

**Legend**

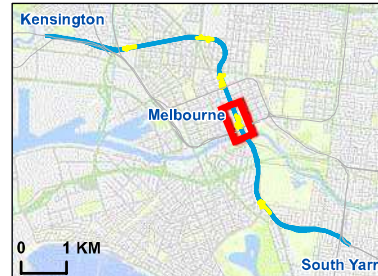
**Result Set 6**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct

Map 9 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2016;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Day Target - CBD South Station

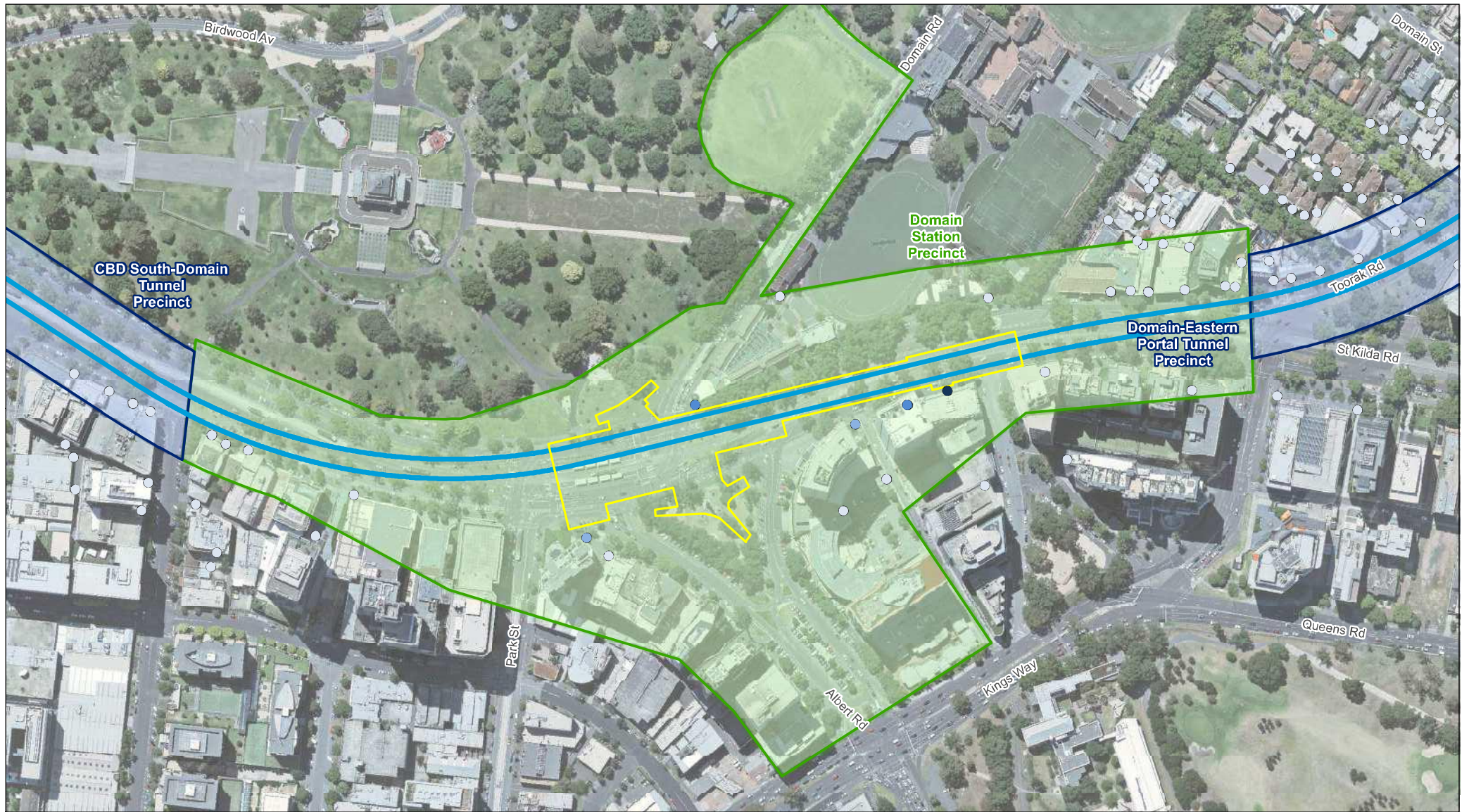
Drawing Number: MMR-AJM-UGAA-MP-NO-500293  
 Revision: P1

Drawn By: A. Davy  
 Approved By: D. Timms  
 Date: 11/04/2016  
 Map Size: A4



Figure B.75: Colour coded VDV day assessment for Additional Construction Works – CBD South Station Precinct





**Legend**

**Result Set 6**

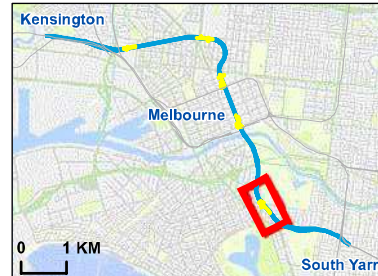
**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct

Map 11 of 13

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2016;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Day Target - Domain Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500293  
 Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 11/04/2016	Map Size: A4
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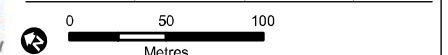


Figure B.76: Colour coded VDV day assessment for Additional Construction Works – Domain Station Precinct





**Legend**

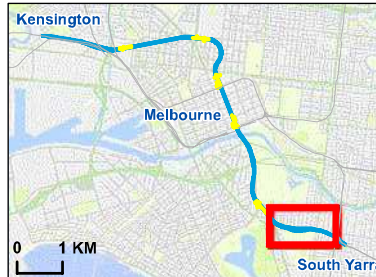
**Result Set 6**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct

Map 12 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2016;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title: Additional Construction Works Vibration Dosage Value (VdV) - Guideline Day Target - Domain to Eastern Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500293

Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 11/04/2016	Map Size: A4
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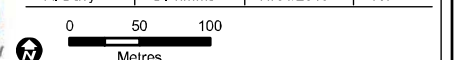
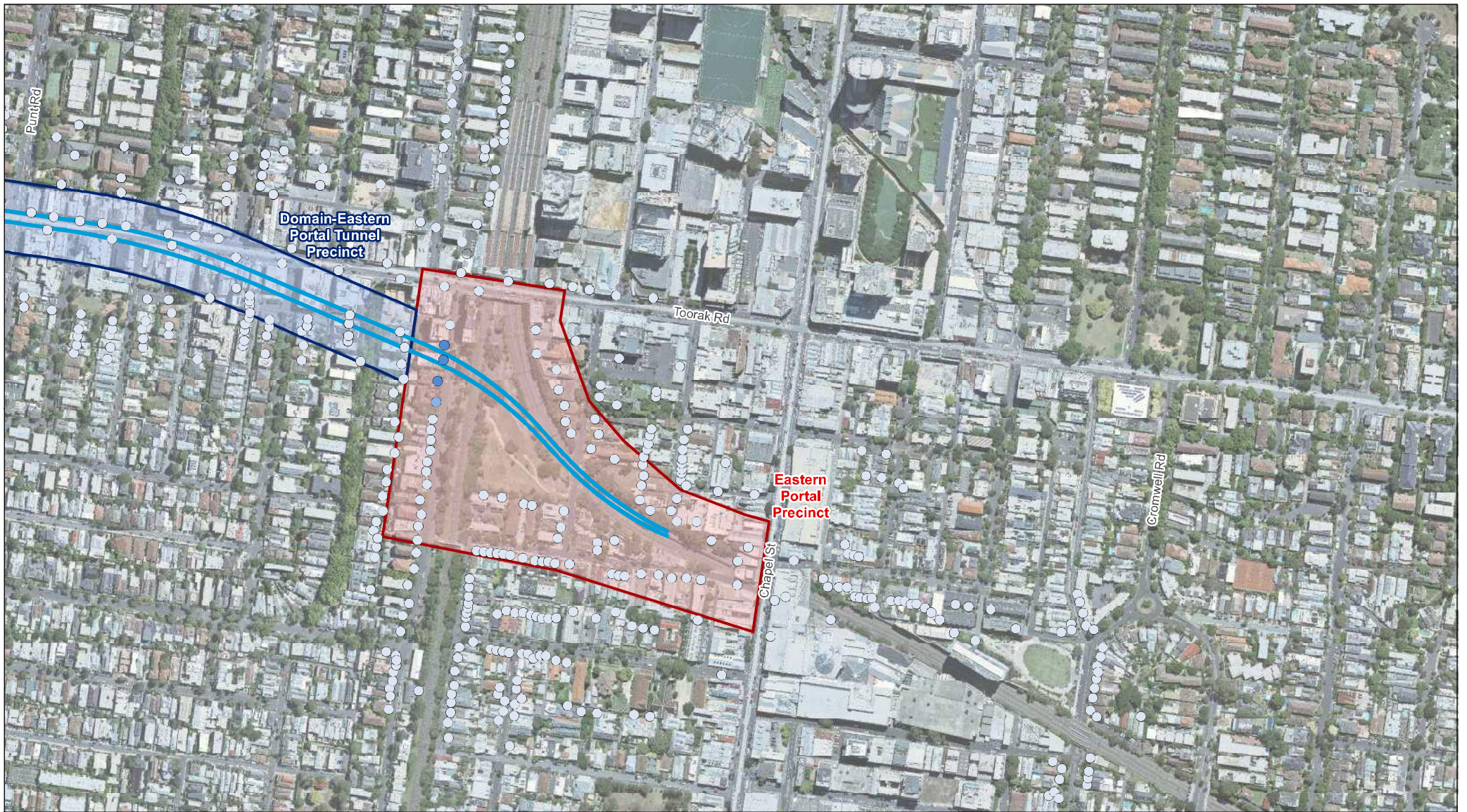


Figure B.77: Colour coded VDV day assessment for Additional Construction Works – Domain to Eastern Portal Tunnels Precinct





**Legend**

**Result Set 6**

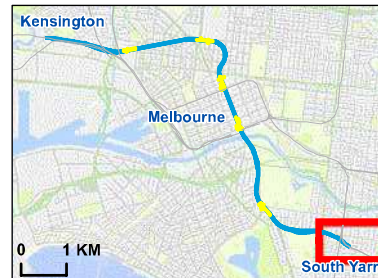
**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Portal Precinct

Map 13 of 13

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2016;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Day Target - Eastern Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500293  
 Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 11/04/2016	Map Size: A4
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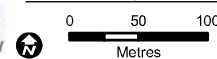


Figure B.78: Colour coded VDV day assessment for Additional Construction Works – Eastern Portal Precinct





**Legend**

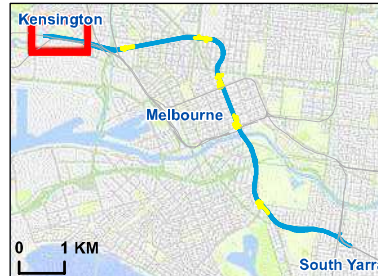
**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Portal Precinct

Map 1 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - Western Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500294  
 Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 11/04/2016	Map Size: A4
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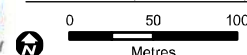
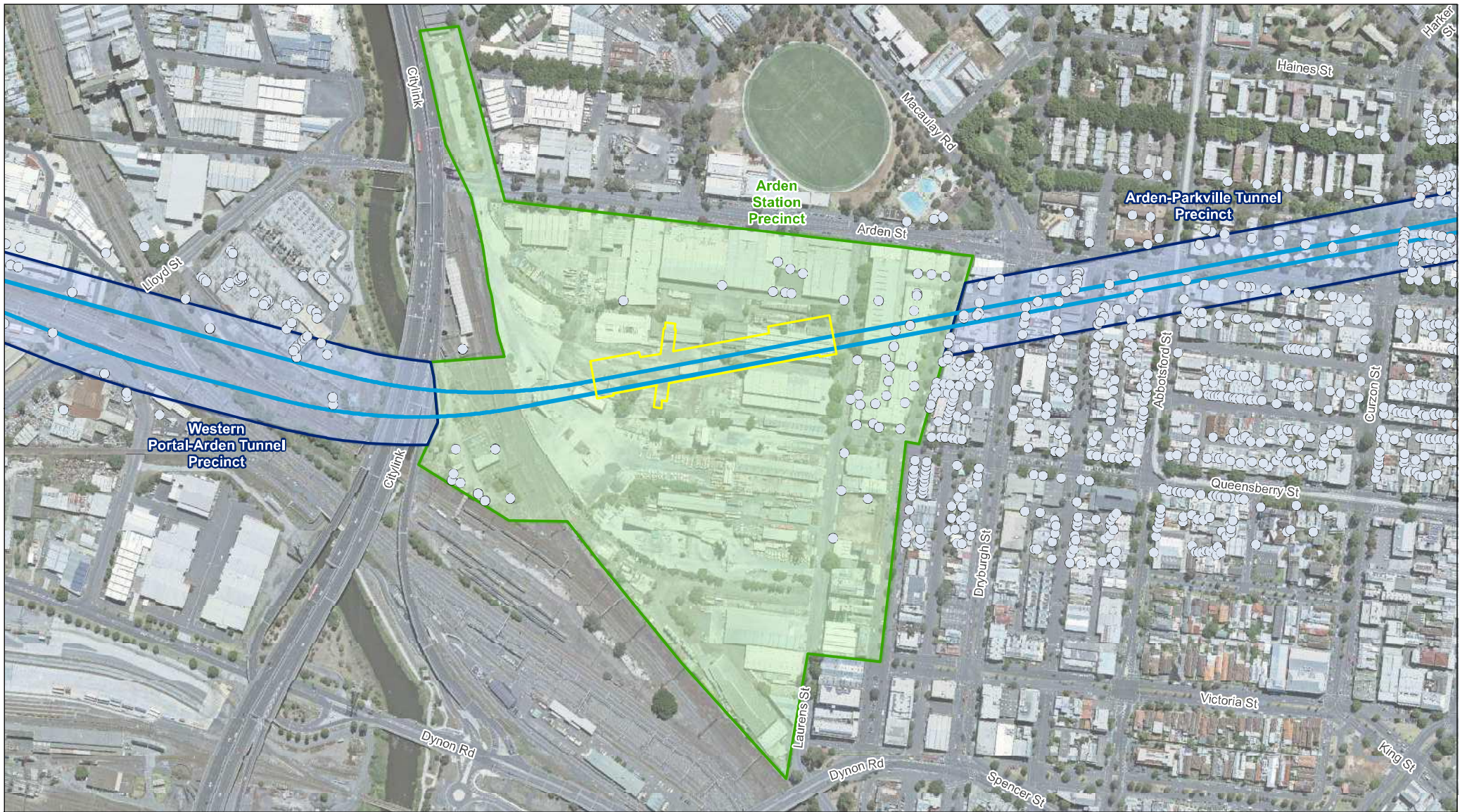


Figure B.79: Colour coded VDV night assessment for Additional Construction Works – Western Portal Precinct





**Legend**

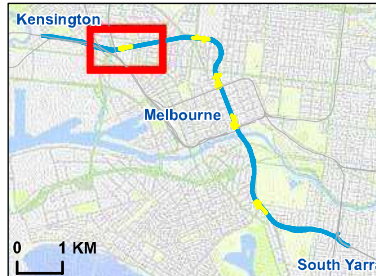
**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct

Map 3 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - Arden Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500294  
 Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 11/04/2016	Map Size: A4
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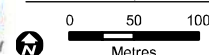
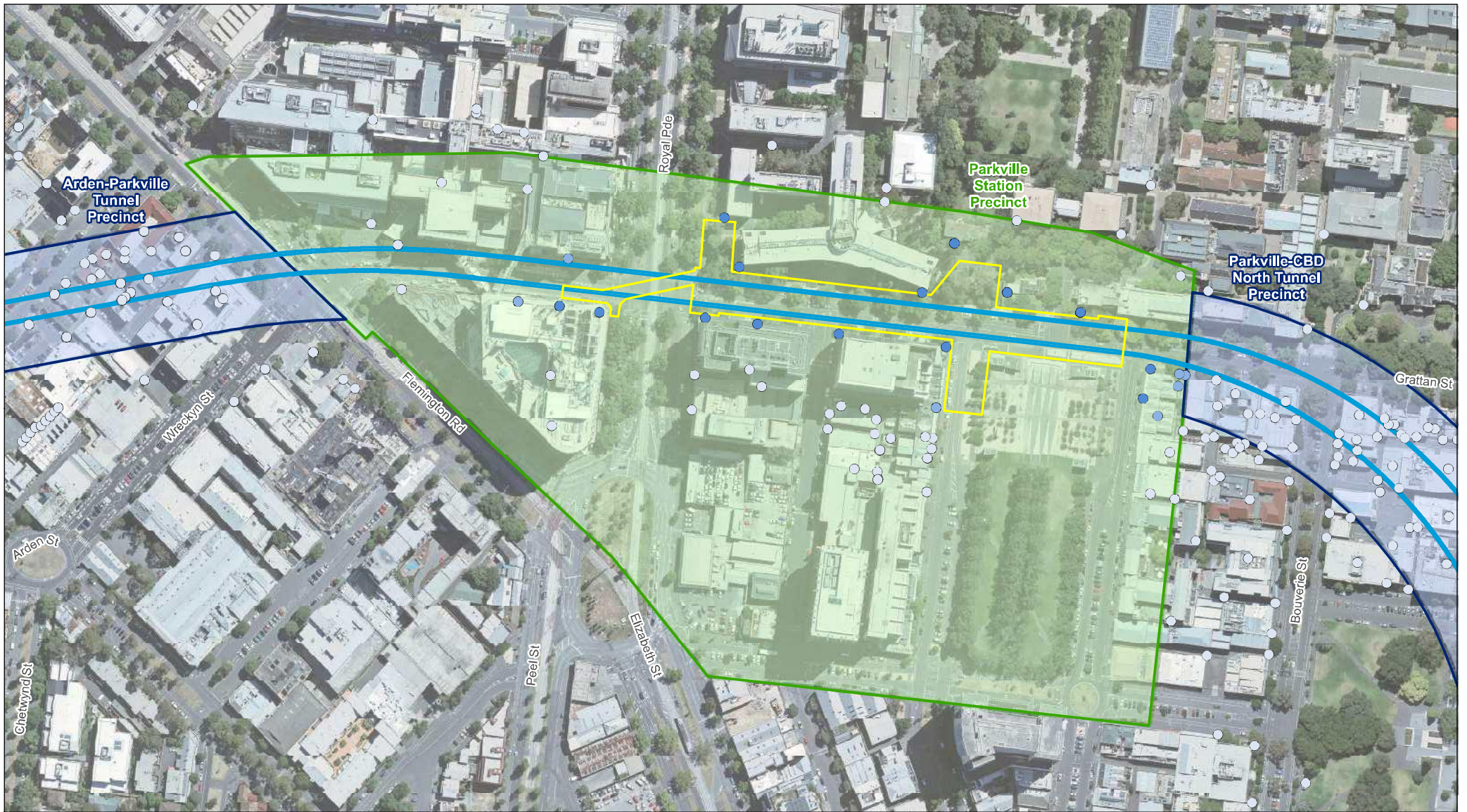


Figure B.80: Colour coded VDV night assessment for Additional Construction Works – Arden Station Precinct





**Legend**

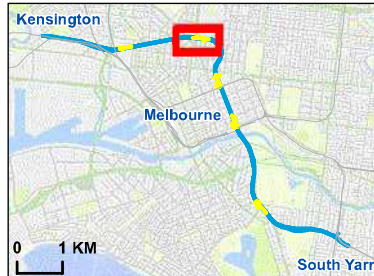
**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct

Map 5 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - Parkville Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500294  
 Revision: P1

Drawn By: A. Davy  
 Approved By: D. Timms  
 Date: 11/04/2016  
 Map Size: A4

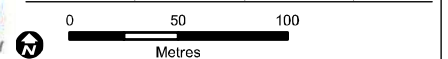
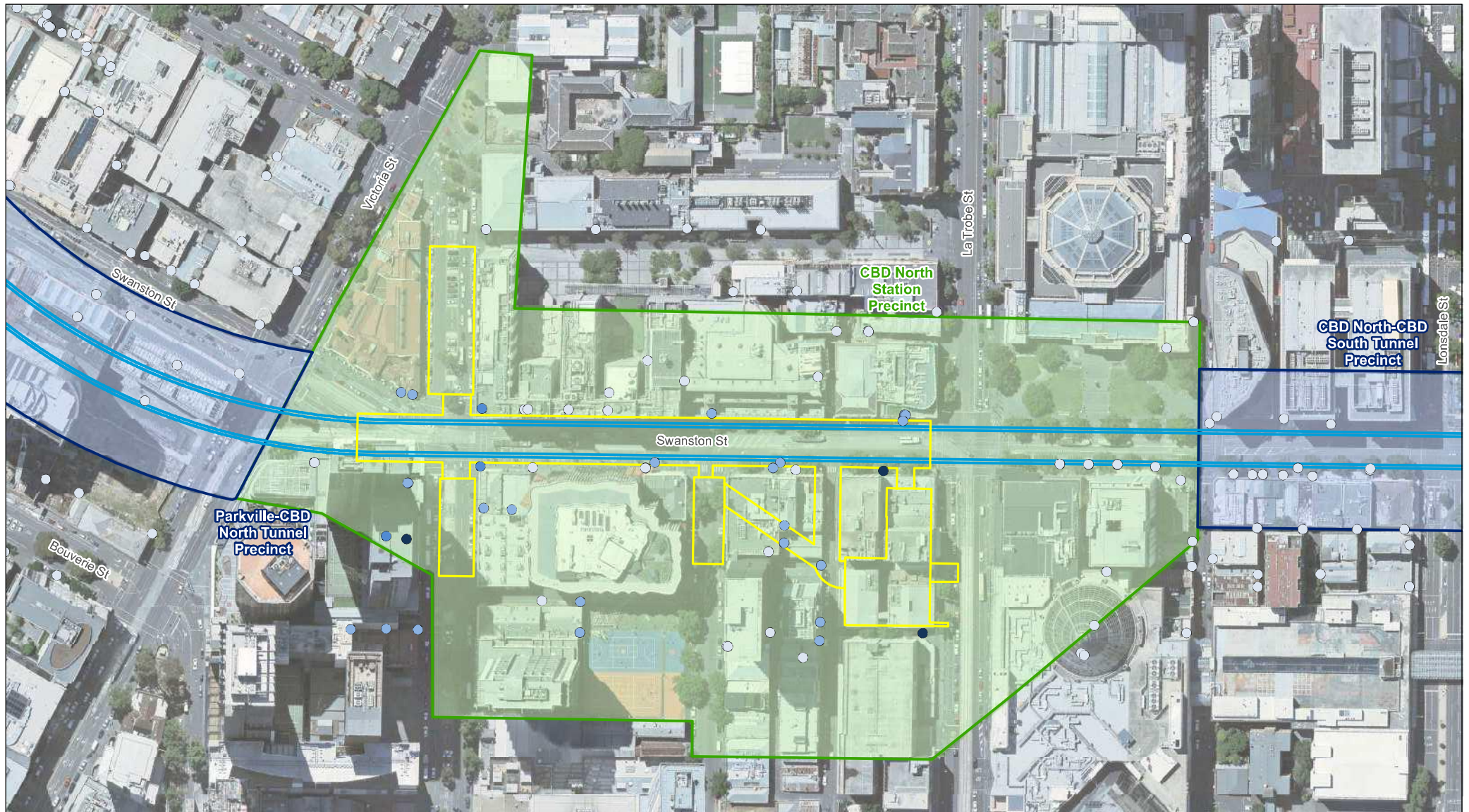


Figure B.81: Colour coded VDV night assessment for Additional Construction Works – Parkville Station Precinct





**Legend**

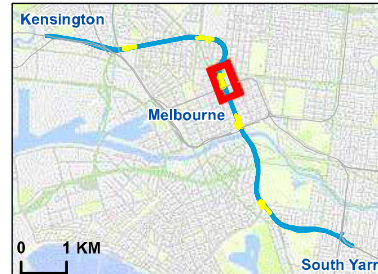
**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct

Map 7 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - CBD North Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500294  
 Revision: P1

