Windsor Bridge replacement project

NOISE AND VIBRATION WORKING PAPER – WORKING PAPER 6

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Roads and Maritime Services

Windsor Bridge Replacement

Noise & vibration working paper – working paper 6

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Glossary

Term	Meaning
Acoustic Spectrum	A representation of a sound sample (usually short term) of the amount of energy or sound level per frequency.
Ambient Noise	Ambient noise encompasses all sound present in a given environment, being usually a composite of sounds from many sources near and far.
Build option	Proposed project design
No Build Option	Existing road layouts with no alterations or upgrades
CONCAWE	Noise modelling algorithm to predict the geographical propagation of noise from various noise sources
CoRTN	Calculation of Road Traffic Noise (CRTN - ISBN 0 11 550847 3, UK Department of Transport 1988)
dB(A)	A unit of sound measurement which has frequency characteristics weighted so that it approximates the response of the human ear to sound waves
ENMM	Environmental Noise Management Manual (RMS, 2001)
Feasible and reasonable	Feasibility relates to engineering considerations and what is practical to build; reasonableness relates to the application of judgement in arriving at a decision, taking into account the following factors
eVDV	The estimated vibration dose for predicting an assessing human comfort exposure, measured as $ms^{-1.75}$
Heavy Vehicle	A truck, transport or other vehicle with a gross vehicle weight above a specified level (for example over 8 tonnes)
L_{A10}	Descriptor used to define noise level which is exceeded 10 per cent of the time and is the average of maximum noise levels
$L_{A10\ (18hr)}$	The arithmetic average of the $L_{10(1hr)}$ levels for the 18-hour period between 0600 and 2400 hours on a normal working day.
L_{A90}	The noise level that is exceeded 90 per cent of the measurement time. This parameter is commonly referred to as the background noise level
L_{Aeq}	Noise level that represents the energy average noise from the source during a specified time period, and is the equivalent continuous sound pressure level for a given period
$L_{Aeq(15hr)}$	The L_{eq} noise level for the period from 7 am to 10 pm.
$L_{Aeq(9hr)}$	The L_{eq} noise level for the period from 10 pm to 7 am.
NCA	Noise Catchment Area. Grouping dwellings or receivers together in terms of similar noise environment.
Noise barrier	Generally a wall or an earth mound that obstructs or restricts the passage of sounds waves from a noise source
Noise Logger	A data logging (data and audio in some cases) which records noise. Usually used for unattended noise monitoring of background or ambient noise.
NML	Noise Management Level as detailed in the NSW Interim Construction Noise Guideline. The NML is the noise goal for construction activities.

Term	Meaning
Octave Bands	Sounds that contain energy over a wide range of frequencies are divided into sections called bands. A common standard division is in 10 octave bands identified by their centre frequencies 31.5, 63, 250, 500, 1000, 2000, and 4000 Hz
PPV	Peak Particle Velocity is used to measure vibration through a solid surface. When a vibration is measured, the point at which the measurement takes place can be considered to have a particle velocity. This particle vibration will take place in three dimensions (x, y and z) and will usually end up back where it started. The Peak Particle Velocity is the maximum velocity that is recorded during a particular event.
RBL	Rating Background Level is the overall single figure background level representing each assessment period over the whole monitoring period. The RBL is used for determining the appropriate construction noise criteria.
RNP	Road Noise Policy (OEH, 2011)
Sound Level Meter	An instrument consisting of a microphone, amplifier and data analysis package for quantifying and measuring noise.
Sound Power Level (L_w)	Sound power level or acoustic power level is a logarithmic measure of the sound power in comparison to a specified reference level.
Sound Pressure Level (SPL or L_p)	The level of noise, usually expressed in dB(A), as measured by a standard sound level meter.
VDV	Measured vibration dose value to indicate compliance with human comfort criteria
Vibration	Vibration is a force which oscillates about some specified reference point. Vibration is commonly expressed in terms of frequency such as cycles per second (cps), Hertz (Hz), cycles per minute (cpm) or (rpm) and strokes per minute (spm). This is the number of oscillations which occurs in that time period. The amplitude is the magnitude or distance of travel of the force.

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1 Introduction

1.1 Overview

The NSW Road and Maritime Service (RMS) are proposing to construct a new bridge across the Hawkesbury River at Windsor to replace the existing bridge that has reached the end of its economic life. To support the design and approval of the Windsor Bridge replacement, the RMS is preparing an Environmental Impact Statement (EIS) under Part 5.1 of the *Environmental Planning and Assessment Act 1979*. This noise and vibration assessment has been prepared as a specialist component of the EIS to identify and assess the impacts of noise and vibration associated with construction and operation of the project and advise mitigation actions to avoid or minimise impacts.

1.2 Project description

1.2.1 Overview

The project would comprise:

- Construction of a new bridge over the Hawkesbury River at Windsor, around 35 metres downstream of the existing Windsor bridge.
- Reconstruction and upgrading of existing intersections and bridge approach roads to accommodate the new bridge, including:
  - Removal of the existing roundabout and installation of traffic signals at the intersection of George and Bridge Streets.
  - Construction of a new dual lane roundabout at the intersection of Freemans Reach Road, Wilberforce Road, northern bridge approach road and the access road to Macquarie Park. All roads serviced by the new roundabout would require minor realignments.
  - Realignment of the southern and northern bridge approach roads. The new southern bridge approach road would generally follow the alignment of Old Bridge Street along the eastern side of Thompson Square. The northern bridge approach road would be a new road connecting the bridge to the new dual lane roundabout.
  - Construction of a shared pedestrian/cycle pathway for access to and across the new bridge.
  - Removal of the existing bridge approach roads and then backfilling, rehabilitating and landscaping these areas.
  - Demolition of the existing Windsor bridge including piers and abutments.
  - Landscaping works within Thompson Square parkland and adjacent to the northern intersection of Bridge Street, Wilberforce Road, Freemans Reach Road and the access road to Macquarie Park.
  - Redevelopment of part of The Terrace to provide continuous access along the southern bank of the river and under the replacement bridge to Windsor Wharf.
  - Construction of scour protection works on the southern and northern banks and around three bridge piers.
  - Construction of a permanent water quality basin to capture and treat stormwater runoff from the bridge and northern intersection prior to stormwater being discharged to the Hawkesbury River.

- Architectural treatments for noise mitigation, as required, where feasible and reasonable and in agreement with affected property owners.
- Flood mitigation works at individual properties.
- Ancillary works including:
    - Adjustment, relocation and/or protection of utilities and services, as required.
    - Construction and operation of temporary construction, stockpiling and compound sites.

In **Figure 1-1** the main elements of the project are shown including the construction zone and project boundary.

In addition to the above-listed work elements, early works for further identification, salvage, recording and protection of Aboriginal and historic heritage, would be carried out as part of impact mitigation for the project. These early works would include:

- Salvage excavation at identified Aboriginal heritage sites on the southern bank of the river in accordance with the procedures identified in the Aboriginal heritage chapter of the Environmental Impact Statement for the project.
- Excavation, recording and protection of historic heritage in accordance with the procedures identified in the historic heritage chapter of the Environmental Impact Statement for the project.

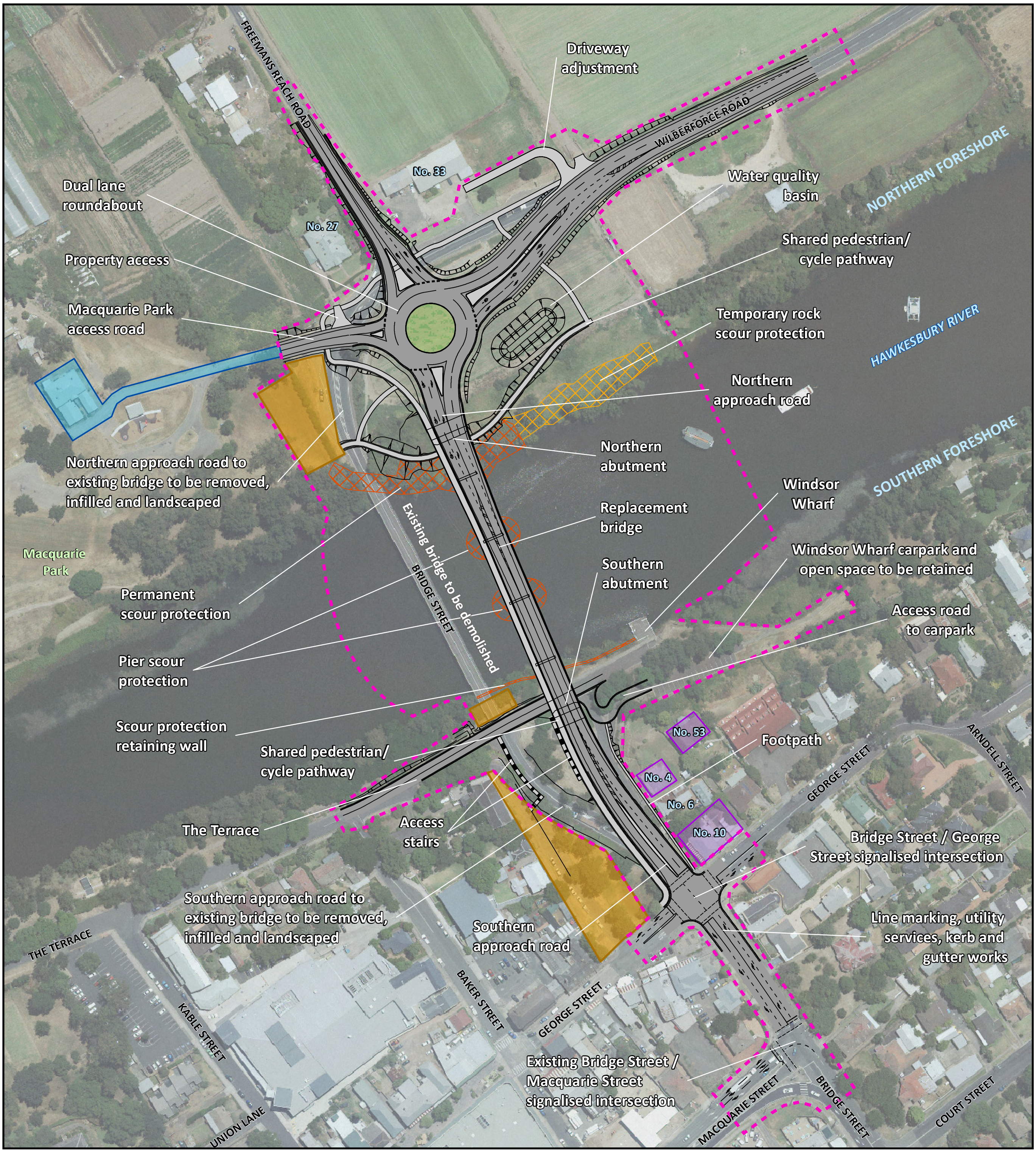
1.2.2 The replacement bridge and intersections

The replacement bridge would be located around 35 metres downstream of the existing Windsor bridge. The southern bridge approach road would be via a new realigned section of Bridge Street, which would start at the existing intersection of George Street and Bridge Street and head generally north-west along the alignment of Old Bridge Street on the eastern side of the Thompson Square parkland. The existing roundabout at the George Street and Bridge Street intersection would be replaced by traffic signals. The replacement bridge would connect with the junction of Wilberforce Road, Freemans Reach Road and the Macquarie Park access road at a new dual lane roundabout intersection.

The replacement bridge would be an incrementally launched bridge constructed of reinforced concrete and comprising five spans. The bridge deck would be about 15.5 metres wide and be supported on up to four piers in the river. It would have an overall length of about 160 metres, spanning both the river and The Terrace. This would enable The Terrace to be reconnected to provide vehicular, pedestrian and cyclist access to Windsor Wharf. The clearance under the bridge where it spans The Terrace would be about 3.6 metres, which would allow a range of service and emergency vehicles to pass under the bridge and access Windsor Wharf.

The replacement bridge would initially comprise two traffic lanes (one in each direction), each about 3.5 metres wide and with an adjacent two metre wide shoulder. There would also be a three metre wide shared pedestrian/cycle path on the western side of the bridge. The two metre wide road shoulders of the replacement bridge would allow the bridge to be re-configured to a three lane bridge in the future, when required. The introduction of the three lane configuration would occur when additional traffic capacity is required. The three traffic lanes would consist of two southbound lanes and one northbound lane.

Figure 1-1 | Key project elements



Indicative only – subject to detailed design

LEGEND
- Concept design
- Construction work zone
- Permanent rock scour protection (if required)
- Temporary rock scour protection (if required)
- Properties requiring flood mitigation works. Works subject to further consultation with and agreement from affected property owners.
- Properties requiring noise mitigation works. Works that are feasible and reasonable would be subject to further consultation with and agreement from affected property owners.
- Works subject to further council and stakeholder consultation

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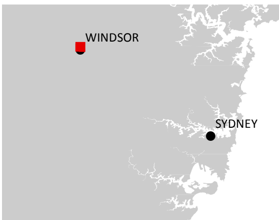

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Sydney Spatial Team - Prepared by : DD
Checked by : JC

The low point of the replacement bridge would be around 9.8 metres Australian Height Datum (AHD), making it around 2.8 metres higher than the lowest point of the existing bridge. The height of the replacement bridge may change slightly during the detailed design phase. This would give the replacement bridge a slightly higher level of flood immunity than the existing bridge. While the existing bridge is overtopped in a one in two year flood event, the replacement bridge is predicted to remain above water for the one in two year flood event but be overtopped in an event just smaller than the one in three year flood. This level of flood immunity is consistent with that of the northern approach roads (Wilberforce Road and Freemans Reach Road), which have a flood immunity that lies about midway between the one in two year and one in three year flood levels.

1.2.3 Demolition of the existing bridge

The existing Windsor bridge would be removed following commissioning of the replacement bridge and associated bridge approach roads. The existing bridge superstructure and substructure would be removed in sections, with temporary bracing installed, as required, to maintain the stability of remaining sections during the demolition process. Where possible the process of demolition would involve cutting or dismantling the superstructure and substructure into sections, with each section transported off-site for further demolition at an appropriately approved and licensed facility. Where possible the dismantled bridge elements would be reused or recycled, however some components of the bridge would require disposal at a landfill. Lead based paint has also been found on the bridge, so demolition activities would need to comply with relevant standards for managing lead based paint. Disruption of waterway traffic would be limited to the greatest extent practicable, with alternative navigation channels provided while the existing navigation span is closed for the demolition works.

1.2.4 Pedestrian and cycling facilities

The project would incorporate facilities for pedestrians and cyclists and include a shared pedestrian/cycle pathway that would be constructed from Wilberforce Road and Macquarie Park, across the western side of the replacement bridge and southern approach road to the corner of George and Bridge Streets. Pedestrian and cyclist access along the southern bank of the river would also be improved with the connection and redevelopment of The Terrace. In addition, the following general works would be undertaken to improve pedestrian safety and access:

- Provision of a new 1.2 metre wide footpath adjacent to properties fronting Old Bridge Street.
- Provision of a new signalised pedestrian crossing on all four approaches to the intersection of Bridge Street and George Street.
- Provision of new pedestrian footpaths for safe access around and across the proposed dual lane roundabout at the junction of Freemans Reach Road, Wilberforce Road and the Macquarie Park access road including a path under the northern bridge abutment.

1.2.5 Water quality basin

The project would include construction of a permanent water quality basin to capture and treat stormwater runoff from the bridge and northern intersection prior to stormwater being discharged to the Hawkesbury River. The water quality basin would be located on the eastern side of the proposed roundabout at the junction of Freemans Reach Road, Wilberforce Road and the Macquarie Park access road.

For the southern approach road a trash net to collect litter and a shut-off-valve to contain any spills in the stormwater system would be installed at the discharge point of the drainage system near Windsor Wharf.

1.2.6 Scour protection

Scour protection would be provided to protect the bridge abutments and piers from the erosive impacts of high river flows. On the southern bank, the scour protection would consist of a concrete panel retaining wall between Windsor Wharf and the existing bridge. Large diameter rocks (900 millimeters) and/or sandstone blocks would also be used to provide scour protection in some locations on the southern bank.

On the northern bank extensive rock and sandstone block scour protection would be required extending up the bank to about five meters above the usual water level. Other forms of scour protection such as a concrete grid planted with grass would be installed in areas above this where scour protection is required.

Scour protection using large rocks would be provided around three of the four bridge piers. Scour protection for each pier would cover an eight metre radius and would be to a depth of 4.5 metres. Dredging around the piers would be required to place the rocks below the river bed level. For the southernmost pier little or no scour protection would be required as bedrock is close to the surface in this location.

During the detailed design phase further work would be undertaken to minimise the visual impact of all visible scour protection.

1.2.7 Public utility works

The existing bridge supports a number of public utilities which would be replicated on the replacement bridge including:

- A 450 millimetre water main (cement lined steel pipe).
- A 50 millimetre sewer rising main (galvanised iron pipe).
- A 100 millimetre electrical conduit.
- Telecommunications conduits (3 x 80 millimetre galvanised iron conduits).

Other public utilities that may need to be adjusted as part of the project include:

- High voltage overhead power lines from Macquarie Street to Wilberforce Road which cross the river on a similar alignment to the replacement bridge. These power lines would need to be relocated prior to bridge construction.
- Power lines near the corner of Wilberforce Road and Freemans Reach Road.
- Local stormwater drainage infrastructure.
- A rising main from Windsor Wharf to the local sewer system, which is used to pump out boat sewage holding tanks.
- A gravity sewer main, which runs beneath Old Bridge and Bridge Streets.
- A number of water mains on both the northern and southern river banks.
- Street lighting on both the northern and southern river banks.
- Telstra assets located on both sides of the river. In particular, Telstra assets located near the proposed southern bridge abutment would need to be relocated prior to construction of the bridge abutment.
- A new recycled water main for future use if required.
- Traffic signal cables along Bridge Street between George Street and Macquarie Street.

1.2.8 Urban and landscape concept design

The urban design and landscape concept design associated with the project was developed by applying project specific urban design principles and treatments. Works associated with the current concept design are described below.

Southern bank and Thompson Square area

At this stage of project development, the scope of works in Thompson Square parkland has yet to be fully defined and would be subject to further consultation with the community, government stakeholders and most importantly Hawkesbury City Council – who would be responsible for managing Thompson Square parkland in the longer term. For the purposes of assessment in the EIS, preliminary urban design and landscaping works for Thompson Square have been identified. These works have been developed with the objectives of providing pedestrian and cyclist access from the replacement bridge to various areas in Thompson Square and providing a base for additional urban design and landscaping works arising from the consultation process. The consultation process for the additional urban design and landscaping works for Thompson Square is ongoing and if possible the full scope of works would be presented and assessed in the Submissions Report. However, it is recognised that the full scope of works may not have been agreed before the completion of the Submissions Report and a post-approval Urban Design and Landscaping Plan for Thompson Square parkland maybe be required.

The scope of works assessed in the EIS include:

- Infilling the southern approach road to the existing bridge.
- Removal of some trees which are either in poor condition or would be impacted by the project.
- Minor earthworks in the Thompson Square lower parkland area to improve the connection of the parkland to the river.
- Construction of stairs from the bridge pedestrian/cyclist path to The Terrace and from Thompson Square road to The Terrace to provide pedestrian access.
- Reinstatement of the section of The Terrace and river bank currently bisected by the existing bridge and approach roads.
- Planting of trees and other vegetation in Thompson Square parkland.
- Landscaping in the road reserve between the three properties on Old Bridge Street and the southern approach road.

Bridge

The project specific urban design principles have been used to refine the visual appearance of the replacement bridge. This includes refinements to the pier shape, bridge superstructure and abutments to minimise its visual impact and provide context to the heritage values of Windsor.

Northern bank

- Infilling the northern approach road to the existing bridge.
- Minor earthworks to improve the visual appearance of the bank.
- Construction of pedestrian/cyclist paths to Wilberforce Road and Macquarie Park.
- Planting of trees and other vegetation.

