Melbourne Metro Rail Project

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Noise and Vibration Impact Assessment

Melbourne Metro Rail Authority

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in association with Grimshaw

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This report should be read in full and no excerpts are to be taken as representative of the findings.

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Glossary and Abbreviations

Term	Definition
General	
AJM JV	Aurecon Jacobs Mott Macdonald Joint Venture - The contracted entity that is providing the Technical, Planning and Engagement Advisory Services for the Melbourne Metro.
Concept Design	A comprehensive design proposal for constructing and operating the proposed Project, used for assessment purposes. The Concept Design is not the final, detailed design for the Project. The design could be refined further within the approved Project Area (see below) by the parties who are contracted by the State to develop Melbourne Metro, provided the final design meet the approved Project objectives and the recommended Environmental Performance Requirements. The Concept Design evaluated in this EES comprises: • The Concept Design and any specified variations to the Concept Design • Recommended Environmental Performance Requirements that define the project-wide environmental outcomes the proposed Melbourne Metro must achieve during its design, construction and operation, regardless of any particular detailed design solutions that are adopted • Proposed project boundary (within which all components of the project would be contained).
Emergency access shaft	A vertical opening to grant access to the twin tunnels for emergency services personnel
MURL	Melbourne Underground Rail Loop (City Loop)
TBM launch site	Working area used for lowering in and launching a TBM. Site is also used for associated activities such as laydown, temporary storage of excavated material etc.
TBM retrieval site	Working area used to retrieve a TBM at the end of its drive and to allow it to be dismantled and lifted to the surface.
Ventilation structure	A surface level structure required as part of the tunnels ventilation system.
Technical	
Additional Construction Works	Construction works not including tunnelling or roadheader excavation of the station caverns.
Ambient Noise Level	The prevailing noise level at a location due to all noise sources but excluding the noise from the specific noise source under consideration.
BCM	Bank cubic metre, (mining term), a cubic metre of rock or material in situ before it is extracted.
Building mitigation	Mitigation measures applied to a building to reduce noise ingress to a building eg improved glazing.
Decibel	Sound pressure levels are expressed in units of decibels - a logarithmic ratio between the measured sound pressure level and the reference pressure (2x10^{-6} Pascal). Typical noise levels are presented below:

Sound Pressure Level dB(A)	Example
130	Threshold of pain
120	Jet aircraft take-off at 100 m
110	Power tool at 1 m

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td></td><td><table>
<tr><td>100</td><td>Nightclub</td></tr>
<tr><td>90</td><td>Heavy trucks at 5 m</td></tr>
<tr><td>80</td><td>Kerbside of busy street, excavator at 15 m</td></tr>
<tr><td>70</td><td>Loud radio (in typical domestic room)</td></tr>
<tr><td>60</td><td>Office</td></tr>
<tr><td>50</td><td>Domestic fan heater at 1 m</td></tr>
<tr><td>40</td><td>Living room</td></tr>
<tr><td>30</td><td>Theatre</td></tr>
<tr><td>20</td><td>Rural environment on still night</td></tr>
<tr><td>10</td><td>Sound insulated test chamber</td></tr>
<tr><td>0</td><td>Threshold of hearing</td></tr>
</table></td></tr>
<tr><td>dB(A)</td><td>The A-weighted sound pressure level in decibels, denoted dB(A) is the unit generally used for the measurement of environmental, transportation or industrial noise. The A-weighting scale approximates the sensitivity of the human ear and correlates well with subjective perception of sounds.
An increase or decrease in sound level of approximately 10 dB corresponds respectively to a subjective doubling or halving in loudness. A change in sound level of 3dB is considered just noticeable.</td></tr>
<tr><td>Frequency</td><td>The rate of repetition of a sound wave. The unit of frequency is Hertz (Hz), defined as one cycle per second. Human hearing ranges approximately from 20 Hz to 20,000 Hz. For design purposes, the octave bands between 63 Hz to 8 kHz are generally used. The most commonly used frequency bands are octave bands. For more detailed analysis each octave band may be split into three one-third octave bands or in some cases, narrow frequency bands.</td></tr>
<tr><td>FTA</td><td>Federal Transit Authority (USA)</td></tr>
<tr><td>FTA Guideline</td><td>FTA Predictive Methodology from FTA document, Transit Noise and Vibration Impact Assessment FTA-VA-90-1003-06, FTA 2006</td></tr>
<tr><td>Ground-borne noise</td><td>Noise heard within a building that is generated by vibration transmitted through the ground and into the structure. It is sometimes referred to as regenerated noise or structure-borne noise.</td></tr>
<tr><td>Habitable room</td><td>Any room in a residential location other than a kitchen, storage area, bathroom, laundry, toilet or pantry.</td></tr>
<tr><td>Highly Sensitive Spaces</td><td>Hospital wards, operating theatres</td></tr>
<tr><td>L_{A90}</td><td>The A-weighted sound pressure level that is exceeded for 90 per cent of the measurement period. Usually used to represent the background noise level.</td></tr>
<tr><td>L_{AE}</td><td>The sound exposure level contains the same amount of acoustic energy over a normalised 1-second period as the actual noise event under consideration. Also referred to as SEL.</td></tr>
<tr><td>L_{eq}</td><td>The equivalent continuous sound pressure level is the steady level that would, over a given period, deliver the same sound energy as the actual time-varying sound over the same period. Hence, fluctuating levels can be described in terms of a single figure level. The A- weighted equivalent continuous sound level is denoted $L_{Aeq.}$</td></tr>
<tr><td>$L_{Max,}$ $L_{FMax,}$ L_{SMax}</td><td>The maximum sound pressure level ‘linear’ (un-weighted or Z), `Fast` and `Slow` networks respectively. The A-weighted variations are also used in various guidelines and standards, L_{AMax}, L_{AFMax} and L_{ASMax}.</td></tr>
<tr><td>$L_{Aeq,8h}$</td><td>Eight-hour equivalent continuous A-weighted sound pressure level in dB(A) referenced to 20 micropascals. It is the steady noise level that would, in the course of an eight-hour period, have the same A-weighted sound energy as that due to the actual noise over an 8-hour working day.</td></tr>
</table>

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td></td><td>$L_{Aeq,8h}$ is to be determined in accordance with Part 1 of AS/NZS 1269.1[1].</td></tr>
<tr><td>$L_{C,peak}$</td><td>The C-weighted peak sound pressure level in decibels measured by a sound level meter with a peak detector-indicator characteristic.</td></tr>
<tr><td>Noise Reduction Index (NRC)</td><td>NRC is the arithmetic average (rounded to the nearest 0.05) of the absorption co-efficient of a material at the 250 Hz, 500 Hz, 1 kHz and 2 kHz octave band frequencies.</td></tr>
<tr><td>Noise Sensitive Area</td><td>A ‘Noise Sensitive Area’, as defined by the <i>State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N1</i> (SEPP N-1) is:
(a) That part of the land within the apparent boundaries of any piece of land which is within a distance of 10 m outside the external walls of any of the following buildings; dwelling and residential building
(b) That part of the land within the apparent boundaries of any piece of land on which is situated any of the following buildings which is within a distance of 10m outside the external walls of any dormitory, ward or bedroom of such buildings:
– Caretaker’s house
– Hospital
– Hotel
– Institutional Home
– Motel
– Reformative Institution
– Tourist Establishment
– Work Release Hostel</td></tr>
<tr><td>Normal Working Hours</td><td>Defined in EPA 1254 Noise Control Guidelines as:
7am to 6pm Monday to Friday, and 7am to 1pm on Saturdays</td></tr>
<tr><td>Peak component particle velocity</td><td>The maximum value of any one of the three orthogonal component particle velocities of the ground movement caused by the passage of vibration.</td></tr>
<tr><td>Peak Particle Velocity (PPV)</td><td>The highest instantaneous sum of velocity vectors of the ground movement caused by the passage of vibration.
Vibration levels and the corresponding human perception descriptor are provided below. Whilst this is from a superseded standard, the information is considered useful.
Human perception of vibration (from German Standard DIN 4150-2 1975 <i>Vibration in Buildings; Influence on Persons in Buildings</i> (superseded))
<table>
<tr><th>Perception</th><th>Typical vibration level
mm/s Peak</th></tr>
<tr><td>Not perceptible</td><td>0.1</td></tr>
<tr><td>Threshold of perception</td><td>0.15</td></tr>
<tr><td>Barely noticeable</td><td>0.35</td></tr>
<tr><td>Noticeable</td><td>1</td></tr>
<tr><td>Easily noticeable</td><td>2.2</td></tr>
<tr><td>Strongly noticeable</td><td>6</td></tr>
</table></td></tr>
<tr><td>Preferred Traffic Routes</td><td>Traffic routes identified by VicRoads where traffic is encouraged to travel as a first priority.</td></tr>
<tr><td>Rail Occupation</td><td>Also known as a ‘track occupation’, a rail occupation is defined as an “Absolute Occupation of</td></tr>
</table>

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[1] Australian / New Zealand Standard AS/NZS 1269.1:2005 Occupational noise management Part 1: Measurement and assessment of noise emission and exposure

Term	Definition
	a defined section of the Access Provider's Network, in order to carry out inspections, repairs, maintenance, up-grade work, improvements, additions or any other works which could interfere with the Access Provider's or an Operator's Services on the Network." Source: www.metrotrains.com.au
Reverberation Time (RT60)	The time, in seconds, taken for a sound within a space to decrease by 60 dB after the sound source has stopped.
Sensitive Receivers / Receptors	Residential dwellings, aged persons homes, hospitals, motels, caravan parks, and other buildings of a residential nature. Schools, kindergartens, libraries and other noise sensitive community buildings. Research laboratories, buildings with sensitive equipment, heritage listed structures and items.
Short Term Vibration	For buildings short term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated - DIN 4150[2]. For human comfort short term vibration is vibration associated with works that occur for a duration of approximately one week – *Assessing Vibration – a technical guide*[3]
Sound Pressure Level	The sound pressure level (SPL) is the logarithmic ratio of the sound pressure (P) to a reference pressure (P_{ref} : 2x 10^{-5} for applications in air) SPL= 20 log(P/P_{ref}) dB
Unavoidable Work	Works that cannot practicably meet the schdule requirements because the work involves continous work – such as a concrete pour or would otherwise pose an unacceptable risk to like or property, or risk a major traffic hazard.
VDV	Vibration Dose Value – the vibration energy received over either the daytime and night periods is accumulated. VDV is dedendent upon level of vibration, spectral content of vibration, duration of operation of equipment.
Vibration	Vibration may be expressed in terms of displacement, velocity and acceleration. Velocity and acceleration are most commonly used when assessing structureborne noise or human comfort respectively. Vibration amplitude may be quantified as a peak value, or as a root mean squared (rms) value. Vibration amplitude can be expressed as an engineering unit value eg 1 mms^{-1} or as a ratio on a logarithmic scale in decibels: vibration velocity level = 20 log (V/V_{ref}) (dB) The preferred reference level, V_{ref}, for vibration velocity is 10^{-9} m/s.
Weighted Sound Reduction Index, R_w	The Sound Reduction Index (or Transmission Loss) of a building element is a measure of the sound insulation of the material, i.e. its attenuation properties. It is a property of a particular building element and is calculated as a function of the area of the element. The weighted sound reduction index, R_W, is a single figure description of sound reduction index which is defined in AS/NZS ISO 717.1:2004 *Acoustics – Rating of sound insulation in buildings and of building elements – Airborne sound insulation* and is calculated from measurements in an acoustic laboratory. Sound insulation ratings derived from site measurements are referred to as the Apparent Weighted Sound Reduction Index (R'_W) ratings. These values are invariably lower than laboratory values due to flanking transmission via other building elements.
Wheel flanging	Flanging occurs when the flange of the wheel rubs against the face of the railhead. The noise that can be heard is often intermittent, spans a broad frequency range and varies in intensity.
Wheel squeal	Mid to high frequency tonal squeal noise produced by the stick-slip action between wheels and rails.

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[2] DIN 4150-3 Structural Vibration Part 3: Effects of vibration on structures, February 1999

[3] Assessing Vibration: A Technical Guideline, DEC 2006/43 December, 2006, NSW DEC

Executive Summary

This report presents the assessment of the potential noise and vibration impacts and benefits of the proposed Melbourne Metro Rail Project (Melbourne Metro) to inform the Environment Effects Statement (EES).

It considers the potential noise and vibration impacts during both construction and operation. It also presents noise and vibration criteria / Guideline Targets, and noise and vibration mitigation measures.

Context

The proposed Melbourne Metro is located through the centre of Melbourne and into inner city suburbs of Kensington, North Melbourne, Carlton and South Yarra. The above ground components of Melbourne Metro connect to existing rail lines in highly urbanised environments. The project would be constructed in an environment that includes the busiest tram routes in Melbourne (Swanston Street / St Kilda Road), high amounts of traffic and all other modes of transport. The centre of Melbourne is continually undergoing development with high-rise building construction, works on railways / tramways and other public infrastructure a common occurrence. The background noise and vibration levels are therefore elevated and a key consideration for the risk and impact assessment undertaken for this EES.

Airborne noise generated during construction of the Melbourne Metro would be managed to comply with *EPA Noise Control Guidelines Publication 1254* (EPA 1254) by a combination of construction management measures including acoustic sheds, barriers and off-site measures such as building mitigation. Airborne noise during operation would be managed to comply with the *Victorian Passenger Rail Infrastructure Noise Policy 2013* (PRINP). Compliance with the *State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N1* (SEPP N-1) would be required for noise from fixed equipment.

In the absence of Victorian or Commonwealth requirements for managing construction vibration, international and NSW guidelines have been used. For building damage, the conservative *DIN 4150-3 Structural Vibration Part 3: Effects of vibration on structures* (DIN 4150) standard is used. DIN 4150 sets vibration levels which when complied with, would not result in damage that would have an adverse effect on the structures' serviceability. If, however, the levels are exceeded, it does not necessarily follow that damage would occur. Therefore, if exceedances were predicted, then further site-specific assessment would be required to determine if construction could proceed without damage.

For human comfort with respect to vibration and ground-borne noise from construction, the Guideline Targets from NSW guidelines that have been successfully used on projects in NSW, have been used to trigger when Management Actions would be required.

For operation, in the absence of local requirements, vibration and ground-borne noise from trains are to comply with the Guideline Targets in NSW guidelines that have been successfully used on projects in NSW.

Methodology

The methodology used for this noise and vibration impact assessment involved:

- Undertaking baseline measurements (noise and vibration)
- Determining appropriate criteria / Guideline Targets
- Undertaking predictions and determining if criteria / Guideline Targets would be met
- Identifying appropriate mitigation options where the assessment predicted an exceedance to a criterion / Guideline Target
- Evaluating residual risks

Impact assessment

Construction Impacts

Construction activities with the potential to generate noise and vibration impacts include tunnelling, tunnelling support, demolition works, excavation works, rockbreaking, piling and construction. Heavy vehicles accessing the construction work sites are expected to increase traffic noise in some areas.

Noise and vibration from construction activities would be managed in accordance with the recommended Environmental Performance Requirements.

Airborne construction noise

Airborne noise associated with the construction of Melbourne Metro would be limited to areas close to construction work sites, with the exception of increased traffic associated with construction vehicles. Airborne noise from construction would be managed in accordance with EPA 1254. In addition to applying good practices on construction work sites, extensive mitigation is proposed. The assessment undertaken predicts that the requirements of EPA 1254 could be achieved.

There would be times when Unavoidable Work occurs outside of Normal Working Hours and the community may be impacted. During these times, consultation would need to be undertaken with the community. Temporary relocation or respite would be an option if the level and duration of disturbance were not well tolerated by a resident. This approach is consistent with other projects where Unavoidable Work occurs outside of Normal Working Hours such as the Regional Rail Link.

Construction vibration and ground-borne noise from tunnelling

Tunnelling works have the potential to generate vibration and ground-borne noise. Tunnelling would generally be undertaken over 24 hours. This program is consistent with other rail tunnelling projects in Australia and around the world; examples in NSW include North Connex, M4 motorway and North West Rail Link. The impact of slowing the tunnelling program (e.g. operational hours of the TBM / roadheader during the daytime) would be significant. It would extend the construction period, which would potentially extend the length of impacts and significantly increase the cost of the project.

DIN 4150 would be used to assess damage to building structures from vibration. DIN 4150 is considered to be a conservative standard and if vibration levels are higher than the Guideline Targets in DIN 4150 it does not follow that damage would occur and further site assessment would be required to assess the risk of damage. If the risk is found to be low then construction could proceed. Vibration levels from tunnelling and mining of the station caverns are predicted to comply with the requirements of DIN 4150.

Properties located above or near tunnelling may experience short-term vibration and ground-borne noise. For the majority of the project duration, vibration and ground-borne noise from tunnelling would be insignificant at sensitive receivers. The Guideline Targets for vibration and ground-borne noise are based on trigger levels for Management Actions. For tunnelling, consistent with other equivalent tunnelling projects, Management Actions would require consultation be undertaken to provide information to the community. If the duration and level of disturbance were not well tolerated by a sensitive receiver, then temporary relocation / respite may be appropriate.

Triggering Management Actions does not necessarily mean that vibration or ground-borne noise would be disturbing during this time. Responses to vibration and ground-borne noise vary according to individual sensitivity as well as the time of day and ambient noise and vibration levels. Ground-borne noise does not usually disturb occupants during the daytime due to higher ambient noise levels. It may, however, be noticed at night when ambient noise levels are low. In some highly urbanised areas, typical of this project, ambient noise levels at night may also provide masking of noise from tunnelling. It is not uncommon for sensitive receivers to experience some vibration or ground-borne noise during construction projects in Victoria (for example, during the construction of the Regional Rail Link and many others).

Vibration Guideline Targets are also provided for vibration-sensitive equipment, Highly Sensitive Areas and Bio-resources. These apply in Precinct 4: Parkville Station and Precinct 5: CBD North Station (for vibration-sensitive equipment only).

Construction vibration and ground-borne noise from Additional Construction Works (activities unrelated to tunnelling)

The Additional Construction Works consist of construction outside of tunnelling activities or the roadheader excavation of stations. Vibration is predicted to comply with the DIN 4150 Guideline Targets. Where the assessment indicates that Management Actions are triggered in relation to vibration for human comfort and / or ground-borne noise the following may be required: use of less vibration intensive equipment, minimum buffer distances for some equipment, time restrictions for some equipment and consultation with the community. Temporary relocation may be appropriate if the duration and level of disturbance are not well tolerated by a resident. Controlled blasting has also been assessed for Precinct 4: Parkville Station as an alternative to rockbreaking to reduce the duration of impact.

Operational Impacts

As trains would operate predominantly in tunnels, the impact of airborne noise from trains is only anticipated near the portals and at the Western Turnback. The portals and the western turnback are located in existing busy rail corridors. Compliance with the PRINP is predicted with the installation of noise barriers at the Western and Eastern Portal Precincts.

There is also the potential for trains using the tunnels to impact sensitive receivers with respect to vibration and / or ground-borne noise. Compliance with project Guideline Targets for vibration (human comfort) and for vibration-sensitive equipment and ground-borne noise is predicted with the installation of vibration isolating trackform. Compliance with the Guideline Targets for vibration (Human Comfort) infers compliance with the Guideline Targets for building damage, as the targets for Human Comfort are more onerous.

Fixed infrastructure such as station and railway tunnel ventilation would generate airborne noise. This noise is required to comply with the SEPP N-1. Noise and Vibration from operation would be designed to comply with criteria using standard engineering techniques.

Precinct 1: Tunnels (Outside Other Precincts)

Construction

Airborne construction noise in this precinct would be negligible except near to construction work sites, which include the Fawkner Park construction work site(s) and the Linlithgow emergency access shaft construction work site. Compliance with EPA 1254 is predicted in these locations. Indicative noise mitigation has been proposed to reduce construction noise impacts and includes noise barriers up to a height of 6 m and an acoustic construction shed for Fawkner Park.

Tunnelling activities would potentially generate vibration in Precinct 1. Vibration from tunnelling is predicted to comply with the DIN 4150 Guideline Targets for structural damage. There are, however, a number of locations across the proposed alignment where vibration with respect to human comfort and ground-borne noise from tunnelling are predicted to trigger Management Actions. At the most impacted location, the period for Management Actions is up to 10 days on two occasions for the TBM (once as each TBM passes by sensitive receivers) and up to 32 days once for the roadheader over the entire construction period. Due to the temporary nature of these impacts, they would principally be managed by communication with potentially affected stakeholders. If the level and duration of disturbance are not well tolerated by a sensitive receiver, then temporary relocation may be required.

Additional Construction Works (activities unrelated to tunnelling) at the proposed construction work sites in this precinct are predicted to comply with the DIN 4150 Guideline Targets for structural damage. At sensitive receivers in the vicinity of the Linlithgow Avenue emergency access shaft site, compliance with the Guideline Targets for vibration for human comfort and ground-borne noise is also predicted. At the Fawkner Park construction work site, Management Actions with respect to vibration for human comfort are predicted to be triggered at one sensitive receiver based on the use of a 20-tonne rockbreaker during the daytime. In this instance, consultation but no further action is proposed.

Operation

Airborne noise impacts from trains using the proposed tunnels are expected to be negligible as the trains would be underground. Noise from the ventilation shafts would need to comply with SEPP N-1.

The vibration and ground-borne noise levels are predicted to comply with the Guideline Targets using mitigation in the form of track vibration isolation.

Precinct 2: Western Portal (Kensington)

Construction

Construction noise would potentially impact upon sensitive receivers in the vicinity of the construction works and noise barriers up to a height of 6 m are proposed to reduce the impact. Compliance with EPA 1254 is predicted.

Vibration from tunnelling is predicted to comply with the DIN 4150 Guideline Targets for structural damage, and the Guideline Targets for human comfort (vibration) and ground-borne noise.

Vibration from Additional Construction Works is predicted to comply with the DIN 4150 Guideline Targets for structural damage and for ground-borne noise. It is predicted that the Guideline Targets for human comfort (vibration) would be achieved when mitigation measures are implemented.

Operation

Airborne train noise has been assessed in accordance with the PRINP. For the Concept Design compliance with the PRINP is predicted with a 4.5 m high 150 m long noise barrier between the railway and Childers Street located on top of the retaining wall. For the Variation, compliance with the PRINP is predicted with a 3 m high and 75 m long noise barrier between the railway and Childers Street located on top of the retaining wall. These noise barriers would be required as houses are proposed to be demolished for construction, which exposes other residences to increased train noise. If equivalent building structures were reinstated in these locations, then the noise barriers would not be required.

The vibration and ground-borne noise levels are predicted to comply with the project Guideline Targets using track vibration isolation.

Precinct 3: Arden Station

Construction

Construction noise would potentially impact upon sensitive receivers in the vicinity of the construction works. Compliance with EPA 1254 is predicted with mitigation comprising of; a noise barrier up to a height of 6 m along a portion of Laurens Street, acoustic construction sheds and potentially providing building mitigation (upgrading the glazing) to the upper levels of two apartment buildings.

Vibration from the proposed tunnelling and Additional Construction Works is predicted to comply with the DIN 4150 Guideline Targets for structural damage and the Guideline Targets for human comfort (vibration) and ground-borne noise.

Operation

Airborne noise impacts from trains using the proposed tunnels are expected to be negligible as the trains are underground. Noise from the ventilation shafts would need to comply with SEPP N-1.

The vibration and ground-borne noise levels are predicted to comply with the project Guideline Targets by using track vibration isolation.

Precinct 4: Parkville Station

Construction

Stakeholders in the Parkville station precinct are accustomed to working with the impacts of construction noise and vibration as construction has been an on-going occurrence in this precinct for many years. Construction projects have included the construction of the Royal Women's Hospital, the Victorian Comprehensive Cancer Centre, the Peter Doherty Institute and significant on-going construction at the Royal Melbourne Hospital including the underground car park and up-grades to the hospitals.

Construction noise for Melbourne Metro is predicted to comply with EPA 1254 with noise barriers up to a height of 6 m and acoustic construction sheds. Noise levels are predicted to be similar to existing levels at the hospitals and laboratory buildings.

Vibration from the proposed tunnelling is predicted to comply with the DIN 4150 Guideline Targets for structural damage. Tunnelling is, however, predicted to trigger Management Actions for vibration for human comfort (based on 'possible adverse comments at night') and ground-borne noise at a small number of locations for a maximum of approximately 9 days at the most affected location within a building. This would occur twice over the extent of the project (once for each tunnel). Due to the short-term nature of tunnelling, the Management Actions would consist of extensive communication with affected receivers. Restrictions on tunnelling operating times to daytime, may be appropriate in the vicinity of the hospitals if the predicted levels occur in practice and staff / patients are disturbed.

Vibration also has the potential to cause disturbance to items of vibration-sensitive equipment (imaging equipment such as MRIs), Highly Sensitive Areas (hospital wards, operating theatres) and laboratories with Bio-resources. The impact due to tunnelling is predicted to occur for up to 17 days for the most affected item of vibration-sensitive equipment. This impact would need to be carefully managed through communication with stakeholders and potentially restricting tunnelling operational times near the hospitals.

Vibration from Additional Construction Works is predicted to comply with the DIN 4150 Guideline Targets for structural damage at all locations. Vibration is, however, predicted to trigger Management Actions with respect to human comfort at a number of locations within 6.5 m of construction activity. This is predicted to affect ground floor locations only and to be for a period of less than one day. Vibration-sensitive equipment is at risk of disturbance from vibration and mitigation measures are provided. Marginal exceedances are predicted at two locations and an exceedance at one location with respect to Bio-resources and detailed actions have been provided to address this. Compliance is predicted at Highly Sensitive Areas. Ground-borne noise is also predicted to comply with Guideline Targets by following the mitigation measures outlined.

Controlled blasting has been assessed and is considered to be a feasible construction methodology for excavation of the station box subject to constraints with respect to charge size, buffer distances and schedule for blasting.

Operation

Airborne noise impacts from trains using the proposed tunnels are expected to be negligible as the trains are underground. Noise from the ventilation shafts would need to comply with SEPP N-1.

The vibration and ground-borne noise levels are predicted to comply with Guideline Targets for human comfort and sensitive equipment using track vibration isolation.

Precinct 5: CBD North Station

Construction

Construction noise is predicted to comply with EPA 1254 with acoustic construction sheds to achieve the Guideline Noise Levels, which apply outside of Normal Working Hours.

Vibration from roadheader excavation of the station cavern is predicted to comply with the DIN 4150 Guideline Targets for structural damage. Station cavern excavation is, however, predicted to trigger

Management Actions for vibration for human comfort and ground-borne noise at a small number of sensitive receivers. The duration for Management Actions is predicted to be up to five weeks up to three times over the entire construction period. This is at the most impacted residential locations based on a trigger for 'no expected adverse comment' during the night period. Based on 'Adverse comments are possible' Management Actions at this same location would be triggered for a period of ten days up to three times. At other locations the duration of impact would be shorter. Management Actions would consist of communication to provide information to affected receivers, reduced hours of operation and temporary relocation if the level and duration of tunnelling were not well tolerated by a sensitive receiver. With respect to vibration-sensitive equipment at RMIT, compliance is predicted to be achieved for all items except one for which Management Actions have been proposed.

Vibration from Additional Construction Works is predicted to comply with the DIN 4150 Guideline Targets for structural damage with less vibration intensive equipment used within 5 m of some buildings (pre-splitting and drilling). Vibration and ground-borne noise would be managed by using buffer distances and time restrictions (i.e. daytime operation only) for some equipment.

Operation

Airborne noise impacts from trains using the proposed tunnels are expected to be negligible as the trains are underground. Noise from the ventilation shafts would need to comply with SEPP N-1.

The vibration and ground-borne noise levels are predicted to comply with the Guideline Targets using track vibration isolation.

Precinct 6: CBD South Station

Construction

Construction noise is predicted to comply with EPA 1254. This includes noise barriers and acoustic construction sheds to achieve the Guideline Noise Levels, which apply outside of Normal Working Hours.

Vibration from roadheader excavation of the station cavern is predicted to comply with the DIN 4150 Guideline Targets for structural damage. Station cavern excavation is, however, predicted to trigger Management Actions for vibration for human comfort and ground-borne noise at a small number of sensitive receivers. The duration for Management Actions is predicted to be up to six weeks up to three times over the entire construction period. This is at the most impacted residential locations based on a trigger for 'no expected adverse comment' during the night period. Based on 'Adverse comments are probable' Management Actions at this same location would be triggered for a period of less than four days up to three times. At other locations the duration of impact would be shorter. Management Actions would consist of communication to provide information to affected receivers, reduced hours of operation and temporary relocation if the level and duration of tunnelling were not well tolerated by a sensitive receiver.

Vibration from Additional Construction Works is predicted to comply with the DIN 4150 Guideline Targets for structural damage with less vibration intensive equipment used within 5 m of some buildings (drilling and pre-splitting). Vibration and ground-borne noise would be managed to comply with the night-time Guideline Targets by using buffer distances and time restrictions for some equipment.

Operation

Airborne noise impacts from trains using the proposed tunnels are expected to be negligible as the trains are underground. Noise from the ventilation shafts would need to comply with SEPP N-1.

The vibration and ground-borne noise levels are predicted to comply with the Guideline Targets using track vibration isolation.

Precinct 7: Domain Station

Construction

Construction noise is predicted to comply with EPA 1254. Noise barriers up to a height of 6 m and acoustic construction sheds are proposed to reduce construction impacts.

Vibration from tunnelling is predicted to comply with the DIN 4150 Guideline Targets for structural damage. Tunnelling is, however, predicted to trigger Management Actions for vibration for human comfort and ground-borne noise at a number of locations for up to 9 days twice at the most impacted locations. Due to the short-term nature of tunnelling impacts, the Management Actions would consist of extensive communication with affected receivers. Temporary relocation may be an option if the level and duration of tunnelling is not well tolerated by a sensitive receiver.

Vibration from Additional Construction Works is predicted to comply with the DIN 4150 Guideline Targets for structural damage. Vibration and ground-borne noise would be managed by using buffer distances and time restrictions for some equipment.

Operation

Airborne noise impacts from trains using the proposed tunnels are expected to be negligible as the trains are underground. Noise from the fixed infrastructure would need to comply with SEPP N-1.

The vibration and ground-borne noise levels are predicted to comply with the Guideline Targets using track vibration isolation.

Precinct 8: Eastern Portal (South Yarra)

Construction

Construction noise is predicted to comply with EPA 1254. Noise barriers up to a height of 6 m and acoustic construction sheds are proposed to reduce construction impacts.

Vibration from the proposed tunnelling is predicted to comply with the DIN 4150 Guideline Targets for structural damage, and to comply with the targets for human comfort and ground-borne noise.

Vibration from Additional Construction Works is predicted to comply with DIN 4150 vibration Guideline Targets for structural damage.

Vibration due to Additional Construction Works with mitigation at Eastern Portal is predicted to trigger Management Actions with respect to human comfort at four residential locations for a short duration (period of days). In this instance, respite or temporary relocation may be appropriate if the level and duration of disturbance are not well tolerated by the resident.

Operation

Airborne train noise has been assessed in accordance with the PRINP. Compliance is predicted with the installation of two noise barriers, 50 m and 70 m in length ranging in height from 2.5 to 3 m above ground height at the top of cut and building mitigation for Level 3 of two apartment buildings.

The vibration and ground-borne noise levels are predicted to comply with the Guideline Targets by using track vibration isolation.

Precinct 9: West Footscray Station

Construction

Construction noise is predicted to comply with EPA 1254. Noise barriers up to a height of 2.5 m are proposed to reduce construction impacts.

Tunnelling is not proposed in this area and it is predicted that the vibration levels would comply with the DIN 4150 Guideline Targets for structural damage for proposed construction activities. Ground-borne noise is expected to be insignificant compared to airborne noise, as tunnelling is not proposed.

Operation

Airborne train noise has been assessed in accordance with the PRINP. Compliance is predicted and mitigation is not proposed.

Vibration is not expected to increase because of the Project. Ground-borne noise is expected to be insignificant compared to airborne noise, as trains are not in tunnels.

Benefits and Opportunities

The proposed approach of tunnelling of the Melbourne Metro has limited airborne construction noise to the vicinity of construction work sites.

A deep alignment has been proposed for the Melbourne Metro tunnels, which reduces the extent of vibration and ground-borne noise when compared to the previously proposed shallow alignment. This is particularly beneficial for sensitive receivers in Precinct 1: Tunnels, Precinct 5: CBD North station and Precinct 6: CBD South station.

Using a TBM to cross under the Yarra River would also minimise potential underwater noise impacts on aquatic life.

Removing crossovers and lowering tracks in Precinct 2: Western Portal would reduce airborne rail noise. An opportunity exists to install permanent (rather than temporary) noise barriers during construction which would reduce construction and operational rail noise at sensitive receivers in Precinct 2: Western Portal and Precinct 8: Eastern Portal, and benefit other nearby residential locations.

A large construction work site at Precinct 3: Arden Station would allow construction activities to be strategically oriented to minimise the impact on sensitive receivers. It would also provide for a number of access points to reduce the combined impact of construction vehicles.

Locating the station box solely below Grattan Street in Precinct 4: Parkville rather than across Royal Parade would shift construction noise and vibration-related disturbance due to station box construction away from nearby hospitals.

In Precinct 5: CBD North Station and Precinct 6 CBD South station, the station cavern construction methodology, would allow for a significant amount of construction to occur underground. This reduces airborne construction noise at nearby sensitive receivers.

Environmental Performance Requirements

Environmental Performance Requirements are recommended throughout this document.

1 Introduction

This report presents the assessment of potential noise and vibration impacts from the proposed Melbourne Metro Rail Project (Melbourne Metro) to inform the Environment Effects Statement (EES). In particular, this report focuses upon:

- Construction airborne noise
- Construction vibration and ground-borne noise
- Operational airborne noise from trains and fixed infrastructure
- Operational vibration and ground-borne noise from trains

It should be noted that the assessment is based on predictions using standard engineering approaches and there would be conservatism in some of the assessments. MMRA would need to appoint an acoustic consultant to undertake an independent assessment and to undertake noise and vibration measurements to refine outcomes e.g. mitigation, buffer distances.

The infrastructure proposed to be constructed, as part of the Melbourne Metro broadly comprises the following:

- Twin nine-kilometre rail tunnels from Kensington to South Yarra connecting the Sunbury and Cranbourne/ Pakenham railway lines (with the tunnels to be used by electric trains)
- Rail tunnel portals (entrances) at Kensington and South Yarra
- New underground stations at Arden, Parkville, CBD North, CBD South and Domain with longer platforms to accommodate longer High Capacity Metro Trains (HCMTs). The stations at CBD North and CBD South would feature direct interchange with the existing Melbourne Central and Flinders Street Stations respectively
- Train/tram interchange at Domain station.

The infrastructure proposed is shown in Figure 1-1.

Proposed construction methods would involve bored and mined tunnels (Tunnelling) as well as ‘top down’ and ‘bottom up’ construction of station boxes and excavation of portals (Additional Construction Work). The project would require planning, environmental and land tenure related approvals to proceed.

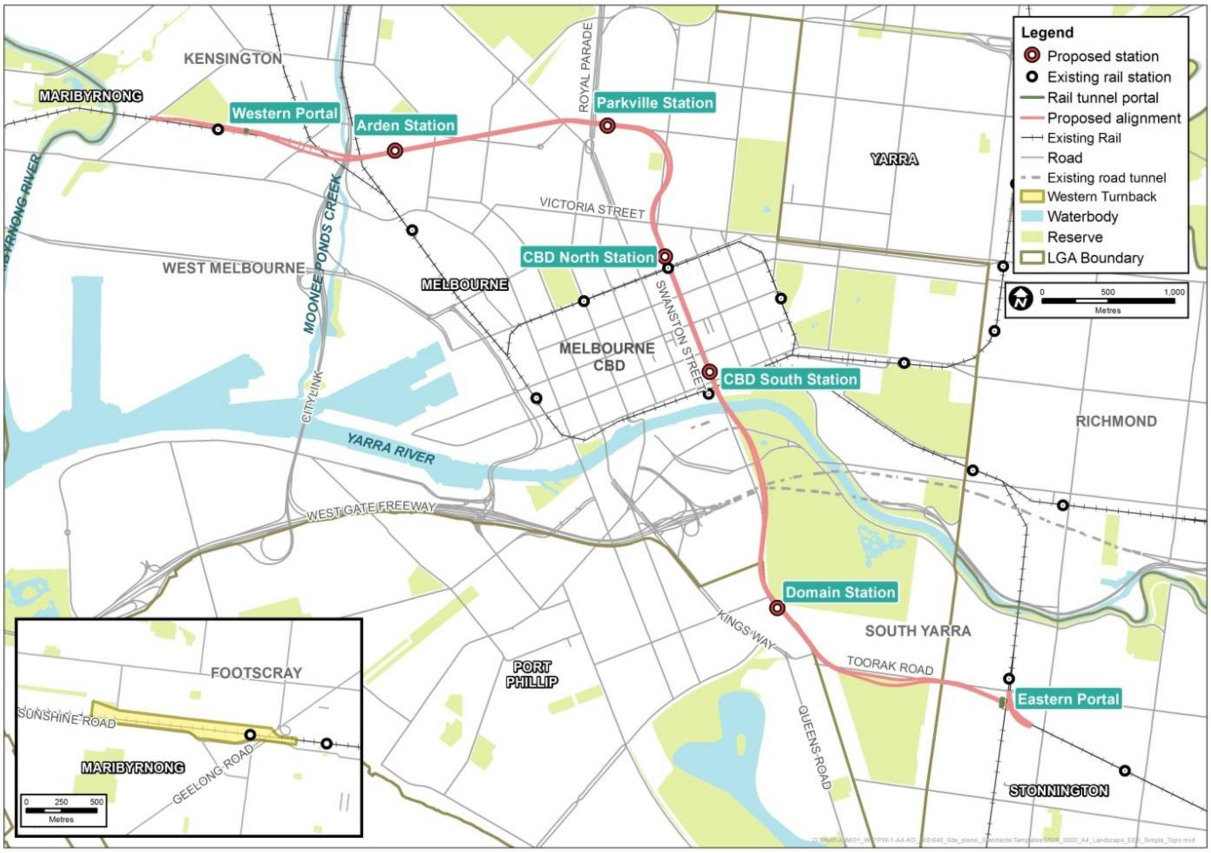

Figure 1-1 Map of the Melbourne Metro alignment and five proposed stations

1.1 Project Precincts

For assessment purposes, the proposed project boundary has been divided into precincts as outlined below, and shown in Figure 1-2. Precincts have been defined based on the location of project components and required construction works, potential impacts on local areas and the character of surrounding communities.

- Precinct 1: Tunnels (outside other precincts)
- Precinct 2: Western Portal (Kensington)
- Precinct 3: Arden Station (including electrical substations)
- Precinct 4: Parkville Station
- Precinct 5: CBD North Station
- Precinct 6: CBD South Station
- Precinct 7: Domain Station
- Precinct 8: Eastern Portal (South Yarra)
- Precinct 9: Western Turnback (West Footscray)

1.2 Study Area

The study area for the noise and vibration assessment includes the full extent of the project as described by the precincts.

For this assessment, general consideration of the construction vehicle routes and the wider Cranbourne / Pakenham to Sunbury Rail Line is also included.

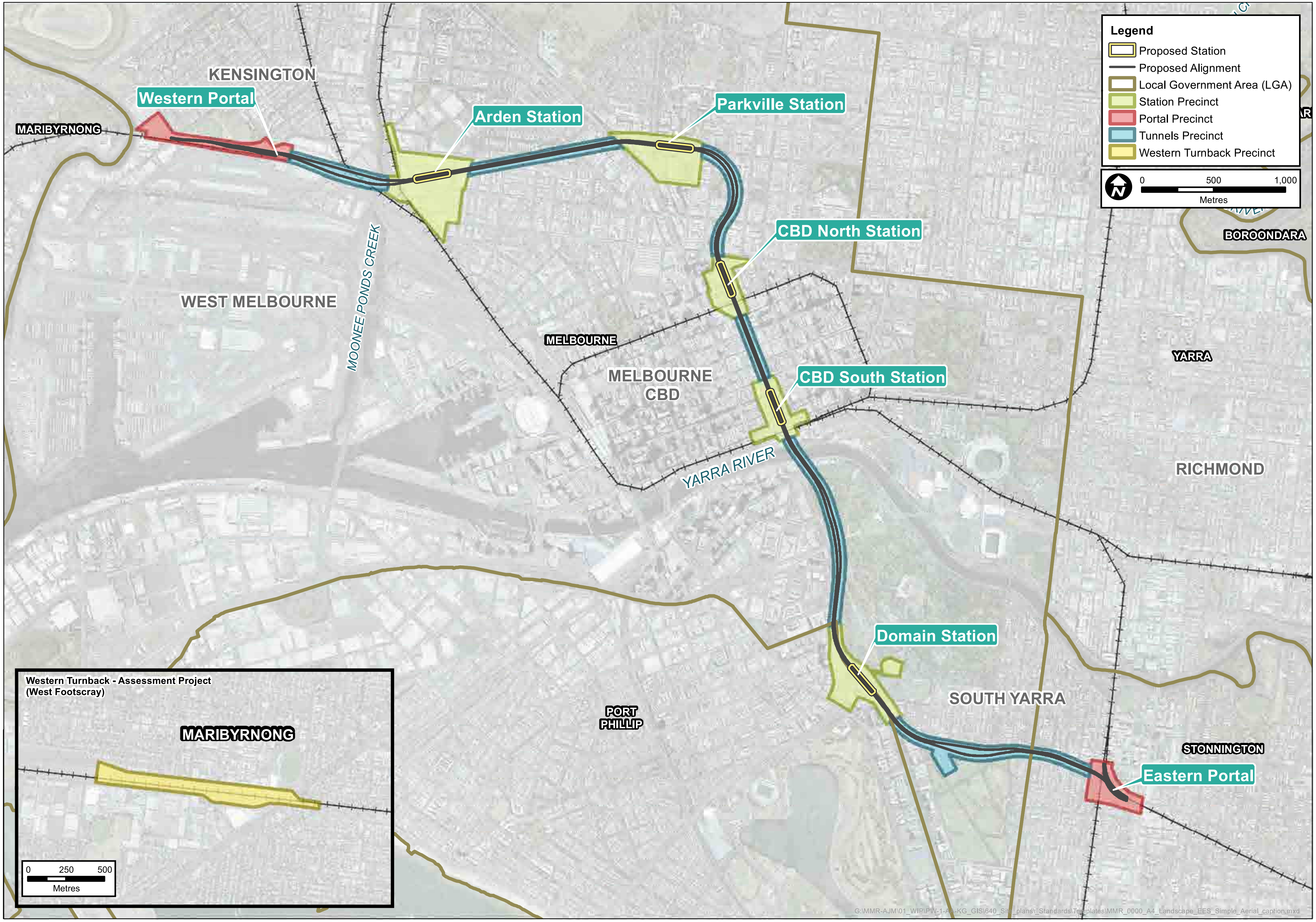

Figure 1-2 Melbourne Metro precincts

1.3 Noise and Vibration Context

The proposed Melbourne Metro is located in an urban environment and the rail tunnels traverse a variety of diverse communities. Receivers include:

- Industrial facilities
- Commercial facilities
- Residential buildings
- Community buildings
- Educational buildings
- Health facilities
  - Research facilities
  - Bio-resources facilities
  - Highly Sensitive Areas (operating theatres, hospital wards)
- Religious institutions
- Performing arts facilities
- Heritage structures.

Each receiver type may be impacted by noise and vibration to a different extent by the construction / operation of Melbourne Metro.

Noise and vibration may be perceptible at sensitive receivers near the railway as:

- Airborne noise: noise propagated through the air from source to the receiver
- Ground-borne vibration (tactile vibration): vibration propagated through the ground and into building structures
- Ground-borne noise: noise heard within a building that is generated by vibration propagating through the ground and into the structure

Adverse impacts of noise on the community may include:

- Loss of amenity
- Sleep disturbance
- Adverse health effects (stress, loss of concentration and increase in blood pressure)

Noise impacts on people vary widely due to differences within the existing acoustic environment (influenced by the time of day and/or proximity to other noise sources such as busy roads), the activities that people are engaged in (e.g. working, relaxing or sleeping) as well as differences in sensitivity to noise within the population.

For construction, the EPA1254 Guidelines are based upon protecting residential premises from unreasonable noise. Construction is expected to be audible at times.

Operation noise guidelines, which relate to assessing and controlling permanent noise impacts, are designed to preserve the amenity of the community.

The adverse impacts of vibration on the community may include:

- Interference with the function of vibration-sensitive equipment and Highly Sensitive Areas
- Interference with human comfort (loss of amenity)

- Sleep disturbance and health effects (stress, loss of concentration and increase in blood pressure)
- Rattling of fixtures
- Vibration that is re-radiated as noise and heard as a low frequency rumble (ground-borne noise)
- Cosmetic (such as minor cracks) or structural damage to buildings and infrastructure.

People feel vibration at much lower levels than those that would cause damage to a building. In addition, vibration-sensitive equipment can be adversely impacted at levels much lower than would be felt by people.

Responses to vibration by people vary widely due to differences in physical sensitivity as well as psychological and environmental factors. As in the case of noise, human responses to vibration are determined through social surveys. These studies show that people may perceive and make adverse comment about vibration levels that are only slightly above the threshold of perception. Commonly experienced building vibrations that result from internal vibration sources include vibration from household appliances and people walking on floors. These vibration levels are often comparable to externally generated vibration levels that may result in adverse comment from residential building occupants (BS 6472-1, 2008). Vibration thresholds for management action target preserving amenity (human comfort) for the overwhelming majority of the population and are set at a ‘low probability of adverse comment’. For residential receivers, the ‘preferred’ vibration threshold is set only slightly above the threshold of perception of vibration, whereas other occupancies such as commercial/work environments have thresholds for management action based on a ‘low probability of adverse comment’ in relation to the context being considered.

Human response to vibration and the potential for adverse comment are also influenced by the duration over which the vibration occurs, with vibration experienced for a limited duration being more acceptable than the same vibration level experienced over a longer period. Building vibration impacts on people are often assessed using the concept of ‘vibration dosage’ (BS6472-1, 2008), which links the probability of adverse comment to both the duration and magnitude of vibration, enabling the impact of intermittent vibration sources such as train operations and certain types of construction activities to be understood and assessed.

The concept of time-related influences on human perception of vibration is also relevant when considering the duration of construction works, with people more accepting of temporarily higher vibration levels over a relatively short period when coupled with appropriate management processes.

In all cases, vibration thresholds aimed at preserving human comfort are far below vibration levels that would cause any damage to structures.

1.3.1 Construction

The construction of the Melbourne Metro would potentially involve 24-hour construction activities at times for each of the major construction work sites. Night work is expected to cause the highest impact as ambient noise levels are lower at night and people are particularly sensitive to noise when they are trying to sleep. For airborne noise, Guideline Noise Levels apply to work undertaken outside of Normal Working Hours except for Unavoidable Work. Unavoidable Work is expected to consist of:

- Railway occupations that must be undertaken 24-hours a day to limit the disruption to the rail network. The railway occupations are proposed to consist of:
  - Two occupations of 1-week at the western portal and 4 to 5 weekends of 24-hour work
  - Two occupations of approximately 1.5 weeks at the eastern portal and 5 weekends of 24-hour work
- TBM launch preparation and TBM launch. This work is proposed to be undertaken during Normal Working Hours, however, if it is not completed then it would extend into other periods. This is anticipated to take 4 to 5 weeks at each of the relevant locations.
- Concrete pour - this work is proposed to be undertaken during Normal Working Hours, however, if it is not completed then it would extend into other periods. This is anticipated to occur on a regular basis.

- Cut and cover construction across Flinders Street is expected to last for 2 to 3 months with a smaller scale operation outside of Normal Working Hours.
- TBM removal at eastern portal - this work is proposed to be undertaken during Normal Working Hours, however, if it is not completed then it would extend into other periods. This is anticipated to take 4 to 6 weeks in total.
- Road occupations:
  - Flinders Street (2 to 3 months)
  - Kensington Road (up to 3 weekends)

Melbourne Metro would be predominantly in tunnels and consequently, airborne construction noise from tunnelling activities would be negligible for much of the project (as the TBM / roadheader would be underground). Tunnelling does, however, have the potential to cause vibration and ground-borne noise in buildings above the tunnels. Vibration and ground-borne noise from tunnelling would occur at the same time and be transient as the TBMs / roadheaders would be continuously moving. They would pass each property at most twice (once for each tunnel). Excavation of station caverns (using roadheaders) would not be transient and is expected for up to 18 months.

There is a risk of vibration and ground-borne noise impact from activities at the construction work sites and from tunnelling. The potential impacts include damage to buildings, infrastructure and underground services, disturbance to occupants of buildings and disturbance to vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas. Guideline Targets apply for vibration and ground-borne noise.

The adverse impact of vibration can vary due to a range of factors, including:

- Magnitude of the vibration source
- Duration of the process generating the vibration levels
- Number of times the vibration generating operation is repeated
- Ground conditions
- The source to receiver distance and depth of works below ground
- Building foundation type
- Construction of the buildings
- Attitude of public towards the project.

The tunnels would be in the ground below the Yarra River. Consequently, underwater construction noise in the Yarra River is expected to be lower than the ambient underwater noise levels due to boat traffic within the river.

Construction vehicles would be using the existing road network and are proposed to utilise VicRoads' Preferred Traffic Routes as efficiently as possible. Where vehicles use local roads, their activity would be during the daytime where possible.

1.3.2 Operation

Sources of noise and vibration impact from operation of the proposed Melbourne Metro include:

- Trains
- Fixed infrastructure associated with Melbourne Metro (e.g. ventilation fans).

Noise and vibration from the operation of trains generally come from the following sources:

- Rolling noise from the wheel-rail interface
- Impact noise from track features such as joints, switches and crossings

- Wheel squeal and flanging on small radius curves
- Mechanical noise from motors, fans and ancillary equipment on the train
- Exhaust (diesel freight and passenger trains would operate adjacent to eastern and western portals).

Aerodynamic noise is generally attributed to rail vehicles at speeds of 250 km/hr or greater. It is therefore, not expected to arise because of the proposed Melbourne Metro.

Noise from trains is affected by a number of factors including:

- Operating speed
- Length of train
- Number of trains
- Type of train
- Joints, switches and crossings
- Rail curvature
- Scheme alignment (depth)
- Trackform (slab or ballast)
- Rail damping (characterised by track decay rate)
- Wheel and rail maintenance regime
- Unsprung mass and suspension stiffness.

2 Scoping Requirements

2.1 EES Objectives

The following evaluation objectives are relevant to the noise and vibration and identify the desired outcomes in the context of potential project effects. The evaluation objectives provide a framework to guide an integrated assessment of environmental effects of the project, in accordance with the *Ministerial Guidelines for assessment of environmental effects under the Environment Effects Act 1978*.

Table 2-1 Amenity evaluation objective

Draft Evaluation objective	Key Legislation
Amenity: To minimise adverse noise or vibration effects on the amenity of nearby residents and local communities, as far as practicable, especially during the construction phase.	*Environment Protection Act 1970,* State Environment Protection Policies and guidelines *Planning and Environment Act 1987* *Transport Integration Act 2010*

2.2 EES Scoping Requirements

The following extracts from the Scoping Requirements, issued by the Minister for Planning, are relevant to the amenity evaluation objective.

Table 2-2 Amenity Scoping Requirements

Aspect	Relevant response
Key Issues	• Emissions of noise resulting from the Project exceeding relevant statutory, policy or guideline levels, adversely affecting amenity of residences or other sensitive land uses. • Generation of airborne or ground-borne vibrations, which could adversely affect amenity of residential or other sensitive premises.
Priorities for characterising the existing environment	• Existing noise conditions and trends in the neighbourhood of the Project alignment and works sites. • Ground conditions, which may influence the transmission of vibrations resulting from construction works or railway operations.
Design and mitigation measures	• Design, management and intervention measures, which may be applied to control emissions of construction noise and noise from train operations within relevant SEPP, policy or guideline levels. • Design, management and intervention measures, which may be applied to control vibrations resulting from construction works and from train operations within relevant guideline levels that are appropriate for the project.

Aspect	Relevant response
Assessment of likely effects	• Analysis of potential for noise standards to be exceeded, with respect to timing, durations, localities, degree of potential exceedance and any relevant special noise characteristics (e.g. tonality, impulsiveness). • Analysis of potential for vibration to cause disturbance to occupants of residential buildings or other sensitive land uses.
Approach to manage performance	• Describe the principles to be adopted for setting key elements of proposed monitoring programs for, noise and vibration, both during construction works and for project operations, as appropriate. • Describe the principles to be adopted for developing contingency measures to be applied if monitoring demonstrates more significant adverse effects than predicted or permitted.

3 Legislation, Policy and Guidelines

3.1 Primary Legislation and Associated Information

Table 3-1 presents a summary of the relevant primary legislation, policy and guidelines that apply to noise and vibration as well as the implications, required approvals and interdependencies and information requirements associated with obtaining approvals. Descriptions of all relevant legislation are also provided.

Table 3-1 Primary legislation and associated information

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies / information requirements
Commonwealth				
Noise Management and Protection of Hearing at Work[4]	Provides a framework for management of exposure to noise at work.	Control of noise levels in areas where employees would be located.		Noise levels in areas where staff are located would need to be considered.
State				
Victorian Passenger Rail Infrastructure Noise Policy[5] **(PRINP)** **Victorian Government**	See Section 3.3.1	Operational Rail noise is to be assessed against this policy.		
Environment Protection Act1970 **State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1**[6] **(SEPP N-1)**	See Section 3.3.2	SEPP N-1 provides a methodology to determine the applicable mandatory Noise Limits at Noise Sensitive Areas.		
Environment Protection Authority Noise Control Guidelines Publication 1254[7] **(EPA 1254)**	See Section 3.2.1.1	Provides a framework for the management of construction noise.	For Unavoidable Work	
Code of Practice for the Housing and Care of Laboratory Mice, Rats,	See Section 3.4.1	Provides information about the impacts of noise and vibration on Bio-resources		

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[4] National Code of Practice for Noise Management and Protection of Hearing at Work [NOHSC: 2009(2004)] 3rd Edition

[5] Passenger Rail Infrastructure Noise Policy, Victorian Government, April 2013

[6] State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N1, 16 May 1989

[7] Environment Protection Authority (EPA) Noise Control Guidelines (Publication 1254), October 2008

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies / information requirements
Guinea Pigs and Rabbits. Prepared by the Victorian Department of Primary Industries, 16 December, 2004				
Local				
Local law: **City of Melbourne, Noise and Vibration Management Guidelines**[8]	-	These do not apply to Melbourne Metro as they do not apply to civil infrastructure works.	Section 258A of the *Major Transport Projects Facilitation Act 2009* states that no permits are required from councils for the purposes of an approved project.	
Local law: **Stonnington City Council**[9]	Times allowed for construction.	Unless permitted by council construction is prohibited: - before 7am and after 8pm. Monday to Friday - before 9am and after 8pm Saturday - on Sunday - Christmas Day, Good Friday or ANZAC day.		
Local law: **City of Port Phillip**[10]	Times allowed for construction.	Standard hours for building works are: - 7am to 6pm Monday to Friday - 9am to 3pm Saturday An out of hours permit must be obtained to carry out works outside these hours.		
Other (Guidelines) – Advisory documents				
Australian Standard AS2187.2-2006 Explosives – Storage and Use Part 2: Use of explosives	Limits for blasting activities	Limits for blasting activities	Yes	
EPA Publication 480, Environmental Guidelines for Major Construction Sites (1996) [11] **(EPA 480)**	Provides guidance for construction noise.	Provides guidance for construction noise; however, EPA 1254 would be the primary document with respect to noise. There is some comment with regard to vibration but no	-	

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[8] Noise and Vibration Management Guidelines, City of Melbourne

[9] http://www.stonnington.vic.gov.au/residents-and-services/building/local-law-permits/building-activity-hours/

[10] http://www.portphillip.vic.gov.au/out-of-hours-permit.htm

[11] Environment Protection Authority (EPA) Environmental Guidelines for Major Construction Site (Publication 480) February 1996

Legislation / policy	Key policies / strategies	Implications for this project	Approvals required	Timing / interdependencies / information requirements
		criteria.		
Australian Standard AS2436-2010[12] (AS 2436)	For information.	For information.	-	
NSW Interim Construction Noise Guideline[13]	See Section 3.2.2.	Provides Guideline Targets for Management Actions for ground-borne construction noise.	-	
DIN 4150-3 Structural Vibration Part 3: Effects of vibration on structures[14] (DIN 4150)	See Section 3.2.3.1.	Provides Guideline Targets for construction vibration with respect to damage to buildings.	-	
ASHRAE Chapter 48, Sound and Vibration Control[15] (ASHRAE)	See Section 3.2.4.	Provides Guideline Targets for management of vibration with respect to vibration-sensitive equipment.	-	
Rail Infrastructure Noise Guideline May 2013[16]	See Section 3.3.2.	Provides Guideline Targets for management of ground-borne noise from trains.	-	
Assessing Vibration: A Technical Guideline December, 2006[17]	See Section 3.2.3.4.	Provides Guideline Targets for Management Actions for vibration with respect to human comfort.	-	
AS/NZS 2107:2000[18]	See below.	Internal noise levels for Highly Sensitive Areas.	-	
British Standard BS6472-1:1992[19]	-	Referred to in other documents	-	-
British Standard BS6472-1:2008[20]	-	Updated of BS6472-1:1992	-	-

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[12] Australian Standard AS2436-2010 Guide to noise and vibration control on construction, demolition and maintenance sites

[13] Interim Construction Noise Guideline, Department of Environment and Climate Change, July 2009

[14] DIN 4150-3 Structural Vibration Part 3: Effects of vibration on structures, February 1999

[15] American Society of Heating, Refrigeration and Air-conditioning Engineers, ASHRAE, Chapter 48, Noise and Vibration Control, 2011

[16] NSW EPA Rail Infrastructure Noise Guideline, May 2013

[17] Assessing Vibration: A Technical Guideline, February 2006, NSW Department of Environment and Conservation

[18] AS/NZS 2107:2000 Australian/New Zealand Standard Acoustics-Recommended design sound levels and reverberation times for building interiors

[19] British Standard BS6472-1:1992[19] Guide to Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)

[20] British Standard BS6472-1:2008. Guide to Evaluation of Human Exposure to Vibration in Buildings. Part 1: Vibration sources other than blasting

3.2 Construction

Currently, there is no Commonwealth or Victorian legislation that relates to noise or vibration associated with construction. There are, however, other guidelines and standards, some used in other parts of Australia, notably NSW and some that have been applied on similar rail projects internationally, which can be used to assess the impact of construction noise and vibration on sensitive receivers. These are given in Table 3-1 and detailed below.

3.2.1 Airborne Noise

Airborne noise is most commonly referred to as sound that reaches the point of interest by propagation through air. The following documents apply to airborne construction noise in Victoria:

- EPA Noise Control Guidelines Publication 1254 (EPA 1254)
- EPA Publication 480, Environmental Guidelines for Major Construction Sites (1996) (EPA 480)
- Australian Standard AS 2436-2010 Guide to noise and vibration control on construction, demolition and maintenance sites.

The noise criteria and approach in EPA 1254 are to apply to the proposed Melbourne Metro as it is widely used for construction noise management in Victoria.

3.2.1.1 EPA 1254

The purpose of EPA 1254 is to protect residences from unreasonable noise and it applies to construction activities. It provides recommended hours of operation of a construction work site and Guideline Noise Levels for works undertaken outside of Normal Working Hours. Time periods and Guideline Noise Levels are defined in Table 3-2. While the Noise Control Guidelines do not have legal effect, it is expected that construction of Melbourne Metro would be required to comply with the Noise Control Guidelines, where practicable, through the planning controls.

Table 3-2 Time periods and Guideline Noise Levels

Time Period	Applicable Hours	Guideline Noise Levels, L_{Aeq}	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday 7am to 1pm Saturday	No specified Guideline Noise Levels - noise reduction measures apply	
Weekend / Evening work	6pm to 10pm Monday to Friday 1pm to 10pm Saturday 7am to 10pm Sunday and Public Holidays	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more.	Noise level at any residential premises not to exceed background noise (L_{A90}) by 5 dB(A) or more.
Night	10pm to 7am Monday to Sunday	Noise is to be inaudible within a habitable room of any residential premises.	

Exceptions include Unavoidable Works, which are works that cannot practicably meet the schedule requirements because the work involves continuous work (such as a concrete pour) or would otherwise pose an unacceptable risk to life or property, or risk a major traffic hazard. Affected premises should be notified of the intended work, its duration and times of occurrence. The relevant authority (to be confirmed with EPA) must be contacted and any necessary approvals sought.

EPA 1254 requires that the following work measures apply:

- Use the lowest noise work practices and equipment to meet the requirements of the job
- Site buildings, access roads and plant should be positioned such that the minimum disturbance occurs to the locality. Barriers such as hoardings or temporary enclosures should be used. The site should be planned to minimise the need for reversing vehicles
- All mechanical plant is to be silenced by the best practical means using current technology. Mechanical plant, including noise suppression devices should be maintained to the manufacturer's specifications. Internal combustion engines are to be fitted with a suitable muffler in good repair
- Fit all pneumatic tools operated near a residential area with an effective silencer on their air exhaust port.
- Install less noisy movement / reversing working systems for equipment and vehicles that would operate for extended periods, during sensitive times or in close proximity to sensitive sites. Occupational health and safety requirements of use of working systems must be followed
- Turn off plant when not in use
- All vehicular movements to and from the site to only occur during the scheduled Normal Working Hours, unless approval has been granted by the relevant authority
- Where possible, no truck associated with work should be left standing with its engine operational in a street adjacent to a residential area
- Special assessment of vibration risks may be needed such as for pile driving or works structurally connected to sensitive premises.

Additional requirements for noise mitigation and communications also apply and these are detailed in Appendix A of this report.

3.2.1.2 AS/NZS 2107

EPA 1254 only provides Guideline Targets for residences and not for Highly Sensitive Areas (operating theatres, hospital wards). AS/NZS 2107:2000 *Australian/New Zealand Standard Acoustics-Recommended Design Sound Levels and Reverberation Times for Building Interiors* (AS/NZS 2107) recommends design criteria for occupied spaces. The ambient sound levels recommended take into account the function of the space and apply to steady-state or quasi steady-state sounds. Some construction noise may be described as quasi-steady state sound. In any case, the Maximum Recommended Design Sound Levels, L_{Aeq}, are to apply within Highly Sensitive Areas for airborne construction noise associated with the Melbourne Metro. The relevant levels are provided in Table 3-3.

Table 3-3 Construction Noise Targets in Highly Sensitive Areas

Highly Sensitive Area	Maximum Internal Construction Noise Level $L_{Aeq, 15mins}$
Intensive Care Wards	45
Operating Theatres	45
Surgeries	45
Wards	40

3.2.2 Ground-borne Noise

There is no Victorian or Commonwealth document that provides guidance with respect to construction ground-borne noise. The following guideline, which addresses ground-borne noise, has been developed in NSW:

- NSW Interim Construction Noise Guideline[13] (*the Guideline*).

This document has been successfully applied on recent projects in NSW, which are similar to Melbourne Metro. Preparation of the document included extensive public consultation and the views of industry stakeholders were considered along with those of the Standards Australia committee. In feedback received during the Technical Reference Group, the EPA stated that that *the NSW Guideline* is appropriate for use in lieu of any Victorian standard.

The relevant section of *the Guideline* is Section 4.2. It presents the ground-borne noise levels at residences when Management Actions should be implemented. These levels recognise the temporary nature of construction and are to protect the amenity and sleep of people when they are at home. For the Melbourne Metro, it is proposed that the values in Table 3-4 from Section 4.2 of *the Guideline* are also used to assess impacts in sleeping areas in hospital wards, student accommodation and hotel rooms. These are to be applied within the Victorian assessment framework for addressing construction impacts.

Table 3-4 Ground-borne noise levels for Management Actions

Time period	Internal $L_{Aeq,15min}$, dB
Evening 6pm to 10pm	40
Night 10pm to 7am	35

Note:

1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.

3.2.3 Vibration

3.2.3.1 Construction Vibration

3.2.3.1.1 EPA 480

The only relevant Victorian document is EPA 480. This document has a requirement to “conduct a study on the impact of ground vibration from construction activities, where these operations occur within 50 m of a building and take appropriate action.” Criteria are not provided in this document.

3.2.3.2 Damage to Buildings

There are no specific Victorian or Commonwealth standards or guidelines, which specifically address structural damage to buildings from construction activities and provide guideline targets. International standards that address damage to buildings are:

- DIN 4150-3 Structural Vibration Part 3: Effects of vibration on structures (DIN 4150)

- BS 7385: Evaluation and Measurement for Vibration in Buildings Part 2[21] (BS 7385)

DIN 4150 sets vibration levels which when complied with would not result in damage that would have an adverse effect of the structures' serviceability. BS 7385 sets guideline values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. The DIN 4150 standard presents a lower risk of building damage and is therefore proposed for this project.

If the levels from DIN 4150 are exceeded it does not necessarily follow that damage would occur. Therefore, if exceedances were predicted then further site-specific assessment would be required to determine if construction could proceed without damage. The DIN 4150 values are provided in Table 3-5 and Table 3-6 for short-term and long-term vibration respectively.

Table 3-5 Guideline Targets for vibration velocity for evaluating short-term vibration on structures

Type of structure	Vibration at the foundation, mm/s (Peak Component Particle Velocity)			Vibration at horizontal plane of highest floor at all frequencies mm/s (Peak Component Particle Velocity)
	1 to 10 Hz	10 to 50 Hz	50 to 100 Hz$^{\text{Note 1}}$	
Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
Type 2: Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15
Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings	3	3 to 8	8 to 10	8

Notes:

1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels slightly exceeding the vibration levels in the table would not necessarily mean that damage would occur.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads), the values for Type 1 buildings may be increased by a factor of two.
4. For buildings, short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

Table 3-6 Guideline Targets for vibration velocity to be used when evaluating the effects of long-term vibration on structures

Type of structure	Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies
Buildings used for commercial purposes, industrial buildings and similar design	10
Dwellings and buildings of similar design and/or occupancy	5

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[21] British Standard 7385: 1993 Evaluation and Measurement for Vibration in Buildings Part 2: Guide to damage levels from ground-borne vibration

Type of structure	Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies
Structures that have a particular sensitivity to vibration e.g. heritage buildings	2.5

Notes:

1. Vibration levels slightly exceeding those in the table would not necessarily mean that damage would occur.
2. In this context long-term means vibration events that may result in resonant structural response.

DIN 4150 sets vibration levels which *when complied with will not result in damage that will have an adverse effect of the structures' serviceability*. DIN 4150 further explains that examples of a reduction in the serviceability of a building or building component due to the effects of vibration include:

- Impairment of the stability of the building and its components
- A reduction in the bearing capacity of floors.

For structures Types 2 and 3, as defined in Table 3-5, the serviceability is considered to be reduced if:

- Cracks form in plastered surfaces of walls
- Existing cracks in the building are enlarged
- Partitions become detached from loadbearing walls or floors.

3.2.3.3 Damage to Underground Infrastructure

DIN 4150 provides Guideline Targets for damage to buried pipework and these are provided in Table 3-7. In addition to DIN 4150, Melbourne Water has specific requirements in their documents *Utility Installation Near Melbourne Water Assets Guide*[22] and *Build Over Guide*[23] for clearance distances for construction near to sewage pipes, storm water / drainage pipes, water mains and natural and artificial channels.

In all cases of buried services, the service provider is to be contacted and requested to provide advice regarding specific vibration criteria for their infrastructure. The vibration criteria provided by asset owners must not be exceeded.

