside normal school hours, where possible.
- Avoiding the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers would result in reduced noise emissions.

- Equipment which is used intermittently is to be shut down when not in use.
- Where possible, the offset distance between noisy plant items and nearby noise sensitive receivers should be as great as possible.
- Where possible, equipment with directional noise emissions should be oriented away from sensitive receivers.
- Regular compliance checks on the noise emissions of all plant and machinery used for the proposal would indicate whether noise emissions from plant items were higher than predicted. This also identifies defective silencing equipment on the items of plant.
- Ongoing noise monitoring during construction at sensitive receivers during critical periods to identify and assist in managing high risk noise events.
- Where possible heavy vehicle movements should be limited to daytime hours.
- Reversing of equipment should be minimised so as to prevent nuisance caused by reversing alarms.
- Loading and unloading should be carried out away from sensitive receivers, where practicable.

12.7.4 Mitigation Summary

A summary of the potential noise benefit from the project noise mitigation measures (refer to **Section 12.7.1**, **Section 12.7.2** and **Section 12.7.3** is presented in **Table 31**.

Table 31 Noise Mitigation Summary

Construction Noise Mitigation Measures	Potential Noise Reduction
Schedule construction works within the standard construction hours	No reduction during standard construction hours Eliminates Out of Hours noise impacts
Schedule a respite period (eg one hour for every three hours of continuous construction activity)	n/a
Schedule high noise generating works to less sensitive times of 9:00 am to 12:00 pm or 2:00 pm to 5:00 pm	n/a
Temporary acoustic fencing/barriers	Typically around 5 to 10 dB
Portable temporary enclosures	Up to around 15 dB
Construct operational noise walls	5-10 dB
Install operational property treatments	n/a
Minimise the number of consecutive nights work impacting the same receivers	n/a
Noisy activities should be scheduled outside normal school hours, where possible	n/a
Avoid the coincidence of noisy plant working simultaneously close together	Up to 3dB for halving the number of similar dominant plant items working together
Shut down equipment when not in use	Negligible reduction in comparison to worst-case predictions, however eliminates noise source during less noise intensive works
Maximise offset distance between noisy plant items and nearby noise sensitive receivers	Approximately 6dB reduction per doubling of offset distance
Regular compliance checks on the noise emissions	n/a
Ongoing noise monitoring during construction	n/a
Where possible heavy vehicle movements should be limited to daytime hours	n/a
Non-tonal reversing alarms	n/a

Construction Noise Mitigation Measures	Potential Noise Reduction
Loading and unloading should be carried out away from sensitive receivers	Approximately 6dB reduction per doubling of offset distance

12.7.5 Construction Environmental Management Plan

A Construction Environmental Management Plan (CEMP) would be prepared during the detailed design phase and implemented through all construction activities. A CNVMP would be included in the CEMP to provide the framework and mechanisms for the management and mitigation of all potential noise and vibration impacts from the construction works. The CNVMP would include restrictions on the hours of construction for specific sites and the construction noise levels at sensitive receivers.

This would address each major stage of the construction works and identify the appropriate mitigation and management measures, consistent with the requirements of the ICNG

The objectives of the CNVMP are as follows:

- Assist in ensuring that the noise emissions during the construction works comply with the noise management levels and goals nominated in **Section 12.3**.
- Determine noise and vibration monitoring, reporting and response procedures.
- Describe specific mitigation treatments, management methods and procedures to be implemented to control noise and vibration during construction.
- Describe construction timetabling to minimise noise impacts including time and duration restrictions, respite periods and frequency.
- Describe procedures for notifying residents of construction activities likely to affect their amenity through noise and vibration.
- Define contingency plans to be implemented in the event of non-compliances and/or noise complaints.

13 ASSESSMENT OF CONSTRUCTION NOISE - PUBLIC ROAD NETWORK

This section provides an assessment of the construction related traffic on the public road network. When trucks and other vehicles are operating within the boundaries of the various construction sites, noise levels are assessed as outlined in **Section 12**. When construction related traffic moves onto the public road network, vehicle movements would be regarded as ‘additional road traffic’ rather than as part of the construction site.

