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Groundwater Impact Assessment

Melbourne Metro Rail Authority

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in association with Grimshaw





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**Appendix I Groundwater Disposal Strategy**



# Glossary and Abbreviations

| Term   | Definition   |
|--|--|
| <b>ASS</b>   | Acid sulfate soil  |
| <b>AASS</b>  | Actual acid sulfate soil   |
| <b>ARMCANZ</b>                                     | Agriculture and Resource Management Council of Australia and New Zealand   |
| <b>Aquifer</b>                                     | An underground layer of permeable rock, sand or gravel that absorbs water and allows it free passage through pore spaces   |
| <b>Aquitard</b>                                    | A low permeability unit that can store groundwater and also transmit it slowly from one aquifer to another   |
| <b>ANZECC</b>                                      | Australian and New Zealand Environment and Conservation Council  |
| <b>AHD</b>   | Australian Height Datum  |
| <b>CSR</b>   | Concept Summary Report   |
| <b>Drawdown (groundwater)</b>                      | Drawdown is the fall in water level or pressure around an excavation or bore   |
| <b>EPA</b>   | Environment Protection Authority   |
| <b>EPR</b>   | Environmental Performance Requirement  |
| <b>ET</b>  | Evapotranspiration   |
| <b>Groundwater aggressivity</b>                    | The potential for the chemistry of the groundwater to corrode and degrade construction materials such as steel and concrete  |
| <b>GDE</b>   | Groundwater Dependent Ecosystem  |
| <b>GMA</b>   | Groundwater management area  |
| <b>GQRUZ</b>                                       | Groundwater Quality Restricted Use Zones   |
| <b>Haack tightness classification (Haack 1991)</b> | <p>A five tier classification system that describes the tightness of constructed tunnels in terms of the volume of inflows that can seep into the tunnels. The two tiers relevant to this assessment are:</p> <ul style="list-style-type: none"> <li>• Haack 3: 0.1 L/m<sup>2</sup> over 100 m length of tunnel per day</li> <li>• Haack 2: 0.05 L/ m<sup>2</sup> over 100 m length of tunnel per day</li> </ul> |
| <b>Hydraulic conductivity</b>                      | A coefficient of proportionally describing the rate at which water can move through a permeable medium. Separated into directional components: horizontal hydraulic conductivity and vertical hydraulic conductivity   |
| <b>Injection bore</b>                              | A bore through which water can be injected into an aquifer   |
| <b>KPP</b>   | King Post Pile   |
| <b>MAR</b>   | Managed Aquifer Recharge   |
| <b>NEPC</b>  | National Environment Protection Council  |
| <b>NEPM</b>  | National Environment Protection Measure  |
| <b>NHMRC</b>                                       | National Health and Medical Research Council   |
| <b>NUDLC</b>                                       | National Uniform Drillers Licensing Committee  |
| <b>NRMMC</b>                                       | Natural Resource Management Ministerial Council  |
| <b>Packer test</b>                                 | An aquifer test performed in an open borehole – the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals (called packers) both above and below the segment  |



| Term  | Definition  |
|---|---|
| <b>PASS</b>                                       | Potential acid sulfate soil   |
| <b>Potentiometric surface</b>                     | A surface that represents the level to which water would rise in a tightly cased well. The watertable is a particular potentiometric surface for an unconfined aquifer  |
| <b>Raymer plot</b>                                | A method for estimating rock-mass permeability based on the assumption that the hydraulic conductivity data is log-normally distributed. Can be used to develop a permeability model for a unit that can be used to calculate potential tunnel inflows. |
| <b>Recharge bore (also called injection bore)</b> | Bores used to inject water into an aquifer to maintain pressure in that aquifer and/or in overlying aquifers  |
| <b>Residual mass rainfall</b>                     | A measure of rainfall trends – represents the cumulative sum of the residuals between actual monthly rainfall and long term mean monthly rainfall   |
| <b>SVOCs</b>                                      | Semi volatile organic compounds   |
| <b>SKM</b>  | Sinclair Knight Merz  |
| <b>Slug test</b>                                  | An aquifer test made either by inducing an instantaneous change in water level in a bore and measuring recovery (by either adding or removing water or inserting or removing a solid 'slug')  |
| <b>Specific storage</b>                           | The amount of water released from or taken into storage per unit volume of a porous medium per unit change in head  |
| <b>SEPP</b>                                       | State Environment Protection Policy   |
| <b>SOBN</b>                                       | State Observation Bore Network  |
| <b>Storativity</b>                                | The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (equal to the product of specific storage and thickness)  |
| <b>SRB</b>  | Sulfate reducing bacteria   |
| <b>Tanking</b>                                    | Construction process that seals structure from groundwater inflow   |
| <b>TDS</b>  | Total dissolved solids  |
| <b>VOCs</b>                                       | Volatile organic compounds  |





## Executive Summary

This report provides an assessment of groundwater related aspects associated with the construction and operation of the Melbourne Metro Rail Project (Melbourne Metro). Groundwater drawdown would occur when groundwater flows into stations, tunnels, shafts and portals during construction and operation of Melbourne Metro. A variety of methods to be used for the construction of the Melbourne Metro would prevent large groundwater inflows into the structures. As such, the volume of groundwater requiring disposal would be small and would be easily managed.