Table 3-7 Vibration Guideline Targets for buried pipework

Pipe material	Vibration Velocity mm/s (PPV)
Steel	100
Clay, concrete, reinforced concrete, pre-stressed concrete, metal	80
Masonry, plastic	50

Notes:

1. These values may be reduced by 50 per cent when evaluating the effects of long-term vibration on buried pipework.
2. It is assumed pipes have been manufactured and laid using current technology.
3. The vibration criteria provided by asset owners must not be exceeded.

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[22] Utility Installation Near Melbourne Water Assets Guide, Melbourne Water

[23] Build Over Guide, Melbourne Water

3.2.3.4 Human Comfort

There is no Victorian or current Commonwealth document that provides guidance with respect to human comfort from construction vibration.

For past projects, including large infrastructure projects, Australian Standard AS2670.2 – 1990 *Evaluation of human exposure to whole body vibration* has been used to provide satisfactory magnitudes of building vibration with respect to human response. This standard is now withdrawn. SAI Global has advised that it has been replaced with ISO 2631-2:2003 *Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 2: Vibration in buildings (1 Hz to 80 Hz)*. This document does not include magnitudes of vibration for human comfort.

The following guideline, which addresses human response to vibration, has been developed in NSW:

- Assessing Vibration: A Technical Guideline[17] (*Vibration Guideline*).

In developing this document Australian and International standards, current scientific research and the practices of other regulating authorities were reviewed. In feedback received during the Technical Reference Group consultation a representative from the Victorian EPA has stated that *the Vibration Guideline* is appropriate for use in lieu of any Victorian standard.

The *Vibration Guideline* is based on BS6472-1:1992[24] which is now superseded. Therefore, in assessing the impact of vibration on human comfort for the proposed Melbourne Metro, the approach described in the *Vibration Guideline* (Sections 2.3 and 2.4) has been used, together with the updated vibration Guideline Targets from the later version of the British Standard, being: BS6472-1:2008[25]. The vibration Guideline Targets for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration (other than blasting) are provided in Table 3-8 and are proposed to apply for Melbourne Metro within the Victorian assessment framework for addressing construction impacts.

Table 3-8 Guideline Targets for Vibration Dose Values (VDV) for construction vibration with respect to adverse comment

Location	VDV ($m/s^{1.75}$)			
	Day 7am to 10pm		Night 10pm to 7am	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Residences	0.20	0.40	0.10	0.20
Offices, schools, educational institutions, places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Notes:

1. The VDVs are based on Table 1 in BS6472-1:2008
2. BS6472-1:2008 states that:
   - Adverse comments are not expected at VDVs less than the Preferred Value
   - There is a low probability of adverse comments at VDVs between the Preferred and Maximum Values
   - Adverse comments are possible at VDVs in the range [Maximum Value to 2 x the Maximum Value]

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[24] British Standard BS6472-1:1992. Guide to Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)

[25] British Standard BS6472-1:2008. Guide to Evaluation of Human Exposure to Vibration in Buildings. Part 1: Vibration sources other than blasting.

  - Adverse comment is probable at VDVs in the range [2 x Maximum Value to 4 x Maximum Value]
  - Adverse comment is very likely at VDVs greater than 4 x Maximum Value.
3. Activities should be designed to meet the Preferred Values where an area is not already exposed to vibration. Where all feasible and reasonable measures have been applied, values up to the Maximum Value may be used if they can be justified. For values beyond the Maximum Value, the operator should negotiate directly with the affected community.
4. The Guideline Targets are not mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
5. Vibration Guideline Targets for hospital operating theatres or precision laboratories are provided in Section 3.2.4.

3.2.4 Sensitive Equipment

Hospitals, laboratories and research institutions may utilise sensitive imaging equipment such as MRI machines and microscopes that are highly sensitive to vibration. Vibration Guideline Targets for sensitive equipment are defined either by referencing equipment supplier data, measured ambient vibration levels where sensitive equipment is successfully operating or if this is not available, the VC curves provided by ASHRAE[15] can be used. The VC curves (and on-site measurements) have been used for this assessment and the VC curves are presented in Figure 3-1. They provide the 1/3 octave RMS vibration tolerances of generic classes of sensitive equipment. The VC curve that applies to a specific site is dependent on the type of equipment and activities being conducted. The equipment vibration requirements from ASHRAE are provided in Table 3-9.

There may be times when the Guideline Targets cannot be achieved. In these situations, management approaches would need to be implemented so that construction activities do not interfere with the use of vibration-sensitive equipment. Existing ambient vibration levels measured adjacent to sensitive equipment (see Table 10-7) may be used to help inform a suitable management approach with respect to when vibration-sensitive equipment may or may not be able to operate. There may be times when, construction activity needs to be reduced.

Table 3-9: Equipment Vibration Guideline Targets - ASHRAE

Equipment requirements	Curve
Bench microscopes up to 100x magnification ; laboratory robots	Operating Room
Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc.	VC-A
Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths	VC-B
Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1 mm detail size	VC-C
Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ½ micro m; includes electron beam systems	VC-D
Un-isolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ¼ micro m; includes electron beam systems	VC-E

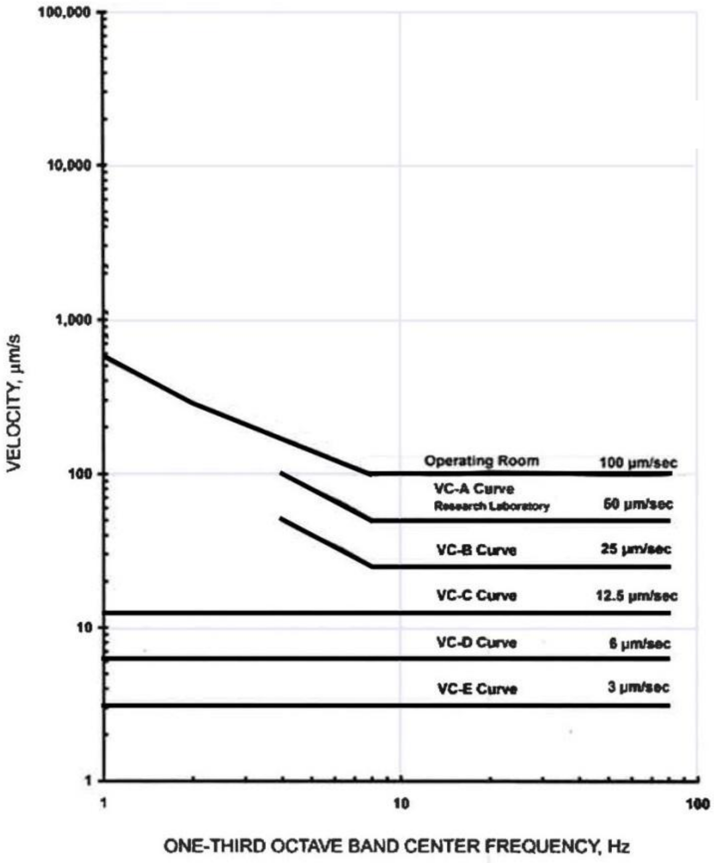


Figure 3-1 VC Curves from ASHRAE

3.2.5 Controlled Blasting

Controlled blasting has been considered at the Parkville station precinct (associated with excavating the station box) in order to reduce the overall duration and severity of vibration and ground-borne noise impacts.

Guidance with respect to noise and vibration limits for blasting is provided in AS2187.2-2006. This standard presents limits for:

- Human comfort from airblast - see Table 3-10
- Control of damage to structures from airblast - see Table 3-11
- Vibration suitable for human comfort - see Table 3-12
- Vibration limits for control of damage to structures – see Table 3-13
- Transient vibration for cosmetic damage - see Table 3-14.

Table 3-10: Recommended airblast limits for human comfort

Category	Type of blasting operations	Peak Sound Pressure Level (dBL)
Sensitive site	Operations lasting longer than 12 months or more than 20 blasts	115 dBL for 95% blasts per year. 120 dBL maximum unless agreement is reached with occupier that a higher limit may apply
Sensitive site	Operations lasting for less than 12 months or less than 20 blasts	120 dBL for 95% blasts. 125 dBL maximum unless agreement with occupier that a higher limit may apply

Category	Type of blasting operations	Peak Sound Pressure Level (dBL)
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	125 dBL maximum unless agreement is reached with the occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation

Notes:

1. A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people

Table 3-11: Recommended airblast limits for control of damage to structures

Category	Type of blasting operations	Peak Sound Pressure Level (dBL)
Structures that include masonry, plaster and plasterboard in their construction and also unoccupied structures of reinforced concrete or steel construction	All blasting	133 dBL maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, powerlines and cables located above the ground	All blasting	Limits to be determined by structural design methodology

Table 3-12: Recommended ground vibration limits for human comfort

Category	Type of blasting operation	Peak component particle velocity mm/s
Sensitive site	Operations lasting longer than 12 months or more than 20 blasts	5 mm/s for 95% blasts per year, 10 mm/s maximum unless agreement is reached with occupier that a higher limit may apply
Sensitive Site	Operations lasting for less than 12 months or less than 20 blasts	10 mm/s maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	25 mm/s maximum unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation

Notes:

1. A sensitive site includes houses, low rise residential buildings, theatres, schools, similar occupied buildings.
2. Does not cover high-rise building, buildings with long-span floors, specialist structures such as reservoirs, dams and hospitals, or buildings housing scientific equipment sensitive to vibration. These require special considerations, which may necessitate additional measurements on the structure to detect magnification of ground vibrations that might occur within the structure. Particular attention should be given to the response of suspended floors

Table 3-13: Recommended ground vibration limits for control of damage to structures

Category	Type of blasting operation	Peak component particle velocity mm/s
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	All blasting	Frequency- dependent damage limit criteria

Category	Type of blasting operation	Peak component particle velocity mm/s
Unoccupied structures of reinforced concrete or steel construction	All blasting	100 mm/s maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, power lines and cables	All blasting	Limit to be determined by structural design methodology

Notes:

1. Does not cover high-rise building, buildings with long-span floors, specialist structures such as reservoirs, dams and hospitals, or buildings housing scientific equipment sensitive to vibration. These require special considerations, which may necessitate taking additional measurements on the structure itself, to detect any magnification of ground vibrations that might occur within the structure. Particular attention should be given to the response of suspended floors.

Table 3-14: Transient vibration guide values for cosmetic damage

Type of Building	Peak component particle velocity in a frequency range of predominant pulse mm/s	
	4 to 15 Hz	15 Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	-
Unreinforced or light framed structure. Residential or light commercial type buildings Note 2	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Notes:

1. Values referred to are at the base of the building.
2. At frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

3.3 Operation

Noise and vibration from the operation of Melbourne Metro have the potential to adversely impact on the amenity of sensitive receivers in the vicinity of the rail infrastructure. Noise and vibration can interfere with activities including communication and studying and they can disturb sleep, causing stress and annoyance. These impacts need to be managed to protect the amenity and wellbeing of communities.

Noise and vibration associated with operation are to be assessed and managed to protect sensitive receivers from unreasonable impacts using Victorian requirements where they exist. When there are no local standards, other appropriate standards and guidelines have been identified. The proposed standards (criteria) for Melbourne Metro are detailed below.

3.3.1 Airborne Noise from Passenger Trains

Airborne noise from passenger trains is generated by a combination of noise from the propulsion of the rolling stock and from wheel/rail interaction. Railway noise in the vicinity of the portals and the turnback for the proposed Melbourne Metro would need to comply with Victorian *Passenger Rail Infrastructure Noise Policy*, April 2013 (PRINP).

While not an EPA policy, train noise must be considered against the PRINP. The PRINP provides Investigation Thresholds to guide transport bodies when assessing the impacts of rail noise on nearby communities. The thresholds are not a limit on allowable noise emissions. If they are exceeded, then options for avoiding, minimising and mitigating rail noise should be considered as proposed in the PRINP.

Melbourne Metro would involve the redevelopment of existing passenger rail infrastructure in the vicinity of the proposed portals and at the western turnback. The Investigation Thresholds for redevelopment of existing passenger rail infrastructure are applicable and are provided in Table 3-15.

Table 3-15 External Investigation Thresholds for redevelopment of existing passenger rail infrastructure

Time	Type of receiver	Investigation thresholds
Day **(6am – 10pm)**	• Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks • Noise sensitive community buildings, including schools, kindergartens, libraries	65 dBL_{Aeq} and a change in 3 dB(A) or more or 85 dBL_{Amax} and a change in 3 dB(A) or more
Night **(10pm – 6am)**	• Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks	60 dBL_{Aeq} and a change in 3 dB(A) or more or 85 dBL_{Amax} and a change in 3 dB(A) or more

Notes:

1. If an investigation shows that the thresholds are <u>not</u> exceeded, then no further action is considered under this policy.
2. L_{Amax}, for this assessment, is defined as maximum A-weighted sound pressure level and is the 95 percentile of the highest value of the A-weighed sound pressure level reached within the day or night.
3. For the Melbourne Metro the location of assessment is at 1 m from the centre of the window of the most exposed external façade.

3.3.2 Airborne Noise from Fixed Infrastructure

Operational noise from fixed infrastructure would need to be designed to meet the requirements of State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). SEPP N-1 does not apply to noise from construction and demolition activities on building sites, nor does it apply to noise emanating from roads and railway lines. It would, however, apply to noise from fixed plant and equipment, ventilation systems, maintenance, stabling facilities etc.

The purpose of SEPP N-1 is to protect people from commercial, industrial or trade noise that may affect a Noise Sensitive Area, while taking into consideration the existing land use around the Noise Sensitive Area in the Metropolitan region. A Noise Sensitive Area is defined in SEPP N-1 and consists of dwellings, residential buildings and similar types of accommodation.

The SEPP N-1 assessment includes the following:

- Determination of the Effective Noise Level based upon the noise level measured at the NSA with adjustments for noise character, duration and measurement position
- Determination of the Noise Limit, based on the measured background noise level and land use zoning of the area around the NSA
- A comparison between the Effective Noise Level and the Noise Limit. For compliance, the Effective Noise Level is not to exceed the Noise Limit.

The Noise Limits are determined following the methodology in Schedule B of SEPP N-1 and are dependent on the time of day or night and SEPP N-1 defines specific time periods to be used in the assessment. The time periods as defined in SEPP N-1 are shown in Table 3-16.

Table 3-16 SEPP N-1 time periods

Time period	Time
Day	7am - 6pm Monday to Friday 7am - 1pm Saturday
Evening	6pm - 10pm Monday to Friday 1pm - 10pm Saturday 7am - 10pm Sunday and Public Holidays
Night	10pm - 7am All Days

The Noise Limits determined using this methodology should not be less than the Base Noise Limits, which are provided in Table 3-17. If the Noise Limit determined is lower than the Base Noise Limit, then the Base Noise Limit becomes the Noise Limit.

Table 3-17 SEPP N-1 Base Noise Limits

Time period	Base Noise Limit, dB(A)
Day	45
Evening	40
Night	35

The Noise Limits are applicable to the combination of all noise associated with commerce, industry and trade. This includes noise associated with fixed infrastructure for the Melbourne Metro and noise associated with unrelated facilities. Therefore, noise from each facility may need to be less than the given Noise Limit.

3.3.3 Ground-borne Noise from Passenger Trains

There is no Victorian or Commonwealth document that provides specific requirements with regard to ground-borne noise from trains. However, the NSW EPA, addresses ground-borne noise from trains in:

- Rail Infrastructure Noise Guideline[16] May 2013 (RING).

It is stated in the RING that: 'Limited research into the impact of ground-borne noise is available, and information on practices applied overseas is also scarce. From a review of the available material, it appears that the factors that can affect reaction to ground-borne noise include: the level of noise, how often it occurs, whether an area is already exposed to rail noise and whether the area affected has a low density of development (e.g. low density residential) with associated low levels of ambient noise. This is the basis of the trigger levels proposed.

This document has been successfully applied on recent projects in NSW, which are similar to Melbourne Metro. The relevant section of the RING is Section 2.5. It sets internal trigger levels with respect to ground-borne noise for the assessment of feasible and reasonable mitigation to reduce noise towards the relevant trigger level. The trigger levels are reproduced in Table 3-18. It is proposed that the values in Table 3-18 (from Section 2.5 of the RING) apply for Melbourne Metro. These are to be applied within the Victorian assessment framework of noise impact.

Table 3-18 Guideline Targets for ground-borne noise trigger levels

Sensitive land use	Time of day	Internal noise trigger levels
Residential	Day 7am - 10pm	40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more
	Night 10pm - 7am	35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more
Schools, educational institutions, places of worship	When in use	40 - 45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more

Notes:

1. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources).
2. Assessment location is internal near to the centre of the most affected habitable room.
3. L_{ASmax} refers to the maximum noise level not exceeded for 95 per cent of the rail pass-by events.
4. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.

Ground-borne noise levels are relevant only where they are higher than the airborne noise from railways (such as for the underground rail) and where the ground-borne noise levels are expected to be audible.

The RING does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies are proposed in Table 3-19.

Table 3-19 Guideline Targets for ground-borne noise trigger levels for other sensitive receivers

Sensitive land use	Time of day	Internal noise trigger levels L_{ASMax} (dB)
Hospitals (bed wards and operating theatres)	24-hours	35
Offices	When in use	45
Retail Spaces	When in use	50
Cinemas and Public Halls	When in use	30
Drama Theatres	When in use	25
Concert halls, Television and Sound Recording Studios	When in use	25

3.3.4 Vibration from Passenger Trains

3.3.4.1 Human Comfort and Disturbance

There is no Victorian or Commonwealth document that provides guidance with respect to human comfort from rail operations.

For past projects, including large infrastructure projects, Australian Standard *AS2670.2 – 1990 Evaluation of human exposure to whole body vibration* has been used to provide satisfactory magnitudes of building vibration with respect to human response. This standard is now withdrawn. SAI Global has advised that this standard has been replaced with ISO 2631-2:2003 *Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 2: Vibration in buildings (1 Hz to 80 Hz).* This document does not include acceptable magnitudes of vibration for human comfort.

The NSW EPA comprises documents, which address this, and these are:

- Assessing Vibration: A Technical Guideline (NSW EPA Vibration)
- Railway Infrastructure Noise Guideline, May 2013 (RING) (which references the previous document)

In developing the NSW EPA Vibration document, Australian and International standards, current scientific research and the practices of other regulating authorities were reviewed.

The NSW EPA Vibration document is based on BS6472-1:1992, which is now superseded. Therefore, in assessing the impact of vibration on human comfort for the Melbourne Metro, the methods and approach described in the NSW EPA Vibration (Section 2.3 and 2.4) have been used, together with the updated vibration Guideline Targets from the later version of the British Standard, being: BS6472-1:2008.

Vibration from railway traffic is generally considered intermittent and can be assessed using a Vibration Dose Value (VDV), which accounts for both the magnitude and duration of vibrations from intermittent sources. These values are proposed for Melbourne Metro and are reproduced in Table 3-20. These are proposed to be applied for the Melbourne Metro within the Victorian assessment framework for addressing vibration impacts.

Table 3-20 Guideline Targets for acceptable vibration dose values for intermittent vibration

Location	VDV (m/s$^{1.75}$)			
	Day 7am to 10pm		Night 10pm to 7am	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Residences	0.20	0.40	0.10	0.20
Offices, schools, educational institutions, places of worship	0.40	0.80	0.40	0.80
Workshops	0.8	1.6	0.80	1.60

Notes:

1. The VDVs are based on Table 1 in BS6472-1:2008.
2. BS6472-1:2008 states that:

- Adverse comments are not expected at VDVs less than the Preferred Value
- There is a low probability of adverse comments at VDVs between the Preferred and Maximum Values
- Adverse comments are possible at VDVs in the range [Maximum Value to 2 x the Maximum Value]
- Adverse comment is probable at VDVs in the range [2 x Maximum Value to 4 x Maximum Value]
- Adverse comment is very likely at VDVs greater than 4 x Maximum Value.

3. Activities should be designed to meet the preferred values where an area is not already exposed to vibration. Where all feasible and reasonable measures have been applied, values up to the Maximum may be used if they can be justified. For values beyond the maximum value, the operator should negotiate directly with the affected community.

4. The Guideline Targets are not mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
5. Vibration Guideline Targets for Highly Sensitive Areas such as hospital operating theatres or precision laboratories are provided in Section 3.2.4.

3.3.4.2 Buildings and Services

Human beings are far more sensitive to vibration than buildings and services and therefore the vibration Guideline Targets in Section 3.3.4.1 would govern the operational vibration requirements other than for situations in which sensitive equipment is present.

3.3.4.3 Sensitive Equipment

The Guideline Targets that would apply to vibration from passenger trains are that same as for construction and are provided in Section 3.2.4.

3.4 Other

3.4.1 Bio-resources

Specific criteria have been adopted for both construction and operation for areas housing Bio-resources. This applies for the Parkville Station Precinct only.

The Department of Primary Industries has a Code of Practice for the Housing and Care of Laboratory Mice, Rats, Guinea Pigs and Rabbits. This document sets limits for noise for laboratory animals. These are:

- Background noise should be kept below 50 dBL and should be free of distinct tones
- Short exposure should be kept to less than 85 dBL

In order for the Guideline Targets to be meaningful they need to be considered in the context of the frequency range that are relevant to the different Bio-resources.

Loud, intermittent and unfamiliar sounds are probably more disruptive than constant sounds.

4 Methodology

4.1 Approach

The approach to the noise and vibration impact assessment is as follows:

1. Undertake baseline measurements (noise and vibration)
2. Determine appropriate criteria / Guideline Targets
3. Undertake predictions and determine if criteria / Guideline Targets are met
4. If the assessment predicts an exceedance to a criterion then identify mitigation or management options
5. Evaluation of residual risks.

The assessments undertaken include:

- Construction airborne noise: details in Appendix A of this report
- Construction vibration and ground-borne noise: details in Appendix B of this report
- Operational airborne noise from trains: details in Appendix C of this report
- Operational airborne noise from fixed infrastructure: details in Appendix D of this report
- Operational vibration and ground-borne noise: details in Appendix E of this report.

4.2 Peer Review

This assessment has been independently peer reviewed by both Mr Dave Anderson of Acoustic Studio with respect to noise and vibration issues and Mr John Heilig of Heilig and Partners with respect to vibration. The peer reviewers reviewed and provided feedback on drafts of this report. The peer reviewer's methodology is set out in each of their reports, but in general terms it included a review of the assumptions, methodology, assessment criteria and scope applied in this report. Specifically Mr Heilig's review was limited to the vibration aspects of the report, including reviewing the appendices and the inputs into the assessments presented (modelling). The reports also addressed whether there were any additional matters which should be considered as part of the impact assessment in order to address the EES Scoping Requirements that are relevant to noise and vibration impacts or management. The peer reviewers were also required to consider whether there were any gaps or matters where they disagreed with this assessment. The final peer review report prepared by Mr Anderson is attached at Appendix G of this report, which sets out the peer reviewer's conclusions in relation to this report, and whether or not all of their recommendations were adopted.

The following responses are provided with respect to the recommendations made by Acoustic Studio:

1. Acoustic Studio has recommended that 'the Environmental Performance Requirements should commit to mitigation of noise from works during "Normal Working Hours" and "Unavoidable Works" carried out outside normal working hours.' Mitigation has been provided for the EES. The commitment to this mitigation would need to be made by MMRA.
2. Acoustic Studio has recommended 'consider setting up a framework to better define how additional noise and vibration mitigation and management measures (such as temporary relocation or respite periods) would be implemented.' While this was not included in version P4 of this report which was reviewed by Acoustic Studio it has been included in version P5 in Section 4.9.2.
3. Acoustic Studio has recommended 'consider setting up a framework to better define how additional noise and vibration mitigation and management measures would be implemented. Several recent

infrastructure projects in NSW have established construction noise and vibration management strategies, which include such a framework'. While this was not included in version P4 of this report which was reviewed by Acoustic Studio it has been included in version P5 in Section 4.9.2.

4. Acoustic Studio has recommended that 'While not explicitly covered by the PRINP, it is recommended that consideration is given to the assessment of different characteristics of turn-back noise, such as from stationery idling trains'. This has been addressed in Section 15.4.2.1 and Appendix C of this report.
5. With respect to air-borne noise for fixed infrastructure, representative details for major items of plant were not available at the time of the assessment. Consequently, specific mitigation requirements could not be detailed.

No response has been provided with respect to the Heilig peer review and the document has not been presented.

4.3 Existing Conditions

Noise and vibration measurements have been undertaken in the vicinity of the proposed Melbourne Metro and details of these measurements are provided in Appendix F of this report.

The following site investigations have been undertaken:

- External ambient noise measurements
- Internal noise measurements
- External vibration measurements
- Internal vibration measurements (including near vibration-sensitive equipment and Bio-resources)
- Underwater noise measurements.

4.4 Risk and Impact Assessment

An Environmental Risk Assessment has been completed for impacts of Melbourne Metro. The risk-based approach is integral to the EES as required by Section 3.1 of the Scoping Requirements for the EES. Importantly, an environmental risk is different from an environmental impact.

The limitations associated with this assessment are as follows:

- Vibration impact on underground infrastructure has been assessed for key items of infrastructure only and generic advice and minimum working distances provided for other buried services and infrastructure to enable MMRA manage potential impacts. MMRA would need to identify the location of underground services and ensure that the construction methodologies used do not exceed the vibration Guideline Targets for this infrastructure.

The overall risk assessment process adopted was based on AS/NZS ISO 31000:2009, as illustrated in Figure 4-1.

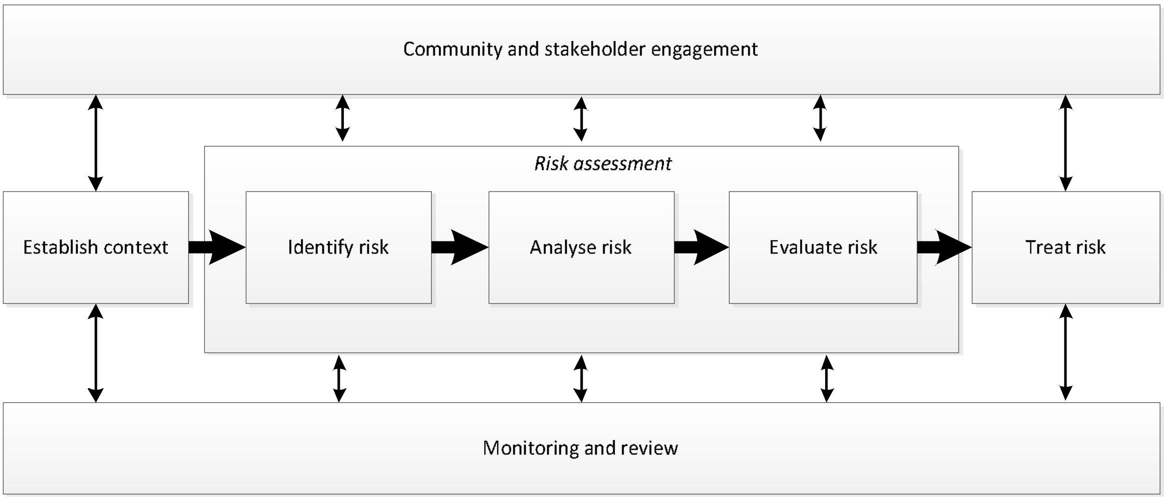


Figure 4-1 Overview of AS/NZS ISO 31000-2009 Risk Process

The following tasks were undertaken to determine the impact pathways and assess the risks:

- Setting of the context for the environmental risk assessment
- Development of consequence and likelihood frameworks and the risk assessment matrix
- Review of project description and identification of impact assessment pathways by specialists in each relevant discipline area
- Allocation of consequence and likelihood categories and determination of preliminary initial risks
- Workshops with specialist team members from different yet related discipline areas and focussing on very high, high and moderate initial risks to ensure a consistent approach to risk assessment and to identify possible interactions between discipline areas
- Follow-up liaison with specialist team members and consolidation of the risk register.

A more detailed description of each step in the risk assessment process is provided in Technical Appendix B *Environmental Risk Assessment Report* of the EES.

4.4.1 Context

The overall context for the risk assessment and a specific context for each specialist study are described in Technical Appendix B *Environmental Risk Assessment Report* of the EES. The context describes the setting for evaluation of risks arising from the Melbourne Metro. The specific context for the noise and vibration impact assessment follows:

> *The Melbourne Metro is located through the centre of Melbourne and into the inner city suburbs of Kensington, North Melbourne, Carlton and South Yarra. The above ground components of Melbourne Metro connect to existing rail lines in highly urbanised environments. The project would be constructed in an environment that includes the busiest tramline in Melbourne (Swanston St/ St Kilda Road), high amounts of traffic and all other modes of transport. The centre of Melbourne is continually undergoing development with high-rise building construction, works on tramways and other public infrastructure a common occurrence. The background noise and vibration levels are therefore already elevated and a key consideration for the risk and impact assessment undertaken for this EES.*
>
> *For airborne noise there are separate sets of criteria in Victoria relating to construction noise, operational noise from trains and operational noise from fixed plant. Airborne noise generated*

during construction of the project would be managed to comply with EPA Noise Control Guidelines Publication 1254. Airborne noise generated during operation would be managed to comply with the Victorian Passenger Rail Infrastructure Noise Policy 2013. Compliance with the SEPP (Control of Noise from Industry Commerce and Trade) No. N1 would be required for noise from fixed plant post construction.

Airborne noise generated during construction of the project could be managed to comply with the relevant statutory requirement of SEPP (Control of Noise from Industry Commerce and Trade) and guideline EPA Noise Control Guidelines Publication 1254 during construction by a combination of construction management measures, acoustic screening and off-site measures such as double glazing, where required. Airborne noise during operation could be managed to comply with the Victorian Passenger Rail Infrastructure Noise Policy 2013 by design, and by selection of equipment such as fans and acoustic fencing, where required.

In the absence of Victorian or Commonwealth requirements for managing ground borne noise the conservative NSW Department of Environment & Climate Change Interim Construction Noise Guideline 2009 has been used to provide Guideline Targets for ground borne noise from construction and the NSW EPA Rail Infrastructure Noise Guideline 2013 has been used to provide Guideline Targets for ground-borne noise from trains during operation of the Melbourne Metro. In the absence of Victorian or Commonwealth requirements for management of vibration generated during construction, the internationally recognised DIN 4150-3 Structural Vibration Part 3: Effects of Vibration on Structures, 1999 has been used to provide Guideline Targets for vibration impacts on structures from both construction and operation of the Melbourne Metro and the NSW Department of Environment & Climate Change Assessing Vibration: A Technical Guideline 2006 has been used to provide Guideline Targets for managing vibration with respect to human comfort.

The likelihood rating criteria used in the risk assessment by all specialists is shown in Table 4-1.

Table 4-1 Likelihood rating criteria

Level	Description
Rare	The event is very unlikely to occur but may occur in exceptional circumstances.
Unlikely	The event may occur under unusual circumstances but is not expected.
Possible	The event may occur once within a five-year timeframe.
Likely	The event is likely to occur several times within a five-year timeframe.
Almost Certain	The event is almost certain to occur one or more times a year.

The consequence criteria framework used in the risk assessment follows and is shown in Table 4-2. Each specialist has used this framework to develop criteria specifically for their assessment.

Table 4-2 Consequence framework

Level	Qualitative description of biophysical/ environmental consequence	Qualitative description of socio-economic consequence
Negligible	No detectable change in a local environmental setting.	No detectable impact on economic, cultural, recreational, aesthetic or social values.
Minor	Short term, reversible changes, within natural variability range, in a local environmental setting.	Short term, localised impact on economic, cultural, recreational, aesthetic or social values.

Level	Qualitative description of biophysical/ environmental consequence	Qualitative description of socio-economic consequence
Moderate	Long term but limited changes to local environmental setting that are able to be managed.	Significant and/or long-term change in quality of economic, cultural, recreational, aesthetic or social values in local setting. Limited impacts at regional level.
Major	Long term, significant changes resulting in risks to human health and/or the environment beyond the local environmental setting.	Significant, long-term change in quality of economic, cultural, recreational, aesthetic or social values at local, regional and State levels. Limited impacts at national level.
Severe	Irreversible, significant changes resulting in widespread risks to human health and/or the environment at a regional scale or broader.	Significant, permanent impact on regional economy and/or irreversible changes to cultural, recreational, aesthetic or social values at regional, State and national levels.

The consequence rating criteria used in the risk assessment specifically for noise and vibration is shown in Table 4-3.

Table 4-3 Consequence rating criteria

Consequence level	Consequence criteria
CONSTRUCTION	
Airborne Noise: High levels of airborne construction noise can adversely impact on noise sensitive receivers	
Negligible	Just audible.
Minor	Construction noise audible but within project noise criteria.
Moderate	Construction noise occasionally above applicable project noise criteria at sensitive receptors.
Major	Extended period(s) during which construction noise would be greater than project noise criteria at sensitive receptors.
Severe	-Not applicable as noise would not result in regional-scale impacts.
Ground-borne noise: Construction activity can result in ground-borne noise inside noise sensitive buildings that can cause disturbance	
Negligible	Not audible.
Minor	Ground-borne construction noise audible but within project guideline targets.
Moderate	Ground-borne construction noise occasionally above project guideline targets.
Major	Extended period(s) during which ground-borne construction noise would be greater than project guideline targets.
Severe	Not applicable as noise would not result in regional-scale impacts.
Vibration: Damage to buildings. High levels of vibration can cause damage to heritage or other property assets	
Negligible	Construction vibration is within project vibration Guideline Targets and no damage to buildings.
Minor	Construction vibration is marginally greater than the project vibration Guideline Targets for cosmetic damage but not structural damage to buildings.
Moderate	Construction vibration is greater than the project vibration Guideline Targets for cosmetic damage but not structural damage to buildings.
Major	Construction vibration is greater than the project vibration Guideline Targets for cosmetic damage and for structural damage to buildings.
Severe	Construction vibration is greater than the project vibration Guideline Targets for structural damage to buildings and would result in widespread structural damage.

Consequence level	Consequence criteria
Vibration: Damage to Underground Infrastructure. Vibration damage to underground infrastructure can result in major environmental impact or can adversely impact on the use of infrastructure	
Negligible	Construction vibration is within project vibration Guideline Targets and no damage to underground infrastructure.
Minor	Construction vibration is greater than project vibration Guideline Targets but no damage no damage to underground infrastructure.
Moderate	Construction vibration is greater than project vibration Guideline Targets and causing superficial damage to underground infrastructure.
Major	Construction vibration is greater than project vibration Guideline Targets and causing structural damage to underground infrastructure.
Severe	Construction vibration is greater than project vibration Guideline Targets and causing structural damage to underground infrastructure.
Vibration: Human comfort	
Negligible	Construction vibration is within project vibration Guideline Targets.
Minor	Isolated exceedances of project construction vibration Guideline Targets.
Moderate	Extended period of exceedances to project construction vibration Guideline Targets.
Major	Long-term exceedances of project construction vibration Guideline Targets.
Severe	Not applicable
Vibration-sensitive equipment: Vibration (even at very low levels) can disturb the performance of vibration-sensitive equipment	
Negligible	Construction vibration is within project vibration guideline targets.
Minor	Isolated exceedances of project construction vibration guideline targets.
Moderate	Extended period of exceedances to project construction vibration guideline targets.
Major	Long-term exceedances of project construction vibration Guideline Targets and inability to use equipment.
Severe	Not applicable
OPERATION	
Airborne noise from trains: train noise can cause disturbance at noise sensitive receptors	
Negligible	No increase in noise level.
Minor	Airborne noise levels increase but comply with project criteria.
Moderate	Airborne noise levels increase and are greater than project criteria.
Major	Airborne noise levels significantly increase and are greater than project criteria.
Severe	Not applicable
Airborne noise from fixed infrastructure: noise from fixed infrastructure can adversely impact on noise sensitive receivers	
Negligible	No increase in fixed plant and equipment noise level.
Minor	Compliant with SEPP N-1.
Moderate	Noise from fixed plant and equipment is greater than SEPP N-1 criteria by 2 to 5 dB at sensitive receptors.
Major	Noise from fixed plant and equipment is greater than SEPP N-1 criteria by more than 5 dB at sensitive receptors.
Severe	Noise from fixed plant and equipment is greater than SEPP N-1 criteria by more than 5 dB, intrudes into internal areas within buildings and strongly affects the function and utility of the premises.

Consequence level	Consequence criteria
Ground-borne noise from trains: underground railway movements can result in ground-borne noise inside sensitive buildings that can cause disturbance	
Negligible	Not audible.
Minor	Ground-borne noise potentially audible during quiet times and does not exceed ground-borne noise project guideline targets.
Moderate	Ground-borne noise audible and exceeding ground-borne noise project Guideline Targets by up to 5 dB.
Major	Ground-borne noise likely to be clearly audible and greater than ground-borne noise project Guideline Targets by up to 10 dB.
Severe	Ground-borne noise audible, intrusive and more than 10 dB above than ground-borne noise project guideline targets.
Vibration from trains: Human Comfort – When occupants of a building can detect vibration it can impact upon their quality of life or working efficiency.	
Negligible	Operational Vibration is within vibration Guideline Targets.
Minor	Isolated exceedances of vibration Guideline Targets.
Moderate	Extended period of exceedances.
Major	Long-term exceedances of applicable vibration Guideline Targets at sensitive receptors.
Severe	Not applicable
Vibration from trains: Damage to buildings: High levels of vibration can cause damage to heritage or other property assets	
Negligible	Operational vibration is within Guideline Targets and no damage to buildings.
Minor	Exceedance of project vibration Guideline Targets but no damage to buildings.
Moderate	Superficial damage to < 3 buildings.
Major	Widespread superficial damage to > 3 buildings. Widespread structural damage to < 3 buildings. Damage to heritage structures / buildings.
Severe	Widespread superficial damage to > 3 buildings. Widespread structural damage to > 3 buildings. Structural damage to heritage structures / buildings.
Vibration from trains: Disturbance to vibration-sensitive equipment Vibration (even at very low levels) can disturb the performance of vibration-sensitive equipment	
Negligible	Operational vibration is within Guideline Targets, no disturbance to equipment.
Minor	Isolated exceedances of vibration Guideline Targets.
Moderate	Extended period of exceedances.
Major	Inability to use essential vibration-sensitive equipment due to construction vibration over a long-term period.
Severe	Not applicable

The environmental risk assessment matrix used by all specialists to determine levels of risk from the likelihood and consequence ratings is shown in Table 4-4.

Table 4-4 Risk Matrix

		Consequence rating				
		Negligible	**Minor**	**Moderate**	**Major**	**Severe**
Likelihood rating	**Rare**	Very Low	Very Low	Low	Medium	Medium
	Unlikely	Very Low	Low	Low	Medium	High
	Possible	Low	Low	Medium	High	High
	Likely	Low	Medium	Medium	High	Very High
	Almost Certain	Low	Medium	High	Very High	Very High

Section 6 provides a summary of the noise and vibration risks assessed as part of the EES.

4.5 Assumptions

The following assumptions apply to this assessment:

- Stations would operate 24-hours
- All acquired properties would be demolished
- Future development at the Arden station site comprise residential lots with multi-story buildings founded on piles down to bedrock
- Future development (other than at Arden station site) has not been included
- Buildings with planning permits where construction has not commenced as of the date of the assessment have not been assessed at this stage but would need to be considered by MMRA
- Construction work sites are not considered to contain sensitive receivers
- Different construction methods may be used by MMRA. However, they would need to comply with the recommended Environmental Performance Requirements
- Grattan Street heritage fence and gates are to be removed and relocated along with Royal Parade and Grattan Street corner bluestone column and fence
- The ground-borne noise and vibration propagation model contains approximately 3,000 receivers, which have been individually assessed against ground-borne noise and vibration criteria according to their occupancy type, building type and distance from the alignment. MMRA may be required to include additional receivers in their assessment and to verify building and occupancy types in order to verify compliance with project criteria.

4.6 Stakeholder Engagement

As part of this assessment specific engagement with stakeholders was undertaken and details are provided in Table 4-5. Stakeholder engagement is ongoing.

Table 4-5 Summary of stakeholder engagement

Activity	When	Matters discussed/ issues raised	Consultation outcomes
Meeting with Royal Melbourne Hospital	7 September 2015	Noise and Vibration	Discussion regarding noise and vibration-sensitive equipment and locations for measurements to be undertaken.
Meeting with Melbourne Private Hospital (MPH)	7 September 2015	Noise and Vibration	Discussion regarding noise and vibration-sensitive equipment and locations for measurements to be undertaken.
Walter and Eliza Hall Institute	7 September 2015	Noise and Vibration	Discussion regarding noise and vibration-sensitive equipment and locations for measurements to be undertaken.
Meeting with University High School	7 September 2015	Noise and Vibration	No requirement for additional measurements.
Meeting with Royal Women's Hospital	8 September 2015	Noise and Vibration	Discussion regarding noise and vibration-sensitive equipment and locations for measurements to be undertaken.
Meeting with University of Melbourne	8 September 2015	Noise and Vibration	Discussion regarding noise and vibration-sensitive equipment and locations for measurements to be undertaken.
Meeting with Peter Doherty Institute	22 October 2015	Noise and Vibration	Discussion regarding noise and vibration-sensitive equipment and locations for measurements to be undertaken.
Meeting with RMIT	28 January 2016	Noise and Vibration	Discussion regarding noise and vibration-sensitive equipment and locations for measurements to be undertaken.
Meeting with Bio 21 Institute	16 February 2016	Vibration	Discussion regarding vibration-sensitive equipment.
Meeting with ACMI	25 February 2016	Noise and Vibration	Discussion regarding noise and vibration impacts.

Engagement has been undertaken with not only the groups listed above, it has also been undertaken with specific agencies and Technical Reference Group engagement. General engagement and consultation with the community has also been conducted as part of this assessment. Written feedback was obtained through feedback forms and the online engagement platform, and face-to-face consultation occurred at the drop-in sessions (refer to Technical Appendix C *Community and Stakeholder Feedback Summary Report* for further information). Noise and vibration specialists attended all drop-in sessions across the alignment, so that the attendees could raise concerns and engage with someone with specialist expertise.

Questions and concerns were raised about the level of noise and vibration that would be generated as a result of construction works and the impacts that this would have on the surrounding environment.

Additionally, specific issues were raised about sensitive receptors. For example, the University of Melbourne raised concerns about the impact additional noise and vibration would have on Bio-resources housed in close proximity to construction works. In response to this, further investigation into the tolerance to noise and vibration of a range of Bio-resources was completed. In instances where impacts to sensitive receivers were identified, further assessment was undertaken.

4.7 Methodologies for the Assessment of Construction Noise and Vibration

4.7.1 Airborne Noise

Airborne construction noise is to be managed in compliance with EPA 1254. The objective is to avoid subjecting sensitive receivers to unreasonable noise or vibration during construction.

The proposed approach to construction is to maximise construction work during Normal Working Hours (as defined in EPA 1254) and works undertaken outside of Normal Working Hours are to comply with the Guideline Noise Levels (as defined in EPA 1254). The exception to this would be Unavoidable Works - works that cannot practicably meet the scheduled requirements because the work involves continuous work or would pose an unacceptable risk to life or property, or risk a major traffic hazard.

Approach

The following approach has been used to assess airborne construction noise:

- Typical construction scenarios have been identified. They include construction equipment, time of use (e.g. during Normal Working Hours or outside of Normal Working Hours) and location
- Sensitive recievers in the vicinity of the construction works have been identified
- Specific Guideline Noise Levels (as per EPA 1254) have been established based on baseline noise measurements at the sensitive receivers
- An acoustic model has been built using the environmental noise modelling software package SoundPLAN version 7.2
- The ISO 9613-2:1996 Acoustics – *Attenuation of sound during propagation outdoors – Part 2: General method of calculation* (ISO 9613-2) methodology has been used to predict construction noise levels for each of the typical construction scenarios
- Neutral meteorological conditions have been used. As the sensitive receivers are close to the noise sources, meteorology is not expected to have a significant impact
- Where Guideline Noise Levels are predicted to be exceeded options for alternative construction methodologies and/or mitigation have been considered.

Acoustic Model

The acoustic model in SoundPLAN includes:

- Topography
- Building structures
- Noise sources
- Noise sensitive receivers
- Ground absorption
- Air absorption
- Meteorology.

Source Noise Levels

The source noise levels of construction equipment used in the acoustic model are provided in Table 4-6.

Table 4-6 Source Noise Levels for Construction Equipment

Equipment	Sound Power Level (SWL) (dB) Octave Band Frequency (Hz)								SWL dB(A)	Source of data
	63	125	250	500	1k	2k	4k	8k		
Material Delivery Trucks, Forklifts	100	97	94	92	88	87	86	84	95	Jacobs Database
Water Treatment Plant, Bentonite	98	103	88	86	93	94	87	90	99	DEFRA Noise Database
Grouting Plant	104	100	98	95	91	91	89	88	99	Jacobs Database
Concrete Pump	112	104	98	99	101	101	94	86	106	DEFRA
Concrete Trucks	111	102	94	97	98	106	88	83	108	DEFRA
Spoil Trucks	101	92	83	83	88	84	78	71	91	DEFRA
500/600t Crane	108	107	101	102	101	101	92	83	106	DEFRA
Crane (Gantry/Crawler)	101	99	96	98	94	91	82	77	99	DEFRA
Jackhammer	110	103	101	96	91	95	108	97	110	DEFRA
Excavator With Rock Breaker	109	108	108	111	110	107	104	101	114	DEFRA
Excavator	113	106	105	105	101	99	96	91	107	DEFRA
Road Header	125	125	119	120	112	110	102	92	120	Jacobs Database
Back-Up Power Generators	85	99	93	89	88	84	80	72	93	DEFRA
Cooling Towers	88	91	90	88	84	81	75	67	90	Jacobs Database
Ventilation Fans	45	60	68	78	81	83	76	63	87	Jacobs Database
TBM	109	111	109	109	106	104	102	95	112	Jacobs Database
Desanding Plant	108	109	109	111	104	103	95	90	111	Jacobs Database
D-wall Rig	102	99	91	88	84	82	78	72	91	DEFRA
Piling Rig (Bored)	112	120	109	108	106	104	96	89	111	DEFRA
Drilling Rig	113	121	106	107	108	107	104	102	114	DEFRA
Loaders / Back Hoe	102	94	92	92	91	88	87	78	96	DEFRA
Concrete Agitator Idling	95	86	87	92	88	87	84	72	94	Jacobs Database
Concrete Agitator Driving Inside Plant	99	88	84	85	88	87	80	71	92	Jacobs Database
Strand Feeder	80	78	80	82	93	92	91	89	98	Jacobs Database
Grinder/Hand Held Power Tools	76	74	80	85	97	95	100	96	104	Jacobs Database
1500 Super T Beam Concrete Mould, Normal Operation	122	134	115	111	107	106	107	99	120	Jacobs Database
Rail Cutter (Husqvarna K 1260 Rail)	114	106	98	97	111	112	110	103	117	Jacobs Database / Husqvarna Catalogue

Note: DEFRA – Department for Environment, Food and Rural Affairs, UK

Assumptions

The following assumptions have been made:

- All plant for each scenario is operating concurrently. This is a conservative approach as in practice this is unlikely to occur
- Noise sensitive receivers are based upon the land use survey prepared for Melbourne Metro
- Construction vehicles on public roads are not included in the assessment.

4.7.2 Vibration / Ground-borne Noise

Construction activities on Melbourne Metro have been divided into two broad categories:

1. Tunnelling
2. Additional Construction Works

Tunnelling

Underground tunnelling activities are proposed to occur along Melbourne Metro alignment and consist of:

- Tunnel Boring Machines (TBM) for tunnelling along the alignment between:
  - the Western Portal and CBD North station
  - CBD South station and the Eastern Portal

  The TBMs are large cylindrical machines with a rotating cutting wheel at the head of the machine.
- Roadheaders for mining the section of tunnels between CBD North and CBD South stations. Roadheaders consist of a cutting head mounted on a boom.
- Roadheaders for excavating the two cavern stations; CBD North and CBD South.

Tunnelling does not relate to excavation works that are to be completed using piling rigs, excavators, rippers and rock breakers. These activities are included in the Additional Construction Works.

Additional Construction Works

The Additional Construction Works include all non-tunnelling construction activities. They include construction of the stations and construction of TBM launch / recovery sites. The locations where the Additional Construction Works are proposed to take place are shown in Figure 4-2.

The relevant vibration intensive equipment for the Additional Construction Works are listed in Table 4-7.

Most of the above ground equipment (e.g. piling rigs) would be operated during Normal Working Hours. Exceptions include Unavoidable Work. At many of the construction work sites it is expected that underground works (including excavation and rockbreaking) would occur over 24-hours once the station roofs have been constructed.

Table 4-7: Additional Construction Works – construction equipment

Location / Precinct	Key vibration generating equipment							
	Excavator with hydraulic rock breaker	Piling Rig (bored)	Clam shovel (diaphragm walls)	Hydromill (diaphragm walls)	Excavator	Excavator with Ripper Attachment	Heavy vehicles	Fixed plant
Western Portal	o	o			o		o	o
Arden Station		o			o		o	o

Location / Precinct	Key vibration generating equipment							
	Excavator with hydraulic rock breaker	Piling Rig (bored)	Clam shovel (diaphragm walls)	Hydromill (diaphragm walls)	Excavator	Excavator with Ripper Attachment	Heavy vehicles	Fixed plant
Parkville Station	o	o			o	o	o	o
CBD North	o	o			o	o	o	o
CBD South	o	o	o	o	o	o	o	o
Linlithgow Avenue emergency access shaft	o	o			o		o	o
Domain	o	o	o	o	o		o	o
Fawkner Park construction work site	o	o			o		o	o
Eastern Portal	o	o			o		o	o

Notes:

1. Fixed plant includes: water treatment, concrete batching, de-sanding plant
2. Heavy vehicles includes: concrete trucks, spoil removal trucks, material delivery trucks

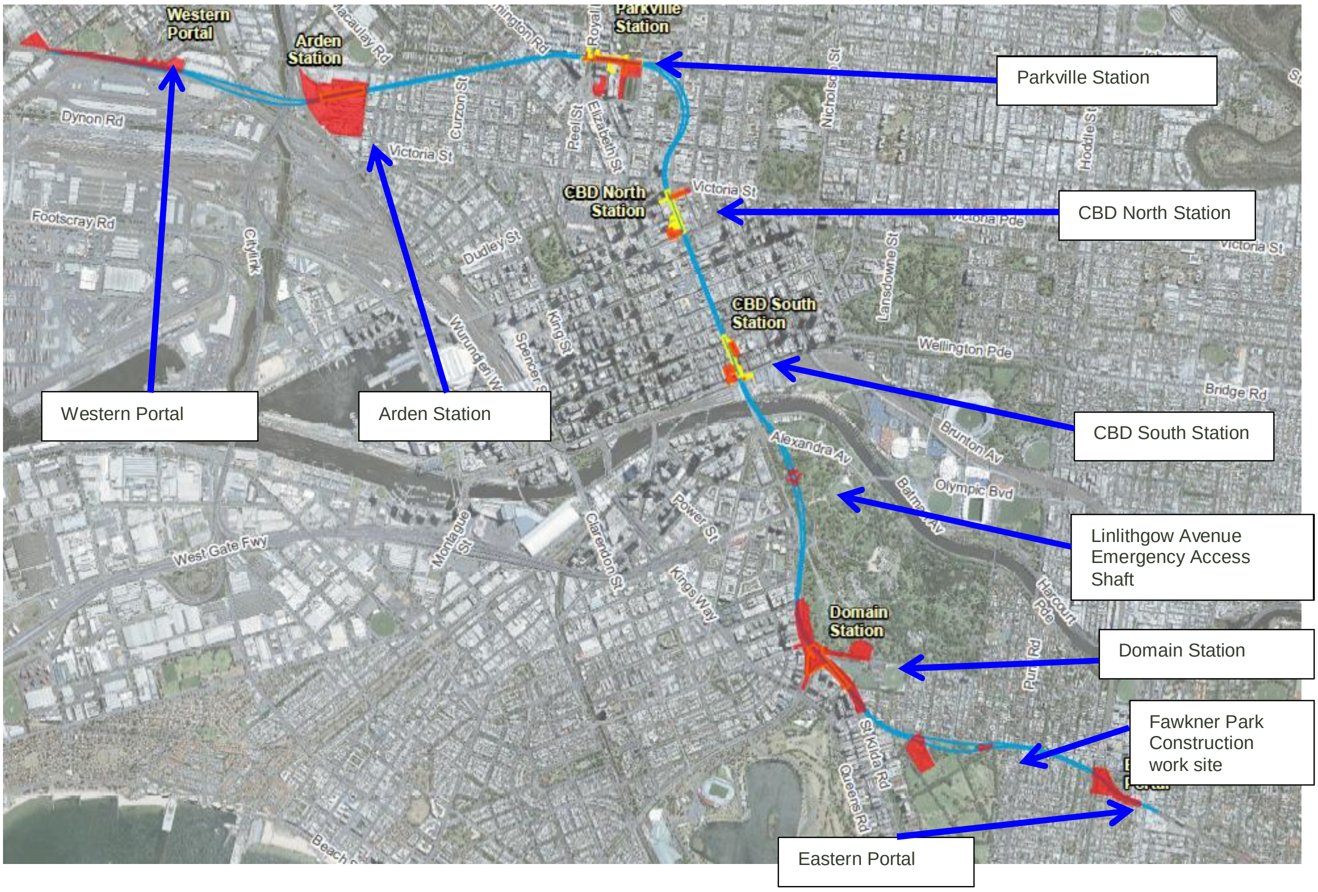


Figure 4-2: Melbourne Metro Additional Construction Work sites

Methodology

The vibration and ground-borne noise levels at buildings in the vicinity of the tunnels alignment and station construction work sites have been predicted as follows:

1. Guideline Targets for vibration and ground-borne noise were established using Australian and international standards and guidelines – see Section 3 Legislation, Policy and Guidelines
2. Vibration source levels were determined for the proposed vibration intensive equipment
3. Predictions were undertaken to determine the reduction of vibration with distance and the extent of vibration transmitted from the ground into buildings. The vibration predictions were completed at approximately 3000 buildings in the vicinity of the rail alignment and construction work sites
4. Detailed vibration assessments were completed at receiver locations where the predicted vibration and/or ground-borne noise levels were higher than the Guideline Targets. The detailed assessments considered additional factors such as existing levels and the anticipated duration of the construction works. The detailed assessments aided in determining appropriate Management Actions for these receivers.

The overall modelling process has been summarized in the flowchart shown in Figure 4-3.

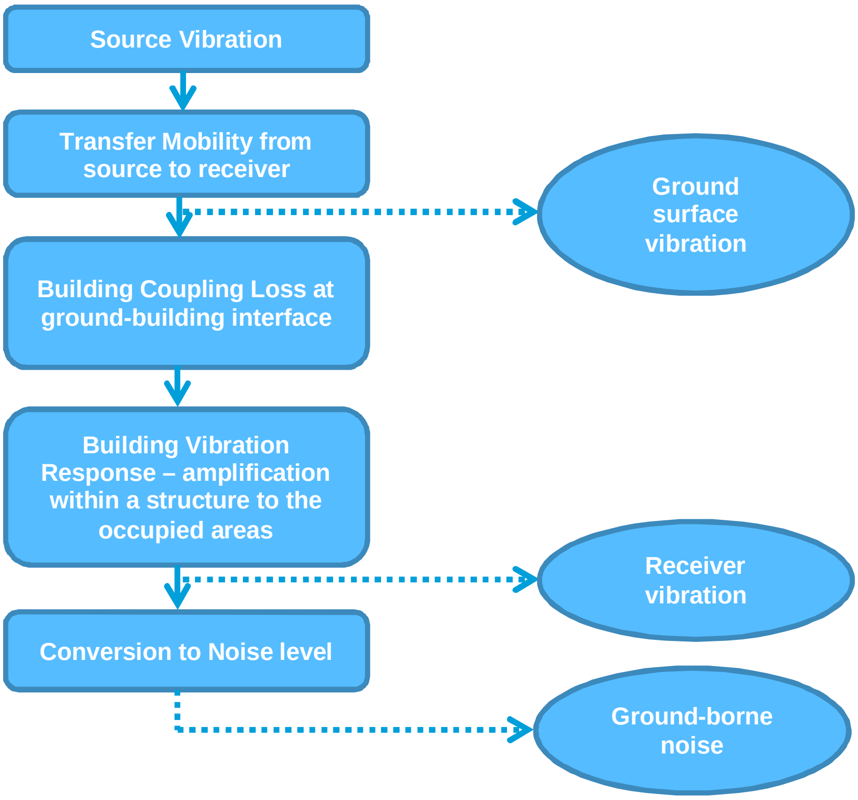


Figure 4-3: Construction vibration and ground-borne noise modelling process (based on FTA guideline with modifications)

Vibration / Ground-borne Noise Prediction

The following approach has been used for the assessment of vibration and ground-borne noise from tunnelling construction:

- The type of occupancy has been identified for each receiver e.g. residential, commercial, other sensitive use

- A sophisticated spreadsheet modelling tool has been developed based on the Federal Transit Administration (FTA) predictive methodology (the US Department of Transportation FTA document, *Transit Noise and Vibration Impact Assessment* FTA-VA-90-1003-06, FTA 2006) (FTA Guideline)
- Vibration source spectra (one-third octave band vibration levels) for the TBM and roadheader have been estimated using a combination of literature-based data along with an internal library of test data
- The ground vibration attenuation characteristics for the alignment have been derived from a combination of literature-based data and interpretation of geotechnical measurements at borehole locations
- The model has been used to predict vibration and ground-borne noise levels for receivers in the vicinity of the rail alignment
- The vibration and ground-borne noise predictions were based upon worst-case vibration levels. The predicted vibration levels relate to the point in time at which the most vibration intensive equipment is operating at the minimum distance from each receiver. As the equipment would not always be operating at that minimum distance, the predicted vibration levels would be lower for the majority of the construction works e.g. the distance from the tunnelling equipment to a receiver would vary as the tunnelling equipment move along the alignment
- There would also be changes in the types of construction equipment used throughout the construction e.g. rockbreakers would only be required for a portion of the station excavation works (rather than throughout the entire period of construction).

Assessment

Tunnelling Equipment

Vibration source levels and spectral characteristics are dependent on machine type / size and the ground conditions through which tunnelling is to occur. TBM / roadheader vibration source levels and spectral characteristics have been determined based on literature and test results for similar size / type machines in comparable soil / rock conditions.

The frequency spectra defined for the TBM and roadheader are based on the assumption that the majority of vibration is in the 16 to 80 Hz frequency bands.

The ground vibration at the receiver location has been estimated using the formula:

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

Where PPV = peak particle velocity, in mm/s
k = site/machine specific constant
d_{ref} = reference distance for source vibration data (m)
d = slope distance from the receiver location to the closest edge of the tunnel (m)
α = site specific ground attenuation constant (varies with frequency)

The mathematical models used are represented graphically in Figure 4-4.

The equations are a best-fit vibration estimate and vibration measurements should be undertaken at the commencement of work to confirm the mathematical prediction model.

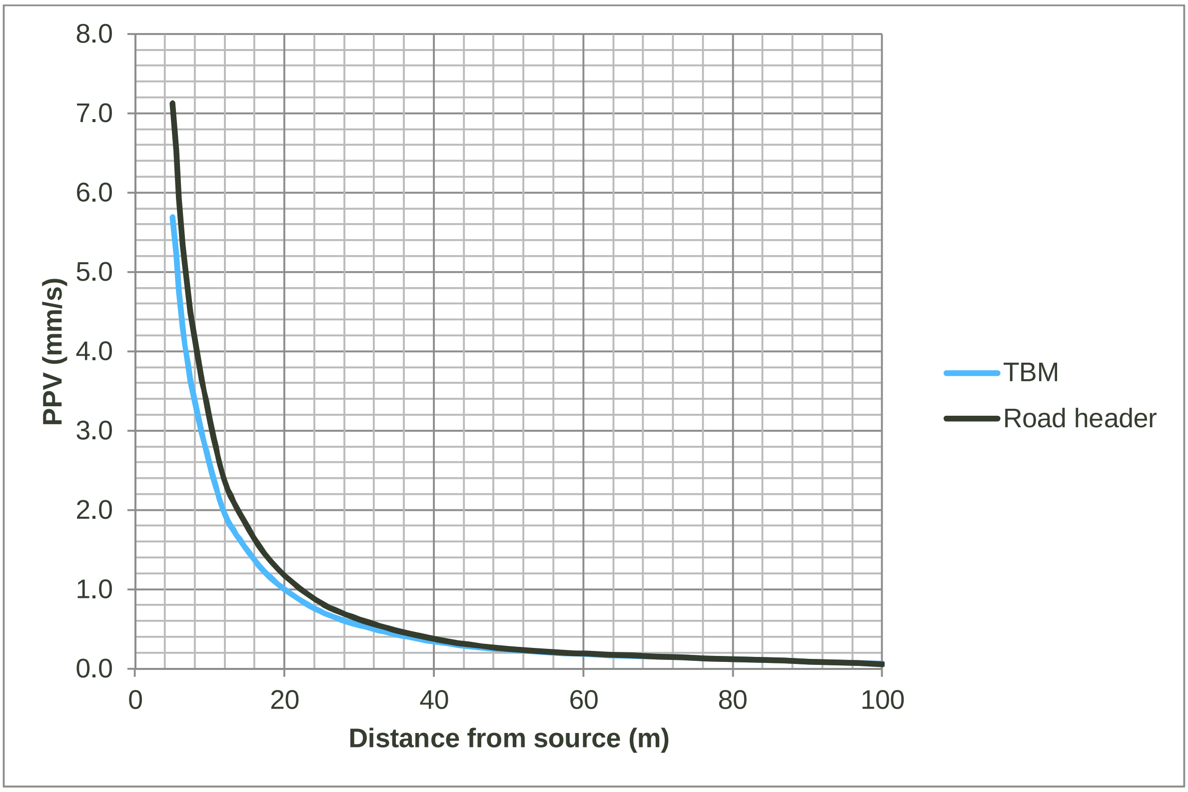


Figure 4-4: Ground-borne Vibration Attenuation Models for TBM and Road headers

The vibration adjacent to the receiver location has been predicted by calculating the minimum slope distance from each receiver to the top of the tunnels alignment.

Additional Construction Works Equipment

Source vibration levels used to model the Additional Construction Works equipment are presented in Table 4-8.

Table 4-8: Source vibration levels for equipment for Additional Construction Works

Description of vibration source	PPV at 7.6 m (mm/s)	Reference/Comment
32 tonne excavator with hydraulic rockbreaker	6.9	Based on representative data
20 tonne excavator with hydraulic rockbreaker	4.7	Based on representative data
12-15 tonne excavator with hydraulic rockbreaker	3.3	Based on representative data
7 tonne excavator with hydraulic rockbreaker	2.4	Based on representative data
Excavator with ripper attachment	1.3	Based on representative data
Hydromill in rock (diaphragm wall construction)	0.4	FTA Guideline
Piling rig (bored)	1.0	British Standard BS5228
Heavy vehicle traffic	1.9	FTA Guideline
Fixed plant	1.9	Expected to be better than or equal to heavy vehicle traffic

For rockbreakers, the ground vibration at each receiver (adjacent to the building foundation) has been estimated using a relationship similar to the tunnelling equipment. Equipment other than rockbreakers has been using the formula from the FTA Guideline:

$$PPV_{Receiver} = PPV_{Ref} \times \left(\frac{d_{ref}}{d}\right)^{1.5}$$

Where $PPV_{Receiver}$ = peak particle velocity at the receiver in mm/s
$PPV_{Equipment\ Ref}$ = peak particle velocity of the source, measured at the reference distance (7.6 m)
d_{ref} = reference distance for the vibration source (7.6 m)
d = horizontal distance from the source to the receiver (m)

The vibration attenuation models are presented graphically in Figure 4-5.

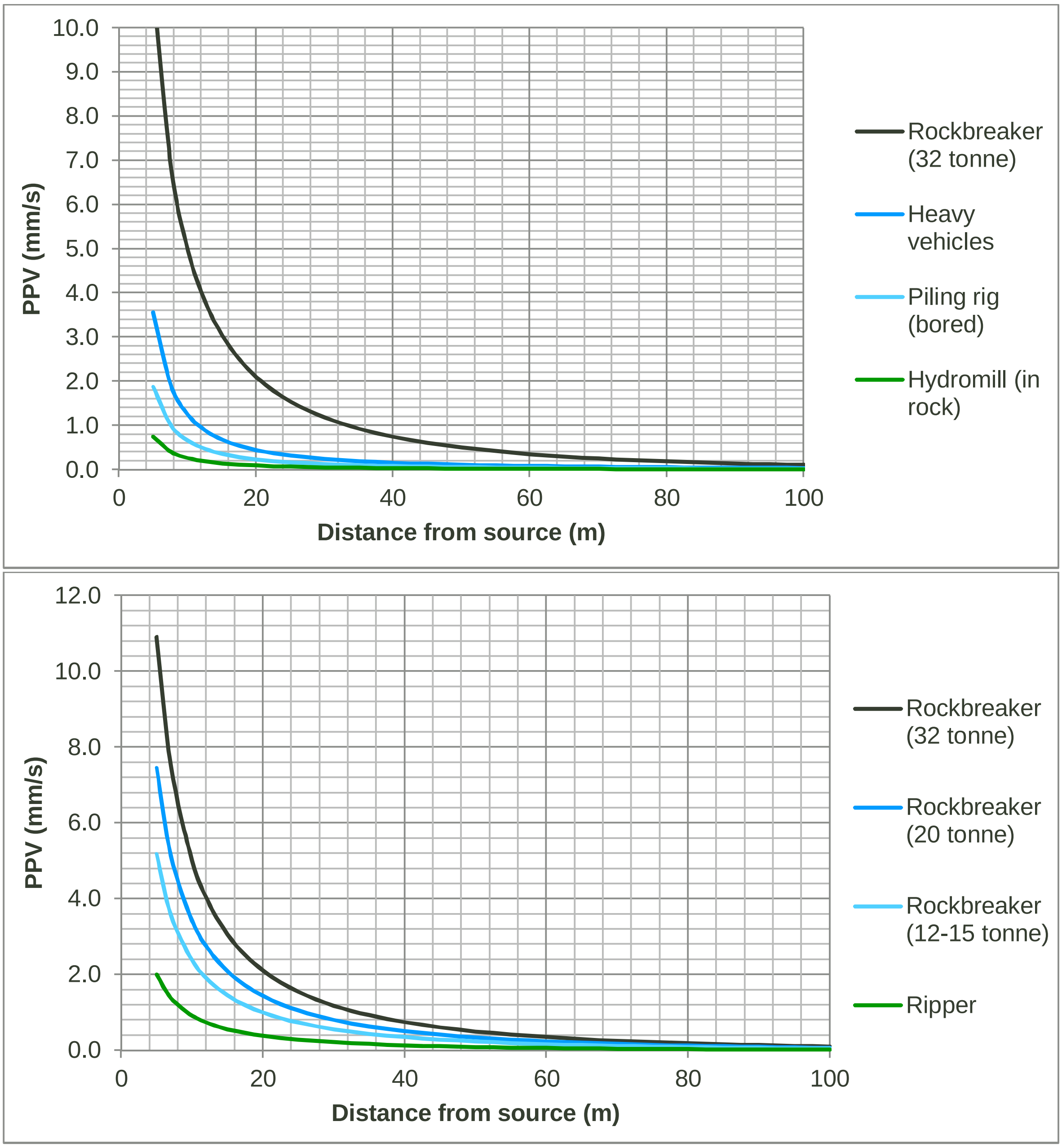


Figure 4-5: Vibration attenuation models for equipment associated with Additional Construction Works

The assumed depths of to undertake vibration measurements to confirm that the Guideline Targets would be met when vibration construction equipment is less than 5 m from the nearest building.

