The Northern Road upgrade: Glenmore Parkway, Glenmore Park to Jamison Road, South Penrith

Final Design

Roads and Maritime Services

Noise and vibration assessment

19 September 2016

The Northern Road - Stage 3N

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Contents

Executive Summary

Roads and Maritime Services (RMS) proposes to upgrade four kilometres of The Northern Road between Glenmore Parkway, Glenmore Park and Jamison Road, Penrith.

This report presents the assessment of the potential operational and construction noise and vibration impacts of the proposal on the 3,105 receivers included in the study area. The assessment has been undertaken in accordance with the RMS' Noise Criteria Guideline and Noise Mitigation Guideline.

In considering the potential for operational noise impacts from the proposal, the assessment concluded that:

- 265 receivers qualified for consideration of noise mitigation (approximately 9% of all receivers)
- No mitigation was found to be required for 2,840 receivers.

Many of the receivers identified as qualifying for mitigation directly front the existing The Northern Road and many of those are presently exposed to acute noise levels, ie, currently exposed to traffic noise greater more than 5 dB(A) above RMS noise criteria.

In general, operational noise levels to receivers not directly fronting the proposal, the M4 Motorway, Maxwell Street or Smith Street were predicted to comply with RMS noise criteria.

Where found to be required, mitigation of operational noise has been proposed in the form of noise barriers and/or at-property treatments. The use of low-noise pavement is not considered feasible for this proposal given the number of traffic lights and their potential causation of stop-start traffic as well as considerations relating to constructability, debris-management, maintenance, and traffic switch requirements.

The assessment proposes the following noise barriers:

- a 5.0 m high (460 m long) noise barrier along the western side of project between Aspen Street and Tukara Road, and
- a 5.0 m high (838 m long) noise barrier on the western side of the project extending south from of Tukara Road to the western end of the eastbound M4 Motorway Off Ramp.

The proposed noise barriers would result in 42 receivers no longer requiring at-property mitigation, with 223 receivers still requiring at-property mitigation.

The potential for noise impacts from construction of the proposal considered construction staging, duration and the plant to be used, as well as whether the works would be undertaken during standard hours (daytime) or out of hours (broadly, evenings and night times).

The assessment has found that, in general, noise from proposed daytime construction works will comply with Noise Management Levels (NMLs) at most receivers other than those situated immediately adjacent to the proposal. In general, any noise impacts predicted for these receivers will be contained to 0-10 dB(A) above the relevant NML.

The majority of receivers that directly front the proposal are predicted to experience exceedances of the NML at some time.

Of all construction stages, it is predicted that early demolition works incorporating concrete sawing and/or jackhammering will cause the greatest number of receivers to be impacted. More than 200 receivers are predicted to be "Highly Noise Affected" (i.e. exposed to noise levels greater than 75 dB(A)) at some time during the demolition works. This number of "Highly Noise Affected"

receivers will reduce by more than half for other works stages, and for most receivers in the wider community, reduce to zero for works other than demolition.

Predicted worst case construction noise levels from out of hours (generally, evening and night time) works will comply with NMLs for most receivers not directly fronting the proposal. However, exceedances of the NMLs are predicted at most receivers fronting the road corridor. Impacts for the potentially most affected of these receivers are predicted to exceed NMLs by more than 25 dB(A) in some instances, particularly in the northern half of the project where works are anticipated to approach to within 7-15 metres of some receivers.

Of the two proposed out-of-hours works scenarios, road paving works are predicted to generate the greater number of noise impacts. Measures to reduce or in some cases, eliminate these impacts are presented in this report. Activity-specific measures such as restricting truck movements and programming night time paving works such that they are undertaken only at locations away from residences will be further investigated at the detailed design stage.

Noise impacts predicted from bridge works may range above 25 dB(A) for worst affected receivers. Any exceedance of NMLs at receivers several hundred metres removed from the works will generally be contained to 5dBA above the NML.

As the application of standard noise mitigation measures will not completely eliminate all exceedances of the NMLs during either daytime or out of hours works, the proposal will consider the application of additional mitigation measures prescribed by the RMS' Construction Noise and Vibration Guideline at the detailed design stage.

The assessment has identified that noise from some of the proposal's night time construction activities may generate noise levels within residences in excess of the sleep disturbance screening criterion. This result does not indicate that sleep disturbance will be caused necessarily, but rather that sleep disturbance may be possible and therefore, that more detailed investigation is warranted. A detailed assessment of, and management plan for the potential for sleep disturbance impact would be assessed in the proposal's Construction Noise and Vibration Management Plan to be prepared at the detailed design stage.

The assessment concludes that all construction vibration criteria will be complied with where the operation of the project's (10-12 tonne) vibratory roller is operated not closer than 20 m from any dwelling or structure. Vibration criteria are unlikely to be exceeded by any jack hammering or pile boring undertaken given where these activities are not undertaken within 10 m from any dwelling or structure.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to assess potential noise impacts associated with the proposed upgrade of the Northern Road Stage 3N in accordance with the scope of services set out in the contract between Jacobs and Roads and Maritime Services for this project. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by Roads and Maritime Services and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from Roads and Maritime Services and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of Roads and Maritime Services, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and Roads and Maritime Services. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

1. Introduction

Roads and Maritime Services (Roads and Maritime) is proposing to upgrade The Northern Road between Glenmore Parkway, Glenmore Park and Jamison Road, South Penrith ('the proposal') situated 47 kilometers west of the Sydney Central Business District. The proposal will upgrade The Northern Road to an eight-lane divided road, with three general traffic lanes and a kerbside bus lane in each direction, separated by a raised concrete median. The Northern Road will be continued as a six lane carriageway north of Jamison Road.

The Northern Road is classified as a State road and forms part of Route A9 arterial road connecting Campbelltown and Windsor. The Northern Road also provides connections between the Western Sydney Priority Growth Area, the Western Sydney Employment Area, the M4 Motorway, and the site for the proposed western Sydney airport at Badgerys Creek.

This section of The Northern Road is currently a four lane road, largely divided by a narrow median. The 1.3 km section of The Northern Road between 200 metres south of Smith Street and 200 meters north of Frogmore Road is undivided. This section of The Northern Road includes five signalised and six unsignalised intersections as well as various uncontrolled property accesses. At some unsignalised intersections and property accesses, right turn movements can be made across a painted median.

Roads and Maritime is upgrading The Northern Road as part of the Australian and NSW Governments' Western Sydney Infrastructure Plan which will deliver $3.6 billion in road infrastructure improvements over the next 10 years. The proposal was announced in April 2014 by the Prime Minister as part of the Western Sydney Infrastructure Plan's program of works to support the proposed western Sydney airport at Badgerys Creek.

It is anticipated that construction of the proposal would commence in 2017 and would be open to traffic by mid-2020.

1.1 Purpose of this Report

This report assesses the potential for noise or vibration impacts upon residences and other sensitive receivers within the study area that may arise from the construction and operation of the Project. The report also outlines the measures that will be used to mitigate these impacts.

1.2 Location and context

The proposal is located in the Penrith local government area, within the Roads and Maritime Sydney region. The topography of the study area is mostly flat to undulating.

The study area is divided into distinct geographies. To the east of The Northern Road and south of Bringelly Road, the land uses are predominately semi-rural or rural residential while the areas west of The Northern Road, and north of Bringelly Road are characterised by low density residential development comprising the southern suburbs of the City of Penrith. The region also includes some commercial, educational, community and recreational land uses.

The proposal crosses the M4 Motorway roughly equal distance between Mulgoa Road and Mamre Road. The Northern Road is the main arterial road to and from the M4 through the area.

1.3 Relevant Guidelines

This assessment of impacts has been prepared in accordance with the following regulatory guidelines:

- *Secretary's Environmental Assessment Requirements for The Northern Road Upgrade, Mersey Road Bringelly to Glenmore Parkway, Glenmore Park* Department of Planning & Environment
- *Road Noise Policy*, NSW EPA, 2011
- *Noise Criteria Guideline*, Roads and Maritime Services, April 2015
- *Noise Mitigation Guideline*, Roads and Maritime Services, April 2015
- *Environmental Noise Management Manual*, Roads and Maritime Services, December 2001
- *Construction Noise and Vibration Guideline*, Transport (Roads and Maritime), April 2016
- *Interim Construction Noise Guideline*, Department of Environment and Climate Change NSW, July 2009
- *Assessing Vibration: a technical guideline*, DEC, 2006
- *AS1055 Acoustics - Description and measurement of environmental noise*, Standards Australia, 1997
- *AS IEC 61672.1—2004 - Electroacoustics—Sound level meters, Part 1: Specifications*, Standards Australia, 2004
- *BS 7385 Part 2-1993 Evaluation and measurement for vibration in buildings Part 2*, BSI, 1993
- *DIN 4150:Part 3-1999 Structural vibration - Effects of vibration on structures*, Deutsches Institute fur Normung, 1999

2. Description of the Project

2.1 Description of the proposal

Roads and Maritime proposes to upgrade four kilometres of The Northern Road between Glenmore Parkway, Glenmore Park and Jamison Road, Penrith. The proposal is shown in **Figure 2-1**, and illustrated in greater detail in the design drawings included in the REF document. The main features of the proposal include:

- An eight-lane divided road (three general traffic lanes and a kerbside bus lane in each direction) from just south of Glenmore Parkway, Glenmore Park to Jamison Road, Penrith
- An upgrade to the M4 Motorway interchange, including:
  - Construction of a new two-span bridge over the M4 Motorway, located to the east of the existing bridge alignment
  - Replacement of the existing two sets of traffic signals at the M4 Motorway interchange, with a single set of traffic signals to control all movements at the interchange
  - Widening of ramps to accommodate future Smart Motorway requirements
  - Demolition of the existing bridge over the M4 Motorway
- New traffic signals on The Northern Road at:
  - The Northern Road intersection with Glenmore Parkway and Wentworth Road
  - The Northern Road intersection with Frogmore Road and Tukara Road
- Altered intersection arrangements at:
  - The Northern Road and Homestead Road (left-in, left-out only)
  - The Northern Road and Castle Road (left-in, left-out only)
  - Maxwell Street and Aspen Street (a new four-leg roundabout realigned to include direct access to Hilliger Road)
- Upgrade of The Northern Road and Glenmore Parkway / Wentworth Road intersection, comprising:
  - Traffic signals to replace the existing roundabout, allowing all movements
  - Separate left-turn lanes on all approach roads to the intersection
  - Additional left-turn and right-turn capacity from both approach roads onto The Northern Road
  - A new dedicated access road into the Penrith Golf and Recreation Club, accessed off Glenmore Parkway
  - A new single single-lane roundabout on Glenmore Parkway west of the proposed new Golf Club access road, to facilitate U-turn movements for traffic entering or leaving Fairwater Court and Garswood Road
- Dedicated left-turn lanes in and out of The Northern Road at all intersections, except for left turns out from:
  - Garswood Road
  - Homestead Road
  - Aspen Street
  - Castle Road

- Smith Street

- Changes to local roads, including:
  - Extension of Cross Road to provide a new local connection between Wentworth Road and Homestead Road
  - A new roundabout on Frogmore Road, west of the existing intersection with Simeon Road
  - Removal of the existing roundabout at Maxwell Street and Aspen Street, and replacement with a new four-leg roundabout realigned to include direct access to Hilliger Road, with traffic signals on the Aspen Street leg only
- New pedestrian and cyclist facilities, including:
  - A three-metre wide shared path along the western side of The Northern Road between Glenmore Parkway and Jamison Road
  - A three-metre wide shared path along the eastern side of The Northern Road between Wentworth Road and Bringelly Road
  - A 1.5 metre wide footpath on the eastern side of The Northern Road between Bringelly Road and Jamison Road
- New or additional pedestrian signals at:
  - The intersection of Glenmore Parkway and Wentworth Road
  - The M4 Motorway interchange
  - The intersection of Frogmore Road and Tukara Road
  - The intersection of The Northern Road and Jamison Road
- New retaining walls along:
  - The eastern side of The Northern Road, south of Homestead Road
  - Both sides of the M4 Motorway beneath the proposed bridge (reinforced soil walls)
  - The western side of The Northern Road, south of Tukara Road
  - The eastern side of The Northern Road adjacent to the Flower Power Garden Centre, south of Castle Road
  - The eastern side of The Northern Road, south of Bringelly Road
  - The eastern and western side of The Northern Road at numerous locations between Maxwell Street / Bringelly Road and Smith Street
  - The southern side of Smith Street, west of the intersection with The Northern Road
  - The eastern and western side of The Northern Road at numerous locations between Smith Street and Jamison Road
- Upgrade of drainage infrastructure, including:
  - New culverts to replace most existing cross-drainage structures or to upgrade cross-drainage
  - New longitudinal drainage including open concrete or grass-lined catch drains, grassed swales, pits and pipes
- Existing noise barriers or those proposed by other approved projects
- New noise barriers at the following locations:
  - A 5.0m high (838 m long) noise barrier extending along the northern side of the eastbound M4 Motorway off-ramp extending north along the western boundary of the proposal to Tukara Road

    - A 5.0m high (460 m long) noise barrier on the western side of The Northern Road extending from Tukara Road extending north to Aspen Street
- Two permanent variable message signs (VMS) on The Northern Road approaches to the M4 Motorway interchange
- New street lighting
- Landscaping
- Relocation of utility services and construction/installation of new utility services
- Relocation of some bus stops and construction of new bus stops
- Changes to property accesses along The Northern Road to left-in, left-out only
- Adjustments to private properties to accommodate the proposal, including driveways and fencing
- Establishment and use of temporary site compounds during construction (detailed in **Section 0**).

It is anticipated that construction of the proposal would start during 2017 and would be expected to complete by the end of 2019.

Figure 2-1 Site layout, study area, NCAs and monitoring locations

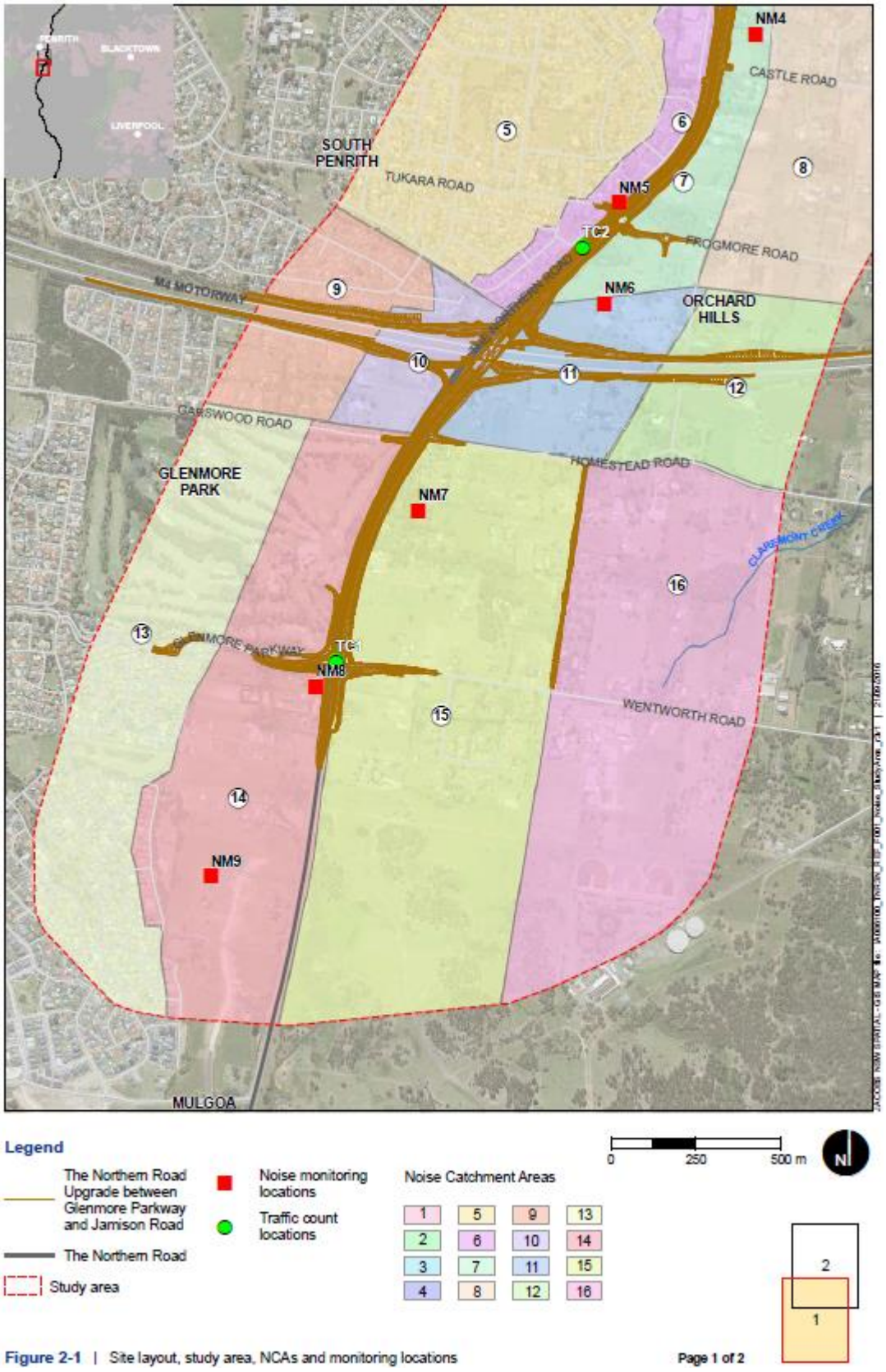

Figure 2-1 | Site layout, study area, NCAs and monitoring locations

Page 1 of 2

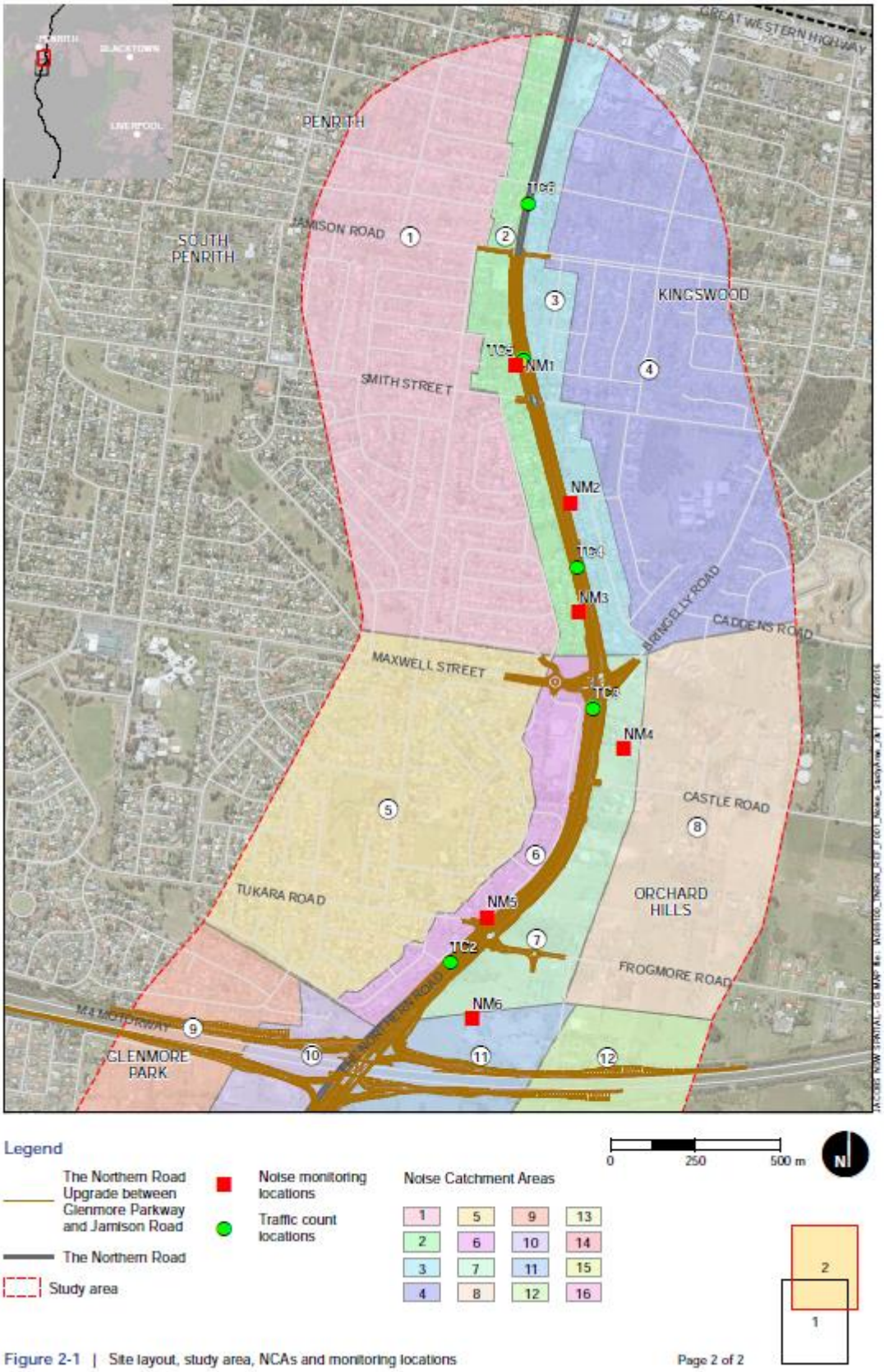

Figure 2-1 | Site layout, study area, NCAs and monitoring locations

Page 2 of 2

2.2 Acoustically-significant aspects of the Project

Both operation and construction of the project may potentially generate noise or vibration impacts to nearby residences or other acoustically-sensitive land uses (eg, schools, offices). Noise impacts may potentially result from:

- Increased traffic utilising the road
- Increased traffic utilising side roads as a result of the proposal.
- Changes in the composition of traffic utilising the road, such as increased heavy vehicles
- Changes in the transmission of traffic noise due to alignment changes under the Proposal design
- Operation of construction equipment used to construct the Proposal (including during night periods)
- The installation of audio tactile pedestrian push buttons.

Vibration impacts to sensitive receivers may potentially result from vibration intensive construction works such as impact piling (required for bridge construction).

Measures to mitigate any noise or vibration impacts that may result include:

- Quieter road pavement to reduce traffic noise;
- Permanent noise barriers to reduce traffic noise;
- Property treatments to reduce operational noise impacts
- Temporary noise barriers / hoarding adjacent to construction compounds
- Confining construction works to daytime hours whenever possible

Residential consultation / notification regarding construction works Specific mitigation measures are detailed in **Section 9** (in relation to operational noise impacts) and **Section 10.11.1** (construction noise impacts).

