SLR
global environmental solutions

BaT project

Environmental Impact Statement

Technical Report 3 – Construction Noise and Vibration

August 2014

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by the SKM-AECOM Joint Venture (JV) to prepare an assessment of the noise and vibration aspects of the construction phase for BaT (Bus and Train) project (BaT project) for inclusion in the Environmental Impact Statement (EIS).

The BaT project is a major project for the City of Brisbane, South East Queensland and the State of Queensland. It will provide a new north-south rail line in Brisbane's inner city that includes a new river crossing and inner city train stations.

The BaT project will run from Dutton Park in the south to Victoria Park in the north with new underground stations at Woolloongabba, George Street and Roma Street. The BaT project would connect with the Eastern Busway in Woolloongabba and the Northern Busway in Herston, and with the Gold Coast Line at Dutton Park and the Exhibition Line in Spring Hill.

STUDY METHODOLOGY

The study methodology for the BaT project construction noise and vibration assessment 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 BaT project documents including the Terms of Reference (TOR) January 2014 and Initial Advice Statement (IAS) November 2013.
- Identification of sensitive locations in relation to construction 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 noise and vibration impacts at sensitive locations may be evaluated.
- Describing noise and vibration levels associated with the BaT project through detailed computer noise modelling.
- Evaluating the extent of resulting impacts and the scope for the reduction of these impacts through reasonable and feasible mitigation strategies.
- Recommending appropriate mitigation measures and noise and vibration performance requirements in order to protect community values and sensitive locations.

The above study methodology for the construction noise and vibration assessment for the BaT project was developed for the purpose of achieving the objective of the TOR, being:

> *Development is planned, designed, constructed and operated to protect the environmental values of the acoustic environment.*

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LEGISLATIVE AND POLICY FRAMEWORK

The Environmental Protection Act 1994 (EP Act) enables the framework for environmental assessments to be developed in Queensland. The EP Act is applicable to all members and bodies in the community, including industry and governmental. It provides a method for governmental departments to incorporate environmental factors into their decision-making process.

A summary of the objective of the EP Act is as follows:

> *The object of the Environmental Protection Act 1994 is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.*

The EP Act allows the Environmental Minister to produce Environmental Protection Policies, designed to protect environmental aspects in Queensland. The Environmental Protection (Noise) Policy (EPP (Noise)) was developed under this framework and the most recent revision was published in 2008 and was in force as of 1 January 2009.

With regard to the objective of the Act, the noise goals applied to the assessment of the BaT project are summarised in **Table 1**.

Table 1 Construction Noise Goals

Construction Noise				**Blasting Airblast**	**Surface Track Worksites Queensland Rail Code of Practice**	**Construction Road Traffic**
Monday to Saturday	**Monday to Saturday (6.30pm to 6.30am); Sundays and Public Holidays**					
(6.30am – 6.30pm)	**Sleep Disturbance**		**Low Frequency $L_{pA.LF}$**			
	Continuous	**Intermittent**				
Steady State ($L_{Aeq,adj,15min}$) Maximum Design Level according to AS 2107 **Non-Steady State** ($L_{A10,adj,15min}$) Maximum Design Level according to AS 2107 + 10 dBA	35 dBA $L_{Aeq,adj(15min)}$	42 dBA L_{Amax}	25 dBA $L_{pA.LF}$	132 dB Linear Peak	87 dBA L_{Amax} 65 dBA $L_{Aeq,adj(24hour)}$	$\leq$ 2 dBA change in existing $L_{A10(1hour)}$, $L_{A10(12hour)}$ and $L_{A10(18hour)}$

The noise goals presented in **Table 1** have been developed on the basis of the following:

1. Sleep disturbance criteria contained in the World Health Organisation's Night Noise Guidelines for Europe (2009).
2. 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).
3. Queensland Rail's Code of Practice planning levels for the assessment of surface track construction noise.
4. Airblast overpressure from blasting, it is recommended not to exceed 132 dB Linear peak in line with the cosmetic damage limits from USBM and the goal from recent large tunnelling projects in Brisbane.

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5. A threshold of significance in relation to changes in the noise emission level from roads due to the introduction of construction related traffic at 2 dBA.

For the BaT project, the facade adjustment methodology applied to the assessment takes into consideration the type of receivers 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 CBD.

A summary of applicable vibration goals at sensitive receptors associated with the construction phase of the BaT project is shown in **Table 2**.

Table 2 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 (refer to Table 33) reduced by 50%	According to BS7385 (refer to Table 33)	50	According to AS2670 (refer to Table 30)	0.5	-
Commercial	According to BS7385 (refer to Table 33) reduced by 50%	According to BS7385 (refer to Table 33)	50	According to AS2670 (refer to Table 30)	-	0.5
Heritage Structures	2		10	-	-	-

The vibration goals presented in **Table 2** have been developed on the basis of the following:

1. BS 7385 for cosmetic damage guide values from all construction vibration sources including blasting.
2. AS 2670 for daytime human comfort guide values and 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.
3. 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.

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EXISTING ENVIRONMENT

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 were taken from a previous project where monitoring was conducted in May 2010. These locations were considered representative of the current BaT project. Both attended and unattended ambient noise measurements have been conducted at an additional seven (7) locations in order to accurately document the existing noise environment. The measured ambient noise levels have been used in part to determine applicable project noise goals.

The noise monitoring undertaken in 2010, was performed between 7 May and 28 May 2010 for at least seven (7) days at each monitoring location. These locations are highlighted green in **Figure 1**. Noise monitoring at the additional seven (7) locations was undertaken between 11 March and 1 May 2014. These locations are highlighted orange in **Figure 1**.

Noise monitoring locations have been selected to be representative of residential areas as well as special receivers (ie Educational and Health Care Facilities) along the corridor that may be potentially affected by the BaT project. Noise monitoring locations have been selected to provide spatial coverage of the areas with sensitive receivers along the length of the study corridor.

An overview of the selected monitoring locations is shown in **Figure 1**.