Drawn By: A. Davy  
 Approved By: D. Timms  
 Date: 12/04/2016  
 Map Size: A4

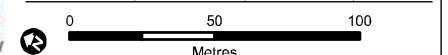
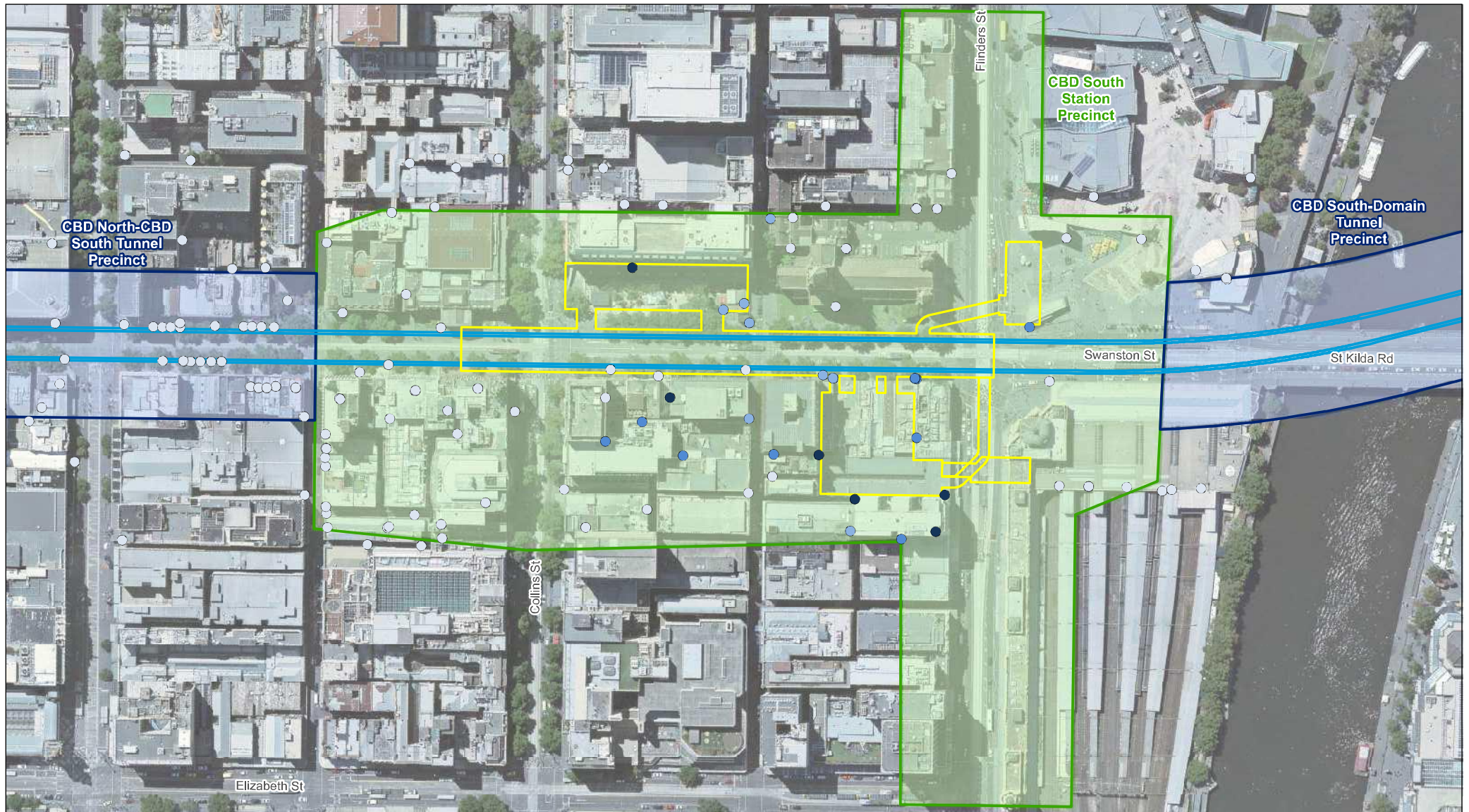


Figure B.82: Colour coded VDV night assessment for Additional Construction Works – CBD North Station Precinct





**Legend**

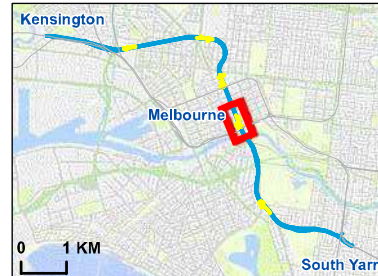
**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct

Map 9 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title: Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - CBD South Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500294

Revision: P1

Drawn By: A. Davy

Approved By: D. Timms

Date: 11/04/2016

Map Size: A4



Figure B.83: Colour coded VDV night assessment for Additional Construction Works – CBD South Station Precinct





**Legend**

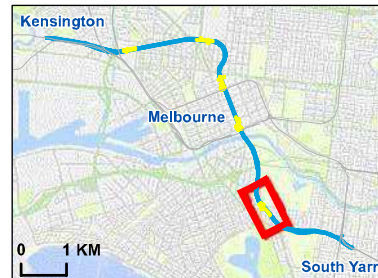
**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct

Map 11 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - Domain Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500294  
 Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 11/04/2016	Map Size: A4
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Figure B.84: Colour coded VDV night assessment for Additional Construction Works – Domain Station Precinct





**Legend**

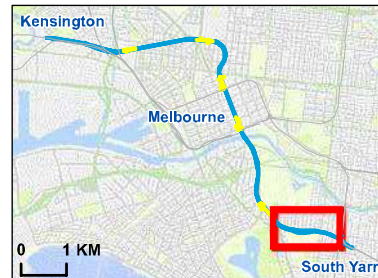
**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct

Map 12 of 13



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title: Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - Domain to Eastern Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500294  
 Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 11/04/2016	Map Size: A4
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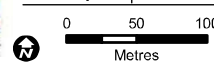
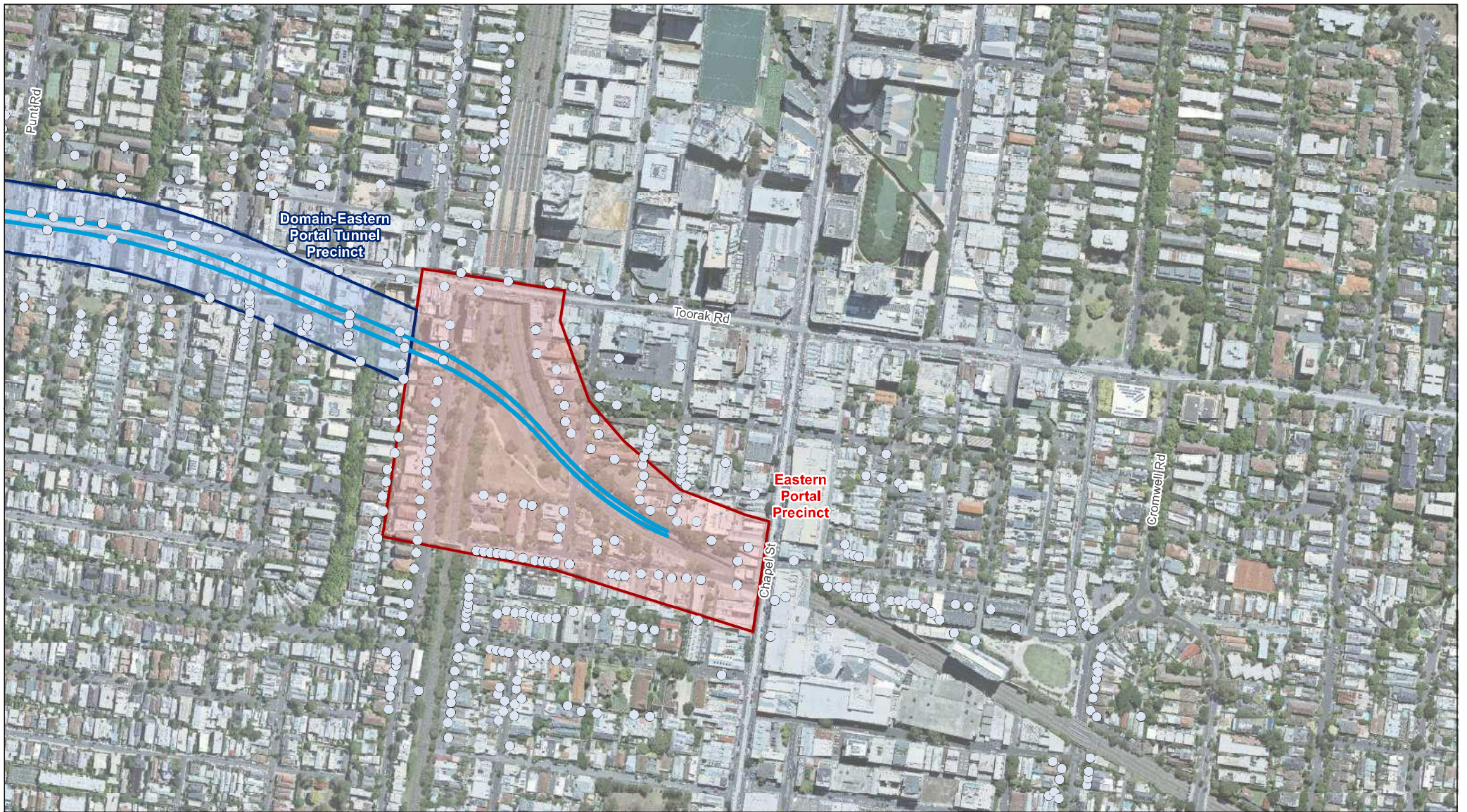


Figure B.85: Colour coded VDV night assessment for Additional Construction Works – Domain to Eastern Portal Tunnels Precinct





**Legend**

**Result Set 7**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- Below maximum guideline target (low probability of adverse comment)
- < 2 x maximum guideline target (adverse comment possible)
- > 2 x maximum guideline target (adverse comment probable)

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Portal Precinct

Map 13 of 13

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Vibration Dosage Value (VdV) - Guideline Night Target - Eastern Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500294  
 Revision: P1

Drawn By: A. Davy  
 Approved By: D. Timms  
 Date: 11/04/2016  
 Map Size: A4

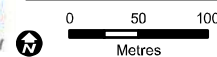
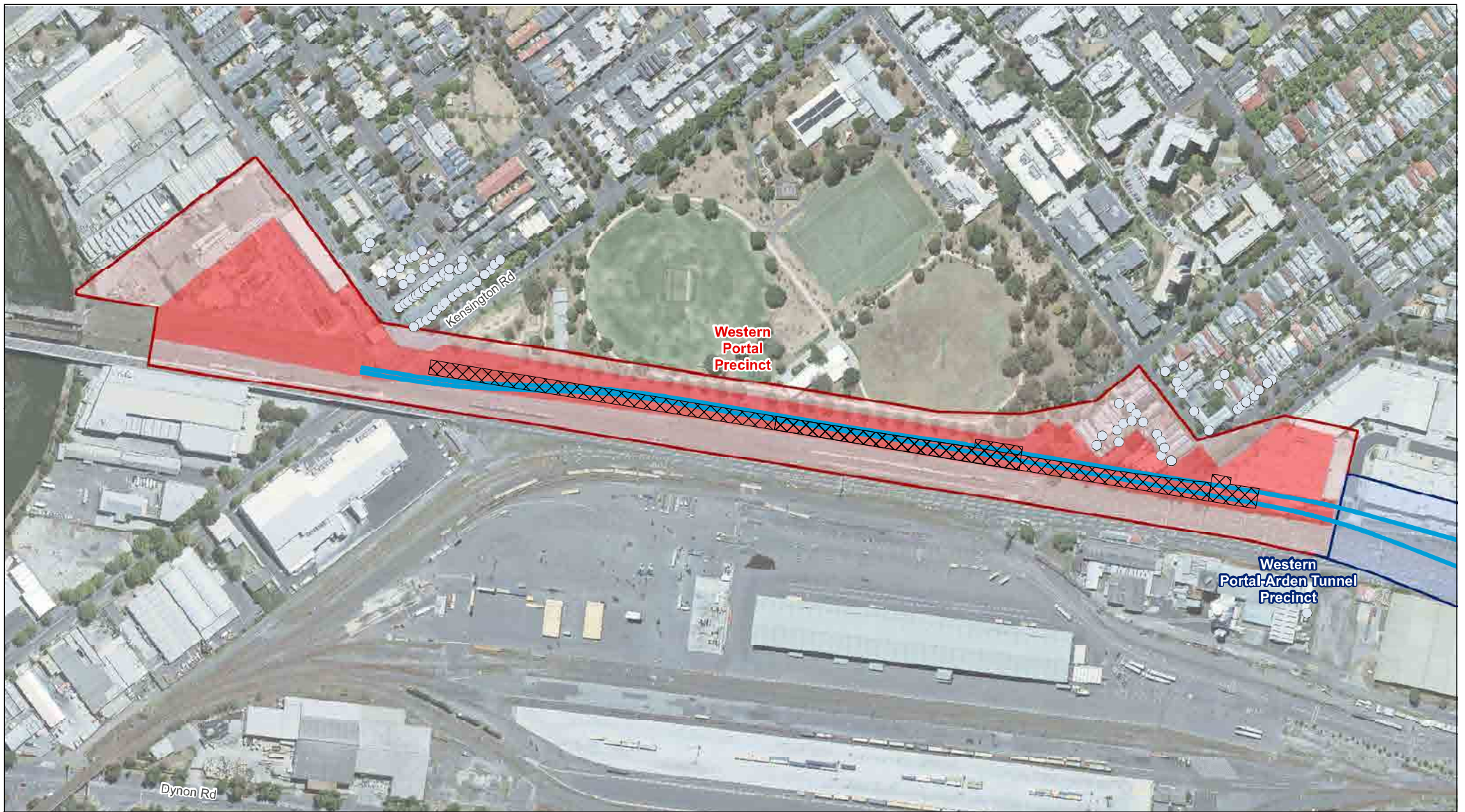


Figure B.86: Colour coded VDV night assessment for Additional Construction Works – Eastern Portal Precinct





**Legend**

**Result Set 5**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

**Map 1 of 9**

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct
- Proposed Construction Site
- ▣ Proposed Excavation Area

Data Sources:  
Proposed Infrastructure: AJM 2016  
Contains Vicmap Information  
© State of Victoria 2015.  
Aerial photo (DELWP, February 2015)

Joint Venture GRIMSHAW

**Melbourne Metro Rail Project**

Title:  
Additional Construction Works Ground-borne Noise - Western Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500207		Revision: P1	
Drawn By: A. Davy	Approved By: D. Timms	Date: 14/04/2016	Map Size: A4

Figure B.87: Colour coded ground-borne noise assessment for Additional Construction Works – Western Portal Precinct





### Legend

**Result Set 5**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

**Map 2 of 9**

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct
- Proposed Construction Site
- ⊠ Proposed Excavation Area

Data Sources:  
Proposed Infrastructure: AJM 2016  
Contains Vicmap Information  
© State of Victoria 2015.  
Aerial photo (DELWP, February 2015)

### Melbourne Metro Rail Project

Title:  
Additional Construction Works Ground-borne Noise - Arden Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500207		Revision: P1	
Drawn By: A. Davy	Approved By: D. Timms	Date: 14/04/2016	Map Size: A4

0 50 100  
Metres

Figure B.88: Colour coded ground-borne noise assessment for Additional Construction Works – Arden Station Precinct





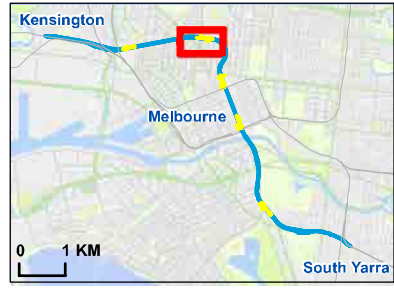
Map 3 of 9

**Legend**

- Result Set 5**
- Rating**
- Below preferred guideline target (adverse comment not expected)
  - 0 – 5 dBA above night guideline target / below evening guideline target
  - 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
  - > 10 dBA above night guideline target / > 5 dBA above evening guideline target

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct
- Proposed Construction Site
- ▨ Proposed Excavation Area

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Ground-borne Noise - Parkville Station

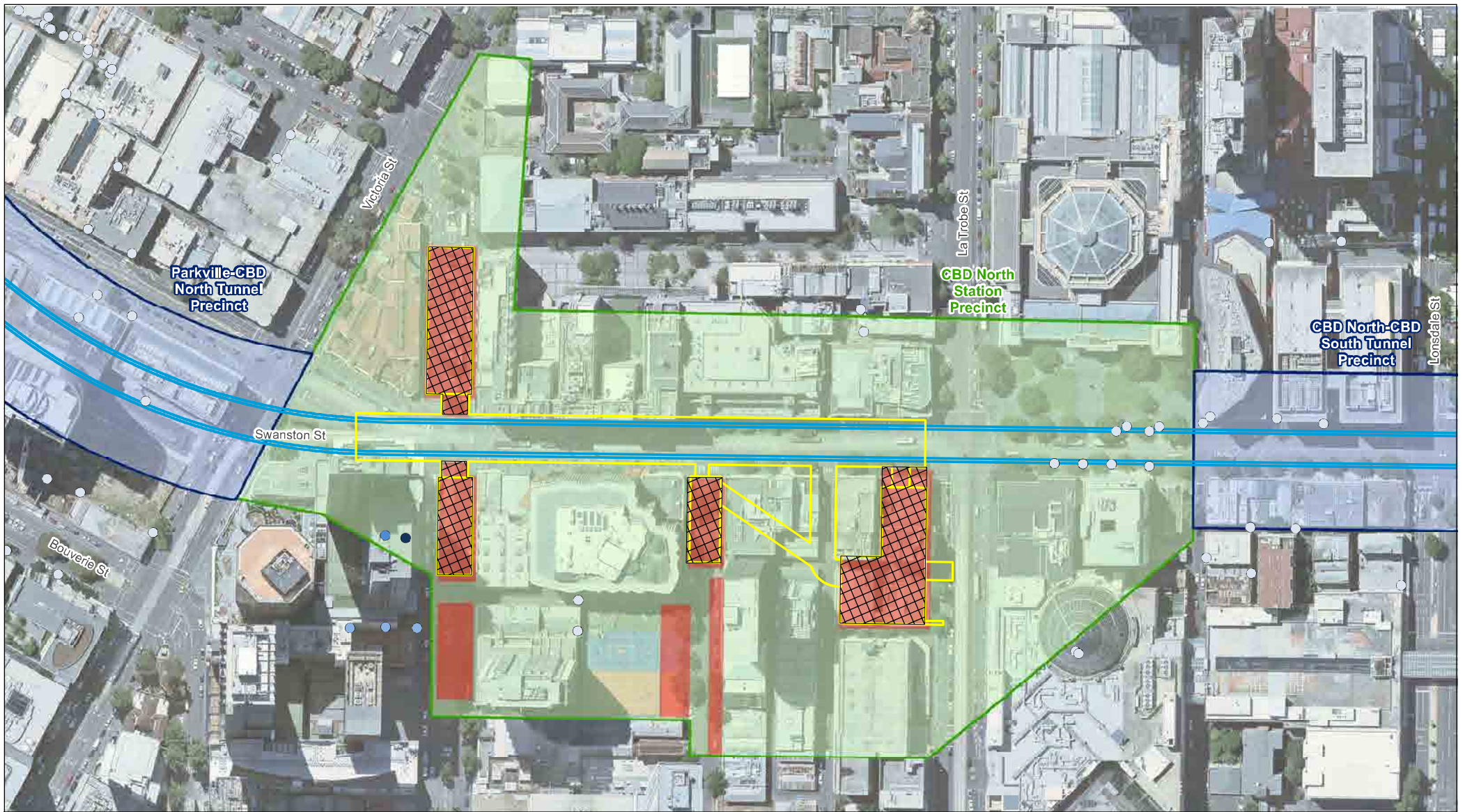
Drawing Number: MMR-AJM-UGAA-MP-NO-500207	Revision: P1
Drawn By: A. Davy	Approved By: D. Timms
Date: 14/04/2016	Map Size: A4



Figure B.89: Colour coded ground-borne noise assessment for Additional Construction Works – Parkville Station Precinct

G:\MMR-AJM\01\_WIP\1-AA-<G\_GIS\040\_Site\_plans\MMR\_0322\_NoiseVibration\_EES\MMR\_0322\_Result\_Set\_5.mxd





**Legend**

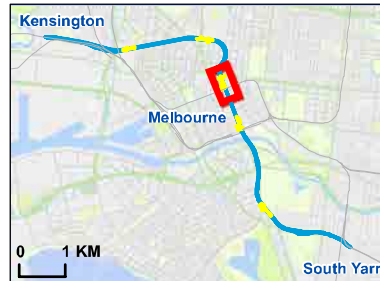
**Result Set 5**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct
- Proposed Construction Site
- Proposed Excavation Area

**Map 4 of 9**



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015.  
 Aerial photo (DELWP, February 2015)

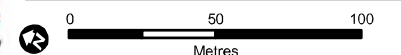


**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Ground-borne Noise -  
 CBD North Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500207  
 Revision: P1

Drawn By: A. Davy	Approved By: D. Timms	Date: 14/04/2016	Map Size: A4
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**Figure B.90: Colour coded ground-borne noise assessment for Additional Construction Works – CBD North Station Precinct**





**Legend**

**Result Set 5**

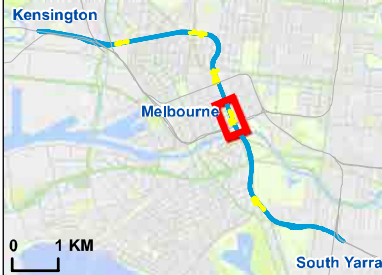
**Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

— Proposed Station Footprint    ■ Proposed Construction Site  
— Proposed Alignment      Proposed Excavation Area  
  Tunnel Precinct      Station Precinct  
  Portal Precinct

**Map 5 of 9**

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015.  
 Aerial photo (DELWP, February 2015)




**Melbourne Metro Rail Authority**

**aurecon JACOBS**  
AJM Mott MacDonald  
Joint Venture GRIMSHAW

**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Ground-borne Noise -  
 CBD South Station

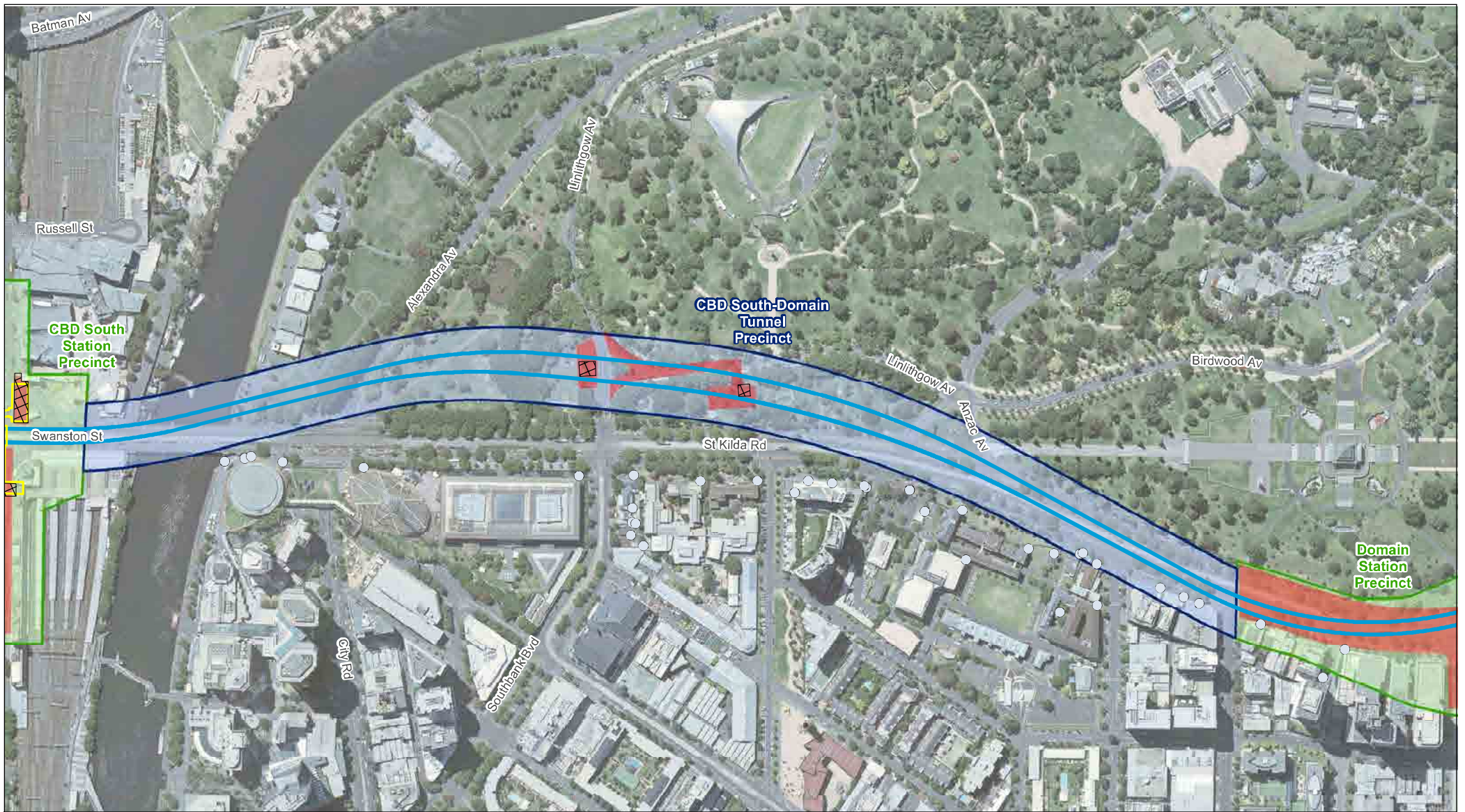
Drawing Number: MMR-AJM-UGAA-MP-NO-500207		Revision: P1	
Drawn By: A. Davy	Approved By: D. Timms	Date: 14/04/2016	Map Size: A4