1.2.9 Construction works

Temporary construction and compound sites

There would be two main construction and compound sites required for the duration of the project (about 18 months, excluding pre-construction and early works). One of these sites would be located within the turf farm between the Hawkesbury River and Wilberforce Road (Lot 2 DP 1096472 and Lot 2 DP65136); while the other would be sited on land between Old Bridge Street and Windsor Wharf (refer to **Figure 1-1**). The lower Thompson Square parkland would also be closed to public access and used to provide access for the construction of the southern abutment and approach road. The majority of the construction activity would be concentrated on the northern bank as this would be the location of casting yard for the incrementally launched bridge and would be the location where access to the river would predominately occur.

The construction compound on the southern bank would be located in the car parks and grassed areas and would support the construction of the southern approach road and other minor works.

Offices may be leased near Thompson Square for construction personnel.

Order of Construction Works

The order of construction works would be implemented to minimise environmental and traffic impacts as far as practical. The likely order of construction works would consist of the following:

- Pre-construction activities and early works – including construction compound and casting bed establishment, installation of environmental controls, public utility relocations or adjustments and additional investigations and heritage salvage.
- Construction of the bridge - including construction of the piers in the river, two bridge abutments and construction and launching of the bridge superstructure.
- Installation of scour protection on the banks and in the river.
- Construction of the northern roundabout and approach road and most of the southern approach road.
- Construction of temporary pavement both at Wilberforce Road and near the corner of George and Bridge Streets to provide additional road width to enable construction of the subsequent stages.
- Construction of the remainder of the southern approach road and the new sections of Freemans Reach Road, Wilberforce Road and Macquarie Park access road.
- Commissioning and opening of the replacement bridge to traffic.
- Demolition of the existing bridge and urban design works in Thompson Square, on the southern bank, northern bank and other adjacent areas.
- Removal of temporary structures and demobilisation of the construction facilities.

This proposed order of construction works is indicative and may change once detailed construction planning is completed. It is likely that some aspects of construction may overlap.

Construction period

It is anticipated that a construction period of around 18 months (excluding pre-construction and early works) would be required to complete the proposed works including demolition of the existing bridge.

Work hours

The majority of the construction works would be carried out during standard working hours, as detailed in **Table 1-1**. Some construction activities, in particular those requiring road closures, would need to be undertaken outside of standard working hours to prevent major disruptions to traffic and access. Other construction activities such as service relocations and cutovers may also need to be undertaken outside normal working hours. Low noise activities may also be undertaken outside of normal working hours to optimise construction efficiency.

Table 1-1 Standard working hours

Day	Start time	Finish time
Monday to Friday	7am	6pm
Saturday	8am	1pm
Sunday and public holidays	No work	

Construction equipment

The types of construction equipment likely to be used for the project would include (but would not necessarily be limited to) the following:

- Excavation plant, such as excavators, back hoes and front end loaders for pavement cutting, removal and general earthworks.
- Bobcats and sweepers.
- Compaction plant, including rollers, vibrating rollers, concrete vibrators and trench plate compactors.
- Pneumatic jack hammers.
- Profiling, milling and road paving plant.
- Jet-blasting and shot-blasting machines.
- Miscellaneous vehicles, including utilities, trucks, bogies and semi-trailers.
- Miscellaneous hand tools and equipment.
- Generators, lighting towers, signage and variable message boards.
- Various barges, workboats and pontoons.
- Piling rigs and various mobile and fixed cranes.
- Concrete and grouting pumps and transport vehicles.
- Support trusses, stress jacks and scaffold systems.

1.3 Director General's Environmental Assessment Requirements

The Director General's Environmental Assessment Requirements (DGRs) related to noise and vibration are provided in **Table 1-2** with reference to where these are addressed in this report.

Table 1-2 Director General's Environmental Assessment Requirements

Requirements	Where addressed
Assess construction and operational noise and vibration impacts of the project, in accordance with the *Interim Construction Noise Guideline (*(Department of Environment and Climate Change, 2009), *NSW Road Noise Policy* (Department of Environment, Climate Change and Water, 2011), and *Assessing Vibration: a Technical Guideline (*Department of Environment and Conservation, 2006*).*	Section 4 – Operational noise and vibration Section 5 – Construction noise and vibration

2 Assessment methodology

This noise and vibration assessment for the project has been undertaken in accordance with the requirements of the Director General of Planning and Infrastructure. The noise and vibration study is to assist in future design decisions, including development of mitigation strategies where noise or vibration impacts have the potential to affect the broader community.

2.1 Operational noise

The assessment of road traffic noise impacts has been undertaken using the guidance detailed in the 'Road Noise Policy' (RNP) (DECCW, 2011) and the 'Environmental Noise Management Manual' (ENMM) (RTA, 2001). These guidelines detail the criteria and methods used to assess impacts on noise sensitive receivers for road projects undertaken in NSW.

The detailed operational noise modelling and assessment applies the noise level targets from these guidelines to residential and non residential noise sensitive receivers identified for the project. The assessment of operational noise is specified in the RNP as up to 600 metres from the project alignment depending on the location of identified noise sensitive receivers. Where noise goals cannot be achieved through design strategies, additional mitigation may be required to address and mitigate noise impacts where necessary.

The noise assessment is comprised of discrete tasks that form the basis of determining the mitigation requirements, which can be generalised as follows.

2.1.1 Receiver identification and baseline noise monitoring

Noise sensitive receivers for the project were identified from previous reports undertaken for the heritage and urban landscape specialist studies. These studies provided the classification of residential and non residential sensitive receivers immediately adjacent to the project and those that are located further from the project but which may still be affected by traffic noise from the replacement bridge (see **Section 3**). Non-residential receivers for the purpose of this project were those receivers classed as commercial or buildings/locations of heritage importance.

Targeted noise and vibration monitoring at residential locations was undertaken to establish the influence of road traffic from the existing alignment. The noise levels at these locations were quantified using noise monitoring equipment that collect long term data; this was undertaken in conjunction with vehicle counts during the survey period.

Monitoring was undertaken between February and March 2012 at three residential locations considered to be representative of noise impacts adjacent to the alignment. The unattended monitoring employed ARL Ngara Type 1 Environmental Noise Loggers with current calibration certificates.

The noise monitoring equipment complies with Australian Standard 1259.2-1990 '*Acoustics – Sound Level Meters*'. The calibration of each logger was checked prior to and after the measurement period, with the calibration found to be within acceptable limits (±0.5dB (A)). **Section 3.2** presents details of the monitoring locations and a summary of the results of the noise monitoring survey.

The monitoring survey was used to establish the existing traffic noise levels for the day and night periods, being the $L_{Aeq,\ (15\ hour)}$ and $L_{Aeq,\ (9\ hour)}$ respectively. For the purposes of road traffic noise assessments, these periods are defined as:

- $L_{Aeq,\ (15\ hour)}$ represents the L_{Aeq} noise level for the period 7 am–10 pm.
- $L_{Aeq,\ (9\ hour)}$ represents the L_{Aeq} noise level for the period 10 pm–7 am.

Monitoring data of the existing noise environment was used for the operational traffic noise assessment. The same data set was analysed to extract different parameters to describe specific aspects of the noise environment. For the operational assessment the data provided baseline noise levels and was used to establish the predictive noise model, which was calibrated against these measurements. Once calibrated using the measurement locations, the noise model is used to determine the operational noise levels for the all identified receivers for both the existing and proposed scenarios.

2.1.2 Modelling of existing and proposed road alignments

While monitoring can be used to identify specific details of the noise environment at an individual location, the objective of noise modelling is to establish the noise impacts across the broader study area.

The assessment of noise impacts at noise sensitive receiver locations draws on the predictive ability of the noise model to assess future operational scenarios. The information gathered for the project is combined in the noise model to produce scenarios representing the current situation and also the future layout if the project proceeds.

The parameters of each of the modelling elements for the existing and proposed road alignments was used to calculate traffic noise levels for the project, which were then compared to the project noise goals in **Section 4.1**. Only significant factors in the prediction of noise levels for a project were considered such as the number of vehicles that use the road, their speed, road gradient and the road surface type, as these values determine the source noise level.

The parameters used in the assessment of road traffic noise for the replacement bridge are presented in **Table 2-1** and were incorporated into the noise models for the existing and proposed alignments accordingly.

Table 2-1 Modelled noise parameters

Variable	Description	Parameters used in noise modelling
Traffic volumes and mix	The number of vehicles using the road as well as the proportion of heavy to light vehicles. A higher ratio of heavy vehicles increases the noise levels proportionally.	*Calibration:* Traffic numbers based on monitored data for 2012. *Assessment:* Traffic numbers based on predicted data for year opening 2016 and design year 2026 for the build and no build options.
Traffic speed	Higher traffic speeds generate higher noise levels due to the road/tyre influence.	*Existing:* Speeds of 30-60km/h. *Proposed:* posted speeds of 50-60km/h.
Road surface types	Can be asphaltic concrete, rigid concrete pavement or other types as applicable. Each surface type generates different levels of tyre noise.	*Existing:* The existing wearing surface is dense grade asphalt (DGAC). In some locations the pavement is in fair condition and in other locations (eg. the bridge) the pavement and joints are in very poor condition. *Proposed:* The surface type for the upgrade is assumed to be DGAC.

Variable	Description	Parameters used in noise modelling
Gradient of roadway	Noise levels change as a result of traffic climbing or descending hills compared with traffic travelling along flat gradients. The road upgrade tends to flatten the alignment compared to the steep gradient on the southern entry/exit of the existing bridge.	Gradients are automatically calculated in the model based on the existing and proposed road alignments.
Ground topography	Natural topographic features such as hills and valleys can shield residences from traffic noise.	Terrain contours and survey obtained from the RMS.
Height of receivers	May be single or multiple storey residential dwellings. The height of the receiver would influence the exposure to traffic noise and the ability to mitigate adverse impacts.	Assessment height of 1.5 metres above ground terrain.
Air and ground absorption	Softer surfaces increase noise attenuation with distance. In contrast, harder surfaces reduce attenuation.	Ground absorption is assumed to be 50 % for modelling.
Corrections	Corrections for modelling for façade and L_{A10} to L_{Aeq}.	L_{A10} to L_{Aeq} has a -3dB(A) correction Facade reflection is +2.5 dB (A).

The wearing surface identified for the existing road is a dense grade asphalt. The assessment of the existing road surface includes a correlation with the measured noise levels and while identified as a dense grade asphalt surface, still provides a noise level correction of +2 dB(A) for the calibration modeling. This recognises that while theoretical road surface corrections are identified for specific surface types, these are averages and in practice, there is a degree of variability in the construction and application of a pavement.

The existing pavement shows signs of wear and it's condition is variable. On the southern approach road the condition of the pavement is fair. However on the bridge the pavement is in poor condition and the joints of the bridge slab protrude substantially. On the northern approach road the pavement varies in quality and there is a change in pavement type (from DGAC to a chip seal) near the intersection of Freemans Reach Road and Wilberforce Road. Based on replacing the variable pavement condition and type the re-application of a new DGAC road surface across the whole project would provide an acoustic benefit in the order of -2 dB(A) for the project design speed.

2.1.3 Project traffic

Traffic volumes for the project have been provided in the Traffic and Transport working paper prepared for the EIS and included consideration of the future growth in traffic numbers (see **Table 2-1**) and include both the build and no build options. There is no anticipated increase in traffic as a result of the project and therefore the traffic numbers for the build and no build options were assumed to be the same.

The data used in the modelling of traffic noise impacts are based on the average flows over the whole year and represent the Annual Average Daily Traffic (AADT) flows. These flows are calculated from Sydney Coordinated Adaptive Traffic System (SCATS) data, RMS permanent counting stations and actual site measurements from tube counts. In practice the estimated vehicle movements vary on a daily or weekly basis depending on seasonal traffic flows and other factors.

Table 2-2 presents the traffic volumes for the year of opening and includes composition details for the noise modelling scenario in terms of total traffic numbers for day and night time and the percentage of heavy vehicles included in the traffic mix.

Table 2-2 Modelling traffic data input for year of opening (2016)

Location	Daytime (15hour)				Night time (9hour)			
	Light	Heavy	Total	% Heavy	Light	Heavy	Total	% Heavy
Bridge Street (north bound)	9072	659	9731	7%	1343	143	1487	10%
Bridge Street (south bound)	7831	539	8370	6%	2614	275	2889	10%

Table 2-3 presents the traffic data for the design year for the build and no build modelling scenario.

Table 2-3 Modelling traffic data input for year of design (2026)

Location	Daytime (15hour)				Night time (9hour)			
	Light	Heavy	Total	% Heavy	Light	Heavy	Total	% Heavy
Bridge Street (north bound)	10,501	763	11,264	7%	933	100	1033	10%
Bridge Street (south bound)	9057	623	9680	6%	1814	191	2005	10%

2.1.4 Calibration of the noise model

The noise model was used to predict future traffic noise impacts but was first calibrated with the measured noise levels from the noise monitoring survey, which were correlated with the simultaneous traffic counts. The differences from the modelled and actual measured levels were corrected in the model by a calibration factor. This factor was then used in the correction of all the project assessment scenarios.

The traffic counts were undertaken in conjunction with the noise monitoring for the project between 8 and 19 of March 2012 and are presented in **Table 2-4**. These counts represent a snapshot of traffic at the time of monitoring and are Average Daily Traffic (ADT) flows as opposed to the annualised traffic data (AADT) used in the modelling of the future scenarios and therefore may be higher or lower depending on seasonal variations. The monitoring traffic counts were modelled in conjunction with the existing road parameters to generate noise level predictions that represent the traffic noise impacts for the existing road and traffic conditions.

Table 2-4 Calibration traffic data for the year (2012)

Location	Daytime (15hour)				Night time (9hour)			
	Light	Heavy	Total	% Heavy	Light	Heavy	Total	% Heavy
Bridge Street (north bound)	10,371	1054	11,425	9%	742	142	884	16%
Bridge Street (south bound)	8968	932	9901	9%	1069	222	1290	17%

The predicted levels from the noise model of the existing situation were compared to the measured traffic noise levels in **Table 3-3** to determine any variation between the two. **Table 2-5** presents the predicted noise levels from the calibration scenario and the measured noise levels from the unattended monitoring at each receiver location. The model calibration includes standard corrections of -3dB(A) for the conversion from an L_{A10} to L_{Aeq} parameter and +2.5 dB(A) for facade correction. The reported median results for day and night are taken as the calibration factors required for the project.

Table 2-5 Comparison of measured and modelled road traffic noise levels

Location ID	Day $L_{Aeq(15h)}$ dB(A)			Night $L_{Aeq(9h)}$		
	Measured	Modelled	Difference	Measured	Modelled	Difference
R1	68.1	69.5	1.4	62.8	63	0.2
R3	71	70.6	-0.4	66.5	64.8	-1.7
R4	56.6	58.9	2.3	51.4	52.7	1.3
Median result			**1.4**			**0.2**
Standard deviation			**1.4**			**1.5**

In practice, modelling cannot account for all aspects of the existing environment and therefore variations to measured and modelled noise levels will occur. Both the day time and night time predicted noise levels vary from the measured noise levels over the monitoring period and therefore require a correction to calibrate the noise model for existing conditions. A correction of -1.4 dB(A) for the daytime and -0.2 dB(A) for the night-time was added to the predicted results to maintain an acceptable level of predictive accuracy for the future assessment scenarios.

2.1.5 Mitigation recommendations

Where predicted noise at sensitive receivers exceeded the project specific noise management levels, mitigation would be recommended to reduce the level of external impacts where possible. Where the external noise environment was unable to be controlled at source, for feasible and reasonable reasons in terms of costs, benefit and practicality, options for treatment of individual properties were also considered.

Any noise mitigation measures would need to be developed in consideration of the heritage, urban design and landscape aesthetics and requirements of the local environment.

2.2 Operational vibration

The project has the potential to alter the generation and propagation of ground borne vibration. The purpose of the vibration study was to quantify and assess the level of ground borne vibration to which residents and buildings are already exposed, and to predict and assess any changes in these levels as a result of the project.

The potential for impact is likely to be the greatest at properties currently located along Old Bridge Street, immediately adjacent to the southern approach road and bridge abutment. As these buildings are heritage structures the potential for adverse impacts from vibration may be greatly increased due to the construction and age of the buildings.

Predictions of operational vibration, in terms of both acceleration and velocity, were assessed against Australian and International Standards and Guidelines, including:

- ‘Assessing Vibration: A Technical Guideline’ (DEC, 2006)
- Australian Standard AS2670.2 ‘Evaluation of human exposure to whole-body vibration’. Identical to International Standard ISO 2631-1:1997
- British Standard BS7385: Part 2 Evaluation and measurement of vibration in buildings, 0 580 22188 1 (British Standards Institution, 1993)
- BS5228:2009 Part 2 Code of Practice for noise and vibration control on construction and open sites-Vibration (British Standards Institution, 2009)
- German Standard DIN 4150: Part 3 – 1999 Effects of Vibration on Structures (German Institute for Standardisation, 1999)

At the closest receivers, existing vibration sources may include road traffic movements on Bridge Street and, therefore, these levels were measured to establish a baseline vibration level. While it is recognised that the vibration criteria used for the assessment were absolute and not compared to the existing conditions, collection of these data assisted with the prediction of vibration associated with traffic movements for the project.

The prediction of vibration for future scenarios was based on measurements of traffic from the existing alignment and through establishing a vibration site law (as attenuation or propagation factor) for the intervening terrain between the proposed alignment and existing receivers on Bridge Street. The site law was developed using sensitive accelerometers and geophones to measure the vibration at different distances from the force generated by a controlled impact (described in **Section 6.4.1**) between the existing road and the residences on Bridge Street.

The vibration associated with the movement of existing road traffic moving along Bridge Street was monitored at a number of distances from the kerbside and at the facades of sensitive dwellings. Short term measurements (about 5 - 15 minute) were undertaken of standard traffic flows throughout daytime periods. Measurements were undertaken until a representative sample of different vehicles passing, at different speeds and in different directions were observed and recorded.

Average road speeds on Bridge Street were between 5 km/h and 35 km/h, depending on their direction of travel and the amount of traffic in each direction. The condition of the road surface in the areas adjacent to the monitoring and across this road stretch in general is in fair condition with no signs of potholes, cracks or other features which would result in high levels of vibration. In addition, the asphalt surface is relatively fine grade which again reduces potential high vibration events.

The controlled impact produced a vibration wave which propagates through the ground. The propagation is dependent on the specific ground characteristics at each measured location. The measurement of the vibration at different distances provided a site-specific indication as to how vibration was attenuated through the ground over a given distance and was used to develop a site law. The existing road traffic movements in each location were also measured and the site law was then applied to the vibration levels generated by the vehicles to predict levels at the building footings. These predictions were then repeated for the proposed new alignment to identify areas of potential risk from vibration impacts caused by road traffic.

The baseline measurements for the controlled impacts and traffic were undertaken at residential locations along Old Bridge Street in February 2012. At receivers on Bridge Street there was sufficient distance between the road and the residence to obtain measurements that allow the development of the empirical site law. The development of the site law and data from the site measurements are presented in **Section 6.2**.

2.3 Construction noise

The assessment of construction noise impacts is guided by the 'Interim Construction Noise Guidelines' (ICNG) (DECC 2009). Prediction of noise levels from both general and specific road construction activities at the most-affected residences are compared to the recommended noise management levels outlined in the ICNG. These guidelines recognise the significance of construction noise within the community and have identified noise goals and standard working hours to minimise these impacts (see **Section 7.1**).

The baseline monitoring undertaken for the project was used to develop project specific noise management levels for the project. The monitoring was undertaken on both banks of the river to reflect any changes in the noise environment on either side of the project. Unlike the operational noise assessment periods, the construction assessment includes consideration of the evening period to reflect the change in the environment and the transition between day and night activities. The ICNG standard hours for construction are presented in **Table 2-6**.