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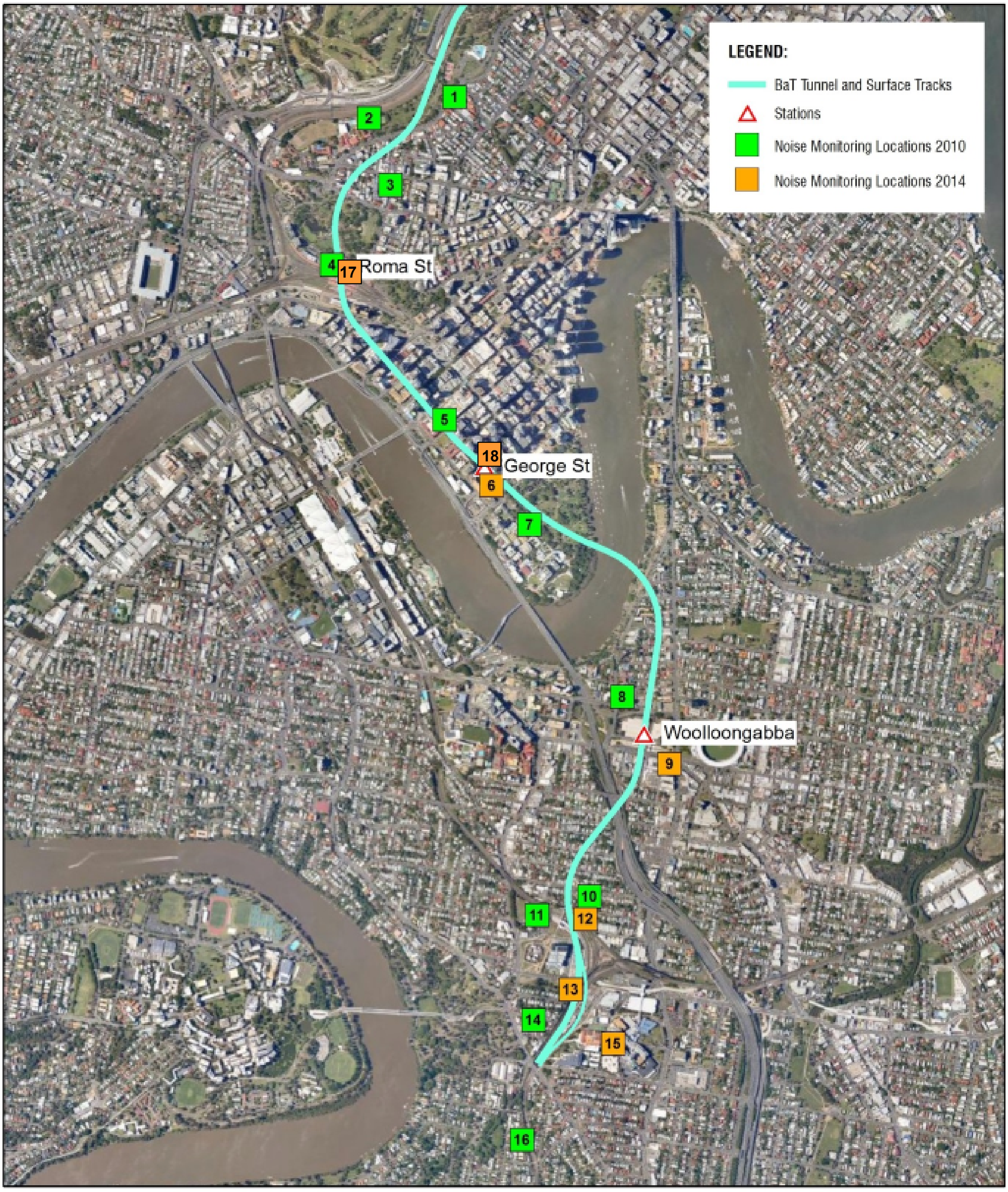
Figure 1 Overview of Noise Monitoring Locations



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The unattended ambient noise measurements were used to determine the Rating Background Levels (RBL) for the daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location. The RBL is the median of the 90th percentile background (L_{A90}) noise levels in each assessment period (day, evening and night) over the duration of the monitoring (as defined in the *Ecoaccess PNC*). **Table 3** contains the determined RBL for each measurement location.

Table 3 Measured Rating Background Levels

Monitoring Location		Rating Background Levels (RBL), LA90 (dBA)		
		Day	Evening	Night
1	St Josephs College	50	48	40
2	Brisbane Girls Grammar	61	60	46
3	St Andrews War Memorial Hospital	55	53	51
4	Parkland Cres	54	50	47
5	191 George St	58	57	54
6	40 George Street, The Mansions	59	55	51
7	QUT Gardens Point	49	48	46
8	58 Leopard St	53	50	46
9	803 Stanley St [1]	58	57	51
10	143 Park Rd	43	39	34
11	Dutton Park State School	44	40	35
12	26 Elliot St	46	44	40
13	68 Railway Tce, Leukaemia Centre	47	45	41
14	19 Dutton St	43	42	37
15	Princess Alexandra Hospital	54	54	53
16	4 Fenton St	39	38	34
17	Parkland Boulevard (Level 3 conference meeting room, Building 3) [2]	RBL: 53 (30) LAeq: 61 (37)	RBL: 50 (27) LAeq: 58 (35)	RBL: 44 (<24)[3] LAeq: 55 (31)
18	21 Mary Street (Level 27 unit 1) [2]	RBL: 56 (33 – Living room) LAeq: 58 (34)	RBL: 55 (-)[4] LAeq: 56 (-)[4]	RBL: 53 (27 - Bedroom) LAeq: 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 ambient 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 (1) 15 minute period during each of the daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location (ie three (3) 15 minute attended measurements were taken at each location). The results of these measurements are summarised in the **Section 4.1.4.**

The attended measurements and observations identified that railway noise and/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.

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Vibration

Existing vibration levels along the study corridor were measured to (if required) compare with future vibration levels with the BaT project in operation. The data for eight (8) of these locations were taken from a previous project where monitoring was conducted in May 2010. These locations were considered representative of the current BaT project. Ambient vibration measurements have been conducted at an additional two (2) locations in order to accurately document the existing vibration environment.

Vibration monitoring locations have been selected to be representative of residential areas as well as special receivers (ie educational/research or health care facilities) along the corridor that may be potentially affected by the BaT project. Vibration monitoring locations have been selected to provide spatial coverage of the areas having sensitive receivers within the whole study corridor.

An overview of the selected vibration monitoring locations is shown in **Figure 2**, with locations monitored in 2010 highlighted green and locations monitored in 2014 highlighted orange.

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 (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location. **Table 4** contains the determined vibration levels for each measurement location.

Table 4 Measured Existing 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	0.04	0.04	0.04	0.05	0.05	0.05	0.08	0.05	0.05
2	0.03	0.03	0.02	0.08	0.05	0.04	0.17	0.08	0.06
3	0.04	0.04	0.03	0.06	0.05	0.04	0.07	0.07	0.06
4	0.08	-	-	0.09	-	-	0.10	-	-
5	0.02	-	-	0.02	-	-	0.03	-	-
6	0.01	0.01	0.01	0.04	0.14	0.02	0.16	0.57	0.16
7	0.04	0.04	0.04	0.06	0.10	0.05	0.19	0.49	0.10
8	0.03	0.03	0.03	0.04	0.04	0.03	0.31	0.04	0.04
9	0.13	0.11	0.11	0.79	0.53	0.13	2.50	1.53	0.36
10	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 V90 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 **Appendix D**.

