BaT project

Chapter 11

Noise and vibration

Contents

11. Noise and vibration ... 11-1

11.1 Introduction ... 11-1

11.1.1 Noise terminology ... 11-1

11.1.2 Vibration ... 11-3

11.1.3 Ground-borne noise ... 11-4

11.1.4 Methodology ... 11-4

11.1.5 Legislative and policy framework ... 11-5

11.2 Existing environment ... 11-12

11.2.1 Noise ... 11-12

11.2.2 Vibration ... 11-15

11.3 Impact assessment ... 11-17

11.3.1 Construction activities ... 11-17

11.3.2 Surface track construction noise ... 11-75

11.3.3 TBM tunnelling works ... 11-76

11.3.4 Low frequency noise impacts ... 11-80

11.3.5 Construction heavy vehicle noise and vibration impact assessment ... 11-80

11.3.6 Operations ... 11-83

11.4 Impact management ... 11-93

11.4.1 Construction noise and vibration mitigation measures ... 11-93

11.4.2 Operational noise management ... 11-102

11.4.3 Noise and vibration monitoring ... 11-103

11.5 Summary ... 11-106

11.5.1 Construction noise and vibration impacts ... 11-106

11.5.2 Operational noise and vibration impacts ... 11-107

List of Figures

Figure 11-1 Graphical display of typical noise indices 11-2
Figure 11-2 Typical vibration levels..11-4
Figure 11-3 Overview of noise monitoring locations 11-13
Figure 11-4 Overview of vibration monitoring locations 11-16
Figure 11-5 Southern Connection receiver areas 11-18
Figure 11-6 Southern Connection Scenario 1 11-27
Figure 11-7 Southern Connection Scenario 2 11-28
Figure 11-8 Southern Connection Scenario 3 11-29
Figure 11-9 Southern Connection Scenario 4 11-30
Figure 11-10 Southern Connection Scenario 5 11-31
Figure 11-11 Southern Connection Scenario 6 11-32
Figure 11-12 Woolloongabba Station receiver areas 11-33
Figure 11-13 Woolloongabba Station Scenario 1...11-39
Figure 11-14 Woolloongabba Station Scenario 2...11-40
Figure 11-15 Woolloongabba Station Scenario 3...11-41
Figure 11-16 Woolloongabba Station Scenario 4...11-42
Figure 11-17 George Street Station receiver areas 11-43
Figure 11-18 George Street Scenario 1 11-52
Figure 11-19 George Street Scenario 2 11-53
Figure 11-20 George Street Scenario 3 11-54
Figure 11-21 George Street Scenario 4 11-55
Figure 11-22 Roma Street Station Receiver Areas 11-56
Figure 11-23 Roma Street Scenario 1 11-64
Figure 11-24 Roma Street Scenario 2 11-65
Figure 11-25 Roma Street Scenario 3 11-66
Figure 11-26 Roma Street Scenario 4 11-67
Figure 11-27 Northern Connection construction worksite and receiver areas....................................11-68
Figure 11-28 Northern Connection Scenario 1...11-71
Figure 11-29 Northern Connection Scenario 2...11-72
Figure 11-30 Northern Connection Scenario 3...11-73
Figure 11-31 Northern Connection Scenario 4...11-74

List of Tables

Table 11-1 Typical noise levels 11-2
Table 11-2 Construction noise goals 11-7
Table 11-3 Construction vibration goals 11-8
Table 11-4 Categories and criteria (operations) 11-9
Table 11-5 Ground-borne vibration goals (operations) 11-10
Table 11-6 Ground-borne noise goals (operations) 11-11
Table 11-7 Operational mechanical plant noise goals 11-11
Table 11-8 Measured rating background levels 11-14
Table 11-9 Measured ambient vibration 11-15
Table 11-10 Nearest sensitive receivers – Southern Connection 11-18
Table 11-11 Southern Connection predicted construction noise goal exceedances (scenarios 1 to 3) 11-21
Table 11-12 Southern Connection predicted construction noise goal exceedances (scenarios 4 to 6) 11-22
Table 11-13 Southern Connection predicted ground-borne noise and vibration levels – TBM launch shaft excavation, pipe jacking and cut and cover excavation 11-23
Table 11-14 Nearest sensitive receivers – Woolloongabba Station 11-33
Table 11-15 Woolloongabba Station predicted worst case noise levels 11-35
Table 11-16 Woolloongabba Station predicted ground-borne noise and vibration levels – station shaft and cavern excavation 11-36
Table 11-17 Nearest sensitive receivers – George Street Station 11-43
Table 11-18 George Street Station predicted construction noise goal exceedances 11-45
Table 11-19 George Street Station predicted ground-borne noise and vibration levels – station shaft and cavern excavation 11-46
Table 11-20 George Street Station predicted ground-borne vibration and airblast overpressure levels – blasting of station shaft 11-48
Table 11-21 Nearest sensitive receivers – Roma Street Station 11-56
Table 11-22 Roma Street Station predicted worst case construction noise levels 11-58
Table 11-23 Roma Street Station predicted ground-borne noise and vibration levels – station shaft and cavern excavation 11-59
Table 11-24 Roma Street Station predicted ground-borne vibration and airblast overpressure levels – blasting of station shaft 11-61
Table 11-25 Nearest sensitive receivers – Northern Connection 11-68
Table 11-26 Northern Connection predicted worst case construction noise levels 11-70
Table 11-27 Surface track construction plant noise emissions 11-75
Table 11-28 Summary of TBM ground-borne vibration levels along the tunnel alignment 11-77
Table 11-29 Summary of TBM ground-borne noise levels along the tunnel alignment 11-79
Table 11-30 Comparison of linear and A-weighted TBM and roadheader sound pressure levels 11-80
Table 11-31 Effect of construction truck movements on traffic noise levels along spoil routes 11-82
Table 11-32 Summary of predicted ground-borne vibration levels (reference project trackform) 11-85
Table 11-33 Summary of predicted ground-borne noise levels (direct fixation trackform) 11-87

Table 11-34	Proposed trackforms to comply with the ground-borne noise goals	11-88
Table 11-35	Summary of predicted ground-borne noise levels (proposed trackform)	11-89
Table 11-36	Ventilation outlets and station ancillary facilities - maximum acceptable noise emissions	11-93
Table 11-37	Site and issue specific mitigation measures	11-95
Table 11-38	Summary of potential operational noise and vibration impacts and recommended impact management measures	11-102
Table 11-39	Construction noise monitoring	11-104
Table 11-40	Construction vibration monitoring	11-105

11. Noise and vibration

11.1 Introduction

The purpose of this chapter is to assess the potential noise and vibration impacts of the Project and to protect the environmental values of the acoustic environment. It provides an overview of the current acoustic environment and assesses the potential for impacts from the Project during both construction and operation. Strategies to manage potential impacts are also recommended, where required.

This chapter addresses sections 11.8 to 11.12 of the Terms of Reference (ToR).

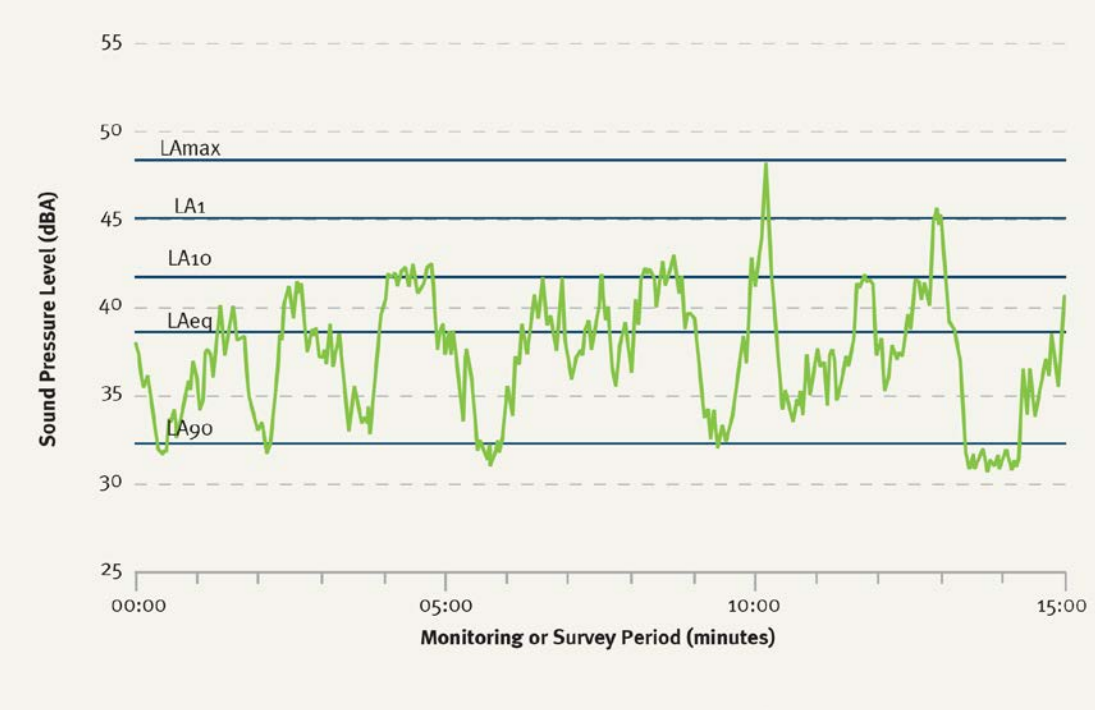
11.1.1 Noise terminology

The terms 'sound' and 'noise' are almost interchangeable, except that in common usage 'noise' is often used to refer to unwanted sound. Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The noise level descriptors that have been utilised within this report are illustrated in **Figure 11-1** and described below.

- L_{Amax} – the maximum A-weighted noise level associated with a sampling period
- L_{A1} – the A-weighted noise level exceeded for 1 per cent of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given period
- L_{A10} – the A-weighted noise level exceeded 10 per cent of a given measurement period and is utilised normally to characterise average maximum noise levels
- L_{Aeq} – the A-weighted average noise level. It is defined as the steady noise level that contains the same amount of acoustical energy as a given time-varying noise over the same measurement period
- L_{A90} – the A-weighted noise level exceeded 90 per cent of a given measurement period and is representative of the average minimum background noise level (in the absence of the source under consideration), or simply the 'background' level.

Figure 11-1 Graphical display of typical noise indices



Examples of typical noise levels are shown in **Table 11-1**.

Table 11-1 Typical noise levels

Sound pressure level (dBA)	Typical source	Subjective evaluation
130 120 110	Threshold of pain Heavy rock concert Grinding on steel	Intolerable Extremely noisy
100 90	Loud car horn at 3 m Construction site with pneumatic hammering	Very noisy
80 70	Kerb side of busy street Loud radio or television	Loud
60 50	Department store General Office	Moderate to Quiet
40 30	Inside private office Inside bedroom	Quiet to Very quiet
20	Unoccupied recording studio	Almost silent

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given location for a particular time of day. A standardised method is available for determining these representative levels. This method produces a level representing the 'average minimum' background (L_{A90}) noise level over the relevant daytime, evening and night-time periods, and is referred to as the Rating Background Level (RBL).

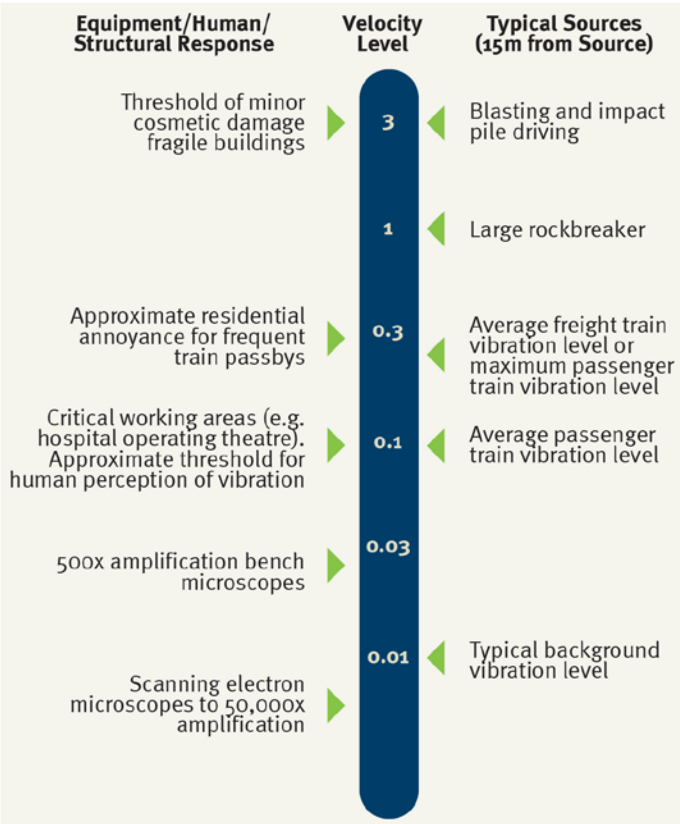
A change of up to 3 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness.

11.1.2 Vibration

Vibration is the term used to describe the oscillating or transient motions in physical bodies. This motion can be described in terms of vibration displacement, vibration velocity or vibration acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of 'peak' velocity or 'rms' velocity. The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as 'peak particle velocity' (PPV). The latter incorporates 'root mean squared' (rms) averaging over some defined time period. The common units for velocity are millimetres per second (mm/s).

As with noise, decibel units can also be used, in which case the reference level should always be stated. Usually, the vibration velocity level is expressed in dBV (ref 10^{-9} m/s). The character of vibration emissions can be continuous, intermittent or impulsive. As for noise, the vibration can be described with the same level descriptors (ie V_{max}, V_1, V_{10}, V_{eq}, V_{90}).

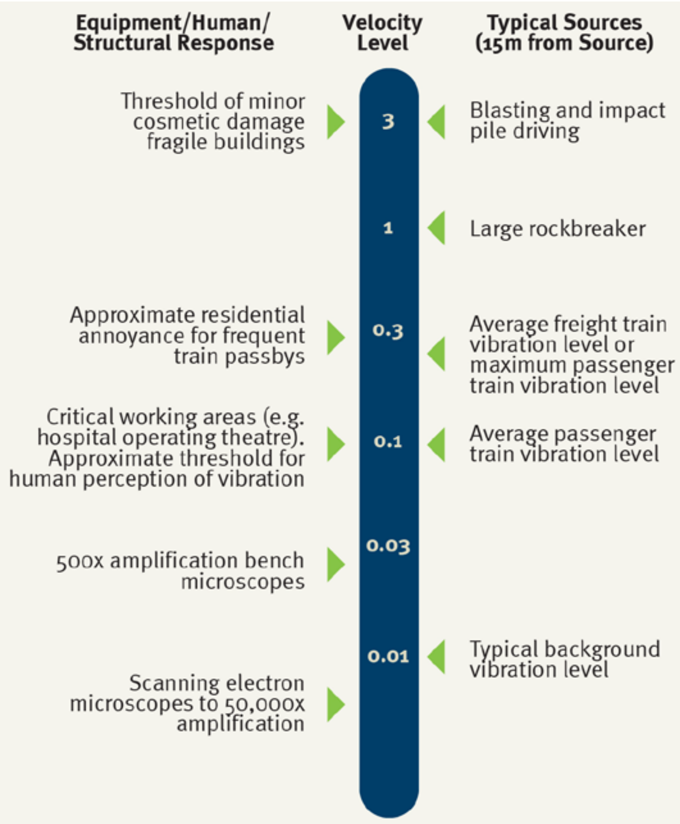
Examples of typical vibration levels associated with surface and underground railway projects together with the approximate sensitivities of buildings, people and precision equipment is provided in Figure 11-2



. The vibration levels are expressed in terms of the vibration velocity (in mm/s).

Vibration and sound are intimately related. Vibrating objects can generate (radiate) sound and, conversely, sound waves (particularly lower frequencies) can also cause objects to vibrate.

Figure 11-2 Typical vibration levels



11.1.3 Ground-borne noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall, ceiling and floor surfaces is termed 'ground-borne noise', 'regenerated noise', or sometimes 'structure-borne noise'. Ground-borne noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne noise include tunnelling construction works, underground railway operation, excavation plant (eg rock breakers), and building services plant (eg fans, compressors and generators).

11.1.4 Methodology

This assessment focusses on activities required for the Project's construction and operation that could result in noise or vibration impacts to sensitive receivers along the study corridor (as defined in **Chapter 1 – Introduction**).

The assessment of potential noise impacts due to the transport of excavated spoil material has considered transport routes outside the study corridor. The study methodology involved:

- a review of literature prepared for current and completed major tunnelling projects in Brisbane including construction methodologies relevant to noise and vibration minimisation
- a review of existing legislation, standards and guidelines as well as Project documents including the Terms of Reference (TOR) released in January 2014 and Initial Advice Statement (IAS) submitted in November 2013
- identification of sensitive locations in relation to construction and operational noise and vibration

- carrying out field studies to characterise the existing noise and vibration environment within the study corridor
- defining noise and vibration goals by which construction and operational noise and vibration impacts at sensitive locations may be evaluated
- describing noise and vibration levels associated with the Project through detailed computer noise modelling
  - the assessment undertaken for this report has been based on the single point calculations at each receiver point.
  - a separate model run was also carried out using a fixed calculation grid with a spacing of 10m to produce noise contours. The resultant contours were interpolated between the grid points
- evaluating the extent of resulting impacts and the scope for the reduction of these impacts through reasonable and feasible mitigation strategies
- recommending mitigation measures and noise and vibration performance requirements in order to protect environmental values and sensitive locations.

11.1.5 Legislative and policy framework

Environment Protection Policy (Noise)

The *Environmental Protection Act 1994* (EP Act) allows the Minister to produce Environmental Protection Policies (EPP), designed to protect environmental aspects in Queensland. The Environmental Protection (Noise) Policy 2008 (EPP (Noise)) has been developed under the EP Act.

The EPP (Noise) defines the values to be protected as the qualities of the acoustic environment that are conducive to:

- protecting the health and biodiversity of ecosystems
- human health and wellbeing, including by ensuring a suitable acoustic environment for individuals to do any of the following:
  - sleep – a person's ability to sleep is perhaps the most important value that can be impacted by noise and/or vibration. Noise and vibration effects on sleep are generally referred to as sleep disturbance
  - education and work – the needs for education and work in relation to the acoustic environment relate to the need to be able to communicate effectively either face-to-face or by telephone, and the ability to think or focus on auditory information without undue intrusion from other sources of noise
  - recreation – recreation is an important aspect of a healthy lifestyle. Recreation may include time spent both indoors and outdoors. In terms of acoustic function, recreation may involve communication with others in verbal conversation or simple enjoyment of an outdoor or indoor soundscape
- protecting the amenity of the community.

Environmental values can also be impacted by vibration. Humans can detect and possibly even be annoyed at vibration levels which are well below those causing any risk of damage to a building or its contents. Vibration can also impact structures, services or building contents over the frequency range typical of vibration from construction and excavation activities and road and rail traffic.

The EPP (Noise) includes long term acoustic quality objectives. It is intended that the acoustic quality objectives be progressively achieved as part of achieving the purpose of the EPP (Noise) policy over the long term. Due to construction noise being short term and not permanent, it would be inappropriate to assess construction noise against the long term acoustic quality objectives. This position is supported in the EPP (Noise). The policy is not applicable for assessing noise mentioned in the *Environmental Protection Act 1994*, Schedule 1, Part 1 which refers to safety and transportation noise.

The acoustic quality objectives are also not considered applicable for assessing the operational noise associated with rail or bus operations for this Project. The acoustic quality objectives would be relevant for assessing the ventilation and mechanical plant noise associated with the new rail and ventilation stations as these will be permanent long term noise sources.

Project specific goals have been developed for construction and are based on a number of recognised, industry standards. These goals also are broadly consistent with the approach taken with previous major transport infrastructure projects in Brisbane in recent years.

An overview of these goals is provided in the following section will further detail in Section 3 of **Technical Report 3 – Construction noise and vibration**.

Noise and vibration goals

Construction noise goals

The noise goals used for the assessment of the Project are presented in **Table 11-2** and have been developed on the basis of the following:

- sleep disturbance criteria contained in the World Health Organisation's Night Noise Guidelines for Europe (2009)
- recommended internal noise levels for various building uses specified in AS/NZS 2107: 2000 Acoustics – Recommended design sound levels and reverberation times for building interiors (AS 2107)
- Queensland Rail's Code of Practice planning levels for the assessment of surface track construction noise
- air-blast overpressure from blasting is recommended not to exceed 132 dB Linear peak, consistent with the cosmetic damage limits from United States Bureau of Mines (USBM) and recent large tunnelling projects in Brisbane
- a threshold of significance of 2 dBA in relation to changes in the noise emission level from roads due to the introduction of construction traffic
- a 'shoulder period' between day-time and night-time (6.30pm-10.00pm) for Monday to Friday, with a balanced transition of the criteria has been developed for the Brisbane CBD and Woolloongabba worksites. The shoulder period goal is proposed due to the elevated evening noise levels in these locations (compared to night-time background noise levels) and the potential benefit of reducing the overall duration of works. Detailed justification for the proposed goal is provided in the addendum to **Technical Report 3 – Construction noise and vibration.**

Noise modelling was undertaken using the ISO 9613:2 industrial noise algorithm as implemented in SoundPLAN acoustic modelling software. The output from the SoundPLAN noise model is a predicted noise level external to the receiver building of interest. In order to compare the relevant internal noise goals with the external predicted noise levels, the internal goals were adjusted (i.e. increased) to an external free-field noise level. The adjustment was determined by the type of facade through which noise transmission would occur.

For this Project, the facade adjustment methodology applied to the assessment takes into consideration the type of receiver buildings present across the study area. In summary:

- for residential type receivers in standard suburban-type dwellings, a +10 dBA inside to outside adjustment for windows partially open (7 dBA in the free-field)
- for residential type receivers in high-rise apartment buildings, such as those in the vicinity of the George Street Station worksite, a +25 dBA inside to outside adjustment for windows closed (22 dBA in the free-field)
- for commercial type receivers, a +25 dBA inside to outside adjustment for single glazed closed windows (22 dBA in the free-field). As discussed above, this is consistent with the findings of the facade noise reduction measurements carried out in the Brisbane CBD.

Table 11-2 Construction noise goals

Construction noise time periods – relevant goals			Blasting air-blast	Surface track worksites Queensland Rail Code of Practice (CoP)	Construction road traffic
Day	**Evening**	**Night**			
Monday to Saturday (6.30am – 6.30pm)	**Monday to Friday (6.30pm-10.00pm)** **CBD and Woolloongabba only**	**Sundays and Public Holidays Monday to Saturday (6.30pm-6.30am)**			
Steady state ($L_{Aeq,adj,15min}$) Maximum Design Level according to AS 2107 **Non-steady state** ($L_{A10,adj,15 min}$) Maximum Design Level according to AS 2107 + 10 dBA	**Steady state** 40 dBA $L_{Aeq,adj(15min)}$ **Non-steady state** 50 dBA $L_{A10,adj(15min)}$	**Continuous** 35 dBA $L_{Aeq,adj(15min)}$ **Intermittent** 42 dBA L_{Amax} **Low Frequency** 25 dBA $L_{pA.LF}$	132 dB Linear Peak	87 dBA LAmax 65 dBA $L_{Aeq,adj(24hour)}$	≤ 2 dBA change in existing $L_{A10(1hour)}$, $L_{A10(12hour)}$ and $L_{A10(18hour)}$

Construction vibration goals

A summary of applicable vibration goals at sensitive receptors associated with the construction phase of the Project is shown in **Table 11-3** and have been developed on the basis of the following:

- for cosmetic damage guide values, BS 7385 from all construction vibration sources including blasting
- for daytime human comfort guide values AS 2670. For the night-time period, vibration guide values based on human perception nominated in AS 2670 and the qualitative perception scale for continuous vibration outlined in German Standard DIN 4150 Part 2-1975
- the vibration guide value for sensitive building contents has been based on the threshold for visible movement of susceptible building contents, which is approximately 0.5 mm/s.

Table 11-3 Construction vibration goals

Receiver type	Cosmetic damage			Human comfort (mm/s PPV)		Sensitive building contents (mm/s PPV)
	Continuous vibration (mm/s PPV)	Transient vibration (mm/s PPV)	Blasting vibration (mm/s PPV)	Day	Night	
Residential	According to BS7385. Reduced by 50% if resonance is present[1].	According to BS7385	50	According to AS2670	0.5	-
Commercial	According to BS7385. Reduced by 50% if resonance is present[1].	According to BS7385	50	According to AS2670	-	0.5
Heritage structures	2		10	-	-	-

Note 1: Or if investigations to detect resonance were not able to be undertaken due to a lack of access

Operational noise and vibration

Surface rail operations

The applicable noise goals for the railway surface track airborne noise emissions are in accordance with Queensland Rail's Code of Practice – Railway Noise Management (Queensland Rail's Code of Practice). Queensland Rail's Code of Practice outlines the operational 'planning levels' applicable to this Project. The Planning Levels are:

- 65 dBA, evaluated as the 24 hour average equivalent continuous A-weighted sound pressure level, $L_{Aeq(24hour)}$.
- 87 dBA, evaluated as a Single Event Maximum sound pressure level.

The planning levels refer to an assessment location one metre in front of the facade of an affected noise sensitive building.

Surface bus and road operations

The applicable noise criteria for the surface busway and road alignments are in accordance with the Department of Transport and Mains Roads (TMR) Transport Noise Management Code of Practice (Code of Practice). Table **11-4** lists the Code of Practice noise goals applicable to this Project.

Table 11-4 Categories and criteria (operations)

Categories	Criteria (dBA)		
	Existing residences (facade corrected)[1,2]	Educations, community and health buildings (facade corrected)[1,2]	Outdoor educational and passive recreational areas (parks) (free-field)[1,2]
Multi-modal corridor			
New road – access controlled	63 L_{A10} (18hour) existing level > 55 L_{A10} (18(hour) 60 L_{A10} (18hour) existing level ≤ 55 L_{A10} (18(hour)	58 L_{A10} (1hour)	63 L_{A10} (12 hour)
Upgrading existing road	68 L_{A10} (18 hour)	65 L_{A10} (1hour)	
Busway			
New busway	55 L_{Aeq} (1hour) day and evening 50 L_{Aeq} (1hour) night 64 L_{Amax} night	55 L_{Aeq} (1hour) operation hours 64 L_{Amax} night	57 L_{Aeq} (1hour) day 66 L_{Amax} day
Upgrading existing busway	60 L_{Aeq} (1hour) day and evening 55 L_{Aeq} (1hour) evening 69 L_{Amax} night	60 L_{Aeq} (1hour) operation hours 69 L_{Amax} night	

Note 1: The criteria levels are façade corrected for building facades, and free-field for outdoor open areas

Note 2: The noise measurement/ calculation/ prediction height shall be 1.5m above Finished Floor Level (FFL) or mid window height, whichever is the higher, for each storey of the building (1.0m in front of most exposed façade). Otherwise, the receptor heights shall be assumed at 1.8m and 4.6m above the building platform level for the ground and first floors respectively. A height of 0.5m below the eaves height is also acceptable. For free-fields, the noise measurement/ calculation/ prediction height shall be 1.5m above the ground level.

Ground-borne vibration (operations)

There are several sources from which relevant vibration criteria may be drawn. These include:

- Australian Standard AS 2670.2: 1990 – Evaluation of Human Exposure to Whole Body Vibration – Part 2: Continuous and Shock Induced Vibration in Buildings (1 Hz to 80 Hz)
- the United States Federal Transit Administration (FTA) guideline – Transit Noise and Vibration Impact Assessment
- British Standard BS 6472-1: 2008 – Guide to Evaluation of Human Exposure to Vibration in Buildings Part 1: Vibration Sources Other Than Blasting
- the NSW Department of Environment, Climate Change and Water (now Environment Protection Authority) document – Assessing Vibration: A Technical Guideline.

The vibration goals have been expressed both in terms of vibration velocity (mm/s) and decibels (dBV re 10-9 m/s). A level of 100 dB corresponds to 0.1 mm/s (rms) and a level of 120 dB corresponds to 1 mm/s (rms).

Based on the above references, the proposed operational vibration goals are listed in **Table 11-5**. For assessment purposes, these goals may be regarded as applicable to the maximum 1 second rms vibration level, not to be exceeded by more than 5 per cent of train passbys.

Table 11-5 Ground-borne vibration goals (operations)

Receiver Type	Period	Vibration goal[1,2] (vibration velocity)
Residential	Day/ night	0.2 mm/s (106 dB_V)
Commercial (including schools and places of worship)	When in use	0.4 mm/s (112 dB_V)
Industrial	When in use	0.8 mm/s (118 dB_V)
Sensitive equipment within medical or research facilities	When in use	0.013 mm/s (82 dB_V) [3]

Note 1: The vibration goals are based on the maximum 1 second rms vibration level, not to be exceeded by more than 5 per cent of train passbys

Note 2: dBV re 10-9 m/s

Note 3: Unless actual equipment manufacturer data are available

In the case of railway tunnels, the ground-borne noise goals, presented below, almost always dictate lower vibration emission levels than the vibration goals indicated in **Table 11-5**. Hence other than at specific facilities with equipment with particularly high sensitivity to vibration, compliance with the ground-borne noise goals ensures that the vibration goals will also be achieved.

Ground-borne noise (operations)

There are no Australian Standards specifically addressing the issue of ground-borne noise from railway operations. Guidance can be obtained, however, from the following International and Australian references:

- International Standard ISO 14837-1:2005(E) Mechanical vibration - Ground-borne Noise and Vibration Arising From Rail Systems - Part 1: General Guidance, First Edition 2005
- American Public Transit Association (APTA), Guidelines for Design of Rapid Transit Facilities, 1991
- Federal Transit Administration (FTA), US Department of Transport, Transit Noise and Vibration Impact Assessment, May 2006
- the Association of Noise Consultants Measurements & Assessment of Groundborne Noise and Vibration, 2001
- Harris Miller Miller and Hanson Inc. Transit Noise and Vibration Impact Assessment, 1995 (a guideline prepared for the United States Department of Transportation)
- NSW EPA Rail Infrastructure Noise Guideline (RING), May 2013.

All the above standards and guidelines are designed specifically to take into account the intermittent and low frequency character of ground-borne noise and the subjective characteristics of underground rail operations as part of the assessment criteria. These guidelines are considered more relevant than the more general (ie not specific to ground-borne noise from underground rail operations) Ecoaccess Draft Guideline Assessment of Low Frequency Noise.

The current version of ISO14837 provides guidance only in relation to the prediction of ground-borne noise levels and factors that need to be considered in the prediction process. Acceptability criteria are currently not included in ISO14837.

Based on the criteria within the above Australian and International standards and guidelines, **Table 11-6** provides a summary of the proposed operational ground-borne noise goals for the Project. These goals form the basis of the impact assessment presented in **section 11.4**.

Table 11-6 Ground-borne noise goals (operations)

Receiver	Time of day	Noise goals (dBA)[1]
Residential	Day (7.00am to 10.00pm)	40 dBA
	Night (10.00pm to 7.00am)	35 dBA
Schools, educational institutions, places of worship[2]	When in use	40 dBA to 45 dBA
Retail areas	When in use	50 dBA to 55 dBA
General office areas	When in use	45 dBA
Private offices and conference rooms	When in use	40 dBA
Theatres	When in use	35 dBA

Note 1: Evaluated as the LAmax 'Slow' response noise level (interpreted as applicable to the 95th percentile train passby event ie typically the highest 1 in 20 event)

Note 2: The lower value of the range is primarily applicable where low internal noise levels are expected, such as in areas assigned to studying, listening, quiet contemplation and praying

Mechanical plant and ventilation

The applicable statutory requirement for noise emissions associated with fixed mechanical plant is the EPP (Noise). The EPP (Noise) nominates long term acoustic quality objectives and background creep criteria applicable to stationary mechanical plant.