Appendix A contains a glossary outlining common, technical acoustic terms.

3. Noise and vibration sensitive receivers

The type and number of different acoustically-sensitive receivers potentially affected by noise or vibration emissions from either the construction or operation of The Northern Road proposal is indicated in **Table 3-1** and detailed in **Appendix B**. These are the receivers that fall within 600 m of the proposed road alignment which includes all potentially noise affected receivers, in accordance with Roads and Maritime's Noise Criteria Guideline, forms the Study Area for this assessment.

Table 3-1 Noise sensitive receivers

Receiver type	Number of properties	Number of buildings
Residential properties	2,970	2,972
Commercial and industrial properties	38	48
Educational institutions	7	49
Childcare centres	1	1
Medical facilities	1	10
Places of worship	4	4
Outdoor recreational areas	21	21
Total	**3,042**	**3,105**

Note: Commercial receivers are not included in the list of classified "receivers" in the RMS' Noise Criteria Guideline, resulting in commercial properties being considered acoustically-sensitive only to noise or vibration emissions from construction of the Proposal but not from operation of the Proposal (ie, once the Northern Road is open to public traffic).

Further details of specific non-residential receivers are provided in Table 10-5.

These receivers have been identified using aerial photography, GIS databases and information gathered from site visits. The location of each receiver and each receiver type is indicated in Appendix B.

Residential receivers located along the proposal alignment may be exposed to vibration impacts during construction, in addition to particularly vibration sensitive commercial land uses such as medical imaging or electronics facilities. No receivers of this type have been identified along the proposal alignment. However, this should be confirmed during the detailed design phase.

4. Existing noise environment

Establishing the construction noise criteria for the proposal requires knowing the existing (pre-proposal) level of background noise at receivers. This section outlines how the baseline levels of background and traffic noise were determined for the proposal.

4.1 Grouping receivers into Noise Catchment Areas

While not a Roads and Maritime or EPA requirement it is common for receivers to be grouped into Noise Catchment Areas (NCAs) for assessing construction noise impact. An NCA can provide a logical grouping of receivers affected by the same works to assist with assessment, consultation or notification. The NCAs used in this assessment are detailed in Table 4-1, and are indicated in **Figure 2-1**.

Noise logging should be completed in a location that is representative of the worst case impact (exceedance of background level by construction noise) to determine the background noise level and criteria. Additional spot check measurements should be completed to understand the range in background noise levels and associated criteria within the catchment which may vary between receiver locations or between alternate facades with different exposure.

The spot checks should be used to provide greater certainty that the mitigation measures designed to manage the impact at the assumed worst case receiver address the noise impact across the catchment. While it may not be possible to accurately identify the background noise level at each receiver, noise levels should be predicted for all receivers within the catchment.

Table 4-1 Noise Catchment Areas used in this assessment

NCA	Description
NCA 1	Receivers set back from The Northern Road and located to the north west of Smith Street. Background noise levels are primarily influenced by noise from side roads in the local area, including Smith Street and Jamison Road.
NCA 2	Receivers in the north along the western edge of proposal and influenced primarily by noise from The Northern Road.
NCA 3	Receivers in the north and along the eastern edge of proposal and influenced primarily by noise from The Northern Road.
NCA 4	Receivers set back from The Northern Road and located to the north east of Smith Street. Background noise levels are primarily influenced by noise from side roads in the local area, including Smith Street and Jamison Road.
NCA 5	Receivers set back from The Northern Road and located to the south west of Smith Street. Background noise levels are primarily influenced by noise from side roads in the local area, including Smith and Maxwell Streets.
NCA 6	Receivers in the central area of the proposal, located along the western edge of The Northern Road. Background noise levels primarily influenced by traffic on the Northern Road.
NCA 7	Receivers in the central area of the proposal, located along the eastern edge of The Northern Road. Background noise levels primarily influenced by traffic on The Northern Road.
NCA 8	Receivers set back from The Northern Road and located to the south east of Smith Street. Background noise levels are primarily influenced by noise from side roads in the local area, including Smith Street and Bringelly Road.

NCA	Description
NCA 9	Receivers set back from The Northern Road and located to the north west of the M4. Background noise levels are primarily influenced by noise from the M4 and side roads in the local area.
NCA 10	Receivers in the central area of the proposal, located along the western edge of The Northern Road and on either side of the M4. Background noise levels primarily influenced by traffic on the M4 and The Northern Road.
NCA 11	Receivers in the central area of the proposal, located along the eastern edge of The Northern Road and on either side of the M4. Background noise levels primarily influenced by traffic on the M4 and The Northern Road.
NCA 12	Receivers set back from The Northern Road and located to the north east of the M4. Background noise levels are primarily influenced by noise from the M4.
NCA 13	Receivers set back from The Northern Road and located in the southern suburb of Glenmore Park. Background noise levels are primarily influenced by noise from local side roads.
NCA 14	Semi-rural receivers in the southern area of the proposal, located along the western edge of The Northern Road. Background noise levels primarily influenced by traffic on The Northern Road.
NCA 15	Semi-rural receivers in the southern area of the proposal, located along the eastern edge of The Northern Road. Background noise levels primarily influenced by traffic on The Northern Road.
NCA 16	Semi-rural receivers set back from The Northern Road and located in the southern areas to the east of The Northern Road. Background noise levels are primarily influenced by low levels of traffic noise from local side roads and rural noise sources.

4.2 Existing Sources of Environmental Noise

The proposal extends approximately 4 km in a north / south orientation between Glenmore Parkway, Glenmore Park and Jamison Road, Penrith and carries approximately 18,500 vehicles per day in each direction.

Suburban residential properties are located directly adjacent to the alignment northwest of the M4 and north east of Bringelly Road. Suburban development is also present in the vicinity of the Glenmore Parkway in the south west proposal area. Other areas are generally semi-rural in nature.

Existing sources of day and night time noise in the area are generally related to road traffic along the existing Northern road and the M4 motorway. Traffic on local roads and generic residential and natural noise sources also contribute to the overall noise environment.

4.3 Background Noise Survey Methodology

Long-term, unattended noise surveys were undertaken along the study corridor to determine the existing level of background noise at all receivers potentially affected by the Proposal.

Monitoring sites were selected according to the noise sources affecting the site (eg, traffic and/or other ambient sources), land access permission and equipment security. The sites at which these background noise monitoring surveys were undertaken are indicated in **Figure 2-1** and detailed in

Table 4-2 and **Table 4-3**, which also detail the sources of background noise as identified by Jacobs at the time of installing and retrieving the noise loggers.

The background noise monitoring surveys were conducted between 9 February and 17 February 2016 and were undertaken in accordance with:

- The Roads and Maritime Procedure *Preparing an operational traffic and construction noise and vibration assessment report* (April 2016)
- The DECC's Interim Construction Noise Guideline (ICNG), and
- Australian Standard AS1055 Acoustics - Description and measurement of environmental noise.

The surveys were undertaken using unattended ARL Ngara noise loggers which continuously measured the level of ambient noise over 15-minute periods throughout the survey period. The loggers measure the L_{Aeq}, L_{A90} and other relevant statistical noise levels during each daytime, evening and night time period. Each logger was fitted with a wind shield and its calibration confirmed both prior to and immediately following each logging period.

After excluding results captured during periods of adverse weather (excessive rain or wind), the survey noise level data were used to determine the Rating Background Level (RBL) (as shown in **Table 4-2**) and existing daytime (15 hour) and night time (9 hour) traffic noise levels (refer **Table 4-3**), which were also used to validate the noise model (discussed further in **Section 7.2**).

4.4 Existing Background and Traffic Noise Levels

The results of unattended noise monitoring are presented in **Table 4-2** and **Table 4-3**.

Table 4-2 Unattended monitoring results (Construction noise parameters)

Ref	Monitored noise level $L_{Aeq(period)}$ dB(A)			Notes
	L_{A90}	L_{Aeq}	L_{Amax}	
Daytime (7:00 to 18:00)				
1	48	62	78	HV passbys frequent (up to 82), constant traffic (59)
2	53	66	81	HV passbys frequent (up to 80), constant traffic (65), faint birds
3	54	68	82	HV very frequent (up to 84), LV constant (63-66), distant birds during low traffic noise (<40)
4	52	60	71	Cicadas constant (52), distant traffic noise constant (56), HV passbys common (Up to 72)
5	55	66	80	Constant traffic (64), distant birds (<40)
6	45	54	73	Distant traffic (50), occasional peaks (up to 62)
7	52	62	69	Constant traffic noise (59-62), frequent birds (up to 50 / rare max to 70), HV passbys (up to 68)
8	53	70	75	Braking / accelerating HV LV (up to 76), constant traffic noise (53-56), birds, occasional
9	48	55	64	HV intermittent (58-63), LV constant (48-52), insects / birds (up to 57)
Evening (18:00 to 22:00)				
1	48	59	74	Constant distant traffic (up to 56), LV passbys (up to 67), HV passbys infrequent (up to 72)
2	49	64	77	HV passbys frequent (< 80), nearly constant traffic (62 - 69), faint birds
3	50	66	78	LV passbys frequent (62-72), HV rare (up to 75), distant traffic / crickets (<48)
4	51	59	69	Crickets constant (54), LV passbys common (63-66)
5	52	64	79	LV passbys constant (62-65), motorbikes max, infrequent HV passbys (68-74)

Ref	Monitored noise level $L_{Aeq(period)}$ dB(A)			Notes
	L_{A90}	L_{Aeq}	L_{Amax}	
6	41	49	63	Distant traffic (46-49), occasional LV peaks (50-56), distant crickets (<41)
7	49	57	67	Constant traffic (53-56), occasional HV passbys (63-65)
8	46	57	71	Constant traffic (43-45), braking / accelerating LV HV frequent (58-62)
9	49	55	62	Crickets (<59), LV (53-56), HV infrequent (62-64), motorbikes (70-74)
Night (22:00 to 7:00)				
1	41	57	71	LV passbys common (up to 68), constant traffic (53-58), crickets late night only (45)
2	35	63	77	LV passbys (62-69), HV passbys rare (75-80), distant traffic (57)
3	44	64	76	LV passbys common (63-66), motorbikes max, crickets in absence of traffic (approx. 40)
4	49	59	68	Crickets constant (54), LV passbys common (59-64), distant traffic noise (48)
5	42	66	76	Distant traffic (40-44), LV passbys common (60-65), crickets (38)
6	34	48	57	Distant traffic (39-43), occasional LV peaks (up to 56), infrequent crickets (38-48)
7	38	53	61	Distant traffic (45-52), frogs / crickets occasional (up to 46), LV passbys common (58-61)
8	36	54	67	Crickets constant (42), braking / accelerating LV and HV (54-66), distant traffic (35-42)
9	44	54	60	Insects constant (up to 51), LV intermittent (49-55), HV occasional (56-62)

HV Heavy Vehicles LV Light Vehicles

Table 4-3 Unattended noise monitoring results (Traffic noise parameters)

Monitoring location	Site	L_{Aeq} (1hour) Daily max	L_{Aeq} (15hour)	L_{Aeq} (9hour)	L_{Amax} (15hour)	L_{Amax} (9hour)
1	165 Parker St, South Penrith	64	62	57	77	73
2	198 Parker St, Kingswood	68	66	63	81	77
3	227 Parker Street, Kingswood	69	68	64	81	77
5	30 Flavel Street, South Penrith	67	66	62	80	77
6	Penrith Christian School	56	52	48	69	61
7	1954/1962 The Northern Road,	64	61	53	69	64

1: $L_{Aeq(1\ hour)}$ noise levels presented are the average of all hourly values within the daytime (7am-10pm) or night periods (10pm-7am)

4.5 Concurrent Traffic Survey

Traffic count surveys were undertaken concurrently with the long term unattended noise monitoring surveys. These traffic counts have been used only for the specific purpose of validating the noise model (**Section 7.2**) and do not form part of the traffic modelling undertaken for the proposal's Transport assessment.

The tube count traffic surveys along The Northern Road were undertaken by Austraffic (All Traffic Surveys (NSW) Pty Ltd) during the period 9 February and 17 February 2016 at the locations indicated in **Table 4-4**. The traffic data collected during the tube counts are detailed in **Table 4-4**. The bulk flow vehicle speeds recorded by the surveys indicated traffic to be free flowing and not affected by congestion. At most survey locations, average hourly vehicle speeds of between 60-70 km/h were recorded.

Table 4-4 Measured day and night traffic counts used to validate the noise model

Location (Parker Street / The Northern Road)	Direction	Avg speed km/h	Predicted traffic flows							
			Daytime (15 hour)				Night time (9 hour)			
			Light	Heavy	Total	% Heavy	Light	Heavy	Total	% Heavy
North of Jamison Rd	Northbound	-*	14,871	1,079	15,950	7	2,348	183	2,531	7
	Southbound	-*	15,131	1,038	16,169	6	2,717	221	2,938	8
South of Jamison Rd	Northbound	59	14,001	1,123	15,124	7	2,150	101	2,251	4
	Southbound	55	14,196	993	15,189	7	2,486	152	2,638	6
Between Smith & Maxwell Sts	Northbound	-*	15,414	1,077	16,491	7	2,303	196	2,499	8
	Southbound	-*	14,628	953	15,581	6	2,823	207	3,030	7
Between Castle & Frogmore Rds	Northbound	-*	21,064	1,269	22,333	6	2,946	218	3,164	7
	Southbound	-*	21,219	1,160	22,379	5	4,209	300	4,509	7
Between Frogmore Road & M4	Northbound	68	20,608	1,734	22,342	8	2,845	148	2,993	5
	Southbound	63	19,755	1,266	21,021	6	3,576	235	3,811	6
Between Homestead & Wentworth Rds	Northbound	70	13,682	1,313	14,995	9	2,423	158	2,581	6
	Southbound	65	15,452	1,117	16,569	7	2,205	161	2,366	7

** These locations were monitored using cameras and speeds were not obtained.*

4.6 Penrith Christian School building facade acoustic performance

The Penrith Christian School is located immediately north-east of the junction of the M4 Motorway and The Northern Road. The school's existing exposure to traffic noise from these roads is such that the property was considered to be at a higher than usual risk of noise impacts. Roads and Maritime therefore commissioned acoustic testing of the building facades of school's noise-sensitive uses (eg, classrooms, library, place of worship).

On behalf of Roads and Maritime, Jacobs undertook acoustic testing of the building facade performance of all learning spaces, child sleeping spaces and the ImagineNations Church on 14 July 2016. The L_{Aeq} traffic noise level was monitored simultaneously within and external to each room and the results used to determine the facade insertion loss for that room. These tests were undertaken with building windows closed. The results of this testing are indicated in **Table 4-5**. For situations where the insertion loss of a facade could not be accurately measured due to traffic noise levels within the space being either inaudible or too low, **Table 4-5** provides a conservative estimate of the facade insertion loss based on published data and guidelines.

Figure 4-1 Penrith Christian School – building layout

Table 4-5 Monitored façade losses at Penrith Christian School

Building	Room	Facade construction details	Monitored noise level L_{Aeq} dB(A)		Difference dB(A)	Internal Noise Criterion dB (A)		Facade Insertion Loss dB(A)	External Noise Criterion dB (A)	
			External	Internal		Day	Night		Day	Night
1	Office / Reception[1]	N/A	N/A							
2	COLA (Covered Outdoor Learning Area) [1]	N/A	N/A							
3	Play & Sleeping Area[2]	Double-brick wall with no windows	-	-	-	35	-	40	75	-
4	Central Classrooms	Brick with large windows covering more than 50% of the facade surface area. Windows single glazed with rubber seals generally of good quality.	53	36	17	40	-	17	57	-
	Eastern Classrooms	Brick with large windows covering more than 50% of facade surface area. Windows single glazed with older, deteriorated seals.	52	35	17	40	-	17	57	-
5	Classrooms on Western Facade	Brick with large windows covering more than 50% of facade surface area. Windows single glazed with rubber seals generally of good quality.	52	35	17	40	-	17	57	-
	Classrooms on Southern Façade	Brick with large windows comprising more than 50% of facade surface area. Windows single glazed with rubber seals generally of good quality.	55	39	16	40	-	16	56	-
6	Sport centre	Brick-corrugated iron composite with limited small windows (~0.5mx0.5m). Windows closed with winding handle and of good quality.	51	35	16	55	-	16	71	

Building	Room	Facade construction details	Monitored noise level L_{Aeq} dB(A)		Difference dB(A)	Internal Noise Criterion dB (A)		Facade Insertion Loss dB(A)	External Noise Criterion dB (A)	
			External	Internal		Day	Night		Day	Night
7	Reading Rooms	Brick with windows covering approximately 50%. Windows single glazed with deteriorated seals.	50	33	17	40	-	17	57	-
	General Library	Brick with windows covering approximately 25% of facade surface area. Single glazed windows with rubber seals generally of good quality.	47	27	20	40	-	20	60	-
8	Classrooms on Southern Facade[2]	Brick with windows covering approximately 50% of facade surface area. Single glazed windows with rubber seals generally of good quality.	-	-	-	40	-	16	56	-
	Classrooms on Western Facade[2]	Double-brick wall with no windows.	-	-	-	40	-	40	80	-
9	Music Rooms	Brick with windows covering approximately 50% of facade surface area. Single glazed windows with rubber seals generally of good quality.	59	43	16	40	-	16	56	-
	Manual Arts Room	Brick with several small windows (0.5m x 0.5m). Single glazed windows with deteriorated rubber seals.	64	44	20	40	-	20	60	-
10	Classrooms on Southern Facade[3]	Brick with windows comprising approximately 25%.	56	32	24	50	-	24	74	-
11	Classrooms on Southern Façade	Brick with windows covering approximately 50% of facade surface area. Single glazed windows with deteriorated rubber seals.	57	40	17	40	-	17	57	-
12	Imagine Nations	Corrugated iron cladding with some medium sized	58	43	15	40	40	15	55	-

Building	Room	Facade construction details	Monitored noise level L_{Aeq} dB(A)		Difference dB(A)	Internal Noise Criterion dB (A)		Facade Insertion Loss dB(A)	External Noise Criterion dB (A)	
			External	Internal		Day	Night		Day	Night
	Church	windows (0.5m x 0.9m). Single glazed windows with deteriorated rubber seals. Noted that there was a large air gap between the ground and floor of the building								

1 Office spaces and the Covered Outdoor Learning Area not eligible for acoustic treatment

2 Facade insertion loss has been estimated based on published data for similar building constructions.

3 Workshops

5. Operational noise criteria

5.1 Noise Criteria Guideline

Operational noise from the proposal refers to the noise from traffic using the road once it is opened to the public – the 'operational' phase of the proposal. The potential for operational noise impacts is assessed against the Noise Criteria Guideline (NCG) which describes the Roads and Maritime implementation of the Road Noise Policy (RNP).

The NCG applies more stringent noise criteria for new roads than for redeveloped roads given the greater opportunity to minimise noise impacts, especially in greenfield locations.

Above all, the intention of the NCG in all situations is to meet the following principles. These principles take precedence over even the procedures of the NCG:

- Criteria are based on the road development type a residence is affected by due to the road proposal
- Adjacent and nearby residences should not have significantly different criteria for the same road
- Criteria for the surrounding road network are assessed where a road proposal generates and increase in traffic noise greater than 2 dB(A) on the surrounding road network
- Protect existing quiet areas from excessive changes in amenity due to traffic noise.

5.2 Applying the Noise Criteria Guideline

The NCG applies noise criteria to sensitive receivers for both the proposal's year of opening (in this case, 2021) and 10 years after its opening (2031).

The study area adopted for this assessment extends 600 metres either side of any road being assessed, including Cross Road. The study area adopted for this assessment is indicated **Figure 2-1**.

Non-residential sensitive receiver types (eg, child care centres and hospital wards) are assigned fixed noise criteria irrespective of the road type to which they are exposed.

The NCG's noise criteria for residences however are based on the type of the road development a residence is affected by, specifically, whether a "new" or "redeveloped" section of the road proposal.

5.2.1 Operational noise criteria for residential receivers

A residence may be assigned new road, redeveloped road, transition zone or relative increase criteria depending on how the proposal will influence noise levels. For each facade of the residence the most stringent applicable criteria are used in the assessment.

Criteria are based on the road development type a residence is affected by due to the proposal. In some instances residences may be exposed to noise from both new and redeveloped roads. In this instance the proportional contribution from each road is used to determine "transition zone" criteria.

An additional test – known as the relative increase criteria - is applied to protect residences within quiet areas from large (more than 12 dB(A)) increases in noise due to the proposal.

For the purposes of assessment against the NCG, the proposal is a redeveloped road except for the new road segment at the extension of Cross Road to the east of The Northern Road and south of the M4 Motorway.

The proposal includes transition points at the junction of all major side roads. Assessed side roads and all road classifications and functional classes are presented below in Table 5-1. These considerations inform the development of noise criteria for residential receivers.

Table 5-1 Assessed roads, functional classes and development types

Road	Functional class	Development type
Glenmore Parkway (West)	Collector	Existing
Glenmore Parkway (East)	Collector	Redeveloped
The Northern Road	Arterial	Redeveloped
Wentworth Road (East)	Local	Existing
Wentworth Road (West)	Local	Redeveloped
Garswood Road	Local	Existing
Homestead Road	Local	Existing
M4 Motorway	Freeway	Existing
Tukara Road	Collector	Existing
Frogmore Road (East)	Local	Existing
Frogmore Road (West)	Local	Redeveloped
Maxwell Street (West of Tania Avenue)	Collector	Existing
Maxwell Street (East of Tania Avenue)	Collector	Existing
Tania Avenue (South of Hilliger Road)	Local	Redeveloped
Hilliger Road (North of Tania Avenue)	Local	Existing
Bringelly Road	Collector	Existing
Smith Street	Collector	Existing
Jamison Road – west of proposal (West)	Sub arterial	Existing
Jamison Road – west of proposal (East)	Sub arterial	Redeveloped
Cross Road (North)	Local	Existing
Cross Road (South)	Local	New

The noise criteria for residential receivers are summarised in **Table 5-2**.