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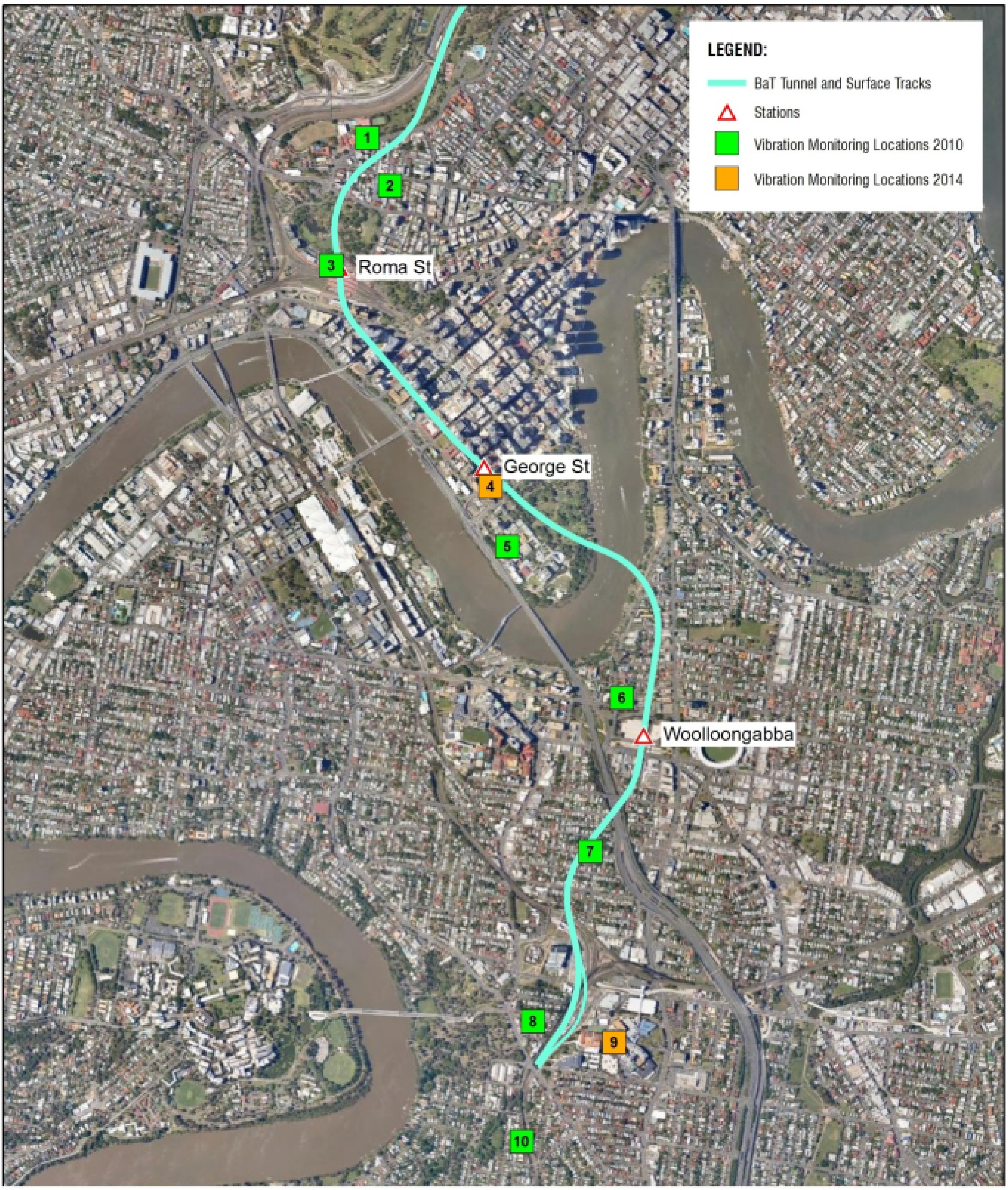
Figure 2 Overview of Vibration Monitoring Locations



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.

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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 (i.e. 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 2.3**.

For receivers with vibration sensitive equipment locations 3 (St Andrews Hospital), location 5 (QUT) and location 9 (PA Hospital), background vibration levels (V_{90}) of 0.02 mm/s to 0.06 mm/s and maximum vibration levels (V_1) of 0.03 mm/s to 2.69 mm/s, were measured. 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 Andrews Hospital.

CONSTRUCTION NOISE AND VIBRATION IMPACT ASSESSMENT

TBM launch site construction activities representative of the typical noise emissions expected to occur during the BaT project are:

- Demolition of existing buildings, site establishment including spoil handling facilities.
- Installation of perimeter retaining walls using piling, precast concrete segments etc.
- Initial excavation using excavators, rockbreakers and other construction plant.
- TBM site and associated facilities for tunnel construction.
- Spoil removal from behind the TBM and removal by heavy vehicle.
- Tunnel fit out including railway and busway systems.

Station site construction activities representative of the typical noise emissions expected to occur during the BaT project are:

- Demolition of existing buildings, site establishment including spoil handling facilities.
- Installation of perimeter retaining walls using piling
- Excavation using excavators, rockbreakers drill and blast and other construction plant.
- Spoil removal by heavy vehicle.
- Station construction, fitout and commissioning.

Southern Connection and TBM Launch Site - Noise and Vibration Assessment

Scenarios were developed for Southern Connection construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Site Establishment and removal of existing railway infrastructure:
  - Duration ~ 3 months
  - Dominant noise sources include rockbreakers, 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, rockbreakers and spoil trucks
  - Mostly daytime construction and potentially weekend work during track possessions

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- 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 24/7
- Scenario 4 - TBM assembly and acoustic shed construction:
  - Duration ~ 3 months
  - Dominant noise sources include delivery trucks, cranes and front end loaders
- 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 (e.g. tunnel ventilation and conveyor system noise):
  - Duration ~ 17 months
  - Dominant noise sources include the spoil conveyor to the loadout 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. Noise goal exceedances associated with the predicted construction noise levels are presented in **Table 5** for Scenarios 1 to 3 and **Table 6** for Scenarios 4 to 6.

Predicted ground-borne noise and vibration impacts for the Southern Connection are presented in **Table 7**. All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building. A "dash" (-) in the tables indicates compliance, and "n/a" in the tables indicates it is not applicable for the assessment time period.

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Table 5 Southern Connection Predicted Airborne Noise Goal Exceedances – Scenarios 1 to 3

Receiver Area	Period	Noise Goal (dBA)	Predicted 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	
			3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding
A	Day	LA10,adj 77	-	-	-	-	n/a	n/a
B	Day	LA10,adj 57	**8**	**3**	**9**	**4**	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	-	-
C	Day	LA10,adj 72	-	-	**2**	-	n/a	n/a
	Night	LAmax 64	n/a	n/a	n/a	n/a	n/a	n/a
	Night	LAeq,adj 57	n/a	n/a	n/a	n/a	-	-
D	Day	LA10,adj 77	-	-	-	-	n/a	n/a
E	Day	LA10,adj 72	-	-	-	-	n/a	n/a
F	Day	LA10,adj 62	-	-	-	-	n/a	n/a
G	Day	LA10,adj 57	**4**	-	**16**	**11**	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	-	-
H	Day	LA10,adj 77	-	-	-	-	n/a	n/a
I	Day	LA10,adj 77	-	-	-	-	n/a	n/a
J	Day	LA10,adj 72	-	-	-	-	n/a	n/a
	Night	LAmax 64	n/a	n/a	n/a	n/a	n/a	n/a
	Night	LAeq,adj 57	n/a	n/a	n/a	n/a	-	-
K	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	Day	LA10,adj 62	-	-	-	-	n/a	n/a

Receiver Code: A = Railway Tce commercial, B = Railway Tce residential, C = Leukaemia Centre, D = Ecosciences building, E = Police Station & Gaol, F = Dutton Park School, G = Merton Rd to Elliott St, H = Burke St commercial, I = MLS commercial, J = PA Hospital, K = Rusk St & Cornwall St residential and L = PA child care centre.

Note: Exceedances shown in **bold**.