13.1 Construction road traffic noise goals

The ICNG does not provide specific guidance in relation to acceptable noise levels associated with construction traffic. For assessment purposes, guidance is taken from the RNP.

One of the objectives of the RNP is to apply relevant permissible noise increase criteria to protect sensitive receivers against excessive decreases in amenity as the result of a proposal. In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.

On this basis, construction traffic NMLs set at 2 dB above the existing road traffic noise levels during the daytime and night-time periods are considered appropriate to identify the onset of potential noise impacts. Where the road traffic noise levels are predicted to increase by more than 2 dB as a result of construction traffic, consideration would be given to applying feasible and reasonable noise mitigation measures to reduce the potential noise impacts and preserve acoustic amenity.

In considering feasible and reasonable mitigation measures where the relevant noise increase is greater than 2 dB, consideration would also be given to the actual noise levels associated with construction traffic and whether or not these levels comply with the following road traffic noise criteria in the RNP:

- 60 dBA $L_{Aeq(15hour)}$ day and 55 dBA $L_{Aeq(9hour)}$ night for existing freeway/ arterial/ sub-arterial roads.
- 55 dBA $L_{Aeq(1hour)}$ day and 50 dBA $L_{Aeq(1hour)}$ night for existing local roads.

Sleep Disturbance and Maximum Noise Events

In addition to the current legislative guidance on potential sleep disturbance outlined in **Section 12.3**, the RNP refers to Practice Note 3 of the ENMM for specific impacts from road traffic. The ENMM recommends an evaluation of the number and distribution of night-time passby events where the L_{AFmax} - $L_{Aeq(1hour)}$ difference is greater than 15 dB, and the maximum noise level of that event is greater than 65 dBA.

On the basis of the current guidance, an external sleep disturbance screening criterion of RBL + 15 dB and sleep disturbance NML of L_{Amax} 55 dBA (internal) have been adopted – the latter equates to an external NML of 65 dBA (assuming open windows).

13.2 Construction Traffic Noise Assessment

It is understood that the additional heavy construction vehicle movements on public roads would be predominantly required during daytime hours, although some heavy vehicle movements at night would be required to support night-time construction works (when these are required for safety reasons or to minimise disruption to the road network).

As heavy vehicles currently use the sub-arterial roads, L_{Amax} levels at all adjacent receivers would be comparable with existing heavy vehicles using the sub-arterial roads.

Heavy vehicle movements may be required on a number of local roads with likely significantly lower existing traffic flows than the main arterial roads. Noise impacts are considered likely where construction heavy vehicles are required to access compounds via local roads. It is recommended that the detailed design seeks to minimise the number of truck movements adjacent to sensitive receivers on public local roads by favouring access via existing arterial/sub-arterial roads or existing commercial/industrial areas where practicable. It is anticipated that this process would occur during preparation of the CNVMP.

It is noted that when streets are closed to general traffic during construction (with access retained for emergency vehicles and local access), noise from heavy vehicles would fall within the assessment of general construction noise as described in **Section 12**.

Additional assessment for night-time truck movements on public roads when required would be undertaken at the detailed design stage when the finalised traffic plan is determined.

Consideration should be given to the potential noise impact due to trucks idling near construction sites, and for this reason, it is recommended that any of the planned truck queues be located away from residences.

14 CONSTRUCTION GROUND-BORNE NOISE ASSESSMENT

Ground-borne noise results from the transmission of vibration rather than the direct transmission of noise through the air. Ground-borne (or regenerated) construction noise is usually present on tunnelling projects when vibration from activities such as rockbreaking, road heading, rotary cutting, tunnel boring and rock drilling/sawing can be transmitted through the ground and into the habitable areas of nearby buildings. Ground-borne noise occurs when this vibration in the ground and/or building elements is regenerated as audible noise within areas of occupancy inside the building.