Table 5-2 NCG noise criteria for residences

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

Road category	Type of project/land use	Assessment Criteria	
		Daytime (7am-10pm)	Night-time (10pm-7am)
	Existing residences affected by increases in traffic noise of 12 dB(A)or more from **new** freeway/arterial/sub-arterial roads	Existing $L_{Aeq\ (15hour)}$ (external) + 12 dB(A) [capped at 55 dB(A)]	Existing $L_{Aeq\ (9hour)}$ (external) + 12 dB(A) [capped at 50 dB(A)]
	Existing residences affected by increases in traffic noise of 12 dB(A)or more from **redeveloped** freeway/arterial/sub-arterial roads	Existing $L_{Aeq\ (15hour)}$ (external) + 12 dB(A) [capped at 60 dB(A)]	Existing $L_{Aeq\ (9hour)}$ (external) + 12 dB(A) [capped at 55 dB(A)]
Local roads	Existing residences affected by noise from **new** local road corridors Existing residences affected by noise from **redevelopment** of existing local roads	55 dB(A) $L_{Aeq(1\ hour)}$ external	50 dB(A) $L_{Aeq(1\ hour)}$ (external)

5.2.2 Operational noise criteria for non-residential receivers

Noise criteria for non-residential land uses are presented in Table 5-3. These criteria are based on the level of impact, below which, normal operations or use can continue with minimal interruption or disturbance.

Table 5-3 Noise criteria for relevant non-residential land uses

Existing sensitive land use	Assessment criteria dB(A)		Additional Considerations
	Day (7 a.m.– 10 p.m.)	Night (10 p.m.– 7 a.m.)	
School classrooms	40 $L_{Aeq,1hour}$ (internal) when in use	–	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). Due to its exposed location in relation to the proposal, monitoring has been carried out at Penrith Christian School to determine the existing acoustic insertion loss of building facades. For all other schools, a conservative 10dB(A) attenuation across the façade has been adopted for this assessment. An external criterion of 50dB(A) $L_{Aeq,1hour}$ has been adopted.
Places of Worship	40 $L_{Aeq,1hour}$ (internal)	40 $L_{Aeq,1hour}$ (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 what is in these areas that may be affected by road traffic noise. No external worship land uses have been identified in the study area. A conservative 10dB(A) attenuation across the facade has been adopted for this assessment. An external criterion of 50dB(A) $L_{Aeq,1hour}$ has been adopted.

Existing sensitive land use	Assessment criteria dB(A)		Additional Considerations
	Day (7 a.m.– 10 p.m.)	Night (10 p.m.– 7 a.m.)	
Open space (active use)	60 $L_{Aeq,15hour}$, (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. Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, eg playing chess, reading. For areas where there may be a mix of passive and active recreation, eg school playgrounds, the more stringent criteria apply. Open space may also be used as a buffer zone for more sensitive land uses.
Child care facilities	Sleeping rooms 35 $L_{Aeq,1hour}$ (internal) Indoor play areas 40 $L_{Aeq,1hour}$ (internal) Outdoor play areas 55 $L_{Aeq,15hour}$, (external)	–	Unless otherwise stated (e.g. Penrith Christian School), this assessment has conservatively assumed that the acoustic insertion loss of any building facade that includes windows opened for ventilation is 10dB(A).

It is to be noted that the noise criteria for some non-residential uses such as schools and places of worship are assessed internal to the premises. These may be re-interpreted as external noise criteria by adding 10 dB(A) to the internal criterion. This reflects the sound attenuation assumed to be provided by the facade of typical buildings when the facade glazing is open for the purpose of ventilation. This assumption would be reviewed during detailed design. Operational noise criteria for the Penrith Christian School specifically were determined with reference to the measured facade insertion loss values detailed in Table 4-5.

Further, noise criteria for school classrooms and places of worship are assessed against a $L_{Aeq,1hour}$ criterion rather than $L_{Aeq,15hour}$ (day period) and $L_{Aeq,9hour}$ (night period) criteria (refer **Table 5-3**). The numerical corrections applied in noise modelling to account for this difference are outlined in **Table** 7-1.

5.2.3 Operational noise criteria adopted in this assessment

The noise criteria for each receiver considered by this assessment are indicated in Appendix D.

Receivers qualify for the consideration of noise mitigation where their exposure to operational noise from the proposal is predicted to exceed any of the operational noise criteria. The assessment of eligibility for mitigation is discussed further in **Section 6**.

5.3 Assessing potential for sleep disturbance

A guide for assessing the potential for sleep disturbance within residences from the proposal's vehicle passbys is provided in the RNP:

> *"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 iii (NSW Roads and Traffic Authority 2008a) outlines a protocol for assessing and reporting on maximum noise levels and the potential for sleep disturbance."*

ENMM Practice Note iii indicates that:

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

Given that it is generally accepted that the level of traffic noise within a dwelling having its windows open is 10 dB(A) lower than the corresponding noise level immediately outside the facade (refer ICNG), these internal noise goals may be re-expressed as external noise goals as follows:

- Maximum **external** noise levels below 60–65 dB(A) are unlikely to cause awakening reactions, and
- One or two noise events per night with maximum **external** noise levels of 75–80 dB(A) are not likely to significantly affect health and wellbeing.

A "maximum noise event" is defined as any vehicle pass-by for which

- $L_{Amax} - L_{Aeq(1\ hour)} \geq 15$ dB(A)

Practice Note iii states that the maximum noise level assessment should be used as a tool to help prioritise and rank mitigation strategies, but should not be applied as a decisive criterion in itself.

6. Determining noise mitigation

The methodology for mitigating noise impacts resulting from a road proposal are outlined in the Roads and Maritime Noise Mitigation Guidelines (NMG).

6.1 Noise Mitigation Guideline

The NMG outlines the principles to be applied when assessing whether noise mitigation is feasible and reasonable. These are as follows:

- Communities should receive reasonable and equitable outcomes
- Noise mitigation should be designed to reduce noise levels to the criteria at qualifying receivers
- Priority should be first given to reducing noise during corridor planning and road design where there may be greater opportunity to provide cost effective and integrated outcomes with better urban design
- Following corridor and road design residual exceedances of noise criteria may be addressed at qualifying receivers using, in order of preference, quieter road surfaces, barriers and at-property treatments
- Incidental benefits from the noise mitigation designed for qualifying receivers should be recognised at all receivers within a community where noise levels exceed WHO guidelines (facade noise levels of 50 dB(A) day and 45 dB(A) night)
- Noise barrier evaluation processes must:
  - give preference to reducing outdoor noise levels and the number of at-property treatments
  - provide efficient barrier heights and extents without disregarding lengths of effective noise barrier in front of eligible groups of receivers
- Noise mitigation shall be evaluated and installed where feasible and reasonable

6.2 Identifying receivers that may qualify for noise mitigation

Any of the following three triggers qualify a receiver for *consideration* of noise mitigation. Note that these do not prescribe that a receiver shall receive mitigation necessarily, as this also depends on whether the application of mitigation in that instance is both feasible and reasonable (discussed further in Section 9):

- The predicted level of noise from the proposal to a receiver is 5 dB(A) or more above the relevant NCG noise criterion and it is the proposal that contributes most noise to this increase;
- The noise level contribution from the road proposal is “acute”, which is to say, greater than either 65 dB(A)$L_{eq,15hour}$ during daytime periods or 60 dB(A)$L_{eq,15hour}$ during night periods (regardless of the level of noise contributed from non-proposal roads);
- The predicted noise level to a receiver for the proposal “Build” case both exceeds the NCG noise criterion AND the increase in noise created by the proposal (i.e. the Build minus the No Build noise level) is greater than 2 dB(A);

These tests are applied at the receiver prior to the application of noise mitigation measures, and determine whether the proposal is required to provide additional mitigation in accordance with Principle 4 above. This protocol is shown diagrammatically in **Figure 6-1**.

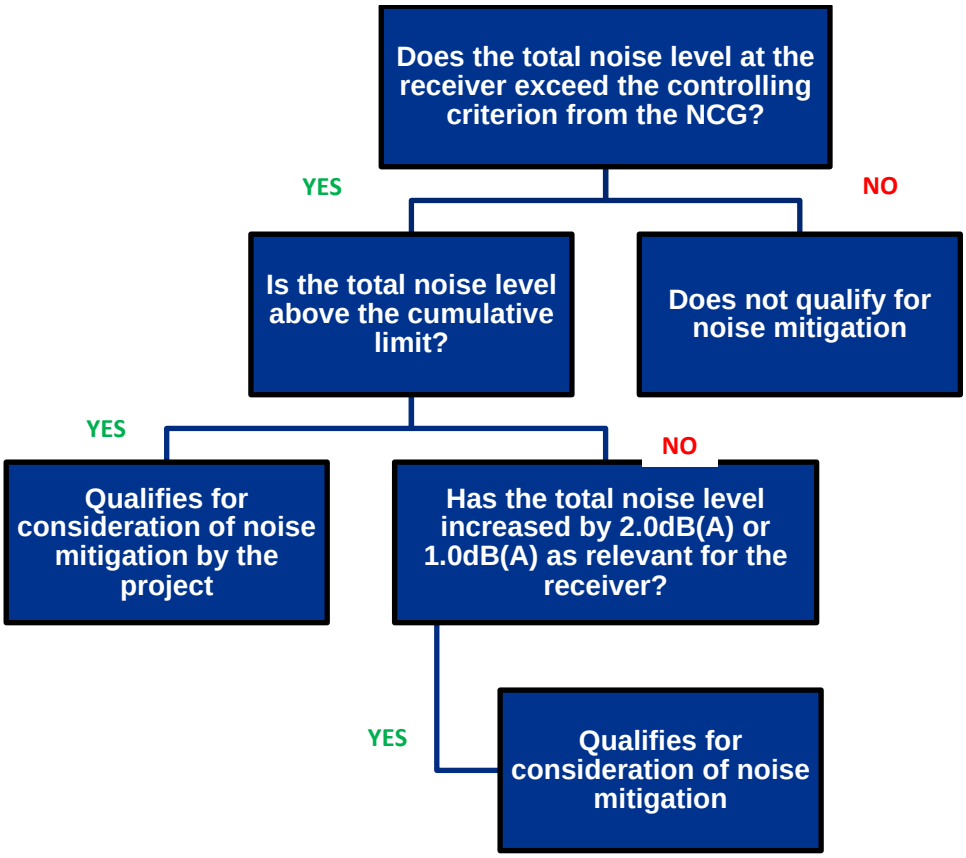

Figure 6-1 Eligibility triggers for consideration of noise mitigation

6.3 Identifying noise mitigation measures

Where operational noise levels from the proposal (without mitigation) are predicted to exceed compliance criteria at receivers, the assessment proceeds to investigate the acoustic benefit that may be provided to those receivers by the following noise mitigation measures, in order:

- The application of quieter road pavements
- Erection of noise mounds
- Erection of noise barriers
- Providing at-property treatments

Receivers do not qualify for these noise mitigation treatment(s) automatically if the predicted level of noise from the proposal exceeds the NCG criteria. The provision of mitigation measures depends also on the mitigation being “feasible and reasonable” to apply. For example the NMG specifies that it is not reasonable to provide mitigation by means of quieter road pavements or noise barriers where there are fewer than four impacted receivers who are closely spaced. In such cases it is more reasonable and cost-effective to provide at-property treatments to each of those dwellings.

Section 7 of the NMG provides further detail on the considerations relating to the deployment of quieter pavements and noise barriers. Where these measures do not exhaustively mitigate all impacts, at-property treatments are considered.

7. Noise modelling methodology and assumptions

7.1 Assessment methodology

7.1.1 Assessment scenarios

The assessment of the proposal's operational noise impacts requires comparing the modelled traffic noise levels resulting from the "Build" and "No Build" ("do nothing") options in order to correctly identify the proposal's contribution to any increase in traffic noise. In accordance with the RNP, the following four scenarios are modelled, where 2021 is taken to be the year of opening of the Northern Road proposal:

- **Year of Opening – 2021, No Build**
  Modelling is based on 2021 traffic volumes based on the existing road network;
- **Year of Opening – 2021, Build**
  Modelling is based on 2021 traffic volumes for the road network that includes the newly-built Northern Rd;
- **10 Years after Opening – 2031, No Build (ie, the "do nothing" case)**
  Modelling is based on the 2031 traffic volumes if the existing road network remains unchanged (i.e. The Northern Road is not built);
- **10 Years after Opening – 2031, Build**
  Modelling is based on the 2031 traffic volumes based on a road network that includes the Northern Road. This future traffic scenario also includes the additional trips ("induced demand") created by the introduction of the road based on offered network efficiency time savings.

Each of these scenarios was modelled for both daytime (7am-10pm) and night (10pm-7am) periods.

7.1.2 Operational modelling inputs

The most significant factors in determining the level of noise received from a road are the receiver's distance from the road, traffic volumes, heavy vehicle numbers, vehicle speeds and the road surface type.

The road and traffic parameters used and values adopted in the noise modelling are presented in Table 7-1.

Table 7-1 Noise modelling inputs

Parameter	Notes
Facades	Standard +2.5dB(A) correction applied to account for façade reflection -1.7dB(A) correction to account for Australian façade conditions
Side roads	Traffic volumes on the following side roads were included in the model. Traffic on other local roads was not included. • M4 Motorway • Cross Road • Jamison Road • Smith Street • Maxwell Street • Bringelly Road • Hilliger Road • Tukara Road • Frogmore Road • Homestead Road • Garswood Road • Glenmore Parkway

Parameter	Notes
	• Tania Avenue • Wentworth Road
Traffic speeds	The Northern Road (no build scenarios): • 70km/h north of M4 • 80km/h south of M4 The Northern Road (build scenarios): • 80km/h north of M4 • 90km/h south of M4 • Sub arterial / collector / local roads (all scenarios): • Homestead Road, Wentworth Road - 70 km/h • Tania Avenue, Bringelly Road, Maxwell Street, Hilliger Road, Glemore Parkway – 50km/hr • All others 60km/hr M4 Motorway: • 110 km/h • Ramps – 80km/hr increasing to 110km/hr
Buildings	• Footprints taken from aerial photography • Heights and number of floors estimated from Google Street-view and site inspections. • Estimates from inspections and Australian building standards indicated an average under floor height of 0.5m, 3m per floor and a typical roof pitch height of 1.5m. As such, single story buildings have been modelled with a height of 4.5m and two story buildings at 7.5m
Terrain	Project terrain data was derived from NSW Land Property Information (LPI) 1m resolution bare earth Digital Elevation Model (DEM). The DEM was produced from a standard LiDAR survey conducted by LPI. *Reference: NSW Land Property Information (LPI) LiDAR Product Specifications, Version 3.0, March 2013.*
Road surfaces / corrections	Unless otherwise stated, all roads are assumed to be Dense Graded Asphalt (0dB(A) correction)
Congestion / intersections	All traffic is assumed to be free flowing (ie no corrections have been applied at intersections) CoRTN Low flow traffic corrections have not been used
Ground surface / absorption	Residential areas: 50% ground factor Open grass areas: 75% ground factor
Bus lane traffic	Proposal bus lane assumed to take 10% of daytime heavy vehicle and no traffic during nights
Source heights / corrections	Traffic has been divided into the following source heights and energy levels: • Car tyres / 0.5m / 100% • Truck tyres / 0.5m / 25% • Truck engines / 1.5m / 60% • Truck exhaust / 3.6m / 15%
Receiver locations	All facades of all receivers within approximately 600m of the alignment have been considered. Ground floor receivers have been placed at an elevation of 1.5m and first floor receivers at an elevation of 4.5m.
L_{A10} : L_{Aeq} conversion	L_{A10} to L_{Aeq} conversion has been assumed to be -3dB(A) at all receivers.
Conversion of $L_{Ae(period)}$ to $L_{Aeq(1\ hr)}$ noise levels	The following corrections have been used to determine LAeq,1hr noise criteria from relevant LAeq,period traffic noise level monitoring data (LAeq,1hr = LAeq,period + Correction): + 2.0dB(A) Day / + 4.1dB(A) Night for receivers located near either The Northern Road or busy side roads, + 1.3dB(A) Day / 3.8dB(A) Night for properties located near low-trafficked side roads.

7.2 Model validation

The noise model used for the assessment was passed through a validation process to ensure the accuracy of its traffic noise predictions. The validation process compares predicted traffic noise levels against the levels of traffic noise measured during the long-term background noise monitoring survey at each of the nine long-term, unattended traffic noise monitoring locations (**Table 4-3**). The original selection of these monitoring locations was informed in part by this need to validate the model. To this end, noise loggers were positioned to have a direct, unscreened exposure to traffic flows on the subject road, and a minimised exposure to noise contributions from other roads.

For each receiver, the validation model was configured to reflect actual site conditions (eg, receiver distance from the road, total angle of view to traffic, type of road surface) and traffic volumes measured during the monitoring period (refer traffic count locations in **Table 4-4**)..

Any difference found between the predicted and measured noise levels would, if required, inform a correction factor which would be applied to noise predictions of future assessment scenarios.

Table 7-2 outlines the validation process for each of the nine unattended noise monitoring locations for both daytime and night time periods.

Table 7-2 Comparison of measured and modelled road traffic noise levels

Location	Day $L_{Aeq(15\ hour)}$ dB(A)			Night $L_{Aeq(9\ hour)}$ dB(A)		
	Modelled	Measured	Difference	Modelled	Measured	Difference
Location 1	62.7	61.9	0.8	56.9	57	-0.1
Location 2	67.6	66.4	1.2	61.9	62.8	-0.9
Location 3	68.2	67.9	0.3	62.8	63.6	-0.8
Location 5	67.2	65.5	1.7	60.7	61.5	-0.8
Location 6	53.4	51.7	1.7	46.0	47.8	-1.8
Location 7	60.0	61.1	-1.1	54.1	53.2	0.9
Median of results			**1.0**			**-0.8**
Standard Deviation (validated results)			**1.1**			**0.9**

Table 7-2 demonstrates the median differences between modelled and measured values to be 1dB for day periods, and -0.8dB for night periods. This indicates that the model predicts traffic noise levels to within an accepted tolerance of +/- 2.0dB(A)), and therefore, there is no need for a correction factor to be applied to the noise model.

As detailed in Section 4.4, monitoring locations 4, 8 and 9 were affected by extraneous noise, making them unsuitable for validating the traffic noise model. Sites 4 and 9 were frequently affected by crickets during the night and cicadas during the day, while location 8 was in the vicinity of the roundabout between The Northern Road and the Glenmore Parkway, and as such was constantly exposed to braking and accelerating heavy vehicles.

7.3 Traffic counts and distribution

The Annual Average Daily Traffic (AADT) data used for the prediction of noise impacts for the proposal has been developed using an Aimsun microsimulation traffic model. This model only provides peak period flows and expansion from peak period to daily was undertaken on the basis of observed daily traffic counts. A complete assessment of traffic data is available in the Traffic and Transport specialist paper which forms part of this REF.

Appendix F present the traffic data used in the noise modelling including total volumes for Light Vehicles (LV) and Heavy Vehicles (HV) and the percentage of Heavy Vehicles (%HV).

8. Operational traffic noise predictions

This section outlines the proposal's predicted operational noise impacts to each of the 3,105 receivers identified within the study area.

8.1 Operational noise impacts prior to consideration of mitigation

Traffic noise levels to each receiver were modelled for the Build and No Build (without mitigation) scenarios and compared against the operational noise criteria presented in **Section 5.1**. This process allows for identification of receivers that qualify for consideration of additional mitigation.

Detailed predictions of operational noise from the proposal at each receiver are presented in **Appendix A**.

Receivers at which operational noise from the proposal is predicted to exceed the NCG criteria and therefore qualify for consideration of mitigation are indicated in **Appendix I**. These are the receivers which qualify for the consideration of additional noise mitigation. A summary of these qualifying receivers is provided in **Table 8-1**.

Table 8-1 : Number of receivers that qualify for consideration of noise mitigation

Noise Catchment Area	Number of receivers assessed	Number of receivers qualifying for consideration of mitigation	Controlling Criterion			
			Cumulative Limit	Acute Noise Exposure	>2dB(A) increase	Combination of Criteria
NCA 1	957	5	2			3
NCA 2	191	61	2		3	56
NCA 3	180	53	6			47
NCA 4	640	23	7		16	
NCA 5	503	31			30	1
NCA 6	101	33	1		3	29
NCA 7	20	9			6	3
NCA 8	46	3	1		2	
NCA 9	118	6	6			
NCA 10	14	10	1		6	3
NCA 11	23	9	6		1	2
NCA 12	6	0				
NCA 13	186	0				
NCA 14	50	6			3	3
NCA 15	38	8			5	3
NCA 16	32	8	3		5	
Total	**3,105**	**265**	**35**	**0**	**80**	**150**

In summary, the following unmitigated traffic noise impacts were identified:

- No mitigation was found to be required for 2,840 receivers (approximately 91% of all receivers)
- 265 receivers (9%) qualify for consideration of noise mitigation

8.1.1 Operational noise impacts - residential receivers

Most receivers found to qualify for the consideration of mitigation are located in the following regions of the study area:

- Properties immediately adjacent to The Northern Road, particularly between Jamison Road and Maxwell St, and Bickley Road and Aspen St. Operational noise at approximately 90% of these properties is predicted to exceed the cumulative limit i.e. exceed the relevant noise criterion by more than 5dB(A).
- Properties on the northern sides of Smith Street (west) and Maxwell Street, to which, operational noise levels are expected to increase by 2 dB(A) or more due to the proposal.
- Properties located most adjacent to the junction of the M4 Motorway and The Northern Road, particularly those situated adjacent to the M4 Motorway's eastbound on-ramp.

Many of the receivers identified as qualifying for mitigation directly front the existing The Northern Road and many are presently exposed to acute noise levels for either day or night periods.

In general, operational noise levels are predicted to comply with criteria at properties not fronting The Northern Road, the M4 Motorway, Maxwell Street or Smith Street.

The list of all receivers identified as qualifying for consideration of mitigation is presented in **Appendix A** and **Appendix I**.

The preferred mitigation options for each of these receivers are discussed in **Section 9**.

8.1.2 Operational noise impacts - non-residential receivers

Of the assessed non-residential receivers presented in **Section 5.2.2**, exceedances of the operational noise criteria have been predicted at the following properties:

- Kingswood South Public School – Operational noise impacts to the school would result from increased noise from The Northern Road and Smith Street. Noise levels at this property are predicted to exceed criteria under both the Build and No Build scenarios.
- Kingswood High School - Operational noise levels to Kingswood High School are predicted to exceed the NCG criteria primarily at two locations as a result of traffic increases on both Bringelly Road and The Northern Road.
- Montgrove College: Traffic increases on Bringelly Road and the proposal both contribute to likely exceedances of external criteria on most facades facing these roads.
- Penrith Christian School: Impacts at Penrith Christian School are predicted along several southern and western building facades. In general, the school's layout situates less acoustically-sensitive buildings (eg, gymnasium and workshops) nearest roads such that they shield the more sensitive uses such as classrooms (refer **Figure 4-1**).