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Table 6 Southern Connection Predicted Airborne Noise Goal Exceedances – Scenarios 4 to 6

Receiver Area	Period	Noise Goal (dBA)	Predicted 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)	
			3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding
A	Day	LA10,adj 77	-	-	n/a	n/a	n/a	n/a
B	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	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	Day	LA10,adj 77	-	-	n/a	n/a	n/a	n/a
E	Day	LA10,adj 72	-	-	n/a	n/a	n/a	n/a
F	Day	LA10,adj 62	-	-	n/a	n/a	n/a	n/a
G	Day	LA10,adj 57	-	-	n/a	n/a	n/a	n/a
	Night	LAmax 49	n/a	n/a	**1**	-	n/a	n/a
	Night	LAeq,adj 42	n/a	n/a	n/a	n/a	**7**	-
H	Day	LA10,adj 77	-	-	n/a	n/a	n/a	n/a
I	Day	LA10,adj 77	-	-	n/a	n/a	n/a	n/a
J	Day	LA10,adj 72	-	-	n/a	n/a	n/a	n/a
	Night	LAmax 64	n/a	n/a	**1**	-	n/a	n/a
	Night	LAeq,adj 57	n/a	n/a	n/a	n/a	-	-
K	Day	LA10,adj 57	-	-	n/a	n/a	n/a	n/a
	Night	LAmax 49	n/a	n/a	-	-	n/a	n/a
	Night	LAeq,adj 42	n/a	n/a	n/a	n/a	-	-
L	Day	LA10,adj 62	-	-	n/a	n/a	n/a	n/a

Receiver Code: A = Railway Tce commercial, B = Railway Tce residential, C = Leukaemia Centre, D = Ecosciences building, E = Police Station & Gaol, F = Dutton Park School, G = Merton Rd to Elliott St, H = Burke St commercial, I = MLS & Busway, J = PA Hospital, K = Rusk St & Cornwall St residential and L = PA child care centre.

Note: Exceedances shown in **bold**.

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Table 7 Southern Connection Predicted Ground-borne Noise and Vibration Levels – TBM Launch Shaft Excavation, Pipe Jacking Activities and Cut and Cover Tunnel 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[3]	Pipe Jacking (Micro TBM)	Rockbreaking[3]	Pipe Jacking (Micro TBM)
			Continuous[1]	Intermittent[2]				
A - Railway Tce Commercial	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	<0.01	24	<25
B - Railway Tce Residential	Day	10	LAeq,adj – 40	LA10,adj – 50	0.27	<0.01	45	<25
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.27	<0.01	**50 (8)**	<25
C - ESA Village (Leukaemia Centre) Residential	Day	25	LAeq,adj – 40	LA10,adj – 50	0.49	<0.01	**52 (2)**	<25
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.49	<0.01	**57 (15)**	<25
D - Ecosciences Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.29	0.06	50	<25
D – Ecosciences TEM	24/7	0.02	n/a	n/a	**0.05 (0.03)**	<0.01	n/a	n/a
G - Merton Rd to Elliott St Residential	Day	10	LAeq,adj – 40	LA10,adj – 50	2.7	0.17[5]	37 [4]	35[5]
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.06	0.17[5]	42	35[5]
H - Burke St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.05	0.03	37	<25
I - MLS Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.07	<0.01	39	<25
J - PA Hospital	Day	25	LAeq,adj – 40	LA10,adj – 50	0.06	<0.01	37	<25
	Night	0.5	LAeq,adj – 35	LAmax – 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 (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.

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Discussion

Based on typical worst case construction noise levels with either 3 m 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 3 m acoustic hoarding around these works, the daytime noise goal is predicted to be exceeded by up to 16 dBA during operation of a rockbreaker. 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. The predicted noise goal exceedance for residences adjacent to Railway Terrace is attributed to spoil truck movements within the site. Consequently it will be important to consider all reasonable and feasible noise mitigation measures to minimise night-time spoil truck impacts to nearby residential receivers including:
    - Upgrade the existing railway noise barrier adjacent to Railway Terrace (required for mitigation of operational rail noise as a consequence of the BaT project) as part of the early works program; or
    - Erecting a noise barrier (approximately 3 to 4 m high) along the north-west side of the on-site spoil route adjacent to the rail track; and
    - Use of quietest available spoil trucks.

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 low performance acoustic shed.

With all practicable noise mitigation measures in place combined with careful management of all heavy vehicle movements on the site, airborne noise impacts should be minimal during the construction phase of the Southern Connection.

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

- The ground-borne noise levels presented in **Table 59** for rockbreaking 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 Leukaemia Centre (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 Leukaemia Centre. The minimum offset distance between the rockbreaker 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:

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  - Leukaemia Centre night-time (42 dBA LAmax): 95 m from the building and 125 m of cut and cover tunnel predicted to exceed the night-time ground-borne noise goal.
  - Railway Terrace night-time (42 dBA LAmax): 95 m from the receiver building and 60 m 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 rockbreaking of the cut and cover sections of tunnel within the exceedance ranges listed above be carried out only during the daytime period.
- The predicted ground-borne noise and vibration from the Pipe Jacking (micro TBM) under the Park Road Railway Station tracks comply with the ground-borne noise and vibration goals at all locations.
- An investigation of the Ecosciences TEM vibration isolation system has not been carried out for the BaT project. Based on the predicted marginal exceedance of the TEM criterion in **Table 7** during rockbreaking 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 rockbreaking 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.

Woolloongabba Station

Scenarios were developed for Woolloongabba Station site construction being representative of activities having potentially the greatest (i.e. worst case) noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Daytime demolition of Goprint building with rockbreakers, excavators and spoil trucks:
  - Duration ~ 2 months
- Scenario 2 – Daytime installation of perimeter piles:
  - Duration ~ 2 months
- Scenario 3 – Daytime initial shaft excavation in hard rock and spoil removal:
  - Duration ~ 5 months
- Scenario 4 – Night-time shaft and cavern excavation including rockbreakers and on-site spoil movements:
  - Duration ~ 15 months inclusive of station shaft and cavern excavation and therefore the initial stages of the station shaft excavation (i.e. typically the worst case stage of this scenario) would be significantly less in duration.

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 8**.

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Predicted ground-borne noise and vibration impacts for the excavation of the Woolloongabba Station shaft are presented in **Table 9**. 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.

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Table 8 Woolloongabba Station Predicted Airborne Noise Goal Exceedances

Receiver Area	Period	Noise Goal (dBA)	Predicted 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	
			3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	Acoustic Shed
A	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
B	Day	$L_{A10,adj}$ 62	**3**	-	-	-	**3**	-	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	n/a	n/a	n/a	n/a	**9**	**1**
C	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
D	24/7	$L_{A10,adj}$ 57	**8**	**3**	**4**	-	**8**	**3**	n/a	n/a
E	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
F	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
G	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
I	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	**3**	-
J	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	n/a	n/a

Receiver Code: A = Allen St residential, B = Vulture St residential, C = Vulture St commercial, D = St Nicholas Cathedral, E = Main St residential, F = Main St commercial, G = Stanley St commercial, H = Busway Station (note: no internal spaces to assess, therefore excluded from table), I = Stanley St residential, J = St Joseph's Church & School.

Note: Exceedances shown in **bold**.

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

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Table 9 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 St Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.01	0.01	20	6
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.01	0.01	25	6
B - Vulture St Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	0.01	28	15
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.02	0.01	33	15
C – Vulture St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.05	0.06	36	28
D - St Nicholas Cathedral (Heritage)	24/7	2	LAeq,adj – 40	LA10,adj – 50	0.05	0.17	37	39
E - Main St Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.03	0.04	32	26
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.03	0.04	37	26
F – Main St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.11	0.07	42	30
G – Stanley St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.06	0.15	37	37
H – Busway Station	Day	25	n/a	n/a	0.39	0.26	n/a	n/a
I - Stanley St Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	0.03	0.03	32	20
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.03	0.03	37	20
J – St Josephs Church & School (Heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	27	16

Note 1: Dominant construction noise during cavern excavation (ie roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

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

EXECUTIVE SUMMARY

Discussion

The predicted noise levels are summarised as follows:

- Predicted noise levels for site establishment works including demolition of the existing GoPrint building at the Woolloongabba Station site indicate exceedances of the daytime noise goal of up to 3 dBA at the nearest residential receivers along Vulture Street with 3 m high acoustic hoarding around the site.
- Similar exceedances are predicted during the initial station shaft excavation (ie Scenario 3).
- Higher exceedances (i.e. by 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 the commencement of construction works at the site 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 (e.g. 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 (i.e. Scenario 4) are also predicted to exceed the night-time residential noise goal at the nearest receivers. 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.