Table 2-6 Standard hours of construction

Day	Time
Monday to Friday	7 am to 6 pm
Saturday	8 am to 1 pm
Sunday and Public Holidays	No work

Typical construction scenarios for the project include linear construction tasks, such as clearing, earthworks and paving, and noisy activities such as piling. The predicted construction noise levels at noise sensitive receiver locations were estimated using SoundPlan with a similar noise model to the operational noise model. The construction noise model included several construction scenarios based on the scheduling and methodology provided for the concept design. Once the detailed design phase has been completed, and actual construction locations and activities are known, a more comprehensive assessment of construction noise impacts may be required. A detailed assessment would usually be undertaken through the development of a Construction Noise and Vibration Management Plan following approval. This would aim to take account of any changes in construction methodology as identified in this document.

Based on the predicted construction noise levels, recommendations to mitigate or eliminate potential short and long term noise impacts generated by the project have been made (see **Section 7** for mitigation measures).

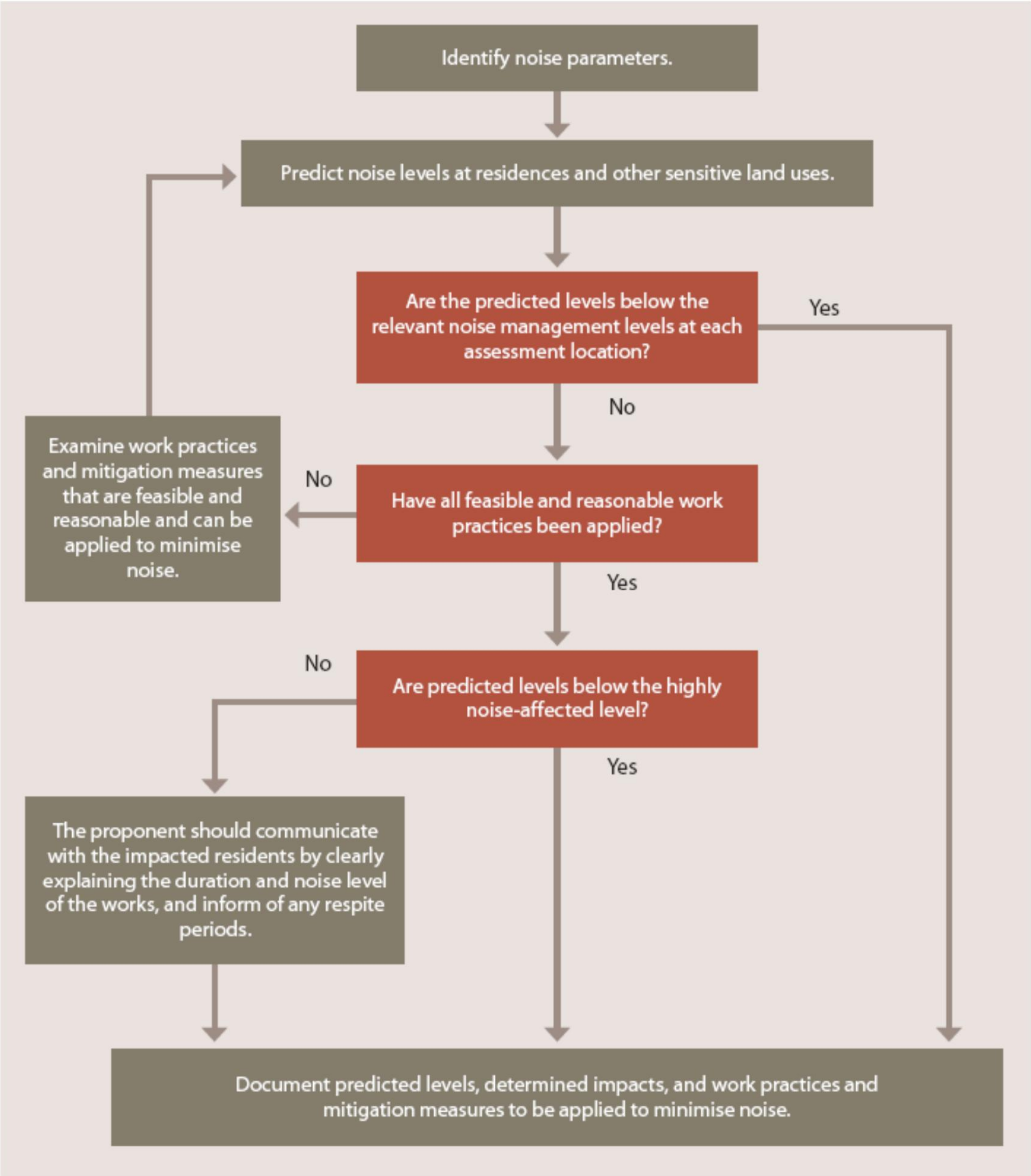
Using the baseline noise levels and constructions scenarios, an assessment of potential construction noise levels at receiver locations has been made following the general flow chart methodology identified in the ICNG shown in **Figure 2-1**.

2.4 Construction vibration

Where construction activities were identified within 20 metres of the existing residences, impacts have been quantified and assessed using the site laws developed for the operational vibration assessment. Works that are likely to generate an impact include the use of standard construction equipment (excavators, trucks etc) in close proximity to buildings or the use of rock hammers, rock breakers, compactors or piling rigs.

Using in-house and published data to determine typical vibration levels associated with these activities, a prediction of the resulting level at nearby receiver locations was undertaken using the site law and empirical formulas developed for the operational assessment to determine the potential for propagation of ground borne vibration.

Figure 2-1 Construction assessment methodology flow chart (*DEC 2009*)



3 Existing environment

Information on the location of noise and vibration sensitive receivers and the existing acoustic environment was used in establishing a baseline for the project. Noise monitoring was undertaken at key receiver locations to quantify the existing environment, which was later used in calibration of the noise model and the basis of setting construction noise criteria for the project.

For the project, measurement of current vibration levels were also completed for the closest receiver location adjacent to the proposed alignment. The measured vibration levels provide details of the potential impact of existing traffic movements for both human comfort and structural damage to heritage buildings.

A discussion of the existing environment including receiver locations details of the noise and vibration monitoring surveys is presented in this section and the project criteria for assessment of impacts is presented in **Section 4.**

3.1 Identification of sensitive receivers

The study area comprises a mixture of residential and commercial receivers, many of which are buildings or items with local and/or State heritage significance. The closest residences are located along the lower end of Old Bridge Street adjacent to the southern approach road of the existing and replacement bridge and a single residence is located at the northern end of the existing and replacement bridge on the corner of Freemans Reach Road and Wilberforce Road.

There are around 175 sensitive receivers situated within a 200 metre radius of the project, comprising a mixture of residential and commercial buildings (including hotels, retail outlets, and offices. Receivers within 20 metres of proposed works were classed as both noise and vibration sensitive receivers whereas those located further afield would only have the potential to be affected by noise. Many of these receivers are already exposed to traffic noise from Bridge Street, Macquarie Street and Windsor Road, George St, Wilberforce Road, Freemans Reach Road.

The project would extend for approximately 320 metres across the Hawkesbury River and up to the intersection of George Street and Bridge Street, with approximately half of that distance being the replacement of the existing bridge. Due to the local topography and the relatively built up nature of the study area, the impacts of operational and construction noise from project would be limited primarily to the nearest receivers adjacent to the new alignment.

Receivers beyond the first row of houses have the benefit of shielding from the intervening rows of buildings and are additionally affected by other roads in the area. Therefore, only the properties immediately adjacent to the alignment are considered on a quantitative basis in this assessment. The locations of these receivers are presented in **Appendix A** and listed in **Table 3-1**.

Table 3-1 Residential sensitive receivers

ID	Receiver Location	Details	Distance from existing road
R1	27 Wilberforce Road	Single storey residential dwelling	17 metres
R2	4 Bridge Street	Single storey residential dwelling. Lightweight brick and weatherboard construction.	27 metres
R3	10 Bridge Street	Double storey mixed residential upper floor and commercial lower floor, heritage building. Masonry construction	10 metres
R4	53 George Street	Double storey residential building. Masonry construction	40 metres
R5	12 The Terrace	Single storey residential dwelling. Masonry construction	145 metres
R6	14 The Terrace	Single storey residential dwelling. Masonry construction	160 metres
R7	16 The Terrace	Single storey residential dwelling. Masonry construction	172 metres
R8	18 The Terrace	Single storey residential dwelling. Masonry construction	190 metres
R9	20 The Terrace	Single storey residential dwelling. Masonry construction	205 metres
R10	22 The Terrace	Single storey residential dwelling. Masonry construction	223 metres
R11	45 George Street	Single storey residential dwelling. Masonry construction	120 metres
R12	43 George Street	Single storey residential dwelling. Masonry construction	133 metres
R13	41 George Street	Single storey residential dwelling. Masonry construction	150 metres
R14	39 George Street	Single storey residential dwelling. Masonry construction	178 metres
R15	29 George Street	Single storey residential dwelling. Construction unknown	250 metres
R16	16 Bridge Street	Single storey residential dwelling. Masonry construction	8 metres

Table 3-2 Non residential sensitive receivers

ID	Receiver Location	Details	Distance from existing road
H1	4 Bridge Street	Heritage listed brick wall to rear of 4 Bridge Street. Masonry and mortar construction	30 metres
H2	6 Bridge Street	Single storey commercial building. Medium-weight brick construction	15 metres
H3	99 George Street	Double storey commercial, heritage building. Masonry construction	45 metres
H4	7 Thompson Square	Double storey commercial, heritage building. Masonry construction	30 metres
H5	5 Thompson Square	Single storey commercial, heritage building. Masonry construction	25 metres
H6	3 Thompson Square	Double storey commercial, heritage building. Masonry construction	10 metres
H7	70 George Street	Single storey commercial, heritage building, Masonry construction	45 metres
H8	74 George Street	Double storey commercial, heritage building. Masonry construction	40 metres
H9	68 George Street	Double storey commercial, heritage building. Masonry construction	35 metres
H10	62 George Street	Single storey commercial, heritage building. Masonry construction	6 metres
H11	17 Bridge Street	Single storey commercial, heritage building. Timber construction	5 metres
H12	14 Bridge Street	Single storey commercial, heritage building. Masonry construction	<5 metres
C1	Windsor Terrace Motel 47 George Street	Double storey commercial building. Masonry construction	80 metres
C2	Road reserve	Underground services channel/pipe running along Bridge Street	8 metres
C3	Windsor Motel	Double storey commercial building. Masonry construction	15 metres
T1	Thompson Square 1	Passive recreational land	5 metres
T2	Thompson Square 2	Passive recreational land	25 metres

There is an underground services channel (labelled C2) that runs parallel to the road in the nature strip at the front of 4, 6 and 10 Bridge Street. These services are not subject to the same assessment of noise and vibration as residential dwellings however, they would require consideration of vibration impacts during the construction phase.

The receivers identified as T1 and T2 are representative receiver points within the Thompson Square parkland. T1 is representative of users of the parkland close to the existing road, with T2 being in the parkland at the furthest distance from the alignment. Noise predictions at these two points would provide an indication of the highest and lowest levels within Thompson Square parkland.

3.1.1 Consideration of heritage items

Most of the buildings around Thompson Square are heritage listed and must be protected. As noise and vibration may impact upon these items they must be considered in the assessment and any subsequent mitigation measures recommended for the project.

These considerations include the effect of operational and construction vibration on building structures and the use of noise mitigation such as noise barriers and architectural treatments that impact on the visual aspects and heritage values of the area. The noise and vibration study has been undertaken incorporating these requirements in the discussion and recommendation of noise mitigation.

Heritage buildings at 10 Bridge Street (H3) and 6 Bridge Street (H2) and the heritage listed brick retaining wall within the grounds of number 4 Bridge Street (H1) are closest to the southern approach road of the project, with the new road around 10 metres from the property boundaries at the closest point. A study of vibration impacts with reference to these structures is included in **Section 6.4**.

Thompson Square parkland has been assessed in accordance with the RNP for this category of space. This parkland is a place of passive recreation, which provides seating and tables for public use. The Thompson Square parkland is currently split by Bridge Street and is subject to high levels of traffic noise from Bridge Street and Windsor bridge. The noise environment for this area for the existing and future scenarios has been modelled for comparison to the RNP guidelines with the results presented in **Section 5.1.1.**

3.2 Noise and vibration monitoring

3.2.1 Existing noise

Monitoring of the existing noise environment consisted of long-term measurements of traffic noise adjacent to the existing alignment for Bridge Street, Wilberforce Road, and Freemans Reach Road.

Weather data was obtained from the Bureau of Meteorology from the Windsor Weather Station site for the duration of the monitoring to identify periods which may be adversely affected by high winds or rain.

The unattended noise monitoring locations selected for the study area are presented in **Table 3-3** and are shown on the aerial photography in relation to the existing alignment in **Appendix A**.

The primary noise source at the monitoring locations was traffic noise from Bridge Street, Wilberforce Road, and Freemans Reach Road. There were no industrial noise influences noted at any of the monitoring sites.

Table 3-3 Unattended noise monitoring locations

Receiver		Logger location and description	Monitoring period	Noise sources
R1	27 Wilberforce Road	One metre from the building façade facing onto Wilberforce Road. About 15 metres from Wilberforce Road.	9 March – 19 March 2012	Road traffic noise from Wilberforce Road and Freemans Reach Road.
R3	10 Bridge Street	Edge of Veranda facing onto Bridge Street. Located on the upper floor terrace, about six metres high relative to Bridge Street.	9 March – 19 March 2012	Road traffic noise from Bridge Street dominant.
R4	53 George Street	Free field, at rear of property boundary. About four metres from the building. Has a clear view of lower Bridge Street, existing Windsor Bridge and Wilberforce Road. About 70 metres from Bridge Street and 250 metres from Wilberforce Road.	9 March – 19 March 2012	Road traffic noise from Bridge Street, Wilberforce Road and bird/insect noise.

The monitoring data was processed to provide information on traffic noise influences and background noise levels used in the assessment of construction noise impacts for the project. The summary of traffic noise parameters at the monitoring locations is provided in **Table 3-4**. The traffic noise for the $L_{Aeq\ 15hr\ and\ 9\ hr}$ (day and night) periods represented the noise levels at the time of monitoring only, which were correlated with traffic counts undertaken at the same time.

Table 3-4 Summary of traffic noise monitoring descriptors

ID	Receiver	L_{A10} 18 hour dB(A)	L_{A10} 1 hour dB(A)	L_{Aeq} 15 hour dB(A)	L_{Aeq} 9 hour dB(A)	L_{Amax} 15 hour dB(A)	L_{Amax} 9 hour dB(A)
R1	27 Wilberforce Road	68.9	62.7	68.1	62.8	92.0	88.4
R3	10 Bridge Street	72.3	65.0	71.0	66.5	87.5	83.7
R4	53 George Street	57.9	51.7	56.6	51.4	74.8	72.4

By analysing the monitoring data using alternative parameters, an indication of the background noise levels present at the time of the survey was also obtained. These data provide the basis for setting criteria for the construction noise assessment (see **Section 4.2**). A summary of the environmental noise parameters used in the construction assessment is provided in **Table 3-5**. The graphical output of the monitoring data, for each of the three logger locations is presented in **Appendix B**.

Table 3-5 Summary of Rating Background Level (RBL), dB (A)

ID	Receiver Locations	Rating Background Level (RBL) dB(A)		
		Day 7am-6pm	Evening 6pm -10pm	Night 10pm-7am
R1	27 Wilberforce Road	57.7	50.3	38.8
R3	10 Bridge Street	61.7	56.1	41.1
R4	53 George Street	45.1	42.1	27.2

The RBL from **Table 3-5** were applied to the ICNG guidelines to provide the project construction noise management levels. The noise management levels relate to the measurement locations but may also be applied to other areas that experience similar existing noise impacts. A detailed discussion of construction noise criteria is provided in **Section 4.2**, with a summary of the project noise management levels in **Section 4.2.3**.

3.2.2 Existing vibration

Attended vibration monitoring was undertaken at two locations along Bridge Street; these being at the kerbside (about 0.5 metres from the kerb and one metre from the line of the closest wheel) in front of 4 Bridge Street (R2) and at the kerbside in front of 10 Bridge Street (R3). Monitoring was also undertaken simultaneously at the structural facade of 4 and 10 Bridge Street.

The results of traffic vibration monitoring are provided in **Table 3-6** which also identifies vehicle types, direction and speed estimations. The monitoring data show that, in general, where traffic was moving from the George Street / Bridge Street intersection northbound, vibration levels for the same type of vehicles were lower than those travelling southbound towards the intersection. This was primarily due to the greater separation distance (ie the southbound travel lane is closer to residences).

The road traffic vibration frequencies at the kerbside and receiver building structure were all between 12 and 200 hertz (Hz).

Table 3-6 Road traffic vibration data

Vehicle Class	Speed	Maximum recorded PPV / mms^{-1}							
		Bridge to Roundabout (north to south) @5m from source			Roundabout to Bridge (south to north) @1m from source			Maximum PPV At Structure (mms^{-1})	Maximum PPV At Structure (mms^{-1})
		x	y	z	x	y	z	z	z
Car/SUV/4wd (under 2.5T)	5-20kmh^{-1}	0.06	0.07	0.09	0.07	0.08	0.10	<0.002	<0.002
	>20kmh^{-1}	0.06	0.07	0.09	0.07	0.08	0.11	<0.002	<0.002
Van/Lightweigh t truck (2.5T -)	5-20kmh^{-1}	0.06	0.07	0.10	0.08	0.09	0.11	<0.002	<0.002
	>20kmh^{-1}	0.06	0.07	0.09	0.08	0.08	0.12	<0.002	<0.002
Large Van (2 axel 5T -)	5-20kmh^{-1}	0.07	0.08	0.09	0.11	0.11	0.16	<0.002	<0.002
	>20kmh^{-1}	0.08	0.08	0.10	0.12	0.11	0.20	<0.002	<0.002
Small Truck	5-20kmh^{-1}	0.09	0.08	0.14	0.27	0.22	0.28	<0.002	<0.002
	>20kmh^{-1}	0.10	0.10	0.18	0.30	0.22	0.44	<0.002	<0.002
Large Truck	5-20kmh^{-1}	0.22	0.31	0.87	0.25	0.35	0.87	<0.002	<0.002
	>20kmh^{-1}	0.24	0.33	0.88	0.26	0.40	1.02	<0.002	<0.002

The maximum peak particle velocity (PPV) (along the z axis), as recorded at the building structure, was the general background vibration at each of the receivers, and was less than 0.002 millimetres per second during all traffic monitoring. At these locations, the road traffic is likely to be the only source contributing to the ambient vibration levels. For short periods of time, localised and normal domestic activities can create vibrations that are perceptible to humans (>0.02 millimetres per second).

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4 Assessment criteria

4.1 Operational noise

4.1.1 Base criteria

The Road Noise Policy (RNP) classifies work to an existing road as a "redevelopment", a definition that may be applied to a freeway, arterial or local road category. Depending on the road type, noise level assessment criteria are nominated for both the day and night periods (outlined in **Section 2.1**).

The influence of traffic noise on existing receivers due to the proposed road and bridge works is defined in the RMS Environmental Noise Management Manual in Practice Note (i) as:

"A site is defined as having an "existing road traffic noise exposure" if the prevailing noise level from the existing road alignment(s) under consideration is equal to or greater than 55 dB(A) $L_{Aeq\ (15hr)}$ (day) or 50 dB(A) $L_{Aeq\ (9hr)}$ (night)."

The noise goals for both day and night aim to achieve these levels for at least a period of ten years after project completion. The criteria for the road redevelopment for the project have been summarised from the RNP and are presented in **Table 4-1**.