Table 4-9: Rockbreaker sizes, assumed geology and depths of operation

Precinct	Assumed geology	Rockbreaker excavator size (tonnes)	Depth (m)
Western Portal	Older Volcanics	12	-
Arden	Coode Island Silt	Not required	-
Parkville	Melbourne Formation (MF4-3)	20	>25
CBD North (Franklin Street excavation)	Melbourne Formation (MF2)	20	10 – 25
CBD North (A'Beckett and southern entrance excavations)	Melbourne Formation (MF2)	20	15 – 25
	Melbourne Formation (MF1)	32	>25
CBD South (City Square and Flinders/Swanston Street excavations)	Melbourne Formation (MF2)	20	>20
CBD South (Federation Square excavation)	Melbourne Formation (MF4-2)	12	>15
Fawkner Park	Melbourne Formation (HW)	Not required	0 – 20
	Melbourne Formation (MW)	20	> 20
Domain	Brighton Group	Not required	0 – 10
	Melbourne Formation (HW)	20	> 10
Eastern portal	Brighton Group	Not required	0 – 10
	Melbourne Formation (HW)	7	> 10

Model

The modelling and assessment methodology described in the FTA Guideline, with modifications to allow for the use of point sources typical for the TBM cutting face, roadheaders, piling equipment etc. The FTA Guideline approaches have been used to create a model for the entire alignment. The overall modelling process has been summarized in the flowchart shown above in Figure 4-3.

Predictions

Vibration levels have been predicted at each sensitive receiver based on relevant vibration source spectra and vibration propagation functions and adjusted for building coupling loss factors and vibration amplification due to floor resonances.

Building Damage

At each receiver, the overall Peak Particle Vibration (PPV) has been calculated for comparison with the Guideline Targets for structural damage.

Human Comfort

The Vibration Dose Value (VDV) is dependent on three key parameters:

- Level of vibration
- Spectral content of the vibration
- Duration of operation

VDVs for the TBM have been based on continuous operation and VDVs for the roadheader have been based on 60% operation. The VDV for tunnelling works has been calculated based on the methodology presented in BS6472-1:2008 using weighting Wb (the weighting for vertical motion) and the predictions compared to the human comfort Guideline Target trigger for Management Action.

Where spectral data for the Additional Construction Equipment is not known, the VDV was predicted using the following formula:

$$VDV = 1.4 \times V_{RMS\ Receiver} \times \left(\frac{2 \times \pi \times 31.5 \times 0.49}{1000}\right) \times t^{0.25}$$

Where $V_{RMS\ Receiver}$ = RMS vibration level at the receiver location in mm/s and ‘t’ is the duration of operation in seconds.

This was calculated from the PPV vibration using a crest factor of four (consistent with the crest factor used in the FTA guideline). The calculation also included coupling loss factors for the building and amplifications due to building resonance.

This equation assumes that the dominant vibration is at 31.5 Hz (where the BS6472 Wb frequency weighting is 0.49). It is noted that this calculation can lead to conservative VDV estimates.

Sensitive Equipment, Bio-resources and Highly Sensitive Areas

For vibration-sensitive equipment and Bio-resources, the receiver vibration frequency spectrum has been assessed and compared with the relevant VC curve from ASHRAE (and baseline measurements where applicable).

The assessment of impact of tunnelling on Vibration-sensitive equipment, Bio-resources and Highly Sensitive Spaces and Bio-resources is addressed in the relevant precincts.

Ground-borne Noise

Tunnelling

For the tunnelling works, the ground-borne noise model is based on the method outlined above for vibration prediction, with the addition of a conversion factor between maximum floor vibration level and maximum interior sound pressure level using the method described in the publication – Measurement and assessment of ground-borne noise and vibration (Association of Noise Consultants 2012).

TBM and road header vibration is considered to be continuous in nature, but is not necessarily sinusoidal. A factor of 2.5 has been used for the conversion of peak to RMS vibration levels for the road header, while a factor of 1.4 has been used in the case of the TBM. These factors are considered conservative and therefore likely to produce conservative RMS values as well as conservative results for ground-borne noise.

The calculated 1/3 octave band interior sound pressure levels have been A-weighted, logarithmically summed and converted to overall noise levels for comparison with the Guideline Targets for the different occupancy types.

Additional Construction Works

A simplification of this method has been used to predict ground-borne noise for the Additional Construction Works (where estimates of the vibration spectra were not available). The formula used to compute ground-borne noise is (FTA Guideline, Table 10.1):

$$L_{Aeq\ 15min} = 20 \times LOG_{10}\left(\frac{L_V}{2.54^{-5}}\right) - 35$$

Where $L_{Aeq\ 15min}$ = the equivalent noise level over a 15 minute period in dB

L_V = the RMS vibration level in the occupied area (mm/s). The RMS vibration level was calculated from the PPV using a crest factor of 4 (FTA guideline).

Note: This $L_{Aeq,15min}$ calculation assumes that that equipment (including heavy vehicle traffic) operates continually. It is expected that actual $L_{Aeq,15min}$ values would be lower at construction work sites where equipment operates intermittently.

4.7.3 Controlled Blasting

Controlled blasting has been considered at the Parkville Station Precinct (associated with excavating the station box) in order to reduce the overall duration and severity of vibration and ground-borne noise impacts. The methodology associated with blasting is provided in Section 10.5.1.4.

4.8 Methodologies for the Assessment of Operational Noise and Vibration

4.8.1 Operational Airborne Noise from Trains

Approach

Airborne noise from trains has been assessed in compliance with the PRINP at locations where there are changes to the existing rail infrastructure. This includes:

- Precinct 2: Western Portal
- Precinct 8: Eastern Portal
- Precinct 9: Western Turnback.

When the trains are in tunnels they would be underground and airborne noise is not expected.

The following approach has been adopted to assess airborne noise from trains:

- Train source noise measurements have been conducted
- Noise measurements at sensitive receivers in the vicinity of the portals have been conducted
- An acoustic model for the existing operational railway in the vicinity of the portals has been created
- The acoustic model has been updated to include the infrastructure associated with Melbourne Metro including portals
- Train noise levels have been predicted for the following scenarios:
- Existing noise levels (at the western and eastern portal locations – this information was used to verify the acoustic model by comparison with measured baseline noise levels)
- Future base-case noise levels, Year 2026 (the base-case is defined as the day before the proposed opening of Melbourne Metro assuming Melbourne Metro does not proceed)
- Future noise levels 10-years after opening of Melbourne Metro, Year 2036 (assuming Melbourne Metro does proceed)

- Where the Investigation Thresholds, as defined in the PRINP, are predicted to be exceeded options for avoiding, minimising and mitigating rail noise have been considered.

Scenarios

Airborne train noise levels have been predicted for the following scenarios:

Precinct 2: Western Portal (Kensington)

- Scenario 1: Existing noise levels
- Scenario 2: Future (2026) base-case noise levels (assuming the Melbourne Metro does not proceed)
- Scenario 3: Concept Design (2036) noise levels (assuming Melbourne Metro proceeds)
- Scenario 4: Variation option future (2036) noise levels (assuming Melbourne Metro proceeds with Variation)

Precinct 8: Eastern Portal (South Yarra)

- Scenario 1: Existing noise levels
- Scenario 2: Future (2026) base-case noise levels (assuming Melbourne Metro does not proceed)
- Scenario 3: Future (2036) noise levels (assuming Melbourne Metro does proceed)

Precinct 9: Western Turnback

- Scenario 1: Future (2026) base-case noise levels (assuming Melbourne Metro does not proceed)
- Scenario 2: Future (2036) Melbourne Metro noise levels (assuming Melbourne Metro does proceed)

For Precinct 9 existing noise levels have not been predicted as they were not required for validation of the acoustic model.

Methodology

Airborne train noise levels have been predicted at nearby noise sensitive receivers using the methodology from Nord 2000 - *New Nordic Prediction Method for Rail and Traffic Noise* (NORD2000). This methodology allows the prediction of the daytime ($L_{Aeq,16hour}$), night time ($L_{Aeq, 8hour}$) and the L_{Amax} noise levels. NORD2000 has been implemented in SoundPLAN version 7.2.

The model has been used to predict train noise levels at the nearby noise sensitive receivers and is based upon:

- Air absorption
- Atmospheric refraction
- Split height source modelling
- Ground effects
- Meteorological effects
- Screening
- Reflection
- One-third octave band source levels
- Operational timetables
- Train lengths / speed.

Source Noise Levels

Train Noise Emissions

Train noise emissions have been based on the following:

- The NSW Rail Noise Database Stage III Measurement and Analysis - January 2015 prepared by SLR for the NSW Transport Asset Authority (TfNSW database) and NORD2000 for the reference source noise levels for trains.

  In addition, reference source noise levels of all rail vehicles (EMU, DMU and freight locomotives) used have been compared with noise measurements (undertaken by Jacobs staff and those used for the Regional Rail Link from the document Regional Rail Link Guideline for Railway Noise Predictions and Assessment Section 4 – January 2016 (RRL Guideline))
- Noise levels for all speeds, as contained within the TfNSW database, have been processed in accordance with the NORD2000 methodology. This involved a regression analysis of each 1/3 octave bandwidth for all train speeds to obtain the source inputs. These levels were then compared to the train noise measurements taken of the existing Melbourne train fleet and adjustments made accordingly to match the actual train noise emissions. Freight noise levels were sourced from the RRL Guideline
- Noise source heights above rail level were defined by default in NORD2000:
  - 0.01 m (wheel / rail)
  - 0.35 m (wheel)
  - 0.7 m (engine)

  For the exhaust for the DMUs / Freight Locos, a height of 4.2 m above rail level has been used.
- Noise levels have been predicted at all residential building levels and facade reflection has been included.

EMU and DMU Rail Noise Measurements

Noise measurements were undertaken to determine the noise level emissions for Melbourne's existing rail fleet. Noise measurements were conducted for the following trains:

- Comeng
- X'Trapolis
- Siemens
- VLocity.

The purpose of the measurements was to compare the Sound Exposure Level (SEL) and the 95th percentile of the maximum noise levels from the rail bound vehicle ($L_{Amax,95\%}$) with the reference source noise levels from the TfNSW database. The reference source noise levels have then been adjusted to develop the noise emissions for each of the above trains.

Measurements were conducted in compliance with AS2377-2002 *Acoustics – Methods for the measurement of railbound vehicle noise,* with trains travelling at speeds in the order of 60 to 95 km/h. Measurement equipment was placed at a distance of 15 m from the centreline of the tracks, with microphones placed 1.5 m and 3.5 m above the rail level.

The train noise emission for the HCMTs is based upon the average measured noise levels of the two newest (and quietest) EMU train types (X'Trapolis and Siemens). Table 4-10 presents the corresponding SEL and L_{Amax} values upon which the noise sources have been based. Checks have been undertaken in the SoundPLAN noise model to ensure these values have been achieved for each train type.

Table 4-10: Noise Levels at 80 km/h, 15 m distance

Train set	SEL dB(A)	L_{Amax} dB(A)
Comeng	88	82
X'trapolis	87	82
Siemens	85	79
HCMT	86	81
VLocity	89	87
Freight (Locomotive)	98	96

Notes:

1. Freight noise levels were sourced from RRL Guideline
2. As passenger wagons are always hauled by an accompanying locomotive, the maximum noise level is determined by the locomotive

Rail Bridge Noise

The bridges along the rail alignment, in the vicinity of the Western Portal, have been modelled as ballasted concrete bridge structures. The following correction has been applied for the appropriate span length:

- Concrete with Ballast, +0 dB (Reference: TfNSW database, Table 19: Bridge Noise Level Correction Factors)

Curve Noise

Tight radius curves along rail tracks can result in noise from flanging and / or wheel squeal. This can occur on tracks with a curve radius of less than 500 m. There are areas near to the eastern portal where it has not been possible to achieve radii of 500 m or greater. The following overall corrections have been applied to these curved sections of track:

- 8 dB to the source noise levels for curve radii less than 300 m
- 3 dB to the source noise levels for curve radii between 300 and 500 m.

Reference: TfNSW database, Section 6.9: Curve Noise

Flanging or wheel squeal are typically controlled using gauge face lubrication or top-of-rail friction modifiers supplied from trackside applicators.

Track Joint, Switch and Crossing Noise

Switches and crossings built into rail tracks can result in noise from interaction with the wheel and the rail head joints. Noise from this effect can increase with severity depending on the complexity of the joint (i.e. diamond crossings). For Melbourne Metro, there are sections of track that include turnout crossings at the western and eastern portals and also at the western turnback.

The following overall noise corrections have been applied to these sections of track:

- 6 dB addition to the source noise levels for turnout crossings.

Reference: Nord 2000, Section 2.3.4 'Corrections for track conditions'

Train Timetables

The type and number of rail vehicles assumed to be travelling in the rail corridor are provided in Appendix C of this report. This information has been supplied by MMRA and is based on the Concept of Operations (the COO) developed by the PTV and current PTV Timetables.

Assumptions

The following assumptions apply for Melbourne Metro:

- Level crossing bells and train horns have not been modelled as they are safety features
- Continuously welded track is assumed unless there are known joints, switches or crosses.

Meteorology

Meteorological conditions were modelled under the following conditions:

- Relative Humidity: 70 per cent
- Temperature: 15 degrees Celsius
- Air Pressure: 1013 mbar
- Wind Speed: 1 ms^{-1}
- Wind Direction: Receiver directly downwind

These meteorological conditions are conducive to the propagation of noise, and as such represent a reasonable worst-case prediction of the propagation of rail noise.

Verification

Noise levels have been predicted based on the existing train timetable. The levels predicted have been compared with noise monitoring at strategically selected properties (e.g. those that have an unobscured view of the railway and are not impacted significantly by noise sources other than the railway).

For the western portal, 3 Childers Street in Kensington was selected. At this location, the rail noise levels were predicted to be less than 2 dB lower than the measured noise level. This is considered to be a satisfactory correlation.

For the eastern portal, 6 William Street in South Yarra was selected. At this location, the predicted rail noise levels were less than 2 dB higher than the measured noise level. This is considered to be a satisfactory correlation.

4.8.1.1 Airborne Noise from Fixed Infrastructure

Operational noise from fixed infrastructure associated with Melbourne Metro including fixed plant and equipment, ventilation systems, maintenance, stabling facilities etc, need to meet the requirements of SEPP N-1.

The SEPP N-1 assessment includes the following:

- Determination of the Effective Noise Level based upon the noise level measured in the Noise Sensitive Area (NSA) with adjustments for noise character, duration and measurement position. The NSA is defined in SEPP N-1 as the part of the land within the apparent boundaries of any piece of land which is within a distance of 10 m outside the external walls of the sensitive building (e.g. residences, hotels, hospitals)
- Determination of the Noise Limit, based on the measured background noise level and land use zoning of the area around the NSA

- A comparison between the Effective Noise Level and the Noise Limit. For compliance, the Effective Noise Level is not to exceed the Noise Limit.

The Noise Limits are determined following the methodology in Schedule B of SEPP N-1. This involves:

- Determination (by measurement) of the existing background noise level
- Determination of the Influencing Factor (based on the zoning type in a circle of 140 m and 400 m in diameter, centred on the NSA)
- Calculation of the Zoning Level, based on the Influencing Factor (for each Time Period)
- Determination of the Noise Limit based on the Zoning Level and background noise level.

In addition, the Noise Limits are dependent on the time period and SEPP N-1 defines specific time periods to be used in the assessment. The time periods as defined in SEPP N-1 are shown in Table 4-11.

Table 4-11: SEPP N-1 time periods

Time Period	Time
Day	7am - 6pm Monday to Friday 7am - 1pm Saturday
Evening	6pm - 10pm Monday to Friday 1pm - 10pm Saturday 7am - 10pm Sunday and Public Holidays
Night	10pm - 7am All Days

The Noise Limits determined using this methodology should not be less than the Base Noise Limits provided in Table 4-12. If the Noise Limit is lower than the Base Noise Limit then the Base Noise Limit becomes the Noise Limit.

Table 4-12: SEPP N-1 Base Noise Limits

Time Period	Base Noise Limit, dB(A)
Day Period	45
Evening Period	40
Night Period	35

The Noise Limits are applicable to the combined level of noise associated with all commerce industry and trade associated with Melbourne Metro and other facilities). Therefore, the noise from each facility may need to be less than the given Noise Limit.

Influencing Factor (IF)

The Influencing Factor takes into account the types of planning zone around the NSA. The Victoria EPA has designated all planning zones as Type 1, Type 2 or Type 3 (*Designation of Types of Zones and Reservations in the Metropolitan Region Planning Schemes for the Purposes of the SEPP N-1*, February 2000, EPA State Government of Victoria).

Two circles, centred on the NSA, are drawn, one with a diameter of 140 metres and one with a diameter of 400 metres. The Influencing Factor is calculated from the following formula (SEPP N-1, Schedule B2);

$$IF = \frac{1}{2}\left[\frac{area\,Type\,3 + {}^{1}/_{2}\,(area\;of\;Type\;2)}{total\;area\;of\;140\;m\;diameter\;circle}\right]140\;m\;circle + \frac{1}{2}\left[\frac{area\,Type\,3 + {}^{1}/_{2}\,(area\;of\;Type\;2)}{total\;area\;of\;400\;m\;diameter\;circle}\right]400\;m\;circle$$

Zoning Level

The Zoning Level is calculated based on the Influencing Factor for each time period as follows:

Day Period	Zoning Level = (18 x IF) + 50
Evening Period	Zoning Level = (17 x IF) + 44
Night Period	Zoning Level = (17 x IF) + 39

Noise Limit

The Noise Limit is calculated based on the Zoning Level and the measured background noise level for each time period, depending on whether the background noise level is Neutral, High or Low.

The background noise level is High if:

• Day Period	Background Noise Level + 6 > Zoning Level
• Evening or Night Period	Background Noise Level + 3 > Zoning Level

The background noise level is Neutral if:

• Day Period	Background Noise Level is between 6 dB(A) and 12 dB(A) below the Zoning Level
• Evening or Night Period	Background Noise Level is between 3 dB(A) and 9 dB(A) below the Zoning Level

The background noise level is Low if:

• Day Period	Background Noise Level + 13 < Zoning Level
• Evening or Night Period	Background Noise Level + 10 < Zoning Level

The Noise Limit is then determined, based on the type of background noise level (High, Neutral or Low), the background noise level, and the Zoning Level, as shown in Table 4-13.

Table 4-13: SEPP N-1 Noise Limits

Background Noise Level	Period	Noise Limit, dB L_{Aeq}
High	Day	Background Noise Level + 6
	Evening or Night	Background Noise Level + 3
Neutral	Day	Zoning Level
	Evening or Night	Zoning Level

Background Noise Level	Period	Noise Limit, dB L_{Aeq}
Low	Day	½(Zoning Level + Background Noise Level) + 4.5
	Evening or Night	½(Zoning Level + Background Noise Level) + 3

Noise Limits and Emergency Equipment

SEPP N-1 states that the Policy does not apply to noise from fire pumps in an emergency but states that the Noise Limit for standby generators, standby boilers and fire pumps during testing is increased by 10 dB for the Day period and 5 dB for all other periods. It is assumed that this applies to the testing of these plant items only and not to their use in emergency conditions.

This approach would also apply to the noise associated with other emergency equipment, including stair pressurization fans, smoke extract fans and similar items of equipment.

Where items of plant have been identified as being for use under emergency conditions only (and not used during normal operation) a correction of +10 dB has been applied to the calculated Noise Limits for the Day period and a correction of +5 dB has been applied to the calculated Noise Limits for the Evening and Night periods.

4.8.2 Operational Vibration and Ground-borne Noise from Trains

Approach

The following approach has been used for the assessment of operational vibration and ground-borne noise from trains:

- Models have been developed to predict vibration and ground-borne noise from the trains in tunnels.
- The models incorporate:
  - Operating speed profiles (Figure 4-6) with 50 kph speed floor applied through stations
  - Maximum train length of 10 cars (225 m) (7 cars only would operate initially)
  - Operational timetable

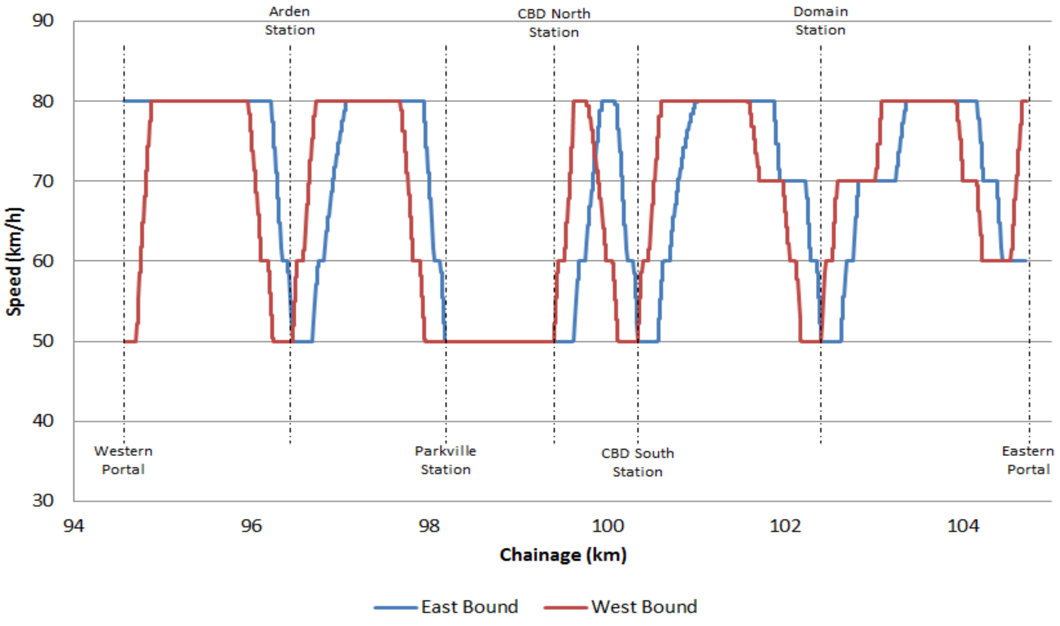
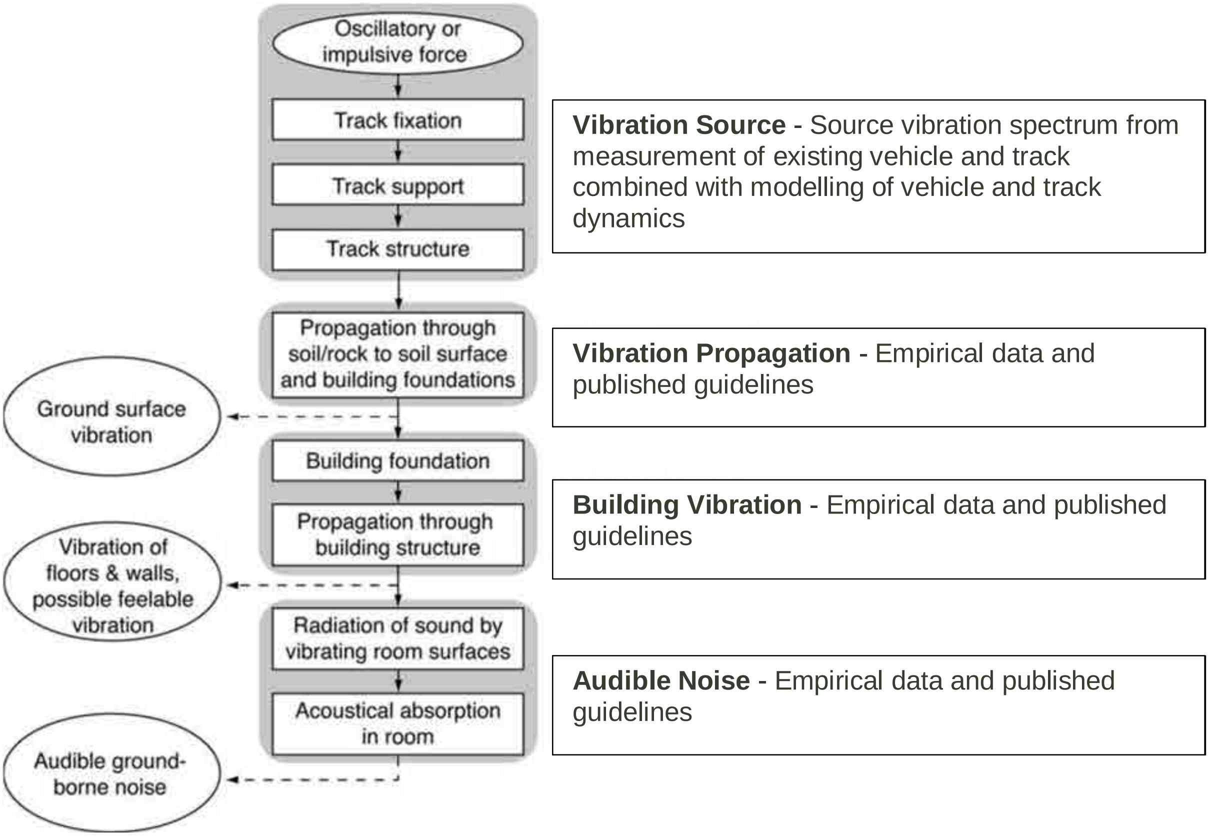


Figure 4-6 – Speed profile (with 50km/h speed floor through stations)

- The type of occupancy has been identified for each of the receivers (residential, commercial, other sensitive use)
- A sophisticated spreadsheet modelling tool was used based on the Federal Transit Administration (FTA) predictive methodology described in US Department of Transportation FTA document, Transit Noise and Vibration Impact Assessment, (FTA-VA-90-1003-06, FTA 2006) incorporating test data and data from literature to define vibration source spectra and ground propagation parameters
- Vibration source spectra (one-third octave band slow-weighted vibration levels) have been derived from measurements of rail fleet vibration data from the existing City Loop. Utilising measured data in the model in addition to generic data from literature provides a higher degree of confidence that the modelled vibration source adequately accounts for the current rail and wheel maintenance regime and the statistical variation in wheel condition that it produces. This is important as the proposed vibration and ground-borne noise criteria are statistically based
- A 5 dB tolerance was applied in the predictions to account for any differences in the key parameters for vibration and ground-borne noise between the existing and new rolling stock (axle and wheel mass and primary suspension stiffness) as well as uncertainties in geotechnical conditions and modelling tolerances. Allowances for rail quality degradation, reflected vibrations from bedrock, tight radius curves, tunnel foundation stiffness and lining thickness have also been made
- Ground vibration attenuation characteristics for the alignment have been derived from a combination of literature-based data and interpretation of geotechnical measurements at borehole locations. Measurements of vibration attenuation through the ground from the existing City Loop operation have been used for verification
- The model has been used to predict vibration and ground-borne noise levels for receivers in the vicinity of the rail alignment
- The predicted vibration and ground-borne noise levels have been compared with the proposed Guideline Targets for each occupancy type
- Where vibration and ground-borne noise levels are predicted to be higher than Guideline Targets, mitigation in the form of track-form vibration isolation has been developed to mitigate the responses
- Finite element modelling of track-form isolation schemes has been conducted as part of the input to the assessment design.

Vibration and ground-borne noise model

Operational vibration and ground-borne noise levels for the project have been predicted using the modelling and assessment methodology described in FTA 2006. Aspects of the general and detailed FTA modelling approach have been used to create a model for the entire alignment. The parameters described in ISO14837-1 Mechanical vibration - Ground-borne noise and vibration arising from rail systems -- Part 1: General guidance (ISO 2005) have been taken into consideration in the modelling, verification and validation strategies. A flow diagram describing the modelling process is shown in Figure 4-7.



Vibration Source - Source vibration spectrum from measurement of existing vehicle and track combined with modelling of vehicle and track dynamics

Vibration Propagation - Empirical data and published guidelines

Building Vibration - Empirical data and published guidelines

Audible Noise - Empirical data and published guidelines

Figure 4-7: Operational vibration and ground-borne noise modelling process (source - FTA guideline)

Source Vibration Levels

Rail operational vibration source levels and spectral characteristics were determined by measuring vibration data from X'Trapolis trains operating within the City Loop. The City Loop trackform on the City Circle Loop consists of 60 kg rails on rubber pads mounted to twin sleeper floating track slabs on rubber bearings. Vibrations were measured on the rails, track slabs, tunnel invert and wall.

The maximum one-second vibration level, LVmax, was recorded for each train passby. Average and 95th percentile LVmax vibration levels were established for the current X'Trapolis rolling stock. The train speeds at the two test sites ranged from 45 kph to 60 kph. Data were normalised to a train speed of 80 kph.

The measured invert vibration spectra were transformed into equivalent tunnel wall vibration spectra for a range of other trackforms for use in the vibration and ground-borne noise propagation model for Melbourne Metro tunnels. The insertion loss of alternative trackforms has been calculated and applied to the invert vibration spectra using a wheel-rail interaction model.

The measured / modelled data were compared with invert and wall vibration spectra obtained on previous projects and rolling stock vibration data from the FTA Guideline to define vibration source spectra for input to the vibration and ground-borne noise propagation model. Figure 4-8 shows the vibration spectra on the tunnel wall for three trackform alternatives that are used in the assessment design:

- Standard attenuation track: 28 kN/mm dynamic stiffness direct fix track or 'booted sleeper'
- High attenuation track: 8.5 kN/mm dynamic stiffness direct fix track or 'booted sleeper'
- Very high attenuation track: Floating Slab Track with 20 kN/mm per metre rail dynamic stiffness bearings and 28 kN/mm dynamic stiffness baseplates

In general, a lower dynamic stiffness for the track isolation system results in a better attenuation performance across a broader range of frequencies. The performance of the very high attenuation track also benefits from the mass of the floating track slab, which lowers the natural frequency of the track and provides attenuation beginning at a lower frequency. Other trackforms may provide equivalent performance and trackform selection during detailed design may vary from the above, being guided by refinements to the required noise and vibration performance as well as number of other parameters.

The following factors were allowed for in the model (the adjusted tangent track spectra for tunnel sections founded in moderately weathered to highly weathered Melbourne Formation, ‘MF2’) and are shown in Table 4-14:

- Degradation in rail surface condition: + 3dB at all 1/3 octave band frequencies and alignment locations
- Tight radius curves: + 3dB at all 1/3 octave band frequencies between chainages:
  - Ch 98+300 and Ch 98+915 as well as between Ch 98+970 and Ch 99+240 (300 m radius curves between Parkville and CBD North)
  - Ch 101+950 and Ch 102+215 as well as between Ch 102+725 and Ch 102+995 (400 m and 450 m radius curves between Domain and the eastern portal)
- Tunnel foundation impedance and wall thickness: various adjustments based on parametric modelling related to geotechnical conditions at each chainage and the use of a 300 mm thick tunnel lining in place of the 500 mm thick City Loop tunnel lining
- Reflected energy from stiff rock layers underlying softer residual soils, silt and sand: 0 to +3 dB adjustment depending on geotechnical conditions at each chainage.

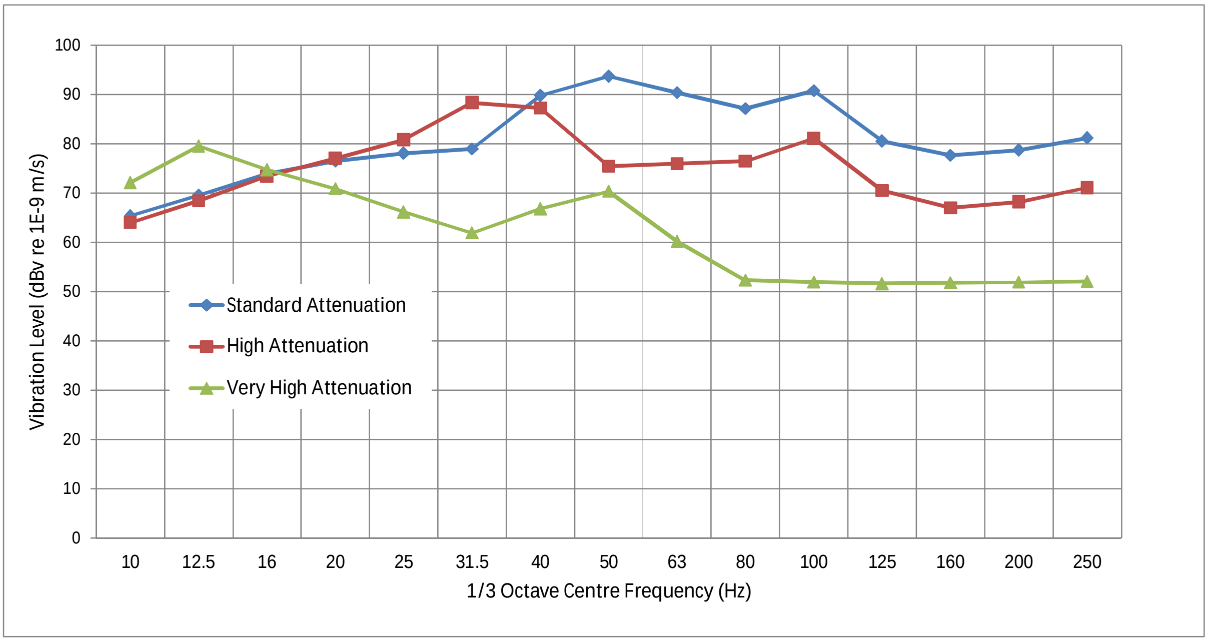


Figure 4-8: Tunnel wall vibration source spectra for standard, high and very high attenuation track forms (95th percentile train passby LVmax,slow referenced to a train speed of 80kph)

A summary of the reference vibration source spectra for the three reference design track forms is given in Table 4-14.

Table 4-14: Reference source tunnel wall vibration spectra for MRL trains (95th percentile passby $L_{Vmax,slow}$ referenced to a train speed of 80kph)

Track Type	Tunnel Wall Vibration Velocity Levels (dB re 1e-9 m/s)															
	1/3 Octave Band Frequency (Hz)															Overall Level
	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	
Standard Attenuation	65	70	74	76	78	79	90	94	90	87	91	81	78	79	81	98
High Attenuation	64	68	73	77	81	88	87	75	76	76	81	70	67	68	71	92
Very High Attenuation	72	80	75	71	66	62	67	70	60	52	52	52	52	52	52	82

A line source is used to model the vibrations from trains operating inside a tunnel or on the surface.

A $20.\log_{10}(v/v_{ref})$ vibration-speed relationship was used to predict vibration levels at speeds other than the reference speed of 80 kph for input to the propagation model.

Vibration Propagation

The transfer of vibrations from the tunnels invert into receiver buildings above the alignment involves a transmission path through the tunnel lining and surrounding soil/rock into building foundations and potentially through multiple floors before presenting as tactile vibration or structure-borne noise to be assessed at receiver sites. For the purposes of vibration and ground-borne noise predictive modelling, the vibration propagation path has been divided into path components each described in terms of frequency-dependent functions and coupling loss factors:

- Tunnel lining
- Ground attenuation (geometric spreading and damping losses)
- Building foundation
- Floor–to–floor transmission
- Amplification due to floor resonances

Coupling loss factors for building foundations, floor-to-floor vibration transmission and floor resonances were taken from The Transportation Noise Reference Book, Nelson, 1987.

Vibration propagation through the ground is a complex phenomenon, producing multiple wave types with different propagation characteristics. It is influenced by the source-receiver geometry and geotechnical properties such as the soil/rock density, modulus and damping levels. At the planning stage it is appropriate to utilise empirical relationships from the literature to enable corridor-wide vibration propagation modelling. Further detailed measurement and modelling may be undertaken at the detailed design stage of the project to validate or refine predictive modelling.

The ground attenuation has two components:

- Geometric loss due to a loss of vibration intensity with distance as the vibration wavefront spreads out
- Damping loss due to the dissipation of energy in soil and rock between the source and receiver.

The frequency-dependent ground vibration attenuation functions for use in Melbourne Metrovibration and ground-borne noise propagation model were derived from the work of Unger and Bender, 1973 and supplemented by more recent studies for weathered rock by Nishi et al, 1989 and Chandler et al, 2005.

An examination of the geotechnical reports for the alignment indicates that much of the tunnels are to be located in moderately weathered to highly weathered siltstone (Melbourne Formation), with some zones of sand/silt/gravel between the western portal and Arden, and at the Yarra River crossing, Domain and the eastern portal.

Vibration attenuation in rock due to damping mechanisms is expected to be very low, resulting in the overall ground coupling loss being dominated by geometric losses. Higher damping losses are expected to occur in weathered rock and in sand/silt/gravel soils. The range of ground vibration attenuation functions used in the vibration and ground-borne noise predictive model are given in shown in Figure 4-9.

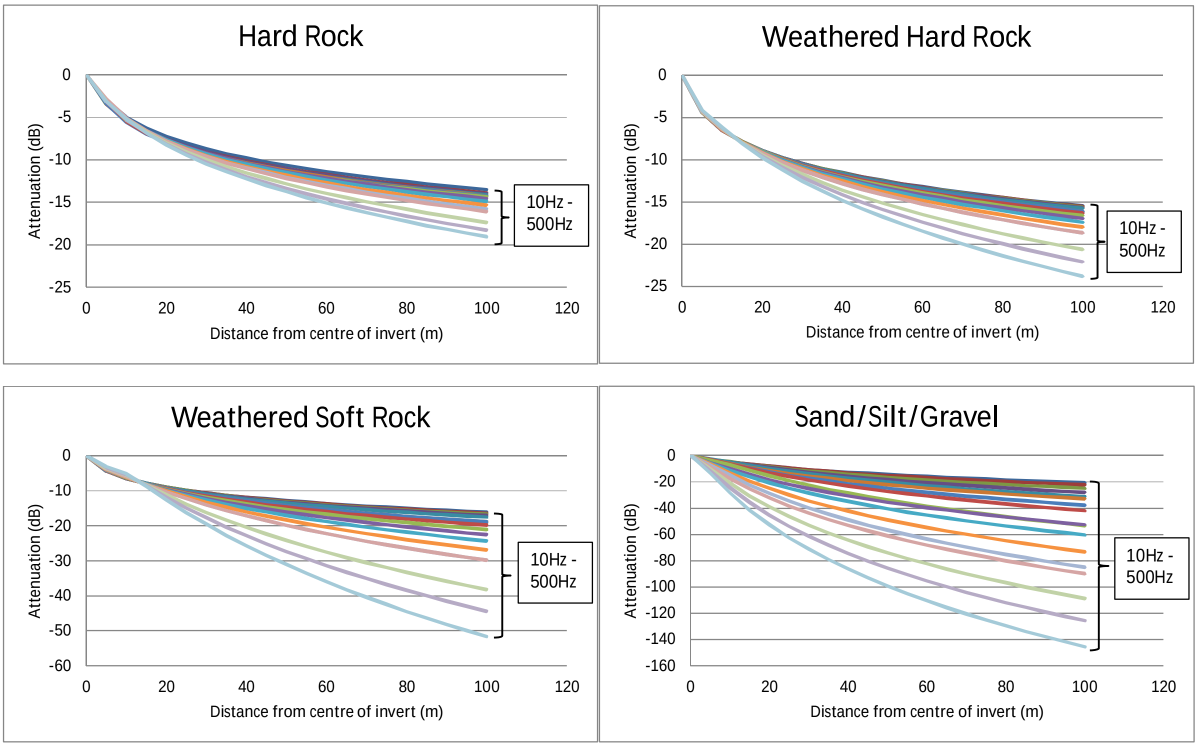


Figure 4-9: Ground vibration attenuation vs. distance from centre of invert for rail vehicles operating in tunnels

Vibration measurements taken at the tunnel invert and at the surface above the City Circle Loop were used in order to provide a means of validating the ground attenuation losses for the project. The difference between vibration levels on the tunnel invert and surface was compared to the expected difference based on the propagation functions using the literature shown in Figure 4-9.

Figure 4-10 presents the average vibration spectra measured at the City Loop invert and at the surface compared with the surface vibration spectrum predicted using the propagation function for 'hard weathered rock' in the vibration propagation model.

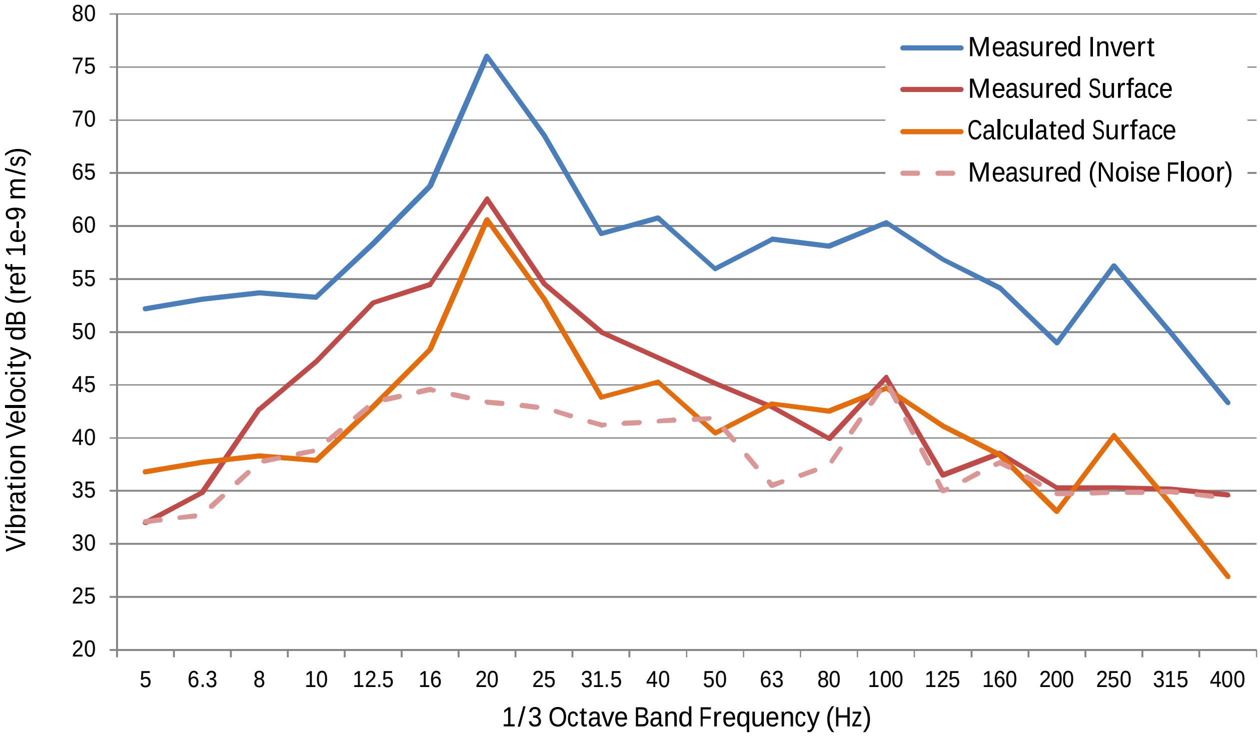


Figure 4-10: Average vibration spectrum at the tunnel invert and surface at Ch 5039 (State Library), ref speed 50km/h

Figure 4-10 shows that there is a reasonable correlation between the test and model data at the low to mid frequencies at which measured data is valid.

Vibration Prediction

Predicted levels of vibration for each vibration-sensitive receiver were based on the vibration source spectra and ground vibration attenuation functions as presented above and adjusted for:

- Vehicle speed
- Building coupling loss factors – see Table 4-15
- Floor resonance factors – see Figure 4-11
- Distance of each receiver to the track centreline
- Other adjustments as noted.

For each receiver point in the model a maximum vibration level (L_{Vmax}) and Vibration Dose Value (VDV) were calculated for comparison with Guideline Targets for sensitive equipment/highly sensitive areas and for human comfort respectively.

Table 4-15: Building coupling loss factors used in vibration prediction (Source: FTA Transit Noise and Vibration Impact Assessment Figure 11-5)

Building Type	Building Coupling Loss Factor (dB re 1e-9 m/s) 1/3 Octave Band Frequency (Hz)															
	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250
Single Level Residential	0	2	3	4	5	5	5	5	5	5	5	5	4	4	4	3
1-2 Story Residential	2	5	6	7	8	8	8	9	8	8	8	8	7	7	6	5
2-4 Story Masonry	3	7	9	10	11	12	12	12	12	12	12	12	11	10	9	8

Notes:

1. For buildings of five stories or more that may be founded in bedrock (including all buildings between CBD North and CBD South) zero coupling loss was assumed.

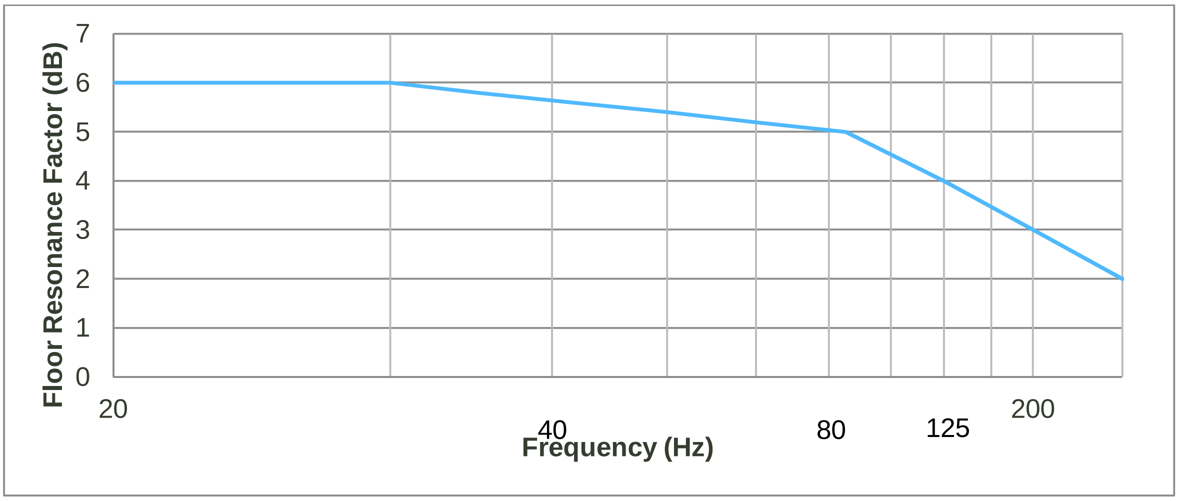


Figure 4-11: Floor resonance amplification factors

The L_{Vmax} vibration levels were used in the prediction of ground-borne noise as described below.

Ground-borne Noise Prediction

The ground-borne noise model was based on the method outlined above for receiver vibration prediction with the addition of a conversion factor between maximum floor vibration level and maximum interior sound pressure level using the method described in the ANC publication – Measurement and assessment of ground-borne noise and vibration (Association of Noise Consultants 2012). The calculated 1/3 octave band interior sound pressure levels were then 'A'-weighted and logarithmically summed and converted to overall L_{ASmax} noise levels for comparison with ground-borne noise guideline targets for the different occupancy types.

Assumptions

- The existing ground-borne noise and vibration levels for receivers at the portals have not been accounted for in the assessment. The need for ground-borne noise attenuation is only triggered if levels due to the project exceed the existing levels by the margins defined in the criteria for the project. A further assessment taking existing ground-borne noise levels into consideration during detailed design may be used to optimise the trackform selection at the portals.

- The 'Unmitigated' case for vibration and ground-borne noise prediction was taken to be standard attenuation track as per Table 4-14.
- The 'mitigated' case for vibration and ground-borne noise uses a mix of the three trackforms from Table 4-14. Further optimisation of the trackforms may be undertaken at detailed design stage based on more detailed vibration and ground-borne noise modelling.
- The ground-borne noise and vibration propagation model contains approximately 3000 receivers, which have been individually assessed against ground-borne noise and vibration criteria according to their occupancy type, building type and distance from the alignment. MMRA may be required to include additional receivers in their assessment and to verify building and occupancy types in order to verify compliance.
- No allowance has been made for future land development or future alternative land usage except as noted.

4.9 Mitigation Approach

4.9.1 Construction

EPA 1254 requires that the following work measures apply:

- Use the lowest noise work practices and equipment to meet the requirements of the job
- Site buildings, access roads and plant should be positioned such that the minimum disturbance occurs to the locality. Barriers such as hoardings or temporary enclosures should be used. The site should be planned to minimise the need for reversing vehicles
- All mechanical plant is to be silenced by the best practical means using current technology. Mechanical plant, including noise suppression devices should be maintained to the manufacturer's specifications. Internal combustion engines are to be fitted with a suitable muffler in good repair
- Fit all pneumatic tools operated near a residential area with an effective silencer on their air exhaust port
- Install less noisy movement / reversing working systems for equipment and vehicles that would operate for extended periods, during sensitive times or in close proximity to sensitive sites. Occupational health and safety requirements of use of working systems must be followed
- Turn off plant when not in use
- All vehicular movements to and from the site to only occur during the scheduled Normal Working Hours, unless approval has been granted by the relevant authority
- Where possible, no truck associated with work should be left standing with its engine operational in a street adjacent to a residential area
- Special assessment of vibration risks may be needed such as for pile driving or works structurally connected to sensitive premises.

The following work measures would also apply to Melbourne Metro:

- Scheduling noisy activities for less sensitive times (e.g. daytime) and providing periods of respite
- Stockpiling excavated material at work sites overnight for daytime removal
- Providing acoustic doors at tunnel entrances
- Planning daytime deliveries where possible
- Turning off equipment/ vehicles when not in use

- Use of barriers (noise barriers / stockpiles / shipping containers / site buildings) to block line of sight between construction activities and sensitive receivers
- Use of temporary enclosures
- Maintaining equipment - use of the quietest equipment available that is suitable to fulfil a task.
- Use of broad band reversing alarms and / or variable level alarms (adjust in level according to the background noise level)
- Avoid dropping materials from heights
- Use of resilient materials to avoid metal to metal contact and or damping to reduce radiated noise
- Improving sound insulation at the receiver e.g. upgrading glazing (optional)
- Appropriate work behaviour (e.g. no shouting, slamming doors, loud radios etc).

Mitigation has been identified for construction work sites which reduce the extent of airborne noise impact and includes:

- High performance acoustic construction sheds (assumed to have a weighted sound reduction index of the order of R_w 50). The acoustic construction sheds would include noise locks, attenuated openings and overlapping sliding doors (that incorporate sealing elements)
- Noise barriers (assumed to be of the order of 10 to 15 kg/m^2 contiguous with no gaps or holes).

Examples of these are shown in Figure 4-12 and Figure 4-13. MMRA may propose alternative mitigation.

Figure 4-12: Acoustic Construction Shed

Figure 4-13 Noise Barriers

Mitigation for vibration is based on alternative construction methodologies and these include:

- Minimum Buffer distances: these are the minimum distances from which major items of construction equipment can operate with respect to sensitive receivers. In some cases these apply all of the time and in other cases they apply during evening and night
- Hydraulic Splitting: rock splitting is the prying of a rock or hard material with the use of an initial drilled hole. It requires a specific tool called a hydraulic splitting cylinder that contains a plug and two feathers either side of the plug. The plug is placed within the drilled hole and the feathers then spread which creates direct side force to crack the hard material. The breaks are highly controlled with the direction of the break being manipulated with the positioning of the cylinder and its feathers. The hydraulic pump for the hydraulic splitting cylinder can be powered using air, gas or electrical means, with electrical power being the quietest of the available techniques
- Chemical Splitting or Chemical Rockbreaking: a non-explosive rock demolition technique that utilises the expansion of mortar to break down existing concrete, granite, stone or any hard material. It requires an initial entry point for the mortar to be injected (usually a slight crack or drilled hole). Once injected and set, the mortar expands, splitting the rock into several pieces. Acting within a few hours, the tensile strength of the rock would be overcome by the hardened cracking agent and the split would tend to follow the pre-drilled hole pattern
- Controlled blasting: underground blasting is proposed as an option for the station excavation at Parkville to minimise the length of time of vibration impact. Typically the impact would be for seconds every day or every other day
- Reduced construction operating hours.

4.9.2 Additional Mitigation Measures (Construction)

When reasonable and feasible mitigation measures do not achieve compliance with the construction Guideline Targets or when no limits apply then Additional Mitigation Measures may be appropriate to manage impact. There is no guidance in Victoria with respect to Additional Mitigation Measures, however guidance is provided in *Construction Noise Strategy PE-ST-157/1.0 2011* prepared by the NSW Transport Construction Authority.

The Additional Mitigation Measures include:

- Alternative accommodation (AA)
- Monitoring (M)
- Individual briefings (IB)

- Letter box drops (LB)
- Project specific respite offer (RO)
- Phone calls (PC)
- Specific notifications (SN)

The process for determination of the applicability of the Additional Mitigation Measures is:

1. Determine the period when the work is to be undertaken
2. Predict the noise/ vibration level relative to the Guideline Target
3. Identify the Additional Mitigation Measures from the relevant table.

4.9.2.1 Airborne Construction Noise

For airborne construction noise due to Unavoidable Work, the additional mitigation measures in Table 4-16 may apply.

Table 4-16: Additional Mitigation Measures for Airborne Construction Noise (Unavoidable Work)

Time Period	Mitigation Measures $L_{Aeq,15\ minutes}$, level about background noise level (L_{A90})			
	0 to 10 dB Noticeable	10 to 20 dB Clearly Audible	20 to 30 dB Moderately Intrusive	> 30 dB Highly Intrusive
6pm to 10pm **Saturday, 1pm to 10pm** **Sunday / Public Holiday - 7am to 6pm**	-	LB	M, LB	M, IB, LB, RO, PC, SN
10pm to 7am	LB	M, LB	M, IB, LB, PC, SN	AA, M, IB, LB, PC, SN

4.9.2.1 Ground-borne Construction Noise

For ground-borne construction noise the Additional Mitigation Measures in Table 4-17 may apply if the Guideline Targets are exceeded.

Table 4-17: Additional Mitigation Measures for Ground-borne Construction Noise

Time Period	Mitigation Measures Predicted $L_{Aeq,15\ minutes}$, level above Ground-borne Noise Target Level		
	0 to 10 dB Clearly Audible	10 to 20 dB Moderately Intrusive	> 20 dB Highly Intrusive
Evening, 6pm to 10pm	LB	M, LB, RO,SN	M, IB, LB, RO, PC, SN
Night, 10pm to 7am	M, LB, SN	AA, M, IB, LB, RP, PC, SN	AA, M, IB, LB, RP, PC, SN

4.9.2.2 Vibration

For construction vibration the Additional Mitigation Measures in Table 4-18 may apply if the Guideline Targets are exceeded.

Table 4-18: Additional Mitigation Measures for Construction Vibration

Time Period	Mitigation Measures Predicted Vibration Level exceeds Maximum Guideline Target Level
Day 7am to 6pm	M, LB, RP
Evening 6pm to 10pm	M, IB, LB, RO,PC, RP, SN
Night, 10pm to 7am	AA, M, IB, LB, RP, PC, SN

4.9.3 Construction Environmental Management Plan

MMRA would need to prepare a construction environmental management plan that covers noise and vibration. This plan would include:

- Details of the project and proposed construction works methodology and timeframe
- Contact details of the key staff
- Project noise and vibration limits
- Hours of operation
- Details of the affected receivers
- Details of the expected sources, impacts and mitigation measures
- Noise and vibration monitoring requirements
- Stakeholder engagement / community consultation
- Complaints handling
- Construction staff induction with respect to noise and vibration
- Details of requirements for documentation for quality assurance and for approvals.

4.9.4 Community Consultation

Effective community consultation would be essential to the management of noise and vibration impacts. This would be managed by the Stakeholder and Engagement team. The following would be employed:

- Neighbours predicted to be impacted by the project should be informed of the nature and duration of the specific works. Information should be provided a suitable amount of time prior to the impact occurring
- Potentially noise affected neighbours should be informed about the nature of construction stages and noise reduction measures. Activities should be described along with information about duration
- 24-hour contact details should be provided through letters and site signage
- A register of complaints is to be kept (which includes a description of the complaint, details of the complainant and the actions that were taken), and a complaint response procedure to be followed which provides a quick response to handling complaints.

4.9.5 Operation

Operational mitigation includes:

- Noise barriers for airborne train noise
- Building mitigation for upper levels of apartments for airborne train noise

- Low noise fans, acoustic attenuators, lined duct, plenums, acoustic barriers or screens for airborne noise from fixed infrastructure
- Track vibration attenuation for vibration and ground-borne noise.

5 Regional Context

5.1 Construction vehicles

Noise and vibration impacts associated with construction vehicles would be limited to areas near construction activities. The exception to this is the potential for an increase in traffic noise associated with construction vehicles.

The impact of construction vehicles would depend upon:

- Number of Melbourne Metro construction vehicles
- Number of other vehicles
- Proximity to sensitive locations
- Time of travel i.e. night time is more sensitive.

Significant numbers of construction vehicles associated with spoil removal and material and equipment delivery are anticipated as part of Melbourne Metro (approximately 465,000 round trips). Of the construction vehicles, approximately 155,000 return truckloads of spoil are anticipated.

Construction vehicles would use the existing road network. The project approach is for construction vehicles to utilise arterial roads as efficiently as possible to mix in with general traffic. The roads proposed for use over 24-hours are mostly ‘preferred traffic routes’ where traffic is encouraged to travel as a first priority. Where construction vehicles are using local roads they would be restricted to the Normal Working Hours (where possible).

If a resident is within the vicinity of a construction work site and is adversely impacted by noise from construction vehicles (e.g. construction vehicles are regularly passing by and creating noise levels that are clearly audible and distinguishable from other noise sources internally in a habitable room), then negotiation would need to occur directly with the resident. Building mitigation in the form of improved glazing may need to be provided if it is considered to be appropriate to reduce the noise impact. Communication with the community would be essential for managing potential disturbance.

Precinct 1: Tunnels

Construction vehicles would access the proposed Fawkner Park construction work site from Toorak Road West (an arterial road), where they would pass a number of residential locations. From Toorak Road West, they would access Punt Road or Kings Way (both arterial roads) and from these they would access freeways. The number of construction vehicle movements would be managed in accordance with the spoil disposal strategy including the use of temporary stockpile areas during the day.

The Linlithgow Avenue construction worksite is proposed to be for construction during Normal Working Hours only.

Precinct 2: Western Portal

Construction vehicles servicing the proposed Western Portal precinct construction work sites have a number of routes to access arterial roads. Most of the proposed routes include roads which are busy and carry a large numbers of heavy vehicles. The routes are mostly through industrial / commercial areas with very few sensitive receivers. It is noted that there are residential receivers on the corner of Kensington Road and Childers Street and while the construction vehicles would not be travelling directly past the residences, they would be in close proximity. It is understood that the construction vehicles servicing the proposed Western Portal would only service the site during Normal Working Hours except during a rail occupations when they would service the site over a 24-hour period.

Precinct 3: Arden Station

Construction vehicles servicing the Arden station precinct have a number of routes to access arterial roads. They would be entering and leaving the proposed Arden station construction work site over a 24-hour period. It is anticipated that the number of construction vehicles would be reduced outside of Normal Working Hours. Vehicles accessing the site outside of Normal Working Hours would be required to access and exit the site directly onto Arden Street at the north-west end of the site away from residences.

It is expected that the construction of Melbourne Metro would result in a reduction in truck movements associated with existing industries, which currently have truck movements during all hours of the day, so that the increase in Melbourne Metro construction traffic may be offset by a decrease in existing industrial traffic. This may potentially maintain the local amenity of noise generated by truck movements in the Arden station precinct and improve amenity following completion of the project.

Most of the proposed access routes are busy roads, which carry a large number of heavy vehicles. They are mostly through industrial / commercial areas with few sensitive receivers. There are residential land uses on Laurens Street near Mills Street, Queensberry Street and Boundary Road as well as on Macaulay Road, Dryburgh Street and Victoria Street. Where the construction vehicles are travelling past residential locations, there would be a risk that the residents may be disturbed, particularly during the night period when ambient noise levels are low. It is noted that Boundary Road and Macaulay Road are arterial roads and their function as defined by VicRoads is to convey heavy vehicles. Local roads would be avoided as far as practicable outside Normal Working Hours.

Precinct 4: Parkville Station

Construction vehicles servicing the Parkville station precinct are proposed to use a number of local roads in order to access arterial roads. There is a mix of health-care facilities, commercial and residential properties adjacent to these often busy local roads. There would be a risk that the residents may be disturbed, particularly during the night period when ambient noise levels are lower than during the daytime. Other sensitive receivers are patients at the health care facilities and research activities in the medical precinct of Parkville. These sensitive receivers may also be impacted by noise from construction vehicles. It should be noted, however, that the hospitals and commercial / research buildings are air-conditioned sealed buildings. This type of façade would provide a higher level of noise reduction when compared to naturally ventilated buildings.

Precinct 5: CBD North Station

Construction vehicles servicing the CBD North station precinct are proposed to use Latrobe, Victoria, A'Beckett, Franklin and / or Exhibition Streets to access the construction work site. These streets mostly have commercial buildings however, there are some sensitive receivers. As they are already heavily used roads, the impact of the construction vehicles is not expected to be significant although impact would be increased at night when ambient noise levels are lower. As it is a busy urban location, some sensitive buildings may have been designed to mitigate noise ingress.

Precinct 6: CBD South Station

Construction trucks servicing the CBD South station precinct are proposed to use Collins Street, Flinders Lane, Flinders Street, Exhibition Street and Queens Street. These streets mostly have commercial buildings however, there are some sensitive receivers. As they are already heavily used roads, the impact of the construction vehicles would not be expected to be significant during the day period, although increased at night when ambient noise levels are lower. As it is a busy urban location, some sensitive buildings may have been designed to mitigate noise ingress.

Precinct 7: Domain Station

Construction vehicles servicing the Domain station precinct are proposed to use Park Street, Albert Road, Domain Road and Birdswood Avenue before accessing an arterial road. These streets have a combination of residential and commercial buildings. The roads are heavily used so the impact of the construction vehicles is not expected to be significant during the day, although impacts are expected to be increased at night when ambient noise levels are lower. As it is a busy urban location, some of the sensitive buildings may have been designed to mitigate noise ingress.

Precinct 8: Eastern Portal

Construction vehicles servicing the proposed eastern portal would only service the site during Normal Working Hours where possible. To access the eastern portal, construction vehicles would need to pass a number of residences on Osborne Street and other local roads such as Fawkner, Arthur and William Streets. The intention is for the construction vehicles to access roads such as Toorak, Commercial and Punt Roads.

Precinct 9: Western Turnback

There would be minimal requirement for spoil removal from the western turnback and none anticipated to occur at night.

5.2 Operation

The operation of Melbourne Metro would allow for an increase in trains on the Melbourne Rail Network. The increase in noise level on the Pakenham to Sunbury rail line (outside the proposed project boundary) has been considered. The change in source noise level for the trains on various sections of the line is provided in Table 5-1. This information is based upon information provided by MMRA. A full assessment has not been undertaken. The change in source noise levels in 2036 with Melbourne Metro has been compared to 2026 without Melbourne Metro to determine any increase. If the increase is less than 3 dB in an area where there is no change to the infrastructure then the Investigation Thresholds in the Passenger Rail Infrastructure Noise Policy would not trigger further action.

Table 5-1: Change in source noise level on the Pakenham to Sunbury rail line

Section of Rail line	No of rail vehicles on Up-tracks and Down-tracks combined EMU / DMU / Freight		Change in source noise level dB(A)	Comments
	Base case (2026) without Melbourne Metro (EMU / DMU / Freight)	Operation (2036) with Melbourne Metro (EMU / DMU / Freight)		
Daytime				
Pakenham to Dandenong	176 / 52 / 2	176 / 52 / 2	0	No change
Cranbourne to Dandenong	128 / 0 / 0	128 / 0 / 0	0	No change
Dandenong to Westall	328 / 52 / 13	368 / 52 / 17	+1	Increase in volume
Westall to Caulfield	328 / 52 / 13	368 / 52 / 17	+1	Increase in volume
Caulfield to South Yarra	604 / 52 / 13	660 / 52 / 17	+1	Increase in volume
South Kensington to Footscray	660 / 266 / 2	852 / 362 / 2	+2	Change in train type from Comeng to HCMT; increase in volume

Section of Rail line	No of rail vehicles on Up-tracks and Down-tracks combined EMU / DMU / Freight		Change in source noise level dB(A)	Comments
	Base case (2026) without Melbourne Metro (EMU / DMU / Freight)	Operation (2036) with Melbourne Metro (EMU / DMU / Freight)		
Footscray to Sunshine	288 / 266 / 23	440 / 362 / 27	+2	Change in train type from Comeng to HCMT; increase in train volume
Sunshine to Albion	208 / 56 / 15	256 / 56 / 17	0	Change in train type from Comeng to HCMT; increase in volume
Albion to Watergardens	208 / 56 / 0	256 / 56 / 0	+1	Change in train type from Comeng to HCMT; increase in volume
Watergardens to Sunbury	136 / 56 / 0	136 / 56 / 0	-1	Change in train type from Comeng to HCMT
Night time				
Pakenham to Dandenong	30 / 12 / 4	36 / 12 / 4	+1	Increase in train volume
Cranbourne to Dandenong	30 / 0 / 0	36 / 0 / 0	+1	Increase in train volume
Dandenong to Westall	60 / 12 / 5	72 / 12 / 5	0	Small increase in train volume
Westall to Caulfield	60 / 12 / 5	72 / 12 / 5	0	Small increase in train volume
Caulfield to South Yarra	90 / 12 / 5	108 / 12 / 5	0	Small increase in train volume
South Kensington to Footscray	120 / 28 / 1	168 / 44 / 1	+1	Change in train type from Comeng to HCMT; increase in train volume
Footscray to Sunshine	60 / 28 / 19	96 / 44 / 19	+1	Change in train type from Comeng to HCMT; increase in train volume
Sunshine to Albion	30 / 8 / 15	36 / 8 / 15	0	Small increase in train volume; change in train type from Comeng to HCMT
Albion to Watergardens	30 / 8 / 0	36 / 8 / 0	0	Change in train type from Comeng to HCMT

Section of Rail line	No of rail vehicles on Up-tracks and Down-tracks combined EMU / DMU / Freight		Change in source noise level dB(A)	Comments
	Base case (2026) without Melbourne Metro (EMU / DMU / Freight)	Operation (2036) with Melbourne Metro (EMU / DMU / Freight)		
Watergardens to Sunbury	30 / 8 / 0	36 / 8 / 0	0	Change in train type from Comeng to HCMT

Notes:

1. EMU: Electrical Multiple Unit, DMU: Diesel Multiple Unit.
2. HCMT: High capacity metro trains (currently being procured by PTV).
3. Comeng is an EMU currently operating on the rail network.
4. The year 2036 has been used as the basis for the assessment as it is expected to be10 years following opening of Melbourne Metro.
5. If Melbourne Metro does not proceed then Comeng passenger trains would be used on the Sunbury Line.
6. If Melbourne Metro does proceed then the HCMT would be used on the Pakenham/Sunbury Line.
7. The noise level of the HCMT is based upon an average of the noise levels of the X'trapolis and Siemens passenger trains (which are quieter and newer than the Comeng trains). It is assumed the noise levels of the HCMT would be better aligned with noise performance of Melbourne's newer trains.
8. All trains are included in the rail corridor (from all lines).
9. Full details of the train numbers, speed and length are provided in Appendix C of this report.
10. Assessment is based upon EMUs 150 m long (7 car sets), DMUs 150 to 200 m, freight 800 to 1800 m long.

This simplified assessment assumes all trains operating on the same line and compares the source noise levels both without and with Melbourne Metro. The following are outcomes of this assessment:

- There would be minimal change to the L_{Amax} (less than 1 dB)
- In all cases the increase in source noise level is less than 3 dB and the Investigation Thresholds from the PRINP would not trigger further action.

Full assessments have been undertaken at the portals for Melbourne Metro and the western turnback where there are changes to infrastructure in accordance with the PRINP and noise mitigation proposed.

6 Risk Assessment

The noise and vibration risks associated with the project, based on a precinct basis, is presented in Table 6-1. The environmental risk assessment methodology is outlined in Section 4.4.