  Exceedances have been predicted for all the following building facades:

  - Primary school classrooms (Building 4) – southern facades at western end of building
  - Infants school classrooms (Building 5) – southern and western facades
  - Sports centre (Building 6) – south-western facade

- Library (Building 7) – south-western facade
- Music and arts rooms (Building 9) – eastern and northern facades

- Some habitable spaces of Imagine Nations Church located in the south of the Penrith Christian School
- Mary McKillop High School: minor exceedances have been predicted for eastern and some southern facades
- Penrith Anglican College: Forecast traffic increases on Wentworth Road may result in traffic noise exceeding NCG criteria on several building facades. This impact is focused on the western buildings although there are some minor exceedances on eastern facades
- Jehovah's Witnesses: exceedances are predicted for most facades of this building resulting from noise contributions from both the proposal and the increase in traffic volumes on Homestead Road.

Schools (other than the Penrith Christian School) and churches have been assessed on assumption that the insertion loss of the building facade with windows open (as may be required for ventilation) is 10 dB(A). Where such spaces include manual ventilation and windows can remain closed, higher facade insertion loss values may apply, and therefore, internal noise levels may be found to comply with criteria. Further investigation of site specific facade reductions may be further investigated at the detailed design stage.

8.1.3 Operational noise impacts from other sources

Audio tactile pedestrian crossing devices

The following four intersection upgrades will involve the installation of audio tactile pedestrian crossing devices (audio-enabled pedestrian push buttons):

- The intersection of Glenmore Parkway and Wentworth Road
- The M4 Motorway interchange
- The intersection of Frogmore Road and Tukara Road
- The intersection of The Northern Road and Jamison Road

These units improve accessibility for hearing and vision impaired people by signaling safe crossing times by emitting vibration and audible signals at times of safe crossing. The audible signal can, however, impact the acoustic amenity of nearby receivers.

Noise management strategies presented in the RMS's management framework may be implemented to mitigate these noise impacts. An investigation of these noise management strategies would need to be undertaken to determine the most appropriate management measure.

The assessment method in that document requires the assessment of the potential for impact on sleeping areas located within 18 m of each device. Where impacts are found to exceed an external noise level of 60dB(A) L_{Amax} at the nearest sleeping areas, remedial action may be required. The noise management strategies available in the RMS's management framework include:

- Noise barriers and boundary fences
- Architectural acoustic treatment of noise sensitive receivers
- Restriction of operation of the audio signal
- Volume adjustment

Nine properties have been identified to be situated within 18 m of the aforementioned intersection upgrades, and all of these properties have been recommended for property treatments which will improve the noise reduction provided by the existing building facades, further reducing the level of noise within the dwelling from outside sources.

It is recommended that potential impacts upon dwelling sleeping areas within 18m of each proposed unit be assessed further during the detailed design stage. This investigation may identify the location of sleeping areas in each building and may determine the effectiveness of site specific property treatments or provide a response in accordance with the audit procedure in the management document.

9. Mitigation of operational noise impact

This section identifies options for the mitigation of the operational noise impacts predicted for the 265 receivers identified in **Section 8**. The consideration of mitigation is undertaken consistent with the NMG.

9.1 Additional noise mitigation option: low noise pavement

The use of low-noise pavements is a preferred form of noise mitigation on road proposals as its use has the potential to benefit the largest number of receivers. The use of Open Graded Asphalt or Stone Mastic pavements can reduce noise levels by -2 dB(A) compared to Dense Graded Asphalt.

The NMG specifies that low noise pavement may be considered subject to its acoustic benefit being able to be conferred to groups of four or more closely spaced properties. (The NMG formally defines the concept of “closely-spaced”).

Engineering constraints limit the use of low noise pavement along the proposal corridor due to the number of traffic lights and their potential causation of stop-start traffic as well as considerations relating to constructability, debris-management, maintenance, and traffic switch requirements. These issues will negate the potential acoustic benefit of using low-noise pavement, such that it cannot be considered a reasonable mitigation measure for this proposal.

9.2 Additional noise mitigation option: noise barriers

The feasibility and reasonableness of noise barriers as a form of mitigation for each of the 265 mitigation-eligible receivers considered their spatial dispersion in relation to each other, property access requirements and the source of traffic noise in accordance with the NMG.

The assessment found that noise barriers would not be feasible alongside the following roads due to the need to preserve property driveway accesses:

- Jamison Road
- The Northern Road between Jamison Road and Smith Street
- Smith Street
- The Northern Road between Smith Street and Maxwell Street
- Montgrove College on Bringelly Road
- Maxwell Street, and
- Tukara Road.

The assessment also found that barriers would not present as a reasonable form of mitigation alongside the following roads due to benefiting receivers being too spatially dispersed:

- Cross Road,
- Wentworth Road and
- Homestead Road.

The assessment then investigated opportunities to apply barriers in regions of closely-spaced, mitigation-eligible receivers where, in general, no constraints on engineering feasibility exist.

Dedicated, iterative modelling was undertaken in accordance with the NMG to determine the viability of barriers at the following locations:

- **Kingswood South Primary School**

  Operational noise impacts to the school would result from traffic noise contributed by both Smith Street and sections of The Northern Road west and south of the school. Except for a short section of tie-in works, the project boundary does not extend into Smith St (west), and as such, a noise barrier cannot be provided by the proposal.

  Removing all noise from either of these roads would still leave facades facing other roads requiring treatment. Any wall along The Northern Road would not be expected to provide any substantial benefit to southern facades and western facades located to the east of the school.

  Additionally a wall running along the southern site boundary was also found to be ineffective in reducing traffic noise by any substantial margin.

  As such, mitigation by means of noise barriers is not a reasonable treatment option for this property. Mitigation options for Kingswood South Primary school should be investigated further at detailed design phase pending investigation of the noise reduction achieved by building facades.

- **Penrith Christian School**

  Operational noise impacts to Penrith Christian School would result from noise contributed by the future traffic volumes on The Northern Road, the M4 Motorway and the eastbound M4 Motorway on-ramp. There are two aspects to the impact: a small increase in noise level; and a continuation of the existing noise level that already exceeds road noise criteria.

  Several noise barrier options were considered for the school. However, none of these – including a barrier extending from Simeon Road to the northern end of The Northern Road / M4 Motorway southbound slip lane – would mitigate all exceedances of noise criteria at eligible receivers.

  A noise wall with a maximum height of eight metres was found to bring too few receivers into compliance with traffic noise criteria, and as such a noise wall is not considered an effective form of treatment at this property. A lower barrier height, while also not sufficient to achieve compliance with noise criteria, may be able to address the predicted noise level increase from the proposal only.

  At-property treatments would potentially deliver more effective noise mitigation for each qualifying receiver. Preliminary site investigations indicate that the construction type of the qualifying receiver buildings could limit the effectiveness of at-property treatments for the school.

  To determine the most effective type of noise mitigation, further consultation with Penrith Christian School and specific examination of the construction of the qualifying buildings is required prior to or during detailed design. The findings of such assessment could be used to finalise a preferred noise mitigation treatment for road noise at Penrith Christian School.

- **Six properties on Nardi Terrace overlooking The Northern Road**

  Properties at this location are exposed to traffic noise contributed from both the proposal and Bringelly Road. All noise barrier options – including a barrier to the eastern side of the proposal extending north from Castle Road to Bringelly Road – would bring fewer than half of the impacted properties into compliance with noise criteria. As such a noise wall is not considered a reasonable or feasible form of treatment at this site.

Iterative noise modelling resolved that noise barriers could provide an effective form of treatment for receivers in close proximity to the following road sections:

- Eastbound off ramp of the M4 Motorway (north west of M4/The Northern Road junction)
- On the western side of the proposal between the M4 Motorway and Powys Close
- On the western side of the proposal between Tukara Road and Aspen Street (ie, Flavel St residences)

Additional noise modelling was undertaken to optimise the horizontal and vertical extents of noise barriers for these locations in accordance with the guidance provided in the NMG. These barrier design analyses are presented in **Appendix J**, and are summarised below.

9.2.1 Proposed M4 Motorway eastbound off-ramp-to-Powys Close noise barrier

Predicted criteria exceedances at receivers in Pebworth Place, Bickley Road (east) and Powys Close are determined by noise contributions from the proposal. Exceedances at the northern-most of these receivers results also due to noise contributed from Tukara Road. Similarly, predicted exceedances at the southern-most of these receivers are predicted to result also from noise contributed by the M4 Motorway and its eastbound off-ramp.

The optimal horizontal extent for a barrier that mitigates noise to all of these impacted properties was found to extend from the western end of the M4 eastbound off- ramp to Tukara Rd. This wall has a footprint length of 838 metres.

Once the potential acoustic benefits to the wider community had been considered, the NMG optimised height for this noise wall was found to be 5.0m.

Figure 9-1 Horizontal extent of proposed noise wall at M4 Motorway to Powys Close (noise barrier shown over existing, not future, road alignment)

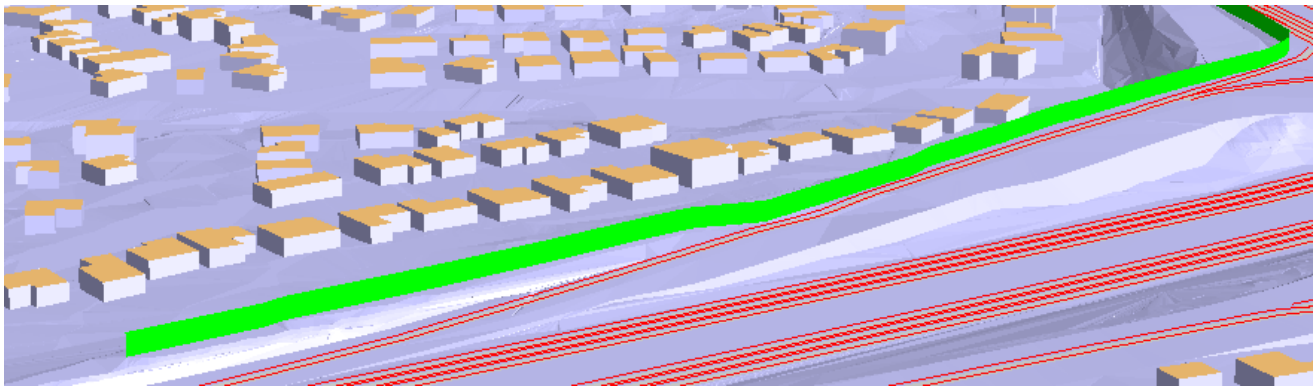

Figure 9-2 : Southern end of M4 to Powys Close barrier (view from south)

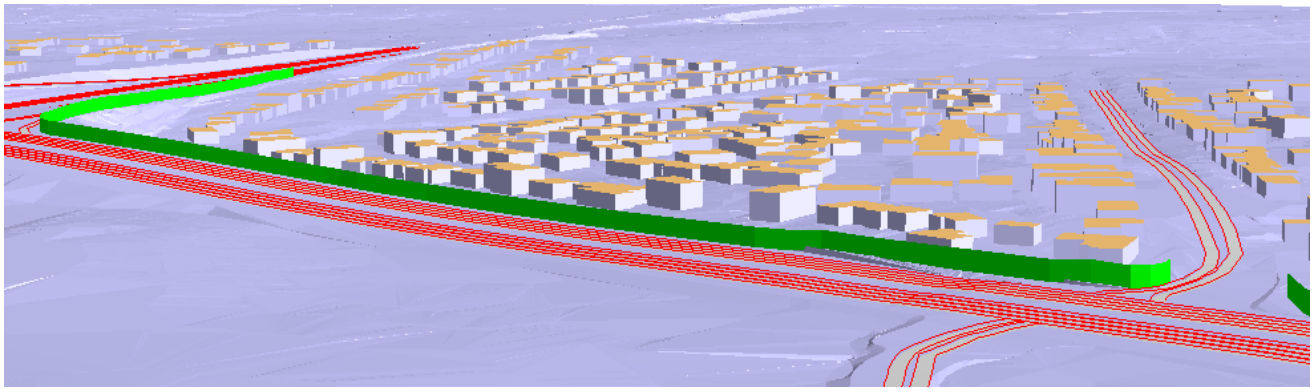

Figure 9-3 Northern end of M4 to Powys Close barrier (view from east)

9.2.2 Proposed Tukara Road-to-Aspen St noise barrier

Predicted exceedances of the operational noise criteria at receivers in Flavel St are determined by noise contributed by the proposal. Operational noise impacts at receivers located at the western end of Tukara Road arise also due to the noise contributed by Tukara Road.

The optimal horizontal extent for a barrier that mitigates noise to all of these impacted properties was found to extend north from Tukara Road to Aspen St. This wall has a footprint length of 460 metres.

Once acoustic benefits to the wider community had been factored in, the NMG optimised height for this noise wall was found to be 5.0m.

Figure 9-4 Horizontal extent of proposed Tukara Road to Aspen Street noise barrier

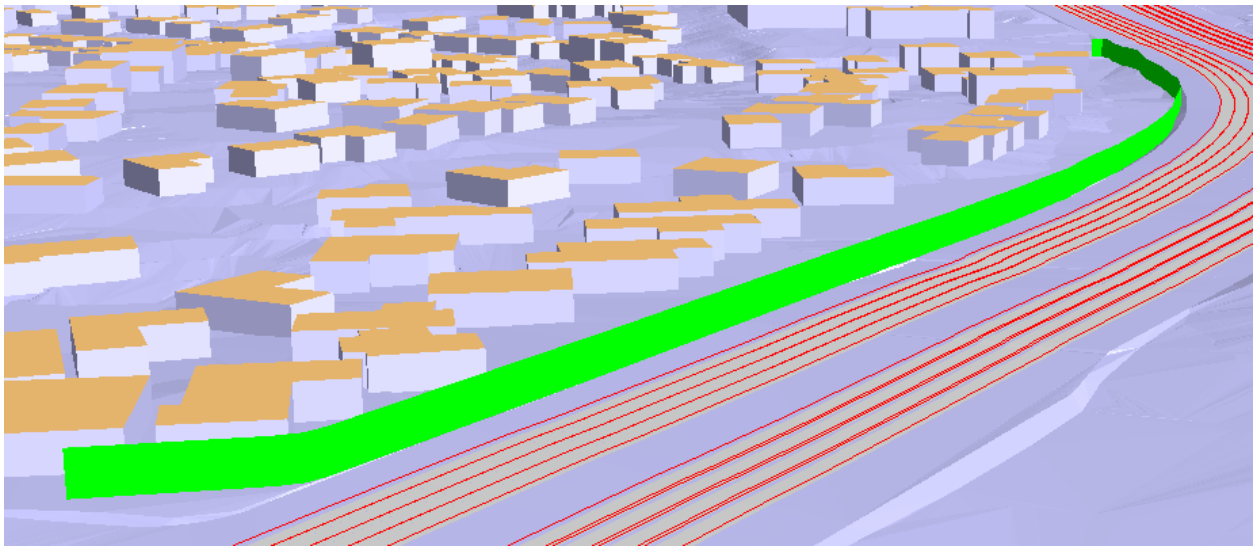

Figure 9-5 : Southern end of Tukara Road to Aspen Street barrier (view from south east)

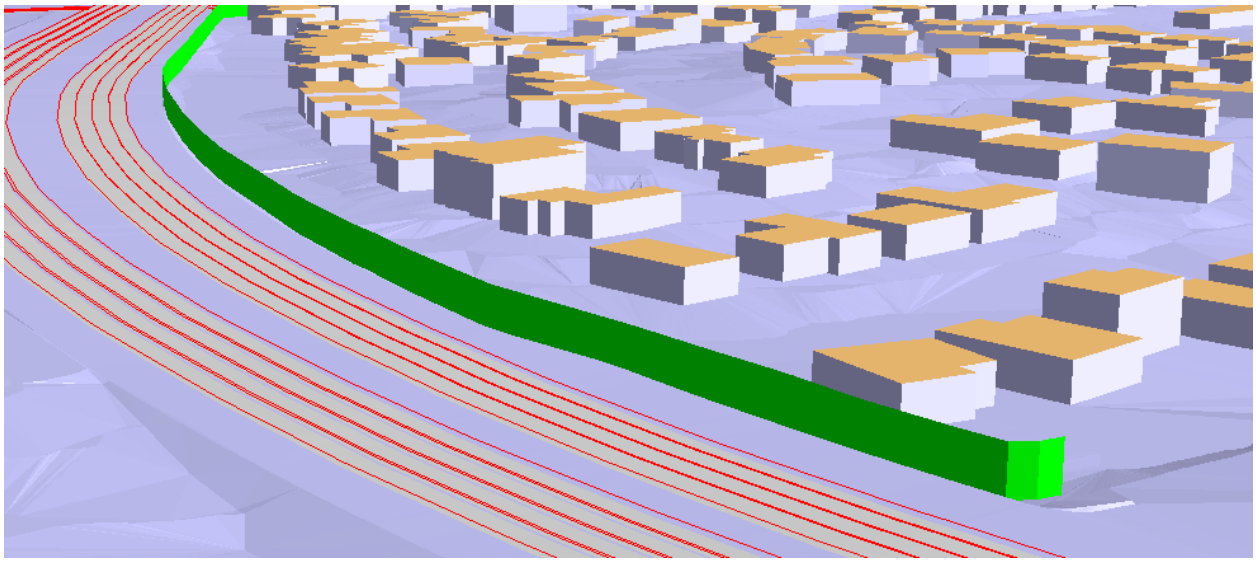

Figure 9-6 : Northern end of Tukara Road to Aspen Street barrier (view from north east)

The final extent and form of both proposed noise barriers would be determined at the detailed design stage once other factors such as urban design, community preferences and traffic and road engineering considerations (eg, wind loading and drainage) have been resolved.

9.3 Additional noise mitigation option: at-property treatments

Where mitigation could not be effected by noise barriers, noise impacts at mitigation-eligible dwellings would be mitigated using at-property treatments. The objective of this form of mitigation is to achieve noise reduction from outside to inside that would achieve an internal noise level within a habitable room at least 10dB(A) below external noise goals.

The specific form of acoustic building treatment applied to achieve these reductions is determined on an individual basis in response to the existing construction of the dwelling. Building element treatments are more effective when applied to masonry structures than to lightly clad timber frame structures. Caution should be exercised before providing treatments for buildings in a poor state of repair, as they may be less effective in these cases and may not provide any appreciable noise reduction benefit.

Any treatments proposed would be considered in consultation with the landowner.

The NMG identifies that the treatments provided by the Roads and Maritime would be limited to:

- The installation of courtyard screen walls
- Fresh air ventilation systems that meet Building Code of Australia requirements with the windows and doors shut
- Upgraded windows and glazing and solid core doors on the exposed facades of masonry structures only (these techniques would be unlikely to produce any noticeable benefit for light frame structures with no acoustic insulation in the walls)
- Upgrading window and door seals and treatment of sub floor ventilation
- The sealing of wall vents
- The sealing of the underfloor below the bearers

- The sealing of eaves.

At-property treatments are considered the most reasonable form of noise mitigation for the 223 receivers still requiring mitigation after the acoustic benefit of the proposed noise barriers has been accounted for. All receivers identified as requiring at-property treatments are indicated in **Appendix M**.

Further assessment of individual dwellings and consultation with landowners will be required to identify the specific acoustic treatments to be applied to each of these dwellings.

9.4 Noise assessment sensitivity analysis

A sensitivity analysis of the assessment outcomes was undertaken in order to assist in deciding potential changes in the level of mitigation that occur due to potential variations in the speed or mix (light/heavy vehicles) of traffic using the proposal road in future.

A sensitivity factor of between 0.5 - 2.0 dB(A) has been added iteratively to all predicted noise levels. Increasing sensitivity by 1 dB(A) allows for an increase in speed of approximately 15 km/h to 20 km/h or a corresponding increase in heavy vehicle volumes of approximately 15 to 20 percent for the upgraded sections of the proposal respectively.

Figure 9-7 indicates the change in the number of at-property treatments that would be recommended by this assessment if 0.5 dBA is added to or subtracted incrementally from the assessment's noise level predictions.

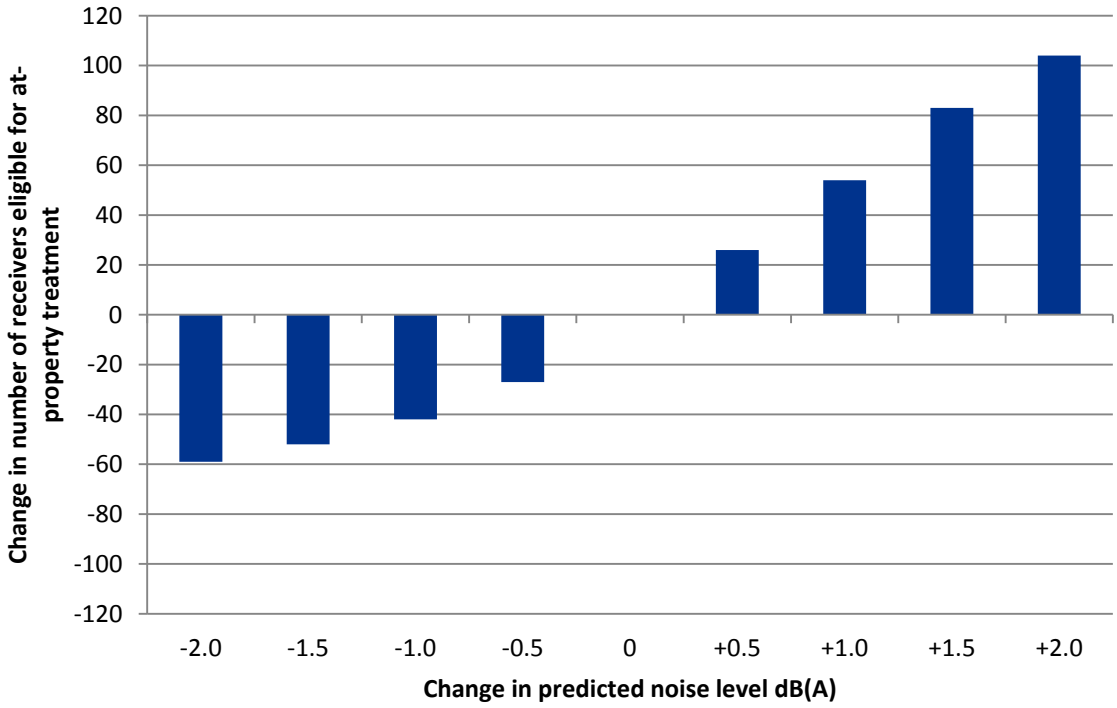

Figure 9-7 Noise assessment sensitivity analysis

This analysis demonstrates that where +2dB(A) is added to all noise level predictions, the number of receivers qualifying for at-property treatment (assessed as 223) would increase by 104 to a total of 327 receivers (an increase of 47%). Where 2dB(A) is subtracted from all predicted noise levels, the number of at-property treatments would reduce to 164, a reduction of 59 receivers (26% reduction).