With all practicable noise mitigation measures in place combined with careful management of all heavy vehicle movements on the site, noise impacts associated with the construction phase of the Woolloongabba Station for the BaT project should be largely avoided.

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.

George Street Station

Scenarios were developed for George Street Station construction works being representative of activities having potentially the greatest (i.e. worst case) noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Daytime site establishment including demolition of existing buildings with rockbreakers, excavators, spoil trucks and cranes:
  - Duration ~ 3 months
- Scenario 2 – Daytime piling of station access shaft (Mary Street staging):
  - Duration ~ 1 month
- Scenario 3 – Daytime initial station access shaft excavation with rockbreakers, excavators, front end loaders and spoil trucks:
  - Duration ~ 5 months
- Scenario 4 – Night-time shaft excavation including rockbreakers and on-site spoil movements:
  - Duration ~ 18 months inclusive of station shaft and cavern excavation and therefore the initial stages of the station shaft excavation (i.e. typically the worst case stage of this scenario) would be significantly less in duration.

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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 10**.

Predicted ground-borne noise and vibration impacts for the excavation of the George Street Station access shaft and cavern is presented in **Table 11**. 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.

Predicted ground-borne vibration and airblast overpressure impacts associated with blasting for the George Street Station access shaft are presented in **Table 12**.

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Table 10 George Street Station Predicted Airborne Noise Goal Exceedances

Receiver Area	Period	Noise Goal (dBA)	Predicted 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	
			3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	Acoustic Shed
A	Day	LA10,adj 62	-	-	-	-	-	-	n/a	n/a
B	Day	LA10,adj 77	-	-	-	-	-	-	n/a	n/a
C	Day	LA10,adj 77	-	-	-	-	**3**	**3**	n/a	n/a
D	Day	LA10,adj 77	-	-	-	-	-	-	n/a	n/a
	Night	LAmax 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
E	Day	LA10,adj 77	-	-	-	-	-	-	n/a	n/a
F	Day	n/a	-	-	-	-	-	-	n/a	n/a
G	Day	LA10,adj 77	**7**	**7**	-	-	**5**	**5**	n/a	n/a
	Night	LAmax 64	n/a	n/a	n/a	n/a	n/a	n/a	**20**	-
H	Day	LA10,adj 77	**9**	**9**	**5**	**5**	**12**	**12**	n/a	n/a
I	24/7	LA10,adj 57	-	-	-	-	-	-	n/a	n/a

Receiver Code: A = QUT, B = Parliament, C = 41 George St commercial, D = George St residential, E = Alice St commercial, F = City Botanic Gardens, G = 21 Mary St residential, H = 21 Mary St commercial, I = Brisbane Synagogue.

Note: Exceedances shown in **bold**.

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

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Table 11 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) Continuous[1]	Internal Ground-borne Noise (dBA) Intermittent[2]	Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
A - QUT (heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.01	0.01	23	12	14
B – Parliament House (heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	28	19	20
C – 41 George St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	10.5	0.16	**78 (23)** [3]	39	**68 (13)** [3]
C – 41 George St Commercial: predicted effect of working at RL 0 (ie 10 m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5 m of rock					n/a	n/a	**62 (7)** [3]	n/a	53
C – George St (Harris Tce - heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	**2.13 (0.13)** [3]	0.14	**63 (8)** [3]	36	**56 (1)** [3]
D – George St Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	0.14	0.15	42	35	34
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.14	0.15	**47 (5)** [3]	35	39
E – Queensland Club (heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.05	0.16	35	38	40
G – 21 Mary St Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	6.43	0.06	**64 (9)** [3]	27	55
G – 21 Mary St Residential (Day): predicted effect of working at RL 0 (ie 10 m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5 m of rock					n/a	n/a	51	n/a	42
G – 21 Mary St Residential	Night	0.5	LAeq,adj – 35	LAmax – 42	**6.43 (5.93)** [3]	0.06	**69 (27)** [3]	27	**60 (18)** [3]
G – 21 Mary St Residential (Night): predicted effect of working at RL 0 (ie 10 m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5 m of rock					**0.57 (0.07)** [3]	n/a	**56 (14)** [3]	n/a	**47 (5)** [3]
H – 21 Mary St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	19.62	0.17	**83 (28)** [3]	39	**73 (18)** [3]

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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)						
			Continuous[1]	Intermittent[2]	Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
H – 21 Mary St Commercial (Day): predicted effect of working at RL 0 (ie 10 m deeper into shaft) or working at RL 10 adjacent to a cut-off trench cut into approximately 5 m 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 cavern excavation (i.e. roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2: Dominant construction noise during shaft excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax (night-time) assessment parameters are most relevant.

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

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Table 12 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		PCF Blasting [1]	
		Vibration PPV (mm/s)	Airblast Overpressure (dBL Peak)	Vibration	Airblast Overpressure	Vibration	Airblast Overpressure
A - QUT (heritage)	Day	10	132	>100	>100	>100	>100
B – Parliament House (heritage)	Day	10	132	>100	>100	>100	>100
C – George St Commercial	Day	50	132	0.18	0.08	0.20	5.57
C – George St Heritage	Day	10	132	0.17	1.36	0.14	99
D – George Street Residential	Day	50	132	33	>100	36	>100
E – Queensland Club (heritage)	Day	50	132	>100	>100	>100	>100
G – Mary Street Residential	Day	50	132	0.31	0.17	0.34	12
H – Mary Street Commercial	Day	50	132	0.16	0.06	0.17	4.46
I – Brisbane Synagogue (heritage)	Day	10	132	0.58	8.72	0.47	>100

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

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Discussion

The predicted noise levels 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 7 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 initial shaft excavation works at this site.

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 will be required to achieve compliance with the airborne noise goals during the night-time period.

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

- Ground-borne noise levels for rockbreaking 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 (i.e. Mary Street, Day: 9 dBA and Night: 27 dBA) as well as during the night-time period for the George Street residential building (i.e. 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 (i.e. Mary Street: 23 dBA) and south-east (i.e. George Street: 28 dBA) boundary of the site is also predicted to be significantly exceeded during rockbreaking 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 (i.e. C - George Street heritage) during the initial stages of heavy rockbreaking of the station shaft.
- Based on the predicted vibration levels, it is recommended that a survey of potentially sensitive building contents (e.g. 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 (i.e. 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 rockbreaking 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).
- 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.

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- Ground-borne noise levels from rockbreaking 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.

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

- Rockbreaking be restricted to the daytime period 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 rockbreaking during the detailed design stage of the BaT 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.

Acoustically, exposure to a short-term blast event would be preferred to long term rockbreaking where ground-borne noise impacts have been identified. Furthermore, the predicted ground-borne noise levels in **Table 11** indicate that drilling of blast holes results in a better environmental outcome compared with rockbreaking 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 required to deal with these exceedances:

- Restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Investigate the benefits from making deep vertical cuts into the rock using rock saws or diamond wire (e.g. 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 (e.g. 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 (i.e. blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

Roma Street Station

Scenarios were developed for Roma Street Station construction works being representative of activities having potentially the greatest (i.e. worst case) noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Daytime site establishment including removal of Roma Street Station infrastructure:
    - Duration ~ 3 months
- Scenario 2 – Daytime piling of station access shaft:
    - Duration ~ 1 month
- Scenario 3 – Daytime initial station access shaft excavation with rockbreakers, excavators, front end loaders and spoil trucks:

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  - Duration ~ 5 months

- Scenario 4 – Night-time shaft excavation including rockbreakers and on-site spoil movements:
  - Duration ~ 17 months inclusive of station shaft and cavern excavation and therefore the initial stages of the station shaft excavation (i.e. typically the worst case stage of this scenario) would be significantly less in duration.