0 50 100  
Metres

Figure B.91: Colour coded ground-borne noise assessment for Additional Construction Works – CBD South Station Precinct





**Legend**

**Result Set 5**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

**Map 6 of 9**

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct
- Proposed Construction Site
- ▨ Proposed Excavation Area

**Melbourne Metro Rail Project**

Title:  
Additional Construction Works Ground-borne Noise -  
CBD South to Domain

Drawing Number: MMR-AJM-UGAA-MP-NO-500207 Revision: P1

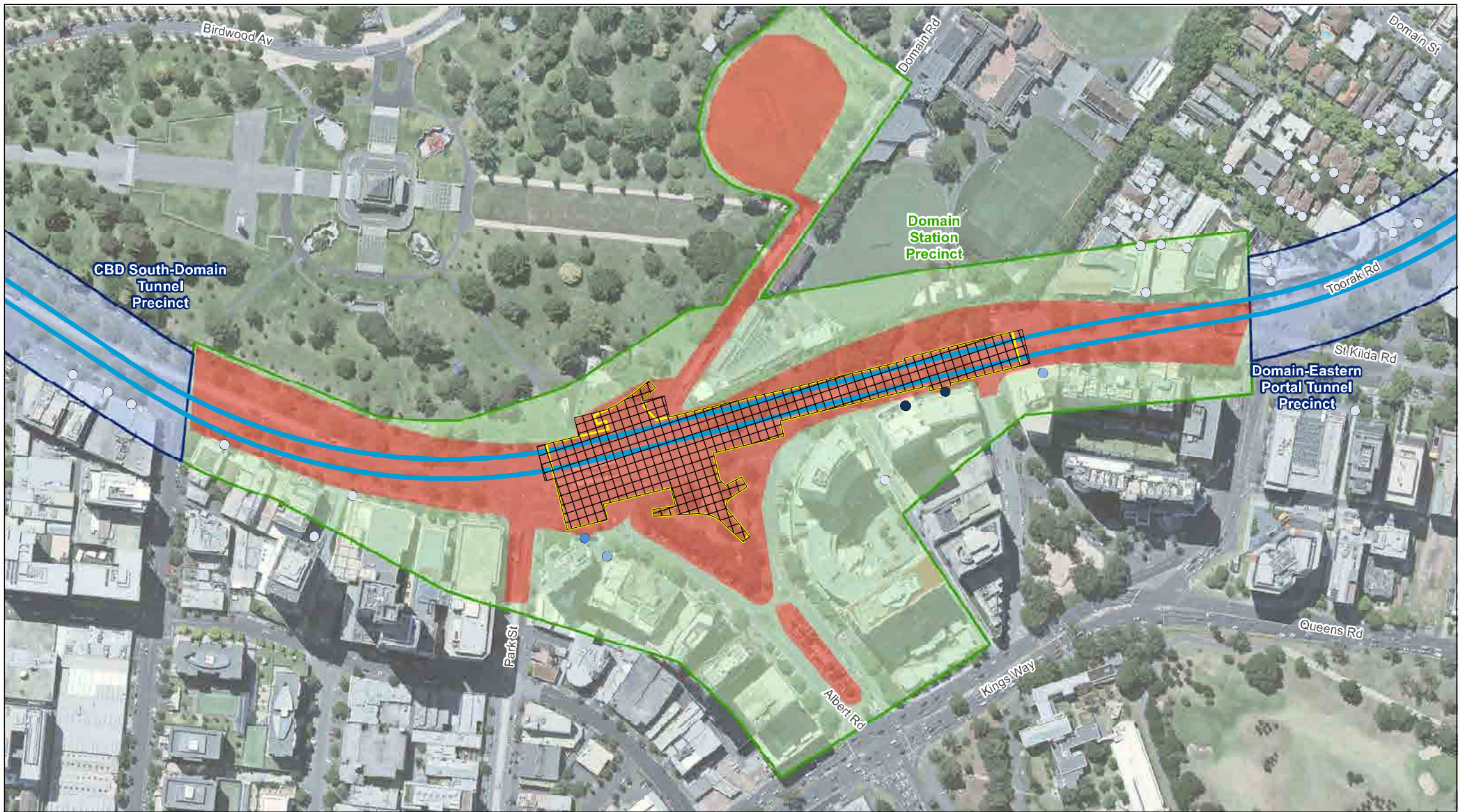
Drawn By: A. Davy Approved By: D. Timms Date: 14/04/2016 Map Size: A4

Scale: 0 50 100 Metres

Data Sources:  
Proposed Infrastructure: AJM 2016  
Contains Vicmap Information  
© State of Victoria 2015.  
Aerial photo (DELWP, February 2015)

Figure B.92: Colour coded ground-borne noise assessment for Additional Construction Works – CBD South to Domain Tunnel Precinct





Map 7 of 9

**Legend**

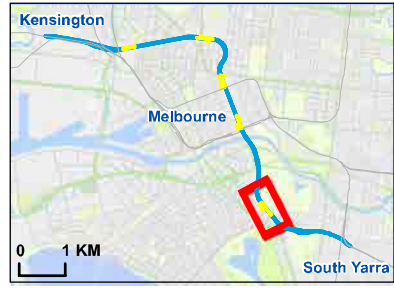
**Result Set 5**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

— Proposed Station Footprint    — Proposed Construction Site  
— Proposed Alignment    Proposed Excavation Area  
  Tunnel Precinct      Station Precinct  
  Portal Precinct

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015.  
 Aerial photo (DELWP, February 2015)



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**AJM**  
 Mott MacDonald  
 Joint Venture GRIMSHAW

**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Ground-borne Noise - Domain Station

Drawing Number: MMR-AJM-UGAA-MP-NO-500207	Revision: P1
Drawn By: A. Davy	Approved By: D. Timms
Date: 14/04/2016	Map Size: A4

0 50 100 Metres

Figure B.93: Colour coded ground-borne noise assessment for Additional Construction Works – Domain Station Precinct





Map 8 of 9

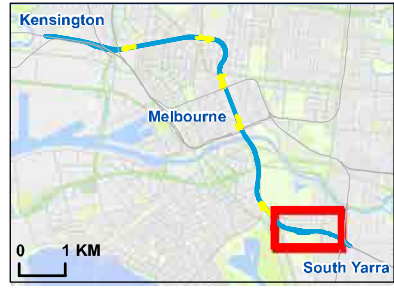
**Legend**

**Result Set 5 Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

- Proposed Station Footprint
- Proposed Alignment
- Tunnel Precinct
- Station Precinct
- Portal Precinct
- Proposed Construction Site
- ⊠ Proposed Excavation Area

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 Additional Construction Works Ground-borne Noise - Domain to Eastern Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500207	Revision: P1
Drawn By: A. Davy	Approved By: D. Timms
Date: 14/04/2016	Map Size: A4

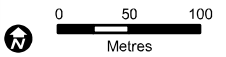
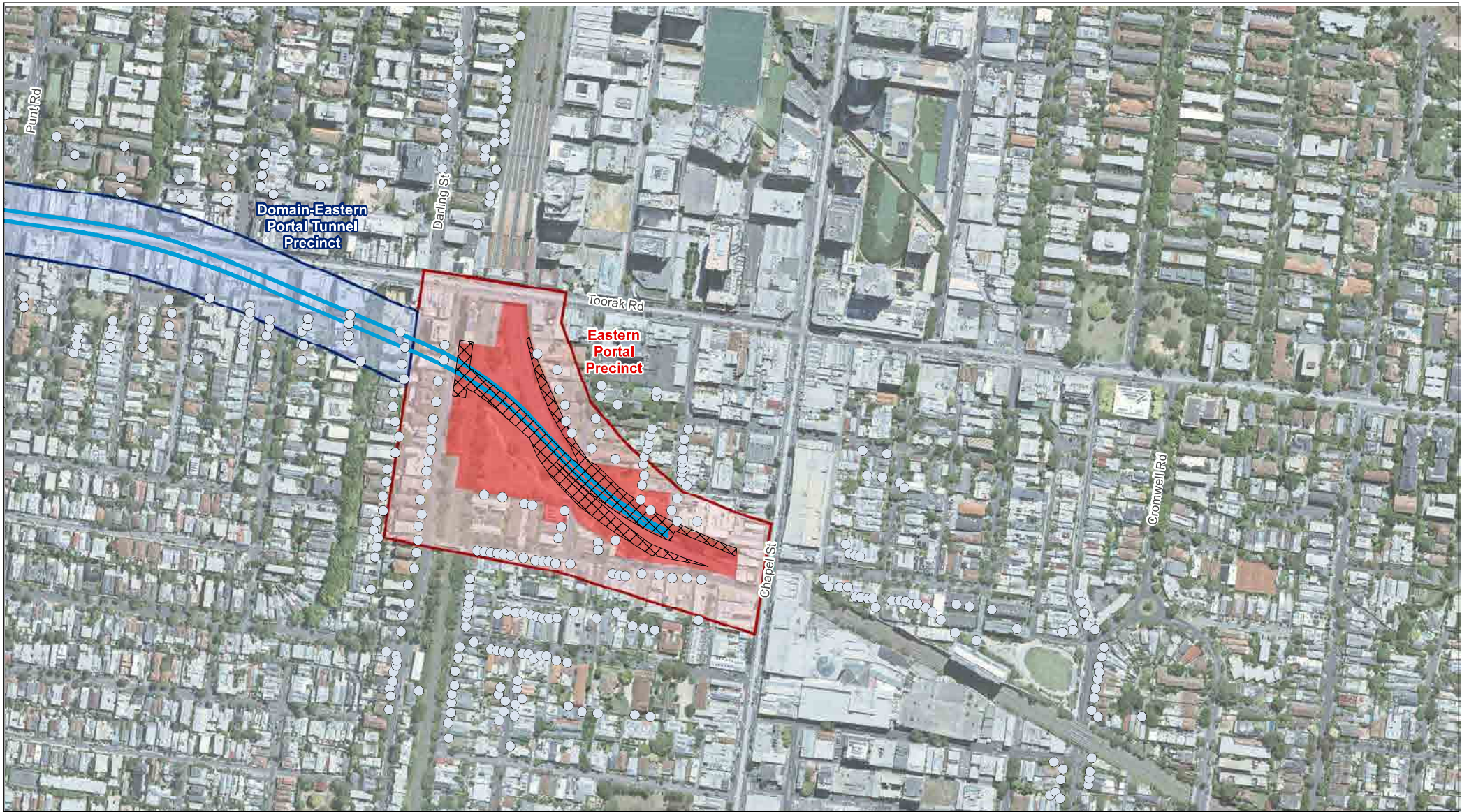


Figure B.94: Colour coded ground-borne noise assessment for Additional Construction Works – Domain to Eastern Tunnel Precinct

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### Legend

**Result Set 5**

**Rating**

- Below preferred guideline target (adverse comment not expected)
- 0 – 5 dBA above night guideline target / below evening guideline target
- 5 – 10 dBA above night guideline target / 0 – 5 dBA above evening guideline target
- > 10 dBA above night guideline target / > 5 dBA above evening guideline target

**Map 9 of 9**

<span style="color: yellow;">—</span> Proposed Station Footprint	<span style="background-color: red; border: 1px solid black;"> </span> Proposed Construction Site
<span style="color: blue;">—</span> Proposed Alignment	<span style="border: 1px dashed black; padding: 2px;"> </span> Proposed Excavation Area
<span style="background-color: lightblue; border: 1px solid black;"> </span> Tunnel Precinct	<span style="background-color: lightgreen; border: 1px solid black;"> </span> Station Precinct
<span style="background-color: pink; border: 1px solid black;"> </span> Portal Precinct	

Data Sources:  
Proposed Infrastructure: AJM 2016  
Contains Vicmap Information  
© State of Victoria 2015;  
Aerial photo (DELWP February 2015)

0 1 KM

Joint Venture GRIMSHAW

### Melbourne Metro Rail Project

Title:  
Additional Construction Works Ground-borne Noise - Eastern Portal

Drawing Number: MMR-AJM-UGAA-MP-NO-500207		Revision: P1	
Drawn By: A. Davy	Approved By: D. Timms	Date: 14/04/2016	Map Size: A4

0 50 100  
Metres

Figure B.95: Colour coded ground-borne noise assessment for Additional Construction Works – Eastern Portal Precinct





## B.6 Discussion

### B.6.1 Precinct 1 – Tunnels (Outside Other Precincts)

The Tunnels precinct includes the entire tunnel alignment that is not within the station or portal precincts. For construction activity this includes:

- Tunnels bored by TBM – Western portal to CBD North and CBD South to Eastern Portal
- Tunnels mined by road header – CBD North to CBD South
- Fawknor Park construction site, Fawknor Park emergency access shaft, Linlithgow Avenue emergency access shaft. A variety of construction equipment is proposed to be used at these sites. The vibration and ground-borne noise predictions are based on assessments of vibration for 20 tonne rockbreakers, as these are the most vibration intensive items of equipment. It has been assumed that the 20 tonne rockbreakers would work from a depth of 20 m and below.

#### B.6.1.1 Vibration – Assessment with respect to guideline targets for building damage

##### (i) Tunnelling

It is predicted that receivers greater than 5 to 10 m distance from the tunnelling would comply with the guideline targets (DIN 4150). Given that the tunnel is at least this distance underground, compliance is predicted to be achieved for all receiver types.

There are no predicted exceedances with respect to the guideline targets for building damage 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 the 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 Australian Government Department of Environment.

Table B.10 presents the predicted vibration due to tunnelling, along with the measured baseline vibration levels.

Table B.10: Vibration levels at other sensitive sites

Sensitive Site	Baseline PPV (mm/s)	Predicted PPV (mm/s)	Comments
<b>Tunnels Precinct</b>			
Victoria Barracks	0.6	0.4	Predicted level is less than existing.

The predicted level is lower than both the DIN 4150 criterion for structurally sensitive (heritage) buildings and baseline vibration level measured at this site. Damage at this site due to tunnelling is therefore not anticipated.

##### (ii) Additional Construction Works

Vibration levels are predicted to comply with the applicable guideline targets for building damage (DIN 4150) in the tunnels precinct due to the Additional Construction Works.

#### B.6.1.2 Vibration – Assessment with respect to guideline targets for damage to utilities

##### (i) Tunnelling

There are a significant number of utilities that cross the tunnel alignment at various locations in the tunnels precinct. In general, the critical distance the tunnel should be from utilities to avoid damage is listed in Table B.11.

Table B.11: Critical distances from utilities

Equipment	Critical distance (m)	
	General utilities (20 mm/s)	Melbourne Water unreinforced assets (10 mm/s)
TBM	1.6	3.0
Road header	2.0	3.7

These distances are slope distance as defined in Figure B.5.

In most cases the depth of the tunnel would be sufficient to achieve the minimum distances to the various utilities. However, location of the assets should be confirmed by the Proponent prior to the commencement of work to assess compliance.

The tunnel alignment crosses the Citylink tunnel in section from the CBD South Station Precinct to Domain Tunnel Precinct. Two alternatives are being considered:

- Assessment Design: the tunnel alignment passes over the Citylink tunnel, within 1 m of the top of the Citylink tunnel
- Variation: the tunnel alignment passes under the Citylink tunnel, within 3 m of the bottom of the Citylink tunnel.

The operation of the TBM within 1 m of the top of the Citylink is predicted to result in vibration levels approaching or exceeding the DIN 4150 continuous vibration criterion of 10 mm/s PPV. It does not necessarily follow that the Citylink tunnel would be subject to damage, as DIN 4150 is considered to be a conservative standard. If this option is selected the Proponent may need to reduce vibration levels by changing the operating parameters for the TBM whilst monitoring vibrations on the Citylink structure.

Vibration levels due to the TBM operating within 3 m of the bottom of the Citylink are predicted to be below the DIN 4150 continuous vibration criterion of 10 mm/s PPV. The risk of damage to the Citylink tunnel for construction of the variation design is therefore low.

##### (ii) Additional Construction Works

In general, damage to utilities is not expected in the Tunnels Precinct due to the Additional Construction Works. The Proponent is to confirm the location of utilities and ensure that guideline vibration targets are met.

#### B.6.1.3 Vibration – Human Comfort

##### (i) Tunnelling

When the TBM / road header is tunnelling directly below residential receivers the trigger for management action is predicted to be met. For the TBM, receivers within approximately 25 - 45 m of the tunnel alignment are predicted to meet the trigger for management actions associated with a low probability of adverse comment during the day, while receivers within 40 – 55 m of the tunnel alignment are predicted to meet the trigger for





management actions during the night. For the road header, receivers within approximately 30 – 45 m of the tunnel alignment are predicted to meet the trigger for management actions associated with a low probability of adverse comment during the day, while receivers within 40 – 60 m of the tunnel alignment are predicted to meet the trigger for management actions during the night.

Management actions for the TBM / road header include significant community consultation and potential respite / relocation if vibration levels are not well tolerated by a resident. Mitigation of vibration from TBMs or road headers is very challenging and there are few options available to reduce vibration aside from changing the tunnel alignment to increase distance from the affected receivers. Any change to the operating parameters of these machines which has the potential to reduce vibration would increase the duration of vibration impacts for receivers and significantly add to the project program. However, as the TBM/road header progresses along the tunnel the distance to the receiver changes relatively quickly, which has a significant effect on the predicted vibration. As the TBM/road header approaches the receiver, the vibration would increase to a peak and then reduce again as the TBM/road header moves further away.

An analysis of the change in vibration has been conducted for example residential and commercial receivers subject to vibration caused by TBM and road header tunnelling. The worst-case receivers in each tunnel segment (ie between station precincts) have been selected in order to show the maximum duration of exceedance predicted for the tunnel segment (i.e. at other locations the vibration would be lower).

The TBM has been assumed to move 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 road header has been assumed to move along the tunnel at a rate of approximately 5 m per day, with road headers at similar positions in both east and west tunnels at the same time. The road header is assumed to be operational for 60% of the time both day and night.

The receivers analysed are listed in Table B.12 along with the duration where the criterion level for management actions is triggered. Plots are provided of the predictions for:

- Residential receiver in the Parkville – CBD North segment (worst-case residential receiver for TBM tunnelling): Figure B.96
- Commercial receiver in the Parkville – CBD North segment (worst-case commercial receiver for TBM tunnelling): Figure B.97
- Residential receiver in the CBD North – CBD South segment (worst-case residential receiver for road header tunnelling): Figure B.98
- Commercial receiver in the CBD North – CBD South segment (worst-case commercial receiver for road header tunnelling): Figure B.99.

Figure B.96 and Figure B.97 show the VDV results with respect to construction time for a residential and a commercial receiver impacted by TBM boring. The criterion level for management actions is triggered for approximately one week (6-9 days) at the residential locations due to TBM tunnelling underneath the site (based on a maximum level which relates to low probability of adverse comments). At the commercial locations, the criterion level for management actions is triggered for up to half a week (based on a maximum level). At these sites this occurs during both east and west alignment tunnelling.

Figure B.98 and B.99 show the VDV results with respect to construction time for a residential and a commercial receiver impacted by road header mining of the tunnel in the CBD North – CBD South segment. At the receivers shown in the figures the trigger for management action for Vibration Dose Value is met during both east and west alignment tunnelling, so that the total vibration is a combination of the influence of both tunnels. The worst case combination, where road headers are at the same chainage in the two tunnels, is also presented in the figures. The criterion level for management actions is triggered for up to one month at residential receivers due to road header tunnel mining, and for up to 2 weeks at commercial receivers (based on a preferred level under which adverse comment is not expected). The duration is longer than for the TBM tunnelling primarily due to the slower progression of the road header along the tunnel.

Table B.12: Receiver Addresses and VDV Results for Duration Analysis

Receiver Type	Address	Time duration where the criterion level for management actions is triggered (days)*	
		Vibration Dose Value - Day	Vibration Dose Value - Night
<b>Western Portal – Arden: TBM</b>			
Residential	No exceedances for residential receivers in this segment		
Commercial	3 Lloyd St, Kensington	3½ days	3 days
<b>Arden – Parkville: TBM</b>			
Residential	193 Errol St, North Melbourne	5½ days	8 days
Commercial	99 Munster Terrace, North Melbourne	3½ days	3 days
<b>Parkville – CBD North: TBM</b>			
Residential	20-24 Church St, Carlton	6½ days	9 days
Commercial	213 Grattan St, Carlton	2 days	1 days
<b>CBD North – CBD South: Road Header</b>			
Residential	207 Swanston St, Melbourne	22 days	32 days
Commercial	119 Swanston St, Melbourne	15 days	13 days
<b>CBD South – Domain: TBM</b>			
Residential	340 St Kilda Rd, Melbourne	6 days	8 days
Commercial	336 St Kilda Rd, Melbourne	3½ days	3 days
<b>Domain – Eastern Portal: TBM</b>			
Residential	51 Myrtle St, South Yarra	6 days	9 days
Commercial	53 Myrtle St, South Yarra	3½ days	3 days

\* For durations of approximately one week or less the *maximum* VDV guideline target has been used as the trigger for management actions (i.e. for all TBM durations). For the road header tunnelling in the CBD North – CBD South segment the *preferred* VDV guideline target has been used as the trigger for management action in accordance with the standard.

An assessment of the vibration at higher floors of the buildings in the CBD tunnel segment has been undertaken. For residential receivers the impact is predicted to affect floors up to and including level 10, with any higher floors having vibration levels below the criterion for management actions. For commercial receivers the impact is predicted to affect floors up to and including level 5, with level 6 and above having vibration levels below the criterion for management actions.



