4 - 6 Bligh Street, Sydney NSW

Infrastructure Impact Assessment on Sydney Metro & CBD Rail Link

19/12/2022 **Ref: 301351060**

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Revision

Revision	Date	Comment	Approved By
001	19/12/2022	First Issue	Mathew McGrory

Contents

1. Executive Summary

This report has been prepared to provide evidence to the NSW Transport authorities that the noise and vibration generated on the site by the demolition, excavation and construction works or operation related to the proposed development are not going to adversely impact the Sydney Metro and CBD Rail Link rail tunnels near the site. The impact on the nearest tunnel sections is estimated through a quantitative assessment and compared to the criteria outlined by the relevant regulatory documents and guidelines.

This report has been prepared by Stantec to accompany a detailed State Significant Development Application (SSDA) for the mixed-use redevelopment proposal at 4-6 Bligh Street, Sydney. The site is legally described as Lot 1 in Deposited Plan 1244245. This report has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) issued for the project (SSD-48674209).

This report concludes that the proposed mixed-use hotel and commercial development is suitable and warrants approval subject to the implementation of the following mitigation measures.

- Management plans
- Vibration monitoring

Following the implementation of the above mitigation measures, the remaining impacts are reasonable for construction works and manageable.

2. Introduction

This report has been prepared to accompany an SSDA for the for the mixed-use redevelopment proposal at 4-6 Bligh Street, Sydney.

The Council of the City of Sydney, as delegate for the Minister for Planning and Public Spaces (the Minister), is the Consent Authority for the SSDA under an Instrument of Delegation issued by the Minister on 3 October 2019.

The application seeks consent for the construction of a 59-storey mixed-use hotel and commercial development. The purpose of the project is to revitalise the site and deliver new commercial floorspace and public realm improvements consistent with the City's vision to strengthen the role of Central Sydney as an international tourism and commercial destination.

A separate development consent (D/2018/892) relating to early works for the proposed application was granted for the site on 31 January 2020. Consent was granted for the demolition of the existing site structures, excavation and shoring of the site for three basement levels (to a depth of RL9.38m) to accommodate the proposed mixed-use hotel and commercial development. As such, this application does not seek consent for these components and instead seeks to rely upon and activate D/2018/892 for early works.

Specifically, development consent is sought for:

- Site establishment, including removal of two existing trees along the Bligh Street frontage and de- commissioning and removal of an existing substation (s2041) on the site.
- Construction of a 59-storey hotel and commercial office tower. The tower will have a maximum building height of RL225.88 (205m) and a total gross floor area (GFA) provision of 26,796sqm, and will include the following elements:
  - Three basement levels accommodating a substation, rainwater tank, hotel back of house, plant and services. A porte cochere and four service bays will be provided on basement level 1, in addition to 137 bicycle spaces and end of trip facilities on basement level 2.
  - A 12-storey podium accommodating hotel concierge and arrival at ground level, conference facilities, eight levels of commercial floor space and co-working facilities, and hotel amenities including a pool and gymnasium at level 12.
  - 42 tower levels of hotel facilities including 417 hotel keys comprising standard rooms, suites and a penthouse.
  - Two tower levels accommodating restaurant, bar, back of house and a landscaped terrace at level 57.
  - Plant, servicing and BMU at level 59 and rooftop.

- Increase to the width of the existing Bligh Street vehicular crossover to 4.25m and provision of an additional 4m vehicular crossover on Bligh Street to provide one-way access to the porte cochere and service bays on basement level 1.
- Landscaping and public domain improvements including:
    - Replacement planting of three street trees in the Bligh Street frontage,
    - Construction of a landscape pergola structure on the vertical façade of the north-eastern and south-eastern podium elevations,
    - Awning and podium planters, and
    - Provision of a feature tree at the level 57 terrace.
- Identification of two top of awning building identification signage zones with a maximum dimension of 1200mm x 300mm. Consent for detailed signage installation will form part of a separate development application.
- Utilities and service provision.
- Installation of public art on the site, indicatively located at ground level.

This report has been prepared in response to the requirements contained within the Secretary's Environmental Assessment Requirements (SEARs) dated 01 October 2022 and issued for the SSDA. Specifically, this report has been prepared to respond to the SEARs requirement issued below.

Item	**Description of requirement**	**Section reference (this report)**
12. Noise and Vibration	Provide a noise and vibration assessment prepared in accordance with the relevant NSW Environment Protection Authority (EPA) guidelines. The assessment must detail construction and operational noise and vibration impacts on nearby sensitive receivers and structures and outline the proposed management and mitigation measures that would be implemented.	Section 7

3. The Site

The site for the purposes of this SSDA is a single allotment identified as 4-6 Bligh Street, Sydney and known as Lot 1 in Deposited Plan 1244245. The site has an area of 1,218sqm, and is identified in Figure 1.
The site is relatively flat, with a slight slope ranging from 21m AHD in the north-western corner to 19.5m AHD in the south-western corner.

The site is located within the north-eastern part of Central Sydney in a block bound by Bligh Street to the west, Hunter Street to the south, Chifley Square/Phillip Street to the east, and Bent Street to the north. The surrounding buildings are generally characterised by a mix of commercial office and hotel uses with ground level retail, restaurant and café uses and are of varying heights, ages and styles, including a number of State and local listed heritage buildings.

The site is also located in proximity to a number of Sydney Metro City & Southwest (opening 2024) and Sydney Metro West (opening 2030) station sites.

Specifically, the site is located to the immediate east of the Sydney Metro Hunter Street station (east site), which is located on the corner of Hunter Street and Bligh Street, and approximately 350m east of the Sydney Metro Hunter Street station (west site). The Hunter Street station sites are part of the Sydney Metro West project. SEARs for the preparation of Concept SSDAs for the sites were issued in August 2022.

Approximately 150m to the south of the site is Sydney Metro Martin Place Station site, located to the south of Hunter Street between Castlereagh Street and Elizabeth Street. The Martin Place Station site is currently under construction and forms part of the Sydney Metro City & Southwest project.

The site is occupied by a vacant commercial office building with ground floor retail and basement car parking known as "Bligh House". Completed in 1964, Bligh House is a 17-storey tower inclusive of a three-storey podium with the podium levels built to the Bligh Street alignment and the tower setback from the street frontage. The building was designed by Peddle Thorp and Walker and was constructed as part of the post-World War II development boom in the Sydney CBD. The podium overhang along the footpath provides continuous pedestrian protection. Vehicle access to the site is off Bligh Street via a single 2.6m wide driveway that is restricted by a security gate under one-lane, two-way access arrangements. The driveway provides access to the basement car park, containing 21 car parking spaces.

