# MELBOURNE AIRPORT RAIL

## MAR STATE LAND VIBRATION IMPACT ASSESSMENT

MAR-AJM-PWD-PWD-REP-XEV-NAP-0001719

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Revision B

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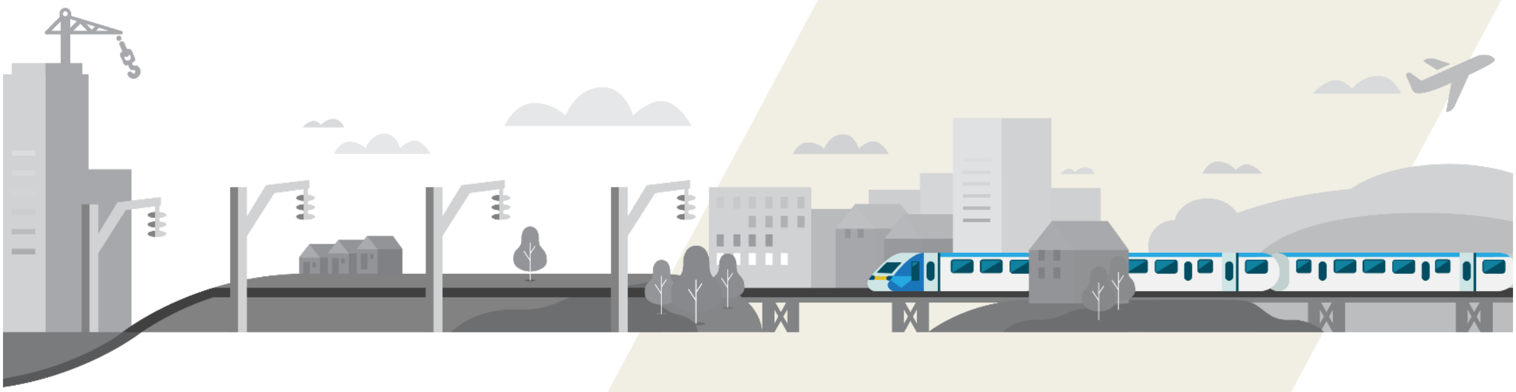
Prepared for Rail Projects Victoria



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222 Exhibition Street
Melbourne VIC 3000

PO Box 23061
Docklands VIC 8012
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| Author Signature | | Approver Signature | |
| Name | David Larner | Name | Ruth Macdonald |

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# Table of Abbreviations and Terminology

Table of Abbreviations

| Abbreviation | Definition |
|---|---|
| dBA | The A-weighted sound pressure level in decibels, denoted dB(A) is the unit generally used for the measurement of environmental, transportation or industrial noise. The A-weighting scale approximates the sensitivity of the human ear when it is exposed to normal levels and correlates well with subjective perception of typical sounds.<br>An increase or decrease in sound level of approximately 10 dB corresponds to a subjective doubling or halving in loudness respectively. A change in sound level of 3 dB is considered just noticeable. |
| dBV | The vibration velocity level in decibels, using the velocity reference level of 1 nm/s. |
| Vibration dose value (VDV) /<br>Estimated vibration dose value (eVDV) | The vibration dose value (VDV) is a parameter that combines the magnitude of vibration and the time for which it occurs. When assessing intermittent vibration, it is assessed as a cumulative impact of the vibration level received over a specific time period.<br>The estimated vibration dose value (eVDV) is determined using the equation presented in BS6472-1:2008 *Guide to evaluation of human exposure to vibration in buildings – Vibration sources other than blasting*. |
| Ground-borne noise | Typically observed as a 'low frequency rumbling' noise. This noise can result from vibration-intensive activities, such as train pass-bys, when the vibration from the activity excites a nearby building, and noise is emitted from vibration surfaces within the building. Ground-borne noise is typically only audible in locations where the accompanying airborne noise is not audible. |
| $L_{eq,T}$ | The $L_{eq}$ is the average level (either noise or vibration) over a defined period of "T". The following subscripts may be seen with this term throughout the report:<br>• A subscript "95" is represents that this value is the 95$^{th}$ percentile.<br>• A subscript "A" denotes that the value is A-weighted |
| $L_{max}$ | $L_{max}$ is the maximum level, in decibels, of noise or vibration. The following subscripts may be seen with this term throughout the report:<br>• A subscript "95" is represents that this value is the 95$^{th}$ percentile<br>• A subscript "A" denotes that the value is A-weighted<br>• A subscript "S" denotes that the value is "slow weighted", a time weighting applicable to ground vibration levels |
| Peak Particle Velocity (PPV) | The Peak Particle Velocity is defined as the highest instantaneous particle velocity during a given time period. The PPV is typically measured in 3-axes (2x horizontal, 1x vertical), at which the PPV is the vector sum of the peak vibration in these directions. |
| $R_W$ | $R_W$ is the weighted sound insulation index, a single number value which describes he airborne sound insulation of a building element over a range of frequencies, based on laboratory measurements. |

# 1. Executive Summary

Aurecon Jacobs Mott Macdonald Joint Venture (AJM-JV) has been engaged by Rail Projects Victoria (RPV) to prepare the MAR State Land Vibration Impact Assessment (the Impact Assessment) for the State-based approvals.

The Project Land relevant to State-based approvals generally includes:

- The Albion-Jacana rail corridor between Jacana Station and south of Barwon Avenue, Sunshine North and state land between Sharps Road, Tullamarine and the Albion-Jacana rail corridor.
- The existing rail corridor between Barwon Avenue, Sunshine North and Middle Footscray Station.
- The Sunbury rail corridor between Sunshine Station to Ginifer Station, and the Brooklyn freight corridor between Sunshine Station to Newport Station.

The purpose of the Impact Assessment is to assess both construction and operational vibration impacts from the project. This includes:

- Assessing the vibration impact from construction activities in relation to:
  - Building structural damage
  - ExxonMobil jet-fuel pipeline (EJP) structural damage
  - Human comfort (Vibration)
- Assessing the vibration impact from operational rail activities in relation to:
  - Building structural damage
  - EJP structural damage
  - Human comfort (Vibration)
  - Human comfort (Ground-borne noise)

A summary of the potential vibration impacts for the project and recommendations for managing vibration impacts is presented in Table 1-1.

Table 1-1 Summary of potential impacts for the MAR project

| Item | Comments |
|---|---|
| **Construction** | |
| Structural damage to structures | • Of the construction equipment proposed, large vibratory rollers are predicted to present the highest risk of structural damage to buildings. Vibration levels due to the large vibratory rollers are predicted to exceed the structural damage guideline values at up to 54 residential buildings, up to 19 industrial buildings and up to eight heritage structures. To reduce potential impacts, smaller vibratory rollers or static rollers are proposed in lieu of large vibratory rollers in locations where there is a risk of damage to structures. These reductions are presented below:<br>– Vibratory roller (10T): 14 residential properties / 17 industrial buildings / four heritage structures<br>– Static roller (18T): One heritage structure<br>• Excavation is predicted to present a risk of structural damage (predicted vibration levels exceed the structural damage guideline values) at one residential property, one industrial building, and at the existing heritage Maribyrnong River Bridge. To reduce potential impacts, smaller excavators are proposed in lieu of larger plant when there is a risk of structural damage to structures.<br>• Piling is not predicted to exceed the structural damage guideline values.<br>• Other construction activities assessed present low risk of structural damage (predicted vibration levels do not exceed the structural damage guideline values).<br>Note: Exceeding the guideline values does not necessarily lead to damage. |
| EJP structural damage | • Vibration from most construction activities is predicted to exceed the asset owner’s vibration limit for the EJP in limited (specific) areas of the EJP. |

| Item | Comments |
|---|---|
| | • Vibratory rollers and piling are predicted to exceed the pipeline vibration limit for a large percentage of the EJP alignment.<br>Note: Exceeding the vibration limit does not necessarily mean that damage would occur. |
| Human Comfort (Vibration) | • With respect to human comfort (vibration), use of vibratory rollers is predicted to cause significant impacts at sensitive receivers for this project. |
| Mitigation measures | • An Environmental Management Framework (EMF) with Environmental Management Requirements (EMRs) has been produced for the project with which the contractor will be required to comply.<br>• Selection of lower vibration generating equipment (generally smaller equipment)<br>• Use of alternative rolling techniques, such as use of static rollers rather than vibratory rollers<br>• Use of alternative construction techniques<br>• Mitigating risk by undertaking vibration monitoring to verify source vibration levels and to manage vibration levels by operator intervention during construction<br>• Potential use of an alternative track form design that makes use of lower vibration construction techniques (cement stabilised sand/aggregate track foundation)<br>• Protection or renewal of the vibration sensitive asset (e.g. by concrete encasing the EJP)<br>• Use of respite and/or offer of alternative accommodation to highly affected residential properties (as per the CNVS) when exceeding human comfort criteria (vibration)<br>• Verification of vibration levels associated with equipment prior to equipment being introduced to site.<br>• Vibration monitoring throughout the construction period in proximity to buildings, heritage structures and EJP.<br>• Piling trials at distances from the EJP.<br>• Mitigation measures in Civil construction, building and demolition guide (CCBDG):<br>– Use non-explosive demolition agents and/or chemical agents to facilitate concrete/rock breaking activities to reduce vibration.<br>– Substitute demolition methods not involving impact where feasible (e.g. use hydraulic rock splitters rather than rock breakers).<br>– Schedule the use of vibration-causing equipment such as jackhammers, demolition, earthmoving and ground-impacting operations at the least sensitive time of day, when feasible.<br>– Routing, operating or locating high vibration sources as far away from people who could be affected by vibration, when feasible.<br>– Sequencing operations so that vibration-causing activities do not occur simultaneously.<br>– Isolate equipment causing vibration on resilient mounts.<br>– Isolate activities from adjoining structures.<br>– Maintain equipment in accordance with manufacturer's specifications. |
| **Operation** | |
| Building structural damage | • Structural damage to nearby buildings from rail operations is of low risk to the project (predicted vibration levels do not exceed the structural damage guideline values). |
| EJP structural damage | • Operational rail risks exceeding the structural damage criterion for the pipeline in locations where the pipeline is located directly underneath the proposed or existing rail. |
| Human Comfort (Vibration) | • Predicted vibration levels are at-risk of exceeding the "preferred" human comfort criteria at one property for both day and night, due to the proximity of a crossover. These predicted levels are lower than the "maximum" criteria. Site specific measurements and inspections are proposed to occur during the next phase of design, with a feasible and reasonable mitigation approach to be undertaken if needed. |
| Human Comfort (Ground-borne noise) | • The predicted ground-borne noise levels are at-risk of exceeding criteria at four buildings. Site specific measurements and inspections are proposed to occur during the next phase of design, with a feasible and reasonable mitigation approach undertaken if needed. |
| Mitigation measures | • An EMF with EMRs has been produced for the project with which the contractor will be required to comply.<br>• Pipeline protection should be implemented in locations where the EJP crosses beneath future rail lines. This may be in the form of the existing pipe casing mitigation, located throughout the project area. |

Vibration impacts due to the project have been predicted. Most vibration impacts are expected to be adequately managed with the use of smaller construction equipment or other mitigation strategies identified in this report. The proposed changes to construction equipment should be reviewed to ensure that the use of such equipment is practical and would meet construction requirements and schedules.

Human comfort criteria (both vibration and ground-borne) are predicted to be exceeded due to operational rail movements in discrete locations (four buildings, three properties). While some mitigation techniques have been identified, a feasible and reasonable approach should be undertaken. Site specific measurements are proposed to occur at locations where vibration is predicted to be at risk of exceedance during the next phase of design.

# 2. Introduction

Aurecon Jacobs Mott Macdonald Joint Venture (AJM-JV) has been engaged by Rail Projects Victoria (RPV) to prepare the Melbourne Airport Rail (MAR) State Land Vibration Impact Assessment (the Impact Assessment).

## 2.1 Purpose

The purpose of the Impact Assessment is to assess both construction and operational vibration impacts due to the project and provide recommendations for mitigating these impacts. This includes:

- Review of the scope of works and mapping presented in the 'MAR Project Description for Environmental Specialists' (MAR-AJM-PWD-PWD-MEM-XLP-NAP-0001505, Revision C) (the Project Description).
- Assessment of the vibration impact from construction activities, in relation to:
  - Building structural damage
  - ExxonMobil jet-fuel pipeline (EJP) structural damage
  - Human Comfort (Vibration)
- Assessment of the vibration impact from operational rail activities, in relation to:
  - Building structural damage
  - EJP structural damage
  - Human Comfort (Vibration)
  - Human Comfort (Ground-borne noise)

The outcomes from this Impact Assessment will support the State-based approvals for the project and assessment against the *Ministerial Guidelines for Assessment of Environmental Effects* (the Ministerial Guidelines) under the *Environment Effects Act 1978* to determine the potential need for referral of the project.

## 2.2 Overview of assessment

The vibration impacts from the construction and operation of MAR have been assessed and mitigation proposed to manage the impacts. Adverse impacts of vibration on the community could include:

- Structural damage
- Audible noise from vibration (i.e. rattling windows or ground-borne noise)
- Disturbance, startling, annoyance, or interfere with work activities.

Vibration impacts on people vary widely due to differences within the existing environment (proximity of sources such as existing rail or busy roads), what people are doing, (i.e. working, relaxing, sleeping) and differences in sensitivities within the population.

This Impact Assessment includes:

- Summary of the MAR project – Section 3
- Review of existing conditions in the project area – Section 4
- Identification of relevant criteria in relation to vibration impacts – Section 5
- Assessment of vibration impacts from construction activities – Section 6

- Assessment of vibration and ground-borne noise impacts from operational rail – Section 7

## 2.3 Assumptions and limitations

The following overall assumptions and limitations apply to this assessment:

- The Impact Assessment relates only to public and privately owned State land and does not consider Commonwealth-owned land or the ‘Airport’ section. Impact Assessments associated with infrastructure on Commonwealth land, specifically land at Melbourne Airport, will form part of a separate suite of impact assessments.
- The Impact Assessment is based on the scope of works detailed in the Project Description and State Project Land derived from MAR ‘Project Land’ Revision A.7 (MAR-AJM-PWD-PWD-MAP-XLP-MMN-0111172).
- The following items are not covered in this assessment:
  - Ground-borne noise from construction activities - ground-borne noise from construction activities are assumed to be negligible compared to airborne noise from construction activities
  - Assessment of construction or operational rail vibration with respect to vibration sensitive equipment, such as medical scanners, located in proximity to the alignment. This is because no vibration sensitive equipment has been identified in proximity to the alignment.
  - Effects of construction or operational vibration on the EJP coating.
  - Assessment of vibration from rail operations outside of the trackwork construction areas
  - Assessment of noise and vibration from pressure waves exciting buildings
  - Ground settlement from construction and operational vibration

For detailed assumptions and limitations specific to the vibration assessment of construction activities see Section 6.1.6.

## 2.4 References

The following information was reviewed in the preparation of this assessment:

- Reports
  - *MAR State Land Noise Impact Assessment*[1]
  - *MAR State Land Historical Heritage Impact Assessment*[2]
- Other
  - Building footprints, 2017-2018 Greater Melbourne LiDAR Project
  - Train information, provided by RPV (operational train data) and AJM design team (line speeds) – summarised in Appendix A.
  - Construction equipment provided by RPV, dated 26 November 2020 and 1 December 2020

[1] MAR State Land Noise Impact Assessment, Doc. No.: MAR-AJM-PWD-PWD-REP-XEV-NAP-0001716
[2] MAR State Land Historical Heritage Impact Assessment, Rev A.1, 27 November 2020, Doc. No.: MAR-AJM-PWD-PWD-REP-XCH-NAP-0001709

# 3. Background

## 3.1 Strategic Context

The MAR project (the Project) is a once-in-a-generation transformation of Victoria's transport network, connecting Melbourne Airport's Integrated Terminal Precinct with a rail service for the first time.

Melbourne Airport handled more than 37 million passenger movements in 2018-19[3] and by 2038, this figure is projected to almost double to more than 67 million[4], which is an average growth of 3.2% per annum. Transport connectivity from Melbourne Airport to Melbourne's Central Business District (CBD) is currently limited to the Tullamarine Freeway, and therefore, the Victorian Government is committed to delivering an efficient, competitive alternative to cater for the ongoing increase in passenger numbers at Melbourne Airport.

In 2002, the Victorian Government considered possible corridor and alignment options for a Melbourne Airport Rail Link, ultimately selecting the Sunshine route as the preferred option. At this time, land was reserved between the Albion-Jacana rail corridor and extending through to Sharps Road, Tullamarine for the construction of a rail link.

In 2018, the Victorian Government released the Melbourne Airport Rail Link Sunshine Route Strategic Appraisal, which confirmed that the Sunshine route remains the best solution for an airport rail link. The Sunshine route would provide superior connections to regional Victoria, Melbourne's growth areas in the north and west and Melbourne's south eastern suburbs and could be delivered sooner and at a significantly lower cost than other route options.

## 3.2 State Project Land

The State Project Land is defined as the land within which the Project components and construction activities are planned to be contained. It sets out the full extent of land identified as potentially required for the delivery of the Project.

The Project Land encompasses all State land areas that would be used for permanent structures and temporary construction areas. It provides the basis for and informs the Impact Assessment.

Project Land relevant to State-based approvals generally includes:

- Land between Sharps Road and the Albion-Jacana rail corridor, including land crossing the M80 Freeway
- The existing Albion-Jacana rail corridor generally between Jacana and Albion Stations
- Land around Sunshine and Albion Stations, including the existing rail corridor
- Land required for the Project from Jacana Station in the north-east to Newport Station in the south-west and Middle Footscray Station in the east. This largely includes the Albion-Jacana rail corridor via Sunshine and Albion stations and land required for a new rail corridor between Sharps Road and the Albion-Jacana rail corridor.

The extent of the State Project Land is shown in Figure 3-1.

[3] https://www.bitre.gov.au/publications/ongoing/airport_traffic_data
[4] https://www.melbourneairport.com.au/Corporate/Planning-projects/Master-plan

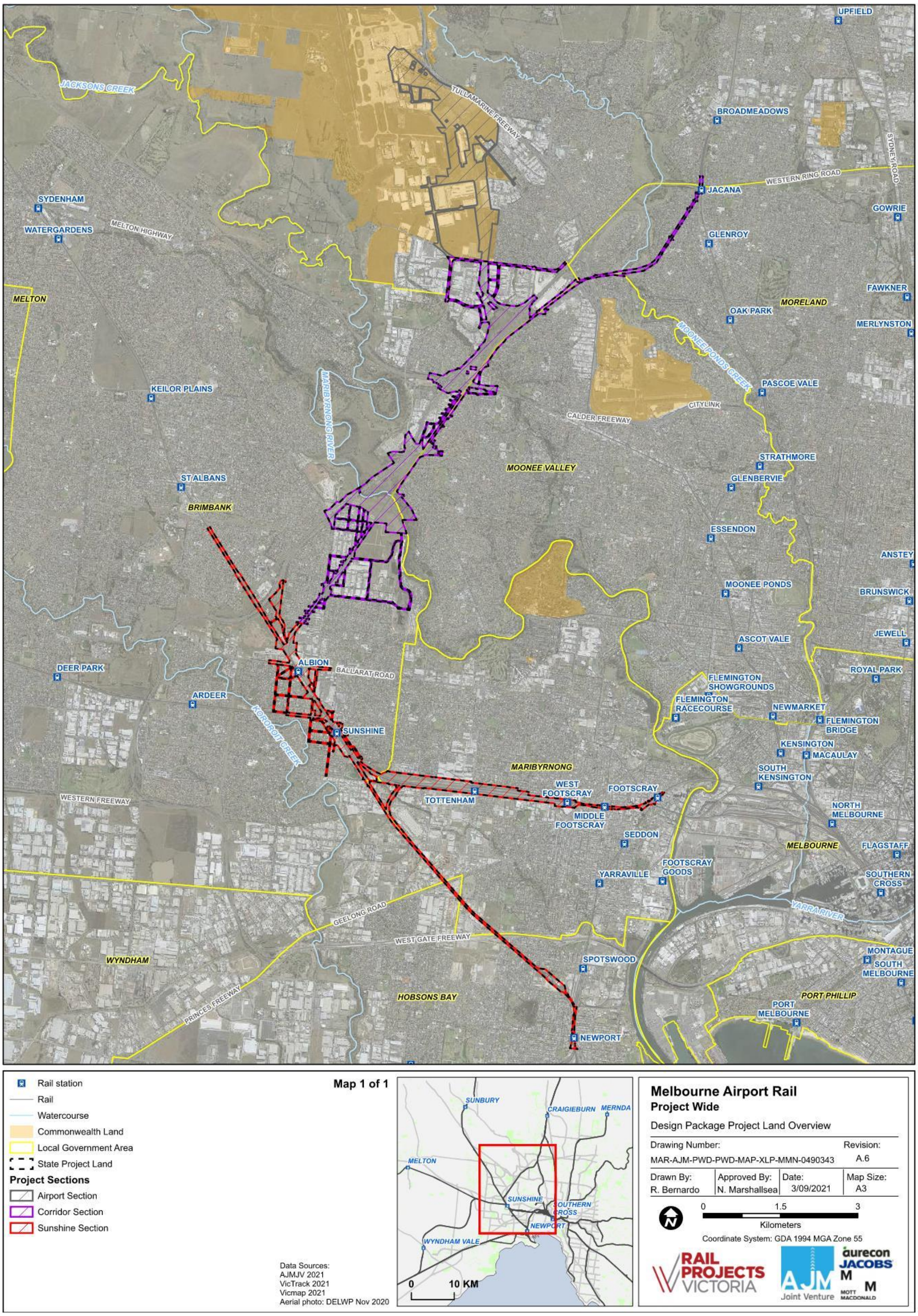



Figure 3-1 MAR State Project Land

## 3.3 Main Works Scope

### 3.3.1 Project Sections

The main works for the Project comprise of three geographically distinct sections. The sections are summarised in Table 3.1 and the location of the sections are shown in Figure 3-1.