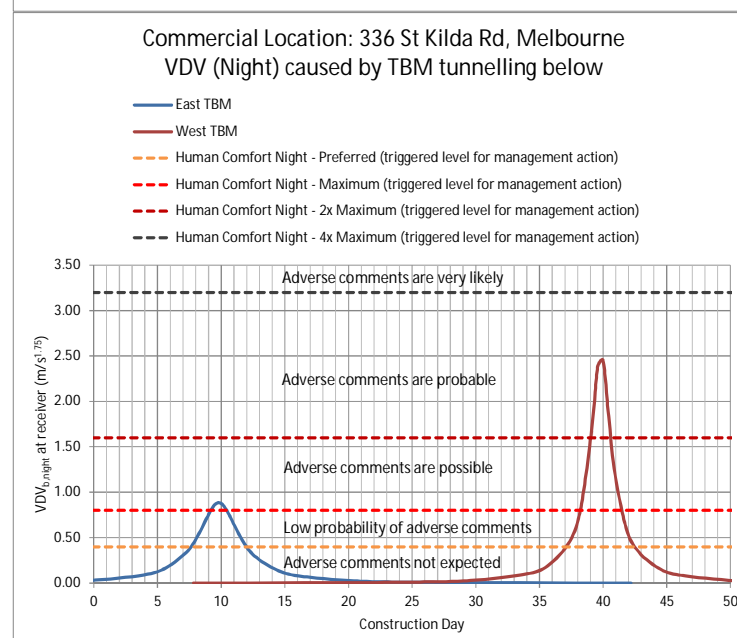
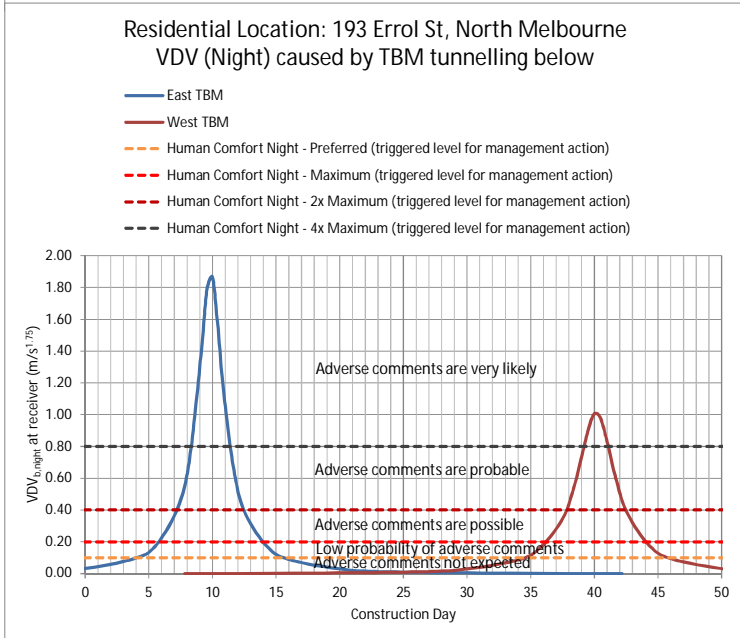
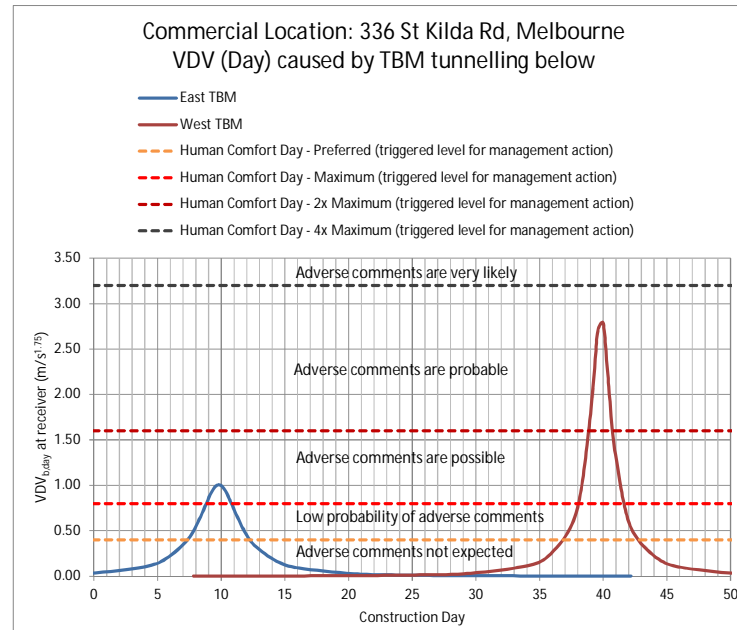
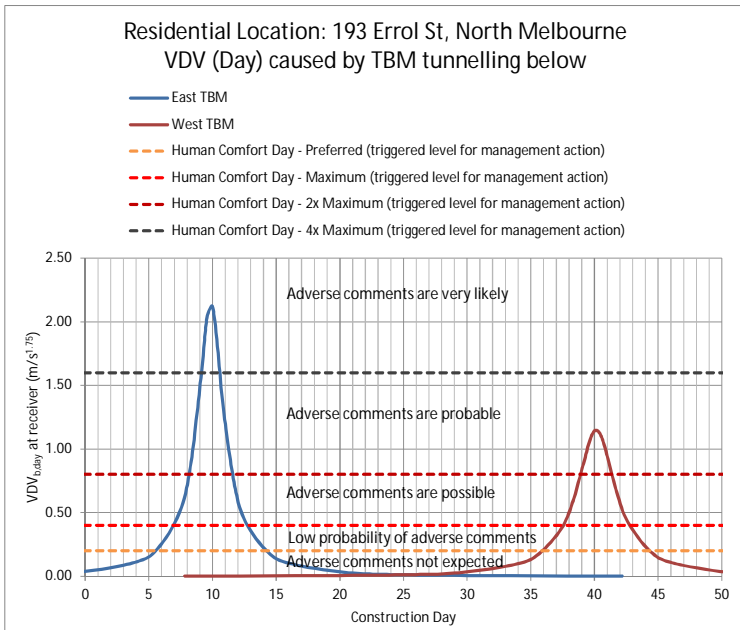


Figure B.96: Time of Duration of VDV Exceedances for Example Residential Receiver – Tunnelling using TBM

Figure B.97: Time of Duration of VDV Exceedances for Example Commercial Receiver – Tunnelling using TBM



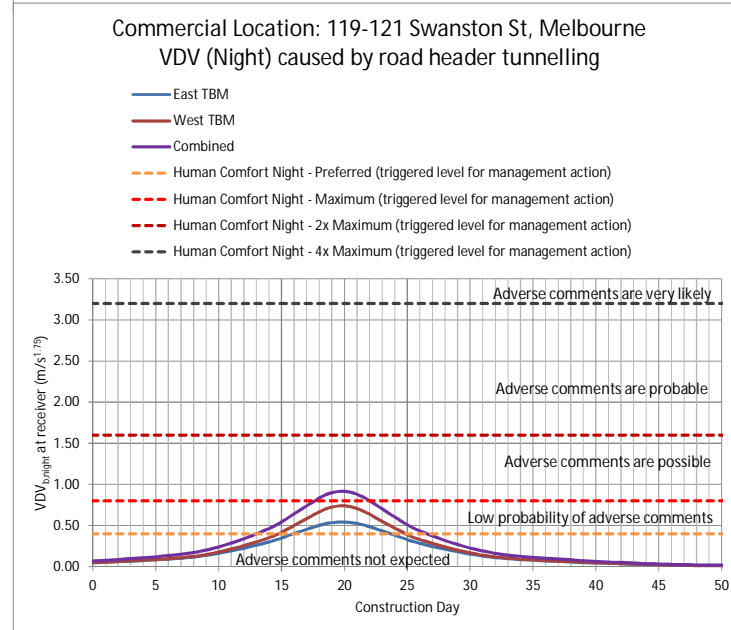
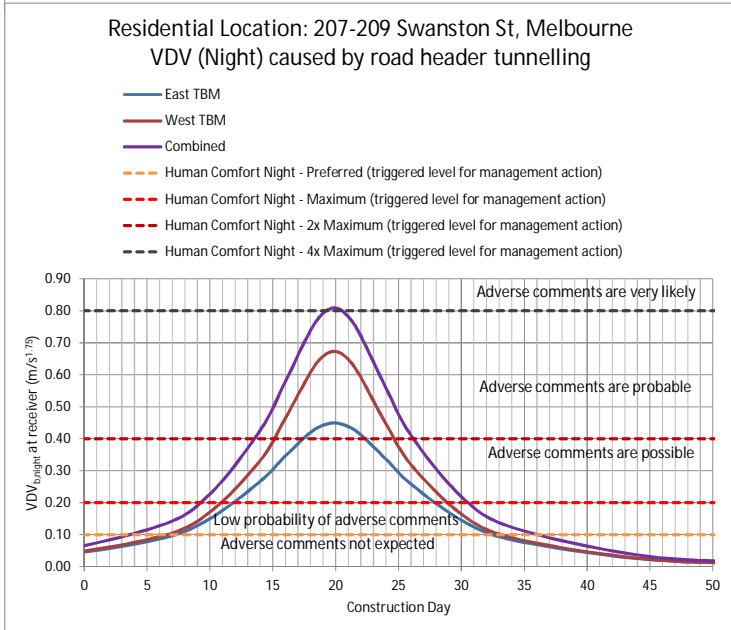
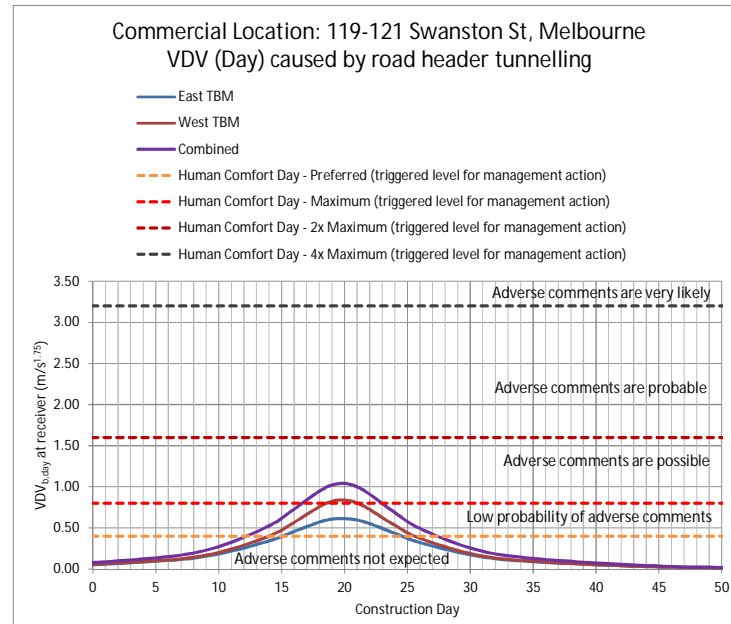
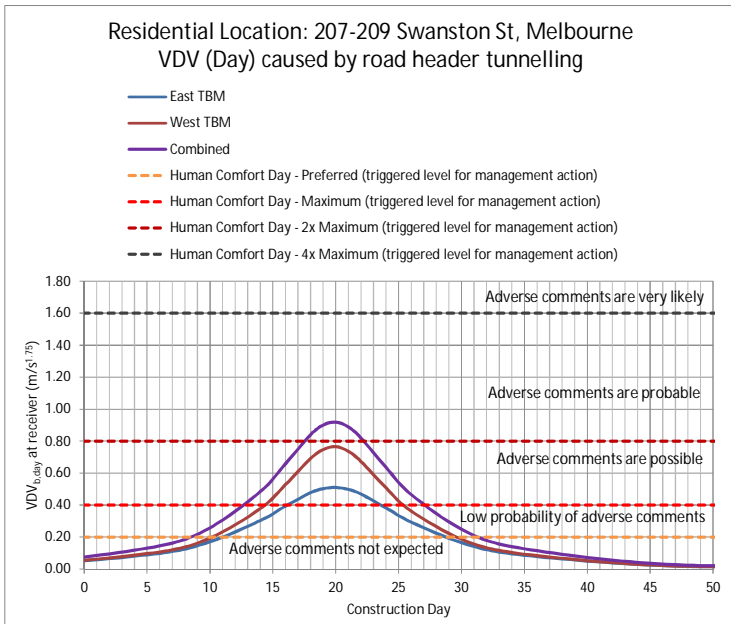


Figure B.98: Time of Duration of VDV Exceedances for Example Residential Receiver – Tunnelling using Road header

Figure B.99: Time of Duration of Exceedances for Example Commercial Receiver – Tunnelling using Road header





**(ii) Additional Construction Works**

The Linlithgow Avenue emergency access shaft site is located away from receivers and vibration levels are predicted to comply with the guideline targets.

A VDV of 0.3 m/s<sup>1.75</sup> is predicted at one residential address on Toorak Road which is located near the Fawkner Park Intervention Shaft excavation. This is less than the maximum guideline value (0.4 m/s<sup>1.75</sup>) and relates to a low probability of adverse comment. Nevertheless, consultation and negotiation with residents at this address and adjacent buildings is recommended.

**B.6.1.4 Vibration-sensitive Equipment, Bio-resources and Highly Sensitive Areas**

Vibration-sensitive equipment, Bio-resources and Highly Sensitive Areas have not been identified in the tunnels precinct.

**B.6.1.5 Ground-borne Noise**

**(i) Tunnelling**

Ground-borne noise levels at residential receivers located close to the alignment are predicted to trigger the requirement for management actions when the TBM / road header is tunnelling directly below. For the TBM, this occurs when receivers are within approximately 35 – 50 m of the tunnel alignment during the evening and when receivers are within 45 – 60 m of the tunnel alignment during the night. For the road header, this occurs for receivers within approximately 40 – 55 m of the tunnel alignment during the evening, and receivers within 50 – 65 m of the tunnel alignment during the night.

Management actions include extensive community consultation to determine the acceptable level of disruption and the provision of respite accommodation in some circumstances.

Mitigation of ground-borne noise from TBMs is very challenging and there are few options available aside from changing the tunnel alignment to increase distance from the affected receivers. Mitigation of ground-borne noise from the road header work is again very challenging but it may be possible to reduce hours of operation and/or modify the construction sequencing and operating practices to reduce impacts in some circumstances.

As the TBM/road header progresses along the tunnel the distance to the receiver changes relatively quickly, which has a significant effect on the predicted ground-borne noise. As the TBM/road header approaches the receiver, the ground-borne noise would increase to a peak and then reduce again as the TBM/road header moves further away. This results in noise exceedances for a limited time only.

An analysis of the change in ground-borne noise has been conducted for example residential and commercial receivers subject to ground-borne noise caused by TBM and road header tunnelling. The worst-case receivers in each tunnel segment (ie between station precincts) have been selected in order to show the maximum duration of exceedance predicted for the tunnel segment (i.e. at other locations the vibration would be lower).

The TBM has been assumed to move 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 road header has been assumed to move along the tunnel at a rate of approximately 5 m per day, with road headers at similar positions in both east and west tunnels at the same time.

The receivers analysed are listed in Table B.13 along with the duration where the criterion level for management actions is triggered. Plots are provided of the predictions for:

- Residential receiver in the Parkville – CBD North segment (worst-case residential receiver for TBM tunnelling): Figure B.100
- Residential receiver in the CBD North – CBD South segment (worst-case residential receiver for road header tunnelling): Figure B.101

Figure B.100 shows the ground-borne noise results with respect to construction time for a residential receiver impacted by TBM boring. The criterion level for management actions is triggered for approximately one week due to TBM tunnelling underneath the site during the evening and for up to one and a half weeks during the night. At these sites this occurs during both east and west alignment tunnelling.

Figure B.101 shows the ground-borne noise results with respect to construction time for a residential receiver impacted by road header mining of the tunnel in the CBD North – CBD South segment. The trigger for management action for ground-borne noise is met during both east and west alignment tunnelling, so that the total ground-borne noise is a combination of the influence of both tunnels. The worst case combination, where road headers are at the same chainage in the two tunnels, is also presented in the figures. The criterion level for management actions is triggered for up to two and a half weeks during the evening and three weeks at night. The duration is longer than for the TBM tunnelling primarily due to the slower progression of the road header along the tunnel.

An assessment of the vibration at higher floors of the building in the CBD tunnel segment has been undertaken. For residential receivers the impact is predicted to affect floors up to and including level 7, with higher floors having vibration levels below the criterion for management actions.

**Table B.13: Receiver Addresses for Detailed Analysis**

Receiver Type	Address	Time duration where the criterion level for management actions is triggered (days) for Ground-borne Noise	
		Evening	Night
<b>Western Portal – Arden: TBM</b>			
Residential	No exceedances for residential receivers in this segment		
<b>Arden – Parkville: TBM</b>			
Residential	193 Errol St, North Melbourne	7½ days	9 days
<b>Parkville – CBD North: TBM</b>			
Residential	20-24 Church St, Carlton	8 days	10 days
<b>CBD North – CBD South: Road Header</b>			
Residential	207 Swanston St, Melbourne	17 days	22 days
<b>CBD South – Domain: TBM</b>			
Residential	340 St Kilda Rd, Melbourne	7½ days	9 days
<b>Domain – Eastern Portal: TBM</b>			
Residential	51 Myrtle St, South Yarra	7 days	9 days

The potential for ground-borne noise impacts due to tunnelling also exists for performance spaces within the Arts Centre, Melbourne. These include the Hammer 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 tunnels passing these sites.



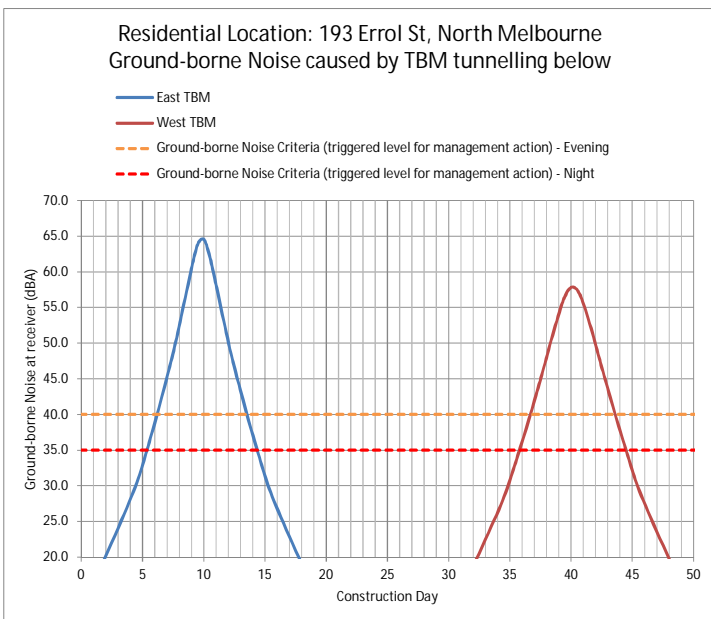


Figure B.100: Duration of Exceedances for Example Residential Receiver – Tunnelling using TBM

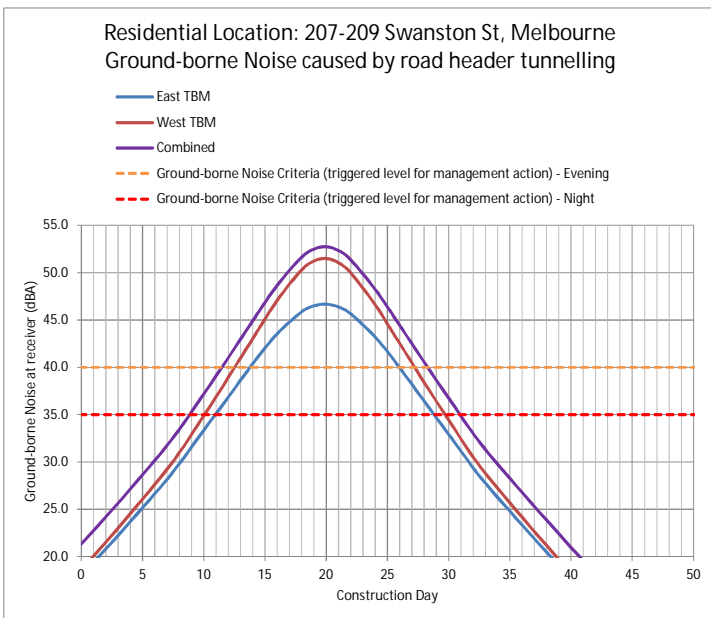


Figure B.101: Groundborne noise at Example Residential Receiver – Tunnelling using Road Header

## (ii) Additional Construction Works

The Linlithgow Avenue emergency access shaft site is located away from receivers and it is predicted that ground-borne noise would comply with the guideline targets.

Construction works at the Fawkner Park construction work site and at the Fawkner Park emergency access shaft would be completed during Normal Working Hours. As such there are no exceedances of the guideline targets for evening or night-time ground-borne noise.

## B.6.2 Precinct 2 – Western Portal (South Kensington)

A variety of construction equipment would be used at this site during Normal Working hours. The ground-borne noise and vibration predictions are based on assessments of vibration for 12-15 tonne rockbreakers, as these are the most vibration intensive items of equipment.

### B.6.2.1 Vibration – Damage to Buildings

Vibration in this precinct is predicted to comply with the guideline targets for building damage.

### B.6.2.2 Vibration – Damage to Utilities

There are a number of utilities, particularly clustered in the north-eastern part of the Western Portal precinct. To avoid damage, the critical 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 the Proponent prior to the commencement of work.

### B.6.2.3 Vibration – Human Comfort

A VDV of  $0.84 \text{ m/s}^{1.75}$  is predicted at one residential building on Altona Street. This is approximately two times the maximum guideline target and relates to probable adverse comments. Possible adverse comments are predicted at four residential buildings (VDV greater than  $0.4 \text{ m/s}^{1.75}$ ) and there is a low probability of adverse comments at four residential buildings (VDV between  $0.2$  and  $0.4 \text{ m/s}^{1.75}$ ).

Management actions would be required for a short period of time when the rockbreaker is working in a region of the excavation which is close to residential receivers. It is predicted that the maximum guideline VDV target of  $0.4 \text{ m/s}^{1.75}$  (low probability of adverse comment) is met when the rockbreaker is working outside a buffer zone of 25 m or more.

There are a number of management actions that the Proponent could use to minimise impacts on these residences:

- Consultation and negotiation with residences
- Based on the rock type in the Western Portal precinct it is expect that rock would fracture easily and that vibration levels may be lower than predicted. Vibration monitoring is recommended when construction commences in order to confirm the vibration levels and verify the buffer zone
- It is recommended that initial cuts should be made along the Northern boundary of the excavation so as to “buffer” residents from the vibration source
- The Proponent could consider the use of lower vibration methods of rock removal when working inside the buffer zone. These methods could include hydraulic splitting or chemical splitting (both of these methods would meet the guideline vibration targets). The Proponent may use other low vibration methods of rock removal, however, it is recommended that the vibration levels are assessed or measured.





#### B.6.2.4 *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.

#### B.6.2.5 *Ground-borne Noise*

Construction works would be completed during Normal Working hours and as such there are no exceedances of the guideline targets for evening or night-time ground-borne noise.

### B.6.3 Precinct 3 – Arden Station

A variety of construction equipment is proposed to be used at this site. Vibration predictions have been completed for vibration intensive equipment including piling rigs, excavators and heavy vehicles. Rockbreakers are not expected to be needed at Arden Station.

#### B.6.3.1 *Vibration – Damage to Buildings*

Vibration in this precinct is predicted to comply with the guideline targets for building damage.

#### B.6.3.2 *Vibration – Damage to Utilities*

There are a number of utilities within the Arden Station precinct and its surrounds. To avoid damage, the Highly Sensitive 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 the Proponent prior to the commencement of work.

#### B.6.3.3 *Vibration – Human Comfort*

Compliance with the guideline levels for human comfort is predicted.

#### B.6.3.4 *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.

#### B.6.3.5 *Ground-borne Noise*

Compliance with the guideline targets for Ground-borne noise is predicted.

### B.6.4 Precinct 4 – Parkville Station

A variety of construction equipment is proposed for this site. The ground-borne noise and vibration predictions are based on assessments of vibration for rippers and 20 tonne rockbreakers. It has been assumed that the rippers would operate from ground level to a depth of 25 m. 20 tonne rockbreakers would operate at depths greater than 25 m below ground level. It has been proposed that ripping and rockbreaking works continue 24 hours a day and 7 days a week once the station roof has been constructed.

Vibration predictions have also been made for the TBM which would be operating in the vicinity of receivers which are located in the western side of the Parkville precinct.