9.5 Maximum noise level assessment

The potential for sleep disturbance from the project is assessed by considering the frequency and extent of maximum noise level events during night periods (as detailed in **Section 5.3**) and whether the proposal will change (increase) these events.

The assessment is neither definitive nor acts as a trigger for mitigation, but can assist in *prioritising* noise mitigation options.

The assessment of maximum noise level considers both:

- maximum noise levels captured in the assessment's background noise monitoring data for night time periods (**Section 4.4**), and
- the proposal's projected number of heavy vehicle events (discussed in **Section 7.3**).

9.5.1 Assessment of maximum noise events based on background monitoring data

The assessment considers maximum noise level events from night time heavy vehicle passbys and the extent to which they exceed the hourly L_{Aeq} noise level for each hour of the night, that is:

where both $L_{Amax} - L_{Aeq(1\ hour)} \geq 15$ dB(A) and L_{Amax} noise >65dBA

The assessment of prevailing maximum noise events presented below is based on the night time traffic noise data acquired from noise monitoring location 1 (refer Figure 2.1). This dataset was chosen for the assessment as the monitoring location best reflects the exposure of receivers likely to be most impacted from the proposal's night time traffic movements.

The extent and distribution of noise events greater than 65 dB(A)L_{Amax} in a typical night period currently on The Northern Road are indicated in **Figure 9-8**.

The number of emergence events during a typical night are indicated in **Figure 9-9**.

The typical number of "maximum noise level events" on the existing The Northern Road are indicated in **Figure 9-10**.

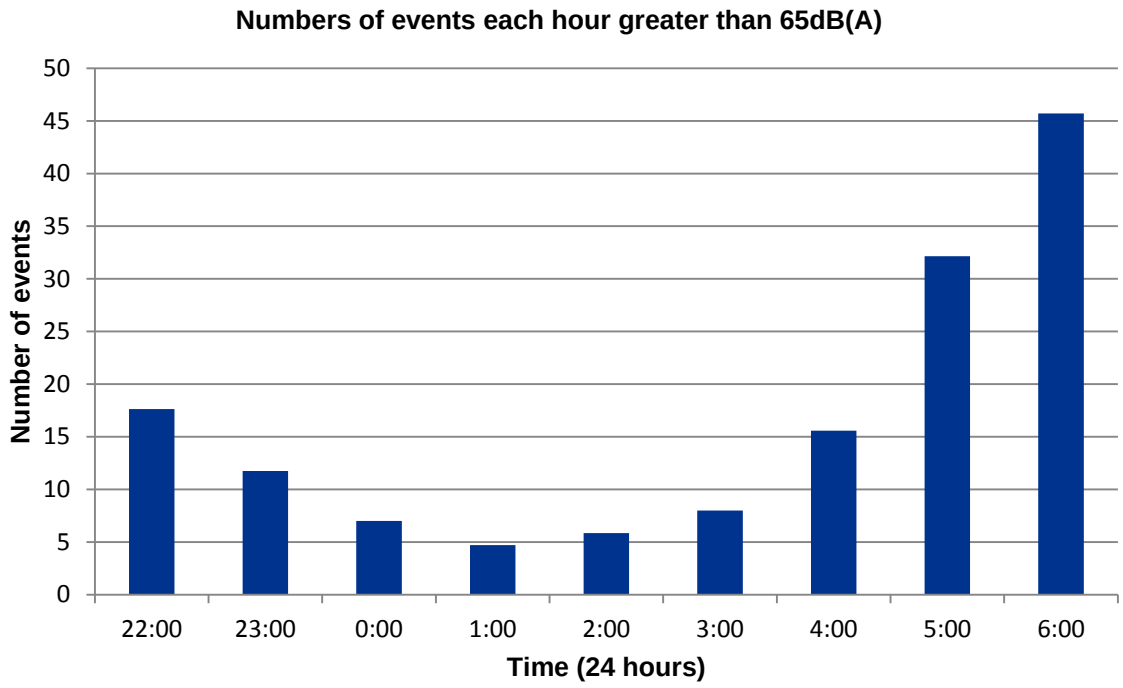

Figure 9-8 Typical number of night time noise events greater than 65 dB(A)L_{Amax}

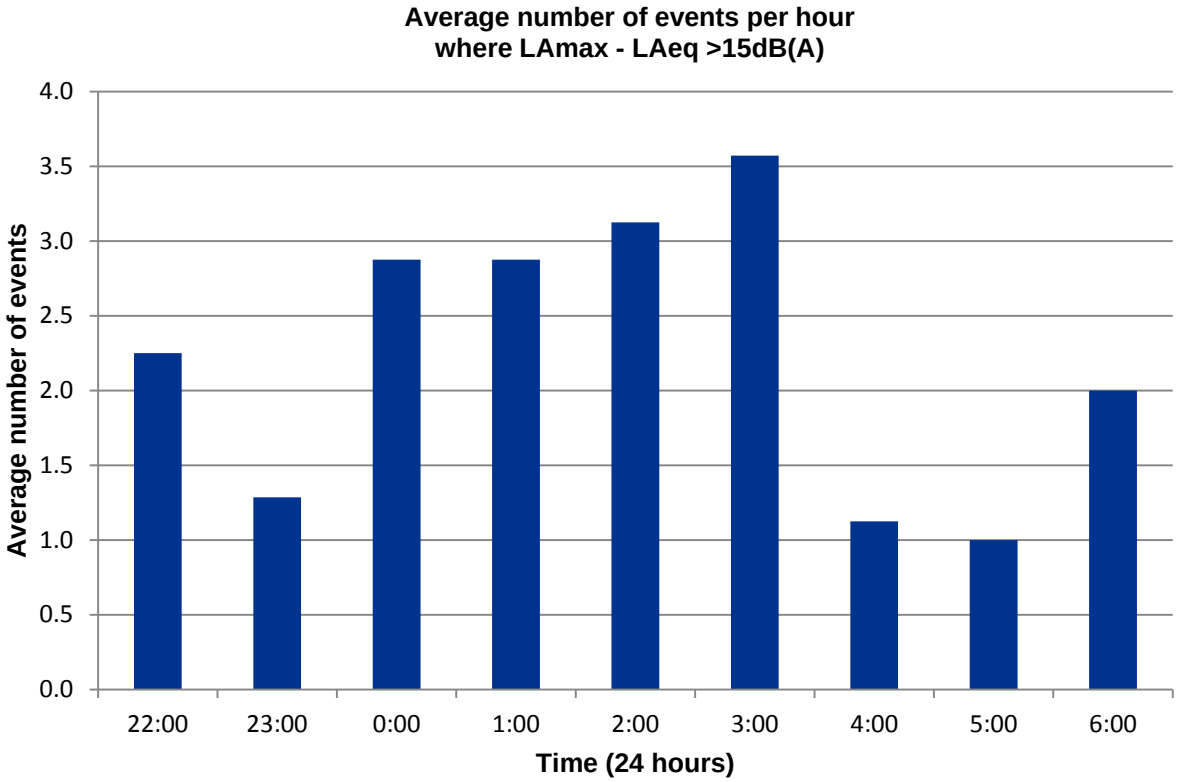

Figure 9-9 Typical number of events for which L_{Amax} >65 dB(A) and $L_{Amax} - L_{Aeq}$ ≥15 dB(A)

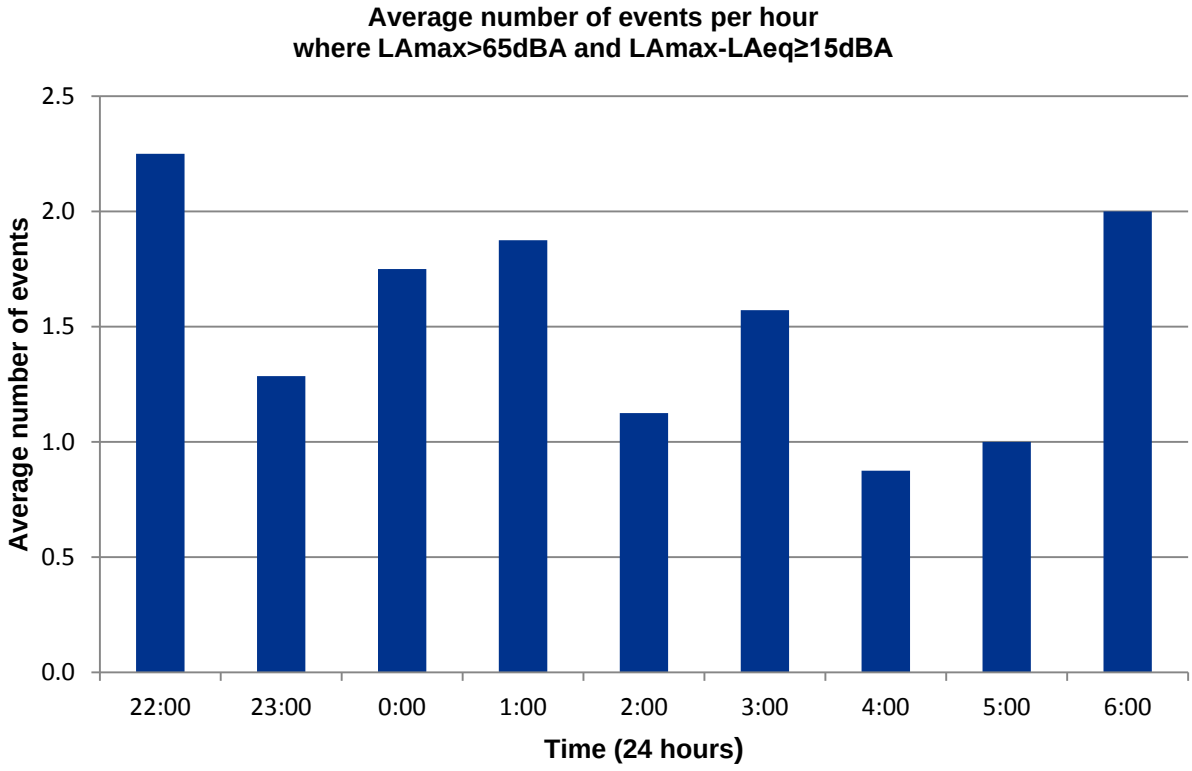

Figure 9-10 Typical number of events for which L_{Amax} >65 dB(A) and $L_{Amax} - L_{Aeq}$ ≥15 dB(A)

Figure 9-10 indicates that the typical prevailing number of maximum noise events on The Northern Road occur between 10pm – 1pm and 6am-7am. Most receivers will be located further from the road than noise monitoring location 1, and as such are likely to be exposed to fewer and lower maximum noise events than are presented in **Figure 9-10**.

9.5.2 Assessment of maximum noise events based on modelled traffic volumes

Analysis of night time L_{Amax} noise levels captured as part of the assessment's background noise monitoring (**Section 4.4**) indicated the sound power level for a typical worst case heavy vehicle passby on The Northern Road to be 119 dB(A)L_{Amax}.

Based on this information, and on the proposal's projected future heavy vehicle movements, **Table** 9-1 indicates how maximum noise events are likely to change by the design year (2031) of the proposal.

The analysis in **Table 9-1** uses as a baseline condition, the number heavy vehicles expected at project opening (year 2021) operating on the existing The Northern Road alignment. This approach allows for comparison of a consistent traffic dataset and also for any change in distance from truck passbys due to changes in road alignment. This approach is sufficient to indicate whether the proposal will increase or decrease the number of maximum noise events into the future. This analysis is used in conjunction with the information provided in **Section 9.5.1** to determine whether, overall, the project will increase or decrease the number of night time maximum noise events.

Table 9-1 Projected number of night time Maximum Noise Events due to the Proposal

NCA	Existing Alignment / 2021 Volumes				Upgraded Alignment / 2031 Volumes			
	L_{Amax} Trucks	Projected Truck Count	$L_{Aeq\ (1hr)}$	L_{Amax}- $L_{Aeq\ (1hr)}$	Modelled L_{Amax} Trucks	Projected Truck Count	$L_{Aeq\ (1hr)}$	L_{Amax}- $L_{Aeq\ (1hr)}$
1	70	15	55	15	70	23	59	11
2	87	15	66	21	89	23	68	21
3	94	15	66	28	94	23	67	27
4	74	15	59	15	75	23	64	11
5	72	29	58	14	72	43	65	7
6	91	29	70	21	94	43	72	22
7	72	29	58	14	75	43	60	15
8	66	29	53	13	67	43	56	11
9	66	70	56	10	65	83	60	5
10	75	70	66	9	75	83	70	5
11	69	70	66	3	71	83	69	2
12	59	70	59	0	59	83	66	0
13	61	23	62	0	61	59	68	0
14	80	23	63	17	81	59	67	14
15	76	27	63	13	77	43	65	12
16	57	27	54	3	57	43	58	0

Table 9-1 (refer columns 5 and 9) indicates that the number of predicted maximum noise events will decrease in 2031. However, this outcome results primarily as the baseline $L_{eq,1hour}$ noise levels from

which maximum noise events are calculated increase significantly in 2031. Notably, the predicted number of heavy vehicle movements will increase in 2031 compared to the 2021 case.

As indicated in **Section 2.1**, the proposal will introduce new signalised intersections at both:

- The Northern Road intersection with Glenmore Parkway and Wentworth Road, and
- The Northern Road intersection with Frogmore Road and Tukara Road.

While, the operational noise barriers proposed in the vicinity of the Frogmore Road/Tukara Road intersection would provide acoustic attenuation for most (but not all) receivers west of this intersection upgrade, the introduction of these signalised intersections would be expected to increase the number braking and acceleration noise at nearby residences, the two most common causes of maximum noise level events.

In consideration of all factors, it is expected that the proposal will increase the number – and in some cases, the magnitude of - maximum noise events.

10. Construction noise assessment

10.1 Overview

The effects of construction noise on the community relate to the type, timing and duration of the works, existing background noise level, and the intensity and character (eg, whether a constant or impulsive noise) of the noise from the works. This section outlines the assessment of noise from construction of the proposal in accordance with the Roads and Maritime Construction Noise and Vibration Guideline (CNVG). Where impact is predicted, "reasonable and feasible" noise mitigation is outlined in **Section 10.11**.

10.2 Principles for managing construction noise

The CNVG outlines the following principles which are to be applied when reviewing and assessing construction noise, vibration and construction traffic:

- Good engagement with the community will be maintained to facilitate effective proposal delivery with consideration of community impact, including procedures for notifying residents, business owners and other sensitive receivers, of any noise- or vibration-intensive construction activities likely to affect their amenity.
- Construction noise and vibration levels at sensitive receivers will be minimised where feasible and reasonable.
- Feasible and reasonable mitigation will reflect the time of day, and the degree and duration of the impact.
- The community will be informed of the dates for the intended works, sequencing and timing of noisy events. Where possible this will include an indicative schedule over a 24 hour period.
- Minimising construction noise and vibration will be viewed as a continuous improvement exercise that is inclusive of stakeholders where no idea is too small to be considered.
- Staff and community will be informed of the effort and methods undertaken to reduce noise and vibration for the works.
- Any operational noise and vibration improvements resulting from the works will be promoted to the community.

The CNVG pursues these principles by outlining how Noise Management Levels (NMLs) may be determined for a construction proposal and identifying feasible and reasonable noise mitigation options where construction noise levels are predicted to exceed these NMLs.

10.3 Proposed works

It is expected that the proposal would be constructed over a 2 year period, and incorporate the following main construction phases (staging durations are indicative only):

- Demolition and earthworks, including vegetation clearance and stripping (indicatively, lasting 6-9 months)
- Roadworks, including placement and compaction of sub-base course and base course on new areas of road surface (indicatively, 4-6 months)
- Pavement works, including construction of pavement and median (indicatively, 6 months)
- Drainage (including culverts) and utilities works (indicatively, 4-6 months)

- Works relating to the installation of the M4 Motorway bridge (indicatively, 8-12 months)

This basic construction methodology will be refined and updated by the contractor during the detailed design phase.

Construction stages involving rockbreakers or concrete saws have the highest potential to generate noise impacts. As a standard management measure the operation of such plant would be contained to daytime periods where feasible.

The prediction of noise from each of the construction stages is presented in Section **10.11**.

10.4 Ancillary facilities

Preliminary proposed ancillary locations and uses are provided below in **Table 10-1** and **Figure 10-1**. Exact locations and proposed use of ancillary sites would be confirmed by the construction contractor before the start of construction. Further information on these sites is provided in Section 3.4 of the REF.

Table 10-1 Ancillary facilities and likely use

Site Reference	Location	Proposed activities and operating hours
1	South of Wentworth Road (Lot 2 DP 711076)	Daytime operations 7am to 6pm: • Recycled concrete stockpile area • Plant and equipment parking area • Material laydown and storage area
2	South of Wentworth Road, corner of The Northern Road (Lot 40 DP 853672)	• Materials laydown and storage • Delivery of materials • Loading of material into tipper trucks for delivery to site
3	North of Wentworth Road (Lot 5 DP 548308)	Daytime operations 7am to 6pm: • Office, crib sheds, parking, first aid post, daytime deliveries • Arrival and departure of office staff, workforce and daytime deliveries to compound • Plant storage, materials laydown and storage, stockpiling and construction parking • Delivery of excavated material from site by tipper trucks • General stockpile management and loading of final product into tipper trucks for delivery to site • General delivery of other construction materials for storage. • Evening and night operations: • Arrival and departure of workforce and night time deliveries to compound • Loading of material into tipper trucks for delivery to site.
4	South of M4 Westbound off-ramp (Lot 27 DP 238741).	Daytime operations 7am to 6pm: • Materials laydown and storage • Bridge elements storage area • Delivery of materials • Loading of material into tipper trucks for delivery to site • Temporary roadway area
5	South of Frogmore Road (Lot 11 DP 831409)	Daytime operations 7am to 6pm: • Materials laydown and storage • Delivery of materials • Loading of material into tipper trucks for delivery to site
6	North of Frogmore Road (Lot (Lot 13 DP 831409)	Daytime operations 7am to 6pm: • Materials laydown and storage • Delivery of materials • Loading of material into tipper trucks for delivery to site.
7	Northern side of Castle Road, corner of The Northern Road (Lot 19 DP 1028818)	Daytime operations 7am to 6pm: • Materials laydown and storage • Delivery of materials • Loading of material into tipper trucks for delivery to site.

Site Reference	Location	Proposed activities and operating hours
8	In Kingswood Lions Park, north-east corner of Bringelly Road and The Northern Road (Lot 26 DP 247948).	Daytime operations 7am to 6pm: • Materials laydown and storage • Delivery of materials • Loading of material into tipper trucks for delivery to site.
9	North-west corner of Maxwell Street and The Northern Road (Lot 11 DP 236368)	Daytime operations 7am to 6pm: • Materials laydown and storage • Delivery of materials • Loading of material into tipper trucks for delivery to site.
10	North of Maxwell Street, to the west of The Northern Road (Lot 10 DP 236368).	Daytime operations 7am to 6pm: • Office, crib sheds, parking, first aid post, daytime deliveries • Arrival and departure of office staff, workforce and daytime deliveries to compound • Plant storage, materials laydown and storage, stockpiling and construction parking • Delivery of excavated material from site by tipper trucks • General stockpile management and loading of final product into tipper trucks for delivery to site • General delivery of other construction materials for storage. • Evening and night operations: • Arrival and departure of workforce and night time deliveries to compound • Loading of material into tipper trucks for delivery to site.
11	North of Smith Street, to the west of The Northern Road (Lot 11 DP220581 and Lot 12 DP220581)	Daytime operations 7am to 6pm: • Materials laydown and storage • Delivery of materials • Loading of material into tipper trucks for delivery to site.