The site contains no vegetation; however, two existing street trees are located adjacent to the site boundary on Bligh Street. Development consent for the demolition of the existing site structures, excavation and shoring of the site for five basement levels (to a depth of RL9.38m) was granted by City of Sydney on 31 January 2022 (D/2018/892).

Source: nearmap.com

Figure 1: Site Identification Plan

4. Project Overview

This report has been prepared to provide evidence to the NSW Transport authorities that the noise and vibration generated on the site by the demolition, excavation and construction works or operation related to the proposed development are not going to adversely impact the Sydney Metro and CBD Rail Link rail tunnels near the site. The impact on the nearest tunnel sections is estimated through a quantitative assessment and compared to the criteria outlined by the relevant regulatory documents and guidelines.

This report provides:

- Projected acoustic criteria for the noise and guideline levels for vibration generated on the proposed site
- A quantitative assessment of the ground-borne noise generated by the works for the proposed development and the impact on the rail tunnels
- An assessment of the vibration generated by the works and the impact on the nearest tunnel sections

- General conclusions and professional opinion on potential acoustic impacts from the works of the proposed development on the rail tunnels
- Indicative recommendations for noise and vibration mitigation measures during the works in order to meet the relevant criteria and guidelines
- A proposal for a noise and vibration monitoring program
- Commentary on noise and vibration generated during the operation of the proposed development and their impact on the underground rail tunnels

The overall works related to building the proposed development are described below and are expected to occur across approximately 13 months for demolition and excavation and 31 months for new construction. The works are generally split into three periods which are:

1. Demolition
   - Existing office building demolition
   - Basement demolition
2. Excavation
   - Shoring
   - Bulk excavation
   - Detailed excavation
3. Structure
   - Piling
   - Basement slab and walls
   - Concrete structures for podium and tower
   - Installing façade elements

This report will consider all the above periods and their relevant noise and vibration impacts on the underground rail tunnels along with the operation of the finished building. However, certain tasks will be carried out concurrently with other tasks for particular time periods that are significant in duration. In a given combination of events, the noise emitted by performing the tasks simultaneously will be considered. Acoustic impacts on the surrounding buildings are not addressed here as they will be a part of other acoustic reports.

The assessment has been prepared with the following references:

- Interim Construction Noise Guideline (ICNG), NSW DECC, 2009
- Construction Noise Strategy, Transport for NSW, 2013
- Assessing Vibration: A Technical Guideline, NSW DEC, 2006
- AS 2436:2010 *Guide to Noise and Vibration Control on Construction, Demolition and Maintenance Sites*
- AS/NZS 2107:2016 *Acoustics – Recommended design sound levels and reverberation times for building interiors*
- British Standard BS 5228: Part 1:1997 *Noise and Vibration Control on Construction and Open Sites*
- British Standard BS 7385:1993 *Evaluation and Measurement for Vibration in Buildings – Part 2: Guide to Damage Levels from Ground-borne Vibration*
- British Standard BS 6472-1:2008 *Guide to evaluation of human exposure to vibration in buildings – Part 1: Vibration sources other than blasting*

- German Standard DIN 4150-Part 3 *Structural vibration in buildings – Effects on structures*

- Transit Noise and Vibration Impact Assessment FTA-VA-1003-06, United States Department of Transportation – Federal Transit Administration (FTA), 2006
- Melbourne Metro Rail Project Environment Effects Statement Technical Appendix I, Appendix B Construction: Vibration and Ground-Borne Noise, 20 April 2016
- Construction Noise and Vibration on Sensitive Premises, conference paper by Cedric Roberts, Acoustics 2009 conference in Adelaide
- Interim Rail Corridor CBD Rail Link & CBD Metro, Map 6 out of 9, dated 27 June 2009
- Sydney Metro Underground Corridor Protection, Transport for NSW, 16 October 2017

The predicted noise and vibration levels are based on the proposed works program and equipment lists provided in this report.

5. Project Description

5.1 Site Description and Underground Tunnel Locations

The site is identified as 4-6 Bligh Street, Sydney (the site) as illustrated in Figure 2. The site comprises of a single allotment and is legally described as Lot 1 DP 1244245 with a total area of 1,128 m². Currently, there is a commercial building on site. The site is bound by Bligh Street to the northwest and commercial buildings to east, south and west. To the northeast there is additionally the Sofitel Sydney Wentworth hotel.

Future rail corridors for CBD Rail Link and CBD Metro have also been planned near and below the site The nearest underground rail corridors to the site are currently under construction and form a part of the Sydney Metro City & Southwest, running north-south on the western and eastern sides of the site. The southbound tunnel reserve partially overlaps with the site footprint in the eastern corner, but the tunnel will be approximately 1 metres below the lowest proposed basement level. As such, the proposed development will be within the second reserve as defined by Sydney Metro protection guidelines. The distance between the first reserve and the closest point of the proposed development is approximately 1.4 metres. The location of the tunnels respective to the site is shown in Figure 2. The survey details have been provided in APPENDIX A.