The small groundwater inflows would also minimise groundwater drawdown around Melbourne Metro structures during construction and operation. This impact assessment predicts the extent of this groundwater drawdown in order to assess impacts on groundwater dependent values. Groundwater dependent values in the context of this impact assessment cover existing bore users, current and future beneficial uses of groundwater, vegetation that may use groundwater, and surface water features that interact with groundwater such as rivers, creeks and lakes.

The risk of contaminant migration caused by changing groundwater gradients and the risk of restricting aquifer flow ('aquifer damming') are also assessed. Other aspects related to groundwater levels and quality are covered in other impact assessments, in particular:

- Ground settlement in Technical Appendix P *Ground Movement and Land Stability*
- The human health impacts of contaminated groundwater and vapour migration into Melbourne Metro structures in Technical Appendix Q *Contaminated Land and Spoil Management*.

## Groundwater Context

The Melbourne Metro consists of the construction of two nine-kilometre rail tunnels from Kensington in the west to South Yarra in the south east. The tunnels would connect the existing Sunbury and Pakenham/Cranbourne rail lines. Melbourne Metro also involves the construction of five new railway stations at Arden, Parkville, CBD North, CBD South and Domain, significantly increasing inner city station capacity, and opening the Parkville and Domain precincts to the heavy rail network for the first time.

Groundwater would be encountered across almost the entire alignment. For planning purposes, the alignment has been divided into the following precincts:

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



## Methodology

The methodology for the groundwater impact assessment included:

- Review of previous studies and other relevant literature describing the hydrogeological conditions along the alignment
- Collation and review of bore data collected for the Melbourne Metro, including bore logs, groundwater level monitoring, aquifer permeability testing, and groundwater quality analysis
- Identification of risks associated with changes in groundwater conditions as a result of construction and operation of the Melbourne Metro
- Identification of values and assets that rely on groundwater within the Study Area
- Assessment of groundwater drawdown during construction and operation of Melbourne Metro, using both analytical approaches and numerical models where available

## Risk Assessment

The risk assessment considered the following potential risks that may arise from changes to groundwater conditions due to Melbourne Metro construction and operation across the study area:

- The risk of groundwater drawdown lowering the watertable such that existing bore owners have reduced access to groundwater
- The risk of groundwater drawdown lowering the watertable such that groundwater dependent vegetation can no longer access groundwater, resulting in impacts to vegetation health
- The risk of groundwater drawdown lowering the watertable and changing the water balance of surface water bodies (such as rivers, creeks, wetlands and lakes) that may interact with groundwater
- The risk of groundwater drawdown causing existing groundwater contaminant plumes to migrate to areas previously unaffected by contamination, precluding the beneficial uses of groundwater at those neighbouring properties. Beneficial uses of groundwater that may be impacted by contaminant migration include drinking water, irrigation, recreational use, and ecosystem uses. Potential vapour migration into underground structures and human health impacts as a result of contaminant migration are also assessed
- The risk of groundwater drawdown occurring where Potential Acid Sulfate Soils (PASS) exist resulting in increased groundwater acidity
- The risk of the Melbourne Metro structures blocking aquifer flow and causing a groundwater 'damming' effect, that increases groundwater levels upstream, and decreases groundwater levels downstream of the structure.

Other risks associated with groundwater contamination are addressed in Technical Appendix Q *Contaminated Land and Spoil Management*, including the risk of contaminated groundwater ingress to the tunnels and stations. The risk of groundwater drawdown causing land settlement is discussed in Technical Appendix P *Ground Movement and Land Stability*, however because groundwater drawdown controls the likelihood of settlement, the mitigation measures required to minimise this risk are discussed in this report.

The risks were assessed based on the design and construction features assumed in the Concept Design. Many of these features, such as tunnel construction using a Tunnel Boring Machine (TBM), or station construction with diaphragm walls or secant piles, restrict groundwater inflows and associated drawdown around the structures. With consideration of these design features, the risk assessment concluded that the majority of groundwater related initial risk ratings are 'low' or 'very low'. For risks with an initial risk rating of 'medium' or higher, a range of mitigation measures can be implemented to reduce the residual risk rating to 'very low' or 'low'. With the appropriate design and implementation of mitigation measures, it is expected that almost all risks can be reduced to a low or very low residual risk, in accordance with the draft EES evaluation objective for Hydrology, Water Quality and Waste Management.



After mitigation measures have been considered, there is only one residual risk that remains 'medium'. This is potential drawdown associated with the construction of CBD North station causing migration of groundwater contaminant plumes, precluding beneficial uses of the groundwater at third party properties.

## Impact Assessment

This impact assessment reviewed the possible degree of impact on groundwater dependent assets and values resulting from construction and operation of Melbourne Metro. Possible impact pathways include changes in groundwater conditions such as groundwater drawdown and gradients. The potential for these pathways to link Melbourne Metro structures to groundwater dependent values (i.e. the receptors) has been assessed to predict the magnitude of potential impacts, and the likelihood of those impacts occurring. Groundwater dependent assets within the areas of drawdown or altered gradients are susceptible to impacts. The results of the impact assessment were used to either revise or confirm the initial risk ratings, to recommend Environmental Performance Requirements to achieve a low residual risk and identify mitigation measures that could be implemented to achieve the recommended Environmental Performance Requirements.