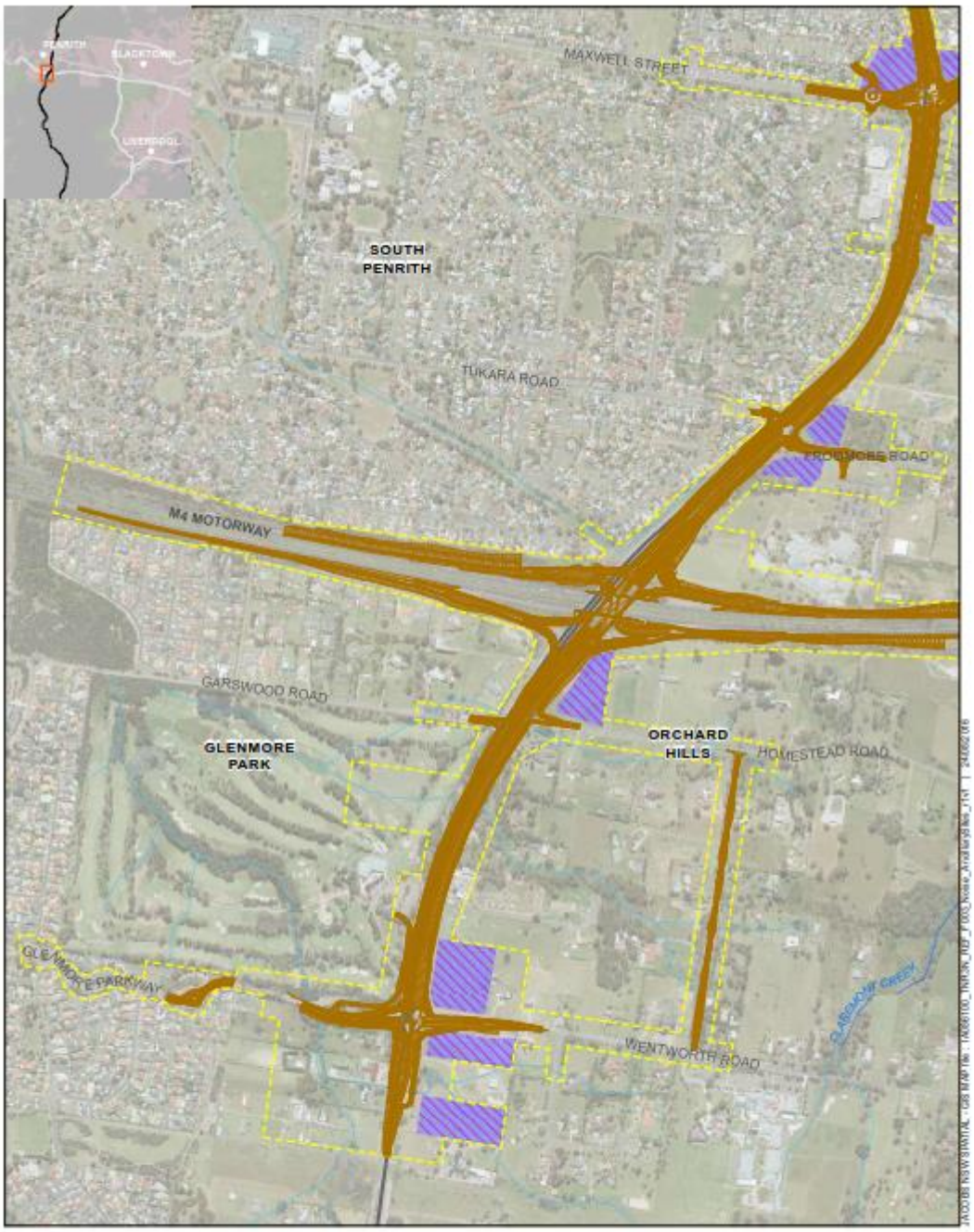

Figure 10-1a | Ancillary facilities - proposed locations

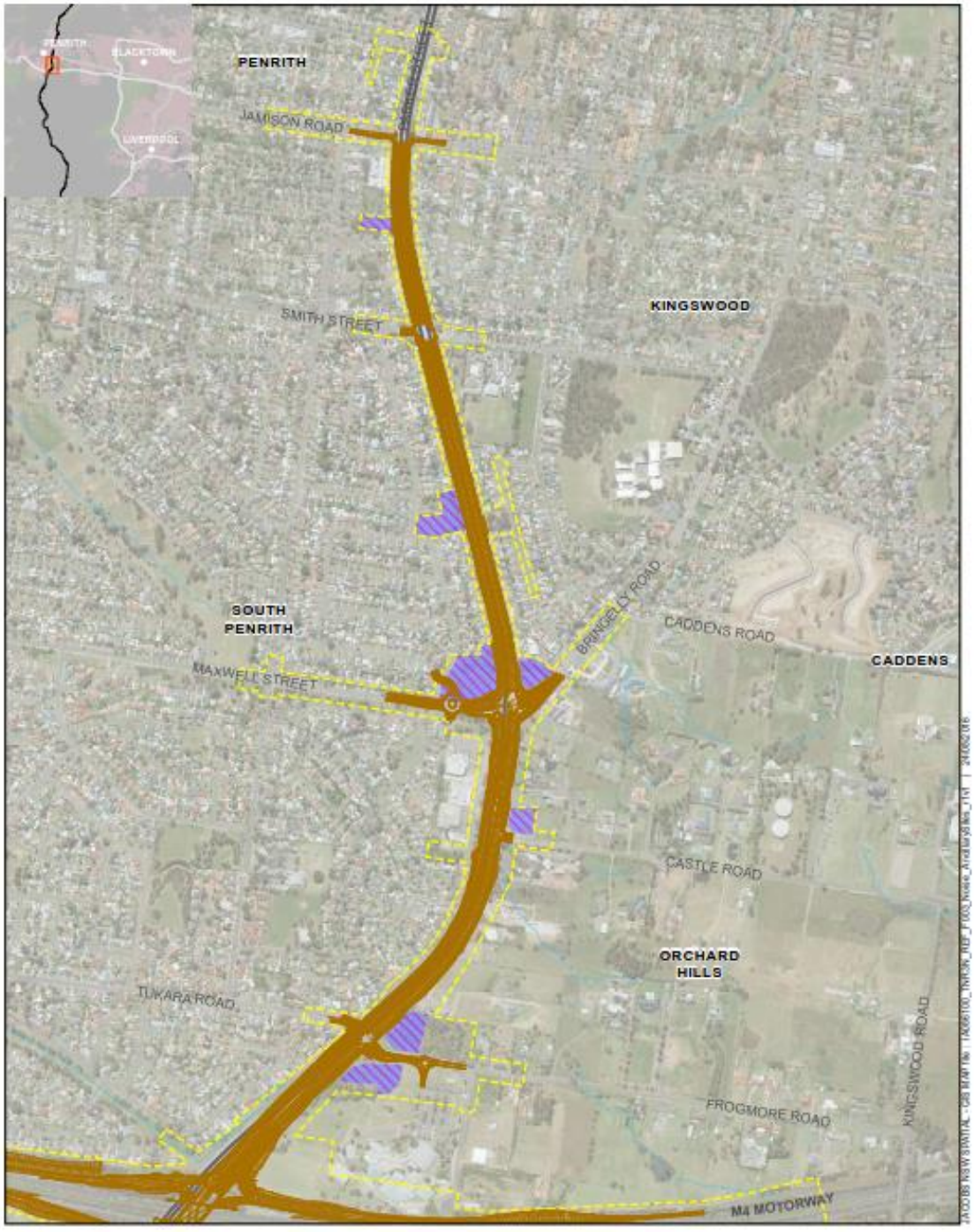

Figure 10-1b | Ancillary facilities - proposed locations

10.5 Construction Hours

Construction of the proposal would typically be contained to the hours indicated in **Table 10-2** where feasible and reasonable.

Table 10-2 Standard construction hours

Construction hours	Monday to Friday	Saturday	Sunday / Public holiday
Standard construction hours	7:00 to 18:00	8:00 to 13:00	No work
Activities with impulsive or tonal noise emissions	8:00 to 17:00	9:00 to 13:00	No work
Blasting	9:00 to 17:00	9:00 to 13:00	No blasting

Note: 1 Works may be carried out in continuous blocks not exceeding three hours each with a minimum respite from those activities and works of not less than one hour between each block. 'Continuous' includes any period during which there is less than a one hour respite between ceasing and recommencing any of the work the subject of this condition.

Some works would likely need to be undertaken during evening, night or weekend periods as may be required to ensure safe work practices or to avoid unacceptable impacts on traffic and disruptions to the road network.

10.6 Construction Noise Management Levels

The CNVG specifies that each sensitive receiver potentially impacted by construction of the proposal be assigned a Noise Management Level (NML). Non-residential receivers are assigned fixed-value NMLs, while the NML for each residential receiver is determined as an allowable exceedance above the level of background noise (refer **Section 4.4**).

Where construction noise is predicted to exceed these targets, the CNVG requires that all feasible and reasonable mitigation measures be applied.

10.6.1 Noise Management Levels for residential receivers

Table 10-3 outlines how NMLs are determined for residential receivers potentially impacted by noise from construction of the proposal. **Table 10-3** also outlines how receivers that may be 'highly noise affected' by the proposal's construction works may be identified. In such instances, restrictions to construction hours may apply to minimise these impacts.

Table 10-3 Construction Noise Management Levels (NMLs)

Time of day	Management level (NML) L_{Aeq} (15 min)*	How to apply
Recommended standard hours: • Monday to Friday 7.00am to 6.00pm • Saturday 8.00am to 1.00pm	Noise affected (RBL + 10 dB)	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured LAeq (15 min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices 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 the duration, as well as contact details.

Time of day	Management level (NML) L_{Aeq} (15 min)*	How to apply
• No Work on Sundays or public holidays	Highly noise affected (75 dB(A))	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 restricting the hours that the very noisy activities can occur, taking into account: 1. 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 2. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected (RBL + 5 dB)	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 practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community For guidance on negotiating agreements see Section 7.2.2 of the ICNG (DECC, 2009).

Source: Interim Construction noise Guideline (DECC 2009)

10.6.2 Non-residential receivers

For other land uses within the area of the proposal, the following noise criteria apply

- Industrial premises: external $L_{Aeq(15min)}$ 75 dB(A)
- Offices, retail outlets: external $L_{Aeq(15min)}$ 70 dB(A)
- Classrooms: internal $L_{Aeq(15min)}$ 45 dB(A)
- Places of worship: internal $L_{Aeq(15min}$ 45 dB(A)
- Active recreational areas; external $L_{Aeq(15min)}$ 65 dB(A)
- Passive recreational areas: external $L_{Aeq(15min)}$ 60 dB(A)
- Hospital wards: internal $L_{Aeq(15min)}$ 45 dB(A)

10.6.3 Construction traffic noise

Application notes for the RNP state that:

> *'…for existing residences and other sensitive land uses affected by additional traffic on existing roads generated by land use developments, any increase in the total traffic noise level as a result of the development should be limited to 2 dB above that of the noise level without the development. This limit applies wherever the noise level without the development is within 2 dB of, or exceeds, the relevant day or night noise assessment criterion.'*

This is also considered to apply to noise arising from construction activities. Hence a relative increase criterion of 2 dB(A) has been adopted for the assessment of construction traffic impacts associated with the proposal.

In general, there will be no re-routing of traffic required during the construction period. Occasional re-routing of small local roads may be required for short periods of construction, however no roads will be required to carry substantially increased traffic volumes.

Construction traffic mitigation measures are outlined in Appendix C4 of the RMS CNVG.

10.7 Sleep disturbance screening criterion

Guidance on the assessment of the potential for sleep disturbance within residences from night time construction works is taken from the *NSW Road Noise Policy* (RNP). The RNP provides the following sleep disturbance "screening criterion":

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

In order to account for the opportunity for residents to leave bedroom windows open for ventilation, the screening criterion is conventionally reinterpreted as the following external noise goal based on the accepted approach of assuming a bedroom facade with windows open to provide a noise reduction of 10 dB(A):

- maximum external noise levels below 60–65 dB(A) are unlikely to awaken people from sleep
- one or two noise events per night, with maximum external noise levels of 75–80 dB(A), are not likely to affect health and wellbeing significantly.

The sleep disturbance screening criterion adopted for this assessment is 65 dB(A) L_{Amax}.

10.8 Proposal specific construction Noise Management Levels (NMLs)

10.8.1 Noise Management Levels for residential receivers

The construction NMLs and sleep disturbance screening criterion for residential receivers adopted in this assessment are summarised in **Table 10-4.**

The NMLs are derived as an emergence allowance above the RBL (**Table 4-2**). As a conservative measure, the lowest of all RBLs within any one NCA has been used to determine the NML.

Table 10-4 Construction NMLs

NCA	Monitoring Location	Monitored RBL dB(A)				Allowance dB(A)			NML $L_{Aeq(15\ minute)}$ dB(A)				Sleep disturbance screening criterion L_{Amax} dB(A)
		Day	Day (OOH periods)*	Evening	Night	Day	Eve & Day (OOH)	Night	Day	Day (OOH)*	Evening	Night	
1	1	48	48	48	41	+10	+5		58	53	53	46	65
2	1	48	48	48	41				58	53	53	46	65
3	2	53	52	49	35				63	57	54	40	65
4	2	53	52	49	35				63	57	54	40	65
5	3	54	50	50	44				64	55	55	49	65
6	3	54	50	50	44				64	55	55	49	65
7	4	52	54	51	49				62	59	56	54	65
8	3	54	50	50	44				64	55	55	49	65
9	9	48	52	49	44				58	57	54	49	65
10	6	45	43	41	34				55	48	46	39	65
11	6	45	43	41	34				55	48	46	39	65
12	9	48	52	49	44				58	57	54	49	65
13	9	48	52	49	44				58	57	54	49	65
14	8	53	48	46	36				63	53	51	40	65
15	7	52	52	49	38				62	57	54	43	65
16	9	48	52	49	44				58	57	54	49	65

** Standard Hours are defined in Table 10-2. "Day (Out of Hours periods) refers to Saturday 1pm-6pm*

10.8.2 Noise Management Levels for non-residential receivers

Receivers have been separated into residential and non-residential and therefore the criteria outlined in **Table 10-3** will be used in conjunction with the criteria for offices/retail outlets identified within the proposal area. The location of schools and churches has been identified along the proposal corridor, and are shown in **Table 10-5**.

Table 10-5 Non residential areas within proposal area*

Receiver	Designation	Distance to alignment (m)	NML $L_{Aeq(15\ minute)}$**
Penrith Christian School (Classrooms)	Classroom	150	45dB(A) (internal)
Penrith Christian School (Playground/ fields)	Active recreation	50	65dB(A)
Hilliger Road Park	Active recreation	50	65dB(A)
Mazepa Park	Active recreation	50	65dB(A)
Penrith Golf Course	Active recreation	100	65dB(A)
Kingswood South Public School (Classrooms)	Classroom	40	45dB(A) (internal)
Kingswood South (Playground/ fields)	Active recreation	50	65dB(A)
Kingswood High School (Classrooms)	Classroom	330	45dB(A) (internal)
Kingswood High School (Playground/fields)	Active recreation	250	65dB(A)
Greenway Drive Park	Active recreation	600	65dB(A)
Oberon Crescent Park	Active recreation	200	65dB(A)
Penrith Anglican College (Classrooms)	Classroom	120	45dB(A) (internal)
Penrith Anglican College (Playground/ fields)	Active recreation	140	65dB(A)
Mary Mackillop Public School (Classrooms)	Classroom	300	45dB(A) (internal)
Mary Mackillop Public School (Playground)	Active recreation	320	65dB(A)
Samuel Foster Drive Park	Active recreation	580	65dB(A)
Stafford Street Park	Active recreation	300	65dB(A)
Butler Crescent Park	Active recreation	400	65dB(A)
Platypus Playground Childcare	Classroom	220	45dB(A) (internal)
Montgrove College	Classroom	150	45dB(A) (internal)
Nepean Hospital	Hospital ward	480	45dB(A) (internal)
Nepean Baptist Church	Place of worship	30	45dB(A) (internal)
Jehovahs Witnesses	Place of worship	40	45dB(A) (internal)
Church at the College	Place of worship	120	45dB(A) (internal)
ImagineNations Church	Place of worship	200	45dB(A) (internal)

* *Excluding commercial premises*

** *When in use*

10.9 Construction noise modelling

Prediction of construction noise levels at sensitive receivers was modelled using the Soundplan (Version 7.4) noise modelling software based on the CONCAWE prediction algorithm. This three-dimensional model accounts for noise source and receiver locations, ground and air absorption as well as any acoustic shielding provided by intervening topography and structures. Where relevant,

construction modelling parameters were held consistent with those used for the operational modelling outlined in **Table 7-1**.

10.10 Construction staging and proposed plant and equipment

The sound power level adopted for each item of plant and equipment in the modelling of construction noise has been prepared using information provided in Section 3.3.3 of the proposal REF and is indicated in **Table 10-6**. The schedule of plant and equipment to be used would be confirmed with the final construction program.

Table 10-6 indicates the periods of exposure to any particular activity any one receiver may expect. These periods will vary according to a receiver's set back and line of view to the works between buildings.

Table 10-6 Plant sound power levels used in the modelling of construction noise

Construction phase	Typical plant and equipment	Sound Power Level dB(A) $L_{Aeq(15min)}$
Stage 1a Demolition (indicative time of exposure to any one receiver: 1-2 weeks)	Jackhammer Concrete Saw Excavator (20T) Spoil Truck **TOTAL**	119 114 105 106 **125***
Stage 1b Earthworks (indicative time of exposure to any one receiver: 4-12 weeks)	Excavator (20T) Smooth barrel and pad foot rollers (x2) Water cart (16,000L) Truck and dog (x4) Grader (14G) **TOTAL**	105 105 107 110 112 **116**
Stage 2 Sub base preparation (indicative time of exposure to any one receiver: 4-12 weeks)	Truck and dog (x4) Smooth barrel and pad foot rollers (x2) Water cart Grader **TOTAL**	110 105 107 112 **115**
Stage 3 Paving (indicative time of exposure to any one receiver: 1-4 weeks)	Truck and dog (x4) Smooth barrel and pad foot rollers (x2) Paving machine Bobcat **TOTAL**	110 105 108 104 **113**
Stage 4 Culvert (indicative time of exposure to any one receiver: 2-12 weeks)	Mobile crane (150T) Franna Crane Smooth barrel and pad foot rollers (x2) Excavator (20T) Truck and dog (x2) Wacker packer Compressor Concrete truck and pump **TOTAL**	102 99 105 105 110 107 96 108 **116**

Construction phase	Typical plant and equipment	Sound Power Level dB(A) $L_{Aeq(15min)}$
Stage 5 Bridge installation (indicative time of exposure to any one receiver: 12-26 weeks)	Mobile crane (500T)	106
	Mobile crane (750T)	107
	Franna Crane	99
	Impact piling rig	115 (including screen)
	Concrete pump	105
	Compressor	96
	Concrete truck and pump (x4)	106
	Smooth barrel and pad foot rollers (x2)	105
	TOTAL	**122***

** Note: these levels include a 5dB(A) penalty for impulsive or annoying noise characteristics*

10.11 Predicted construction noise impact with standard mitigation applied

10.11.1 Standard noise mitigation measures

The CNVG outlines standard mitigation measures that should be incorporated by default in all construction projects. Those most relevant to the construction of the proposal are listed below. A Construction Noise and Vibration Management Plan (CNVMP) would be prepared in consultation with relevant stakeholders prior to commencement of construction. The CNVMP would identify the main sources of noise impact, describe the measures to be taken to minimise the risk of specific adverse impacts, provide procedures for consultation with and notification of the community, address complaints and monitor noise impacts throughout the duration of the proposal

Viable mitigation measures that could be expected to be deployed by the construction contractor once the final construction sequencing and scheduling is known include:

- Restricting works to standard construction hours as far as practicable, considering safety and traffic management requirements, and timings agreed upon during community consultation
- Erecting temporary acoustic hoarding to reduce noise form works within a confined area such as site compounds or long-term drainage works.
- Deploying mobile hoardings (eg, acoustic screen curtains mounted on a wheeled trailer) to track moving, but tightly-contained processes.
- Selecting quieter construction methods, and where such are not available, opting for quieter plant and equipment, using only the necessary equipment power and size required
- Adoption of quieter methods of construction where reasonable and feasible
- Avoiding the use of noisy plant equipment simultaneously and close together where practicable
- Minimising the number of consecutive nights of works adjacent to any particular set of receivers
- Scheduling works for times outside of heightened sensitivity for the impacted receiver, eg, outside of school hours
- Scheduling respite periods for noise-intensive processes undertaken near receivers, e.g. limiting operation of pavement sawing to three hours at a time
- Planning any out of standard construction hours works so that noisier works are carried out in the earlier part of the evening or night time
- Maximising offset distances between receivers and noisy plant or activities

- Orientating plant and processes away from residences
- Restricting heavy vehicle movements, heavy deliveries and loading and unloading processes to daytime periods and to areas well away from receivers
- Limiting the use of vehicles compression brakes to daytime and away from receivers, and ensuring vehicles on site are fitted with a maintained exhaust silencer
- Regularly maintaining and monitoring plant and equipment to ensure that their noise emissions are not excessive
- Minimising the annoyance from reversing alarms by either fitting closed circuit monitors or non-tonal reversing alarms ("quackers") on vehicles or deploying 'spotters' to oversee reversing movements. Sites should be designed to minimise or remove the need for plant to undertake reversing maneuvers.
- Reducing throttle settings and switching off equipment when not being used.

The feasibility of applying these measures would be assessed as part of the CNVMP once the construction program is known.

10.11.2 Proposal-specific mitigation measures

The following proposal-specific mitigation measures could reasonably be expected to be implemented for construction of the proposal and have been included in the noise modelling:

- Restricting the following construction stages (refer **Table 10-6**) to standard hours only:
  - Demolition works (Stage 1a)
  - Earthworks (Stage 1b)
  - Sub-base preparation (Stage 2)
  - Culverts (Stage 4)
- Restricting crushing and rockbreaking to standard hours where feasible, unless it can be demonstrated that sensitive receivers will not be impacted.
- Restricting impact piling to standard, daytime hours even though the contractor may elect to undertake the remaining, quieter elements of Bridge construction (Stage 5) works during evening or night periods. In addition it is recommended that temporary screening is placed around impact piling sites. Any such screen should be positioned, and of a height to at least interrupt the line-of-sight to the piling impact point from all noise-sensitive receivers. Noise modelling has assumed the level of noise reduction from the mitigation technique would be 7 dB(A).
- Installing 2.5m-high perimeter hoarding to all sides and gates of all 11 site compounds so as to interrupt the line-of-sight to ground-based construction activity within compounds. This measure will reduce noise from compounds by 3-8 dB(A) depending on the height of the compound noise source relative to the hoarding height.

Other standard mitigation measures that also should be implemented by the proposal, but that have not been included in the noise modelling include:

- Screening noise-intensive processes such as crushing plants, jackhammers, rockbreaking and concrete sawing by the use of mobile screens (e.g. acoustic screens mounted on trailers) that track the progress of works. Such screens can reduce noise levels by up approximately 5-10 dB(A) where the line of sight to a receiver from the works is heavily screened. This level of acoustic screening is significantly reduced for receivers positioned obliquely or "end on" to the

screen. Noise modelling has therefore not included this standard mitigation measure given that the acoustic benefit of this measure cannot be reliably applied to all receivers at all locations along the proposal due to their spread about any works site. The use of mobile acoustic screens would be assessed when developing the CNVMP.

- Maximising offset distances of construction works such that works nearest noise-sensitive receivers is undertaken at times less sensitive to them. The acoustic benefit of offsetting works in this way is approximately 6 dB(A) noise reduction per doubling of offset distance. This measure has not been included in the noise modelling as there is no reliable method to determine the noise reduction that can be achieved at all receivers from this measure.

- Constructing the operational noise walls (**Section 9.2**) ahead of commencement of proposal (road) construction activities in that area. Where feasible, construction noise to some receivers could be reduced by 5-10 dB(A) where they are undertaken from behind the proposed 5.0m high operational noise barrier. The level of noise reduction offered by the noise wall would depend significantly on the location of the works and the receiver in relation to it. By way of example, receivers positioned obliquely or “end on” to the wall would receive limited if any acoustic benefit from the wall. For this reason, the noise modelling has not included this potential benefit. However, the opportunity to construct the operational noise barrier prior to proposal (road) works should be considered when developing the CNVMP.

- Screening or enclosing stationary noise sources such as pumps and compressors which can provide up to 15 dB(A) in noise reduction for these items. This benefit has not been included in the noise modelling.

- Shielding sensitive receivers from noisy construction activity by the judicious placement of structures (eg, site sheds, fencing or signage) or use of site topography to screen plant. This benefit has not been included in the noise modelling.

10.12 Construction noise predictions

The predicted L_{Aeq} noise level from each stage of the construction works (**Table 10-6**) for standard (daytime) and out of hours (evening and night) periods are presented in full for each receiver in **Appendix N**. These predictions include the acoustic benefit of the standard proposal-specific noise mitigation measures discussed above.

Table 10-7 (works during standard hours) and **Table 10.8** (out of hours works) indicate the range of predicted construction noise levels at the nearest and furthest receiver from the works within an NCA once proposal-specific mitigation has been applied.