The ICNG defines internal ground-borne noise goals for residential receivers of 40 dBA $L_{Aeq(15minute)}$ during the evening (6:00 pm to 10:00 pm) and 35 dBA $L_{Aeq(15minute)}$ during the night-time (10:00 pm to 7:00 am). The goals are only applicable when ground-borne noise levels are higher than airborne noise levels

The nature of the works (surface works with minimal screening effects) means that ground-borne noise impacts are expected to be negligible. This is because the airborne noise emissions in most circumstances are much higher than the ground-borne noise levels. For this reason ground borne noise is not anticipated to be the controlling factor for these proposed works and therefore further assessment is not warranted.

15 CONSTRUCTION VIBRATION ASSESSMENT

15.1 Vibration Damage Criteria Overview

Most commonly specified "safe" structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

In terms of the most recent relevant vibration damage criteria, British Standard 7385:Part 2-1993 *Evaluation and Measurement for Vibration in Buildings Part 2*[vii] is an internationally accepted standard against which the likelihood of building damage from ground vibration can be assessed. This is the Standard recommended in Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives*[viii] as the vibration guideline values and assessment methods "are applicable to Australian conditions".

Another reference, German Standard DIN 4150:Part 3-1999[ix] also provides guidelines for evaluating the effects of vibration on structures. For vibration frequencies of less than 10 Hz, the DIN Standard gives a "safe limit" of peak vibration for dwellings of 5 mm/s and for historic buildings (with preservation orders or the like) of 3 mm/s. As opposed to the "minimal risk of cosmetic damage" approach adopted in BS 7385, the "safe limits" given in DIN 4150 are the vibration levels up to which no damage due to vibration effects has been observed. Hence the guideline limits in DIN 4150 are somewhat lower than those in BS 7385.

Although there is a lack of reliable data on the threshold of vibration-induced damage in buildings both in countries where national standards already exist and in the UK, BS7385:Part 2 has been developed from an extensive review of UK data, relevant national and international documents and other published data. The standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95 per cent probability of no effect.

Sources of vibration which are considered in the standard include blasting (carried out during mineral extraction or construction excavation), demolition, piling, ground treatments (e.g. compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

15.2 Vibration Damage Goals

Australian standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* recommends the frequency dependent vibration guideline values and assessment methods given in British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2* as they 'are applicable to Australian conditions'.

The Standard sets guide values for vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk is usually taken as a 95 per cent probability of no effect.

The recommended guideline limits for transient vibration to minimise risk of cosmetic damage to residential and industrial buildings are presented in **Table 32** and graphically in **Figure 9**.