The impact assessment confirmed that most potential impacts are classified as being 'low' or 'very low' initial risk. This is largely because the Concept Design features and assumed construction techniques incorporate features that prevent large groundwater inflows, and therefore minimise groundwater drawdown and associated impacts on groundwater dependent values. These design features and construction techniques are part of the fundamental Concept Design, and include features such as tunnel excavation using TBMs and retaining wall construction (e.g. diaphragm and secant pile walls), which prevent large groundwater inflows during construction. The design feature adopted to prevent inflows during operation is tanking of all structures that are below the watertable, which would achieve specified levels of water tightness. This would mean that groundwater inflows to all stations, portals, tunnels, shafts, adits and cross passages during operation would be minor.

Any future changes to these design features or construction techniques may alter the groundwater inflows and drawdown, and therefore impacts to groundwater dependent values would need to be reassessed. A detailed design phase groundwater model is therefore required to confirm impacts associated with any alterations to project construction or design. The model would assist detailed design of mitigation measures to ensure their effectiveness. This modelling requirement has been included as an overarching Environmental Performance Requirement. Another over-arching Environmental Performance Requirement is for a groundwater management plan to be developed that addresses monitoring, management of drawdown and groundwater disposal.

Based on the Concept Design features, very small impacts that do not require management are anticipated for existing groundwater bore users, and on surface water features such as creeks, rivers, lakes and ponds. The potential for aquifer damming as a result of Melbourne Metro structures creating a barrier to groundwater flow has been assessed and deemed to be low.

Where the impact assessment predicted that there was a 'medium' or higher risk of impacts occurring, Environmental Performance Requirements and mitigation measures have been identified to reduce the initial risk to a lower residual risk ranking. Effective implementation of these mitigation measures would be expected to achieve the Environmental Performance Requirements and reduce the majority of residual risks to either 'low' or 'very low' risk. Mitigation measures could include grouting of tunnels and caverns during construction, which would limit groundwater inflows and drawdown, and also the use of temporary injection bores to maintain groundwater levels during the construction phase. In the Concept Design temporary injection bores are proposed to maintain groundwater levels by injecting water into aquifers during construction at the western portal, Arden station and CBD South station. Effective grouting together with injection wells are reliable measures for preventing impacts to groundwater dependent values as proven by their extensive use in similar projects.



Because of the intensive development and industrial land uses along the alignment, several areas of contamination have been identified that may be affected by groundwater drawdown. There is the potential for migration of these contaminants to neighbouring properties, where it may reduce the beneficial uses of groundwater at those properties, and also potentially cause vapour issues in existing underground structures. However, in most areas the risk of this impact occurring is low, due to both poor quality groundwater (i.e. there are few beneficial uses to be protected), and mitigation measures that prevent drawdown and contaminant migration. The only precinct where this risk remains 'medium' is at CBD North, as discussed below. This report recommends further investigation and consultation with the EPA through the detailed design phase to understand any contamination migration that may occur as a result of groundwater drawdown predicted from the final project design. Environmental Performance Requirements are proposed to require these further investigations, modelling of drawdown and a groundwater management plan to address monitoring and management of contamination.

There is potential that some large trees may have reduced access to groundwater as a result of Melbourne Metro. The EES assessment has found that trees within the project boundary are not considered to be groundwater dependent other than potentially, one tree at the eastern portal (Technical Appendices R and S *Arboriculture*). Trees outside the project boundary have not been assessed but deep-rooted trees in low-lying areas such as near watercourses or waterbodies are considered potentially groundwater dependent. These should be identified and irrigated through the period of drawdown, if necessary. Environmental Performance Requirements have captured this requirement for the precincts where potentially groundwater dependent vegetation has been identified.

Potential Acid Sulfate Soils (PASS) and rock may exist along the alignment, and groundwater drawdown could expose these soils and rock, causing them to oxidise and release acid and metals. However, with achievement of the Environmental Performance Requirements and implementation of mitigation measures to reduce drawdown, the risk of groundwater acidification and quality impacts due to PASS activation is low. Drawdown at CityLink bores during construction is predicted to be minor, but Environmental Performance Requirements have been assigned for the relevant precincts to ensure that mitigation measures are implemented and are effective.

The predicted volume of groundwater inflow to project structures during the construction phase is minor due to the proposed construction techniques and the tanking of structures for operation. Disposal of this groundwater needs to be confirmed with relevant authorities but due to the small volumes, it is considered to be relatively easily managed. Options for the disposal of groundwater derived from predicted construction inflows over time have been assessed and are summarised in Section 17. As the groundwater over the route is generally moderately saline, groundwater inflows usually would have a high salt load. Feasible options to dispose of the up to 7 L/sec inflows are to sewer and/or to stormwater, with sewer being the proposed option.

The development of a Groundwater Management Plan (GMP) is included as an overarching Environmental Performance Requirement. The GMP would be based on the impacts predicted in the detailed design phase groundwater model, and would detail the management approaches, mitigation measures, and monitoring required to satisfy the Environmental Performance Requirements in this report. Monitoring of groundwater levels and inflows during construction would also be implemented to confirm that drawdown stays within predicted levels, and that the possible anticipated impacts on groundwater dependent assets are being appropriately mitigated.