Further reduction of construction noise levels will be possible once additional, tailored mitigation is applied as part of the CNVMP which will be developed at the detailed design stage. For example, the results above do not include any acoustic benefit from the use of temporary hoardings, the use of which will likely be viable in many locations of maximum noise impact, where works are to be located very close to residences.

Table 10-7 Predicted daytime construction noise impacts by NCAs

NCA	NML	Distance (m)			Construction Stage (refer Table 10-6)					
					1a	1b	2	3	4	5
1	58	110-590	Range of predicted noise levels (dB(A))		**36 - 76**	**>30 - 66**	**26 - 66**	**>30 - 64**	**>30 - 67**	**>30 – 40**
			Number of Receivers per Band	Complies	616	879	886	911	871	801
				< NML+10	272	80	73	48	88	0
				<NML+20	71	0	0	0	0	0
				>NML+20	0	0	0	0	0	0
			Highly noise affected rec.	≥75dBA	3	0	0	0	0	0
2	58	15-140	Range of predicted noise levels (dB(A))		**44 - 93**	**34 - 84**	**34 - 84**	**32 - 82**	**35 - 85**	**>30 – 37**
			Number of Receivers per Band	Complies	41	56	57	61	55	134
				< NML+10	17	36	41	63	35	0
				<NML+20	43	52	46	47	53	0
				>NML+20	92	49	49	22	50	0
			Highly noise affected rec.	≥75 dBA	113	52	52	50	52	0
3	63	7-130	Range of predicted noise levels (dB(A))		**53 - 95**	**44 – 86**	**44 - 85**	**42 - 83**	**44 - 86**	**>30 – 37**
			Number of Receivers per Band	Complies	36	57	62	78	55	173
				< NML+10	28	71	68	61	70	0
				<NML+20	71	51	51	43	44	0
				>NML+20	47	3	1	0	13	0
			Highly noise affected rec.	≥75dBA	101	44	43	43	45	0
4	63	70-580	Range of predicted noise levels (dB(A))		**40 - 80**	**31 – 71**	**30 - 70**	**>30 - 69**	**31 - 71**	**>30 – 36**
			Number of Receivers per Band	Complies	532	634	636	640	631	545
				< NML+10	105	10	8	4	13	0
				<NML+20	7	0	0	0	0	0
				>NML+20	0	0	0	0	0	0
			Highly noise affected rec.	≥75 dBA	4	0	0	0	0	0

NCA	NML	Distance (m)			Construction Stage (refer Table 10-6) 1a	1b	2	3	4	5
5	64	90-570	Range of predicted noise levels (dB(A))		**48 - 79**	**39 – 70**	**38 - 69**	**37 - 67**	**39 - 70**	**>30 – 68**
			Number of Receivers per Band	Complies	395	503	504	505	501	491
				< NML+10	109	5	4	3	7	17
				<NML+20	4	0	0	0	0	0
				>NML+20	0	0	0	0	0	0
			Highly noise affected rec.	≥75dBA	3	0	0	0	0	0
6	64	10-100	Range of predicted noise levels (dB(A))		**66 – 92**	**56 - 83**	**56 - 82**	**54 - 80**	**57 - 83**	**>30 – 78**
			Number of Receivers per Band	Complies	0	21	23	30	17	75
				< NML+10	24	58	60	65	60	19
				<NML+20	61	23	19	7	25	8
				>NML+20	17	0	0	0	0	0
			Highly noise affected rec.	≥75 dBA	74	17	13	4	19	5
7	62	85-200	Range of predicted noise levels (dB(A))		**67 – 94**	**58 - 85**	**57 - 84**	**55 - 82**	**58 - 85**	**34 – 50**
			Number of Receivers per Band	Complies	0	4	4	4	3	22
				< NML+10	4	13	14	16	14	0
				<NML+20	14	4	3	2	4	0
				>NML+20	4	1	1	0	1	0
			Highly noise affected rec.	≥75dBA	17	2	1	1	2	0
8	64	180-700	Range of predicted noise levels (dB(A))		**48 – 72**	**38 – 62**	**38 - 62**	**36 - 60**	**39 - 63**	**>30 - 52**
			Number of Receivers per Band	Complies	44	51	51	51	51	51
				< NML+10	7	0	0	0	0	0
				<NML+20	0	0	0	0	0	0
				>NML+20	0	0	0	0	0	0
			Highly noise affected rec.	≥75 dBA	0	0	0	0	0	0
9	58	170-550	Range of predicted noise levels (dB(A))		**52 – 81**	**43 – 72**	**43 - 71**	**41 - 69**	**44 - 72**	**43 – 78**
			Number of Receivers per Band	Complies	25	73	78	87	69	50

NCA	NML	Distance (m)			Construction Stage (refer Table 10-6)					
					1a	1b	2	3	4	5
				< NML+10	55	42	37	32	45	45
				<NML+20	36	6	6	2	7	26
				>NML+20	5	0	0	0	0	0
			Highly noise affected rec.	≥75dBA	21	0	0	0	0	6
10	55	60-210	Range of predicted noise levels (dB(A))		**66 – 93**	**57 - 84**	**57 - 84**	**55 - 82**	**58 - 85**	**62 – 83**
			Number of Receivers per Band	Complies	0	0	0	1	0	0
				< NML+10	0	5	6	5	4	2
				<NML+20	6	10	9	11	11	6
				>NML+20	11	2	2	0	2	9
			Highly noise affected rec.	≥75 dBA	11	2	2	0	2	9
11	55	120-430	Range of predicted noise levels (dB(A))		**60 – 84**	**51 – 74**	**51 - 74**	**49 - 72**	**51 - 75**	**50 – 80**
			Number of Receivers per Band	Complies	0	1	1	2	1	1
				< NML+10	1	13	14	15	12	2
				<NML+20	14	9	8	6	10	18
				>NML+20	8	0	0	0	0	2
			Highly noise affected rec.	≥75dBA	8	0	0	0	0	2
12	58	380-560	Range of predicted noise levels (dB(A))		**49 - 71**	**40 – 61**	**40 - 61**	**38 - 59**	**41 - 62**	**39 – 67**
			Number of Receivers per Band	Complies	3	6	6	7	6	5
				< NML+10	3	2	2	1	2	3
				<NML+20	2	0	0	0	0	0
				>NML+20	0	0	0	0	0	0
			Highly noise affected rec.	≥75 dBA	0	0	0	0	0	0
13	58	315-550	Range of predicted noise levels (dB(A))		**33 – 59**	**>30 - 49**	**>30 - 49**	**22 - 47**	**>30 - 50**	**>30 - 43**
			Number of Receivers per Band	Complies	183	186	186	186	186	184
				< NML+10	3	0	0	0	0	0

NCA	NML	Distance (m)			Construction Stage (refer Table 10-6)					
					1a	1b	2	3	4	5
				<NML+20	0	0	0	0	0	0
				>NML+20	0	0	0	0	0	0
			Highly noise affected rec.	≥75dBA	0	0	0	0	0	0
14	63	35-390	Range of predicted noise levels (dB(A))		**46 – 85**	**37 - 75**	**37 - 75**	**35 - 73**	**38 - 76**	**>30 – 56**
			Number of Receivers per Band	Complies	40	49	50	50	49	53
				< NML+10	10	3	2	3	3	0
				<NML+20	2	1	1	0	1	0
				>NML+20	1	0	0	0	0	0
			Highly noise affected rec.	≥75 dBA	3	0	0	0	1	0
15	62	55-550	Range of predicted noise levels (dB(A))		**57 – 89**	**47 - 79**	**47 - 79**	**45 - 77**	**48 - 80**	**>30 – 71**
			Number of Receivers per Band	Complies	8	27	27	28	26	36
				< NML+10	19	6	7	8	6	2
				<NML+20	7	5	4	2	6	0
				>NML+20	4	0	0	0	0	0
			Highly noise affected rec.	≥75dBA	10	2	2	1	2	0
16	58	520-870	Range of predicted noise levels (dB(A))		**41 – 93**	**32 – 84**	**32 - 84**	**30 - 82**	**33 - 84**	**>30 – 54**
			Number of Receivers per Band	Complies	18	35	35	38	34	45
				< NML+10	17	7	7	4	8	0
				<NML+20	7	1	2	2	1	0
				>NML+20	3	2	1	1	2	0
			Highly noise affected rec.	≥75 dBA	4	3	3	2	3	0

Table 10.8 Predicted Out of Hours construction noise impacts by NCA

NCA	NML	Distance (m)			Stage (refer table 10-6) 3N	Stage (refer table 10-6) 5N
1	46	110-590	Range of predicted noise levels (dB(A))		**>30 - 63**	**>30 – 37**
			Number of Receivers per Band	Complies with NML	639	801
				0-5 dB(A) above NML	151	0
				5-15 dB(A) above NML	166	0
				15-25 dB(A) above NML	3	0
				>25 dB(A) above NML	0	0
2	46	15-140	Range of predicted noise levels (dB(A))		**>30 - 81**	**>30 – 33**
			Number of Receivers per Band	Complies with NML	42	134
				0-5 dB(A) above NML	7	0
				5-15 dB(A) above NML	24	0
				15-25 dB(A) above NML	68	0
				>25 dB(A) above NML	52	0
3	40	7-130	Range of predicted noise levels (dB(A))		**41 - 82**	**14 – 33**
			Number of Receivers per Band	Complies with NML	0	173
				0-5 dB(A) above NML	22	3
				5-15 dB(A) above NML	17	0
				15-25 dB(A) above NML	59	0
				>25 dB(A) above NML	84	0
4	40	70-580	Range of predicted noise levels (dB(A))		**>30 - 67**	**>30 – 33**
			Number of Receivers per Band	Complies with NML	213	545
				0-5 dB(A) above NML	197	0
				5-15 dB(A) above NML	181	0
				15-25 dB(A) above NML	50	0
				>25 dB(A) above NML	3	0
5	49	90-570	Range of predicted noise levels (dB(A))		**35 - 66**	**>30 – 65**
			Number of Receivers per Band	Complies with NML	349	389
				0-5 dB(A) above NML	88	60
				5-15 dB(A) above NML	69	58
				15-25 dB(A) above NML	2	1
				>25 dB(A) above NML	0	0
6	49	10-100	Range of predicted noise levels (dB(A))		**53 - 79**	**>30 – 74**
			Number of Receivers per Band	Complies with NML	0	62
				0-5 dB(A) above NML	1	9
				5-15 dB(A) above NML	40	7
				15-25 dB(A) above NML	57	24
				>25 dB(A) above NML	4	0
7	54	85-200	Range of predicted noise levels (dB(A))		**54 - 81**	**30 - 47**
			Number of Receivers per	Complies with NML	1	22

NCA	NML	Distance (m)			Stage (refer table 10-6)	
					3N	5N
			Band	0-5 dB(A) above NML	3	0
				5-15 dB(A) above NML	14	0
				15-25 dB(A) above NML	3	0
				>25 dB(A) above NML	1	0
8	49	180-700	Range of predicted noise levels (dB(A))		**35 - 59**	**>30 - 48**
			Number of Receivers per Band	Complies with NML	41	51
				0-5 dB(A) above NML	6	0
				5-15 dB(A) above NML	4	0
				15-25 dB(A) above NML	0	0
				>25 dB(A) above NML	0	0
9	49	170-550	Range of predicted noise levels (dB(A))		**40 - 68**	**39 - 74**
			Number of Receivers per Band	Complies with NML	51	18
				0-5 dB(A) above NML	18	27
				5-15 dB(A) above NML	45	48
				15-25 dB(A) above NML	7	28
				>25 dB(A) above NML	0	0
10	39	60-210	Range of predicted noise levels (dB(A))		**54 - 74**	**58 - 80**
			Number of Receivers per Band	Complies with NML	0	0
				0-5 dB(A) above NML	0	0
				5-15 dB(A) above NML	1	0
				15-25 dB(A) above NML	5	3
				>25 dB(A) above NML	11	14
11	39	120-430	Range of predicted noise levels (dB(A))		**48 - 71**	**47 – 77**
			Number of Receivers per Band	Complies with NML	0	0
				0-5 dB(A) above NML	0	0
				5-15 dB(A) above NML	2	2
				15-25 dB(A) above NML	15	8
				>25 dB(A) above NML	6	13
12	49	380-560	Range of predicted noise levels (dB(A))		**37 - 58**	**36 - 63**
			Number of Receivers per Band	Complies with NML	4	2
				0-5 dB(A) above NML	2	2
				5-15 dB(A) above NML	2	4
				15-25 dB(A) above NML	0	0
				>25 dB(A) above NML	0	0

NCA	NML	Distance (m)			Stage 3N	Stage 5N
13	49	315-550	Range of predicted noise levels (dB(A))		**>30 - 46**	**14 – 39**
			Number of Receivers per Band	Complies with NML	186	184
				0-5 dB(A) above NML	0	0
				5-15 dB(A) above NML	0	0
				15-25 dB(A) above NML	0	0
				>25 dB(A) above NML	0	0
14	40	35-390	Range of predicted noise levels (dB(A))		**34 - 72**	**>30 – 52**
			Number of Receivers per Band	Complies with NML	27	49
				0-5 dB(A) above NML	9	2
				5-15 dB(A) above NML	9	2
				15-25 dB(A) above NML	5	0
				>25 dB(A) above NML	3	0
15	43	55-550	Range of predicted noise levels (dB(A))		**44 - 76**	**>30 - 67**
			Number of Receivers per Band	Complies with NML	0	33
				0-5 dB(A) above NML	6	1
				5-15 dB(A) above NML	18	2
				15-25 dB(A) above NML	8	2
				>25 dB(A) above NML	6	0
16	49	520-870	Range of predicted noise levels (dB(A))		**>30 - 81**	**>17 – 51**
			Number of Receivers per Band	Complies with NML	25	44
				0-5 dB(A) above NML	9	1
				5-15 dB(A) above NML	8	0
				15-25 dB(A) above NML	1	0
				>25 dB(A) above NML	2	0

10.12.1 Predicted impact from works undertaken during standard hours

Table 10-7 indicates that, in general, predicted worst case construction noise levels from daytime works will comply with Noise Management Levels (NMLs) at most receivers within the study area. The exceptions are receivers in NCAs 2, 3, 6, 7, 10 and 11 - NCAs that abut the road corridor - within which the majority of receivers will experience some exceedance of the NML at some time. It is to be noted that **Table 10-7** reports worst case predicted construction noise exposure which is expected to occur when plant operates nearest to the receiver.

Noise impacts to receivers within NCAs that do not abut the road corridor (NCAs 1, 4, 5, 8, 9, 12, 13 and16) are significantly lower than those described above, and in most cases, contained to 0-10 dB(A) above the NML.

Of all construction stages, it is predicted that Stage 1a Demolition works incorporating concrete sawing and/or jackhammering will cause the greatest number of receivers to be impacted. More than 100 receivers in each of NCA 2 and NCA 3 are predicted to be “Highly Noise Affected” (exposed to noise levels greater than 75 dB(A)) at some point of Stage 1a Demolition works. The number of “Highly Noise Affected” receivers will reduce by more than half for other works stages, and in most NCAs reduce to zero for works other than demolition.

Construction noise impacts will largely be contained to dwellings directly exposed to the works. The number and extent of NML exceedances drops off significantly at dwellings screened by a "first row" of houses.

The worst case impacts arising from demolition works result due to the proximity of the works to worst affected receivers. As can be seen from **Table 10-7**, works are scheduled to occur as close as 7-15m for some receivers in NCAs 2, 3 and 6.

The predicted level of construction noise at dwellings several rows of houses back from the works are indicated by the lower value of the range of construction noise levels reported in Table 10-7.

Any one receiver's direct exposure to demolition works is expected to be limited to 1-2 weeks before the works move on.

The additional noise mitigation measures that may be applied to the works which are predicted to generate noise impacts are outlined in **Section 10.13**.These

10.12.2 Predicted impact from out of hours (evening and night) works

Table 10.8 indicates that predicted worst case construction noise levels from out of hours (generally, evening and night time) works will comply with NMLs for most receivers within the study area.

Exceedances of the NMLs are predicted to be greatest at receivers within those NCAs adjacent to the road corridor – NCAs 2, 3, 4, 6, 9, 10 and 11. Impacts for the potentially most affected of these receivers are predicted to exceed NMLs by more than 25 dB(A) in some instances, particularly in NCA 2 and NCA 3 where works are anticipated to approach to within 7-15 metres of some receivers.

Of the two proposed out-of-hours works scenarios, paving works (Stage 3N) is predicted to impact the greater number of receivers. General measures to reduce or in some cases, eliminate these impacts are discussed further in **Section 10.13**, although activity-specific measures such as restricting truck movements and programming night time paving works such that they are undertaken only at locations away from residences will be further investigated as part of the CNVMP to be determined at the detailed design stage.

It is be noted that the duration of the worst case impacts reported is expected to be 2-3 nights for most worst affected receivers, before paving moves on, even if not completely out of audible range immediately.

Noise impacts predicted from bridge works (Stage 5N) will be greatest in NCAs 5, 6, 9, 10 and 11 within which, predicted worst case impacts may range above 25 dB(A). Any exceedance of NMLs in other NCAs or at any receiver within the study area several hundred metres removed from the works, will generally be contained to 5dBA above the NML.

As the application of standard mitigation measures will not completely eliminate all exceedances of the NMLs during either daytime or out of hours works, the proposal will consider the application of the additional mitigation measures identified in the CNVG (refer **Section 10.13**).

10.13 CNVG additional mitigation measures

In instances where after the application of standard noise mitigation measures there still remain receivers at which NMLs are exceeded, the CNVG directs that the proposal should consider implementing the additional mitigation measures detailed in Appendix C of the CNVG where feasible and reasonable. Table 10-9 indicates these additional measures and the triggers for their application.

Table 10-9 Triggers for additional mitigation measures (from CNVG Appendix C)

Predicted airborne $L_{Aeq(15min)}$ noise level at receiver			Additional mitigation measures	
Perception[1]	**dB(A) above RBL**	**dB(A) above NML**	**Type[2]**	**Mitigation level[3]**
All hours				
75 dB(A) or greater	-	-	N, V, PC, RO	HA
Standard Hours: Mon-Fri (7am – 6pm), Sat (8am-1pm), Sun/Pub Hol (Nil)				
Noticeable	5 to 10	0	-	NML
Clearly Audible	10 to 20	< 10	-	NML
Moderately Intrusive	20 to 30	10 to 20	N, V	NML + 10
Highly Intrusive	> 30	> 20	N, V	NML + 20
Out of Hours Works Period 1: Mon-Fri (6pm-10pm), Sat (7am-8am & 1pm-10pm), Sun/Pub Hol (8am-6pm)				
Noticeable	5 to 10	< 5	-	NML
Clearly Audible	10 to 20	5 to 15	N, R1, DR	NML + 5
Moderately Intrusive	20 to 30	15 to 25	V, N, R1, DR	NML + 15
Highly Intrusive	> 30	> 25	V, IB, N, R1, DR, PC, SN	NML + 25
Out of Hours Works Period 1: Mon-Fri (10pm-7am), Sat (10pm-8am), Sun/Pub Hol (6pm-7am)				
Noticeable	5 to 10	< 5	N	NML
Clearly Audible	10 to 20	5 to 15	V, N, R2, DR	NML + 5
Moderately Intrusive	20 to 30	15 to 25	V, IB, N, PC, SN, R2, DR	NML + 15
Highly Intrusive	> 30	> 25	AA, V, IB, N, PC, SN, R2, DR	NML + 25

1 Perception relates to the level above the RBL

2 AA = Alternative Accommodation, V = Verification, IB = Individual Briefing, N = Notification, R1 = Respite Period 1, R2 = Respite Period 2, DR = Duration Respite, PC = Phone Calls, SN = Specific Notifications

3 NML = Noise Management Level (refer Appendix D of CNVG) HA = Highly Affected (>75dB(A) – applies to residences only)

The detailed description of each additional mitigation measure is provided in Appendix C of the NCVG.

10.14 Sleep Disturbance from night time construction works

Appendix E of the CNVG requires that, where works are expected to extend over more than two consecutive nights, the assessment should address the likelihood of sleep disturbance within nearby residences.

The suite of standard mitigation measures assumed for the construction of the proposal (**Section 10.11.1**) has assumed some construction stages (i.e. Stages 1, 2 and 4) would be restricted to standard (daytime) hours. The proposed undertaking of Stage 3 and Stage 5 works during night periods may potentially result in night time noise impacts, including sleep disturbance. Equipment L_{Amax} levels presented in **Table 10-10** have been used to estimate the potential extent of these impacts.

Table 10-10 Plant L_{Amax} sound power levels used to assess the potential for sleep disturbance

Construction phase	Typical plant and equipment	Sound Power Level dB(A) L_{Amax}
Stage 3 (Paving) (indicative time of exposure to any one receiver: 2-8 weeks)	Paving machine and truck	115
Stage 4 (Bridge installation) (indicative time of exposure to any one receiver: 12-26 weeks)	Mobile crane (750T)	114

Table 10-11 identifies the number of receivers at which the sleep disturbance screening criterion may be exceeded. Based on monitoring data from similar construction proposals, these calculations are based on representative L_{Amax} noise levels for the equipment proposed during each work stage. A 10dB(A) insertion loss has been assumed to determine the difference between noise levels external and internal to a bedroom facade that has a window open for ventilation.

Maximum L_{Amax} noise levels from each work stage have been predicted and are presented in **Table 10-11** below.