Table 4-1: Road traffic noise base criteria

Road category	Type of project/land use	Noise Criteria Day 7am -10pm	Noise Criteria Night 10pm – 7am
Freeway/arterial/ sub-arterial roads	Existing residences affected by noise from redevelopment of existing freeway/arterial/sub-arterial roads	$L_{Aeq\ (15hour)}$ 60 dB (A)	$L_{Aeq\ (9hour)}$ 55 dB (A)

The criteria are assessed against a set of standard evaluation scenarios for road projects outlined in the RNP. These are necessary to provide a fixed assessment for all road projects on which to base consideration of impacts. The evaluation of noise impacts is undertaken for two timeframes:

- within one year of changed traffic conditions
- for a design year (typically ten years) after changed traffic conditions

For each of these timeframes, a comparison is made between:

- the road traffic noise levels if the project proceeds, known as the 'build option'
- the corresponding road traffic noise levels, due to general traffic growth, that would have occurred if the project had not proceeded, known as the 'no build option'.

4.1.2 Additional criteria

In addition to the base criteria, the ENMM identifies a category of highly affected noise sensitive receivers that have been termed "acute". These receivers experience noise levels that would be greater than or equal to $L_{Aeq\ (15hour)}$ 65dB(A) and $L_{Aeq\ (9hour)}$ 60 dB(A). In these instances an assessment of noise mitigation in accordance with ENMM practice note (iv) is required.

In areas of new or existing impact, where the increase in noise is due to a road redevelopment, the RNP recommends that a relative increase greater than 12 dB(A) in total traffic noise levels should be considered for mitigation. This relative increase criterion does not apply for open spaces or where the main road to be assessed is a local road. Due to the very short length of road to be assessed and its location in an existing road corridor within an existing road network, the relative increase criterion would not apply to the identified receivers for the project.

Assessment criteria for other non residential land uses are presented in **Table 4-2** and are taken from Section 2.3.2 of the RNP. These are a special category of receiver that are not necessarily residential, but require consideration due the nature of activities associated with their use. These criteria do not require an assessment against a 'build' and 'no build' scenario in the same ways as residential requirements. The guideline levels for non residential uses identify functional performance requirements, where normal operation or use is expected when these levels are achieved.

The occupancies for the adjacent and nearby premises to the project have been determined as residential and commercial use including a motel on George Street which overlooks the river. There are no schools, childcare facilities or places of worship identified in the immediate vicinity of the project. Thompson Square open space area has been identified as an area of passive recreation adjacent to the project and as such has an $L_{Aeq\ 15\ hour}$ daytime noise criterion of 55 dB(A).

Table 4-2: Noise criteria for non-residential land use

Existing sensitive land use	Assessment criteria dB(A)		Additional considerations
	Day 7am -10pm	Night 10pm – 7am	
5. Open space (passive use)	L_{Aeq}, (15 hour) 55 (external) when in use	Not applicable	Passive recreation is characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, e.g. playing chess, reading. In determining whether areas are used for active or passive recreation, the type of activity that occurs in that area and its sensitivity to noise intrusion should be established. For areas where there may be a mix of passive and active recreation, e.g. school playgrounds, the more stringent criteria apply. Open space may also be used as a buffer zone for more sensitive land uses.
7. Mixed use development	Various	Various	Each component of use in a mixed use development should be considered separately. For example, in a mixed use development containing residences and a childcare facility, the residential component should be assessed against the appropriate criteria for residences in Table 3, and the childcare component should be assessed against point 8 below.

4.1.3 Maximum noise level assessment – sleep disturbance

According to Practice Note III of the 'Environmental Noise Management Manual' (RTA 1999), a maximum noise level assessment is to be undertaken for potential sleep disturbance impacts from road traffic noise.

The Environmental Noise Management Manual identifies the purpose of the maximum noise assessment as a method to prioritise and rank mitigation strategies, but states that it should not be applied as a decisive criterion in itself.

The RNP discusses the potential for disruption of normal sleep patterns due to road traffic noise but concludes that there is insufficient evidence to assist in setting trigger levels for this type of impact. The work to date indicates that:

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

The Environmental Noise Management Manual employs a methodology to assess these impacts based on the emergence of the L_{Amax} over the $L_{Aeq\ (1hr)}$ noise level. A maximum noise pass-by event is defined as the emergence of the L_{Amax} level above the $L_{Aeq\ (1hr)}$ noise level by 15 dB(A) or more, ie:

$$L_{Amax} \geq L_{Aeq\ (1hr)} + 15\ dB(A)$$

Maximum noise level events are identified for a project where a pass by event meets this criterion and is above 65 dB(A). Internal noise levels have been assumed to be 10 dB(A) lower than the external noise level. This is based on the reduction of noise levels from the outside to the inside of a dwelling with windows open for ventilation. Where windows are closed a greater degree of attenuation would be expected. For assessment purposes the minimum transmission loss was assumed. The outcome of this assessment is used in informing the application and type of noise mitigation measures determined as part of the project traffic noise impact assessment outlined in **Section 4.1.1**.

4.2 Construction noise

A preliminary construction methodology for the project has been developed. Noise associated with each phase of these works has been predicted at each receiver identified in **Table 3-1** and **Table 3-2** or qualitatively assessed in terms of risk of impact across the project area. Predicted construction noise was assessed against specific noise management goals at each of the sensitive receivers. Where exceedances were shown; mitigation and management measures were recommended.

4.2.1 Interim Construction Noise Guideline (ICNG)

The risk of adverse impact of construction noise within a community is determined by the extent of its emergence above the existing background noise level, the duration of the event and the characteristics of the noise. Impacts can then be exacerbated by the proximity of construction to residences or other sensitive land uses and the scheduled times of construction activities.

To address potential construction noise impacts the NSW Government has prepared an Interim Construction Noise Guideline (DECC 2009). The guideline has been developed to assist with the management of noise impacts, rather than to present strict noise criteria for construction activities. Although not mandatory, the ICNG recommends standard hours for construction work, these are presented in **Table 4-3**.

It is understood that, where practical, the majority of works would be undertaken within these standard hours, however there would be a component of works or specific activities that would be required to be undertaken outside of the standard construction hours. Where an extension to these hours is required or works are to be undertaken beyond these hours, i.e. night-time works, technical justification and the associated impacts would be required, see **Section 4.2.2**.

Table 4-3 Standard construction hours

Work type	Standard hours of work
General construction	Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays

The ICNG describes two methods of assessing noise impacts from construction activities: the quantitative method, which is suited to major and complex construction projects; and the qualitative method, suited to short-term (less than three weeks) works undertaken during standard construction hours. As the construction works for the project would last for substantially longer than three weeks it is classified as a major project.

The ICNG states Noise Management Levels (NML), should be set at each affected sensitive receiver, and that they will apply at the property boundary that is most exposed to the construction noise, at a height of 1.5 metres above ground level. In cases where the property boundary is more than 30 metres from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 metres of the residence.

Table 4-4 outlines NMLs for noise sensitive receivers and how they were derived and would be applied. Restrictions to the hours of construction may apply to activities that generate noise at noise sensitive receivers above the 'highly noise affected' NML. The rating background level (RBL - see glossary for definition) was used when determining the NML.

The ICNG also sets out assessment criteria for non-residential receivers such as commercial premises, educational buildings and recreational land. As there are a number of commercial premises within the study area along with Thompson Square parkland, the ICNG criteria is to be used for assessment. For non-residential receivers within the study area, the following are criteria apply:

- Industrial premises: external $LAeq_{(15min)}$ 75 dB(A)
- Offices, retail outlets: external $LAeq_{(15min)}$ 70 dB(A)
- Classrooms: internal $LAeq_{(15min)}$ 45 dB(A)
- Places of worship: internal $LAeq_{(15min)}$ 45 dB(A)
- Hotels Motels: external $LAeq_{(15min)}$ 60dB(A)
- Passive recreational land: external $LAeq_{(15min)}$ 60 dB(A)

(Non-residential criteria are taken from the ICNG guideline and Australian Standard 2107:2000 *Acoustics – Recommended design sound levels and reverberation times for building interiors).*

Table 4-4 General construction noise management levels (NMLs)

Time of day	Management level (LAeq (15 min)	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	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 $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all reasonable and feasible 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, expected noise levels and the duration of activities. Contact details for a construction representative should also be provided.
	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)	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 then undertake negotiations with the community. For guidance on negotiating agreements refer to Section 7.2.2 of the ICNG (DECC, 2009).

4.2.2 Out of hours noise

As with any construction project, some construction activities would need to be undertaken outside of the standard construction hours as a result of safety, avoidance of traffic delays during peak periods, engineering practicalities and timetable. At this stage an indication of out of hours activities has been provided and will be assessed in accordance with the construction methodology presented in **Section 0**. Potential outside proposed hours works are likely to include the following activities:

- Bridge works – where bridges are located or proposed for the existing alignment there is a potential that these works would need to be undertaken outside the proposed hours.
- Existing and new road tie-in works – The tie-in of the project with existing road networks would potentially have a major impact on the flow of traffic on existing roads and therefore outside of standard hour works may be required to reduce impact
- Utility adjustments – Where utility renewal or movement is required from the existing alignment, health and safety may dictate that traffic must be stopped and again outside of standard hours may be more suitable and have least overall impact
- Work on the existing roads with justification (this may also include the use of paving and sawcutting equipment and the use of ancillary sites)
- Major traffic diversions, including full or partial road closures of the existing roads.
- The delivery of oversize elements, such as components of the concrete batching plant and large construction equipment.

For the purpose of this project out of standard construction activities are likely to include road tie-in works, paving, asphalting and concrete pours. Reasoning for the outside of standard hours activities includes practical and technical nature of some construction activities, including concrete pours and paving works. In addition it may not always be possible to obtain a Road Occupancy Licence (ROL) for daytime works on the existing road network. This report assesses the works, known at the time of preparing this report, that are likely to be undertaken outside of standard hours; this includes assessment of sleep disturbance. However once the exact construction hours and activities are confirmed during detailed design, a detailed noise impact assessment would be prepared, along with proposed mitigation measures, negotiated agreements with the community, consultation with EPA and substantial justification as to why these works have to be undertaken outside standard construction hours. It is likely that these areas of works and the process for undertaking the outside proposed hours assessment would be developed within a project specific Construction Noise and Vibration Management Plan (CNVMP). This is discussed further in **Section 7.3**.

In addition, it may be possible to undertake certain activities outside standard hours, where the following can be shown:

- The works are theoretically predicted to be inaudible or perceived to be inaudible, i.e. generally 10dB(A) below the RBL depending upon the character of the noise. Often inaudible works do not require specific approval from regulatory authorities.
- Works that comply with the relevant NML for the respective time period of the day. These still may require approval from regulatory authorities.
- For works required by the police or other emergency services.
- Where it is required in an emergency to avoid the loss of lives, property and/or to prevent environmental harm.

4.2.3 Project specific construction noise objectives

General Works

Where noise monitoring has been undertaken, either unattended or attended, at a specific receiver, Noise Management Levels (NML) have been derived using the ICNG guidelines for each assessment period, in line with the method set out in **Section 4.2.1**.

The NML for each assessment period and each receiver within the study area is presented in **Table 4-5**.

Table 4-5 Project construction Noise Management Levels

Receiver			*NML / dB(A)		
			Daytime 7:00am – 6:00 pm (L_{Aeq})	**Evening 6:00 pm – 10:00 pm (L_{Aeq})**	**Night-time 10:00 pm – 7:00 am – (L_{Aeq})**
R1	27 Freemans Reach Road		68	55	44
R2	4 Bridge Street		72	61	46
R3	10 Bridge Street	Ground Floor	70	70	70
		First Floor	72	61	46
R4	53 George Street		55	47	32
R5 – R15**	See Table 3-1 for ID		55	47	32
R16***	16 Bridge Street		72	61	46
C1, C3,	See Table 3-2 for ID		60	60	60
H2 – H12	See Table 3-2 for ID		70	70	70
C2	Services channel		N/A	N/A	N/A

Daytime NML = RBL +10dB(A), Evening RBL = RBL +5dB(A), Night-time NML = RBL +5dB(A), or absolute levels for commercial receivers. **In the absence of measured background noise levels at these specific locations, monitoring data at R4 assumed to be representative of noise at receivers R5-R15. * In the absence of measured background noise levels at R16, monitoring data at R3 (first floor) assumed to be representative of noise at this receiver.*

In addition to the NMLs identified in **Table 4-5**, where receivers are exposed to construction noise above 75dB(A), they would be classed as being 'highly noise affected' in line with the ICNG criteria, and therefore would be prioritised for mitigation.

Construction road traffic noise

The RNP does not provide a direct reference to the assessment of road traffic resulting from construction activities. Due to the scale of the project, no specific haul roads would be built to facilitate the works.

Where construction traffic utilises the existing road network it has been assumed the increase in traffic numbers due to construction would be sufficiently small that they are absorbed into general traffic numbers. For this project construction traffic numbers would be up to a peak of 40 truck/wagon/plant movements in any daytime assessment period and up to five movements during any out of hour's works. This equates to an increase in heavy vehicle movements during daytime periods along Bridge Street of 2 per cent, and 1 per cent during out of hours periods. For assessment, an increase in traffic numbers of at least 25 per cent, or decrease in 20 per cent would be required to have change in noise of 1dB(A). Using this general methodology, noise levels associated with project construction traffic would increase noise levels on existing roads by a maximum of 0.15 dB(A) during either daytime or night time periods. A level change of this magnitude would not be perceivable and therefore the risk of impacts from construction traffic would be low and has not been quantitatively assessed.

4.3 Operational and construction vibration

For the purpose of both operation and construction works, there are two types of vibration criteria that are used when assessing impacts. The first is the human comfort criteria / task proficiency, which as the name suggests is designed to minimise impacts that may disrupt day to day activities of residents/employees etc. The other form of vibration criteria is designed to avoid damage to buildings and structures.

Acceptable vibration levels are outlined in Australian Standard AS2670.2, *Evaluation of human exposure to whole-body vibration: Continuous and shock-induced vibration in buildings*. This standard identifies the 1/3 octave spectra of vibration magnitudes that correspond to human annoyance and/or complaints about interference with activities. These levels are noted to be well below the level of vibration that can cause damage to buildings and take account of both the velocity and the acceleration of the ground particle.

Building damage is not practically assessed by the Australian Standards, but refers instead to the British and German standard for a discussion of vibration impacts in buildings. German Standard DIN 4150: *Part 3 – 1999 Effects of Vibration on Structures* (German Institute for Standardisation, 1999 may therefore be used as a guide to assess the likelihood of building damage from ground vibration, which include impacts from continuous and non-continuous sources such as, piling, compaction, construction equipment, and road traffic.

4.3.1 Human comfort / task proficiency

Vibration from construction activities with regard to human comfort within a building must comply with the *Assessing Vibration: A Technical Guideline* and AS2670.2' (DEC 2006). It is not always possible to undertake major infrastructure projects in very close proximity to residential dwellings and comply with the criteria. However, the criteria within this guideline should always be used as the objective, and represents the basis of the human comfort assessment.

When assessing vibration, the NSW OEH 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 – where continuous vibration activities are regularly interrupted, or where impulsive activities recur. This may include activities such as rock hammering, drilling, and pile driving and heavy vehicle or train movements.

Continuous and impulsive vibration criteria have not been included in this assessment as they are unlikely to occur given the proposed methodologies for the project. Where vibration is classed as intermittent, OEH uses a vibration dose value (VDV) to assess levels of vibration (refer **Table 4-6**). VDV is calculated using the acceleration rate of the vibration event and the time duration over which it occurs. This method is more sensitive to the level of vibration than its duration, and is a measure of the total quantity of vibration perceived. The VDV method is the most suitable for assessing human comfort from intermittent vibration sources.

Table 4-6 Acceptable Vibration Dose Values (VDV's) for Intermittent Vibration ($ms^{-1.75}$) 1- 80 Hz (DECC 2006)

Location	Day $ms^{-1.75}$ 7am-10pm		Night $ms^{-1.75}$ 10pm-7am	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Residential buildings	0.20	0.40	0.13	0.26
Offices, Schools, Churches, etc	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Note: Human Perception ≈ 0.02mms^{-2}

Due to the nature of the human comfort criteria, it is necessary to undertake vibration measurements in terms of acceleration at the location of human occupancy, whether residential or commercial. Actual exposure criteria are determined by exposure time (15 hour day, 9 hour night averaging periods), acceleration magnitude and vibration direction and can either be measured using integrating equipment or derived from particle velocity, estimated dose value (eVDV).

The OEH guideline does make an allowance for higher limit levels, above those identified in **Table 4-6**. This applies in circumstances "where work is short term, and all feasible and reasonable mitigation measures have been applied, and the project has demonstrated high level of social worth and broad community benefits". For the purpose of the OEH guidelines, short term work is defined as construction works that occur for duration of about one week, which is not applicable in this case.

4.3.2 Building damage

Due to the heritage significance of the buildings and items adjacent to the alignment the more conservative approach of the German Standard DIN 4150: *Part 3 – 1999 Effects of Vibration on Structures* (German Institute for Standardisation, 1999) have been adopted for the project rather than the criteria set out in British Standards. The German standard provides levels for structures other than commercial or residential, such as heritage type buildings, which may be structurally sensitive due to their age.

The DIN guideline values for peak particle velocity (millimeters per second or mms^{-1}) measured at the foundation of the building are summarised in **Table 4-7**.

4.3.3 Buried utilities/underground pipes

The Australian Standards do not reference or provide criteria for underground services and utilities. Vibration criteria for this type of infrastructure are often specific to an industry and should be identified by the appropriate service/utility provider. British Standard BS5228-2:2009 *Code of Practice for noise and vibration control on construction and open sites – vibration*, provides basis criteria levels for underground services, in the absence of specific criteria from the utility/service provider. The BS5228-2:2009 recommends the following general guideline levels:

- Maximum PPV for intermittent or transient vibrations 30 millimetres per second.
- Maximum PPV for continuous vibrations 15 millimetres per second.

British Standard BS5228-2:20009 also states that 'a PPV of 30 millimetres per second gives rise to dynamic stress which is equivalent to approximately 5 per cent only of the allowable working stress in typical concrete and even less in iron and steel'. Vibration criteria for underground services would also depend on the actual condition of that particular structure.

Where underground services are in poor condition or dilapidated, there would be a higher risk of damage.

Table 4-7 DIN Guideline values of vibration velocity for building structures

Line	Type of Structure	Guideline values for Velocity in mms^{-1}			
		Vibration at the foundation at a frequency of			Vibration at Horizontal Plane of Highest Floor
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz*	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15
3	Structures that, because of their sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (eg buildings that are under a preservation order or heritage listed)	3	3-8	8-10	N/A
* For frequencies above 100Hz, at least the values specified in this column shall be applied					

4.3.4 Project specific criteria

Human comfort criteria will be based on the maximum levels presented in **Table 4-6**, as taken from *Assessing Vibration: A Technical Guideline*. The building damage criteria are taken from the German DIN standard and have been summarised in **Table 4-8***.*

Table 4-8 Project specific building damage vibration criteria

Building type	Guideline values for velocity mms^{-1}			
	Vibration at Foundation			Vibration at horizontal plane – highest floor
	1-10Hz	10-50 Hz	50-100 Hz	All frequencies
Residential Properties / Lightweight Commercial	5	5	15	15
Heritage Buildings (including receiver H1)	3	3	8	-
Underground services	15	15	15	-

5 Operational impact

5.1 Noise modelling results

The modelling of noise impacts for the project and the "do nothing" option included natural growth in traffic between the year of opening and the design year scenarios. The results of the noise modelling have been provided as point predictions for each of the identified receiver locations and have also been presented as noise contours overlaid on aerial photography.

The noise contours represent the day and night time noise levels for the potential future year of operation in 2026.

Table 5-1 presents the results of the modelling for the unmitigated noise levels for both day and night time for the proposed year of opening and the design year, as well as the predicted change in noise level for the "no-build" and "build" scenarios at these times.

The no build scenario indicates that receivers adjacent to Bridge Street and Wilberforce Road currently exceed, and would continue to exceed, the acute noise level criteria for the project. This is confirmed with measurements of the existing noise environment in **Table 3-4**.

For receivers not directly adjacent to the road alignment R5-R10 on The Terrace and R11-R15 on George Street, the predictions for the build scenario indicate a general reduction in noise levels for receivers. To the west of the bridge on The Terrace, a reduction of about 4 dB(A) due in part to the resurfacing of the road and the relocation and realignment of the bridge further to the east is expected. Receivers along George Street would experience a change in level due to the vertical and horizontal realignment of the bridge which would be offset by the anticipated noise benefit from the road resurfacing resulting in a 1 dB(A)reduction.