Table 3.1 Summary of Project sections

| Section | Summary |
|---|---|
| **Airport section**<br>Not considered in State land approvals. | The Airport section generally includes all land relevant to the Project between Sharps Road, Tullamarine and Melbourne Airport and is located on Commonwealth owned land and is subject to a separate approvals process under the *Commonwealth Airports Act 1996* |
| **Corridor section** | The COR section generally includes the Albion-Jacana rail corridor between Jacana Station and south of Barwon Avenue, Sunshine North, as well as land between Sharps Road, Tullamarine and the Albion-Jacana rail corridor. |
| **Sunshine section** | The SUN section generally includes the existing rail corridor between Barwon Avenue, Sunshine North and Middle Footscray Station. The SUN Section also includes the Sunbury rail corridor to Ginifer Station and the Brooklyn freight corridor to Newport Station. |

## 3.4 Corridor Section Summary

The COR section of the Project includes the following main works:

- Construction of the new MAR tracks, comprising an approximately 8 km dual track railway and associated overhead line equipment (OHLE), combined services route (CSR) and track drainage works, including:
  - > A 2.3 km long elevated twin track viaduct structure between Sharps Road, Tullamarine and the Albion-Jacana rail corridor, crossing Steele Creek and the Western Ring Road including emergency and maintenance access points.
  - > New at-grade MAR tracks within the existing Albion-Jacana rail corridor, located on the Western side of the existing Australian Rail Track Corporation (ARTC) tracks.
  - > An elevated twin track viaduct structure across the Maribyrnong River valley, adjacent to the Western side of the existing state significant heritage bridge.
  - > Slewing of ARTC tracks between Keilor Park Drive and the Calder Freeway.
- Signalling works along the Albion-Jacana rail corridor between Jacana Station and Barwon Avenue, Sunshine North and within the new MAR corridor North of the Western Ring Road.
- Construction of an intake supply substation at Terror Street or the Northeast area of Brimbank Park and two traction substations at Fullarton Road and within the McIntyre Sidings, Sunshine North.
- Construction of two new Digital Train Radio System (DTRS) facilities one North or South of Keilor Park Drive, Keilor East and a second at Airport Drive, Tullamarine.
- Diversion, relocation and replacement works associated with utilities and underground services, including the existing ARTC CSR, high voltage (HV) transmission lines and numerous miscellaneous assets
- Protection works associated with the Exxon Mobil jet fuel pipeline along the Albion-Jacana rail corridor.
- Modifications to existing structures, including structural modifications and strengthening works at Calder Freeway inbound and outbound bridges, Fullarton Road bridge, Western Ring Road on-ramp and off-ramp bridges, Keilor Park Drive and McIntyre Road bridges.
- Replacement of shared use path (SUP) connections at Calder Freeway / Fullarton Road, provision of a new SUP overpass at Cranbourne Avenue, and provision of a Strategic Cycling Corridor link between Western Ring Road and Airport Drive via Steele Creek.

- The provision of retention basins at several locations along the Albion-Jacana rail corridor
- Establishment of temporary construction laydown areas, site offices, worksites, storage, parking areas and access roads

## 3.5 Sunshine Section Summary

The SUN section of the Project includes the following main works:

- Construction of a new 1.8 km long MAR twin track viaduct structure, including associated OHLE and CSR between Sunshine Station and the Albion-Jacana corridor, crossing Anderson Road, Ballarat Road, the Sunbury rail corridor, St Albans Road and Stony Creek.
- Signalling works, including the installation of trackside equipment along the Sunbury line towards Ginifer Station, along the Brooklyn freight corridor towards Newport Station, and along the Western rail corridor to West Footscray Station.
- Modifications to the tracks, formation, drainage, CSR, OHLE and signalling equipment for the MAR, Sunbury and Bendigo tracks from Albion to the beginning of the Jacana freight corridor
- Modifications to the Western and Eastern Albion Station forecourts and car parks.
- Modifications to Sunshine Station, including modifications to platforms, the Sunshine Station western car park and the construction of a new concourse.
- Modifications to the existing Sunshine and Sunshine West substations
- Diversion, relocation and protection of existing utilities and underground services.
- Establishment of temporary construction laydown areas, site offices, worksites, storage, parking areas and access roads

# 4. Existing conditions

The proposed MAR is in an urban environment and will traverse diverse communities including residential, commercial and industrial.

The current occupancy/building types in proximity to the project include:

- Residential properties throughout Sunshine, Sunshine North, Keilor East, and Airport West
- Commercial precinct in proximity to Sunshine Station
- Industrial areas, located in Sunshine North, Keilor East and Tullamarine
- A small number of learning centres or places of worship
- Heritage structures throughout project area

The receivers included in this assessment are shown in Appendix B.

Many rail operations occur within the project area, including:

- Passenger (V/Line) and freight services to Deer Park via the Regional Rail Link
- Passenger (V/Line and Metro Trains Melbourne (MTM)) and freight services to Sunbury via the Sunbury Line
- Passenger (V/Line and XPT) and freight services to Jacana via the Albion-Jacana Rail Link

These rail operations are the likely source of vibration in the area. No other significant vibration sources have been identified within the project area.

Baseline vibration measurements are planned for late 2021 to document the existing vibration conditions. These will include measuring vibration levels in the vicinity of the project area and will be provided as an addendum to this report.

Currently, no vibration sensitive equipment has been identified adjacent to the project area and therefore no assessment has been undertaken with respect to the strict vibration limits that would apply for sensitive equipment to be able to operate without disturbance.

# 5. Criteria

## 5.1 Civil construction, building and demolition guide

The Environmental Protection Act 2017 imposes a general environmental duty (GED) on any person engaging in an activity that may give rise to risks of harm to human health or the environment from pollution or waste to minimise those risks so far as reasonably practicable.

The Victorian EPA has released the Civil construction, building and demolition guide (CCBDG)[5] to support the construction industry to comply with the GED. The CCBDG provides high-level mitigation controls for construction vibration associated with large infrastructure projects in Victoria. While the CCBDG does not provide specific vibration limits or targets for projects, it states that to manage risk, a vibration impact assessment can be undertaken to predict the characteristics of vibration generated by planned works. This assessment can be used to:

- Inform the risk assessment process
- Predict the effects of implementing vibration controls
- Identify the need for vibration monitoring

The CCBDG states the EPA's expectation that compliance with the GED requires the project to minimise impacts of construction vibration in relation to human health as reasonably practicable. "Normal working hours" and "Outside normal working hours" are specified for major infrastructure projects and these times should be used to inform project planning and should be considered in the community information and consultation period.

- Normal working hours
  - Monday to Friday, 7 am – 6 pm
  - Saturday, 7 am – 1 pm
- Outside normal working hours
  - Monday to Friday, 6 pm – 10 pm
  - Saturday, 1 pm – 10 pm
  - Sundays and Public Holidays, 7 am – 10 pm

The CCBDG provides controls which may be applied to limit vibration and regenerated noise from onsite activities. These controls include:

- Use alternative lower - impact equipment or methods (e.g. substitute impact piling with bored piling, grip jacking or the use of hammer cushion when driving steel piles that minimise the vibration).
- Use non-explosive demolition agents and/or chemical agents to facilitate concrete/rock breaking activities to reduce the noise generated.
- Substitute demolition methods not involving impact where feasible (e.g. use hydraulic rock splitters rather than rock breakers).
- Schedule the use of vibration-causing equipment such as jackhammers, demolition, earthmoving and ground-impacting operations at the least sensitive time of day.
- Routing, operating or locating high vibration sources as far away from people who could be affected by noise.
- Sequencing operations so that vibration-causing activities do not occur simultaneously.

[5] Civil construction, building and demolition guide, Publication 1834, November 2020

- Isolate equipment causing vibration on resilient mounts.
- Isolate activities from adjoining structures.
- Maintain equipment in accordance with manufacturer's specifications.

In terms of the assessment of structural damage, human comfort, and ground-borne noise from construction activities, applicable standards have been used to assess the potential impacts from the project in relation to these items.

## 5.2 Structural building damage

There are no Victorian or Australian standards that provide vibration criteria relating to structural damage from construction or operational activities. The German standard DIN4150-3[6] has been used to provide criteria to assess the potential for vibration related damage to buildings for this project. DIN4150-3 is a widely used and accepted standard and has been used for other major Victorian projects such as Melbourne Metro Rail Project and North East Link.

Damage is defined in DIN4150-3 as:

*"Any permanent consequence of an action that reduces the serviceability of a structure or one of its components".*

Examples of reduced serviceability include:

- Impairment of the stability of the building
- A reduction in the load-bearing capacity of floors and other components
- At residential or like occupancy buildings and heritage structures:
  - > Cracks form in plastered or rendered surfaces of walls
  - > Existing cracks in a structure are enlarged
  - > Partitions become detached from load-bearing walls or floor slabs

DIN4150-3 provides guideline values for vibration levels in terms of Peak Particle Velocity (PPV) for evaluating the effects of either short-term or long-term vibration on structures. DIN4150-3 states: *These guideline values have been obtained by experience, compliance with which ensures that damage does not occur*.

DIN4150-3 also states: *Exceeding the guideline values does not necessarily lead to damage*.

For this assessment, both the "short-term" and "long-term" vibration guideline values were considered, and are presented in Table 5-1 and Table 5-2 respectively. Cyclic construction activities, such as vibratory rolling, are at risk of resonances occurring and therefore "long-term" vibration guideline values are applicable to these works.

Table 5-1 Guideline values for vibration velocity (peak particle velocity) for evaluating the effects of short-term vibration on buildings Note 1

| Type of structure | Foundation, all directions (x/y/z), at a frequency of: | | Topmost floor, horizontal direction (x/y) | Floor slabs, vertical direction (z) | |
|---|---|---|---|---|---|
| | 1 – 10 Hz | 10 – 50 Hz | 50 – 100 Hz Note 2 | All frequencies | |
| Buildings used for commercial purposes, industrial buildings, and buildings of similar design | 20 | 20 – 40 | 40 – 50 | 40 | 20 |
| Residential buildings and building of similar | 5 | 5 – 15 | 15 – 20 | 15 | 20 |

[6] DIN 4150-3 *Structural Vibration Part 3: Effects of vibration on structures*, December 2016

| Type of structure | Foundation, all directions (x/y/z), at a frequency of: | | Topmost floor, horizontal direction (x/y) | Floor slabs, vertical direction (z) | |
|---|---|---|---|---|---|
| | 1 – 10 Hz | 10 – 50 Hz | 50 – 100 Hz Note 2 | All frequencies | |
| design and/or occupancy | | | | | |
| Structures that, because of their particular sensitivity to vibration, cannot be classified as above **and** are of great intrinsic value | 3 | 3 – 8 | 8 – 10 | 8 | 20 Note 3 |

Notes:

1. Short-term vibration is defined as "Vibration that does not occur often enough to cause material fatigue and whose development over time and direction is not suitable for producing a significant increase in vibration due to resonance in the particular structure"
2. At frequencies above 100 Hz, the guideline values for 100 Hz can be used as minimum values
3. It may be necessary to lower the relevant guideline value markedly to prevent minor damage

Table 5-2 Guideline values for vibration velocity (peak particle velocity) for evaluating the effects of long-term vibration on buildings

| Type of structure | Guideline values for $v_{i,max}$ in mm/s | |
|---|---|---|
| | Topmost floor, horizontal direction (x/y) | Floor slabs, vertical direction (z) |
| Buildings used for commercial purposes, industrial buildings, and buildings of similar design | 10 | 10 |
| Residential buildings and building of similar design and/or occupancy | 5 | 10 |
| Structures that, because of their particular sensitivity to vibration, cannot be classified as above **and** are of great intrinsic value | 2.5 | 10 |

Notes:

1. Long-term vibration is defined as "any type of vibration that is not covered by the definition of 'short-term vibration"

## 5.3 Structural damage to EJP

Throughout the project area, the EJP runs within the existing rail corridor. An RFI was raised with ExxonMobil to establish any asset owner vibration criteria. ExxonMobil has provided the following vibration criteria for the pipeline:

"*6.5 Vibration and Impulse*

*Pile driving, and other Works that create excessive vibration or impulse, have the potential to damage Pipeline coasting and will not be approved within 3 m of the Pipeline. This includes vibrating rollers.*

*6.6 Explosives*

*Mobil shall be notified of the intention to use any explosives within 100 m of the Pipeline. This includes seismic surveys or blasting to remove rock.*

*The use of explosives within 3 m of the Pipeline will not be approved.*

*Mobil shall review an engineering assessment impact study for any seismic survey or blasting proposed within 100 m. An evaluation of seismic impacts will be required by measuring the Peak Particle Velocity (mm/s). The following limits can be used for the purposes and managing the works, where a field demonstration may be required to validate a desktop study at a safe location acceptable to Mobil:*

- *0 – 10; acceptable*
- *10 – 15; acceptable, monitor for changes*

- *15 – 19; proceed with caution and assess potential alternatives*
- *20 or greater; cease activity and proceed with an alternative acceptable to Mobil engineering*"

ExxonMobil also responded to the RFI by stating that "these levels are to be applied to all vibration sources within the extent of 100 m from the pipeline".

For this assessment 20 mm/s PPV has been used as the criterion for evaluating the potential for structural damage to the EJP for both construction works and operational rail.

## 5.4 Human comfort (Vibration)

There are no Victorian guidelines or Australian standards that provide vibration criteria from either construction or operational vibration relating to human comfort. Therefore, BS6472-1:2008 and the NSW guideline *Assessing Vibration: A technical guideline*[7] (AVATG) has been used to identify suitable vibration goals due to their applicability to large infrastructure projects.

The estimated vibration dose value (eVDV) method has been used for the assessment. This approach is consistent with that used on other major Victorian projects such as Melbourne Metro Rail Project and North East Link.

The eVDV is based on the summation of frequency weighted vibration levels, taking into account the operational duration of each vibration source. This means that a continuous vibration source at low amplitude operating over a long duration may produce the same eVDV as a high amplitude impulsive vibration source acting over a short duration.

AVATG provides the acceptable vibration dose values for various receiver location. Surface construction vibration is typically stop-start in nature, such as interrupted continuous vibration (i.e. drilling) or repeated impulsive vibration (i.e. pile driving). As a result, vibration from these construction activities would be considered *intermittent vibration*. The acceptable vibration dose values for intermittent vibration are provided in Table 5-3.

Table 5-3 Acceptable vibration dose values for intermittent vibration ($m/s^{1.75}$)

| Location | Daytime, 7 am to 10 pm | | Night-time, 10 pm to 7 am | |
|---|---|---|---|---|
| | Preferred value | Maximum value | Preferred value | Maximum value |
| Critical areas | 0.10 | 0.20 | 0.10 | 0.20 |
| Residences | 0.20 | 0.40 | 0.10 | 0.20 |
| Offices, school, educational institutions and places of worship | 0.40 | 0.80 | 0.40 | 0.80 |
| Workshops | 0.80 | 1.60 | 0.80 | 1.60 |

Notes:

1. Workshop criteria was adopted for industrial park buildings

## 5.5 Human comfort (Ground-borne noise)

There are no Victorian guidelines or Australian standards that provide ground-borne noise criteria. In the absence of relevant local guidelines, the NSW EPA's *Rail Infrastructure Noise Guideline,* May 2013 (RING) was used to assess ground-borne noise impacts. This approach is consistent with the approach used for the Melbourne Metro Rail Project.

The RING states that consideration of ground-borne noise in buildings is only necessary where the ground-borne noise level is greater than the airborne noise level. Furthermore, the RING provides a threshold consisting of both an absolute and a relative level, for consideration of management actions for

[7] *Assessing Vibration: A technical guideline*, Department of Environment and Conservation, February 2006

redevelopment of existing rail infrastructure. These triggers, based on receiver type, are provided in Table 5-4.

Table 5-4 Ground-borne noise trigger levels for heavy rail projects

| Sensitive land use | Time of day | Internal noise trigger levels ($L_{ASmax}$) |
|---|---|---|
| Residential | Day (7 am – 10 pm) | 40 $dBL_{ASmax}$ and project increases existing rail noise levels by 3 dBA or more |
| | Night (10 pm – 7 am) | 35 $dBL_{ASmax}$ and project increases existing rail noise levels by 3 dBA or more |
| Schools, educational institutions, places of worship | When in use | 40 – 45 $dBL_{ASmax}$ and project increases existing rail noise levels by 3 dBA or more |
| Offices | When in use | 45 $dBL_{ASmax}$ and project increases existing rail noise levels by 3 dBA or more |
| Cinemas | When in use | 30 $dBL_{ASmax}$ and project increases existing rail noise levels by 3 dBA or more |
| Retail spaces | When in use | 50 $dBL_{ASmax}$ and project increases existing rail noise levels by 3 dBA or more |

Notes:

1. Specified noise levels refer to noise from light or heavy rail transportation only and do not include ambient noise from other noise sources.
2. The noise levels represent internal noise levels and are to be assessed near to, but not at the centre of the most affected habitable room. For example, at night this may be the bedroom experiencing the highest levels of ground-borne noise, while during the day another habitable room might experience the highest levels of ground-borne noise.
3. The triggers are relevant only where ground-borne noise levels are audible and are of a higher level than airborne noise levels from rail operations.
4. 'Residential' land use typically means any residential premises and includes aged-care facilities and caravan parks incorporating long-term residential use.
5. For schools, educational institutions and places of worship, the lower value of the range is most applicable where low internal noise levels are expected, such as in areas assigned to studying, listening and praying.

# 6. Construction - vibration impact assessment

This section presents the methodology for the prediction of vibration from construction activities for MAR and presents the corresponding predicted impacts.

## 6.1 Methodology

### 6.1.1 Procedure

The following procedure was undertaken to assess the impacts of vibration from construction activities:

1) Review of geological conditions and project information
2) Investigation of appropriate source vibration levels of proposed equipment in similar substrate
3) Determination of distance between source and receiver
4) Prediction of vibration levels (PPV) at receiver
5) Comparison of predicted PPV to applicable structural damage guideline values in Sections 5.2 and 5.2
6) Conversion of external PPV to external eVDV
7) Incorporation of coupling loss factors for building foundations and amplifications of vibration within buildings due to building resonance to determine the eVDV within buildings
8) Comparison of predicted eVDV to applicable vibration criteria for human comfort in Section 5.4

### 6.1.2 Project information

The following information has been used for the assessment:

- The distances of EJP to the construction works have been based engineering drawings
- List of construction equipment proposed to be used for the project, provided by RPV
- Based on site investigations, the ground strata generally consists of fill of varying properties or residual volcanic rock soil (Newer Volcanic Residual Soil – Qvn-RS[8]), which is located over volcanic rock (Newer Volcanic Basalts – Qvn[9]) at a depth between 3 to 8 m. There are pockets of alluvium (Qra[10]) located at certain chainages, with Brighton Group (Tpb[11]) located around the M80 area. The EJP is generally located in the fill or residual volcanic rock layer.
- Heritage structures identified as per the *MAR State Land Historical Heritage Impact Assessment*

### 6.1.3 Source vibration levels

Construction activities which produce intensive vibration have been identified from the construction methodology provided by RPV and their typical source vibration levels have been derived from literature and/or the AJM database of vibration source levels. Vibration source levels for relevant construction equipment are presented in Table 6-1.

[8] High plasticity clays, typically very stiff, fissured and containing boulders of relatively unweathered basalt rock
[9] Basaltic lava flows and pyroclastic deposits compromising variable weathered ballast rock and residual soil. Deposited on undulating erosional surface of Red Bluff Sandstone.
[10] Clays, silts and gravels recently deposited along water courses
[11] Clays and sands, variably iron stained and cemented. Motted colours of red, orange, brown and grey.

Table 6-1 Construction equipment source vibration levels

| Equipment | PPV (mm/s) | Reference distance (m) | Reference |
|---|---|---|---|
| Bored piling | 1.9 | 5 | BS5228-2[12] |
| Impact piling | 13.3 | 5 | BS5228-2 |
| 30 t Rockbreaker | 10.3 | 5 | AJMJV database |
| 20 t Rockbreaker | 7.5 | 5 | AJMJV database |
| 14 t Rockbreaker | 5.8 | 5 | AJMJV database |
| 8 t Rockbreaker | 4.0 | 5 | AJMJV database |
| 5 t Rockbreaker | 3.2 | 5 | AJMJV database |
| 32 t Excavator (travelling) | 8.0 | 5 | AJMJV database |
| 20 t Excavator (travelling) | 1.1 | 5 | AJMJV database |
| 30-45 t Dozer | 2.6 | 5 | FTA guideline[13] |
| 25 t Grader | 2.0 | 5 | AJMJV database |
| 18 t Vibratory roller | 24.0 | 5 | AJMJV database |
| 10 t Vibratory roller | 17.7 | 5 | AJMJV database |
| 18 t Static roller | 3.3 | 5 | AJMJV database |

### 6.1.4 Ground attenuation

All construction vibration propagation (besides impact piling) has been determined from:

$$PPV(d) = (K/d) * e^{-\alpha.d}$$

Where d is the propagation distance in metres, K is the site-machine constant at a reference distance, and α is the site-specific ground attenuation constant.

The impact piling was determined using[14]:

$$PPV(d) = PPV_{ref} * (d_{ref}/d)^{1.1}$$

The site-specific vibration attenuation curves are provided in Figure 6-1 and Figure 6-2.