Existing performance requirements were identified to inform the assessment of initial risk ratings. These existing performance requirements are based on standard requirements that are typically incorporated into construction contracts for rail projects.

As a result of the impact assessment, project-specific performance requirements ('Environmental Performance Requirements') have been proposed to reduce impacts by their achievement and hence determine the 'Residual Risk Rating'. The Environmental Performance Requirements are outlined in the following sections of the impact assessment and collated in Table 16-1 Environmental Performance Requirements. All Environmental Performance Requirements are incorporated into the Environmental Management Framework for the project (Chapter 23).

For further details refer to the Technical Appendix B *Environmental Risk Assessment Report* of the EES which includes the full Risk Register, with existing performance requirements and Environmental Performance Requirements assigned to each risk.

Refer to the Performance Requirements for mitigation measures for each of the risks.

Table 6-1 Risk register for impact assessment

Impact Pathway		Precinct	Initial Risk			Residual Risk			Risk No.
Category	Event		C	L	Risk	C	L	Risk	
Construction									
Airborne Noise Construction of Melbourne Metro – general construction activities	Noise levels exceeding relevant criteria	All	Minor	Almost Certain	Medium	Minor	Possible	Low	NV001
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for structural damage and resulting in structural damage	1 - Tunnels 2 - Western Portal 4- Parkville Station 5 - CBD North station 6 - CBD South station 7 - Domain station 8 - Eastern Portal	Moderate	Possible	Medium	Minor	Possible	Low	NV002
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for structural damage and resulting in structural damage	3 - Arden station	Minor	Possible	Low	Negligible	Possible	Low	NV003
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for human comfort	1 - Tunnels 4 - Parkville station	Moderate	Almost Certain	High	Moderate	Likely	Medium	NV004
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for human comfort	5 - CBD North station 6 - CBD South station	Major	Almost Certain	Very High	Major	Possible	High	NV005
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for human comfort	2 - Western Portal 3 - Arden station 7 - Domain station 8 - Eastern Portal	Minor	Possible	Low	Minor	Unlikely	Low	NV006

Impact Pathway		Precinct	Initial Risk			Residual Risk			Risk No.
Category	Event		C	L	Risk	C	L	Risk	
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for vibration-sensitive equipment	1 - Tunnels 2 - Western Portal 3 - Arden station 6 - CBD South station 7 - Domain station 8 - Eastern Portal	Negligible	Rare	Very Low	Negligible	Rare	Very Low	NV007
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for vibration-sensitive equipment	4 - Parkville station	Major	Almost Certain	Very High	Moderate	Likely	Medium	NV008
Vibration Construction of Melbourne Metro - tunnelling	Vibration levels from tunnelling exceeding Guideline Targets for vibration-sensitive equipment	5 - CBD North station	Minor	Likely	Medium	Minor	Possible	Low	NV009
Ground-borne noise and vibration Construction of Melbourne Metro - tunnelling	Ground-borne noise and vibration levels from tunnelling impacting on Highly Sensitive Areas (hospital wards, operating theatres)	4 - Parkville station	Moderate	Likely	Medium	Moderate	Likely	Medium	NV010
Ground-borne noise and vibration Construction of Melbourne Metro - Addition Construction Works	Ground-borne noise and vibration levels from general construction impacting on Highly Sensitive Areas (hospital wards, operating theatres)	4 - Parkville station	Moderate	Possible	Medium	Minor	Possible	Low	NV011
Ground-borne noise and vibration Construction of Melbourne Metro – Tunnelling	Ground-borne noise and vibration levels from tunnelling impacting on Bio-resources	4 - Parkville station	Moderate	Possible	Medium	Moderate	Unlikely	Low	NV012
Ground-borne noise and vibration Construction of Melbourne Metro - Addition Construction Works	Ground-borne vibration levels from general construction impacting on Bio-resources	4 - Parkville station	Moderate	Possible	Medium	Moderate	Unlikely	Low	NV013

Impact Pathway		Precinct	Initial Risk			Residual Risk			Risk No.
Category	**Event**		**C**	**L**	**Risk**	**C**	**L**	**Risk**	
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration levels from general construction exceeding Guideline Targets for structural damage	1 - Tunnels	Moderate	Likely	Medium	Minor	Possible	Low	NV014
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration levels from general construction exceeding Guideline Targets for structural damage	2 - Western Portal 9 – Western Turnback	Moderate	Possible	Medium	Negligible	Possible	Low	NV015
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration levels from general construction exceeding Guideline Targets for structural damage	3 - Arden station 5 - CBD North station 6 - CBD South station 7 - Domain station 8 - Eastern Portal	Moderate	Likely	Medium	Minor	Possible	Low	NV016
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration levels from general construction exceeding Guideline Targets for structural damage	4 - Parkville station	Moderate	Likely	Medium	Moderate	Possible	Medium	NV017
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration from general activities exceeds Guideline Targets for human comfort.	1 - Tunnels 5 - CBD North station 6 - CBD South station	Moderate	Almost Certain	High	Minor	Likely	Medium	NV018
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration from general activities exceeds Guideline Targets for human comfort.	4 - Parkville station	Moderate	Almost Certain	High	Moderate	Possible	Medium	NV019
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration from general activities exceeds Guideline Targets for human comfort.	2 – Western Portal 7 - Domain station 8 - Eastern Portal	Moderate	Possible	Medium	Minor	Possible	Low	NV020

Impact Pathway		Precinct	Initial Risk			Residual Risk			Risk No.
Category	Event		C	L	Risk	C	L	Risk	
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration from general activities exceeds Guideline Targets for human comfort.	2 - Western Portal 3 - Arden station 9 - Western Turnback	Minor	Possible	Low	Negligible	Possible	Low	NV021
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration exceeds Guideline Targets for vibration-sensitive equipment.	1 - Tunnels 2 - Western Portal 3 - Arden station 6 - CBD South station 7 - Domain station 8 - Eastern Portal	Minor	Rare	Very Low	Minor	Rare	Very Low	NV022
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration exceeds Guideline Targets for vibration-sensitive equipment.	4 - Parkville station	Major	Almost Certain	Very High	Moderate	Almost Certain	High	NV023
Vibration Construction of Melbourne Metro - general construction activities (not including tunnelling)	Vibration exceeds Guideline Targets for vibration-sensitive equipment.	5 - CBD North station	Minor	Possible	Low	Minor	Likely	Medium	NV024
Ground-borne Noise Construction of Melbourne Metro - tunnelling	Ground-borne noise exceeds Guideline Targets.	1 - Tunnels	Moderate	Almost Certain	High	Moderate	Almost certain	High	NV025
Ground-borne Noise Construction of Melbourne Metro - tunnelling	Ground-borne noise exceeds Guideline Targets.	4 - Parkville station 5 - CBD North station 6 - CBD South station	Major	Almost Certain	Very High	Moderate	Almost certain	High	NV026
Ground-borne Noise Construction of Melbourne Metro - tunnelling	Ground-borne noise exceeds Guideline Targets.	2 - Western Portal 3 - Arden station 7 - Domain station 8 - Eastern Portal	Minor	Possible	Low	Minor	Possible	Low	NV027

Impact Pathway		Precinct	Initial Risk			Residual Risk			Risk No.
Category	Event		C	L	Risk	C	L	Risk	
Ground-borne Noise Construction of Melbourne Metro – Additional Construction Works (not including tunnelling)	Ground-borne noise exceeds Guideline Targets.	1 - Tunnels 2 - Western Portal 3 - Arden station 4 - Parkville station 5 - CBD North station 6 - CBD South station 7 - Domain station 8 - Eastern Portal	Moderate	Likely	Medium	Minor	Possible	Low	NV028
Ground-borne Noise Construction of Melbourne Metro - Additional Construction Works (not including tunnelling)	Ground-borne noise exceeds Guideline Targets.	9 - Western turnback	Minor	Unlikely	Low	Minor	Unlikely	Low	NV029
Operation									
Airborne noise - trains Operation of passenger trains causes increase in airborne noise	Exceeds criteria	1 - Tunnels 4 - Parkville station 5 - CBD North station 6 - CBD South station 7 - Domain station	Minor	Possible	Low	Minor	Unlikely	Low	NV030
Airborne noise - trains Operation of passenger trains causes increase in airborne noise	Exceeds criteria	2 - Western Portal 8 - Eastern Portal 9 - Western Turnback	Moderate	Possible	Medium	Minor	Possible	Low	NV031
Airborne noise – fixed Infrastructure Operation of fixed infrastructure causes increase in airborne noise	Exceeds criteria	1 - Tunnels 2 - Western Portal 3 - Arden station 4 - Parkville station 5 - CBD North station 6 - CBD South station 7 - Domain station 8 - Eastern Portal	Moderate	Possible	Medium	Minor	Possible	Low	NV032

Impact Pathway		Precinct	Initial Risk			Residual Risk			Risk No.
Category	Event		C	L	Risk	C	L	Risk	
Airborne noise – fixed Infrastructure Operation of fixed infrastructure causes increase in airborne noise	Exceeds criteria	9 - Western Turnback	Minor	Possible	Low	Minor	Unlikely	Low	NV033
Vibration Operation of passenger trains generates vibration	Exceeds human comfort Guideline Targets (and building damage Guideline Targets)	All	Minor	Likely	Medium	Minor	Rare	Very Low	NV034
Vibration Operation of passenger trains generates vibration	Exceeds Guideline Targets for vibration-sensitive equipment	1 - Tunnels 2 - Western Portal 3 - Arden station 6 - CBD South station 7 - Domain station 8 - Eastern Portal 9 - Western Turnback	Minor	Possible	Low	Minor	Unlikely	Low	NV035
Vibration Operation of passenger trains generates vibration	Exceeds Guideline Targets for vibration-sensitive equipment	4 - Parkville station	Major	Almost Certain	Very High	Negligible	Likely	Low	NV036
Vibration Operation of passenger trains generates vibration	Exceeds Guideline Targets for vibration-sensitive equipment	5 - CBD North station	Minor	Likely	Medium	Negligible	Likely	Low	NV037
Ground-bourne Noise Operation of passenger trains generates ground-borne noise	Exceeds Guideline Targets	1 - Tunnels 2 - Western Portal 3 - Arden station 4 - Parkville station 5 - CBD North station 6 - CBD South station 7 - Domain station 8 - Eastern Portal	Minor	Possible	Low	Minor	Unlikely	Low	NV038

7 Precinct 1: Tunnels

7.1 Project Components

The following components of the project are relevant to the noise and vibration impact assessment.

7.1.1 Infrastructure

The Concept Design infrastructure includes:

- Tunnels alignment (10 m to 40 m below existing ground level)
- Yarra River crossing by TBM under the river
- Tunnels alignment above the CityLink tunnels
- Southern TBM launch site at Domain or Domain and Fawkner Park
- Emergency access shaft combined with TBM launch site
- Emergency access shaft adjacent to Linlithgow Avenue (in Queen Victoria Gardens).

7.1.1.1 Alternative Design Options

The alternative design options are:

- Tunnels alignment below the City Link tunnels (approximately 3 m below)
- Emergency access shaft in Fawkner Park (north east section) on the basis that the TBM is launched at Domain Precinct
- Emergency access shaft adjacent to Linlithgow Avenue (in Tom's Block).

7.1.2 Locality

The Tunnels Precinct includes all tunnel areas within Melbourne Metro that are not within the station or portal precincts.

The sensitive receivers in the vicinity of Precinct 1 include:

- Residential locations above or near to the tunnels
- Residential locations in the vicinity of construction work sites (relevant during construction only)
- Community building / childcare facility in Fawkner Park (relevant during construction only)
- Christ Church Grammar School
- Christ Church
- Performing arts facilities at the Melbourne Arts Centre, Melbourne Recital Centre and MTC Theatre
- Melbourne Hebrew Congregation.

7.1.3 Construction

The relevant construction components of the Concept Design are:

- Bored tunnels (using TBMs / roadheaders)
- Spoil disposal

- The siting of a construction work site at Fawkner Park including a possible TBM launch site and other construction related activities such as material laydown, equipment storage and maintenance, site office and amenities and spoil loading facilities. There would also be a temporary above ground substation (to power the TBM). The Edmund Herring Oval in the Domain station precinct would be utilised as a laydown area to support the TBM and spoil activities.

Tunnelling operations are proposed to occur over 24-hours. When tunnelling equipment is underground, no airborne noise emissions are expected.

Specific construction activities would include:

- Fawkner Park:
  - Shaft construction, including bored piling, excavation, rockbreaking, spoil removal and concrete pouring
  - Possible TBM launch preparation
  - Possible TBM launch operations
  - Emergency access shaft
- Linlithgow Avenue emergency access shaft:
  - Shaft construction including piling, excavation, rockbreaking, spoil removal and concrete pouring.

Above ground construction activities (such as piling) are proposed to occur during Normal Working Hours. Underground shaft construction works (excavations, rockbreaking, concrete pouring and TBM launch) are proposed to occur 24-hours and seven day a week. Full details of the construction scenario activities are provided in Appendix A of this report.

7.1.3.1 Alternative Design Options

The alternative design options consist of construction of an:

- Emergency access shaft in Fawkner Park (north east section)
  - Shaft construction, including piling, excavation, rockbreaking, spoil removal and concrete pouring
- Emergency access shaft in Tom's Block on Linlithgow Avenue.

7.1.4 Operation

Operation would include:

- Trains travelling below ground in the tunnels
- Fixed plant including emergency stair pressurisation fans.

7.2 Existing Conditions

Full details of baseline noise and vibration measurements are provided in Appendix F of this report.

7.2.1 External Ambient Noise

The results of external ambient noise measurements are provided in Table 7-1. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in vicinity of proposed construction work sites or proposed fixed infrastructure sites, then the parameters provided are consistent with information needed for the EPA 1254 and SEPP N-1 assessments.

Table 7-1 External ambient noise measurements

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
68 Toorak Road, South Yarra	55	69	51	68	44	65
2/1 Park Street, South Yarra	50	64	49	63	40	58
The Melburnian, 250 St Kilda Road, Melbourne, Level 1	53	63	54	62	43	59

The area around 68 Toorak Road where the measurements were undertaken is a busy road with a high level of vehicular traffic and tram movements. The location at 2/1 Park Street is on the corner of Park Street and Toorak Road, and is also exposed to noise from traffic and trams on Toorak Road. The Melburnian is in a busy area on St Kilda Road (near to vehicle and tram movements).

7.2.1.1 External Vibration Measurements

Vibration measurements have been undertaken across the proposed alignment. The maximum external vibration levels measured are provided in Table 7-2.

Table 7-2 External vibration measurements

Location	Maximum PPV Levels (mm/s)	Comments
736-738 Queensberry Street, North Melbourne	1	Truck at 3 m
201 Abbotsford Street, North Melbourne	1.3	Tram at 15 m and trolley at 10 m
760 Queensberry Street, North Melbourne	4.2	Truck at 3 m travelling over a road imperfection
Princes Walk Vaults	0.2	
Princes Bridge / St. Kilda Road	4	Tram at 7 m travelling over rail joints
Hamer Hall	3.1	Tram at 10 m
Marquis of Linlithgow Memorial	0.3	Tram at 50 m
Victoria Barracks	0.6	Tram at 15 m
340 St. Kilda Road, Melbourne	0.7	Tram at 20 m
Melbourne Hebrew Congregation, South Yarra	1	Truck at 3 m
68 Toorak Road, South Yarra	1.7	Tram at 5 m
723 Punt Road, South Yarra	3.2	Tram at 5 m
162 Toorak Road, South Yarra	2	Tram at 5 m

7.2.1.2 Underwater Noise Measurements

The range of underwater noise levels measured in the Yarra River is provided in Table 7-3. Details are provided in Appendix F of this report.

Table 7-3 Underwater noise levels in the Yarra River

Location	Acoustic parameters				
	dB L_{Z90}	dB L_{Z50}	dB L_{Zeq}	dB L_{ZFMax}	dB L_{ZE}
Off the western side (downstream) of the Princes Bridge (St Kilda Road) approximately 4 metres from the northern bridge pier	132 to 137	135 to 140	139 to 143	146 to 156	159 to 168
Approximately 4 m to the south of the northern bridge pier of the Pony Island / Southbank footbridge, off a viewing platform of the bridge	126 to 137	134 to142	136 to 149	141 to 171	156 to 167

7.3 Key Issues

The key issues potentially associated with the Concept Design for Precinct 1 are identified in Table 7-4.

Table 7-4: Key issues associated with the Concept Design

Concept Design	Potential issue
Construction	
Airborne noise	• Fawkner Park construction work site: impact on sensitive receivers including residences and the community building • Emergency access shaft in Fawkner Park (northeast section): impact on sensitive receivers including Christ Church School and residences • Emergency access shaft at Linlithgow Avenue (Queen Victoria Gardens): impact on sensitive receivers including residences and arts buildings
Vibration	• Fawkner Park construction work site: impact on sensitive receivers including residences and the community building • Emergency access shaft in Fawkner Park (northeast section): impact on sensitive receivers including Christ Church School and residences • Emergency access shaft at Linlithgow Avenue (Queen Victoria Gardens): impact on sensitive receivers including residences and arts buildings • The management of potential vibration impacts from construction on the Commonwealth-heritage-listed Victoria Barracks is the subject of an Environment Protection and Biodiversity Conservation Act 1999 decision (EPBC 2015/7549), which requires that construction be carried out in a ‘particular manner’, incorporating vibration monitoring during construction in accordance with the requirements of the Australian Government Department of Environment. • The Yarra River crossing is proposed to be constructed using TBM under the river. Underwater noise levels are expected to be lower than the ambient noise levels in the river due to noise from water vehicles.

Concept Design	Potential issue
	- Impact on CityLink tunnel with respect to structural damage. The tunnels are 1 m above the CityLink tunnels. Vibration would need to be considered.
Ground-borne noise	- Fawkner Park construction work site: impact on residences including residences and the community building - Emergency access shaft in Fawkner Park (northeast section): impact on residences including residences and the community building - Emergency access shaft at Linlithgow Avenue (Queen Victoria Gardens): impact on sensitive receivers including residences and arts buildings
Operation	
Airborne noise	- Noise from fixed infrastructure such as fans must meet the requirements of SEPP N-1 at residences
Vibration	- Impact on residential amenity - The Yarra River crossing is under the river. This would reduce the extent of underwater noise in the river due to train movement. Underwater noise levels are expected to be lower than the ambient noise levels in the river due to water vehicles. - Impact on City Link tunnels with respect to structural damage.
Ground-borne noise	- Impact on residential amenity

7.3.1 Alternative Design Option

The key issues potentially associated with the alternative design options are identified in Table 7-5.

Table 7-5 Key issues associated with variations

Alternative Design Options	Potential issue
Construction	
Airborne noise	- Fawkner Park emergency access shaft: This construction work site would be separate from the existing construction work site. The emergency access shaft would be located at the north-east corner of Fawkner Park. - Tom's Block emergency access shaft: closer to residential locations (the Melburnian) than at Queen Victoria Gardens.
Vibration	- The tunnels are proposed to be 3 m below the CityLink tunnels which is greater than for the Concept Design. Vibration would still need to be considered.
Operation	
Vibration	- The tunnels are 3 m below the CityLink tunnels which is greater than for the Concept Design. Vibration would still need to be considered.

7.4 Benefits and Opportunities

The benefits and opportunities associated with the Concept Design and the alternative design options are provided in Table 7-6 and Table 7-7 respectively.

Table 7-6 Benefits and opportunities associated with the Concept Design

Concept Design	Benefits	Opportunities
Vertical Alignment	A deep alignment has been adopted at the CBD. Reduction in the extent of vibration and ground-borne noise at some locations when compared with the previously proposed shallow alignment.	-
Yarra River Crossing – TBM under the river	Reduces potential underwater noise impacts on aquatic life.	-
Fawkner Park Emergency Access Shaft	This emergency access shaft would be combined with the TBM launch site at Fawkner, which would result in impact on fewer sensitive receivers.	-

Table 7-7 Benefits and opportunities associated with alternative design options

Alternative design option	Benefits	Opportunities
Tunnels below the CityLink tunnel	Greater distance between Melbourne Metro and the CityLink tunnel, therefore vibration levels and risk of damage to the CityLink would be lower.	-

7.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria / Guideline Targets relevant to this assessment are provided in Section 2.1.

7.5.1 Construction

7.5.1.1 Airborne Noise

Airborne construction noise has the potential to impact sensitive receivers in the vicinity of the:

(i) Proposed Fawkner Park construction work site

(ii) Proposed Linlithgow Avenue emergency access shaft

(iii) Proposed Fawkner Park emergency access shaft.

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report.

For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

(i) Fawkner Park Construction Work Site

The Guideline Noise Levels for construction activity, in accordance with EPA 1254, at nearby houses on Toorak Road are provided in Table 7-8 and are based on the baseline noise levels measured at 68 Toorak Road, South Yarra.

Table 7-8 Construction Guideline Noise Levels for Fawkner Park

Time period	Applicable hours	Guideline Noise Levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday 7am to 1pm Saturday	No specified Guideline Noise Levels - noise reduction measures apply	
Weekend / Evening work	6pm to 10pm Monday to Friday 1pm to 10pm Saturday 7am to 10pm Sunday and Public Holiday	61 dB(A)	56 dB(A)
Night	10pm to 7am Monday to Sunday	55 dB(A)	
Unavoidable Works	Anytime	No specified Guideline Noise Levels - noise reduction measures apply	

The construction scenarios assessed for the Fawkner Park construction work site are:

- Scenario A - Shaft construction (Normal Working Hours)
- Scenario B - TBM launch preparation (24-hours, Unavoidable Work)
- Scenario C - TBM launch (24-hours, Unavoidable Work).

These construction scenarios are sequential and do not overlap in time.

The construction works for Scenarios B and C would be predominantly undertaken during Normal Working Hours and Guideline Noise Levels do not apply. If this work could not be completed during Normal Working Hours, it would need to continue until complete. This Unavoidable Work is anticipated to occur twice for a period of four to five weeks each. The Guideline Noise Levels do not apply Unavoidable Work .

The Domain precinct may be the preferred choice of location for TBM operations in the eastern area. In this case, TBM operations in Fawkner Park and therefore Scenarios B and C would not occur.

The predicted construction noise levels for Scenarios A, B and C are provided in figures in Appendix A.

While Guideline Noise Levels do not apply for this construction work, there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation.

Both general and specific noise mitigation are provided in Appendix A of this report. Specific noise mitigation includes:

- Noise barrier surrounding most of the construction work site up to a height of 6 m
- Acoustic construction shed over the TBM launch site.

The predicted construction noise levels with mitigation are provided in figures in Appendix A of this report for construction Scenarios A, B and C. The proposed indicative locations for construction noise mitigation are shown in Figure 7-1.

Figure 7-1: Proposed indicative construction noise mitigation

The assessment shows that the requirements of EPA 1254 can be achieved. As the barriers shown are not required to achieve Guideline Noise Levels there may be scope to optimise the barriers to take into consideration visual impact.

The construction activities at Fawkner Park are proposed to occur during Normal Working Hours or be Unavoidable Work and Guideline Noise Levels do not apply. At this location a noise barrier is proposed (around the works) up to a height of 6 m to reduce construction noise at sensitive receivers. With this mitigation the construction noise levels are predicted to be in the order of 55 dB(A) at the nearby residential locations. This is lower than the existing measured noise levels at the sensitive receivers on Toorak Road of 69 dB$L_{Aeq,day}$, 68dB $L_{Aeq,evening}$ and 65 dB$L_{Aeq,night.}$

The highest noise level predicted at the Fawkner Park Community Building is in the order of 61 dB$L_{Aeq.}$ This is on the façade of the building closest to the construction and in most areas at the façade of the building the predicted noise levels are lower. The highest predicted noise level is in the order of the measured daytime external noise level at this facility of 61 dBL_{Aeq}.

Although not proposed, if work is undertaken outside of Normal Working Hours (not including Unavoidable Work) then the Guideline Noise Levels in Table 7-8 would apply.

(ii) Linlithgow Avenue (Emergency Access Shaft)

The Guideline Noise Levels for construction activity, in accordance with EPA 1254, at the nearest residences are provided in Table 7-9 and are based on the noise levels measured at Level 1 of the Melburnian Apartments (250 St Kilda Road, Melbourne).

Table 7-9 Construction Guideline Noise Levels for Linlithgow Avenue

Time period	Applicable hours	Guideline Noise Levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday 7am to 1pm Saturday	No specified Guideline Noise Levels - noise reduction measures apply	
Weekend / Evening work	6pm to 10pm Monday to Friday 1pm to 10pm Saturday 7am to 10pm Sunday and Public Holiday	64 dB(A)	59 dB(A)
Night	10 pm to 7am Monday to Sunday	58 dB(A)	
Unavoidable Works	Anytime	No specified Guideline Noise Levels - noise reduction measures apply	

The construction scenario considered for the Linlithgow Avenue emergency access shaft was:

- Scenario A - Shaft construction (during Normal Working Hours).

The predicted construction noise levels for Scenario A are provided in the figures in Appendix A of this report.

While Guideline Noise Levels do not apply for this construction work, there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation measures.

General noise mitigation is provided in Appendix A of this report. Compliance with the requirements of EPA 1254 is predicted to be achieved.

At The Melburnian, 250 St. Kilda Road, Melbourne, in the vicinity of the Linlithgow Avenue emergency access shaft, the average daytime noise level measured was 63 $dBL_{Aeq,day}$.

The construction of the emergency access shaft at Linlithgow Avenue is proposed to be undertaken during Normal Working Hours. The construction noise level predicted at the Arts Centre is in the order of the measured noise level and the construction noise level predicted at the Melburnian is lower than the measured level (without additional mitigation).

If avoidable work were undertaken outside of Normal Working Hours, then the criteria in Table 7-9 would apply.

(iii) Fawkner Park Emergency Access Shaft

The Guideline Noise Levels for construction activity, in accordance with EPA 1254, at nearby houses on Toorak Road are provided in Table 7-8 and are based on the noise levels measured at 68 Toorak Road, South Yarra.

The construction scenario considered for the Fawkner Park emergency access shaft was:

- Scenario A Shaft construction (Normal Working Hours).

The predicted construction noise levels for Scenario A are provided in Appendix A of this report.

While Guideline Noise Levels do not apply for this construction work, there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation measures.

Details of the above, including both general and specific noise mitigation are provided in Appendix A of this report. Specific noise mitigation includes:

- A noise barrier surrounding most of the construction work site up to a height of 6 m.

The predicted construction noise levels with mitigation are provided in the figures in Appendix A of this report.

Compliance with the requirements of EPA 1254 is predicted to be achieved.

The construction activities are proposed to occur during Normal Working Hours. With a noise barrier up to a height of 6 m, construction noise levels at most residential locations in the vicinity of the Fawkner Park emergency access shaft are predicted to be less than the existing average noise level measured at 68 Toorak Road of 69 dB$L_{Aeq,day}$. At times, some residences are predicted to experience noise levels marginally higher which would be of the order of or lower that short-term noise events which regularly occur.

At the Christ Church Grammar School, noise levels of up to 50 dB(A) are predicted. This is lower than the noise level measured at the community building in Fawkner Park.

If any avoidable work were to be undertaken outside of Normal Working Hours then the Guideline Noise Levels in Table 7-8 would apply.

7.5.1.2 Vibration

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are provided in Section 4.7.2 and details of the results results of the assessment are provided in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to buildings

b) Underground infrastructure

c) Human comfort (VDV)

d) Vibration-sensitive equipment.

(i) Tunnelling

a) Damage to Buildings

Ground vibration levels are predicted to comply with the DIN 4150 Guideline Targets for all receivers due to tunnelling.

The Victoria Barracks has been identified by the Commonwealth Department of the Environment as a structurally sensitive heritage site for which specific consideration is required with respect to vibration. The management of potential vibration impacts from construction on the Commonwealth-heritage-listed Victoria Barracks is the subject of a decision on the referral of Melbourne Metro under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC 2015/7549), which requires that construction be carried out in a 'particular manner', incorporating vibration monitoring during construction in accordance with the requirements of the Commonwealth Government Department of Environment. The vibration level predicted at this site is 0.4 mm/s, which is well below the Guideline Target for this location and below the vibration level measured at the Victoria Barracks of 0.6 mm/s.

b) Underground Infrastructure

There are a significant number of utilities crossing the tunnels alignment. In general, the minimum buffer distances (slope distance) for a low risk of damage to underground infrastructure are provided in Table 7-10.

Table 7-10: Minimum Buffer Distances for underground infrastructure

Equipment	Minimum Buffer Distance (m)	
	General Utilities	Melbourne Water Unreinforced Assets
TBM	1.6	3
Roadheader	2	3.7

Note:

1. Based on a Guideline Target of 20 mm/s for general utilities
2. Based on a Guideline Target of 10 mm/s for Melbourne Water assets

The location of underground infrastructure would need to be confirmed prior to the commencement of work and compliance with any asset owner's Utility Standards.

Melbourne Metro tunnels would also be in close proximity to the CityLink tunnels. Vibration levels due to TBM within 1 m of the top of the CityLink are predicted to result in vibration levels approaching or higher than the DIN 4150 continuous Guideline Target of 10 mm/s PPV, which implies a risk of damage to the CityLink tunnels for construction of the Concept Design. This does not necessarily mean that the CityLink tunnels would be subject to damage as DIN 4150 is considered a conservative standard. The rotational speed and advance rate of the TBM would need to be reduced whilst monitoring vibration on the CityLink structure. There is also an alternative design option to this proposal which is also assessed and details are provided in Section 7.5.3.1.2.

c) Human Comfort

Tunnelling has been assessed with respect to the vibration Guideline Targets for Human Comfort, which are presented as Vibration Dose Values (VDVs). The results of this assessment are provided in Appendix B of this report.

Along the tunnels alignment in Precinct 1, vibration levels are predicted to trigger Management Actions during the day and night at a number of receiver locations above and near to the tunnels alignment. These locations are shown in Appendix B of this report. The minimum buffer distances within which Management Actions are predicted to be triggered based on a 'low probability of adverse comment' are provided in Table 7-11.

Table 7-11: Minimum Buffer Distances for VDV levels to trigger Management Actions based on a 'low probability of adverse comment'

Equipment	Minimum Buffer Distance (m)	
	Day	Night
TBM	25-45	40-55
Roadheader	35-45	40-60

Management Actions when triggered for the TBM / roadheader include community consultation with the potentially affected receivers. Potential respite / relocation would need to be discussed with affected residents as a potential mitigation of the impact.

Any change to the operating parameters of the TBM / roadheader that have the potential to reduce vibration (such as reducing the work-rate), would increase the duration of the impacts and significantly add to the project program and cost. However, the extent of potential impacts is limited. As the TBM or roadheader progress along the tunnels, the distance to any sensitive receiver changes relatively quickly. As the TBM / roadheader approaches the receiver, the vibration increases to a peak and then reduces as it moves away. Analysis of the change in ground-borne noise has been conducted based on the following assumptions:

- The TBM moves along the tunnel at a rate of 11.5 m per day, with the western alignment TBM following the eastern TBM with a spacing of approximately 300 m (30 days).
- The roadheader moves along the tunnel at a rate of approximately 5 m per day for tunnelling, with roadheaders at similar positions in both east and west tunnels at the same time. The roadheader is assumed to be operational for 60 per cent of the time (both day and night).

The longest duration predicted for Management Actions in each area are provided in Table 7-12. These durations are over the entire construction period. At other locations in the area the durations which trigger Management Actions would be shorter. The results in 7-12 are based on a 'low probability of adverse comment' for the TBM tunnelling and 'adverse comment not expected' for the roadheader due to the long duration of the impact. Therefore it is very likely that there would be times when there would be no adverse comment. The times periods for a higher probability of adverse comments would be shorter.

Table 7-12: Duration for Management Actions

Location / Equipment	Receiver Type	Address	Time duration for Management Actions with respect to VDV (days)
Western Portal to Arden: TBM	Residential	None	
	Commercial	3 Lloyd Street, Kensington	3.5 (twice)
Arden to Parkville: TBM	Residential	193 Errol Street, North Melbourne	8 (twice)
	Commercial	99 Munster Terrace, North Melbourne	3.5 (twice)
Parkville to CBD North: TBM	Residential	20-24 Church Street, Carlton	9 (twice)
	Commercial	213 Grattan Street, Carlton	2 (twice)

Location / Equipment	Receiver Type	Address	Time duration for Management Actions with respect to VDV (days)
CBD North to CBD South: Roadheader	Residential	207 Swanston Street, Melbourne	32 (once)
	Commercial	119 Swanston Street, Melbourne	15 (once)
CBD South to Domain: TBM	Residential	340 St Kilda Road, Melbourne	8 (twice)
	Commercial	336 St Kilda Road, Melbourne	3.5 (twice)
Domain to Eastern Portal: TBM	Residential	51 Myrtle Street, South Yarra	9 (twice)
	Commercial	53 Myrtle Street, South Yarra	3.5 (twice)

Note:

1. The duration for which Management Actions are triggered with respect to VDV level would overlap with the duration for which Management Actions are triggered with respect to ground-borne noise.
2. The durations provided for the TBM tunnelling are based on a 'low probability of adverse comment' and therefore it is very likely that there would be times when there would be no adverse comment. The durations provided for the roadheader are based on 'adverse comment not expected' due to the long duration of the impact.
3. The time periods for a higher probability of adverse comments would be shorter than those provided.

d) Vibration-sensitive Equipment

Vibration-sensitive equipment has not been identified in the Tunnels Precinct (the impact of tunnelling on vibration-sensitive equipment is addressed in individual precincts).

(ii) Additional Construction Works

Additional Construction Works in the Tunnels precinct includes the construction of the Fawkner Park construction work site, Fawkner Park emergency access shaft and Linlithgow Avenue emergency access shaft. At these sites, the activities that are most relevant to vibration include bored piling, excavation and rockbreaking (underground works only). The highest vibration levels are predicted to occur when underground rockbreakers are removing rock from the lower levels of the excavation. Vibration modelling has assessed the potential for vibration impacts from rockbreaking works on nearby receivers. Results of the vibration assessment are as follows:

(a) Damage to buildings

Vibration levels are predicted to comply with the DIN 4150 Guideline Targets at sensitive receivers.

(b) Underground Infrastructure

Damage to underground infrastructure is not expected in the Tunnels precinct due to Additional Construction Works. MMRA would, however, need to confirm the location of utilities and ensure that compliance with criteria is achieved.

(c) Human Comfort

Compliance with vibration for human comfort is predicted in the vicinity of the Linlithgow Avenue construction work site.

Rockbreaking is proposed to be undertaken during Normal Working Hours at Fawkner Park. A 'low probability of adverse comment' during the daytime with respect to human comfort is predicted at one dwelling on Toorak Road due to a 20-tonne rockbreaker working at a depth of 20 m. MMRA would need to consult with this resident, however, as the vibration level is lower than the maximum Guideline Targets for this receiver no additional mitigation is expected to be needed.

(d) Vibration-sensitive equipment

There has been no vibration-sensitive equipment identified in the Tunnels Precinct.

7.5.1.3 Ground-borne Noise

Details of the the methodology and model used for the assessment of ground-borne noise are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

Tunnelling has been assessed with respect to the ground-borne noise Guideline Targets in Section 3.2.2.

The resultant ground-borne noise level is at the centre of the most affected habitable room of a building.

Along the tunnels alignment in Precinct 1, ground-borne noise levels are predicted to trigger Management Actions during the evening and night at a number of sensitive locations above and near to the tunnels alignment. These locations are shown in figures in Appendix B of this report.

The minimum buffer distances from the tunnelling equipment within which Management Actions are predicted to be triggered are provided in Table 7-13.

Table 7-13: Minimum Buffer distances for Ground-borne Noise Levels to trigger Management Actions based on a 'low probability of adverse comment'

Equipment	Minimum Buffer Distance (m)	
	Evening	Night
TBM	35-50	45-60
Roadheader	40-55	50-65

Management Actions when triggered for the TBM / roadheader include community consultation with the potentially affected receivers. Potential respite / relocation would need to be discussed with affected residents as a potential mitigation of the impact.

Any change to the operating parameters of the TBM / roadheader that has the potential to reduce vibration would increase the duration of the impacts and significantly add to the project program and cost. However, the extent of potential impacts is limited. As the TBM or roadheader progress along the tunnels, the distance to the sensitive receiver changes relatively quickly. As the TBM / roadheader approaches the receiver, the vibration increases to a peak and then reduces as it moves away. Analysis of the change in ground-borne noise has been conducted based on the following assumptions:

- The TBM moves along the tunnel at a rate of 11.5 m per day, with the western alignment TBM following the eastern TBM with a spacing of approximately 300 m (30 days)
- The roadheader moves along the tunnel at a rate of approximately 5 m per day for tunnelling, with roadheaders at similar positions in both east and west tunnels at the same time.

The longest time durations predicted for Management Actions are provided in Table 7-14. These durations are over the entire construction period. It should be noted that it does not necessarily follow that residents would be disturbed during these time periods. In particular, where ambient noise levels are higher they may mask construction noise.

Table 7-14: Duration for Management Actions for Ground-borne Noise

Location / Equipment	Receiver Type	Address	Duration for trigger of Management Actions
Western Portal – Arden: TBM	Residential	None	
Arden – Parkville: TBM	Residential	193 Errol Street, North Melbourne	Up to 9 days twice
Parkville – CBD North: TBM	Residential	20-24 Church Street, Carlton	Up to 10 days twice
CBD North – CBD South: Roadheader	Residential	207 Swanston Street, Melbourne	Up to 22 days once
CBD South – Domain: TBM	Residential	340 St Kilda Road, Melbourne	Up to 9 days twice
Domain – Eastern Portal: TBM	Residential	51 Myrtle Street, South Yarra	Up to 9 days twice

Notes:

1. The durations for which Management Actions are triggered with respect to ground-borne noise would overlap with the duration for which Management Actions are triggered with respect to VDV.
2. In areas where there are tram-passbys ground-borne noise may already be audible and more noticeable than construction ground-borne noise.

The potential for ground-borne noise impacts due to tunnelling also exists for performance spaces within the Arts Centre, Melbourne. These include the Hamer Hall (over 50 m from the nearest tunnel) and State Theatre (approximately 100 m from the nearest tunnel). The ground-borne noise level, based on a simplified calculation method, has been predicted to be of the order of 30 dB(A) in the Hamer Hall during tunnelling for up to 3 days occurring twice (once for each tunnel). At this level it is possible that ground-borne noise may at times be audible within the performance spaces. These ground-borne noise impacts, should they eventuate, are expected to be manageable by undertaking early consultation and coordination with Arts Centre Management. Monitoring of ground-borne noise and vibration levels post commencement of TBM activity and a more detailed assessment should be used to verify any potential impacts ahead of the TBMs passing these sites.

(ii) Additional Construction Works

Vibration intensive construction activities which can cause ground-borne noise are not proposed to be undertaken outside of Normal Working Hours at either the Linlithgow Avenue construction work site or the Fawkner Park construction work sites and therefore compliance is predicted with the ground-borne noise Guideline Targets at sensitive receivers in the vicinity of the Linlithgow or Fawkner Park construction work sites.

7.5.2 Operation

7.5.2.1 Airborne Noise

Airborne Noise from Trains

Details of the methodology and model used for the assessment of airborne noise from trains is provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

Operation would consist of trains travelling in the tunnels below ground. The two tunnels would be located 10 m to 40 m below the existing ground level. Consequently, airborne rail noise would be insignificant in the Tunnels precinct.

The emergency access shafts are within building structures and, therefore, it is not expected that they would result in operational airborne noise.

Airborne Noise from Fixed Infrastructure

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure is provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

Fixed plant in Precinct 1 is expected to consist of emergency stair pressurisation fans, which are proposed to be located in Fawkner Park and Linlithgow Avenue. The fans would be enclosed and / or located underground and the intake air louvre would effectively be a noise source to the surrounding environment.

Apart from regular testing, these fans would only operate during emergency conditions. SEPP N-1 states that the policy does not apply to equipment used in an emergency and the Noise Limit for standby testing of emergency equipment is increased by 10 dB for the Day period and 5 dB for all other periods. This approach would apply to the emergency stair pressurisation fans.

The proposed location of the intake louvre for the pressurisation fans is shown in Figure 7-2. The nearest Noise Sensitive Areas (NSAs) are the residences to the north on Toorak Road. Noise measurements have been conducted at 68 Toorak Road, which are considered representative of the background noise levels in this area. The SEPP N-1 Noise Limits for the nearest residence are provided in Table 7-15.

Figure 7-2 Approximate location of stair pressurisation fan intake louvre

Stair pressurization fans are also proposed for the Linlithgow Avenue emergency access shaft. The approximate location of this shaft and intake grille of the stair pressurization fan is shown in Figure 7-3.

The nearest NSA are the residential areas to the south. Noise measurements have been conducted at the Melburnian, 250 St Kilda Road.

Figure 7-3 Approximate location of stair pressurisation fan intake louvre

Table 7-15: SEPP N-1 Noise Limits for Precinct 1 (for testing of emergency fans)

Location	Period	Noise Limit, $dBL_{Aeq,30\ minutes}$
1 Millswyn Street, South Yarra	Day	71
	Evening	59
	Night	52
The Melburnian, 250 St Kilda Rod, Melbourne	Day	69
	Evening	62
	Night	51

The fan selections have not been made at this stage, but it is expected that the Noise Limits would be achieved with the use of one or more of the following standard mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ductwork
- Plenums
- Acoustic barriers or screens

7.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels have been compared with the Guideline Targets for each type of building / occupancy. Where the Guideline Targets have been predicted to be exceeded, mitigation has been proposed.

a) Damage to Buildings and Underground Infrastructure

Compliance with Guideline Targets for damage to buildings is predicted.

Vibration levels on the CityLink structure should be no greater than vibration levels on Melbourne Metro tunnel walls or invert and are therefore not expected to exceed allowable vibration levels for the CityLink structure.

b) Human Comfort

Without mitigation receivers in the tunnels precinct generally comply with the 'Maximum' VDV Guideline Target for human comfort, however a small number of receivers exceed the 'Preferred' VDV Guideline Target, as shown in the figures in Appendix E of this report. With mitigation in the form of track vibration isolation all receivers in the tunnels precinct are predicted to meet the 'Preferred' VDV Guideline Target. For further information regarding the track vibration isolation refer to Figure 7-4.

c) Vibration-sensitive Equipment, Highly Sensitive Areas and Bio-resources

Vibration-sensitive equipment, highly sensitive areas and bio-resources have not been identified in this precinct.

7.5.2.2.1 Ground-borne noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

The predicted ground-borne noise levels are at the centre of the most affected habitable room of a building.

The predicted ground-borne noise levels have been compared with the Guideline Targets for each type of building/occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

Without mitigation the ground-borne noise levels are predicted to exceed the Guideline Targets by up to and greater than 10 dB at a number of locations across the alignments as shown in the figures in Appendix E of this report. To mitigate this noise for the Tunnels Precinct, modelling indicates that a mix of direct fix track with 'Standard Attenuation', direct fix track with 'High Attenuation' and floating slab track with 'Very High Attenuation' properties would be required.

The indicative extent of trackforms required to comply with Guideline Targets are provided in Figure 7-4. The distribution and selection of trackforms may be adjusted during detailed design in order to optimise reliability, maintenance and cost parameters while still achieving the noise and vibration Guideline Targets.

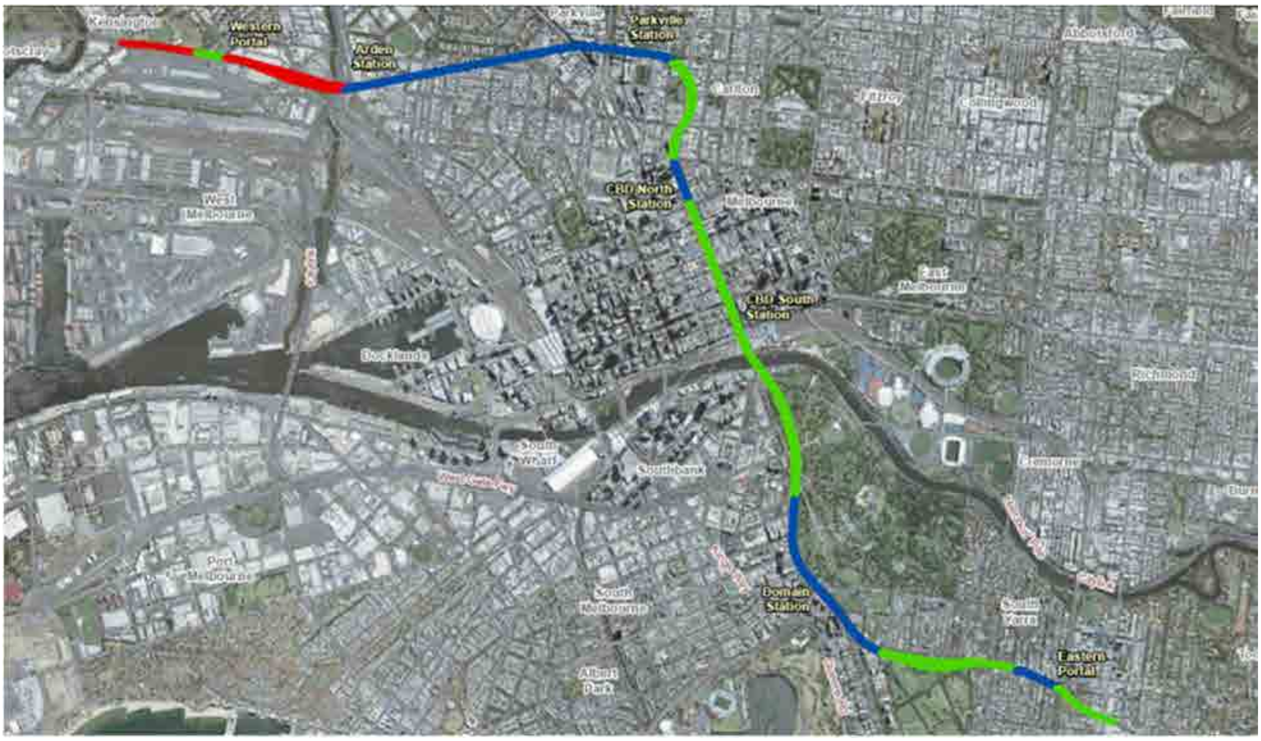


Figure 7-4 Graphical representation of the indicative extent of track form mitigations.

Red - ‘standard attenuation’, Green - ‘high attenuation’, Blue - ‘very high attenuation’

7.5.3 Alternative Design Options

7.5.3.1 Construction

7.5.3.1.1 Airborne Noise

Noise impacts associated with construction at the proposed emergency access shaft at Tom’s Block are predicted to be approximately 15 dB higher at the Melburnian than for a construction work site located at the Queen Victoria Gardens. The noise levels, however, are of the order of the ambient noise levels measured at the Melburnian. As construction would only be undertaken during Normal Working Hours, Guideline Noise Levels do not apply.

7.5.3.1.2 Vibration

No difference is predicted with respect to the Concept Design except for at the CityLink tunnel.

Vibration levels due to the Melbourne Metro tunnel boring within 3 m of the bottom of the CityLink tunnel are predicted to result in vibration levels that comply with the DIN 4150 continuous vibration limit of 10 mm/s PPV, and there should be low risk of damage to the CityLink tunnel for construction of the alternative design optiondesign. Vibration levels would still need to be monitored by MMRA.

7.5.3.1.3 Ground-borne Noise

No difference is predicted with respect to the Concept Design.

7.5.3.2 Operation

7.5.3.2.1 Airborne Noise

No difference is predicted with respect to the Concept Design.

7.5.3.2.2 Vibration

In general, no difference is predicted with respect to the Concept Design. Vibration levels on the CityLink structure, however, would be lower.

7.5.3.2.3 Ground-borne Noise

No difference is predicted with respect to the Concept Design.

7.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 7-16.

Table 7-16: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA 1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting underground infrastructure	Manage vibration in compliance with Guideline Targets in DIN 4150	To be assessed by Proponent.	-
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for tunnelling	Non-compliances for various time periods which are considered to be manageable.	Medium
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for Additional Construction Works	Compliance (a 'low probability of adverse comment at one location during the day)	Low
Ground-borne noise	Manage vibration with respect to the Guideline Targets provided for tunnelling	Non-compliances for various time periods, which are considered to be manageable.	Medium
Ground-borne noise	Manage vibration with respect to the Guideline Targets provided for Additional Construction Works	Compliance	Low
Operation			
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

7.7 Environmental Performance Requirements

Table 7-17 and Table 7-18 provide the recommended Environmental Performance Requirements for the noise and vibration for Precinct 1: Tunnels for construction and operation respectively.

Table 7-17 Environmental Performance Requirements for construction for Precinct 1: Tunnels

Asset / value	Impact	Environmental Performance requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV002, NV004, NV007, NV014, NV018, NV022, NV025, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.		NV001, NV002, NV004, NV007, NV014, NV018, NV022, NV025, NV028
Building / Structural integrity	Damage from construction vibration	For construction works conducted between CBD South station and Domain station, comply with the requirements of the Notification of Referral Decision for the Melbourne Metro Rail Project (EPBC 2015/7549, dated 22 September 2015) under the EPBC Act for vibration monitoring and measurement, as follows: • Conduct preconstruction dilapidation surveys of the nearest Commonwealth Heritage listed structures to the construction activity, including the Former Guardhouse (Block B), to record structural condition and structural integrity prior to commencement of tunnelling • Conduct vibration monitoring at the commencement of tunnelling in geological conditions that are similar to those at Victoria Barracks in order to quantify the actual tunnel boring machine vibration characteristics (level and frequency) for comparison to the values derived from the literature and the German DIN (DIN 4150) target • Conduct continuous vibration monitoring at the nearest Victoria Barracks heritage structures to the construction activity, including the Former Guardhouse (B Block), to assess the actual tunnelling vibration for acceptability, taking into account both the vibration frequency and condition of structures, until monitoring of vibration at the Former Guardhouse (B Block) shows measurements equivalent to preconstruction vibration readings at the Former Guardhouse (B Block) • If monitoring conducted according to the above demonstrates the condition of heritage structures may be degraded as a result of vibration, ground vibration must be reduced by adjusting the advance rate of the tunnel boring machine until monitoring of vibration at the Former Guardhouse (B Block) shows consistent measurements equivalent to preconstruction vibration readings at the Former Guardhouse (B Block).		

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Residential amenity</td><td>Airborne noise from Construction</td><td>Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.</td><td>– Requirements of EPA 1254
– Community consultation
– Fawkner Park: noise barrier up to a height of 6 m
– Fawkner Park Emergency Access Shaft: noise barrier up to a height of 6 m
– Construction methodology / equipment
– Prepare and implement a construction noise and vibration management plan
– Noise monitoring</td><td>NV001</td></tr>
<tr><td>Building / Structural integrity</td><td>Building damage from construction vibration</td><td>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.

<i>Short-term vibration on structures</i>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies
mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:
1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
4. Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.</td><td>– Selection of construction -equipment / construction methodology
– Bored piling
– Community consultation
– Building / Structural Condition Assessments prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded</td><td>NV002,
NV014</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td><i>Long term vibration on structures</i>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
Notes:
1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.</td><td></td><td></td></tr>
<tr><td>Underground Infrastructure</td><td>Damage to underground infrastructure</td><td>Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved.
<table>
<tr><th>Pipe Material</th><th>Vibration Velocity, mm/s (PPV)</th></tr>
<tr><td>Steel</td><td>100</td></tr>
<tr><td>Clay, concrete, reinforced concrete, prestressed concrete, metal</td><td>80</td></tr>
<tr><td>Masonry, plastic</td><td>50</td></tr>
</table>
Notes:
1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework.
2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro).
3. Compliance is to be achieved with asset owner’s Utility Standards</td><td>– Selection of methodology / equipment
– Building / Structural Condition Assessments prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Bored piling
– Minimum buffer distances</td><td></td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV (m/s$^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future noise and vibration construction management plan</td><td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite/ temporary relocation
– Selection of construction equipment / construction methodology
– Bored piling</td><td>NV004,
NV018</td></tr>
<tr><td>Residential amenity</td><td>Ground-borne noise from tunnelling</td><td>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.
<table>
<tr><th>Time Period</th><th>Internal Target, $L_{Aeq,15min}$ (dB)</th></tr>
<tr><td>Evening, 6pm to 10pm</td><td>40</td></tr>
<tr><td>Night, 10 pm to 7am</td><td>35</td></tr>
</table>
Note:
1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.</td><td>– Community consultation
– Provision of respite/ temporary relocation
– Selection of equipment / methodology</td><td>NV025,
NV028</td></tr>
</table>

Table 7-18 Environmental performance requirements for operation for Precinct 1: Tunnels

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="5">Operation</td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td></td><td>NV030, NV032, NV035, NV038</td></tr>
<tr><td>Residential amenity</td><td>Airborne noise from fixed infrastructure</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork/plenums
– Acoustic barriers / screens</td><td>NV032</td></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV (m/s$^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>– Track vibration isolation</td><td>NV034</td></tr>
</table>

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Operational ground-borne noise impacting upon amenity</td><td>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td rowspan="2">Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>
1. RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
2. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
3. Assessment location is internal near to the centre of the most affected habitable room.
4. L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
5. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.
6. The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue.</td><td>– Track vibration isolation</td><td>NV038</td></tr>
</table>

8 Precinct 2: Western Portal (Kensington)

8.1 Project Components

8.1.1 Infrastructure

The project infrastructure in Precinct 2 consists of:

- Connection to existing tracks
- Lowering the existing Sunbury line tracks
- Decline structure and tunnel entrance structure
- Relief shaft in the western corner of the 50 Lloyd Street Business Estate.

8.1.2 Locality

This precinct includes residential locations, public open space, industry and a freight terminal servicing the Port of Melbourne. The proposed portal is located predominantly within the existing rail corridor.

Noise sensitive receivers in Precinct 2 include:

- JJ Holland Park and pavilions
- Residential locations in the vicinity of the portal and construction work sites including residences on:
  - Ormond Street
  - Altona Street
  - Tennyson Street
  - Kensington Road
  - Hobsons Road.

There are no sensitive receivers south of the construction activities as this is a freight terminal. There are nine residential properties in Childers, Ormond and Tennyson Streets, in the vicinity of the rail line, that are proposed to be acquired and demolished.

8.1.3 Construction

Specific construction activities would include:

- Demolition of structures
- Relocation of utilities
- Establishment of a work site at the existing industrial site on Hobsons Road (site offices, laydown areas, materials and equipment storage)
- Piling (bored) for retaining wall along Childers Street
- Construction of the decline structure
- Cut and cover tunnel construction
- Construction of services and relief shaft
- Construction of bored tunnel entrance and TBM removal
- Track works (rail occupation)
- Spoil removal and concrete pour.

8.1.4 Operation

The operation would include:

- A portal within a current rail corridor
- Fixed plant consisting of emergency stair pressurisation fans.

8.1.5 Alternative Design Option

The western portal alternative design option has the portal located further west than the Concept Design. The TBM access shaft is proposed to be located in Childers Street immediately west of its junction with Ormond Street and the decline structure and associated widening of the railway embankment extends to Kensington Road. A widened railway bridge is required at Kensington Road. The construction work sites are in the south east corner of JJ Holland Park, Childers Street road reserve, 135-143 Ormond Street and 1–39 Hobsons Road. No construction works are located in the 50 Lloyd Street Business Estate, 1-15 Childers Street or 124-126 Tennyson Street.

8.2 Existing Conditions

External Ambient Noise

The results of external ambient noise measurements in the vicinity of the rail corridor are provided in Table 8-1 and for general areas in the vicinity of the works in Table 8-2. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in the vicinity of the rail corridor, the parameters provided are consistent with the PRINP. Where noise measurements have been undertaken in the vicinity of construction or future fixed infrastructure, then the parameters provided are consistent with information needed for the EPA 1254 and the SEPP N-1 assessment.

Table 8-1 External ambient noise measurements in the vicinity of the rail corridor

Precinct / address	$L_{Aeq,day}$, dB 6am to 10pm	$L_{Aeq,night}$, dB 10pm to 6am
148 Kensington Road, Kensington	54	46
138 Kensington Road, Kensington	68	62
3 Childers Street, Kensington (to be demolished)	69	61
1 Altona Street, Kensington	60	54

Table 8-2 External ambient noise measurements

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
148 Kensington Road, Kensington	46	53	41	49	38	45
138 Kensington Road, Kensington	54	67	50	65	45	61
3 Childers Street, Kensington	51	67	46	65	46	60
1 Altona Street, Kensington	47	59	43	57	43	53

The noise logger at 148 Kensington Road was in the backyard of the property and was well shielded from external noise sources. The noise loggers at 138 Kensington Road and 3 Childers Road, on the other hand, were located in the front-yards of the properties without shielding and were affected by both road and rail noise. At 1 Altona Street, Kensington, the noise logger had a view of both the road and rail. Altona Street is a reasonably quiet back street.

External Vibration Measurements

The maximum external vibration levels measured are provided in Table 8-3.

Table 8-3 External vibration measurements

Location	Maximum PPV levels (mm/s)	Comments
148 Kensington Road, Kensington	1.5	Truck at 15 m travelling over a road imperfection
9-15 Childers Street, Kensington	1	Comeng and Siemens trains passing at 20 m

8.3 Key Issues

The key issues potentially associated with the Concept Design are identified in Table 8-4.

Table 8-4 Key issues associated with the Concept Project

Concept Design	Potential issue
Construction	
Airborne noise	Impact on the amenity of nearby residential locations.
Vibration	Impact on the amenity of nearby residential locations.
Ground-borne noise	Impact on the amenity of nearby residential locations.
Operation	
Airborne noise	Impact on amenity at residential locations currently shielded from rail noise which would become more exposed following the demolition of properties.
Vibration	Impact on the amenity of nearby residential locations.
Ground-borne noise	Impact on the amenity of nearby residential locations.

8.4 Benefits and Opportunities

Table 8-5 provides the benefits and opportunities associated with the Concept Design compared with the current situation.

Table 8-5 Benefits and opportunities associated with the Concept Design

Concept Design	Benefits	Opportunities
Removal of cross overs and lowering of tracks	Reduction in airborne rail noise	
Trains in tunnels	Reduction in airborne rail noise	-
Noise barriers	Construction noise barriers would also reduce rail noise at sensitive receivers. Noise barriers for the reduction of rail noise would reduce the noise levels at residences eligible for mitigation. Other residential locations nearby would also benefit from these noise barriers.	Provide additional noise barriers to reduce rail noise in general at residential locations. Use permanent noise barriers for construction barriers and maintain them to reduce train noise.

8.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria / Guideline Targets relevant to this assessment are provided in Section 2.1.

8.5.1 Construction

8.5.1.1 Airborne Noise

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report. For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

The Guideline Noise Levels for construction, in accordance with EPA 1254, at the nearby residences are provided in Table 8-6 and are based on the noise levels measured at 138 Kensington Road and 1 Altona Street, Kensington.

Table 8-6 Construction Guideline Noise Levels

Time period	Applicable hours	Guideline Noise levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday 7am to 1pm Saturday	No specified Guideline Noise Level - noise reduction measures apply	
Weekend / Evening work	6pm to 10pm Monday to Friday 1pm to 10pm Saturday 7am to 10 pm Sunday and Public Holidays	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more. 138 Kensington Road: 60 dB(A) 1 Altona Street: 53 dB(A)	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more. 138 Kensington Road: 55 dB(A) 1 Altona Street: 48 dB(A)
Night	10pm to 7am Monday to Sunday	Noise to be inaudible within a habitable room of any residential premises. 138 Kensington Road: 51 dB(A)	

Time period	**Applicable hours**	**Guideline Noise levels, $L_{Aeq,15\ minutes}$**	
		Up to 18 months after project commencement	**18 months or more after project commencement**
		1 Altona Street: 43 dB(A)	
Unavoidable Works	All times	No specified Guideline Noise Level - noise reduction measures apply	

8.5.1.1.1 Concept Design

Noise levels have been predicted for the following construction scenarios:

- Scenario A: Rail Occupation - track and bridge works, excavation and spoil removal (24-hours, Unavoidable Work)
  - (i) All work except cutting of rail track (outside of Normal Working Hours)
  - (ii) Includes cutting of rail tracks (within Normal Working Hours)
- Scenario B: Decline structure and TBM removal (Unavoidable Work)
- Scenario C: Track work preparation and cut and cover (Normal Working Hours).

The predicted construction noise levels for Scenarios A, B and C are provided in figures in Appendix A of this report.

Scenario A (Unavoidable Work) is expected to consist of occupations on weekends and weekdays/nights on some occasions.

While Guideline Noise Levels do not apply for this construction work, as it is either undertaken during Normal Working Hours or is Unavoidable Work, there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation.

Both general and specific noise mitigation requirements are detailed in Appendix A of this report. Recommended specific noise mitigation includes:

- Noise barrier adjacent to the construction work site on Hobsons Road up to a height of 6 m
- Noise barrier in car park on Childers Street at western end near Kensington Road up to a height of 6 m
- Noise barrier along Childers Street between Ormond Street and Tennyson Street up to a height of 6 m.

The proposed indicative locations for construction noise mitigation are shown in Figure 8-1. As the barriers shown are not required to achieve Guideline Noise Levels there may be scope to optimise the barriers to take into consideration visual impact.

These barriers would mitigate both construction and train noise. However, they are anticipated to be temporary and for the purpose of construction noise only.

Figure 8-1 Proposed construction Noise mitigation

The predicted construction noise levels with mitigation and the indicative location of the mitigation are provided in figures in Appendix A of this report.

Compliance with the requirements of EPA 1254 is predicted to be achieved. As the barriers shown are not required to achieve the Guideline Noise Levels there may be scope to optimise the barriers to take into consideration the visual impact.

In the vicinity of the western portal, the average baseline noise levels during the day period were measured to be 67 dBL_{Aeq} at 138 Kensington Road and at 3 Childers Street and 59 dBL_{Aeq} at 1 Altona Street, Kensington. During the night period the measured noise levels were 61 dBL_{Aeq} at 138 Kensington Road, 60 dBL_{Aeq} at 3 Childers Street and 53 dBL_{Aeq} at Altona Street.

In this precinct construction work is proposed to be generally undertaken during Normal Working Hours. The only construction works proposed to be undertaken outside of Normal Working Hours are Unavoidable Works and Guideline Noise Levels do not apply.

To manage noise impact, all rail cutting work would be conducted during Normal Working Hours as it is a noise intensive activity.

With mitigation (barriers up to 6 m high), the construction noise levels in the vicinity of the sensitive receivers on Kensington Road are predicted to be lower than the measured baseline noise level during Normal Working Hours. During the night period, the construction noise levels are predicted to be in the order of the measured baseline noise level for all scenarios except for Scenario A where some residences are predicted to experience noise levels that are marginally higher.

With mitigation, the construction noise levels in the vicinity of the sensitive receivers on Childers Street are predicted to be lower than the measured baseline noise level during Normal Working Hours for all construction scenarios except for Scenario C where the noise levels are predicted to be higher than the existing noise levels by the order of 3 dB at a small number of properties. During the night period, the construction noise levels are predicted to be in the order of the measured baseline noise levels for all scenarios.

With mitigation the construction noise levels in the vicinity of the sensitive receivers on Altona Street are predicted to be in the order of the measured baseline levels during the day period. During the night period the construction noise levels in this area are predicted to be higher than the existing noise levels for all scenarios by up to 6 dB at a small number of properties. This would be similar to or less than other maximum noise levels. The model has allowed for the residences between Altona Street and the construction work site to be removed as proposed, thereby exposing these properties to construction noise (and also to noise from the railway and vehicles on Childers Street) for all scenarios.

Extensive community consultation would be required along with a construction noise (and vibration) management plan.

If avoidable work were undertaken outside of Normal Working Hours then the criteria in Table 8-6 would apply.

8.5.1.1.2 Alternative Design Option

Noise levels have been predicted for the following construction scenarios:

- Scenario A: Kensington Bridge Works
- Scenario B: Rail Occupation - decline structure, track and bridge works, excavation and spoil removal (24-hours – Unavoidable Work)
  - (i) Excludes cutting of rail tracks (outside of Normal Working Hours)
  - (ii) Includes cutting of rail tracks (within Normal Working Hours)
- Scenario C: Shaft construction (Normal Working Hours)
- Scenario D: TBM Removal (24-hours – Unavoidable Work).

The predicted construction noise levels for Scenarios A, B, C and D are provided in figures in Appendix A of this report. While Guideline Noise Levels do not apply for this construction work, as it is either being undertaken during Normal Working Hours or is Unavoidable Work, there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation.

Both general and specific noise mitigation requirements are detailed in Appendix A of this report. Recommended specific noise mitigation includes:

- Noise barrier adjacent to the construction work site on Hobsons Road up to a height of 6 m
- Noise barrier in the car park on Childers Street at the western end near Kensington Road up to a height of 6 m
- Noise barrier along Childers Street between Ormond Street and Tennyson Street up to a height of 6 m.

The proposed indicative locations for construction noise mitigation are shown in Figure 8-1.

These barriers would mitigate both construction and train noise. However, they are anticipated to be temporary and for the purpose of construction noise only.

The predicted construction noise levels with mitigation and the indicative location of the mitigation are provided in figures in Appendix A of this report.

Compliance with the requirements of EPA 1254 is predicted to be achieved.

The average baseline noise levels are described in Section 8.5.1.1.1.

In this precinct construction work is proposed to be generally undertaken during Normal Working Hours. The only construction works proposed to be undertaken outside of Normal Working Hours are Unavoidable Works and Guideline Noise Levels do not apply.

To manage noise impact, all rail cutting work would be conducted during Normal Working Hours as it is a noise intensive activity.

With mitigation (barriers up to 6 m high), the construction noise levels in the vicinity of the sensitive receivers on Kensington Road are predicted to be lower than the measured baseline noise level during Normal Working Hours. During the night period, the construction noise levels are predicted to be in the order of the measured baseline noise level for all scenarios.

With mitigation, the construction noise levels in the vicinity of the sensitive receivers on Childers Street are predicted to be lower that the measured baseline noise level during Normal Working Hours for all construction scenarios. During the night period, the construction noise levels are predicted to be in the order of the measured baseline noise levels for all scenarios.

With mitigation the construction noise levels in the vicinity of the sensitive receivers on Altona Street are predicted to be in the order of the measured baseline levels except for Scenario B, where the predicted noise levels at some residences are marginally higher than existing.

Extensive community consultation would be required along with a construction noise (and vibration) management plan that may include respite / relocation where appropriate.

If avoidable work were undertaken outside of Normal Working Hours then the criteria in Table 8-6 would apply.

8.5.1.2 Vibration

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to buildings
b) Underground utilities
c) Human comfort
d) Vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas.

(i) Tunnelling

Refer to Precinct 1: Tunnels

(ii) Additional Construction Works

Additional Construction Works in the Western Portal Precinct relevant to vibration include bored piling for the retaining wall along Childers Street, excavation works and rockbreaking works, which may be required to remove rock from lower levels of the excavation. The piling, excavation and rockbreaking are expected to occur during Normal Working Hours. The peak vibration levels are expected to occur during rockbreaking works. A model has been used to predict the vibration levels at nearby residences due to a 12 to 15-tonne rockbreaker and to assess the likely vibration impacts. Results of the vibration impact assessment are as follows:

a) Damage to Buildings

Vibration levels due to the Additional Construction Works are predicted to comply with DIN 4150 Guideline Targets for damage to buildings.

b) Underground infrastructure

There are a number of utilities, particularly clustered in the north-eastern part of the Western Portal precinct. To avoid damage, the minimum buffer distances construction work should be from utilities are:

- 3 m for general utilities
- 5.5 m for Melbourne Water unreinforced assets.