In determining the appropriate background creep goals, the EPP (Noise) and Brisbane City Council criteria have been adopted. The proposed noise goals for mechanical plant are presented in **Table 11-7**.

Table 11-7 Operational mechanical plant noise goals

Receiver	Time of day	Background noise creep[1] dBA L_{A90} (1hour)	Acoustic quality objectives[2] dBA L_{Aeq} (1hour)
Residential (for outdoors)	7.00am to 10.00pm	b/g + 0[3]	50[3]
	10.00pm to 7.00am	b/g + 0	-
Residential (for indoors)	7.00am to 10.00pm	-	35
	10.00pm to 7.00am	-	30
Library and educational institution (including a school, college and university) (for indoors)	when open for business or when classes are being offered	-	35
Commercial and retail activity (for indoors)	when the activity is open for business	-	45

Note 1: Background creep criteria in accordance with the EPP (Noise) and BCC NIAPSP for continuous noise sources, adopting the Rating Background Level in accordance with the DERM Ecoaccess PNC. Applicable for noise contribution from the source only

Note 2: Long term acoustic quality objectives according to EPP (Noise)

Note 3: The lower of the background creep L_{A90} (1hour) and Acoustic Quality Objectives L_{Aeq} (1hour) is applicable

11.2 Existing environment

11.2.1 Noise

Ambient noise monitoring was conducted at 18 residential and special use (ie educational or medical) locations providing good spatial coverage of the study corridor. The data for 11 of these locations was taken from a previous project where monitoring was conducted in May 2010. These locations were considered representative of the current acoustic environment within the study corridor.

Noise measurements were also conducted between March and May 2014, at an additional seven locations. The measured noise levels from both 2010 and 2014 have been used to determine project noise goals. An overview of the selected monitoring locations is shown in **Figure 11-3**.

All noise measurement equipment used complied with the requirements of all applicable Australian Standards. For every measurement period and at each location, there was no drift in equipment calibration signal beyond that allowed by Australian Standards (ie 94 ± 0.5 dB(A)) for any equipment used.

The unattended ambient noise measurements were used to determine the rating background levels (RBL) for the daytime (7.00am to 6.00pm), evening (6.00pm to 10.00pm) and night-time (10.00pm to 7.00am) periods at each location. Table **11-8** contains the determined RBL for each measurement location.

Figure 11-3 Overview of noise monitoring locations

Table 11-8 Measured rating background levels

Monitoring location		Rating background levels (RBL), L_{A90} (dBA)		
		Day	Evening	Night
1	St Joseph's College	50	48	40
2	Brisbane Girls Grammar	61	60	46
3	St Andrew's War Memorial Hospital	55	53	51
4	Parkland Crescent	54	50	47
5	191 George Street	58	57	54
6	40 George Street, The Mansions	59	55	51
7	Queensland University of Technology (QUT) Gardens Point	49	48	46
8	58 Leopard Street	53	50	46
9	803 Stanley Street [1]	58	57	51
10	143 Park Road	43	39	34
11	Dutton Park State School	44	40	35
12	26 Elliot Street	46	44	40
13	68 Railway Terrace, Leukaemia Foundation ESA Village (ESA Village)	47	45	41
14	19 Dutton Street	43	42	37
15	Princess Alexandra Hospital (PA Hospital)	54	54	53
16	4 Fenton Street	39	38	34
17	Parkland Boulevard (Level 3 conference meeting room, Building 3)[2]	RBL: 53 (30) L_{Aeq}: 61 (37)	RBL: 50 (27) L_{Aeq}: 58 (35)	RBL: 44 (<24)[3] L_{Aeq}: 55 (31)
18	21 Mary Street (Level 27 unit 1)[2]	RBL: 56 (33 – Living room) L_{Aeq}: 58 (34)	RBL: 55 (-)[4] L_{Aeq}: 56 (-)[4]	RBL: 53 (27 - Bedroom) L_{Aeq}: 56 (30)

Note 1: RBL based on only one (1) full day of data due to logger malfunction and access restrictions

Note 2: Levels in brackets were measured inside the building

Note 3: Actual noise level was below the instrument noise floor of 24 dBA

Note 4: Evening period data not available due to logger malfunction at 21 Mary Street

Attended noise measurements were also conducted at each site to confirm background noise levels and to observe typical noise sources associated with the ambient noise environment during the daytime, evening and night-time periods. The attended ambient noise measurements were conducted for one 15 minute period during each of the daytime (7.00am to 6.00pm), evening (6.00pm to 10.00pm) and night-time (10.00pm to 7.00am) periods at each location (ie three 15 minute attended measurements were taken at each location).

The detailed results of these measurements are provided in **Technical Report 3 – Construction noise and vibration**.

The attended measurements and observations identified that railway noise or road traffic noise is dominant at the majority of monitoring locations during daytime and evenings. The night-time period was dominated by road traffic noise at most locations, though it was mostly a distant traffic noise.

11.2.2 Vibration

Existing vibration levels along the study corridor were measured to compare with future vibration levels with the Project in operation. The data for eight of these locations was taken from a previous project where monitoring was conducted in May 2010. These locations were considered representative of the Project. Supplementary vibration measurements have been undertaken during 2014 at an additional two locations.

Vibration monitoring locations were selected to be representative of residential areas as well as special receivers (ie educational/research or health care facilities) along the study corridor, that could be affected by the Project. An overview of the selected vibration monitoring locations is shown in **Figure 11-4**. The details of the selected vibration monitoring locations are summarised in **Appendix C** of the **Technical Report 3 – Construction noise and vibration**.

The unattended ambient vibration measurements were used to determine the average minimum background level (V_{90}), average maximum level (V_{10}) and maximum level (V_1) for the daytime (7.00am to 6.00pm), evening (6.00pm to 10.00pm) and night-time (10.00pm to 7.00am) periods at each location. **Table 11-9**contains the measured vibration levels for each location.

Table 11-9 Measured ambient vibration

Monitoring location[1]		Average minimum background vibration V_{90} (mm/s) [2]			Average maximum vibration V_{10} (mm/s) [3]			Maximum vibration V_1 (mm/s) [4]		
		Day	Evening	Night	Day	Evening	Night	Day	Evening	Night
1	Brisbane Girls Grammar	0.04	0.04	0.04	0.05	0.05	0.05	0.08	0.05	0.05
2	St Andrew's War Memorial Hospital	0.03	0.03	0.02	0.08	0.05	0.04	0.17	0.08	0.06
3	3 Parkland Crescent	0.04	0.04	0.03	0.06	0.05	0.04	0.07	0.07	0.06
4	40 George Street (the Mansions)	0.08	-	-	0.09	-	-	0.10	-	-
5	QUT	0.02	-	-	0.02	-	-	0.03	-	-
6	58 Leopard Street	0.01	0.01	0.01	0.04	0.14	0.02	0.16	0.57	0.16
7	46 Ross Street	0.04	0.04	0.04	0.06	0.10	0.05	0.19	0.49	0.10
8	19 Dutton Street	0.03	0.03	0.03	0.04	0.04	0.03	0.31	0.04	0.04
9	PA Hospital	0.13	0.11	0.11	0.79	0.53	0.13	2.50	1.53	0.36
10	4 Fenton Street	0.04	0.06	0.04	0.70	0.84	0.23	2.69	1.61	0.71

Note 1: All monitoring locations are residential excluding locations 2 to 5

Note 2: The V_{90} is the vibration velocity exceeded 90% of a given measurement period and is representative of the average minimum background vibration

Note 3: The V10 is the vibration velocity exceeded 10% of a given measurement period and is utilised normally to characterise average maximum vibration.

*Note 4: The V1 is the vibration velocity exceeded for 1% of a given measurement period. This parameter is sometimes used to represent the maximum vibration in a given period. The absolute maximum peak particle velocity is higher than this V1 as can be seen in **Technical Report 4 – Operational noise and vibration**.*

Figure 11-4 Overview of vibration monitoring locations

The background vibration level (V_{90}) for all sites varies between 0.01 mm/s to 0.13 mm/s during daytime and evening. During the night-time, the background vibration level (V_{90}) varies between 0.01 mm/s to 0.11 mm/s. Maximum vibration levels (V_1) for the residential monitoring locations were in the range of 0.11 mm/s to 2.69 mm/s during daytime and evening. During night-time, vibration levels (V_1) of 0.04 mm/s to 0.71 mm/s were measured. The average maximum levels (V_{10}) for the residential monitoring locations ranged 0.04 mm/s to 0.84 mm/s during daytime and evening.

It can be noted that high vibration levels have been monitored at residential locations 6, 7 and 10, which are on floors in residential dwellings. This shows that normal activities (ie closing doors, drawers and cupboards, walking, moving and sitting on furniture etc) in these residential dwellings generated vibration levels above the vibration goals presented in **section 11.1.5**.

For receivers with vibration sensitive equipment; locations 3 (St Andrew's War Memorial Hospital), monitoring was conducted at location 5 (Queensland University of Technology (QUT)) and location 9 Princess Alexandra Hospital (PA Hospital). Background vibration levels measured at those sites ranged from (V_{90}) 0.02 mm/s to 0.06 mm/s and maximum vibration levels (V_1) of 0.03 mm/s to 2.50 mm/s. It can be noted that the monitoring location just outside the MRI room at the PA Hospital registered significantly higher vibration levels than at QUT and St Andrew's War Memorial Hospital.

11.3 Impact assessment

11.3.1 Construction activities

At each of the worksites, a range of activities will be undertaken that may result in noise or vibration. The range of activities that are expected to be representative of typical noise emissions during the Project include:

- demolition of existing buildings, site establishment including spoil handling facilities
- installation of perimeter retaining walls using piling or precast concrete segments
- excavation using excavators, rock breakers, drill and blast techniques, and other construction plant
- spoil removal by heavy vehicle
- tunnel boring machines (TBM) assembly and associated facilities for tunnel construction
- TBM retrieval and disassembly
- tunnel fit out including railway and busway systems
- station construction, fitout and commissioning.

Not all activities will occur at each site and specific scenarios have been developed to produce noise modelling representative of the key proposed activities for each site.

For each of the construction scenarios presented in the assessment of construction, there is also presented an indicative duration, mostly expressed in months. These are approximations only and are based on the reference project and the construction method adopted for the purposes of assessment to inform this EIS. Should government decide to proceed with the Project, there is a high probability that the procurement process would result in a different or varied construction method, involving different timeframes and different impacts. In that situation, the Proponent would likely refer the changes to the Coordinator-General for further assessment.

A range of mitigation options have also been considered and range from 3m to 6m hoarding, up to acoustic enclosures of low, medium or high performance. Greater detail on the performance requirements of each mitigation option is provided in **Technical Report 3 - Construction noise and vibration.**

Southern Connection

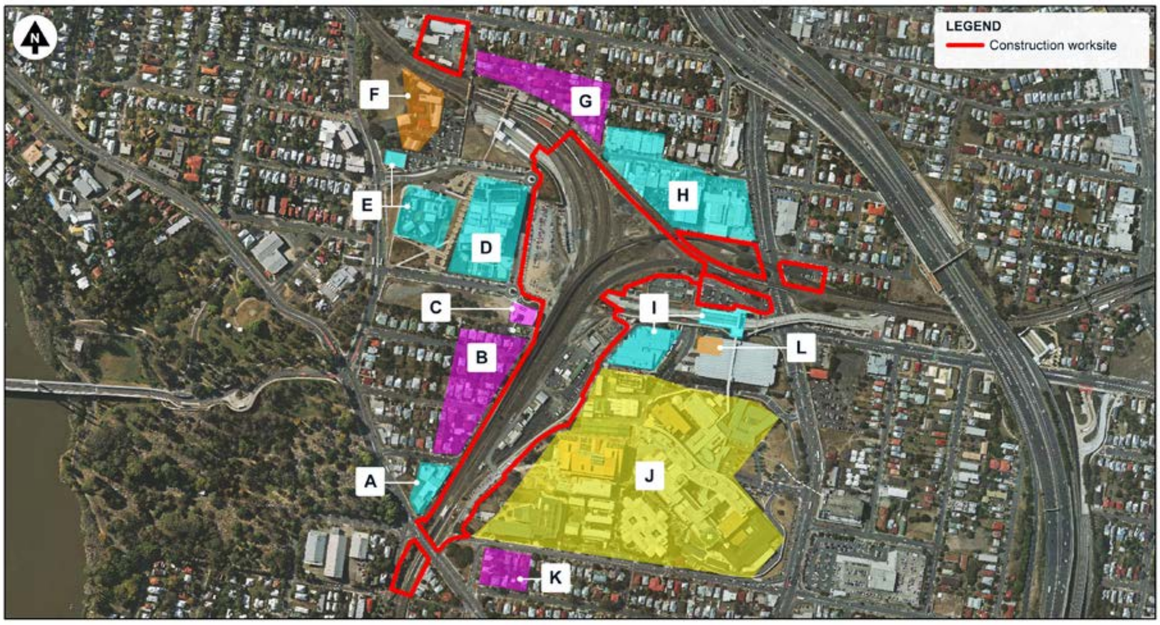
Nearest sensitive receivers

The nearest noise and vibration sensitive receivers to the Southern Connection worksite are identified in **Table 11-10** with the receiver areas illustrated in **Figure 11-5**.

Table 11-10 Nearest sensitive receivers – Southern Connection

Worksite/ excavation	Receiver area	Distance to worksite boundary
Southern Connection	A – Railway Terrace Commercial	10m
	B – Railway Terrace (Pound Street to Rawnsley Street)	14m
	C – ESA Village	<10m
	D – Ecosciences Building	20m
	E – Police Station and Gaol	145m
	F – Dutton Park Primary School	130m
	G – Merton Road to Elliott Street Residential	20m
	H – Burke Street Commercial	12m
	I – MLS and PA Busway Station	10m
	J – PA Hospital	20m
	K – Rusk Street and Cornwall Street Residential	75m
	L – PA Early Education Centre	55m

Figure 11-5 Southern Connection receiver areas



Note: for the construction site and receiver plans, the following colour codes have been used throughout this Chapter:

- *Pink: Residential;*
- *Light blue: Commercial*
- *Yellow: Hospital*
- *Orange: Educational*

Construction scenarios

Construction scenarios were developed for the Southern Connection worksite to enable modelling to be representative of the expected 'worst case' noise emissions. These scenarios are:

- Scenario 1 – site establishment and removal of existing railway infrastructure:
  - duration ~ 3 months
  - dominant noise sources include rock breakers, excavators and spoil trucks
  - daytime construction only.
- Scenario 2 – pile installation along cut and cover tunnel sections, excavation of the TBM launch shaft and excavation of the pipe jacking retrieval shaft adjacent to Quarry Street:
  - duration ~ 4 months
  - dominant noise sources include piling rigs, rock breakers and spoil trucks
  - mostly daytime construction and potentially weekend work during railway track possessions.
- Scenario 3 – night-time pipe jacking activities:
  - duration ~ 3 months
  - dominant noise sources include bentonite plant, generator, front end loader and cranes
  - pipe jacking construction activities required 24 hour per day, 7 days per week.
- Scenario 4 - TBM assembly and acoustic shed construction:
  - duration ~ 3 months
  - dominant noise sources include delivery trucks, cranes and front end loaders.
  - daytime activities
- Scenario 5 – night-time TBM operations including spoil loading inside the acoustic shed and spoil removal from site by haul trucks:
  - duration ~ 17 months
  - dominant noise sources include spoil trucks entering and leaving the acoustic shed on the southern side of the railway corridor
  - 24 hour per day movements through the site.
- Scenario 6 – night-time TBM operations based on steady state noise sources inside the acoustic shed (eg tunnel ventilation and conveyor system noise):
  - duration ~ 17 months
  - dominant noise sources include the spoil conveyor to the load-out hopper and tunnel ventilation fans
  - 24 hour per day activities.

For the above scenarios, typical worst case construction noise levels have been predicted at the nearest noise sensitive receivers. Possible noise goal exceedances associated with the predicted construction noise levels are presented in **Table 11-11** for Scenarios 1 to 3 and **Table 11-12** for Scenarios 4 to 6. Predicted ground-borne noise and vibration levels from the Southern Connection worksite are presented in Table 11-13. All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building. Since the excavation activity will be moving around the worksite, the levels modelled are conservative.

Typical levels would be expected to be lower than those predicted over the duration of each scenario. A ‘dash’ (-) in the tables indicates compliance, and ‘n/a’ not applicable for the assessment period.

Airborne noise impacts

Based on anticipated worst case construction noise levels with either 3m acoustic hoarding surrounding the site or existing railway noise barriers, the following is noted:

- For site establishment works, including demolition of existing structures within the rail corridor, exceedances of up to 8 dBA of the daytime noise goal are predicted for the nearest residential receivers adjacent to Railway Terrace and Merton Street to Elliott Street.
- A similar exceedance of the noise goal is anticipated during the operation of piling rigs at the cut and cover areas and excavation of the TBM launch shaft. The notable exceedance during Scenario 2 is associated with excavation of the pipe jacking retrieval shaft adjacent to Quarry Road. With 3m acoustic hoarding around these works, the daytime noise goal is predicted to be exceeded by up to 16 dBA during operation of a rock breaker. It should be noted that noise emission levels associated with the shaft excavation would decrease significantly as the shaft progresses downwards. Notwithstanding this, it is recommended that excavation of the pipe jacking retrieval shaft be carried out during the daytime period only.
- Predicted noise emission levels associated with night-time pipe jacking activities (ie operation of the slurry separation unit, centrifuge, jacks, generator etc) comply with the night-time noise goals for steady state noise sources at all noise sensitive receiver locations.
- A marginal 1 dBA exceedance of the daytime noise goal is predicted for the residential receivers adjacent to Railway Terrace during the assembly stage of the TBM.
- Predicted noise emission levels based on night-time spoil removal during TBM operation indicate an exceedance of the night-time noise goal (for intermittent noise sources) of up to 6 dBA at Railway Terrace. The predicted noise goal exceedance is attributed to spoil truck movements within the site. Potential mitigation measures to minimise night-time spoil truck impacts to nearby residential receivers would include:
    - erecting a noise barrier (approximately 3m to 4m high) along the north-west side of the onsite spoil route adjacent to the rail track
    - increasing the height of the existing rail noise barrier along Railway Terrace (height and extent of upgrade to be confirmed during detailed design)
    - consideration for noise emissions when selecting and procuring spoil truck fleet.
- The assessment of steady state noise sources associated with long-term construction activities within the spoil load out facility indicated compliance with the night-time noise goal for all sensitive receivers with the provision of a ventilated low performance acoustic shed.

With appropriate noise mitigation measures in place, combined with careful management of all heavy vehicle movements on the site, airborne noise impacts can be managed to an acceptable level during the construction phase of the Southern Connection.

Noise mapping for each modelled scenario (with nominated noise mitigation) is shown in **Figure 11-6** to **Figure 11-11**.

Table 11-11 Southern Connection predicted construction noise goal exceedances (scenarios 1 to 3)

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)					
			Scenario 1 – Site establishment		Scenario 2 – Cut and cover and shafts		Scenario 3 – Night-time pipe jacking	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding
A – Railway Terrace commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	n/a	n/a
B – Railway Terrace residential	Day	$L_{A10,adj}$ 57	**8**	**3**	**9**	**4**	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	n/a	n/a	n/a	n/a
	Night	$L_{Aeq,adj}$ 42	n/a	n/a	n/a	n/a	n/a	n/a
C – ESA Village residential	Day	$L_{A10,adj}$ 72	-	-	**2**	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a
	Night	$L_{Aeq,adj}$ 57	n/a	n/a	n/a	n/a	-	-
D – Ecosciences building	Day	$L_{A10,adj}$ 77	-	-	-	-	n/a	n/a
E – Police Station and Gaol,	Day	$L_{A10,adj}$ 72	-	-	-	-	n/a	n/a
F – Dutton Park School	Day	$L_{A10,adj}$ 62	-	-	-	-	n/a	n/a
G – Merton Road to Elliott Street	Day	$L_{A10,adj}$ 57	**4**	-	**16**	**11**	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	n/a	n/a	n/a	n/a
	Night	$L_{Aeq,adj}$ 42	n/a	n/a	n/a	n/a	-	-
H - Burke Street commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	n/a	n/a
I – MLS and Busway	Day	$L_{A10,adj}$ 77	-	-	-	-	n/a	n/a
J – PA Hospital	Day	$L_{A10,adj}$ 72	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a
	Night	$L_{Aeq,adj}$ 57	n/a	n/a	n/a	n/a	-	-

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)					
			Scenario 1 – Site establishment		Scenario 2 – Cut and cover and shafts		Scenario 3 – Night-time pipe jacking	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding
K – Rusk Street and Cornwall Street residential	Day	LA10,adj 57	-	-	-	-	n/a	n/a
	Night	LAmax 49	n/a	n/a	n/a	n/a	n/a	n/a
	Night	LAeq,adj 42	n/a	n/a	n/a	n/a	-	-
L – PA child care centre	Day	LA10,adj 62	-	-	-	-	n/a	n/a

Note: Exceedances shown in bold.

Table 11-12 Southern Connection predicted construction noise goal exceedances (scenarios 4 to 6)

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)					
			Scenario 4 – TBM setup		Scenario 5 – night TBM spoil (non-steady)		Scenario 6 – night TBM spoil (steady)	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding
A – Railway Terrace commercial	Day	LA10,adj 77	-	-	n/a	n/a	n/a	n/a
B – Railway Terrace residential	Day	LA10,adj 57	**1**	-	n/a	n/a	n/a	n/a
	Night	LAmax 49	n/a	n/a	**6**	**3**	n/a	n/a
	Night	LAeq,adj 42	n/a	n/a	n/a	n/a	**4**	-
C – ESA Village residential	Day	LA10,adj 72	-	-	n/a	n/a	n/a	n/a
	Night	LAmax 64	n/a	n/a	-	-	n/a	n/a
	Night	LAeq,adj 57	n/a	n/a	n/a	n/a	-	-
D – Ecosciences building	Day	LA10,adj 77	-	-	n/a	n/a	n/a	n/a
E – Police Station and Gaol,	Day	LA10,adj 72	-	-	n/a	n/a	n/a	n/a
F – Dutton Park School	Day	LA10,adj 62	-	-	n/a	n/a	n/a	n/a

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)					
			Scenario 4 – TBM setup		Scenario 5 – night TBM spoil (non-steady)		Scenario 6 – night TBM spoil (steady)	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding
G – Merton Road to Elliott Street	Day	$L_{A10,adj}$ 57	-	-	n/a	n/a	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	**1**	-	n/a	n/a
	Night	$L_{Aeq,adj}$ 42	n/a	n/a	n/a	n/a	**7**	-
H – Burke Street commercial	Day	$L_{A10,adj}$ 77	-	-	n/a	n/a	n/a	n/a
I – MLS & Busway	Day	$L_{A10,adj}$ 77	-	-	n/a	n/a	n/a	n/a
J – PA Hospital	Day	$L_{A10,adj}$ 72	-	-	n/a	n/a	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	**1**	-	n/a	n/a
	Night	$L_{Aeq,adj}$ 57	n/a	n/a	n/a	n/a	-	-
K – Rusk Street and Cornwall Street residential	Day	$L_{A10,adj}$ 57	-	-	n/a	n/a	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	-	-	n/a	n/a
	Night	$L_{Aeq,adj}$ 42	n/a	n/a	n/a	n/a	-	-
L – PA child care centre	Day	$L_{A10,adj}$ 62	-	-	n/a	n/a	n/a	n/a

*Note: Exceedances shown in **bold**.*

Table 11-13 Southern Connection predicted ground-borne noise and vibration levels – TBM launch shaft excavation, pipe jacking and cut and cover excavation

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)	
		Vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rock breaking[3]	Pipe jacking (micro TBM)	Rock breaking[3]	Pipe jacking (micro TBM)
			Continuous[1]	Intermittent[2]				
A – Railway Terrace commercial	Day	10	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.02	<0.01	24	<25
B – Railway Terrace residential	Day	10	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.27	<0.01	45	<25
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.27	<0.01	**50 (8)**[6]	<25

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)	
		Vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rock breaking[3]	Pipe jacking (micro TBM)	Rock breaking[3]	Pipe jacking (micro TBM)
			Continuous[1]	Intermittent[2]				
C – ESA Village residential	Day	25	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.49	<0.01	**52 (2)**[6]	<25
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.49	<0.01	**57 (15)**[6]	<25
D – Ecosciences commercial	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.29	0.06	50	<25
D – Ecosciences TEM	24/7	0.02	n/a	n/a	**0.05 (0.03)**[6]	<0.01	n/a	n/a
G – Merton Road to Elliott Street residential	Day	10	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	2.7	0.17[5]	37 [4]	35[5]
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.06	0.17[5]	42	35[5]
H – Burke Street commercial	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.05	0.03	37	<25
I – MLS and PA Busway Station commercial	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.07	<0.01	39	<25
J – PA Hospital	Day	25	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.06	<0.01	37	<25
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.06	<0.01	42	<25

Note 1: Dominant construction noise during pipe jacking likely to be steady state and continuous. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2: Dominant construction noise during cut and cover tunnel excavation (ie rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameter is most relevant.

Note 3: Assessment assumes that the cut and cover sections of the Down and Up track tunnels would be top down constructed (i.e. carried out below a ground slab).

Note 4: Predicted from the cut and cover tunnel excavation site as the TBM launch shaft and pipe jacking retrieval pit will be open and therefore airborne noise from rockbreaking at these locations would be more significant than ground-borne noise.

Note 5: Worst case ground-borne vibration and noise levels predicted at the nearest residential receiver on Quarry Street based on the final stages of each pipe jacking drive (i.e. just before reaching the retrieval shaft). All other residential receivers on Merton Road to Elliott Street will experience significantly lower levels.

Note 6: Exceedances of noise or vibration goal shown in ( ).

Ground-borne noise and vibration impacts

The ground-borne noise levels for rock breaking under the existing rail tracks between the TBM launch shaft site and the tunnel portal indicate an exceedance of the night-time noise goal for the ESA Village (by up to 15 dBA) and the nearest Railway Terrace residential receivers (by up to 8 dBA). A marginal 2 dBA exceedance of the daytime noise goal has also been predicted for the ESA Village. The minimum offset distance between the rock breaker and receiver building required to achieve compliance with the night-time ground-borne noise goal and the length of tunnel predicted to exceed the ground-borne noise goal have been calculated as follows:

- ESA Village night-time (42 dBA L_{Amax}): 95m from the building and 125m of cut and cover tunnel predicted to exceed the night-time ground-borne noise goal
- Railway Terrace night-time (42dBA L_{Amax}): 95m from the receiver building and 60m of cut and cover tunnel predicted to exceed the night-time ground-borne noise goal.

On the basis of the predicted exceedances of the night-time ground-borne noise goal, it is recommended that rock breaking of the cut and cover sections of tunnel within the exceedance ranges listed above be carried out only during the daytime period, where alternative mitigation (eg quietest economically feasible equipment, ripping and temporary relocation) are ineffective.

The predicted ground-borne noise and vibration from the proposed ‘pipe jacking’ (micro TBM) complies with the ground-borne noise and vibration goals at all sensitive receivers.

A detailed investigation of the Ecosciences TEM vibration isolation system has not been carried out for the Project. Based on the predicted marginal exceedance of the TEM criterion during rock breaking and roadheading, it is anticipated that an effective vibration isolation system would prevent interference to the operation of the TEM. It is recommended that the performance of the Ecosciences TEM vibration isolation system be checked prior to commencement of vibration intensive construction works at the TBM launch shaft site. If this system is found to be inadequate and the findings of vibration trials confirm the need to mitigate vibration interference to the TEM, then further investigations are recommended to develop an effective mitigation strategy. This strategy may involve (but not be limited to) upgrading the TEM vibration isolation system or scheduling of rock breaking at times when the TEM is not used.

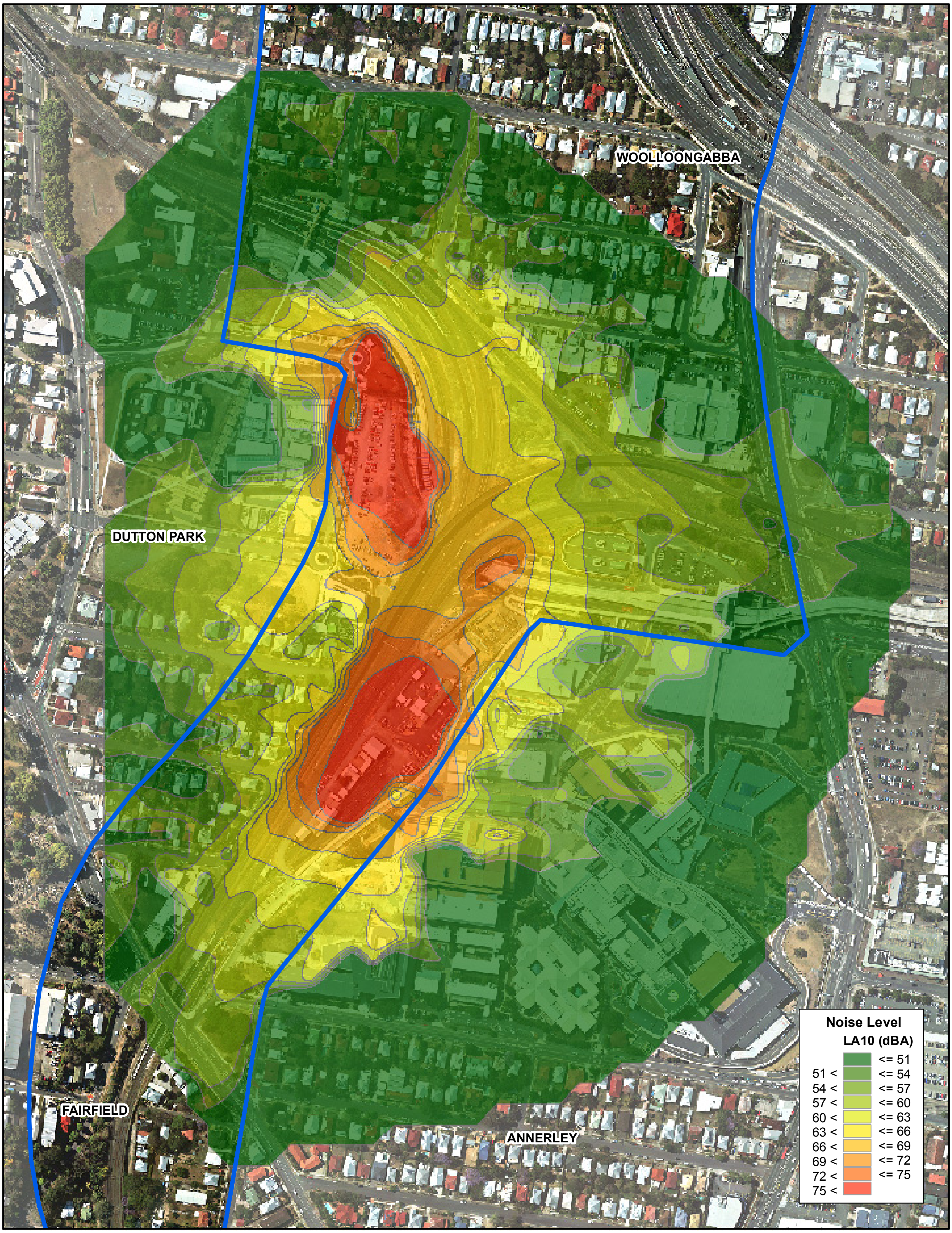
All predicted daytime construction vibration levels are well below the guide values, judged to result in a minimal risk of cosmetic damage, as provided in BS 7385 for buildings surrounding the worksites.