Receivers directly adjacent to the alignment include R1, R2, R3 and R4. The receiver R1, at the northern approach to the bridge would benefit from a reduction in noise levels due to the relocation of the intersection of Freemans Reach Road and Wilberforce Road further to the south east. At the receiver locations R2 and R3, an existing acute noise impact was predicted. This acute noise impact would continue with the project and therefore requires further consideration of noise mitigation options.

At receiver location R4 the relocation of the bridge would increase existing levels by approximately 2 dB(A) even with the benefit of an improved road surface. The predicted noise levels for the 2026 design year are predicted to exceed the design year night time noise levels resulting in the requirement for additional mitigation.

The majority of the reduction in noise levels would result from the replacement of the existing pavement with a new layer of dense grade asphalt for the wear surface, which would be expected to provide a reduction of around 2 dB(A) over the existing pavement. In addition, the reduction in road gradient of the southern approach road in conjunction with the replacement of the existing roundabout with a signalised intersection would reduce noise associated with stop/start vehicle movements at the Bridge Street/George Street intersection.

A discussion of noise mitigation options for receivers R2, R3 and R4 is presented in **Section 7.1**.

5.1.1 Thompson Square

Table 4-2 presents the criteria used to assess Thompson Square parkland which has been determined to be an area of heritage importance as well as a space dedicated to passive recreational activities. The criteria for the parkland would be a daytime noise criterion of 55 dB(A). The square is split by the southern approach road to the existing bridge and is currently subject to high levels of traffic noise from Bridge Street, Windsor Bridge and to a lesser extent George Street. The daytime levels for the existing alignment and design year scenario are predicted to be within the range of 72 dB(A) close to Bridge Street, down to about 63 dB(A) closer to The Terrace road.

The noise levels for the project are similar to existing levels ranging from 72 dB(A) to about 64 dB(A) for the same locations. The predicted noise levels for both the build and no build daytime scenarios for the design year (2026) indicate that both scenarios would exceed the criterion for this land use category. The area of Thompson Square parkland impacted by the higher noise levels would decrease slightly with the project especially the northern area of the parkland near the river.

5.1.2 Operational maximum noise level assessment

An analysis of the measured maximum noise events at R3 was undertaken for the night of 25-26 February 2012 to further examine the noise impacts for the existing alignment. This period of assessment was chosen to be representative of the closest receivers for night time hours. **Figure 5-1** and **Figure 5-2** present the graphs of the daily maximum noise event data averaged over the assessment period.

Figure 5-1 Typical maximum noise events for night time hours

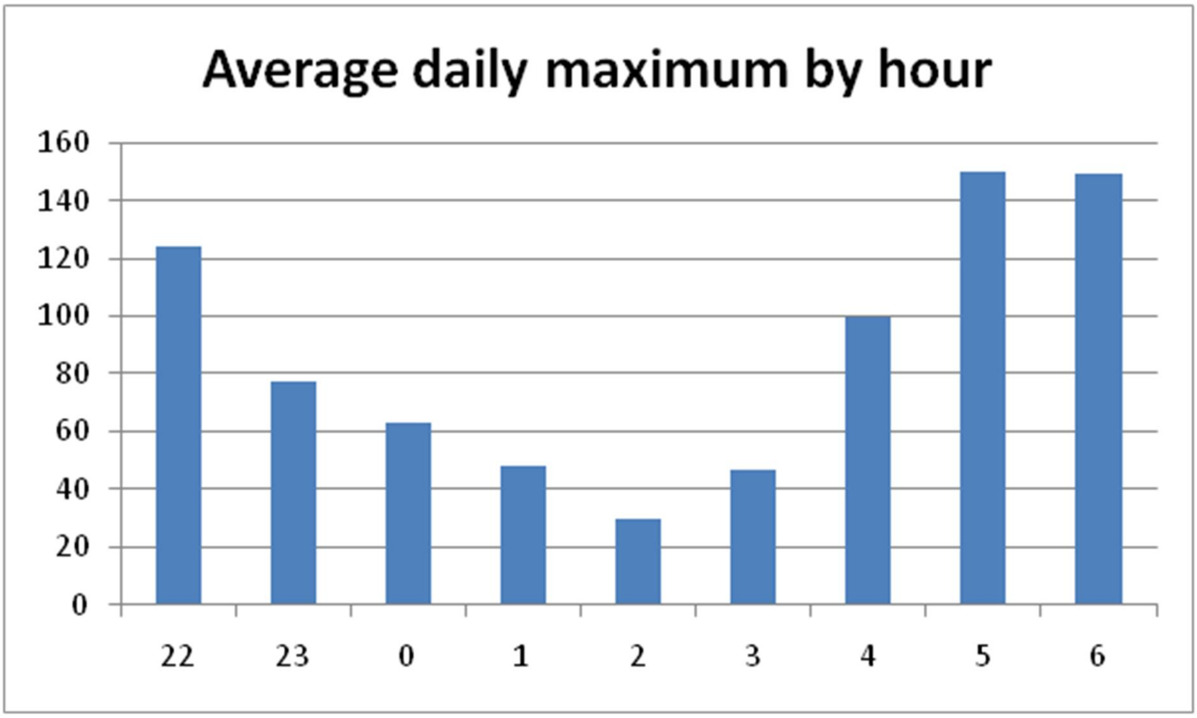
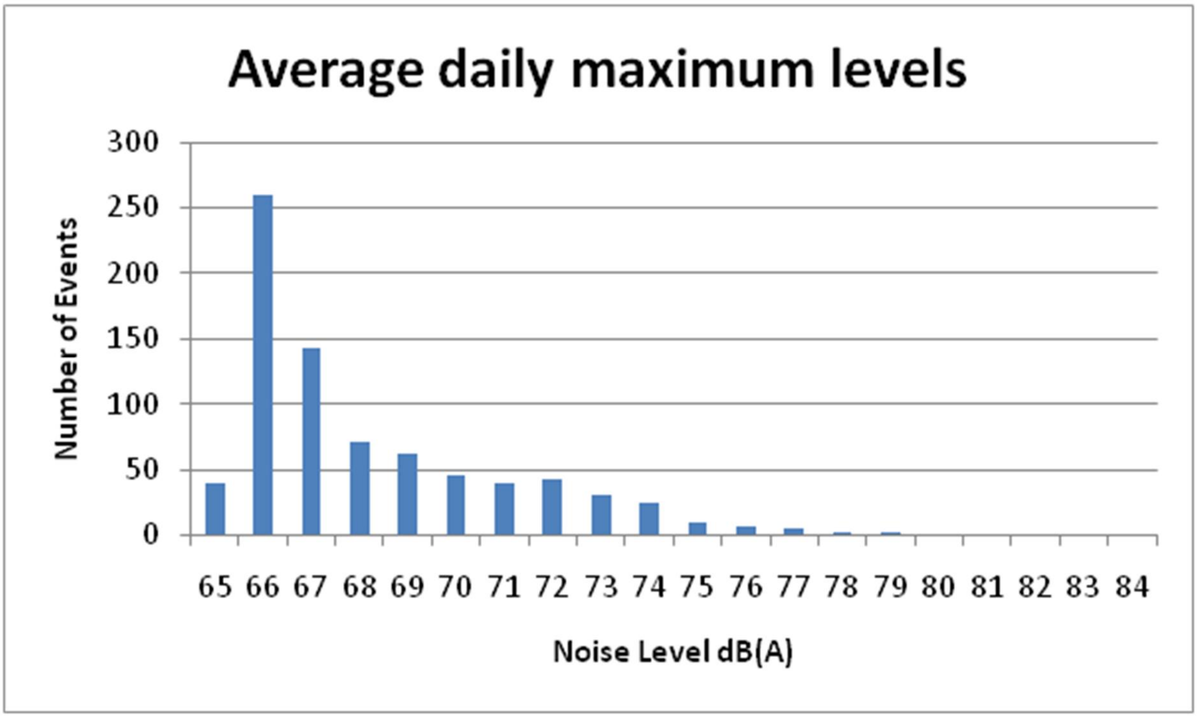


Figure 5-1 indicates how maximum noise events are distributed over the night time hours. This event profile indicates that the frequency of events at the start of the night time period gradually reduce to their lowest levels at 2am before increasing from about 4am onwards. Between 5am and 6am the greatest frequency of events were recorded, which would coincide with early morning commuter traffic.

The night time L_{Aeq} noise level for this location were measured as 66.5 dB(A). Maximum noise level events are typically characterised by their emergence above the L_{Aeq} noise level and therefore levels in the order of about 81.5 dB(A) would meet the criteria for a maximum event for this location.

Figure 5-2 indicates that there were only about two maximum noise events above 77 dB(A). The majority of maximum noise events were marginally above the reporting threshold of 65 dB(A) at 66-67 dB(A), which were similar to the night time L_{Aeq}.

Figure 5-2 Maximum noise events by level



It is expected that this pattern of events would continue with similar traffic profiles forecast for the project however, a realignment of the existing road and introduction of a signalised intersection would potentially provide a small reduction in noise levels for a maximum noise event as Bridge Street traffic would have less stoppages and a smoother driving line without the need to negotiate the roundabout.

Table 5-1 Predicted noise levels – without mitigation

ID	Year opening 'no build' scenario dB(A)		Year opening 'build' scenario dB(A)		Design year 'no build' scenario dB(A)		Design year 'build' scenario dB(A)		RNP criteria, dB(A)		Are the RNP Criteria exceeded?		Change in noise level dB(A)				Acute level of noise		Consider mitigation?
													Opening Year		Design year				
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
R1	66	61	62	58	67	61	63	58	60	55	**YES**	**YES**	-3.7	-3.8	-3.7	-3.3	NO	NO	NO
R2	65	61	70	66	65	61	71	67	60	55	**YES**	**YES**	5.3	5.4	5.4	6.0	**YES**	**YES**	**YES**
R3	71	67	71	68	71	67	72	68	60	55	**YES**	**YES**	0.6	0.2	0.5	0.8	**YES**	**YES**	**YES**
R4	61	57	63	59	61	57	63	59	60	55	**YES**	**YES**	1.9	2.0	1.9	2.6	NO	NO	**YES**
R5	59	54	54	50	60	54	55	51	60	55	NO	NO	-4.6	-4.4	-4.7	-3.8	NO	NO	NO
R6	58	53	53	49	58	53	54	50	60	55	NO	NO	-4.2	-4.1	-4.3	-3.6	NO	NO	NO
R7	57	53	53	49	58	53	53	49	60	55	NO	NO	-4.3	-4.1	-4.4	-3.5	NO	NO	NO
R8	56	52	53	49	57	52	53	49	60	55	NO	NO	-3.1	-3.0	-3.2	-2.5	NO	NO	NO
R9	55	51	51	47	56	51	52	47	60	55	NO	NO	-3.9	-3.9	-4.0	-3.5	NO	NO	NO
R10	55	51	51	47	56	51	52	48	60	55	NO	NO	-3.9	-3.7	-3.8	-3.0	NO	NO	NO
R11	56	52	55	51	57	52	56	52	60	55	NO	NO	-0.9	-0.9	-1.0	-0.2	NO	NO	NO
R12	57	53	55	51	57	53	56	52	60	55	NO	NO	-1.3	-1.3	-1.4	-0.7	NO	NO	NO
R13	56	52	55	51	57	52	55	51	60	55	NO	NO	-1.5	-1.5	-1.5	-0.9	NO	NO	NO
R14	57	52	55	51	57	52	56	51	60	55	NO	NO	-1.6	-1.7	-1.6	-1.1	NO	NO	NO
R15	55	51	53	49	56	51	54	50	60	55	NO	NO	-1.9	-1.9	-1.8	-1.3	NO	NO	NO

5.2 Operational vibration

The ground borne vibration associated with existing traffic flows varied from 0.06 millimetres per second to just over 1 millimetres per second PPV at a distance of one metre from the closest moving vehicle tyre. Levels were shown to be dependent on vehicle size and, as would be expected, vibration levels generally increased with speed and vehicle weight.

During vibration monitoring, traffic induced ground borne vibration at 4 and 10 Bridge Street was undetectable and did not show any significant fluctuation in levels as a result of any traffic movement. Levels were consistently below 0.002 millimetres per second, which is not perceivable by humans. To put into perspective a general level for human perception or a change in vibration level is in the region of 0.2-0.3 millimetres per second, whereas a level greater than 1.2 millimetres per second is classed as being strongly perceptible but does not necessarily cause annoyance. Annoyance criteria is a function of duration and axial component.

The frequency of the road traffic movements are between 10 and 50Hz, therefore the corresponding criteria from **Table 4-7** for lightweight and heritage structures (in terms of damage) is 3 millimetres per second. Even at a separation distance of one metre from a moving vehicle, the levels predicted were considerably below the criteria outlined for structural damage of heritage or light weight buildings. Therefore existing traffic movements on Bridge Street do not produce enough energy to cause structural or cosmetic damage to any of the identified sensitive receivers, including heritage structures on Bridge Street.

Based on the design of the project, the shortest separation distance between receivers on Bridge Street and road vehicles would be similar to the existing scenario. Although, the existing separation distance between 4 Bridge Street, 6 Bridge Street and the road would decrease, the distance would be no smaller than the existing distance between the road and residence at 10 Bridge Street. Since the shortest separation would not change as a result of the project, and considering the road surface would be new (ie, without vibration causing imperfections), the magnitude of operational vibration would be similar to the existing environment and below perceptible levels at the closest receivers.

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6 Construction impact assessment

6.1 Construction method overview

6.1.1 Construction activities

A preliminary concept of the timing, programming and construction methodology for this project has been developed. The noise associated with each phase of works during representative operating periods has been predicted and assessed. In terms of vibration, some activities have the potential to generate substantial vibration, however the separation distance between source and receivers, and the geotechnical characteristics of the separating ground, would be the determining factors as to whether plant induced vibration may exceed criteria. An indication of vibration impact has also been predicted and assessed for certain plant items.

The short separation distance between the new road alignment of Bridge Street and the closest receivers means that the potential for noise and vibration impacts would be high. The location of heritage-listed buildings and items in close proximity to the new alignment would also play an important part in determining suitable methods of construction and mitigation measures. For the purpose of the EIS, the following phases of work have been identified and subsequently been assessed for noise impact, and where appropriate vibration impact:

- Site establishment/early works:
  - archaeological investigations
  - utility adjustments on northern approach
  - site clearing of northern bridge approach
  - earthworks on northern bridge approach
  - erection of tower crane
  - minor utility relocations on southern approach
- Bridge pier and northern abutment construction
  - Non-terrestrial impact piling (riverbed) up to 9 piles per pier (4 piers)
  - Concrete pumping from northern approach
  - Terrestrial bored piling at northern abutments
- Incrementally launched bridge construction (including casting yard)
  - Bridge casting in northern casting yard
  - Bridge form and steel work
  - Incrementally launch bridge
  - Concrete pumping on bridge
  - Concrete pours and surface construction
- Southern approach road construction
  - Terrestrial bored piling at southern bridge abutment
  - Construction of land bridge or concrete panel fill southern approach road
  - Paving and asphalting
- Removal of casting yard and northern road construction
  - Earthworks and clearing for new round about and northern approach road
  - Paving and asphalting
- Southern end of Bridge Street tie-in and junction construction
  - Standard road construction including earthworks

    - Paving and asphalting
    - Fill of existing southern cutting
- Existing bridge demolition
    - Superstructure removal – road saws, grinders, cranes
    - Substructure removal – oxy cutters and cranes
- Use of laydown/construction compound
    - Use of area at the Windsor Wharf car park as a laydown area (plant storage and potential materials stockpile). To be used throughout each construction phase.

6.1.2 Timeframe of works

The works in total would take about 18 months to complete with the bridge construction works taking between 9 and 14 months to complete. With the exception of the construction of the southern approach road, all other phases would be undertaken consecutively. The phases containing the construction of the southern approach road would be undertaken during the bridge pier construction phase and the incremental bridge launching phase. The impact of these simultaneous works has been assessed.

6.1.3 Out of hours works

A number of activities would be required to be undertaken outside of standard construction hours. Generally works outside of standard construction hours works are considered reasonable where the works are below the relevant NML. However often the noise of works undertaken outside of standard construction hours would be above NMLs and cannot be easily mitigated. Works that may be required outside standard construction hours are detailed in **Table 6-1**. These works are compared to sensitive receiver NMLs for evening and night time periods in **Table 6-6**.

Following detailed construction planning, additional activities may need to be undertaken outside of standard construction hours. The process of assessing additional works outside of standard construction hours would be identified in the Construction Noise and Vibration Management Plan.

Table 6-1 Works outside standard construction hours

Construction phase	Justification
The delivery of oversize bridge elements.	Delivery outside of standard hours of construction may be required due to road safety requirements. Oversize loads are generally only allowed on the roads during night time periods when traffic levels are low.
The delivery and demobilisation of plant and large construction equipment.	Delivery outside of standard hours of construction may be required due to road safety requirements. Oversize loads are generally only allowed on the roads during night time periods when traffic levels are low.
Emergency work.	Work may be required outside of standard construction hours to respond to emergency situations that pose a risk to safety or the environment.
Utility adjustments	Some services may be located within the existing alignment and traffic on the existing alignment may require diversion to allow a service adjustment to be undertaken safety. Traffic diversions on busy roads are generally only permitted outside standard construction hours to minimise the impact on the road network. Also the cutover of existing services to new services may need to be undertaken in off-peak periods which are generally outside standard construction hours
Major traffic diversions, including full or partial road closures.	Due to traffic disruptions it would be unlikely that daytime Road Occupancy Licences would be granted and therefore night-time works would be required where works is undertaken on existing network.
Bridge works – including concrete pours, concrete bridge casting, steel fixing, formwork construction and the craning of materials during incremental launch.	These works may be required outside of standard hours due to timing constraints and requirements associated with concrete pours.
Road tie-in works (including paving and asphalting) –	The tie-in of the proposed northern and southern approach roads, along with bridge road surface construction. These works may be required outside of standard construction hours as they will involve possible 24 hour concrete pours and will involve working on the existing road network. Due to traffic disruptions it would be unlikely that daytime Road Occupancy Licences would be granted and therefore night-time works would be required where works is undertaken on existing network.
Other works that are required outside standard hours and are approved by the appropriate regulatory authority	These would be justified, assessed and approval sought as required.

6.1.4 Construction plant

Activities, duration and equipment proposed for the project (daytime, evening and night-time periods) are summarised in **Table 6-2**. It should be noted that to limit noise impacts, the highest noise emitting plant (such as bored piling, rock breakers and saws) would be limited to daytime works only. For an indication of construction locations see **Figure 6-1**.