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 13**.

Predicted ground-borne noise and vibration impacts for the excavation of Roma Street Station access shaft and station cavern are presented in **Table 14**. 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.

Predicted ground-borne vibration and airblast overpressure impacts associated with blasting for the Roma Street Station access shaft are presented in **Table 15**.

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Table 13 Roma Street Station Predicted Airborne Noise Goal Exceedances

Receiver Area	Period	Noise Goal (dBA)	Predicted 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	
			3 m Hoarding	**6 m Hoarding**	**3 m Hoarding**	**6 m Hoarding**	**3 m Hoarding**	**6 m Hoarding**	**3 m Hoarding**	**Acoustic Shed**
A	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	n/a	n/a
	Night	L_{Amax} 49	n/a	n/a	n/a	n/a	n/a	n/a	-	-
B	Day	$L_{A10,adj}$ 77	-	-	-	-		-	n/a	n/a
C	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	24/7	$L_{A10,adj}$ 57	-	-	-	-		-	n/a	n/a
E	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	Day	$L_{A10,adj}$ 62	-	-	-	-		-	n/a	n/a
G	Day	$L_{A10,adj}$ 77	-	-	-	-		-	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	-	-
I	Day	$L_{A10,adj}$ 77	**4**	**4**	**10**	**10**	**9**	**9**	n/a	n/a
	Night	L_{Amax} 64	n/a	n/a	n/a	n/a	n/a	n/a	**19**	-
J	Day	$L_{A10,adj}$ 77	**2**	**2**	**3**	**3**	**7**	**7**	n/a	n/a
K	Day	n/a	-	-	-	-	-	-	n/a	n/a

Receiver Code: A = Wickham Tce residential, B = Wickham Tce commercial, C = Memorial Hospital, D = St Alban Church, E = Brisbane Private Hospital, F = Dentist School, G = Traders Hotel, H = Roma St Station (note: no internal spaces on ground level to assess, therefore excluded from table), I = Parkland Blvd residential, J = Parkland Blvd commercial, K = Roma St parkland.

Note: Exceedances shown in **bold**.

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

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Table 14 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)		Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
			Continuous[1]	Intermittent[2]					
A – Wickham Tce Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	31	15	22
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.02	0.02	36	15	27
B – Wickham Tce Commercial	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	30	15	22
C – Memorial Hospital	Day	2	LAeq,adj – 40	LA10,adj – 50	0.01	0.01	21	10	13
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.01	0.01	26	10	18
D – St Alban Church	24/7	10	LAeq,adj – 40	LA10,adj – 50	0.02	0.02	31	15	22
E – Brisbane Private Hospital	Day	25	LAeq,adj – 40	LA10,adj – 50	0.01	0.01	24	10	16
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.01	0.01	29	10	21
F – Brisbane Dental	Day	25	LAeq,adj – 45	LA10,adj – 55	0.00	0.01	18	5	10
G – Traders Hotel Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	28	18	20
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.02	0.02	33	18	25
H – Old Train Station Heritage	Day	2	n/a	n/a	0.06	0.24	n/a	n/a	n/a
I – Parkland Blvd Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	4.31	0.16	**68 (13)** [3]	36	**59 (4)** [3]
I – Parkland Blvd Residential (Day): predicted effect of working at RL 10 (i.e. 9 m deeper into shaft) or working at RL 19 adjacent to a cut-off trench cut into approximately 5 m of rock					n/a	n/a	**56 (1)**	n/a	47
I – Parkland Blvd Residential	Night	0.5	LAeq,adj – 35	LAmax – 42	**4.31 (3.81)** [3]	0.16	**73 (31)** [3]	**36 (1)** [3,4]	**64 (22)** [3]
I – Parkland Blvd Residential (Night): predicted effect of working at RL 10 (ie 9 m deeper into shaft) or working at RL 19 adjacent to a cut-off trench cut into approximately 5 m of rock					**0.87 (0.37)** [3]	n/a	**61 (19)** [3]	**n/a**	**52 (10)** [3]

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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) Continuous[1]	Internal Ground-borne Noise (dBA) Intermittent[2]	Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
J – Parkland Blvd Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	6.74	0.25	**74 (19)** [3]	42	**65 (10)** [3]
J – Parkland Blvd Commercial (Day): predicted effect of working at RL 10 (i.e. 9 m deeper into shaft) or working at RL 19 adjacent to a cut-off trench cut into approximately 5 m of rock					n/a	n/a	**62 (7)** [3]	n/a	53

Note 1: Dominant construction noise during cavern excavation (i.e. roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2: Dominant construction noise during shaft excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax (night-time) assessment parameters are 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 2 m of rock roadheaded from the station cavern).

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Table 15 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 Tce Residential	Day	50	132	>100	>100	>100	>100
B – Wickham Tce Commercial	Day	50	132	>100	>100	>100	>100
C – Memorial Hospital	Day	10	132	>100	>100	>100	>100
D – St Alban Church	Day	50	132	>100	>100	>100	>100
E – Brisbane Private Hospital	Day	50	132	>100	>100	>100	>100
F – Brisbane Dental Educational	Day	50	132	>100	>100	>100	>100
G – Traders Hotel Residential	Day	50	132	>100	>100	>100	>100
H – Old Train Station Heritage	Day	10	132	11	>100	9.27	>100
I – Parkland Boulevard Residential	Day	50	132	0.31	0.17	0.34	12
J – Parkland Boulevard Commercial	Day	50	132	0.31	0.17	0.34	12

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

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Discussion

The predicted Roma Street Station construction noise levels 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 rockbreakers, particularly during the initial stages of the shaft excavation prior to the construction of acoustic enclosure over the shaft.

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

- The ground-borne noise levels for rockbreaking 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 13 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 rockbreaking.
- 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 rockbreaking required for the BaT 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 (i.e. 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 both the commercial receiver floor (by 7 dBA) and the closest residential floor by a marginal 1 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, only the first residential floor of the Parkland Boulevard building is predicted to exceed the internal ground-borne noise goal during the daytime period.
- 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.

Given the predicted regenerated noise and vibration exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that:

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- Rockbreaking be restricted to the daytime period 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 rockbreaking during the detailed design stage of the BaT 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 of impact compared with rockbreaking, 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 the residential receivers in this building is also predicted to be significantly exceeded as a result of ground-borne noise from drilling.

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

- Restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Investigate the benefits from making deep vertical cuts into the rock using rock saws or diamond wire (e.g. 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 (e.g. 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 (i.e. blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

Northern Connection (TBM Retrieval Site)

Scenarios were developed for Northern Connection construction works being representative of activities having potentially the greatest (i.e. worst case) noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Daytime site establishment and construction of the ICB bridge with cranes, trucks, excavators and front end loaders:
  - Duration ~ 3 months
- Scenario 2 – Daytime trough excavation and spoil removal with rockbreakers, excavators and spoil trucks:
  - Duration ~ 1 month
- Scenario 3 – Daytime completion of the transition structure with concrete trucks, cranes and trucks:
  - Duration ~ 10 months
- Scenario 4 – Daytime TBM disassembly with cranes, trucks, power tools, generators:
  - Duration ~ 1 month

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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 16**.