The Translational Research Institute (TRI) laboratory located within the PA Hospital grounds off Kent Street includes a basement rodent holding facility. Medical and specialist research facilities holding rodents are sensitive to noise and vibration, however specific industry guidelines are limited. Following a review of the literature, the following criteria are likely to be acceptable:

- noise levels of L_{AmaxF} 55dB during construction
- floor vibration levels of 0.1 mm/s or less when measured as a peak vector sum over a minimum 1 second period, in accordance with ISO 2631 series or other recognised Australian equivalent standard.

At the TRI facility, ground-borne construction noise emissions from the Project are predicted to be L_{AmaxF} 42 dBA or less, which is well below the above-mentioned noise criteria limits. Construction vibration from the Project is estimated (at 0.06 mm/s) to be below the above criteria. Additionally, it is noted that noise levels experienced by the rodents within TRI facility are, and will continue to be, typically higher than the above values during normal activities. Such activities include door closing/slamming, normal speech, spray hoses (cleaning and maintenance), bench activities, cage feedstocking, cage ventilation systems and radios/ public address systems.

Higher vibration levels experienced by the rodents may also arise from general footfall/ walking, doorstrikes and manual handling of cages, feedstock and heavy items within the building floorplate. On this basis, it is expected noise and vibration emissions from the Project would not impact the rodent holding facilities.



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-6

Southern Connection Scenario 1 - Daytime site establishment and removal of existing railway infrastructure

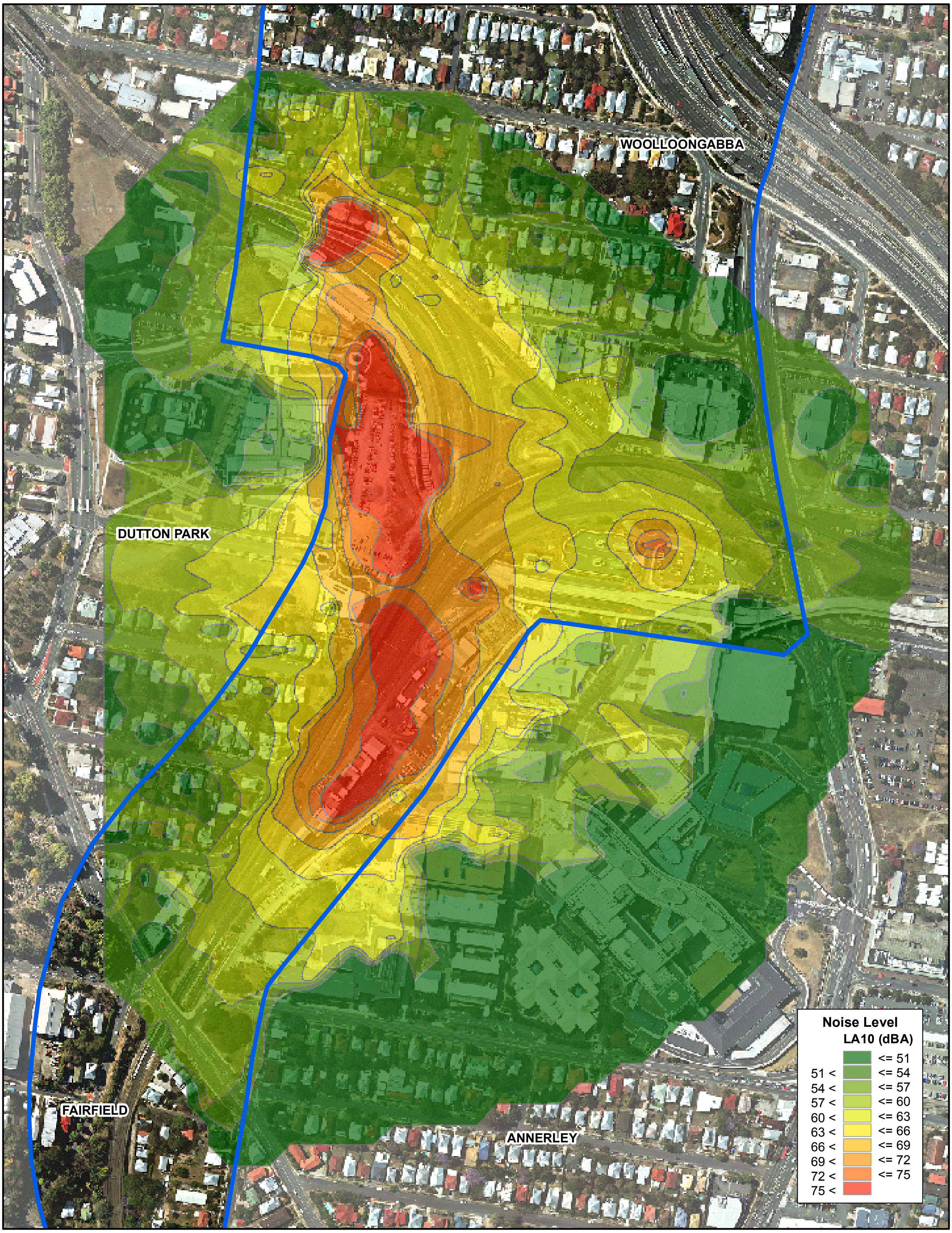
N

0 0.05 0.1
Kilometres
1:5,000 (at A4)

Aerial Photo: Brisbane City Council 2012

Projection: GDA 1994 MGA56

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-6_SouthConnection_Scenario1.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-7

Southern Connection Scenario 2 - Daytime piling and excavation of the TBM launch shaft and pipe jacking shaft

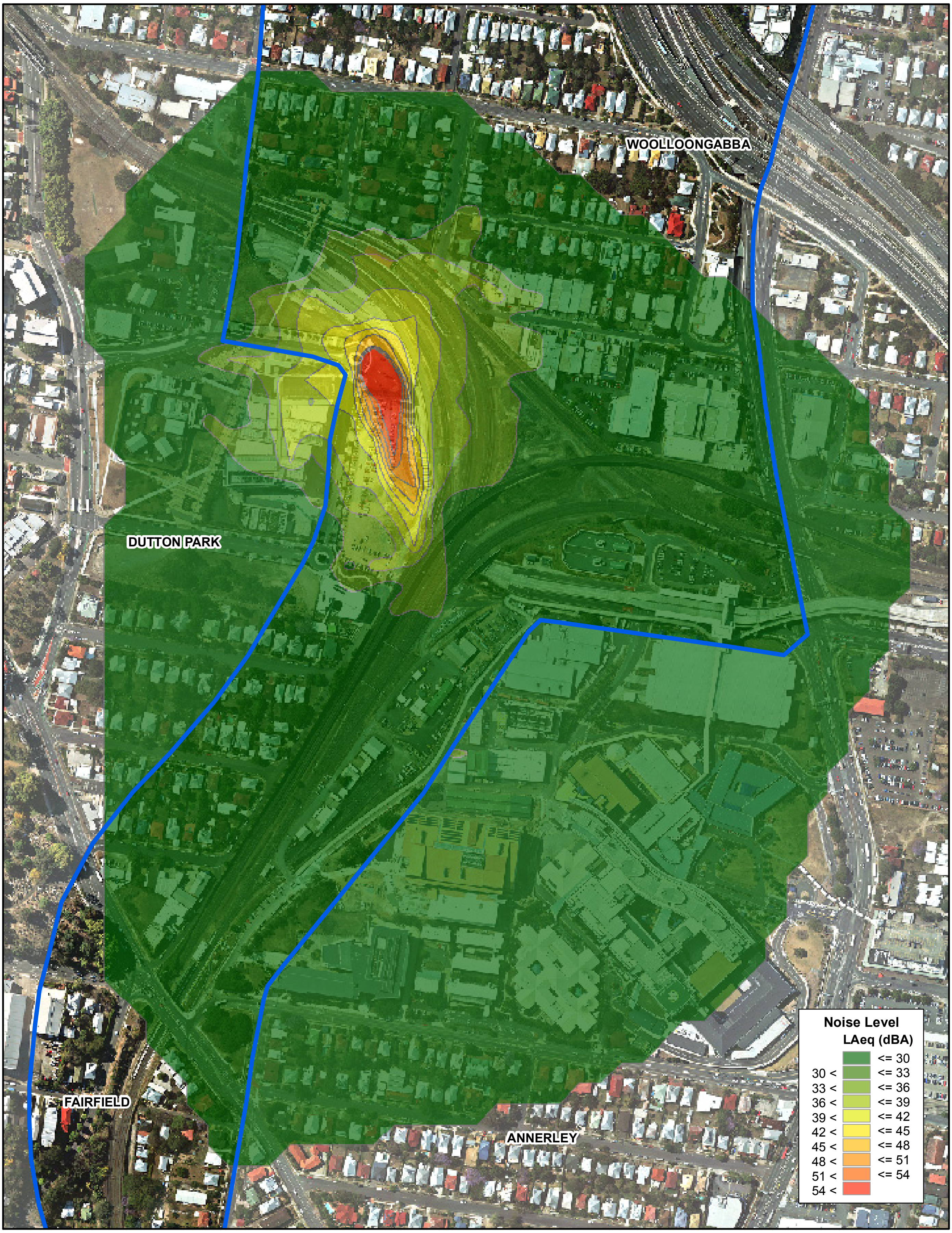
N

0 0.05 0.1
Kilometres
1:5,000 (at A4)

Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-7_SouthConnection_Scenario2_v2.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-8

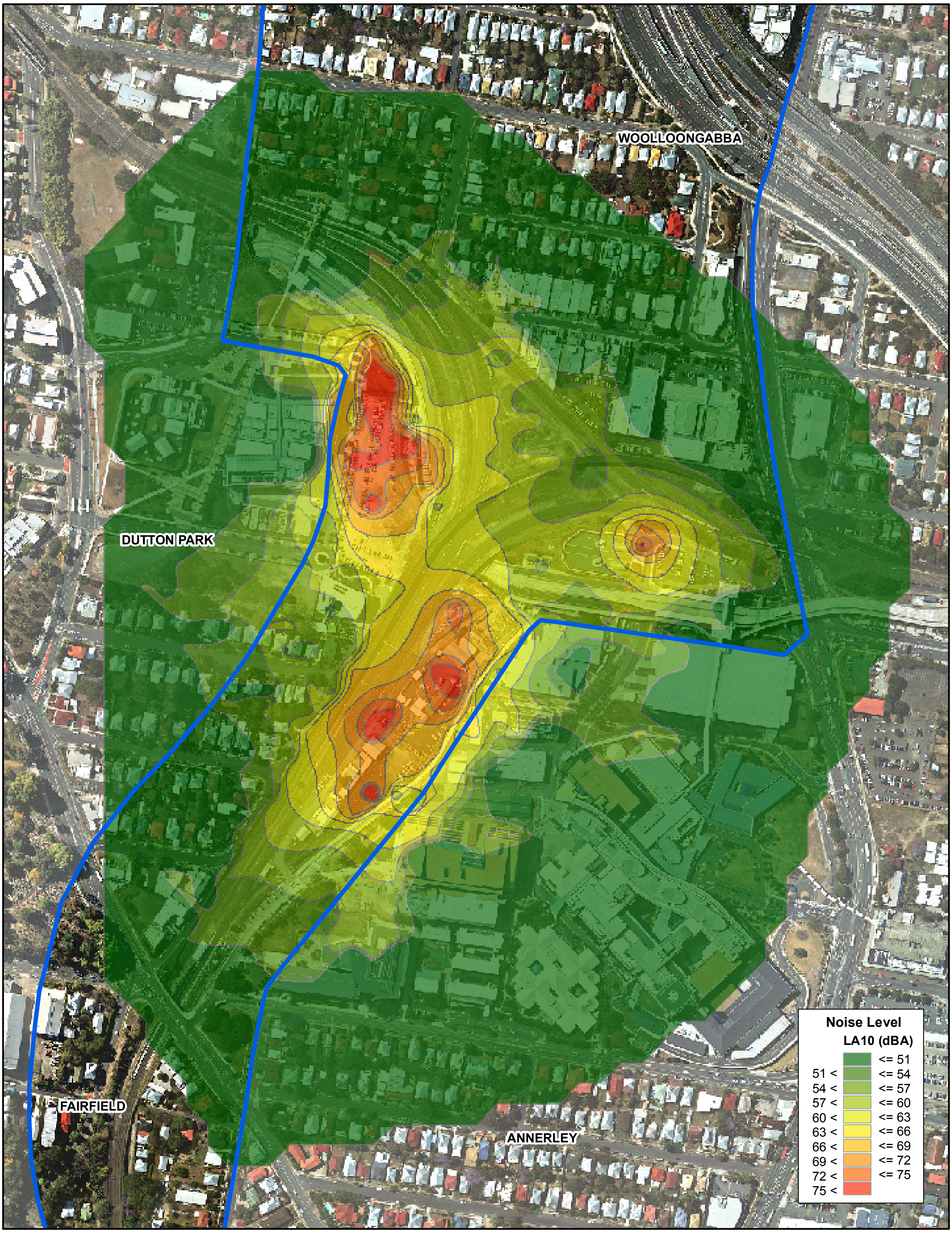
Southern Connection Scenario 3 - Night-time pipe jacking

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-8_SouthConnection_Scenario3_v2.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-9

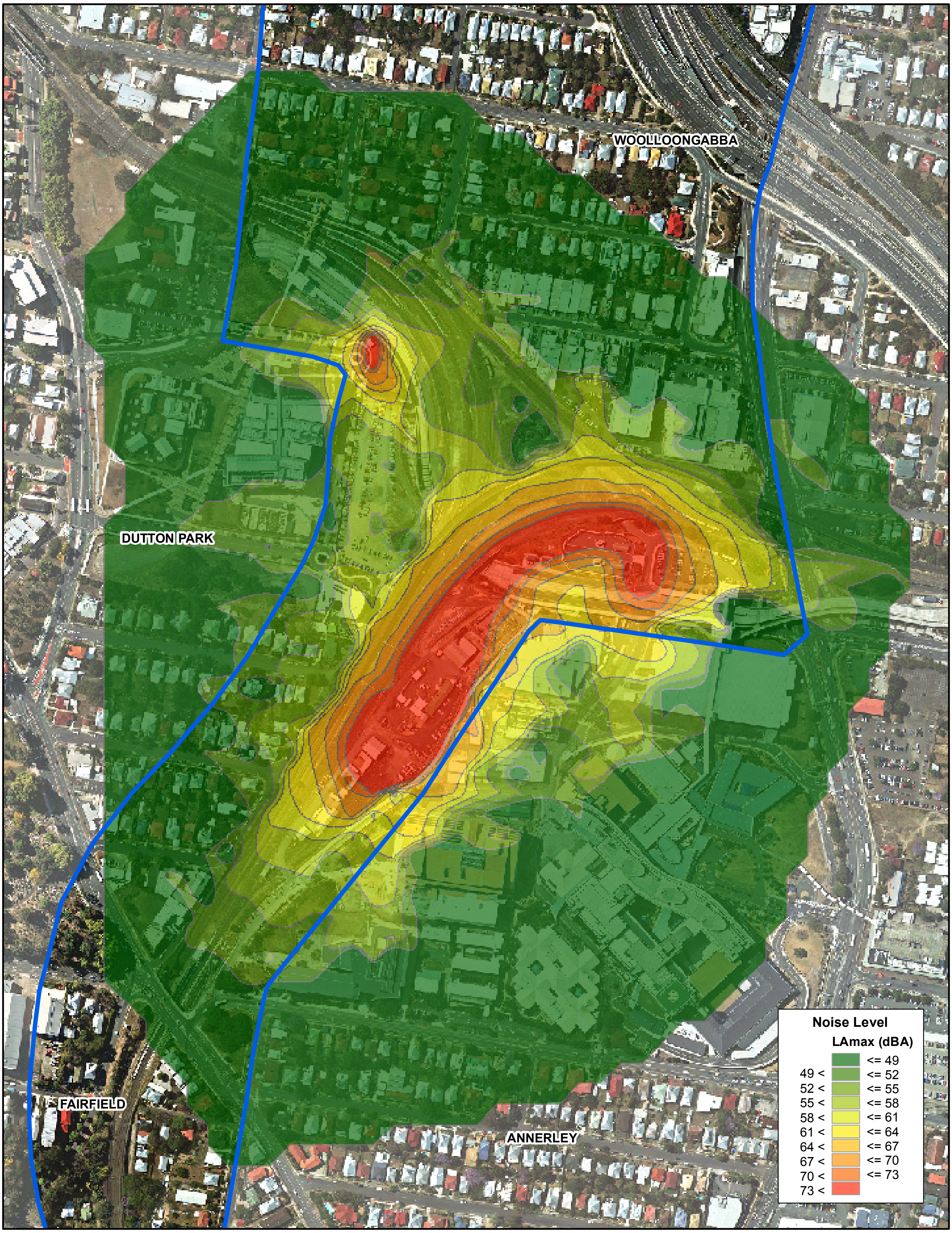
Southern Connection Scenario 4 - Daytime TBM assembly and acoustic shed construction

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-9_SouthConnection_Scenario4.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-10

Southern Connection Scenario 5 - Night-time spoil removal (transient noise)

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-10_SouthConnection_Scenario5.mxd Date: 12/08/2014

LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-11

Southern Connection Scenario 6 - Night-time spoil removal (steady state noise)

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-11_SouthConnection_Scenario6.mxd Date: 12/08/2014

Woolloongabba Station

Nearest sensitive receivers

The nearest noise and/or vibration sensitive receivers to the Woolloongabba Station worksite are identified in Table **11-14** with the receiver areas illustrated in Figure **11-12**.

Table 11-14 Nearest sensitive receivers – Woolloongabba Station

Worksite/ excavation	Receiver area	Distance to worksite boundary
Woolloongabba Station	A – Allen Street Residential	250m
	B – Vulture Street Residential	25m
	C – Vulture Street Commercial	10m
	D – St Nicholas Cathedral	25m
	E – Main Street Residential	85m
	F – Main Street Commercial	10m
	G – Stanley Street Commercial	60m
	H – Busway Station	10m
	I – Stanley Street Residential	100m
	J – St Joseph's School and Church	160m

Figure 11-12 Woolloongabba Station receiver areas

Note: for the construction site and receiver plans, the following colour codes have been used throughout this Chapter:

- *Pink: Residential*
- *Light blue: Commercial*
- *Orange: Educational*
- *Dark blue: Church or Place of Worship*

Construction scenarios

Construction scenarios were developed for the Woolloongabba Station worksite to enable modelling to be representative of the expected 'worst case' noise emissions. These scenarios are:

- Scenario 1 – demolition of GoPrint building:
  - duration ~ 2 months
  - dominant noise sources include rock breakers, excavators and spoil trucks
  - daytime construction only.
- Scenario 2 – installation of perimeter piles:
  - duration ~ 2 months
  - dominant noise sources include piling rigs
  - daytime construction only.
- Scenario 3 – initial shaft excavation in hard rock and spoil removal:
  - duration ~ 5 months
  - dominant noise sources include rock breakers, excavators, front end loaders and spoil trucks
  - daytime construction only until acoustic enclosure constructed.
- Scenario 4 – night-time shaft and cavern excavation including rock breakers and on-site spoil movements:
  - duration ~ approximately 15 months inclusive of station shaft and cavern excavation and therefore the initial stage of the station shaft excavation (ie typically the worst case stage of this scenario) would be significantly less in duration.
  - dominant noise sources include rock breakers, excavators, front end loaders and spoil trucks
  - 24 hour per day construction with night-time works carried out inside a low performance acoustic enclosure.

A scenario assessing the noise emissions associated with the construction of an acoustic shed or construction of station infrastructure at the surface has not been included on the basis that noise levels during these stages are typically lower than levels experienced during the four stages described above, particularly if the structure is prefabricated and only assembled at the site.

For the above scenarios, typical worst case construction noise levels have been predicted at the nearest noise sensitive receivers. Noise goal exceedances associated with the predicted construction noise levels are presented in Table **11-15**. Predicted ground-borne noise and vibration impacts for the excavation of the Woolloongabba Station shaft are presented in **Table 11-16**.

All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building, that is the distance from the receiver building to existing rock level for shaft excavation and the top of station cavern for roadheading. Since the excavation activity will be moving around the worksite, and progressively deeper over time, the levels modelled are conservative. Typical levels would be expected to be lower than those predicted over the duration of each scenario.

Table 11-15 Woolloongabba Station predicted worst case noise levels

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)							
			Scenario 1 – GoPrint demolition		Scenario 2 – Piling		Scenario 3 – shaft excavation		Scenario 4 – night shaft excavation	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	Acoustic shed
A – Allen Street Residential	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Evening	$L_{A10,adj}$ 72	-	-	-	-	-	-		
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
B – Vulture Street Residential	Day	$L_{A10,adj}$ 62	**3**	-	-	-	3	-	n/a	n/a
	Evening	$L_{A10,adj}$ 57	**8**	**3**	**5**	-	**8**	**3**	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	n/a	n/a	n/a	n/a	**9**	**1**
C – Vulture Street Commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
D – St Nicholas Cathedral	24/7	$L_{A10,adj}$ 57	**8**	**3**	**4**	-	**8**	**3**	n/a	n/a
E – Main Street Residential	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Evening	$L_{A10,adj}$ 72	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
F – Main Street Commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
G – Stanley Street Commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
H – Busway Station	Day	$L_{A10,adj}$ 65	**2**	-	**5**	-	**5**	-	n/a	n/a

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)							
			Scenario 1 – GoPrint demolition		Scenario 2 – Piling		Scenario 3 – shaft excavation		Scenario 4 – night shaft excavation	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	Acoustic shed
I – Stanley Street Residential	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Evening	$L_{A10,adj}$ 72	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	**3**	-
J – St Josephs Church and School	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	n/a	n/a

*Note: Exceedances shown in **bold**.*

Note: Airborne noise predictions have been carried out for all floors of multi-storey buildings.

Table 11-16 Woolloongabba Station predicted ground-borne noise and vibration levels – station shaft and cavern excavation

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)	
		Vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rockbreaking	Roadheading	Rockbreaking	Roadheading
			Continuous[1]	Intermittent[2]				
A – Allen Street Residential	Day	10	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.01	0.01	20	6
	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.01	0.01	20	6
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.01	0.01	25	6
B – Vulture Street Residential	Day	10	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.02	0.01	28	15
	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.02	0.01	28	15
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.02	0.01	33	15
C – Vulture Street Commercial	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.05	0.06	36	38
D – St Nicholas Cathedral (Heritage)	24/7	2	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.05	0.17	37	39

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)	
		Vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rockbreaking	Roadheading	Rockbreaking	Roadheading
			Continuous[1]	Intermittent[2]				
E – Main Street Residential	Day	10	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.03	0.04	32	26
	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.03	0.04	32	26
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.03	0.04	37	26
F – Main Street Commercial	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.11	0.07	42	30
G – Stanley Street Commercial	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.06	0.15	37	37
H – Busway Station	Day	25	$L_{Aeq,adj}$ – 55	$L_{A10,adj}$ – 65	0.39	0.26	n/a	n/a
I – Stanley Street Residential	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.03	0.03	32	20
	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.03	0.03	32	20
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.03	0.03	37	20
J – St Joseph's Church and School (Heritage)	Day	2	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.02	0.02	27	16

Note 1: Dominant construction noise during shaft excavation (ie rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2: Dominant construction noise during cavern excavation (ie roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Airborne noise impacts

The predicted noise levels are summarised as follows:

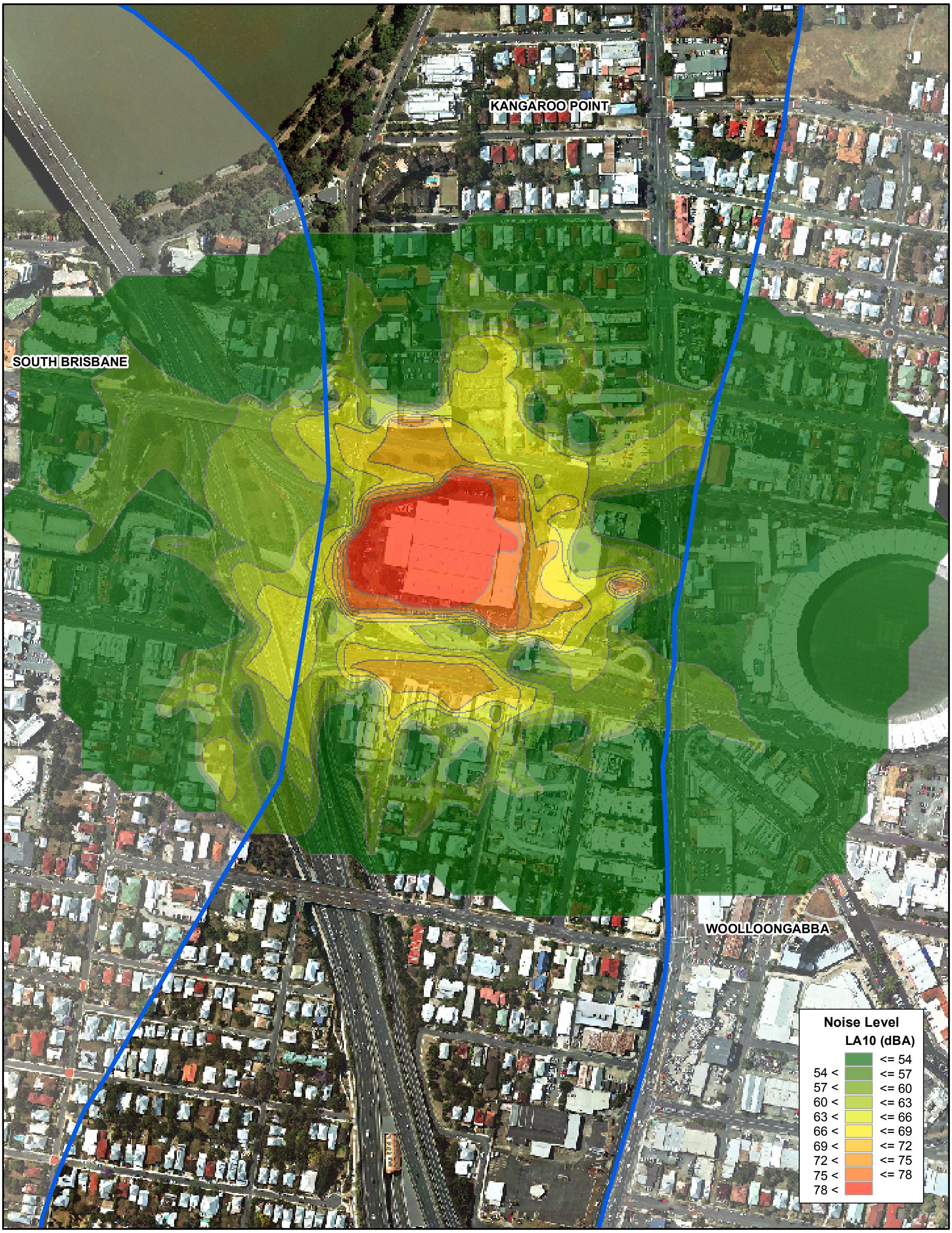
- Predicted noise levels for site establishment works including demolition of the existing GoPrint building indicate exceedances of the daytime noise goal of up to 3 dBA at the nearest residential receivers along Vulture Street with 3m high acoustic hoarding around the site. Similar exceedances are predicted during the initial station shaft excavation (ie Scenario 3).
- Higher exceedances (ie up to 8 dBA) are predicted for Scenario 1 to 3 at St Nicholas Cathedral due to the lower daytime noise goal. The assessment has assumed a 7 dBA outside to inside construction noise reduction through the facade. It is recommended that facade noise measurements be carried out prior to construction to determine the actual acoustic performance of the façade, as it is likely to be achieving higher than 7 dBA being situated adjacent to Vulture Street. Subsequent to the findings of the facade noise measurements, temporary (or permanent) upgrades to the facade (eg double glazing, acoustic seals around doors etc) may need to be considered in tandem with respite periods during services.
- Activities associated with night-time excavation and spoil removal from the site (ie Scenario 4) are also predicted to exceed the night-time residential noise goal at the nearest receivers. A marginal 1 dBA night-time sleep disturbance noise goal exceedance is predicted as a result of spoil truck movements through the site, which are required to occur outside the acoustic shed.
- The proposed 'shoulder period' or evening noise goals are proposed to enable the Project to progress efficiently and reduce the duration of impacts. The modelling indicates exceedances of up to 8 dBA of the evening airborne noise goal when assessed against the full daytime construction scenario, as such mitigation would be required. Mitigation could include restriction on particularly noisy activities, consultation with affected receivers prior to such activities, or increased height of noise hoarding to achieve the required outcomes. Further noise mitigation options are outlined in **section 11.4** and **Chapter 18 – Draft Outline EMP**.

With reasonable and practicable noise mitigation measures in place, combined with careful management of all heavy vehicle movements on the site, airborne noise impacts can be managed to an acceptable level during the construction phase of the Woolloongabba Station.

Noise mapping for each modelled scenario (incorporating the nominated mitigation) is shown in **Figure 11-13** to **Figure 11-16**.

Ground-borne noise and vibration impacts

The predicted ground-borne noise and vibration levels indicate compliance with the relevant goals primarily due to the Woolloongabba Station worksite being bordered by existing roads and therefore set back from sensitive receivers.