Location of the utilities is to be confirmed by MMRA prior to the commencement of work.

c) Human Comfort

Vibration levels are predicted to trigger Management Actions with respect to residences on Ormond Street and Altona Street when rockbreaking is occurring in the vicinity of these residences. Management Actions are only predicted to be required when the rockbreaker is working in a small portion of the excavation, which is close to residential receivers (at a slope distance of less than 25 m).

MMRA would need to implement the following actions in order to avoid or minimise this impact. Mitigation measures include:

- Use of lower vibration methods of rock removal when working within 25 m of residential buildings. These methods could include chemical splitting or pre-drilling and rockbreaking with a smaller sized rockbreaker
- Making initial cuts along the northern boundary of the excavation to “buffer” residents from the vibration source
- Close consultation and negotiation with residences.

Based on the rock type in the Western Portal precinct it is expected that rock would fracture easily and that vibration levels may be lower than predicted. Vibration monitoring is therefore recommended when construction commences in order to confirm the vibration levels. If the vibration levels are lower than predicted, then it would be possible to adopt smaller buffer zones i.e undertake construction work closer to the sensitive receivers.

With the above mitigation it is expected that construction works would comply with the Guideline Targets.

d) Vibration-sensitive Equipment, Bio-resources and Highly Sensitive Areas

Vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas have not been identified in the Western Portal Precinct.

8.5.1.3 Ground-borne Noise

Details of the methodology and model used for the assessment of ground-borne noise is provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

Construction activities associated with tunnelling have been assessed for ground-borne noise with respect to the ground-borne noise Guideline Targets.

Predicted ground-borne noise levels are lower than the Guideline Levels and Management Actions are not triggered.

(ii) Additional Construction Works

Vibration intensive construction activities are only proposed to be undertaken during Normal Working Hours and ground-borne noise levels due to construction work are predicted to comply with the Guideline Target Levels.

8.5.2 Operation

8.5.2.1 Airborne Noise

Airborne noise from trains

Details of the methodology and model used for the assessment of airborne noise from trains is provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

8.5.2.1.1 Concept Design

Rail noise levels in Precinct 2 are to comply with the Investigation Thresholds in the PRINP for the redevelopment of existing rail infrastructure. The day, night and maximum noise levels have been predicted at sensitive receivers in the vicinity of the railway line.

Predictions have been undertaken for the following scenarios:

- Scenario 1: existing train noise levels (this information was used to verify the acoustic model and has been used for comparison with measured baseline noise levels only)
- Scenario 2: train noise levels in 2026 assuming Melbourne Metro does not proceed (base-case)
- Scenario 3: train noise levels in 2036 assuming Melbourne Metro does proceed (with Melbourne Metro).

The year 2026 has been used as the base-case as it is the anticipated year of opening.

The year 2036 has been used for the assessment as it is 10 years after the anticipated opening of Melbourne Metro.

The prediction for the existing train noise levels has been compared with the measured noise levels at 3 Childers Street and was within 2 dB. This is considered a satisfactory correlation. 3 Childers Street was selected for the verification because it has an unobstructed view of the railway and is a reasonably quiet road.

Noise levels have been predicted at all residential building levels. The predicted day, night and maximum train noise levels for the base-case and with Melbourne Metro are provided in figures in Appendix C of the report.

The scenarios for the base-case includes all residences while the scenarios with Melbourne Metro have removed the houses / buildings to be acquired and demolished.

The predictions are based on timetables provided by MMRA and provided in Appendix C of the report.

The Investigation Thresholds are predicted to be exceeded at some residences in the western portal precinct. Noise level increases were associated with:

- Increased rail traffic on the Sunbury, Werribee and RRL rail corridors
- Removal of houses on Childers Street exposing properties on Ormond Street and Altona Street to additional train noise.

Mitigation to achieve compliance with the PRINP consists of a 4.5 m high barrier between the railway and Childers Street for a length of approximately 150 m. The base of the noise barrier is to be at the grade level of the adjacent rail tracks, on top of the retaining wall located along Childers Street. Noise barriers are to have a minimum mass per unit area of 15 kg/m^2 and be contiguous without any gaps or holes. The location of the proposed barrier is shown in Figure 8-2.

It should be noted that if the houses on Childers Street, that have been removed for construction, were replaced with equivalent (or larger) constructions then the noise barrier would not be required.

Figure 8-2 Noise barrier location at Western Portal

8.5.2.1.2 Alternative Design Option

For the alternative design option, the Investigation Thresholds are predicted to be exceed at one location.

Noise level increases were associated with:

- Increased rail traffic on the Sunbury, Werribee and RRL rail corridors
- Loss of shielding from the property removed on Ormond Street.

Mitigation to achieve compliance with the PRINP consists of a 3 m high barrier between the railway and Childers Street for a length of approximately 75 m. The base of the noise barrier is to be at the grade level of the adjacent rail tracks, on top of the retaining wall located along Childers Street. Noise barriers are to have a minimum mass per unit area of 15 kg/m^2 and be contiguous without any gaps or holes. The location of the proposed barrier is shown in Figure 8-3.

It should be noted that if the residence on Ormond Street that was removed for construction, were replaced with an equivalent or larger building then the noise barrier would not be required.

Figure 8-3 Noise barrier location at Western Portal - Variation

Airborne Noise from Fixed Infrastructure

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure is provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

Fixed items of plant are not currently proposed in Precinct 2. Stair pressurization fan may, however, be included in the design. If this were to occur it is expected that they would be located near the Western Portal. The potential fans would be enclosed or located underground and the intake air louvre would effectively be a noise source to the surrounding environment.

Apart from regular testing, these fans would only operate during emergency conditions. The SEPP N-1 policy does not apply to noise from the operation of emergency equipment. For testing of emergency equipment, the SEPP N-1 Noise Limits are increased by 10 dB for the Day period and 5 dB for all other periods.

The potential location of the future intake louvre of the pressurisation fan is shown in Figure 8-4.

Figure 8-4 Approximate location of stair pressurization fan intake louvre

The nearest NSAs are in the residential areas to the east on Ormond and Childers Streets, Kensington. Noise measurements have been conducted at 3 Childers Street, which is representative of the background noise level in this area. The SEPP N-1 Noise Limits are provided in Table 8-7. The Noise Limits apply to all industrial, commercial and retail noise sources, so that the effective Noise Limit for any individual source may be less than the Noise Limit.

Table 8-7 SEPP N-1 Noise Limits for Precinct 2 (for emergency equipment)

Location	Period	Noise Limit, $dBL_{Aeq,30\ minutes}$
135 Ormond Street, Kensington	Day	67
	Evening	54
	Night	54

The fan selections have not been made at this stage however, it is expected that the Noise Limits may be achieved with the use of one or more of the following mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ducts
- Plenums
- Acoustic barriers or screens.

8.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels for operation have been compared with the Guideline Targets for each type of building/occupancy. Where the Guideline Targets have been predicted to exceed the Guideline Targets mitigation has been proposed.

a) Damage to Buildings

Compliance with Guideline Targets is predicted.

b) Human Comfort

Without mitigation, a small number of receivers in the Western Portal Precinct exceed the 'Preferred' VDV Guideline Target, as shown in the figures in Appendix E of this report. With mitigation in the form of track vibration isolation, all receivers in the Western Portal Precinct are predicted to meet the 'Preferred' VDV Guideline Target.

c) Vibration-sensitive Equipment, Highly Sensitive Areas and Bio-resources

Vibration-sensitive equipment, highly sensitive areas and bio-resources have not been identified in this precinct.

8.5.2.3 Ground-borne noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

The predicted ground-borne noise levels for operation have been compared with the Guideline Targets for each type of building/occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

The ground-borne noise levels are predicted to exceed the Guideline Targets at several locations across the proposed alignment with 'Standard Attenuation' as shown in the figures in Appendix E of this report. To mitigate this noise for the Western Portal Precinct it is predicted that a combination of direct fix track with 'Standard Attenuation' and direct fix track with 'High Attenuation' would be required. Indicative track vibration mitigation measures are presented in Appendix E of this report. With this mitigation, ground-borne noise levels are predicted to comply with the Guideline Targets.

8.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 8-8.

Table 8-8: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to with EPA1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting underground infrastructure	Manage vibration with respect to the Guideline Targets in DIN 4150	To be assessed by Proponent	-

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for tunnelling	See Section 7	See Section 7
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for Additional Construction Works	Compliance	Low
Ground-borne noise	Manage vibration with respect to the Guideline Targets provided for tunnelling	See Section 7	See Section 7
Ground-borne noise	Manage vibration with respect to the Guideline Targets provided for Additional Construction Works	Compliance	Low
Operation			
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

8.7 Environmental Performance Requirements

Table 8-9 and Table 8-10 provide the recommended Environmental Performance Requirements for the noise and vibration for Precinct 2: Western Portal for construction and operation respectively.

Table 8-9 Environmental Performance Requirements for construction for Precinct 2: Western Portal

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV002, NV006, NV007, NV015, NV021, NV022, NV027, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.	-	NV001, NV002, NV006, NV007, NV015, NV021, NV022, NV027, NV028
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements of EPA 1254 – Community consultation – Noise barriers up to a height of 6 m – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Noise monitoring	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Building / structural integrity</td>
<td>Building damage from construction vibration</td>
<td>
Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.
<i>Short-term vibration on structures</i>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies
mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz¹</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:
1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
4. Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.
<i>Long term vibration on structures</i>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
</td>
<td>– Selection of methodology / equipment
– Bored piling
– Community consultation
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Minimum buffer distances</td>
<td>NV002
NV015</td>
</tr>
</table>

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
		Notes: 1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage. 2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.		
Underground Infrastructure	Damage to underground infrastructure	Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved. **Pipe Material** — **Vibration Velocity, mm/s (PPV)** **Steel** — 100 **Clay, concrete, reinforced concrete, prestressed concrete, metal** — 80 **Masonry, plastic** — 50 Notes: 1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework. 2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro). 3. Compliance is to be achieved with asset owner's Utility Standards	– Selection of methodology / equipment – Building / Structural Condition Assessment prior to starting works – Vibration monitoring if vibration Guideline Targets are predicted to be exceeded – Bored Piling – Minimum buffer distances	

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Amenity</td>
<td>Construction vibration impacting upon amenity</td>
<td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan</td>
<td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
— Bored piling</td>
<td>NV006
NV020</td>
</tr>
<tr>
<td>Residential amenity</td>
<td>Construction ground-borne noise impacting upon amenity</td>
<td>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.
<table>
<tr><th>Time Period</th><th>Internal Target, $L_{Aeq,15min}$ (dB)</th></tr>
<tr><td>Evening, 6pm to 10pm</td><td>40</td></tr>
<tr><td>Night, 10 pm to 7am</td><td>35</td></tr>
</table>
Note:
1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances</td>
<td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite/temporary relocation
– Selection of construction equipment/construction methodology
— Bored piling</td>
<td>NV027
NV028</td>
</tr>
</table>

Table 8-10: Environmental Performance Requirements for operation for Precinct 2: Western Portal

<table>
<thead>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance requirements</th><th>Possible mitigation measures</th><th>Risk no</th></tr>
</thead>
<tbody>
<tr><td colspan="5">Operation</td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td>–</td><td>NV031, NV032, NV035, NV038</td></tr>
<tr><td>Amenity</td><td>Operational airborne noise impacting on amenity</td><td>Avoid, minimise or mitigate rail noise where the following PRINP (Victorian Passenger Rail Infrastructure Noise Policy, April 2013) Investigation Thresholds are exceeded during operation.
<table>
<thead>
<tr><th>Time</th><th>Type of Receiver</th><th>Investigation Thresholds</th></tr>
</thead>
<tbody>
<tr><td>Day
(6am – 10pm)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks
Noise sensitive community buildings, including schools, kindergartens, libraries</td><td>65 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
<tr><td>Night
(10pm – 6am)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks</td><td>60 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
</tbody>
</table>
Notes:

If an investigation shows that the thresholds are not exceeded, then no further action is considered under the PRINP
L_{Amax}, for this assessment, is defined as maximum A-weighted sound pressure level and is the 95 percentile of the highest value of the A-weighed sound pressure level reached within the day or night
For the Melbourne Metro the location of assessment is at 1 m from the centre of the window of the most exposed external façade
</td><td>– Concept Design: Noise barrier of height 4.5 m (above rail head height) length approximately 150 m
– Alternative Design Option: Noise barrier of height 3 m (above rail head height) length approximately 75 m
– Note: If the houses that have been demolished for construction are reinstated with equivalent or larger buildings then the barriers would not be required</td><td>NV031</td></tr>
<tr><td>Residential amenity</td><td>Airborne noise from fixed infrastructure</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork/plenums
– Acoustic barriers / screens</td><td>NV032</td></tr>
</tbody>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance requirements</th><th>Possible mitigation measures</th><th>Risk no</th></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:

The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
Compliance with these values implies no structural damage due to operation
</td><td>– Track vibration isolation</td><td>NV034</td></tr>
<tr><td>Amenity</td><td>Operational ground-borne noise impacting upon amenity</td><td>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td rowspan="2">Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table></td><td>– Track vibration isolation</td><td>NV038</td></tr>
</table>

Asset / value	Impact	Environmental Performance requirements	Possible mitigation measures	Risk no
		1. RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge. 2. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources) 3. Assessment location is internal near to the centre of the most affected habitable room. 4. L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events. 5. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected. 6. The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue		

9 Precinct 3: Arden Station

9.1 Project Components

9.1.1 Infrastructure

The proposed project infrastructure in Precinct 3 consists of:

- Arden station which would be underground on a 14 Ha site currently in industrial use.

9.1.2 Locality

This precinct includes low-rise development and a mix of land uses, including heavy and light industrial as well as residential. Extensive urban renewal is expected in this precinct over the next 20 years.

Sensitive receivers in the vicinity of the construction work site include:

- Residential locations on:
  - Laurens Street
  - Munster Terrace
  - Stawell Street
  - Queensbury Street West
- Pavilions at the North Melbourne Recreational Centre
- Future land uses on the site following completion of the project.

9.1.3 Construction

Specific construction activities would include:

- Demolition of structures on VicTrack land
- Protection works for the North Yarra main sewer; relocation of the brick storm water drain
- Establishment of a construction work site on the VicTrack land. This would be a major staging area and would include:
  - Fabrication sheds
  - Major Site offices
  - Major storage areas
  - Spoil extraction and handling facilities
  - Water treatment plant
  - Tunnel air ventilation and extraction plant
- Tunnel excavation and TBM launch
- Station works – 'bottom- up cut and cover construction method'
- Station architectural and service fit out
- Track works and installation of rail systems (underground)
- Spoil removal and concrete pour
- Access shaft.

There would be a significant amount of construction traffic accessing the site for materials delivery and spoil removal.

Station Construction

The work to construct Arden station and launch the TBMs is planned to occur over a period of approximately 2 years, from years 2018 to 2020. The main activities and expected duration to complete the work are:

1) Diaphragm wall works (7 months)
2) Excavation works (7 months)
3) Concrete works (15 months)
4) TBM preparation and launch operations (15 months).

9.1.4 Operation

Operation would include:

- Trains travelling below ground in the tunnels and station
- Fixed infrastructure for ventilation.

9.2 Existing Conditions

Full details of the baseline noise and vibration measurements are provided in Appendix F of this report.

External Ambient Noise

The results of external ambient noise monitoring are provided in Table 9-1. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in the vicinity of construction or future fixed infrastructure, then the parameters provided are consistent with information needed for the EPA 1254 assessment or the SEPP N-1 assessment.

Table 9-1 External ambient noise measurements

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
141 Laurens Street, North Melbourne	53	62	50	58	48	56
724 Queensberry Street, North Melbourne	45	50	42	45	43	46
2/3 Miller Street, West Melbourne	56	63	52	59	51	57

These residences were exposed to traffic on nearby roads. The measurement on Queensberry Street was shielded by a fence, which has resulted in lower noise levels.

External Vibration Measurements

The maximum external vibration levels measured in Precinct 3 are provided in Table 9-2.

Table 9-2 External vibration measurements

Location	Maximum PPV (mm/s)	Comments
760 Queensberry Street, North Melbourne	4.2	Truck at 3 m travelling over a road imperfection
736-738 Queensberry Street, North Melbourne	1	Truck at 3 m
201 Abbotsford Street, North Melbourne	1.3	Tram at 15 m and trolley at 10 m

9.3 Key Issues

The key issues potentially associated with the Concept Design are identified in Table 9-3.

Table 9-3 Key issues associated with the Concept Design

Issue	
Construction	
Airborne noise	• Noise impact on amenity of sensitive receivers due to 24-hour construction.
Vibration	• Structural damage to buildings. • Impact on amenity.
Ground-borne noise	• Impact on amenity.
Operation	
Airborne noise	• Impact on amenity from fixed infrastructure
Vibration	• Impact on amenity from train operation.
Ground-borne noise	• Impact on amenity from train operation.

9.4 Benefits and Opportunities

Table 9-4 provides the benefits and opportunities associated with the Concept Design.

Table 9-4 Benefits and opportunities associated with the Concept Design

Concept Design		Benefits and Opportunities
Construction work site	Large site	A large construction work site allows construction activities to be strategically located and oriented to minimise impact of noise and vibration on sensitive receivers.
Construction work site	Number of access points	Reduce impact of construction vehicles by using a number of different routes and access points.

9.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria / Guideline Targets (and indicators) relevant to this assessment are provided in Section 2.1

9.5.1 Construction

9.5.1.1 Airborne Noise

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report. For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

The Guideline Noise Levels at sensitive locations in the vicinity of construction activity are provided in Table 9-5 and are based on the noise levels measured at 141 Laurens Street in North Melbourne.

Table 9-5 Construction Guideline Noise Levels

Time period	Applicable hours	Guideline Noise levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday	No specified Guideline Noise Level - noise reduction measures apply	
	7am to 1pm Saturday		
Weekend/Evening work	6pm to 10pm Monday to Friday	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more. 60 dB(A)	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more. 55 dB(A)
	1pm to 10pm Saturday		
	7am to 10 pm Sunday and Public Holidays		
Night	10pm to 7am Monday to Sunday	Noise to be inaudible within a habitable room of any residential premises. 46 dB(A)	
Unavoidable Works	All times	No specified Guideline Noise Level - noise reduction measures apply	

The construction scenarios assessed were:

- Scenario A Station Box with no roof deck (Normal Working Hours)
- Scenario B TBM launch preparation (24-hours, Unavoidable Work)
- Scenario C TBM launch (24-hours, Unavoidable Work)
- Scenario D Site works (24-hours).

The construction works for Scenarios B and C would be predominantly undertaken during Normal Working Hours. If, however, they cannot be completed during Normal Working Hours then construction work would need to continue until complete - this is classed Unavoidable Work. It is anticipated that this work would occur twice for a period of four to five weeks each over the duration of the project construction. The predicted construction noise levels for Scenarios A, B, C and D are provided in figures in Appendix A of this report.

While Guideline Noise Levels do not apply for construction work for Scenarios A, B and C there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation.

For Scenario A, it is expected that construction equipment below ground would benefit from additional shielding from the excavated station box.

Both general and specific noise mitigation is provided in Appendix A of this report. Specific noise mitigation includes:

- A noise barrier adjacent to the construction work site situated along a portion of Laurens Street with a height of up to 6 m
- Off-reservation treatment (building mitigation such as improved glazing) for the upper levels of two apartment buildings on Queensbury Street and Laurens Street
- Acoustic construction sheds over the concrete batching plant and TBM launch area.

The proposed indicative locations for construction noise mitigation are shown in Figure 9-1.

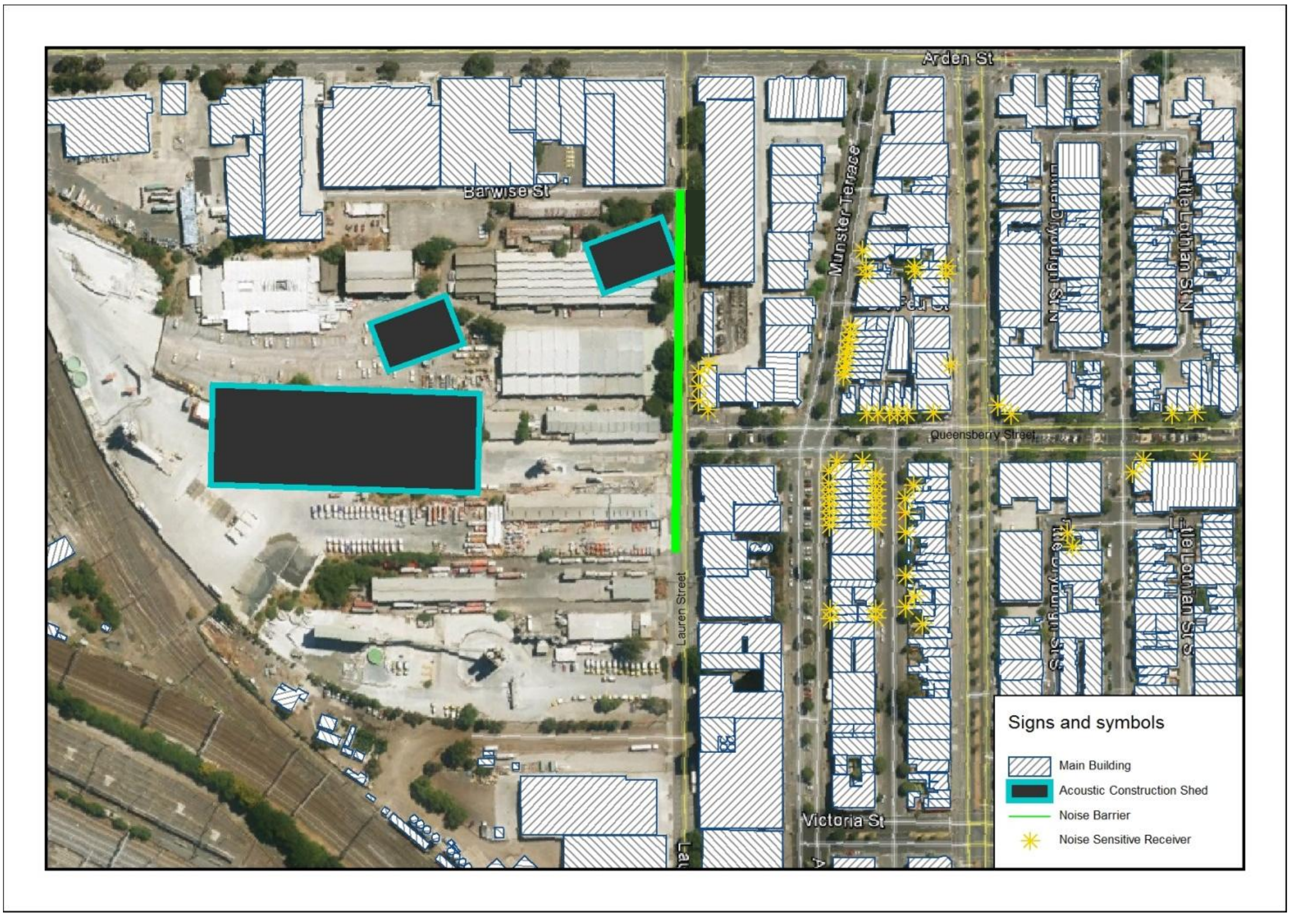


Figure 9-1 Noise mitigation for the Arden station construction work site

The predicted construction noise levels with mitigation are provided in figures in Appendix A of this report.

Scenario D works and any other avoidable work undertaken outside of Normal Working Hours would need to comply with the Guideline Noise Levels in Table 9-5 at all levels of the nearest residential buildings.

Compliance with the requirements of EPA 1254 is predicted to be achieved with the mitigation proposed.

In the vicinity of the Arden Station construction worksite, at 41 Laurens Street, the average baseline noise levels were measured to be 62 dBL_{Aeq} during the day and 56 dBL_{Aeq} during the night.

With noise mitigation (acoustic construction sheds and a noise barrier up to 6 m in height) noise levels are predicted to be equal to or less than the existing levels, with the exception of Level 3 of 142-144 Laurens Street for Scenario A (during Normal Working Hours) and Scenario C (during the night time period) where construction noise levels predicted to be up to 4 dB higher than the average daytime and night time baseline noise levels. They would, however, be in the order of or lower than short-term noise events in this area.

The Guideline Noise Levels, which apply for construction work outside of Normal Working Hours (for Scenario D), are predicted to be complied with at ground and first levels of the nearby apartment buildings. At levels 2 and 3 of 142-144 Laurens Street and Level 3 of 731-735 Queensberry Street it is predicted that the internal requirement for inaudibility may not be achieved (by up to 3 dB). If in practice this is the case and the residents are disturbed by construction noise then building mitigation in the form of improved glazing may be appropriate. With building mitigation of this type it is expected that the requirement for inaudibility would be able to be achieved.

9.5.1.2 Vibration

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to buildings

b) Underground infrastructure

c) Human comfort

d) Vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas.

(i) Tunnelling

Refer to Precinct 1: Tunnels.

(ii) Additional Construction Works

The Additional Construction Works in the Arden Station precinct relevant to vibration include bored piling and excavation of the station box. It is expected that peak vibrations would occur when rockbreakers are removing rock from the lower levels of the station excavation. Underground excavation works (including rockbreaking) are proposed to be conducted over 24-hours. A model has been developed to predict vibration during rockbreaking works and to assess the impacts on nearby receivers. Results of the vibration assessment are as follows.

a) Damage to Buildings

Vibration is predicted to comply with the Guideline Targets in DIN 4150 at nearby buildings.

b) Underground Infrastructure

There are a number of utilities within the Arden station precinct and its surrounds. To avoid damage, the minimum buffer distances construction work should be from utilities are:

- 3 m for general utilities
- 5.5 m for Melbourne Water unreinforced assets.

Location of the utilities would be confirmed by MMRA prior to the commencement of work.

c) Human Comfort

Vibration from construction is predicted to comply with the vibration Guideline Targets for human comfort.

d) Vibration-sensitive Equipment, Bio-resources and Highly Sensitive Areas

Vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas have not been identified in this precinct.

9.5.1.3 Ground-borne Noise

Details of the methodology and model used for the assessment of ground-borne noise is provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

Refer to Precinct 1: Tunnels. Construction activities associated with tunnelling have been assessed for ground-borne noise with respect to the Guideline Targets. Predicted ground-borne noise levels are lower than the Guideline Targets and Management Actions are not triggered.

(ii) Additional Construction Works

The ground-borne noise levels are predicted to comply with the ground-borne noise Guideline Targets at sensitive receivers in the vicinity of the construction work site.

9.5.2 Operation

Future residential occupancy of the Arden station construction work site has been considered in the assessment of operational impacts. It has been assumed that the site may contain residential lots with multi-story buildings founded on bedrock near to the alignment. This forms the assessment of potential vibration and ground-borne noise impacts.

9.5.2.1 Airborne Noise

Airborne Noise from Trains

Details of the methodology and model used for the assessment of airborne noise from trains is provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

Airborne noise from trains is predicted to be insignificant as the trains would be below ground in the tunnels.

Airborne Noise from Fixed Plant

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure are provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

Ventilation and other fixed plant may operate 24-hours and must meet the relevant SEPP N-1 Noise Limits at the nearest Noise Sensitive Area (NSA). Design of the fixed plant and ventilation to achieve with the SEPP N-1 Noise Limit for the Night Period also implies achieving the Day and Evening Limits as the background noise levels and therefore Noise Limits are lower at night.

The fixed plant noise in Precinct 3 is expected to include:

- Tunnel Ventilation System
- Over Track Extract fans
- Over Platform Extract Fans
- Over Concourse Extract fans)

- Back of House ventilation systems
- Chiller plant (location of this plant is still to be determined).

The fans would be enclosed or located underground and the louvre/grilles would effectively be a noise source to the surrounding environment. The proposed location/zone of the louvres/grilles fan is shown in Figure 9-2.

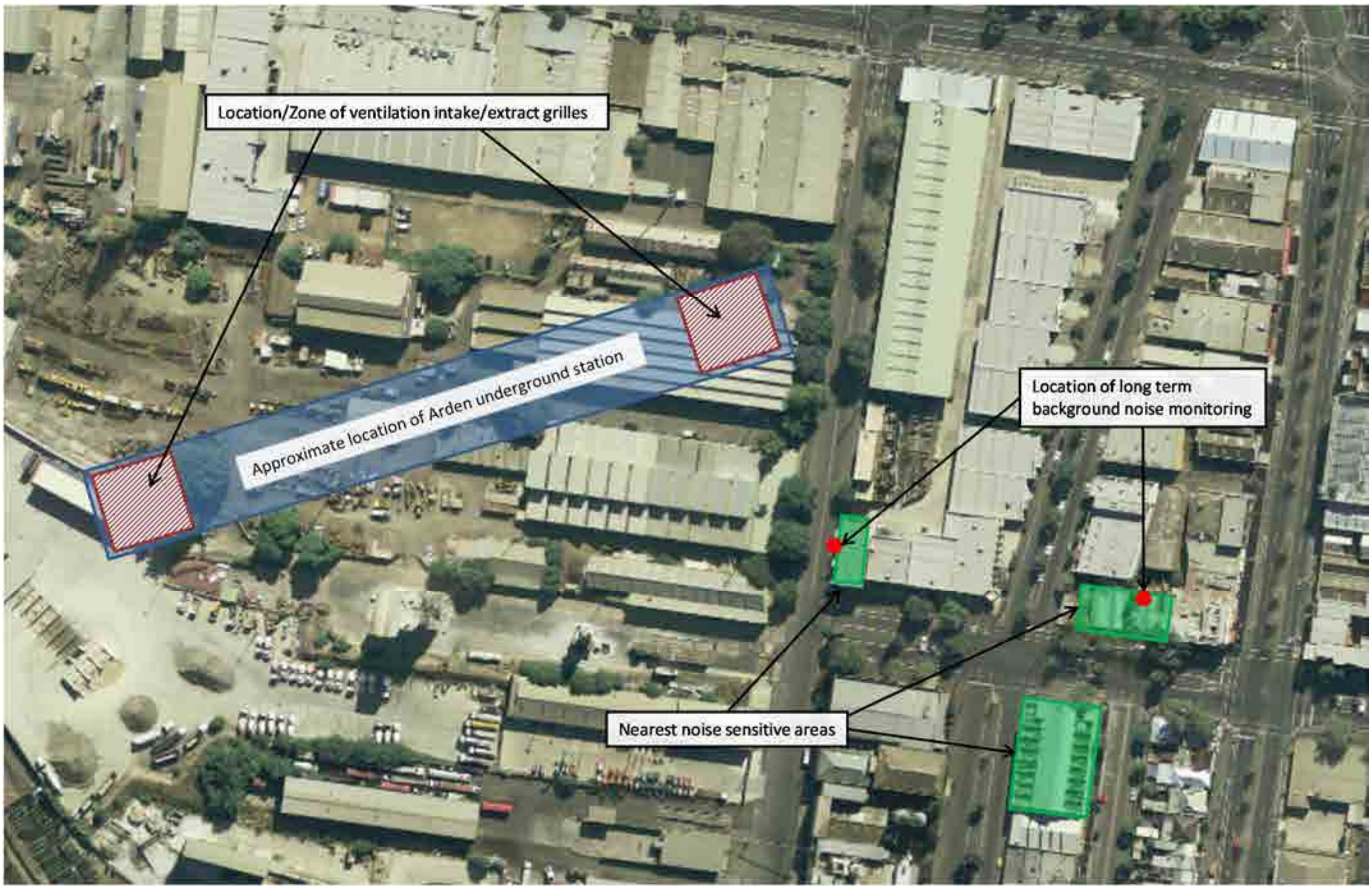


Figure 9-2 Location of fixed noise sources, background noise level locations and NSAs for Precinct 3

The nearest NSAs are dwellings in the mixed-use zone, which are the residential areas to the east and south east of Arden station on Laurens Street, Queensbury Street and on the corner of Queensberry Street and Munster Terrace.

Noise measurements have been conducted at 141 Laurens Street and in the rear garden at 724 Queensberry Street in North Melbourne. These are representative of the background noise levels in this area. The SEPP N-1 Noise Limits are provided in Table 9-6. The Noise Limit at the NSA applies to noise from all industrial sources at this location considered in aggregate so that the Noise Limit from any individual item of plant may be lower than the Noise Limit.

Table 9-6: SEPP N-1 Noise Limits for Precinct 3

Location	Period	Noise Limit, dBL$_{Aeq,30\ minutes}$
141 Laurens Street, North Melbourne	Day	59
	Evening	53
	Night	51

Location	Period	Noise Limit, dBL$_{Aeq,30\ minutes}$
724 Queensbury Street, North Melbourne	Day	57
	Evening	51
	Night	48

The fan selections have not been made at this stage, however, it is expected that the Noise Limits may be achieved with the use of one or more of the following mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ducts
- Plenums
- Acoustic barriers or screens.

9.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels for operation have been compared with the Guideline Targets for each type of building/occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed. The outcomes are as follows:

a) Damage to Buildings

Compliance with Guideline Targets is predicted.

b) Human Comfort

In anticipation of residential development of the Arden station precinct, mitigation of track vibration would be required to meet human comfort vibration targets. Predictive modelling indicates that a track with ‘Very High Attenuation’ properties would be required to mitigate vibration at this site. With this mitigation, compliance with the ‘Preferred’ VDV Guideline Targets is predicted.

c) Vibration-sensitive Equipment, Highly Sensitive Areas and Bio-resources

Vibration-sensitive equipment, highly sensitive areas and bio-resources have not been identified in this precinct.

9.5.2.3 Ground-borne Noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

The predicted ground-borne noise levels for operation have been compared with the Guideline Targets for each type of building / occupancy. For the Arden station precinct, it has been assumed that future development may include multi-story residential buildings founded on rock. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

In anticipation of residential development of the Arden Station precinct, mitigation of track vibrations would be required to meet ground-borne noise targets. Predictive modelling indicates that a track with ‘Very High Attenuation’ properties would be required to mitigate ground-borne noise at this site. With this mitigation, compliance with the Guideline Targets is predicted.

9.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 9-7.

Table 9-7: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA 1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting underground infrastructure	Manage vibration with respect to Guideline Targets in DIN 4150	To be assessed by Proponent.	-
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for tunnelling	See Section 7	See Section 7
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for Additional Construction Works	Compliance	Low
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided for tunnelling	See Section 7	See Section 7
Ground-borne noise	Manage ground-borne noise with respect to with Guideline Targets provided for Additional Construction Works	Compliance	Low
Operation			
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

9.7 Environmental Performance Requirements

Table 9-8 and Table 9-9 provide the recommended Environmental Performance Requirements for the noise and vibration for Precinct 3: Arden Station for construction and operation respectively.

Table 9-8 Environmental Performance requirements for construction for Precinct 3: Arden Station

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV003, NV006, NV007, NV016, NV021, NV022, NV027, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.	-	NV001, NV003, NV006, NV007, NV016, NV021, NV022, NV027, NV028
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements of EPA 1254 – Community consultation – Noise barriers up to a height of 6 m – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Noise monitoring – Off-reservation treatment	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>**Building/structural integrity**</td>
<td>Building damage from construction vibration</td>
<td>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.

Short-term vibration on structures
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies

mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th></tr>
<tr><td>**Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design**</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>**Type 2: Dwellings and buildings of similar design and/or occupancy**</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>**Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings**</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:
1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
4. Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

Long term vibration on structures
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>**Buildings used for commercial purposes, industrial buildings and similar design**</td><td>10</td></tr>
<tr><td>**Dwellings and buildings of similar design and/or occupancy**</td><td>5</td></tr>
<tr><td>**Structures that have a particular sensitivity to vibration e.g. heritage buildings**</td><td>2.5</td></tr>
</table>
Notes:
1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.</td>
<td>– Selection of construction equipment / construction methodology
– Bored piling
– Community consultation
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded</td>
<td>NV003, NV016</td>
</tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td>2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.</td><td></td><td></td></tr>
<tr><td>Underground Infrastructure</td><td>Damage to underground infrastructure</td><td>Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved.
<table>
<tr><th>Pipe Material</th><th>Vibration Velocity, mm/s (PPV)</th></tr>
<tr><td>Steel</td><td>100</td></tr>
<tr><td>Clay, concrete, reinforced concrete, prestressed concrete, metal</td><td>80</td></tr>
<tr><td>Masonry, plastic</td><td>50</td></tr>
</table>
Notes:
1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework.
2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro).
3. Compliance is to be achieved with asset owner’s Utility Standards</td><td>– Selection of methodology / equipment
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Minimum buffer distance</td><td></td></tr>
<tr><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.</td><td>– Community consultation
– Provision of respite or temporary relocation
– Selection of methodology / equipment
– Bored piling</td><td>NV006, NV016</td></tr>
</table>

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Residential amenity	Construction ground-borne noise impacting upon amenity	Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction. **Time Period** — **Internal Target, $L_{Aeq,15min}$ (dB)** **Evening, 6pm to 10pm** — 40 **Night, 10 pm to 7am** — 35 Note: 1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels. 2. The noise levels are assessed at the centre of the most affected habitable room. 3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.	– Community consultation – Provision of respite or temporary relocation – Selection of methodology / equipment – Bored piling	NV027, NV028

Time Period	Internal Target, $L_{Aeq,15min}$ (dB)
Evening, 6pm to 10pm	40
Night, 10 pm to 7am	35

Table 9-9 Environmental Performance requirements for operation for Precinct 3: Arden Station

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="4">Operation</td><td></td></tr>
<tr><td>Residential amenity</td><td>Airborne noise from fixed infrastructure</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork / plenums
– Acoustic barriers / screens</td><td>NV032</td></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV (m/s^{1.75})</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>– Track vibration isolation</td><td>NV035</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Operational ground-borne noise impacting upon amenity</td><td>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td rowspan="2">Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Night (10pm - 7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>
1. RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
2. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
3. Assessment location is internal near to the centre of the most affected habitable room.
4. L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
5. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.
6. The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue</td><td>— Track vibration isolation</td><td>NV038</td></tr>
</table>

10 Precinct 4: Parkville Station

10.1.1 Infrastructure

The proposed infrastructure in this precinct includes:

- Parkville station located under Grattan Street between Royal Parade and Leicester Street
- Station entrances on Royal Parade, Grattan Street and within the University of Melbourne) campus
- Pedestrian tunnel beneath Royal Parade between the station box and the entrance on the southwest corner of Grattan Street.

10.1.2 Locality

This precinct is dominated by health and education uses. It is a very busy precinct with helicopter movements, tramlines along Royal Parade and Flemington Road, bus routes along Grattan Street and Royal Parade and significant traffic. There has also been major construction in the area at the Victorian Comprehensive Cancer Centre, Royal Women's Hospital, Peter Doherty Institute and on-going construction work at the Royal Melbourne Hospital for which the noise and vibration impacts have been adequately managed.

Sensitive receivers in the vicinity of the construction activities and operation include:

- Health and laboratories in the immediate vicinity of the tunnels and station:
  - Royal Melbourne Hospital
  - Royal Women's Hospital
  - Victorian Comprehensive Cancer Centre
  - University of Melbourne Faculty of Medicine
  - Peter Doherty Institute
- Further back from the tunnels and station, are:
  - Melbourne Private Hospital
  - Howard Florey Laboratories
  - Walter and Eliza Hall Institute
  - Kenneth Myer Building
  - Bio21 Institute (Bio 21)
- Other education buildings associated with the University of Melbourne (including the Alan Gilbert building and the Engineering Building)
- IQ Apartments
- Graduate House
- Melbourne Business School
- Residential buildings in the backstreets.

A number of these buildings house vibration-sensitive equipment, Bio-resources and other Highly Sensitive Areas. Key items of vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas have been identified based on information provided by stakeholders and are provided in Table 10-1, Table 10-2 and Table 10-3, respectively. In some cases, local vibration isolation has been provided for sensitive items.

Table 10-1 Key items of vibration-sensitive equipment

Location	Vibration-sensitive Equipment
Royal Women's Hospital	• CT Scanner, MRI/ Level 1 (Adjacent to Grattan Street) • Microscopy /Level 2 (Infertility) • Theatres / Level 3
Royal Melbourne Hospital, Building	• MRI, CT, Ultra sound, Mammography / Ground Level • Gamma cameras, PET Scanners / Ground Level (Adjacent to Royal Parade) • CT scanners / Ground Level (Emergency Department) • MRI, CT Scanners / Level 1 • Haematology / Level 2 • Operating Theatres / Level 3 • MRI / Level 3 • MRI / Level 5 • WEHI Instrument Laboratory / Level 8 RMH
Melbourne Private Hospital	• MRI, CT, Ultra sound, Mammography / Ground Level • CT scanners, X-ray Equipment / Ground Level • Micro Biology / Level 2 • Brain navigation systems / Level 7
Victorian Comprehensive Cancer Centre	• Cylcotron / Basement 2 (Haymarket Corner of the building) • Linear accelerators / Basement 1 (adjacent to Grattan Street) • CT Scanners / Basement 1 (towards Flemington Road) • MRIs / Level 4 • MRI, X-ray, Ultrasounds, PET, CT / Level 5 • Operating theatre, future MRI / Level 6
Peter Doherty Institute	• Electron Microscope / Basement • Genomics Room / Level 1 • Microscopy / Level 7 • Photon / Level 8
University of Melbourne	• Laser Diagnostics Equipment / Ground Level Building 170 • Fluroscopes, Robotic gantry Equipment / Level 1 Building 170 • Helium Ion Microscopes / Ground Level Building 261 • Network Analysers and Dielectric Permitivity Probes / Basement Building 175 • Thermal Gravity Analysis / Ground Level Building 165 • JPK Nanowizard / Level 1 Building 165

Location	Vibration-sensitive Equipment
	• 3D Atomic Force Microscope / Level 1 building 165 • Sorption Analyser / Ground Level Building 165 • Nanomaterials Nanoindenter / Ground Level Building 165 • 20nm resolution Microscope / Level 1 Building 165 • 200nm resolution Microscope / Level 1 Building 165 • 3D Atomic Force Microscope / Level 2 Building 165 • Confocal microscopes / Faculty of Medicine
Howard Florey Laboratories	• MRI / Basement
Walter and Eliza Hall Institute (WEHI)	• Future Crystallography facility / Ground Level • Laser and analysis equipment / Level 3 • High sensitivity microscopes / Level 4 • Structural Biology Crystal Store / Level 7
Bio 21 Institute	• Electron microscope / Level 1
Kenneth Myer Building	• Small bore MRI (4.7 T) / Basement • MRI (7 T), PET, CT Camera / Ground level • Nano PET / Level 1 • 2 Photon microscopes / Level 2 • Advanced microscopy / Level 3 • Mass spectroscopy / Level 4 • Sensitive Equipment / Level 7
University High School	• Scanning Electron Microscope / Gene Technology Access Centre

Table 10-2 Location of Bio-resources

Facility	Location of Bio-resources
Victorian Comprehensive Cancer Centre	Level 8 Adjacent to Grattan Street
	Level 4 Adjacent to Flemington Road
Royal Melbourne Hospital	On Royal Parade façade, Level 6
	Basement
Peter Doherty Institute	Level 9 – in the middle of building
	Level 8 and 9 Grattan Street facade

Facility	Location of Bio-resources
Howard Florey Laboratories	Ground Floor, On the northern side of the building, eastern section
	Level 3, On the northern side of the building, eastern section
	Level 4, On the northern side of the building, eastern section
	Level 5, On the northern side of the building, eastern section
	Level 7, On the northern side of the building, eastern section
University of Melbourne Faculty of Medicine	Level 9, Grattan Street Façade, West Wing and East Wing
	Level 9, North façade of the East Wing, (facing away from Grattan Street)
WEHI	Level 1 Level 2 Level 4

Table 10-3 Location of other Highly Sensitive Areas

Facility	Location of Highly Sensitive Areas
Royal Women's Hospital	Level 4 – Wards
	Level 5 – Staff Accommodation
	Level 7 – Maternity
Royal Melbourne Hospital	Level 2 – ICU, Cardiology Ward 2B and Ward 2W
	Level 3 – Ward 3S
	Level 5 – Ward 5S and Ward 5E
	Level 6 – Ward 6S
	Level 7 – Ward 7S and Ward 7W
	Level 9 Ward 9E and 9W
Victorian Comprehensive Cancer Centre	Level 1 – Country patient accommodation
	Level 3 – Medical Ward
	Level 5 – Haematology Ward
	Level 6 – Surgical Ward
Peter Doherty Institute	Ground – Auditorium

10.1.3 Construction

Grattan Street would be closed to traffic during construction between Royal Parade and Leicester Street. Specific construction activities would include:

- Demolition of structures
- Protection or relocation of major underground facilities (including sewer, gas and water mains) fibre optic cables and storm water drains
- Establishment of a construction works site at 750 Elizabeth Street (currently City Ford). This would include site offices and general construction work site activities
- TBMs pulled through station box
- Station works – 'top-down cut and cover' construction method
- Underground pedestrian access – mined construction method
- Station architectural and service fit-out
- Underground track-works and installation of rail systems.

Above ground construction work would be undertaken during Normal Working Hours. Underground construction work (e.g. TBMs and excavation works after the station roof is established) is proposed to continue 24-hours a day.

Station Construction

The work to construct Parkville station is planned to occur over a period of approximately 2.5 years. The main activities and expected duration to complete the work are:

- Bored piling works (7 months)
- 'Top down' excavation and concrete works (approximately 2 years) consisting of:
  - Stage 1: Excavate to below the roof slab and casting of the roof slab (approximately 4 months)
  - Stage 2: Excavate to below the concourse and upper concourse slab and casting of each respective slab (approximately 7 months)
  - Stage 3: Excavate to below the upper concourse and casting of remaining slab (4 months)
  - Stage 4: Excavate to formation level and cast base slabs (approximately 9 months)
  - Excavation with rippers and rockbreakers
- Royal Parade entrance works (approximately10 months).

10.1.4 Alternative Design Option

'Bottom up cut and cover' construction for the station

10.1.5 Operation

Operation of Melbourne Metro is proposed to consist of:

- Trains travelling below ground in the tunnels and station
- Fixed infrastructure for ventilation.

10.2 Existing Conditions

Full details of the baseline noise and vibration measurements are provided in Appendix F of this report.

Ambient External Noise

The results of the external ambient noise measurements are provided in Table 10-4. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in the vicinity of construction or future fixed infrastructure, then the parameters provided are consistent with information needed for the EPA 1254 and SEPP N-1 assessments.

Table 10-4 External Ambient Noise Measurements

Address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
Royal Women's Hospital - on Grattan Street	62	67	55	68	51	57
Victorian Comprehensive Cancer Centre - near corner of Grattan Street and Flemington Road	61	70	58	67	52	59
Victorian Comprehensive Cancer Centre - near corner of Grattan Street and Royal Parade	61	70	59	67	53	62
Royal Melbourne Hospital - near corner of Grattan Street and Royal Parade	61	70	59	67	55	61
University of Melbourne Faculty of Medicine - Royal Parade	64	72	58	67	53	58
Peter Doherty Institute - Grattan Street	66	73	58	70	54	58
Corner of Pelham and Elizabeth Streets	60	70	56	67	48	60
University Square – corner of Barry and Pelham Streets	54	59	49	55	44	45
University Square – corner of Pelham and Leicester Streets	54	65	50	60	42	44
University Square – corner of Grattan and Leicester Streets	57	69	53	66	44	57
University Square – corner of Barry and Grattan Streets	58	74	56	64	47	55
Howard Florey Laboratories – Royal Parade	61	65	58	63	55	62
Melbourne Private Hospital – Royal Parade	59	66	57	62	53	58
University High School – Royal Parade	57	66	54	64	49	57

Note: All attended measurements consisted of two measurements of minimum duration 10 minutes each during each time period (consistent with the requirements of SEPP N-1).

Internal Noise

The internal noise levels measured in Precinct 4 are provided in Table 10-5.

Table 10-5: Internal Noise Measurements

Location	Noise Level, dBL		
	L_{max}	L_{eq}	L_{90}
Walter and Eliza Hall Institut – Level 4 Bio-resources room Note 1	77 (>500 Hz)	61 (>500 Hz)	58 (>500 Hz)
Royal Melbourne Hospital – Level 6 Bio-resources room Note 1	79 (>500 Hz)	60 (>500 Hz)	57 (>500 Hz)
Royal Melbourne Hospital - Basement Bio-resources room	88	78	76
Peter Doherty Institute – Level 9 Bio-resources facility	78	70	68
University of Melbourne Faculty of Medicine – Level 9 Bio-resources east wing Note 1	46 (>500 Hz)	45 (>500 Hz)	44 (>500 Hz)
University of Melbourne Faculty of Medicine – Level 9 Bio-resources west wing Note 1	58 (>500 Hz)	49 (>500 Hz)	40 (>500 Hz)
Peter Doherty Institute Auditorium Note 2	45 Note 2	37 Note 2	36 Note 2

Note:

1. The frequency range depends upon the hearing range of the Bio-resource and this has been applied to the measurement.
2. This measurement is A-weighted unlike the other measurements that are un-weighted

External Vibration

The maximum external vibration levels measured in Precinct 2 are provided in Table 10-6.

Table 10-6 External vibration measurements

Location	Maximum PPV Levels (mm/s)	Comments
Grattan Street, Parkville (between Flemington Road and Royal Parade)	1.1	Taxi at 2 m
Grattan Street, Parkville (between Flemington Road and Royal Parade)	2.9	Bus and dump truck at 1 m
Grattan Street, Parkville (between Flemington Road and Royal Parade)	1.7	Pedestrian at 0.1 m
Royal Melbourne Hospital Royal Parade, Parkville	0.5	Tram at 20 m
Grattan Street/Royal Parade, Parkville	0.8	Tram at 20 m
Grattan Street/Elizabeth Street, Parkville	0.9	Tram at 20 m
Grattan Street/Berkeley Street, Parkville	1	Bus at 5 m
Corner of Pelham and Elizabeth Streets	0.8	Tram at 15 m

Location	Maximum PPV Levels (mm/s)	Comments
University Square – corner of Barry and Pelham Streets	0.8	Pedestrians at 0.3 m
University Square – corner of Pelham and Leicester Streets	0.2	
University Square – corner of Grattan and Leicester Streets	0.3	
University Square – corner of Barry and Grattan Streets	0.2	
Howard Florey Laboratories (HFL)	0.7	Tram at 15 m
Melbourne Private Hospital (MPH)	1	Tram at 20 m
University High School	0.6	Tram at 20 m

Internal Vibration

A summary of the vibration measurements undertaken in areas where there is vibration-sensitive equipment or similar is provided in Table 10-7.

Table 10-7 Summary of baseline floor vibration measurements

Location	Baseline 1/3rd octave level (µm/s RMS)	Baseline VC from ASHRAE
Royal Melbourne Hospital		
Building 1B, Level 1, adjacent to Grattan Street	13	VC-C / VC-B
Clinical Sciences Building, Basement (Biological Resource)	6	VC-D
Building 1B, Level 6 (Sensitive Biological Resource - University of Melbourne)	20	VC-B
Royal Women’s Hospital		
Level 1, adjacent to Grattan Street (3.5T MRI)	17	VC-B
Walter and Eliza Hall Institute		
Building 1, Level 4 (Microscopy)	58	VC-A
Building 1, Level 4 (Sensitive Biological Resource)	43	VC-A
Peter Doherty Institute		
Level 7 (1000 x Microscopy)	48	VC-A
Level 9 (Sensitive Biological Resources Facility)	35	VC-A
Basement (Electron Microscope)	6	VC-D* Instrument is base-isolated
Howard Florey Laboratories		
MRI	11	VC-C

Location	Baseline 1/3rd octave level (µm/s RMS)	Baseline VC from ASHRAE
Melbourne Private Hospital		
X-Ray Labs	63	Operating Room
The University of Melbourne		
Bio-resources Level 9, East Wing, Faculty of Medicine Building	29	VC-A
Bio-resources Level 9, West Wing, Faculty of Medicine Building	20	VC-B
Laboratory Level 9, Faculty of Medicine Building	24	VC-B
Microscopy Room, Ground Floor, Faculty of Medicine Building	28	VC-B
Confocal Room, E505, Faculty of Medicine Building	24	VC-B
Plant Room, C901, Faculty of Medicine Building	63	Operating Room
Bio-resource Nerve Testing Lab, E702C, Faculty of Medicine Building	21	VC-B
Laboratory, E708, Faculty of Medicine Building	48	VC-A
Laboratory, E638, in Faculty of Medicine Building	30	VC-A
Laboratory, E609, in Faculty of Medicine Building	88	Operating Room
Laboratory, E709, in Faculty of Medicine Building	44	VC-A
Anatomy Museum Storage, E113, Faculty of Medicine Building	3	VC-E
Anatomy Museum, E301, Faculty of Medicine Building	9	VC-C
Foyer, N201, Faculty of Medicine Building	12	VC-C
Lecture Theatre, C216, Faculty of Medicine Building	31	VC-A
Conference Room,W206, Faculty of Medicine Building	14	VC-B
Anatomy Lab, E403, Faculty of Medicine Building	45	VC-A
X-Ray Labs (G04A – G04B in Building 167)	17	VC-B
Laboratories (115 – 118 in Building 165)	15	VC-B
PC2 Lab (112 in Building 165)	15	VC-B
Atomic Force Microscope (217 in Building 165)	15	VC-B
Leading Thermal Analyser (G04 – G10 in Building 165)	14	VC-B
Substance Analyser (G04 – G10 in Building 165)	18	VC-B

Location	Baseline 1/3rd octave level (µm/s RMS)	Baseline VC from ASHRAE
3D X-Ray (107 in Building 170)	20	VC-B
Kenneth Myer Building		
MRI, Ground Floor	5	VC-D
Bio21 Institute		
Electron Microscope, Level 1, North Building	20	VC-B

10.3 Key Issues

The key issues associated potentially with the Concept Design are identified in Table 10-8.

Table 10-8 Key issues associated with the Concept Design

Concept Design	Potential issue
Construction	
Airborne noise	• Airborne noise impact on sensitive receivers. • Impact on amenity and health of patients. • Impact on laboratory Bio-resources. • Impact on sensitive surgery operations.
Vibration	• Impact on amenity of sensitive receivers. • Impact on vibration-sensitive equipment. • Impact on laboratory Bio-resources. • Damage to buildings / existing infrastructure. • Impact on sensitive Highly Sensitive Areas.
Ground-borne noise	• Impact on amenity and health of patients. • Impact on laboratory Bio-resources. • Impact on Highly Sensitive Areas.
Operation	
Airborne noise	• Impact on amenity and health of patients. • Impact on laboratory. • Impact on laboratory Bio-resources • Impact on Highly Sensitive Areas.

Concept Design	Potential issue
Vibration	• Impact on vibration-sensitive equipment. • Impact on amenity. • Impact on laboratory Bio-resources. • Impact on Impact on laboratory Bio-resources.
Ground-borne noise	• Impact on amenity and health of patients. • Impact on laboratory Bio-resources. • Impact on Impact on laboratory Bio-resources.

10.3.1 Alternative Design Option

The alternative design option is expected to result in similar noise and vibration outcomes when compared with the Concept Design.

10.4 Benefits and Opportunities

Table 10-9 provides the benefits and opportunities associated with the Concept Design.

Table 10-9: Benefits and opportunities associated with the Concept Design

Concept Design	Benefits	Opportunities
Station box located beneath Grattan Street.	Locating the station box solely below Grattan Street rather than across Royal Parade moves most construction noise and vibration related disturbance away from the hospital receivers and some sensitive research facilities.	

10.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria / Guideline Targets (and indicators where relevant) relevant to this assessment are provided in Section 2.1.

10.5.1 Construction

10.5.1.1 Airborne noise

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report.

For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

The Guideline Noise Levels at sensitive locations in the vicinity of construction activity are provided in Table 10-10 and are based on the noise levels measured at the Royal Melbourne Hospital.

Table 10-10 Construction Guideline Noise Levels

Time period	Applicable hours	Guideline Noise levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday	No specified Guideline Noise Level - noise reduction measures apply	
	7am to 1pm Saturday		
Weekend / Evening work	6pm to 10pm Monday to Friday	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more. 69 dB(A)	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more. 64 dB(A)
	1pm to 10pm Saturday		
	7am to 10pm Sunday and Public Holidays		
Night	10pm to 7am Monday to Sunday	Noise to be inaudible within a habitable room of any residential premises. 51 dB(A)	
Unavoidable Works	All times	No specified Noise Limit - noise reduction measures apply	

The construction scenarios assessed were:

- Scenario A: Station Box with no roof deck (Normal Working Hours)
- Scenario B: Station Box with roof deck (24-hours)
- Scenario C: Works for access across Royal Parade (Normal Working Hours)
- Scenario D: Concrete pour (Unavoidable Work).

The construction work for Scenario D would be undertaken predominantly during Normal Working Hours. However, it is anticipated there would be times when it cannot be completed during Normal Working Hours and would need to extend to outside of these times. This is expected to occur on a regular basis.

The predicted construction noise levels for Scenarios A, B, C and D are provided in the figures in Appendix A of this report.

Guideline Noise Levels apply for Scenario B only and would need to be met outside of Normal Working Hours. While Guideline Noise Levels do not apply during Normal Working Hours or for Unavoidable Works, there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation measures.

In addition to the above, general and specific noise mitigation are provided in Appendix A of this report. Specific noise mitigation includes:

- Roof deck over the station box
- Acoustic construction sheds over opening in the roof deck
- Noise barrier on the outside of the roof deck to be up to a height of 6 m (trucks would service the site within the noise barrier)

- Noise barrier between the construction work site on University Square and the residences on Leicester Street to be up to a height of 6 m
- Noise barrier between the construction work site on University Square and the residences on Barry Street to be up to a height of 6 m.

The proposed indicative locations for construction noise mitigation are shown in Figure 10-1.

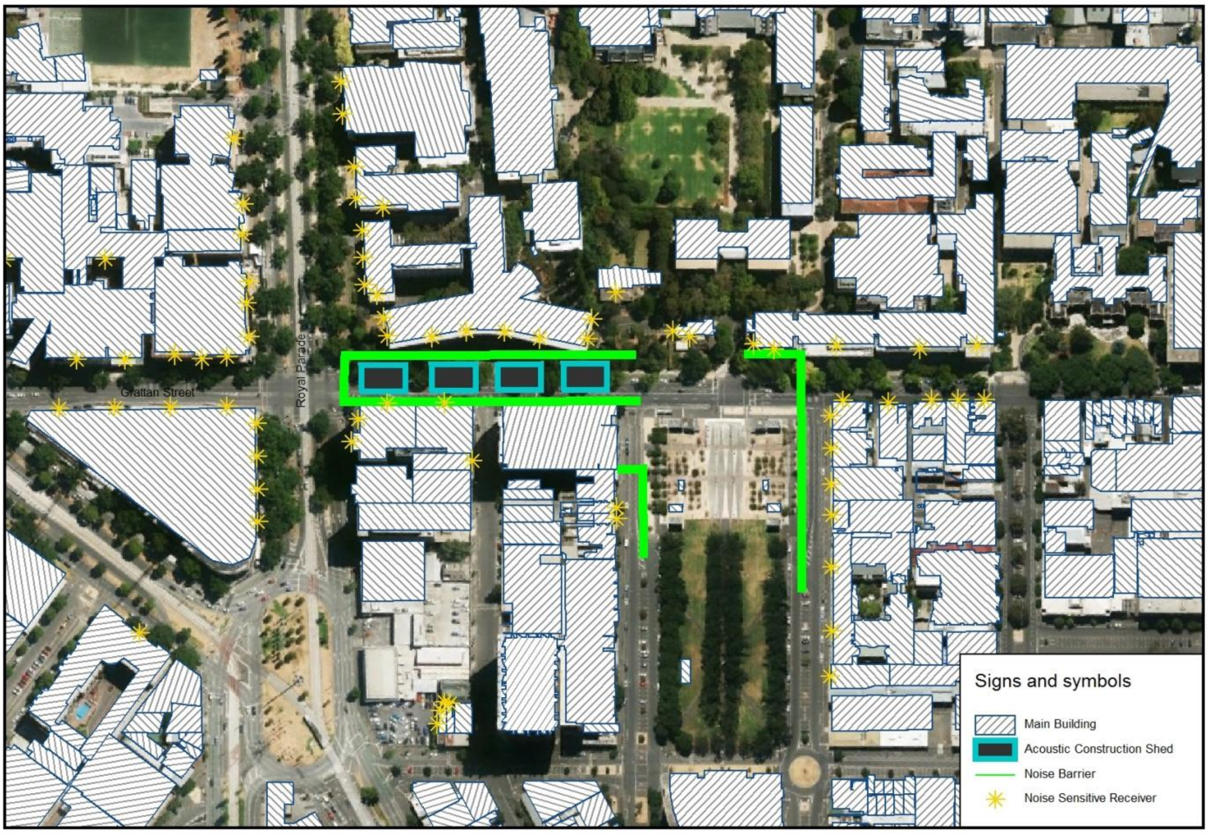


Figure 10-1 Mitigation for construction at Parkville

Compliance with the requirements of EPA 1254 is predicted to be achieved.

Parkville Station is a very busy area with trams, traffic, helicopters and recent construction work. In the vicinity of the construction work site the average daytime baseline noise levels were measured to be up to 74 dBL_{Aeq}. Many of the buildings in this area are sealed air-conditioned buildings and therefore the building façade provides a higher level of mitigation with respect to noise ingress than typical residential buildings that may rely upon natural ventilation.

For Scenario A, prior to the installation of acoustic mitigation, the noise levels at the nearby hospitals are predicted to be in the order of the existing noise levels. At the University of Melbourne Faculty of Medicine building and the Peter Doherty Institute the construction noise levels are predicted to be higher than the existing noise levels and potentially up to 77 dB(A) externally. This noise level would be regularly experienced in this precinct due to local sources.

Once the roof deck is located over the station box (Scenario B) and noise barriers up to 6 m are in place construction noise levels are predicted to be similar to existing baseline noise levels at the nearest residential / hospital sensitive receivers. Noise levels at all residential and hospital locations are predicted to comply with the Guideline Noise Levels outside of Normal Working Hours. The noise levels at the University of Melbourne Faculty of Medicine Building and the Peter Doherty Institute are predicted to be up to 74dB(A) (similar to existing).

With the mitigation proposed, external noise levels due to construction at the Victorian Comprehensive Cancer Centre, Royal Melbourne Hospital Melbourne Private Hospital are predicted to be in the order of the day time baseline noise levels for all construction scenarios at all levels of the buildings.

While compliance with the Guideline Noise Levels is predicted at the residences on Pelham and Berkeley Streets, it is recommended that construction vehicle use associated with the laydown site nearby to the properties is kept to a minimum outside of Normal Working Hours.

Scenario C is to be undertaken during Normal Working Hours and is for access across Royal Parade. This work is proposed to be conducted underground with an acoustic shed over the opening. Bored piling would occur during this time. Noise levels are predicted to be in the order of baseline daytime noise level at the Victorian Comprehensive Cancer Centre and the Royal Melbourne Hospital (and lower elsewhere). It is noted that both the Royal Melbourne Hospital and the Victorian Comprehensive Cancer Centre have sealed facades that would mitigate noise ingress.

For Scenario D, which includes Unavoidable Works, noise levels are predicted to be lower than the night time baseline noise levels at the nearby hospitals and residential locations.

10.5.1.1.1 Bio-resources

Bio-resources can be found in the Victorian Comprehensive Cancer Centre, Royal Melbourne Hospital, Peter Doherty Institute, Howard Florey Laboratories and the University of Melbourne Faculty of Medicine. Bio-resources can be sensitive to noise and in particular loud intermittent or unfamiliar noises. In the following locations the Bio-resources are located adjacent to the facades of the buildings facing the construction works:

- Victorian Comprehensive Cancer Centre – Level 8
- Royal Melbourne Hospital – Level 6
- PDI – Levels 8 and 9
- University of Melbourne Faculty of Medicine – Level 9.

In all cases the Bio-resources are in sealed air-conditioned buildings which provide a higher level of noise reduction with respect to airborne noise ingress when compared with naturally ventilated buildings.

As the airborne construction noise levels at the facilities are predicted to be similar to existing noise levels, the Bio-resources are not expected to be adversely impacted.

In the case of the University of Melbourne Faculty of Medicine and the Peter Doherty Institute, the construction noise levels are predicted to be higher than baseline average noise levels but no greater than the baseline noise levels associated with short-term events e.g. vehicle passbys. In these facilities the Bio-resources are located on the upper levels of the buildings adjacent to the Grattan Street façade. In the case of the University of Melbourne Faculty of Medicine the space has no windows. If, in practice, construction noise levels are at risk of causing disturbance to the Bio-resources then the façade to the relevant space may be able to be upgraded.

10.5.1.2 Vibration

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to Buildings

b) Underground Infrastructure

c) Human Comfort

d) Vibration-sensitive equipment, Highly Sensitive Areas and Bio-resources.

(i) Tunnelling

a) Damage to Buildings

It is predicted that vibration due to tunnelling would comply with the Guideline Targets in DIN 4150 for structural damage.

b) Underground Infrastructure

Refer to Table 7-10.

c) Human Comfort

Vibration levels are predicted to trigger Management Actions with respect to 'adverse comment' at some receiver locations and communication with affected parties would be required. These locations are:

- Royal Melbourne Hospital – at night 'adverse comments are probable' for up to 8 days
- Victorian Comprehensive Cancer Centre – at night 'adverse comments are probable' for up to 8 days.

The distance of the TBM to the receiver changes relatively quickly as the TBM progresses along the tunnel. As the TBM approaches the receiver, the vibration would increase to a peak and then reduce again as the TBM moves away. This results in the risk of 'adverse comment' for a limited time only. An analysis of the change in vibration has been conducted at the worst-case internal location directly over the alignment. Assuming that the TBM moves at a rate of approximately 11.5 m per day, the risk of adverse comment is predicted for approximately 9 days at the worst-case location within a building. This would occur twice (once for each tunnel) over the entire construction period.

Due to the short-term nature of disturbance-related impacts from tunnelling, these impacts would principally be managed by communication with potentially affected stakeholders. If vibration or ground-borne noise level and duration are not well tolerated by the sensitive receiver, then temporary relocation / respite may be an option. For University and hospital staff and patients relocation would not be a practical option and therefore close coordination and consultation with the affected parties and / or respite may be required. In the vicinity of the hospitals a restriction in operating hours of the TBM may be appropriate.

d) Vibration-sensitive Equipment, Bio-resources and Highly Sensitive Areas

Vibration-sensitive Equipment

An assessment of vibration-sensitive equipment in the vicinity of the Parkville construction work site has been undertaken and details are provided in Appendix B of this report.

The following locations have equipment that may be impacted based on the vibration prediction:

- Royal Women's Hospital
- Royal Melbourne Hospital
- Victorian Comprehensive Cancer Centre
- Peter Doherty Institute
- University of Melbourne, Buildings 170, 261(minor), 181
- Howard Florey Laboratories.

Vibration impacts would be of limited duration – approximately two weeks (twice), based on 24-hour operation, as each TBM progresses along the tunnel. If in practice this equipment is not able to be used for a period during tunnelling then the following is recommended:

- Communication with the stakeholders
- Temporarily reschedule the use of the equipment or utilise equipment at non-affected facilities
- Temporarily relocate the equipment to other non-affected facilities.

Bio-resources and Highly Sensitive Areas

There are a number of Highly Sensitive Areas within the Parkville Precinct such as hospital wards, operating theatres and there are also Bio-resources where Management Actions are predicted to be triggered for a period of approximately one week (twice). These include:

- Royal Melbourne Hospital - ICU, south wards and cardiology ward, Bio-resources in basement (marginal)
- Victorian Comprehensive Cancer Centre - Country patient accommodation and wards, Bio-resources on Level 8 (marginal)
- Howard Florey Laboratories - Bio-resources on the ground floor (marginal).