Ground Floor Plan

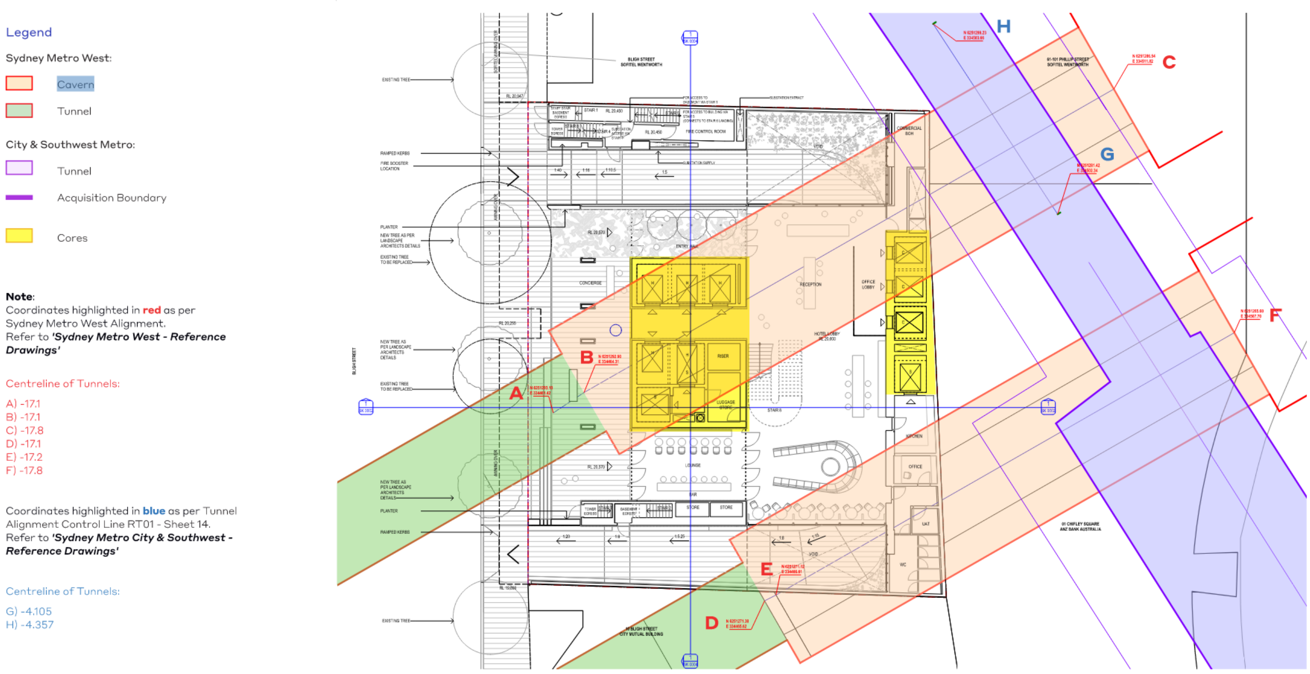


Figure 2: Site Aerial View and Sydney Metro Tunnel Locations.

5.2 Proposed Works

At the start of the works, the existing 20-storey office building will be demolished. Due to the proximity of sensitive buildings, it is likely that this process will be conducted level by level using hand tools and smaller machinery. Additionally, the existing basement levels will be dismantled and prepared for further excavation. Excavators with ripping and rock breaker attachments are expected to be required during these activities.

In the excavation stage, the extent of the basement will be increased as shown in APPENDIX A. Smaller elements such as lift pits extend deeper but they are expected to be located further away from the tunnels than the closest edge of the lowest basement level. According to the geotechnical investigation, the ground type at these elevations is mainly medium to high strength sandstone, which will require excavators with rock breakers and/or rock saws to extract the material.

During the structure period, the new building is constructed using mainly concrete in the structural elements. Concrete trucks and pumps along with a selection of hand tools will form the majority of the equipment needed during this period. At this stage of the design, it is not yet clear whether piling will be required for the foundations of the building.

5.3 Potential Vibration Impacts

The vibration from the demolition, excavation and construction activities must be considered for the followings:

- Risk of damage to the tunnel structures of Sydney Metro and CBD Rail Link due to repeated intense shock loads from e.g. rock breakers.
- Ground-borne noise within the tunnels caused by transmitted vibrations being radiated as noise by the tunnel structures.
- Human discomfort due to ground vibrations exceeding the threshold of perception within the tunnels.

The operation of the proposed development will not include any vibration intensive activities or plant. Any vibrating plant will be isolated from the building structures to provide amenity for occupants within the development itself, resulting in negligible impacts on any underground infrastructure. Therefore, this report and the assessments below focus on the acoustic impacts from demolition and excavation.

6. Vibration Criteria

The acoustic criteria presented in the sections below aim to address the requirement as outlined in the Sydney Metro protection guideline to assess potential impacts on underground rail infrastructure, when constructing within the second reserve. It is considered that by complying with these criteria, the conditions within the guideline are also satisfied.

6.1 Ground-Borne Noise Criteria

Ground-borne noise can be generated when vibration transmits through the ground and into a structure that has the possibility to radiate the vibration energy as noise into a space. If such works happen completely underground, the ground-borne noise impact can be greater than that from airborne noise.

In the ICNG, noise criteria for ground-borne noise are only given for residences to protect the acoustic amenity and sleep of the occupants. Consequently, the criteria are not relevant for the underground rail corridors. Instead, a maximum internal steady state noise level $L_{Aeq,15min}$ of less than 65 dB(A) is recommended, following the recommended noise levels in AS/NZS 2107:2016 for enclosed carparks.

6.2 Vibration Criteria

6.2.1 Human Comfort – Continuous and Impulsive Vibration Criteria

Structural vibration in buildings can be detected by occupants and can affect them in many ways including reducing their quality of life and their working efficiency. Complaint levels from occupants of buildings subject to vibration depend upon their use of the building and the time of the day. The vibration emitted from construction works should be such that it does not exceed the maximum limits set out in the criteria presented in to Table 4. The guide on preferred values for human comfort have been extracted from the NSW DEC *Assessing Vibration: A Technical Guideline* (2006). The criteria for continuous and impulsive vibration are summarized in Table 1.

Table 1: Criteria for Exposure to Continuous and Impulsive Vibration

Place	Time	Vibration Acceleration (m/s^2)			
		Preferred		Maximum	
Continuous Vibration		z axis	x and y axis	z axis	x and y axis
Workshops	Day or night time	0.040	0.029	0.080	0.058
Impulsive Vibration		z axis	x and y axis	z axis	x and y axis
Workshops	Day or night time	0.64	0.46	1.28	0.92

Note: The applicable criteria within a rail tunnel have been considered to correspond to the workshop criteria

Disturbance caused by vibration will depend on its duration and its magnitude. This methodology of assessing intermittent vibration levels involves the calculation of a parameter called the Vibration Dose Value (VDV) which is used to evaluate the cumulative effects of intermittent vibration. The criteria applicable when considering periods of intermittent vibration are presented in Table 2.

Table 2: Acceptable Vibration Dose Values for Intermittent Vibration (1.75 m/s)

Location	Daytime		Night-time	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Workshops	0.80	1.60	0.80	1.60

Note: The applicable criteria within a rail tunnel have been considered to correspond to the workshop criteria

6.2.2 Cosmetic/Structural Damage – Vibration Criteria

Ground vibration criteria are defined in terms of levels of vibration emission from construction activities that will not cause cosmetic or structural damage to surrounding buildings or structures. It should be noted that human comfort criteria are normally expressed in terms of acceleration whereas cosmetic/structural damage criteria are normally expressed in terms of velocity. The human comfort criteria are also often exceeded long before a risk of cosmetic/structural damage occurs.

Cosmetic and structural damage criteria are presented in German Standard DIN 4150-Part 3 *Structural vibration in buildings – Effects on structures* and British Standard BS 7385-2:1993 *Evaluation and Measurement for Vibration in Buildings*. The British Standard BS 7385-2:1993 establishes vibration values for buildings based on the lowest vibration levels above which damage has been credibly demonstrated. These values are evaluated to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as 95% probability of no effect. The aforementioned values are summarised in .