Table 6-2 Proposed equipment and associated sound power levels (per area of works)

Construction phase	Activity	Out of ours works proposed	Plant	L_{Aeq} Sound power level dB(A)	Indicative total project duration
Site establishment and early works	Archaeological investigations	No	8 tonne excavator	103	3-4 weeks
			5 tonne vibratory roller	107	
			Spoil truck	103	
	Northern approach utility adjustments	No	Backhoe	108	2 weeks
	Northern approach site clearing / casting yard construction	No	30 tonne excavator	103	3 months
			Spoil truck	103	
			Backhoe	108	
	Erection of tower crane / concrete pad footing	No	30 tonne excavator	103	1 week
			Concrete truck and pump	111	
			Poker vibrator	112	
			Mobile 45 tonne crane	105	
	Southern approach utility adjustments	No	Backhoe	108	2 weeks
Bridge pier and northern abutment construction	Non-terrestrial impact piling (riverbed)	No	Impact piling rig	121	3 months
			Construction river barge	95	
			Tower crane	103	
			Barge crane	103	
			Truck	103	
	Northern bridge abutment piling	No	Bored piling rig	110	1 – 2 months
			Mobile 45 tonne crane	105	
			Truck	103	

Construction phase	Activity	Out of ours works proposed	Plant	L_{Aeq} Sound power level dB(A)	Indicative total project duration
Incrementally launched bridge (from north to south)	Bridge casting	Yes	Truck	103	9 months
			Concrete truck and pump	111	
			Poker vibrator	112	
			Grinders/saws	117	
	Bridge form and steel work	Yes	Mobile 45 tonne crane	105	9 months
			Tower crane	103	
			Barge crane	103	
			Hand tools (ratchet gun, grinder etc)	115	
	Incrementally launch bridge	Yes	Tower crane	103	9 months
			Hydraulic rams	85	
			Barge crane	103	
	Concrete pours and surface construction	Yes	Concrete truck and pump	111	9 months
			Poker vibrator	112	
	Paving and asphalting	Yes	Paver	111	
			18 tonne smooth barrel roller	108	2 weeks
			Road Saw	117	1-2 weeks
Southern approach road construction	Terrestrial bored piling – southern bridge abutment	No	Bored piling rig	110	1 – 2 months
			Mobile 45 tonne crane	105	
			Truck	103	
	Land Bridge (precast)*	No	Bored piling rig	110	3 months
			Mobile 45 tonne crane	105	
			Truck	103	
			30 T excavator	103	
			Mobile 45 tonne crane	103	
	Concrete panel fill*	No	Truck	103	3 months
			30 T excavator	103	
			Concrete truck and pump	111	
			Poker vibrator	112	
			20 tonne mobile crane	103	

Construction phase	Activity	Out of ours works proposed	Plant	L_{Aeq} Sound power level dB(A)	Indicative total project duration
	Paving and asphalting	Yes	Paver	111	1 week
			18 tonne smooth barrel roller	108	
			Grinders/saws	117	1 -2 weeks
Northern approach road construction	Earthworks	No	30 tonne excavator	103	1 month
			Spoil trucks	103	
			15 tonne roller	108	
			Bobcat	103	
			Dump truck	105	
	Paving and asphalting	Yes	Paver	111	1 – 2 weeks
			18 tonne smooth barrel roller	108	
			Grinders/saws	117	1 -2 weeks
Southern Bridge Street tie-in and junction construction	Existing road removal	Yes	Backhoe	108	1 - 2 weeks
			Road saw	115	
			30 tonne excavator	103	
			Road miller	113	
			truck	103	
	Paving and asphalting	Yes	Paver	111	1 week
			18 tonne smooth barrel roller	108	
			Grinders/saws	117	1 -2 weeks
Existing bridge demolition	Superstructure removal	No	Barge crane	103	2 months
			Road saw	117	
			Grinders	117	
			Truck	103	
			30 tonne mobile crane	103	
	Substructure removal	No	Barge crane	103	2 months
			Road saw	117	
			Grinders	117	
			Truck	103	
			Oxy cutters	105	
			30 tonne crane	103	

Construction phase	Activity	Out of ours works proposed	Plant	L_{Aeq} Sound power level dB(A)	Indicative total project duration
Laydown area/compound use	Plant removal	yes	Truck idling	103	Up to 18 months
			Excavator idling	103	

** One of these two methods would be adopted however has not been confirmed at the time of writing this report.*

Each activity in each phase was modelled and assessed individually, however where activities have the potential to be undertaken simultaneously, the total impact was qualified. This takes account of the potential simultaneous works during the construction of the bridge and the southern approach road.

For the purpose of assessing the impact from vibration emitting plant, the following plant items have been assessed.

- Non-terrestrial impact piling (for bridge piers).
- Potential for rock breakers during existing road removal along Bridge Street and to the northern side of the bridge.
- Compactors/ Vibratory rollers.

In the absence of exact plant location for the above vibration emitting plant, worst case separation distance to receivers in proposed work areas have been assumed.

6.1.5 Construction noise modelling

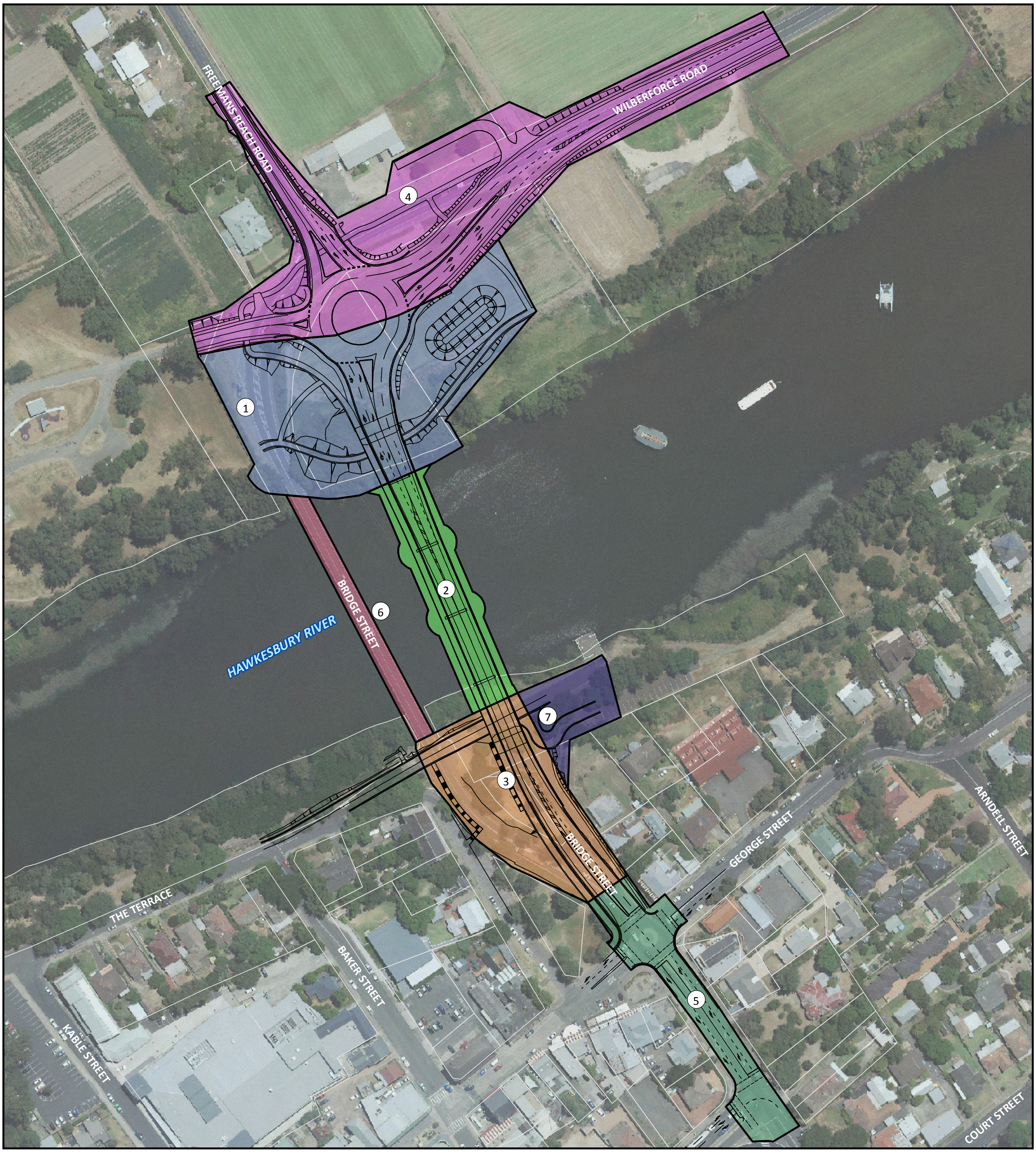
The plant associated with each work activity has been modelled at representative areas of the work. Noise emissions from individual plant items were corrected for standard usage factors; however as the ICNG assessment period is 15 minutes, the correction was often minimal.

The noise model took into account terrain features and the acoustic absorption, barrier effect and reflective properties of separating ground, buildings and other structures. Following the prediction of individual activities, where activities or stages of work had the potential to continue concurrently, and the cumulative impact of these was assessed.

Potential construction noise impacts were modelled at each sensitive receiver location using the ISO 9613-1993 *Attenuation of sound during propagation outdoors* algorithm in the SoundPLAN noise modelling software. During the modelling of construction noise impacts, the equipment outlined in **Table 6-2** was located in likely operating areas to provide a reasonable prediction of noise impacts from construction activities.

Although the equipment types and numbers would vary in practice, the modelling scenarios provided a suitable indication of the likely magnitude of noise impacts where construction activities are undertaken in close proximity to residential areas. Specific modelling parameters are set out in **Table 6-3**.

Figure 6-1 | Proposed construction phases



Indicative only – subject to detailed design

LEGEND

Concept design

Cadastral boundary

Construction phase

- 1, Site establishment and early works
- 2, Bridge construction
- 3, Southern Approach roads
- 4, Northern tie-in
- 5, Southern tie-in
- 6, Bridge demolition
- 7, Lay down

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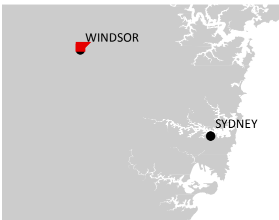


AUSIMAGE SKM

Table 6-3 Summary of modelling inputs

Input Variable	Modelling Parameters
Construction equipment	As set out in **Table 6-2**
Receiver locations and land use	Nearest sensitive receivers identified through aerial photography and site visits
Ground topography	Large scale topography was generally sourced from previous environmental assessments. Modelling was undertaken using best available terrain data.
Air and ground absorption	Ground surfaces were assumed as soft, and absorption as per SoundPLAN implementation of the ISO 9613 algorithm
Height of receivers	1.5 metres above ground terrain

6.2 Predicted construction noise levels

The actual noise levels associated with the construction works would vary on an hour to hour basis due to the inconsistent and intermittent nature of construction works. However, based on typical construction activities, typical plant noise emissions and likely working methods, predictions were made at each of the closest noise sensitive receivers (those within the study area) during each phase of works. These take account of the plant identified in **Table 6-2** working for the highest duration in any 15 minute assessment period and at the closest location to receivers. Therefore noise predictions are the highest $L_{Aeq,15mins}$ from the works.

A summary of the construction noise predictions for each activity within each phase of works is presented in **Table 6-4** alongside the adopted daytime NML. Where out of hours works are possible for certain phases of work, the evening and night-time NMLs are also presented for comparison.

Some of the activities within each phase of work have the potential to be undertaken simultaneously and therefore noise levels at receivers for some periods of time could be higher in duration. A summary of each phase of work is presented in **Table 6-5**. This shows the cumulative noise predictions from activities within each phase, when undertaken simultaneously. This only takes account of longer term activities within each phase. For example during the site establishment phase, the installation of the tower crane would only take a maximum of one week out of a total of three months for this phase of works. Therefore the potential impact from tower crane installation noise and other establishment activities when being undertaken together is considered to be low.

6.3 Discussion of results

6.3.1 Site establishment and early works

At this stage during the site establishment phase of works, all of which are proposed to be undertaken during standard construction hours, the daytime NML is only predicted to be exceeded at one sensitive receiver. The highly noise affected criteria is not predicted to be exceeded at any receiver.

The daytime NML at R4 (54 George Street) would be exceeded as a result of potential archaeological investigations towards the southern abutment. At this stage, the location of these works is indicative of potential works and in practice these works may not actually be required. In addition, these works are short term with the noisiest part of the works being as a result of the excavations. Once the trial pit is opened, works are manual with hand tools with no noise emissions. Therefore the impacts associated with daytime archaeological works and the site establishment works as a whole would be considered to be minimal.

6.3.2 Bridge pier construction

At the time of producing this report, bridge pier construction works are scheduled for daytime works only. Through the whole construction works, bridge pier construction utilises potentially the highest noise emitting piece of plant; an impact piling rig. The location of this plant within the river itself means that although the separation distance from receivers is relatively large, more receivers are exposed to the noise.

As a result of the non-terrestrial impact piling (within riverbed), the daytime NML/criteria at 16 sensitive receivers is predicted to be exceeded. This includes exceedances of the daytime criteria at receivers along the southern riverbank and within Thompson Square. The highly noise affected criteria of 75dB(A) is not predicted to be exceeded at any receiver.

The noise emission from this piling (at the pile strike) is hard to mitigate as it is at a relatively high locations where barriers would not be effective or practical, and the location within the river means other forms of mitigation are not practical.

Other works included within the Bridge pier construction works includes work at the northern bridge abutment. Where works are undertaken at this location without the non-terrestrial piling be undertaken at the same time, noise predictions at all receivers will be below the daytime criteria.

Table 6-4 Predicted $L_{Aeq,15min}$ – Construction activities noise summary

Receiver	Daytime NML / dB(A)	Evening NML / dB(A)	Night-time NML / dB(A)	Activity noise prediction / dB(A): Site establishments and early works					Bridge pier construction		Incrementally launched bridge					Southern approach road				Northern approach road		Southern Bridge Street tie-in		Existing bridge demolition		Compound
				Archaeology investigations	Northern approach utilities	Northern approach site clearing	Tower crane erection	Southern approach utilities	Non-terrestrial impact piling	Northern bridge abutment	Bridge casting	Form and steel work	Incrementally launch bridge	Concrete pour surface	Paving	Terrestrial bored piling	Land bridge	Concrete panel and fill	Paving	Earthworks	Paving	Existing road removal	Paving	Superstructure removal	Substructure removal	Plant idling
R1	68	55	44	43	60	61	59	44	63	40	62	50	46	53	55	47	51	56	55	63	67	52	48	56	57	44
R2	72	61	46	65	49	49	47	61	67	48	51	55	48	54	60	60	76	74	76	45	50	67	59	61	64	43
R3	72	61	46	52	32	34	30	51	61	33	36	44	36	41	48	53	61	63	72	31	44	82	69	55	59	31
R4	55	47	32	62	52	52	51	60	71	51	54	59	51	58	63	63	69	73	71	50	54	47	40	61	65	63
R5	55	47	32	34	50	51	49	46	63	49	53	54	48	54	58	50	50	56	54	49	53	39	34	60	64	45
R6	55	47	32	34	49	50	48	34	62	48	52	51	47	54	56	48	49	55	53	49	52	41	36	59	62	38
R7	55	47	32	31	50	51	49	36	63	49	53	52	47	54	57	49	49	55	53	49	52	38	33	59	62	37
R8	55	47	32	35	48	49	47	43	62	47	51	50	46	53	55	47	48	53	53	48	52	37	32	57	61	42
R9	55	47	32	30	48	49	47	32	59	47	51	48	44	52	54	35	39	43	43	47	51	39	34	56	59	31
R10	55	47	32	32	48	49	47	34	59	46	52	50	45	52	55	38	41	46	45	47	51	43	38	56	60	34
R11	55	47	32	36	51	51	50	41	64	49	53	53	48	55	58	44	47	51	52	49	53	52	54	54	59	43
R12	55	47	32	36	51	51	49	42	65	49	53	54	48	55	59	51	49	54	53	49	53	46	47	56	60	50
R13	55	47	32	37	50	51	49	48	64	48	52	53	47	54	58	52	52	58	58	48	52	48	52	56	60	51
R14	55	47	32	44	48	48	47	46	61	45	50	50	44	51	55	49	50	57	56	46	50	44	39	53	57	48
R15	55	47	32	45	49	49	48	45	61	46	51	50	45	52	55	49	51	57	56	48	53	43	41	54	57	47
R16	72	61	46	36	34	35	33	35	45	30	37	34	29	36	39	37	44	47	57	34	39	68	73	49	51	30
H2	70	-	-	57	42	45	41	55	65	47	47	53	47	48	58	57	69	68	72	43	47	71	61	57	60	38
H3	70	-	-	50	48	48	47	51	63	47	52	52	46	53	57	54	61	64	65	46	50	70	65	55	57	48
H4	70	-	-	55	50	50	49	55	66	49	53	54	48	55	59	57	64	68	68	47	51	67	61	57	58	52
H5	70	-	-	56	50	50	49	56	67	48	53	55	48	55	60	58	65	69	68	47	52	66	60	57	60	53
H6	70	-	-	58	51	52	50	60	71	51	54	58	51	57	63	62	67	72	71	48	53	64	58	64	66	55
H7	70	-	-	43	47	47	46	44	60	45	50	49	44	51	54	47	53	57	59	46	49	68	63	52	55	41
H8	70	-	-	44	47	48	46	45	61	45	51	50	44	51	55	47	55	57	62	46	49	71	67	54	57	42
H9	70	-	-	46	47	47	46	45	61	45	51	50	44	51	54	48	55	58	63	46	49	73	76	55	56	41
H10	70	-	-	45	47	47	45	44	60	44	50	48	43	50	53	47	54	57	61	45	49	73	83	52	54	35
H11	70	-	-	39	43	43	40	38	54	40	46	43	38	46	48	41	48	51	55	38	45	67	71	45	48	29
H12	70	-	-	45	37	38	36	45	58	32	40	38	31	39	43	47	55	58	62	35	44	76	82	53	55	32
C1	60	-	-	41	51	52	50	41	67	50	54	56	50	56	61	54	54	60	58	49	53	45	39	59	62	55
C3	60	-	-	35	44	45	43	34	56	41	47	48	43	47	50	37	43	47	63	45	49	74	66	43	45	39
T1	60	-	-	53	46	47	45	51	63	45	50	51	45	51	56	53	61	63	76	45	49	82	67	55	59	49
T2	60	-	-	49	46	47	45	50	62	45	49	50	44	51	55	52	59	63	65	45	49	71	64	55	58	46

***Green** notes exceedance of daytime NML, **Red** notes daytime prediction exceeds ICNG 'highly noise affected criteria'*

Table 6-5 Predicted $L_{Aeq,15min}$ – Construction phase noise summary

Receiver	NML / dB(A) Daytime	Evening	Night	Phase of construction noise predictions / dB(A): Site establishment and early works	Bridge pier construction	Incremental launched bridge	Southern approach road	Northern approach road	Southern Bridge Street tie-in	Existing bridge demolition	Southern compound
R1	68	55	44	63	64	63	57	**69**	54	58	44
R2	72	61	46	67	69	61	**77**	51	69	65	43
R3	72	61	46	54	62	50	65	46	**84**	60	31
R4	55	47	32	**64**	**72**	**65**	**74**	**55**	49	**66**	**63**
R5	55	47	32	52	**65**	**60**	**58**	54	41	**65**	45
R6	55	47	32	52	**64**	**57**	**56**	54	43	**64**	38
R7	55	47	32	52	**65**	**58**	**56**	54	40	**64**	37
R8	55	47	32	51	**63**	**56**	55	53	39	**63**	42
R9	55	47	32	50	**60**	**56**	45	53	41	**61**	31
R10	55	47	32	51	**61**	**57**	47	53	45	**61**	34
R11	55	47	32	53	**65**	**59**	53	54	**56**	**60**	43
R12	55	47	32	53	**66**	**60**	**55**	54	49	**62**	50
R13	55	47	32	52	**65**	**59**	**60**	54	54	**61**	51
R14	55	47	32	50	**62**	**56**	**59**	52	46	**58**	48
R15	55	47	32	51	**63**	**57**	**59**	54	45	**59**	47
R16	72	61	46	37	47	40	49	41	**75**	52	30
H2	70	-	-	59	67	60	**70**	48	**73**	62	38
H3	70	-	-	53	65	58	65	52	**72**	59	48
H4	70	-	-	56	67	61	69	53	69	60	52
H5	70	-	-	58	68	62	**70**	53	68	61	53
H6	70	-	-	62	**72**	64	**74**	54	66	68	55
H7	70	-	-	49	62	55	58	51	**70**	56	41
H8	70	-	-	49	63	56	59	51	**73**	58	42
H9	70	-	-	49	63	56	59	51	**78**	58	41
H10	70	-	-	49	61	54	58	51	**85**	55	35
H11	70	-	-	45	56	49	52	46	**73**	49	29
H12	70	-	-	47	59	45	59	46	**84**	56	32
C1	60	-	-	53	**68**	**62**	**61**	55	47	**64**	55