The investigations undertaken to date provide a good understanding of the hydrogeological conditions across the Melbourne Metro alignment. Numerical and analytical modelling of the Concept Design has identified that, with the use of commonly used design features and construction techniques, groundwater inflow into underground infrastructure would be low and manageable during construction. The groundwater drawdown predicted for construction of the Concept Design is manageable and direct impacts to groundwater dependent ecosystems, beneficial uses and surface water bodies of the Concept Design would be acceptable. For Melbourne Metro, the impacts of groundwater drawdown on ground settlement and



movement of existing contaminated groundwater are the key drivers for further reduction of groundwater inflow into the underground structures and therefore reduction of groundwater drawdown. For this reason, it is not appropriate to identify a fixed target for acceptable groundwater drawdown, as the acceptable level would vary across the alignment depending on hydrogeological conditions and groundwater quality, and impacts of drawdown in those prevailing conditions. Settlement and contamination are discussed in Technical Appendix P *Ground Movement and Land Stability* and Technical Appendix Q *Contaminated Land and Spoil Management*, but this groundwater impact assessment identifies mitigation measures that are commonly used in construction, additional to the Concept Design features that minimise groundwater inflows, that could be used to reduce groundwater drawdown and achieve the Environmental Performance Requirements to manage those issues.

Because all underground structures would be tanked (sealed) post construction, groundwater inflow and consequent drawdown during the operational phase would be very low and manageable. Impacts on groundwater dependent ecosystems, surface water bodies, beneficial uses of properties and settlement impacts are predicted to be acceptable.

## Environmental Performance Requirements

The following Environmental Performance Requirements are recommended:

### Environmental Performance Requirements

Design the tunnel and underground structures so that they minimise groundwater drawdown during construction and operation to minimise impacts on groundwater dependent values, ground movement and contamination plume migration.

Develop a groundwater model for the detailed design phase to predict impacts associated with any changes to construction techniques or operational design features proposed during detailed design, and reconfirm that the Environmental Performance Requirements and mitigation measures are sufficient to mitigate impacts from changes in groundwater levels, flow and quality.

Undertake monitoring during construction to ensure that predictions are accurate and mitigation measures are appropriate.

Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction.

The GMP must be based on the detailed design phase groundwater model, and should include the following details:

- Approach to collection, treatment and disposal of groundwater collected during construction in accordance with the MMRA Groundwater Disposal Strategy
- Identifying and if necessary, specifying mitigation measures to protect groundwater dependent vegetation during periods of drawdown
- An approach identified in consultation with the EPA so that contaminant migration cause no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach
- Methods for minimising drawdown in areas of known PASS and establishing appropriate monitoring networks to confirm effectiveness of approach
- Methods for minimising drawdown at any existing recharge bores, and establishing appropriate monitoring networks to confirm effectiveness of mitigation
- Groundwater drawdown trigger levels for groundwater dependant values at which additional mitigation measures must be adopted
- Design, operation and management of groundwater injection borefields
- Contingency measures if impacts occur at existing active groundwater bores and surface water bodies



## Environmental Performance Requirements

- Contingency measures should unexpected groundwater conditions be encountered.

The GMP must satisfy the EPA and relevant water authorities that groundwater dependent values will be protected. The groundwater management plan should also address MMRA's sustainability requirements where appropriate.

Use the Groundwater Disposal Strategy and GMP to obtain a Trade Waste Agreement with the relevant Water Retailers for groundwater disposal.

Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:

- Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures
- Activation of PASS and groundwater acidification
- Reduction in access to water for bore owners in the area around the project
- Reduction in access to groundwater for trees– particularly in the Tunnels precinct between CBD South and Domain stations, and the CBD South station and eastern portal precincts
- Change in groundwater levels in any existing recharge bores that may be present in the area around the project.

## Benefits and Opportunities

No benefits and opportunities associated with the tunnels, stations or portals have been identified in relation to groundwater at Melbourne Metro station, portal or tunnel precincts. There are two potential benefits associated with the planned early works on the South Yarra Main Sewer.

| Concept Design   | Benefits  | Opportunities |
|--|---|---------------|
| Early works: South Yarra Main Sewer relocation and replacement works – Domain station. | Replacement would decrease the volume of regional groundwater ingress to the sewer. | None          |
| Early works: South Yarra Main Sewer relocation and replacement works – Domain station. | Recovery of groundwater levels in the vicinity of the replaced sewer section.       | None          |



# 1 Introduction

This report provides an assessment of the groundwater impacts associated with the Melbourne Metro Rail Project (Melbourne Metro). Related issues are addressed in other impact assessments:

- Technical Appendix N *Surface Water*
- Technical Appendix P *Ground Movement and Land Stability*
- Technical Appendix Q *Contaminated Land and Spoil Management*
- Technical Appendix R and S *Arboriculture*
- Technical Appendix T *Terrestrial Flora and Fauna*
- Technical Appendix U *Aquatic Ecology and River Health*.

## 1.1 Project Description

The Melbourne Metro comprises two nine-kilometre long rail tunnels from Kensington to South Yarra, travelling underneath Swanston Street in the Central Business District (CBD), as part of a new Sunbury to Cranbourne/Pakenham line to form the new Sunshine-Dandenong Line.