Table 3: Transient Vibration Guide Values for Cosmetic Damage – BS 7385-2:1993

Type of Building	Peak component particle velocity in frequency range of predominant pulse	
	4 Hz to 15 Hz	15 Hz and above
Reinforced or framed structures Industrial or light commercial type buildings	50mm/s	N/A
Unreinforced or light framed structures Residential or light commercial type buildings	15mm/s	20mm/s (50mm/s at 40Hz and above)

The BS 7385 Part 2-1993 state that the guide values in relate to transient vibration which does not give rise to resonant responses in structures and to low-rise buildings. This standard recognises adjustments to the guide values in depending on the type of activity and the vibration receiver. For construction activities involving intermittent vibration sources (i.e. rock breakers, piling rigs, vibratory rollers, excavators), guide values in may need to be reduced by up to 50% as a conservative vibration damage screening levels.

Table 4 and Table 5 indicate the vibration limits presented in DIN 4150-Part 3 to ensure structural damage does not occur during short-term and long-term vibration, respectively.

Table 4: Guideline Value of Vibration Velocity (v_i) for Evaluating the Effects of Short-Term Vibration – DIN 4150-

Line	Type of Structure	Vibration velocity, v_i, in mm/s Foundation At a frequency of			Plane of floor of uppermost full storey
		Less than 10 Hz	10 to 50 Hz	50 to 100 Hz *	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that, because of their particular sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order)	3	3 to 8	8 to 10	8
*For frequencies above 100 Hz, at least the values specified in this column shall be applied.					

Note: Vibration levels slightly exceeding those vibration levels in the table would not necessarily mean that damage would occur.

Table 5: Guideline Value of Vibration Velocity for Evaluating the Effects of Long-Term Vibration – DIN 4150-Part 3.

Line	Type of Structure	Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies.
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	10
2	Dwellings and buildings of similar design and/or use	5
3	Structures that, because of their particular sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order)	2.5

Note: Vibration levels slightly exceeding those vibration levels in the table would not necessarily mean that damage would occur.

6.2.3 Sydney Metro Underground Corridor Protection Guideline

The Sydney Metro protection guideline outlines maximum vibration impact on the metro infrastructure that must be satisfied by all developments within a horizontal distance of 25 metres from the first reserve. The criteria are expressed in peak particle velocity, as for structural damage above, and are as follows:

- 15 mm/s for tunnel and cavern cast in situ concrete linings that are in good condition.
- 20 mm/s at the running tunnels supported using a precast concrete segment lining.

The above criteria apply at all frequencies and are thus partially more stringent than the relevant criteria in and Table 4

7. Noise & Vibration Assessment

7.1 Equipment & Assumptions

The demolition of the existing building, the excavation of the new basement and the construction of the new structures will involve various vibration generating construction equipment. These projected items have been listed in Table 6 together with their estimated peak particle velocities (PPV) at a reference distance of 7.6 metres from the equipment. Where spectral information is used in the calculations below, the vibration of the equipment has been assumed to be concentrated between 30 and 60 Hz, similar to the Melbourne Metro Rail Project. It should be noted that the actual vibration values depend on the selected equipment and exact ground conditions, and should be adjusted based on on-site measurements.

Table 6: Expected Demolition, Excavation & Construction Equipment.

Type of equipment	PPV at 7.6 m, mm/s	Comments
20t excavator with hydraulic rock breaker	4.7	Melbourne Metro Rail Project
20t excavator with rock saw	4.7	Assumed to vibrate less than or equal to excavator with rock breaker
12-15t excavator with hydraulic rock breaker	3.3	Melbourne Metro Rail Project
Excavator with ripper	1.3	Melbourne Metro Rail Project
Hydromill in rock (diaphragm wall construction)	0.4	FTA Guideline
Piling rig (bored)	1.0	British Standard BS 5228
Heavy vehicle traffic	1.9	FTA Guideline (loaded trucks)
Bobcat	0.1	FTA Guideline (small bulldozer)
Fixed plant	1.9	Expected to vibrate less than or equal to heavy traffic

In the assessments in the sections below, it has been assumed that the vibration intensive equipment is working within the proposed development in a location closest to an underground rail tunnel. Based on information currently available, for most of the equipment this will be the southbound Sydney Metro tunnel at a slope distance of approximately 8 metres from Basement 5 eastern corner. For piling, the shortest distance is assumed to be 5 metres, which is the horizontal extent of the first reserve.

Note: If vibration impact is estimated at distances shorter than the PPV reference distance, predictions are likely to be less accurate. Measurements should be conducted especially in cases where vibration generating machinery operates this close to a sensitive receiver.

Note: It is assumed in the report that the shoring will be carried out without the use of viratory or impactive equipment.

7.2 Structural Damage Assessment

To assess whether vibration from the works has a potential to cause structural damage to the underground rail tunnels, the peak particle velocity (PPV) transmitted from each of the expected construction equipment types is estimated at the closest section of the southbound Sydney Metro tunnel. For excavators with rock breakers, the following formula was used (similar to Melbourne Metro Rail Project):

$$PPV_{receiver} = k\frac{d_{ref}}{d}e^{-\alpha(d-d_{ref})},$$

where $PPV_{receiver}$ = peak particle velocity in mm/s at receiver

k = site/machine specific constant

d_{ref} = reference distance for source vibration data in m (7.6 metres in this assessment)

d = slope distance from the source location to the closest edge of the tunnel in m

α = site specific ground attenuation constant, which varies with frequency

Note: Soil attenuation coefficient is dependant on the operation dominant frequency. For the purpose of this assessment an attenuation coefficient of 0.0003 m^{-1} at 5 Hz is used (based on assumption of hard rock, *Amick 1999*).

For other equipment listed in Table 6, a simplified version of the above formula was adopted (as per the FTA Guideline):

$$PPV_{receiver} = PPV_{ref}\left(\frac{d_{ref}}{d}\right)^n,$$

where $PPV_{receiver}$ = peak particle velocity in mm/s at receiver

PPV_{ref} = machine specific reference peak particle velocity in mm/s (at 7.6 metres in this assessment)

d_{ref} = reference distance for source vibration data in m (7.6 metres in this assessment)

d = slope distance from the source location to the closest edge of the tunnel in m

n = value related to vibration amplitude attenuation rate through ground (1.0 used in this assessment).

The estimated peak vibration curves over distance for the various machinery can be found in Figure 3 and Figure 4. The values at nominated the distances from the source (5.0 m for piling, 7.0 m for other equipment) have been listed in Table 7 and compared to the criteria in Section 1 to represent the predicted impact on the closest Sydney Metro tunnel section.