Receiver	NML / dB(A)			Phase of construction noise predictions / dB(A)							
	Daytime	Evening	Night	Site establishment and early works	Bridge pier construction	Incremental launched bridge	Southern approach road	Northern approach road	Southern Bridge Street tie-in	Existing bridge demolition	Southern compound
C3	60	-	-	47	58	51	48	51	**76**	46	39
T1	60	-	-	54	**64**	57	**65**	50	**84**	**60**	49
T2	60	-	-	52	**63**	56	**64**	50	**73**	60	46

Green *notes exceedance of daytime NML,* ***Red*** *notes daytime prediction exceeds ICNG 'highly noise affected criteria'*

Table 6-6 Potential works outside standard construction hours compared to noise management levels

Receiver	Evening NML / dB(A)	Activity noise prediction / dB(A)						Night-time NML / dB(A)	Activity noise prediction / dB(A)					
		Site establish-ment and early works	Bridge pier	Northern approach road		Southern approach road			Site establish-ment and early works	Bridge pier	Northern approach road		Southern approach road	
		Southern utilities	Bridge casting	Earthworks	Paving	road removal	Paving		Southern utilities	Bridge casting	Earthworks	Paving	road removal	Paving
R1	55	44	62	63	67	52	48	44	44	62	63	67	52	49
R2	61	61	51	45	50	67	59	46	61	51	45	50	67	59
R3	61	51	36	31	44	82	69	46	51	36	31	44	82	69
R4	47	60	54	50	54	47	40	32	60	54	50	54	47	40
R5	47	46	53	49	53	39	34	32	46	53	49	53	39	34
R6	47	34	52	49	52	41	36	32	34	52	49	52	41	36
R7	47	36	53	49	52	38	33	32	36	53	49	52	38	33
R8	47	43	51	48	52	37	32	32	43	51	48	52	37	32
R9	47	32	51	47	51	39	34	32	32	51	47	51	39	34
R10	47	34	52	47	51	43	38	32	34	52	47	51	43	38
R11	47	41	53	49	53	52	54	32	41	53	49	53	52	54
R12	47	42	53	49	53	46	47	32	42	53	49	53	46	47
R13	47	48	52	48	52	48	52	32	48	52	48	52	48	52
R14	47	46	50	46	50	44	39	32	46	50	46	50	44	39
R15	47	45	51	48	53	43	41	32	45	51	48	53	43	41
R16	61	35	37	34	39	68	73	46	35	37	34	39	68	73
H2	70	55	47	43	47	71	61	70	55	47	43	47	71	61
H3	70	51	52	46	50	70	65	70	51	52	46	50	70	65
H4	70	55	53	47	51	67	61	70	55	53	47	51	67	61
H5	70	56	53	47	52	66	60	70	56	53	47	52	66	60
H6	70	60	54	48	53	64	58	70	60	54	48	53	64	58
H7	70	44	50	46	49	68	63	70	44	50	46	49	68	63
H8	70	45	51	46	49	71	67	70	45	51	46	49	71	67
H9	70	45	51	46	49	73	76	70	45	51	46	49	73	76
H10	70	44	50	45	49	73	83	70	44	50	45	49	73	83
H11	70	38	46	38	45	67	71	70	38	46	38	45	67	71
H12	70	45	40	35	44	76	82	70	45	40	35	44	76	82
T1	70	51	50	45	49	82	67	70	51	50	45	49	82	67
T2	70	50	49	45	49	71	64	70	50	49	45	49	71	64

Light grey shading denotes exceedance of NML

6.3.3 Incrementally launched bridge construction

The launching of the bridge from the north has the potential to occur during daytime or out of hours periods. This is due to the nature of the concrete pours and the requirement to continue launching each section until secure. This would sometimes run beyond standard construction hours.

During daytime works, the noise associated with the bridge launching is predicted to exceed criteria at up to 13 receivers, however the highly noise affected criteria is not predicted to be exceeded. The exceedances are mainly as a result of concrete pours on the bridge and the final activity of paving to create the road surface. The actual activity associated with casting, launching bridge sections and form work results in only two exceedances. The operation of jacks to push the bridge over the river and the fixing of steel and formwork in the casting yard would result in the exceedances of the NML at one sensitive receiver (R4).

During evening and night-time bridge works, exceedances of the evening and night time NMLs, respectively, are predicted at 14 out of the 16 closest receivers. The highest predict noise levels are as a result from potential out of hours paving works on the bridge and casting within the northern casting yard.

A noise prediction of 62dB(A) is predicted to occur at R1 (27 Freemans Reach Road) during out of hours casting, however the project would aim to confine casting to daytime periods only. In addition the location and nature of the casting may make simple barrier mitigation an option.

It is important to note that the impacts summarised in for these activities are representative of the worst case 15 minute period of each activity and period average noise levels would be lower than these. These predictions also included all plant identified for each activity operating simultaneously and at the closest location to each sensitive receiver. In reality, separation distances would vary between plant and sensitive receiver as the works are linear in nature, and the time at which each receiver would be exposed to such high levels would be short.

Where receivers are predicted to be exposed to levels exceeding the adopted NML, some form of management, administrative or mitigation measures would be required. These are detailed further in **Section 7.3.**

6.3.4 Southern approach road construction

Certain activities associated with the southern approach road construction phase may be required outside of standard construction hours, however this would be limited to paving works only. Paving works and concrete pours maybe required outside standard construction hours due to the nature of road surface construction requiring works at specified times following pours.

In total 15 receivers are predicted to be exposed to noise levels from southern approach road works during standard construction hours. This includes the potential exceedance of highly noise affected criteria at R2 (4 Bridge Street). Exceedances of the daytime criteria within Thompson Square are also predicted. These exceedances are due to the close proximity of works to receivers rather than excessively noisy plant. Works are likely to be within 5-10 metres of 4 Bridge Street and Thompson Square during the construction of the southern approach road.

During out of hours works, where paving is undertaken in close proximity to receivers on the lower end of Bridge Street, noise levels are predicted to exceed both evening and night time NMLs by up to 30dB(A). Therefore there is potential for sleep disturbance at the closest receivers.

The ICNG states that where a receiver is exposed to noise levels of 75dB(A) or greater, as a result of construction activities, the receiver is to be classed as ‘highly noise affected’ and must be afforded additional consideration. At receivers where levels are predicted to be ‘highly noise affected’, additional management and possible mitigation measures would be required. Measures would include consultation with residents, substitution of noisy plant, provision of temporary barriers, potential reduced hours of work and the provision of respite periods. These are detailed further in **Section 7.3**.

6.3.5 Northern approach road construction

Certain activities associated with the northern approach road construction phase may be required outside of standard construction hours, however this would be limited to paving works only. Paving works and concrete pours maybe required outside standard construction hours due to the nature of road surface construction requiring works at specified times following pours.

In total two receivers are predicted to be exposed to noise associated with the construction of the northern approach road above the daytime NML, these being R1 (27 Freemans Reach Road) and R4 (53 George Street). Predictions are only just predicted to exceed the respective levels by up to 1dB(A), therefore the impact is considered to be low. It should also be noted that this assumes that earthworks in the area and paving is undertaken simultaneous which in practice unlikely to occur. Where either activity is undertaken independently of the other, no exceedances of daytime NMLs are predicted.

Where paving is proposed to be undertaken during out of hours works, for practical and technical reasons, up to 12 sensitive receivers may be exposed to noise levels above evening and night time NMLs. These works are likely to be short term and therefore the impact is reduced. However, where these works are required out of hours, an additional out of hours assessment would be undertaken following approval and prior to works. This would identify specific impacts and mitigation measures.

6.3.6 Southern Bridge Street road tie-in

The tie in of the new alignment with Bridge Street, George Street and up to the junction with Macquarie Street has the potential to be undertaken during standard and out of hours construction periods. Due to work being required on the existing road network to fulfil these tie-in works, out of hours works using a Road Occupancy Licence (ROL) would be likely to be required. The highest noise emitting activities such as road breaking and milling would be restricted to daytime periods where possible to reduce potential impacts.

During standard construction hours, the noise from tie-in works would be likely to exceed the NML and criteria at 14 receivers, with up to seven predicted to be exposed to noise classed as ‘highly noise affected’. This includes the receivers to the upper end of Bridge Street on the junction with George Street.

During out of hours works, the same receivers impacted within standard hours would be impacted upon. However as the majority of these receivers are commercial the impacts during night time and evening periods would be restricted to residential dwellings on Bridge Street including R2, R3 and R16. Depending on the plant being used during out of hours periods, the highly noise affected criteria of 75dB(A) still would have the potential to be exceeded as a result of close proximity working areas.

The ICNG states that where a receiver is exposed to noise levels of 75dB(A) or greater, as a result of construction activities, the receiver is to be classed as ‘highly noise affected’ and must be afforded additional consideration. At receivers where levels are predicted to be ‘highly noise affected’, additional management and possible mitigation measures would be required. Measures would include consultation with residents, substitution of noisy plant, provision of temporary barriers, potential reduced hours of work and the provision of respite periods. These are detailed further in **Section 7.3**.

6.3.7 Existing bridge demolition

Bridge demolition works would be restricted to standard construction hours only and therefore the impact on receivers within the area would be reduced. During these works, there would be the potential that up to 14 receivers being exposed to construction noise above the standard hours NML however the highly noise affected criteria is not predicted to be exceeded.

Noise exceedances would result from activities such as saw and grinder use during the removal of the existing bridge superstructure. However noise levels would be likely to only be emitted for short periods of time therefore reducing the impact. Where receivers are predicted to be exposed to levels exceeding the adopted NML, some form of management, administrative or mitigation measures would be required. These are detailed further in **Section 7.3**.

6.3.8 Southern laydown/compound use

The operation of the southern laydown area, next to the Windsor wharf car park, would be unlikely to have significant impact throughout the duration of works. Noise would be restricted to short durations of time where plant is being collected or dropped off in the area. However out of hours operations may be required but again noise emissions would be likely to be restricted to short periods of time at the start and end of a shift.

Predictions during daytime show that only the closest receiver to this area, R4 (53 George Street) would potentially be exposed to noise levels exceeding the NML.

During out of hours periods, noise exceedances of respective NMLs would only likely to occur at the start and end of shifts for short periods of time, and therefore the impact is expected to be low.

6.3.9 Haulage routes

Haulage routes for construction would be via major arterial roads such as Windsor Road and Macquarie Street, which are high traffic environments. The majority of truck movements associated with construction would be generated by the delivery of material to the site. Haulage routes for demolition of the existing bridge would include local roads such as The Terrace and Baker Street on the southern bank and Wilberforce Road and Kurmond Road on the northern bank. The demolition of the bridge would generate about 800 truck movements over a 6 month period, averaging 6 truck movements a day which equates to less than 0.1 percent of daily traffic movements. Due to the minimal traffic movements associated with haulage for construction and operation, it is anticipated that noise impacts associated with haulage routes would be negligible.

6.3.10 Maximum construction noise assessment (sleep disturbance)

In accordance with the ICNG, the maximum noise assessment for construction works is considered applicable where works would potentially be undertaken over two or more consecutive nights. This is to assess the potential for sleep disturbance as a result of maximum noise levels, not just average noise levels. Although the ICNG does not specifically provide criteria for assessing maximum noise events, it does refer to methods within the NSW Road Noise Policy (RNP - DECCW, 2011)

The RNP discusses the potential for disruption of normal sleep patterns due to irregular noise events, but concludes that there is insufficient evidence to assist in setting trigger levels for this type of impact. The work to date on the subject specifies that:

- Maximum noise levels below 50-55 dB(A) are unlikely to cause an awakening from a sleep state.
- One or two noise events per night with maximum noise levels of 65-70 dB(A) are not likely to affect the health and wellbeing significantly.

Maximum noise emissions from construction works usually result from unforeseen and sporadic incidents such as the dropping of an excavator bucket, rock dropping into metal containers or metal plant hitting hidden metal/rock ground conditions. These events and the magnitude of emission are heavily dependent on the types of activities undertaken, plant being used, materials being processed and a number of other variables.

The one off nature of maximum noise emissions means the accurate prediction of maximum noise emissions for a particular activity relatively difficult. In addition to the magnitude of the maximum noise emission, the frequency and number of events over a particular night time period is also important when determining sleep disturbance. The accurate determination of the number of maximum noise events in a particularly night time period, as a result of construction works is not practical. Therefore for worst case assessment it would be assumed that maximum noise events could occur at receiver more than two times in one night.

For the purpose of this project an estimation of maximum noise emissions from any general construction activity has been predicted at each residential receiver within the study area. These predictions are presented in **Table 6-7.** Predictions are based on file data collected during construction activities throughout different projects. On average, for one of events such as bucket drops and truck filling, maximum noise levels are up to 8dB(A) higher than the $L_{Aeq,T}$ value.

Table 6-7 Maximum construction noise assessment

Receiver		*Maximum noise assessment criteria L_{Amax} / dB(A)	Maximum noise prediction L_{Amax} / dB(A)
R2	4 Bridge Street	70	77
R3	10 Bridge Street	70	85
R4	53 George Street	70	92
R5	12 The Terrace	70	82
R6	14 The Terrace	70	73
R7	16 The Terrace	70	72
R8	18 The Terrace	70	73
R9	20 The Terrace	70	71
R10	22 The Terrace	70	69
R11	45 George Street	70	69
R12	43 George Street	70	73
R13	41 George Street	70	74
R14	39 George Street	70	73
R15	29 George Street	70	71
R16	16 Bridge Street	70	83

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

Table 6-7 shows that a number of receivers within the study area have the potential to be exposed to maximum noise levels above those identified within the RNP. However the actual number would be dependent on the variables outlined above and are unlikely to be calculated accurately prior to the finalising of construction methods and commencement of works. An additional detailed assessment would be undertaken following approval and prior to the commencement of construction works to provide further information on maximum noise impacts. It should be noted that even a detailed assessment would not be able to accurately predict the occurrence of events due to the nature of maximum noise emissions.

6.4 Construction vibration

Ground borne vibration from standard construction works (not including blasting) travels much shorter distances compared to air borne noise from the same activity. Therefore the number of receivers at risk from construction vibration would be much fewer than construction noise, restricting impact to the closest receivers to works only.

Within this project, receivers within 50 metres of high risk plant for vibration emissions have been identified for vibration assessment. Through general predictions, other receivers within the project area would be separated sufficiently from proposed work activities not experience any form of construction vibration and hence have not been assessed.

6.4.1 Site law development

To assist with the prediction of construction induced vibration at vibration sensitive receivers, vibration simulations and monitoring were undertaken at sensitive receivers along the lower end of Bridge Street. The data from the vibration simulations and monitoring was used to predict and assess how the ground conditions along Bridge Street affects the propagation of ground borne vibration waves in the area proposed for the new alignment. As a result of vibration simulations and monitoring a 'Site Law' for the land between the existing Bridge Street alignment and the structure edge of 4, 6 and 10 Bridge Street was generated. A number of assumptions were made during the vibration simulations and monitoring to enable an indicative site law to be derived. These assumptions are discussed below. The vibration testing equipment used on site is described in **Appendix C.**

6.4.2 Assessment assumptions

At this stage the exact geotechnical nature of the ground between the roadside kerb of Bridge Street and properties at 4, 6 and 10 Old Bridge Street is unknown and therefore an assumption was made of the likely existing conditions. For assessment and prediction purposes the ground was considered to be relatively well compacted, consisting of a uniform combination of low down gravel/hardcore as foundations for the existing road and pavement, compacted soil for the grassed area and compacted red sand below the pedestrian pavement, similar to other road and verges.

From initial analysis of geological data and vibration data it is not believed that the structural foundations of the nearest receivers are coupled to the same foundations or bedrock of the road. Therefore the only substrate for the transmission of vibration associated with road traffic movement and structures would be medium compacted earth - which would have a greater damping effect on vibration waves than denser materials such as rock or highly compacted ground. When predicting the future impact of the operational road and construction impacts, these assumptions along with other data findings were used within empirical formulas.

In terms of human comfort for occupants of 4, 6 and 10 Bridge Street, the transfer function of the sensitive dwellings would not have any effect on the inside measurements and therefore levels measured externally would be assumed to be the same as internal levels. In most cases a structure has a damping effect on the external vibration wave and therefore reduces associated internal levels. However, on some occasions the structure can become 'excited' by the vibration wave (frequency dependent) and can marginally increase the internal vibration levels.

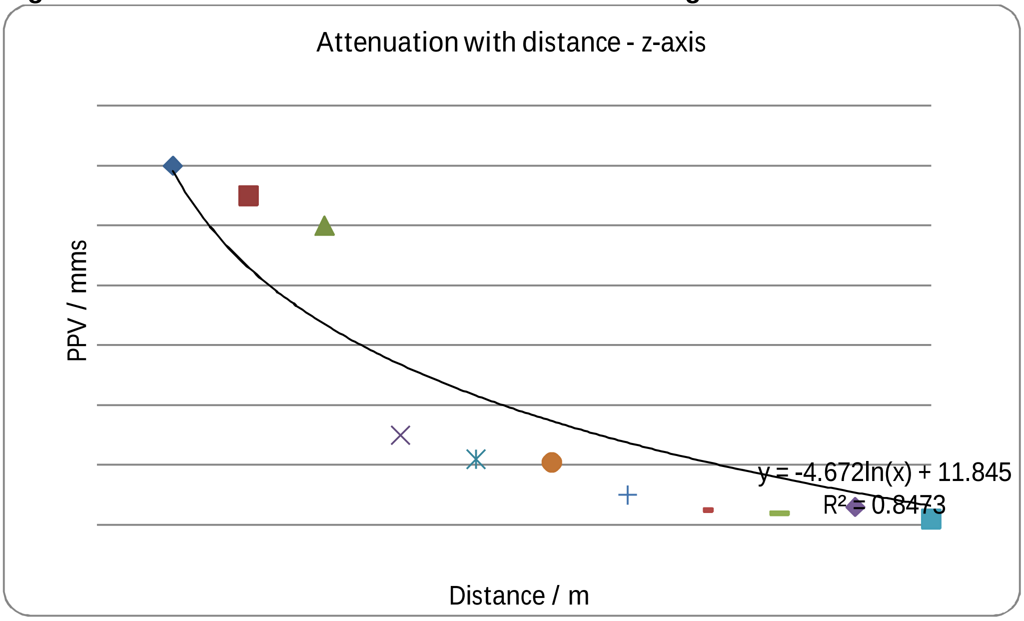
Vibration simulations and monitoring

Vibration simulations and monitoring was undertaken to gain an understanding of the way in which ground borne vibration (PPV) propagates through the ground between Bridge Street (existing) and the closest receivers at 4, 6 and 10 Bridge Street. Although the vibration simulations and monitoring does not identify specific ground types or buried obstacles, the results were used to give an indication of how much the vibration was dampened by existing ground conditions.

Vibration simulations and monitoring involved dropping a known weight (24 kilograms) from a predetermined height (1400 millimetres), onto a wooden block located on the ground at the edge of the Bridge Street kerb. A geophone and tri-axial accelerometer block were located at varying distances from the impact site, with the corresponding velocity and acceleration (including frequency spectrum), along with the separation distance being recorded. The same source energy was created during each drop by using the same weight and drop height.

A number of drops were undertaken at each separation distance to allow for an average to be calculated. The data obtained during this exercise has been collated, presented in **Appendix D**, and in **Figure 6-2**.

Figure 6-2 Measured vibration levels – vibration testing



The testing data in **Appendix D** was used to predict the vibration attenuation per metre. The attenuation per metre was calculated using the data at each distance in combination with the reference data at the sensitive receiver building structure. This was undertaken for each of the three axes, with the minimum attenuation per metre being reported to provide a conservative assessment. **Table 6-8** provides a summary of the ground attenuation provided per linear metre. The difference in attenuation between minimum, maximum and average was a function of the geotechnical nature of the ground between the testing location and building structure. This showed that the ground is not entirely uniform, and may be as a result of anomalies within the testing area or the location of the services running along Bridge Street. The attenuation per metre was used alongside empirical formulas to calculate the vibration associated with various construction activities.