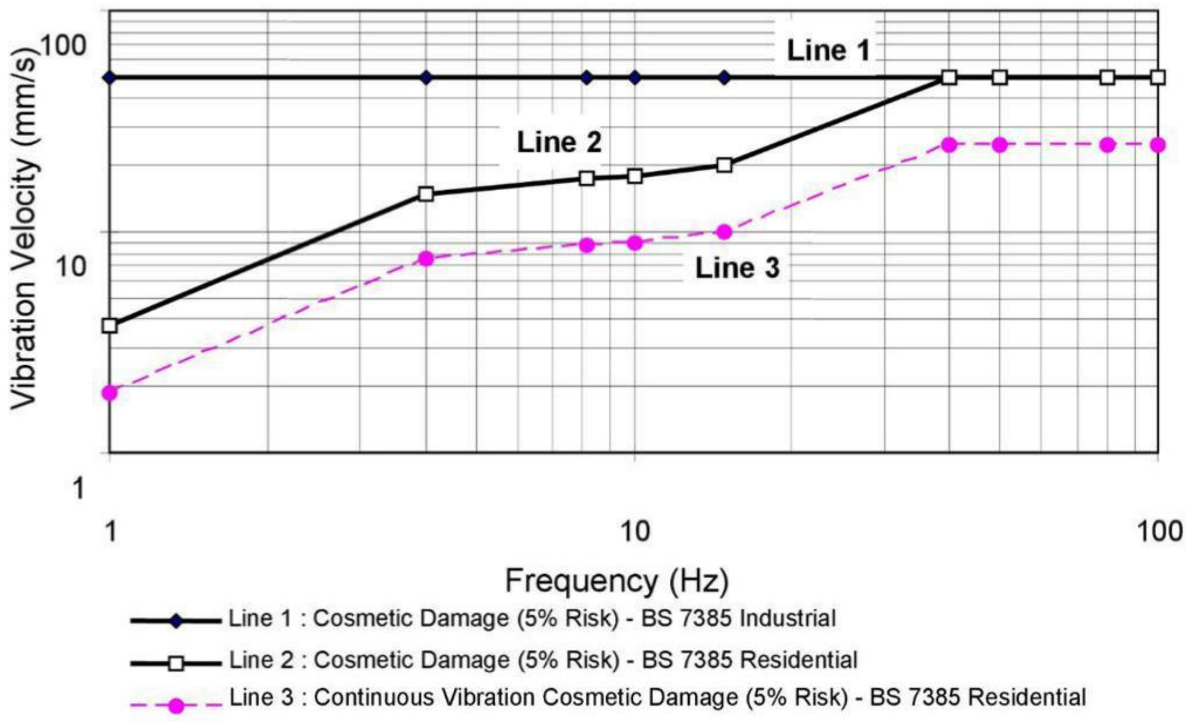
Table 32 Transient Vibration Guide Values – Minimal Risk of Cosmetic Damage

Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	**15 Hz and Above**
1	Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures. Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The guide values in **Table 32** relate predominately to transient vibration which does not give rise to resonant responses in structures and low-rise buildings. In the event continuous vibration gives rise to magnification of vibration by resonance (specific conditions where the structure can readily store and transfer vibration energy), then the guide values in **Table 32** may need to be reduced by up to 50 per cent (**Figure 9**).

Rockbreaking, rock hammering and sheet piling are considered to have the potential to cause dynamic loading in some structures and it may therefore be appropriate to reduce the transient values by 50 per cent for these construction activities.

Figure 9 Transient Vibration Guide Values for Cosmetic Damage



For most sources of intermittent vibration during construction, such as rockbreakers, piling rigs, vibratory rollers and excavators, the predominant vibration energy occurs at frequencies usually in the 10 Hz to 100 Hz range. On this basis a vibration damage screening level of 7.5 mm/s has been adopted for the purpose of assessing potential impacts.

In the lower frequency region below 4 Hz the guide values for building types are reduced as a high displacement is associated with relatively low peak component particle velocity. To minimise risk of structural damage a guide value of 3.7 mm/s has been adopted.

It is noteworthy that further to the guide values the Standard advises that:

> *A building of historical value should not (unless it's structurally unsound) be assumed to be more sensitive.*

For this reason, vibration impacts on heritage listed buildings have not been specifically considered.

15.3 Human Comfort Goals for Construction Vibration

For most construction activities that generate perceptible vibration in nearby buildings, the character of the vibration emissions is intermittent. The *Assessing Vibration: A Technical Guideline* nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers as shown in **Table 33**. The guideline advises a low probability of adverse comment or disturbance to building occupants would be expected at or below the preferred values.

The applicable human comfort vibration goal for intermittent vibration source is defined in terms of Vibration Dose Values (VDVs) where the permissible vibration level corresponding to the VDV varies according to the duration of exposure.

Table 33 Preferred and Maximum Vibration Dose Values for Intermittent Vibration

Building Type	Preferred Vibration Dose Value ($m/s^{1.75}$)	Maximum Vibration Dose Value ($m/s^{1.75}$)
Critical Working Areas (e.g. hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: Daytime is 7:00 am to 10:00 pm and night-time is 10:00 pm to 7:00 am

In applying the preferred and maximum VDV the guidelines states that:

> *Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project.*

The guideline also advises that:

> *Where all feasible and reasonable measures have been applied to control potential ground vibration levels the maximum values may be used. For values above the maximum value the proponent should negotiate directly with the affected community.*

15.4 Safe Working Distances for Vibration Intensive Plant

The propagation of vibration emitted from a source would be site specific with the level of vibration potentially experienced at a receiver dependent upon the vibration energy generated by the source, the predominant frequencies of vibration, the localised geotechnical conditions and the interaction of structures and features which can dampen vibration.