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-13

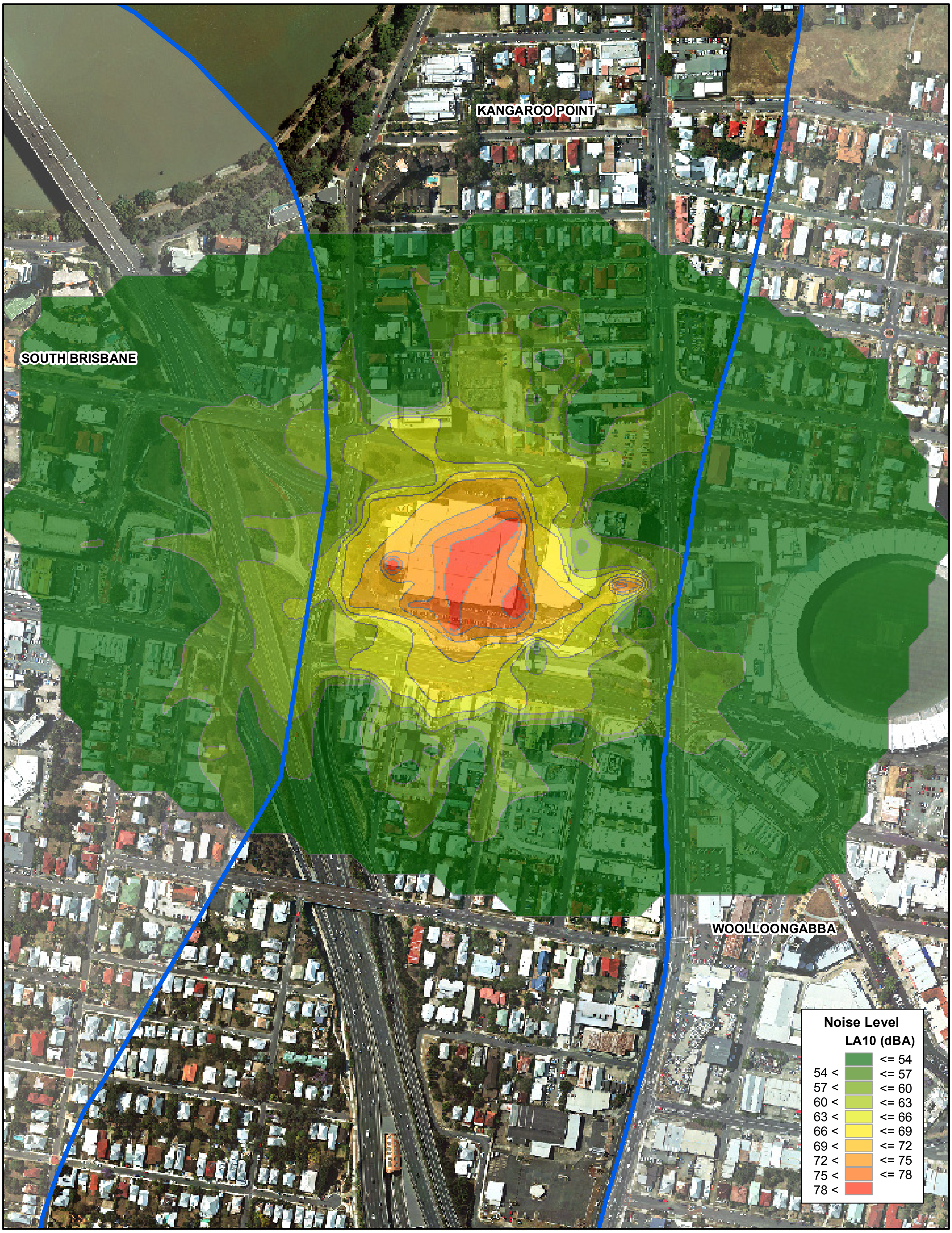
Woolloongabba Station Scenario 1 - Daytime site establishment including demolition of GoPrint building

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-13_Woolloongabba_Scenario1.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-14

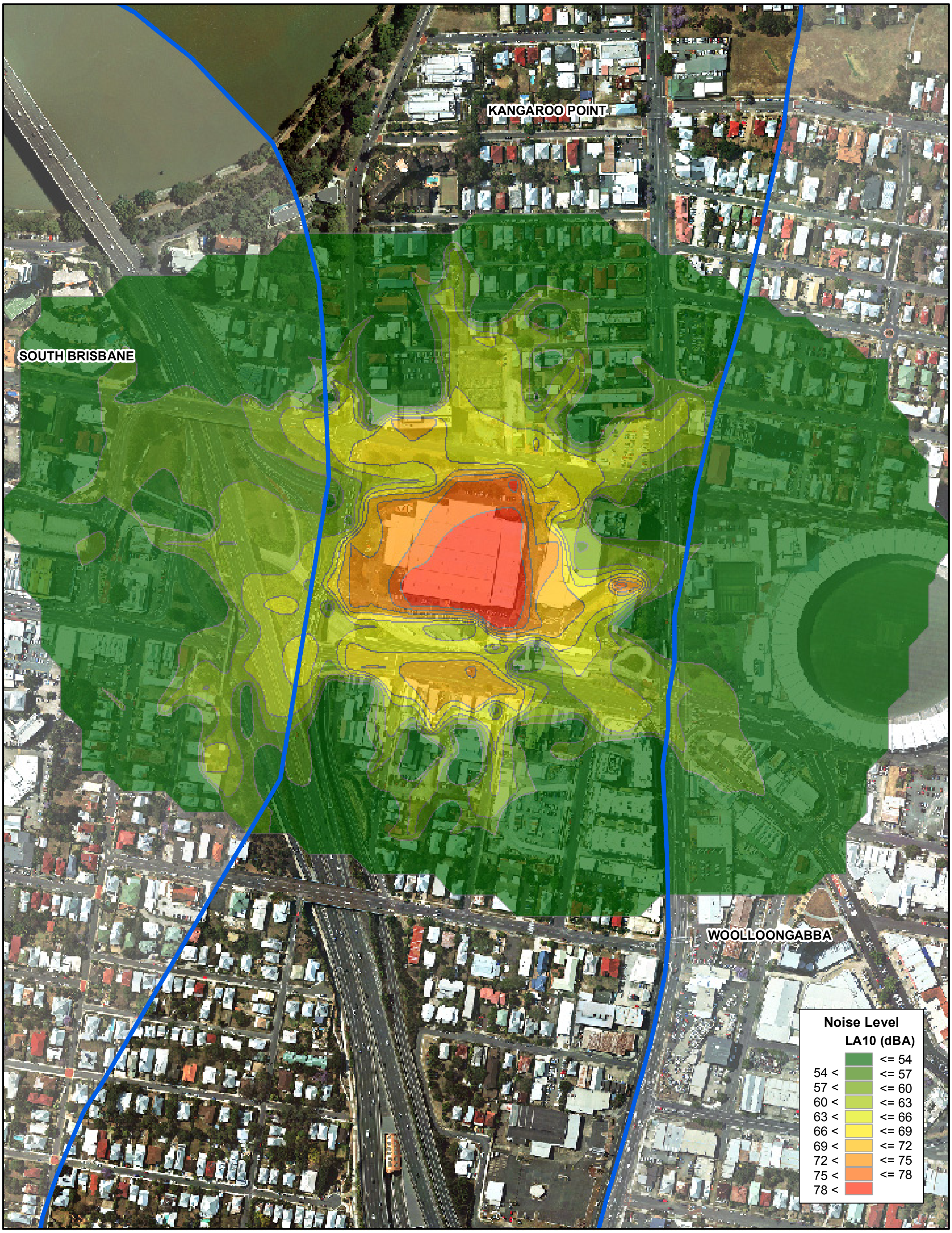
Woolloongabba Station Scenario 2 - Daytime piling of station shaft

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-14_Woolloongabba_Scenario2.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-15

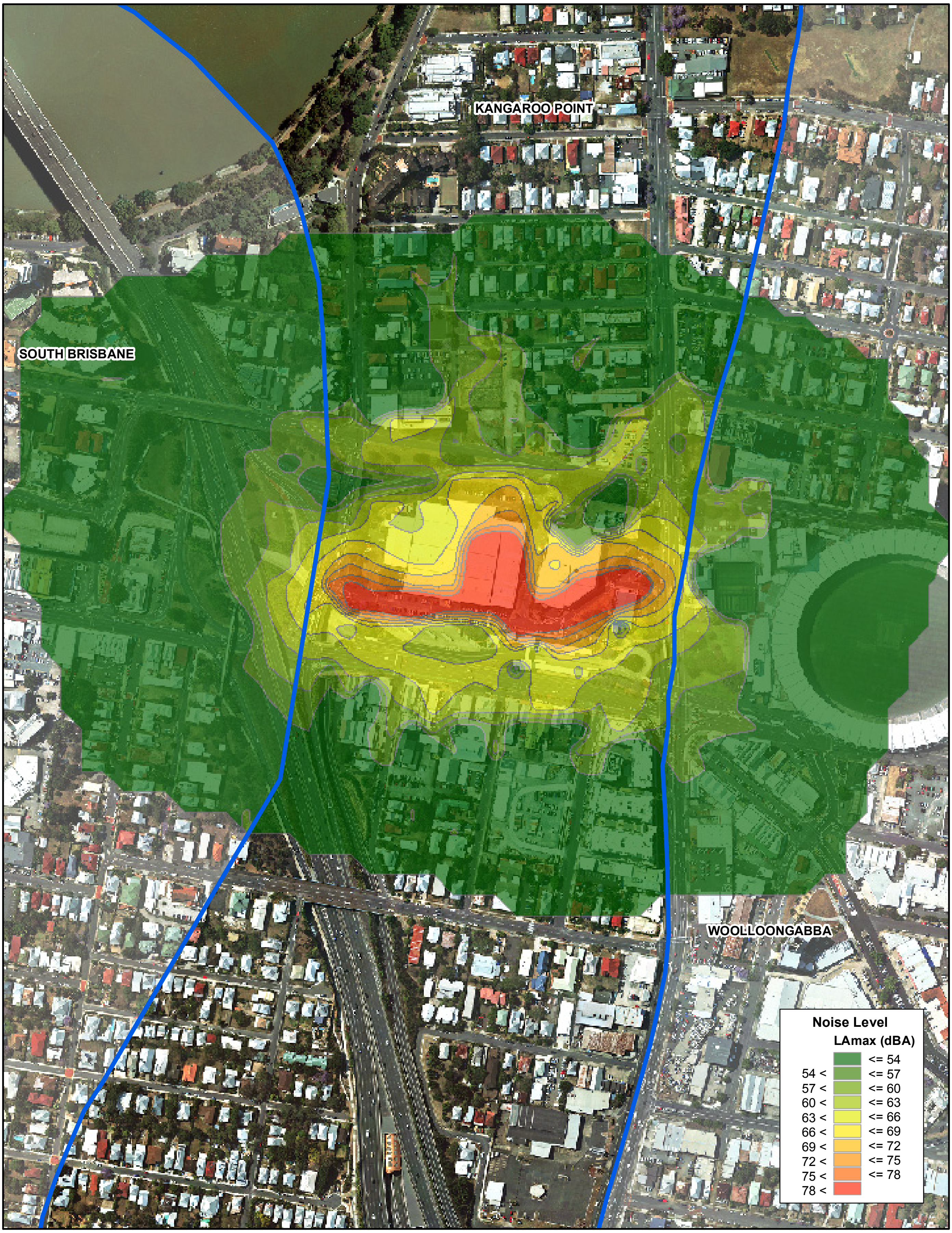
Woolloongabba Station Scenario 3 - Daytime initial shaft excavation

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-15_Woolloongabba_Scenario3.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-16

Woolloongabba Station Scenario 4 - Night-time shaft excavation

N

0 0.05 0.1
Kilometres
1:5,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-16_Woolloongabba_Scenario4.mxd Date: 12/08/2014

George Street Station

The nearest noise and/or vibration sensitive receivers to the George Street Station site are identified in Table **11-17** with the receiver areas illustrated in Figure **11-17**.

Table 11-17 Nearest sensitive receivers – George Street Station

Worksite/ excavation	Receiver area	Distance to worksite boundary
George Street Station	A – QUT	300m
	B – Parliament	190m
	C – George Street Commercial	< 10m
	D – 103 George Street Residential	65m
	E – Alice Street Commercial	115m
	F – City Botanic Gardens	170m
	G – 21 Mary Street Residential	20m
	H – 21 Mary Street Commercial	25m
	I –- Brisbane Synagogue (Margaret Street)	20m

Figure 11-17 George Street Station receiver areas

Note: for the construction site and receiver plans, the following colour codes have been used throughout this Chapter:

- *Pink: Residential*
- *Light blue: Commercial*
- *Orange: Educational*
- *Dark blue: Church or Place of Worship*
- *Green: Park*

Construction scenarios

Construction scenarios were developed for the George Street Station worksite to enable modelling to be representative of the expected 'worst case' noise emissions. These scenarios are:

- Scenario 1 – site establishment including demolition of existing buildings:
  - duration ~ 3 months
  - dominant noise sources include rock breakers, excavators, spoil trucks and cranes
  - mostly daytime construction works with potential for night-time work to avoid impact on existing road operations.
- Scenario 2 – piling of station access shaft (Mary Street staging):
  - duration ~ 1 month
  - dominant noise sources include piling rigs
  - mostly daytime construction works with potential for night-time work to avoid impact on existing road operations.
- Scenario 3 – initial station access shaft excavation:
  - duration ~ 5 months
  - dominant noise sources include rock breakers, excavators, front end loaders and spoil trucks
  - daytime construction only until acoustic enclosure constructed.
- Scenario 4 – night-time shaft excavation including rock breakers and on-site spoil movements:
  - duration ~ 18 months inclusive of station shaft and cavern excavation. The initial stage of the station shaft excavation (ie typically the worst case stage of this scenario) would be significantly less in duration
  - dominant noise sources include rock breakers, excavators, front end loaders and spoil trucks
  - 24 hour per day construction with night-time works carried out inside a medium performance acoustic enclosure.

Table 11-18 George Street Station predicted construction noise goal exceedances

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)							
			Scenario 1 – Site establishment		Scenario 2 – Piling		Scenario 3 – shaft excavation		Scenario 4 – night shaft excavation	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	Acoustic shed
A – QUT	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	n/a	n/a
B – Parliament	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
C – George Street Commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	**3**	**3**	n/a	n/a
D – 103 George Street Residential	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Evening	$L_{A10,adj}$ 72	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
E – Alice Street Commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
F – City Botanic Gardens	Day	n/a	-	-	-	-	-	-	n/a	n/a
G – 21 Mary Street Residential	Day	$L_{A10,adj}$ 77	**7**	**7**	-	-	**5**	**5**	n/a	n/a
	Evening	$L_{A10,adj}$ 72	**12**	**12**	-	-	**10**	**10**	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	**20**	-
H – 21 Mary Street Commercial	Day	$L_{A10,adj}$ 77	**9**	**9**	**5**	**5**	**12**	**12**	n/a	n/a
I –- Brisbane Synagogue (Margaret Street)	24/7	$L_{A10,adj}$ 57	-	-	-	-	-	-	n/a	n/a

Note: Exceedances shown in bold.

Note: Airborne noise predictions have been carried out for all floors of multi-storey buildings.

Table 11-19 George Street Station predicted ground-borne noise and vibration levels – station shaft and cavern excavation

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)		
		Continuous vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rock breaking	Roadheading	Rock breaking	Roadheading	Drilling
			Continuous[1]	Intermittent[2]					
A – QUT (heritage)	Day	2	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.01	0.01	23	12	14
B – Parliament House (heritage)	Day	2	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.02	0.02	28	19	20
C – 41 George Street commercial	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	10.5	0.16	**78 (23)**[3]	39	**68 (13)**[3]
C – 41 George Street commercial: predicted effect of working at RL 0 (ie 10m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5m of rock					n/a	n/a	**62 (7)**[3]	n/a	53
C – George Street (Harris Terrace - heritage)	Day	2	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	**2.13 (0.13)**[3]	0.14	**63 (8)**[3]	36	**56 (1)**[3]
D – George Street residential	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.14	0.15	42	35	34
	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.14	0.15	**42 (2)** [3]	35	34
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.14	0.15	**47 (5)**[3]	35	39
E – Queensland Club (heritage)	Day	2	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.05	0.16	35	38	40
G – 21 Mary Street residential	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	6.43	0.06	**64 (9)**[3]	27	55
G – 21 Mary Street Residential (Day): predicted effect of working at RL 0 (ie 10m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5m of rock					n/a	n/a	51	n/a	42
G – 21 Mary Street residential	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	**6.43 (5.93)** [3]	0.06	**64 (14)**[3]	27	55

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)		
		Continuous vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rock breaking	Roadheading	Rock breaking	Roadheading	Drilling
			Continuous[1]	Intermittent[2]					
G – 21 Mary Street residential	Night	0.5	LAeq,adj – 35	LAmax,adj – 42	**6.43 (5.93)**[3]	0.06	**69 (27)**[3]	27	**60 (18)**[3]
G – 21 Mary Street Residential (Night): predicted effect of working at RL 0 (ie 10m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5m of rock					**0.57 (0.07)**[3]	n/a	**56 (14)**[3]	n/a	**47 (5)**[3]
H – 21 Mary Street commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	19.62	0.17	**83 (28)**[3]	39	**73 (18)**[3]
H – 21 Mary Street Commercial (Day): predicted effect of working at RL 0 (ie 10m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5m of rock					n/a	n/a	**64 (9)** [3]	n/a	55
I – Brisbane Synagogue (heritage)	24/7	2	LAeq,adj – 40	LA10,adj – 50	0.76	0.15	**55 (5)** [3]	38	48

Note 1: Dominant construction noise during shaft excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night time) assessment parameters are most relevant.

Note 2: Dominant construction noise during cavern excavation (i.e. roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 3: Exceedances of noise or vibration goal shown in ( )

Table 11-20 George Street Station predicted ground-borne vibration and airblast overpressure levels – blasting of station shaft

Receiver area	Period	Blasting criteria		Maximum allowed blast MIC to meet noise & vibration goal (kg)			
				Conventional blasting		Penetrating cone fracture (PCF) blasting [1]	
		Vibration PPV (mm/s)	Airblast overpressure (dBL Peak)	Vibration	Airblast overpressure	vibration	Airblast overpressure
A – QUT heritage	Day	10	132	>100kg	>100kg	>100kg	>100kg
B – Parliament House heritage	Day	10	132	>100kg	>100kg	>100kg	>100kg
C – George Street commercial	Day	50	132	0.18kg	0.08kg	0.20kg	5.57kg
C – George Street heritage	Day	10	132	0.17kg	1.36kg	0.14kg	99kg
D – George Street residential	Day	50	132	33kg	>100kg	36kg	>100kg
E – Queensland Club heritage	Day	50	132	>100kg	>100kg	>100kg	>100kg
G – Mary Street residential	Day	50	132	0.31kg	0.17kg	0.34kg	12kg
H – Mary Street commercial	Day	50	132	0.16kg	0.06kg	0.17kg	4.46kg
I – Brisbane Synagogue heritage	Day	10	132	0.58kg	8.72kg	0.47kg	>100kg

Note:

1: PCF is a rock breaking process using a high pressure gas pulse, which creates a spherical fracture that propagates 45 degrees from the base corner of the drill hole developing a characteristic cone shaped fracture pattern

Note 2: A PCF cartridge mass as little as 10 grams may be practicable.

Airborne noise impacts

The modelling results are summarised as follows:

- Predicted noise levels for site establishment works including demolition of the existing buildings at the George Street Station worksite indicate exceedances of up to 12 dBA of the daytime noise goal at the high-rise apartment building in 21 Mary Street adjacent to the site.
- Similar noise goal exceedances are predicted during the perimeter piling and initial shaft excavation works at this site.
- Whilst most activities for Scenario 1 and 2 would be expected to occur during the daytime or evening period, where night work is unavoidable (eg due to road access of traffic management restrictions) exceedances may occur and suitable mitigation would be required. Mitigation options would include standard mitigation measures, with a particular focus on early notification of affected receivers and careful planning of activities to minimise impacts (such as undertaking noisiest activities as early in the night time period as possible).
- The proposed ‘shoulder period’ or evening noise goals are proposed to enable the Project to progress efficiently and reduce the duration of impacts. The modelling indicates exceedances of up to 12 dBA of the evening airborne noise goal when assessed against the full daytime construction scenario, as such mitigation would be required. Mitigation could include restriction on particularly noisy activities (such as rockbreaking), consultation with affected receivers prior to such activities or increased height of noise hoarding to achieve the required outcomes. Further noise mitigation options are outlined in **section 11.4** and **Chapter 18 – Draft Outline EMP**.

Once excavation of the station shaft has progressed far enough to allow for installation of the acoustic enclosure, noise emission levels from the site would decrease significantly. The airborne construction noise assessment has indicated that a medium performance acoustic shed or equivalent would enable compliance with the airborne noise goals during the night-time period.

Noise mapping for each modelled scenario (incorporating nominated mitigation) is shown in **Figure 11-18** to **Figure 11-21**.

Ground-borne noise and vibration impacts

The predicted ground-borne noise and vibration levels are summarised as follows:

- Ground-borne noise levels for rock breaking during excavation of the George Street Station shaft is predicted to significantly exceed the daytime and night-time noise goals for the residential receiver building located along the north-east boundary of the site (ie Mary Street, Day: 14 dBA and Night: 27 dBA) as well as during the night-time period for the George Street residential building (ie Receiver D – on the corner of George and Charlotte Streets, Night: 5 dBA).
- The daytime noise goal applicable to the commercial receiver buildings on the north-east (ie Mary Street: 23 dBA) and south-east (ie George Street: 28 dBA) boundary of the site is also predicted to be significantly exceeded during rock breaking of the station shaft.
- A 6 dBA exceedance of the night-time noise goal and a marginal 1 dBA exceedance of the daytime noise goal are predicted inside the George Street residential receiver building during roadheading of the station cavern.
- A marginal exceedance of the 2 mm/s vibration goal for heritage structures is predicted for Harris Terrace (ie receiver C - George Street heritage) during the initial stages of heavy rock breaking of the station shaft.

- Based on the predicted vibration levels, it is recommended that a survey of potentially sensitive building contents (eg sensitive computer systems, instruments etc) be carried out inside the adjacent Mary Street and George Street buildings prior to the commencement of shaft excavation works.

Notwithstanding the worst-case predicted ground-borne noise and vibration impacts summarised above, further predictions were carried out for the two buildings adjacent to the George Street Station shaft worksite (ie 21 Mary Street and 41 George Street). These predictions were carried out for the purpose of taking into consideration the effect of increased shaft depth (ie as shaft excavation progresses downwards) or interrupting the direct transmission path of vibrations by creating a cut-off trench along the shaft wall adjacent to the receiver building.

Based on these two scenarios, the findings are summarised as follows:

- Ground-borne noise levels from blast hole drilling are predicted to comply with the noise goal during the daytime for the commercial receivers at 41 George Street and 21 Mary Street and the residential floors of 21 Mary Street.
- Ground-borne noise levels from rock breaking are predicted to exceed the noise goal during the daytime for the commercial receivers at 41 George Street (by 7 dBA) and 21 Mary Street (by 9 dBA) and by a marginal 1 dBA for the closest residential receiver floor of 21 Mary Street.
- Ground-borne noise levels from blast hole drilling are predicted to exceed the noise goal during the night-time for the closest residential floor of 21 Mary Street by 5 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, the first three residential floors of 21 Mary Street are predicted to exceed the internal ground-borne noise goal.
- Ground-borne noise levels from rock breaking are predicted to exceed the noise goal during the night-time for the closest residential floor of 21 Mary Street by 14 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, the first seven residential floors of 21 Mary Street are predicted to exceed the internal ground-borne noise goal.

Considering the predicted regenerated noise and vibration exceedances, in particular at 21 Mary Street and 41 George Street, it is proposed that:

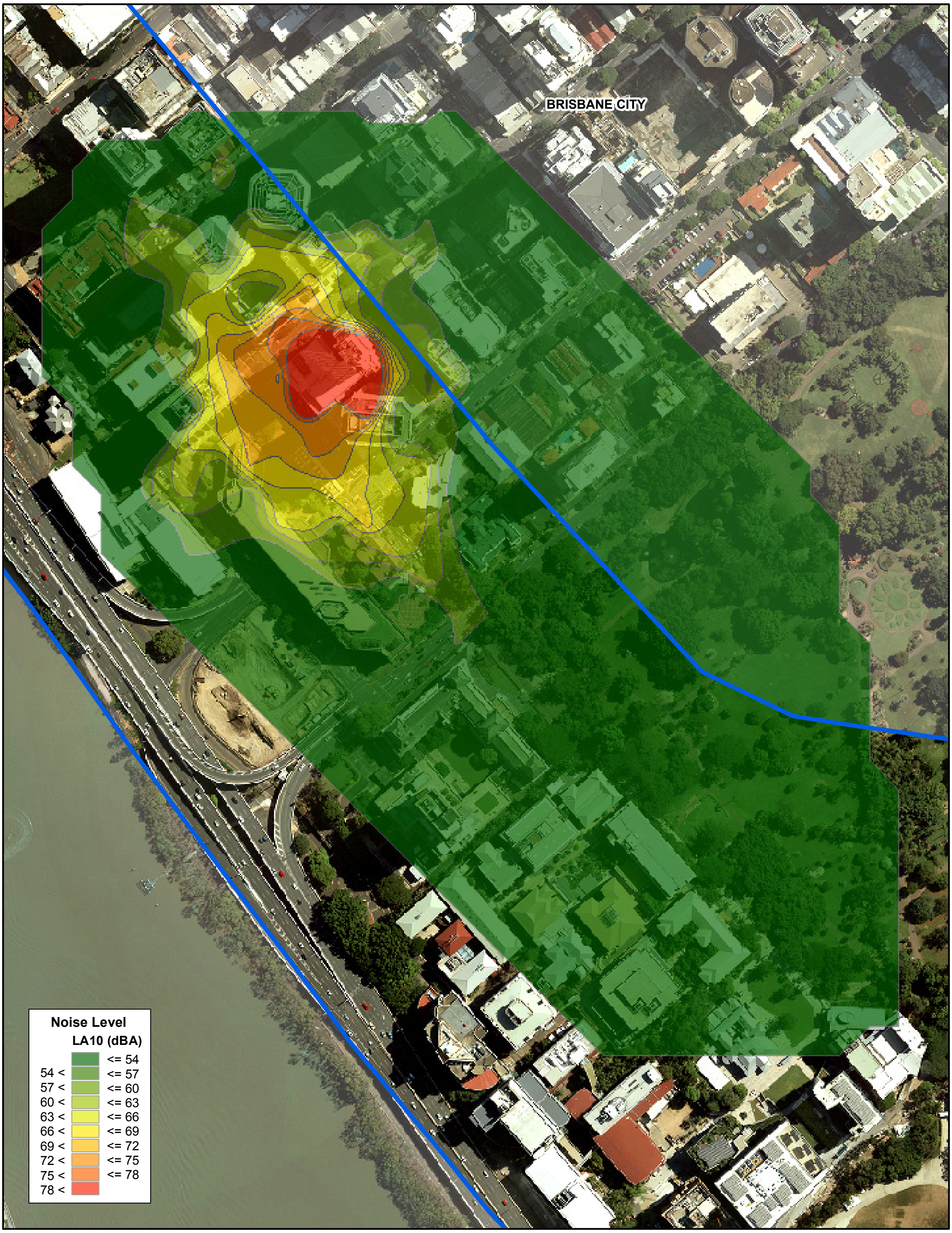
- Rock breaking be limited to the daytime period until measurement results achieve compliance with the ground-borne noise goals or agreements are reached with affected residents (including potential for temporary relocation).
- Ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to more accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy.
- Preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted during the night-time period.

Acoustically, exposure to a short-term blast event would be preferred to long term rock breaking where ground-borne noise impacts have been identified. Furthermore, the predicted ground-borne noise levels in **Table 11-19** indicate that drilling of blast holes results in a better environmental outcome compared with rock breaking the entire station shaft.

Considerable exceedances of the internal noise goals are still predicted to occur within the commercial and residential levels of the adjacent Mary Street building as well as the adjacent George Street commercial building.

Should drill and blast be required for this worksite, the following management measures would be available to mitigate impacts:

- restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals or agreement is reached with affected residents (eg temporary relocation)
- investigate further the benefits from making deep vertical cuts into the rock using rock saws or diamond wire (eg blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting)
- use of latest available blasting technology (eg PCF, double decking etc)
- pre-blasting condition survey of adjacent buildings
- appropriate attention to blast design and commence blasting with a low charge to develop a site law (ie blast design model) based on measurement data from the site
- monitoring of the blast emissions.