The infrastructure to be constructed as part of Melbourne Metro is shown in Figure 1-1 and broadly comprises:

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

Proposed construction methods would involve bored and mined tunnels, cut and cover construction of station boxes at Arden, Parkville and Domain and portals, and cavern construction at CBD North and South. The project would require planning, environmental and land tenure related approvals in order to proceed.

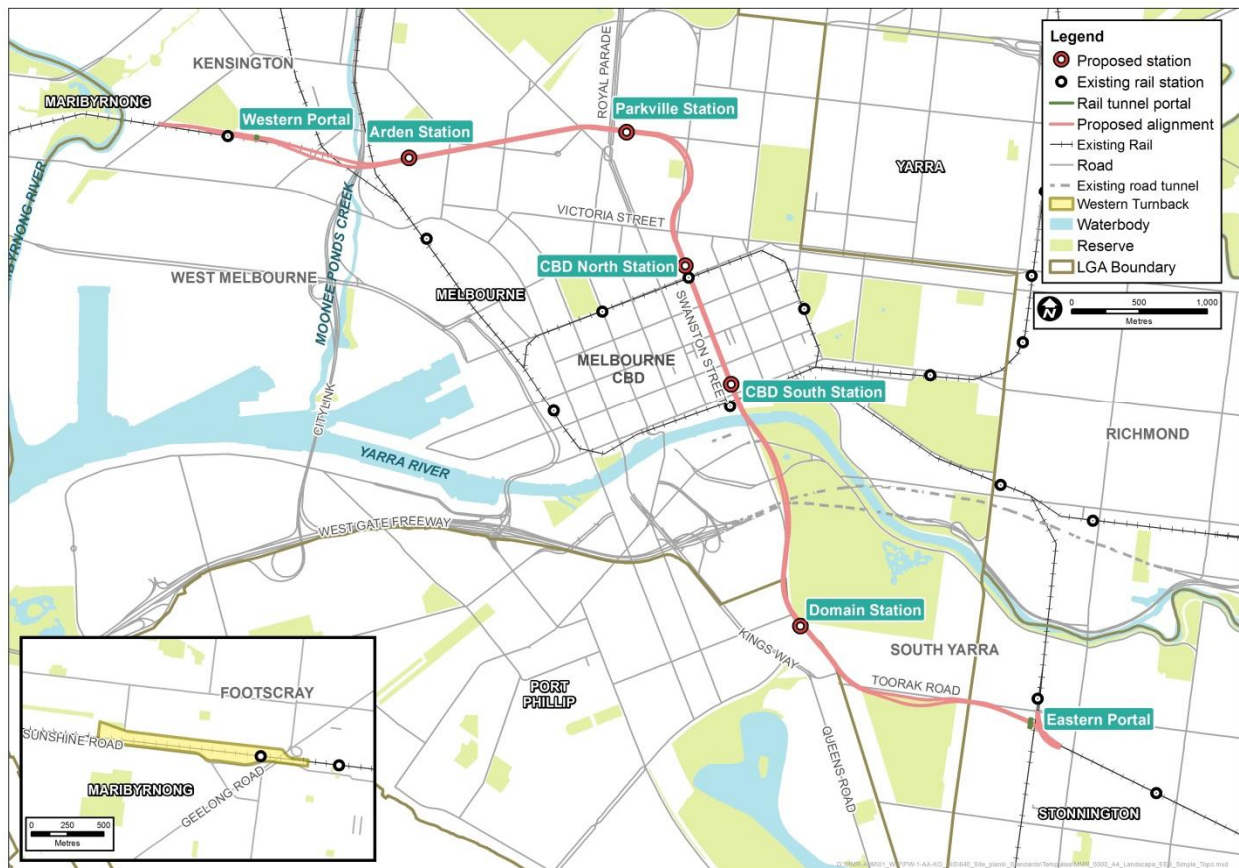


Figure 1-1 Map of the Melbourne Metro alignment and five underground stations

### 1.1.1 Purpose of this Assessment

The purpose of this assessment is to identify the risks and assess the impacts to groundwater values within the vicinity of the project boundary.

This report considers all the risks that may arise as a result of changes in groundwater levels and flow. The primary way that construction and operation of Melbourne Metro may change groundwater levels and flow is when groundwater inflow to the structures causes lower groundwater levels in the surrounding aquifer. Drawdown in groundwater levels may occur over a large area surrounding the structure if inflows are large, or may occur over a small area if inflows are minor. The risk of impacts on environmental, social and economic receptors caused by groundwater drawdown are assessed in this report.

Other risks associated with subsurface processes are covered in other impact assessments. Specifically:

- Potential impacts associated with land subsidence are assessed in Technical Appendix P *Ground Movement and Land Stability*
- Groundwater contamination, vapour migration and human health considerations for Melbourne Metro workers and users in Technical Appendix Q *Contaminated Land and Spoil Management*.

The reason for this split is the different scales of investigation required. Groundwater impacts such as drawdown may affect a wider area and as such, a broader understanding of existing conditions and potential receptors is required. Risks associated with contaminated land occur through direct contact with contaminants within the project boundary, and as such, the impact assessment must focus on contaminants at specific sites along the alignment.