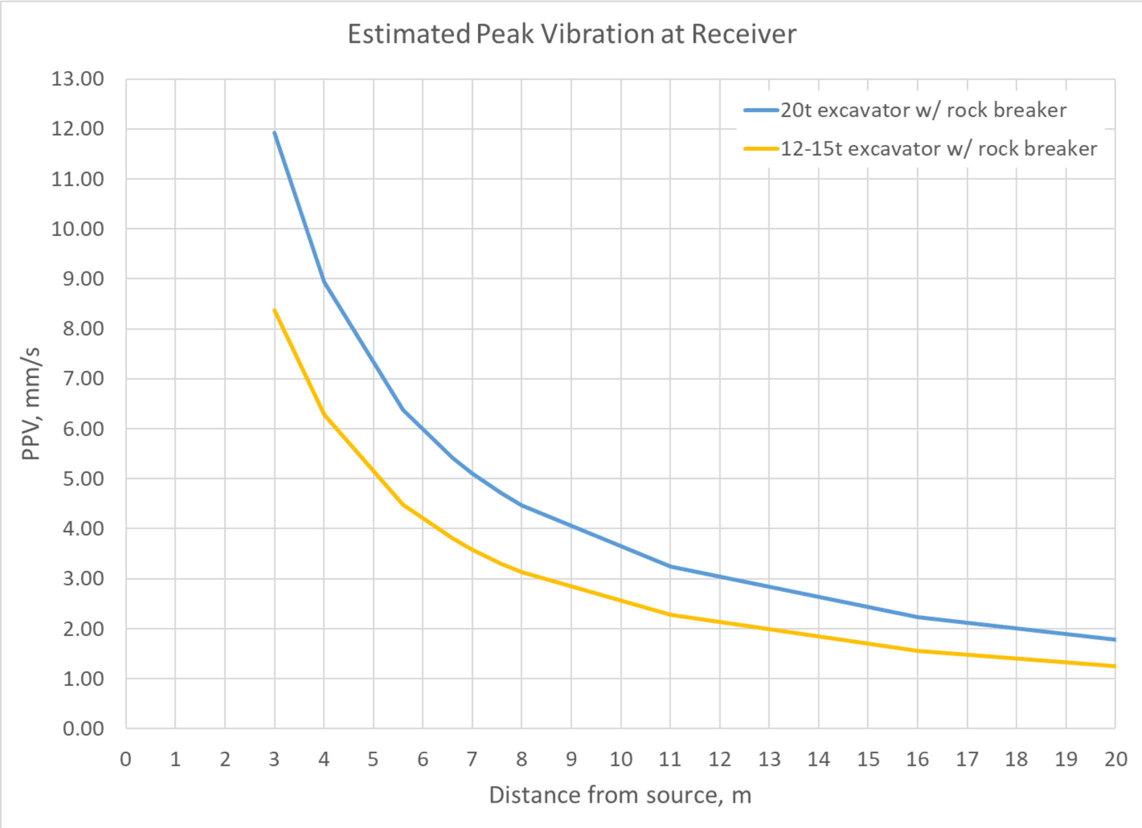


Figure 3: Estimated Peak Vibration at Receiver over Distance – Excavators.

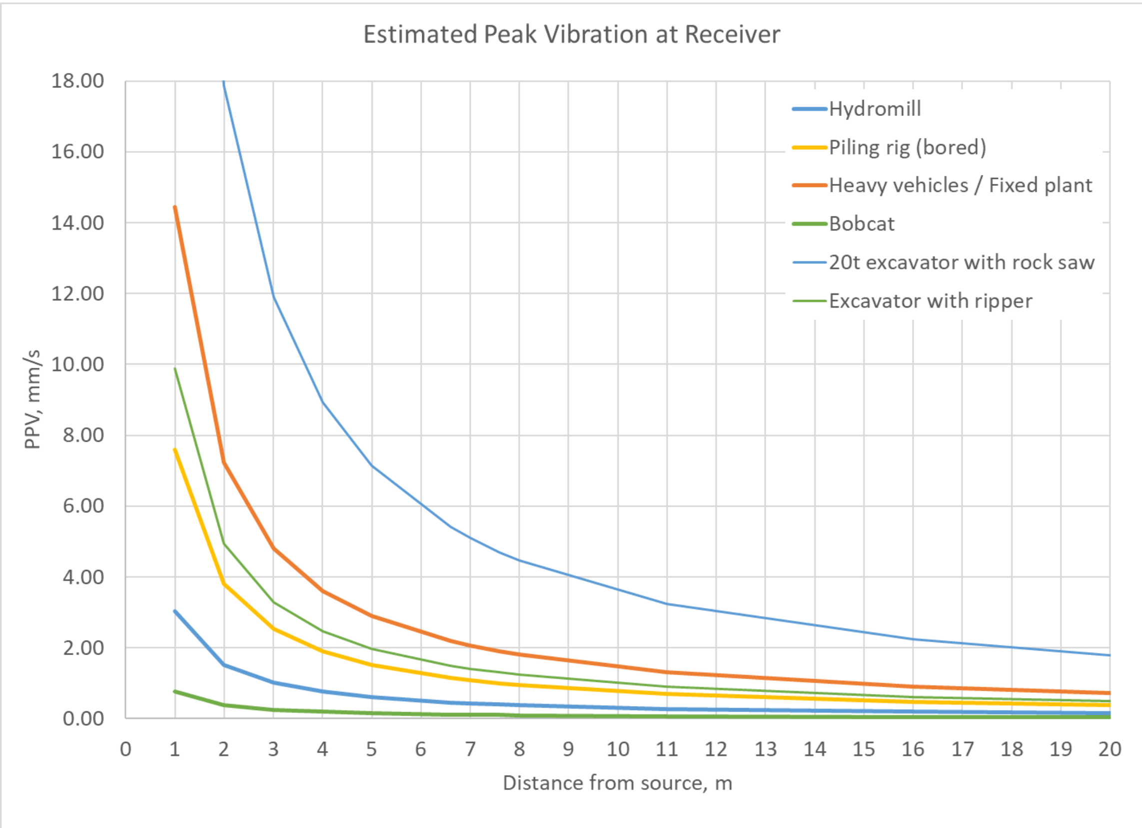


Figure 4: Estimated Peak Vibration at Receiver over Distance – Other Equipment.

Table 7: Estimated Peak Particle Vibration at Sydney Metro Tunnel (Southbound).

Equipment	Estimation distance	Estimated PPV, mm/s	Compliance?
20t excavator with hydraulic rock breaker	11 m	5.1	Yes
20t excavator with rock saw	11 m	5.1	Yes
12-15t excavator with hydraulic rock breaker	11 m	3.6	Yes
Excavator with ripper	11 m	1.4	Yes
Hydromill in rock (diaphragm wall construction)	11 m	0.4	Yes
Piling rig (bored)	5 m	1.5	Yes
Heavy vehicle traffic	11 m	2.1	Yes
Bobcat	11 m	0.1	Yes
Fixed plant	11 m	2.1	Yes

The highest PPV value in Table 7 is 5.1 mm/s for 20t excavator with hydraulic rock breaker and the excavator with a rock saw. The lowest criterion outlined in Section 1 applicable to an underground rail tunnel (DIN 4150-Part 3, line 1) is 10 mm/s for long-term vibration in horizontal plane at all frequencies, whereas the lower Sydney Metro protection guideline criterion is 15 mm/s. Since the peak vibration decreases very quickly over distance, it is expected that the total PPV values will remain below the criteria even if several of the equipment listed are active simultaneously.