#### B.6.4.1 *Vibration – Damage to Buildings*

All buildings are predicted to meet the guideline targets for building damage. This includes heritage sites where a low vibration guideline target of 2.5 mm/s PPV applies.

It is noted that calculations are less accurate 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 the Proponent to undertake vibration monitoring to verify vibration levels when equipment is operated within 5 m of a building. This applies to rockbreaking, ripping and piling equipment.

#### B.6.4.2 *Vibration – Damage to Utilities*

There are a number of utilities within the Parkville Station precinct and its surrounds. To avoid damage, the critical 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 the Proponent prior to the commencement of work.

#### B.6.4.3 *Vibration – Human Comfort*

It is predicted that the maximum guideline VDV targets would be exceeded for a very brief period of time at buildings that are adjacent to the Parkville excavation. The affected buildings include the Peter Doherty Institute, Alan Gilbert Building, the University of Melbourne Faculty of Medicine, Howard Florey Laboratories, University of Melbourne Engineering Block and a small number of University of Melbourne buildings which are located on the Northern end of Barry Street.

The exceedances relate to ripping and would only occur when the ripper is working within 6.5 m of a receiver. The exceedances would only apply to receivers located on the ground floor of these buildings and in rooms that face the excavation. It is predicted that the duration of exceedance would be less than one day at the most affected receiver location. It is expected that the Proponent would be able to manage these exceedances through community consultation and careful scheduling of ripping works that are required in close proximity of receivers.

It is predicted that the maximum night-time guideline VDV target would be exceeded at the Vice Chancellor's House and at a small number of residential dwellings on Leicester Street. These exceedances relate to rockbreaking (not ripping). It is anticipated that the 20 tonne rockbreakers would only be required periodically and as such it is expected that any exceedances would be short in duration. It is expected that the proponent would be able to manage these exceedances by scheduling rockbreaking works in the vicinity of these receivers for the daytime (when the guideline VDV target is higher). A buffer distance of 35 m would be required for night-time rockbreaking.

#### B.6.4.4 *Ground-borne Noise*

It is predicted that the guideline target for ground-borne noise would be exceeded at one residential building on Barry St (141 Barry Street), the Vice Chancellor's House and a small number of residential dwellings on Leicester Street. Ground-borne noise is predicted to reach 38 dBA at the Barry St address, 43 dBA at the Vice Chancellor's House and up to 42 dBA at the Leicester Street dwellings. At most of these residential locations, the exceedances relate to rockbreaking (not ripping). It is anticipated that the 20 tonne rockbreakers would only be required periodically – when more competent material is encountered in the excavation. As such, it is expected that any exceedances would be short in duration. It is also expected that the proponent would be able to manage these exceedances by scheduling rockbreaking works in the vicinity of these receivers for normal working hours (when Ground-borne Noise targets do not apply). A buffer distance of 55 m would be required rockbreaking works outside of normal working hours.

It is also predicted that the 35 dBA night time target would be exceeded at the Vice Chancellor's House when the ripper is working within a buffer distance of 20 m. As such it is also recommended that the Proponent maintains a 20 m buffer distance when ripping at night.





#### B.6.4.5 Vibration-sensitive Equipment, Bio-resources and Highly Sensitive Areas

##### (i) Vibration-sensitive Equipment

An assessment of vibration-sensitive equipment in the vicinity of the Parkville Construction site has been undertaken with respect to the ASHRAE Vibration Curves and the outcomes are provided in Table B14. Note that the reference for the vibration assessment is taken to be the greater of the VC-curve and baseline measurement (where available). Vibration guideline targets are predicted to be exceeded for some equipment at the following buildings:

- Royal Women's Hospital (due to TBM tunnelling activities)
- Royal Melbourne Hospital (due to both TBM tunnelling activities and rockbreakers used in the Additional Construction Works)
- VCCC (due to both TBM tunnelling activities and rockbreakers used in the Additional Construction Works)
- Peter Doherty Institute (due primarily to rockbreakers used in the Additional Construction Works)
- University of Melbourne (due primarily to rockbreakers used in the Additional Construction Works)
- Howard Florey Laboratories (ground floor and basement only due primarily to rockbreakers used in the Additional Construction Works).

Vibration exceedances due to TBM tunnelling activities (Royal Women's Hospital, Royal Melbourne Hospital and VCCC, University of Melbourne, Peter Doherty Institute and Howards Florey Laboratories) would be of limited duration as the TBM progresses along the tunnel. At the locations with the highest exceedances this impact is predicted to have a duration of up to 17 days. Mitigation should be used to manage any sensitive equipment vibration exceedances as follows:

- Consultation with stakeholders
- Temporarily reschedule the use of sensitive equipment to other times or non-affected facilities
- Monitoring of current vibration levels which may potentially increase the criterion for individual items (as applicable – some monitoring has already taken place and the results are included in the table for reference)
- Vibration monitoring during construction to ensure compliance with the vibration requirements.

The vibration predictions for Additional Construction Works are based on the maximum vibration levels predicted due to occur when rippers and rockbreakers are working in the nearest part of the excavation. The exceedances would reduce as the rippers and rockbreakers move away from sensitive receiver locations (both horizontally and as they move deeper underground).

Rockbreakers are expected to affect equipment in the VCCC and Royal Melbourne Hospital during excavation of the pedestrian entrance which is located in front of the VCCC 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 VCCC linear accelerators are the only items of sensitive equipment in the VCCC 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). There are a number of management actions that the Proponent would be able to take in order to mitigate vibration impacts on sensitive equipment in the VCCC and Royal Melbourne Hospital. These actions include:

- Consultation with stakeholders
- Vibration monitoring and monitoring of the performance of sensitive equipment when rippers and rockbreakers are working in the VCCC pedestrian entrance
- Temporarily reschedule the use of sensitive equipment to other times or non-affected facilities
- Careful scheduling of ripping rockbreaking works that are required in the VCCC pedestrian entrance
- The use of low vibration methods of material removal when excavating the pedestrian entrance outside the VCCC. Low vibration methods of rock removal could include methods such as hydraulic splitting or chemical

splitting (both methods predicted to meet the guideline targets). The Proponent may also use other methods of rock removal provided that vibration levels meet the guideline targets.

Careful scheduling of ripping and rockbreaking works would be required in order to manage impacts on sensitive receivers that are immediately adjacent to the main station excavation (Howard Florey Laboratories, University of Melbourne and the Peter Doherty Institute). The Proponent would need to consult and negotiate closely with stakeholders in these buildings in order to develop a mutually acceptable schedule for ripping and rockbreaking work. It would also be necessary for the Proponent to maintain buffer distances between excavation machinery and vibration-sensitive equipment whilst the vibration-sensitive equipment is in use. It is expected that the Proponent would refine the buffer distances during the excavation works (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. The proponent may also consider the option of relocating certain pieces of sensitive equipment during construction.

Vibration predictions have also been made for bored piling which would be undertaken around the perimeter of the Parkville Station excavation. Vibration levels due to bored piling are expected to be significantly lower than the rockbreaker levels and exceedances are only predicted in three buildings. The exceedances include the Peter Doherty Institute (Electron microscope and photon laboratory), VCCC (linear accelerators and Level 5 MRI) and the University of Melbourne (confocal microscopes). The exceedances would only occur when piling works are occurring within a horizontal distance of 50 m of these pieces of equipment. It is expected that these exceedances would be managed through close consultation between the Proponent and the affected receivers and through careful scheduling of the piling works.

##### (ii) Biological Resources

An assessment of biological resources housed in the Parkville precinct has been undertaken and the outcomes are presented in Table B15. Management actions would be required due to vibration exceedances which are predicted for biological resources that are housed in the Howard Florey Laboratories, University of Melbourne Faculty of Medicine, and VCCC. The impact on biological resources due to TBM tunnelling is minor and predicted to have a duration of approximately one week. Slightly higher exceedances are predicted due to Additional Construction Work.

It is expected that the Proponent would consult with the relevant stakeholders to develop management actions. In most instances it is expected that vibration isolation mounting could be used to reduce vibration levels at the biological resources.

##### (iii) Highly Sensitive Areas

There are a number of Highly Sensitive areas identified in the Parkville precinct. These include wards and patient accommodation in the Royal Women's Hospital (RWH), the Royal Melbourne Hospital (RMH) and the Victorian Comprehensive Cancer Centre (VCCC).

An assessment of the Highly Sensitive areas has been undertaken and the outcomes are presented in Table B.16.

Human comfort vibration and ground-borne noise results indicate that management actions would be triggered for the following locations due to tunnelling:

- Wards and staff accommodation at the RWH (due to ground-borne noise above evening and night guidelines)
- ICU, south wards and cardiology ward at the RMH (due to vibration metrics and ground-borne noise being above guidelines)
- Country patient accommodation and wards at the VCCC (due to vibration metrics and ground-borne noise being above guidelines).





The duration of the impact at the worst affected area is predicted to be up to 9 days as the TBM moves past the location.

Mitigation is required for these areas and should include, in the first instance, consultation with stakeholders. Monitoring of current noise and vibration levels in some areas may be of assistance in potentially increasing the guideline limits. For some areas respite may be an option for the relatively short duration of the impact (typically expected to be less than one week).

Within each Highly Sensitive area there is expected to be a large variation in the noise and vibration impact. Locations directly adjacent to the façade closest to the tunnel alignment would have the largest impact, with this impact reducing with distance from that façade. At most locations vibration metrics are within guidelines for positions on the far side of the Highly Sensitive area from the tunnel alignment, indicating that at least some portion of these Highly Sensitive areas may not have significant impact due to tunnelling works. Monitoring of noise and vibration during construction should be undertaken to guide management of facilities.

Further mitigation for this area may include reduced working hours for the TBM, which would reduce the extent of the impact but have the effect of extending the duration of the works and therefore the corresponding impact. Limiting working hours to daytime hours for the section of tunnel adjacent to these three buildings would result in noise and vibration meeting the guidelines for all locations except:

- ICU and cardiology ward (level 2) and Ward 3S at the Royal Melbourne Hospital are predicted to have some portion of the wards triggering management actions as a result of the VDV – Day metric
- Country patient accommodation (level 1) and the medical ward (level 3) at the VCCC are predicted to have some portion of the area triggering management actions as a result of the VDV – Day metric.

Management actions are not required due to additional construction works (guideline vibration and ground-borne noise targets are predicted to be met).

#### B.6.4.6 Assessment of Vibration and Ground-borne noise from Controlled Blasting - Parkville Station Box Excavation

In order to reduce the overall duration and severity of vibration and ground-borne noise impacts at Parkville that are associated with excavating the station box, an alternative construction methodology has been assessed based on the use of controlled blasting. 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 usage. Blasting would occur once the concrete cover is placed over the excavation and would therefore not involve air overpressure, dust and fly rock impacts. This technique has been used on numerous other 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 and highly sensitive areas.

The method used to conduct the assessment of impacts from controlled blasting is based on AS2187.2 using the following expression, where R is the source-receiver separation distance (m), W is the Maximum Instantaneous Charge weight (kg), K and B are site-specific constants dependent on geotechnical conditions and blast design.

$$V = K \left( \frac{R}{W^{0.5}} \right)^{-B}$$

For the purpose of estimating the mean (50% probability of exceedance) peak particle velocities for when blasting is carried out to a free face in average field conditions, K is taken as 1140 and B is 1.6. For the purpose

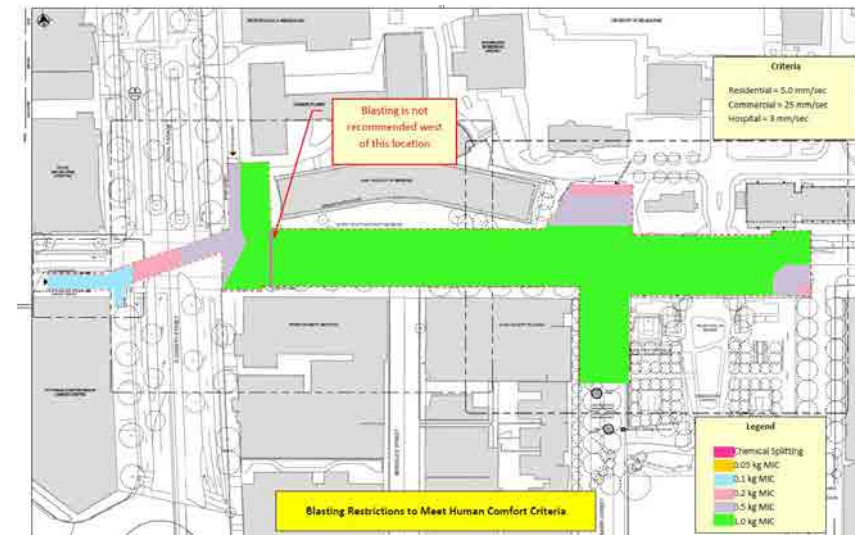
of estimating 95<sup>th</sup> percentile peak particle velocities for the blasting carried out to a free face in average field conditions for comparison with vibration limits in AS2187.2, K is taken as 2462 and B is 1.6.

The assessment assumes that controlled blasting begins at 25 m below ground level in relatively hard rock that 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. 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 181 by providing 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 or using lower vibration excavation techniques as determined on site.

The following diagram (Figure B.102) shows the charge weights and probable buffer and restriction zones for blasting at the Parkville Station excavation based on the following analysis of blasting impacts and the constraints noted therein. 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, the Proponent may modify the charge weights and buffer distances shown.



**Figure B.102: 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)**





**(i) Vibration – Damage to buildings**

The Parkville Station box excavation is surrounded by large commercial buildings belonging to research institutions and hospitals. 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 AS2187.2 and DIN4150-3, 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 a buffer distance of 12 m to commercial buildings, 30 m for residential building types and 70 m to heritage buildings. Smaller charges could be used at closer distances to commercial and residential structures in conjunction with a buffer zone of 15 m to the heritage building, inside which low vibration techniques would need to be used in place of blasting. The restriction on blasting within 70 m slope distance of the 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 made of the heritage buildings to increase the blasting vibration limit to 12.7 mm/s matching the residential structures, in which case 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.

**(ii) 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 (1966) 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 a buffer of about 20 m (slope distance) would be required for commercial receivers, and 50 m for residential receivers, in order to preserve human comfort. 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 to be conducted outside of the hours when the commercial buildings are normally occupied, then there are some 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 and restrictions at the eastern end of the excavation related to human comfort for 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.

**(iii) Vibration – Sensitive Equipment and Highly Sensitive Areas**

Vibration limits for the operation of vibration-sensitive imaging equipment and for highly sensitive areas are the most stringent of the vibration requirements for the Parkville station site. In general, vibration-sensitive equipment is many times more sensitive to vibration than people. It is therefore not considered to be practicable to meet the vibration requirements for the operation of vibration-sensitive equipment during blasting and it is recommended that mitigation involve close consultation with the affected parties, notification of any blasting schedule and that sensitive imaging equipment not be used during blasting. Negotiation would be required 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 181. Potential mitigations for these sites include providing 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 or using lower vibration excavation techniques.

Highly sensitive areas include operating theatres and wards at the Royal Melbourne Hospital, Melbourne Private Hospital, Royal Women's Hospital and the VCCC as well as biological resources at the Peter Doherty Institute, VCCC, the Howard Florey Laboratories and the 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 that all highly sensitive areas at the Royal Melbourne Hospital, Royal Women's Hospital, Melbourne Private Hospital and VCCC would experience vibration levels of less than 3 mm/s PPV, which is considered to be acceptable. Biological resources at the Peter Doherty Institute and at the University of Melbourne Faculty of Medicine building 181 are also predicted to have vibration levels below 3 mm/s PPV.

Ground-borne noise estimates for controlled blasting have been generated for biological resources for comparison with guideline targets of 85 dBL (short exposure) and ambient noise measurements taken at some of the biological resource locations. Ground-borne noise estimates were developed based on a vibration spectra for construction blasts derived 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 noise level inside the room that is less than the 85 dBL guideline noise target for biological resources once the frequency thresholds for biological resources are applied (the frequency range relating to the 85 dBL guideline target must be determined in relation to each facility depending on its usage). This means that if vibration levels are maintained at below 3 mm/s PPV in biological resource receiver spaces then the ground-borne noise guideline target is also likely to be achieved. Therefore it is likely that biological resources in buildings adjacent to the Grattan Street excavation, which are located at high levels within those buildings would 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.





Table B.14: Vibration predictions for vibration-sensitive equipment due to construction activities

Location	Vibration-sensitive Equipment	Vibration assessment reference <sup>see note e</sup>		Vibration assessment (maximum 1/3 octave vibration level (RMS) for comparison with VC curve <sup>see Note d</sup> )			Comments
		Vibration guideline target (magnitude of peak 1/3 octave band, RMS)	Baseline measurements (magnitude of peak 1/3 octave band, RMS)	Due to tunnelling activities	Due to Rockbreaking	Due to Ripping	
<b>Royal Women's Hospital</b>							
Level 1 adjacent to Grattan Street	CT Scanner MRI	VC-A 50 µm/s VC-C 12.5 µm/s	VC-B 17 µm/s	Exceeds (69 µm/s)	Complies (4 µm/s)	Complies (1 µm/s)	Equipment was not impacted upon by construction at VCCC
Level 2: Infertility	Microscopy	VC-A 50 µm/s	N/A	Minor exceedance (55 µm/s)	Complies (3 µm/s)	Complies (1 µm/s)	
Level 3: Theatres	Typical equipment	Operating Room 100 µm/s	N/A	Complies (43 µm/s)	Complies (3 µm/s)	Complies (1 µm/s)	
<b>Royal Melbourne Hospital, Building</b>							
Ground Level	Gamma cameras, PET Scanner	VC-A 50 µm/s	N/A	Complies (13 µm/s)	Complies (21 µm/s)	Complies (6 µm/s)	Adjacent to Royal Parade RMH Nuclear medicine department
Ground Level	CT scanner	VC-A 50 µm/s	N/A	Exceeds (72 µm/s)	Complies (12 µm/s)	Complies (4 µm/s)	Emergency Department
Level 1	MRI (1.5 T, MRI (3 T) CT Scanner	VC-C 12.5 µm/s VC-A 50 µm/s	VC-B 13 µm/s	Exceeds (217 µm/s) Exceeds (112 µm/s)	Exceeds (67 µm/s) Minor exceedance (57 µm/s)	Exceeds (25 µm/s) Complies (4 µm/s)	
Level 2	Sensitive equipment	VC-A 50 µm/s	N/A	Complies (16 µm/s)	Complies (46 µm/s)	Complies (16 µm/s)	Haematology
Level 3	Operating theatres	100 µm/s	N/A	Exceeds near façade (180 µm/s) Becomes compliant approximately 13m from façade	Complies (46 µm/s)	Complies (16 µm/s)	
Level 3	MRI	VC-C 12.5 µm/s	N/A	Exceeds (22 µm/s)	Minor exceedance (15 µm/s)	Complies (4 µm/s)	Cardio and neurology surgery General and Angiography theatres
Level 5 (north corner)	MRIs	VC-C 12.5 µm/s	VC-B 20 µm/s	Complies (3 µm/s)	Complies (9 µm/s)	Complies (3 µm/s)	
Level 8 East Wing Main Block	Instrument Lab	VC-A 50 µm/s	N/A	Complies (6 µm/s)	Complies (5 µm/s)	Complies (1 µm/s)	Belonging to WEHI
<b>Melbourne Private Hospital</b>							
Ground Level	MRI (1.5 T), MRI (3 T) CT scanner, X-ray equipment Ultra sound, Mammography	VC-C 12.5 µm/s VC-A 50 µm/s 100 µm/s	N/A	Complies (7 µm/s) Complies (7 µm/s) Complies (72 µm/s)	Complies (12 µm/s) Complies (12 µm/s) Complies (12 µm/s)	Complies (4 µm/s) Complies (4 µm/s) Complies (4 µm/s)	Private Medical Centre Radiology
Level 2	Sensitive equipment	VC-A 50 µm/s	N/A	Complies (16 µm/s)	Complies (46 µm/s)	Complies (16 µm/s)	Micro Biology Lab
Level 7	Brain navigation systems	Operating Room 100 µm/s	N/A	Complies (3 µm/s)	Complies (3 µm/s)	Complies (1 µm/s)	Operating theatres, Cath lab, Use radiology at RMH
<b>Victorian Comprehensive Cancer Centre</b>							
Basement 2 (Haymarket corner of the building)	Cyclotron	VC-C 12.5 µm/s	N/A	Exceeds (19 µm/s)	Minor exceedance (19 µm/s)	Complies (6 µm/s)	
Basement 1 (adjacent to Grattan Street)	Linear accelerators	VC-C 12.5 µm/s	N/A	Exceeds (405 µm/s)	Exceeds (>300 µm/s)	Exceeds (>300 µm/s)	
Basement 1 (towards Flemington Road)	CT Scanners	VC-A 50 µm/s	N/A	Minor exceedance (51 µm/s)	Complies (33 µm/s)	Complies (10 µm/s)	





Location	Vibration-sensitive Equipment	Vibration assessment reference <sup>see note e</sup>		Vibration assessment (maximum 1/3 octave vibration level (RMS) for comparison with VC curve <sup>see Note d</sup> )			Comments
		Vibration guideline target (magnitude of peak 1/3 octave band, RMS)	Baseline measurements (magnitude of peak 1/3 octave band, RMS)	Due to tunnelling activities	Due to Rockbreaking	Due to Ripping	
Level 4	MRIs	VC-A 50 µm/s <sup>see note c</sup>	N/A	Complies (13 µm/s)	Complies (10 µm/s)	Complies (3 µm/s)	
Level 5	MRI, Xray, Ultrasounds, PET, CT	VC-A 50 µm/s <sup>see note c</sup> 100 µm/s VC-A 50 µm/s	N/A	Exceeds (104 µm/s) Complies (85 µm/s) Complies (13 µm/s)	Exceeds (123 µm/s) Complies (58 µm/s) Complies (8 µm/s)	Exceeds (123 µm/s) Complies (56 µm/s) Complies (2 µm/s)	
Level 6	Operating theatre Future MRI	100 µm/s VC-A 50 µm/s <sup>see note c</sup>	N/A	Complies (64 µm/s) Exceeds (58 µm/s)	Complies (47 µm/s) Complies (41 µm/s)	Complies (45 µm/s) Complies (28 µm/s)	
<b>Peter Doherty Institute</b>							
Basement	Electron microscope	VC-A 50 µm/s (on floor slab)	VC-D 6 µm/s	Exceeds (57 µm/s)	Exceeds (178 µm/s)	Exceeds (172 µm/s)	Located on independent concrete inertia block with pneumatic isolation. Criterion is based on information from Marshall Day Acoustics Report dated 13 February 2011 Reference SP0032010065.
Ground	Auditorium	Operating Room 100 µm/s	N/A	Complies (79 µm/s)	Minor exceedance (158 µm/s)	Minor exceedance (105 µm/s)	
Level 1	Genomics room	VC-C 12.5 µm/s	N/A	Exceeds (45 µm/s)	Exceeds (80 µm/s)	Exceeds (32 µm/s)	
Level 7	Microscopy	VC-A 50 µm/s	VC-A 48 µm/s	Complies (17 µm/s)	Complies (33 µm/s)	Complies (22 µm/s)	
Level 8	Photon	VC-C 12.5 µm/s	N/A	Minor exceedance (14 µm/s)	Exceeds (63 µm/s)	Exceeds (63 µm/s)	Located on vibration table
<b>University of Melbourne</b>							
Ground, Bio21	Electron microscope	VC-D 6 µm/s	VC-B 20 µm/s	Complies (5 µm/s)	Complies (0 µm/s)	Complies (0 µm/s)	Electron microscope isolated from structure.
Ground, Building 170	Laser diagnostics equipment	VC-A 50 µm/s	N/A	Exceeds (85 µm/s)	Complies (10 µm/s)	Complies (3 µm/s)	
Level 1, Building 170	Fluroscopes and Robotic Gantry Equipment	100 µm/s	N/A	Complies (77 µm/s)	Complies (8 µm/s)	Complies (2 µm/s)	
Ground, Building 261	Helium Ion Microscope	VC-D 6 µm/s	N/A	Minor exceedance (7 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	
Basement, Building 175	Network Analysers and Dielectric Permittivity Probes	200 µm/s	N/A	Complies (153 µm/s)	Complies (170 µm/s)	Complies (138 µm/s)	
Ground, Building 165	Thermal Gravity Analysis	100 µm/s	N/A	Complies (5 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	
Ground, Building 165	Sorption Analyser	VC-A 50 µm/s	N/A	Complies (5 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	
Ground, Building 165	Nanomaterials Nanoindenter	VC-C 12.5 µm/s	N/A	Complies (5 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	On air isolated table
Level 1, Building 165	JPK Nanowizard	VC-C 12.5 µm/s	N/A	Complies (4 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	
Level 1, Building 165	3D Atomic Force Microscope	VC-D 6 µm/s	VC-B 15 µm/s	Complies (4 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	Located on air dampened table
Level 1, Building 165	20nm Resolution Microscope	VC-B 25 µm/s	N/A	Complies (4 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	On air isolated table
Level 1, Building 165	200nm Resolution Microscope	VC-B 25 µm/s	N/A	Complies (4 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	
Level 2, Building 165	3D Atomic Force Microscope	VC-D 6 µm/s	N/A	Complies (3 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	Located on air dampened table
Level 3, Building 181	Confocal Microscope (Leica SP2)	VC-C 12.5 µm/s	VC- 24 µm/s	Exceeds (40 µm/s)	Exceeds (51 µm/s)	Complies (21 µm/s)	Vibration limit from supplier data. On isolation table
Ground, Building 181	Confocal Microscope	314 µm/s on floor	VC- 28 µm/s	Complies (173 µm/s on floor)	Complies (178 µm/s on floor)	Complies (172 µm/s on floor)	On isolation table. Vibration limit from supplier data.