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-18

George Street Station Scenario 1 - Daytime site establishment including demolition of existing building

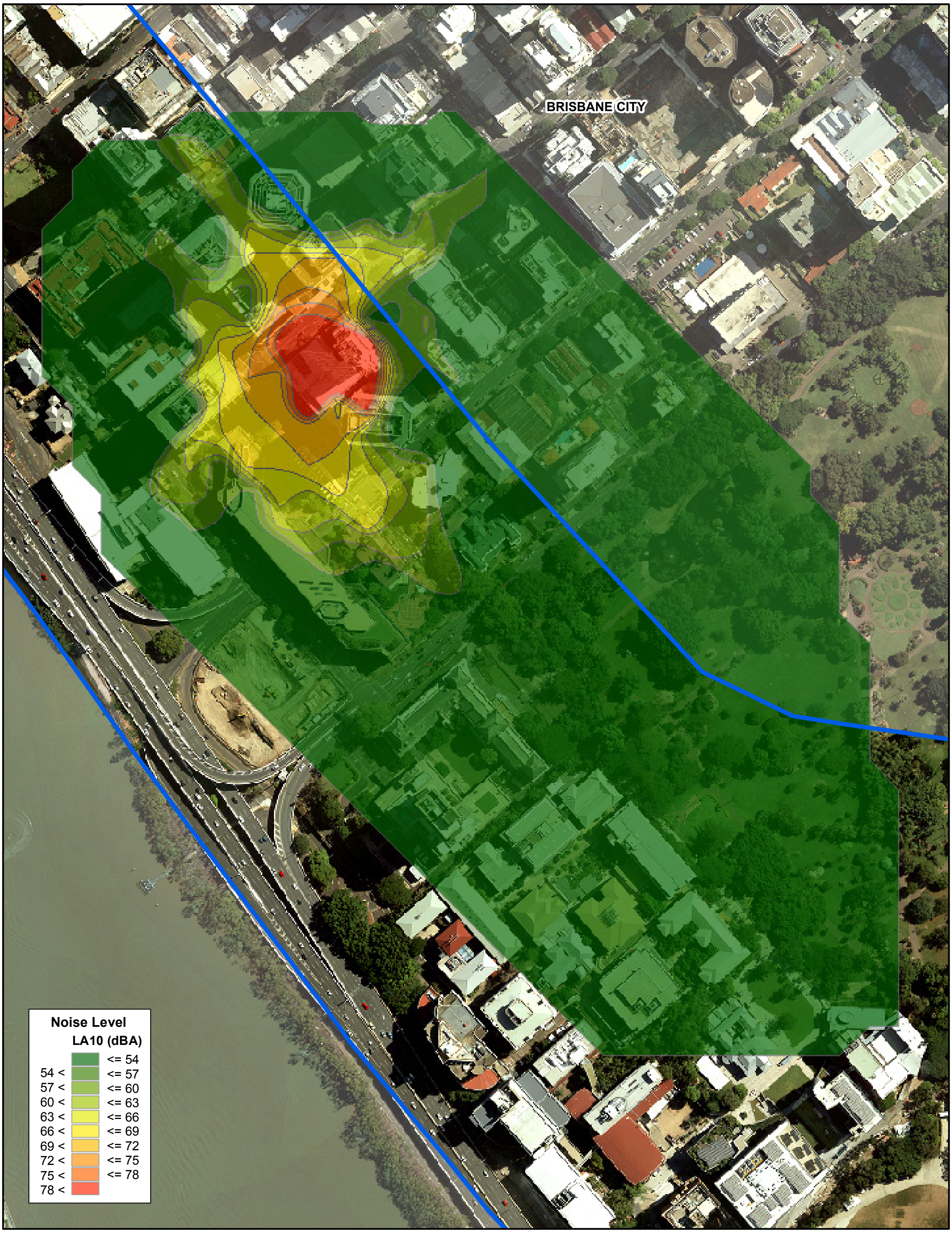
N

0 0.05 0.1
Kilometres
1:3,500 (at A4)

Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-18_GeorgeStreet_Scenario1.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-19

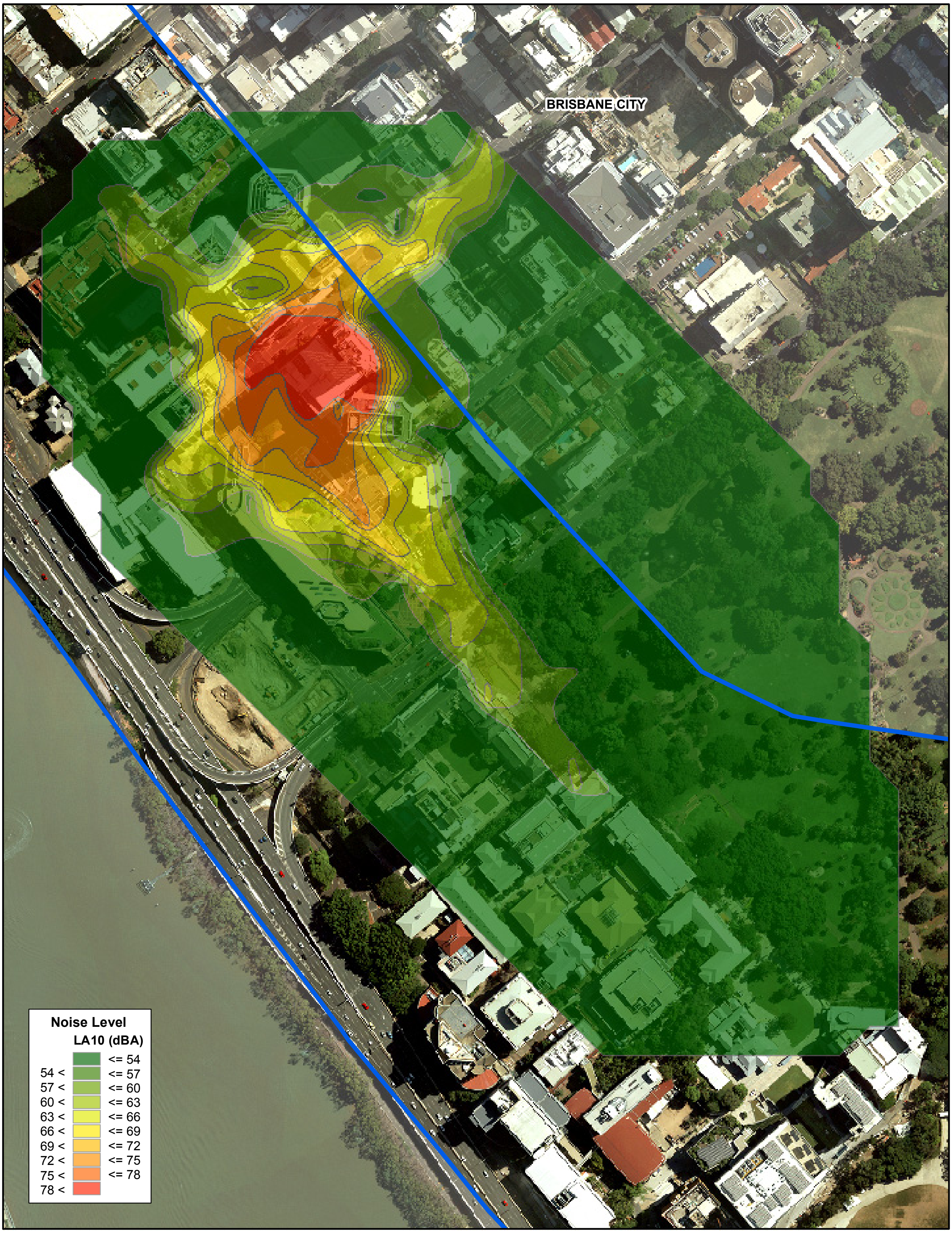
George Street Station Scenario 2 - Daytime piling of station shaft

N

0 0.05 0.1
Kilometres
1:3,500 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-19_GeorgeStreet_Scenario2.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-20

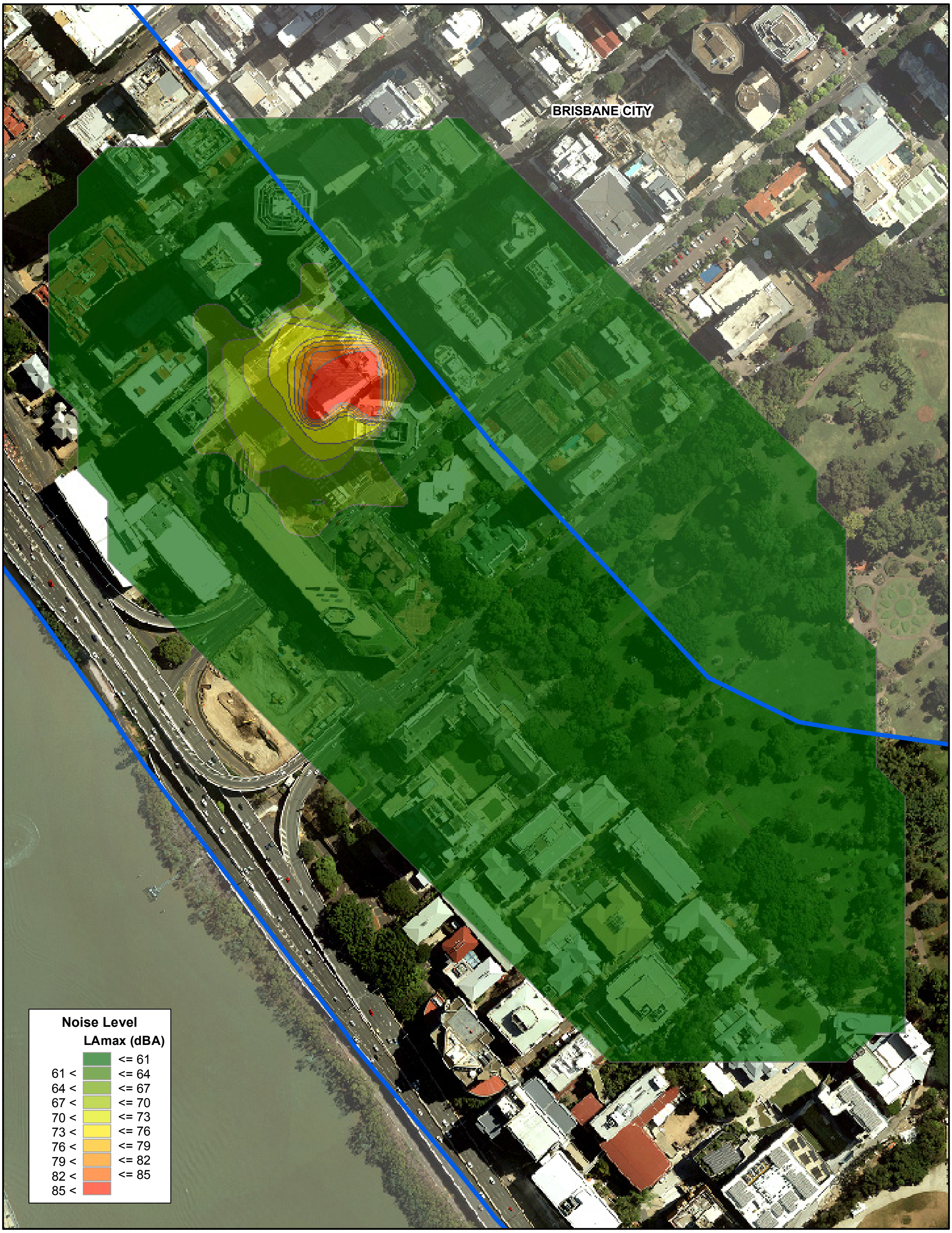
George Street Station Scenario 3 - Daytime initial shaft excavation

N

0 0.05 0.1
Kilometres
1:3,500 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-20_GeorgeStreet_Scenario3.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-21

George Street Station Scenario 4 - Night-time shaft excavation

N

0 0.05 0.1
Kilometres
1:3,500 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-21_GeorgeStreet_Scenario4.mxd Date: 12/08/2014

Roma Street Station

Nearest sensitive receivers

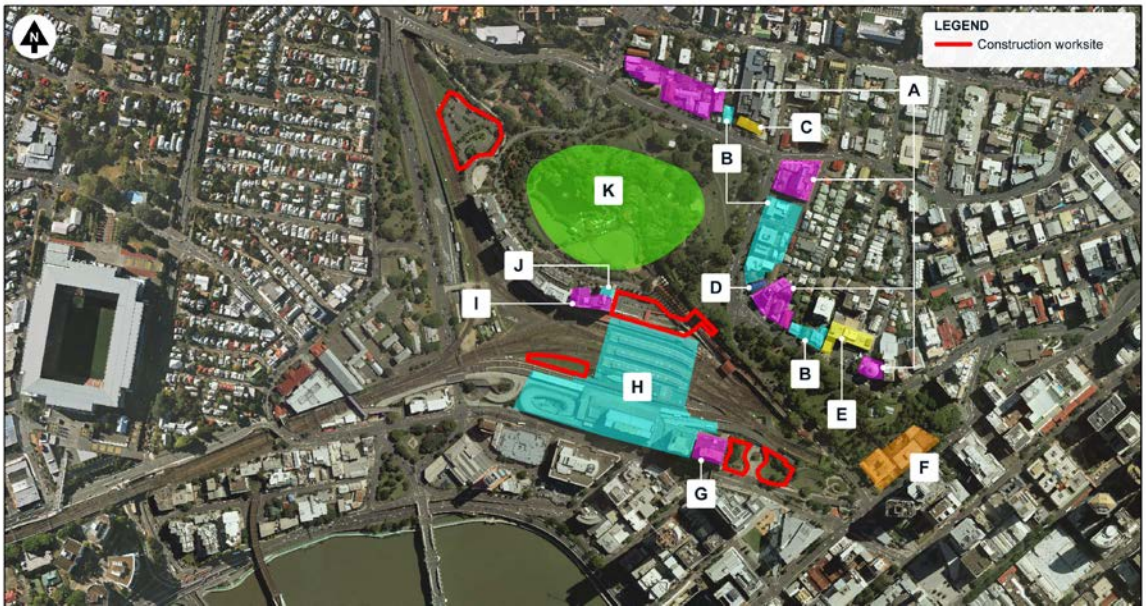
The nearest noise and/or vibration sensitive receivers to the Roma Street Station site are identified in **Table 11-21** with the receiver areas illustrated in **Figure 11-22**.

Table 11-21 Nearest sensitive receivers – Roma Street Station

Work site/ excavation	Receiver area	Distance to worksite boundary
Roma Street Station	A – Wickham Terrace Residential	95m
	B – Wickham Terrace Commercial	100m
	C – Memorial Hospital	270m
	D – St Alban Catholic Church	95m
	E – Brisbane Private Hospital	140m
	F – Dental School	300m
	G – Roma Street Residential (Traders Hotel)	120m
	H – Roma Street Station 1	10m
	I – Parkland Boulevard Residential	<10m
	J – Parkland Boulevard Commercial	<10m
	K – Roma Street Parkland	<10m

Note 1 – Receiver includes Brisbane Transit Centre and Roma Street Station platforms of which the southern building is heritage listed.

Figure 11-22 Roma Street Station Receiver Areas



Note: for the construction site and receiver plans, the following colour codes have been used throughout this Chapter:

- *Pink: Residential*
- *Light blue: Commercial*
- *Yellow: Hospital*
- *Orange: Educational*
- *Dark blue: Church or Place of Worship*
- *Green: Park*

Construction scenarios

Construction scenarios were developed for the Roma Street Station worksite to enable modelling to be representative of the expected 'worst case' noise emissions. These scenarios are:

- Scenario 1 – site establishment including removal of Roma Street Station infrastructure:
  - duration ~ 3 months
  - dominant noise sources include rock breakers, excavators, spoil trucks and cranes
  - mostly daytime construction works with potential for night-time work to avoid impact on existing rail operations.
- Scenario 2 – piling of station access shaft:
  - duration ~ 1 month
  - dominant noise sources include piling rigs
  - daytime construction only.
- Scenario 3 – initial station access shaft excavation:
  - duration ~ 5 months
  - dominant noise sources include rock breakers, excavators, front end loaders and spoil trucks
  - daytime construction only until acoustic enclosure constructed.
- Scenario 4 – night-time shaft excavation including rock breakers and on-site spoil movements:
  - duration ~ 17 months inclusive of station shaft and cavern excavation and therefore the initial stage of the station shaft excavation (ie typically the worst case stage of this scenario) would be significantly less in duration.
  - dominant noise sources include rock breakers, excavators, front end loaders and spoil trucks
  - 24 hour per day construction with night-time works carried out inside a high performance acoustic enclosure.

For the above scenarios, typical worst case construction noise levels have been predicted at the nearest noise sensitive receivers. Noise goal exceedances associated with the predicted construction noise levels are presented in **Table 11-22**.

Predicted ground-borne noise and vibration impacts for the excavation of Roma Street Station access shaft and station cavern are presented in **Table 11-23**. All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building, that is the distance from the receiver building to existing rock level for shaft excavation and the top of station cavern for roadheading. Since the excavation activity would actually be moving around the worksite, and progressively deeper, the levels modelled are conservative. Typical noise levels would be expected to be lower than those predicted over the duration of each scenario.

Predicted ground-borne vibration and airblast overpressure impacts associated with blasting for the Roma Street Station access shaft are presented in **Table 11-24**.

Table 11-22 Roma Street Station predicted worst case construction noise levels

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)							
			Scenario 1 – Site est		Scenario 2 – Piling		Scenario 3 – shaft excavation		Scenario 4 – night shaft excavation	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	Acoustic shed
A – Wickham Terrace residential	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	n/a	n/a
	Evening	$L_{A10,adj}$ 57	-	-	-	-	1	-	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	n/a	n/a	n/a	n/a	-	-
B – Wickham Terrace commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
C – Memorial Hospital	Day	$L_{A10,adj}$ 72	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
D – St Alban Church	24/7	$L_{A10,adj}$ 57	-	-	-	-	-	-	n/a	n/a
E – Brisbane Private Hospital	Day	$L_{A10,adj}$ 72	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
F – Dentist School	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	n/a	n/a
G – Traders Hotel	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Evening	$L_{A10,adj}$ 72	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
I – Parkland Boulevard residential	Day	$L_{A10,adj}$ 77	**4**	**4**	**10**	**10**	**9**	**9**	n/a	n/a
	Evening	$L_{A10,adj}$ 72	**9**	**9**	**15**	**15**	**14**	**14**	n/a	n/a
	Night	L_{Amax} 67	n/a	n/a	n/a	n/a	n/a	n/a	**16**	-
J – Parkland Boulevard commercial	Day	$L_{A10,adj}$ 77	**2**	**2**	**3**	**3**	**7**	**7**	n/a	n/a
K – Roma Street Parkland	Day	n/a	-	-	-	-	-	-	n/a	n/a

Note: Exceedances shown in bold. Note: Airborne noise predictions have been carried out for all floors of multi-storey buildings.

Table 11-23 Roma Street Station predicted ground-borne noise and vibration levels – station shaft and cavern excavation

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)		
		Continuous vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rock breaking	Roadheading	Rock breaking	Roadheading	Drilling
			Continuous[1]	Intermittent[2]					
A – Wickham Terrace residential	Day	10	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.02	0.02	31	15	22
	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.02	0.02	31	15	22
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.02	0.02	36	15	27
B – Wickham Terrace commercial	Day	10	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.02	0.02	30	15	22
C – Memorial Hospital	Day	2	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.01	0.01	21	10	13
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.01	0.01	26	10	18
D – St Alban Church	24/7	10	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.02	0.02	31	15	22
E – Brisbane Private Hospital	Day	25	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.01	0.01	24	10	16
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.01	0.01	29	10	21
F – Brisbane Dental	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.00	0.01	18	5	10
G – Traders Hotel residential	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	0.02	0.02	28	18	20
	Evening	0.5	$L_{Aeq,adj}$ – 40	$L_{A10,adj}$ – 50	0.02	0.02	28	18	20
	Night	0.5	$L_{Aeq,adj}$ – 35	$L_{Amax,adj}$ – 42	0.02	0.02	33	18	25
H – Old Train Station heritage	Day	2	$L_{Aeq,adj}$ – 55	$L_{A10,adj}$ – 65	0.06	0.24	n/a	n/a	n/a
I – Parkland Boulevard residential	Day	25	$L_{Aeq,adj}$ – 45	$L_{A10,adj}$ – 55	4.31	0.16	**68 (13)**[3]	36	**59 (4)**[3]
I – Parkland Boulevard Residential (Day): predicted effect of working at RL 10 (ie 9m deeper into shaft) or working at RL 19 adjacent to a cut-off trench cut					n/a	n/a	**56 (1)**	n/a	47

Receiver area	Period	Construction sources noise and vibration goals			Predicted ground-borne vibration level (mm/s)		Predicted ground-borne noise level (dBA)		
		Continuous vibration PPV (mm/s)	Internal ground-borne noise (dBA)		Rock breaking	Roadheading	Rock breaking	Roadheading	Drilling
			Continuous[1]	Intermittent[2]					
into approximately 5m of rock									
I – Parkland Boulevard Residential	Evening	0.5	LAeq,adj – 40	LA10,adj – 50	**4.31 (3.81)** [3]	0.16	**68 (18)**[3]	36	**59 (9)**[3]
	Night	0.5	LAeq,adj – 35	LAmax,adj – 42	**4.31 (3.81)** [3]	0.16	**73 (31)**[3]	**36 (1)**[3,4]	**64 (22)**[3]
I – Parkland Boulevard Residential (Night): predicted effect of working at RL 10 (ie 9m deeper into shaft) or working at RL 19 adjacent to a cut-off trench cut into approximately 5m of rock					**0.87 (0.37)** [3]	n/a	**61 (19)**[3]	**n/a**	**52 (10)**[3]
J – Parkland Boulevard Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	6.74	0.25	**74 (19)**[3]	42	**65 (10)**[3]
J – Parkland Boulevard Commercial (Day): predicted effect of working at RL 10 (ie 9m deeper into shaft) or working at RL 19 adjacent to a cut-off trench cut into approximately 5m of rock					n/a	n/a	**62 (7)**[3]	n/a	53

Note 1: Dominant construction noise during shaft excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2: Dominant construction noise during cavern excavation (i.e. roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 3: Exceedances of noise or vibration goal shown in ( ).

Note 4: Compliance with the ground-borne noise goal predicted from RL 0 and below (ie after approximately the top 2m of rock roadheaded from the station cavern).

Table 11-24 Roma Street Station predicted ground-borne vibration and airblast overpressure levels – blasting of station shaft

Receiver area	Period	Blasting criteria		Maximum allowed blast mic to meet noise & vibration goal (kg)			
				Conventional blasting		PCF blasting 1	
		Vibration PPV (mm/s)	Airblast overpressure (dBL Peak)	Vibration	Airblast overpressure	Vibration	Airblast overpressure
A – Wickham Terrace residential	Day	50	132	>100kg	>100kg	>100kg	>100kg
B – Wickham Terrace commercial	Day	50	132	>100kg	>100kg	>100kg	>100kg
C – Memorial Hospital	Day	10	132	>100kg	>100kg	>100kg	>100kg
D – St Alban Church	Day	50	132	>100kg	>100kg	>100kg	>100kg
E – Brisbane Private Hospital	Day	50	132	>100kg	>100kg	>100kg	>100kg
F – Brisbane Dental educational	Day	50	132	>100kg	>100kg	>100kg	>100kg
G – Traders Hotel residential	Day	50	132	>100kg	>100kg	>100kg	>100kg
H – Old Train Station heritage	Day	10	132	11kg	>100kg	9.27kg	>100kg
I – Parkland Boulevard residential	Day	50	132	0.31kg	0.17kg	0.34kg	12kg
J – Parkland Boulevard commercial	Day	50	132	0.31kg	0.17kg	0.34kg	12kg

Note 1: A PCF cartridge mass as little as 10 grams may be practicable.

Airborne noise impacts

The noise modelling results are summarised as follows:

- For worst-case construction Scenarios 1 to 3, the predicted noise emission levels for Roma Street Station works exceed the noise goals at the Parkland Boulevard building adjacent to the site.
- A similar exceedance of the noise goal is anticipated during the operation of rock breakers, particularly during the initial stages of the shaft excavation prior to the construction of acoustic enclosure over the shaft.
- Considering the height of the receiver building and its proximity to the worksite, increasing the 3m high acoustic barrier around the site would have a negligible effect on construction noise emission levels at the Parkland Boulevard receiver building. The airborne noise assessment has recommended a high performance acoustic shed over the Roma Street Station worksite.
- Whilst most activities for Scenario 1 would be expected to occur during the daytime or evening period, where night work is unavoidable (eg due to rail access restrictions) exceedances may occur and suitable mitigation would be required. Mitigation options would include standard mitigation measures, with a particular focus on early notification of affected receivers and careful planning of activities to minimise impacts (such as undertaking noisiest activities as early in the night time period as possible).
- The proposed ‘shoulder period’ or evening noise goals are proposed to enable the Project to progress efficiently and reduce the duration of impacts. The modelling indicates exceedances of the evening airborne noise goal when assessed against the full daytime construction scenario, as such mitigation would be required. Mitigation could include restriction on particularly noisy activities (such as rock breaking), consultation with affected receivers prior to such activities, or increased height of noise hoarding to achieve the required outcomes. Further noise mitigation options are outlined in **section 11.4** and **Chapter 18 – Draft Outline EMP**.

Noise mapping for each modelled scenario (incorporating noise mitigation) is shown in **Figure 11-23** to **Figure 11-26**.

Ground-borne noise and vibration impacts

The predicted ground-borne noise and vibration levels are summarised as follows:

- The ground-borne noise levels for rock breaking during excavation of the Roma Street Station shaft is predicted to significantly exceed the daytime noise goals for both the commercial receivers (by up to 19 dBA) and residential receivers (by up to 18 dBA) inside the adjacent Parkland Boulevard receiver building.
- The night-time noise goal for the residential receivers in this building is also predicted to be significantly exceeded as a result of ground-borne noise from rock breaking.
- A marginal 1 dBA exceedance of the night-time noise goal is predicted inside the Parkland Boulevard apartment building during roadheading of the station cavern.

The close proximity of the Parkland Boulevard receiver building to the rock breaking required for the Project is the reason for the predicted exceedance of the vibration criteria for the night-time period. Notwithstanding this, it is noteworthy that the predicted construction vibration levels at the Parkland Boulevard apartment building is well below the guide values, judged to result in a minimal risk of cosmetic damage, as provided in BS 7385 for heavy reinforced buildings such as the Parkland Boulevard building.

Further to the worst-case predicted ground-borne noise and vibration impacts summarised above, predictions were carried out for the Parkland Boulevard building taking into consideration the effect of increased shaft depth (ie as shaft excavation progresses downwards) or interrupting the direct transmission path of vibrations by creating a cut-off trench along the shaft wall adjacent to the receiver building. Based on these two scenarios, the findings are summarised as follows:

- Ground-borne noise levels from blast hole drilling are predicted to comply with the noise goal during the daytime for both the commercial receiver floor and the closest residential floor.
- Ground-borne noise levels from rockbreaking are predicted to exceed the noise goal during the daytime for the commercial receiver floor (by 7 dBA) and the closest residential floor by 6 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, the first three residential floors of the Parkland Boulevard building are predicted to exceed internal ground-borne noise goals.
- Ground-borne noise levels from blast hole drilling are predicted to exceed the noise goal during the night-time for the closest residential floor by 10 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, the first five residential floors of the Parkland Boulevard building are predicted to exceed the internal ground-borne noise goal.
- Ground-borne noise levels from rockbreaking are predicted to exceed the noise goal during the night-time for the closest residential floor by 19 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, the first ten residential floors of the Parkland Boulevard building are predicted to exceed the internal ground-borne noise goal.

Considering the predicted regenerated noise and vibration exceedances for the Parkland Boulevard apartment building adjacent the site, the following potential mitigation measures have been proposed:

- rock breaking be restricted to the daytime until measurement results achieve compliance with the ground-borne noise goals or agreements reached with residents (eg temporary relocation)
- ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy
- preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted during the night-time period.

Although to a lesser extent than rock breaking, ground-borne noise from blast hole drilling is also predicted to exceed the daytime noise goals for both the commercial and residential receivers inside the adjacent Parkland Boulevard receiver building. The night-time noise goal for residential receivers in this building is predicted to be significantly exceeded as a result of ground-borne noise from drilling.

Should drill and blast be required for this site, reasonable and practicable noise and vibration management measures would include:

- restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals. Otherwise, consult with residents to determine preferred management responses (eg temporarily relocation of residents from affected premises).
- investigate further the benefits from making deep vertical cuts into the rock using rock saws or diamond wire (eg blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting)
- use of latest available blasting technology (eg PCF, double decking etc)
- pre-blasting condition survey of adjacent buildings
- appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site
- monitoring of the blast emissions.

LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-23

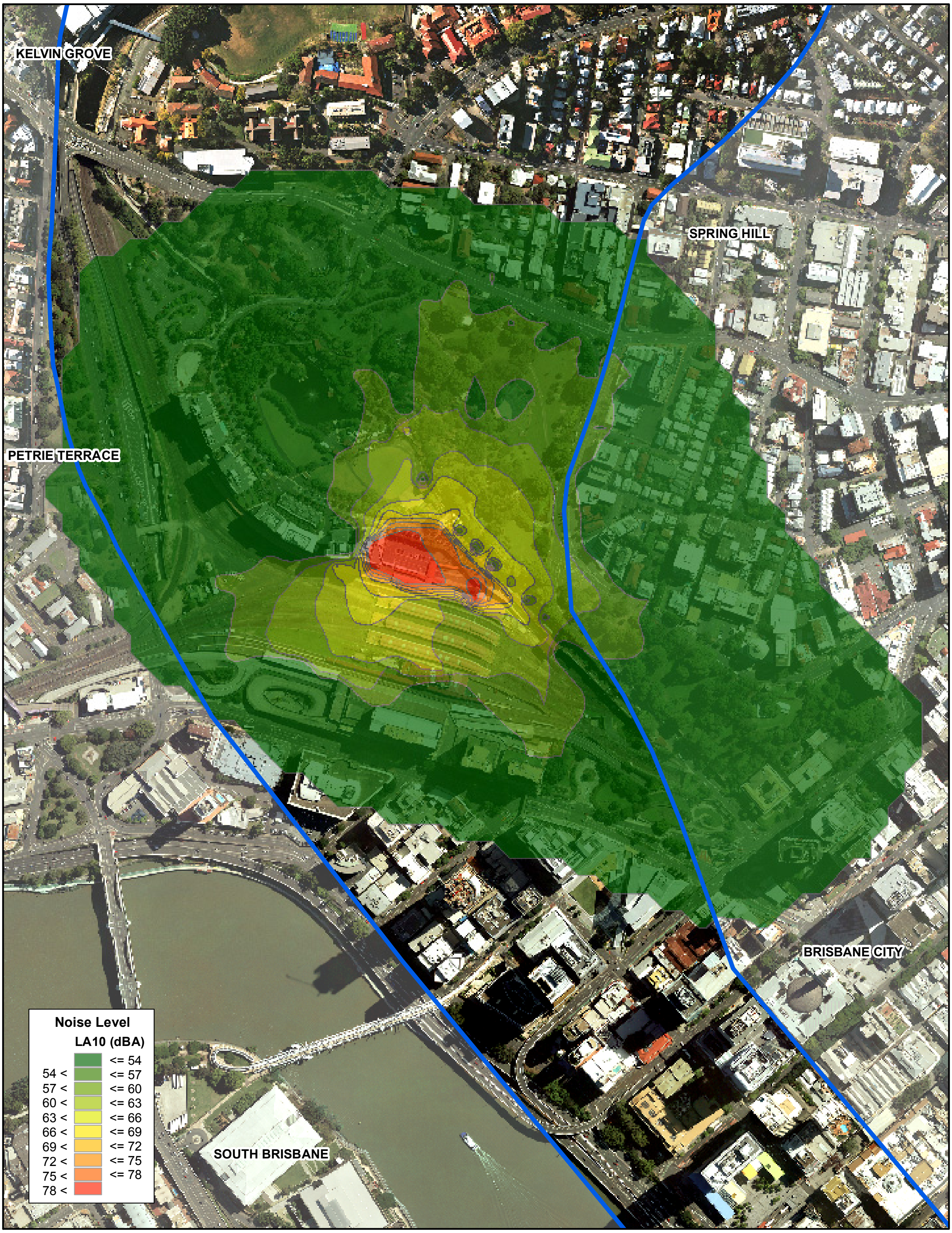
Roma Street Station Scenario 1 - Daytime site establishment

N

0 0.1 0.2
Kilometres
1:6,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-23_RomaStreet_Scenario1.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-24

Roma Street Station Scenario 2 - Daytime piling of station shaft

N

0 0.1 0.2

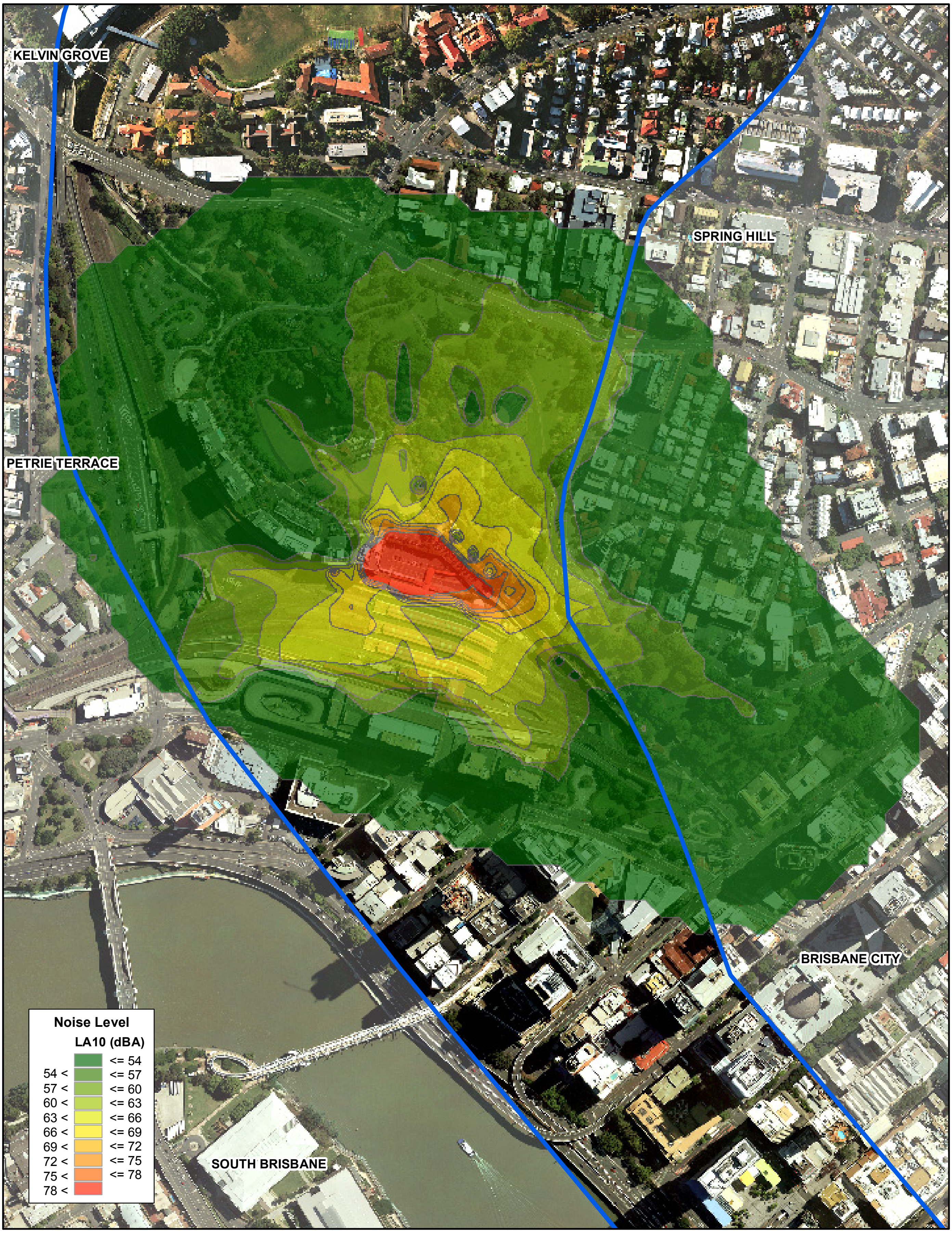
Kilometres

1:6,000 (at A4)

Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-24_RomaStreet_Scenario2.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-25

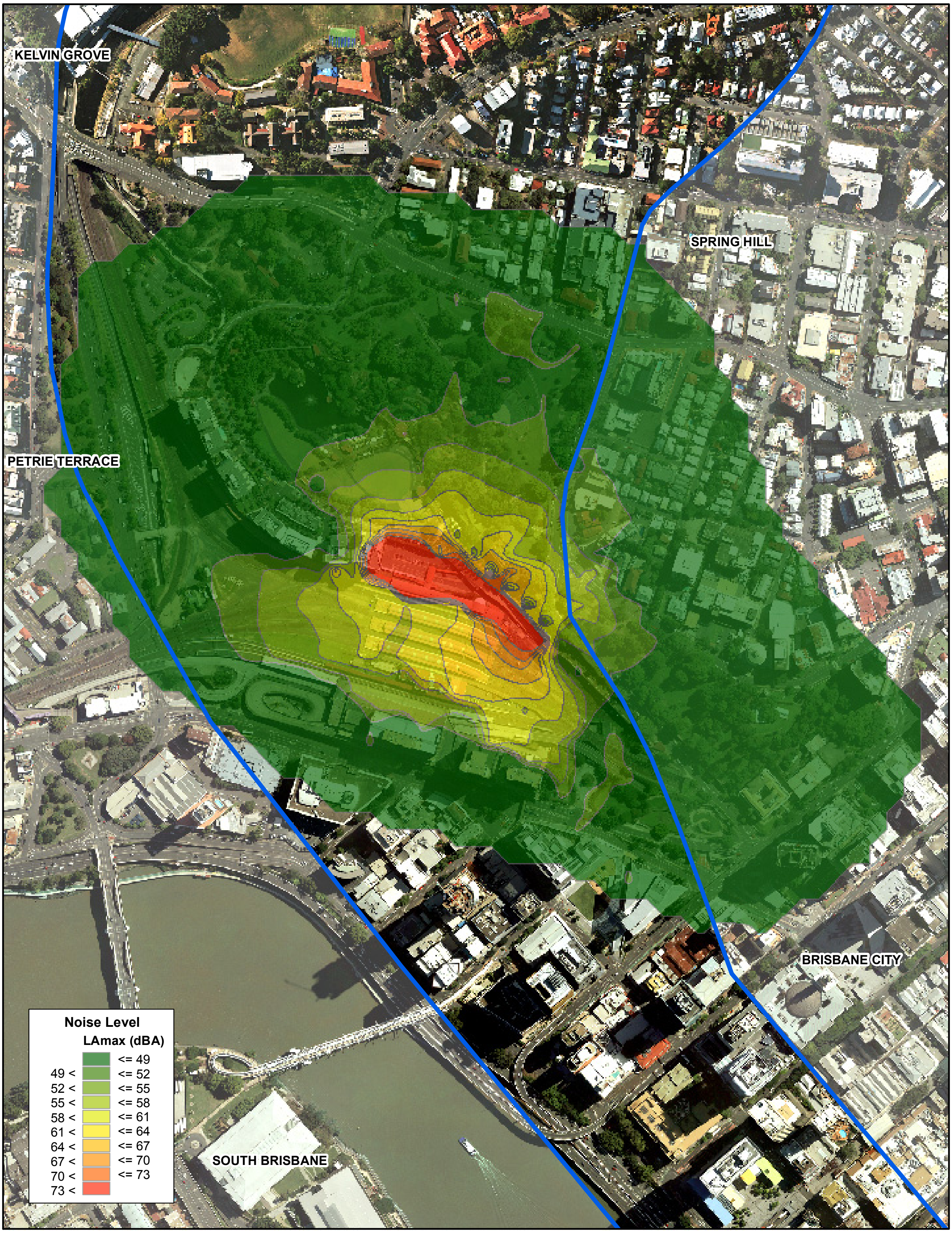
Roma Street Station Scenario 3 - Daytime initial shaft excavation

N

0 0.1 0.2
Kilometres
1:6,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-25_RomaStreet_Scenario3.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-26

Roma Street Station Scenario 4 - Night-time shaft excavation

N

0 0.1 0.2
Kilometres
1:6,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-26_RomaStreet_Scenario4.mxd Date: 12/08/2014

Northern Connection

Nearest sensitive receivers

The nearest noise and/or vibration sensitive receivers to the Northern Connection site are identified in **Table 11-25** with the receiver areas illustrated in **Figure 11-27**.

Table 11-25 Nearest sensitive receivers – Northern Connection

Work site/ excavation	Receiver area	Distance to worksite boundary
Northern Connection	A – Brisbane Girls Grammar School	230m
	B – Gregory Terrace Residential	85m
	C – St Joseph's College	90m
	D – Gregory Terrace Commercial	160m
	E – Centenary Pool	85m
	F – Royal Children's Hospital	100m

Figure 11-27 Northern Connection construction worksite and receiver areas

Note: for the construction site and receiver plans, the following colour codes have been used throughout this Chapter:

- *Pink: Residential*
- *Light blue: Commercial*
- *Yellow: Hospital*
- *Orange: Educational*
- *Green:Park*

Construction scenarios

Construction scenarios were developed for the Northern Connection worksite to enable modelling to be representative of the expected ‘worst case’ noise emissions. These scenarios are:

- Scenario 1 – site establishment and construction of the ICB bridge:
  - duration ~ 3 months
  - dominant noise sources include cranes, trucks, excavators and front end loaders
  - mostly daytime construction and potentially night-time/ weekends for work required over the ICB.
- Scenario 2 – trough excavation and spoil removal:
  - duration ~ 1 month
  - dominant noise sources include rock breakers, excavators and spoil trucks
  - daytime construction only.
- Scenario 3 – completion of the transition structure:
  - duration ~ 10 months
  - dominant noise sources include concrete trucks, cranes and trucks
  - daytime construction only.
- Scenario 4 – TBM disassembly:
  - duration ~ 1 month
  - dominant noise sources include delivery trucks, cranes and power tools
  - daytime construction only.

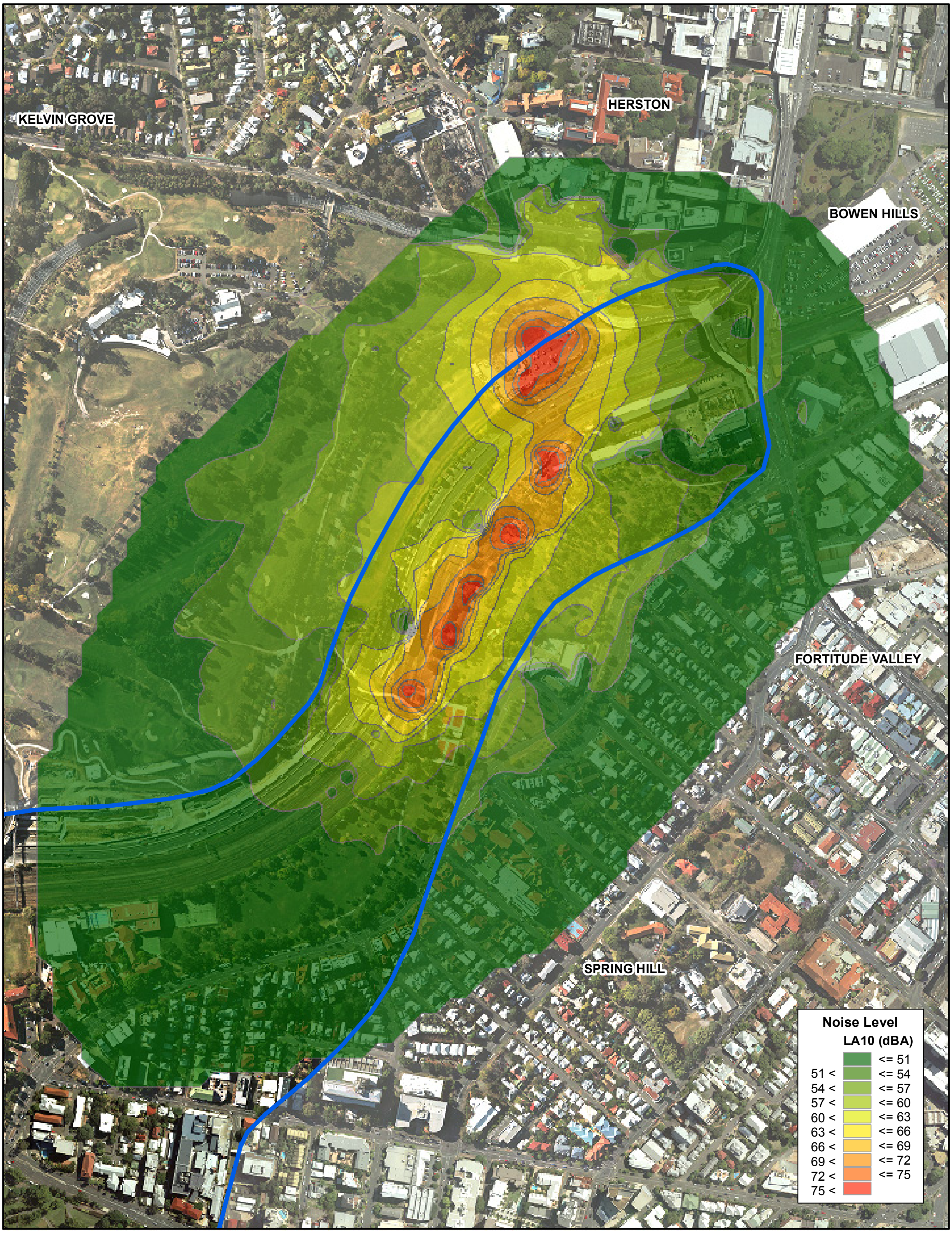
For the above scenarios, typical worst case construction noise levels have been predicted at the nearest noise sensitive receivers.

Noise goal exceedances associated with the predicted construction noise levels are presented in **Table 11-26**.

Table 11-26 Northern Connection predicted worst case construction noise levels

Receiver area	Period	Noise goal (dBA)	Predicted construction noise goal exceedance with nominated level of noise mitigation (dBA)							
			Scenario 1 – Site Est & ICB Bridge		Scenario 2 – trough excavation		Scenario 3 – transition structure		Scenario 4 – TBM disassembly	
			3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding	3m hoarding	6m hoarding
A – Brisbane Girls Grammar School	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	-	-
B – Gregory Terrace Residential	Day	$L_{A10,adj}$ 57	-	-	**4**	-	**2**	-	-	-
C – St Joseph's College	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	-	-
D – Gregory Terrace Commercial	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	-	-
E – Centenary Pool	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	-	-
F – Royal Children's Hospital	Day	$L_{A10,adj}$ 72	-	-	-	-	-	-	-	-

*Note: Exceedances shown in **bold**.*



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-28

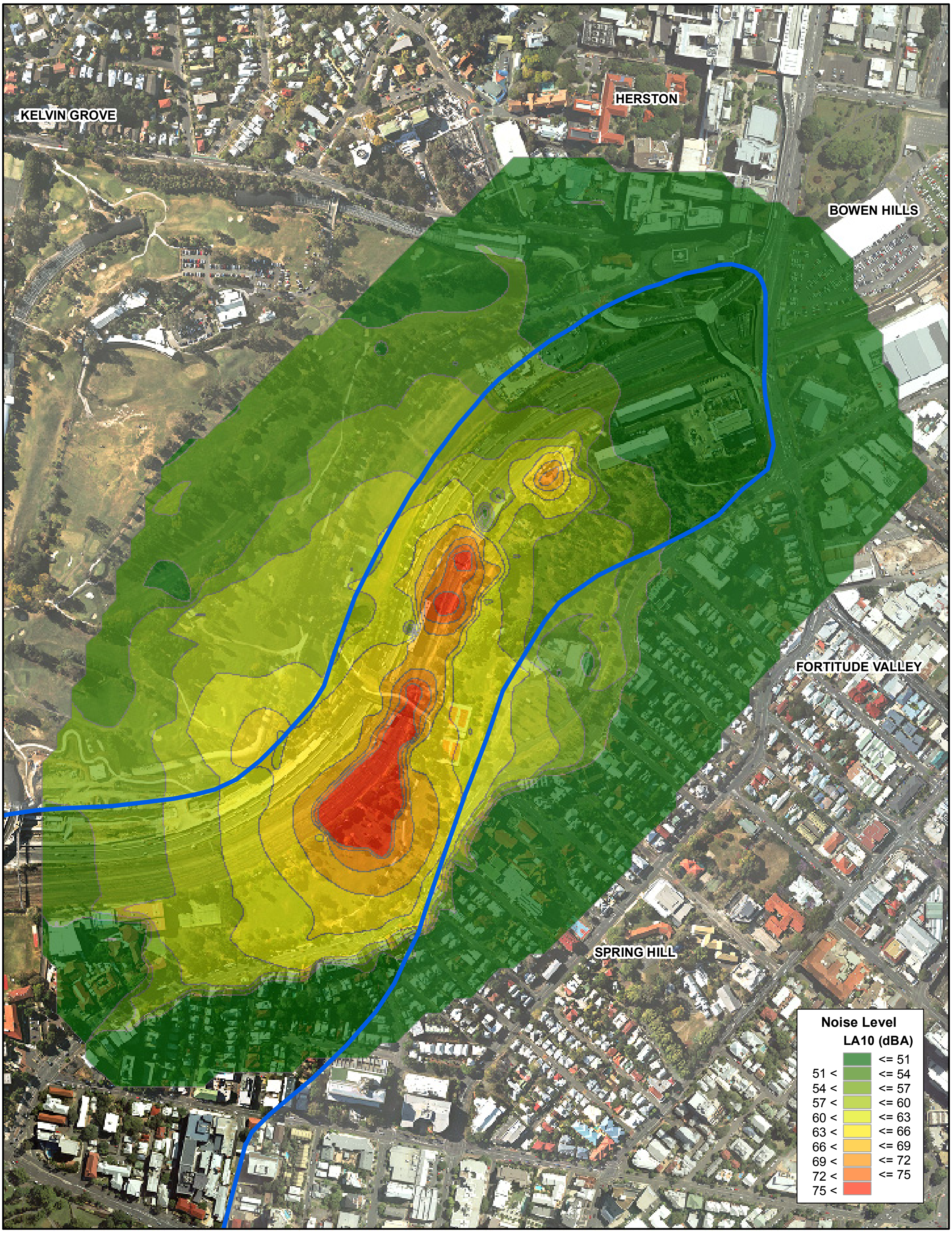
Northern Connection Scenario 1 - Daytime site establishment and ICB bridge construction

N

0 0.1 0.2
Kilometres
1:7,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-28_NorthConnection_Scenario1.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-29

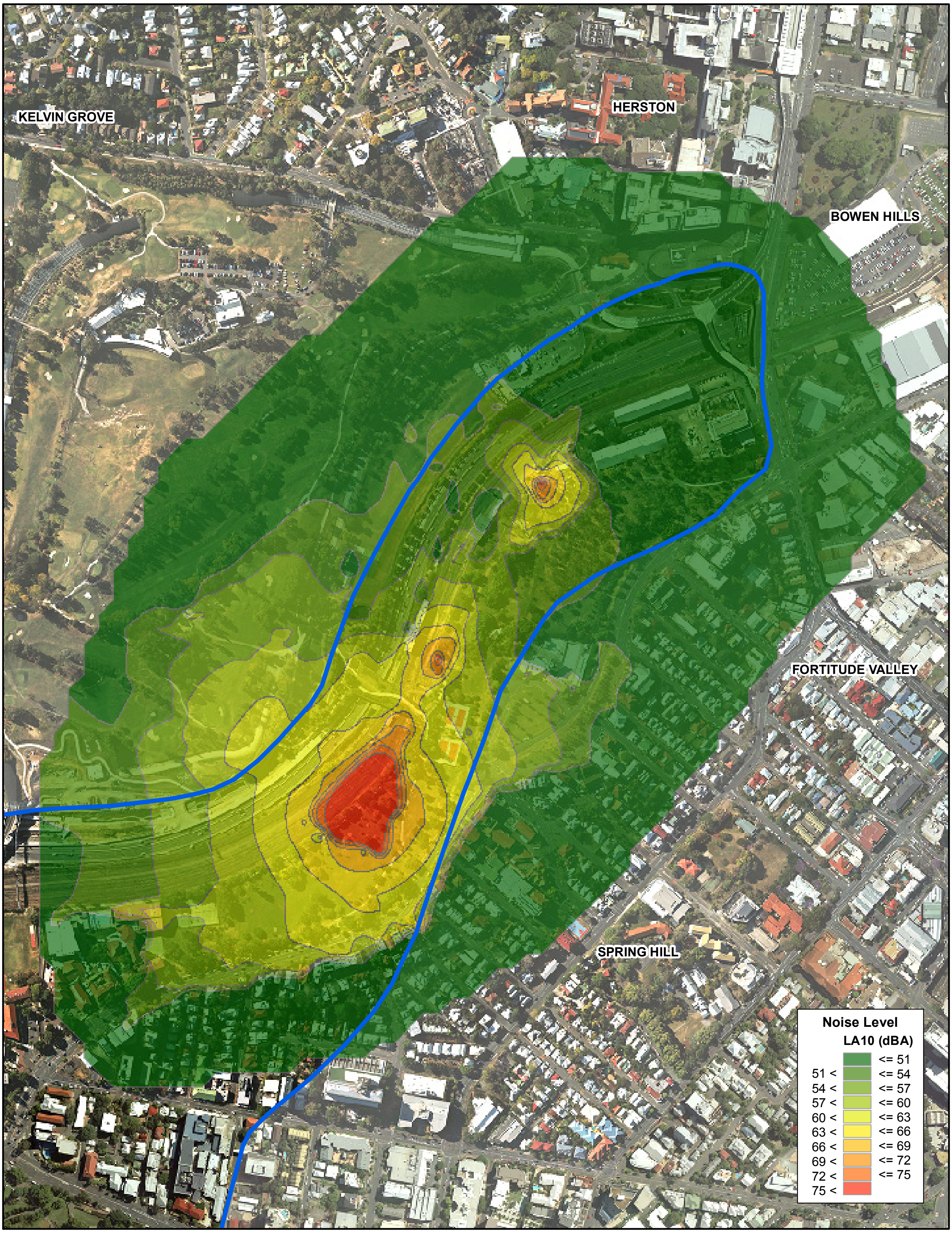
Northern Connection Scenario 2 - Daytime trough excavation

N

0 0.1 0.2
Kilometres
1:7,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-29_NorthConnection_Scenario2.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-30

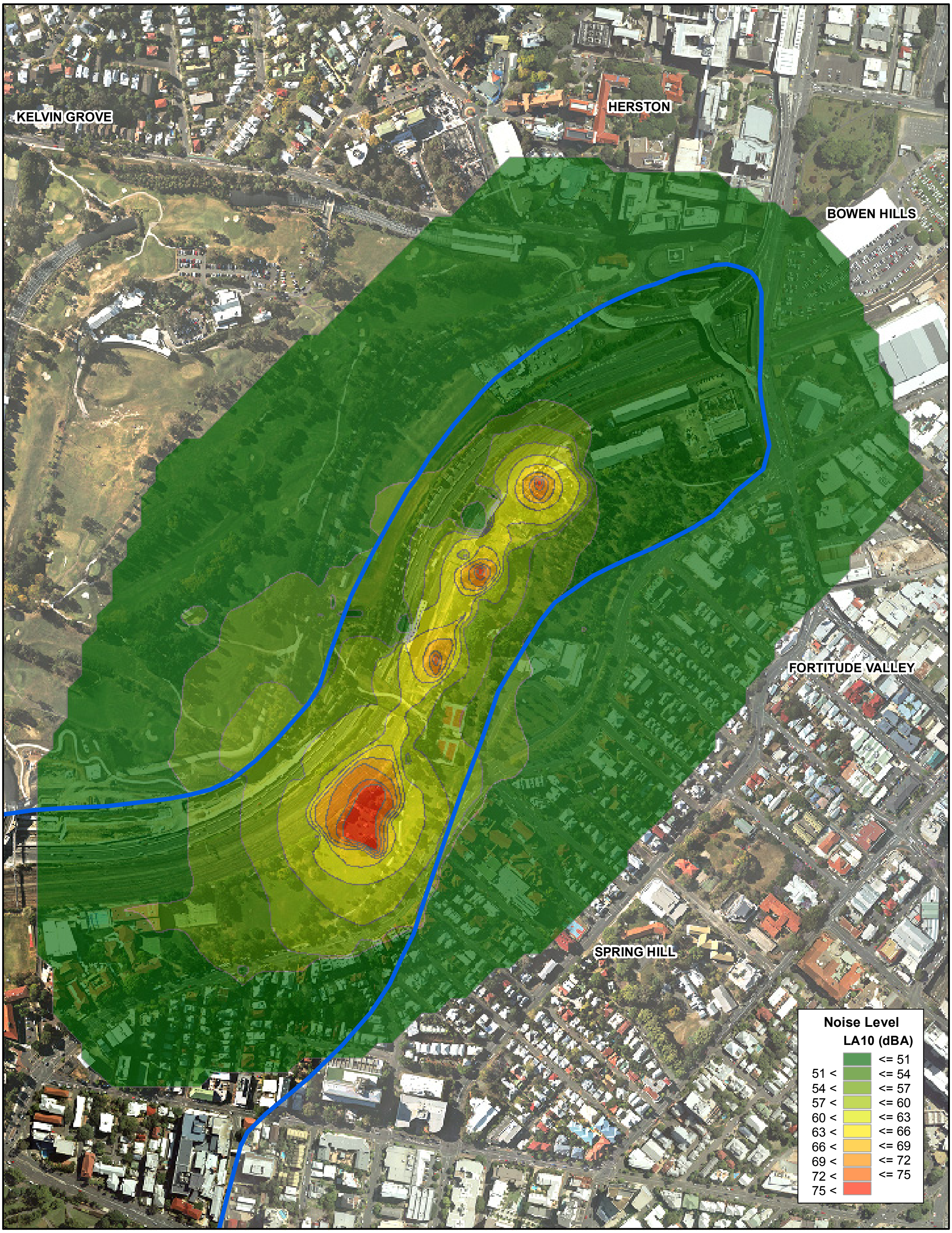
Northern Connection Scenario 3 - Daytime transition structure construction

N

0 0.1 0.2
Kilometres
1:7,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-30_NorthConnection_Scenario3.mxd Date: 12/08/2014



LEGEND

Study corridor

BUS AND TRAIN PROJECT
ENVIRONMENTAL IMPACT STATEMENT

FIGURE 11-31

Northern Connection Scenario 4 - Daytime TBM disassembly

N

0 0.1 0.2
Kilometres
1:7,000 (at A4)
Projection: GDA 1994 MGA56

Aerial Photo: Brisbane City Council 2012

E:\QENV2\Projects\QE06863\Spatial\ArcGIS\Figures\Final_EIS_Figures\11_Noise\Noise_Figure11-31_NorthConnection_Scenario4.mxd Date: 12/08/2014

11.3.2 Surface track construction noise

Track work required for the Project would include the use of typical Queensland Rail rollingstock for delivery of both rail and concrete sleepers to site, specialised plant including switch tampers, mainline tampers, ballast regulators, rail grinder, overhead wiring plant etc.

The majority of rail track for the Project will be located within the tunnel and therefore potential airborne noise impacts from construction of the rail track will be limited to the southern and northern connections. In comparison to the long-term construction of the connections themselves and ongoing tunnelling support, installation of the surface track would be significantly shorter in duration. Also, where the Project rail tracks tie-in to the existing rail network, this work will likely involve weekend and/or night-time rail possessions to enable the works to be carried out safely.

For assessment of airborne noise impacts associated with surface track construction works carried out in isolation from the major project worksite activities, it is relevant to apply QR's Code of Practice. The Code of Practice planning noise levels have been adopted as a guide to assessing the impact of relatively short term construction noise levels from the Project surface track upgrades:

- 65 dBA, assessed as the L_{Aeq} (24hour)
- 87 dBA, assessed as the L_{Amax}.

Surface track construction noise levels at various set back distances are shown in **Table 11-27**. The L_{Amax} parameter is more relevant than the L_{Aeq} (24hour) parameter for assessing the typically transient (ie passby) noise associated with surface track construction work. The calculated noise emission levels do not take into consideration the shielding effects from topography or noise barriers.

Table 11-27 Surface track construction plant noise emissions

Plant Item	Sound Power Level (dBA)	Distance to comply with 87 dBA L_{Amax} (m)	Noise Level at Setback Distance				
			10m	25m	50m	100m	250m
Flat bed truck with crane	110	6	82	74	68	62	54
Ballast truck (rail)	110	6	82	74	68	62	54
Ballast truck (road)	110	6	82	74	68	62	54
Speed swing (360)	114	9	86	78	72	66	58
Locomotive	111	7	83	75	69	63	55
Ballast regulator	122	23	94	86	80	74	66
Tamper	115	11	87	79	73	67	59
Hand held compactor	114	9	86	78	72	66	58
CWR welding plant	93	1	65	57	51	45	37
Cherry Picker	104	3	76	68	62	56	48
Wiring equipment	111	7	83	75	69	63	55
Engineers train	111	7	83	75	69	63	55

A 'footprint' noise contour developed on the basis of typical Queensland Rail track work consisting of a subset of the plant listed in is provided in **Technical Report 3 – Construction noise and vibration**. Similar noise emission levels would prevail across the surface track sections of the project during track construction.

High noise levels (potentially in excess of Queensland Rail's 87 dBA L_{Amax} planning level) may result from track work over small setback distances. In addition to limiting the duration of track construction works near sensitive receivers, all reasonable and feasible noise mitigation measures would need to be applied consistent with the measures listed in Queensland Rail's CoP. These measures include:

- locate mobile plant (eg compressors, generators) as far as practicable away from neighbouring noise-sensitive places
- direct principal noise sources (eg exhausts) away from noise sensitive places as far as possible.
- utilisation of quietest available equipment
- fitting of equipment with effective and properly maintained noise suppression equipment consistent with the requirements of the activity, where possible
- ensure equipment utilised is maintained and operated as per manufacturers' specifications
- minimise the use of warning devices to within operational health and safety constraints
- co-ordination of loading/unloading of material activities to be within standard daytime working hours wherever practicably possible.

Comprehensive advance notice would be provided to potentially affected receivers. Part of the consultation process should include information regarding the scheduled works, duration and monitoring regime.

11.3.3 TBM tunnelling works

Approximately 5km of driven tunnelling will be required for the Project. The tunnel will mainly be constructed using a TBM. The underground stations at Woolloongabba, George Street and Roma Street are likely to be excavated by a combination of rock breaking and drill and blast for the shaft and roadheader for the station caverns. The TBM is proposed to be launched from the Southern Connection site. The TBM is estimated to travel 140m per week on a 24 hour per day basis.

Predicted ground-borne vibration levels from TBM tunnelling works at the nearest receivers along the Project alignment are presented in **Table 11-28**. In some locations, the predicted vibration levels from TBM tunnelling would extend beyond the theoretical threshold for human perception (0.15 mm/s PPV) and could be noticeable (0.5 to 1.0 mm/s PPV) and even 'easily noticeable' (1.0 to 2.0 mm/s PPV) for some people. Predicted vibration from TBM tunnelling would exceed the 'strongly noticeable' level (>2.0 mm/s PPV) only for a few commercial buildings in the CBD. It should be noted that these vibrations will only occur during a relatively short period (less than 1 week for the TBM passby).

Predicted ground-borne noise levels from TBM tunnel excavation at nearest sensitive receivers along the Project alignment are presented in **Table 11-29**.

There are predicted exceedances of the night-time sleep disturbance criterion for residential receivers along the tunnel alignment as well as some daytime exceedance for commercial and educational recievers. It should be noted that these exceedances will only occur during a relatively short period (typically less than 1 week for the TBM passby).

There are several hotels in the Brisbane CBD where because of the size of the building footprint, exceedances of the night-time ground-borne noise goal are predicted to occur for up to ten days. However it should be noted that the noise predictions are for the ground floor and the noise level will be lower higher up in the buildings. As a guide, ground-borne noise levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter.

Table 11-28 Summary of TBM ground-borne vibration levels along the tunnel alignment

Tunnel section	Type of building	Min slant distance to tunnel crown	Indicative maximum vibration level	Possible impact NF – Not felt TP – Threshold of perception BN – Barely noticeable SD – Sleep Disturbance N – Noticeable EN – Easily noticeable SN – Strongly noticeable VSN – Very strongly noticeable	Mitigation options P = pre notification BCS = building condition survey BSS = building sensitive study M = monitoring TR = temporary relocation
Southern Connection to Woolloongabba Station	Residential Commercial Educational Worship Hotel	15m – 133m 29m – 236m 98m – 178m 114m – 153m 76m	0.18 to **1.91** mm/s 0.10 to 1.00 mm/s 0.14 to 0.26 mm/s 0.16 to 0.22 mm/s 0.34 mm/s	EN, SD N TP TP BN	P, M, TR
Woolloongabba Station to George Street Station	Residential Commercial Educational Worship Medical Hotel	31m – 310m 48m – 294m 100m – 176m 28m – 311m 311m 45m – 258m	0.08 to **1.52** mm/s 0.08 to 0.55 mm/s 0.18 to 0.29 mm/s 0.08 to 0.96 mm/s 0.08 mm/s 0.1 to 0.**58** mm/s	EN, SD N BN N NF N, SD	P, M, TR
George Street Station to Roma Street Station	Residential Commercial Educational Worship Medical Hotel	26m – 113m 23m – 313m 70m – 270m 242m – 279m 233m – 250m 25m – 306m	0.39 to **1.87** mm/s 0.13 to 2.13 mm/s[1] 0.16 to 0.65 mm/s 0.15 to 0.17 mm/s 0.17 to 0.18 mm/s 0.14 to **1.97** mm/s	EN, SD SN N TP TP EN, SD	P, M, BCS, TR

Tunnel section	Type of building	Min slant distance to tunnel crown	Indicative maximum vibration level	Possible impact NF – Not felt TP – Threshold of perception BN – Barely noticeable SD – Sleep Disturbance N – Noticeable EN – Easily noticeable SN – Strongly noticeable VSN – Very strongly noticeable	Mitigation options P = pre notification BCS = building condition survey BSS = building sensitive study M = monitoring TR = temporary relocation
Roma Street Station to Northern Connection	Residential Commercial Educational Medical Hotel	29m – 124m 33m – 103m 29m – 159m 86m 48m – 119m	0.09 to **0.90** mm/s 0.20 to 0.80 mm/s 0.07 to 0.44 mm/s 0.29 mm/s 0.10 to **0.54** mm/s	N, SD N BN BN N, SD	P, TR

Note: Ground-borne vibration goals based on BS 7385 (halved values) for cosmetic damage, 2 mm/s for Heritage sites and a residential (and hotel) sleep disturbance of 0.5 mm/s

*Note: Exceedances shown in **bold**.*

Note 1: No heritage listed structures exceeding the 2 mm/s.