The groundwater impacts are the result of groundwater movement whereas contaminated groundwater investigations are concentrated on an individual site/s where movement of groundwater is generally insignificant. A regional assessment of groundwater movement induced by Melbourne Metro is therefore the focus of this document.

## 1.2 Project Precincts

For assessment purposes, the project boundary has been divided into precincts as outlined below. The precincts have been defined based on the location of project components and required construction works, the potential impacts on local areas and the character of surrounding communities.

The precincts are:

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

The nine precincts are shown in Figure 1-2.

## 1.3 Study Area

The two tunnels are 9 km long from Kensington in the west to South Yarra in the east and comprise above ground and below ground infrastructure. In order to capture the hydrogeological setting for the project, a wider study area than the immediate vicinity of the tunnels has been considered (Figure 1-3).

The wider study area includes an approximately 3 km wide corridor through central Melbourne from the Maribyrnong River to South Yarra. The western turnback would be located at West Footscray station to the west of the main study area.

The study area for the groundwater impact assessment is much larger than the Concept Design boundary, and has been based on the extent of the regional groundwater model developed by Golder (Golder Associates, 2016b, Appendix H p8). The study area covers an area of approximately 26 km<sup>2</sup>, as shown on Figure 1-3. The vertical extent of the study area is based on the vertical alignment of Melbourne Metro infrastructure (as shown in the EES Map Book) and is up to 40 m below ground level.