7.3 Human Comfort

Vibration impact on humans depends on the duration and magnitude of the vibration events. Demolition, excavation and construction works typically result in intermittent vibration, and the impact on people potentially occupying the closest section of the southbound Sydney Metro tunnel is assessed as vibration dose value (VDV). The parameters defining the VDV are:

- Level of vibration
- Spectral distribution of vibration
- Duration of vibration activity

Assuming that the vibration frequencies produced during the works focus on a narrow range, the estimated VDV (eVDV) can be assessed from the associated root-mean-square (RMS) velocity at the receiver using the following formula (see Assessing Vibration guideline):

$$eVDV = 1.4 \times v_{RMS,receiver} \times \left(\frac{2\pi f W}{1000}\right) \times t^{0.25},$$

where $v_{RMS,receiver}$ = RMS vibration velocity at receiver in mm/s

f = frequency of vibration in Hz (31.5 Hz assumed in this assessment)

W = weighting factor for frequency and axis of vibration

curve in BS 6472-1:2008 as per current *'Assessing Vibration: A Technical Guideline, NSW DEC, 2006'* requirements)

t = duration of vibration in s (8h assumed in this assessment).

Assumptions:

- the vibration of the equipment has been assumed to be concentrated between 30 and 60 Hz. For this assessment it is assumed that the dominant vibration is at 31.5 Hz;
- It is assumed that the expected PPV values presented in Table 6 are dominated in Z axis;
- As per *'Assessing Vibration: A Technical Guideline, NSW DEC, 2006',* Wg frequency weighting curve is used. It is noted that this calculation can lead to conservative VDV estimates. Therefore, Wg = 0.254 is assumed in this assessment.

The RMS velocity for the various equipment can be obtained from the $PPV_{Receiver}$ values predicted at the rail tunnel receiver in Section 7.2 above. The conversion from peak value to RMS has been done using a crest factor of 4, consistent with the FTA Guideline.

The resulting VDVs within the closest section of the southbound Sydney Metro tunnel have been outlined in Table 8. The values represent the worst-case dose over an 8h work shift, the equipment operating for the majority of the time.

Table 8: Predicted VDV over 8h Work Shift within Sydney Metro Tunnel (Southbound).

Equipment	Estimation distance	eVDV, $m/s^{1.75}$	Compliance?
20t excavator with hydraulic rock breaker	11 m	0.74	Yes
20t excavator with rock saw	11 m	0.74	Yes
12-15t excavator with hydraulic rock breaker	11 m	0.52	Yes
Excavator with ripper	11 m	0.21	Yes
Hydromill in rock (diaphragm wall construction)	11 m	0.06	Yes
Piling rig (bored)	5 m	0.35	Yes
Heavy vehicle traffic	11 m	0.30	Yes
Bobcat	11 m	0.02	Yes
Fixed plant	11 m	0.30	Yes

The applicable VDV criteria within a rail tunnel have been considered to correspond to the workshop criteria in Section 1 . The preferred and maximum VDVs are 0.8 and 1.6 $m/s^{1.75}$, respectively. Comparing the prediction results to the criteria, it is expected to be unlikely for the simultaneously operating machinery to exceed the maximum value.

7.4 Ground-Borne Noise Assessment

The levels of ground-borne noise from vibration intensive works can be estimated from the average vibration amplitude of the room surfaces and the sound absorption properties of the space. Ideally, the calculations would be conducted over a frequency range, however in the absence of spectral vibration information, a simplified assessment has been done following the FTA Guideline. In the guideline, an approximation has been made between the vibration velocity level, which is vibration velocity in decibels, and the sound levels resulting from the vibration.

The vibration velocity level can be calculated from:

$$L_v = 20 \times \log_{10}\left(\frac{v_{RMS}}{v_{ref}}\right),$$

where L_v = vibration velocity level in dB

v_{RMS} = RMS vibration velocity from source in mm/s

v_{ref} = reference vibration velocity in mm/s (2.54E-5 mm/s, as per FTA Guideline).

The vibration velocity level L_v, calculated as above, approximately equals to the unweighted sound level within a space with average level of acoustic absorption. Estimating the A-weighted sound level requires knowledge of the general vibration spectrum shape. Assuming the vibration frequencies are concentrated e.g. within one octave band, the A-weighting factor for that band can be applied directly.

In this assessment, it has been assumed that the vibration spectrum peaks between 30 and 60 Hz. According to the FTA Guideline, the vibration level should then be adjusted by -35 dB to obtain the approximate A-weighted ground-borne noise level. The resulting formula is:

$$L_{Aeq,15min} = L_v - 35\ dB = 20 \times \log_{10}\left(\frac{v_{RMS}}{v_{ref}}\right) - 35\ dB,$$

where $L_{Aeq,15min}$ is the ground-borne noise level within a space, an equivalent noise level over 15 minutes in dB(A). Using the RMS velocities from Section 7.3 above, the ground-borne noise levels in Table 9 were calculated.

Table 9: Estimated Ground-Borne Noise Levels within Sydney Metro Tunnel (Southbound).

Equipment	$L_{Aeq,15min}$, dB(A)	Compliance?
20t excavator with hydraulic rock breaker	54	Yes
20t excavator with rock saw	55	Yes
12-15t excavator with hydraulic rock breaker	51	Yes
Excavator with ripper	44	Yes
Hydromill in rock (diaphragm wall construction)	33	Yes
Piling rig (bored)	49	Yes
Heavy vehicle traffic	47	Yes
Bobcat	21	Yes
Fixed plant	47	Yes

It is acknowledged that a rail tunnel is likely to have less than an average amount of acoustic absorption, which would result in higher noise levels than listed in Table 9 above. It should, however, be noted that the calculations assumed the equipment is running continuously, which in practice is not likely. Overall, it is estimated that the total ground-borne noise level in the tunnel will not continuously exceed the criterion of $L_{Aeq,15min}$ <65 dB(A) outlined in Section 6.1.

7.5 Minimum Working Distances

To avoid structural damage to the surrounding buildings along with the underground rail tunnels, minimum working distances were determined for each structure type. It should be noted that the values are only estimates and rely on assumptions on the vibration spectrum shape. Measurements should be undertaken before conducting works near existing structures. The minimum distances for short-term vibration impact have been listed in Table 10.