Location	Vibration-sensitive Equipment	Vibration assessment reference <sup>see note e</sup>		Vibration assessment (maximum 1/3 octave vibration level (RMS) for comparison with VC curve <sup>see Note d</sup> )			Comments
		Vibration guideline target (magnitude of peak 1/3 octave band, RMS)	Baseline measurements (magnitude of peak 1/3 octave band, RMS)	Due to tunnelling activities	Due to Rockbreaking	Due to Ripping	
<b>Howard Florey Laboratories</b>							
Basement	MRI	VC-C 12.5 µm/s	VC-C 11 µm/s	Exceeds (31 µm/s)	Exceeds (99 µm/s)	Exceeds (41 µm/s)	At Northern end of the building
<b>Walter and Eliza Hall Institute (WEHI)</b>							
Ground Level, WEHI 1		VC-C 12.5 µm/s	N/A	Complies (7 µm/s)	Complies (6 µm/s)	Complies (2 µm/s)	Potential Crystallography facility
Level 3C WEHI 1	Laser and analysis equipment	VC-A 50 µm/s	N/A	Complies (4 µm/s)	Complies (3 µm/s)	Complies (1 µm/s)	
Level 4C WEHI 1	High sensitivity microscopes	VC-B 25 µm/s	VC-A 58 µm/s	Complies (4 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	
Level 7W WEHI 2		VC-A 50 µm/s	N/A	Complies (2 µm/s)	Complies (1 µm/s)	Complies (0 µm/s)	Structural Biology Crystal Store
<b>Kenneth Myer Building</b>							
Basement Level	Small bore MRI (4.7 T)	VC-B 25 µm/s	VC-D 5 µm/s	Complies (5 µm/s)	Complies (10 µm/s)	Complies (3 µm/s)	
Ground Level	MRI (7 T), PET CT Camera	VC-C 12.5 µm/s VC-A 50 µm/s	N/A	Complies (5 µm/s)	Complies (10 µm/s)	Complies (3 µm/s)	
All Levels	Extremely sensitive equipment	VC-C 12.5 µm/s	N/A	Complies (5 µm/s)	Complies (10 µm/s)	Complies (3 µm/s)	Equipment that is extremely sensitive to vibration
Level 1	Nano PET	VC-C 12.5 µm/s	N/A	Complies (4 µm/s)	Complies (10 µm/s)	Complies (3 µm/s)	Some equipment is pneumatically isolated
Level 2	2 photon microscopes	VC-C 12.5 µm/s	N/A	Complies (4 µm/s)	Complies (6 µm/s)	Complies (2 µm/s)	Equipment pneumatically isolated
Level 3	Advanced microscopy	VC-B 25 µm/s	N/A	Complies (3 µm/s)	Complies (5 µm/s)	Complies (1 µm/s)	Advance microscopy Equipment pneumatically isolated
Level 4	Mass spectroscopy	VC-C 12.5 µm/s	N/A	Complies (3 µm/s)	Complies (4 µm/s)	Complies (1 µm/s)	Mass spectroscopy
Level 7	Sensitive equipment	VC-A 50 µm/s	N/A	Complies (2 µm/s)	Complies (2 µm/s)	Complies (1 µm/s)	Equipment pneumatically isolated
	University High School						
Gene Technology Access Centre	Scanning Electron Microscope	VC-C 25 µm/s	N/A	Complies (3 µm/s)	Complies (5 µm/s)	Complies (1 µm/s)	In the Pittard Room (desk-mounted teaching resource)

- a) The list in this table is representative of the most sensitive equipment at closest proximity to the alignment. Other vibration-sensitive equipment may also be present at some sites.
- b) AHSRAE does not provide vibration guideline targets for all of the sensitive equipment that is listed in this table. The following assumptions have been made with regards to equipment that is not listed in AHSRAE:
- Bio-resource facilities must comply with the VC curve for laboratories VC-A curve 50 µm/s
  - X-Rays, Ultrasound, Mammography, Gamma Cameras must comply with the VC curve for laboratories VC-A curve 50 µm/s
  - Generally sensitive equipment must comply with VC-A curve 50 µm/s
  - PET scanners and Mass Spectroscopy machines have similar vibration requirements to MRI machines (VC-C 12.5 µm/s)
  - CT scanners must comply with the VC-A curve 50 µm/s
  - Hospital operating rooms are **not** used for microsurgery, eye surgery, or neurosurgery (ie they can be classified as a standard "Operating Room" 100 µm/s)
  - Electron microscopes have a magnification of 30,000 x or greater (VC-D 6 µm/s)
  - Photon Microscopes, Crystallography sites, Linear accelerators and Cyclotrons have similar vibration requirements to Electron microscopes and MRIs (VC-C 12.5 µm/s)
  - General microscopes (for which the magnification is not listed are assumed) must comply with VC-A curve 50 µm/s
  - Advanced or sensitive microscopes (for which the magnification is not listed are assumed) must comply with VC-B curve 25 µm/s
- c) MRIs located in the VCCC have a limit of 50µm/s as specified in *Victorian Comprehensive Cancer Centre Project, Volume 2, Part C, Technical Specification* (DH-PDOC-F84-C-000\_04-150525-rm.docx).
- d) For rockbreaking, PPV vibration levels were first converted in to overall RMS vibration using a crest factor of 4 (consistent with the FTA guideline). A factor of 1.5 reduction in overall vibration was used to calculate the 1/3<sup>rd</sup> Octave vibration. This factor of 1.5 reduction is intended to reflect some spread in vibration across the different frequency bands.
- e) Note that the reference for the vibration assessment is taken to be the greater of the VC-curve and baseline measurement (where available).





Table B.15: Vibration and ground-borne noise predictions for biological resources due to construction activities

Location	Vibration target		Ground-borne noise target		Vibration assessment (maximum 1/3 octave vibration level (RMS) for comparison with VC curve <sup>see Note c)</sup>		Ground-borne Noise Assessment	
	Guideline Target (magnitude of peak 1/3 octave band, RMS)	Baseline measurements (magnitude of peak 1/3 octave band, RMS)	Guideline Target	Baseline measurements (Leq)	Due to tunnelling activities	Due to additional construction works (ripping and rockbreaking)	Due to tunnelling activities	Due to additional construction works (ripping and rockbreaking)
<b>Royal Melbourne Hospital, Building</b>								
Basement	VC-A 50 µm/s	VC-D 6 µm/s	50 dB	78 dB	Minor exceedance (69 µm/s)	Exceeds (117 µm/s)	Complies (75 dBL)	Complies (77 dBL)
Level 6	VC-A 50 µm/s	N/A	50 dB (>500Hz)	60 dB	Complies (18 µm/s)	Complies (31 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
<b>Peter Doherty Institute</b>								
Level 8	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Complies (11 µm/s)	Complies (16 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 9	VC-A 50 µm/s	VC-A 35 µm/s	50 dB (>500Hz)	N/A	Complies (9 µm/s)	Complies (13 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 9	VC-A 50 µm/s	VC-A 35 µm/s	50 dB	70 dB	Complies (9 µm/s)	Complies (13 µm/s)	Complies (58 dBL)	Complies (58 dBL)
<b>Howard Florey Laboratories</b>								
Ground Floor	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Minor exceedance (53 µm/s)	Minor exceedance (79 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 3	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Complies (27 µm/s)	Complies (40 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 4	VC-A 50 µm/s	N/A	50 dB (>100Hz)	N/A	Complies (21 µm/s)	Complies (32 µm/s)	Complies (19 dBL)	Complies (<50 dBL)
Level 5	VC-A 50 µm/s	N/A	50 dB (>100Hz)	N/A	Complies (17 µm/s)	Complies (26 µm/s)	Complies (16 dBL)	Complies (<50 dBL)
Level 7	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Complies (12 µm/s)	Complies (17 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
<b>Walter and Eliza Hall Institute (WEHI)</b>								
Level 1C, WEHI 1	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Complies (6 µm/s)	Complies (4 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 2 WEHI 2	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Complies (5 µm/s)	Complies (4 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 4C WEHI 1	VC-A 50 µm/s	VC-A 43 µm/s	50 dB (>500Hz)	61 dB	Complies (4 µm/s)	Complies (1 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
<b>University of Melbourne Faculty of Medicine</b>								
Level 9	VC-A 50 µm/s	VC-B 20 µm/s	50 dB (>500Hz)	49 dB	Complies (18 µm/s)	Complies (35 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 9	VC-A 50 µm/s	VC-A 29 µm/s	50 dB (>500Hz)	45 dB	Complies (18 µm/s)	Complies (18 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
<b>VCCC</b>								
Level 4	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Complies (9 µm/s)	Complies (7 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)
Level 8	VC-A 50 µm/s	N/A	50 dB (>500Hz)	N/A	Minor exceedance (63 µm/s)	Minor exceedance (63 µm/s)	Complies (<50 dBL)	Complies (<50 dBL)

Note: Targets for noise and vibration are taken as the greater of the guideline target and the baseline measurement (where available).





Table B.16: Vibration and ground-borne noise predictions for Highly Sensitive areas due to construction activities

Location	Highly Sensitive Area	Noise and vibration due to tunnelling <sup>See note 1</sup>			Noise and vibration due to additional construction works (ripping and rockbreaking)			Comments
		Vibration - VDV day (m/s <sup>1.75</sup> )	Vibration - VDV Night (m/s <sup>1.75</sup> )	Ground-borne Noise (dBA)	Vibration - VDV day (m/s <sup>1.75</sup> )	Vibration - VDV Night (m/s <sup>1.75</sup> )	Ground-borne Noise (dBA)	
Trigger levels for management action:		0.4 (maximum)	0.2 (maximum)	35	0.4 (maximum)	0.2 (maximum)	35	
<b>Royal Women's Hospital</b>								
Level 4	Wards	Complies (0.23)	Complies (0.20)	Minor exceedance (21-37)	Complies (0.01)	Complies (0.00)	Complies (< 20)	
Level 5	Staff Accommodation	Complies (0.18)	Complies (0.16)	Complies (19-35)	Complies (0.00)	Complies (0.00)	Complies (< 20)	
Level 7	Maternity	Complies (0.12)	Complies (0.11)	Complies (15-31)	Complies (0.00)	Complies (0.00)	Complies (< 20)	
<b>Royal Melbourne Hospital</b>								
Level 2	ICU	Exceeds (0.14-0.71)	Exceeds (0.12-0.62)	Exceeds (30-50)	Complies (0.04)	Complies (0.04)	Complies (24)	
Level 3	Ward 3S	Exceeds (0.11-0.57)	Exceeds (0.10-0.50)	Exceeds (28-48)	Complies (0.03)	Complies (0.03)	Complies (22)	
Level 5	Ward 5S	Complies (0.37)	Exceeds (0.07-0.33)	Exceeds (24-44)	Complies (0.02)	Complies (0.02)	Complies (< 20)	
Level 6	Ward 6S	Complies (0.30)	Exceeds (0.05-0.27)	Exceeds (22-42)	Complies (0.02)	Complies (0.02)	Complies (< 20)	
Level 7	Ward 7S	Complies (0.25)	Exceeds (0.04-0.22)	Exceeds (20-40)	Complies (0.01)	Complies (0.01)	Complies (< 20)	
Level 2	Cardiology ward 2b	Exceeds (0.09-0.82)	Exceeds (0.08-0.72)	Exceeds (24-51)	Complies (0.19)	Complies (0.16)	Minor exceedance (37)	Minor exceedance relates to the 20 tonne rockbreaker
Level 2	Ward 2W	Complies (0.07)	Complies (0.06)	Complies (22)	Complies (0.01)	Complies (0.01)	Complies (<20)	
Level 5	Ward 5E	Complies (0.04)	Complies (0.03)	Complies (15)	Complies (0.01)	Complies (0.01)	Complies (< 20)	
Level 7	Ward 7W	Complies (0.03)	Complies (0.02)	Complies (11)	Complies (0.00)	Complies (0.00)	Complies (< 20)	
Level 9	Ward 9E & 9W	Complies (0.02)	Complies (0.02)	Complies (7)	Complies (0.00)	Complies (0.00)	Complies (< 20)	
<b>Victorian Comprehensive Cancer Centre</b>								
Level 1	Country patient accommodation	Exceeds (0.23-0.88)	Exceeds (0.2-0.77)	Exceeds (35-52)	Complies (0.05)	Complies (0.05)	Complies (26)	
Level 3	Medical ward	Exceeds (0.11-0.57)	Exceeds (0.09-0.50)	Exceeds (27-48)	Complies (0.07)	Complies (0.06)	Complies (29)	
Level 5	Haematology ward	Complies (0.37)	Exceeds (0.06-0.33)	Exceeds (23-44)	Complies (0.05)	Complies (0.04)	Complies (25)	
Level 6	Surgical ward	Complies (0.30)	Exceeds (0.05-0.27)	Exceeds (21-42)	Complies (0.04)	Complies (0.03)	Complies (23)	
<b>Peter Doherty Institute</b>								
Ground	Auditorium	Complies (0.26) <sup>See note 2</sup>	N/A	37 <sup>See note 3</sup>	Complies (0.6) <sup>See note 2</sup>	N/A	44 <sup>See note 3</sup>	

Note 1: Some results are presented as ranges with the largest values occurring adjacent to the closest facade to the alignment. The smaller values are predicted for the regions furthest from the alignment. Where results are presented as a single figure it is the worst-case prediction for the area.

Note 2: A VDV day maximum guideline target of 0.8 applied to the Auditorium space.

Note 3: There is no guideline target for ground-borne noise for educational receivers (such as the Peter Doherty Auditorium). Predicted ground-borne noise levels of up to 44 dBA are not expected to impact on persons using the auditorium.





## B.6.5 Precinct 5 – CBD North Station

The CBD North Station assessment has taken into account two main areas of construction:

- The station cavern mined using multiple road headers
- Additional Construction Work using a variety of other equipment. The ground-borne noise and vibration predictions for this are based on assessments of vibration for rockbreakers and rippers, as these are the most vibration intensive items of construction equipment. Vibration predictions have been made under the following assumptions:
  - Franklin Street excavation: Rippers would be used to remove material to a depth of 25 m below ground level. 20 tonne rockbreakers would be used to remove material from depths greater than 25 m below ground
  - A'Beckett Street shaft excavation: Rippers would be used to remove material to a depth of 15 m below ground level. 20 tonne rockbreakers would be used to remove material between 15 and 25 m below ground level. 32 tonne rockbreakers would be used to remove material that is greater than 25 m below ground level
  - Southern entrance excavation: Rippers would be used to remove material to a depth of 20 m below ground level. 20 tonne rockbreakers would be used to remove material that is between 20 and 30 m below ground level. 32 tonne rockbreakers would be used to remove material that is greater than 30 m below ground level.

### B.6.5.1 Vibration – Damage to Buildings

#### (i) Tunnelling (Station Cavern Road Headers)

Compliance with DIN 4150 guideline targets for structural damage is predicted due to road header excavation of the station cavern.

Several structurally sensitive (heritage) sites have been identified in this precinct and Table B.17 presents the predicted PPV levels at these sites along with current measured levels. At all locations the predicted vibration level due to road header activity complies with the DIN 4150 guideline target and is less than the baseline peak vibration level measured. Consequently, damage from tunnelling is not expected.

Table B.17: Vibration levels at other sensitive sites

Sensitive Site	Baseline PPV (mm/s)	Predicted PPV (mm/s)	Comments
<b>CBD North</b>			
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

#### (ii) Additional Construction Works

A guideline PPV target of 10 mm/s applies to most of the buildings in the vicinity of the excavations. 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 not predicted to be an issue due to the depth of 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. Management actions may be required at one building on Swanston St (RMIT building 393-397 Swanston Street) which is immediately adjacent to the Southern Entrance excavation. The potential for cosmetic building damage to at this location could be mitigated by adopting lower vibration methods of excavation when removing material in the immediate vicinity of the

building. Lower vibration methods could include the use of smaller sized ripper attachments. Pre-splitting could also be used to lessen the vibration associated with the removal of any hard material. Vibration measurements would need to be undertaken in order to verify the vibration levels.

Heritage sites, where a low guideline target of 2.5 mm/s PPV applies, have been assessed. It is predicted that this guideline target may be exceeded at three buildings that are on the Heritage Overlay. These buildings include the Old Cyclone Wire Fence Co. building (HO1042), the Oxford Hotel (HO1085) and 411-423 Swanston Street (HO1084). It is recommended that vibration monitoring is conducted at these locations during construction. If vibration levels exceed the 2.5 mm/s guideline target, the proponent should seek to use lower vibration methods of construction. Dilapidation surveys should also be conducted. It is noted that baseline vibration levels of up to 5.2 mm/s have been recorded in the vicinity of these buildings and that the proponent may be able to justify the adoption of higher vibration limits for construction.

Whilst vibration levels do not exceed 2.5 mm/s at the City Baths (Victorian Heritage Register H0466), vibration monitoring and dilapidation surveys are recommended as a precautionary measure.

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.

### B.6.5.2 Vibration – Damage to Utilities

#### (i) Tunnelling (Station Cavern Road Headers)

There are a number of utilities within the CBD North station precinct and its surrounds. To avoid damage, the critical distances construction work should be from utilities are:

- 2.0 m for general utilities
- 3.7 m for Melbourne Water unreinforced assets

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

The tunnel alignment crosses the Melbourne Underground Rail Link (MURL) tunnels in the CBD North station precinct. The peak vibration level predicted at the MURL due to road header mining of the CBD North-CBD South tunnel is predicted to be 12 mm/s. This level is the peak predicted to occur when the road header is excavating soil from the top of the tunnel and the closest alignment to the MURL tunnels. Vibration would reduce as the cutter face moves away from the top of the tunnel and as the road header progresses along the tunnel. Predicted vibration levels at such a close distance is beyond the typical limits for the regression formula derived for the road header vibration attenuation curve, and as such may be somewhat overly conservative.

This predicted vibration level is slightly in excess 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% of transient vibration guide value, for industrial and heavy commercial buildings). Thus, while at the MURL predicted vibration exceeds the DIN 4150 guideline target selected for this project, the risk should be able to be addressed by utilising vibration monitoring at the MURL tunnel during road header mining.

#### (ii) Additional Construction Works

The critical distance that Additional Construction Works should be from the utilities 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 by the Proponent to the commencement of work.





### B.6.5.3 Vibration – Human Comfort

#### (i) Tunnelling (Station Cavern Road Headers)

It is predicted that adverse comment due to vibration VDV may occur at a small number of receivers in the CBD North Station Precinct. Mitigation of vibration from the road header may be possible by utilising reduced hours of operation and/or modifications to the construction sequencing.

The methodology of construction of 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 with the heading (top) completed first, then the bench (middle) and finally the invert (bottom). The predictions have been based on two road headers working at the header level, with one road header 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 road header 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 road header 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.

As for the tunnel predictions, the road header progresses along the station cavern which changes the distance to the receiver. Due to the much larger cross section of the station cavern, the road headers would progress at a slower rate. Furthermore, due to the three separate passes required the same receiver would experience the exceedances over three distinct periods of time. For receivers that have foundations or piles in bedrock there may be no reduction in levels of vibration and ground-borne noise during the excavation of the bench and invert.

An analysis of the change in VDV over time due to road header station cavern works has been conducted for two sample receivers in the CBD North station precinct – one residential and one commercial:

- Residential Receiver Address: 8 Franklin Street, Melbourne (see Figure B.103)
- Commercial Receiver Address: 393-397 Swanston Street, Melbourne (see Figure B.103).

These receivers have been selected as they present some of the highest preliminary vibration results and therefore are expected to have some of the longest durations of high vibration/noise.

The road header 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.

Figure B.104 and Figure B.105 show the VDV results with respect to construction time for the residential and commercial locations respectively.

Note that at these two particular receivers the criterion level for management actions is triggered by road headers working on both sides of the station cavern, so that the combined noise and vibration is a combination of the influence of both road headers. The impact of both road headers is presented in the figures.

The criterion level for management actions is triggered at the residential location for up to 2 weeks during the day and up to 5 weeks at night (based on a preferred level which relates to no expected adverse comment). At the commercial location the criterion level is triggered for approximately 4 weeks during the day or night (based on a preferred level which relates to no expected adverse comments). This duration is longer than for road header tunnelling primarily due to the staggered position of the two road headers, as well as a slightly slower assumed advance rate. The human comfort vibration level at the commercial receiver remains within the 'low probability of adverse comment' range while for the residential receiver the level is in the 'adverse comments are possible' range for approximately 10 days.

These management triggering vibration levels may occur up to three times as the heading, the bench and the invert are excavated.

An assessment of the vibration at higher floors of these buildings has been undertaken. For residential receivers the impact is limited to the ground floor, with higher floors having vibration levels below the criterion for management actions. For commercial receivers the impact is limited to the ground, first and second floors, with level 3 and above having vibration levels below the criterion for management actions.