Table 10-11 Number of receivers that may be exposed to construction noise in excess of the sleep disturbance screening criterion

NCA	Criterion	Distance (m)			Stage 3N	Stage 5N
1	65	110-590	Range of predicted noise levels (dB(A))		<30 - 64	<30 - 41
			Number of Receivers per Band	Complies with criterion	959	801
				0-5 dB(A) above	0	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
2	65	15-140	Range of predicted noise levels (dB(A))		41 - 82	<30 - 37
			Number of Receivers per Band	Complies with criterion	142	134
				0-5 dB(A) above	47	0
				5-15 dB(A) above	4	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
3	65	7-130	Range of predicted noise levels (dB(A))		47 - 84	<30 - 38
			Number of Receivers per Band	Complies with criterion	137	173
				0-5 dB(A) above	22	0
				5-15 dB(A) above	21	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
4	65	70-580	Range of predicted noise levels (dB(A))		37 - 77	<30 - 37
			Number of Receivers per Band	Complies with criterion	642	545
				0-5 dB(A) above	2	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
5	65	90-570	Range of predicted noise levels (dB(A))		37 - 68	23 – 69
			Number of Receivers per Band	Complies with criterion	508	508
				0-5 dB(A) above	0	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
6	65	10-100	Range of predicted noise levels (dB(A))		54 - 81	27 - 78
			Number of Receivers per Band	Complies with criterion	97	95
				0-5 dB(A) above	4	7
				5-15 dB(A) above	1	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
7	65	85-200	Range of predicted noise levels (dB(A))		56 - 83	34 -51
			Number of Receivers	Complies with criterion	21	22

NCA	Criterion	Distance (m)			Stage 3N	Stage 5N
			per Band	0-5 dB(A) above	0	0
				5-15 dB(A) above	1	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
8	65	180-700	Range of predicted noise levels (dB(A))		36 - 60	18 - 53
			Number of Receivers per Band	Complies with criterion	51	51
				0-5 dB(A) above	0	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
9	65	170-550	Range of predicted noise levels (dB(A))		41 - 70	43 - 78
			Number of Receivers per Band	Complies with criterion	121	115
				0-5 dB(A) above	0	6
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
10	65	60-210	Range of predicted noise levels (dB(A))		55 - 76	63 - 84
			Number of Receivers per Band	Complies with criterion	16	8
				0-5 dB(A) above	1	7
				5-15 dB(A) above	0	2
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
11	65	120-430	Range of predicted noise levels (dB(A))		49 - 81	51 – 81
			Number of Receivers per Band	Complies with criterion	21	19
				0-5 dB(A) above	1	2
				5-15 dB(A) above	1	2
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
12	65	380-560	Range of predicted noise levels (dB(A))		47 - 60	40 - 68
			Number of Receivers per Band	Complies with criterion	8	8
				0-5 dB(A) above	0	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
13	65	315-550	Range of predicted noise levels (dB(A))		30 - 52	18 - 43
			Number of Receivers per Band	Complies with criterion	186	184
				0-5 dB(A) above	0	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0

NCA	Criterion	Distance (m)			Stage 3N	Stage 5N
14	65	35-390	Range of predicted noise levels (dB(A))		44 - 73	28 - 57
			Number of Receivers per Band	Complies with criterion	53	53
				0-5 dB(A) above	0	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
15	65	55-550	Range of predicted noise levels (dB(A))		45 - 77	21 - 71
			Number of Receivers per Band	Complies with criterion	37	38
				0-5 dB(A) above	1	0
				5-15 dB(A) above	0	0
				15-25 dB(A) above	0	0
				>25 dB(A) above	0	0
16	65	520-870	Range of predicted noise levels (dB(A))		39 – 91	22 - 55
			Number of Receivers per Band	Complies with criterion	42	45
				0-5 dB(A) above	1	0
				5-15 dB(A) above	1	0
				15-25 dB(A) above	1	0
				>25 dB(A) above	0	0

Table 10-11 indicates that noise from some of the proposal's night time construction activities may generate noise levels within residences in excess of the sleep disturbance screening criterion. Generally, the extent of exceedance in most cases will be 0-5 dB(A).

Residences in NCAs 2, 3, 6, 7, 10 and 11 are predicted to be at highest risk of sleep disturbance impact from the proposal's out of hours works. The sleep disturbance screening criterion is predicted to be exceeded at up to 51 and 43 residences respectively in NCA's 2 and 3 when works are situated nearest these residences.

This result does not indicate that sleep disturbance will be caused necessarily, but rather that sleep disturbance is possible and therefore, that more detailed investigation is warranted. This may include noise monitoring during initial stages of work to verify predicted noise levels or further assessment when more detailed construction methods are available. It is recommended that noise-intensive construction processes not be undertaken out of hours wherever possible.

A detailed assessment of, and management plan for the potential for sleep disturbance impact from any out of hours works would be assessed in the proposal's Construction Noise and Vibration Management Plan.

In-principle noise management measures for any prospective out of hours works are outlined in **Section 10.11.1**.

10.15 Site compounds and ancillary facilities

Site compounds will house the proposal's administrative functions and would include offices, toilet and shower facilities, repair and maintenance facilities, equipment laydown areas and stores. In

addition they would be used as stockpile and laydown locations. The location and use of the proposal's site compounds are presented in **Section 0**.

Exact location and proposed use of ancillary sites would be confirmed by the construction contractor before the start of construction. Further information on these sites is provided in **Section 3.4** of the REF.

In most times, noise emissions from standard-sized compounds will be relatively low, however, any use of heavy vehicles and reversing beepers at stockpile, laydown or maintenance facilities may impact nearby receivers, particularly during night time operations (potentially Sites 2, 3 and 10). Noise impacts may be expected during loading operations at larger compounds during night time works.

The exact location and proposed use of ancillary sites would be confirmed by the construction contractor before the start of construction. Noise assessment from these sites should be carried out during detailed design, when locations and precise operations at each site are confirmed.

In-principle noise management measures for any prospective out of hours works are outlined in **Section 10.11.1**.

10.16 Construction traffic noise impact

The assessment of noise impact arising from construction vehicles on public roads (as opposed to when they operate within a construction site) is assessed in accordance with the CNVG, which states that where construction traffic will not increase existing traffic noise levels by more than 2 dB(A), then no further assessment is required. Where the increase in existing traffic noise due to construction traffic is predicted to be greater than 2 dB(A) then further assessment using the NCG is required.

The proposal's detailed construction traffic plan was not available at the time of this assessment. However it would be reasonable to assume that construction traffic generated by the proposal would access worksites using only designated heavy vehicle routes such as the Great Western Highway, the M4 Motorway and The Northern Road. As a result, it is expected that construction traffic would not substantially increase the traffic volumes on these roads. It is expected that the increase to existing traffic noise levels resulting from construction traffic would be less than 2dB(A) in all cases.

10.17 Construction noise and vibration management plan

A Construction Noise and Vibration Management Plan (CNVMP) would be prepared during the detailed design stage of the proposal and applied to all construction processes throughout the proposal.

The CNVMP would nominate:

- noise goals at all sensitive receivers
- restrictions on the hours of construction activity
- works programming that has the aim of minimising impacts on sensitive receivers
- noise and vibration mitigation measures consistent with the RMS' CNVG
- the proposal's commitments to noise and vibration monitoring and reporting
- protocols for engaging with and notifying residents of any work processes that may impact them
- a complaints mechanism so that residents may contact the project manager

- a protocol to enable the proposal to respond quickly to non-compliances

11. Construction vibration assessment

11.1 Overview of vibration impact

The potential for vibration impact to either residents or buildings from the proposal may reasonably be expected to be contained to the construction phase of the proposal. The construction program is expected to include the use of equipment such as rock breakers, vibratory rollers or pile boring that could give rise to vibration impact.

The proposal's construction activities may give rise to three types of vibration impact, each of which is assessed against different standards. Vibration from construction works may:

- adversely affect human comfort: this is assessed EPA, *Assessing Vibration: A Technical Guideline* (DEC 2006);
- cause cosmetic damage (eg surface cracks) to conventional buildings such as residences and light commercial buildings: this risk is assessed against the guidance of Australian Standard AS2187.2-2006 *Explosives – Storage, Transport and Use provides guidance for the assessment of structural damage to buildings caused by vibration*, or
- cause cosmetic damage to buildings or structures of "particular sensitivity" (eg, heritage or structurally unsound items): for such structures, the assessment is made against German Standard DIN 4150: Part 3-1999.

No blasting is expected to be required in the construction of the proposal.

11.2 Vibration Criteria

11.2.1 Vibration criteria to ensure the preservation of Human comfort

Vibration from construction activities should comply with the EPA vibration guideline and AS2670.2 (DEC 2006). The NSW EPA classifies vibration as one of three types:

- Continuous – Where vibration occurs uninterrupted and can include sources such as machinery and constant road traffic.
- Impulsive – Where vibration occurs over a short duration (typically less than 2 seconds) and occurs less than three times during the assessment period, which is not defined. This may include activities such as occasional dropping of heavy equipment or loading / unloading activities.
- Intermittent – Occurs where continuous vibration activities are regularly interrupted, or where impulsive activities recur. This may include activities such as rock hammering, drilling, pile driving and heavy vehicle or train pass-bys.

Maximum and preferred values for continuous and impulsive vibration are defined in **Table 11-1**. Application of the criteria considers the level as well as the duration of exposure and the time of day, and similar to the noise criteria, also has separate values for residential and non-residential receivers.

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

Location	Assessment period	Preferred values		Maximum values	
		z-axis	x and y axis	z-axis	x and y axis
Continuous vibration					
Critical areas[2]	Day or night time	0.0050	0.0036	0.010	0.0072
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and places of worship	Day or night time	0.020	0.014	0.040	0.028
Workshops	Day or night time	0.04	0.029	0.080	0.058
Impulsive vibration					
Critical areas[2]	Day or night time	0.0050	0.0036	0.010	0.0072
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and places of worship	Day or night time	0.64	0.46	1.28	0.92
Workshops	Day or night time	0.64	0.46	1.28	0.92

Note

1. Daytime is 7.00am to 10.00pm and night-time is 10.00pm to 7.00am
2. Such as hospital operating theatres or precision laboratories.

Intermittent vibration impacts may be present when continuous vibration sources operate sporadically throughout the assessment period. This type of impact is assessed using vibration dose values (VDVs). The VDV method is more sensitive to peaks in the acceleration waveform and makes corrections to the criteria based on the duration of the source's operation. The VDV is calculated using the overall weighted rms acceleration of the vibrating source in each orthogonal axis and the duration which the vibration occurs. Preferred and maximum VDVs are defined in Table 2.4 of DECC (2006) and are reproduced in **Table 11-2**.

Table 11-2 Acceptable vibration dose values for intermittent vibration (ms$^{-1.75}$)

Locations	Daytime (7.00am – 10.00pm)		Night-time (10.00pm – 7.00am)	
	Preferred values	Maximum values	Preferred values	Maximum values
Critical areas[1]	0.10	0.20	0.10	0.02
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

1. Includes operating theatres, precision laboratories and other areas where vibration sensitive activities may occur.

11.2.2 Vibration criteria to ensure prevention of structural damage

The OEH vibration guideline does not address the potential for damage to structures. Instead, the *Australian Standard AS2187.2-2006 Explosives – Storage, Transport and Use* provides guidance for the assessment of structural damage to buildings caused by vibration. This section of the standard is based on the British Standard 7385: Part 2 *Evaluation and measurement of vibration in buildings* and is used as a guide to assess the likelihood of building damage from ground vibration including piling, compaction, construction equipment and road and rail traffic. The standard recommends levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur based on the type of structure affected.

The standard uses the peak particle velocity (PPV) parameter to quantify vibration and specifies damage criteria for frequencies within the 4 Hz to 250 Hz range for buildings. The criteria levels identified in the standard are outlined in **Table 11-3**.

Table 11-3 BS 7385 Structural damage criteria

Group	Type of structure	Peak particle velocity (PPV) - mm/s		
		4Hz to 15Hz	15Hz to 40Hz	40Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50		
2	Un-reinforced or light framed structures Residential or light commercial type buildings	15 to 20	20 to 50	50

The levels for structural damage outlined in the standard refer to non-continuous vibration sources and are considered 'safe limits' up to which no damage due to vibration effects are expected to occur for the various building types. Where vibration is continuous these levels may be reduced by up to 50 per cent and additional assessment against the standard would be necessary.

Although no heritage structures have been identified in the study area, should any be discovered, the German DIN Standard 4150-3 Structural Vibration, Part 3: Effects of Vibration on Structures can be used for guidance. This standard recommends guideline values for short term vibration impacts on heritage structures and have been summarised in Table 11-4.

Table 11-4 DIN 4150-3 Vibration guidelines for heritage buildings

Type of structure	Guideline values for velocity - mm/s			
	Vibration at the foundation at a frequency of:			Vibration at the horizontal plane of the highest floor at all frequencies
	1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz	
Heritage buildings	3	3 – 8	8 – 10	8

11.3 Construction Vibration Assessment

Where vibration intensive plant is used, such as rock breakers and vibratory rollers, vibration must be managed to minimise disturbance to building occupants and avoid damage to buildings and other structures. The Roads and Maritime Construction Noise and Vibration Guideline (CNVG, 2016)

recommends safe working distances for typical items of vibration intensive plant that must be complied with, unless otherwise approved by Roads and Maritime.

The safe working distances presented in **Table 11-5** are indicative and will vary depending on the item of plant and local geotechnical conditions. The cosmetic damage thresholds apply to typical buildings under typical geotechnical conditions and vibration monitoring is recommended at specific sites. Where structures are more sensitive such as heritage items, more stringent conditions may be applicable and should be considered individually.

In relation to human response, the safe working distances relate to continuous vibration. For most construction activities, vibration emissions are intermittent and higher vibration levels over shorter periods are acceptable. Additional assessment should be undertaken where the human response criteria are exceeded.

Vibration intensive plant scheduled to be operated during the construction program include:

- vibratory rollers during earthworks
- jack hammers during demolition of existing structures/pavement
- pile boring for bridgeworks

Based on the safe working distances to preserve both the structural integrity of dwellings and human comfort recommended in **Table 11-5**, all vibration criteria will be complied with where the operation of the proposal's (10-12t) vibratory roller is operated not closer than 20 m from any dwelling or structure. These criteria are unlikely to be exceeded for any jack hammering or pile boring undertaken by the proposal given that these activities are not expected to be undertaken within 10 m from any dwelling or structure.

Table 11-5 Safe working distances for vibration intensive plant (TfNSW 2013)

Plant item	Rating/description	Safe working distance	
		Cosmetic damage (British Std 7385)	Human response (DECCW)
Vibratory roller	<50 kN (typically 1-2 t) <100 kN (typically 2-4 t) <200 kN (typically 4-6 t) <300 kN (typically 7-13 t) >300 kN (typically 13-18 t) >300 kN (> 18 t)	5 m 6 m 12 m 15 m 20 m 25 m	15 m to 20 m 20 m 40 m 100 m 100 m 100 m
Small hydraulic hammer	300 kg – 5 to 12 t excavator	2 m	7 m
Medium hydraulic hammer	900 kg – 12 to 18t excavator	7 m	23 m
Large hydraulic hammer	1600 kg – 18 to 34 t excavator	22 m	73 m
Vibratory pile driver	Sheet piles	2 m to 20 m	20 m
Pile boring	≤800 mm	2 m	n/a
Jackhammer	Hand held	1 m	Avoid contact with structure

More stringent conditions may apply for heritage or other sensitive structures such as heritage listed stations or vibration sensitive premises (eg high technology facilities, recording studios and cinemas).

The safe working distances presented in **Table 11-5** are indicative and will vary depending on the particular item of plant and local geotechnical conditions. They apply to transmission of ground vibration to buildings under typical geotechnical conditions.

In assessing potential vibration impacts associated with construction activities, the following methodology should be followed:

- Identification of vibration generating equipment required at each site
- Identify land use in the immediate proximity of each work area
- Where vibration intensive equipment could potentially be operating at distances less than those outlined in Table 11-5, consideration should be given to the use of smaller, less vibratory plant.
- Where heritage structures or vibration sensitive premises are located within 50m of the proposed work location, further, site specific assessments should be carried out to assess potential vibration impacts.

It is noted that at this stage of the assessment, no heritage structures or vibratory sensitive premises have been identified within the distances outlined above.

For the proposal, a building condition survey and vibration monitoring would be undertaken where residences are within the “cosmetic damage” buffer distances outlined above.

Potential site specific impacts should be quantified at the commencement of construction with a vibration monitoring survey during the initial phase of the works to account for actual site conditions and representative distances to the works at these locations.

In addition the following vibration management measures are recommended:

- Where hydraulic rock breakers or dynamic compactors are proposed for use within 20 metres of any structure (residential or commercial) or utility/service, a building condition survey would be conducted and preliminary vibration monitoring undertaken by a qualified contractor.
- Heritage structures such as culverts and walls may not be adequately addressed by the building vibration criteria outlined in this report. Where these structures are identified, a condition assessment survey is required to assess and identify appropriate construction vibration levels and mitigation measures.
- Appropriately sized equipment would be selected in order to minimise vibration emissions where required.
- Vibratory compacters would be replaced with normal compactors where vibration issues have been identified, and it is considered feasible and reasonable.
- Where vibration is found to exceed project criteria, management measures should be implemented to control vibration. In terms of human comfort criteria, measures will include modifications of construction methods and respite periods. For potential structural damage impacts, modification of construction methods would be necessary.

12. Conclusion

Roads and Maritime Services (RMS) proposes to upgrade four kilometres of The Northern Road between Glenmore Parkway, Glenmore Park and Jamison Road, Penrith.

This report presents the assessment of the potential operational and construction noise and vibration impacts of the proposal on the 3,105 receivers included in the study area. The assessment was undertaken in accordance with the RMS' Noise Criteria Guideline and Noise Mitigation Guideline.

In considering the potential for operational noise impacts from the proposal, the assessment concluded that:

- 265 receivers qualified for consideration of noise mitigation (approximately 9% of all receivers)
- No mitigation was found to be required for 2,840 receivers.

Most receivers found to qualify for the consideration of mitigation are located as follows:

- Properties immediately adjacent to The Northern Road, particularly between Jamison Road and Maxwell St, and Bickely Road and Aspen St
- Properties on the northern sides of Smith Street (west) and Maxwell Street,
- Properties adjacent to the junction of the M4 Motorway and The Northern Road, particularly those near the M4 Motorway's eastbound on-ramp.
- Kingswood South Public School
- Kingswood High School
- Montgrove College
- some buildings at the Penrith Christian School, including the ImagineNations Church

Many of the receivers identified as qualifying for mitigation directly front the existing The Northern Road and many of those are presently exposed to acute noise levels, ie, currently exposed to traffic noise greater more than 5 dB(A) above RMS noise criteria.

In general, operational noise levels to receivers not directly fronting the proposal, the M4 Motorway, Maxwell Street or Smith Street were predicted to comply with RMS noise criteria.

Where found to be required, mitigation of operational noise is proposed in the form of noise barriers and/or at-property treatments. The use of low-noise pavement is not considered feasible for the proposal given the number of traffic lights and their potential causation of stop-start traffic as well as considerations relating to constructability, debris-management, maintenance, and traffic switch requirements.

The assessment concluded that noise barriers would serve as a reasonable form of noise mitigation for receivers in proximity to the following road sections:

- Eastbound off ramp of the M4 Motorway (north west of M4/The Northern Road junction)
- On the western side of the proposal between the M4 Motorway and Powys Close
- On the western side of the proposal between Tukara Road and Aspen Street (ie, Flavel St residences)

Resulting from this, the assessment proposes the following noise barriers:

- a 5.0m high (460m long) noise barrier along the western side of project between Aspen Street and Tukara Road, and
- a 5.0m high (838m long) noise barrier on the western side of the project extending south from of Tukara Road to the western end of the eastbound M4 Motorway Off Ramp.

The final extent and form of both proposed noise barriers would be determined at the detailed design stage once other factors such as urban design, community preferences and traffic and road engineering considerations (eg, wind loading and drainage) have been resolved.

The proposed noise barriers would result in 42 receivers no longer requiring at-property mitigation, with 223 receivers still requiring at-property mitigation.

The potential for noise impacts from construction of the proposal considered construction staging, duration and the plant to be used, as well as whether the works would be undertaken during standard hours (daytime) or out of hours (broadly, evenings and night times).

Noise modelling of impacts incorporated the acoustic benefit of proposal-specific noise mitigation measures. The assessment also identified other mitigation measures that may be expected to be applied to the proposal once a detailed construction plan is developed at the detailed design stage.

In general, the assessment predicts that worst case construction noise levels from daytime works will comply with Noise Management Levels (NMLs) at most receivers within the study area situated not immediately adjacent to the proposal. In general, any noise impacts predicted for these receivers will be contained to contained to 0-10 dB(A) above the relevant NML.

The majority of receivers that directly front the road corridor are predicted to experience exceedances of the NML at some time, and at least when construction activities are undertaken nearest to that receiver.

Of all construction stages, it is predicted that early demolition works incorporating concrete sawing and/or jackhammering will cause the greatest number of receivers to be impacted. More than 200 receivers are predicted to be “Highly Noise Affected” (i.e. exposed to noise levels greater than 75 dB(A)) at some time during demolition works. This number of “Highly Noise Affected” receivers will reduce by more than half for other works stages, and for most receivers in the wider community, reduce to zero for works other than demolition.

Predicted worst case construction noise levels from out of hours (generally, evening and night time) works will comply with NMLs for most receivers within the study area.

Exceedances of the NMLs are predicted, however, at most receivers fronting the road corridor. Impacts for the potentially most affected of these receivers are predicted to exceed NMLs by more than 25 dB(A) in some instances, particularly in the northern half of the project where works are anticipated to approach to within 7-15 metres of some receivers.

Of the two proposed out-of-hours works scenarios, road paving works are predicted to generate the greater number of out of hours noise impacts. Measures to reduce or in some cases, eliminate these impacts are discussed in this report, although activity-specific measures such as restricting truck movements and programming night time paving works such that they are undertaken only at locations away from residences will be further investigated at the detailed design stage.

It is be noted that the duration of the worst case impacts reported is expected to be 2-3 nights for most worst affected receivers, before paving moves on, even if not completely out of audible range immediately.

Noise impacts predicted from out of hours bridge works may range above 25 dB(A) for worst affected receivers. Any exceedance of NMLs in other NCAs or at any receiver within the study area several hundred metres removed from the works will generally be contained to 5dBA above the NML.

As the application of standard noise mitigation measures will not completely eliminate all exceedances of the NMLs during either daytime or out of hours works, the proposal will consider the application of additional mitigation measures prescribed by the RMS' Construction Noise and Vibration Guideline at the detailed design stage. These measures include (but are not limited to) informing affected residents with project timings and other information to undertaking noise monitoring of equipment, offering respite periods and even offering alternative accommodation during times of high impact.

The assessment has identified that noise from some of the proposal's night time construction activities may generate noise levels within residences in excess of the sleep disturbance screening criterion. Generally, any exceedance of the criterion would be contained to 0-5 dB(A) in most cases.

This result does not indicate that sleep disturbance will be caused necessarily, but rather that sleep disturbance may be possible and therefore, that more detailed investigation is warranted.

A detailed assessment of, and management plan for the potential for sleep disturbance impact would be assessed in the proposal's Construction Noise and Vibration Management Plan to be prepared at the detailed design stage.

The assessment concludes that all construction vibration criteria will be complied with where the operation of the project's (10-12 tonne) vibratory roller is operated not closer than 20 m from any dwelling or structure. Vibration criteria are unlikely to be exceeded by any jack hammering or pile boring undertaken given where these activities are not undertaken within 10 m from any dwelling or structure.