Table 10: Minimum Working Distances.

Equipment	Minimum working distance, m		
	Typical commercial building PPV ≤ 10 mm/s	Sydney Metro and CBD RL tunnels PPV ≤ 20 mm/s	Heritage building PPV ≤ 2.5 mm/s
20t excavator with hydraulic rock breaker	4	5	16
20t excavator with rock saw	4	3	16
12-15t excavator with hydraulic rock breaker	2	5	11
Excavator with ripper	-	-	4
Hydromill in rock (diaphragm wall construction)	-	-	2
Piling rig (bored)	2	-	3
Heavy vehicle traffic	-	1	7
Bobcat	-	-	-
Fixed plant	-	1	7

8. Vibration Management Strategies

8.1 General Recommendations

Vibration can be more difficult to control than noise, and there are few generalisations that can be made about its control. It should be kept in mind that vibration may cause disturbance by causing structures to vibrate and radiate noise in addition to perceptible movement. Impulsive vibration can, in some cases, provide a trigger mechanism that could result in the failure of building components that had previously been in a stable state.

During the demolition, excavation and construction works, some vibrations (transmitted through the structure from the sites) are expected, being more of a concern for the surrounding sensitive receivers. Vibrations can also trigger annoyance, which might get elevated into action by occupants of exposed buildings, and should therefore be included in the planning of communication with impacted communities.

It should be remembered that failures, sometimes catastrophic, can occur as a result of conditions not directly connected with the transmission of vibrations, e.g. the removal of supports from retaining structures to facilitate site access. BS 7385-2 provides more information on managing ground-borne vibration and its potential effects on buildings. Where site activities may affect existing structures, a thorough engineering appraisal should be made at the planning stage.

General principles of seeking minimal vibration at receiving structures should be followed in the first instance. Predictions of vibration levels likely to occur at sensitive receivers are recommended to be based on on-site measurements to assess site transmission and propagation characteristics between source and receiver locations.

Guidance for measures available for the mitigation of vibration transmitted can be sought in more detailed standards, such as BS 5228-2 or policy documents, such as the NSW DEC *Assessing Vibration: A Technical Guideline*. Identifying the strategy best suited to the control of vibration follows a similar approach to that of noise: avoidance, control at the source, control along the propagation path, control at the receiver, or a combination of these. It is noted that vibration sources can include stationary plants (pumps and compressors), portable plants (jackhammers and pavement vibrators), mobile plants, pile-drivers, tunnelling machines and activities, and blasting, amongst others. Unusual ground conditions, such as a high water-table, can also cause a difference to expected or predicted results, especially when considering the noise propagated from piling.

8.2 Monitoring Strategy

8.2.1 General Methodology

Noise and vibration levels should be monitored on site and within the Sydney Metro tunnel to ensure that the risk of structural damage and disturbance by high noise levels is minimised. Monitoring may be in the form of regular checks by the builder or indirectly by an acoustic consultant engaged by the builder, and in response to any noise or vibration complaints.

Monitoring is to be undertaken by an experienced noise and vibration monitoring professional or an acoustic consultant. The results of any noise or vibration monitoring are to be provided to the relevant party or person in a timely manner allowing the builder to address the issue and respond to the complaints.

Noise and vibration monitoring can take two forms:

1. Short-term monitoring
2. Long-term monitoring

Both of these approaches are elaborated below.

8.2.2 Short-term monitoring

Short-term monitoring consists of attended monitoring when critical stages of the works are occurring. This normally provides real-time assistance and guidance to the subcontractor on site, telling them when the noise and vibration criteria are exceeded. Thus, the selection of alternative method on construction or equipment selection is allowed in order to minimise noise and vibration impacts.

8.2.3 Long-term monitoring

Similar to short-term monitoring, long-term monitoring provides real-time alerts to the builder / site manager when the noise and vibration criteria are exceeded. Instead of someone being on site measuring, noise and vibration loggers are used.

Typically, the noise and vibration loggers stay on site for a period of several months for the critical stages of the project. Sometimes the period of noise and vibration monitoring is dictated by the local authorities through the DA conditions.

Both methodologies are complementary and normally used simultaneously providing a significant amount of data via the long-term monitoring, but also providing information on the sources of noise and vibration generating exceedances via the short-term or attended monitoring.

8.2.4 Proposed Monitoring Program

The following monitoring program is proposed for this project:

1. Attended and unattended background vibration monitoring, also within the southbound Sydney Metro tunnel, to establish existing conditions.
2. Attended vibration monitoring of all involved demolition, excavation and construction equipment/activities on site prior to commencing works. The aim is to calibrate this desktop study and to ensure the calculations are relevant to the specific site conditions.
3. Unattended vibration monitor installed within southbound Sydney Metro tunnel during demolition for a period representing average works, as agreed with the Acoustic Engineer and Contractor.
4. Unattended vibration monitor installed within southbound Sydney Metro tunnel during excavation and potential piling.

The monitoring program is to be carried out during the stages likely to generate the most acoustic impact as agreed with the Acoustic engineer and Contractor. It should be noted that the program as shown above focuses on monitoring the acoustic impacts on the underground rail tunnels. Potential monitoring proposed for the surrounding buildings during demolition, excavation and construction should be determined in a noise and vibration management plan submitted as a part of a separate development application for these works.

9. Conclusion

An acoustic infrastructure impact assessment has been provided for the SSDA of the mixed-use development located at 4-6 Bligh St, Sydney. The report provides information to NSW Transport authorities regarding the potential acoustic impacts of the demolition, excavation and construction works and building operation on the nearby underground rail infrastructure.

The operation of the proposed development will not include any vibration intensive activities or plant. Any vibrating plant will be isolated from the building structures to provide amenity within the development itself, resulting in negligible impacts on any underground infrastructure, including any underground rail tunnels.