Table 6-8 Generic ground attenuation – Bridge Street

Data	Attenuation per metre / mms^{-1}		
	x	y	Z
Minimum	1.5	1.5	1.2
Maximum	2.7	2.7	3.8
Average (mean)	2.1	2.1	2.6

6.4.3 Construction vibration predictions

Sources of vibration during construction would include plant identified in **Section 6.1**, in particular impact pile driving, compactors and rock hammering/breaking. No blasting would be undertaken for the project.

The highest vibration emitting plant would be used during pier construction. The bridge piers would be constructed by driving permanent steel liners into the rock followed by augering out and filling with concrete. Elsewhere other activities resulting in vibration would be bored piling, vibratory rollers and rock breakers

At this stage of the project, it has been assumed that impact piling would only occur during the installation of the new bridge piers which is a minimum of 50 metres distant from the nearest residential or non-residential structure. Other piling within the project would comprise of bored piling. Rock hammering and breaking may occur during the road removal during tie in works to the south of Bridge Street and on the northern side of the bridge.

Vibration predictions used empirical formulas (taking account for site specific corrections gained from testing) and file data from previous assessments to predict velocity (PPV) at given distances and then used these predictions and assumptions in terms of work durations, prediction of acceleration and Vibration Dose Values (VDV) have been produced.

Table 6-9 to **Table 6-11** provide predictions of the wave propagation associated with impact driven piles, the activities of rock hammering and compaction. This identifies the vibration level prediction in terms of velocity (PPV) and the associated VDV. The VDV was calculated from the acceleration (converted from PPV using assumed frequency character) and was based on an assumed total duration of any one vibration causing activity (time for which the vibration is actually produced). The total duration of vibration was set at 2 hours in any working day.

Table 6-9 Typical maximum vibration levels from rock hammering

	PPV vibration level (mm/s) at distance (metres)					
Distance from activity (metres)	**5**	**10**	**20**	**30**	**40**	**50**
Heavy rock hammer (1.5 t)	4.5	3	1.5	0.4	0.35	0.3
Medium rock hammer (0.6 t)	0.2	0.06	0.02	0.01	-	-
	Estimated Vibration Dose Value ($ms^{-1.75}$)					
Heavy rock hammer (1.5 t)	2.9	1.9	1.0	0.3	0.2	0.2
Medium rock hammer (0.6 t)	0.1	0.0	0.0	0.0	-	-

Table 6-10 Typical maximum vibration levels from impact piling

	PPV vibration level (mm/s) at distance (metres)					
Distance from activity (metres)	**5**	**10**	**20**	**30**	**40**	**50**
Impact Piling Rig	21	9	3	2	1	0.2
	Estimated Vibration Dose Value ($ms^{-1.75}$)					
Impact Piling Rig	3.2	2.1	1.1	0.35	0.26	0.18

Table 6-11 Typical maximum vibration levels from 10 tonne roller (70 Hz vibrating frequency) or vibratory plate

	PPV vibration level (mm/s) at distance (m)					
Distance from activity (m)	**5**	**10**	**20**	**30**	**40**	**50**
Compactor/ Roller	4	3	2	0.5	0.1	0
	Estimated Vibration Dose Value ($ms^{-1.75}$)					
Compactor/ Roller	2.0	1.2	0.8	0.2	0.1	<0.1

Using the predictions in **Table 6-10**, the maximum impact piling vibration levels (PPV and VDV were predicted at each of the receivers within 50 metres of potential piling, rolling and rock breaking activities. **Table 6-12** summarises these maximum levels alongside project specific assessment criteria.

Table 6-12 shows that the potential to cause cosmetic or structural damage to buildings within the study area as a result of bridge impact piling works would be minimal, as long as separation distance between source and receiver is greater than 50 metres. The closest structures would be sufficiently separated from the potential piling locations that the energy from the process is substantially attenuated and maximum predicted vibration exposure value is more than half that of the criteria. The levels predicted for the potential piling works would be unlikely to be perceivable by the closest receivers. In the same way, the risk of causing exceedances in human comfort criteria, and therefore disturbance to occupants of properties within the study area would be minimal.

The activity of rock breaking/hammering and vibratory compaction would occur closer to receivers than piling and although the energy associated with these works would be lower, the risk of impact would be potentially higher. From **Table 6-12** the impacts are shown to be minimal from these works at the closest receivers however due to the exact location of vibratory plant being unknown at the time of writing this assessment, and the sensitive nature of heritage structures within the study area, a detailed vibration assessment would be undertaken following approval and prior to the commencement of works. This would be accompanied by attended monitoring during works to confirm compliance.

Table 6-12 Maximum vibration predictions

ID	Receiver	Criteria		Impact Piling		Rock Breaking		Vibratory Roller	
		Structural Damage (PPV)	Human Comfort (VDV)	PPV	VDV	PPV	VDV	PPV	VDV
R1	27 Freemans Reach Road	5	0.4	<0.2mms^{-1}	<0.25	0.4	0.3	2.5	1
R2	4 Bridge Street	5	0.4	<0.2mms^{-1}	<0.25	3	1.9	2.5	1
R3	10 Bridge Street	3	0.8	<0.2mms^{-1}	<0.25	1.8	0.2	2.5	1
R16	16 Bridge Street	5	0.4	-	-	1.8	0.2	2.5	1
H1	4 Bridge Street (wall)	3	-	<0.2mms^{-1}	-	-	-	2.5	1
H2	6 Bridge Street	3	0.4	<0.2mms^{-1}	<0.25	-	-	2.5	1
H6	3 Thompson Square	3	0.4	<0.2mms^{-1}	<0.25	0.4	0.3	2.5	1
H7	70 George Street	-	0.4	-	-	0.4	0.3	2.5	1
H8	74 George Street	3	0.4	-	-	0.4	0.3	2.5	1
H9	68 George Street	3	0.4	-	-	0.4	0.3	2.5	1
H10	62 George Street	3	0.4	-	-	0.4	0.3	2.5	1
H11	17 Bridge Street	3	0.4	-	-	0.4	0.3	2.5	1
H12	14 Bridge Street	3	0.4	-	-	0.4	0.3	2.5	1
C2	Utilities Channel	3	0.4	15	-	3	-	2.5	1

Exceedance are highlighted in red

7 Environmental management measures

7.1 Operational noise

The use of noise barriers and low noise pavement options would not be feasible for mitigation of noise impacts for the Thompson Square parkland and the conservation area in general. In particular, the use of noise barriers would not be possible as visual impacts of noise barriers on the heritage vistas and values of the area would be significant. The use of low noise pavements on the bridge deck, approach roads or at roundabouts would not be possible due to operational and safety considerations, particularly for motorbikes and cyclists, and therefore would not be considered for the project. Additionally, low noise pavements are not considered effective for low speed environments and short distances and the use of such pavement on bridges is not consistent with RMS policy.

Mitigation for the receivers at R2, R3 and R4 is to be considered based on the outcome of the assessment of operation traffic noise impacts for the design year scenario. As low noise pavements and noise walls are not options for noise mitigation architectural treatments are recommended.

As receiver R3 is operated as a commercial premise it does not qualify for architectural treatment. The receiver locations at R2 and R4 are residential properties of weatherboard and masonry construction respectively. Practice Note (iv) of the ENMM identifies that:

'*Architectural Treatments should aim to achieve internal noise levels in habitable rooms 10 dB(A) below the external noise level targets. 10 dB(A) is equivalent to the traffic noise reduction that can be achieved for most building structures with the windows sufficiently open to satisfy minimum fresh air requirements.*'.

Practice Note iv (b) of the RMS ENMM limits acoustic building treatments to:

- 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 of window and door seals.
- The sealing of wall vents.
- The installation of external screen walls.

Recent RMS projects and the Development near rail corridors and busy roads - interim guideline (DoP, 2008) recommend that for non-masonry structures, such as weatherboard, where design quantifies an acoustic improvement, noise mitigation options should be considered. The mitigation measures outlined below are those which are likely to form part of property treatment recommendations. Options for the architectural treatment of properties to achieve a minimum 10 dB(A) may include a combination of the options in **Table 7-1**.

Table 7-1 Architectural treat mitigation options

Option	Potential reduction in noise levels
Windows Closed with mechanical ventilation	5 - 13 dB(A)[1]
Sealing doors and windows	1 - 4 dB(A)[1]
Solid Core Doors with seals on doors	4 - 10 dB(A)[1]
Sealing of eaves	1 - 3 dB(A)[1]
Glazing of windows or replacement with thicker glass	20 - 25 dB(A)[2]
Double glazing of windows (Masonry buildings only)	35 dB(A)[2]
Sealing of wall vents	2 - 5 dB(A)[1]

Notes 1 - SPCC, 1991, 2 - RTA, 2001

In implementing the mitigation options outlined in **Table 7-1**, the overall construction of the building needs to be considered to provide the optimum internal noise benefit. Further assessment of specific noise impacts and specific building elements would be undertaken to identify the most effective mitigation options to minimise traffic noise impacts from the project. Selection of any architectural treatments would also be undertaken in consultation with the owners of affected properties.

At the receiver location R3, the implementation of architectural treatments are not straightforward as the other properties due to the heritage significance of the structure. This property is recognised as; "*..a rare and excellent example of Victorian Regency Style* architecture.." and is listed as a heritage item on the LEP. Therefore any mitigation measures must be sympathetic to the character and style of the property. Also the ground floor of the building is currently operated as a commercial premise, whereas the upper floor is a residential premise. Therefore only the upper floor qualifies for architectural treatment under the ENMM.

A qualified heritage architect was engaged to inspect the residential section of R3 and recommend potential architectural treatments that provide noise mitigation while not impacting on the heritage values of the building (CityPlan, 2012) (See **Appendix E**). The heritage architect recommended that duplicate custom-made windows and French doors could be manufactured and fitted to provide double glazing for all glass areas facing the project. Providing these were made and fitted by an experienced carpenter to exactly match the existing windows and French doors, they would not result in a significant impact to heritage values of the building. Ventilation could also be provided via a ducted ceiling system, however this would have to designed and installed to integrate with the existing patterned ceiling.

For receiver R2 and R4, a building inspection and identification of architectural treatments would be undertaken before construction commences. This was not undertaken for this report as the building is not heritage listed and therefore specific architectural treatments do not have to be identified at this stage.

Wherever possible architectural treatments of buildings would be installed before major construction activities commence.

7.2 Operational vibration

The findings of this report have shown that the potential for vibration impact, to either structures or residents, would be minimal as a result of operational road traffic along the new bridge and road alignment. Therefore no mitigation measures would be recommended.

7.3 Construction noise

Exceedances of the project NMLs have been predicted to occur at a number of residential properties during different construction activities. Where these exceedances are predicted, construction noise would be mitigated through management of the proposed works. Prior to commencing construction, a Construction Noise and Vibration Management Plan (CNVMP) would be prepared and adopted, see **Section 7.5**. This document would detail how work is to be carried out to minimise the impacts of noise and vibration on adjacent properties.

Exceedances of the project NMLs would occur at most sensitive receivers and would depend upon the location and type of construction activities. Construction noise mitigation measures will be implemented wherever possible to minimise noise impacts. These noise mitigation measures will be detailed in a Construction Noise and Vibration Management Plan (CNVMP) and will include general controls such as:

- As the location and type of construction works may change, further detailed noise impact assessments will be undertaken of all construction works and works outside standard construction hours once detailed construction planning is complete. These detailed noise impact assessments will be used to identify affected sensitive receivers and develop detailed mitigation measures.
- The nearest noise sensitive receivers will be notified of future works and expected levels of noise well in advance of the works occurring.
- Construction programming will be developed to minimise noise impacts - this may include time and duration restrictions and respite periods, and will be developed after consultation with affected receivers.
- Where possible, works outside of standard construction hours will be planned so that noisier works are carried out in the earlier part of the evening or night time.
- Where noisy works are required outside of standard construction hours, negotiated agreements will be sought with affected sensitive receivers.
- Where possible, the use of noisy plant simultaneously and/or close together will be avoided.
- Equipment and excavation work sites will be orientated away from sensitive receivers where possible to reduce noise emissions.
- Equipment will be maintained in efficient working order.
- Quieter construction methods will be used where feasible and reasonable. This may include grinding, rock splitting or terrain levelling instead of rock breaking where it is feasible and reasonable.
- Where acceptable from a work health and safety perspective, quieter alternatives to reversing alarms (such as spotters, closed circuit television monitors and ‘smart’ reversing alarms) will be used particularly during out of hours activities.
- All noise complaints will be investigated and appropriate mitigation measures implemented where practicable to minimise further impacts.
- Truck movements will be restricted to identified haulage routes and the routes outlined in the Construction Traffic Management Plan.
- Noise monitoring will be undertaken to assess compliance with NMLs and assess the effectiveness of noise mitigation The use of temporary noise shielding will be considered at locations along Bridge Street where substantial exceedances of noise criteria are predicted. In addition where work is undertaken in close proximity to Thompson Square or along Freemans Reach Road, temporary noise barriers will be considered

7.4 Construction vibration

A Construction Noise and Vibration Management Plan will be prepared for the project and it will contain detailed assessment methods for high risk works, identification of sensitive receivers, complaints handling process, consultation protocols, monitoring requirements and mitigation measures. Mitigation measures that will be contained in the plan include:

- Buildings/structural conditions surveys will be undertaken prior to and following construction works at receivers within 50 metres of piling, rock breaking and vibratory compaction activities, including the heritage retaining wall at 4 Bridge Street
- No impact piling works will be undertaken within 20 metres of any heritage structure, unless additional assessment and monitoring confirm that vibration levels will be below project specific criteria
- Rock breaking/hammering will not be undertaken within seven metres of any heritage item or building unless additional assessment and monitoring confirm that vibration levels will be below project specific criteria
- Rock breaking/hammering will not be undertaken within five metres of any non heritage building unless additional assessment and monitoring confirm that vibration levels will be below project specific criteria.
- Where rock breaking/hammering is planned within 10 metres of any occupied dwelling, the occupants will be notified of the works and the duration of the activity will be restricted, unless otherwise agreed with affected residents.
- Where heavy plant is used within seven metres of a heritage structure, attended vibration monitoring will be undertaken to assess compliance with project specific vibration criteria.
- Where an exceedance of project specific vibration criteria for structural damage is recorded during monitoring, work will cease immediately and alternative construction methods will be used.

7.5 Construction noise and vibration management plan

The construction works would be undertaken within appropriate project criteria and with noise and vibration in mind, a detailed construction noise and vibration management plan (CNVMP) would be developed. The plan would be developed to detail the process of noise and vibration management of construction activities. The information incorporated into the CNVMP would include the assessment undertaken for the EIS and additional noise impact statements undertaken for the detailed design of the construction phase. The CNVMP would be produced prior to the commencement of works.

The CNVMP would include and outline the following:

- Description and identification of all construction activities, including work areas, plan and activity duration.
- Identification of associated construction impacts in terms of noise and vibration for each activity.
- Generic noise and vibration control measures to be implemented during works.
- Works specific or receiver specific mitigation or management measures that are to be implemented for the duration of the works.
- Noise monitoring procedure, both periodic and in response to complaints.
- Vibration monitoring procedure, both periodic and in response to complaints.
- Process for applying for specific out of hours works (including production of Noise Impact Statements)
- Overview of community consultation required for identified and high impact works.

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8 Conclusion

A comprehensive construction and operational noise and vibration impact assessment was undertaken in compliance with relevant Director General's requirements and noise and vibration guidelines and policies.

Background noise monitoring was undertaken in late 2011 to provide noise data for the development and calibration of a noise model for the project. Other information that contributed to the noise model included topographical and building survey information, meteorological data, design information on the existing and new bridge and approach roads and other data that detail the local characteristics of the environment.

Based on the noise model and relevant noise and vibration guidelines and policies, noise and vibration criteria and potentially impacted sensitive receivers for the project were identified.

8.1 Operation

As the project would be considered a redevelopment of an existing road by the Road Noise Policy, the operational noise criteria at sensitive receivers would be 60 dB(A) for daytime and 55 dB(A) for nighttime. Noise modelling using the current design of the project and the predicted traffic movements in 2026 identified three sensitive receivers where noise levels would increase and exceed the operational noise criteria. These three sensitive receivers were 4, 6 and 10 Bridge Street (R2, R3 and R4) and were impacted predominately because the new alignment of the approach road and bridge is closer to the properties than the existing alignment. Operational noise criteria at the sensitive receiver R1 on the northern bank of the Hawkesbury River were also exceeded, however as the future noise levels would be lower than the existing noise levels, consideration of mitigation measures was not required. All other sensitive receivers were predicted to experience a small decrease in noise levels due to the project.

Noise levels in Thompson Square parkland were predicted with and without the project. The predicted minimum and maximum noise levels for both scenarios were similar and both exceeded the operational noise criteria for recreational areas. With the project there was a slightly larger area with lower noise levels as the new alignment of the southern approach road would be located at the eastern boundary of the parkland, rather than the existing situation where the southern approach road bisects the parkland.

While the three sensitive receivers on Bridge Street meet the criteria for consideration of noise mitigation, R3 and the ground floor of R4 do not qualify for noise mitigation under the ENMM as they are commercial premises. As R4 is a locally listed heritage building, a heritage architect was engaged to provide advice on architectural treatments for the upper residential floor. Potential options for noise mitigation were identified that did not impact upon the heritage value of the building. Noise mitigation options for R2 would be identified once the project is approved.

Other noise mitigations options such as low noise pavement and noise barriers were not feasible as there are operational and safety issues associated with low noise pavement and noise barriers would have unacceptable visual impacts on the heritage vistas of Thompson Square.

Vibration from the operation of the project was assessed to identify impacts on both human comfort and heritage buildings and items. The vibration assessment concluded that the vibration generated by the operation of the project would be insignificant and there would no impacts on human comfort or heritage buildings or items.

8.2 Construction

Using the Interim Construction Noise Guidelines and noise monitoring and modelling data, noise management levels were established for sensitive receivers in the vicinity of the construction areas. Using the preliminary construction methodology and the types of plant that would be used, the noise levels from different of stages of construction were predicted and compared and against the noise management levels.

At sensitive receivers in close proximity to new alignment, there would be exceedance of the noise management levels – especially for stages which required the use of rock breakers and other noisy plant. Construction of the southern approach road especially would result in exceedances at a large number of sensitive receivers due to the nature of the works and the number and proximity of sensitive receivers. The bridge pier construction would also result in exceedances of noise management levels at a larger number of sensitive receivers. However it was assumed that impact pile driving would be used for pier construction and if bored piles were used there would be significantly reduced impacts. Construction and launching of the bridge would be a relatively quiet activity, however noise levels would increase during the construction of the bridge deck and paving. The sensitive receivers R2, R3 and R4 would be most impacted by construction noise due to their close proximity to the work site.

The requirement to undertake some noisy construction activities outside the standard working hours was identified and assessed. These activities would include the final tie-ins of the southern and northern approach roads to existing roads, some service adjustments and concrete pours.

Mitigation measures to minimise the generation and impact of construction noise were identified. These are generally management, consultation and monitoring measures that would be further developed during the construction planning and implementation phase. A Construction Noise and Vibration Management Plan based on more detailed noise assessments would be developed and implemented.

The impact of vibration from construction activities was quantified and assessed in consideration of the close proximity of some sensitive receivers and of heritage buildings and items that are more prone to structural damage due to their age and sensitivity. The potential risks are predominately from construction activities on the southern approach road and would require comprehensive mitigation measures to be implemented to minimise potential vibration impacts. These mitigation measures would include exclusion zones around heritage buildings or items for specific high vibration activities, low vibration construction techniques, monitoring and dilapidation surveys.

9 References

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ANZEC, 1990 – Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration

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British Standard BS7385: Part 2 Evaluation and measurement of vibration in buildings, 0 580 22188 1 (British Standards Institution, 1993)

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DECCW (2009) Interim Construction Noise Guidelines

Department of Planning (2008) Development Near Rail Corridors and Busy Roads – Interim Guideline

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