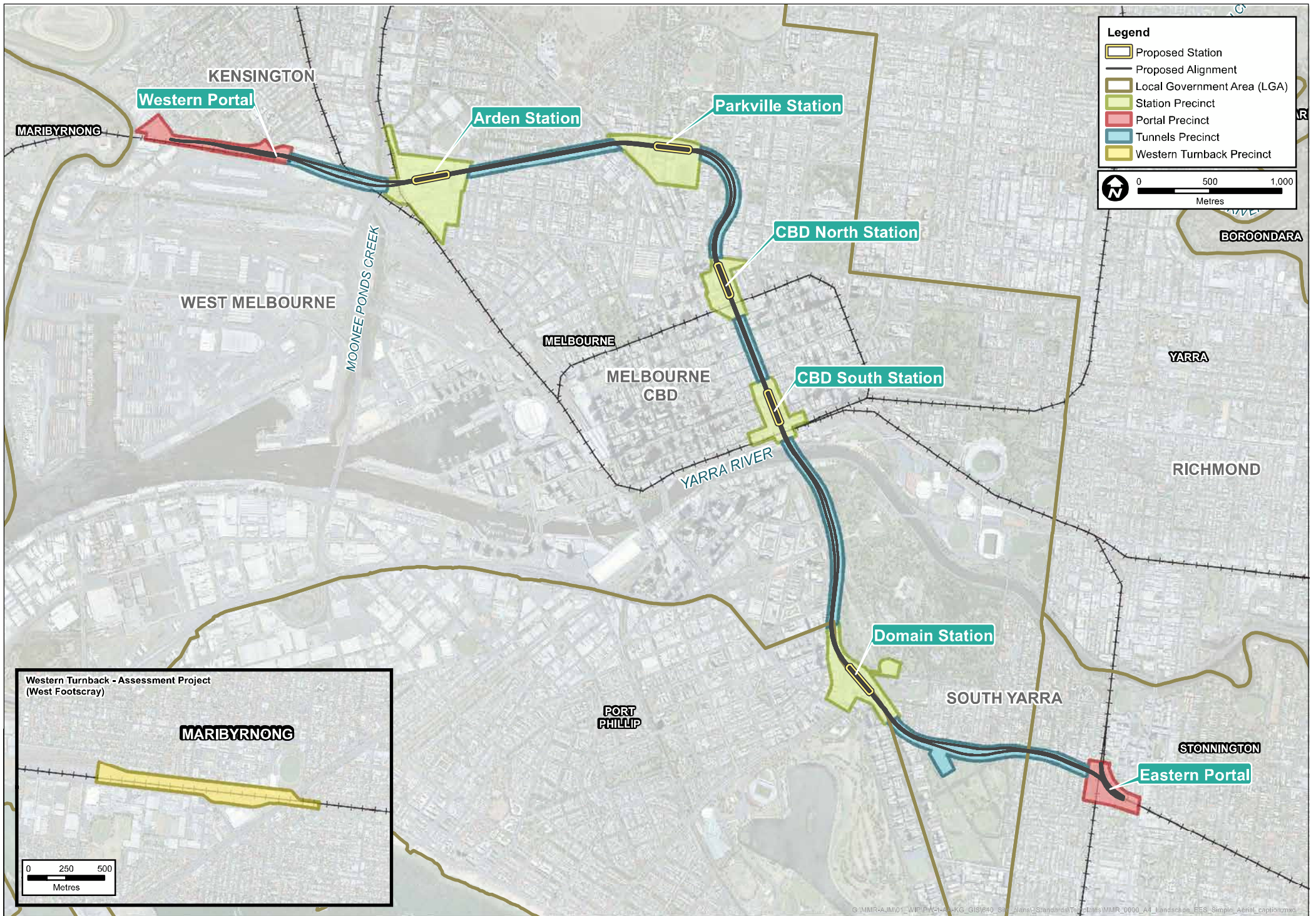
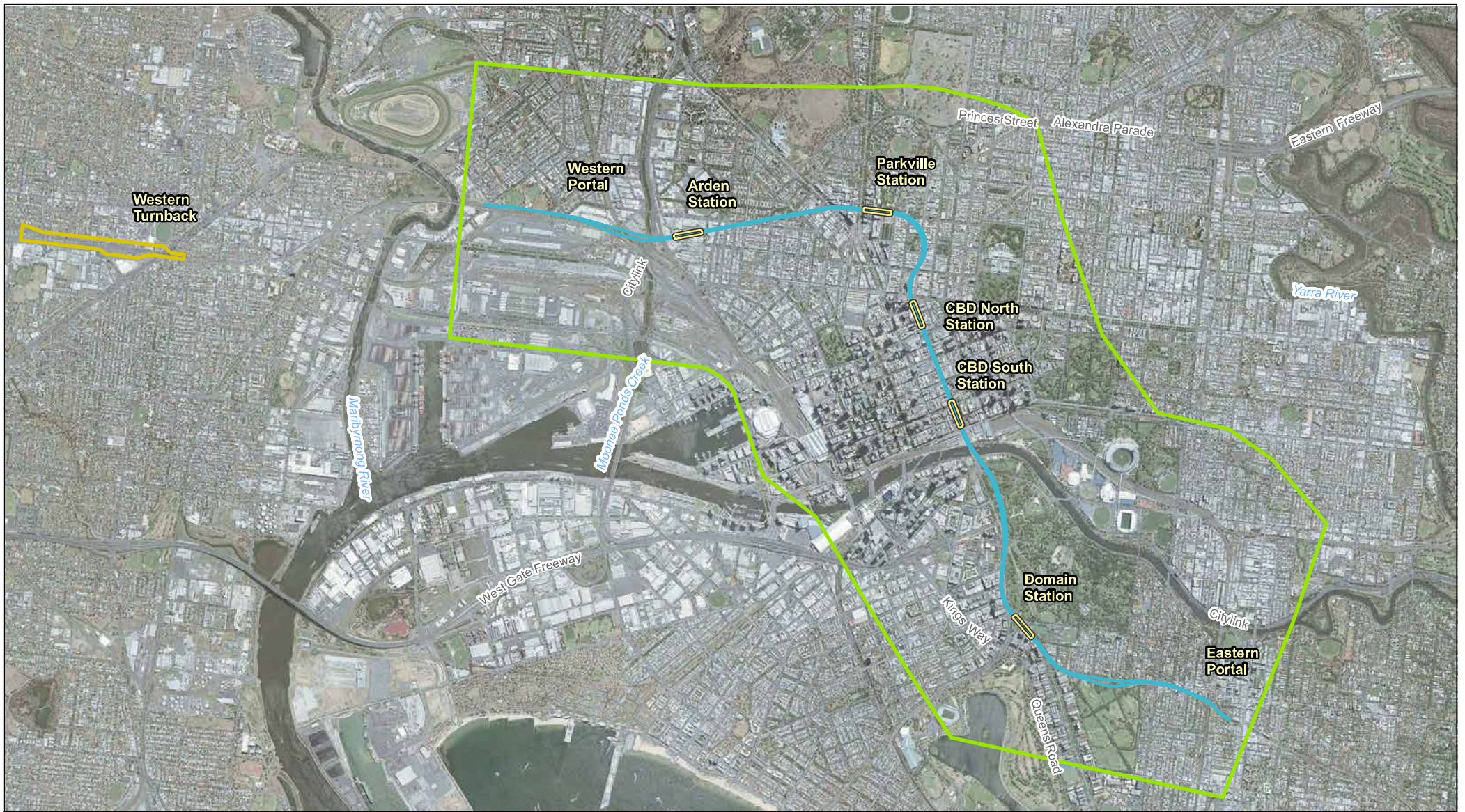
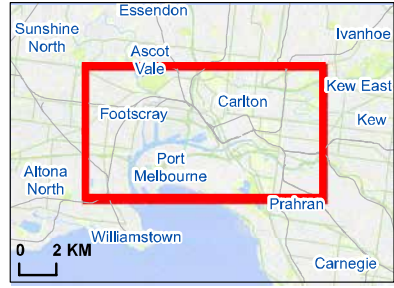


Figure 1-2 Melbourne Metro precincts



- Legend**
- Proposed Alignment
  - Proposed Station Footprint
  - Western Turnback Precinct
  - Study Area

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



**Melbourne Metro Rail Project**

|  |                            |                    |                 |
|--|----------------------------|--------------------|-----------------|
| Title:<br>Groundwater study area             |                            |                    |                 |
| Drawing Number:<br>MMR-AJM-UGAA-MP-NK-500190 |                            | Revision:<br>P1    |                 |
| Drawn By:<br>A. Davy                         | Approved By:<br>K. Dowsley | Date:<br>7/04/2016 | Map Size:<br>A4 |

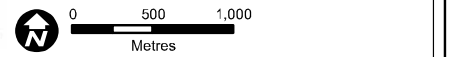


Figure 1-3 Study area for Melbourne Metro groundwater impact assessment

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## 2 Scoping Requirements

### 2.1 EES Objectives

The following draft evaluation objective (Table 2-1) is relevant to groundwater and identifies the desired outcomes in the context of potential project effects. The draft evaluation objective and associated assessment criteria provide a framework to guide an integrated assessment of potential environmental impacts of the project, in accordance with the *Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978*.