Table 11-29 Summary of TBM ground-borne noise levels along the tunnel alignment

Tunnel section	Type of building	Min slant distance to tunnel crown	Indicative maximum ground-borne noise level (dBA)	Possible impact Very Low: <35 dBA Low: 35 – 40 dBA Moderate: 40 to 45 dBA High: > 45 dBA	Mitigation options P = pre notification M = monitoring TR = temporary relocation
Southern Connection to Woolloongabba Station	Residential Commercial Educational Worship Hotel	15m – 133m 29m – 236m 98m – 178m 114m – 153m 76m	29 dBA to **58** dBA 21 dBA to 49 dBA 25 dBA to 33 dBA 27 dBA to 31 dBA **36** dBA	Very low to high Very low to high Very low Very low Low	P, M, TR
Woolloongabba Station to George Street Station	Residential Commercial Educational Worship Medical Hotel	31m – 310m 48m – 294m 100m – 176m 28m – 311m 311m 45m – 258m	18 dBA to **53** dBA 19 dBA to 42 dBA 29 dBA to 33 dBA 18 dBA to 49 dBA 18 dBA 21 dBA to **43** dBA	Very low to high Very low to moderate Very low Very low to high Very low Very low to moderate	P, M, TR
George Street Station to Roma Street Station	Residential Commercial Educational Worship Medical Hotel	26m – 113m 23m – 313m 70m – 270m 242m – 279m 233m – 250m 25m – 306m	36 dBA to **55** dBA 23 dBA to **57** dBA 25 dBA to 42 dBA 24 dBA to 26 dBA 26 dBA to 27 dBA 23 dBA to **56** dBA	Low to high Very low to high Very low to moderate Very low Very low Very low to high	P, M, TR
Roma Street Station to Northern Connection	Residential Commercial Educational Medical Hotel	29m – 124m 33m – 103m 29m – 159m 86m 48m – 119m	23 dBA to **49** dBA 32 dBA to 47 dBA 20 dBA to 42 dBA 35 dBA 24 dBA to **42** dBA	Very low to high Very low to high Very low to high Low Very low to moderate	P, M, TR

Note: Ground-borne noise goals: Commercial = 40 to 50 dBA, Residential night-time = 35 dBA and Educational = 45 dBA

*Note: Exceedances shown in **bold**.*

11.3.4 Low frequency noise impacts

Low frequency noise from the Project will be assessable in accordance with the EHP's draft guideline Assessment of Low Frequency Noise (EHP, 2013). The intent of this guideline is to accurately assess annoyance and discomfort to persons at noise sensitive places. For this assessment, the initial screening test from the guideline has been undertaken to investigate if there is potential for low frequency noise impacts from the driven tunnelling associated with the Project.

Ground-borne noise measurements for a 12m diameter TBM used for the Clem Jones Tunnel project (CLEM7) have been used for the low frequency assessment. All measurement data have been adjusted to account for the Project 15m diameter TBM in accordance with an assumed 10 x log (area) relationship (ie the Project TBM generates 1.9 dBA higher ground-borne noise emission).

The CLEM7 TBM and roadheader measurement results, over slant distances of approximately 45m and 20m respectively (shown in **Table 11-30**), indicate that the 55 dBZ level will be exceeded when tunnelling at close distance (within approximately 180m and 40m from the TBM and roadheader respectively). The results in **Table 11-30** also indicate that the difference between the Linear and A-weighted sound pressure level is more than 15 dB indicating the ground-borne noise is of low frequency character.

Table 11-30 Comparison of linear and A-weighted TBM and roadheader sound pressure levels

Tunnelling plant	12.5Hz	16Hz	20Hz	25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz
TBM linear SPL	60 dB	63 dB	62 dB	69 dB	69 dB	59 dB	55 dB	53 dB	53 dB
TBM A-weighted SPL	-3 dBA	6 dBA	11 dBA	24 dBA	29 dBA	25 dBA	25 dBA	27 dBA	30 dBA
Roadheader linear SPL	55 dB	56 dB	57 dB	55 dB	55 dB	54 dB	53 dB	51 dB	51 dB
Roadheader A-weighted SPL	-8 dBA	-1 dBA	7 dBA	10 dBA	16 dBA	19 dBA	23 dBA	25 dBA	29 dBA
	100Hz	**125Hz**	**160Hz**	**200Hz**	**315Hz**	**400Hz**	**Overall**		
TBM linear SPL	54 dB	51 dB	50 dB	47 dB	39 dB	32 dB	73 dB Linear		
TBM A-weighted SPL	35 dBA	35 dBA	37 dBA	36 dBA	30 dBA	25 dBA	43 dBA		
Roadheader linear SPL	50 dB	48 dB	48 dB	43 dB	38 dB	30 dB	64 dB Linear		
Roadheader A-weighted SPL	31 dBA	32 dBA	35 dBA	32 dBA	29 dBA	23 dBA	40 dBA		

Note – TBM data at slant distance of 45m; Roadheader data at slant distance of 20m

11.3.5 Construction heavy vehicle noise and vibration impact assessment

Selection of a suitable destination for spoil from a large tunnelling project such as this is a complex process requiring consideration of many factors, including potential impacts associated with noise and vibration from heavy vehicle movements. Five potential spoil destinations have been investigated as part of this process including:

- a site accessed from Swanbank Road, Swanbank
- the disused quarry at Pine Mountain Road, Carindale
- Brisbane Airport site at the intersection of Sugarmill Road and Lomandra Drive
- a reclamation area at the Port of Brisbane
- a site at Larapinta (sand pits adjacent to the intersection of Paradise Road and the Logan Motorway).

At this stage, the quantitative assessment of noise and vibration impacts from spoil movements has been limited to the Brisbane Airport, Swanbank Road and Pine Mountain Road sites.

The effect of construction related heavy vehicle traffic on the noise emission from roadways has been assessed by calculating how the additional truck traffic would alter the level of noise emission from roadways using the CoRTN prediction algorithms.

The change in road traffic noise levels was assessed over the following time periods to cover the proposed spoil transfer times from each worksite:

- $L_{A10\ (12hour)}$ for between 6.30am and 6.30pm for Scenario 1 to Pine Mountain Road, Carindale
- $L_{A10\ (18hour)}$ for between 6.00am and 12 midnight for Scenario 2 to Swanbank Road, Swanbank
- $L_{A10\ (1hour)}$ for maximum heavy vehicle movements from Woolloongabba Station or the Southern Connection during any hour between 12 midnight and 6.00am.

For the purpose of this analysis, the $L_{A10\ (12hour)}$ and $L_{A10\ (18hour)}$ is the average L_{A10} traffic noise level between the hours of 6.30am to 6.30pm and 6.00am to 12 midnight respectively.

The assessment of noise impact associated with the Project construction heavy vehicle traffic is summarised in **Table 11-31.** The assessment takes into consideration the cumulative effect of the Project heavy vehicles from multiple worksites on the assessed road segments.

From **Table 11-31** it can be seen that increases in road traffic noise levels of more than 2 dBA have been predicted for Peter Doherty Street and Swanbank Road. The reason for the predicted exceedances is outlined as follows:

- forecast 2016 traffic volumes on Peter Doherty Street are low (ie 24 hour weekday average of 224 vehicles) and therefore the introduction of 57 heavy vehicle movements (ie approximately 5 truck passbys per hour) between 6.30 am and 6.30 pm will potentially be noticeable. It should be noted that subject to the final layout of the Boggo Road site, it would be feasible for spoil trucks to use Peter Doherty Street, Joe Baker Street and Boggo Road as a one way circuit off and back on to Annerley Road. Joe Baker Street and Boggo Road currently have no adjacent residential receivers
- forecast 2016 night-time hourly minimum traffic volumes on Swanbank Road are low (ie 1 hour night-time minimum of 9 vehicles). Consequently, the introduction of (a maximum of) 16 heavy vehicle movements per hour during the night-time period would be noticeable.

For all other assessed road segments, construction heavy vehicles from the Project are anticipated to result in increases to forecast 2016 road traffic noise levels of 2 dBA or less. It is generally recognised in acoustics that changes in noise levels of 2 dBA or less are undetectable to the human ear and therefore negligible.

It is noteworthy that absolute maximum noise levels associated with vehicle passbys would not be altered by the Project construction vehicles, however, the frequency of such events would increase.

Fully loaded trucks travelling on properly maintained public roadways would not generate significant levels (ie able to be clearly felt) of ground vibration at buildings adjacent to spoil routes.

Table 11-31 Effect of construction truck movements on traffic noise levels along spoil routes

Scenario	Road segment	Worksite traffic[1]	Change in road traffic noise level (dBA)		
			$L_{A10(12hr)}$	$L_{A10(18hr)}$	$L_{A10(1hr)}$
Scenario 1 Pine Mountain 6.30 to 18.30 and Swanbank at all other times	ICB	NC	0.0	-	-
	Centenary Highway	NC	0.0	-	-
	Ipswich Motorway	NC	0.0	-	-
	Cunningham Highway	NC	0.0	-	-
	Swanbank Road	NC	0.2	-	-
	Herschell Street	RSS	0.3	-	-
	Riverside Express	RSS	0.0	-	-
	George Street	GSS	0.3	-	-
	Leopard Street	WS	0.1	-	-
	Vulture Street	WS, RSS, GSS	0.1	-	-
	Main Street	WS, RSS, GSS	0.1	-	-
	Ipswich Road	WS, RSS, GSS	0.1	-	-
	O'Keefe Street	SC	2.3	-	-
	O'Keefe Street	WS, RSS, GSS, SC	0.4	-	-
	Peter Doherty Street	BR	**3.5**	-	-
	Annerley Road	BR	0.2	-	-
	Cornwall Street	BR	0.3	-	-
	Logan Road	BR	0.3	-	-
	Old Cleveland Road	WS, RSS, GSS, SC, BR	0.2	-	-
	Creek Road	WS, RSS, GSS, SC, BR	0.3	-	-
	Pine Mountain Road	WS, RSS, GSS, SC, BR	0.5	-	-
Scenario 2 Swanbank	ICB	NP	-	0.0	-
	George Street	GSS	-	0.3	-
	Riverside Expressway	GSS	-	0.0	-
	Milton Road	RSS, GSS	-	0.0	-
	Centenary Highway	NC, RSS, GSS	-	0.0	-
	Leopard Street	WS	-	0.1	0.8
	Vulture Street	WS	-	0.2	0.8
	Main Street	WS	-	0.1	0.5
	Peter Doherty Street	BR	-	**3.0**	-
	Annerley Road	BR	-	0.2	-
	Cornwall Street	BR	-	0.2	-
	O'Keefe Street [2]	SC	-	2.1	-
	Ipswich Road	WS, SC, BR	-	0.1	0.3
	Ipswich Motorway	NC, RSS, GSS, WS, SC, BR	-	0.1	0.4

Scenario	Road segment	Worksite traffic[1]	Change in road traffic noise level (dBA)		
			$L_{A10(12hr)}$	$L_{A10(18hr)}$	$L_{A10(1hr)}$
	Cunningham Highway	NC, RSS, GSS, WS, SC, BR	-	0.2	1.2
	Swanbank Road	NC, RSS, GSS, WS, SC, BR	-	1.0	**6.6**
Scenario 3 Brisbane Airport	Peter Doherty Street	BR	-	**3.0**	-
	Annerley Road	BR	-	0.2	-
	Cornwall Street	BR	-	0.2	-
	O'Keefe Street [2]	SC	-	2.1	-
	Ipswich Road	WS, SC, BR	-	0.1	0.3
	Leopard Street	WS	-	0.1	0.8
	Vulture Street	WS	-	0.2	0.8
	Main Street	WS	-	0.1	0.5
	George Street	GSS	-	0.3	-
	Riverside Expressway	GSS	-	0.0	-
	ICB		-	0.0	0.0
	East-West Arterial Road	NC,RSS,GSS,WS,SC,BR	-	0.2	0.2

Note 1 – Abbreviation code: NC = Northern Connection, RSS = Roma Street Station, GSS = George Street Station, WS = Woolloongabba Station, SC = Southern Connection and BR = Boggo Road

11.3.6 Operations

The following discusses the potential impact from operational bus and train noise and vibration on the existing environment.

Ground-borne vibration assessment

Railway vibration is generated by dynamic forces at the wheel-rail interface and occurs, to some degree, even with continuously welded rail and smooth wheel and rail surfaces (due to the moving loads, finite roughness and elastic deformation of the surfaces). Higher vibration levels occur in the presence of rail and wheel surface irregularities.

This vibration propagates via the rail mounts into the ground or track support structures. It then travels through the ground or structures and in some circumstances may be felt as vibration by the occupants of buildings. If the levels of vibration are sufficiently high (ie in buildings very close to rail tracks), then rattling or visible movement of loose objects (crockery, plants, etc) may also occur.

For ground-borne noise and vibration modelling, there are currently no commercially available modelling software packages. The modelling for the Project was therefore carried out using a modelling process developed by SLR Consulting Pty Ltd for the core calculations. The algorithms incorporated into the model are well documented in authoritative references and are widely used within the acoustical consulting profession, both in Australia and internationally.

For more detail on the modelling approach refer to **Technical Report 4 - Operational noise and vibration**.

This model was validated using measurement data collected from the Epping to Chatswood Railway Line (ECRL) in Sydney. The ECRL and the Project share similar design characteristics in relation to a circular tunnel cross-section embedded in rock and similar slab track design. Where differences exist between the ECRL and the Project (eg tunnel dimensions, ground conditions, rolling stock and track/rolling stock maintenance practices), these have been accounted for in the ground-borne noise and vibration predictions. To ensure ground conditions along the Project alignment were taken into account, borehole vibration testing at three locations was undertaken to determine the ground vibration attenuation versus distance characteristics.

The modelling approach was based on the guidelines contained in International Standard ISO 14837-1 2005 'Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General Guidance', taking into account the source vibration levels, the propagation in the ground between the source and receiver and the vibration propagation within the building.

For most new railway lines, the standard track design usually incorporates resilient rail fasteners to reduce the dynamic forces that occur at the wheel-rail interface. This resilience also serves to provide some isolation of ground-borne vibration, which in turn reduces the ground-borne noise levels in buildings near the railway tunnel.

For the Project, three trackforms have been proposed to achieve the ground-borne vibration and noise objectives. These comprise a 'Direct Fixation' trackform incorporating standard 'stiff' rail fasteners (ie not specifically designed for vibration isolation – merely track durability), 'Resilient' trackform incorporating moderately resilient rail fasteners and 'Highly Resilient' trackform incorporating highly resilient rail fasteners. The latter two types are specifically designed to reduce both ground-borne vibration and ground-borne noise propagation.

A summary of the predicted ground-borne vibration levels for buildings located above or near the proposed rail tunnel alignment is presented in Table **11-32**.

Compliance with the ground-borne vibration goals is predicted for all sensitive receiver locations above or near the proposed alignments.

The predicted ground-borne vibration levels for the electron microscope at the Ecoscience building complies with the instrument specific vibration criteria supplied by the tenant.

The PA Hospital, QUT at 2 George Street and St Andrew's War Memorial Hospital have been identified as having special vibration sensitive equipment (ie electron microscope or Magnetic Resonance Imaging (MRI) systems). For the purpose of assessment, it has been assumed all nearby research and medical facilities may contain vibration sensitive equipment. All identified special receivers have predicted ground-borne vibration velocity below the limit of 0.013 Mm/s (82 dBv) per octave band.

The predicted vibration levels associated with train operations in the tunnels are less than 0.144 mm/s at any buildings near the tunnels and therefore the risk to any heritage buildings is negligible. Similarly, the potential for damage to other key utilities/ infrastructure is also negligible on the basis that the tunnel wall vibration levels are anticipated to be approximately 0.1 mm/s (100 dBV).

Table 11-32 Summary of predicted ground-borne vibration levels (reference project trackform)

Chainage (km)	Type of building	Min. slant distance to track level	Predicted ground-borne vibration level (mm/s)[1]	Residential night-time vibration goal (mm/s)[1,2]	Reference design
0.37 – 1.8 Southern Connection to Woolloongabba Station	Residential Commercial Educational Worship Hotel	23m – 134m 40m – 234m 98m – 176m 116m – 154m 79m	0.002 to 0.048 mm/s 0.001 to 0.018 mm/s 0.002 to 0.002 mm/s 0.001 to 0.002 mm/s 0.005 mm/s	0.2 mm/s	Direct fixation rail fasteners
1.8 – 3.55 Woolloongabba Station to George Street Station	Residential Commercial Educational Worship Medical Hotel	43m – 310m 42m – 293m 103m – 173m 39m – 312m 311m 54m – 251m	0.00 to 0.019 mm/s 0.00 to 0.012 mm/s 0.001 to 0.003 mm/s 0.00 to 0.015 mm/s 0.00 mm/s 0.00 to 0.008 mm/s	0.2 mm/s	Direct fixation rail fasteners
3.55 – 4.8 George Street Station to Roma Street Station	Residential Commercial Educational Worship Medical Hotel	37m – 97m 33m – 311m 67m – 267m 241m – 278m 232m – 249m 35m – 304m	0.003 to 0.043 mm/s 0.00 to 0.041 mm/s 0.00 to 0.003 mm/s 0.001 to 0.001 mm/s 0.001 to 0.001 mm/s 0.00 to 0.050 mm/s	0.2 mm/s	Direct fixation rail fasteners
4.8 – 6.05 Roma Street Station to Northern Connection	Residential Commercial Educational Medical Hotel	41m – 124m 40m – 131m 41m – 161m 88m 58m – 119m	0.001 to 0.020 mm/s 0.002 to 0.015 mm/s 0.002 to 0.020 mm/s 0.005 mm/s 0.003 to 0.012 mm/s	0.2 mm/s	Direct fixation rail fasteners

Note 1: The predicted vibration levels and vibration goal are based on the maximum 1 second rms vibration level, not to be exceeded by more than 5% of train passbys.

Note 2: The residential night-time vibration goal is the most stringent operational vibration goal, except at a few special receivers with potentially highly vibration sensitive equipment.

Ground-borne noise assessment

Train noise in buildings adjacent to rail tunnels is predominantly caused by the transmission of ground-borne vibration rather than the direct transmission of noise through the air. The vibration is initially generated by wheel/rail interaction (as described above) and is transmitted from the trackbed, through the tunnel structure, via the ground and into the adjacent building structures. After entering a building, this vibration causes the walls and floors to vibrate faintly and hence to radiate noise (commonly termed ‘ground-borne noise’).

If it is of sufficient magnitude to be audible, this noise has a low frequency rumbling character, which increases and decreases in level as a train approaches and departs the site. This type of noise can be commonly experienced in buildings adjacent to urban underground rail systems.

The ground-borne noise modelling methodology followed the same calculation procedure discussed in the ground-borne vibration modelling section, with the addition of two final steps to account for the conversion of vibration in a building into noise. For more detail on the modelling approach refer to **Technical Report 4 - Operational noise and vibration**.

The ground-borne noise predictions for the sensitive receivers along the tunnel alignment (with the Reference Project trackform configuration) are provided in Table **11**-**33**.

Potential exceedences are shown in **bold**.

Table 11-33 Summary of predicted ground-borne noise levels (direct fixation trackform)

Chainage (km)	Type of building	Min. slant distance to track level	Predicted ground-borne noise level (dBA)	Ground-borne noise goal (dBA)	Base case mitigation measure
0.37 – 1.8 Southern Connection to Woolloongabba Station	Residential Commercial Educational Worship Hotel	23m – 134m 40m – 234m 98m – 176m 116m – 154m 79m	<10 dBA to **46 dBA** <10 dBA to 36 dBA <10 dBA to 11 dBA <10 dBA 15 dBA	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Direct fixation rail fasteners
1.8 – 3.55 Woolloongabba Station to George Street Station	Residential Commercial Educational Worship Medical Hotel	43m – 310m 42m – 293m 103m – 173m 39m – 312m 311m 54m – 251m	<10 dBA to 33 dBA <10 dBA to 29 dBA <10 dBA <10 dBA to 32 dBA <10 dBA <10 dBA to 24 dBA	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Direct fixation rail fasteners
3.55 – 4.8 George Street Station to Roma Street Station	Residential Commercial Educational Worship Medical Hotel	37m – 97m 33m – 311m 67m – 267m 241m – 278m 232m – 249m 35m – 304m	<10dBA to **42dBA** <10dBA to **42dBA** <10dBA <10dBA <10dBA 10dBA to **43dBA**	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Direct fixation rail fasteners
4.8 – 6.05 Roma Street Station to Northern Connection	Residential Commercial Educational Medical Hotel	41m – 124m 40m – 131m 41m – 161m 88m 58m – 119m	<10dBA to 35dBA <10dBA to 33dBA <10dBA to 35dBA 10dBA <10dBA to 25dBA	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Direct fixation rail fasteners

Note: Predictions are for the LAmax,Slow noise level and refers to the 95th percentile train passby event. The ground-borne noise level of the 'average' or median train event would be approximately 3 dB lower than the 95th percentile event.

The predicted ground-borne noise levels indicate that there are three track sections where there are residential receivers exceeding the night-time ground-borne noise goal of 35 dBA for the direct fixation trackform.

The assessment concluded that the track forms contained in **Table 11-34** are required to achieve compliance with the nominated goals.

Table 11-34 Proposed trackforms to comply with the ground-borne noise goals

Down track			Up track		
Chainage (km)		Trackform	Chainage (km)		Trackform
From	To		From	To	
0	0.35	Direct fixation	0	0.79	Direct fixation
0.35	0.45	Resilient	0.79	1.245	Resilient
0.45	0.78	Direct fixation	1.245	4.43	Direct fixation
0.78	1.25	Resilient	4.43	4.64	Resilient
1.25	4.41	Direct fixation	4.64	6.735	Direct fixation
4.41	4.63	Resilient			
4.63	6.725	Direct fixation			

*Note 1: The direct fixation, resilient and highly resilient trackforms are specified in **Table 11-33**.*

A summary of the predicted ground-borne noise levels with the proposed trackform configuration including the additional 'Resilient' trackform discussed above is shown in **Table 11-35**. In total, 790m of resilient rail fasteners for the Down Track and 665m of resilient rail fasteners for the Up Track are proposed to achieve compliance with the ground-borne noise goals at all sensitive receiver locations. Compliance with the ground-borne noise goals is achieved at all sensitive receivers with the proposed 'Resilient' trackform.

Table 11-35 Summary of predicted ground-borne noise levels (proposed trackform)

Chainage (km)	Type of building	Min. slant distance to track level	Predicted ground-borne noise level (dBA)	Ground-borne noise goal (dBA)	Proposed mitigation measure1
0.37 – 1.8 Southern Connection to Woolloongabba Station	Residential Commercial Educational Worship Hotel	23m – 134m 40m – 234m 98m – 176m 116m – 154m 79m	<10 dBA to 35 dBA <10 dBA to 36 dBA <10 dBA <10 dBA 15 dBA	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Resilient rail fasteners (chainage 0.35 – 0.45km, only for down track) and (chainage 0.78 – 1.25km, both tracks) Direct fixation rail fasteners (elsewhere)
1.8 – 3.55 Woolloongabba Station to George Street Station	Residential Commercial Educational Worship Medical Hotel	43m – 310m 42m – 293m 103m – 173m 39m – 312m 311m 54m – 251m	<10 dBA to 33 dBA <10 dBA to 29 dBA <10 dBA <10 dBA to 32 dBA <10 dBA <10 dBA to 24 dBA	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Direct fixation rail fasteners
3.55 – 4.8 George Street Station to Roma Street Station	Residential Commercial Educational Worship Medical Hotel	37m – 97m 33m – 311m 67m – 267m 241m – 278m 232m – 249m 35 m – 304m	<10 dBA to 34 dBA <10 dBA to 37 dBA <10 dBA <10 dBA <10 dBA 10 dBA to 35 dBA	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Resilient rail fasteners (chainage 4.41 – 4.63km, both tracks) Direct fixation rail fasteners (elsewhere)
4.8 – 6.05 Roma Street Station to Northern Connection	Residential Commercial Educational Medical Hotel	41m – 124m 40m – 131m 41m – 161m 88m 58m – 119m	<10dBA to 35 dBA <10dBA to 33 dBA <10dBA to 35 dBA 10dBA <10dBA to 25 dBA	35 dBA (night-time) 40 dBA 40 dBA 40 dBA 35 dBA (night-time)	Direct fixation rail fasteners

Note: The $L_{Amax,Slow}$ noise level refers to the 95th percentile train passby event. The ground-borne noise level of the 'average' or median train event would typically be approximately 3 dB lower than the 95th percentile event.

*Note 1: The extent of the proposed mitigation measures (ie trackforms) is detailed in **Table 11-34**.*

Airborne noise assessment – train operations

Methodology

A SoundPLAN (version 6.5) computer noise model has been used for the prediction of noise levels at sensitive receivers. The noise model includes topography, buildings, number of trains and calibrated noise emission levels (against measurements), rail movements and the location of noise sensitive receivers.

Train noise source data for the existing fleet have been taken from Queensland Rail's standard table of noise emissions. All suburban trains were modelled as the proposed new 7-car equivalent passenger trains. These new trains have similar specifications to the existing Electric Multiple Unit (EMU) fleet, therefore the noise emission levels were extrapolated from those for a 6-car EMU citytrain.

A 'typical-maximum' speed profile for passenger trains was applied to all passenger trains within the study corridor. Acceleration and deceleration rates (for approach to and departure from stations) have been subject to initial estimates as no data was available for the proposed new 7-car equivalent passenger trains.

In the absence of any data, all freight traffic was modelled as double-header locomotives (current generation) with 1,500m consist. All freight movements were assumed to travel at a constant speed of 60km/h and the locomotives were assumed to be at a notch setting of 6.

Portal noise emissions have been modelled as a vertical area noise source across the tunnel portal openings. A sound power level has been assigned to these portal noise sources based on in tunnel noise measurements in rail tunnels in Sydney.

The predicted noise levels include contributions from the through traffic and tunnel portals and include shielding from any existing noise barriers. All predicted levels include a +3.0 dBA facade correction.

Portals

At the Northern Connection, all sensitive locations are predicted to comply with Queensland Rail's operational planning levels in 2031. Therefore, no mitigation measures are required in this section.

At the Southern Connection, 19 sensitive locations are predicted to exceed Queensland Rail's operational planning levels in 2031. Noise barriers have been designed (as far as practicable – eg noise barrier heights have been limited to 6m) for these locations to target compliance with Queensland Rail's operational planning levels.

Upgrading the existing Railway Terrace noise barrier to a height of 6m provides a significant noise reduction at most facades. However, this noise barrier would not achieve compliance with Queensland Rail's operational planning levels at all residences. This noise barrier in front of the ESA Village building at the northern end is not proposed to be extended as the building's height would make any noise barrier ineffective. The total area of the upgraded noise barrier is approximately 1,919 m^2.

Due to the current Queensland Rail's policy to not build noise barriers adjacent to existing train stations for safety reasons, there are seven additional sensitive receivers adjacent to the Dutton Park (5) and Park Road (2) Stations exceeding Queensland Rail's operational planning levels. Rail noise levels of up to 77 dBA $L_{Aeq(24hour)}$ and 97 dBA L_{Amax} are predicted at these residences (directly adjacent station platforms), being an exceedance of 12 dBA and 10 dBA respectively.

During the detailed design phase, noise barriers will need to be designed in consultation with Queensland Rail to take into account all aspects of noise, visual amenity and safety.

Furthermore, it is recommended that the following actions take place at the detailed design phase:

- review recent Development Applications (DAs) to ensure existing rail noise levels are adequately addressed at the time of development (eg through the use of upgraded building facades where required)
- undertake further detailed modelling to include a more accurate composition of passenger trains on surface tracks (eg mix of SMU and EMU, mix of 3-car, 6-car and 7-car sets), instead of the current conservative modelling assumption that all suburban train movements are EMU trains)
- obtain the (external) passby noise level specifications for the new-generation rolling stock passenger trains and incorporate this into the detailed design stage modelling.

As part of Queensland Rail's ongoing community consultation process, Queensland Rail has committed to progressively introduce quieter 'new generation' freight locomotives. The noise reduction with the introduction of the quieter freight locomotives is expected to be 7 to 8 dBA. This is another aspect that is recommended to be considered in the detailed design phase.

Rail network between portals

The railway tracks between the portals in Dutton Park and Victoria Park will not be changed as part of the Project. However, the Project will free up capacity on these surface tracks by redirecting a significant portion of the passenger rail operation through the Project's railway tunnels.

The predicted noise levels indicate that the $L_{Aeq\ (24hour)}$ noise emission levels increase up to 2.5 dBA due to the change in passenger train traffic for 2031 at the Northern Connection.

The $L_{Aeq\ (24hour)}$ noise emission levels decrease -0.7 dBA due to the change in passenger train traffic for the year 2031 at the Southern Connection.

It is generally recognised in acoustics that changes in noise levels of 2 dBA or less are undetectable to the human ear and therefore negligible impacts are predicted for the general rail network (given absolute noise levels in the Northern Connection area are below Queensland Rail's noise limits).

The maximum noise level during train passbys will not change due to the change in passenger and freight train numbers. There would only be a change to the number of train passby events. In fact over time it is likely that the maximum noise levels from train passbys would be reduced as new generation rollingstock are progressively introduced into Queensland Rail's operation.

Airborne noise assessment – bus operations

Methodology

In order to predict both L_{Aeq} and L_{Amax} noise levels using the SoundPLAN software, the Nordic Rail Model was utilised, calibrated to the specific noise emission characteristics of BCC buses, to predict noise levels associated with the proposed busway corridor. Noise modelling of the section of alignment adjoining the ICB (multi-modal) was carried out using the UK Department of Transport, 'Calculation of Road Traffic Noise' (CORTN 1988) algorithms incorporated in the SoundPLAN 7.2 noise software.

The modelling allows for traffic volume and mix, type of road surface, vehicle speed, road gradient, reflections off building surfaces, ground absorption and shielding from ground topography and physical noise barriers. In addition, calculations have also taken into consideration the contribution to overall traffic noise levels from the tunnel portals. All predicted levels include a +2.5 dBA facade correction.

Noise emissions from the tunnel portals have been modelled as vertical area noise sources across the tunnel portal openings. The noise predictions for the portal noise model has then been added logarithmically to the noise predictions for the standard Kilde traffic noise predictions to generate overall noise levels for the combination of portals and busways.

Results and mitigation

There are three educational buildings (St Joseph's College buildings) and two health buildings (RBH QIMR and RBH Surgical Building) which are predicted to exceed the TMR Code of Practice 65 dBA $L_{A10\ (1hour)}$ noise criterion in the Northern Connection area. Also at the Northern Connection, one health building (RBH Block 7) is predicted to exceed the DTMR Code of Practice 69dBA L_{Amax} noise criteria for upgraded busway.