[12] British Standard BS5228-2:2009 *Code of practice for noise and vibration control on construction and open sites - Vibration*
[13] *Transit Noise and Vibration Impact Assessment Manual*, Federal Transit Authority, September 2018
[14] Transportation and Construction Vibration Guidance Manual – September 2013, CT-HWANP-RT-13-069.25.3

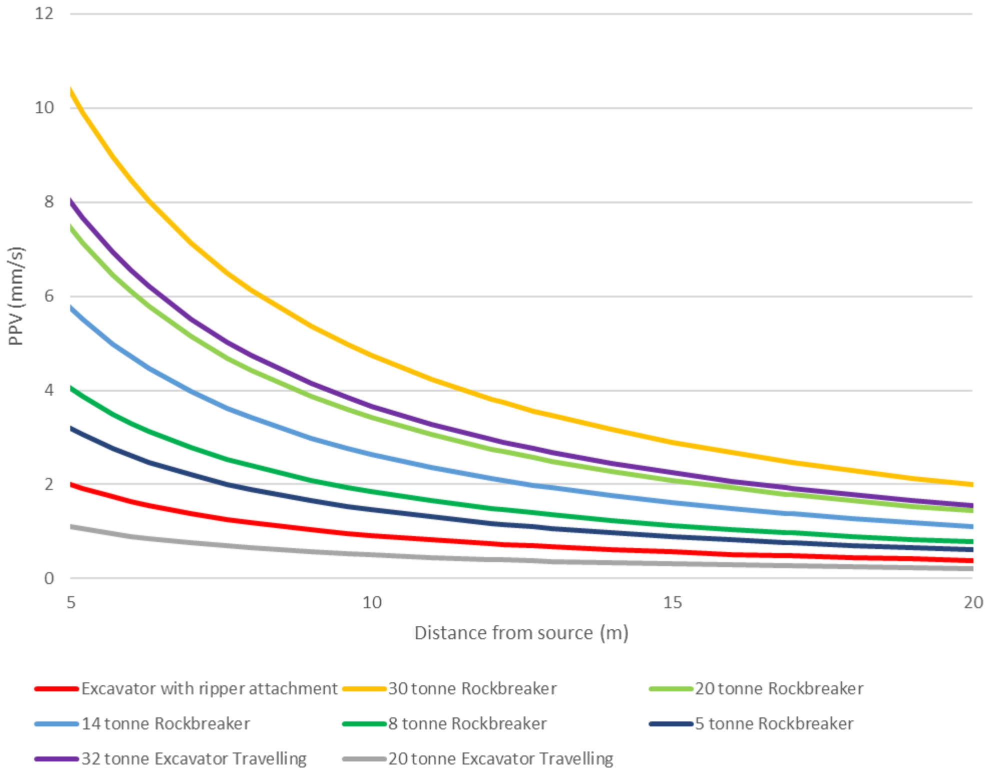



Figure 6-1 Site-specific vibration attenuation curves – excavators and rockbreakers

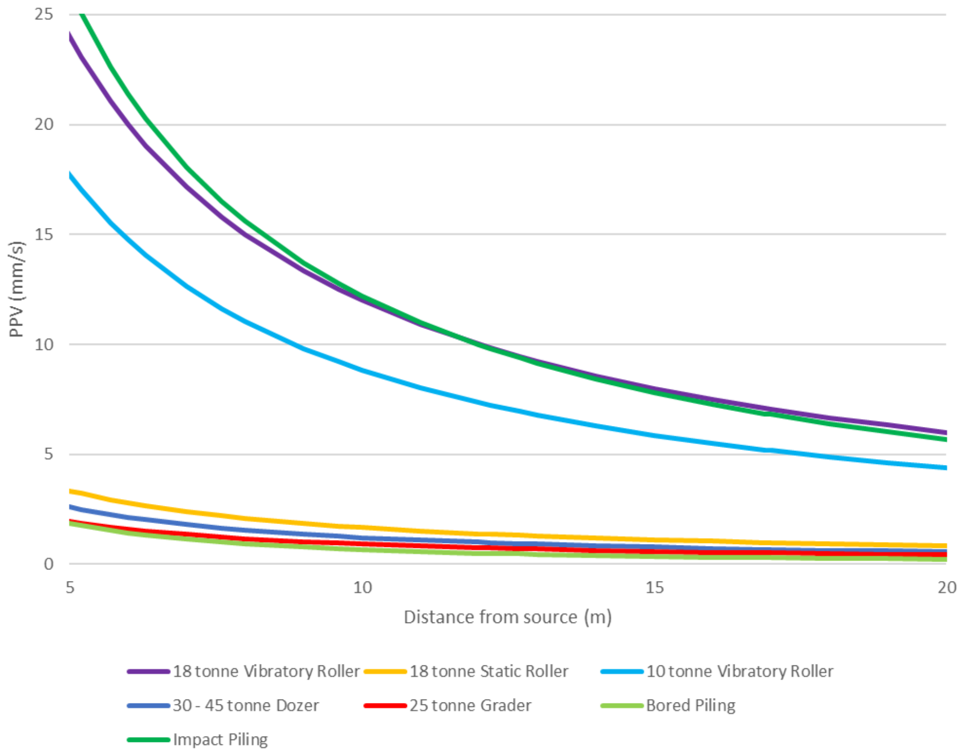



Figure 6-2 Site-specific vibration attenuation curves – piling, rollers, dozer and grader

Caution should be used when extrapolating the vibration data to closer than 5 m from a source. This is because at these distances vibration levels are likely to be overpredicted. However, for this assessment, vibration was predicted at locations less than 5 m to understand the potential risk of exceedance.

Once the PPV is predicted at a defined distance it has been compared to the applicable criteria contained in Sections 5.2 and 5.3.

### 6.1.5 Converting external PPV to internal eVDV

The predicted eVDV can be calculated from the predicted PPV from the structural damage impact assessment using simple correction factors, consistent with the approach nominated in the AVATG, and inputs from the FTA guideline. This approach is consistent with that used on the Melbourne Metro Rail Project. The external eVDV (at the building foundation) can be calculated using the following formulae:

$$eVDV = 1.4 \times V_{RMS} \times \frac{2\pi f\ W_b}{1000} \times t^{0.25}$$

where

- $V_{RMS}$ is the root mean square (RMS) vibration level at the foundation, convert from PPV using a crest factor of 4 (as defined in the FTA guideline)
- $f$ is the dominant vibration frequency of the machinery, which is assumed to be 31.5 Hz
- $W_b$ is the BS6472-1:2008 frequency weighting at frequency $f$, which at 31.5 Hz is 0.49
- $t$ is the exposure time of works, in seconds. For this assessment, it is assumed that construction works will occur for 75% of the applicable time period.

The internal eVDV can then be calculated incorporating building foundation coupling loss and building resonance amplification factors. The following factors have been adopted for this assessment as stated in the FTA guideline:

- Coupling loss factors
  - > Single storey residential locations: -5 dB
  - > Double story residential locations, commercial and industrial buildings: -7 dB
- Amplification due to building resonance: +6 dB

### 6.1.6 Assumptions and limitations

The following assumptions and limitations apply to the construction impact assessment:

- Assumptions
  - > Based on cross-section drawings, the site preparation and earthworks associated with the installation of the tracks are assumed to occur 3 m from the closest track to the EJP (typically 3.5 to 4.0 m from the rail centreline outwards), except in the following locations:
    - – Chainage 12700 to 13450 (Sunbury/Bendigo lines), where the subgrade is 4.5 m from track centreline (AJM only has cross sections at chainages lower than chainage 12980, so this distance was applied to the whole track until it ties into existing trackwork)
  - > Piling was assessed to structures (buildings and heritage items) using the trackworks footprint
  - > The following are minimum distances from the EJP for overhead wiring gantries, noise barriers and retaining walls:
    - – Sunshine area:
      - 0.9 m, chainage 12700 to 12750
      - 2.3 m, chainage 12750 to 12850
      - 2.6 m, chainage 12850 to 12980

    - 4.2 m, chainage 12980 to 13200
  – Corridor area:
    - 1.2 m, chainage 14500 to 17400 and 17900 to 18400
    - 5.4 m, chainage 18400 to 20200
    - 3 m, chainage 20200 to 20700

- Limitations
  > Vibration levels will vary with chainage due to variation in soil parameters and source-receiver distances. This report summarises the expected “worst-case” predicted vibration levels i.e. closest segment of EJP. EJP may be located further from the tracks than is reported in some instances.

  > As the eVDV is based on the PPV, the predicted eVDV may present an overprediction for a single piece of plant in operation. The eVDV is based on exposure time and vibration level and the overall vibration level will decrease as the plant moves away from the receiver during works. For this assessment, the minimum distance between the stationary plant and receiver is used.

  > This assessment does not include the potential cumulative impacts of concurrent works (i.e. two vibration intensive pieces of plant operating simultaneously). Higher vibration levels than predicted may occur if simultaneous plant equipment is in operation, however this is of low risk, because:
  – Due to the corridor width, large equipment would need to be operate at a distance apart from each other, and consequently the vibration from the closest item of equipment will dominate the eVDV
  – The assessed equipment is considered stationary at the closest point to the receiver, and likely to produce conservative eVDVs (as in practice the equipment will at times move further from the receiver).

  > Buildings typically located within 150 – 200 m of the works were assessed. Addressing any impacts at these buildings would benefit buildings further away.

## 6.2 Construction vibration impact

The impacts of vibration from construction activities are presented in this section.

### 6.2.1 Vibration impact on structures

The construction vibration impact assessment has been undertaken for the following scenarios based on the construction equipment listed in Table 6-1:

- Piling (trackwork)
  > Bored: for overhead wiring, noise walls, elevated rail footings etc
  > Impact: for select piers on M80 viaduct
- Excavation (trackwork) – use of excavators and rockbreakers
- Rollers (trackwork) – use of rollers
- Surface works (trackwork) – use of dozers and graders
- Carpark works – localised mix of grading and rolling

Vibration levels have been predicted (based on the minimum source-receiver distances between the construction activities and the receiver) and a summary of the results is provided in Table 6-2. A graphical representation of the results is presented in Appendix C.

Table 6-2 Predicted vibration impact on buildings and structures (Structural damage)

| Receiver | Piling (trackwork) | Excavation (trackwork) | Rollers (trackwork) | Surface works (trackwork) | Carpark works |
|---|---|---|---|---|---|
| Residential | No predicted exceedances | Risk of exceedance to criteria at 1 residential property | • Use of 18T vibratory roller: risk of exceedance to criteria at 54 properties<br>• Use of 10T vibratory roller: risk of exceedance to criteria at 14 properties<br>• Use of 18T static roller: No predicted exceedances | No predicted exceedances | No predicted exceedances |
| Heritage | No predicted exceedances | Risk of exceedance to criteria at:<br>• Maribyrnong River Bridge | • Use of 18T vibratory roller: risk of exceedance to criteria at eight structures Note 1<br>• Use of 10T vibratory roller: risk of exceedance to criteria at four structures<br>• Use of 18T static roller: risk of exceedance to criteria at one structure | No predicted exceedances | No predicted exceedances |
| Commercial | No predicted exceedances | No predicted exceedances | No predicted exceedances | No predicted exceedances | No predicted exceedances |
| Industrial | Piling is predicted to risk exceeding guideline vibration levels where buildings will be demolished for the project (Sharps Road area) | Excavation is predicted to risk exceeding guideline vibration levels in the following locations:<br>• Utility structure at ~Ch 20+700 | • Use of 18T vibratory roller: risk of exceedance to criteria at 19 buildings<br>• Use of 10T vibratory roller: risk of exceedance to criteria at 17 buildings<br>• Use of 18T static roller: No predicted exceedances | No predicted exceedances | No predicted exceedances |

Note:

1) The eight heritage structures at risk of structural damage include:

- HO5: Maribyrnong rail bridge
- HO10: HV Mckay Gardens
- HO28: Albion Substation
- HO39: Sunshine railway signal box
- HO42: Sugar Gum Row
- HO53: HV Mckay gates
- HO91: Sunshine Market
- Brooklyn stabling yard silos

Vibratory rollers are predicted to present the highest risk of exceedance to the structural damage guideline levels. Where trackworks, in the vicinity of buildings and heritage structures, are at risk of exceeding the structural damage guideline, smaller plant equipment or static rollers may be required to reduce vibration impact. Vibration monitoring may be required.

### 6.2.2 Construction impact on the EJP

The results of the construction vibration assessment on the EJP for the construction equipment listed in Table 6-1 are provided in this section. Vibration levels on the EJP have been predicted for each of the chainage segments (based on the minimum source-receiver distances between the construction activities and the EJP) and a summary of the results is provided in Table 6-3 for the Sunshine Section and Table 6-4 for the Corridor Section. Detailed tabulated results are provided in Appendix D and the chainages and activities where vibration levels greater than 20 mm/s are predicted are highlighted.

Table 6-3 Construction vibration impact and constraints – Sunshine Section (Based on the Cease Activity threshold of 20 mm/s PPV)

| Impact / constraints | % of alignment and chainages where the criterion is exceeded | Mitigation |
|---|---|---|
| **Trackworks** | | |
| Major construction activities (rock breaking, grading/dozing, roller usage) have potential to generate vibration greater than 20 mm/s PPV | For 8% of alignment<br>(Ch 11500 – 11600)<br>(Ch 12200 – 12350) | A different approach to the current design (alternative track) may be required or pipe encasement could be provided. |
| Rockbreakers have potential to generate vibration greater than 20 mm/s PPV | For 5% of alignment<br>(Ch 12200 – 12350) | Installation of pipeline protection prior to undertaking trackworks. Protection to the EJP to be designed to achieve less than 20 mm/s PPV on EJP. |
| Large rockbreakers (≥8 t) have potential to generate vibration greater than 20 mm/s PPV | For 8% of alignment<br>(Ch 11500 – 11600)<br>(Ch 12200 – 12350) | Installation of pipeline protection prior to undertaking trackworks. Protection to the EJP to be designed to achieve less than 20 mm/s PPV on EJP. |
| Large rockbreakers (i.e.≥14 t) have potential to generate vibration greater than 20 mm/s PPV | For 12% of alignment<br>(Ch 11500 – 11600)<br>(Ch 12200 – 12350)<br>(Ch 12400 – 12500)<br>(Ch 13250 – 13251) | Installation of pipeline protection prior to undertaking trackworks. Protection to the EJP to be designed to achieve less than 20 mm/s PPV on EJP. |
| ≥10 t Vibratory rollers have potential to generate vibration greater than 20 mm/s PPV | For 54% of alignment<br>(Ch 11500 – 11700)<br>(Ch 12200 – 13251)<br>(Ch 14125 – 14500) | Installation of pipeline protection prior to undertaking trackworks. Protection to the EJP to be designed to achieve less than 20 mm/s PPV on EJP. Use of static or smaller roller. |
| Piling has potential to generate vibration greater than 20 mm/s PPV | For 8% of alignment<br>(Ch 12500 – 12750) | Carry out trial piling in representative ground conditions to better understand the risks. |
| **Carpark** | | |
| Vibratory rollers (i.e.≥10 t) have potential to generate vibration greater than 20 mm/s PPV | For carpark area to west of Sunshine Station<br>(Ch 11900 – 12200) | Installation of pipeline protection prior to undertaking trackworks. Protection to the EJP to be designed to achieve less than 20 mm/s PPV on EJP. Use static or smaller roller. |

Table 6-4 Construction vibration impact and constraints – Corridor Section (Based on the Cease Activity threshold of 20 mm/s PPV)

| Impact / constraints | % of alignment and chainages where the criterion is exceeded for design options | Mitigation |
|---|---|---|
| Major construction activities (rock breaking, grading/dozing, roller usage) have potential to generate vibration greater than 20 mm/s PPV | For 8% of alignment<br>(Ch 17900 – 18400) | A different approach to the current design (alternative track) may be required or pipe encasement could be provided. |
| Several construction activities (i.e.≥20 t rock breaker in use, 32 t excavator travelling, vibratory rollers) have the potential to generate vibration greater than 20 mm/s PPV | For 8% of alignment<br>(Ch 17900 – 18400) | Use of smaller rock breakers, static rolling and vibration test to enable piling or pipe encasement could be provided. |

| Impact / constraints | % of alignment and chainages where the criterion is exceeded for design options | Mitigation |
|---|---|---|
| 18 t vibratory roller has the potential to generate vibration greater than 20 mm/s PPV | For 65% of alignment<br>(Ch 14500 – 17000)<br>(Ch 17900 – 18400)<br>(Ch 18900 – 19900) | Use of smaller vibratory roller or static rolling is likely required to achieve compliance with criterion. |
| 10 t vibratory roller has the potential to generate vibration greater than 20 m/s PPV | For 50% of alignment<br>(Ch 14500 – 17000)<br>(Ch 17900 – 18400) | Use of static rolling or alternative track foundation design is likely required to achieve compliance with criterion. |
| Piling has the potential to generate greater than 20 mm/s PPV (based on noted minimum separation distances) | For 60% of alignment<br>(Ch 14500 – 17400)<br>(Ch 17900 – 18400)<br>(Ch 19900 – 20200) | Carry out trial piling in representative ground conditions to better understand the risks. |

## 6.2.3 Construction impact on human comfort (vibration)

The results of the construction vibration assessment on the nearby buildings and heritage structures for the construction equipment listed in Table 6-1 are provided in Table 6-5. A graphical representation of the results is presented in Appendix E.

Vibration levels have been predicted based on the minimum source-receiver distances between the construction activities and the receiver.

Table 6-5 Predicted vibration impact - human comfort

| Construction equipment | Day period | Night period |
|---|---|---|
| Piling (trackwork) | • Preferred criterion<br>– Risk of exceeding at one residential location<br>– Risk of exceeding at three industrial areas<br>• Maximum<br>– Risk of exceeding at two industrial areas | • Preferred criterion<br>– Risk of exceeding at one residential location<br>• Maximum<br>– Risk of exceeding at two industrial areas |
| Excavation (trackwork) | • Preferred criterion<br>– Risk of exceeding at 87 residential locations<br>– Risk of exceeding at five industrial areas<br>• Maximum criterion<br>– Risk of exceeding at 88 residential locations<br>– Risk of exceeding criterion at 44 industrial areas | • Preferred criterion<br>– Risk of exceeding at 61 residential locations (preferred)<br>– Risk of exceeding criterion at four industrial areas<br>• Maximum criterion<br>– Risk of exceeding at 172 residential locations<br>– Risk of exceeding at 18 industrial areas |
| Rollers (trackwork) | • Preferred criterion<br>– Risk of exceeding at 442 residential locations<br>– Risk of exceeding at five commercial locations<br>– Risk of exceeding at 37 industrial areas<br>• Maximum criterion<br>– Risk of exceeding at 728 residential locations<br>– Risk of exceeding at six commercial locations<br>– Risk of exceeding at 45 industrial areas | • Preferred criterion<br>– Risk of exceeding at 106 residential locations<br>– Risk of exceeding at 31 commercial locations<br>– Risk of exceeding at 28 industrial areas<br>• Maximum criterion<br>– Risk of exceeding at 1170 residential locations<br>– Risk of exceeding at 12 commercial locations<br>– Risk of exceeding at 33 industrial areas |
| Surface works (trackwork) | • Preferred criterion<br>– Risk of exceeding at 29 residential locations<br>– Risk of exceeding at two industrial areas<br>• Maximum criterion | • Preferred criterion<br>– Risk of exceeding at 92 residential locations<br>• Maximum criterion<br>– Risk of exceeding at 35 residential locations |

| Construction equipment | Day period | Night period |
|---|---|---|
| | – Risk of exceeding at three residential locations | – Risk of exceeding at one industrial area |
| Carpark works | • Preferred criterion<br>– Risk of exceeding at 59 residential locations<br>• Maximum criterion<br>– Risk of exceeding at two residential locations<br>– Risk of exceeding at one industrial area | • Preferred criterion<br>– Risk of exceeding at 37 residential locations<br>• Maximum criterion<br>– Risk of exceeding at 52 residential locations<br>– Risk of exceeding at one industrial area |

Significant vibration impacts are predicted if vibratory rollers are used for this project. The largest vibratory roller (18 t) was used to predict the potential impacts. When substituting with a 18t static roller, the predicted night-time impacts reduce to:

- From 106 to 87 residential locations (preferred)
- From 1170 to 107 residential locations (maximum)
- From 28 to nine industrial areas (preferred)
- From 33 to one industrial areas (maximum)
- From 31 to zero commercial areas (preferred)
- From 21 to zero commercial areas (maximum)

For context, the *Construction Noise and Vibration Strategy*[15] (CNVS) states that the minimum "safe working distance" between receivers and vibratory rollers of 7+ tonnes for human comfort is 100 m. As there are several buildings within this distance along the project corridor, vibratory rolling will require management during construction.

As in the case of the rollers, the use of smaller excavators is predicted to reduce the vibration impacts when compared with larger excavators.

## 6.3 Mitigation for construction

Vibration mitigation and management measures proposed for construction are:

- Environmental Management Requirements (EMRs) will be in place for the project. The contractor will need to manage impacts in relation to these requirements.
- Selection of lower vibration generating equipment (generally smaller equipment)
- Use of alternative rolling techniques, such as use of static rollers rather than vibratory rollers
- Use of alternative construction techniques
- Mitigating risk by undertaking vibration monitoring to verify source vibration levels and to manage vibration levels by operator intervention during construction
- Potential use of alternative track form design that makes use of lower vibration construction techniques (cement stabilised sand/aggregate track foundation)
- Protection or renewal of the vibration sensitive asset (e.g. by concrete encasing the pipeline)
- Use of respite and/or offer of alternative accommodation to highly affected residential properties (as per the CNVS)
- Mitigation measures consistent with the CCBDG, such as:
  - > Use non-explosive demolition agents and/or chemical agents to facilitate concrete/rock breaking activities to reduce vibration

[15] Construction noise and vibration strategy, Transport for NSW, V4.1, 24 April 2019

> Substitute demolition methods not involving impact where feasible (e.g. use hydraulic rock splitters rather than rock breakers).

> Schedule the use of vibration-causing equipment such as jackhammers, demolition, earthmoving and ground-impacting operations at the least sensitive time of day, when feasible.

> Routing, operating or locating high vibration sources as far away from people who could be affected by vibration, when feasible.

> Sequencing operations so that vibration-causing activities do not occur simultaneously.

> Isolate equipment causing vibration on resilient mounts.

> Isolate activities from adjoining structures.

> Maintain equipment in accordance with manufacturer's specifications.

Due to the proximity of works to the EJP and heritage structures, a vibration monitoring regime is recommended to manage vibration impacts during delivery of the project.

Vibration measurements should be undertaken for all construction vibration sources when they are first brought to site. This will help to manage the risk of pipe vibration levels exceeding the vibration criterion. Field vibration measurements are particularly important for:

i. Any activity conducted within 5 m of the EJP due to the inherent variability in construction vibration models at short source-receiver distances.

ii. Any predicted vibration level over 15 mm/s

Piling is an activity planned to be undertaken very close to the EJP (< 1 m). A piling trial should be conducted, at distances away from the EJP, with the same sized piles in representative ground conditions to accurately establish the piling vibration levels. Attention should be given to the transient vibration associated with start-up and shutdown of the pile boring rig.