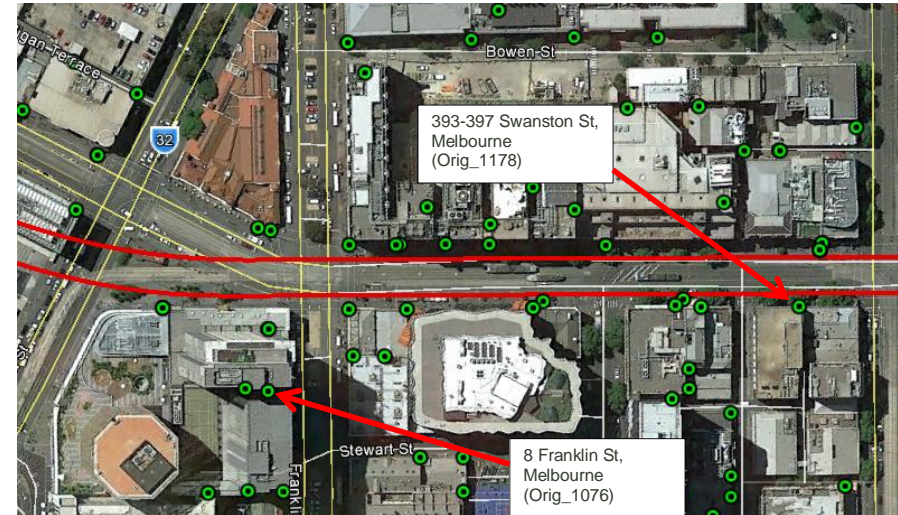


Figure B.103: Example Receivers for CBD North road header station cavern works calculations



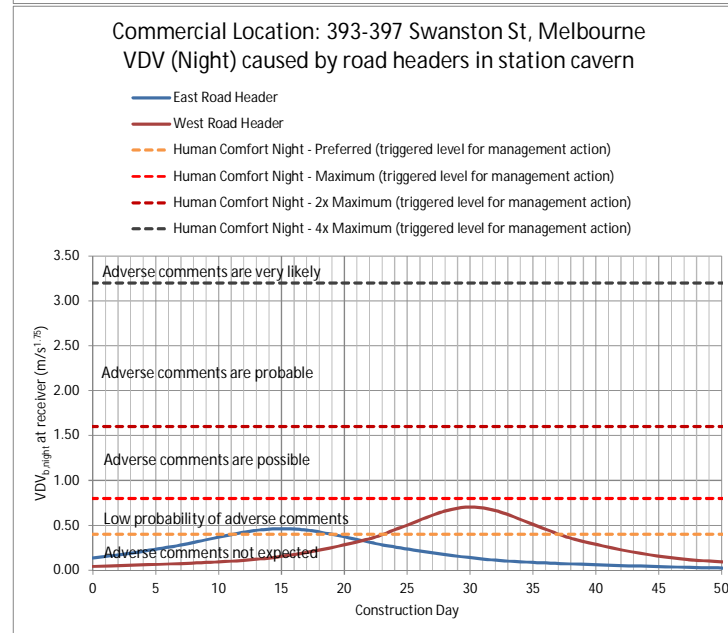
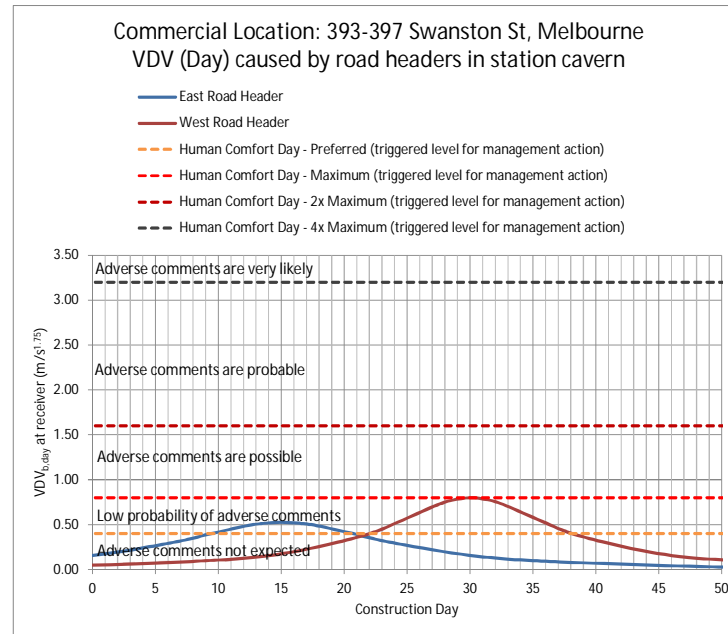
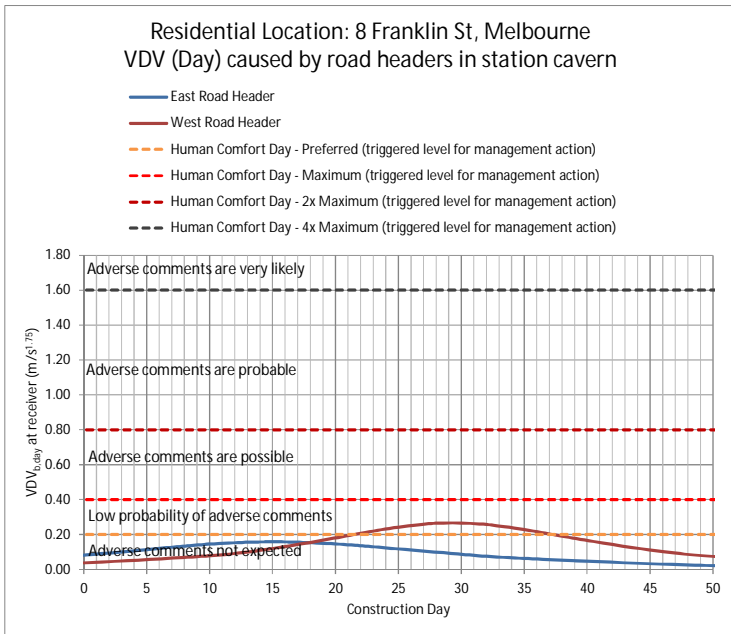


Figure B.104: Time of Duration of Exceedances at Example Residential Receiver – North CBD Station Cavern Works using Road header

Figure B.105: Time of Duration of Exceedances at Example Commercial Receiver – North CBD Station Cavern Works using Road header





## (ii) Additional Construction Works

There are residential receivers on the lower levels of buildings on Franklin Street where VDV levels are expected to exceed the day and night guideline targets. The exceedances are only expected to occur when rippers and rockbreakers are working in close proximity to these buildings. The maximum daytime VDV guideline target of  $0.4 \text{ m/s}^{1.75}$  (low probability of adverse comment) would only be exceeded when the ripper is working within a slope distance of 12 m and the 20 tonne rockbreaker is working within a slope distance of 30 m from the building façade. The maximum night VDV guideline target of  $0.2 \text{ m/s}^{1.75}$  would only be exceeded when the ripper is working within a slope distance of 18 m and the 20 tonne rockbreaker is working within a slope distance of 45 m from these buildings. The VDV exceedances are only predicted for residential receivers that reside on the lower levels of these buildings (ground up to level 4). It is expected that the Proponent would manage these VDV exceedances through a combination of community consultation and scheduling of the excavation works. The VDV night exceedances would be managed by maintaining buffer distances of 18 m (ripper) and 45 m (rockbreaker) during the night. In order to maintain these distances, the Proponent would need to schedule ripping and rockbreaking works west of Swanston Street during daytime hours only. It is expected that VDV exceedances arising from daytime excavation works within close proximity of residential buildings would be managed through close consultation and negotiation with residents.

It is predicted that adverse comments due to vibration are possible from occupants at a number of commercial receivers and RMIT buildings located on Franklin Street. Adverse comments due to vibration are also possible at a number of commercial receivers on Swanston Street, Little Latrobe and Latrobe Streets. The exceedances are predicted to be very short in duration (only occurring when rippers are working within 7 m slope distance of receivers). It is predicted that the maximum guideline VDV target for commercial and educational receivers would be met when rippers are working at a slope distance greater than 7 m from receivers. Due to the depth of operation, a low probability of compliant is predicted regardless of the location of the 20-tonne and 32-tonne rockbreakers. It is expected that the Proponent would be able to manage the vibration impacts of rippers by maintaining a 7 m buffer zone whilst buildings are occupied. Alternatively, the Proponent may use lower vibration methods of material removal within 7 m of receivers.

### B.6.5.4 Vibration-sensitive Equipment, Bio-resources and Highly Sensitive Areas

An assessment of vibration-sensitive equipment in the vicinity of the CBD North construction worksite has been undertaken with respect to the ASHRAE Vibration Curves and measurements of existing vibration levels. The outcomes of this assessment are presented Table B.18.

Ground-borne vibration from the road header excavating the station cavern could potentially impact on the operation of the RMIT Photonics Lab which is located on level 9 of building 12. Vibration levels are predicted to exceed existing vibration levels due to road header excavation of the CBD North station cavern. It is expected that this exceedance can be managed through consultation with RMIT and monitoring of the laboratory during the station cavern excavation. Mitigation may also be possible by utilising reduced hours of operation and/or modification to the construction sequencing at this location.

The 20 tonne rockbreaker and ripper could potentially impact on the operation of the RMIT electron microscope which is located on level 7 of building 14 as well as the confocal microscope located on level 5 of building 14. Vibration levels are only expected to exceed existing vibration levels when the rockbreaker and ripper are working in the Eastern end of the Franklin Street excavation (when the rockbreaker is within a slope distance of 65 m of building 14 and the ripper is working within a 30m slope distance of building 14). It is expected that the Proponent would be able to manage this exceedance through consultation with the RMIT and monitoring the performance of the microscopes when the rockbreaker and ripper are working within the buffer zones noted above. The Proponent may need to negotiate with the RMIT and alter the schedule for the rockbreaking works if the performance of the electron and confocal microscopes are affected. It may also be feasible to temporarily reschedule the use of sensitive equipment to other times or non-affected facilities.

Bio-resources and Highly Sensitive Areas have not been identified in this precinct.

### B.6.5.5 Ground-borne Noise

#### (i) Tunnelling (Station Cavern Road Headers)

Ground-borne noise levels are predicted to trigger management actions at a very small number of receivers in the CBD North Station Precinct. Mitigation of ground-borne noise and vibration from the road header 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 road header station cavern works has been conducted for a sample residential receiver in the CBD North station precinct:

- Residential Receiver Address: 8 Franklin Street, Melbourne (see Figure B.103).

The same assumptions have been used as were applied to the prediction of VDV values in Section B.6.5.3.

Figure B.106 shows the ground-borne noise results with respect to construction time for this location.

At this particular receiver management actions for ground-borne noise are predicted to be triggered by road headers working on both sides of the station cavern, consequently, noise and vibration is a combination of the influence of both road headers. The impact of both road headers is presented in the figure.

Mitigation actions for the ground-borne noise guideline target are predicted to be triggered for the residential receiver for approximately 2 weeks during the night.

These management triggering levels may occur up to three times as the heading, the bench and the invert are excavated.

An assessment of the vibration at higher floors of this building has been undertaken. The impact is limited to the ground and first floor, with higher floors having vibration levels below the criterion for management actions based on the night guideline target.



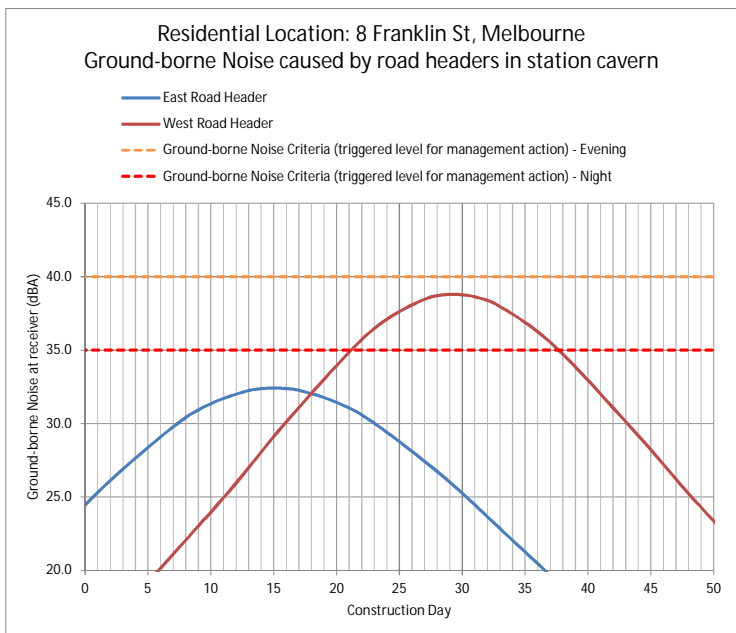


Figure B.106: Time of Duration of Exceedances for Example Residential Receiver –CBD North Station Cavern Works using Road header

**(ii) Additional Construction Works**

There residential addresses on Franklin Street (west of Swanston) where the ground-borne noise levels are predicted to reach up to 48 dBA. Buffer distances to achieve compliance with the 35 dBA night-time guideline target are: 25 m and 55 m for the ripper and 20 tonne rockbreaker respectively. These distances are slope distances. It is expected that the Proponent 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.





Table B.18: Vibration predictions for vibration-sensitive equipment due to construction activities

Location	Vibration-sensitive Equipment	Vibration guideline target (magnitude of peak 1/3 octave band, RMS)	Baseline measurements (magnitude of peak 1/3 octave band, RMS)	Vibration assessment (magnitude of peak 1/3 octave band, RMS)		Comments
				Due to tunnelling activities (including road header excavation of station cavern)	Due to excavation (ripping and rockbreaking)	
<b>RMIT</b>						
Basement 2, Building 100	Robotics lab	100 µm/s	VC-D 3 µm/s	Complies (35 µm/s)	Complies (5 µm/s)	
Level 7, Building 14	Electron microscope	6 µm/s	VC-B 18 µm/s	Complies (9 µm/s)	Minor exceedance (31 µm/s)	Exceedance relates to the 20 tonne rockbreaker. 19 µm/s is predicted for the ripper.
Level 5, Building 14	Confocal microscope	VC-C 12.5 µm/s	VC-B 14 µm/s	Complies (10 µm/s)	Exceeds (50 µm/s)	Exceedance relates to the 20 tonne rockbreaker as well as ripper. 32 µm/s is predicted for the ripper.
Ground Floor, Building 3	NMR Spectrometer	VC-C 12.5 µm/s	VC-D 6 µm/s	Complies (12 µm/s)	Complies (7 µm/s)	
Building 12	Acoustic Chambers	200 µm/s	N/A	Complies (149µm/s)	Complies (76 µm/s)	
Level 4, Building 7	The Fib (Ion beam manufacturing tool)	12.5 µm/s	VC-B 22 µm/s	Complies (15 µm/s)	Complies (21 µm/s)	
Level 9, Building 12	Photonics Lab	VC-C 12.5 µm/s	VC-B 19 µm/s	Exceeds (44 µm/s)	Complies (9 µm/s)	

Note: Vibration has been assessed against the highest of either the guideline target level or the baseline vibration level.





## B.6.6 Precinct 6 – CBD South Station

The CBD South Station Precinct assessment has taken into account two main areas of construction:

- The station cavern mined using multiple road headers
- Additional Construction Work using a variety of other equipment. The ground-borne noise and vibration predictions for this are based on assessments of vibration for rockbreakers and rippers, as these are the most vibration intensive items of construction equipment. Vibration predictions have been made under the following assumptions:
  - City Square excavation: Rippers would be used to remove material to a depth of 10 to 20 m below ground level. 20 tonne rockbreakers would be used to remove material from depths greater than 20 m below ground level
  - Southern Entrance excavation: Rippers would be used to remove material to a depth of 20 m below ground level. 20 tonne rockbreakers would be used to remove material from depths greater than 20 m below ground level
  - Federation Square excavation: Rippers would be used to remove material to a depth of 15 m below ground level. 12 tonne rockbreakers would be used to remove material from depths greater than 15 m below ground level.

### B.6.6.1 Vibration – Damage to Buildings

#### (i) Tunnelling (Station Cavern Road Headers)

There are no predicted vibration exceedances with respect to building damage issues due to tunnelling.

Several sensitive sites have been identified in this precinct and Table B.19 presents the predicted PPV results along with current measured vibration levels. At all locations the predicted vibration level due to road header activity is less than or equal to the current peak vibration experienced. The predicted vibration at all locations complies with the DIN 4150 guideline target for structural damage.

Table B.19: Vibration levels at other sensitive sites

Sensitive Site	Baseline PPV (mm/s)	Predicted PPV (mm/s)	Comments
<b>CBD South</b>			
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 vibration is below the sensitive structure DIN 4150 guideline target
The Arts Centre	3.1	0.2	Predicted level less than existing
Melbourne Recital Centre and MTC Theatre		<0.1	Trams passing and turning corner at close proximity expected to be higher than predicted vibration levels

#### (ii) Additional Construction Works

A guideline PPV targets of 10 mm/s applies to the non-heritage buildings in the vicinity of the CBD South excavations. For these buildings, the 10 mm/s guideline PPV target would be met when the ripper is working at a distance of 1.5 m or more from buildings. Exceedances are not predicted for the 12 tonne or 20 tonne rockbreakers due to the depth at which these rockbreakers would be working. The Proponent would need to take management actions if it is necessary to use rippers within 1.5 m of buildings. Management actions could

include the use of lower vibration methods of material removal such as hydraulic splitting or chemical splitting. The Proponent would need to undertake vibration monitoring in order to ensure that the 10 mm/s guideline PPV target is achieved. Alternatively, the Proponent may be able to justify higher vibration limits based on detailed assessments of the buildings.

Heritage sites, where a low guideline target of 2.5 mm/s PPV has been applied, have been assessed separately. Vibration levels are only predicted to exceed the 2.5 mm/s target when rippers are working within 5 m of heritage buildings. Vibration levels are not expected to exceed 2.5 mm/s due to rockbreaking because of the depth at which the rockbreakers would be operating. Most heritage buildings in CBD South are located more than 5 m from the excavations and as such vibration levels are predicted to be less than the 2.5 mm/s target. However, there are six heritage structures that are located immediately adjacent to the station entrance excavations and vibration levels are predicted to exceed 2.5 mm/s PPV. These heritage buildings are identified in Table B.20. Specific mitigation measures for each of the buildings are provided in the table.

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 the Proponent 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.6.6.2 Vibration – Damage to Utilities

#### (i) Tunnelling (Station Cavern Road Headers)

There are a variety of utilities within the CBD South Station Precinct and its surrounds. In general, the critical distance utilities should be from the station cavern excavation to avoid damage is:

- 2.0 m for general utilities
- 3.7 m for Melbourne Water unreinforced assets.

The location of the assets should be confirmed prior to the commencement of work.

Construction in this area is likely to be close to the 2.0 m critical distance of sewer pipework at the south end of the station cavern. The pipework may be subject to vibration up to 20 mm/s. The Proponent should use less vibration intensive methods for excavating the station cavern roof section in the vicinity of these sewer lines. This may include reduction in power of the road headers.

#### (ii) Additional Construction Works

The critical 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.

### B.6.6.3 Vibration – Human Comfort

#### (i) Tunnelling (Station Cavern Road Headers)

It is predicted that adverse comment due to vibration VDV may occur at a number of receivers in the South CBD Station Precinct. Mitigation of vibration from the road header may be possible by utilising reduced hours of operation and/or modifications to the construction sequencing.

The methodology of construction of 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 with the heading (top) completed first, then the bench (middle) and finally the invert (bottom). The predictions have been based on two road headers working at the header level, with one road header 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 road header 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 road header 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.

As for the tunnel predictions, the road header progresses along the station cavern which changes the distance to the receiver. Due to the much larger cross section of the station cavern, the road headers would progress at a slower rate. Furthermore, due to the three separate passes required the same receiver would experience the exceedances over three distinct periods of time. For receivers that have foundations or piles in bedrock there may be no reduction in levels of vibration and ground-borne noise during the excavation of the bench and invert.

An analysis of the change in VDV over time due to road header station cavern works has been conducted for two sample receivers in the South CBD Station Precinct – one residential and one commercial:

- Residential Receiver Address: Level 1, 233-239 Collins Street, Melbourne (see Figure B.107)
- Commercial Receiver Address: 31-41 Swanston Street, Melbourne (see Figure B.107).

These receivers have been selected as they present the highest preliminary vibration results and therefore are expected to have some of the longest durations of high vibration/noise.

The road header 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.

Figure B.108 and Figure B.109 show the VDV results with respect to construction time for the residential and commercial locations respectively.

Note that at these two particular receivers the criterion level for management actions is triggered by road headers working on both sides of the station cavern, so that the combined noise and vibration is a combination of the influence of both road headers. The impact of both road headers is presented in the figures.

The criterion level for management actions is triggered at the residential location for up to 4 weeks during the day and up to 6 weeks at night (based on a preferred level which relates to no expected adverse comment). At the commercial location the criterion level is triggered for approximately 5 weeks during the day or night (based on a preferred level which relates to no expected adverse comments). This duration is longer than for road header tunnelling primarily due to the staggered position of the two road headers, as well as a slightly slower assumed advance rate.

These management triggering vibration levels may occur up to three times as the heading, the bench and the invert are excavated.

An assessment of the vibration at higher floors of these buildings has been undertaken. For residential receivers the impact is predicted to affect floors up to and including level 7, with higher floors having vibration levels below the criterion for management actions. For commercial receivers the impact is predicted to affect floors up to and including level 6, with level 7 and above having vibration levels below the criterion for management actions.



Figure B.107: Example Receivers for Road header Station Cavern Works Calculations



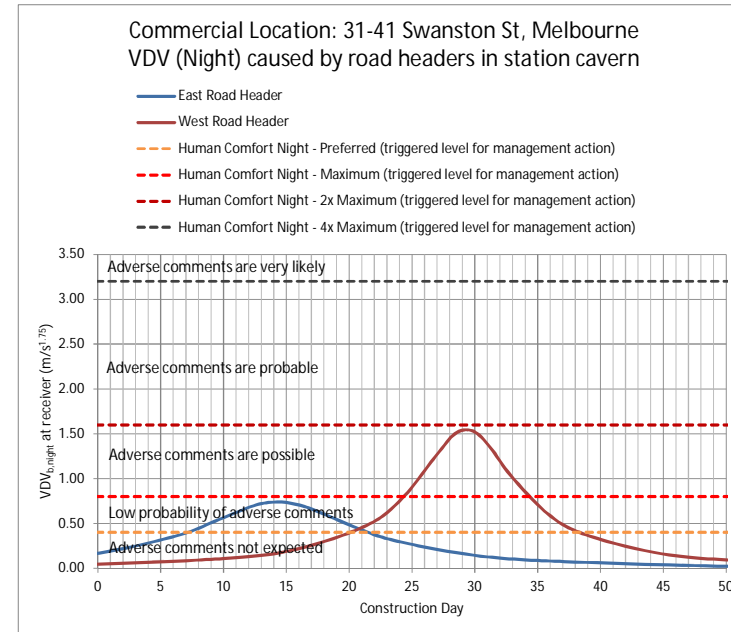
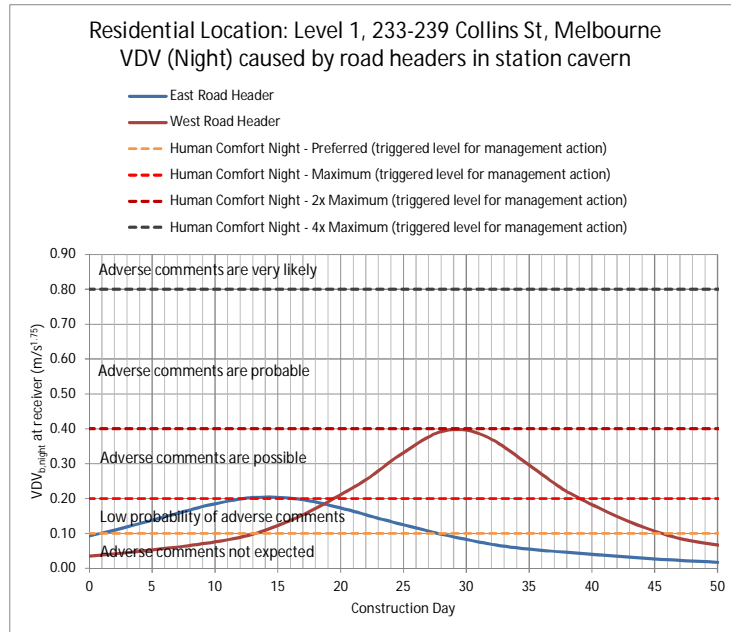
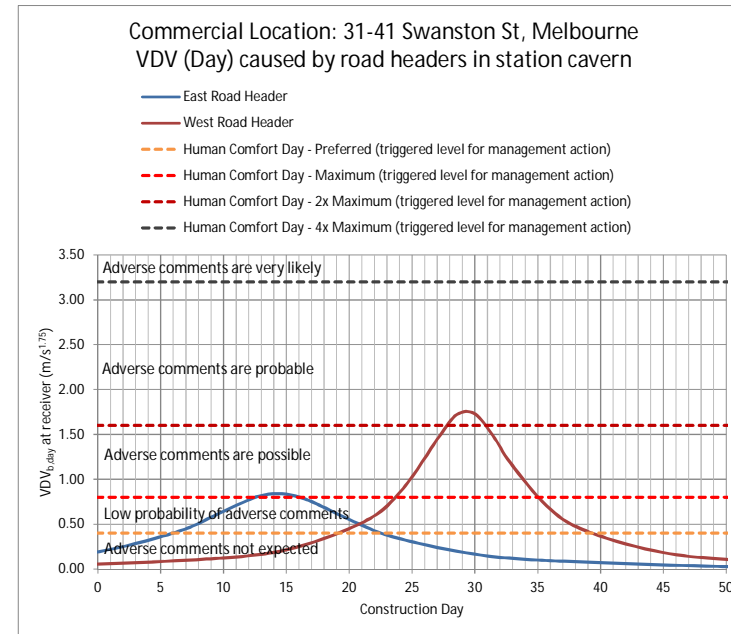
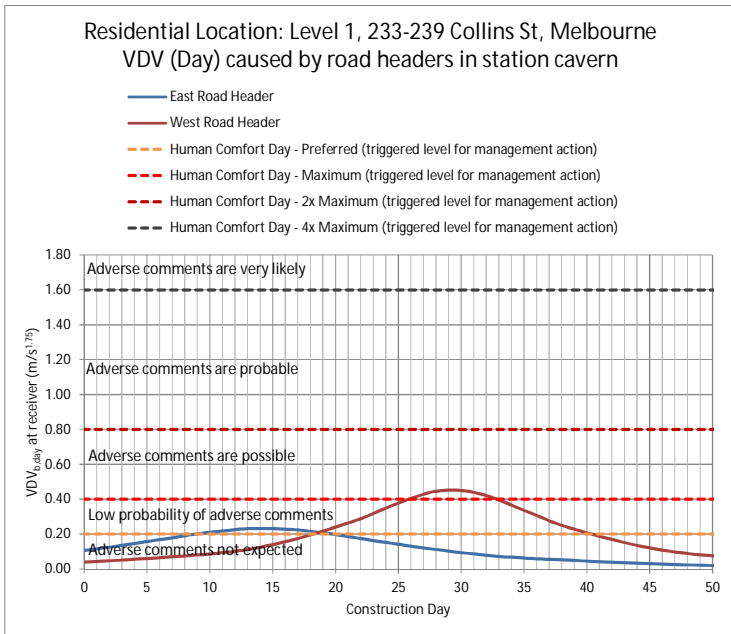


Figure B.108: Time of Duration of Exceedances for Example Residential Receiver – Station Cavern Works using Road header

Figure B.109: Time of Duration of Exceedances for Example Commercial Receiver – Station Cavern Works using Road header





## (ii) Additional Construction Works

It is predicted that the maximum daytime VDV target for residential receivers ( $0.4 \text{ m/s}^{1.75}$ ) would be exceeded when rippers are working within a slope distance of 12 m and when 20 tonne rockbreakers are working within a slope distance of 30 m. It is predicted that the maximum night VDV target for residential receivers ( $0.2 \text{ m/s}^{1.75}$ ) would be exceeded when rippers are working within a slope distance of 18 m and when the 20 tonne rockbreaker is working within a slope distance of 45 m. There are several residential buildings that are located within these buffer zones. There are some residential buildings that are located on the perimeter of the Flinders/Swanston Street 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% of the ripper work. The night VDV target would be exceeded for approximately 9% of the ripping work. It is expected that rockbreakers would only be needed periodically (when more competent rock is encountered) and the duration of VDV exceedances due to rockbreaking is expected short.