The approach for Management Actions in for these areas would include:

- Consultation with stakeholders
- Monitoring of the internal vibration levels to assess the actual impact during construction and level of disturbance
- Potential restriction of operational hours (to Normal Working Hours) of the TBM if the impact is causing disturbance.

Within each Highly Sensitive Area, a large variation in extent of the impact is predicted. An impact is predicted in some locations directly adjacent the façade closest to the tunnel alignment with this impact reducing with distance from that façade. At most locations, the predicted vibration (VDV) levels are below the Guideline Targets at the far side of the Highly Sensitive Area away from the tunnels alignment.

Limiting working hours to daytime hours for the section of tunnel adjacent to the Royal Melbourne Hospital, the Royal Women's Hospital and the Victorian Comprehensive Cancer Centre would result in vibration meeting the Guideline Targets at all locations except:

- ICU and cardiology ward (level 2) and Ward 3S at the RMH which would have some portion of the wards triggering Management Actions
- Country patient accommodation (level 1) and the medical ward (level 3) at the Victorian Comprehensive Cancer Centre.

(ii) Additional Construction Works

Many items of construction equipment are proposed for this site. The vibration predictions are based on assessment of vibration for rippers and 20-tonne rockbreakers as these are expected to be the most vibration intensive. The construction methodology is based upon rippers operating from ground level to a depth of 25 m and 20-tonne rockbreakers would operate at depths greater than 25 m in localised areas if the rippers are found not be effective. Ripping and rockbreaking works are to continue 24-hours a day, following construction of the station roof.

a) Damage to Buildings

The DIN 4150 Guideline Targets are predicted to be met at all buildings including heritage buildings.

Vibration predictions are less accurate for equipment in close proximity to a receiver (less than 5 m). Therefore, MMRA would need to undertake vibration monitoring to verify vibration levels when equipment is operated within 5 m of a building. This applies to ripping, rockbreaking and piling equipment.

b) Underground Infrastructure

There are a number of utilities within the Parkville station precinct and its surrounds. To avoid damage, the minimum buffer distances construction work should be from utilities are:

- 3 m for general utilities
- 5.5 m for Melbourne Water unreinforced assets.

Location of the utilities is to be confirmed by MMRA prior to the commencement of work.

c) Human Comfort

Management Actions are predicted to be triggered with respect the VDV levels when the ripper is working within 6.5 m of a receiver, which is expected to be for less than a day at the most affected receiver location. The following locations adjacent to the Parkville excavation would fall into this category (ground floor only facing the excavation):

- Peter Doherty Institute
- Alan Gilbert Building
- University of Melbourne Faculty of Medicine
- Howard Florey Laboratories
- University of Melbourne Engineering Building.
- A small number of University of Melbourne buildings located on the northern end of Barry Street.

It is expected that community consultation to inform stakeholders and careful scheduling of ripping works in close proximity of receivers would adequately manage this impact.

d) Vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas

An assessment of vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas in the vicinity of the Parkville construction work site has been undertaken and the details are provided in Appendix B of this report.

Vibration-sensitive Equipment

An assessment of vibration-sensitive equipment in the vicinity of the Parkville construction work site has been undertaken with respect to the ASHRAE Vibration Curves and baseline vibration measurements.

Compliance with the Guideline Targets for Vibration-sensitive equipment is achieved at:

- Royal Women's Hospital
- Melbourne Private Hospital
- University of Melbourne all locations (except as stated below)
- WEHI
- Kenneth Myer Building
- Gene technology Access Centre.

The Guideline Targets are potentially not met at:

- Royal Melbourne Hospital (Level 1 MRI and CT, Level 3 MRI)
- VCCC (Basement 2 Cyclotron and Basement 1 Linear Accelerators, Level 5 MRI
- Peter Doherty Institute (Basement, Ground Floor, Level 1 and Level 8)
- Faculty of Medicine, Confocal Microscopes
- Howard Florey Laboratories, Basement MRI.

The vibration predictions are based on the maximum vibration levels predicted to occur when rippers and rockbreakers are working in the nearest part of the excavation. The impact would reduce as the rippers and rockbreakers move away from sensitive receiver locations (both horizontally and deeper underground).

Rockbreakers are expected to affect equipment in the Victorian Comprehensive Cancer Centre and Royal Melbourne Hospital during excavation of the pedestrian entrance which is located in front of the Victorian Comprehensive Cancer Centre building. Ripping and rockbreaking works in the main station excavation on Grattan Street are not expected to affect equipment in the Royal Melbourne Hospital. The Victorian Comprehensive Cancer Centre linear accelerators are the only items of sensitive equipment in the Victorian Comprehensive Cancer Centre that would be affected by works in the main station excavation (linear accelerators only affected when rockbreakers are working at the western most 40 m of the excavation).

If in practice this vibration-sensitive equipment is not able to be used during certain construction activities then the following is recommended:

- Consultation with relevant stakeholders
- Vibration monitoring and monitoring of the performance of sensitive equipment when rippers and rockbreakers are working in the Victorian Comprehensive Cancer Centre pedestrian entrance
- Careful scheduling of ripping and rockbreaking works required in the Victorian Comprehensive Cancer Centre pedestrian entrance.
- The use of low vibration methods of material removal when excavating the pedestrian entrance outside the Victorian Comprehensive Cancer Centre. Low vibration methods of rock removal could include methods such as hydraulic splitting or chemical splitting of rock removal
- Communication with the stakeholders
- Temporarily reschedule the use of the equipment or utilise equipment at non-affected sites
- Temporarily relocate the equipment to other non-affected facilities – where practicable.

In order to manage the impacts on the sensitive receivers immediately adjacent to the main station excavation (Howard Florey Laboratories, University of Melbourne Faculty of Medicine and Peter Doherty Institute), MMRA would need to:

- Carefully scheduling ripping and rockbreaking works to manage impacts on sensitive receivers immediately adjacent to the main station excavation.
- Consult and negotiate closely with stakeholders in these buildings in order to develop a mutually acceptable schedule for ripping and rockbreaking work.
- Maintain buffer distances between excavation machinery and vibration-sensitive equipment whilst the vibration-sensitive equipment is in use. The buffer distances during the excavation works would be refined using vibration monitoring and by monitoring the performance of sensitive equipment. For the most vibration-sensitive pieces of equipment it is predicted that buffer distances of up to 100 m for the 20-tonne rockbreaker and 60 m for the ripper would be required. MMRA may also consider the option of relocating certain pieces of sensitive equipment during construction.

Vibration predictions have also been undertaken for bored piling which would occur around the perimeter of the Parkville Station excavation. Vibration levels due to bored piling are expected to be significantly lower than the rockbreaker levels. Vibration is, however, predicted to be higher than the Guideline Targets when within 50 m of:

- PDI (electron microscope and photon laboratory)
- VCCC (linear accelerators and Level 5 MRI)
- University of Melbourne Faculty of Medicine (confocal microscopes).

The impact would be managed as for the main station excavation.

Bio-resources

An assessment of vibration at the Bio-resources housed in the Parkville precinct has been undertaken. Compliance with the Guideline Targets is achieved at:

- Peter Doherty Institute
- Howard Florey Laboratories (one minor exceedance on the ground floor)
- WEHI
- University of Melbourne Faculty of Medicine.

Vibration levels are predicted to be higher than the Guideline Targets at:

- The basement of the Royal Melbourne Hospital
- Level 8 of the Victorian Comprehensive Cancer Centre (minor exceedance).

If in practice vibration levels are not considered to be appropriate for the Bio-resources then the following is recommended:

- Isolation of the housing for the Bio-resource
- Relocation of the Bio-resources further from the construction activity
- Use of less vibration intensive construction methods.

Highly Sensitive Areas

There are a number of Highly Sensitive areas identified in the Parkville precinct. These include wards and patient accommodation in:

- Royal Women's Hospital
- Royal Melbourne Hospital
- Victorian Comprehensive Cancer Centre.

The predicted vibration levels comply with the Guideline Targets in these areas.

10.5.1.3 Ground-borne noise

Details of the methodology and model used for the assessment of ground-borne noise are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

In Precinct 4, the predicted ground-borne noise level triggers Management Actions during both the evening and night Guideline Targets at a number of sensitive receivers in the vicinity of the tunnel alignment. These sensitive locations include:

- Royal Women's Hospital
- Royal Melbourne Hospital
- Royal Melbourne Hospital.

The locations are shown on figures in Appendix B of this report.

The highest ground-borne noise levels predicted are 40 to 52 dB(A). These are up to 17 dB above the Guideline Target and could cause disturbance.

Ground-borne noise may be audible in other buildings but should generally be tolerable during the day period when background noise levels are higher.

Highly Sensitive Areas

There are a number of Highly Sensitive Locations within the Parkville Precinct where Management Actions are triggered but where relocations would not be appropriate. Within each Highly Sensitive Area a large variation in extent of the impact is predicted. Locations directly adjacent the façade closest to the tunnel alignment would have the largest impact, with this impact reducing with distance from that façade. At most locations the predicted ground-borne noise levels are below the Guideline Targets at the far side of the Highly Sensitive Areas away from the tunnel alignment. These include:

- Wards and staff accommodation at the Royal Women's Hospital
- ICU, south wards and cardiology ward at the Royal Melbourne Hospital
- Country patient accommodation and wards at the Royal Melbourne Hospital.

The requirement for Management Actions is predicted to be less than one week. The approach for mitigation for these areas would include:

- Consultation with stakeholders
- Monitoring of the internal vibration levels to assess the actual impact during construction
- Restriction of the operational hours of the TBM (potentially to Normal Working Hours) if the impact is causing disturbance. This would extend the duration of the works.

Restricting working hours to daytime hours for the section of tunnel adjacent to these buildings would result in ground-borne noise meeting the Guideline Targets at all locations at night.

Bio-resources

With respect to Bio-resources ground-borne noise levels are predicted to comply with the target level of 50 dB (from the Code of Practice for the Housing and Care of Laboratory Mice, Rats, Guinea Pigs and Rabbits prepared by the Victorian Department of Primary Industries).

(ii) Additional Construction Works

Ground-borne noise is predicted to trigger Management Actions at one residential building on Barry Street (141 Barry St). This is only predicted to occur when the 20-tonne rockbreakers are working within 10 m of the southernmost perimeter of the Barry Street excavation. Compliance with the Guideline Targets would be achieved by scheduling the rockbreaking works in this area to during the daytime.

10.5.1.4 Controlled Blasting

Blasting has been considered for the Parkville station box excavation in order to reduce the overall duration and severity of vibration and ground-borne noise impacts associated with excavating the station box. Controlled blasting involves the use of multiple small explosive charges set off in a short sequence to remove a segment of rock whilst minimising vibration and ground-borne noise impacts. Blasts typically occur once or twice per day or every other day and potential impacts are limited to a short time window (a few seconds) rather than extended periods of heavy rockbreaker or ripper usage.

Blasting would occur once the concrete cover of the station box is placed over the excavation and would therefore not involve air overpressure, dust and fly rock impacts. This technique has been used on numerous tunnelling projects in urban areas within Australia including, CLEM7, Legacy Way and the Inner City Bypass in Brisbane as well as East Link in Melbourne. Controlled blasting has also been approved for the Brisbane Bus and Train Tunnel in Brisbane CBD and for NorthConnex tunnel in Sydney.

An assessment of the use of controlled blasting for the Parkville Station excavation was carried out to determine the potential impacts as well as any likely restrictions in terms of maximum charge weight size, buffer zones and other measures. The assessment was conducted for potential impacts including damage to structures, human comfort, sensitive equipment, Bio-resources and Highly Sensitive Areas.

The method used to for the assessment of impacts from controlled blasting was based on AS2187.2 using the following expression,

$$V = K\left(\frac{R}{W^{0.5}}\right)^{-B}$$

R - source-receiver separation distance (m)

W - Maximum Instantaneous Charge weight (kg)

K and B are site-specific constants dependent on geotechnical conditions and blast design

To estimate the mean (50 per cent probability of exceedance) peak particle velocities for blasting to a free face in average field conditions, K is taken as 1140 and B is 1.6. For the purpose of estimating 95th percentile peak particle velocities for the blasting to a free face in average field conditions for comparison with vibration limits in AS2187.2, K is taken as 2462 and B is 1.6.

The assessment assumes that controlled blasting begins at 25 m below ground level in relatively hard rock which would otherwise require removal using heavy rockbreakers.

The results of the assessment indicate that controlled blasting using productive charge weights is likely to be feasible at the Parkville station excavation and could assist in limiting the duration and severity of vibration impacts from an excavation plan based purely on the use of heavy rockbreakers and rippers. Vibration and ground-borne noise impacts from controlled blasting are expected to be manageable using appropriate mitigation measures as outlined below. Potential mitigations required to limit vibration and ground-borne noise impacts on nearby receivers include:

- Restricting blasting to outside the hours when nearby research buildings are normally occupied
- Observing exclusion zones or reducing charge weights close to the perimeter of the excavation, heritage and residential structures and within 20 m of the western end of the excavation
- Managing the risks associated with non-base-isolated sensitive instrument calibration and/or damage at Peter Doherty Institute and the University of Melbourne Faculty of Medicine Building by:
  - Base isolation for equipment that is not currently base isolated
  - Relocating equipment
  - Preparing non-essential equipment by placing it in a transport mode
  - Reducing charge weights local to the affected areas
  - Using lower vibration excavation techniques as determined on site.

Figure 10-2 shows the charge weights and predicted buffer zones for blasting at the Parkville station excavation based on the following analysis of blasting impacts and the constraints noted. These issues should be reviewed when trial blasting is carried out on site and site-specific factors and blast vibration mitigation mechanisms such as trenches, excavation walls and optimisation of the blast design are accounted for. In that case, MMRA may modify the charge weights and buffer distances shown.

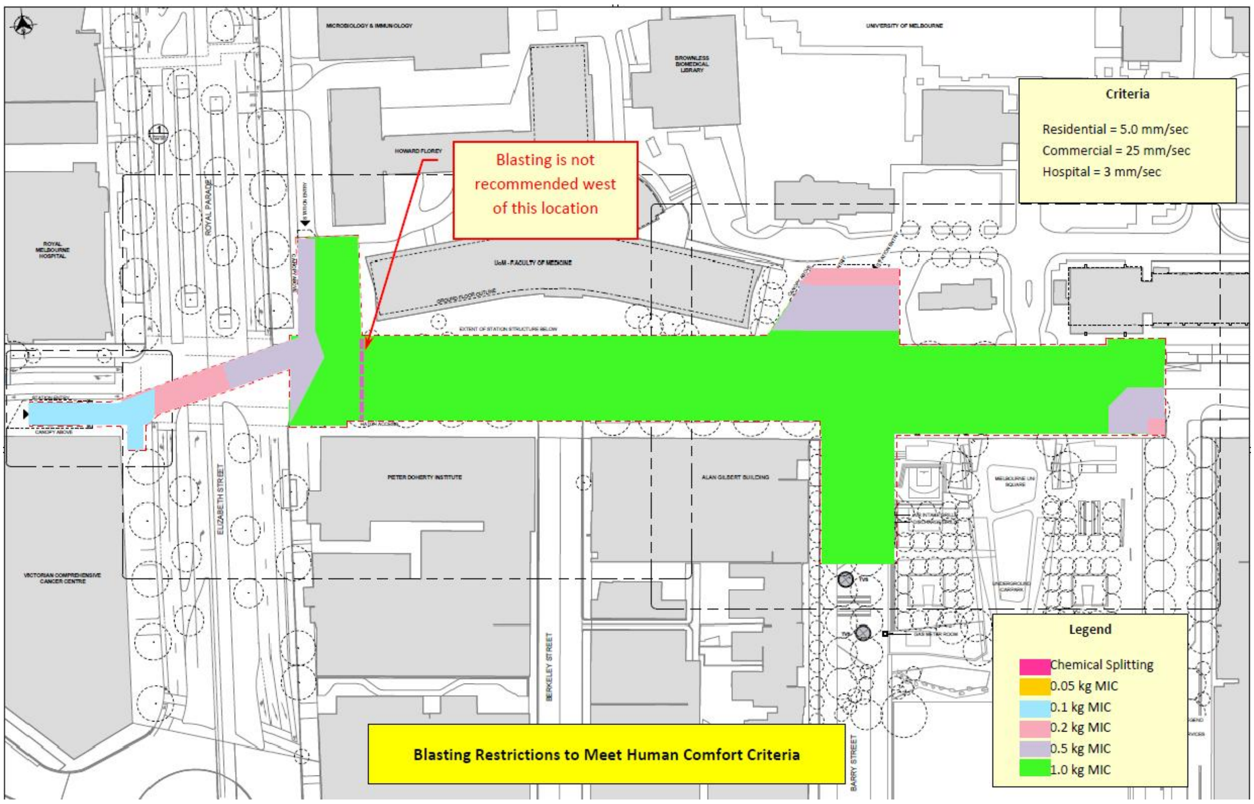


Figure 10-2: Controlled blasting charge weights and probable buffer and restriction zones for the Parkville station excavation for human comfort (contours based on a structural assessment of heritage buildings showing them to be no more vulnerable to vibration than a residential property)

Vibration – Damage to Buildings

Large commercial buildings belonging to research institutions and hospitals surround the Parkville Station box excavation. There are also a small number of terrace houses on Barry Street and Leicester Street that are regarded as being of heritage construction, as is the Vice Chancellor's residence at the University of Melbourne. The gatekeeper's cottage belonging to the University of Melbourne is specifically listed as a heritage structure. Each of these structural types attracts a different vibration guideline target for blasting based on AS 2187.2 and DIN 4150, being 50 mm/s PPV, 12.7 mm/s PPV and 3 mm/s PPV respectively.

The assessment of vibration levels due to blasting indicates that a typical Maximum Instantaneous Charge weight (MIC) of 1 kg could be used with the buffer slope distances in Table 10-11.

Table 10-11: Buffer Distances for Damage from Vibration for Controlled Blasting with a 1 kg MIC

Building Type	Minimum Buffer Distance, m
Commercial Building	12
Residential Buildings	30
Heritage Buildings	70

Note:

1. Smaller charges could be used at closer distances to commercial and residential structures in conjunction with a buffer zone of 15 m slope distance to heritage buildings, inside which low vibration techniques would need to be used in place of blasting

The restriction on blasting within a 70 m slope distance of heritage structures may limit productive blasting to about half of the footprint of the excavation site. It is possible that a structural and building condition assessment could be undertaken of the heritage buildings to enable an increase in the blasting vibration limit to 12.7 mm/s matching the residential structures. If such a reclassification is appropriate the limitations on blast sizes and distances would be the same as for the residential structures and a significantly increased productive blast area could be achieved based solely on structural damage considerations.

Vibration – Human Comfort

Vibration limits for blasting that relate to human comfort are 25 mm/s PPV for commercial receivers, 5 mm/s for residential receivers based on AS2187.2. A 3 mm/s PPV human comfort vibration limit has been proposed for hospital receivers based on research by Lenzen (Lenzen, K.H. 1966. Vibration of steel joist concrete slab floors. Engineering Journal, AISC, Vol. 3, No. 3, pp. 133-136) indicating that this should be no more noticeable than a heel drop or foot slam and therefore likely to be acceptable for human comfort in hospitals for a small number of events per day.

An assessment of the potential vibration impacts on human comfort from blasting indicates that when using a 1kg MIC the buffer slope distances in Table 10-12 would be appropriate.

Table 10-12: Buffer Distances for Human Comfort with respect to Vibration for Controlled Blasting with a 1 kg MIC

Building Type	Minimum Buffer Distance, m
Commercial Building	20
Residential Buildings	50

Note:

1. Commercial receivers are in close proximity to much of the excavation site and this may significantly limit the use of controlled blasting even if smaller charge weights were to be used when closer than 20 m.

In any use of controlled blasting, it would be necessary to conduct trial blasts on site to verify buffer distances and charge weights and this may lead to higher charge weights than forecast being feasible without increasing impacts. However, based on the analysis it is recommended that if controlled blasting is carried out that the blasts be conducted outside Normal Working Hours and in close consultation with the affected parties in order to minimise potential impacts whilst enabling blasting to be productive.

If blasting were conducted outside of the hours when the commercial buildings are normally occupied, then there are some minor restrictions at the western end of the excavation associated with buffer distances and reduced charge weights for preserving human comfort at the Royal Melbourne Hospital. Similar restrictions exist at the eastern end of the excavation in relation the Vice Chancellor’s residence at the University of Melbourne and other residential occupancies. Other limitations in terms of buffer distances and charge weights relate to the requirements for the avoidance of structural damage and for sensitive equipment and Highly Sensitive Areas as described below.

Vibration – Sensitive Equipment, Highly Sensitive Areas and Bio Resources

Vibration limits for the operation of vibration-sensitive imaging equipment, Highly Sensitive Areas and Bio-resources are the most stringent of the vibration requirements. In general, vibration-sensitive equipment is many times more sensitive to vibration than people. It is, therefore, not considered practicable to meet the vibration requirements for the operation of vibration-sensitive equipment during blasting events, however these last only a few seconds and one of the benefits of controlled blasting is that the vibration-sensitive equipment is usable outside of those short intervals. For controlled blasting, it is recommended that Management Actions apply consisting of:

- Close consultation with the affected parties
- Notification of any blasting schedule

- Sensitive imaging equipment not be used during blasting
- Negotiation with stakeholders having special need for the use of sensitive imaging equipment, which may require scheduled breaks in the blasting program.

There are no recognised vibration limits relating to the prevention of calibration issues or damage to the vibration-sensitive equipment due to vibration from controlled blasting, however this is a risk that needs to be managed.

It is recommended that a 3 mm/s PPV threshold on the base of vibration-sensitive equipment be considered as a trigger level for identifying potential issues. Discussions with equipment providers and trial blasts on site may be used to determine whether higher vibration limits can apply for avoidance of equipment recalibration issues.

Equipment that is base isolated or remote from the excavation site is not expected to be at risk. If controlled blasting is avoided until approximately 20 m from the western end of the main Grattan Street excavation, then potential issues are expected to be limited to non-base isolated vibration-sensitive equipment in the Peter Doherty Institute and the University of Melbourne Faculty of Medicine Building. Potential Management Actions for these sites include:

- Provision of base isolation for equipment that is not currently base isolated
- Relocation of equipment
- Preparation of non-essential equipment by placing it in a transport mode
- Reduction of charge weights local to the affected areas
- Use of lower vibration excavation techniques local to the affected areas.

Highly Sensitive Areas include:

- Operating theatres and wards at the Royal Melbourne Hospital
- Operating theatres and wards at the Melbourne Private Hospital
- Operating theatres and wards at the Royal Women’s Hospital
- Victorian Comprehensive Cancer Centre.

There are also Bio-resources at:

- Peter Doherty Institute
- Victorian Comprehensive Cancer Centre
- Howard Florey Laboratories
- Royal Melbourne Hospital.

A blast vibration assessment for a nominal 1 kg MIC and 20 m blast exclusion zone at the western end of the Grattan Street excavation indicates compliance (i.e. vibration levels of less than 3 mm/s PPV) at Highly Sensitive Areas at:

- Royal Melbourne Hospital
- Royal Women’s Hospital
- Melbourne Private Hospital
- Victorian Comprehensive Cancer Centre.

Biological resources at the Peter Doherty Institute and the University of Melbourne are also predicted to have vibration levels below 3 mm/s PPV.

Ground-borne noise estimates for controlled blasting have been generated for bio-resources for comparison with Guideline Targets of 85 dBL (short exposure) and ambient noise measurements taken at some of the Bio-resource locations.

Ground-borne noise estimates were developed based on vibration spectra for construction blasts from US Bureau of Mines research and noise radiation characteristics of a typical brick/concrete room construction. Based on this approach, a vibration level of 3 mm/s PPV in the receiver space would generate a ground-borne noise level inside the room that is less than the 85 dBL Guideline Target (once the frequency thresholds for biological resources are applied).

This means that if vibration levels below 3 mm/s PPV in Bio-resource receiver spaces then the ground-borne noise Guideline Target is predicted to be achieved. Therefore, bio-resources in buildings adjacent to the Grattan Street excavation, which are located at high levels within those buildings are predicted to experience ground-borne noise levels that are below the Guideline Target for the blast design analysed and that ground-borne noise impacts on biological resources at Parkville would be manageable without placing significant additional restrictions on the blast design.

10.5.2 Operation

10.5.2.1 Airborne Noise

Airborne Noise from Trains

Details of the methodology and model used for the assessment of airborne noise from trains is provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

Airborne noise from trains is predicted to be insignificant as the trains would be below ground in the tunnels.

Airborne Noise from Fixed Plant

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure is provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

Ventilation and other fixed plant noise must meet the relevant SEPP N-1 Noise Limits at the Noise Sensitive Areas (NSA). As the ventilation needs to be able to operate 24-hours, achieving the night Noise Limit (the most onerous Noise Limit) implies Day and Evening Period limits would also be met.

The fixed plant noise in Precinct 4 is associated with the:

- Tunnel Ventilation System
- Over Track Extract fans
- Over Platform Extract Fans
- Over Concourse Extract fans
- Back of House ventilation systems
- Chiller plant.

The fans would be enclosed or located underground and the louvre/grilles would effectively be a noise source to the surrounding environment. The proposed location of the intake louvre of the pressurisation fan is shown in Figure 10-3.

The nearest NSAs are the ward areas of the Royal Melbourne Hospital (corner of Grattan Street and Royal Parade) and the residential areas to the south of the proposed Parkville Station on Berkeley Street, Barry Street and Leicester Street.

Noise measurements have been conducted in a number of locations. Those most representative of the background noise levels of the nearest NSAs are shown as red dots in Figure 10-3 and detailed in Table 10-13.

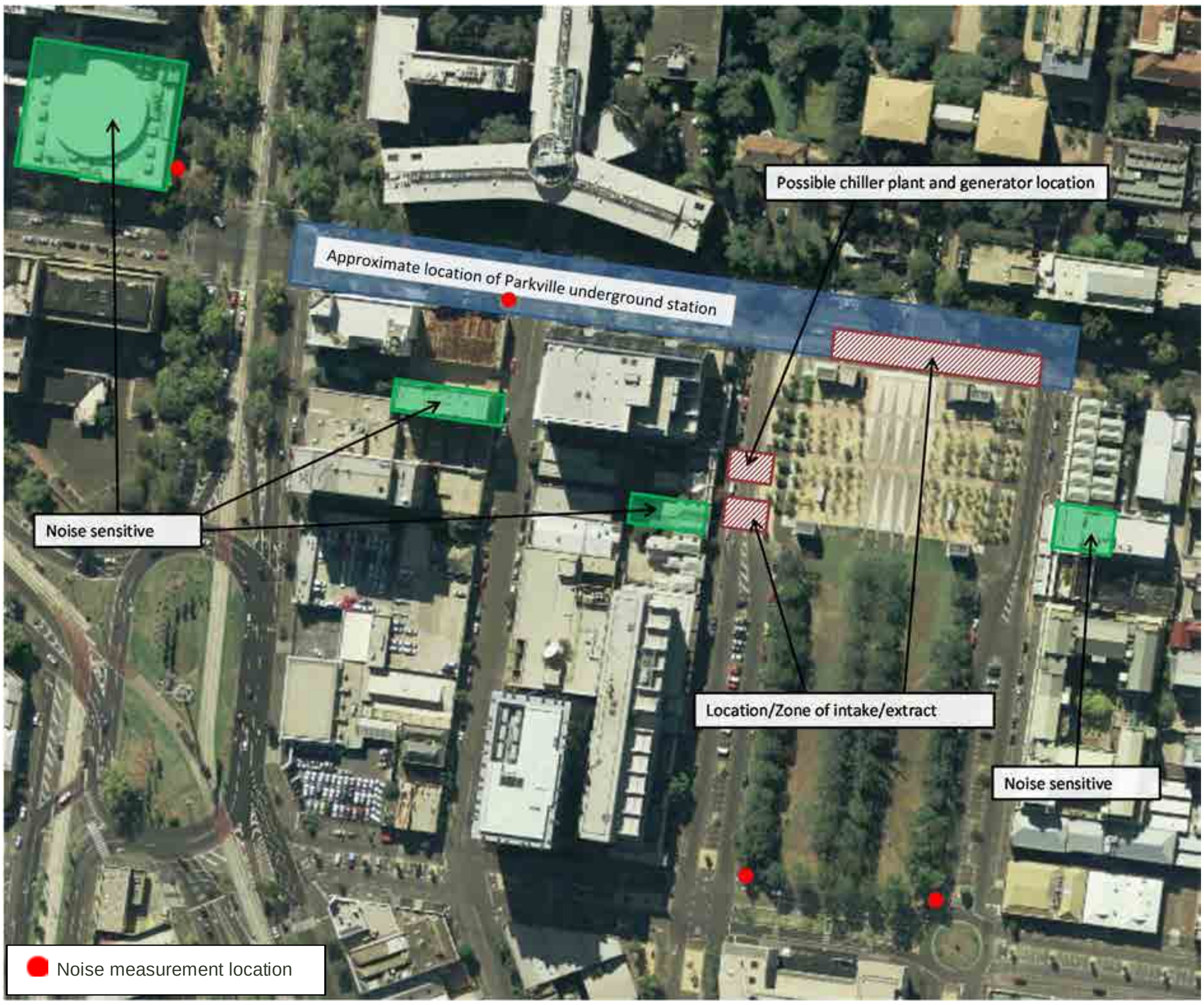


Figure 10-3 Location of fixed noise sources, measurements of attended background noise levels (red dots) and NSAs for Precinct 4

The SEPP N-1 Noise Limits are provided in Table 10-13. The Noise Limits apply to all industrial, commercial and retail noise sources, so that the effective Noise Limit for any individual source may be less than the Noise Limit.

Table 10-13 SEPP N-1 Noise Limits for Precinct 4

Location	Period	Noise Limit dBL$_{Aeq,30\ minutes}$
139 Barry Street, Carlton	Day	60
	Evening	52
	Night	47
223 Berkeley Street, Parkville	Day	64
	Evening	59
	Night	50
224 Leicester Street, Carlton	Day	60

Location	Period	Noise Limit $dBL_{Aeq,30\ minutes}$
	Evening	53
	Night	45
Royal Melbourne Hospital	Day	67
	Evening	62
	Night	58

The fan selections and duct layouts between the fans and the external grilles have not been made but it is expected that the Noise Limits may be achieved with the use of one or more of the following mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ductwork
- Plenum (lined or unlined)
- Acoustic barriers or screens

10.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels for operation have been compared with the Guideline Targets for each type of building/occupancy. Mitigation has been proposed where the Guideline Targets have been predicted to be exceeded. The outcomes are as follows:

a) Damage to Buildings

Compliance with Guideline Targets is predicted.

b) Human Comfort

Based on 'Standard Attenuation' track, the human comfort vibration levels are predicted to comply with vibration 'Preferred' VDV Guideline Targets.

c) Vibration-sensitive equipment, Highly Sensitive Areas and Bio-resources

Without mitigation, several items of vibration-sensitive equipment as well as several highly sensitive areas are predicted to exceed Guideline Targets, while all bio-resources are predicted to comply with Guideline Targets. To mitigate these vibration impacts at Parkville, trackform with 'Very High Attenuation' properties is predicted to be required. After mitigation, all sensitive equipment and highly sensitive areas assessed are predicted to comply with the vibration Guideline Targets.

10.5.2.3 Ground-borne noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

The predicted ground-borne noise levels for operation have been compared with the Guideline Targets for each type of building / occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

Based on 'Standard Attenuation' track, the ground-borne noise levels are predicted to exceed the target values by up to and greater than 10 dB at a number of locations across the alignment as shown in the Figures in Appendix E of this report. To mitigate ground-borne noise for the Parkville station precinct, track with 'Very High Attenuation' properties is predicted to be required. With this mitigation, compliance with Guideline Targets is predicted.

10.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 10-14.

Table 10-14: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting buried pipework	Manage vibration in compliance with Guideline Targets in DIN 4150	To be assessed by Proponent.	To be assessed by Proponent.
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for tunnelling	Period of potential impact up to 9 days (twice)	Medium
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for Additional Construction Works	Period of potential impact <1 day at some buildings	Medium
Construction vibration impacting on vibration-sensitive equipment	Manage vibration with respect to the Guideline Targets provided for tunnelling	Impact for up to 17 days.	Medium
Construction vibration impacting on vibration-sensitive equipment	Manage vibration with respect to the Guideline Targets provided for Additional Construction Works	Impact would be reduced using less vibration intensive construction equipment	Medium
Construction vibration impacting on Highly Sensitive Areas	Manage vibration VDV with respect to the Guideline Targets provided for tunnelling	Impact for up to 9 days.	Medium
Construction vibration impacting on Highly Sensitive Areas	Manage vibration with respect to the Guideline Targets provided for Additional Construction Works	Compliance	Low
Construction vibration impact on Bio-resources	Manage vibration with respect to the Guideline Targets provided for tunnelling	Minor impact for approximately one week	Medium
Construction vibration impacting on Bio-resources	Manage vibration with respect to the Guideline Targets provided for Additional Construction Works	Use of less intensive vibration methods to mitigate this risk	Medium
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided for tunnelling	See Section 7	Medium
Ground-borne noise impact on Highly Sensitive Areas	Manage ground-borne noise with respect to the Guideline Targets provided for tunnelling	Impact for less than one week	See Section 7

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Ground-borne noise impact on Bio-resources	Manage ground-borne noise with respect to the Guideline Targets provided for tunnelling	Compliance	Low
Ground-borne noise	Manage with respect to the Guideline Targets provided for Additional Construction Works	General Compliance	Low
Ground-borne noise – Highly Sensitive Areas	Manage ground-borne noise with respect to the Guideline Targets provided for additional construction works	Compliance	Low
Ground-borne noise – Bio-resources	Manage ground-borne with respect to the Guideline Targets provided for additional construction works	Compliance	Low
Blasting	Compliance with AS2187.2	Compliance with and charge sizes are controlled	Low
Operation			
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets provided	Compliance	Low
Vibration-sensitive Equipment	Compliance with Guideline Targets for Vibration-sensitive Equipment	Compliance	Low
Highly Sensitive Areas	Compliance with Guideline Targets for Vibration-sensitive Equipment	Compliance	Low
Bio-resources	Compliance with Guideline Targets for Vibration-sensitive Equipment	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

Note: General compliance means that any non-compliance is minor, localised and the impacts are not expected to be significant.

10.7 Environmental Performance Requirements

Table 10-15 and Table 10-16 provide the recommended Environmental Performance Requirements for the noise and vibration for Precinct 4: Parkville Station for construction and operation respectively.

Table 10-15 Environmental Performance Requirements for Construction for Precinct 4: Parkville station

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV002, NV004, NV008, NV0010, NV011, NV012, NV013, NV017, NV019, NV023, NV026, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.		NV001, NV002, NV004, NV008, NV0010, NV011, NV012, NV013, NV017, NV019, NV023, NV026, NV028
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements as per EPA 1254 – Community consultation – Noise barriers up to a height of 6 m – Acoustic construction sheds – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Noise monitoring	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Amenity and appropriate acoustic environment</td>
<td>Airborne noise from construction</td>
<td>Implement management actions if construction noise exceeds the internal noise levels below for Highly Sensitive Areas (based on AS/NZS 2107:2000) and a noise sensitive receptor is adversely impacted.
<table>
<tr><th>Highly Sensitive Area</th><th>Maximum Internal Construction Noise Level
$L_{Aeq, 15 mins}$</th></tr>
<tr><td>Intensive Care Wards</td><td>45</td></tr>
<tr><td>Operating Theatres</td><td>45</td></tr>
<tr><td>Surgeries</td><td>45</td></tr>
<tr><td>Wards</td><td>40</td></tr>
</table>
</td>
<td>– Community consultation
– Acoustic construction sheds
– Construction methodology / equipment
– Prepare and implement a construction noise and vibration management plan
– Internal noise monitoring</td>
<td>NV001</td>
</tr>
<tr>
<td>Building / structural integrity</td>
<td>Building damage from construction vibration</td>
<td>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.

Short-term vibration on structures
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies
mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:
1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
4. Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.</td>
<td>– Selection of construction equipment / construction methodology
– Bored piling
– Community consultation
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded</td>
<td>NV002
NV017</td>
</tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td>
<i>Long term vibration on structures</i>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
Notes:
1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.
</td><td></td><td></td></tr>
<tr><td>Underground infrastructure</td><td>Damage to underground infrastructure</td><td>
Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved.
<table>
<tr><th>Pipe Material</th><th>Vibration Velocity, mm/s (PPV)</th></tr>
<tr><td>Steel</td><td>100</td></tr>
<tr><td>Clay, concrete, reinforced concrete, prestressed concrete, metal</td><td>80</td></tr>
<tr><td>Masonry, plastic</td><td>50</td></tr>
</table>
Notes:
1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework.
2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro).
3. Compliance is to be achieved with asset owner’s Utility Standards
</td><td>– Selection of methodology / equipment
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Bored Piling
– Minimum buffer distance</td><td></td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV (m/s^{1.75})</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.</td><td>– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
– Bored piling
– Buffer distances
– Operating hours</td><td>NV004
NV019</td></tr>
<tr><td>Operation of vibration-sensitive equipment</td><td>Construction vibration causing disturbance to vibration-sensitive equipment</td><td>Implement Management Actions if the ASHRAE equipment vibration Guideline Targets or measured background levels (whichever is higher) are exceeded for vibration-sensitive equipment during construction and operation at Parkville and CBD North stations.
<table>
<tr><th>Equipment requirements</th><th>Curve</th></tr>
<tr><td>Bench microscopes up to 100x magnification; laboratory robots</td><td>Operating Room</td></tr>
<tr><td>Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc.</td><td>VC-A</td></tr>
<tr><td>Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths</td><td>VC-B</td></tr>
<tr><td>Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1 mm detail size</td><td>VC-C</td></tr>
<tr><td>Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photo-lithography with line widths of ½ micro m; includes electron beam systems</td><td>VC-D</td></tr>
</table></td><td>– Community consultation
– Selection of methodology / equipment
– Minimum buffer distances</td><td>NV036</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td><table><tr><td>Unisolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ¼ micro m; includes electron beam systems</td><td>VC-E</td></tr></table>Note:
1. The Proponent may undertake consultation with the users and agree alternative Guideline Targets.</td><td></td><td></td></tr>
<tr><td>Residential amenity</td><td>Construction ground-borne noise impacting upon amenity</td><td>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.<table><tr><th>Time Period</th><th>Internal Target, $L_{Aeq,15min}$ (dB)</th></tr><tr><td>Evening, 6pm to 10pm</td><td>40</td></tr><tr><td>Night, 10 pm to 7am</td><td>35</td></tr></table>Note:
1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.</td><td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite/temporary relocation
– Selection of construction equipment/construction methodology
– Bored piling</td><td>NV026
NV028</td></tr>
<tr><td>Amenity</td><td>Structural damage, impact on amenity</td><td>Comply with Australian Standard AS2187.2-2006, Explosives – Storage and use Part 2 – Use of explosives for all blasting
For Highly Sensitive Areas, hospital wards, operating theatres and Bio-resources and areas with vibration-sensitive equipment which are not covered in AS2187.2-2006, develop a plan in consultation with facilities owners that:
– Avoids damage to vibration-sensitive equipment
– Minimises adverse impact on Highly Sensitive Areas and Bio-resources</td><td>- Charge size
- Buffer distances</td><td></td></tr>
<tr><td>Amenity for Bio-resources</td><td>Disturbance to Bio-resources</td><td>To protect the amenity of Bio-resources and sensitive research during construction and operation the following criteria apply:
– Background noise should be kept below 50 dB and should be free of distinct tones (internal).
– Short exposure should be kept to less than 85 dB (internal).
Notes:
1. The levels above should take into consideration the frequency threshold for the Bio-resource under consideration.
2. Higher levels may be acceptable if it can be shown that the Bio-resource under consideration is exposed to higher levels and is not adversely impacted by them.</td><td>– Selection of construction equipment/construction methodology
– Noise monitoring
– Buffer distances</td><td>NV012
NV013</td></tr>
</table>

Table 10-16 Environmental Performance requirements for Operation for Precinct 4: Parkville station

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="5">Operation</td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td></td><td>NV030,
NV032,
NV036,
NV038</td></tr>
<tr><td>Residential amenity</td><td>Airborne noise from fixed infrastructure</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork / plenums
– Acoustic barriers / screens</td><td>NV032</td></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV (m/s^{1.75})</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>– Track vibration isolation.</td><td>NV034</td></tr>
</table>

<table>
<tr>
<td>Operation of vibration-sensitive equipment</td>
<td>Construction vibration causing disturbance to vibration-sensitive equipment</td>
<td>Implement Management Actions if the ASHRAE equipment vibration Guideline Targets or measured background levels (whichever is higher) are exceeded for vibration-sensitive equipment during construction and operation at Parkville and CBD North stations.
<table>
<tr><th>Equipment Requirements</th><th>Curve from ASHRAE</th></tr>
<tr><td>Bench microscopes up to 100x magnification ; laboratory robots</td><td>Operating Room</td></tr>
<tr><td>Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc.</td><td>VC-A</td></tr>
<tr><td>Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths</td><td>VC-B</td></tr>
<tr><td>Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1 mm detail size</td><td>VC-C</td></tr>
<tr><td>Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ½ micro m; includes electron beam systems</td><td>VC-D</td></tr>
<tr><td>Un-isolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ¼ micro m; includes electron beam systems</td><td>VC-E</td></tr>
</table>
Notes: 1. The Proponent may undertake consultation with the users and agree alternative Guideline Targets.</td>
<td>– Community consultation
– Selection of methodology / equipment
– Minimum buffer distances</td>
<td>NV008
NV023</td>
</tr>
<tr>
<td>Amenity</td>
<td>Operational ground-borne noise impacting upon amenity</td>
<td>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td rowspan="2">Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
</table></td>
<td>– Track vibration isolation</td>
<td>NV038</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>
<table>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>
1. RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
2. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
3. Assessment location is internal near to the centre of the most affected habitable room.
4. L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
5. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.
6. The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue
</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amenity for Bio-resources</td>
<td>Disturbance to Bio-resources</td>
<td>To protect the amenity of Bio-resources and sensitive research during construction and operation the following criteria apply:
– Background noise should be kept below 50 dB and should be free of distinct tones (internal).
– Short exposure should be kept to less than 85 dB (internal).
Notes:
1. The levels above should take into consideration the frequency threshold for the Bio-resource under consideration.
2. Higher levels may be acceptable if it can be shown that the Bio-resource under consideration is exposed to higher levels and is not adversely impacted by them</td>
<td>– - Track vibration isolation</td>
<td></td>
</tr>
</table>

11 Precinct 5: CBD North Station

11.1 Project Components

11.1.1 Infrastructure

The project infrastructure in Precinct 5 is proposed to consist of:

- Station under Swanston Street, between Franklin and Latrobe Streets
- Entrances to the station would be on the:
  - East side of Franklin Street
  - Corner of Swanston and Latrobe Streets
  - Underground connection to Melbourne Central station (Option 2), excluding 393 Swanston Street
- Plant room located under Franklin Street, between Swanston and Bowen Streets and Swanston and Stewart Streets
- Plant room located at A'Beckett Street between Swanston Street and Stewart Street.

11.1.2 Locality

Precinct 5 is a busy education and commercial precinct, which includes a range of land uses. It is highly developed with a mix of modern and heritage buildings. Trams run along Latrobe Street and Swanston Street.

Sensitive receivers in the vicinity of the construction activities include:

- RMIT University (including vibration-sensitive equipment)
- Residential apartment towers
- State Library of Victoria
- Melbourne City Baths.

Key items of vibration-sensitive equipment at RMIT are provided in Table 11-1.

Table 11-1 Key items of vibration-sensitive equipment at RMIT

Location	Vibration-sensitive Equipment
Basement 2, Building 100	- Robotics lab
Level 7, Building 14	- Electron microscope
Level 5, Building 14	- Confocal microscope
Ground Floor, Building 3	- NMR Spectrometer
Building 12	- Acoustic Chambers
Level 4, Building 7	- The Fib (Ion beam manufacturing tool)
Level 9, Building 12	- Photonics Lab

11.1.3 Construction

Construction is proposed to consist of:

- Cut and cover box for the Franklin Street shaft and entrance which would include ventilation at the surface
- Cut and cover box for the Latrobe Street shaft and entrance which would include ventilation at the surface
- Mined station cavern and tunnels using roadheaders
- Construction of station entrances and connection to Melbourne Central station ventilation and maintenance access in A'Beckett Street which would require surface construction
- Maintenance access in Franklin Street between Swanston Street and Stewart Street which would require surface construction
- Property demolition
- Protection of underground utilities
- Establishment of work sites at Franklin Street (east of Swanston Street), demolished buildings on Latrobe Street
- Station architectural and service fit out
- Underground track-works and installation of underground rail systems.

The work to construct CBD North Station is planned to occur over a period of approximately 3 years. Cavern lining and excavation / main cavern roadheader works would take approximately 1 year.

Above ground works are proposed to be undertaken during Normal Working Hours. Underground works such as mining of station caverns, tunnelling, underground excavations and underground concrete pouring are proposed to occur over 24-hours.

11.1.4 Operation

Operation is proposed to consist of:

- Trains below ground in the tunnels
- Fixed infrastructure consisting of ventilation for the station
- Pedestrian access.

11.2 Existing Conditions

Details of baseline noise and vibration measurements are provided in Appendix F of this report.

External Ambient Noise

The results of external ambient noise measurements are provided in Table 11-2. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in the vicinity of construction or future fixed infrastructure, then the parameters provided are consistent with information for the EPA 1254 assessment or the SEPP N-1 assessment.

Table 11-2 External ambient noise measurements

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
Level 28, Verve Apartments, 479 Swanston Street, Melbourne	59	61	57	60	53	56
Level 1,QV Apartments, 300 Swanston Street, Melbourne	58	61	60	62	54	58
Latrobe House, 200 Latrobe Street, Melbourne	63	69	63	68	58	63
31 A'Beckett Street, Melbourne	63	66	60	63	50	52
81 Franklin Street, Melbourne	64	69	59	64	54	55

The noise monitoring levels reflect the busy environment in which this project would be undertaken. The measurements taken at QV Apartments were on the first floor balcony overlooking Swanston Street while the measurements at Verve were on the 28th floor.

External Vibration Measurements

The maximum external vibration levels measured are provided in Table 11-3.

Table 11-3 External Vibration Measurements

Location	Maximum PPV Levels (mm/s)	Comments
City Baths, Swanston Street, Melbourne	1.6	Tram at 10 m
Microelectronics and Material Technology Centre, RMIT	5.2	Dual carriage tram at 10 m travelling over rail joints
State Library of Victoria, Melbourne	3.2	Tram at 15 m travelling over rail joints.

Internal Vibration

A summary of the vibration measurements undertaken in areas where there is vibration-sensitive equipment or similar is provided in Table 11-4.

Table 11-4: Summary of baseline floor vibration measurements at RMIT

Location	Baseline 1/3rd octave level (µm/s RMS)	Baseline VC from ASHRAE
Basement 2, Building 100 – Robotics Laboratory	3	VC-D
Level 7, Building 14 – Electron Microscope	18	VC-B
Level 5, Building 14 – Confocal Microscope	14	VC-B
Ground Floor, Building 3 – NMR Spectrometer	6	VC-D
Level 4, Building 7 – The Fib	22	VC-B
Level 9, Building 12 – Photonics Laboratory	19	VC-B

11.3 Key Issues

The key issues associated potentially with the Concept Design are identified in Table 11-5.

Table 11-5 Key issues associated with the Concept Design

Concept Design	Potential Issue
Construction	
Airborne noise	- Impact on amenity from 24-hour construction activity
Vibration	- Damage to structures - Impact on residential amenity - Disturbance to operation of vibration-sensitive equipment
Ground-borne noise	- Impact on amenity from 24-hour construction activity
Operation	
Airborne noise	- Noise from ventilation would need to comply with SEPP N-1
Vibration	- Damage to structures - Impact on amenity - Disturbance to operation of vibration-sensitive equipment
Ground-borne noise	- Impact on amenity

11.4 Benefits and Opportunities

Table 11-6 presents the benefits and opportunities associated with each part of the Concept Design.

Table 11-6: Benefits and opportunities associated with the Concept Design

Concept Design	Benefits	Opportunities
Station cavern construction methodology allows much of the construction to occur underground	Reduction in airborne construction noise at noise sensitive receivers	
Deep alignment	Reduction in noise and vibration from construction and operation at sensitive receivers when compared with the shallow alignment	

11.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria / Guideline Targets (and indicators where relevant) relevant to this assessment are provided in Section 2.1.

11.5.1 Construction

11.5.1.1 Airborne Noise

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report.

For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

Guideline Noise Levels

The at sensitive locations in the vicinity of the construction activity are provided in Table 11-7 and are based on the noise levels measured at the QV Apartments, 300 Swanston Street, Melbourne. This measurement is considered to be suitable for the determination of the Guideline Noise Levels because it was on the Level 1 balcony overlooking Swanston Street.

Table 11-7: Construction Guideline Noise Level

Time Period	Applicable Hours	Guideline Noise levels, $L_{\text{Aeq,15 minutes}}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday	No specified Guideline Noise Level - noise reduction measures apply	
	7am to 1pm Saturday		
Weekend / Evening work	6pm to 10pm Monday to Friday	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more. 70 dB(A)	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more. 65 dB(A)
	1pm to 10pm Saturday		
	7am to 10pm Sunday and Public Holidays		
Night	10pm to 7am Monday to Sunday	Noise to be inaudible within a habitable room of any residential premises. 48 dB(A)	
Unavoidable Works	All times	No specified Guideline Noise Level - noise reduction measures apply	

The construction scenarios assessed were:

- Scenario A Demolition (Normal Working Hours)
- Scenario B Shaft Construction (24-hours)
- Scenario C Cavern Construction (24-hours)
- Scenario D Concrete Pour (24-hours, Unavoidable Work).

The construction work for Scenario D would be undertaken predominantly during Normal Working Hours. However, it is anticipated there would be times when it cannot be completed during Normal Working Hours and would need to extend to outside of these times. This would be Unavoidable Work, which is expected to occur on a regular basis.

Scenarios B and C are to meet the Guideline Noise Levels outside of Normal Working Hours.

The predicted construction noise levels for Scenarios A, B, C and D, are provided in figures in Appendix A of this report.

Guideline Noise Levels apply for Scenarios B and C and while they do not apply for Scenarios A and D there would be requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation

- Implementation of mitigation.

In addition to the above, both general and specific noise mitigation are provided in Appendix A of this report. Specific noise mitigation for which compliance with the Guideline Noise Levels is predicted to be achieved includes:

- Acoustic construction sheds (with noise lock lobbies) so that when trucks enter and leave the sheds there would always be one set of doors between the outside and the construction works). MMRA may propose alternative options, which also achieve compliance.

For Scenarios B and C compliance with the Guideline Noise Levels is predicted when the roadheader is submerged within the tunnels.

Scenario D is for concrete pouring. This work is proposed to be undertaken during Normal Working Hours. However, if it is not completed it could extend into outside of Normal Working Hours. This would be Unavoidable Work and Guideline Noise Levels do not apply. The activity is anticipated to occur daily in varying locations. The proposed indicative locations for construction noise mitigation are shown in Figure 11-1.

Figure 11-1: Mitigation for construction at CBD North station

Compliance with the requirements of EPA 1254 is predicted to be achieved.

In the vicinity of CBD North Station the average noise levels during the day period were measured to be 61 dBL_{Aeq} at the sensitive receivers on Swanston Street and 69 dBL_{Aeq} at the sensitive receivers on Latrobe and Franklin Streets. The average noise levels during the night period were measured to be 57 dBL_{Aeq} at the sensitive receivers on Swanston Street and 63 dBL_{Aeq} at the sensitive receivers on Latrobe and Franklin Streets.

Initially, construction activities (demolition and shaft construction Scenarios A and B) are proposed to be undertaken during Normal Working Hours and Guideline Noise Levels do not apply. Noise associated with these activities is predicted to be higher than the existing noise levels at some locations in the vicinity of these works. The noise levels associated with this work would, however, be similar to other construction work and short term events that occur within the city during Normal Working Hours.

Scenario B (following initial shaft construction) and Scenario C are proposed to be 24-hour work and when undertaken in acoustic construction sheds (with noise lock lobbies so that when trucks enter the sheds there would only be one door open at a time) with the roadheader submerged within the tunnel, compliance with the Guideline Noise Levels is predicted.

MMRA would need to prepare a construction methodology showing compliance with the Guideline Noise Levels for work to be undertaken outside of Normal Working Hours. Noise monitoring to confirm compliance would be required. MMRA may propose alternative mitigation to achieve the Guideline Noise Levels but lower than short-term events which regularly occur such as vehicle passbys.

Scenario D is for a concrete pour and is proposed to be undertaken, where possible, during Normal Working Hours. It is, however, anticipated that it would often extend to outside of Normal Working Hours. This would be Unavoidable Works. The noise levels due to this activity are predicted to be less than the existing baseline night time average noise levels at most sensitive receivers. At some locations, the noise levels are predicted to be marginally higher than the existing noise levels.

11.5.1.2 Vibration

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are in Section 4.7.2 and the detailed results of the assessment are in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to buildings

b) Underground infrastructure

c) Human comfort

d) Vibration-sensitive equipment.

(i) Tunnelling

Refer to Precinct 1: Tunnels for tunnelling of the alignment

Roadheaders would be used to mine the station caverns in the CBD North Station Precinct. The construction methodology for the station caverns involves four road headers working concurrently in various sections of the cavern. Three separate passes of each section of cavern are required:

- The heading (top) completed first
- The bench (middle)
- The invert (bottom).

The predictions have been based on two roadheaders working at the header level, with one roadheader working continually at the cross-sectional position of the cavern that is closest to the receiver in question, and the second working on the opposite side of the cavern at a 15 m longitudinal offset. In reality, each roadheader would work in a methodical way over the entire cross-section of the area, which would result in periodic reductions in vibration and ground-borne noise as the roadheader cutter face moves away from the receiver location. Therefore, these results are expected to be conservative and show the upper bound of vibration and ground-borne noise generated during the station cavern construction.

The roadheader has been assumed to move along the station cavern at a rate of approximately 3.5 m per day, with a 15 m longitudinal offset between road headers on each side of the cavern. The roadheaders are assumed to be operational for 60 per cent of the time during the day and night periods.

The vibration model has been adapted to predict the maximum vibration levels in nearby buildings due to these works.

a) Damage to buildings

Vibration levels from tunnelling (roadheader) between the stations and from the cavern excavation works are predicted to comply with Guideline Targets in DIN 4150 Guideline Targets for structural damage.

Structurally sensitive (heritage) sites identified in this precinct are presented in Table 11-8 along with the predicted PPV levels and current measured levels. At all locations the predicted vibration level due to roadheader activity complies with the DIN 4150 Guideline Targets and is less than the baseline peak vibration level measured. Consequently, damage from tunnelling is not expected (low risk).

Table 11-8: Vibration levels at sensitive sites

Sensitive Site	Baseline PPV (mm/s)	Predicted PPV (mm/s)	Comments
City Baths	1.6	0.3	Predicted level less than existing
RMIT Microelectronics and Material Technology Centre	5.2	0.7	Predicted level less than existing
State Library	3.2	0.2	Predicted level less than existing

b) Underground infrastructure

The location of assets would need to be confirmed by MMRA prior to the commencement of work.

Refer to Table 7-10 for Minimum Buffer Distances for underground infrastructure.

The tunnel alignment also crosses the City Loop tunnels in the CBD North station precinct. The peak vibration level predicted at the City Loop due to roadheader mining of the CBD North-CBD South tunnel is 12 mm/s. This level is the peak predicted to occur when the roadheader is excavating soil from the top of the tunnel and the closest alignment to the City Loop tunnels. Vibration would reduce as the cutter face moves away from the top of the tunnel and as the roadheader progresses along the tunnel. Predicted vibration levels at such a close distance is beyond the typical limits for the regression formula derived for the roadheader vibration attenuation curve, and as such may be somewhat overly conservative. The predicted vibration level is marginally above of the DIN 4150 long-term criterion of 10 mm/s. This standard is considered to be conservative and the British Standard BS 7385-2:1993 gives a guide value for vibration criterion relating to cosmetic damage of 25 mm/s (50 per cent of transient vibration guide value, for industrial and heavy commercial buildings). Thus, while at the MURL predicted vibration is higher than the DIN 4150 Guideline Targets selected for this project, the risk is expected to be low. Vibration monitoring at the City Loop tunnel during roadheader mining is recommended.

c) Human Comfort

Vibration levels are predicted to trigger adverse comments at some receiver locations and communication with affected receivers would be required. These locations are shown in figures in Appendix B of this report. The assessment of vibration for tunnelling is provided in Section 7.5.3.1.3.

The roadheaders would also be used for mining the CBD North station cavern. This work may continue for up to 18 months and the need for Management Actions is predicted to be triggered for human comfort for vibration at a number of receivers in the CBD North station precinct. Mitigation of vibration from the roadheader work may be possible by utilising reduced hours of operation and/or modifications to the construction sequencing.

An analysis of the change in vibration over time due to roadheader station cavern works was conducted for two sample receivers – one residential and one commercial in CBD North. Management Actions are predicted to be triggered at the most-affected residential location for up to 5 weeks (based on 'no expected adverse comment' at night). Of this time 'adverse comments are probable' is predicted for a period of approximately 10 days. At the commercial location Management Actions are triggered for approximately 4 weeks during the day or night (based on 'no expected adverse comments'). During this time, there is a 'low probability of adverse comments'.

These Management Actions triggers may occur up to three times as the heading, the bench and the invert are excavated.

d) Vibration-sensitive Equipment and Highly Sensitive Areas

Vibration has been assessed for vibration-sensitive equipment at RMIT and the outcomes are provided in Table 11-9.

Table 11-9: Assessment of vibration-sensitive equipment at RMIT due to roadheader excavation of the station cavern

Location	Vibration-sensitive Equipment	Vibration assessment
Basement 2, Building 100	Robotics lab	Complies
Level 7, Building 14	Electron microscope	Complies
Level 5, Building 14	Confocal microscope	Complies
Ground Floor, Building 3	NMR Spectrometer	Complies
Building 12	Acoustic Chambers	Complies
Level 4, Building 7	The Fib (Ion beam manufacturing tool)	Risk of non-compliance
Level 9, Building 12	Photonics Lab	Risk of non-compliance

Note:

1. Vibration has been assessed against the highest of either the guideline target level or the baseline vibration level.

If, in practice, this equipment is not able to be used during construction then the following is recommended:

- Communication with the stakeholders
- Temporarily reschedule the use of the equipment
- Temporarily relocate the equipment or usage to other non-affected facilities.

(ii) Additional Construction Works

The Additional Construction Works in CBD North station precinct are proposed to include 24-hour construction with a variety of equipment. The vibration predictions are based on assessment of vibration from rockbreakers and rippers, as these are the most vibration intensive items of construction equipment. Vibration predictions have been based on the following construction methodology:

- Franklin Street excavation: Rippers to remove material to a depth of 25 m below ground level and 20-tonne rockbreakers to remove material from depths greater than 25 m below ground

- A’Beckett Shaft excavation: Rippers to remove material to a depth of 15 m below ground level, 20-tonne rockbreakers to remove material between 15 and 25 m below ground level and 32 tonne rockbreakers to remove material greater than 25 m below ground level
- Southern Entrance excavation: Rippers to remove material to a depth of 20 m below ground level, 20-tonne rockbreakers to remove material between 20 and 30 m below ground level and 32 tonne rockbreakers to remove material greater than 30 m below ground level.

Note: rockbreakers would only be used if necessary in localised areas.

The predicted vibration levels have been compared with the vibration Guideline Targets for each type of building / occupancy.

a) Damage to buildings

The Guideline Target of 10 mm/s applies to most of the buildings in the vicinity of the excavation. It is predicted that the 10 mm/s target would be met provided that a buffer distance of 1.5 m is maintained between the ripper and buildings. Rockbreaker works are predicted to comply with the Guideline Target due to the depth of their operation (25 m or more).

Most buildings in the CBD North precinct are greater than 1.5 m from the excavations and as such it is predicted that vibration would be lower than the 10 mm/s Guideline Target.

Excavation within 1.5 m may occur at one building on Swanston Street (RMIT building 393-397 Swanston Street) which is immediately adjacent to the Southern Entrance excavation. To comply with the Guideline Target for excavation within 1.5 m of this building low vibration methods of excavation would be required such as pre-splitting and/or drilling.

Vibration measurements would need to be undertaken in order to verify the vibration levels.

At heritage sites, a low Guideline Target of 2.5 mm/s PPV applies. This level is predicted to be met using the construction methodologies described above except at three buildings which are within 5 m of the excavation for the Southern Entrance. These buildings are:

- The Old Cyclone Wire Fence Co. Building (63-67 Franklin Street)
- The Oxford Hotel Building (427 Swanston Street)
- 411-423 Swanston Street.

At these locations drilling and presplitting of materials would be required to reduce vibration levels within 5 m of the buildings.

Vibration levels up to 7 mm/s PPV have been measured in the vicinity of buildings on Swanston Street due to trams passing- By. It would therefore be reasonable to consider a higher vibration Guideline Target in this area.

It is important to note that vibration predictions can be inaccurate at distances of less than 5 m. As such it is recommended that vibration monitoring is conducted whenever equipment is operated within 5 m of a building. This applies to rippers, rock-breakers and piling rigs.

Building Condition surveys and vibration monitoring are recommended at all heritage buildings near construction works as a precautionary measure.

e) Underground infrastructure

There are a number of utilities within the Parkville station precinct and its surrounds. To avoid damage, the minimum buffer distances construction work should be from utilities are:

- 3 m for general utilities
- 5.5 m for Melbourne Water unreinforced assets.

Location of the utilities is to be confirmed by MMRA prior to the commencement of work.

c) Human Comfort

The VDV levels have been predicted at all sensitive receivers in the vicinity of the construction works. Compliance with the VDV Guideline Targets is predicted to be achieved within the minimum buffer distances provided in Table 11-10.

Table 11-10: Minimum Buffer Distances for Compliance with VDV Guideline Targets for Human Comfort

Construction Equipment	Minimum Distance (slope) for Compliance with VDV Guideline Targets (m)	
	Daytime	Night time
Residential		
Ripper	12	18
20-tonne rockbreaker	30	45
32-tonne rockbreaker	-	-
Commercial		
Ripper	7	7
20-tonne rockbreaker	-	-
32-tonne rockbreaker	-	-

Note:

1. Residents at upper levels of buildings would be less affected
2. Vibration from rockbreakers complies with the Guideline Targets for Commercial Buildings due to their depth

In most cases compliance with the Guideline Targets is predicted to be achieved. Exceptions to this are receivers located within the minimum buffer distances. Management Actions have been triggered at the following locations:

- Residential receivers on the lower levels (up to Level 4) of buildings on Franklin Street
- Commercial receivers and RMIT buildings located on Franklin Street
- Commercial receivers on Swanston Street, Little Latrobe and Latrobe Streets.

MMRA would manage these VDV through a combination of:

- Community consultation
- Scheduling of the excavation works
- Maintaining buffer distances of 18 m (ripper) and 45 m (rockbreaker) during the night
- Schedule ripping and rockbreaking works west of Swanston Street during daytime hours only.

By undertaking the above actions compliance with the Guideline Targets is predicted to be achieved during the night time at residential receivers. It is expected that VDV exceedances arising from daytime excavation works within close proximity of residential buildings would be manageable with community consultation. In many cases higher vibration levels may be experienced from local events such as tram passbys.

Management Actions for commercial receivers are predicted to be triggered for a short duration (only occurring when rippers are working within 7 m slope distance of receivers). It is expected that MMRA would be able to manage the vibration impacts of rippers by maintaining a 7 m buffer zone whilst buildings are occupied. Alternatively, MMRA may use lower vibration methods of material removal (drilling / rock splitting) within 7 m of receivers.

b) Vibration-sensitive Equipment

An assessment of vibration-sensitive equipment in the vicinity of the CBD North construction work site has been undertaken with respect to the ASHRAE Vibration Curves and measurements of existing vibration levels. The outcomes of this assessment are presented in Table 11-11.

Table 11-11: Assessment of vibration-sensitive equipment at RMIT

Location	Vibration-sensitive Equipment	Vibration assessment (magnitude of peak 1/3 octave band, RMS)
		Due to excavation (ripping and rockbreaking)
Basement 2, Building 100	Robotics lab	Complies
Level 7, Building 14	Electron microscope	Minor exceedance
Level 5, Building 14	Confocal microscope	Non compliance
Ground Floor, Building 3	NMR Spectrometer	Complies
Building 12	Acoustic Chambers	Complies
Level 4, Building 7	The Fib (Ion beam manufacturing tool)	Complies
Level 9, Building 12	Photonics Lab	Complies

Note: Vibration has been assessed against the highest of either the guideline target level or the baseline vibration level.

Vibration is predicted to be non-compliant at the confocal microscope due to the 20-tonne rockbreaker and ripper. It is expected that any impact could be managed by:

- Communication with the stakeholders
- Comply with the following minimum buffer distances
- Temporarily rescheduling use of the vibration-sensitive equipment as required
- Temporarily relocating the equipment to other non-affected facilities
- Scheduling the use of the rockbreaker to reduce impact.

11.5.1.3 Ground-borne Noise

Details of the methodology and model used for the assessment of ground-borne noise are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

Ground-borne noise levels are predicted to trigger the requirement for Management Actions during both the evening and night at some sensitive buildings (residential) in the vicinity of the tunnel alignment.

It is expected that ground-borne noise would be audible in other building types but should generally be tolerable during the daytime when background noise levels are higher.

The locations where Management Actions are required with respect to ground-borne noise are shown in figures in Appendix B of this report.

The assessment of the roadheader tunnelling is provided in Section 7.5.1.3.

The roadheader would also be used for the station cavern construction for a period of up to 18 months.

Ground-borne noise levels are predicted to trigger Management Actions at a number of receivers in the CBD North Station Precinct. Ground-borne noise levels of up to 39 dB(A) are predicted. Mitigation of ground-borne noise from the roadheader may be possible by utilising reduced hours of operation and/or modifications to the construction sequencing.

An analysis of the change in ground-borne noise over time due to roadheader station cavern works has been conducted for a sample residential receiver in the CBD North Station Precinct:

- Residential Receiver Address: 8 Franklin Street, Melbourne.

At this particular receiver Management Actions for ground-borne noise are predicted to be triggered only by the roadheader nearest to the receiver.

Management Actions for the ground-borne noise criteria are predicted to be triggered for the residential receiver for approximately 2 weeks during the night only. Ground-borne noise is predicted to comply with the evening Guideline Targets. This may occur up to three times as the heading, the bench and the invert are excavated.

At other locations the time period for management actions would be expected to be shorter.

(ii) Additional Construction Works

Ground-borne noise levels have been predicted at all residential receivers in the vicinity of the construction works. There are residential addresses on Franklin St (west of Swanston Street) where the ground-borne noise levels are predicted to trigger Management Actions based on 24-hour construction in all locations. Minimum distances for compliance with the ground-borne noise Guideline Targets are provided in Table 11-12.

Table 11-12: Minimum distances for compliance with the ground-borne noise Guideline Targets

Construction Equipment	Minimum distance (slope) for compliance with ground-borne noise Guideline Targets (m)
	Night time
Ripper	25
20-tonne rockbreaker	55

Note:

1. Residents at upper levels of buildings would be less affected.

MMRA would be able to maintain these buffer distances by scheduling ripping and rockbreaking works in the western section of the Franklin Street excavation (the section west of Swanston Street) for daytime hours only and consequently comply with the minimum distances and Guideline Targets for ground-borne noise.

11.5.2 Operation

11.5.2.1 Airborne Noise

Airborne Noise from Trains

Details of the methodology and model used for the assessment of airborne noise from trains are provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

Airborne noise from trains is predicted to be insignificant as the trains would be below ground in the tunnels.