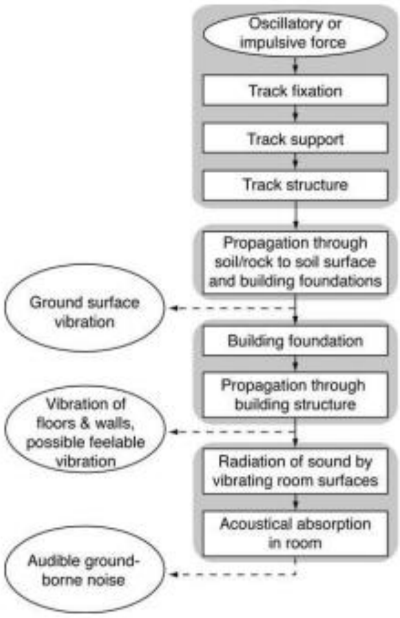
During construction, continuous vibration monitoring with appropriate alert and stop work alarms would be required to manage activities on site and to adjust construction techniques to maintain pipeline vibration levels within acceptable limits.

Project Scope and Technical Requirements (PS&TRs) will apply in relation to protecting the EJP.

# 7. Operational vibration and ground-borne noise impacts

## 7.1 Overview

Operational vibration and ground-borne noise can be predicted using the FTA guideline assessment methodology. This document is a widely accepted document in assessing rail vibration impacts. Both the screening and detailed assessment methodologies have been combined to create the vibration model. An overview of the model is presented in Figure 7-1.




**Vibration source**: Measurements of rail vibration near or at project area

**Vibration propagation**: Propagate rail vibration using empirical data and known distances of design and receivers

**Building vibration**: Use of empirical correction factors

**Ground-borne noise**: Use of empirical correction factors

Figure 7-1 Vibration model developed to assess operational vibration and ground-borne noise impacts for the project (Source: FTA guideline)

## 7.2 Project information

The following inputs have been used in the assessment:

- Alignment information:
- Building footprints, 2017-2018 Greater Melbourne LiDAR Project
- Train information (Shown in Appendix A)

The rolling stock fleet applicable to the assessment are:

- Existing rail operations
  - > EMU (Comeng/Siemens)
  - > DMU (VLocity, XPT)
  - > Locomotive (N-class V/Line passenger)
  - > Freight locomotive and wagons
- Future rail operations

> EMU (High Capacity Metro Train (HCMT), Comeng/Siemens)

> DMU (New Commuter Train (NCT), New Inter-city Commuter Trains (NICT), VLocity, CAF Civity)

> Freight locomotive and wagons

These trains are shown in Table 7-1. For this assessment, the vibration levels for each train type (EMUs, DMUs, freight and passenger locomotives) is assumed to be similar within rolling stock categories.

Table 7-1 Trains referenced in MAR project

| | | | |
|---|---|---|---|
|  **V/Line N-Class locomotive** |  **Freight locomotive** |  **CAF Civity** |  **Siemens EMU** |
|  **XPT** |  **V/Line VLocity DMU** |  **HCMT EMU** |  **Comeng EMU** |

## 7.3 Vibration measurements

Vibration from rail pass-bys was measured along the Albion-Jacana link rail corridor in December 2020, in accordance with FTA guideline and ISO 14837-1:2005[16]. The equipment setup is shown in Figure 7-2. As a part of these site investigations, the following were measured:

- Source vibration levels ($L_{Smax}$, $L_{eq,passby}$, PPV) of the following fleet:
  > XPT

  > N-Class

  > Freight and Freight wagons
- Ground attenuation rate based on rail vibration sources

[16] ISO 14837-1:2005 *Mechanical vibration – Ground-borne noise and vibration arising from rail systems – Part 1: General guidance*


Figure 7-2 Vibration measurement equipment setup for measurement of rail pass-bys along Albion-Jacana link in December 2020

Vibration levels for EMUs and VLocity DMUs were measured in accordance with ISO 14837-1:2005 north of Albion station, on 22 and 23 April 2021. Source vibration levels ($L_{Smax}$, $L_{eq,passby}$) of the following fleet were measured:

- Comeng
- Siemens
- VLocity

These measurements have been processed and are included in the report in Section 7.5.2.

## 7.4 Structural damage from rail operations

### 7.4.1 Procedure

The following procedure was used to assess risk of structural damage to the EJP and buildings from rail vibration:

- Measurement or prediction of rail vibration (PPV) from mixture of applicable rail fleet
- Comparison to FTA guideline curves
- Prediction of rail vibration levels at receivers using FTA guideline methodology
- Comparison of predicted PPV to criteria in Sections 5.2 and 5.3

### 7.4.2 Propagation model

To assess the risk of structural damage, the FTA guideline General Vibration Assessment method (FTA GVA) has been used. This involves:

- Determining vibration level from train type and distance of sensitive receptor at a reference speed
- Adopting speed correction factor for project line speed compared to reference speed
- Applying vehicle parameter/track condition factor of +10 dB
- Converting RMS level to PPV using a crest factor of 5 (based on AJM experience this is consistent with Victorian fleet)
- Comparison with criteria

### 7.4.3 Comparison of measured PPV vs predicted PPV

PPV was measured at several locations along the corridor above the EJP. The measured PPV for freight, N-Class and XPT was less than the predicted PPV using the FTA GVA, as shown in Figure 7-3 for freight trains. Based on this, the FTA GVA method is considered conservative and was used in the assessment. The EMU data was sourced directly from the FTA guideline.

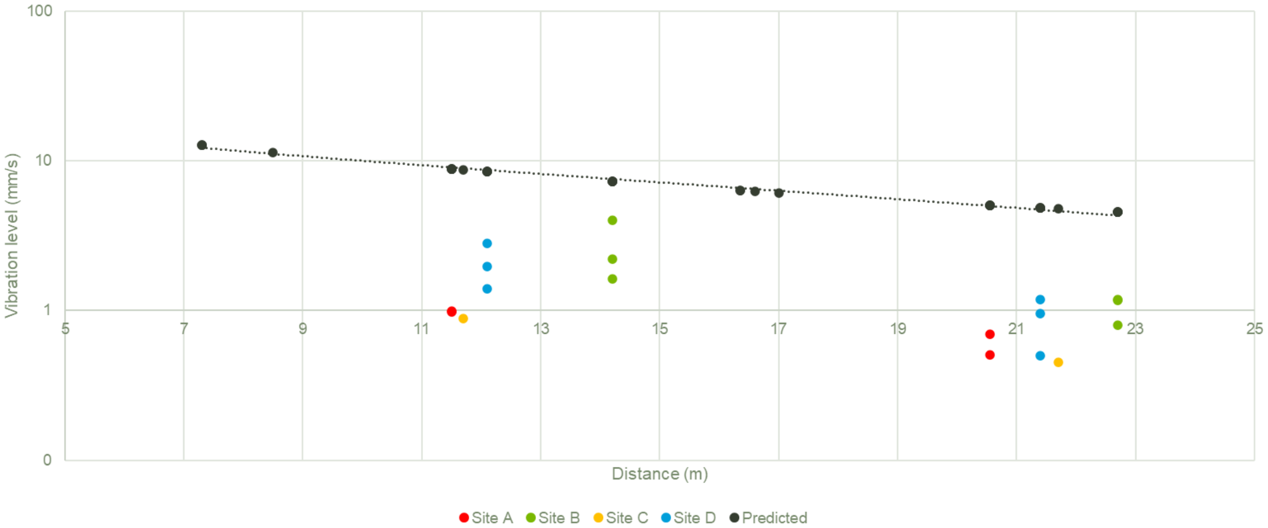



Figure 7-3 Predicted vs measured vibration peak values – Freight train vibration levels normalized to 80 kph

### 7.4.4 Predicted risk of structural damage to EJP and buildings

Vibration from rail operations has been assessed in relation to structural damage to the EJP and nearby buildings.

Vibration impacts on the EJP have been predicted and vibration levels found to be at risk of exceeding the criterion for structural damage when the rail is located below the tracks as it passes from one side of the rail corridor to the other.

Compared to existing vibration levels, the future rail vibration levels are expected to be equal to or lower, due to the change of rail passenger rail fleet from locomotives to DMUs.

Pipeline protection, in the form of pipe casing, is proposed for areas where the new tracks are located above the EJP. Pipe casing is already implemented in locations where existing track is located above the EJP. The design impacts are considered manageable with this pipeline mitigation.

An assessment at the closest buildings to the rail corridor was undertaken (in particular where the freight rail was slewed towards properties). In this area, a PPV of 10 mm/s is predicted (this is considered to be a conservative prediction as discussed in Section 7.4.3). When compared to the residential criterion for short-term vibration of 15 mm/s PPV, compliance is achieved. Consequently, the risk of structural damage to nearby residential properties due to vibration from operational rail is low risk. Industrial buildings are at a similar distance to the rail lines, and have higher structural damage guideline levels and consequently, the risk of structural damage is also low.

## 7.5 Human comfort impacts from rail operations

### 7.5.1 Procedure

The following procedure was used to assess risk of human comfort impacts from rail vibration with respect to vibration and ground-borne noise:

- Measurement of rail vibration ($L_{eq}$, $L_{Smax}$) from mixture of applicable rail fleet
- Normalizing rail vibration data to produce source vibration levels for rolling stock categories
- Determination of ground attenuation rate of the project area from concurrent vibration measurements
- Prediction of $L_{eq}$ rail vibration levels at receivers, using train speed, geometry of rail, and rail correction factors (i.e. crossovers, elevated rail), coupling loss due to building foundations, and building amplification
- Conversion of internal vibration levels to eVDV based on exposure time of vehicles
- Comparison of predicted eVDV to criteria in Section 5.4.
- Prediction of $L_{Smax}$ rail vibration levels at receivers, using train speed, geometry of rail, and rail correction factors (i.e. crossovers, elevated rail), coupling loss due to building foundations, and building amplification
- Conversion of internal vibration levels to ground-borne noise ($dBL_{ASmax}$)
- Comparison of predicted ground-borne noise to criteria in Section 5.5.

### 7.5.2 Measured RMS vibration levels

The measured vertical RMS vibration levels have been normalised to 7.5 m from the rail centreline and a reference speed (dependent on train type), with the background vibration levels ($dBL_{90}$) removed from the source measurements. The source vibration levels used in the assessment are presented below:

- Figure 7-4: $L_{eq,passby,95\%}$
  - > Used for the calculation of eVDV
  - > Based on AJM experience, the eVDV generally lines up with the 95th percentile.
- Figure 7-5: $L_{Smax,95\%}$
  - > Used for the calculation of ground-borne noise

As the EMU and VLocity vibration levels are yet to be measured, the following assumptions have been used:

- All DMUs will have equivalent vibration levels to the XPT/VLocity
- All EMUs will have equivalent vibration levels to the Comeng/Siemens

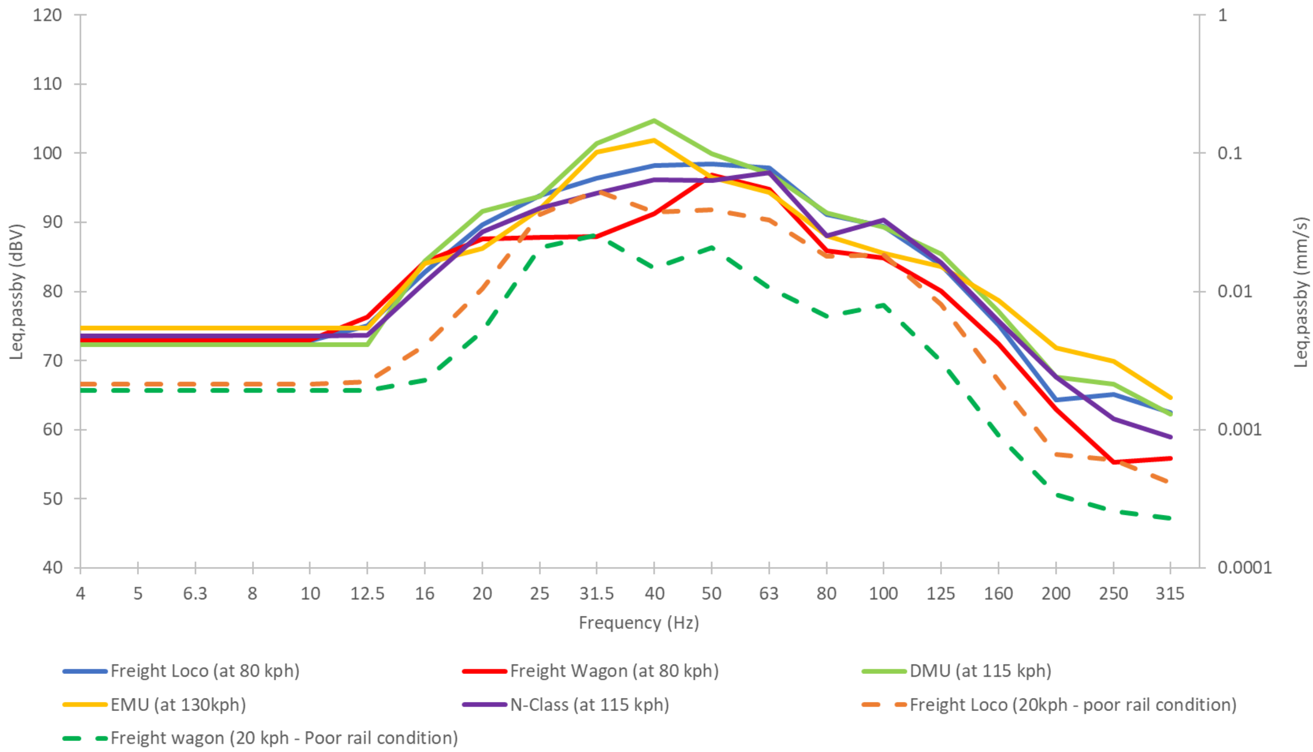



Figure 7-4 Source vibration levels of rail fleet operating within project area ($L_{eq,passby,95\%}$)

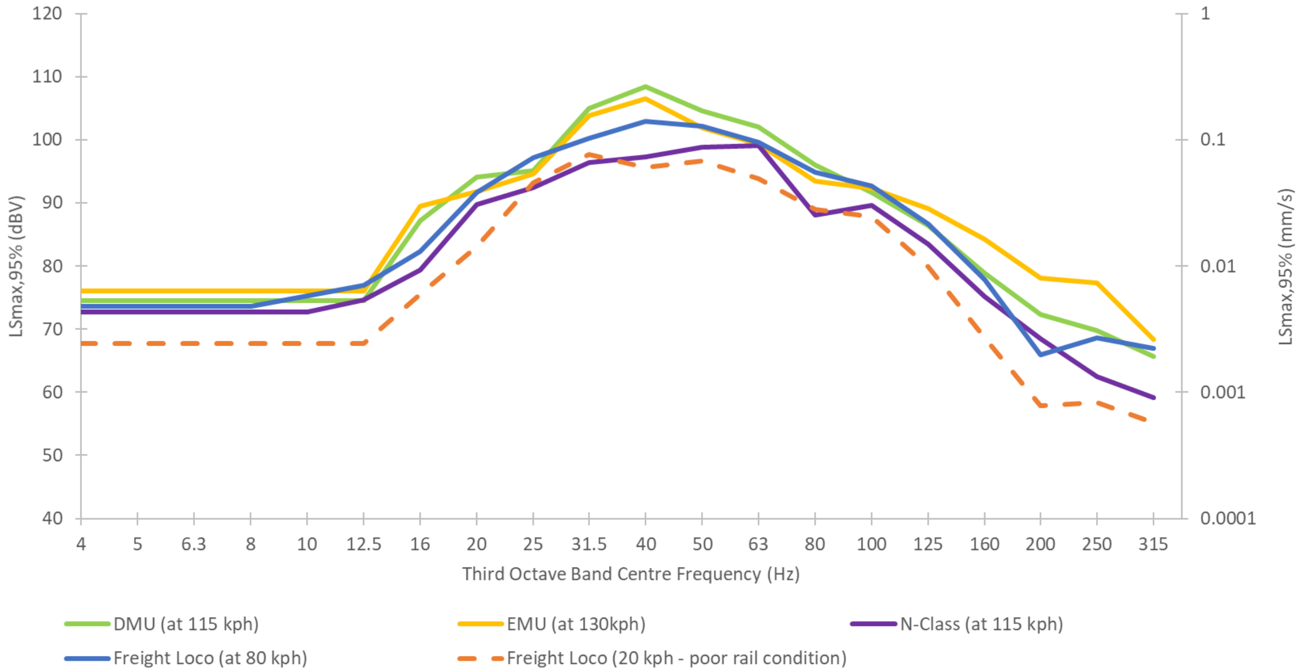



Figure 7-5 Source vibration levels of rail fleet operating within project area ($L_{Smax,95\%}$)

For 12.5 Hz and below data has been adjusted to account for background vibration.

$L_{Smax,95\%}$ values for freight wagons have not been presented, as the maximum will be due to the accompanying locomotive.

## 7.5.3 Ground attenuation rate

To determine the indicative ground vibration attenuation rate two ground pegs with accelerometers were used to measure rail vibrations concurrently. In particular these measurements were undertaken to determine if the ground conditions give rise to efficient propagation of rail vibration. This was investigated due to the existence of a volcanic rock layer below the much softer fill/residual volcanic rock surface layers.

Preliminary studies showed that ground conditions at the measurement sites did not result in efficient vibration propagation (i.e. reflection from rock below). This is because the estimated vibration levels from the FTA GVA were higher than measured values at both peg locations with the efficient propagation correction factor.

The Amick method[17] was used to determine the indicative ground vibration attenuation rate and a suitable material damping loss constant,. This involved a comparison of vibration levels between both measurement locations, and the empirical derivation of the site vibration attenuation rate, assuming exponential decay across the frequency range. The estimated site vibration attenuation rate is presented in Figure 7-6 based on vibration measurements from a sample of the train fleet and removing outlying data (such as slow freight speeds).

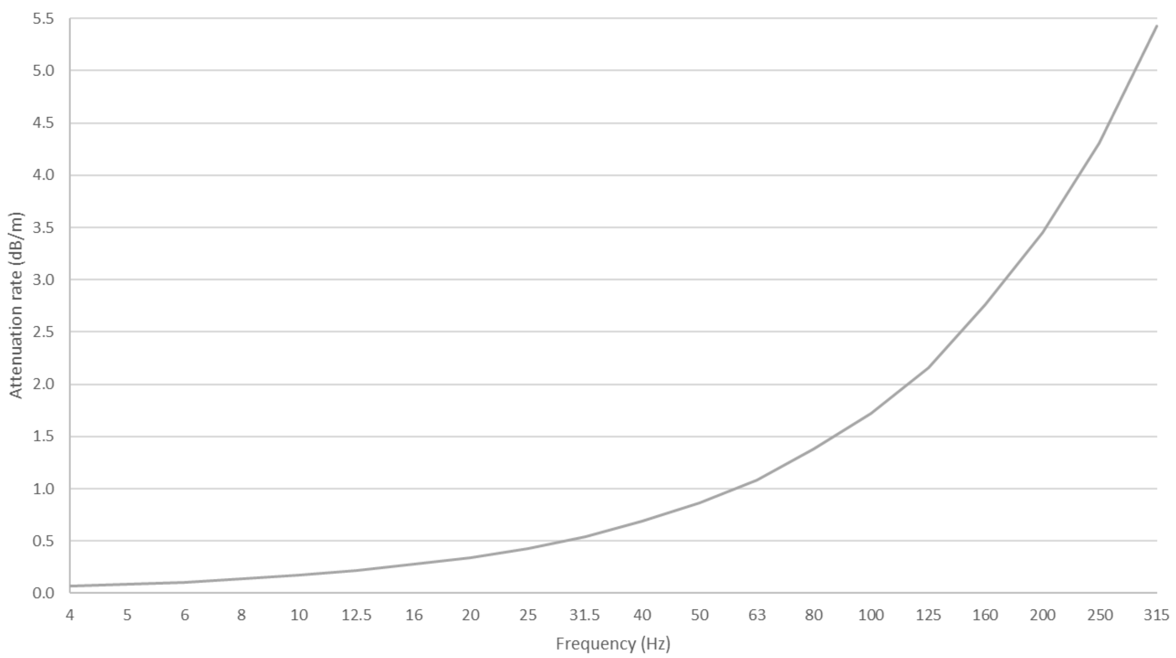



Figure 7-6 Project ground vibration attenuation rate for operational rail vibration

## 7.5.4 Propagation model and correction factors

For the human comfort and ground-borne noise assessment, a spectral propagation model[18] was used to account for the change of vibration over distance. The predicted vibration at a set distance has been determined from known rail vibration levels at a reference distance:

$$V_d = V_{ref}\left(\frac{ref}{d}\right)^{\gamma} e^{\rho\pi f(ref-d)}$$

where

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[17] Amick, H. *A Frequency-Dependent Soil Propagation Model*, Proceeding of SPIE Conference on Current Developments in Vibration Control for Optomechanical Systems, Denver, Colorado, July 20, 1999

[18] Burgemeister, K., Fisher, K. Franklin, K., *Measurement and Prediction of Construction Vibration Affecting Sensitive Laboratories*, Proceedings of ACOUSTICS 2011, 2-4 November 2011, Gold Coast, Australia

- $d$ is the propagated distance, in metres
- $ref$ is the reference distance, in metres
- $V_x$ is the vibration velocity level at $x$ metres, in mm/s
- $\gamma$ is the geometric propagation loss constant, which, for surface rail surface waves is 0 and 0.5 for viaducts[19]
- $\rho$ is the material damping loss constant, which is site dependent, in s/m
- $f$ is the third octave band frequency, in Hz

To calculate the vibration level at a defined distance, source vibration levels must be measured at a reference distance.