The recommended safe working distances for construction plant in **Table 34** are referenced from the *Construction Noise Strategy (*Transport for NSW, 2012)[x].

Consistent with the British Standard and the Assessing Vibration guideline, the recommendations are for the practical management of potential vibration to minimise the likelihood of cosmetic damage to buildings and disturbance or annoyance in humans. The human comfort safe working distances are conservative, developed with reference to the more stringent objectives for continuous vibration for typical residential building constructions.

Table 34 Recommended Safe Working Distances for Vibration Intensive Plant

Plant Item	Rating/ Description	Safe Working Distance	
		Cosmetic Damage[1]	Human Response[2]
Vibratory Roller	< 50 kN (Typically 1-2 tonnes	5 m	15 m to 20 m
	< 50 kN (Typically 2-4 tonnes	6 m	20 m
	< 50 kN (Typically 4-6 tonnes	12 m	40 m
	< 50 kN (Typically 7-13 tonnes	15 m	100 m
	< 50 kN (Typically 13-18 tonnes	20 m	100 m
	< 50 kN (Typically > 18 tonnes	25 m	100 m
Small Hydraulic Hammer	300 kg – 18 to 34t excavator	2 m	7 m
Medium Hydraulic Hammer	1600 kg – 5 to 12t excavator	7 m	23 m
Large Hydraulic Hammer	1600 kg – 12 to 18t 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

Note 1: Referenced from British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2*
Note 2: Referenced from EPA's *Assessing Vibration: a technical guideline (*DEC, 2006)

15.5 Construction Vibration Assessment

15.5.1 Estimated Working Distances and Vibration Intensive Plant

The proposed works have been analysed to determine best estimates of the minimum distances receivers and the equipment to be used that is most likely to be vibration intensive, as shown in **Table 35**. This allows for a comparison to the safe working distances listed in **Table 34** when determining the likely vibration impacts of the construction scenarios.

Table 35 Construction Vibration Assessment

Work Scenario	Vibration Intensive Equipment	NCA	Indicative distance to nearest NCA receiver (m)	Within safe working distance (any plant item)?	
				Cosmetic Damage	Human Response
Main Corridors / Ramp Work	Vibratory Roller (10-12 tonne) Piling Rig (Bored) Vibratory Roller (Light) Excavator (Breaker) Plate Compactor	01	37	No	Yes
		02	36	No	Yes
		03	30	No	Yes
		04	33	No	Yes
		05	33	No	Yes
		06	35	No	Yes
		07	22	No	Yes
		08	44	No	Yes
Site Compounds	n/a[1]	n/a[1]	n/a[1]	n/a[1]	n/a[1]
Structures – Bridge Construction	Piling Rig (Vibratory) Piling Rig (Bored)	01	30	No	No
		02	33	No	No
		03	245	No	No
		04	255	No	No
		05	33	No	No
		06	46	No	No
		07	17	Yes	Yes
		08	48	No	No
Noise Barrier Removal	Excavator (Breaker - Small)	01	35	No	No
		02	30	No	No
		03	163	No	No
		04	173	No	No
		05	30	No	No
		06	38	No	No
		07	10	No	No
		08	20	No	No

Note 1: No significantly vibration intensive equipment proposed.

15.5.2 Cosmetic Damage Assessment

The separation distance(s) between the proposed works and the nearest receivers would generally be sufficient so that nearby buildings are unlikely to suffer 'Cosmetic Damage' for most of the proposed construction equipment. However, based on the general work zones, some items of construction equipment have the potential to be operated within the recommended safe working distances. Receivers in NCA07 may be affected during bridge construction (piling works). The required locations for vibration intensive equipment should be reviewed during detailed design when more specific information is available.