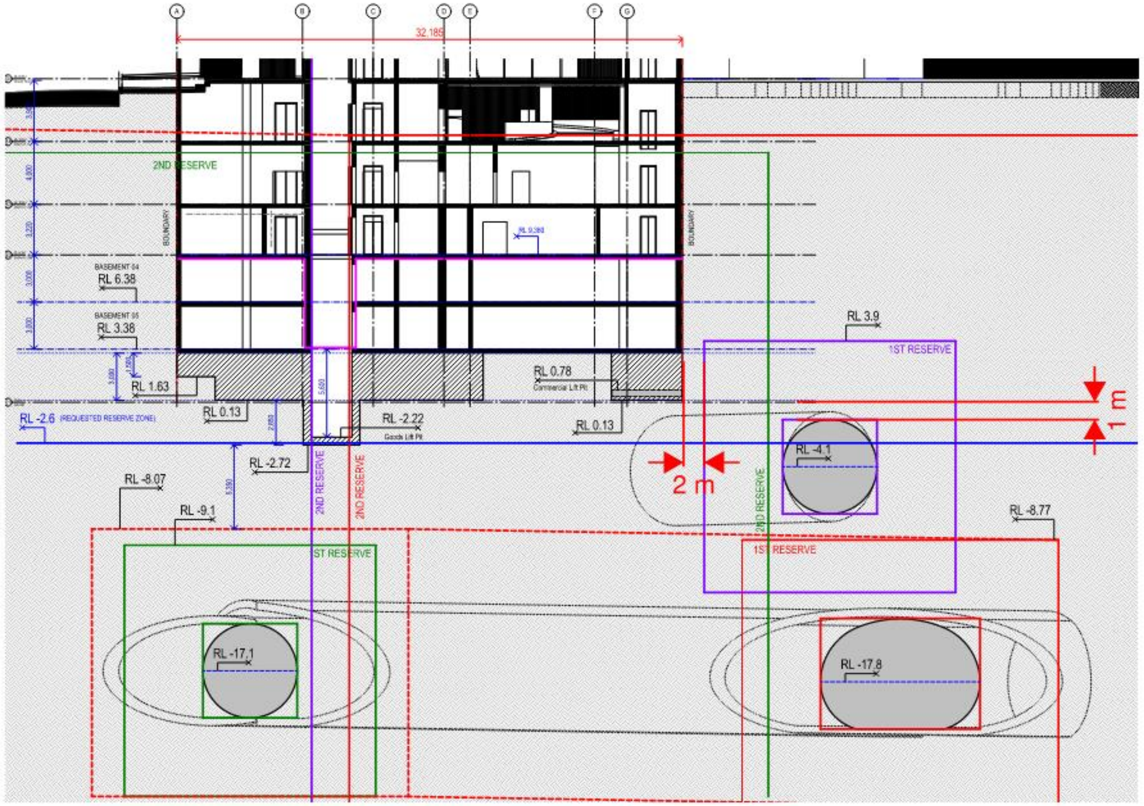
The details of the noise and vibration assessments undertaken to predict the impacts of demolition, excavation and construction activities on the closest underground rail tunnel (southbound Sydney Metro tunnel) have been presented in Section 7. The structural damage and Sydney Metro protection guideline limits for vibration are not expected to be exceeded at the tunnel section closest to the proposed excavation works. The generated ground-borne noise within the tunnel is also likely to comply with the set criterion. However, it should be noted that the assessments are based on a desktop study only and the results may be different in actual site conditions. Measurements are recommended to calibrate the assessments.

Mitigation strategies and a monitoring program are proposed in Section 8. Along with vibration measurements conducted prior to the works, unattended monitoring is recommended within the southbound Sydney Metro tunnel during the demolition and excavation stages, and during piling if required for the foundations, to ensure the relevant acoustic criteria are met.

The information presented in this report shall be reviewed if any modifications to the features of the development specified in this report occur, including and not restricted to selection of equipment/machinery and modifications to the basement.

APPENDIX A Sydney Metro Tunnel Location

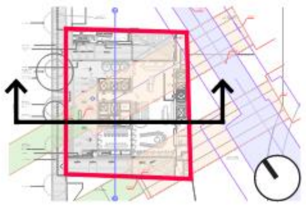
Cross Section - West / East



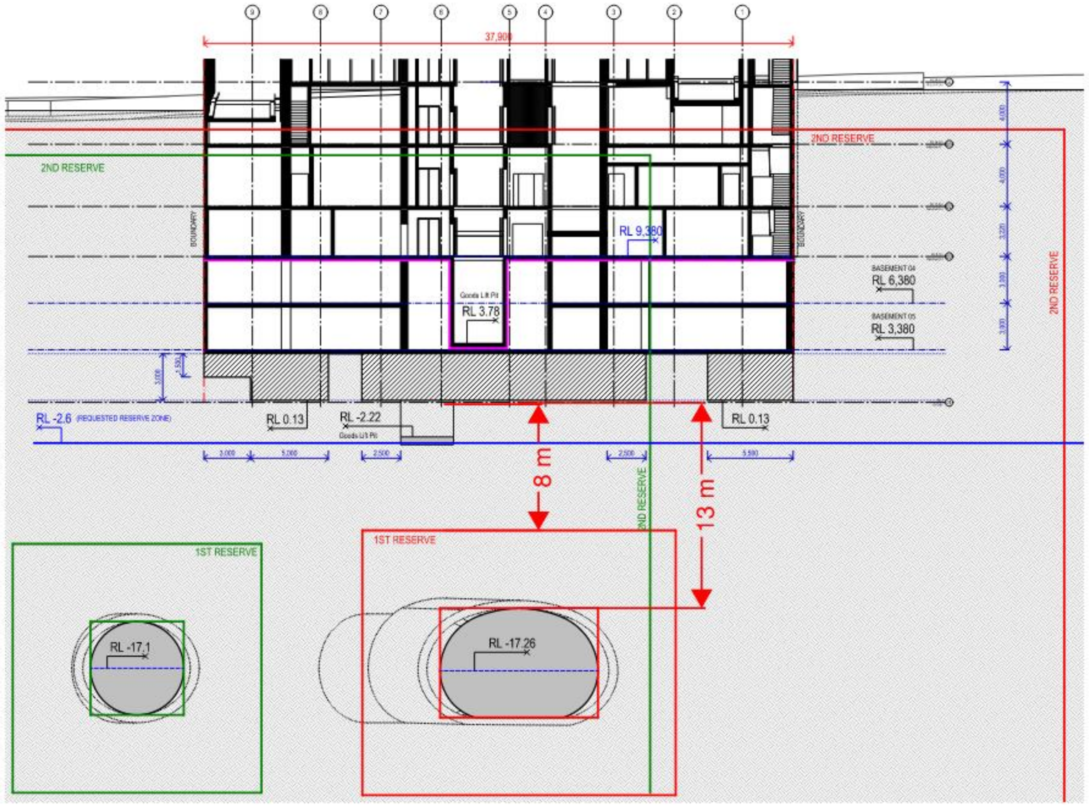
Cross Section - Proposed

Outline of current levels

Rl 9.38 Approved Early Works DA



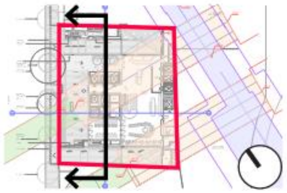
Long Section - North / South



Long Section - Proposed

Outline of current levels

Rl 9.38 Approved Early Works DA



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