A computational model was developed in ArcMap to determine the minimum distance between tracks and receivers. The following broadband source corrections were implemented in the model:

- Speed corrections for trackwork with specified speed limits
  > dB = $20\log_{10}(v/v_{ref})$, where v is proposed speed and $v_{ref}$ is the normalized speed
- Amplification of vibration due to trains operating on crossovers
  > +10 dB for properties within 30 m of a crossover (FTA guideline)
  > +5 dB for properties within 30 to 60 m of a crossover (FTA guideline)
- Reduction of vibration due to elevated structures
  > -10 dB (FTA guideline)
- Amplification of vibration due to tight rail curvature (radius of curvature < 500m)
  > +3 dB (approach taken on Melbourne Metro Tunnel Project)

The predicted ground vibration level at the base of receiver buildings is then corrected to calculate vibration levels within each building using the correction factors provided in Table 7-2.

Table 7-2 Building correction factors

| | Correction factor (dB re 1e-9 m/s) 1/3 Octave Band Frequency (Hz) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 6.3 | 8 | 10 | 12.5 | 16 | 20 | 25 | 31.5 | 40 | 50 | 63 | 80 | 100 | 125 | 160 | 200 | 250 |
| Building coupling loss | | | | | | | | | | | | | | | | | | |
| Single level residential | - | - | 0 | 2 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 |
| 1-2 Storey Residential | - | - | 2 | 5 | 6 | 7 | 8 | 8 | 8 | 9 | 8 | 8 | 8 | 8 | 7 | 7 | 6 | 5 |
| 2-4 Masonry Building | - | - | 3 | 7 | 9 | 10 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11 | 10 | 9 | 8 |
| Amplification of vibration due to building resonance[20] | | | | | | | | | | | | | | | | | | |
| Floor resonance factor (vibration) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 11 | 10 | 9 | 9 | - | - | - | - | - |
| Floor resonance factor (ground-borne noise) | - | - | - | - | - | - | 6 | 7 | 7 | 7 | 6 | 6 | 5 | 5 | 4 | 3 | 2 | 1 |

[19] Kim, D-S., Lee, J-S., *Propagation and attenuation characteristics of various ground vibrations*, Soil Dynamics and Earthquake Engineering 19 (2000), pg 115-126
[20] Chatswood to Sydenham Environmental Impact Statement – Technical Paper 2: Noise and Vibration, May 2016, Correction factors based on Transportation Noise Reference Handbook by Nelson (1987) and adjusted for ground-borne noise.

The eVDV has then be calculated based on the train volumes and exposure time using the equation in Section 6.1.5, with the appropriate frequency-dependent inputs (such as $W_b$ weighting). For this study, the exposure time is based on the length of the train and speed of train.

Finally, once the vibration levels within a room are predicted, the ground-borne noise was calculated using the following equation[21]:

$$dBA = \sum (dBV_{smax,95} - 27 + A_{wgt})$$

Where $dBV_{smax}$ is the frequency dependent 95% percentile maximum linear vibration level within the building (slow weighted), $-27$ is the conversation factor of vibration to ground-borne noise, and $A_{wgt}$ is the frequency dependent A-weighting term.

## 7.5.5 Predicted operational vibration impacts

### 7.5.5.1 Human comfort (Vibration)

Exceedance to the human comfort (vibration) “preferred” criteria is predicted at one residential location, during both the day and night. No exceedances to the human comfort (vibration) “maximum” criteria during either day or night are predicted.

This information is presented in Appendix F. As per BS6472-1, the predicted values at this property are considered to be within the range of “*Low probability of adverse comment*”, where, at these values, “*adverse comment is not expected*”.

This exceedance is due to the introduction of a crossover on the MAR tracks. Mitigation options are presented below, however there are specific constraints that would need to be considered:

- Relocation of the crossover cannot occur by more than a few metres (advised from track team). Due to the proximity of houses in this location, moving the crossover is predicted to shift the predicted exceedances above the “preferred” category to other properties.
- Speed restrictions would reduce vibration levels, however this would impact operational timetables.
- Ballast mats installed between the track and the foundation could reduce vibration (FTA guideline states an approximated 10 dB reduction, however this is strongly dependent on the frequency of the source vibration), specific details regarding ballast mat stiffness would need to be considered during detailed design. A “softer” ballast mat required to isolate the trackform from the foundation may not be suitable from an operational perspective and “stiffer” ballast mats have the potential to “amplify” vibration due to the resonant frequency of the ballast mat and the peak of the source vibration. Installation of ballast mats would require “type-approval” from MTM and is likely dependent on stiffness.
  - A “stiffer” ballast mat could be installed if a foundation with a large difference in impedance to the below sub-grades, is also installed. For example, a concrete “u-trough” foundation, at which a ballast mat and ballast is installed on.
- Bearer pads, or under-sleeper pads (located between the sleeper and ballast), have similar issues to ballast mats, except they are more likely to be less effective due to the lack of ballast mass resting on top of the pad.
- Swing nose crossings have the potential to reduce vibration, however these crossings are not “type-approved” by MTM.

Under the “reasonable and feasible” mitigation approach, a ballast mat is proposed, if approved, to be installed under the crossover extent in this area. Specific stiffness would need to be considered during detailed design.

Site-specific measurements are recommended in the next phase of design to refine the assessment at locations at-risk of exceedance. These measurements may include:

[21] *Measurement & Assessment of Groundborne Noise and Vibration*, Acoustics & Noise Consultants, 3rd Edition, March 2020

- Local ground attenuation rate
- Coupling loss due to foundations
- Amplification of vibration due to floors

#### 7.5.5.2 Human comfort - ground-borne noise

To exceed the ground-borne noise criteria all the following need to occur:

- Ground-borne noise needs to exceed the absolute level
- Increase in ground-borne noise of 3 dBA or more (relative level)
- Ground-borne noise levels audible and a higher level than airborne noise levels from rail operations

For the ground-borne noise, a screening assessment was undertaken to identify if there are properties at which the relevant ‘absolute’ threshold level (as described in Table 5-4) is predicted to be exceeded. Several exceedances were predicted, typically around future rail crossover locations in the Albion-Jacana link, where the freight tracks (Broad Gauge and Standard Gauge) have been slewed towards the residential properties in Keilor Park, and properties where the building footprint was bordering the rail corridor.

As a result of the ‘absolute’ threshold exceedances identified in the screening assessment, the change in ground-borne noise levels (relative level) at these sites have also been predicted by considering the existing ground-borne noise levels. The following impacts were predicted based on the rail volumes presented in Appendix A:

- The ground-borne noise relative threshold during the day is predicted to be at risk of being exceeded at seven properties
- The ground-borne noise relative criterion during the night is predicted to be at risk of being exceeded at 37 properties

The predicted internal airborne rail noise levels (post-mitigation) for the specific rail operations have been compared to the specific ground-borne noise levels at the properties identified at-risk of exceeding the ground-borne noise criteria (i.e. an EMU airborne maximum noise level was compared to the EMU ground-borne noise level). A summary of the predicted outcomes is provided below:

- For the residential properties, four buildings (three properties) were at risk of exceeding the ground-borne noise targets.
  - > There was a risk that the habitable room was located on the least exposed façade to the rail corridor and thus airborne noise was of a lesser magnitude (i.e. façade facing away from the rail corridor), therefore the external airborne $L_{Amax}$ was predicted at this location to compare against the ground-borne noise criteria.
  - > A 15 or 20 dB reduction of external to internal noise across the façade was adopted (dependent on building envelope and building age), consistent with Noise Protocol[22] approach (for indoor adjustments for closed windows that either do not meet/meet energy efficiency and sealing requirements of Building Code of Australia 2006).
  - > At these properties, the exceedance is predicted to occur twice a night.
- For the Albion substation, ground-borne noise is predicted to be less than airborne noise, therefore ground-borne noise is not expected to exceed the criterion.
  - > For the assessment, the predicted $L_{Amax}$ on the most exposed façade to rail noise was used to determine noise break-in via the facade. This was due to the Albion substation being a single large volume, which shares all facades.

[22] EPA 1826.4 *Noise limit and assessment protocol for the control of noise from commercial, industrial and trade premises and entertainment venues*, 20 May 2021

> An assumed composite facade of $R_W$ 34 (based on 4 mm glazing and brick facade) was used in the calculations

The mitigation mentioned in Section 7.5.5.1 (besides the swing noise crossing) would also apply to this section. Under the feasible and reasonable approach, the amount of times the exceedances are predicted to occur (twice) should also be considered.

As the exceedances are marginal (1-4 dB), site-specific measurements are recommended in the next phase of design to further refine the assessment. These measurements may include:

- Local ground attenuation rate
- Coupling loss due to foundations
- Amplification of vibration due to floors
- Inspection of façade details

## 7.6 Mitigation for operation

Pipeline protection should be implemented in locations at which the EJP crosses beneath future rail lines. This may be in the form of the existing pipe casing mitigation, located throughout the project area. Based on the lack of existing issues of this mitigation approach, it is likely the most suitable form of pipeline mitigation. EMRs will apply for the project in relation to protecting the EJP.

As ground-borne noise is likely dominated by airborne noise at the properties predicted to exceed the ground-borne noise criteria, no track mitigation is proposed.

# 8. Conclusion

The potential vibration impacts for the project and recommendations for managing vibration impacts are presented in Table 8-1.

Table 8-1 Summary of potential impacts for the MAR project

| Item | Comments |
|---|---|
| **Construction** | |
| Structural damage to structures | • Of the construction equipment proposed, large vibratory rollers are predicted to present the highest risk of structural damage to buildings. Vibration levels due to the large vibratory rollers are predicted to exceed the structural damage guideline values at up to 54 residential buildings, up to 19 industrial buildings and up to eight heritage structures. To reduce potential impacts, smaller vibratory rollers or static rollers are proposed in lieu of large vibratory rollers in locations where there is a risk of damage to structures. These reductions are presented below:<br>– Vibratory roller (10T): 14 residential properties / 17 industrial buildings / four heritage structures<br>– Static roller (18T): One heritage structure<br>• Excavation is predicted to present a risk of structural damage (predicted vibration levels exceed the structural damage guideline values) at one residential property, one industrial building, and at the existing heritage Maribyrnong River Bridge. To reduce potential impacts, smaller excavators are proposed in lieu of larger plant when there is a risk of structural damage to structures.<br>• Piling is not predicted to exceed the structural damage guideline values.<br>• Other construction activities assessed present low risk of structural damage (predicted vibration level do not exceed the structural damage guideline values).<br>Note: Exceeding the guideline values does not necessarily lead to damage. |
| EJP structural damage | • Vibration from most construction activities is predicted to exceed the asset owner's vibration limit for the EJP in limited areas of the EJP.<br>• Vibratory rollers and piling are predicted cause vibration levels which exceed the pipeline vibration limit for a large percentage of the EJP alignment.<br>Note: Exceeding the vibration limit does not necessarily mean that damage would occur. |
| Human Comfort (Vibration) | • With respect to human comfort, use of vibratory rollers is predicted to cause significant impacts at sensitive receivers. |
| Mitigation measures | • An Environmental Management Framework (EMF) with Environmental Management Requirements (EMRs) has been produced for the project with which the contractor will be required to comply.<br>• Selection of lower vibration generating equipment (generally smaller equipment)<br>• Use of alternative rolling techniques, such as use of static rollers rather than vibratory rollers<br>• Use of alternative construction techniques<br>• Mitigating risk by undertaking vibration monitoring to verify source vibration levels and to manage vibration levels by operator intervention during construction<br>• Potential use of an alternative track form design that makes use of lower vibration construction techniques (cement stabilised sand/aggregate track foundation)<br>• Protection or renewal of the vibration sensitive asset (e.g. by concrete encasing the EJP)<br>• Use of respite and/or offer of alternative accommodation to highly affected residential properties (as per the CNVS) when exceeding human comfort criteria (vibration)<br>• Verification of vibration levels associated with equipment prior to equipment being introduced to site.<br>• Vibration monitoring throughout the construction period in proximity to buildings, heritage structures and EJP.<br>• Piling trials at distances from the EJP.<br>• Mitigation measures in Civil construction, building and demolition guide (CCBDG):<br>– Use non-explosive demolition agents and/or chemical agents to facilitate concrete/rock breaking activities to reduce vibration. |

| Item | Comments |
|---|---|
| | – Substitute demolition methods not involving impact where feasible (e.g. use hydraulic rock splitters rather than rock breakers).<br>– Schedule the use of vibration-causing equipment such as jackhammers, demolition, earthmoving and ground-impacting operations at the least sensitive time of day, when feasible.<br>– Routing, operating or locating high vibration sources as far away from people who could be affected by vibration, when feasible.<br>– Sequencing operations so that vibration-causing activities do not occur simultaneously.<br>– Isolate equipment causing vibration on resilient mounts.<br>– Isolate activities from adjoining structures.<br>– Maintain equipment in accordance with manufacturer's specifications. |
| **Operation** | |
| Building structural damage | • Structural damage to nearby buildings from rail operations is of low risk to the project (predicted vibration levels do not exceed the structural damage guideline values). |
| EJP structural damage | • Rail operational risk of exceeding the structural damage criterion for the pipeline is predicted to occur in locations where the pipeline is located directly underneath the proposed or existing rail. |
| Human Comfort (Vibration) | • Predicted vibration levels are at-risk of exceeding the "preferred" human comfort criteria at one property for both day and night, due to the proximity of a crossover. These predicted levels are lower than the "maximum" criteria. Site specific measurements and inspections are proposed to occur during the next phase of design, with a feasible and reasonable mitigation approach to be undertaken if needed. |
| Human Comfort (Ground-borne noise) | • The predicted ground-borne noise levels are at risk of exceeding the criteria at four buildings. Site specific measurements and inspections are proposed to occur during the next phase of design, with a feasible and reasonable mitigation approach undertaken if needed. |
| Mitigation measures | • An EMF with EMRs has been produced for the project with which the contractor will be required to comply. Pipeline protection should be implemented in locations where the EJP crosses beneath future rail lines. This may be in the form of the existing pipe casing mitigation, located throughout the project area. |

A number of predicted vibration impacts from the project are outlined above.

Most of the predicted construction impacts are expected to be managed with the use of smaller construction equipment or other mitigation strategies identified in this report. The proposed changes to construction equipment such as the use of smaller equipment should be reviewed for consistency with practical construction requirements and schedules.

Human comfort criteria (both vibration and ground-borne) are predicted to be exceeded due to operational rail movements in discrete locations (four buildings, three properties). While some mitigation techniques have been identified, a feasible and reasonable approach should be undertaken. Site specific measurements are proposed to occur at locations where vibration is predicted to be at risk of exceedance during the next phase of design.

# APPENDIX A
# OPERATIONAL MODELLING INPUTS

This section provides the modelling inputs for the operational rail vibration predictions.

Table A-1 Train Volumes

| | Day | | | | Night | | | |
|---|---|---|---|---|---|---|---|---|
| | HCMT | Freight | DMU | N-Class | HCMT | Freight | DMU | N-Class |
| **Existing** | | | | | | | | |
| ARTC SG (interstate) | - | 8 | 4 | 6 | - | 1 | - | - |
| ARTC BG (interstate) | - | 8 | - | - | - | 1 | - | - |
| **Redeveloped** | | | | | | | | |
| SBY UP | 108 | - | - | - | 18 | - | - | - |
| SBY DWN | 108 | - | - | - | 12 | - | - | - |
| MAR UP | 96 | - | - | - | 18 | - | - | - |
| MAR DWN | 96 | - | - | - | 18 | - | - | - |
| ARTC SG (interstate) | - | 8 | 10 | - | - | 1 | - | - |
| ARTC BG (interstate) | - | 8 | - | - | - | 1 | - | - |
| RRL UP | - | 1 | 63 | - | - | - | 4 | - |
| RRL DWN | - | 1 | 63 | - | - | - | 3 | - |
| BGO UP | - | 1 | 40 | - | - | - | 4 | - |
| BGO DWN | - | 1 | 40 | - | - | - | 4 | - |

## Train lengths

- HCMT 10-car: 230 m
- Freight: 1.8 km (2x locos)
- DMU: 150 m
- N-Class: 136 m

## Train speeds

- Throughout Sunshine precinct
  - 40 to 80 kph, depending on rail line and speed restrictions (as per design)
- Albion to Ginifer
  - Up to 90 kph (as per design)
- Albion-Jacana link
  - MAR trains: 130 kph (as per design/RPV information)
  - DMU/N-Class: 115 kph (as per RPV information)
    - 80 kph restriction on slewed ARTC Standard Gauge track in Keilor East (as per design)
  - Freight SG: 60 kph prior to Maribyrnong Bridge, 40 kph on new slewed track until it ties into existing rail (~Ch 20+200)
  - Freight BG: 20 kph for most of corridor, except for down from ~Ch 20+200 where new track ties into existing rail (30 kph)
    - Note: BG track up from Ch 18+300 is considered to be degraded

# APPENDIX B RECEIVERS INCLUDED IN THE MAR VIBRATION IMPACT ASSESSMENT


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 2 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receiver types assessed for structural damage

RAIL PROJECTS VICTORIA
AJM Joint Venture
aurecon JACOBS
MOTT MACDONALD

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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- Rail station
- VicTrack Reserve Boundary
- Rail Alignment (Baseline)
- Watercourse
- Assessment Area

**Receiver types assessed for structural damage**

- Residential
- Commercial
- Heritage structures
- Industrial

**Map 3 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

aurecon JACOBS MOTT MACDONALD

AJM Joint Venture

**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220

Metres

Coordinate System: GDA 1994 MGA Zone 55

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Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 4 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

AJM Joint Venture

aurecon JACOBS MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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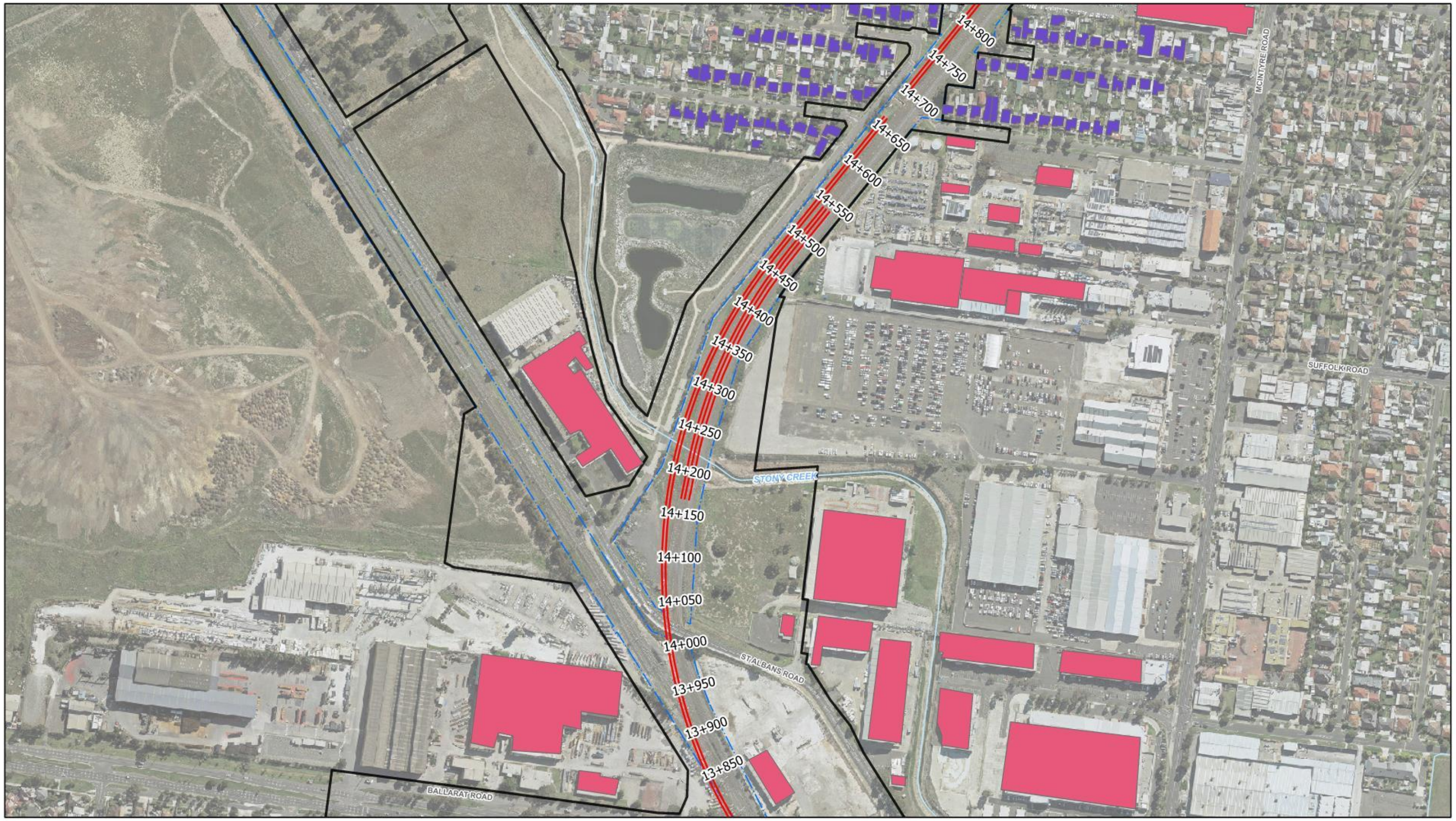


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 5 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