Discussion

Careful planning of the construction footprint for the northern connection worksite has ensured a significant buffer between the worksite and sensitive receivers. This buffer together with the proposed 3 m high acoustic hoarding has resulted in the prediction of relatively minor exceedances of the daytime noise goals. The predicted noise levels in **Table 16** indicate that increasing the proposed 3 m acoustic hoarding along the eastern boundary to up to 6 m should achieve compliance with the noise goals at all sensitive receivers.

The movement of trucks within the worksite should be designed to limit (as much as practicable) the need for reversing and therefore reversing alarms. Where issues with reversing alarms occur, consideration should be given to the use of broadband “buzzer” reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) “beeping” alarms.

As discussed for the airborne noise assessment, the worksite and in particular the location of vibration intensive activities, would occur at significant distances from vibration sensitive receivers. On this basis, prediction of ground-borne vibration and noise is not considered warranted for the Northern Connection worksite.

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Table 16 Northern Connection Predicted Airborne Noise Goal Exceedances

Receiver Area	Period	Noise Goal (dBA)	Predicted 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	
			3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding	3 m Hoarding	6 m Hoarding
A	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	-	-
B	Day	$L_{A10,adj}$ 57	-	-	**4**	-	**2**	-	-	-
C	Day	$L_{A10,adj}$ 62	-	-	-	-	-	-	-	-
D	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	-	-
E	Day	$L_{A10,adj}$ 77	-	-	-	-	-	-	-	-
F	Day	$L_{A10,adj}$ 72	-	-	-	-	-	-	-	-

Receiver Code: A = Brisbane Girls Grammar, B = Gregory Tce residential, C = St Joseph's College, D = Gregory Tce commercial, E = Centenary Pool, F = Royal Children's Hospital.

Note: Exceedances shown in **bold**.

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Surface Track Construction Noise

Track work required for the BaT 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.

Construction noise levels from typical surface track construction activities/plant have been calculated for various setback distances with regards to the 87 dBA L_{Amax} planning noise level. High noise levels (potentially in excess of Queensland Rail's 87 dBA L_{Amax} planning level) may result from BaT project track work over small setback distances. In addition to limiting, where practicable, the duration of track construction works near any sensitive receiver, all reasonable and feasible noise mitigation measures would need to be applied consistent with the measures listed in Queensland Rail's CoP.

TBM Tunnelling Works

Approximately 5 km of driven tunnelling will be required for the Project. The tunnel will mainly be constructed using a Tunnel Boring Machine (TBM). The underground stations at Woolloongabba, George Street and Roma Street will be excavated by a combination of rockbreaking for the shaft and roadheader for the station caverns. The TBM is proposed to be launched from the Southern Connection site. The TBM is proposed to be travelling 140 m per week on a 24 hour per day basis.

Predicted ground-borne vibration levels from TBM tunnelling works at the nearest receivers along the BaT tunnel alignment are presented in **Table 17**. 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 BaT tunnel alignment are presented in **Table 18**.

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. It should be noted that these exceedances will only occur during a relatively short period (less than 1 week for the TBM passby).

There are several hotels in the CBD that exceed the night-time ground-borne noise goal 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.

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Table 17 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	15 m – 133 m	0.18 to **1.91** mm/s	EN, SD	P, M, TR
	Commercial	29 m – 236 m	0.10 to 1.00 mm/s	N	
	Educational	98 m – 178 m	0.14 to 0.26 mm/s	TP	
	Worship	114 m – 153 m	0.16 to 0.22 mm/s	TP	
	Hotel	76 m	0.34 mm/s	BN	
Woolloongabba Station to George St Station	Residential	31 m – 310 m	0.08 to **1.52** mm/s	EN, SD	P, M, TR
	Commercial	48 m – 294 m	0.08 to 0.55 mm/s	N	
	Educational	100 m – 176 m	0.18 to 0.29 mm/s	BN	
	Worship	28 m – 311 m	0.08 to 0.96 mm/s	N	
	Medical	311 m	0.08 mm/s	NF	
	Hotel	45 m – 258 m	0.1 to 0.**58** mm/s	N, SD	
George St Station to Roma St Station	Residential	26 m – 113 m	0.39 to **1.87** mm/s	EN, SD	P, M, BCS, TR
	Commercial	23 m – 313 m	0.13 to 2.13 mm/s[1]	SN	
	Educational	70 m – 270 m	0.16 to 0.65 mm/s	N	
	Worship	242 m – 279 m	0.15 to 0.17 mm/s	TP	
	Medical	233 m – 250 m	0.17 to 0.18 mm/s	TP	
	Hotel	25 m – 306 m	0.14 to **1.97** mm/s	EN, SD	
Roma St Station to Northern Connection	Residential	29 m – 124 m	0.09 to **0.90** mm/s	N, SD	P, TR
	Commercial	33 m – 103 m	0.20 to 0.80 mm/s	N	
	Educational	29 m – 159 m	0.07 to 0.44 mm/s	BN	
	Medical	86 m	0.29 mm/s	BN	
	Hotel	48 m – 119 m	0.10 to **0.54** mm/s	N, SD	

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.

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Table 18 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	15 m – 133 m 29 m – 236 m 98 m – 178 m 114 m – 153 m 76 m	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 St Station	Residential Commercial Educational Worship Medical Hotel	31 m – 310 m 48 m – 294 m 100 m – 176 m 28 m – 311 m 311 m 45 m – 258 m	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 St Station to Roma St Station	Residential Commercial Educational Worship Medical Hotel	26 m – 113 m 23 m – 313 m 70 m – 270 m 242 m – 279 m 233 m – 250 m 25 m – 306 m	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 St Station to Northern Connection	Residential Commercial Educational Medical Hotel	29 m – 124 m 33 m – 103 m 29 m – 159 m 86 m 48 m – 119 m	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**.

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Low Frequency Noise Impacts

Low frequency noise from the operation of 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 BaT Project.

Ground-borne noise measurements for a 12 m diameter TBM used for the CLEM7 project have been used for the low frequency assessment. All measurement data have been adjusted to account for the BaT 15 m diameter TBM in accordance with an assumed 10 x log(Area) relationship (i.e. BaT TBM generate 1.9 dBA higher ground-borne noise emission).

CLEM7 TBM and roadheader measurement results, over slant distances of approximately 45 m and 20 m respectively (shown in **Table 19**), indicate that the 55 dBZ level will be exceeded when tunnelling at close distance (within approximately 180 m and 40 m from the TBM and roadheader respectively). The results in **Table 19** 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 19 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

Construction Heavy Vehicle Noise and Vibration Impact Assessment

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

- A site accessed from Swanbank Road, Swanbank
- The existing 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

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- 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 Pine Mountain Road, Swanbank Road and Brisbane Airport 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 6:30 am and 6:30 pm for Scenario 1 to Pine Mountain Road, Carindale.
- $L_{A10(18hour)}$ for between 6 am 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 am.

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 6:30 am to 6:30 pm and 6:00 am to 12 midnight respectively.

The assessment of noise impact associated with BaT project construction heavy vehicle traffic is summarised in **Table 20**. The assessment takes into consideration the cumulative effect of BaT project heavy vehicles from multiple worksites on the assessed road segments.