Airborne Noise from Fixed Infrastructure

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure are provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

Ventilation and other fixed plant must comply with the relevant SEPP N-1 Noise Limits at the nearest Noise Sensitive Areas (NSAs). As the ventilation needs to be able to operate 24 hours, achieving the night period Noise Limit (the most onerous) would imply that the limits during the other periods are also met.

Fixed plant is proposed to be:

- Tunnel Ventilation System
- Over Track Extract fans
- Over Platform Extract fans
- Over Concourse Extract fans
- Back of House ventilation systems.

Fans would be enclosed or located underground and the louvre/grilles would effectively be a noise source to the surrounding environment. The proposed location of the plant and the nearest NSAs (residential buildings located at 483 Swanston Street, 87 Franklin St, 31 A'Beckett Street, 30 Little Latrobe Street and 200 Latrobe Street, Melbourne) are shown on Figure 11-2.

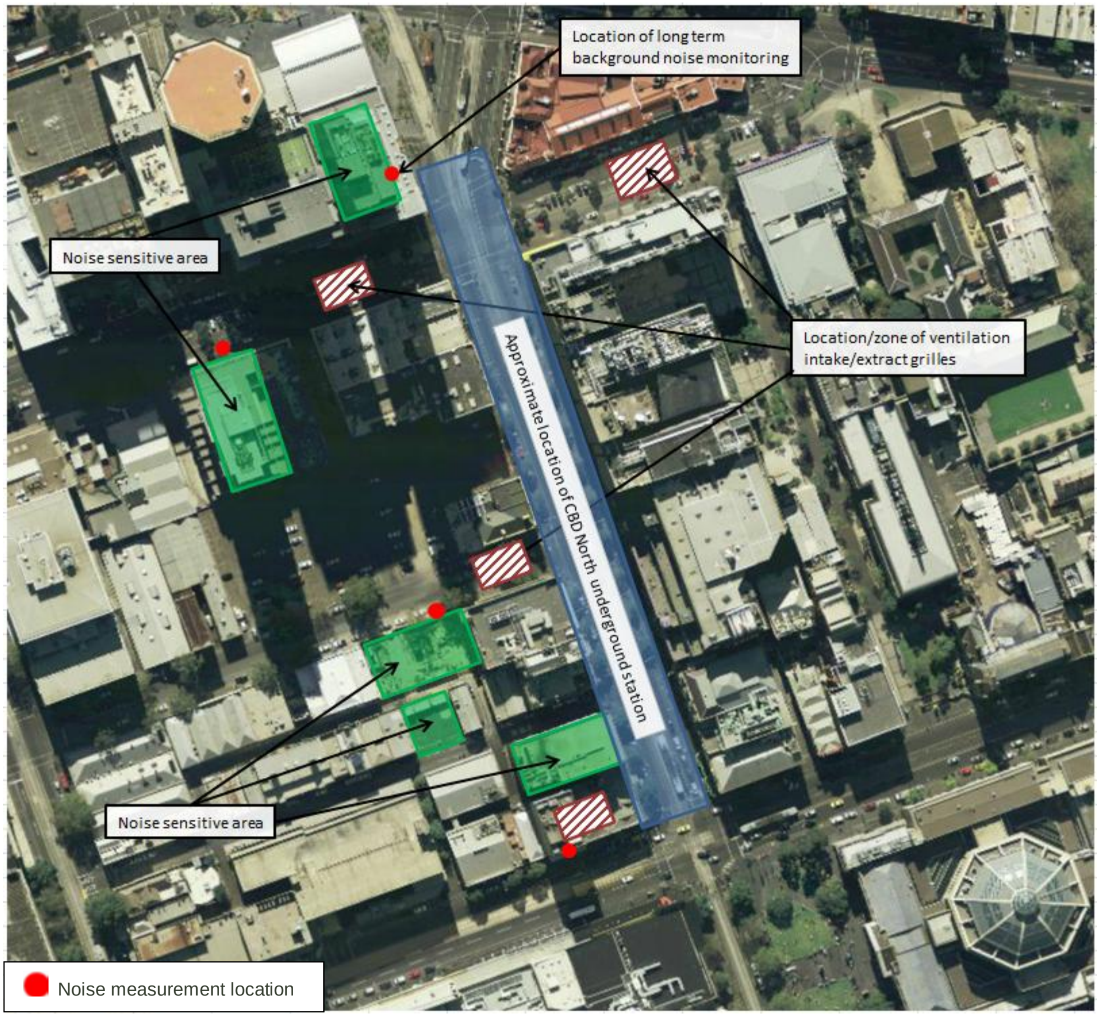


Figure 11-2 Location of fixed noise sources, measurements of attended background noise levels (red dots) and NSAs for CBD North

The SEPP N-1 Noise Limits are provided in Table 11-13. The Noise Limits apply to all industrial, commercial and retail noise sources in combination (inclusive of all sources), so that the effective Noise Limit for any individual source may be less than the Noise Limit.

Table 11-13 SEPP N-1 Noise Limits for Precinct 5

Location	Period	Noise Limit $dBL_{Aeq,30\ minutes}$
31 A'Beckett Street, Melbourne	Day	69
	Evening	63
	Night	53
87 Franklin Street, Melbourne	Day	70
	Evening	62
	Night	57
200 Latrobe Street, Melbourne	Day	69
	Evening	66
	Night	61
483 Swanston Street, Melbourne	Day	65
	Evening	60
	Night	56

The fan selections and duct layouts between the fans and the external grilles have not been made at this stage, however, it is expected that the Noise Limits may be achieved with the use of one or more of the following mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ductwork
- Plenums (lined or unlined)
- Acoustic barriers or screens.

11.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels for operation have been compared with the Guideline Targets for each type of building/occupancy. Mitigation has been proposed where the Guideline Targets have been predicted to be exceeded. The outcomes are as follows:

a) Damage to Buildings

Compliance with Guideline Targets is predicted.

b) Human Comfort

Based on 'Standard Attenuation' track, the human comfort vibration levels are predicted to comply with vibration 'Preferred' VDV Guideline Targets.

c) Vibration-sensitive Equipment, Highly Sensitive Areas and Bio-resources

Without mitigation, several items of vibration-sensitive equipment are predicted to exceed Guideline Targets in the CBD North precinct. To mitigate these vibration impacts, trackform with 'High' to 'Very High Attenuation' properties is predicted to be required. After mitigation, all sensitive equipment assessed is predicted to comply with the vibration Guideline Targets

No highly sensitive areas or bio-resources have been identified in this precinct.

11.5.2.3 Ground-borne noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

The predicted ground-borne noise levels for tunnelling have been compared with the Guideline Targets for each type of building / occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

It is predicted that to mitigate ground-borne noise in the CBD North station precinct, a track with 'Very High Attenuation' properties would be required. This requirement is driven by the low level of ground-borne noise that is required to meet the Guideline Targets for the performance space at nearby RMIT. With this mitigation, it is predicted that the project Guideline Targets would be achieved.

11.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 11-14.

Table 11-14: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA 1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting buried pipework	Manage vibration with respect to the Guideline Targets in DIN 4150	To be assessed by Proponent.	To be assessed by Proponent.
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for tunnelling (Cavern Construction).	Exceed Guideline Targets for up to 5 weeks up to 3 times based on 'no expected adverse comment'. During this time there is a 'low probability of adverse comment.'	High
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for Additional Construction Works	Compliance at night. Risk of non-compliance with Guideline Targets during day for a period of less than one day.	Medium
Vibration-sensitive Equipment	Manage vibration with respect to the Guideline Targets provided for Vibration-sensitive Equipment for tunnelling	Complies at all locations except photonics lab	Low

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Vibration-sensitive Equipment	Manage vibration with respect to the Guideline Targets provided for Vibration-sensitive Equipment for Additional Construction Works	Compliance (1 location with marginal level above the Guideline Target)	Low
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided for tunnelling (Cavern Construction)	Exceed up to 2 weeks 3 times	High
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided for Additional Construction Works	Compliance by maintaining minimum buffer distances	Low
Operation			
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low
Vibration-sensitive Equipment	Compliance with the Guideline Targets provided for Vibration-sensitive Equipment	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

11.7 Environmental Performance Requirements

Table 11-15 and Table 11-16 provide the recommended Environmental Performance Requirements for the noise and vibration for Precinct 5: CBD North station for construction and operation respectively.

Table 11-15 Environmental Performance Requirements for construction for Precinct 5: CBD North Station

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.	–	NV001, NV002, NV005, NV009, NV016, NV018, NV024, NV026, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.		NV001, NV002, NV005, NV009, NV016, NV018, NV024, NV026, NV028
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements as per EPA 1254 – Community consultation – Acoustic construction sheds – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Noise monitoring	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Building / structural integrity</td>
<td>Building damage from construction vibration</td>
<td>
<p>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.</p>
<p><i>Short-term vibration on structures</i></p>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th>Vibration at horizontal plane of highest floor at all frequencies</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th><th>mm/s (Peak Component Particle Velocity)</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
<p>Notes:</p>

At frequencies above 100 Hz, the values given in this column may be used as minimum values.
Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

<p><i>Long term vibration on structures</i></p>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component rticle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
</td>
<td>

Selection of construction equipment / construction methodology
Bored piling
Community consultation
Building / Structural Condition Assessment prior to starting works
Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
Minimum buffer distances

</td>
<td>NV002,
NV016</td>
</tr>
</table>

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
		Notes: 1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage. 2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.		
Underground infrastructure	Damage to underground infrastructure	Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved. **Pipe Material** – **Vibration Velocity, mm/s (PPV)** **Steel** – 100 **Clay, concrete, reinforced concrete, prestressed concrete, metal** – 80 **Masonry, plastic** – 50 Notes: 1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework. 2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro). 3. Compliance is to be achieved with asset owner's Utility Standards.	– Selection of methodology / equipment – Building / Structural Condition Assessment prior to starting works – Vibration monitoring if vibration Guideline Targets are predicted to be exceeded – Bored piling – Minimum buffer distances	

Pipe Material	Vibration Velocity, mm/s (PPV)
Steel	100
Clay, concrete, reinforced concrete, prestressed concrete, metal	80
Masonry, plastic	50

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV (m/s^{1.75})</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.</td>
<td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
– Bored piling
– Minimum buffer distances</td>
<td>NV005
NV018</td></tr>
<tr><td>Vibration-sensitive equipment</td><td>Construction vibration causing disturbance to vibration-sensitive equipment</td><td>Implement Management Actions if the ASHRAE equipment vibration Guideline Targets or measured background levels (whichever is higher) are exceeded for vibration-sensitive equipment during construction and operation at Parkville and CBD North stations.
<table>
<tr><th>Equipment requirements</th><th>Curve</th></tr>
<tr><td>Bench microscopes up to 100x magnification; laboratory robots</td><td>Operating Room</td></tr>
<tr><td>Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc.</td><td>VC-A</td></tr>
<tr><td>Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths</td><td>VC-B</td></tr>
<tr><td>Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1 mm detail size</td><td>VC-C</td></tr>
<tr><td>Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photo-lithography with line widths of ½ micro m; includes electron beam systems</td><td>VC-D</td></tr>
</table></td>
<td>– Community consultation
– Selection of methodology / equipment</td>
<td>NV009</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td><table><tr><td>Unisolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ¼ micro m; includes electron beam systems</td><td>VC-E</td></tr></table>Note:
1. The Proponent may undertake consultation with the users and agree alternative Guideline Targets.</td><td></td><td></td></tr>
<tr><td>Residential amenity</td><td>Construction ground-borne noise impacting upon amenity</td><td>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.<table><tr><th>Time Period</th><th>Internal Target, $L_{Aeq,15min}$ (dB)</th></tr><tr><td>Evening, 6pm to 10pm</td><td>40</td></tr><tr><td>Night, 10 pm to 7am</td><td>35</td></tr></table>Note:
1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.</td><td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of construction equipment/construction methodology
– Timing of construction work
– Minimum buffer distances</td><td>NV026</td></tr>
</table>

Table 11-16 Environmental Performance Requirements for operation for Precinct 5: CBD North station

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="5">Operation</td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td>–</td><td>NV30, NV032, NV034, NV037, NV038</td></tr>
<tr><td>Residential amenity</td><td>Airborne noise from fixed infrastructure.</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork/plenums
– Acoustic barriers / screens</td><td>NV032</td></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>– Track vibration isolation</td><td>NV034</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Operation of vibration-sensitive equipment</td><td>Disturbance to vibration-sensitive equipment</td><td>Implement Management Actions if the ASHRAE equipment vibration Guideline Targets or measured background levels (whichever is higher) are exceeded for vibration-sensitive equipment during construction and operation at Parkville and CBD North stations.
<table>
<tr><th>Equipment requirements</th><th>Curve</th></tr>
<tr><td>Bench microscopes up to 100x magnification; laboratory robots</td><td>Operating Room</td></tr>
<tr><td>Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc.</td><td>VC-A</td></tr>
<tr><td>Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths</td><td>VC-B</td></tr>
<tr><td>Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1 mm detail size</td><td>VC-C</td></tr>
<tr><td>Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photo-lithography with line widths of ½ micro m; includes electron beam systems</td><td>VC-D</td></tr>
<tr><td>Unisolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ¼ micro m; includes electron beam systems</td><td>VC-E</td></tr>
</table>
Note:
1. The Proponent may undertake consultation with the users and agree alternative Guideline Targets.</td><td>— Track vibration isolation</td><td>NV037</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Operational ground-borne noise impacting upon amenity</td><td>
<p>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.</p>
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td rowspan="2">Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>

RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
Assessment location is internal near to the centre of the most affected habitable room.
L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.
The values for performaing arts spaces may need to be reassessed to address the specific requirements of a venue.

</td><td>– Track vibration isolation</td><td>NV038</td></tr>
</table>

12 Precinct 6: CBD South Station

12.1 Project Components

12.1.1 Infrastructure

The infrastructure is proposed to consist of:

- CBD South station located under Swanston Street, between Flinders Street and just north of Collins Street
- Entrances at:
  - Collins Street at the City Square
  - Swanston Street adjacent Young and Jacksons hotel
  - Flinders Street at current Port Phillip Arcade with underground connection to Flinders Street Station
  - Federation Square (underground connection)
- Ventilation in the southern entrance footprint with vents from the north running thought the cavern to the south and vents from the south running under Flinders Street and connecting into the entry box along its far western end. There are also ventilations structures at the City Square entrance.

12.1.2 Locality

Precinct 6 is a highly urbanised and dense inner urban area with retail outlets, cafés, hotels, bars etc. It is highly developed with a mix of modern and heritage buildings. Trams run along Swanston Street, Collins Street and Flinders Street.

Sensitive receivers include:

- Federation Square
- St Paul’s Cathedral
- Melbourne Town Hall (events)
- St Pauls Cathedral
- Flinders Street Station (heritage building)
- Westin Hotel
- Nicholas Building
- Young and Jackson Hotel
- Manchester Unity Building
- Wales Building
- Residential apartments
- Australian Centre for the Moving Image.

12.1.3 Construction

Construction is proposed to consist of:

- Property demolition (excavator, rock breaker, crane (gantry / crawler), spoil trucks)
- Protection of underground utilities

- Relocation of underground services and partial demolition of the car park shared by City Square and the Westin Hotel
- Establishment of work sites (City Square and along Swanston Street and Flinders Street (where buildings are to be demolished) - this would include site offices and general construction work site activities
- Mined cavern (roadheader)
- Station entrances and connections (excavation)
- Cut and cover box for Flinders Street underpass
- Public entrance from Federation Square (mined with decline structures using cut and cover techniques)
- Station architectural and service fit out
- Track works and installation of rail systems (underground).

The work is expected to occur over a period of:

- CBD South Station - approximately 3.5 years
- City square - approximately 1 year
- Main cavern excavation - approximately 2.5 years
- The Flinders / Swanston Street entrance - approximately 2.5 years
- Federation Square entrance - approximately 1.5 years.

12.1.4 Operation

The operation is proposed to consist of:

- Trains travelling in the underground tunnel
- Fixed infrastructure, ventilation
- Pedestrian access.

12.2 Existing Conditions

Full details of baseline noise and vibration measurements are provided in Appendix F of this report.

External Ambient Noise

The results of external ambient noise measurements are provided in Table 12-1. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in the vicinity of construction or future fixed infrastructure, then the parameters provided are consistent with information needed for the EPA 1254 assessment or the SEPP N-1 assessment.

Table 12-1 External ambient noise monitoring

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
Westin Hotel, 210 Collins Street, Melbourne, Level 10	61	65	60	64	56	60
Quay West Apartments, 26 Southgate Avenue, Southbank	59	63	58	62	52	59

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
Uni Lodge Apartments, 238 Flinders Street, Melbourne, ground level	64	71	60	68	55	65

The Westin Hotel overlooks the City Square and Swanston Street and UniLodge Apartments overlook Flinders Street. These are both in busy city areas with trams passing by. The measurement at the Westin Hotel was at an upper level (Level 10) while the measurement at UniLodge was at ground level.

External Vibration Measurements

The maximum external vibration levels are provided in Table 12-2.

Table 12-2 External vibration measurements

Location	Maximum PPV Levels (mm/s)	Comments
St. Paul's Cathedral	2.1	Tram at 10 m
Young and Jackson Hotel	7	Tram at 5 m, tram at 10 m travelling over rail joints
Flinders Street Station	1.3	Tram at 5 m, double decker bus at 2 m
Princes Walk Vaults	0.2	-
Princes Bridge St Kilda Road	4	Tram at 7 m travelling over rail joints
Hamer Hall, Melbourne Arts Centre	3.1	Tram at 10 m

12.3 Key Issues

The key issues potentially associated with the Concept Design are identified in Table 12-3.

Table 12-3 Key issues associated with the Concept Design

Concept Design	Potential Issue
Construction	
Airborne noise	• Impact on amenity from 24-hour construction activity • Impact on events at performing arts building
Vibration	• Damage to structures • Disturbance to residential amenity • Impact on events at performing arts building
Ground-borne noise	• Impact on amenity from 24-hour construction activity • Impact on events at performing arts building

Concept Design	Potential Issue
Operation	
Airborne noise	- As trains are in tunnel airborne noise due to rail movements are expected to be insignificant - Noise from ventilation would need to comply with SEPP N-1
Vibration	- Damage to structures - Disturbance to residential amenity - Impact on events at performing arts building
Ground-borne noise	- Impact on amenity - Impact on events at performing arts building

12.4 Benefits and Opportunities

Table 12-4 below provides the benefits and opportunities associated with each part of the Concept Design.

Table 12-4 Benefits and opportunities associated with the Concept Design

Concept Design	Benefits	Opportunities
Deep alignment	Reduction in vibration and ground-borne noise when compared with the previously proposed shallow alignment.	

12.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria / Guideline Targets (and indicators where relevant) relevant to this assessment are provided in Section 2.1.

12.5.1 Construction

12.5.1.1 Airborne Noise

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report.

For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

The Guideline Noise Levels for construction activity are provided in Table 12-5 and are based on the noise levels measured at UniLodge Apartments, 238 Flinders Street, Melbourne. This location is considered most suitable for the determination of the Guideline Noise Levels because noise levels were measured on the Ground Floor while the noise levels at the Westin Hotel were measured at an upper level (Level 10). Quay West is further away from the construction activity.

Table 12-5 Construction Guideline Noise Levels

Time Period	Applicable Hours	Guideline Noise levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday	No specified Guideline Noise Level - noise reduction measures apply	
	7am to 1pm Saturday		
Weekend / Evening work	6pm to 10pm Monday to Friday	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more. 70 dB(A)	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more. 65 dB(A)
	1pm to 10pm Saturday		
	7am to 10 pm Sunday and Public Holiday		
Night	10pm to 7am Monday to Sunday	Noise to be inaudible within a habitable room of any residential premises. 55 dB(A)	
Unavoidable Works	All times	No specified Guideline Noise Level - noise reduction measures apply	

The construction scenarios assessed for CBD south station were:

- Scenario A Demolition (during Normal Working Hours)
- Scenario B Shaft construction (during Normal Working Hours)
- Scenario C Cavern construction (over 24-hours)
- Scenario D Cut and cover construction of access across Flinders Street (24-hours)
- Scenario E Flinders Street Station access works (24-hours, Unavoidable Works)
- Scenario F Concrete Pour (24-hours, Unavoidable Works).

The predicted construction noise levels for Scenarios A, B, C, D, E and F are provided in figures in Appendix A of this report.

Scenarios E and F are for Unavoidable Works. Scenario E is anticipated to last for up to 3 months (with work to be undertaken within an acoustic construction shed) and Scenario F is proposed to be undertaken during Normal Working Hours, however, could extend beyond Normal Working Hours if not completed and is anticipated to occur daily during the construction period in differing locations.

Guideline Noise Levels apply for Scenario C and for all construction work there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation.

Both general and specific noise mitigation are provided in Appendix A of this report. Specific noise mitigation includes:

- Acoustic treatment surrounding the concrete pour. One example of acoustic treatment is noise barrier hoardings (re-locatable).
- Acoustic construction sheds over the station entrances.

The predicted construction noise levels with mitigation are provided in figures in Appendix A of this report. The proposed indicative locations for construction noise mitigation (for all scenarios of construction as described above) are shown in Figure 12-1.

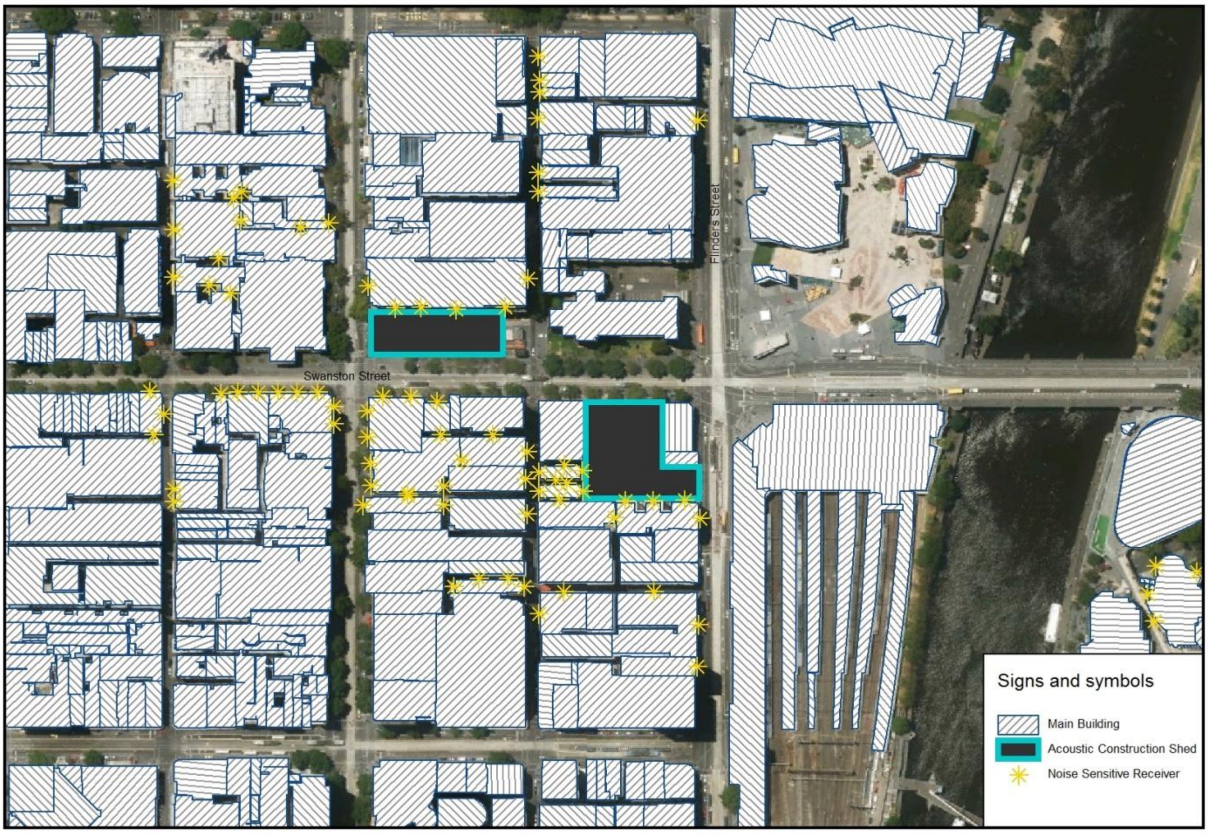


Figure 12-1 Mitigation for construction at CBD South Station

Compliance with the requirements of EPA 1254 is predicted to be achieved.

In the vicinity of CBD South Station the average noise levels were measured to be 71 dBL_{Aeq} and 65 dBL_{Aeq} during the day and night periods respectively at Uni Lodge in Flinders Street and 65 dBL_{Aeq} and 60 dBL_{Aeq} during the day and night periods respectively at the Westin Hotel (Level 10) next to the City Square.

CBD South is a very busy area typical of a city with trams, vehicles and general city noise. There are a number of sensitive receivers in the vicinity of CBD South station including the Westin Hotel, the Town Hall (which hosts concerts and events) and residential dwellings.

Initially, construction activities (Demolition and Shaft Construction - Scenarios A and B) in CBD South would be undertaken during Normal Working Hours. The noise levels associated with these activities are predicted to at times be higher than the baseline noise levels and would be typical of construction / demolition activities that are regularly undertaken in the city and other short-term events.

Once the station box has a roof deck then work for Scenario B is proposed to be undertaken over 24-hours. These works would need to comply with the relevant Guideline Noise Levels that apply outside of Normal Working Hours. Due to the height of the buildings in the vicinity of the construction works noise barriers would be of limited benefit and therefore acoustic construction sheds are proposed.

Scenario C would be 24-hour work and when undertaken in acoustic construction sheds (with noise lock lobbies so that when trucks enter the sheds there would only be one door open at a time) and the roadheader is submerged within the tunnel compliance with the Guideline Noise Levels is predicted to be achieved. MMRA may propose alternative mitigation to achieve the Guideline Noise Levels.

MMRA would need to prepare a construction methodology, which shows compliance with the Guideline Noise Levels for work undertaken outside of Normal Working Hours.

Scenarios D and E are for Unavoidable Works (24-hours) and involve work on Flinders Street. These works are localised to the Flinders Street Area. It is anticipated that this work would take up to three months. Scenario E would include a small acoustic construction enclosure for jack hammering.

Scenario F is for a concrete pour. This is proposed to be undertaken where possible during Normal Working Hours. It is, however, anticipated that it would often extend to outside of Normal Working Hours. This would be Unavoidable Works. The noise levels due to this activity are predicted to be less than the existing baseline night time average noise levels at most sensitive receivers. Some locations are predicted to experience noise levels marginally higher than the average levels at times but no longer than short-term events in the area.

12.5.1.2 Vibration

The assessment of the roadheader tunnelling the alignment is provided in Section 7.5.1.3. The roadheader would also be used for the station cavern construction for a period of up to 18 months.

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to Buildings

b) Underground Infrastructure

c) Human Comfort

d) Vibration-sensitive Equipment.

(i) Tunnelling

Roadheaders would be used to mine the station caverns in the CBD South Station Precinct. The methodology would be the same described in Section 11.5.1.2.

a) Damage to Buildings

There are no predicted vibration exceedances with respect to building damage issues due to tunnelling.

A number of sensitive sites have been identified and are presented in Table 12-6 with the predicted PPV results and the baseline measured levels. At all locations except for the Federation Wharf Vaults the predicted vibration level due to roadheader activity is less than or equal to the current peak vibration experienced. The predicted vibration levels at all locations, including Federation Wharf Vaults comply with the DIN 4150 criteria for structural damage.

Table 12-6: Vibration levels at other sensitive sites

Sensitive Site	Baseline PPV (mm/s)	Predicted PPV (mm/s)	Comments
St Paul's Cathedral	2.1	0.5	Predicted level less than existing
Young and Jacksons Hotel	7	1.0	Predicted level less than existing
Flinders Street Station	1.3	0.5	Predicted level less than existing
Federation Wharf Vaults	0.2	0.4	Predicted level is below the DIN 4150 Guideline Target
The Arts Centre	3.1	0.2	Predicted level less than existing
Melbourne Recital Centre and MTC Theatre (possibly Tunnels Precinct)		<0.1	Trams passing and turning corner at close proximity expected to be higher than predicted vibration levels

b) Underground infrastructure

The location of underground infrastructure would need to be confirmed by MMRA prior to the commencement of work.

Refer to Table 7-10 for minimum buffer distances for underground infrastructure.

Construction in this area is likely to be close to the 2 m minimum buffer distance of sewer pipework at the south end of the station cavern. The pipework may be subject to vibration up to 20 mm/s. MMRA should use less vibration intensive methods for excavating the station cavern roof section near to these sewer lines. This may include reduction in power of the roadheaders.

b) Human Comfort

Management Actions are predicted to be triggered due to vibration (VDV) at a number of receivers in the CBD South Station Precinct. Mitigation of vibration from the roadheader may be possible by utilising reduced hours of operation and/or modifications to the construction sequencing.

The methodology of construction of the station caverns area described in Section 11.5.1.2.

An analysis of the change in vibration (VDV) over time due to roadheader station cavern works has been conducted for two sample receivers in the CBD South station precinct – one residential and one commercial:

- Residential Receiver Address: Level 1, 233-239 Collins Street, Melbourne
- Commercial Receiver Address: 31-41 Swanston Street, Melbourne

These receivers have been selected as they present the highest vibration results and therefore have the longest durations of high vibration.

The roadheader has been assumed to move along the station cavern at a rate of approximately 3.5 m per day, with a 15 m longitudinal offset between road headers on each side of the cavern. The road headers are assumed to be operational for 60 per cent of the time during the day and night periods.

At these two receivers Management Actions are triggered by roadheaders at the residential location for up to 6 weeks at night (based on a preferred level which relates to 'no expected adverse comment' due to night time vibration levels). Of this time 'adverse comments are probable' for a period of less than 4 days. At the commercial location Management Actions are predicted to be triggered for approximately 5 weeks (based on 'no expected adverse comments').

The trigger for Management Actions may occur up to three times as the heading, the bench and the invert are excavated.

c) Vibration-sensitive Equipment

Vibration-sensitive equipment has not been identified in the CBD South station precinct.

(ii) Additional Construction Works

The Additional Construction Works are proposed to include 24-hour work and use a variety of construction equipment. Vibration modelling has been undertaken and the highest vibration levels predicted based on the most vibration intensive equipment; rippers and rockbreakers.

The following construction methodologies have been assessed:

- City Square excavation: Rippers to remove material to a depth of 10 to 20 m below ground level and 20-tonne rockbreakers to remove material from depths greater than 20 m below ground level.
- Flinders/Swanston Street excavation: Rippers to remove material to a depth of 0 to 20 m below ground level and 20-tonne rockbreakers to remove material from depths greater than 20 m below ground level.
- Federation Square excavation: Rippers to remove material to a depth of 15 m below ground level and 12-tonne rockbreakers to remove material from depths greater than 15 m below ground level.
- Potential excavation at 65-73 Swanston St: Rippers to remove material to a depth of 0 to 20 m below ground level and 20-tonne rockbreakers to remove material from depths greater than 20 m below ground level.

Note: rockbreakers would only be used if necessary in localised areas.

a) Damage to Buildings

A Guideline Target of 10 mm/s PPV applies to non-heritage buildings. Compliance with this target is predicted. This target is predicted to be met, however, within 1.5 m of buildings drilling and presplitting of materials would be required to reduce vibration levels.

At heritage sites, a low Guideline Target of 2.5 mm/s PPV applies. This level is predicted to be met using the construction methodologies described above except in six instances in which buildings are within 5 m of the excavation for the Southern Entrance:

- The Nicholas Building (31 to 41 Swanston Street)
- Young and Jacksons Hotel (Corner of Swanston Street and Flinders Street)
- Ross House (247 to 251 Flinders Lane)
- Flinders Street Railway Station Complex
- Some buildings in the Heritage Overlay “The Flinders Gate Precinct”
- Some buildings in the Heritage Overlay “The Block Precinct”.

At these locations drilling and presplitting of materials would be required to reduce vibration levels within 5 m of the buildings.

Vibration levels up to 7 mm/s PPV have been measured in the vicinity of buildings on Swanston Street due to tram passbys. It would therefore be reasonable to consider a higher vibration Guideline Target in this area.

It is also important to note that ground vibration calculations can be inaccurate when predicting vibration levels that occur when equipment is operated in close proximity to a receiver (less than 5 m). Therefore it would be necessary for MMRA to undertake vibration monitoring to verify vibration levels when high vibration equipment is operated within 5 m of a building. In the CBD South precinct, this applies to ripping, rockbreaking, piling and diaphragm wall construction.

b) Underground Infrastructure

The minimum buffer distance utilities should be from the Additional Construction Works to avoid damage to utilities is:

- 3 m for general utilities
- 5.5 m for Melbourne Water unreinforced assets.

The location of the assets should be confirmed prior to the commencement of work.

c) Human Comfort

Compliance with the VDV Guideline Targets would be achieved within the distances provided in Table 12-7.

Table 12-7: Minimum Distances for Compliance with VDV Guideline Targets for Human Comfort

Construction Equipment	Minimum Distance (slope) for Compliance with VDV Guideline Targets (m)	
	Daytime	Night time
Residential		
Ripper	12	18
20-tonne rockbreaker	30	45
Commercial		
Ripper	7	7
20-tonne rockbreaker	-	-

Note:

1. Residents at upper levels of buildings would be less affected.
2. Vibration from rockbreakers complies with the Guideline Targets for Commercial Buildings due to their depth.

There are several residential buildings that are located within these minimum distances on the perimeter of the Flinders/Swanston excavation.

For a residential receiver located on the perimeter of the excavation, it is predicted that the daytime VDV target would be exceeded for approximately 3 per cent of the ripping work and the night VDV target would be exceeded for approximately 9 per cent of the ripping work.

MMRA would be able to comply with the night-time VDV Guideline Target through careful scheduling and sequencing of the ripping and rockbreaking works. Night-time VDV Guideline Targets are predicted to be achieved at all times by:

- Maintaining an 18 m buffer distance between the ripper and residential buildings during the night i.e. rippers would need to work to the east of Cocker Alley during the night
- Scheduling rockbreaking for daytime hours only.

The above restrictions would only be required if in practice the VDV Guideline Targets are not achieved.

Close consultation and negotiation with residential receivers would be required in order to manage daytime impacts. Compensation and/or temporary respite/relocation may need to be provided when rippers and rockbreakers are working in close proximity of residential receivers.

Compliance with the VDV Guideline Targets may not be achieved at the Westin Hotel when rockbreakers are working in the City Square excavation, however, compliance is predicted to be achieved during ripping works. MMRA would be able to manage the impact at the Westin Hotel by:

- Scheduling rockbreaking works to daytime
- Undertaking only ripping during the evening and night (and not rockbreaking).

It would be necessary for MMRA to monitor vibration levels during the City Square excavation works. Close consultation and negotiation with the Westin Hotel would also be required.

It is predicted that the guideline night VDV target (0.2 $m/s^{1.75}$) would be exceeded at two residential buildings that are adjacent to the potential station entrance at 65 – 73 Swanston Street. The exceedances can be mitigated by conducting any rockbreaking works during daytime hours. Rippers can be used during the day and night.

Possible adverse comments due to vibration are predicted for receivers in ACMI when rippers are working in the Federation Square excavation. This could be addressed by either:

- Using low vibration methods of excavation – pre-splitting and or drilling
- Scheduling the work for outside of opening hours.

Management Actions are predicted to be required when rippers are working within 7 m of commercial buildings. There are a small number of commercial buildings that fall within 7 m of the Flinders / Swanston Street excavation (eg the Nicholas building and the Young and Jackson Hotel). There are also a small number of commercial buildings that would fall within 7 m of the potential station entrance at 65-73 Swanston Street. It is expected that MMRA would manage this by:

- Maintaining a 7 m buffer zone when these commercial buildings are occupied; or
- Using low vibration methods such as drilling and presplitting to remove material within this buffer zone.

It should be noted that many of these building would be exposed to higher vibration levels from tram movement.

d) Vibration-sensitive Equipment

Vibration-sensitive equipment has not been identified in the CBD South station precinct.

12.5.1.3 Ground-borne Noise

Details of the methodology and model used for the assessment of ground-borne noise are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

Ground-borne noise levels are predicted to trigger the requirement for Management Actions during both the evening and night at some sensitive buildings (residential) in the vicinity of the tunnel alignment.

It is expected that ground-borne noise would be audible in other building types but should generally be tolerable during the daytime when background noise levels are higher.

The locations where Management Actions are required with respect to ground-borne noise are shown in figures in Appendix B of this report.

The assessment of the roadheader tunnelling is provided in Section 7.5.1.3.

The roadheader would also be used for the station cavern construction for a period of up to 18 months.

Ground-borne noise levels are predicted to trigger Management Actions at a number of receivers in the CBD South Station Precinct. Mitigation of ground-borne noise from the roadheader may be possible by utilising reduced hours of operation and/or modifications to the construction sequencing.

An analysis of the change in ground-borne noise over time due to roadheader station cavern works has been conducted for a sample residential receiver in the CBD South Station Precinct:

- Residential Receiver Address: Level 1, 233-239 Collins St, Melbourne.

At this particular receiver Management Actions for ground-borne noise are predicted to be triggered by roadheaders working on both sides of the station cavern. Consequently, noise and vibration is a combination of the influence of both roadheaders.

Management Actions for the ground-borne noise criteria are predicted to be triggered for the residential receiver for approximately 2 weeks during the evening hours and 5 weeks at night.

This may occur up to three times as the heading, the bench and the invert are excavated. It should be noted that many buildings would be exposed to higher levels of ground-borne noise from tram movements.

(ii) Additional Construction Works

Ground-borne noise levels have been predicted at all residential receivers that are located immediately adjacent to the Flinders / Swanston Street excavation. Guideline targets for ground-borne noise are also predicted to be exceeded at the Westin Hotel (near the City Square excavation) and at two residential buildings (near the proposed 65-73 Swanston Street excavation). Minimum distances for compliance with the ground-borne noise Guideline Targets are provided in Table 12-8.

Table 12-8: Minimum distances for compliance with the ground-borne noise Guideline Targets

Construction Equipment	Minimum distance (slope) for compliance with ground-borne noise Guideline Targets (m)	
	Evening	Night time
Ripper	17	25
20-tonne rockbreaker	40	55

Note:

1. Residents at upper levels of buildings would be less affected.

Compliance with the Guideline Targets for ground-borne noise would be achieved by scheduling works so as to maintain these Minimum Distances during the evening and night time.

12.5.2 Operation

12.5.2.1 Airborne Noise

Airborne Noise from Trains

Details of the methodology and model used for the assessment of airborne noise from trains are provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

Airborne noise from trains is predicted to be insignificant as the trains would be in the tunnels below ground.

Airborne Noise from Fixed Infrastructure

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure are provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

Ventilation and other fixed plant noise must meet the relevant SEPP N-1 Noise Limits at Noise Sensitive Areas (NSAs). As the ventilation may operate continuously, design of the fixed plant and ventilation systems is to achieve the SEPP N-1 Noise Limit for the Night Period (the most onerous limits) which implies.

The fixed plant noise in Precinct 6 would be associated with the:

- Tunnel Ventilation System
- Over Track Extract fans
- Over Platform Extract fans
- Over Concourse Extract fans
- Back of House ventilation systems.

The fans would be enclosed or located underground and the louvre/grilles would effectively be a noise source to the surrounding environment. Cooling towers are also expected to be located on the roof near the corner of Swanston Street and Flinders Street. The proposed location of plant is shown in Figure 12-2 along with the NSA. The nearest NSAs are the Westin Hotel and residential area at 205 Collins Street and the residential areas at 228 Flinders Lane and 228 Flinders Street, Melbourne.

The SEPP N-1 Noise Limits are shown in Table 12-9. Noise Limits apply to all industrial, commercial and retail noise sources, so that the effective Noise Limit for any individual source may be less than the Noise Limit.

Table 12-9 SEPP N-1 Noise Limits for Precinct 6

Location	Period	Noise Limit dBL$_{Aeq,30\ minutes}$
Westin Hotel, 205 Collins St, Melbourne	Day Period	67
	Evening Period	63
	Night Period	59
UniLodge, 228 Flinders Street, Melbourne	Day Period	70
	Evening Period	63
	Night Period	58

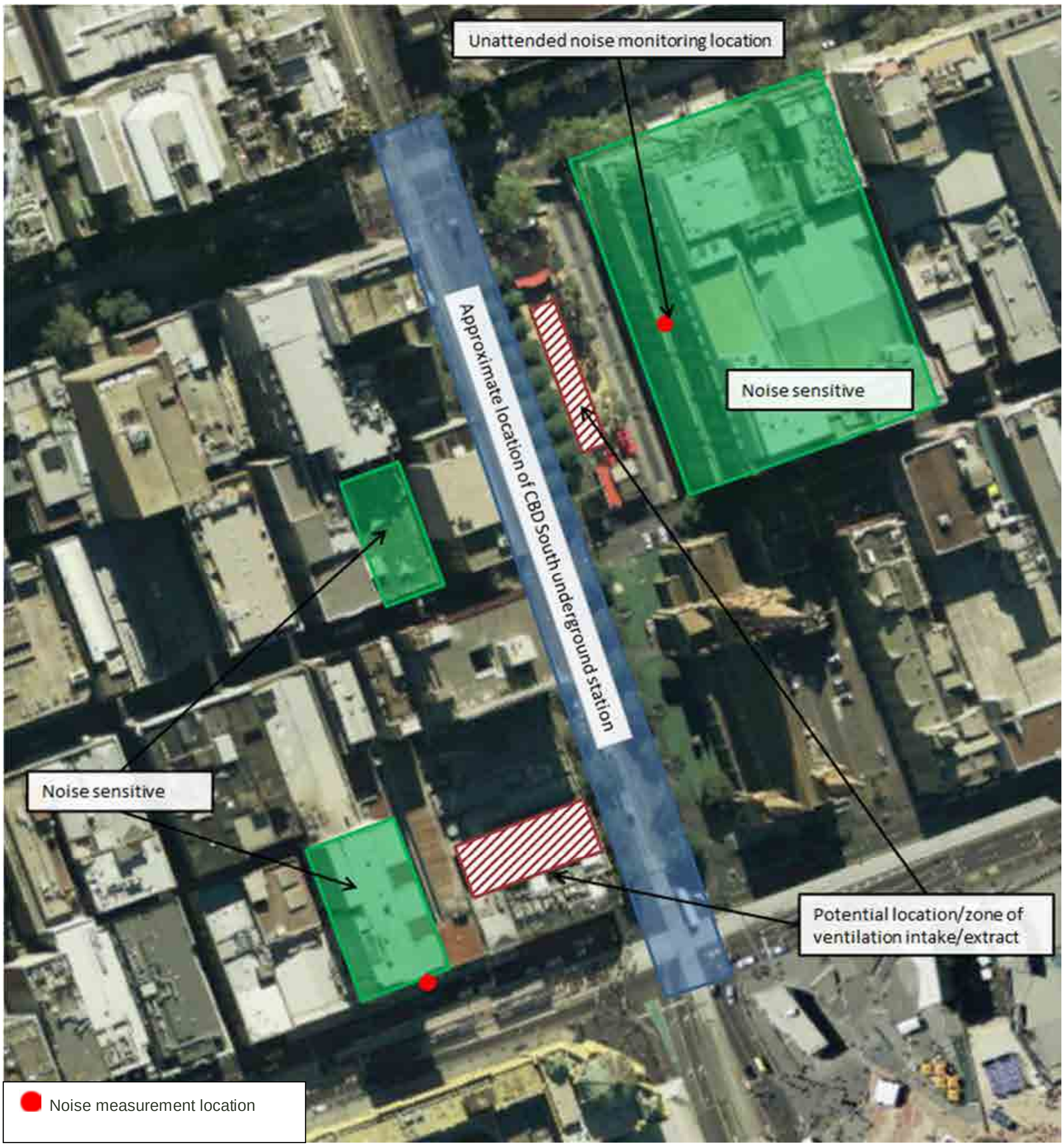


Figure 12-2 Location of fixed noise sources, measurements of attended background noise levels (red dots) and NSAs for Precinct 6

The fan selections and duct layouts between the fans and the external grilles have not been made at this stage, but it is expected that the Noise Limits may be achieved with the use of one or more of the following mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ductwork
- Plenums (lined or unlined)
- Acoustic barriers or screens.

12.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels for operation have been compared with the Guideline Targets for each type of building/occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed. The outcomes are as follows:

a) Damage to Buildings

Compliance with Guideline Targets is predicted.

b) Human Comfort

Based on 'Standard Attenuation' track, the human comfort vibration levels are predicted to comply with vibration 'Preferred' VDV Guideline Targets.

c) Vibration-sensitive Equipment, Highly Sensitive Areas and Bio-resources

Vibration-sensitive equipment, highly sensitive areas and bio-resources have not been identified in this precinct.

12.5.2.3 Ground-borne Noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

To mitigate this noise for the CBD South station precinct, it is predicted that a track with 'High Attenuation' properties would be required. With this trackform, compliance with project Guideline Targets is predicted.

12.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 12-10.

Table 12-10: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA 1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting buried pipework	Manage vibration with respect to the Guideline Targets in DIN 4150	To be assessed by Proponent.	-
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for tunnelling (Cavern Construction)	Exceed Guideline Targets for up to 6 weeks up to 3 times based on 'no expected adverse comment'. For 'adverse comments probable' this period is less than 4 days.	High
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided for Additional Construction Works	Compliance at night. Risk of non-compliance with Guideline Targets during day	Medium

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided <u>for tunnelling (Cavern Construction)</u>	Exceed up to 5 weeks 3 times	High
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided <u>for Additional Construction Works</u>	Compliance	Low
Operation			
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

12.7 Environmental Performance Requirements

Table 12-11 and Table 12-12 provide the Environmental Performance Requirements for the noise and vibration for Precinct 6: CBD South station for construction and operation respectively.

Table 12-11 Environmental Performance Requirements for construction for Precinct 6: CBD South station

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV002, NV005, NV007, NV016, NV018, NV022, NV026, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.		NV001, NV002, NV005, NV007, NV016, NV018, NV022, NV026, NV028
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements as per EPA 1254 – Community consultation – Acoustic construction sheds – Noise barriers 2.5 m around concrete pour – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Noise monitoring	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Building / structural integrity</td>
<td>Building damage from construction vibration</td>
<td>
Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.
<i>Short-term vibration on structures</i>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies
mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:
1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
4. Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.
<i>Long term vibration on structures</i>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
</td>
<td>
– Selection of construction equipment / construction methodology
– Bored piling
– Community consultation
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
</td>
<td>NV002,
NV016</td>
</tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td>Notes:
1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.</td><td></td><td></td></tr>
<tr><td>Underground Infrastructure</td><td>Damage to underground infrastructure</td><td>Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved.
<table>
<tr><th>Pipe Material</th><th>Vibration Velocity, mm/s (PPV)</th></tr>
<tr><td>Steel</td><td>100</td></tr>
<tr><td>Clay, concrete, reinforced concrete, prestressed concrete, metal</td><td>80</td></tr>
<tr><td>Masonry, plastic</td><td>50</td></tr>
</table>
Notes:
1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework.
2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro).
3. Compliance is to be achieved with asset owner’s Utility Standards</td><td>– Selection of methodology / equipment
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Minimum buffer distances</td><td></td></tr>
<tr><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table></td><td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
– Bored piling
– Minimum buffer distances</td><td>NV005,
NV018</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td>Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.</td><td></td><td></td></tr>
<tr><td>Residential amenity</td><td>Ground-borne noise from tunnelling</td><td>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.
<table>
<tr><th>Time Period</th><th>Internal Target, $L_{Aeq,15min}$ (dB)</th></tr>
<tr><td>Evening, 6pm to 10pm</td><td>40</td></tr>
<tr><td>Night, 10 pm to 7am</td><td>35</td></tr>
</table>
Note:
1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.</td><td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
— Selection of methodology / equipment
— Minimum buffer distances
— Timing of use of equipment</td><td>NV026,
NV028</td></tr>
</table>

Table 12-12 Environmental Performance Requirements for Operation for Precinct 5: CBD South Station

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="4">Operation</td><td></td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td></td><td>NV030,
NV032,
NV034,
NV038</td></tr>
<tr><td>Residential amenity</td><td>Operational airborne noise causing adverse impact on amenity</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork/plenums
– Acoustic barriers / screens</td><td>NV032</td></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV (m/s^{1.75})</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>— Track vibration isolation</td><td>NV034</td></tr>
</table>

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>**Amenity**</td>
<td>Operational ground-borne noise impacting upon amenity</td>
<td>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td rowspan="2">**Residential**</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>**Schools, educational institutions, places of worship**</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>**Hospitals (bed wards and operating theatres)**</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>**Offices**</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>**Cinemas and Public Halls**</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>**Drama Theatres**</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>**Concert halls, Television and Sound Recording Studios**</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>

RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
Assessment location is internal near to the centre of the most affected habitable room.
L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.
The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue

</td>
<td>— Track vibration isolation</td>
<td>NV038</td>
</tr>
</table>

13 Precinct 7: Domain Station

13.1 Project Components

13.1.1 Infrastructure

The following infrastructure is proposed for Precinct 7:

- Domain station located under St Kilda Road adjacent to Albert Road
- Connection under St Kilda Road linking both sides of the road
- Underground substation
- Ventilation

13.1.2 Locality

Sensitive receivers in Precinct 7 include:

- Parks and gardens and the Shrine of Remembrance along the east side of St Kilda Road north of Domain Road
- Offices
- Residential apartments
- Melbourne Grammar School

There is significant traffic on St Kilda Road and a busy tram line. In addition, Domain interchange is an interchange for multiple tramlines.

13.1.3 Construction

Specific construction activities are proposed to include:

- Protection or relocation of underground facilities (including South Yarra Main Sewer, water mains, storm-water drain and communications cables)
- Establishment of a construction work site and site compounds at Edmund Herring Oval and Albert Road Reserve. This would include site offices and general construction work site activities
- TBMs operations including launch
- Station works – 'top down cut and cover' construction method
- Station architectural and service fit-out
- Underground track-works and installation of rail systems

Construction is expected to consist of:

- Construction of Domain station and launch the TBMs - approximately 2.5 years
- Diaphragm wall – approximately 8 months
- Excavation works – approximately 1.5 years
- TBM preparation and launch operations – approximately 2 years

13.1.4 Operation

Operation would include:

- Trains travelling below ground in the tunnels and station
- Fixed infrastructure for ventilation

13.2 Existing Conditions

Full details of baseline noise and vibration measurements are provided in Appendix F of this report.

External Ambient Noise Measurements

The results of external ambient noise monitoring are provided in Table 13-1. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in vicinity of construction or future fixed infrastructure then the parameters provided are consistent with information needed for the EPA 1254 and SEPP N-1 assessments.

Table 13-1 External ambient noise measurements

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
214 Albert Road, Hallmark Apartments, South Melbourne	56	63	53	62	45	59
The Domain,1 – 29 Albert Road, Melbourne	56	64	53	63	47	59

External Vibration Measurements

The maximum external vibration levels measured are provided in Table 13-2.

Table 13-2 External vibration measurements

Location	Maximum PPV Levels (mm/s)	Comments
Marquis of Linlithgow Memorial	0.3	Tram at 50 m
340 St Kilda Road, Melbourne	0.7	Tram at 20 m
340 St Kilda Road, Melbourne (Tram shelter)	3.2	Tram at 5 m
South African Soldiers Memorial, South Melbourne	0.3	Tram at 20 m
321 St Kilda Road, South Melbourne	0.9	Tram at 20 m
402 St Kilda Road, Melbourne	0.5	Skateboard at 3 m

13.3 Key Issues

The key issues potentially associated with the Concept Design are identified in Table 13-3.

Table 13-3 Key issues associated with the Concept Design

Concept Design	Potential Issue
Construction	
Airborne noise	• Impact on amenity from 24-hour construction activity • Impact on events at the Shrine of Remembrance
Vibration	• Damage to structures • Disturbance to residential amenity
Ground-borne noise	• Impact on amenity from 24-hour construction activity
Operation	
Airborne noise	• As trains are in tunnels airborne noise due to rail movements are expected to be insignificant • Noise from ventilation would need to comply with SEPP N-1
Vibration	• Damage to structures • Disturbance to residential amenity
Ground-borne noise	• Impact on amenity

13.4 Benefits and Opportunities

No benefits and opportunities relating to noise and vibration have been identified in Precinct 7.

13.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria / Guideline Targets (and indicators where relevant) relevant to this assessment are provided in Section 2.1.

13.5.1 Construction

13.5.1.1 Airborne Noise

Airborne noise due to construction has been predicted at sensitive receivers near the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report.

For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

The Guideline Noise Levels for construction activity, in the vicinity of Precinct 7, are provided in Table 13-4 and are based on the noise levels measured at 2-14 Albert Road, Melbourne.

Table 13-4 Noise criteria for Construction

Time period	Applicable hours	Guideline Noise levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday	No specified Guideline Noise Level - noise reduction measures apply	
	7am to 1pm Saturday		
Weekend / Evening work	6pm to 10pm Monday to Friday	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more 63 dB(A)	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more 58 dB(A)
	1pm to 10pm Saturday		
	7am to 10pm Sunday and Public Holidays		
Night	10pm to 7am Monday to Sunday	Noise is to be inaudible within a habitable room of any residential premises 49 dB(A)	
Unavoidable Works	All times	No specified Guideline Noise Level - noise reduction measures apply	

The construction scenarios assessed for the Domain Station construction work site were:

Scenario A(i)	Shaft construction and station box piling, excavation and construction with no roof deck (Normal Working Hours)
Scenario A(ii)	Shaft construction and station box piling, excavation and construction with no roof deck (Normal Working Hours)
Scenario B	TBM launch preparation (24-hours, Unavoidable Work)
Scenario C	TBM launch (24-hours, Unavoidable Work).

The construction works for Scenarios B and C would be predominantly undertaken during Normal Working Hours. However, if they cannot be completed during Normal Working Hours then construction work would need to continue until complete. This would be Unavoidable Work. It is anticipated that this work would occur twice for a period of four to five weeks each over the duration of the project.

The predicted construction noise levels for Scenarios A(i) and A(ii), B and C are provided in figures in Appendix A of this report.

While Guideline Noise Levels do not apply for this construction work, there is a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation measures.

Both general and specific noise mitigation are provided in Appendix A of this report. Specific noise mitigation includes:

- Noise barrier of height up to a height of 6 m
- Acoustic construction shed over the TBM launch site with a noise lock for truck access.

The predicted construction noise levels with mitigation are provided in figures in Appendix A of this report. The proposed indicative locations for construction noise mitigation are shown in Figure 13-1. The sheds in particular would need to be carefully located to allow for tram and traffic movements.

Figure 13-1 Noise barriers at Domain station for construction noise

Compliance with the requirements of EPA 1254 is predicted to be achieved. As the barriers shown are not required to achieve Guideline Noise Levels there may be scope to optimise the barriers to take into consideration the visual impact.

In the vicinity of Domain Station the average noise levels during the day period were measured to be 64 dBL_{Aeq} and 59 dBL_{Aeq} during the day and night periods respectively at 1-29 Albert Road.

Initially construction would be undertaken during Normal Working Hours and Guideline Noise Levels do not apply. With barriers up to a height of 6 m, construction noise levels are predicted to generally be similar to existing noise levels at sensitive receivers. There would, however, be residential locations on higher floors which would overlook the construction work sites and therefore would not benefit from the mitigation provided by the barriers. At times the construction noise levels at these locations are predicted to be marginally higher than the existing noise levels but less than short-term noise events that regularly occur in this precinct.

The TBM preparation for launch and the launch itself (Scenarios B and C) are Unavoidable Works and Guideline Noise Levels do not apply. This work is intended to be undertaken during Normal Working Hours, however, if it is not completed then it may be necessary to extend into the evening / night period. This is anticipated to occur twice for five to six weeks over the entire construction period. When this work is undertaken acoustic construction sheds would be in place. The noise levels due to these construction works are predicted to be of the order of the existing noise levels at sensitive receivers. There would, however, be residential locations such as The Royce Hotel, 398 St. Kilda Road and The Domain where the predicted noise levels are marginally higher than existing but less than short-term noise events that regularly occur in this precinct.

If any avoidable work were undertaken outside of Normal Working Hours then the Guideline Noise Levels in Table 13-4 would apply.

13.5.1.2 Vibration

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to Buildings

b) Underground Infrastructure

c) Human Comfort

d) Vibration-sensitive Equipment.

(i) Tunnelling

Refer to Precinct 1: Tunnels.

(ii) Additional Construction Works

A variety of construction equipment would be used at this site. The ground-borne noise and vibration predictions are based on assessments of vibration for 20 tonne rockbreakers, as these are the most vibration intensive items of equipment. The predictions are based on the assumption that the rockbreakers would be operating up to 24 hours a day once the station roof has been constructed.

a) Damage to Buildings

Compliance with the vibration Guideline Target levels in DIN 4150 is predicted.

b) Underground Infrastructure

The minimum buffer distance utilities should be from the Additional Construction Works to avoid damage is:

- 3 m for general utilities
- 5.5 m for Melbourne Water unreinforced assets.

The location of the assets should be confirmed prior to the commencement of work.

The South Yarra Sewer Main currently passes directly under the Domain Station Precinct and would sit at the bottom of the completed station floor. It is understood that the South Yarra Sewer Main would be diverted prior to the construction works.

c) Human Comfort

It is predicted that the Guideline Targets would trigger Management Actions at five buildings. These buildings include four residential buildings on St Kilda Road and the Melbourne Grammar School building on the corner of St Kilda Road and Domain Road. For the buildings on St Kilda Road, the probability of adverse comments range from “low probability” for two buildings through to “probable” at the building with the highest VDV. “Possible adverse comments” are predicted from receivers occupying the Melbourne Grammar School building. For the residential receivers the requirement for Management Actions would be for a short period of the construction work in which rockbreakers are working within 20 m (day) and 40 m (night) of the residential buildings.

Options for mitigation include:

- Scheduling rockbreaking works within 40 m of residential buildings for Normal Working Hours only. This 40 m restriction would only affect a relatively small proportion of the excavation (south eastern end of the excavation and north western corner of the excavation)
- Close consultation and negotiation with residential receivers on St Kilda Road
- Monitoring of vibration levels during construction and adjustment of buffer zones as appropriate
- Use of low vibration methods of rockbreaking when removing rock from within 20 m of residential receivers
- Scheduling rockbreaking works in the immediate vicinity of the Melbourne Grammar School building for hours in which the building is not occupied.

Undertaking the above actions is predicted to result in compliance with the Guideline Targets.

13.5.1.3 Ground-borne Noise

Details of the methodology and model used for the assessment of ground-borne noise are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

Refer to Precinct 1: Tunnels.

(ii) Additional Construction Works

Additional Construction Works relevant to vibration include piling, construction of diaphragm walls and excavation of the station and station entrances. It is expected that the highest vibration levels would be experienced when 20-tonne rockbreakers are removing rock from the station excavation. Vibration modelling has been undertaken to predict vibration levels at nearby receivers during rockbreaking works.

Ground-borne noise levels are predicted to trigger Management Actions at four residential buildings on St Kilda Road. Ground-borne noise Guideline Target levels can be achieved by maintaining a buffer distance of 40 m between the 20-tonne rockbreaker and residential buildings during the evening and night.

Compliance with the buffer distances is predicted to achieve compliance with the Guideline Targets.

13.5.2 Operation

13.5.2.1 Airborne Noise

Airborne Noise from Trains

Details of the methodology and model used for the assessment of airborne noise from trains is provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

Airborne noise from trains is predicted to be insignificant as the trains would be below ground in the tunnels.

Airborne Noise from Fixed Infrastructure

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure is provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

Noise from ventilation and other fixed plant must meet the relevant SEPP N-1 Noise Limits at NSAs. Ventilation may operate over 24 hours and design of the fixed plant and ventilation systems is to achieve the SEPP N-1 night period Noise Limit (the most onerous Noise Limit).

The fixed plant noise in Precinct 7 is associated with the:

- Tunnel Ventilation System
- Over Track Extract fans
- Over Platform Extract fans
- Over Concourse Extract fans
- Back of House Ventilation Systems.

The fans would be enclosed or located underground and the louvre/grilles would effectively be a noise source to the surrounding environment. The proposed locations/zones of the intake/extract louvres are shown in Figure 13-2 along with the locations of the baseline measurements.

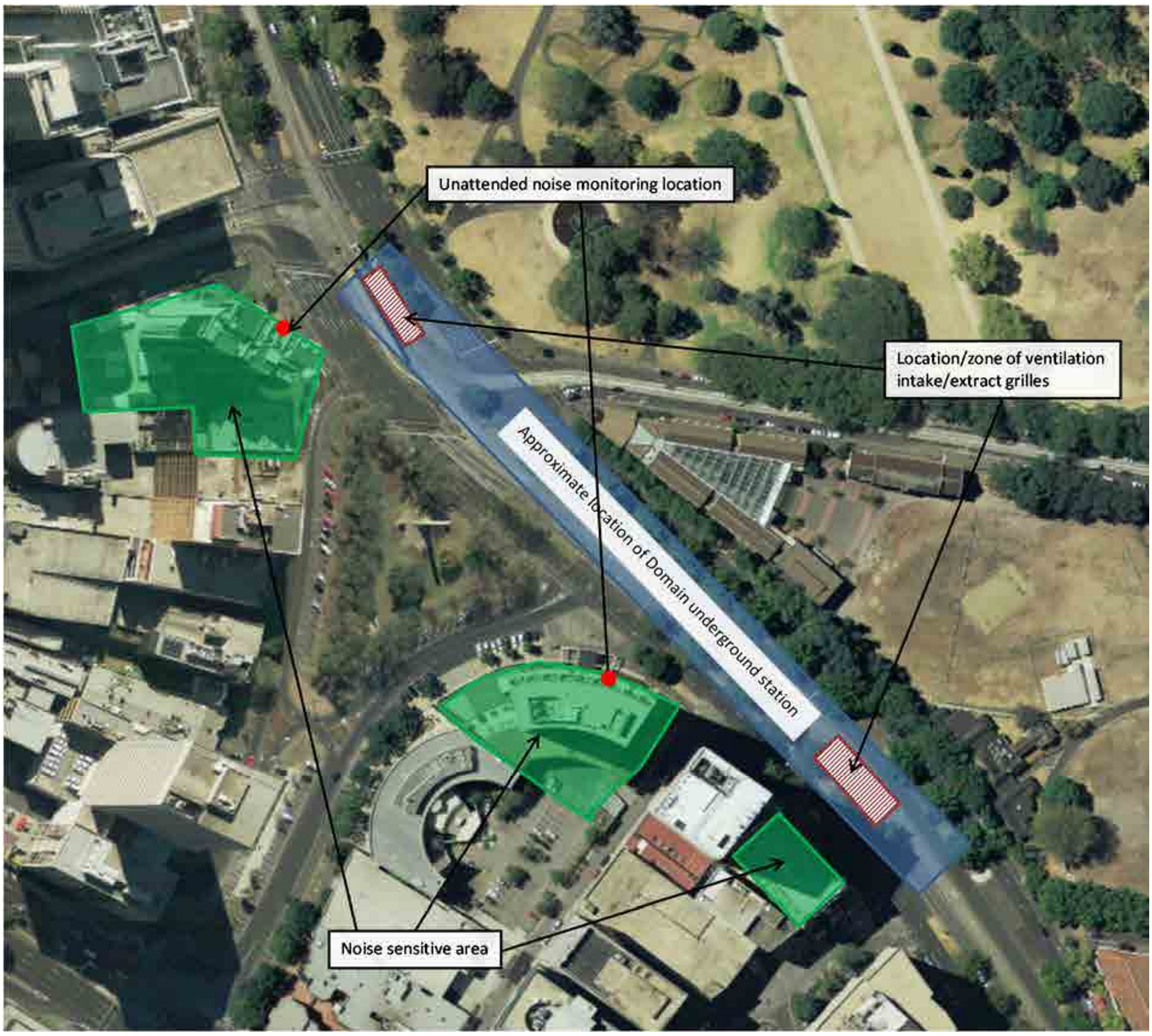


Figure 13-2 Location of fixed noise sources, measurements of attended background noise levels (red dots) and NSAs

The nearest NSAs are residential areas at 2-14 Albert Road, 29 Albert Road and 402 St Kilda Road, Melbourne.

The SEPP N-1 Noise Limits are provided in Table 13-5. The Noise Limits apply to all industrial, commercial and retail noise sources, so that the effective Noise Limit for any individual source may be less than the Noise Limit.

Table 13-5 SEPP N-1 Noise Limits for Precinct 7

Location	Period	Noise Limit, $dBL_{Aeq,30\ minutes}$
29 Albert Road, Melbourne	Day Period	62
	Evening Period	56
	Night Period	50
2-14 Albert Road, Melbourne	Day Period	62
	Evening Period	56
	Night Period	48
402 St Kilda Road, Melbourne	Day Period	62
	Evening Period	56
	Night Period	48

The fan selections and duct layouts between the fans and the external grilles have not been made at this stage, but it is expected that the Noise Limits may be achieved with the use of one or more of the following mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ductwork
- Plenums (lined or unlined)
- Acoustic barriers or screens.

13.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels for operation have been compared with the Guideline Targets for each type of building / occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed. The outcomes are as follows:

a) Damage to Buildings

Compliance with Guideline Targets is predicted.

b) Human Comfort

Without mitigation, a small number of receivers in the Domain Precinct exceed the ‘Preferred’ VDV Guideline Target. With mitigation in the form of track vibration isolation, all receivers in the Domain Precinct are predicted to meet the ‘Preferred’ VDV Guideline Target.

c) Vibration-sensitive Equipment, Highly Sensitive Areas and Bio-resources

Vibration-sensitive equipment, highly sensitive areas and bio-resources have not been identified in this precinct.

13.5.2.3 Ground-borne Noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

The predicted ground-borne noise levels for operation have been compared with the Guideline Targets for each type of building / occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

The ground-borne noise levels are predicted to exceed the target values by up to and greater than 10 dB at a number of locations across the alignment as shown in the figures in Appendix E of this report. To mitigate this noise for the Domain Station Precinct it is predicted that a track with 'Very High Attenuation' properties would be required. With this trackform, compliance with project Guideline Targets is predicted.

13.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 13-7.

Table 13-6: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA 1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting buried pipework	Manage with respect to the Guideline Targets in DIN 4150	To be assessed by Proponent.	-
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided <u>for tunnelling</u>	See Section 7 – Management actions triggered for up to 9 days.	See Section 7
Construction vibration impacting on amenity	Manage with respect to the VDV Guideline Targets provided <u>for Additional Construction Works</u>	Compliance by achieving minimum buffer distances	Low
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided <u>for tunnelling</u>	See Section 7 - See Section 7 – Management actions triggered for up to 9 days.	See Section 7
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided <u>for Additional Construction Works</u>	Compliance by achieving buffer distances.	Low
Operation			
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

13.7 Environmental Performance Requirements

Table 13-7 and Table 13-8 provide the recommended Environmental Performance Requirements for the noise and vibration for Precinct 7: Domain Station for construction and operation respectively.

Table 13-7 Environmental Performance Requirements for construction for Precinct 7: Domain Station

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV002, NV006, NV007, NV016, NV020, NV022, NV027, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.		NV001, NV002, NV006, NV007, NV016, NV020, NV022, NV027, NV028
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements as per EPA 1254 – Community consultation – Noise barriers up to a height of 6 m – Acoustic construction sheds. – Construction methodology / equipment — Prepare and implement a construction noise and vibration management plan — Noise monitoring	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td rowspan="2">Building / structural integrity</td>
<td rowspan="2">Building damage from construction vibration</td>
<td>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.