AJM Joint Venture

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**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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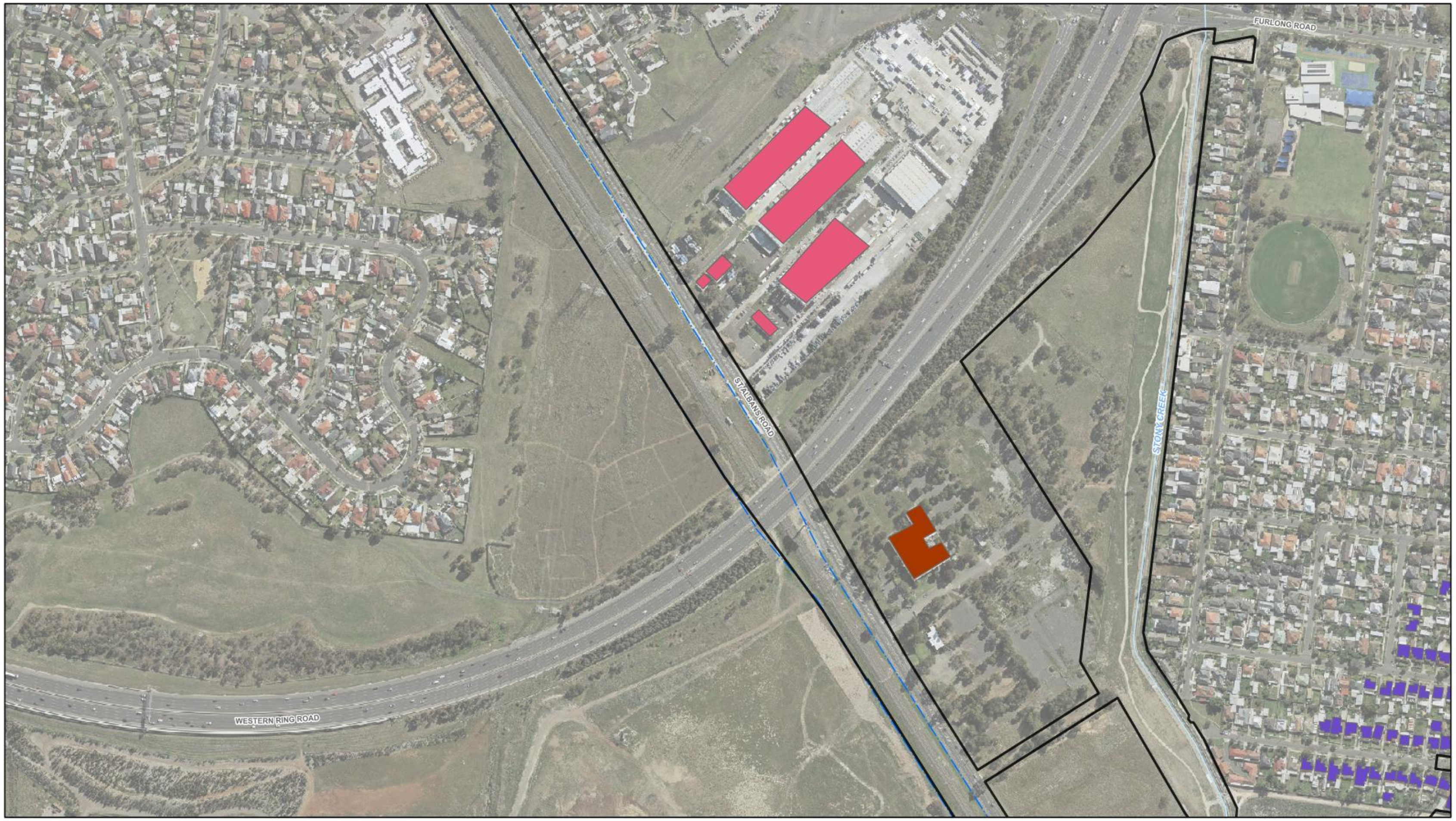


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area
**Receiver types assessed for structural damage**
Residential
Commercial
Heritage structures
Industrial

**Map 6 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA
AJM Joint Venture
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JACOBS
MOTT MACDONALD

**Melbourne Airport Rail**
**Project Wide**
Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 7 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

AJM Joint Venture

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MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: | Approved By: | Date: | Map Size: |
| J. Rivera | D. Larner | 9/08/2021 | A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 8 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
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0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 9 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220

Metres

Coordinate System: GDA 1994 MGA Zone 55

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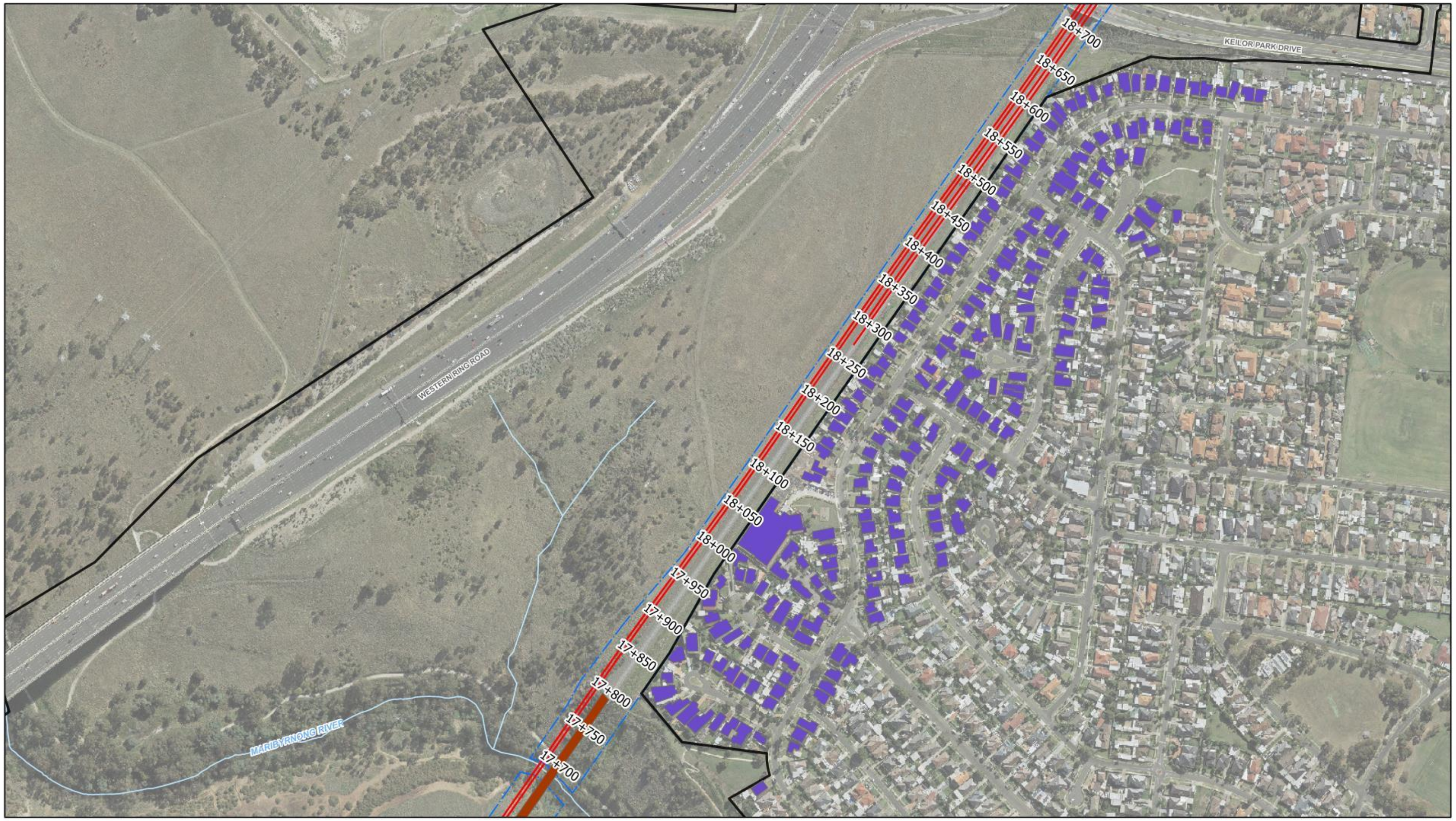


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 10 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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- Rail station
- VicTrack Reserve Boundary
- Rail Alignment (Baseline)
- Watercourse
- Assessment Area

**Receiver types assessed for structural damage**

- Residential
- Commercial
- Heritage structures
- Industrial

**Map 11 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

aurecon JACOBS MOTT MACDONALD

AJM Joint Venture

**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: | Approved By: | Date: | Map Size: |
| J. Rivera | D. Larner | 9/08/2021 | A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

Map 12 of 15

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

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AJM Joint Venture

MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: | Approved By: | Date: | Map Size: |
| J. Rivera | D. Larner | 9/08/2021 | A3 |

0 110 220

Metres

Coordinate System: GDA 1994 MGA Zone 55

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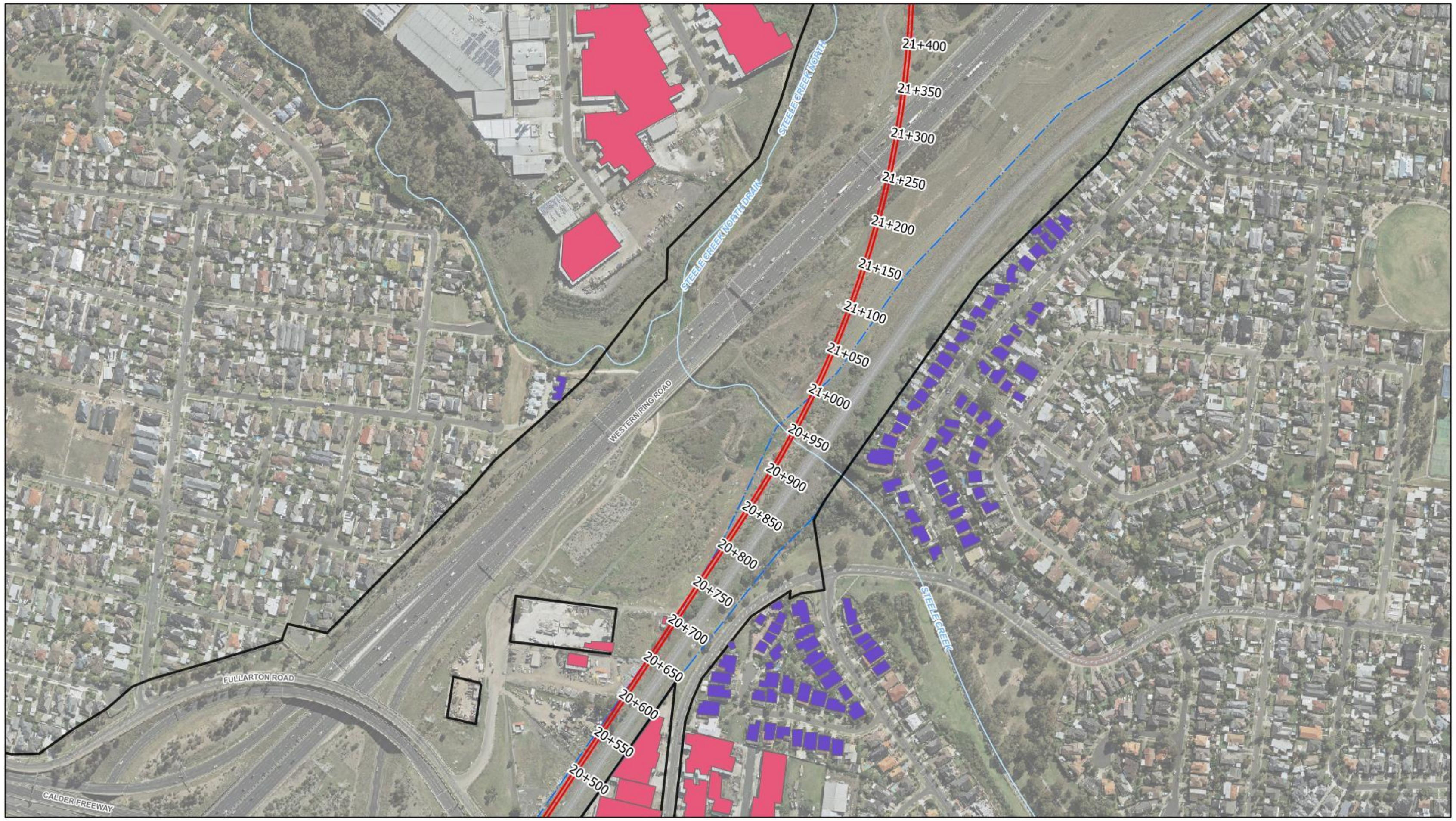


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 13 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA
AJM Joint Venture
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**Melbourne Airport Rail**
**Project Wide**
Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
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0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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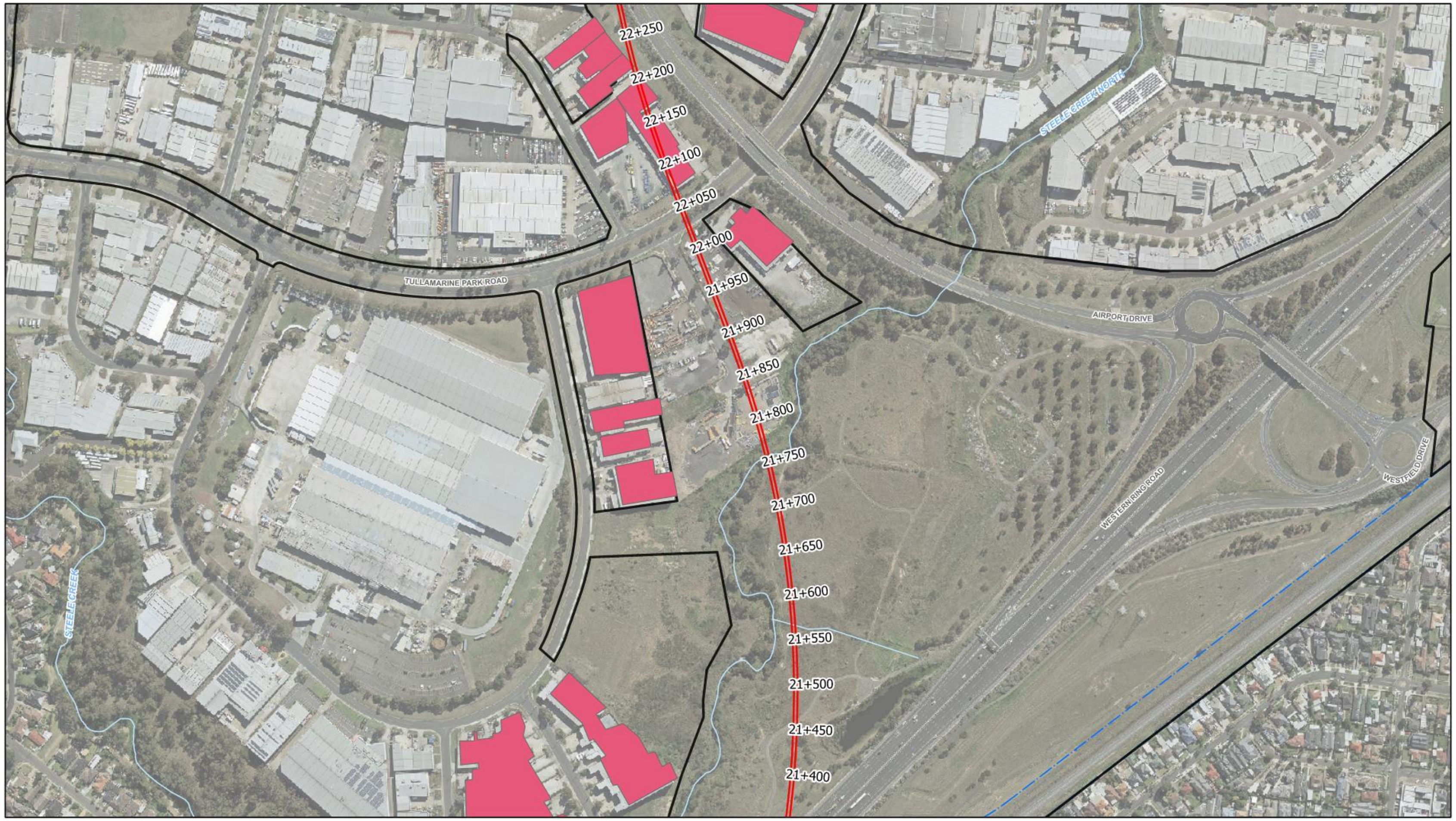


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 14 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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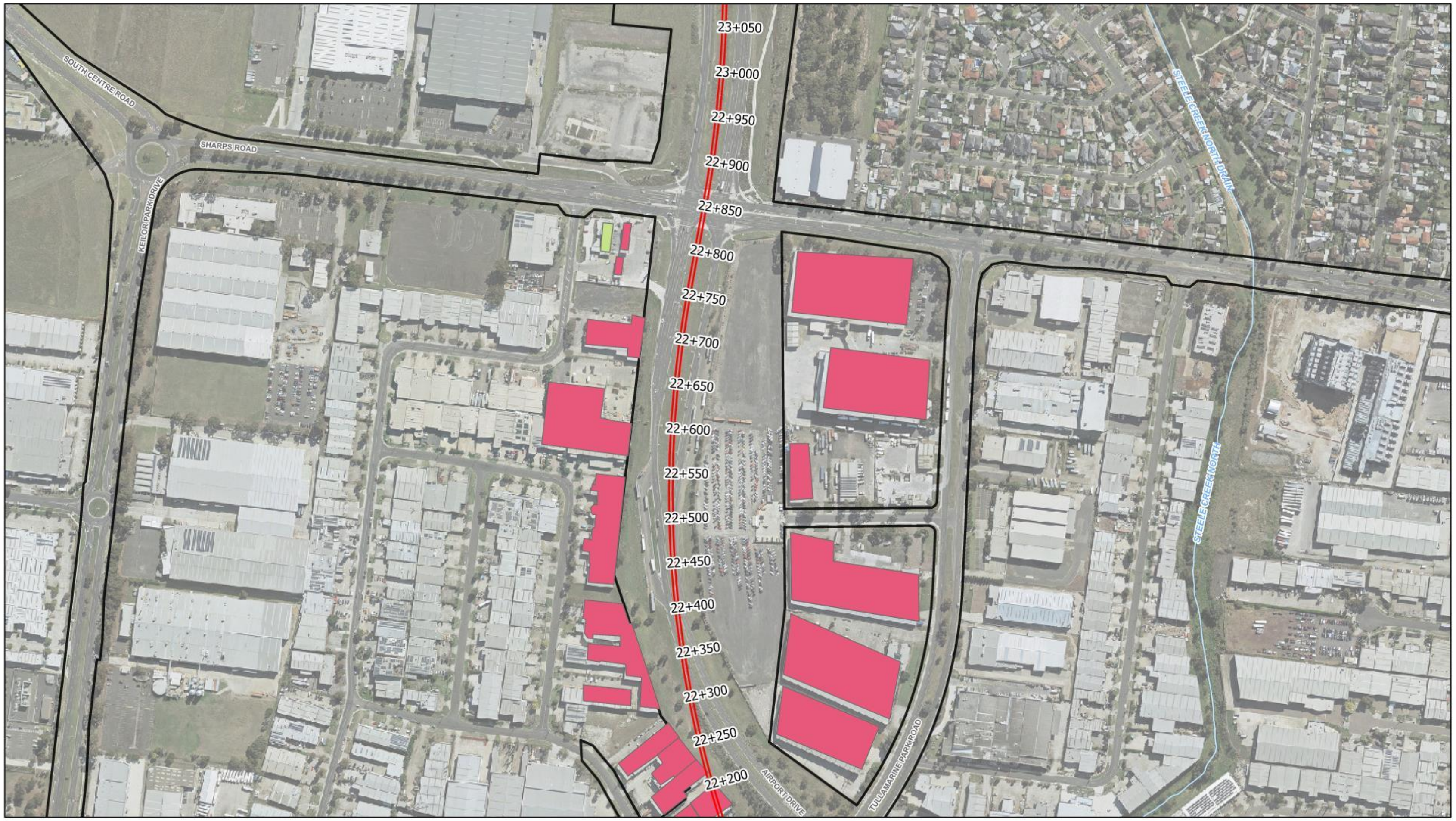


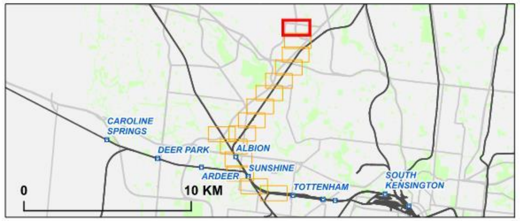

Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for structural damage**

Residential
Commercial
Heritage structures
Industrial

**Map 15 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021




RAIL PROJECTS VICTORIA

AJM Joint Venture

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MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receiver types assessed for structural damage