From **Table 20** 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 (i.e. approximately 5 truck passbys per hour) between 6:30 am and 6:30 pm will potentially be noticeable. It should be noted that the JV have indicated that, subject to the final layout of the Boggo Road site, it might be feasible for spoil trucks to use Joe Baker Street and Boggo Road subsequently avoiding movements along Peter Doherty Street. 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 (i.e. 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.

For all other assessed road segments, BaT project construction heavy vehicles 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 pass-bys would not be altered by BaT 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 (i.e. able to be clearly felt) of ground vibration at buildings adjacent to spoil routes.

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Table 20 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)		
			LA10(12hr)	LA10(18hr)	LA10(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
	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	Peter Doherty Street	BR	-	**3.0**	-

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Brisbane Airport	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.

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SUMMARY OF POTENTIAL IMPACTS AND IMPACT MANAGEMENT

Table 21 Summary of Potential Construction Noise and Vibration Impacts and Recommended Impact Management 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: Upgrade the existing railway noise barrier adjacent to Railway Terrace (required for mitigation of operational rail noise as a consequence of the BaT project) as part of the early works program. Increase site acoustic hoarding to 6 m where practicable and / or erect noise barriers close to particularly noisy equipment (e.g. rockbreakers) General: Apply all practicable noise mitigation measures as outlined in **Section 11**
	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 6 m where practicable and / or erect noise barriers close to particularly noisy equipment (e.g. rockbreakers) until the excavation plant has progressed into the shaft to benefit from shielding from the shaft walls. General: Apply all practicable noise mitigation measures as outlined in **Section 11**
	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: Upgrade the existing railway noise barrier adjacent to Railway Terrace (required for mitigation of operational rail noise as a consequence of the BaT project) as part of the early works program. 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 all practicable noise mitigation measures as outlined in **Section 11**, in particular, continuous noise monitoring.
	Predicted ground-borne noise levels for rockbreaking 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 Leukaemia Centre (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 rockbreaking inside the tunnel to the daytime period. Otherwise temporarily relocate residents from affected premises during rockbreaker operation until the works progress far enough to comply with the internal noise goal. General: Apply all practicable noise mitigation measures as outlined in **Section 11**, in particular, continuous noise monitoring.
	Vibration from rockbreaking at the TBM launch shaft site is predicted to exceed the floor vibration tolerance (i.e. by 0.03	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

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Site / Activity	Potential Impact	Recommended Management Measure
	mm/s) for the TEM located within the basement of the Ecosciences building.	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 rockbreaking at times 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 (i.e. approximately 5 truck passbys per hour) between 6:30 am and 6:30 pm.	<u>Specific</u>: Restrict spoil truck movements to / from the Boggo Road worksite to 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 3 dBA at the nearest residential receivers along Vulture Street. Similar exceedances are predicted during the initial station shaft excavation.	<u>General</u>: Apply all practicable noise mitigation measures as outlined in **Section 11**, in particular, continuous noise monitoring.
	Noise goal exceedances of up to 8 dBA are predicted for St Nicholas Cathedral during surface construction works	<u>General</u>: Apply all practicable noise mitigation measures as outlined in **Section 11**, 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.	<u>Specific</u>: Careful management of all heavy vehicle movements on the site (e.g. speed restrictions, avoidance of queuing etc) combined with all practicable noise mitigation measures in place as outlined in **Section 11**. Install a low performance acoustic shed as soon as practicable.
George Street Station	Significant exceedances (up to 7 dBA) of the daytime noise goal predicted for the adjacent Mary Street apartment building residential receivers during site clearing and initial shaft excavations works.	<u>Specific</u>: Given 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 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 • Install a medium performance acoustic shed as soon as practicable • Expedite initial surface works (i.e. maximum number of plant operating at peak

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Site / Activity	Potential Impact	Recommended Management Measure
		output) to enable long-term works associated with shaft excavation to progress inside the acoustic shed • Continuous noise monitoring • Temporary relocation of residents during particularly noisy stages of the work
	Ground-borne noise levels for rockbreaking 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 (i.e. Mary Street, Day: 9 dBA and Night: 27 dBA) as well as during the night-time period for the George Street residential building (i.e. Receiver D – on the corner of George and Charlotte Streets, Night: 5 dBA).	Specific: Given 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 rockbreaking during the detailed design stage of the BaT project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy if needed. • Rockbreaking 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 (e.g. 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 receiver buildings on the north-east (i.e. Mary Street: 23 dBA) and south-east (i.e. George Street: 28 dBA) boundary of the site is also predicted to be significantly exceeded during rockbreaking of the station shaft.	Specific: Given the predicted regenerated noise goal exceedances for the adjacent Mary Street apartment building, it is strongly recommended that: • Ground-borne noise and vibration measurement trials are carried out for rockbreaking during the detailed design stage of the BaT 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.
	Vibration from rockbreaking 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: Given the predicted night-time vibration goal exceedances for the Mary Street apartment building adjacent the site, it is strongly recommended that: • Rockbreaking be restricted to the day-time period only until measurement results achieve compliance with the vibration goal or affected residents have

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Site / Activity	Potential Impact	Recommended Management Measure
		been temporarily relocated. • Ground-borne noise and vibration measurement trials are carried out for rockbreaking during the detailed design stage of the BaT 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 (i.e. 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 rockbreaking 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 10 dBA) of the daytime noise goal predicted for the Parkland Boulevard residential receivers during site clearing, piling and initial shaft excavations works.	Specific: Given 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 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 (i.e. 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 • Temporary relocation of residents during particularly noisy stages of the work
	Predicted ground-borne noise levels for rockbreaking during excavation of the Roma Street Station shaft is predicted to significantly exceed the daytime noise goals for both the commercial receivers (i.e. by up to 19 dBA) and residential receivers (i.e. by up to 13 dBA) inside the adjacent Parkland Boulevard receiver building.	Specific: Given 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 rockbreaking during the detailed design stage of the BaT 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 (i.e. by as much as 31 dBA) as a result of ground-	Specific: Given the predicted regenerated noise goal exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that: • Rockbreaking be restricted to the daytime period only until measurement results

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Site / Activity	Potential Impact	Recommended Management Measure
	borne noise from rockbreaking.	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 rockbreaking during the detailed design stage of the BaT 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 (e.g. 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 rockbreaking 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.	Specific: Given the predicted night-time vibration goal exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that: • Rockbreaking 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 rockbreaking during the detailed design stage of the BaT 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 4 dBA) of the daytime noise goal predicted for residential receivers adjacent to Gregory Terrace during trough excavation and transition construction works	Specific: Increase site acoustic hoarding to 6 m where practicable and / or erect noise barriers close to particularly noisy equipment (e.g. rockbreakers) General: Apply all practicable noise mitigation measures as outlined in **Section 11**
TBM tunnelling	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	Specific: It should be noted that these exceedances will only occur during 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).

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Site / Activity	Potential Impact	Recommended Management Measure
	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.	• 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. • 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 (i.e. 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.	Specific: 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.
Use of Peter Doherty Street for spoil removal from Boggo Rd work site	Forecast 2016 traffic volumes on Peter Doherty Street are low (i.e. 24 hour weekday average of 224 vehicles) and therefore the introduction of 57 heavy vehicle movements (i.e. approximately 5 truck passbys per hour) between 6:30 am and 6:30 pm will potentially be noticeable and result in an impact.	Specific: It should be noted that the JV have indicated that, subject to the final layout of the Boggo Road site, it might be feasible for spoil trucks to use Joe Baker Street and Boggo Road subsequently avoiding movements along Peter Doherty Street. Joe Baker Street and Boggo Road currently have no adjacent residential receivers.