<i>Short-term vibration on structures</i>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies

mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:

At frequencies above 100 Hz, the values given in this column may be used as minimum values.
Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

</td>
<td rowspan="2">

Selection of construction equipment / construction methodology
Bored piling
Community consultation
Building / Structural Condition Assessment prior to starting works
Vibration monitoring if vibration Guideline Targets are predicted to be exceeded

</td>
<td rowspan="2">NV002

NV016</td>
</tr>
<tr>
<td><i>Long term vibration on structures</i>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td>Notes:
1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.</td><td></td><td></td></tr>
<tr><td>Underground Infrastructure</td><td>Damage to underground infrastructure</td><td>Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved.
<table>
<tr><th>Pipe Material</th><th>Vibration Velocity, mm/s (PPV)</th></tr>
<tr><td>Steel</td><td>100</td></tr>
<tr><td>Clay, concrete, reinforced concrete, prestressed concrete, metal</td><td>80</td></tr>
<tr><td>Masonry, plastic</td><td>50</td></tr>
</table>
Notes:
1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework.
2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro).
3. Compliance is to be achieved with asset owner's Utility Standards</td><td>– Selection of methodology / equipment
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Minimum buffer distances</td><td></td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>
<p>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.</p>
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV (m/s^{1.75})</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
<p>Notes:</p>

The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.

</td><td>
– Feasible and reasonable mitigation
– Community consultation
– Provision of respite/temporary relocation
– Selection of construction equipment/construction methodology
— Bored piling
— Timing of activities
— Minimum buffer distances
</td><td>NV006</td></tr>
<tr><td>Residential amenity</td><td>Construction ground-borne noise impacting upon amenity</td><td>
<p>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.</p>
<table>
<tr><th>Time Period</th><th>Internal Target, L_{Aeq,15min} (dB)</th></tr>
<tr><td>Evening, 6pm to 10pm</td><td>40</td></tr>
<tr><td>Night, 10 pm to 7am</td><td>35</td></tr>
</table>
<p>Note:</p>

Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
The noise levels are assessed at the centre of the most affected habitable room.
Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances

</td><td>
– Feasible and reasonable mitigation
– Community consultation
– Provision of respite/temporary relocation
— Selection of construction equipment/construction methodology
— Timing of activities
— Minimum buffer distances
</td><td>NV027
NV028</td></tr>
</table>

Table 13-8 Environmental Performance Requirements for operation for Precinct 7

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="5">Operation</td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td></td><td>NV030, NV032,
NV034, NV035,
NV038</td></tr>
<tr><td>Residential amenity</td><td>Airborne noise from fixed infrastructure.</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork/plenums
– Barriers</td><td>NV032</td></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>– Track vibration isolation</td><td>NV034</td></tr>
<tr><td>Amenity</td><td>Operational ground-borne noise impacting upon amenity</td><td>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.</td><td>– Track vibration isolation</td><td>NV038</td></tr>
</table>

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td>Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td></td><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>
1. RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
2. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
3. Assessment location is internal near to the centre of the most affected habitable room.
4. L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
5. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.
6. The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue
</td><td></td><td></td></tr>
</table>

14 Precinct 8: Eastern Portal

14.1 Project Components

14.1.1 Infrastructure

The infrastructure for Precinct 8 is proposed to include:

- Cut and cover structure under the Sandringham line, Frankston line, and freight and regional line
- Decline structure (open to the air) which brings Melbourne Metro tracks to the same vertical level as the existing rail corridor
- Turnouts at the tie in to the Cranbourne / Pakenham line
- Realignment of the existing Cranbourne / Pakenham and Frankston line tracks
- TBM retrieval box (in the rail reserve adjacent to Osborne Street
- Emergency access shaft
- Acquisition and demolition of 10 properties
- William Street Bridge, South Yarra Siding Reserve, Osborne Street and Lovers Walk would all be impacted during construction.

14.1.2 Locality

This precinct is highly urbanised and comprises a diverse range of housing types, from low-density detached housing to large-scale residential apartment blocks.

Existing transport connections in the area include the Sandringham, Cranbourne / Pakenham and Frankston rail services, which are in a cutting.

Many residential locations are currently affected by railway noise including wheel squeal/flanging.

Sensitive receivers include:

- Residences.

14.1.3 Construction

Specific construction activities would include:

- Demolition of structures
- Relocation of utilities (including high voltage cables, communications services and a stormwater drain)
- Establishment of worksites - this would include site offices and general construction work site activities
- Demolition of William Street bridge
- Cut and cover excavation of tunnel box
- Widening of existing rail corridor and construction of retaining walls
- Construction of ventilation shaft, emergency access shaft and substation in Osborne Street Reserve
- Retrieval of TBMs from Osborne Street and the adjoining rail reserve
- Track works (rail occupation) and installation of rail systems
- Reinstatement of William Street Bridge
- Reinstatement of South Yarra Siding Park and Lovers Walk.

14.1.4 Operation

Operation of Melbourne Metro is anticipated to include train movements both within and outside of the tunnels.

14.2 Existing Conditions

Full details of baseline noise and vibration measurements are provided in Appendix F of this report.

External Ambient Noise

The results of external ambient noise measurements are provided in Table 14-1 in the vicinity of the rail corridor and

Table 14-2 below for general areas in the vicinity of the works. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in vicinity of the rail corridor the parameters provided are consistent with the PRINP. Where noise measurements have been undertaken in the vicinity of construction or future fixed infrastructure then the parameters provided are consistent with information needed for the EPA 1254 and SEPP N-1 assessments.

Table 14-1 External Ambient noise monitoring in the vicinity of the rail corridor

Precinct / address	$L_{Aeq,day}$ dB 6am to 10pm	$L_{Aeq,night}$ dB 10pm to 6am
139 Osborne Street, South Yarra	59	54
4 William Street, South Yarra	55	50
6 William Street, South Yarra	72	63
10 William Street, South Yarra	52	47
19 William Street, South Yarra	54	49
3 Chambers Street, South Yarra	55	52

Table 14-2 External ambient noise monitoring

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
139 Osborne Street, South Yarra	48	57	46	56	44	54
4 William Street, South Yarra	39	53	39	51	34	45
6 William Street, South Yarra	44	69	41	65	40	62
10 William Street, South Yarra	42	50	38	47	36	46
19 William Street, South Yarra	40	51	38	50	33	44
3 Chambers Street, South Yarra	41	53	39	49	37	50

External Vibration Measurements

The maximum external vibration levels measured are provided in Table 14-3.

Table 14-3: External vibration measurements

Location	Maximum PPV Levels (mm/s)	Comments
162 Toorak Road, South Yarra	2	Tram at 5 m

14.3 Key Issues

The key issues potentially associated with the Concept Design are identified in Table 14-4.

Table 14-4 Key issues associated with the Concept Design

Concept Design	Potential issue
Construction	
Airborne noise	• Impact on amenity from 24-hour construction activity • Construction vehicles in local streets
Vibration	• Damage to structures • Disturbance to residential amenity
Ground-borne noise	• Impact on amenity from 24-hour construction activity
Operation	
Airborne noise	• Noise due to train movements • Noise from ventilation would need to comply with SEPP N-1
Vibration	• Damage to structures, disturbance to residential amenity
Ground-borne noise	• Impact on amenity

14.4 Benefits and Opportunities

Table 14-5 provides the benefits and opportunities associated with each part of the Concept Design.

Table 14-5 Benefits and opportunities associated with the Concept Design

Benefits	Opportunities
Reduction in rail noise once trains are in the tunnel	Use permanent noise barriers for construction barriers and to reduce train noise
The construction noise barriers would also reduce rail noise	Provision of barriers in addition to those required to comply with the PRINP in order to reduce train noise levels in areas where they are particularly high
The rail noise barriers would benefit properties in addition to those that were eligible for mitigation	

14.5 Impact Assessment

The draft EES evaluation objectives and assessment criteria (and indicators where relevant) relevant to this assessment are provided in Section 2.1.

14.5.1 Construction

14.5.1.1 Airborne Noise

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of this report.

For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

Work is proposed to be undertaken during Normal Working Hours or would be Unavoidable Work. However, if avoidable work were proposed to be undertaken outside Normal Working Hours then the criteria in Table 14-6 would apply. These are based on the noise levels measured at:

(i) 139 Osborne Street

(ii) 6 William Street

(iii) 19 William Street.

These levels are considered most suitable for determining Guideline Noise Levels in each area.

Table 14-6 Construction Guideline Noise Levels

Time period	Applicable hours	Guideline Noise Levels, $L_{Aeq,15\ minutes}$	
		Up to 18 months after project commencement	18 months or more after project commencement
Normal Working Hours	7am to 6pm Monday to Friday	No specified Guideline Noise Level - noise reduction measures apply	
	7am to 1pm Saturday		
Weekend / Evening work	6pm to 10pm Monday to Friday	Noise level at any residential premises not to exceed background noise by 10 dB(A) or more. 56 dB(A) - 139 Osborne Street, South Yarra 51 dB(A) - 6 William Street, South Yarra 48 dB(A) - 19 William Street, South Yarra	Noise level at any residential premises not to exceed background noise by 5 dB(A) or more. 51 dB(A) - 139 Osborne Street, South Yarra 46 dB(A) - 6 William Street, South Yarra 43 dB(A) - 19 William Street, South Yarra
	1pm to 10pm Saturday		
	7am to 10 pm Sunday and Public Holidays		
Night	10pm to 7am Monday to Sunday	Noise to be inaudible within a habitable room of any residential premises. 44 dB(A) - 139 Osborne Street, South Yarra 52 dB(A) - 6 William Street, South Yarra 35 dB(A) - 19 William Street, South Yarra	
Unavoidable Works	All times	No specified Guideline Noise Level - noise reduction measures apply	

The construction scenarios assessed are:

- Scenario A Rail Occupation (24 hours, Unavoidable Work)
- Scenario B TBM Retrieval (24 hours, Unavoidable Work).

There would also be construction of two bridges; one purpose built construction vehicle bridge over the Sandringham rail line between Osborne Street and the South Yarra Siding Reserve and the reinstatement of the William Street bridge over the Dandenong / Pakenham and Frankston rail lines. This work has not been modelled, however it is noted that it would be Unavoidable Work and Guideline Noise Levels would not apply.

The construction works for Scenario A are expected to consist of occupations in weekends and even weekdays on some occasions.

The construction works for Scenario B would be predominantly undertaken during Normal Working Hours. If, however, they cannot be completed during Normal Working Hours then construction works would need to continue until complete. It is anticipated that this work would occur twice for a period of four to six weeks each over the duration of the project.

The predicted construction noise levels for Scenarios A and B are provided in Figures in Appendix A of this report.

While noise criteria do not apply for this construction work there would be a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation.

The above and both general and specific noise mitigation is provided in Appendix A of this report. Specific noise mitigation includes:

- Noise barriers up to a height of 6 m surrounding much of the construction area.

The predicted construction noise levels with mitigation are provided in figures in Appendix A of this report. As the barriers shown are not required to achieve Guideline Noise Levels there may be scope to optimise the barriers to take into consideration visual impact.

Mitigation would reduce the construction noise levels in this area. The proposed indicative locations for construction noise mitigation are shown in Figure 14-1.

These barriers would mitigate both construction and train noise. Once construction is complete and the barriers are removed, train noise levels would increase at some sensitive receivers. Despite this increase, the overall train noise level would not necessarily be higher than what the levels were previously, before the installation of the construction noise barriers.

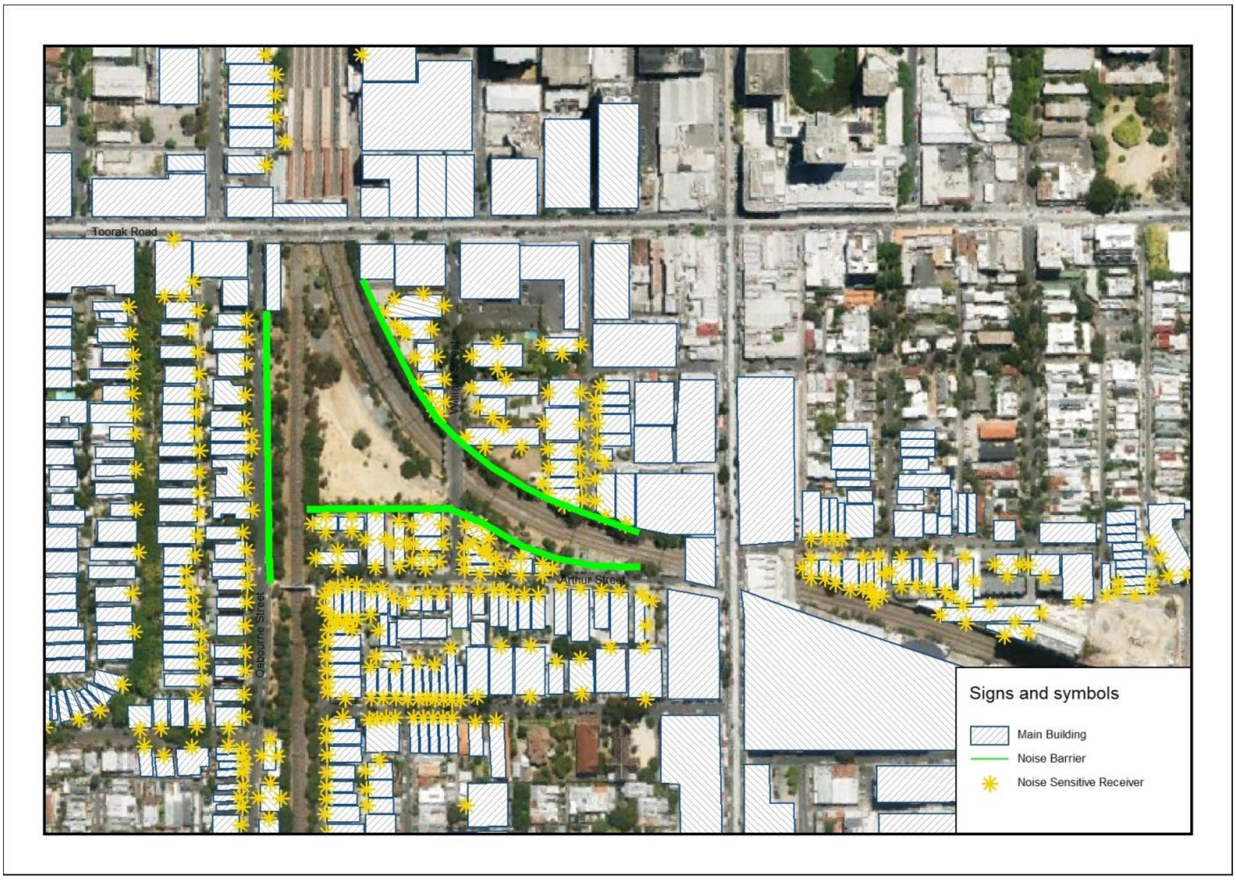


Figure 14-1 Proposed mitigation at Eastern Portal for construction

Compliance with the requirements of EPA 1254 is predicted to be achieved.

The construction work undertaken at the eastern portal would be either Unavoidable Work or during Normal Working Hours and therefore Guideline Noise Levels do not apply. However, it is recommended that noise barriers up to a height of 6 m are located around the construction activities to reduce the impact on the sensitive receivers.

At some locations, at some times, construction noise levels are predicted to be greater than existing average noise levels even with the noise barriers in place. They would not however be expected to be higher than existing short-term events. These barriers would also mitigate noise from trains. Extensive community consultation would be required along with a construction noise (and vibration) management plan.

Baseline noise levels have been measured in a number of locations in this precinct. Where noise levels are predicted to be above the exiting noise levels and residents are adversely impacted then respite and or temporary relocation may be appropriate.

14.5.1.2 Vibration

Construction activities associated with (i) Tunnelling and (ii) Additional Construction Works have been assessed. Details of the model and methodology are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

Vibration has been assessed with respect to:

a) Damage to Buildings

b) Underground Infrastructure

c) Human Comfort

d) Vibration-sensitive Equipment.

(i) Tunnelling

Refer to Precinct 1: Tunnels.

(ii) Additional Construction Works

A variety of construction equipment would be used at this site. The ground-borne noise and vibration predictions are based on assessments of vibration for piling rigs and rockbreakers, as these are the most vibration intensive pieces of equipment. At the Eastern Portal it is expected that 7-tonne rockbreakers would be sufficient for removing a small amount of rock which is located near Osborne Street and at a depth of 10 m. Rockbreaking works would be undertaken during Normal Working Hours.

a) Damage to Buildings

Vibration levels are predicted to comply with the Guideline Targets in DIN 4150.

b) Underground Infrastructure

The minimum buffer distance utilities should be from the Additional Construction Works to avoid damage is:

- 3 m for general utilities
- 5.5 m for Melbourne water unreinforced assets.

Location of the assets should be confirmed prior to the commencement of work.

c) Human Comfort

VDV levels are predicted to trigger Management Actions at three residential addresses on Osborne Street (‘possible’ adverse comments predicted) and there is a ‘low probability of adverse comment’ for one residential receiver located further away from the excavation. Management Actions are predicted to be required for a short duration only (in the order of days) due to the small amount of rock removal that is required. There is also a possibility that vibration levels would be lower than the predicted levels due to the ground condition at the eastern portal.

It is expected that the impacts on these residential receivers can be adequately managed through consultation and negotiation.

d) Vibration-sensitive Equipment

Vibration-sensitive equipment has not been identified in this precinct.

14.5.1.3 Ground-borne Noise

Details of the methodology and model used for the assessment of ground-borne noise are provided in Section 4.7.2 and details of the results of the assessment are provided in Appendix B of this report.

(i) Tunnelling

Refer to Precinct 1: Tunnels.

(ii) Additional Construction Works

Vibration intensive activities such as rockbreaking works are proposed to be undertaken during Normal Working Hours. Compliance with the ground-borne noise Guideline Targets is, therefore, achieved.

14.5.2 Operation

14.5.2.1 Airborne Noise

Airborne Noise from Trains

Details of the methodology and model used for the assessment of airborne noise from trains is provided in Section 4.8 and results of the assessment are provided in Appendix C of this report.

Train noise levels are to comply with the Investigation Thresholds in the PRINP for the redevelopment of existing rail infrastructure. The day, night and maximum noise levels have been predicted at sensitive receivers in the vicinity of the railway line.

Predictions have been undertaken for the following scenarios:

- Scenario 1: existing rail noise levels
- Scenario 2: rail noise levels in 2026 assuming the that Melbourne Metro does not proceed (base-case, no Melbourne Metro)
- Scenario 3: rail noise levels in 2036 assuming that Melbourne Metro does proceed (with Melbourne Metro).

The year 2036 has been selected for the assessment as it is 10 years following the anticipated completion of Melbourne Metro.

The prediction for the existing rail noise levels was compared with the measured noise levels at 6 William Street South Yarra and was within 2 dB. This was considered a satisfactory correlation. 6 William Street was selected for the verification because it had an unobstructed view of the railway and was an otherwise reasonably quiet road.

The predicted rail noise levels for the base case and the Melbourne Metro are provided in figures in Appendix C of this report. The scenarios for the base-case include all residences while the scenarios for Melbourne Metro have removed the houses to be acquired and demolished. The predictions are based on timetables provided by MMRA.

The Investigation Thresholds are predicted to be exceeded at properties on Arthur Street and William Street, South Yarra. This is due to a combination of changes that include:

- increased rail traffic
- widening of the tracks to the south
- ramps for Frankston Line and regional tracks
- removal of properties on Arthur Street and William Street that would otherwise have provided shielding

Compliance with the PRINP is predicted with the installation of noise barriers along the northern side of tracks (2 barriers 50 m and 70 m in length) and southern side of tracks (2 barriers 100 m and 170 m in length). Barrier heights range from 2.5 m to 3 m above the ground height of the adjacent houses and are located at the top of cut.

Noise barriers are to have a minimum mass per unit area of 15 kg/m^2 and be contiguous without any gaps or holes.

The proposed noise barrier locations are presented in Figure 14-2.

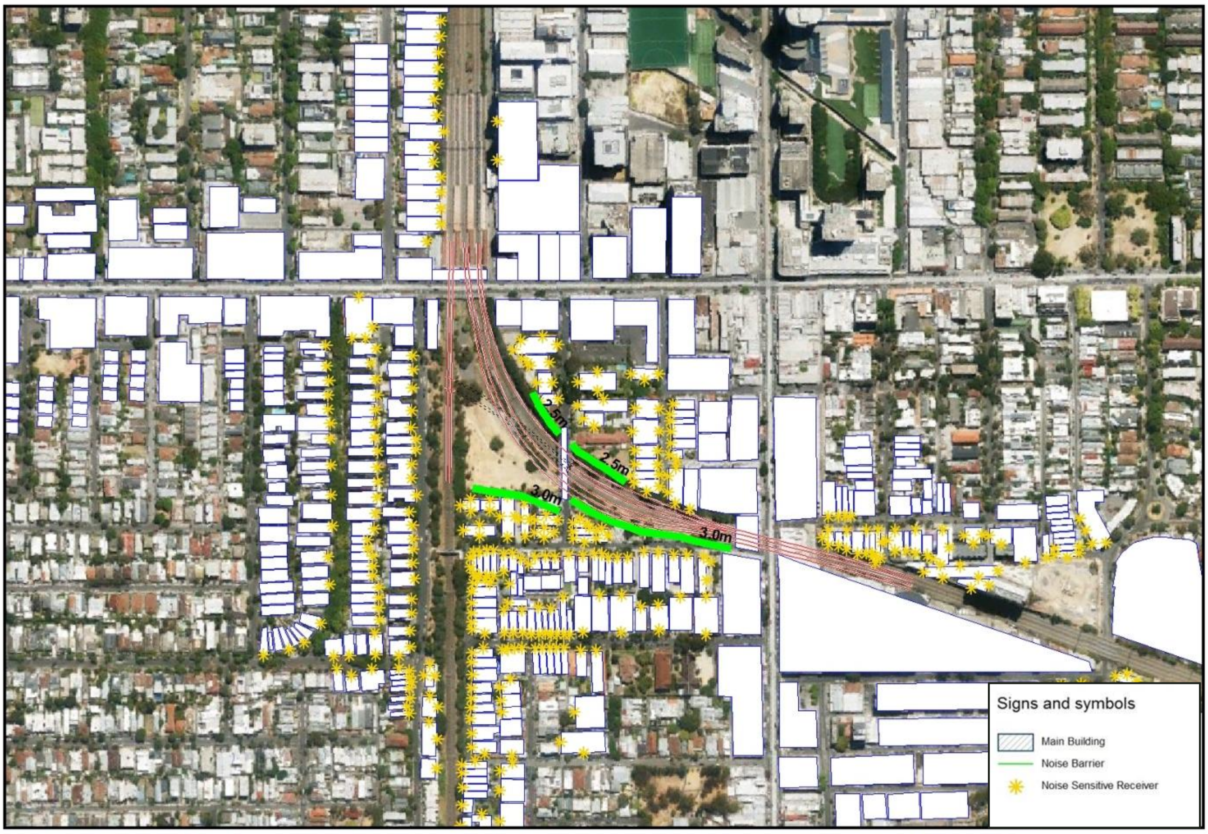


Figure 14-2 Barriers for rail noise at the Eastern Portal

With the mitigation described above the predicted train noise levels at the upper floors of 4 William Street, 10 William Street, 1 Arthur Street and 3 Arthur Street exceed the Investigation Thresholds and building mitigation (upgrade of the building façade) is recommended. It was not considered practical to provide barriers to mitigate for residents at these levels.

Airborne Noise from Fixed Infrastructure

Details of the methodology and model used for the assessment of airborne noise from fixed infrastructure is provided in Section 4.8.1.1 and results of the assessment are provided in Appendix D of this report.

There are a number of items of plant proposed for Precinct 8 including:

- Tunnel Ventilation System - discharge fan
- Stair pressurization fan
- Substation ventilation fans.

The fans would be located at the top of a mostly underground structure located between Osborne Street and the existing rail lines in South Yarra.

Noise from ventilation and other fixed plant must meet the relevant SEPP N-1 Noise Limits at the nearest NSAs. Ventilation needs to be able to operate 24 hours and therefore, design of the fixed plant and ventilation systems to achieve the SEPP N-1 night period Noise Limit (the most onerous Noise Limit) implies compliance for the other periods.

The proposed location of the ventilation fans in Precinct 8 are shown in Figure 14-3.

Figure 14-3 Location of fixed noise sources, measurements of attended background noise levels (red dots) and NSAs

The nearest NSAs are along Osborne Street to the west of the proposed plant and there are NSAs to the east, at the rear of William Street.

Table 14-7 shows the calculated SEPP N-1 Noise Limits in the vicinity of the eastern portal. Noise Limits apply to all industrial, commercial and retail noise sources, so that the effective Noise Limit for any individual source may be less than the Noise Limit.

Table 14-7 SEPP N-1 Noise Limits for Precinct 8

Location	Period	Noise Limit, $dBL_{Aeq,30 minutes}$
139 Osborne Street, South Yarra	Day	55
	Evening	49
	Night	47
19 William Street, South Yarra	Day	52
	Evening	46
	Night	41

As items of plant have not been selected, it is not possible to assess the impact of noise from fixed infrastructure. Noise associated with fixed infrastructure must comply with the SEPP N-1 Noise Limits. It is expected that plant noise would be able to be mitigated to comply with the noise limits using one or more of the following mitigation measures:

- Low noise fans
- Acoustic attenuators
- Lined ducts
- Plenums (lined or unlined)
- Acoustic barriers or screens.

14.5.2.2 Vibration

Details of the vibration assessment methodology and model are outlined in Section 4.8.2 and details of the results of the vibration assessment are provided in Appendix E of this report.

The predicted vibration levels for operation have been compared with the Guideline Targets for each type of building / occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

a) Damage to Buildings

Compliance with Guideline Targets is predicted.

b) Human Comfort

Without mitigation, a small number of receivers in the eastern portal precinct exceed the ‘Preferred’ VDV Guideline Target as shown in the figures in Appendix E of this report. With mitigation in the form of track vibration isolation, all receivers in the Eastern Portal Precinct are predicted to meet the ‘Preferred’ VDV Guideline Target.

c) Vibration-sensitive Equipment, Highly Sensitive Areas and Bio-resources

Vibration-sensitive equipment, highly sensitive areas and bio-resources have not been identified in this precinct.

14.5.2.3 Ground-borne Noise

Details of the ground-borne noise assessment methodology and model are outlined in Section 4.8.2 and details of the results of the ground-borne noise assessment are provided in Appendix E of this report.

The predicted ground-borne noise levels for operation have been compared with the Guideline Targets for each type of building / occupancy. Where the Guideline Targets have been predicted to be exceeded mitigation has been proposed.

The ground-borne noise levels are predicted to exceed the target values at a number of locations across the alignment as shown in the Figures in Appendix E of this report. To mitigate this noise for the eastern portal precinct it is predicted that track with ‘High Attenuation’ properties would be required. With this trackform, compliance with the project Guideline Targets is predicted. The current rail operation related ground-borne noise and vibration levels at receiver locations nearby the portal may be taken into account to determine whether Guideline Targets for this precinct can be relaxed.

14.6 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 14-8.

Table 14-8: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA 1254	Compliance	Low
Building damage from vibration	Manage vibration with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting buried pipework	Manage vibration with respect to the Guideline Targets in DIN 4150	To be assessed by MMRA.	-
Construction vibration impacting on amenity	Manage with respect to the VDV Guideline Targets provided for tunnelling	See Section 7	See Section 7
Construction vibration impacting on amenity	Manage with respect to the Guideline Targets provided for Additional Construction Works	General Compliance Short term (no. of days) exceedance at a few properties	Low
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided for tunnelling	See Section 7	See Section 7
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided for Additional Construction Works	Compliance	Low
Operation			
Airborne noise from trains	Compliance with PRINP	Compliance	Low
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low
Ground-borne Noise	Compliance with Guideline Targets	Compliance	Low

Note:

1. General compliance means that any non-compliance is minor, localised and the impacts are not expected to be significant.

14.7 Environmental Performance Requirements

Table 14-9 and Table 14-10 provide the performance requirements for the noise and vibration for Precinct 8: Eastern Portal for construction and operation respectively.

Table 14-9 Environmental Performance Requirements for construction for Precinct 8: Eastern Portal

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV002, NV006, NV007, NV016, NV020, NV022, NV027, NV028
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.		NV001, NV002, NV006, NV007, NV016, NV020, NV022, NV027, NV028
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements as per EPA 1254 – Community consultation – Noise barriers up to a height of 6 m – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Noise monitoring	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Building / structural integrity</td>
<td>Building damage from construction vibration</td>
<td>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.

<i>Short-term vibration on structures</i>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies
mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:
1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
4. Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

<i>Long term vibration on structures</i>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
</td>
<td>– Selection of construction equipment / construction methodology
– Bored piling
– Community consultation
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded</td>
<td>NV002, NV016</td>
</tr>
</table>

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
		Notes: 1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage. 2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.		
Underground Infrastructure	Damage to underground infrastructure	Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved. **Pipe Material** – **Vibration Velocity, mm/s (PPV)** **Steel** – 100 **Clay, concrete, reinforced concrete, prestressed concrete, metal** – 80 **Masonry, plastic** – 50 Notes: 1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework. 2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro). 3. Compliance is to be achieved with asset owner's Utility Standards	– Selection of methodology / equipment – Building / Structural Condition Assessment prior to starting works – Vibration monitoring if vibration Guideline Targets are predicted to be exceeded – Minimum buffer distances	

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Amenity</td>
<td>Construction vibration impacting upon amenity</td>
<td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.</td>
<td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
– Bored piling</td>
<td>NV006
NV007
NV016</td>
</tr>
<tr>
<td>Residential amenity</td>
<td>Construction ground-borne noise impacting upon amenity</td>
<td>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.
<table>
<tr><th>Time Period</th><th>Internal Target, $L_{Aeq,15min}$ (dB)</th></tr>
<tr><td>Evening, 6pm to 10pm</td><td>40</td></tr>
<tr><td>Night, 10 pm to 7am</td><td>35</td></tr>
</table>
Note:
1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances</td>
<td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment</td>
<td></td>
</tr>
</table>

Table 14-10 Environmental Performance Requirements for operation for Precinct 8: Eastern Portal

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="5">Operation</td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td></td><td>NV031, NV032, NV034</td></tr>
<tr><td>Amenity</td><td>Airborne noise from trains</td><td>Avoid, minimise or mitigate rail noise where the following PRINP (Victorian Passenger Rail Infrastructure Noise Policy, April 2013) Investigation Thresholds are exceeded during operation.
<table>
<tr><th>Time</th><th>Type of Receiver</th><th>Investigation Thresholds</th></tr>
<tr><td>Day
(6am – 10pm)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks
Noise sensitive community buildings, including schools, kindergartens, libraries</td><td>65 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
<tr><td>Night
(10pm – 6am)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks</td><td>60 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
</table>
Notes:
1. If an investigation shows that the thresholds are not exceeded, then no further action is considered under the PRINP
2. L_{Amax}, for this assessment, is defined as maximum A-weighted sound pressure level and is the 95 percentile of the highest value of the A-weighed sound pressure level reached within the day or night
3. For the Melbourne Metro the location of assessment is at 1 m from the centre of the window of the most exposed external façade</td><td>– Northern side of tracks at the same ground height as the properties: 2 barriers 50 m and 70 m in length (2.5 m to 3 m in height)
– Southern side of tracks at the same ground height as the properties:(2 barriers 100 m and 170 m in length (2.5 m to 3 m in height)
– Off-reservation treatment (architectural abatement) at the 3rd level of one property</td><td>NV031</td></tr>
<tr><td>Residential amenity</td><td>Airborne noise from fixed infrastructure</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork/plenums
– Acoustic barriers / screens</td><td>NV032</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>- Track vibration isolation</td><td>NV034</td></tr>
</table>

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Residential amenity</td>
<td>Operational ground-borne noise impacting upon amenity</td>
<td>
Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td rowspan="2">Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>
1. RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
2. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
3. Assessment location is internal near to the centre of the most affected habitable room.
4. L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
5. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.
6. The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue
</td>
<td>- Track vibration isolation</td>
<td>NV038</td>
</tr>
</table>

15 Precinct 9: Western Turnback

15.1 Project Components

15.1.1 Infrastructure

The infrastructure is proposed to include

- A third platform at West Footscray station
- Modifications to existing concourse
- Track work to realign regional, suburban and freight lines
- Construction of new track and turnouts.

15.1.2 Locality

At West Footscray there are a number of residences in the vicinity of the proposed works.

15.1.3 Construction

Construction is proposed to consist of:

- A third platform and track at West Footscray station
- Modifications to the existing concourse.

15.1.4 Operation

Operation would include the occasional turnback of trains.

The Turnback track would have trains standing for a minimum of 5 minutes and maximum 15 minutes in the morning and afternoon peak only (as there are four trains per hour expected to turn back). These would be EMU’s only.

The Pocket Track (downside of the Turnback Track) would have trains standing for a minimum of 5 minutes and may average 15-30 minutes towards the end of the morning peak. However, in delayed running or to provide a replacement service, they may sit there for up to an hour.

No trains are predicted to be idling during off peak times or during the night time period.

Trains would not be stabled at this location.

15.2 Existing Conditions

Full details of the baseline noise and vibration measurements are provided in Appendix F of the report.

External Ambient Noise

The results of external ambient noise measurements are provided in Table 15-1. Measurement locations have been strategically selected for determination of relevant noise criteria. Where noise measurements have been undertaken in the vicinity of construction or future fixed infrastructure, then the parameters provided are consistent with information for the EPA 1254 assessment or the SEPP N-1 assessment.

Table 15-1 External Ambient Noise Measurements

Precinct / address	Day 7am to 6pm		Evening 6pm to 10pm		Night 10pm to 7am	
	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB	L_{A90}, dB	L_{Aeq}, dB
142 Cross Street, Footscray	49	57	-	-	47	49
70 Cross Street, Footscray	52	62	50	59	44	46

The key issues are identified in Table 15-2.

Table 15-2 Key issues associated with the Concept Design

Concept Design	Issue
West Footscray – a third platform and track at Footscray station, with modifications to existing concourse	Construction noise impacting on amenity

15.3 Key Issues

The key issues potentially associated with the Concept Design are identified in Table 15-3.

Table 15-3 Key issues associated with the Concept Design

Concept Design	Potential issue
Construction	
Airborne noise	• Impact on amenity at residential location
Vibration	• Structural damage • Impact on amenity
Ground-borne noise	• No tunnelling and therefore not expected to be an issue
Operation	
Airborne noise	• Impact on amenity at residential locations
Vibration	• Impact on amenity at residential locations
Ground-borne noise	• No tunnelling and therefore not expected to be an issue

15.4 Impact Assessment

The draft EES evaluation objectives and assessment Guideline Targets (and indicators where relevant) relevant to this assessment are provided in Section 2.1.

15.4.1 Construction

15.4.1.1 Airborne Noise

Airborne noise due to construction has been predicted at sensitive receivers in the vicinity of the construction work sites. Details of the methodology are provided in Section 4.7.1 and full details of the predictions are provided in Appendix A of the report.

For the predictions, it is assumed that all construction plant are operating concurrently, which is a conservative approach and unlikely to occur in practice.

The construction scenario assessed is Rail Occupation (24-hours, Unavoidable Work). The predicted construction noise levels are provided in the figures in Appendix A of the report.

While Guideline Noise Levels do not apply for this construction work, there is a requirement to manage noise and vibration impacts including:

- Preparation of a noise and vibration management plan
- Community consultation
- Implementation of mitigation.

Both general and specific noise mitigation are provided in Appendix A of the report. Specific noise mitigation includes:

- Noise barriers 2.5 m high for West Footscray and Station.

Mitigation would reduce the construction noise levels in this area and details are provided in Figures in Appendix A of this report. As the barriers shown are not required to achieve Guideline Noise Levels there may be scope to optimise the barriers to take into consideration visual impact.

The indicative barrier locations for construction at West Footscray station are presented in Figure 15-1. These barriers would mitigate both construction and train noise. Once construction is complete and the barriers are removed then train noise levels would increase at some sensitive receivers, although the train noise level would not be higher than before construction noise barriers are installed.

Figure 15-1 Mitigation at West Footscray Station

Compliance with the requirements of EPA 1254 is predicted to be achieved.

The construction work undertaken at the western turnback options would be either Unavoidable Work or during Normal Working Hours. Therefore, Guideline Noise Levels do not apply. However, it is recommended that noise barriers up to a height of 2.5 m are located around the construction activities to reduce the impact on the sensitive receivers.

With these noise barriers the highest noise levels are predicted to be 60 to 65 dB(A).This is marginally higher than the average daytime levels measured at 70 Cross Street and lower than the short-term events that occur in the area.

15.4.1.2 Vibration

There is no tunnelling associated with construction work in this area. Vibration is not expected to exceed Guideline Targets as residents are at least 20 m from construction work at West Footscray. MMRA would be responsible to meeting the Guideline Targets for human comfort whenever possible by employing low vibration construction methods in the vicinity of occupied buildings.

15.4.1.3 Ground-borne Noise

Ground-borne noise is not expected to be an issue as there is not underground work such as tunnelling and therefore air-borne noise is expected to be higher than ground-borne noise.

15.4.2 Operation

15.4.2.1 Airborne Noise

Train Noise

Details of the methodology and model used for the assessment of airborne noise from trains is provided in Section 4.8 and results of the assessment are provided in Appendix C of the report.

The Investigation Thresholds in the PRINP have been assessed at West Footscray station and are predicted not to be exceeded. Therefore, noise mitigation would not be required.

Noise associated with idling trains on the Turnback Track and Pocket Track is expected to be negligible compared to the trains operating at higher speeds during the peak period.

With respect to idling the turnback track are expected to have trains (emu's only) standing for a minimum of 5 minutes and maximum 15 minutes in the morning and afternoon peak only. No trains are predicted to be idling during off peak times or during the night time period.

Noise from Fixed Infrastructure

There is no fixed infrastructure proposed for Precinct 9. If this situation changes then any fixed infrastructure must meet the relevant SEPP N-1 Noise Limits.

15.4.2.2 Vibration

As trains would be no closer to noise sensitive receivers than they are currently, there is no expectation that vibration levels would change as a result of the infrastructure works.

15.4.2.3 Ground-borne Noise

Ground-borne noise is not expected to be an issue as trains would not be in tunnels.

15.5 Conclusion

The results of the assessment along with the outcomes and residual risk are provided in Table 15-4.

Table 15-4: Conclusions from the Assessment

Impact	Environmental Performance Requirement	Outcome	Residual Risk
Construction			
Airborne noise from construction	Manage noise with respect to EPA 1254	Compliance	Low
Building damage from vibration	Manage with respect to the Guideline Targets in DIN 4150	Compliance	Low
Vibration impacting buried pipework	Manage with respect to the Guideline Targets in DIN 4150	To be assessed by MMRA	-
Construction vibration impacting on amenity	Manage vibration with respect to the VDV Guideline Targets provided.	Compliance	Low
Ground-borne noise	Manage ground-borne noise with respect to the Guideline Targets provided.	Compliance	Low
Operation			
Airborne noise from trains	Compliance with PRINP	Compliance	Low
Airborne noise from fixed infrastructure	Compliance with SEPP N-1	Compliance	Low
Vibration	Compliance with the VDV Guideline Targets	Compliance	Low

15.6 Environmental Performance Requirements

Table 15-5 and Table 15-6 provide the recommended Environmental Performance Requirements for the noise and vibration for Precinct 9: Western Turnback for construction and operation respectively.

Table 15-5 Environmental Performance Requirements for Construction for Precinct 9: Western Turnback

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
Construction				
All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001, NV015, NV021, NV029
All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.	-	NV001, NV015, NV021, NV029
Residential amenity	Airborne noise from construction	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements as per EPA 1254 – Community consultation – 2.5 m high noise barriers – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Noise monitoring	NV001

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Building / structural integrity</td>
<td>Building damage from construction vibration</td>
<td>
Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.
<i>Short-term vibration on structures</i>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th rowspan="2">Vibration at horizontal plane of highest floor at all frequencies
mm/s (Peak Component Particle Velocity)</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:

At frequencies above 100 Hz, the values given in this column may be used as minimum values.
Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

<hr>
<i>Long term vibration on structures</i>
<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>
</td>
<td>
– Selection of construction equipment / construction methodology
– Bored piling
– Community consultation
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
</td>
<td>NV015</td>
</tr>
</table>

Asset / value	Impact	Environmental Performance Requirements	Possible mitigation measures	Risk no.
		Notes: 1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage. 2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.		
Underground infrastructure	Damage to underground infrastructure	Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved. (table below) Notes: 1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework. 2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro). 3. Compliance is to be achieved with asset owner's Utility Standards	– Selection of methodology / equipment – Building / Structural Condition Assessment prior to starting works – Vibration monitoring if vibration Guideline Targets are predicted to be exceeded	

Pipe Material	Vibration Velocity, mm/s (PPV)
Steel	100
Clay, concrete, reinforced concrete, prestressed concrete, metal	80
Masonry, plastic	50

<table>
<tr><th>Asset / value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV (m/s^{1.75})</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.</td><td>– Feasible and reasonable mitigation
– Community Consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
– Bored piling</td><td>NV021</td></tr>
</table>

Table 15-6: Environmental Performance Requirements for operation for Precinct 9: Western Turnback

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr><td colspan="5">Operation</td></tr>
<tr><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td></td><td>NV031, NV033, NV034</td></tr>
<tr><td>Amenity</td><td>Operational airborne noise impacting on amenity</td><td>Avoid, minimise or mitigate rail noise where the following PRINP (Victorian Passenger Rail Infrastructure Noise Policy, April 2013) Investigation Thresholds are exceeded during operation.
<table>
<tr><th>Time</th><th>Type of Receiver</th><th>Investigation Thresholds</th></tr>
<tr><td>Day
(6am – 10pm)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks
Noise sensitive community buildings, including schools, kindergartens, libraries</td><td>65 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
<tr><td>Night
(10pm – 6am)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks</td><td>60 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
</table>
Notes:
1. If an investigation shows that the thresholds are not exceeded, then no further action is considered under the PRINP
2. L_{Amax}, for this assessment, is defined as maximum A-weighted sound pressure level and is the 95 percentile of the highest value of the A-weighed sound pressure level reached within the day or night
3. For the Melbourne Metro the location of assessment is at 1 m from the centre of the window of the most exposed external façade</td><td>– Not required</td><td>NV031</td></tr>
</table>

<table>
<tr><th>Asset / Value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Possible mitigation measures</th><th>Risk no.</th></tr>
<tr>
<td>Amenity</td>
<td>Operational vibration impacting on amenity</td>
<td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7:00 am to 10:00 pm</th><th colspan="2">Night
10:00 pm to 7:00 am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td>
<td></td>
<td>NV034</td>
</tr>
</table>

16 Environmental Performance Requirements

This section provides a comprehensive list of the Environmental Performance Requirements identified as a result of this impact assessment. Table 16-1 provides the performance requirements which apply across the project linked to the draft EES evaluation objective.

Table 16-1 Environmental Performance Requirements

Draft EES evaluation objective	Asset or value	Impact	Environmental Performance Requirements	Proposed Mitigation Measures	Risk no.
Amenity: To minimise adverse noise or vibration effects on the amenity of nearby residents and local communities, as far as practicable, especially during the construction phase.	Tunnels		For construction works conducted between CBD South station and Domain station, comply with the requirements of the Notification of Referral Decision for the Melbourne Metro Rail Project (EPBC 2015/7549, dated 22 September 2015) under the EPBC Act for vibration monitoring and measurement, as follows: • Conduct preconstruction dilapidation surveys of the nearest Commonwealth Heritage listed structures to the construction activity, including the Former Guardhouse (Block B), to record structural condition and structural integrity prior to commencement of tunnelling • Conduct vibration monitoring at the commencement of tunnelling in geological conditions that are similar to those at Victoria Barracks in order to quantify the actual tunnel boring machine vibration characteristics (level and frequency) for comparison to the values derived from the literature and the German DIN (DIN 4150) target • Conduct continuous vibration monitoring at the nearest Victoria Barracks heritage structures to the construction activity, including the Former Guardhouse (B Block), to assess the actual tunnelling vibration for acceptability, taking into account both the vibration frequency and condition of structures, until monitoring of vibration at the Former Guardhouse (B Block) shows measurements equivalent to preconstruction vibration readings at the Former Guardhouse (B Block) • If monitoring conducted according to the above demonstrates the condition of heritage structures may be degraded as a result of vibration, ground vibration must be reduced by adjusting the advance rate of the tunnel boring machine until monitoring of vibration at the Former Guardhouse (B Block) shows consistent measurements equivalent to preconstruction vibration readings at the Former Guardhouse (B Block).		
	All	Noise and Vibration	Appoint an acoustic and vibration consultant to predict construction noise and vibration (through modelling) and update the modelling to reflect current construction methodology, site conditions and specific equipment noise and vibration levels (this would require noise and vibration measurements). The model would be used to determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake noise and vibration monitoring to assess levels with respect to Guideline Targets specified in the Environmental Performance Requirements. Where monitoring indicates exceedances of Guideline Targets, apply appropriate management measures as a soon as possible.		NV001 to NV029
	All	Noise and Vibration	Develop and implement a communications plan to liaise with potentially affected community stakeholders and land owners regarding potential noise and vibration impacts. The plan shall include procedures for complaint management.		NV001 to NV029
	Construction airborne noise	Adverse impact on amenity	Develop and implement a plan to manage construction noise in accordance with EPA Publication 1254 Noise Control Guidelines.	– Requirements as per EPA 1254 – Community consultation – Noise barriers – Construction methodology / equipment	NV001

Draft EES evaluation objective	Asset or value	Impact	Environmental Performance Requirements	Proposed Mitigation Measures	Risk no.
				– respite / temporary relocation – Prepare and implement a construction noise and vibration management plan – Noise Monitoring	
	Amenity and appropriate acoustic environment	Airborne noise from construction	Implement management actions if construction noise exceeds the internal noise levels below for Highly Sensitive Areas (based on AS/NZS 2107:2000) and a noise sensitive receptor is adversely impacted.	– Community consultation – Acoustic construction sheds – Construction methodology / equipment – Prepare and implement a construction noise and vibration management plan – Internal noise monitoring	NV001

Highly Sensitive Area	Maximum Internal Construction Noise Level $L_{Aeq, 15 mins}$
Intensive Care Wards	45
Operating Theatres	45
Surgeries	45
Wards	40

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td>Construction vibration</td><td>Building damage</td><td>Implement management actions if due to construction activity, the following DIN 4150 Guideline Targets for structural damage to buildings (for short-term vibration or long-term vibration) are not achieved.

<i>Short-term vibration on structures</i>
<table>
<tr><th rowspan="2">Type of structure</th><th colspan="3">Vibration at the foundation, mm/s (Peak Component Particle Velocity)</th><th>Vibration at horizontal plane of highest floor at all frequencies</th></tr>
<tr><th>1 to 10 Hz</th><th>10 to 50 Hz</th><th>50 to 100 Hz[1]</th><th>mm/s (Peak Component Particle Velocity)</th></tr>
<tr><td>Type 1: Buildings used for commercial purposes, industrial buildings and buildings of similar design</td><td>20</td><td>20 to 40</td><td>40 to 50</td><td>40</td></tr>
<tr><td>Type 2: Dwellings and buildings of similar design and/or occupancy</td><td>5</td><td>5 to15</td><td>15 to 20</td><td>15</td></tr>
<tr><td>Type 3: Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>3</td><td>3 to 8</td><td>8 to 10</td><td>8</td></tr>
</table>
Notes:
1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Vibration levels marginally exceeding those vibration levels in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
3. For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.
4. Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.</td><td>– Selection of construction equipment / construction methodology
– Bored piling
– Community consultation
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Minimum buffer distances</td><td>NV002,
NV003,
NV014,
NV015,
NV016,
NV017</td></tr>
</table>

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td></td><td>

Long term vibration on structures

<table>
<tr><th>Type of structure</th><th>Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies</th></tr>
<tr><td>Buildings used for commercial purposes, industrial buildings and similar design</td><td>10</td></tr>
<tr><td>Dwellings and buildings of similar design and/or occupancy</td><td>5</td></tr>
<tr><td>Structures that have a particular sensitivity to vibration e.g. heritage buildings</td><td>2.5</td></tr>
</table>

Notes:

1. Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation would be required to determine if higher vibration levels can be accommodated without risk of damage.
2. Long-term vibration during construction to demonstrate compliance with agreed vibration guideline targets. Take remedial action if limits are not met.

</td><td></td><td></td></tr>
<tr><td></td><td>Underground Infrastructure</td><td>Damage to underground infrastructure</td><td>

Implement management actions if the following DIN 4150 Guideline Targets for buried pipework/underground infrastructure from construction are not achieved.

<table>
<tr><th>Pipe Material</th><th>Vibration Velocity, mm/s (PPV)</th></tr>
<tr><td>Steel</td><td>100</td></tr>
<tr><td>Clay, concrete, reinforced concrete, prestressed concrete, metal</td><td>80</td></tr>
<tr><td>Masonry, plastic</td><td>50</td></tr>
</table>

Notes:

1. These values may be reduced by 50% when evaluating the effects of long-term vibration on buried pipework.
2. It is assumed pipes have been manufactured and laid using current technology (however it is noted that this is not the case for the majority of buried pipework potentially affected by Melbourne Metro).
3. Compliance is to be achieved with asset owner’s Utility Standards.

</td><td>

– Selection of methodology / equipment
– Building / Structural Condition Assessment prior to starting works
– Vibration monitoring if vibration Guideline Targets are predicted to be exceeded
– Minimum buffer distances

</td><td></td></tr>
</table>

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td>Amenity</td><td>Construction vibration impacting upon amenity</td><td>Implement Management Actions if the Guideline Targets (VDVs) (based on Table 1 in BS6472-1:2008) for continuous (as for TBMs and roadheaders), intermittent, or impulsive vibration are not achieved.
<table>
<tr><th rowspan="3">Location</th><th colspan="4">Vibration Dose Value, VDV ($m/s^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures. If exceeded then management actions would be required.
2. The VDVs may be converted to PPVs within a future Noise and Vibration Construction Management Plan.</td><td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
– Minimum buffer distances
– Timing of activities</td><td>NV004, NV005, NV006, NV018, NV019, NV020, NV021</td></tr>
<tr><td></td><td>Buildings
Amenity</td><td>Structural damage, impact on amenity</td><td>Comply with Australian Standard AS2187.2-2006, Explosives – Storage and use Part 2 – Use of explosives for all blasting
For Highly Sensitive Areas, hospital wards, operating theatres and Bio-resources and areas with vibration-sensitive equipment which are not covered in AS2187.2-2006, develop a plan in consultation with facilities owners that:
● Avoids damage to vibration-sensitive equipment
● Minimises adverse impact on Highly Sensitive Areas and Bio-resources.</td><td>– Charge size
– Buffer distances</td><td></td></tr>
</table>

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td>Vibration-sensitive equipment</td><td>Construction vibration causing disturbance to vibration-sensitive equipment</td><td>Implement Management Actions if the ASHRAE equipment vibration Guideline Targets or measured background levels (whichever is higher) are exceeded for vibration-sensitive equipment during construction and operation at Parkville and CBD North stations.
<table>
<tr><th>Equipment requirements</th><th>Curve</th></tr>
<tr><td>Bench microscopes up to 100x magnification; laboratory robots</td><td>Operating Room</td></tr>
<tr><td>Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc.</td><td>VC-A</td></tr>
<tr><td>Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths</td><td>VC-B</td></tr>
<tr><td>Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1 mm detail size</td><td>VC-C</td></tr>
<tr><td>Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photo-lithography with line widths of ½ micro m; includes electron beam systems</td><td>VC-D</td></tr>
<tr><td>Unisolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ¼ micro m; includes electron beam systems</td><td>VC-E</td></tr>
</table>
Note:
1. The Proponent may undertake consultation with the users and agree alternative Guideline Targets.</td><td>– Stakeholder consultation
– Selection of methodology / equipment
– Minimum buffer distances</td><td>NV008,
NV009</td></tr>
<tr><td></td><td>Amenity</td><td>Construction ground-borne noise impacting upon amenity</td><td>Implement management actions as determined in consultation with potentially affected land owners to protect amenity at residences, sleeping areas in hospital wards, student accommodation and hotel rooms where the following ground-borne noise Guideline Targets (from the NSW Interim Construction Noise Guideline) are exceeded during construction.
<table>
<tr><th>Time Period</th><th>Internal Target, $L_{Aeq,15min}$ (dB)</th></tr>
<tr><td>Evening, 6pm to 10pm</td><td>40</td></tr>
<tr><td>Night, 10 pm to 7am</td><td>35</td></tr>
</table>
Note:
1. Levels are only applicable when ground-borne noise levels are higher than airborne noise levels.
2. The noise levels are assessed at the centre of the most affected habitable room.
3. Management Actions include extensive community consultation to determine acceptable level of disruption and provision of respite accommodation in some circumstances.</td><td>– Feasible and reasonable mitigation
– Community consultation
– Provision of respite / temporary relocation
– Selection of methodology / equipment
– Bored piling
– Minimum buffer distances
– Timing of activities</td><td>NV025,
NV026,
NV027,
NV028,
NV029</td></tr>
</table>

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td>Amenity for Bio-resources</td><td>Disturbance to Bio-resources</td><td>To protect the amenity of Bio-resources and sensitive research during construction and operation the following criteria apply:
– Background noise should be kept below 50 dB and should be free of distinct tones (internal).
– Short exposure should be kept to less than 85 dB (internal).
Notes:
1. The levels above should take into consideration the frequency threshold for the Bio-resource under consideration.
2. Higher levels may be acceptable if it can be shown that the Bio-resource under consideration is exposed to higher levels and is not adversely impacted by them.</td><td>– Selection of methodology / equipment
– Noise monitoring</td><td>NV012</td></tr>
<tr><td>Operation</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>All</td><td>Noise and Vibration</td><td>Appoint an acoustic and vibration consultant to predict noise and vibration and determine appropriate mitigation to achieve the Environmental Performance Requirements. The acoustic and vibration consultant would also be required to undertake commissioning noise and vibration measurements to assess levels with respect to the Environmental Performance Requirements.</td><td></td><td>NV030 to NV038</td></tr>
<tr><td></td><td>Amenity</td><td>Operational airborne noise impacting on amenity</td><td>Avoid, minimise or mitigate rail noise where the following PRINP (Victorian Passenger Rail Infrastructure Noise Policy, April 2013) Investigation Thresholds are exceeded during operation.
<table>
<tr><th>Time</th><th>Type of Receiver</th><th>Investigation Thresholds</th></tr>
<tr><td>Day
(6am – 10pm)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks
Noise sensitive community buildings, including schools, kindergartens, libraries</td><td>65 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
<tr><td>Night
(10pm – 6am)</td><td>Residential dwellings and other buildings where people sleep including aged persons homes, hospitals, motels and caravan parks</td><td>60 dBL_{Aeq} and a change in 3 dB(A) or more
or
85 dBL_{Amax} and a change in 3 dB(A) or more</td></tr>
</table>
Notes:
1. If an investigation shows that the thresholds are not exceeded, then no further action is considered under the PRINP
2. L_{Amax}, for this assessment, is defined as maximum A-weighted sound pressure level and is the 95 percentile of the highest value of the A-weighed sound pressure level reached within the day or night
3. For the Melbourne Metro the location of assessment is at 1 m from the centre of the window of the most exposed external façade</td><td>– Noise barriers
– Off Reservation Treatment (where applicable)</td><td>NV031</td></tr>
</table>

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td>Amenity</td><td>Operational airborne noise causing adverse impact on amenity</td><td>Comply with State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1). This does not apply to trains and trams.</td><td>– Selection of low noise equipment
– Attenuators
– Lined ductwork/plenums
– Acoustic barriers / screens</td><td>NV032,
NV035</td></tr>
<tr><td></td><td>Amenity</td><td>Operational ground-borne noise impacting upon amenity</td><td>Where operational ground-borne noise trigger levels are exceeded for sensitive occupancies as shown in the table below (trigger levels are based on the Rail Infrastructure Noise Guideline,17 May 2013 (RING(1)), assess feasible and reasonable mitigation to reduce noise towards the relevant ground-borne noise trigger level.
<table>
<tr><th>Sensitive land use</th><th>Time of day</th><th>Internal noise trigger levels</th></tr>
<tr><td>Residential</td><td>Day (7am-10pm)</td><td>40 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td></td><td>Night (10pm -7am)</td><td>35 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Schools, educational institutions, places of worship</td><td>When in use</td><td>40-45 dBL_{ASmax} and an increase in existing rail noise level by 3 dB(A) or more</td></tr>
<tr><td>Hospitals (bed wards and operating theatres)</td><td>24 hours</td><td>35 dB(A) L_{ASMax}</td></tr>
<tr><td>Offices</td><td>When in use</td><td>45 dB(A) L_{ASMax}</td></tr>
<tr><td>Cinemas and Public Halls</td><td>When in use</td><td>30 dB(A) L_{ASMax}</td></tr>
<tr><td>Drama Theatres</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
<tr><td>Concert halls, Television and Sound Recording Studios</td><td>When in use</td><td>25 dB(A) L_{ASMax}</td></tr>
</table>
1. RING provides trigger levels for residential and schools, educational institutions and places of worship, but does not provide guidance on acceptable ground-borne noise levels for other types of sensitive receivers. Ground-borne noise trigger levels for other types of sensitive occupancies have been developed based on RING and industry knowledge.
2. Specified noise levels refer to noise from heavy or light rail transportation only (not ambient noise from other sources)
3. Assessment location is internal near to the centre of the most affected habitable room.
4. L_{ASmax} refers to the maximum noise level not exceeded for 95% of the rail pass-by events.
5. For schools, educational institutions, places of worship the lower value of the range is most applicable where low internal noise levels is expected.</td><td>– Isolated track form</td><td>NV038</td></tr>
</table>

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td></td><td></td><td>6. The values for performing arts spaces may need to be reassessed to address the specific requirements of a venue</td><td></td><td></td></tr>
<tr><td></td><td>Amenity</td><td>Operational vibration impacting on amenity</td><td>During operation, achieve the Guideline Targets (based on Table 1 in BS6472-1:2008) or background levels (whichever is higher) for vibration as follows:
<table>
<tr><th rowspan="3">Location</th><th colspan="4">VDV (m/s$^{1.75}$)</th></tr>
<tr><th colspan="2">Day
7am to 10pm</th><th colspan="2">Night
10pm to 7am</th></tr>
<tr><th>Preferred Value</th><th>Maximum Value</th><th>Preferred Value</th><th>Maximum Value</th></tr>
<tr><td>Residences</td><td>0.20</td><td>0.40</td><td>0.10</td><td>0.20</td></tr>
<tr><td>Offices, schools, educational institutions, places of worship</td><td>0.40</td><td>0.80</td><td>0.40</td><td>0.80</td></tr>
<tr><td>Workshops</td><td>0.80</td><td>1.60</td><td>0.80</td><td>1.60</td></tr>
</table>
Notes:
1. The Guideline Targets are non-mandatory; they are goals that should be sought to be achieved through the application of feasible and reasonable mitigation measures.
2. Compliance with these values implies no structural damage due to operation</td><td>– Isolated track form</td><td>NV034</td></tr>
</table>

<table>
<tr><th>Draft EES evaluation objective</th><th>Asset or value</th><th>Impact</th><th>Environmental Performance Requirements</th><th>Proposed Mitigation Measures</th><th>Risk no.</th></tr>
<tr><td></td><td>Vibration-sensitive equipment</td><td>Disturbance to vibration-sensitive equipment</td><td>Implement Management Actions if the ASHRAE equipment vibration Guideline Targets or measured background levels (whichever is higher) are exceeded for vibration-sensitive equipment during construction and operation at Parkville and CBD North stations.
<table>
<tr><th>Equipment requirements</th><th>Curve</th></tr>
<tr><td>Bench microscopes up to 100x magnification; laboratory robots</td><td>Operating Room</td></tr>
<tr><td>Bench microscopes up to 400x magnification; optical and other precision balances; co-ordinate measuring machines; metrology laboratories; optical comparators; micro electronics manufacturing equipment; proximity and projection aligners, etc.</td><td>VC-A</td></tr>
<tr><td>Microsurgery, eye surgery, neurosurgery; bench microscope at magnification greater than 400x; optical equipment on isolation tables; microelectronic manufacturing equipment such as inspection and lithography equipment (including steppers) to 3mm line widths</td><td>VC-B</td></tr>
<tr><td>Electron microscopes up to 30,000x magnification; microtomes; magnetic resonance images; microelectronics manufacturing equipment such as lithography and inspection equipment to 1 mm detail size</td><td>VC-C</td></tr>
<tr><td>Electron microscopes at magnification greater than 30,000x; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photo-lithography with line widths of ½ micro m; includes electron beam systems</td><td>VC-D</td></tr>
<tr><td>Unisolated laser and optical research systems; microelectronics manufacturing equipment such as aligners, steppers and other critical equipment for photolithography with line widths of ¼ micro m; includes electron beam systems</td><td>VC-E</td></tr>
</table>
Note:
1. The Proponent may undertake consultation with the users and agree alternative Guideline Targets.</td><td>– Isolated track form</td><td>NV035,
NV036,
NV037</td></tr>
<tr><td></td><td>Amenity for Bio-resources</td><td>Disturbance to Bio-resources</td><td>To protect the amenity of Bio-resources and sensitive research during construction and operation the following criteria apply:
– Background noise should be kept below 50 dB and should be free of distinct tones (internal).
– Short exposure should be kept to less than 85 dB (internal).
Notes:
1. The levels above should take into consideration the frequency threshold for the Bio-resource under consideration.
2. Higher levels may be acceptable if it can be shown that the Bio-resource under consideration is exposed to higher levels and is not adversely impacted by them</td><td>– Selection of methodology / equipment
– Noise monitoring</td><td>NV012</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

17 Conclusion

Melbourne Metro has the potential to impact on the community near the project during both construction and operation. An extensive assessment has been conducted which has predicted the extent of these impacts. The report has detailed how the impacts can be managed with mitigation and management.

The assessment is based on predictions using standard engineering approaches and it is expected that there is conservatism in some of the assessments. MMRA would need to appoint an acoustic consultant to undertake an independent assessment and to undertake noise and vibration measurements to refine outcomes e.g. mitigation, buffer distances.

During construction, airborne noise, vibration and ground-borne noise would potentially affect sensitive receivers and Guideline Targets are presented.

For airborne construction noise, compliance with EPA 1254 is predicted. In addition to applying good practice measures on construction work sites, extensive mitigation is proposed. During Unavoidable Work, temporary relocation or respite may be appropriate if noise levels are not well tolerated by a sensitive receiver. This approach is consistent with other projects undertaken in Victoria where Unavoidable Work is required at night (e.g. Regional Rail Link).

The DIN 4150 Guideline Targets for structural damage are predicted to be achieved for all construction work. Vibration monitoring should be conducted during construction to confirm the results of the predictions.

For the majority of the project noise and vibration from the TBM / roadheader tunnelling would be insignificant at sensitive locations along the alignment. The Guideline Targets for vibration (human comfort) and ground-borne noise, however, are predicted to trigger Management Actions at a number of locations above or near the tunnelling for discrete periods. Triggering of Management Actions does not necessarily imply that a resident would be disturbed or if disturbed, that they would be disturbed for the entire period that Management Actions are predicted to be required. MMRA would need to provide information to residents and manage expectations during these times. Should the level and duration of disturbance not be well tolerated by a resident, then temporary relocation or respite may be appropriate. Ground-borne noise does not usually disturb building occupants during the day due to higher ambient noise levels. It may, however, be noticed at times at night when ambient noise levels are low. As the construction works are being undertaken in busy inner city areas, ambient noise levels even at night may provide masking of noise from construction. Tunnelling would occur over 24-hours, which is consistent with major tunnelling projects within Australia and around the world. Constraining this program would result in extending the length of the impact and significantly increasing the cost of the project.

The 24-hour operation of the roadheaders for the excavation of the station caverns (CBD stations) is predicted to trigger Management Actions for vibration (human comfort) and ground-borne noise at a number of locations. The period for Management Actions is up to 6 weeks for up to 3 times (based on a preferred level which relates to ‘no expected adverse comment’ due to night time vibration levels). Of this time, ‘adverse comments are probable’ for a period of less than 4 days. MMRA would need to provide information and manage expectations during these times. Temporary relocation or respite may be appropriate if the duration and levels of noise and vibration are not well tolerated by sensitive receivers. Limiting hours of operation may also be appropriate.

For Additional Construction Works low vibration methods are to be used within 5 m of some buildings. Compliance with the night time Guideline Targets is predicted for vibration for human comfort and ground-borne noise by adhering to minimum buffer distances and limiting the operating hours of some equipment.

The predicted vibration levels do not meet the Guideline Targets for some vibration-sensitive equipment and Highly Sensitive Areas in the Parkville and CBD North Station Precincts. Close collaboration would be required to keep the relevant stakeholders informed of the timing of the potential impacts. It may be appropriate to limit tunnelling to daytime hours near the hospitals in Parkville.

For train noise from operation, the Investigation Thresholds from the PRINP are predicted to be met with the installation of noise barriers at the western and eastern portal precincts. Barriers would not be required for the western turnback. Fixed infrastructure is expected to require standard mitigation techniques to meet the SEPP N-1 Noise Limits.

To meet the Guideline Targets for operation of Melbourne Metro for human comfort and ground-borne noise, track vibration isolation is proposed throughout the alignment. With track vibration isolation, the Guideline Targets for human comfort, ground-borne noise and vibration-sensitive equipment are predicted to be achieved.

There would be noise and vibration impacts associated with Melbourne Metro as for all major infrastructure projects undertaken in urban environments. The impacts associated with construction could be managed with the installation of mitigation, on-going management and measurement of noise and vibration (to reassess the impacts based on actual data) and community consultation. The impacts associated with operation can be mitigated using engineering techniques consistent with equivalent projects.

All of the Scoping Requirements for Melbourne Metro have been addressed in this report as detailed in Table 17-1.

Table 17-1 Scoping requirements summary

Aspect	Relevant response	Impact Assessment
Key Issues	• Emissions of noise resulting from the Project exceeding relevant statutory, policy or guideline levels, adversely affecting amenity of residences or other sensitive land uses. • Generation of airborne or ground-borne vibrations, which could adversely affect amenity of residential or other sensitive premises.	These have been assessed in Appendices A and B for construction and C to E for operation.
Priorities for characterising the existing environment	• Existing noise conditions and trends in the neighbourhood of the Project alignment and works sites. • Ground conditions, which may influence the transmission of vibrations resulting from construction works or railway operations.	The baseline report is provided in Appendix F of this report.
Design and mitigation measures	• Design, management and intervention measures, which may be applied to control emissions of construction noise and noise from train operations within relevant SEPP, policy or guideline levels. • Design, management and intervention measures, which may be applied to control vibrations resulting from construction works and from train operations within relevant guideline levels that are appropriate for the project.	These have been assessed in Appendices A and B for construction and C to E for operation.

Aspect	Relevant response	Impact Assessment
Assessment of likely effects	- Analysis of potential for noise standards to be exceeded, with respect to timing, durations, localities, degree of potential exceedance and any relevant special noise characteristics (e.g. tonality, impulsiveness). - Analysis of potential for vibration to cause disturbance to occupants of residential buildings or other sensitive land uses.	These have been assessed in Appendices A and B for construction and C to E for operation.
Approach to manage performance	- Describe the principles to be adopted for setting key elements of proposed monitoring programs for, noise and vibration, both during construction works and for project operations, as appropriate. - Describe the principles to be adopted for developing contingency measures to be applied if monitoring demonstrates more significant adverse effects than predicted or permitted.	Environmental Performance Requirements.

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Appendices