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490588 | | | A.1 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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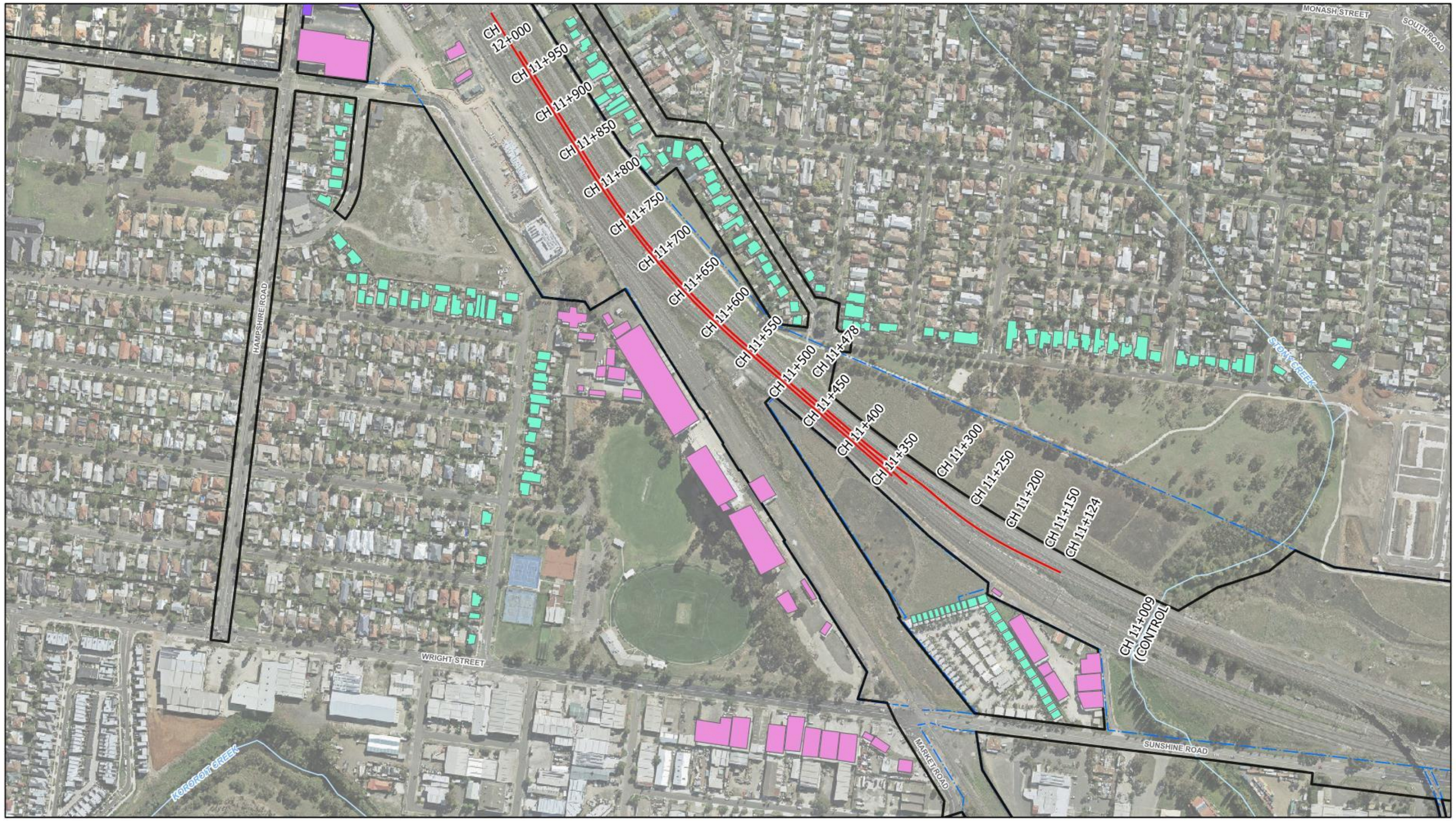


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

Cinema
Offices
Places of Worship
Retail
Educational Institutions
Residential
Industrial/Workshop

**Map 2 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021

0 10 KM

CAROLINE SPRINGS, DEER PARK, ALBION, ARDEER, SUNSHINE, TOTTENHAM, SOUTH KENSINGTON

**Melbourne Airport Rail**
**Project Wide**
Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

RAIL PROJECTS VICTORIA
AJM Joint Venture
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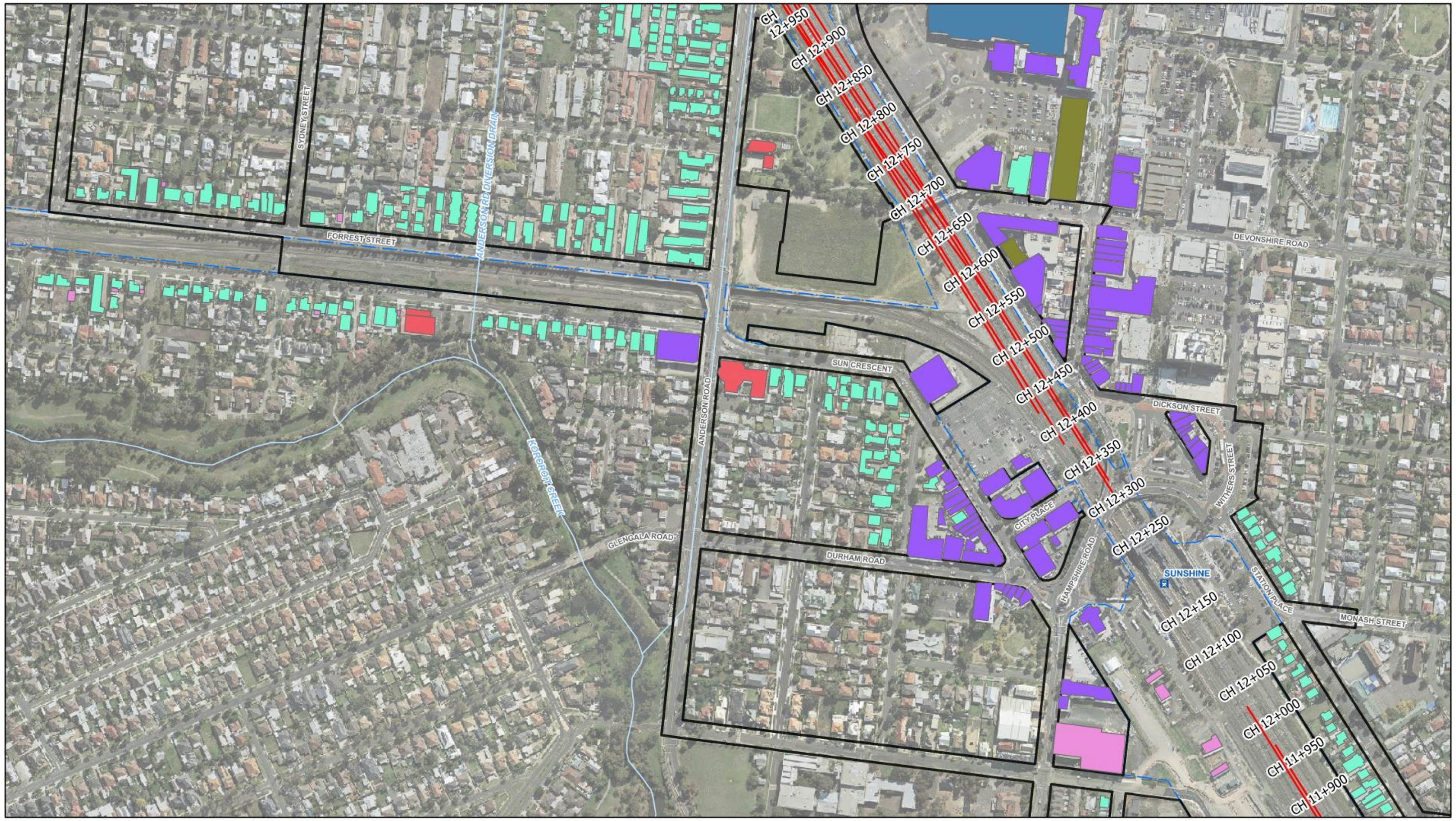
MOTT MACDONALD

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55




Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

- Cinema
- Offices
- Places of Worship
- Retail
- Educational Institutions
- Residential
- Industrial/Workshop

**Map 3 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | Revision: |
|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | A.3 |

| Drawn By: | Approved By: | Date: | Map Size: |
|---|---|---|---|
| J. Rivera | D. Larner | 9/08/2021 | A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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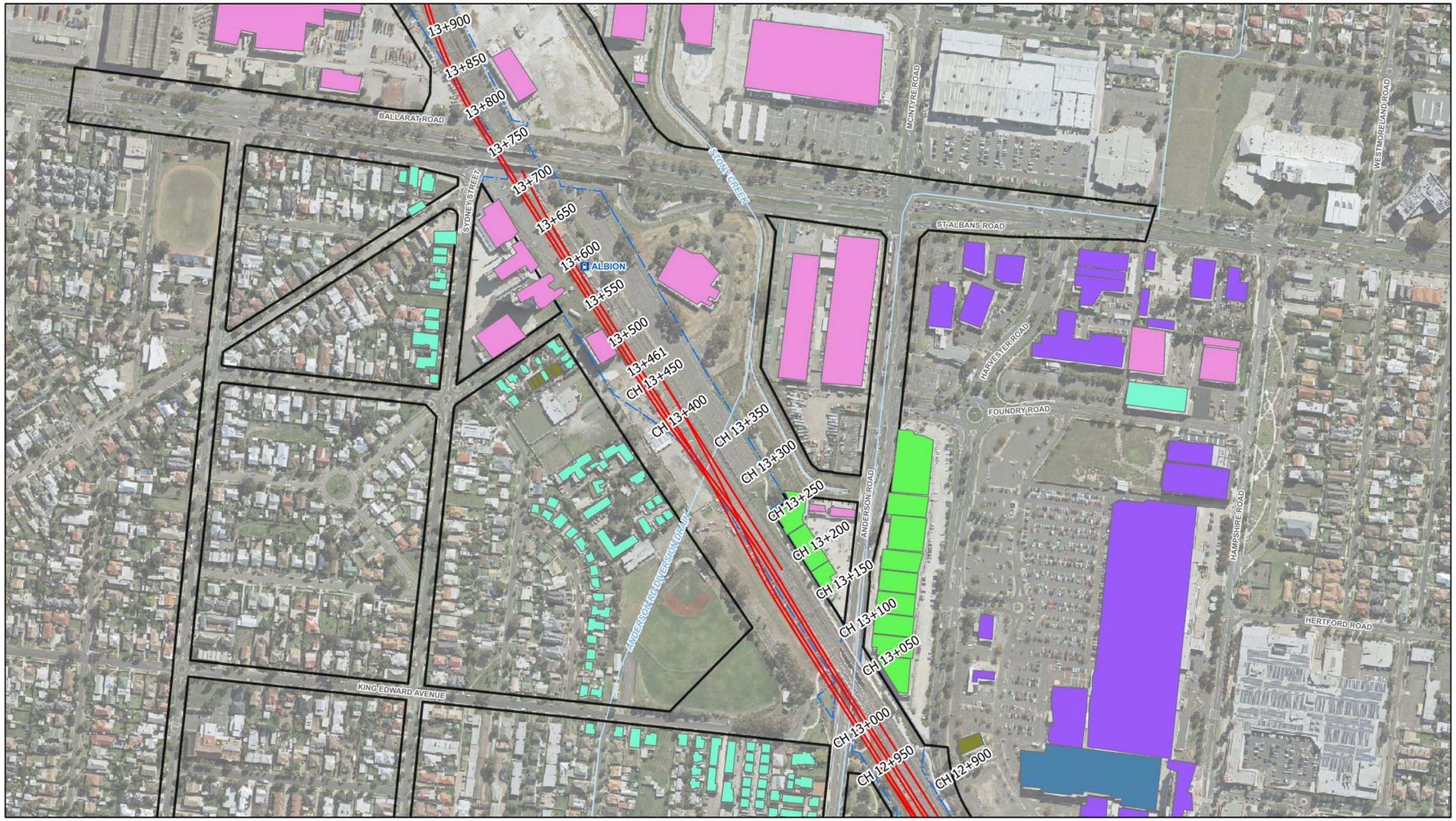


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

- Cinema
- Offices
- Places of Worship
- Retail
- Educational Institutions
- Residential
- Industrial/Workshop

**Map 4 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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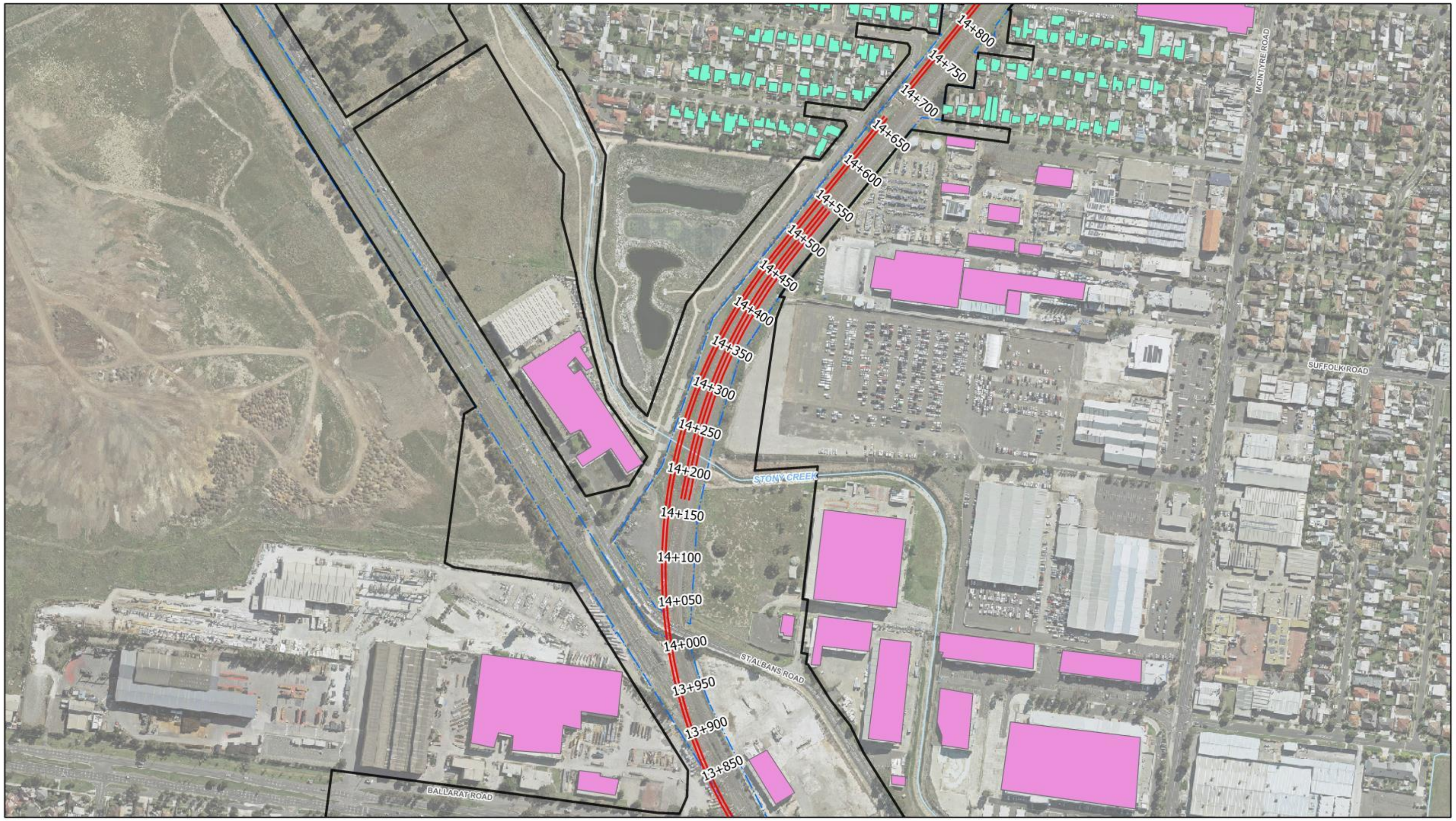


- Rail station
- VicTrack Reserve Boundary
- Rail Alignment (Baseline)
- Watercourse
- Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

- Cinema
- Offices
- Places of Worship
- Retail
- Educational Institutions
- Residential
- Industrial/Workshop

**Map 5 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

AJM Joint Venture

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MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: | Approved By: | Date: | Map Size: |
| J. Rivera | D. Larner | 9/08/2021 | A3 |

0 110 220

Metres

Coordinate System: GDA 1994 MGA Zone 55

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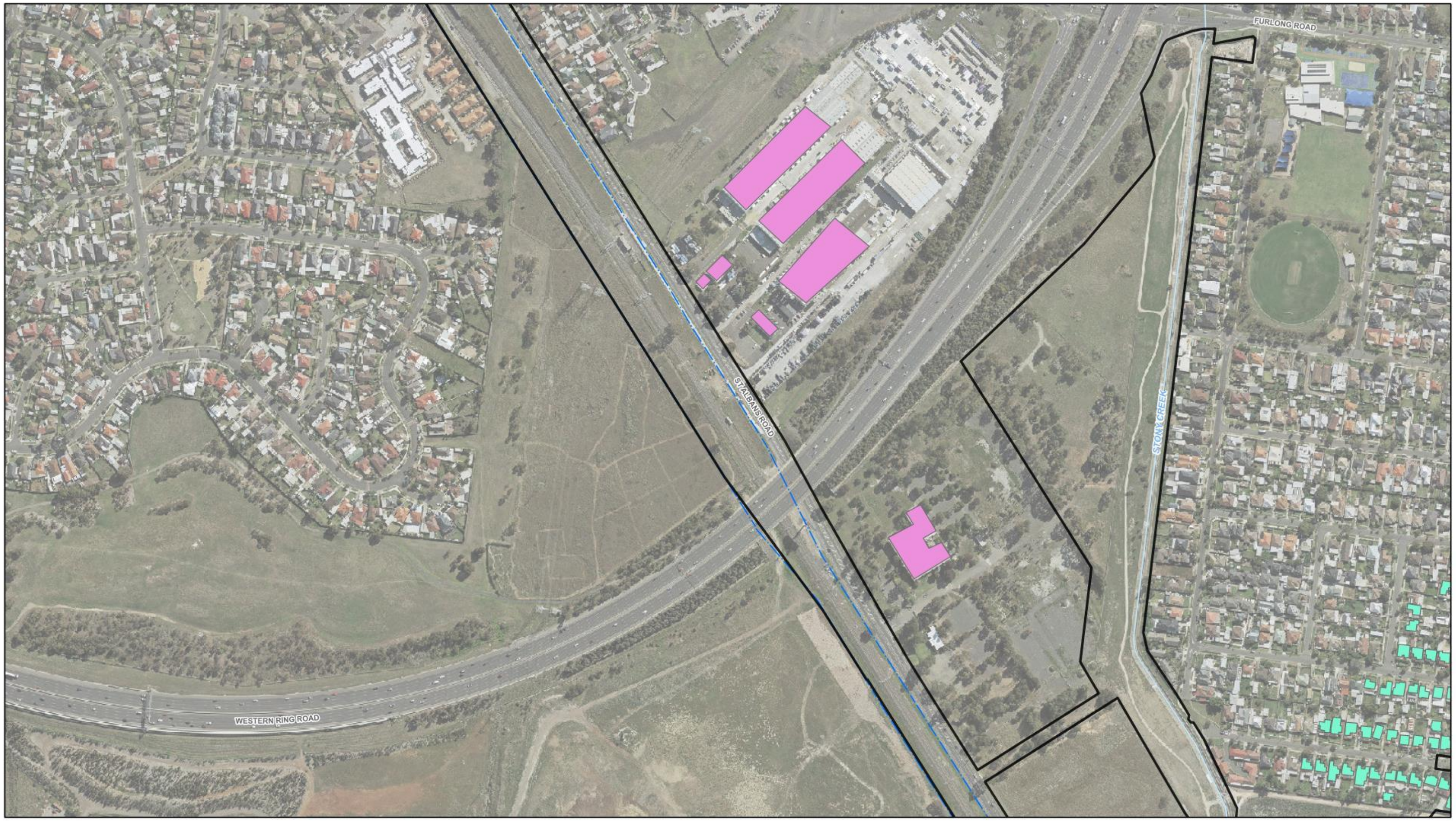


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

- Cinema
- Offices
- Places of Worship
- Retail
- Educational Institutions
- Residential
- Industrial/Workshop

**Map 6 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

Cinema
Offices
Places of Worship
Retail
Educational Institutions
Residential
Industrial/Workshop

**Map 7 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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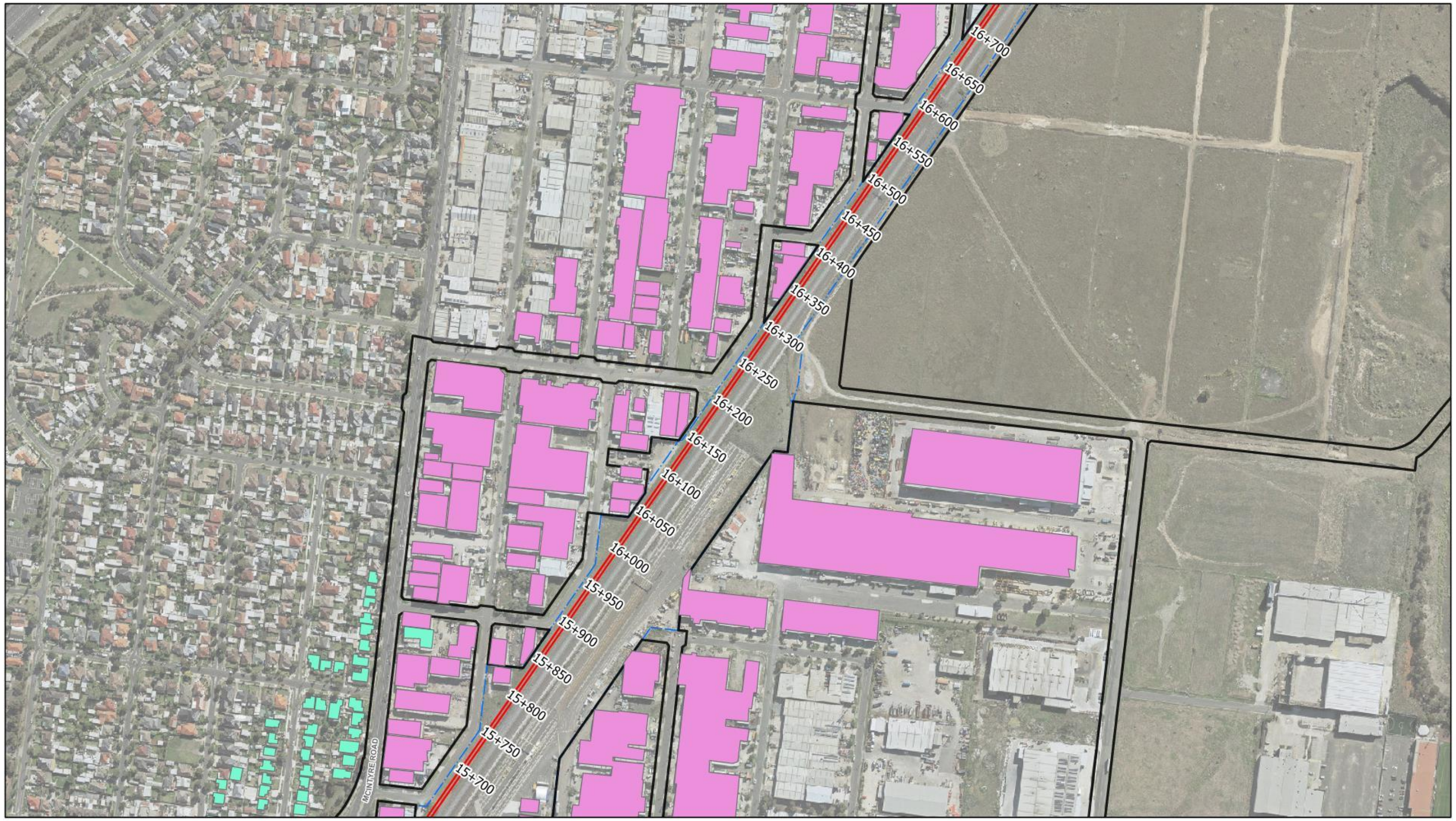