For the Southern Connection, all noise sensitive receivers are predicted to meet the relevant noise criteria.

Noise mitigation has not been recommended at any of the six noise sensitive receivers which exceed the applicable noise goals. Noise modelling predictions have found that all six exceedances listed above are contributable to the existing road networks (ICB and Northern Busway) and not the Project. Noise levels at the six locations from only the Project (not including existing roads) would be significantly below the applicable criteria (at least 15 dBA below the relevant criteria).

There are three proposed bus layovers for the Project. One is to be located at the Southern Connection adjacent the Princess Alexandra Busway Station at Kent Street. Two others are located at the Northern Connection, one to east and another to the immediate west of the ICB. No noise sensitive receptors were identified surrounding the bus layovers. As such no further assessment of the bus layover noise emissions was required.

Airborne noise assessment – mechanical plant and ancillary facilities

Two feeder stations are proposed to service the train operations for the Project. The locations of the feeder stations are near the Northern Connection in the Normanby Yard and near the southern portal at Woolloongabba adjacent to Kent Street. Based on the location of the feeder stations and assuming a Sound Power Level according to AS 2374.6-1994 and a 20 dBA facade reduction for the enclosures, both feeder stations are predicted to comply with the Project noise goals.

The modelling of the mechanical services airborne noise presented in this assessment is based on the preliminary plant locations which may still be subject to change during detailed design. Specific equipment is also not defined at this stage and the expected noise levels can therefore not be predicted with certainty. As such, the maximum total allowable emitted sound power at each ventilation outlet and station ancillary facility has been calculated, specifying the acoustic emission limit for all equipment (combined operation) at each location. These results are shown in **Table 11-36.**

Mitigation measures are likely to be required for some station mechanical plant and ventilation outlets in order to comply with the Project noise goals. Mitigation measures that may need to be considered at some locations include appropriate equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

The locations and designs of the mechanical plants, air exhausts and intakes and tunnel ventilation for the Project will need to be assessed in more detail during future design phases.

Table 11-36 Ventilation outlets and station ancillary facilities - maximum acceptable noise emissions

Site location	Ancillary location	Distance to nearest sensitive receiver (m)	Noise goal (dBA LA90)[1]	Maximum acceptable sound power level (dBA)
Boggo Road Southern ventilation outlet	Vent outlet located above the busway adjacent to its Connection with the Boggo Rd busway, 11m above roof of busway tunnel	~150	40	92
Woolloongabba Station	Main plant room with vent located at the north end of the station.	~75	46	92
Woolloongabba ventilation outlet	Vent outlet located at the north end of the station, 24m above ground level	~ 75	46	92
George Street Station	Main plant room located underground, location of above ground ventilation louvers unknown at this stage.	~4	51	71 (from each ventilation louvre)
George Street ventilation outlet	Along the southeast side of George Street Station	~25	51	87
Roma Street Station	Main plant room located underground under Parkland Crescent car park, location of fresh air shaft east of car park 5m of nearest receiver.	~65	47	91 (from ventilation louvres)
Roma Street ventilation outlet	Two exhaust shafts shown on the drawing, nearest to residences located north of platform 10 adjacent Parkland Crescent, 8m above ground level.	~45	47	88
Victoria Park Northern ventilation outlet	Located west of the Gregory Terrace tennis courts	~160	51	103

*Note 1: Background creep noise goal in accordance with EPP (Noise). The background creep is the RBL + 0 assessed as the LA90 parameter. Existing background noise levels RBLs as presented in Table **11-8**.*

11.4 Impact management

11.4.1 Construction noise and vibration mitigation measures

The extent of any construction noise and vibration impact would depend on the construction methodology ultimately adopted. Well considered construction planning can minimise the potential impacts through equipment selection, maximising distances to sensitive receivers, and the timing and duration of noisy activities.

In addition to the specific potential mitigation measures described in the previous sections of this chapter, the following typical noise control and mitigation are frequently required where surface construction compounds are situated near a sensitive receiver:

- constant review of alternative construction methods aimed at reducing the extent of potential impacts
- selection of the quietest plant and equipment that can economically undertake the work, wherever possible
- regular maintenance of equipment to ensure that it remains in good working order.
- where possible, avoid the coincidence of plant and equipment working simultaneously close together near sensitive receivers
- mobile plant such as excavators, front end loader and other diesel powered equipment to be fitted with residential class mufflers when used for construction activities in or adjacent to residential areas
- use localised acoustic barriers for particular noisy operations such as pile boring, rock breaking, blasting etc
- when residential dwellings are in close proximity to the worksite, use barriers or acoustic enclosures to provide a significant reduction to impacts
- minimise intrusive or high impact night-time construction activities where possible
- provide advanced notice of intended tunnelling and construction activities in the localities near the tunnel alignment. Part of the consultation process should potentially include information regarding the monitoring program which may require involvement from properties located above the tunnel alignment. A thorough information program will assist to allay concerns around the tunnelling process

The mitigation measures for the Projects construction related activities are outlined in **Table 11-37.**

Table 11-37 Site and issue specific mitigation measures

Site/ activity	Potential impact	Recommended management measure
Southern Connection including Boggo Road TBM launch shaft worksite	Minor exceedances (up to 8 dBA) of the daytime noise goal predicted for residential receivers adjacent to Railway Terrace during initial site clearing and piling works	**Specific:** Increase site acoustic hoarding to 6m where practicable and/ or erect noise barriers close to particularly noisy equipment (eg rock breakers) **General:** Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1**
	Exceedances of up to 16 dBA of the daytime airborne noise goal for residential receivers closest to the pipe jacking retrieval shaft excavation works adjacent to Quarry Road	Specific: Increase site acoustic hoarding to 6m where practicable and/ or erect noise barriers close to particularly noisy equipment (eg rock breakers) until the excavation plant has progressed into the shaft to benefit from shielding from the shaft walls. General: Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1**
	Minor exceedances (up to 6 dBA) of the night-time sleep disturbance noise goal predicted for residential receivers adjacent to Railway Terrace during night-time spoil removal works from the Southern Connection acoustic shed	Specific: Use of quietest available spoil trucks during the night-time period. Erect a noise barrier (approximately 3 to 4 m high) along the north-west side of the spoil truck route to mitigate noise levels to residents adjacent Railway Terrace. Install a low performance acoustic shed over the spoil load out shaft as soon as practicable. General: Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1**, in particular, continuous noise monitoring.
	Predicted ground-borne noise levels for rock breaking under the existing rail tracks between the TBM launch shaft site and the tunnel portal indicate exceedances of the daytime and night-time noise goals for the ESA Village (up to 2 dBA and 15 dBA respectively) and nearest residences adjacent to Railway Terrace during the night-time (up to 8 dBA).	Specific: If practicable, restrict rock breaking inside the tunnel to the daytime period. Otherwise, consult with residents to determine preferred management responses such as potential temporarily relocation of residents from affected premises. General: Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1,** in particular, continuous noise monitoring.
	Vibration from rock breaking at the TBM launch shaft site is predicted to exceed the floor vibration tolerance (ie by 0.03 mm/s) for the TEM located within the basement of the Ecosciences building.	Specific: If the Ecosciences TEM does not have an existing vibration isolation system or the existing system is found to be inadequate and the findings of vibration trials confirm the need to mitigate vibration interference to the TEM, then further investigations are recommended to develop an effective mitigation strategy. This strategy may involve (but not be limited to) upgrading the TEM vibration isolation system or scheduling of rock breaking at times

Site/ activity	Potential impact	Recommended management measure
		when the TEM is not used.
	Forecast 2016 road traffic noise levels from Peter Doherty Street predicted to increase by 3.5 dBA due to the introduction of 57 heavy vehicle movements (ie approximately 5 truck passbys per hour) between 6.30am and 6.30pm.	Specific: Develop and implement a traffic management plan for one way truck movements east bound on Pete Doherty Street, Joe Baker Street and Boggo Road.
Woolloongabba Station	Predicted noise levels for site establishment works including demolition of the existing GoPrint building at the Woolloongabba Station site indicate minor exceedances of the daytime noise goal of up to 3dBA at the nearest residential receivers along Vulture Street. Similar exceedances are predicted during the initial station shaft excavation.	General: Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1**, in particular, continuous noise monitoring.
	Noise goal exceedances of up to 8 dBA are predicted for St Nicholas Cathedral during surface construction works	General: Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1** in particular, continuous noise monitoring.
	Activities associate with night-time excavation and spoil removal from the site are predicted to exceed the night-time residential noise goal at the nearest receivers by as much as 9 dBA. Even with the provision of a low performance acoustic shed, a marginal 1 dBA night-time sleep disturbance noise goal is predicted as a result of spoil truck movements through the site, which only a small distance of this on-site journey would occur inside the acoustic shed.	Specific: Careful management of all heavy vehicle movements on the site (eg speed restrictions, avoidance of queuing etc) combined with all practicable noise mitigation measures in place as outlined in **section 11.5.1**. Install a low performance acoustic shed as soon as practicable.

Site/ activity	Potential impact	Recommended management measure
George Street Station	Significant exceedances (up to 12 dBA) of the daytime noise goal predicted for the adjacent Mary Street apartment building residential receivers during site clearing, piling and initial shaft excavations works.	Specific: Considering the nature of the works required for this site and close proximity of the receiver building, it is unlikely that construction noise levels would be reduced sufficiently to comply with the noise goals. Therefore noise mitigation measures would be applied with the aim of reducing the impact insofar as possible, including: • quietest available equipment and construction techniques • install a medium performance acoustic shed as soon as practicable • expedite initial surface works (ie maximum number of plant operating at peak output) to enable long-term works associated with shaft excavation to progress inside the acoustic shed • continuous noise monitoring • consultation with residents to determine other preferred management responses such as potential temporarily relocation of residents from affected premises.
	Ground-borne noise levels for rock breaking during excavation of the George Street Station shaft is predicted to significantly exceed the daytime and night-time noise goals for the residential receiver building located along the north-east boundary of the site (ie Mary Street, Day: 14 dBA and Night: 27 dBA) as well as during the night-time period for the George Street residential building (ie Receiver D – on the corner of George and Charlotte Streets, Night: 5 dBA).	Specific: Considering the predicted ground-borne noise goal exceedances for the adjacent residential apartment buildings, it is strongly recommended that: • ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy if needed • rock breaking be restricted to the daytime period only until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated • preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted during to the day-time period only • investigate the benefits of cut-off trenches in the rock created by either rock saws or diamond wire (eg blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting).
	The daytime noise goal applicable to the commercial	Specific: Considering the predicted regenerated noise goal exceedances for

Site/ activity	Potential impact	Recommended management measure
	receiver buildings on the north-east (ie Mary Street: 23 dBA) and south-east (ie George Street: 28 dBA) boundary of the site is also predicted to be significantly exceeded during rock breaking of the station shaft.	the adjacent Mary Street apartment building, it is strongly recommended that: • ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy • preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted to the day-time period only.
	A 6 dBA exceedance of the night-time noise goal and a marginal 1 dBA exceedance of the daytime noise goal are predicted inside the George Street residential receiver building during roadheading of the station cavern.	Specific: Considering the predicted day and night-time ground-borne noise goal exceedances for the George Street apartment building, it is recommended that: • ground-borne noise measurements are carried out at the commencement of daytime roadheading activities to accurately determine the extent of the impact with particular regard to the feasibility of night-time roadheading at shallow depths.
	Vibration from rock breaking adjacent to the Mary Street apartment building is predicted to exceed the 0.5 mm/s night-time human comfort vibration goal by up to 5.93 mm/s.	Specific: Considering the predicted night-time vibration goal exceedances for the Mary Street apartment building adjacent the site, it is strongly recommended that: • rock breaking be restricted to the day-time period only until measurement results achieve compliance with the vibration goal or affected residents have been temporarily relocated • ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy • preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted to the day-time period only.
	A marginal exceedance (ie 0.13 mm/s) of the 2 mm/s vibration goal for heritage structures is predicted for Harris Terrace during the initial stages of heavy rock breaking of the station shaft.	Specific: It is recommended that a building condition survey be carried out at Harris Terrace prior to the commencement of construction works at the George Street site. Vibration monitoring at Harris Terrace is also recommended during (at least) the initial stages of shaft excavation.
Roma Street Station	Significant exceedances (up to 15 dBA) of the daytime	Specific: Considering the nature of the works required for this site and close

Site/ activity	Potential impact	Recommended management measure
	noise goal predicted for the Parkland Boulevard residential receivers during site clearing, piling and initial shaft excavations works.	proximity of the receiver building, it is unlikely that construction noise levels would be mitigated to comply with the noise goals. Therefore noise mitigation measures would be applied with the aim of reducing the impact insofar as possible, including: • quietest available equipment and construction techniques • expedite initial surface works (ie maximum number of plant operating at peak output) to enable long-term works associated with shaft excavation to progress inside the acoustic shed • continuous noise monitoring • consultation with residents to determine other preferred management responses such as potential temporarily relocation of residents from affected premises.
	During night-time shaft excavation, based on an excavator, rock breaker and front end loader operating inside the high performance acoustic shed, a 4 dBA exceedance of the 64 dBA LAmax noise goal is predicted	Specific: Install a high performance acoustic shed over the spoil load out shaft as soon as practicable. It is recommended that spoil trucks enter and leave the acoustic shed from an opening located along the southern facade of the shed thereby increasing the separation distance between the Parkland Boulevard receiver building and the trucks. General: Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1**, in particular, continuous noise monitoring.
	Predicted ground-borne noise levels for rock breaking during excavation of the Roma Street Station shaft is predicted to significantly exceed the daytime noise goals for both the commercial receivers (ie by up to 19 dBA) and residential receivers (ie by up to 18 dBA) inside the adjacent Parkland Boulevard receiver building.	Specific: Considering the predicted regenerated noise goal exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that: • ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy • preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted to the day-time period only.
	The night-time noise goal for the residential receivers in the Parkland Boulevard building is predicted to be significantly exceeded (ie by as much as 31 dBA) as a	Specific: Considering the predicted regenerated noise goal exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that:

Site/ activity	Potential impact	Recommended management measure
	result of ground-borne noise from rock breaking.	• rock breaking be restricted to the daytime period only until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated • ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy • preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted during the night-time period • investigate the benefits of cut-off trenches in the rock created by either rock saws or diamond wire (eg blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting).
	Vibration from rock breaking adjacent to the Parkland Boulevard building is predicted to exceed the 0.5 mm/s night-time human comfort vibration goal by up to 3.81 mm/s.	<u>Specific:</u> Considering the predicted night-time vibration goal exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that: • rock breaking be restricted to the day-time period only until measurement results achieve compliance with the night-time vibration goal or affected residents have been temporarily relocated • ground-borne noise and vibration measurement trials are carried out for rock breaking during the detailed design stage of the Project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy • preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted to the day-time period only.
Northern Connection	Minor exceedances (up to 4dBA) of the daytime noise goal predicted for residential receivers adjacent to Gregory Terrace during trough excavation and transition construction works	<u>Specific</u>: Increase site acoustic hoarding to 6m where practicable and/ or erect noise barriers close to particularly noisy equipment (eg rock breakers) <u>General</u>: Apply reasonable and practicable noise mitigation measures as outlined in **section 11.5.1**
TBM tunnelling	In some locations, the predicted vibration levels from	<u>Specific:</u> It should be noted that these exceedances would only occur during

Site/ activity	Potential impact	Recommended management measure
	TBM tunnelling would extend beyond the theoretical threshold for human perception (0.15 mm/s PPV) and could be noticeable (0.5 to 1.0 mm/s PPV) and even 'easily noticeable' (1.0 to 2.0 mm/s PPV) for some people. Predicted vibration from TBM tunnelling would exceed the 'strongly noticeable' level (> 2.0 mm/s PPV) only for a few commercial buildings in the CBD. There are predicted exceedances of the night-time sleep disturbance criterion for residential receivers along the tunnel alignment as well as some daytime exceedances for commercial and educational.	a relatively short period (less than 1 week for the TBM passby). Nonetheless, the following management measures would apply: • ground-borne noise and vibration monitoring to be undertaken at the commencement of tunnelling to confirm that the source data utilised for this assessment is applicable to the Project (including the low frequency noise assessment inputs and findings) • comprehensive advance notice as well as educating the public of intended tunnelling activities in the localities near the tunnel alignment. Part of the consultation process should include information regarding the monitoring program which may require involvement from residences located above the tunnel alignment. A thorough education program will assist to allay fears of the tunnelling process • other measures including temporary relocation of residences particularly impacted by ground-borne noise from TBM tunnelling may be required.
Swanbank spoil truck destination	Forecast 2016 night-time hourly minimum traffic volumes on Swanbank Road are low (ie 1 hour night-time minimum of 9 vehicles) and therefore the introduction of (a maximum of) 16 heavy vehicle movements per hour during the night-time period will be potentially noticeable.	<u>Specific</u>: Use an alternative spoil destination during the night-time period. If this is not practicable, consideration should be given to upgrading the facades of the residences located along Swanbank Road. Or limiting the spoil truck movements on Swanbank Road to 0630 – 2200 hrs.
Use of Peter Doherty Street for spoil removal from Boggo Road worksite	Forecast 2016 traffic volumes on Peter Doherty Street are low (ie 24 hour weekday average of 224 vehicles) and therefore the introduction of 57 heavy vehicle movements (ie approximately 5 truck passbys per hour) between 6:30 am and 6:30 pm will potentially be noticeable and result in an impact.	<u>Specific:</u> It should be noted that subject to the final layout of the Boggo Road site, it might be feasible for spoil trucks to use Peter Doherty Street, Joe Baker Street and Boggo Road in a one way traffic flow on and off to Annerley Road.

11.4.2 Operational noise management

During the operational phase of the Project a range of potential impacts would require mitigation as outlined in **Table 11-38**.

Table 11-38 Summary of potential operational noise and vibration impacts and recommended impact management measures

Activity	Potential impact	Recommended management measure
Ground-borne noise from train operations	Southern Connection to Woolloongabba Station - residential receivers exceed the night-time ground-borne noise goal of 35 dBA. Woolloongabba Station to George Street Station – compliance at all locations George Street to Roma Street Station - residential receivers exceed the night-time ground-borne noise goal of 35 dBA.	790m of resilient rail fasteners for the Down Track and 665m of resilient rail fasteners for the Up Track are required to achieve compliance with the ground-borne noise goals at all sensitive receiver locations.
Ground-borne vibration from train operations	Predicted compliance with nominated vibration goals at all locations.	Nil
Airborne noise from train operations	At the Southern Connection noise levels are predicted to exceed the Queensland Rail planning noise levels for 19 sensitive receivers.	Extend an existing noise barrier in the Southern Connection area to help meet the planning noise level at sensitive receivers on Railway Terrace. The total recommended noise barrier requirement is 1,919m^2. Construct any noise barrier required for any operational reasons as part of the first Early Works.
Airborne noise from bus operations	Three educational buildings at St Joseph's College are predicted to exceed the DTMR Code of Practice 65 dBA LA10 (1hour) noise criterion in the northern Connection area. Two (2) health buildings (RBH QIMR and RBH Surgical Building) are predicted to exceed the DTMR Code of Practice 65 dBA LA10 (1hour) noise criterion in the northern Connection area. One (1) health building (RBH Block 7) is predicted to exceed the TMR Code of Practice 69 dBA LAmax noise criteria for upgraded busway.	Noise mitigation is not recommended as the noise levels are attributable to the existing road networks, not the Project. Noise levels attributable to the Project busways only would be at least 15 dBA below the noise goals.

Activity	Potential impact	Recommended management measure
Airborne mechanical plant and ancillary noise	Potential impact at some locations from mechanical plant and ventilation outlets.	The locations and designs of the mechanical plants, air exhausts and intakes and tunnel ventilation for the Project will need to be assessed in more detail during the detailed design phase. Mitigation measures that may need to be considered at some locations include appropriate equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

11.4.3 Noise and vibration monitoring

As with all major construction projects in Brisbane, weekly inspections would be undertaken throughout the construction to ensure that appropriate noise and vibration controls are being implemented and are effective. The need for additional monitoring would be assessed as a result of changes to activities/construction methods and community complaints. Any issues identified during the weekly inspections would be documented in monthly reports.

In addition to regular weekly inspections, the following inspection and monitoring regime is proposed:

- undertake pre- and post-construction building condition surveys where it is considered there may be potential for cosmetic (superficial) building damage from the Project construction activities
- undertake pre-condition surveys for buildings and historical items in vibration sensitive zones prior to commencement of construction
- noise and vibration monitoring should be undertaken at the commencement of tunnelling to confirm that the source data utilised for this assessment is applicable to this Project (including the low frequency noise assessment inputs and findings)
- develop construction noise and vibration monitoring procedures to address the initial and ongoing monitoring of emissions from construction to assist in planning of excavation and construction works. This will be of particular importance where work activities are predicted to exceed goals at noise sensitive receivers
- undertake ongoing spot checks of noise intensive plant and equipment. Construction noise and vibration levels should be monitored throughout the construction phase to verify compliance with the design goals. Monitoring should be undertaken at those locations where predictions indicate exceedance of the nominated Project noise and vibration goals. Supplementary noise and/or vibration monitoring may also be conducted to identify issues of concern in response to any complaints.

A detailed monitoring program would be prepared closer to the commencement of construction as part of the tendering and detailed design processes. Potential construction noise and vibration monitoring programs for the Project are outlined in **Table 11-39** and **Table 11-40**.

Table 11-39 Construction noise monitoring

Monitoring	Schedule	Locations	Procedures and instrumentation
Operator attended noise monitoring - worksites	At the commencement of all noise intensive construction activities then typically once a week thereafter.	Typically at the nearest receiver in each direction to each site specific activity associated with: • Worksite activities (site prep works, day and night tunnelling). • Surface trackworks.	Attended measurements to quantify and qualify construction noise emissions using a calibrated sound level meter capable of measuring LA90, LAeq, LA10 and LA1 statistical noise levels in 15 minute intervals. One 15 minute sample per survey location is generally sufficient. Extraneous noise (eg cars, trains etc) should be excluded from the measurements. Sources contributing to the noise levels are to be noted.
Unattended noise monitoring - worksites	On a continuous basis or as required. Regular (typically weekly or fortnightly) data downloads would be required.	Continuous noise logging to be undertaken at the nearest noise sensitive receiver adjacent to tunnel worksites taking into consideration extraneous noise sources such as major roads, train passby etc.	A calibrated noise logger capable of measuring LA90, LAeq, LA10 and LA1 statistical noise levels in 15 minute intervals would be sufficient. Noise loggers are not typically used where extraneous noise is present. Therefore consideration should be given to using noise loggers capable of recording audio samples by means of preset trigger level exceedances to assist in identifying the source of the noise level exceedance.
Plant noise audits	As required but generally limited to particularly noisy plant items such as piling rigs, hydraulic hammer, haul trucks etc.	On site, typically at 7m from the item of plant (for surface equipment) in the direction of dominant noise emission. Closer to the source if other sources prevent measurement at this distance.	Attended measurements using a calibrated sound level meter capable of measuring LAeq, LA10, LA1 and LAmax statistical noise levels. Select the items of plant which appear to be the most dominant sources of noise. Measure noise emissions under conditions of maximum noise normally occurring for that source. For most noise sources, a one minute sample will be satisfactory, although sampling may be extended up to 15 minutes for sources varying greatly over time. The results of the plant noise audits would enhance the input data fed into the predictive modelling process. Equipment significantly exceeding the plant noise levels used in the predictive modelling would be required to undergo inspection to identify appropriate noise control measures. Where noise control measures are not feasible, predictive modelling would be updated accordingly and additional mitigation measures adopted where required. Haul trucks to be checked against ADR 28/01 before commencing works and at

Monitoring	Schedule	Locations	Procedures and instrumentation
			12 month intervals.
Regenerated noise monitoring	At the commencement of tunnelling/shaft excavation works at each site.	10 receiver locations per working face of short-term operator attended regenerated noise measurements at varying slant distances from the working face.	A calibrated sound level meter capable of measuring LA90, LAeq, LA10, LA1 and LAmax statistical noise levels and one-third octave noise levels in 15 minute intervals would be sufficient The results of the regenerated noise measurements would enhance the input data fed into the predictive modelling process.
Response to complaints	Within a 24 hour period of receiving the complaint	As appropriate to address the particular complaint.	Attended or unattended measurements as appropriate to identify and measure the source in question.

Table 11-40 Construction vibration monitoring

Monitoring	Schedule	Locations	Procedures and instrumentation
Driven tunnelling	A minimum of one vibration logger per working face for first three months for each tunnel section. After initial three months at each section, a minimum of one vibration logger for each tunnel section where: • exceedance of vibration goals are predicted. • complaints have been received (to be addressed within a 24 hour period).	Tunnel sections include: • 2 x mainline tunnels • 2 x portals At the nearest receiver to the cutting face where predictions indicate exceedances. As appropriate to address the particular complaint.	Operator attended measurements using a calibrated instrument capable of measuring peak particle velocity in three axes (ie vertical, longitudinal and transverse). The results of the vibration monitoring would enhance the reference data fed into the predictive modelling process.
Blasting	A minimum of two vibration and blast overpressure monitoring locations during each blast throughout the blasting phase of the Project.	All efforts should be made to locate the monitors at the nearest receivers to the blast site. Monitoring should always be undertaken at a heritage listed structure if close to blasting	Measurements using a calibrated instrument capable of measuring peak particle velocity in three axes (ie vertical, longitudinal and transverse) and blast overpressure. The results of the blast monitoring would enhance the input data fed into the predictive modelling process.
Buffer Distance	At the	At foundation of	Attended measurements using a

Monitoring	Schedule	Locations	Procedures and instrumentation
Tests for: • worksite activities • surface track works	commencement of all vibration intensive activities associated with each worksite and surface track works. To address complaints (within 24 hours) Where exceedances are predicted to occur.	potentially affected structure	calibrated instrument capable of measuring peak particle velocity in three axes.

11.5 Summary

11.5.1 Construction noise and vibration impacts

Worksite construction activities

The noise and vibration modelling undertaken for each of the key worksites predicts the following impacts:

- At the Southern Connection - minor exceedances from airborne noise of the daytime goal and the night-time sleep disturbance goal are predicted for residential receivers adjacent to Railway Terrace. More significant noise exceedance are predicted at Quarry Street during the excavation of the Micro TBM retrieval draft. A range of potential measures including, hoarding and work hour restrictions are identified to mitigate impacts. More significant exceedances of the ground-borne noise daytime and night-time goals are predicted for the ESA Village. Vibration is predicted to exceed the night-time human comfort vibration goal at the ESA Village and marginally exceed the floor vibration tolerance for the TEM located within the basement of the Ecosciences building. Minimal risk of cosmetic building damage is predicted.
- At the Woolloongabba Station - minor exceedances (3 dBA) of the daytime air-borne noise goal are predicted at the nearest residential receivers along Vulture Street and more significant noise goal exceedances are predicted for St. Nicholas Cathedral. Hoarding up to 3m has been proposed as a potential mitigation measure. Other potential measures for St Nicholas Cathedral have also been proposed. Excavation and spoil haul out activities are also predicted to marginally (1dBA) exceed the night-time residential noise goal at the receivers on Vulture Street with the provision of a low performance acoustic enclosure over the worksite. The predicted ground-borne noise and vibration levels indicate compliance with the relevant goals.
- At George Street Station - significant exceedances of the daytime and night-time noise goals are predicted for the residential and accommodation receivers near to the worksite on Mary Street. Once installation of the acoustic enclosure is complete, airborne noise emission levels from the site would decrease significantly. A marginal exceedance of the 2 mm/s vibration goal for heritage structures is predicted for Harris Terrace during the initial stages of heavy rock breaking of the station shaft. Ground-borne noise is predicted to exceed noise goals. As such, alternative construction methods such as drill and blast techniques have been considered in order to mitigate the potential impacts.
- Roma Street – significant exceedances of the day-time and night-time airborne noise goals are predicted for the receivers within the Parkland Boulevard residential building located adjacent to the worksite. An acoustic enclosure has been proposed as a potential mitigation measure. Vibration levels during rock breaking at the Parkland Boulevard building is also predicted to

exceed the night-time human comfort vibration goal. As such, alternative construction methods such as drill and blast techniques have been considered in order to mitigate the potential impacts.

- Northern Connection – minor exceedances of the daytime noise goal are predicted for residential receivers adjacent to Gregory Terrace with the provision of an acoustic hoarding.

TBM tunnelling

Predicted vibration from TBM tunnelling would exceed the 'strongly noticeable' level (> 2.0 mm/s PPV) only for a few commercial buildings in the Brisbane CBD. There are predicted exceedances of the night-time sleep disturbance criterion for some residential receivers along the tunnel alignment as well as some daytime exceedances for commercial and educational. It should be noted that these exceedances would only occur during a relatively short period (generally less than one week for the TBM passby). Nonetheless, management measures have been recommended (eg ground-borne noise and vibration monitoring).

Construction traffic

The increase in road traffic noise due to the Project spoil traffic is predicted to be less than 2 dBA on all spoil roads at adjacent residential receiver locations. Changes in noise levels of 2 dBA or less are considered to be undetectable to the human ear and are therefore negligible. The absolute maximum noise levels associated with vehicle passbys would not be altered by the Project construction vehicles, although the frequency of such events would increase.

Construction noise and vibration management

A range of potential airborne noise mitigation is also proposed such as acoustic enclosures, hoarding and surface work hour restrictions. It is recommended that vibration measurement trials are carried out for rock breaking, and drill and blast activities to accurately determine a 'site law' and allow sufficient time to develop an appropriate management strategy.

During construction weekly inspections would be undertaken to ensure that noise and vibration controls are being implemented and are effective, and changes to construction methods or complaints, are responded to appropriately.

11.5.2 Operational noise and vibration impacts

Ground-borne noise and vibration

It is predicted that the nominated vibration goals would be complied with at all sensitive receivers. This includes vibration levels for the electron microscope at the Ecosciences precinct and all research and medical facilities within the study corridor, including the Princess Alexandra Hospital, the Queensland University of Technology and St. Andrews Hospital. Ground-borne noise modelling predictions show that with the implementation of appropriate trackforms, compliance with the ground-borne noise goals at all sensitive receivers would be achieved.

Air-borne noise

At the Northern Connection, all sensitive locations are predicted to comply with Queensland Rail's operational planning levels in 2031 for rail operations. Therefore, no mitigation measures are required in this section.

For the Southern Connection an additional noise barrier has been proposed to reduce operational noise levels to Queensland Rail's planning levels. Restrictions on the location and height of barriers limits the ability to achieve compliance at all receivers.

For bus operations at the Southern Connection, all noise sensitive receivers are predicted to meet the relevant noise criteria. For the Northern Connection, three educational buildings (St Joseph's College buildings) and two health buildings are predicted to exceed the Department of Transport and Main Roads Code of Practice 65 dBA L_{A10} (1 hour) noise criterion. Also at the Northern Connection, one health building is predicted to exceed the DTMR Code of Practice 69 dBA L_{Amax} noise criteria for upgraded busway. Noise mitigation has not been recommended at any of these six noise sensitive receivers as all exceedances are due to the existing road networks and not the Project. Noise levels at all six locations, attributable to only the Project, would be significantly below the applicable criteria (at least 15 dBA below the relevant criteria).