The Proponent would be able to meet the night-time VDV targets through careful scheduling and sequencing of the ripping and rockbreaking works. Night-time VDV targets would be achieved by maintaining an 18 m buffer distance between the ripper and residential buildings during the night (Rippers would need to work to the East of Cocker Alley during the night). Rockbreaking works would also need to be scheduled for daytime hours.

Daytime vibration impacts on residential receivers would need to be managed through close consultation and negotiation with the affected receivers. Compensation and/or respite may need to be provided when rippers and rockbreakers are working in close proximity of residential receivers.

The guideline VDV targets ( $0.2 \text{ m/s}^{1.75}$  day and  $0.4 \text{ m/s}^{1.75}$  night) are also predicted to be exceeded at the Westin Hotel when rockbreakers are working in the City Square excavation. VDV levels are predicted to each up to  $0.54 \text{ m/s}^{1.75}$  during the day (possible adverse comment) and  $0.48 \text{ m/s}^{1.75}$  during the night (adverse comment probable). It is expected that the Proponent would be able to manage the daytime VDV exceedances through close consultation and negotiation with the Westin Hotel. Night-time VDV exceedances could be avoided by scheduling rockbreaking works for normal working hours only. Alternatively, the Proponent would be able to meet the day and night VDV targets by using low vibration methods of rock removal such as hydraulic splitting or chemical splitting. VDV levels are predicted to meet the maximum guideline targets during ripping works (management actions are not required during ripping works).

It is predicted that the guideline night VDV target ( $0.2 \text{ m/s}^{1.75}$ ) 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 the Australian Centre for the Moving Image (ACMI) when rippers are working in the Federation Square excavation. This can be mitigated by either using lower vibration methods of excavation or by scheduling the work for outside of opening hours.

Exceedances of the guideline VDV targets are predicted 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 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 the proponent would manage this by maintaining a 7 m buffer zone when these commercial buildings are occupied. Alternatively, the Proponent could use lower vibration methods to remove material within this buffer zone. VDV exceedances are not predicted for commercial receivers during rockbreaking (this is due to the depth of operation).

### B.6.6.4 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.

### B.6.6.5 Ground-borne Noise

#### (i) Tunnelling (Station Cavern Road Headers)

Ground-borne noise levels are predicted to trigger management actions at a number of receivers in the South CBD Station Precinct. Mitigation of ground-borne noise and vibration from the road header 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 road header 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 Street, Melbourne (see Figure B.107).

The same assumptions have been used as were applied to the prediction of VDV values in Section B.6.6.3.

Figure B.110 shows the ground-borne noise results with respect to construction time for this location.

At this particular receiver management actions for ground-borne noise are predicted to be triggered by road headers working on both sides of the station cavern, consequently, noise and vibration is a combination of the influence of both road headers. The impact of both road headers is presented in the figure.

Mitigation actions for the ground-borne noise guideline target are predicted to be triggered for the residential receiver for approximately 2 weeks during the evening hours and 5 weeks at night.

These management triggering levels may occur up to three times as the heading, the bench and the invert are excavated.

An assessment of the vibration at higher floors of these buildings has been undertaken. For residential receivers the impact is predicted to affect floors up to and including level 7, with higher floors having vibration levels below the criterion for management actions. For commercial receivers the impact is predicted to affect floors up to and including level 6, with level 7 and above having vibration levels below the criterion for management actions.



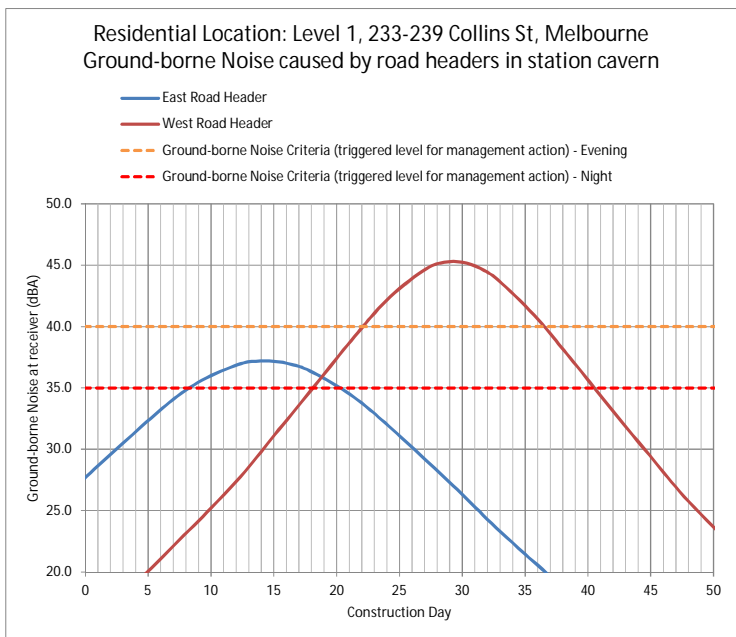


Figure B.110: Time of Duration of Exceedances for Example Residential Receiver – Station Cavern Works using Road header

### (ii) Additional Construction Works

There are a small number of residential buildings that are located immediately adjacent to the Flinders/Swanston excavation where exceedances of guideline ground-borne noise targets are predicted. 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). It is predicted that the night guideline target of 35 dBA would be exceeded when rippers are working within a slope distance of 25 m and when rockbreakers are working within a slope distance 55 m of from residential receivers. The evening target (40 dBA) would be exceeded when rippers are working within a slope distance of 17 m and rockbreakers are working within a slope distance of 40 m. It is expected that the Proponent would mitigate ground-borne noise exceedances by maintaining these buffer distances during the evening and night.





Table B.20: Heritage sites where PPV exceeds DIN 4150-3 guideline targets

Victorian Heritage Register Listing and Heritage Overlay identifier	Heritage Site	Location	Reason for exceedance	Detailed assessment and mitigation strategy
<b>CBD South Station Construction Work Site</b>				
H2119 / HO745	Nicholas Building	31-41 Swanston Street	This building is < 5 m from the Southern Entrance excavation. The PPV vibration level is predicted to exceed 2.5 mm/s due to ripping and bored piling.	<p>There is a possibility that vibration levels would exceed 2.5 mm/s PPV when during ripping and piling. It is expected that the Proponent would be able to manage this by monitoring vibration levels and adjusting construction techniques in order to meet the 2.5 mm/s PPV target. If it is necessary, it is expected that vibration levels could be reduced by using smaller ripper attachments or by pre-drilling and pre-splitting harder material. Alternatively, it may be possible for the Proponent to justify the use of a higher vibration target based on a detailed assessment of this building.</p> <p>Dilapidation surveys should also be completed.</p> <p>It is noted that vibration levels ranging from 0.2 up to 7.0 mm/s PPV have been measured on Swanston St (peak vibrations are associated with the passage of trams). Based on the existing vibration levels, it would be reasonable for the Proponent to adopt a higher vibration target for this building.</p>
H0708 / HO744	Young and Jackson's Princes Bridge Hotel	Corner of Swanston and Flinders Streets	This building is < 5 m from the Southern Entrance excavation. The PPV vibration level is predicted to exceed 2.5 mm/s due to ripping and bored piling.	See above
H0627 / HO642	Ross House	247-251 Flinders Lane	This building is < 5 m from the Southern Entrance excavation. The PPV vibration level is predicted to exceed 2.5 mm/s due to ripping and bored piling.	See above
H1083 / HO649	Flinders Street Railway Station Complex		This building is < 5 m from the Southern Entrance excavation. The PPV vibration level is predicted to exceed 2.5 mm/s due to ripping and bored piling.	See above
HO505	Flinders Gate Precinct		Some buildings in the Heritage Overlay Flinders Gate Precinct are within 5 m of the Southern Entrance Excavation. The PPV vibration level is predicted to exceed 2.5 mm/s due to ripping and bored piling.	See above
HO502	The Block Precinct		Some buildings in the Heritage Overlay Block Precinct are within 5 m of the potential 65 to 73 Swanston Street Station Entrance. The PPV vibration level is predicted to exceed 2.5 mm/s due to ripping and bored piling.	See above



## B.6.7 Precinct 7 – Domain Station

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 and 7 days a week once the station roof has been constructed.

### B.6.7.1 Vibration – Damage to Buildings

Vibration levels comply with applicable guideline PPV targets for all buildings in the Domain Station Precinct.

### B.6.7.2 Vibration – Damage to Utilities

The critical 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.

### B.6.7.3 Vibration – Human Comfort

It is predicted that the guideline targets for VDV would be exceeded 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 it is predicted that exceedances of the maximum guideline target would only occur during a relatively short period of the construction work in which rockbreakers are working within 20 m (day) and 40 m (night) of the residential buildings. It is expected that this can be mitigated as follows:

- 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.

### B.6.7.4 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.

### B.6.7.5 Ground-borne Noise

Ground-borne noise guideline targets (40 dBA evening and 35 dBA night) are predicted to be exceeded for four residential buildings on St Kilda Road (predicted levels ranging from 37 dBA up to 50 dBA). Full compliance with the guideline targets can be achieved by maintaining a 40 m buffer distance between rockbreakers and residential buildings during the evening and night.

## B.6.8 Precinct 8 – Eastern Portal (South Yarra)

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 St and at a depth of 10 m. Works would be undertaken during normal working hours only.

### B.6.8.1 Vibration – Damage to Buildings

There are no predicted building damage issues due to vibration in this precinct.

### B.6.8.2 Vibration – Damage to Utilities

The critical 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.

### B.6.8.3 Vibration – Human Comfort

It is predicted that VDV levels could exceed the maximum guideline target of 0.4 m/s<sup>1.75</sup> (day) at three residential addresses on Osborne St. The highest VDV is 0.63 m/s<sup>1.75</sup> and it relates to a possible of adverse comments. There is a low probability of adverse comment for one residential receiver located further away from the excavation. It is expected that these guideline target exceedances would be very short in duration (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.

### B.6.8.4 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.

### B.6.8.5 Ground-borne Noise

Construction works are expected to be undertaken during normal working hours. As such there are no exceedances with respect to the guideline targets for ground-borne noise.





## B.7 Results Summary and Recommendations for Tunnelling and Additional Construction Works

A summary of results and recommendations is provided in Table B.21.

Table B.21: Results summary table

Construction Methodology	Building damage (minor cosmetic damage)	Ground-borne noise, VDV and Sensitive equipment.	Recommended mitigation
<b>Precinct 1: Tunnels (Outside other precincts)</b>			
<b>Tunnelling</b>	None predicted	<p>Management actions are predicted to be triggered for ground-borne noise for dwellings within 45 m to 60 m of the alignment where TBMs are used for tunnelling and within 50 m to 65 m where road headers are used (in the CBD tunnel).</p> <p>Management actions are predicted to be triggered due to ground-borne noise for up to 10 days due to the TBM, and up to 3 weeks for the road header.</p> <p>VDV levels for adverse comment are predicted for receivers within 40 m to 55 m of the alignment where the TBM is used, and within 40 to 60 m where road headers are used (in the CBD tunnel).</p> <p>VDV levels for adverse comment are predicted for 8-9 days for the TBM and 4-5 weeks for the road header.</p>	<ul style="list-style-type: none"> <li>Community consultation</li> <li>If vibration and/or ground-borne noise guideline targets are exceeded and the level and duration of disturbance is considered unacceptable, then temporary relocation may be an option.</li> </ul>
<b>Additional Construction Works</b>	None predicted.	Management actions are predicted to be triggered at one residence on Toorak Road immediately located immediately opposite Fawkner Park emergency access shaft (minor exceedance of guideline target for daytime VDV).	<ul style="list-style-type: none"> <li>Community consultation</li> </ul>
<b>Precinct 2: Western Portal</b>			
<b>Additional Construction Works</b>	None predicted.	Management actions are predicted to be triggered at a small number of residential dwellings that are located close to the nominated area of excavation. This is due to rockbreaking (35 tonne). Adverse comments due to VDV are also predicted from receivers located immediately adjacent to excavation sites.	<ul style="list-style-type: none"> <li>Community consultation</li> <li>Vibration monitoring to verify vibration levels during construction</li> <li>Use of low vibration rockbreaking techniques when rockbreaking in within 25 m of residential dwellings</li> </ul>
<b>Precinct 3: Arden Station</b>			
<b>Additional Construction Works</b>	None predicted.	None predicted	None required



Construction Methodology	Building damage (minor cosmetic damage)	Ground-borne noise, VDV and Sensitive equipment.	Recommended mitigation
<b>Precinct 4: Parkville Station</b>			
<b>Tunnelling</b>	None predicted.	Vibration-sensitive equipment in several buildings (laboratories and hospitals) may be impacted during tunnelling.	<ul style="list-style-type: none"> <li>Community consultation</li> <li>Vibration monitoring during construction</li> </ul>
<b>Additional Construction Works</b>	None predicted.	<p>Vibration-sensitive equipment in several buildings (laboratories and hospitals) likely to be impacted during rockbreaking works. Adverse comments from some workers due to vibration (VDV) are also possible.</p> <p>Management actions are predicted to be triggered at one residential dwellings located on Barry Street and Leicester Street.</p>	<p>Mitigations for Ground-borne noise, VDV and sensitive equipment include:</p> <ul style="list-style-type: none"> <li>Community consultation</li> <li>Scheduling of rockbreaking works so as to minimise impact on vibration-sensitive equipment</li> <li>Vibration monitoring during construction</li> </ul> <p>Mitigations for residential receivers include:</p> <ul style="list-style-type: none"> <li>Community consultation and careful scheduling of rockbreaking works</li> <li>Alternatively, relocation of residences</li> </ul>
<b>Precinct 5: CBD North</b>			
<b>Road header excavation of station cavern and tunnels</b>	<p>None predicted due to excavation of station caverns.</p> <p>Ground vibration at MURL exceeds the vibration guideline targets during road header mining of tunnels.</p>	<p>Management actions are predicted to be triggered at several receiver locations.</p> <p>Duration is expected to be up to 2 for ground-borne noise and 4 to 5 weeks for VDV and may occur up to 3 times.</p> <p>Vibration-sensitive equipment in one RMIT building may be impacted during tunnelling and station cavern excavation.</p>	<ul style="list-style-type: none"> <li>Vibration monitoring on MURL during mining of tunnels</li> <li>Community consultation</li> <li>Modification of construction sequencing to reduce high vibration during critical periods</li> <li>If vibration and/or ground-borne noise guideline targets are exceeded and the level and duration of disturbance is considered unacceptable, then temporary relocation may be an option.</li> </ul>
<b>Additional Construction Works</b>	It is predicted that the guideline target for PPV may be exceeded at one building which is located next to the southern entrance excavation.	<p>Adverse comments due to VDV are also possible for receivers located immediately adjacent to excavation sites.</p> <p>Management actions are predicted to be triggered at several receiver locations due to ground-borne noise.</p>	<p>Mitigations for building damage include:</p> <ul style="list-style-type: none"> <li>Vibration monitoring</li> <li>Use of low vibration techniques when construction equipment is working immediately adjacent to buildings</li> </ul> <p>Key mitigations for Ground-borne noise, VDV and sensitive equipment include:</p> <ul style="list-style-type: none"> <li>Community consultation and negotiation</li> <li>Careful scheduling of excavation works</li> </ul>





Construction Methodology	Building damage (minor cosmetic damage)	Ground-borne noise, VDV and Sensitive equipment.	Recommended mitigation
<b>Precinct 6: CBD South</b>			
<b>Road header excavation of station cavern</b>	None predicted for buildings. Sewer and other services within 2.0 m of the station cavern may exceed vibration guideline targets.	Management actions are predicted to be triggered at several receiver locations. Duration is expected to be 2 to 5 weeks for ground-borne noise and 4 to 6 weeks for VDV and may occur up to 3 times.	<ul style="list-style-type: none"> <li>Vibration monitoring to accurately assess risk to sewer pipework</li> <li>Community consultation</li> <li>Modification of construction sequencing to reduce high vibration during critical periods</li> <li>If vibration and/or ground-borne noise guideline targets are exceeded and the level and duration of disturbance is considered unacceptable, then temporary relocation may be an option.</li> </ul>
<b>Additional Construction Works</b>	It is predicted that the 2.5 mm/s PPV guideline target for heritage buildings would be exceeded at four buildings including the Nicholas Building, Young and Jackson Hotel, Ross House & Flinders Street Railway Station.	Management actions are predicted to be triggered at several receiver locations.	<p>Mitigations for building damage:</p> <ul style="list-style-type: none"> <li>Dilapidation surveys</li> <li>Vibration monitoring during construction</li> <li>Modification to work practices</li> </ul> <p>Mitigations for Ground-borne noise, VDV and sensitive equipment include:</p> <ul style="list-style-type: none"> <li>Community consultation</li> <li>Modification of construction sequencing to reduce high vibration during critical periods</li> </ul>
<b>Precinct 7: Domain Station</b>			
<b>Domain Station</b>	None predicted.	<p>Management actions are predicted to be triggered at a small number of residential dwellings on St Kilda Road (exceedances of the VDV and Ground-borne noise guideline targets).</p> <p>Management actions are predicted to be triggered at one Melbourne Grammar School building where VDV levels exceed the guideline target.</p>	<p>Mitigations for Ground-borne noise, VDV and sensitive equipment include:</p> <ul style="list-style-type: none"> <li>Community consultation</li> <li>Scheduling of rockbreaking works so as to minimise impact on receivers</li> <li>Vibration monitoring during construction</li> <li>Use of low vibration rockbreaking techniques when rockbreaking in close vicinity of residential receivers</li> </ul>
<b>Precinct 8: Eastern Portal</b>			
<b>Eastern Portal</b>	None predicted.	Management actions are predicted to be triggered at a very small number of residential addresses during rockbreaking works due to minor exceedances of the guideline VDV targets.	<ul style="list-style-type: none"> <li>Community consultation</li> <li>Vibration monitoring during construction</li> </ul>

Note 1: Receiver sites that exist inside the nominated construction areas were not included in the vibration assessment.

Note 2: Predictions are less accurate for equipment operating in close proximity to buildings (i.e. less than 5 m). The Proponent should undertake vibration monitoring when equipment is to be operated within 5 m of a building.



## B.8 Critical distances for different equipment types involved in Construction Works

Critical distances for compliance with various guideline targets are listed in the following tables for reference:

- Table B.22: building damage
- Table B.23: ground-borne noise (residential receivers)
- Table B.24: utility damage

The distances in these tables are provided as a guide and can be used in order to determine whether or not a PPV or ground-borne noise impact is likely. The distances presented in these tables relate to buildings with the lowest coupling loss factor. Critical distances would be lower for large multi-story buildings and buildings with more substantial foundations.

Table B.22: Critical distances for building damage

Vibration source	Receiver type		
	Heritage structures (PPV guideline target = 2.5 mm/s)	Residential construction (PPV guideline target = 5 mm/s)	Warehouse, industry, office, commercial construction (PPV guideline target = 10mm/s)
	Critical distance from source to receiver (m)		
<b>TBM</b>	5-10	3-6	1-3
<b>Road header</b>	7-12	4-7	2-4
<b>32 tonne rock breaker</b>	18	10	5.5
<b>20 tonne rock breaker</b>	13	7.5	4
<b>12-15 tonne rock breaker</b>	10	5.5	3
<b>7 tonne rock breaker</b>	7.5	4	2
<b>Ripper</b>	4.5	2.5	1.5
<b>Hydromill</b>	4.5	3	2
<b>Piling rig (bored)</b>	9	5	3
<b>Heavy vehicle traffic</b>	6	4	3

Table B.23: Critical distances for ground-borne noise (residential receivers)

Vibration source	Evening	Night
	Critical distance from source to receiver (m)	
<b>TBM</b>	35 to 50	45 to 60
<b>Road header</b>	40 to 55	50 to 65
<b>32 tonne rock breaker</b>	50	65
<b>20 tonne rock breaker</b>	40	55
<b>12-15 tonne rock breaker</b>	32	45
<b>7 tonne rock breaker</b>	26	37
<b>Ripper</b>	17	25





Table B.24: Critical distances for utility damage

Vibration source	Critical distance from source to receiver (m)			
	25 mm/s ground vibration limiting guideline target based on DIN 4150, long term vibration for masonry/plastic pipework (worst case)	20 mm/s ground vibration limiting guideline target for utilities	10 mm/s ground vibration limiting guideline target for Melbourne Water unreinforced assets	2 mm/s ground vibration limiting guideline target for South Yarra Sewer Main
<b>TBM</b>	1.3	1.6	3	12
<b>Road header</b>	1.6	2.0	3.7	14
<b>32 tonne rock breaker</b>	2.5	3	5.5	21
<b>20 tonne rock breaker</b>	2	2	4	16
<b>12-15 tonne rock breaker</b>	1.5	1.5	3	12
<b>7 tonne rock breaker</b>	1	1	2	9
<b>Ripper</b>	1	1	1.5	5
<b>Piling rig (bored)</b>	1	1	2	5
<b>Heavy vehicle</b>	1.5	2	3	8
<b>Hydromill (in rock)</b>	1	1	1	3



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