Attended vibration monitoring or vibration trials should be undertaken when proposed works are within the safe working distances to ensure that levels remain below the criterion. Building condition surveys should also be completed both before and after the works at any potentially affected properties to identify existing damage and any proposal related damage.

15.5.3 Human Comfort Vibration Assessment

In relation to human comfort (response), the safe working distances in **Table 34** relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are permitted, as discussed in BS 6472-1.

Vibration at the nearest receivers is likely to be perceptible at times during the works.

Based on the general work zones, some items of proposed construction equipment have the potential to be operated within the recommended safe working distances. If a vibratory roller (10-12 tonne) is used, receivers have been identified within the recommended 100 metre zone within all adjacent NCAs as shown in **Table 35**. There is therefore potential for ground vibration levels to exceed the human comfort criteria depending on the duration and nature of the construction activity. The required locations for vibration intensive equipment should be reviewed during detailed design when more specific information is available. Any exceedances would be expected to be of short duration.

15.6 Cumulative Vibration Impacts

It is understood that the construction period relating to the M5 West Widening project may overlap with the KGRIU works. Works for both projects may therefore occur in close proximity within the works area to the west of King Georges Road (ie NCA01 to NCA 04).

Due to the intermittent nature of construction works, vibration impacts due to multiple works scenarios are considered unlikely to result in concurrent vibration peaks, but rather, may increase the effective duration of the exposure to vibration. Vibration impacts due to multiple simultaneous works would therefore be managed in the same manner as for single works scenarios (dependant on the operating equipment).

15.7 Vibration Mitigation

Dependent upon the equipment to be used, where vibration intensive construction activities are proposed near sensitive receivers, these works should be confined to the less sensitive daytime period as far as reasonably practicable. The potential impacts from vibration are to be considered in the site-specific CNVMPs, to be developed during the detailed design phase when more information is available on the schedule for the works, the equipment to be used and the localised geotechnical conditions. In general, mitigation measures that should be considered are summarised as follows:

- Relocate vibration generating plant and equipment to areas within the site in order to lower the vibration impacts.
- Investigate the feasibility of rescheduling the hours of operation of major vibration generating plant and equipment.
- Use lower vibration generating items of excavation plant and equipment e.g. smaller capacity rockbreaker hammers.
- Minimise consecutive works in the same locality (if applicable).
- Use dampened rockbreakers and/or ‘city’ rockbreakers to minimise the impacts associated with rockbreaking works.
- If vibration intensive works are required within the safe working distances, vibration monitoring or attended vibration trials would be undertaken to ensure that levels remain below the cosmetic damage criterion.
- Building condition surveys would be completed both before and after the works to identify existing damage and any damage due to the works.

Measurements of existing ambient vibration levels would be undertaken at receivers with vibration sensitive equipment during the detailed design phase. This information would be used to inform the site-specific CNVMPS for works near these locations.

16 REFERENCES

[i] Road Noise Policy, NSW EPA, 2011
[ii] Environmental Noise Management Manual, Roads and Maritime, 2001
[iii] Interim Construction Noise Guideline, DECC, 2009
[iv] Assessing Vibration: a technical guideline, DEC, 2006
[v] AS IEC 61672.1—2004 - Electroacoustics—Sound level meters, Part 1: Specifications, Standards Australia, 2004
[vi] Calculation of Road Traffic Noise, UK Department of Transport, 1988
[vii] BS 7385 Part 2-1993 Evaluation and measurement for vibration in buildings Part 2, BSI, 1993
[viii] AS 2187: Part 2-2006 Explosives - Storage and Use - Part 2: Use of Explosives, Standards Australia, 2006
[ix] DIN 4150:Part 3-1999 Structural vibration - Effects of vibration on structures, Deutsches Institute fur Normung, 1999
[x] Construction Noise Strategy, TfNSW, 2012