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

Cinema
Offices
Places of Worship
Retail
Educational Institutions
Residential
Industrial/Workshop

**Map 8 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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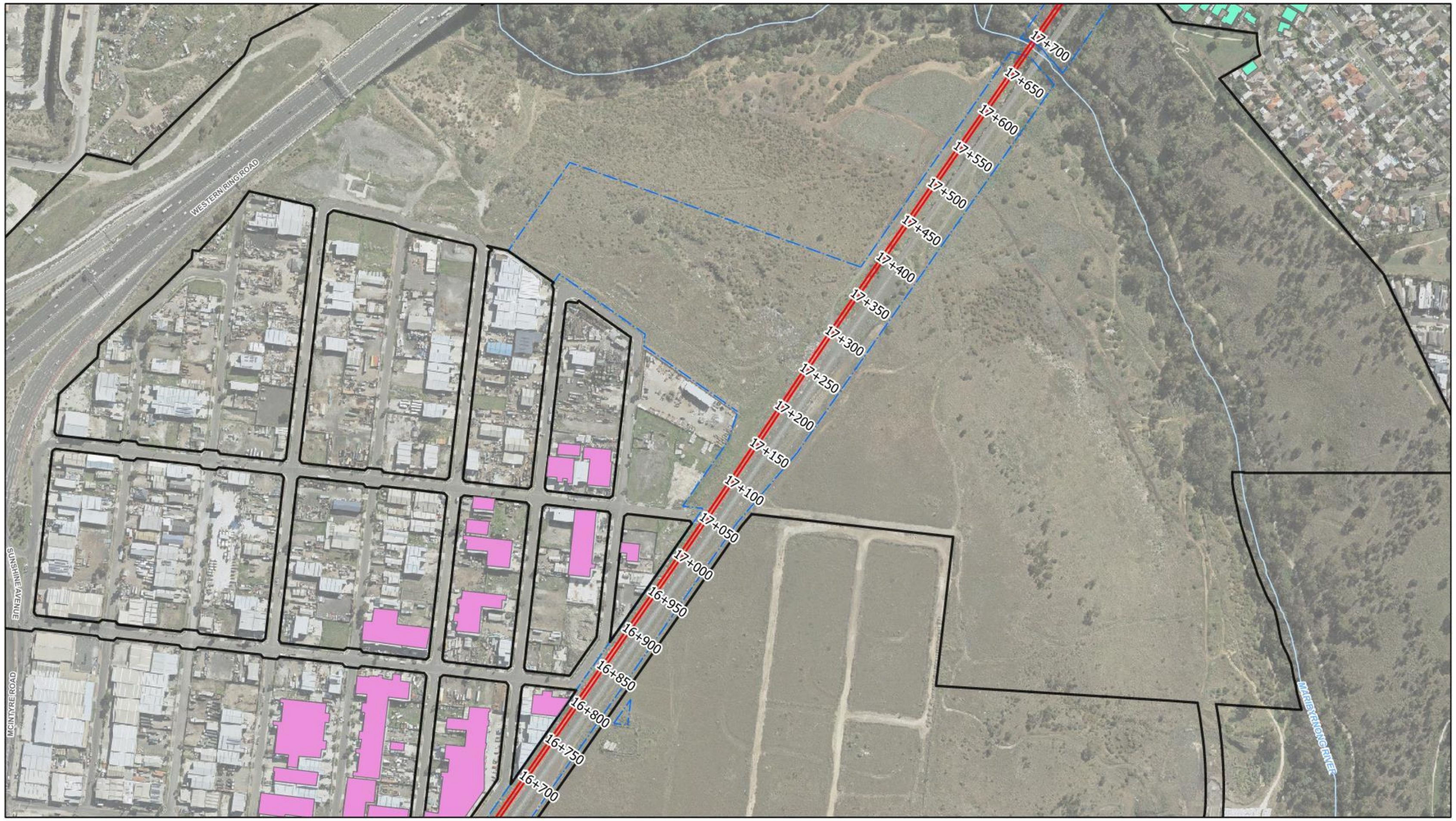


- Rail station
- VicTrack Reserve Boundary
- Rail Alignment (Baseline)
- Watercourse
- Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

- Cinema
- Offices
- Places of Worship
- Retail
- Educational Institutions
- Residential
- Industrial/Workshop

**Map 9 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

AJM Joint Venture | aurecon | JACOBS | MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
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0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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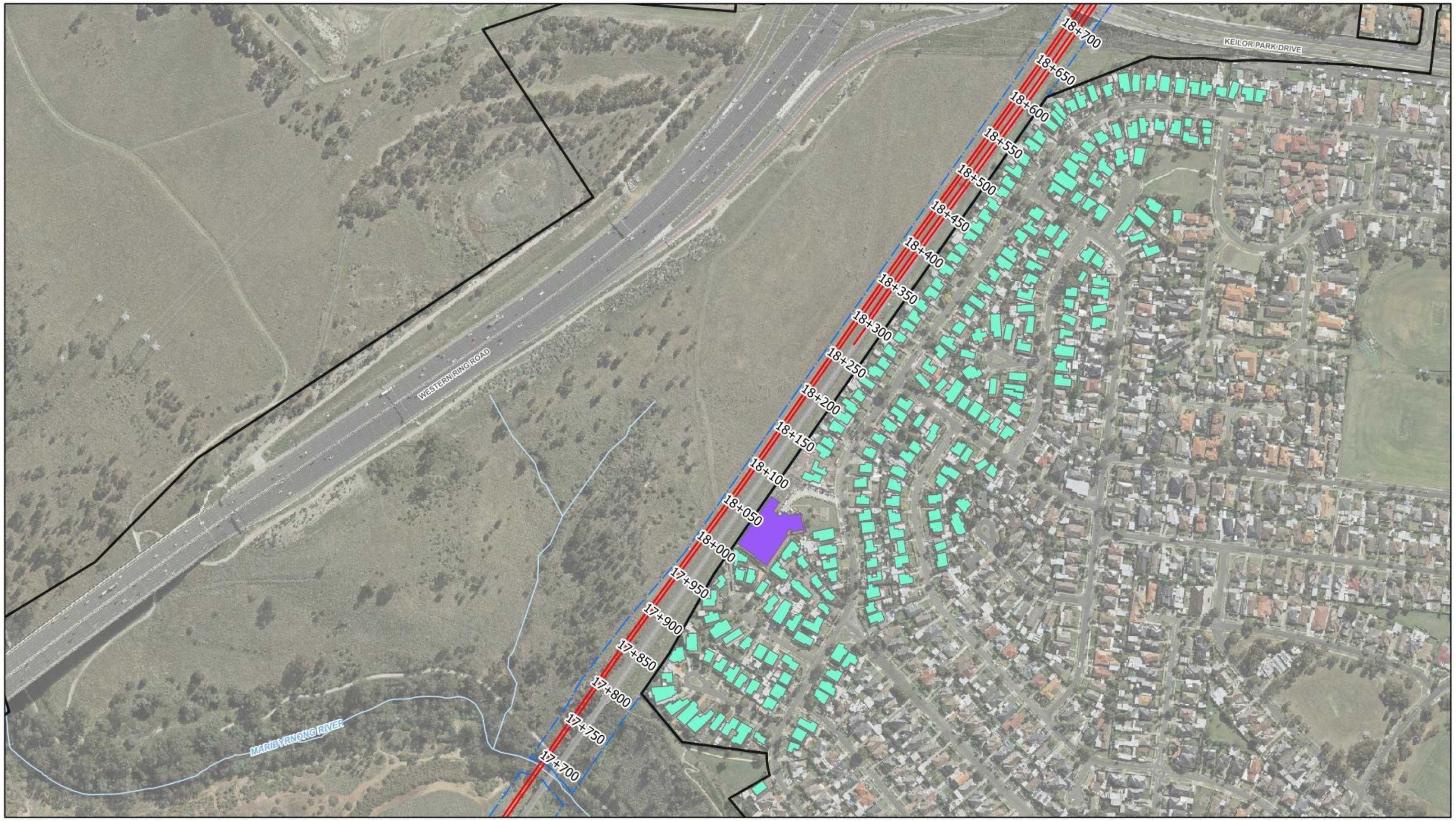


- Rail station
- VicTrack Reserve Boundary
- Rail Alignment (Baseline)
- Watercourse
- Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

- Cinema
- Offices
- Places of Worship
- Retail
- Educational Institutions
- Residential
- Industrial/Workshop

**Map 10 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**

**Project Wide**

Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: | Approved By: | Date: | Map Size: |
| J. Rivera | D. Larner | 9/08/2021 | A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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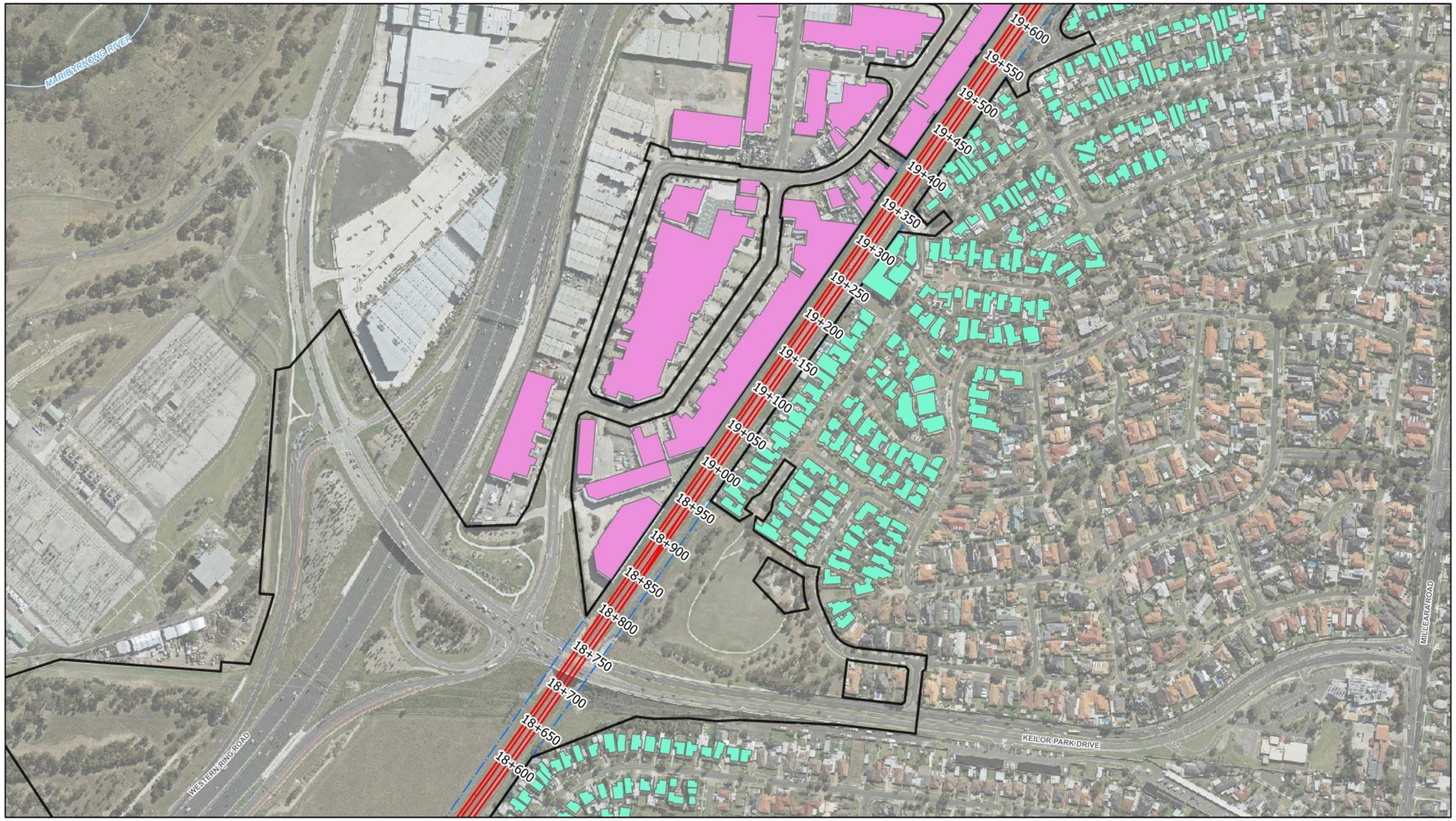


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

Cinema
Offices
Places of Worship
Retail
Educational Institutions
Residential
Industrial/Workshop

**Map 11 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

AJM Joint Venture

aurecon JACOBS

MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: | Approved By: | Date: | Map Size: |
| J. Rivera | D. Larner | 9/08/2021 | A3 |

0 110 220

Metres

Coordinate System: GDA 1994 MGA Zone 55

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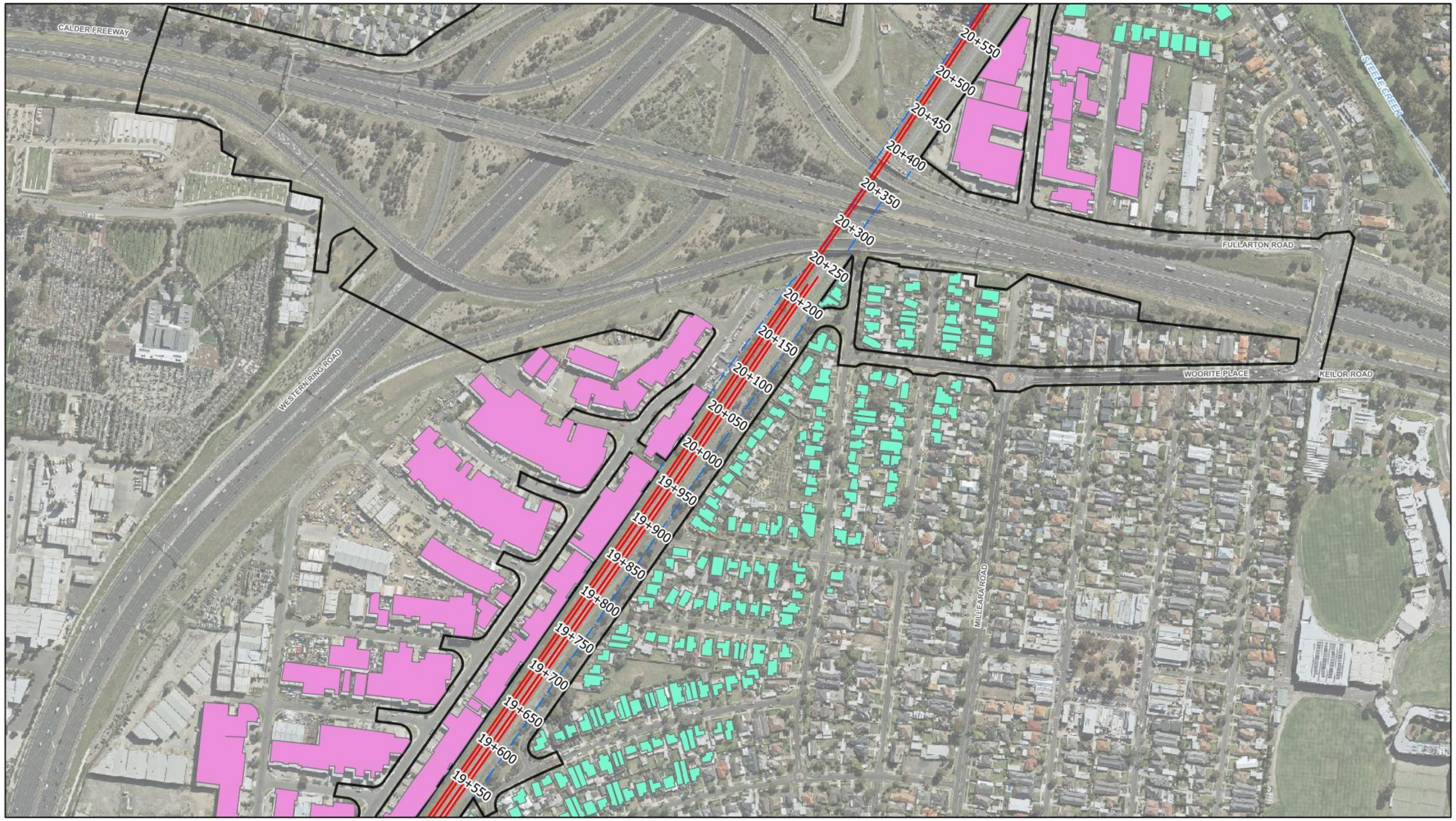


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

- Cinema
- Offices
- Places of Worship
- Retail
- Educational Institutions
- Residential
- Industrial/Workshop

**Map 12 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


**Melbourne Airport Rail**
**Project Wide**
Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220
Metres
Coordinate System: GDA 1994 MGA Zone 55

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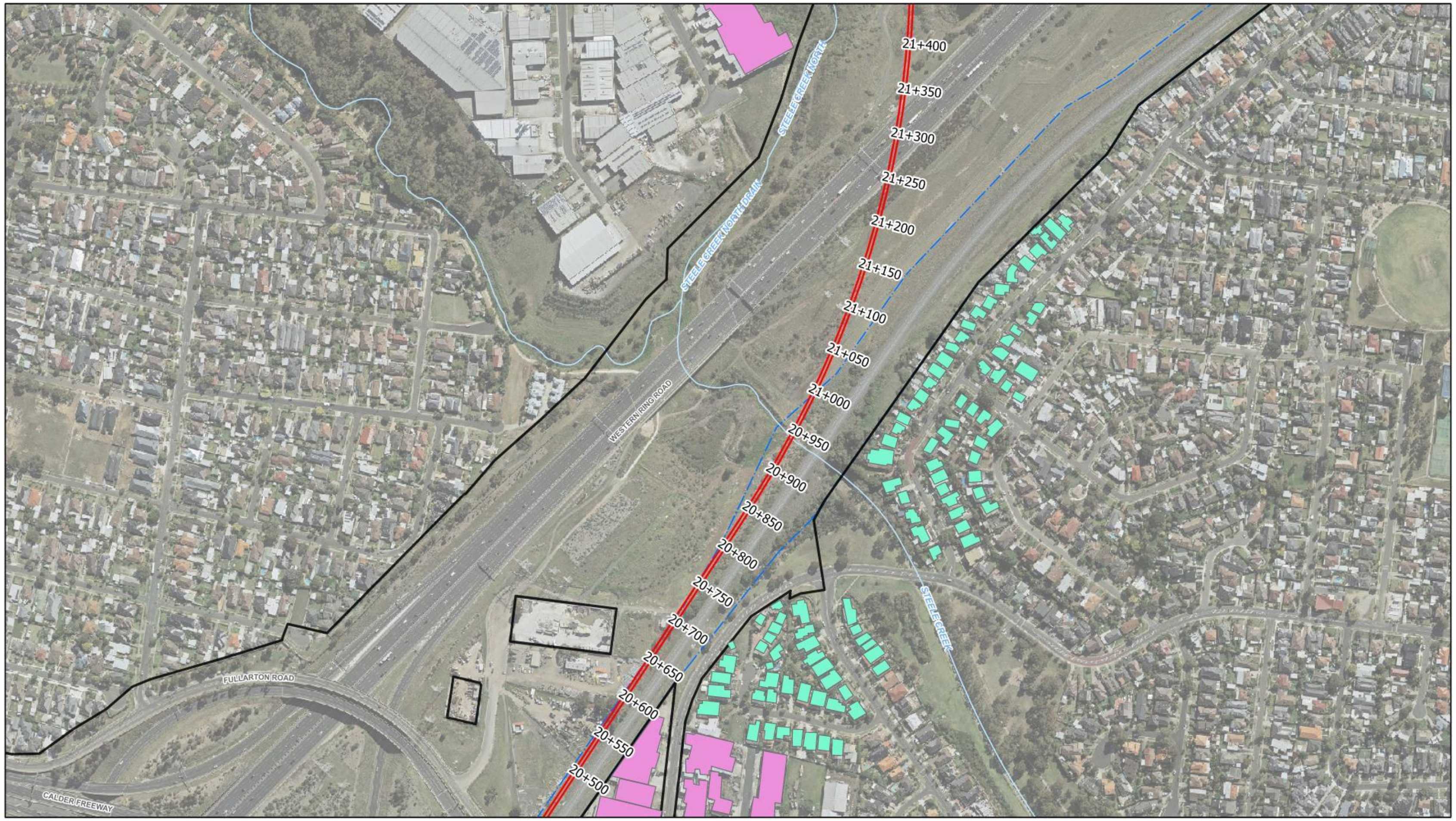


Rail station
VicTrack Reserve Boundary
Rail Alignment (Baseline)
Watercourse
Assessment Area

**Receiver types assessed for human comfort (vibration and ground-borne noise)**

Cinema
Offices
Places of Worship
Retail
Educational Institutions
Residential
Industrial/Workshop

**Map 13 of 15**

Data Sources:
AJMJV 2021
VicTrack 2021
Vicmap 2021
Aerial photo:
DELWP Apr. 2021


RAIL PROJECTS VICTORIA

AJM Joint Venture

aurecon JACOBS MOTT MACDONALD

**Melbourne Airport Rail**

**Project Wide**

Receivers assessed for human comfort (vibration and ground-borne noise)

| Drawing Number: | | | Revision: |
|---|---|---|---|
| MAR-AJM-PWD-PWD-MAP-XAV-MMN-0490587 | | | A.3 |
| Drawn By: J. Rivera | Approved By: D. Larner | Date: 9/08/2021 | Map Size: A3 |

0 110 220

Metres

Coordinate System: GDA 1994 MGA Zone 55

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