Table 2-1 Draft Evaluation objectives for hydrology, water quality and waste management

| Draft EES evaluation objectives   | Key legislation   |
|---|---|
| <p><b>Hydrology, water quality and waste management:</b> To protect waterways and waterway function and surface water and groundwater quality in accordance with statutory objectives, to identify and prevent potential adverse environmental effects resulting from the disturbance of contaminated or acid-forming material and to manage excavation spoil and other waste in accordance with relevant best practice principles.</p> | <p><i>Environment Protection Act 1970</i> and State Environment Protection Policies and guidelines.</p> |

### 2.2 EES Scoping Requirements

The following extracts from the Scoping Requirements, issued by the Minister for Planning, are relevant to the hydrology, water quality and waste management evaluation objectives (Table 2-2).

Table 2-2 Scoping Requirements for hydrology, water quality and waste management

| Aspect   | Relevant response  |
|--|--|
| <p><b>Key Issues</b></p>   | <ul style="list-style-type: none"> <li>• Potential for contaminated run-off or other water, including groundwater, to be discharged into surface waters or groundwater</li> <li>• Potential for disturbance of anthropogenic contaminated soil or groundwater or naturally occurring potential acid sulphate soils.</li> </ul>   |
| <p><b>Priorities for characterising the existing environment</b></p> | <ul style="list-style-type: none"> <li>• Identify existing groundwater conditions and characteristics within the general area that might be affected by project works.</li> </ul>  |
| <p><b>Design and mitigation measures</b></p>                         | <ul style="list-style-type: none"> <li>• Identify proposed design, management and mitigation measures to be used to protect surface water quality, especially during the construction phase, in the light of relevant SEPP objectives and other relevant standards and guidelines</li> <li>• Identify measures to protect groundwater and aquifers, including with respect to the potential effects of constructing and operating the tunnels and underground stations.</li> </ul>   |
| <p><b>Assessment of likely effects</b></p>                           | <ul style="list-style-type: none"> <li>• Assess potential for the project to cause short-term or longer-term changes to groundwater conditions, with particular regard to ground subsidence, tunnel drainage, groundwater quality and beneficial uses</li> <li>• Assess potential for disturbance of contaminated soil, acid sulphate soils or contaminated groundwater to affect users or environmental values</li> <li>• Assess potential for treatment of contaminated material to enable it to be reused or recycled rather than disposed of.</li> </ul> |
| <p><b>Approach to manage performance</b></p>                         | <ul style="list-style-type: none"> <li>• Describe principles to be adopted for setting programs for monitoring flooding events during construction (if they occur), surface water and groundwater quality and groundwater levels.</li> </ul>   |



| Aspect | Relevant response  |
|--------|--|
|        | <ul style="list-style-type: none"><li>Describe principles to be adopted for developing contingency to be implemented if unexpected adverse effects are identified.</li></ul> |

The evaluation objective and associated scoping requirements for hydrology, water quality, and waste management link several of the impact assessments conducted for the EES. This report discusses potential impacts on groundwater and the assets that rely on groundwater, however related issues are addressed in other impact assessments:

- Technical Appendix N *Surface Water*
- Technical Appendix P *Ground Movement and Land Stability*
- Technical Appendix Q *Contaminated Land and Spoil Management*
- Technical Appendix R and S *Arboriculture*
- Technical Appendix T *Terrestrial Flora and Fauna*
- Technical Appendix U *Aquatic Ecology and River Health*.

For groundwater, the primary impact on groundwater as a result of construction and operation of Melbourne Metro is the potential to impact on existing conditions and beneficial uses of groundwater through drawdown of the watertable. Leakage of groundwater into Melbourne Metro structures can cause the watertable around the structures to decline. Where there are existing users of groundwater from the watertable aquifers, the decline in watertable levels may reduce groundwater availability to those users. Users include groundwater dependent vegetation, surface water bodies, and groundwater bores. The drawdown in the watertable may also create a gradient that can cause contaminants within the groundwater to migrate. Where this occurs, contamination may migrate to neighbouring properties, thereby precluding certain beneficial uses of the groundwater at those properties.

Since drawdown in watertable levels would be the primary pathway for impact on existing groundwater users, this impact assessment report focusses on predicting drawdown around Melbourne Metro structures and assessing whether the predicted area over which drawdown occurs coincides with existing groundwater users. Where drawdown and existing users overlap, there would be the potential for impact. In these cases, mitigation measures would be required to avoid or minimise impacts on the identified groundwater users.

Groundwater drawdown can also cause settlement. A detailed assessment of those risks and impacts is set out in Technical Appendix P *Ground Movement and Land Stability*. This groundwater impact assessment assesses groundwater drawdown and recommends a series of mitigation measures that can reduce groundwater drawdown where required, and minimise impacts on groundwater dependent values as well as minimising ground settlement.



### 3 Legislative Framework

Table 3-1 summarises the relevant primary legislation that applies to the project as well as the implications, required approvals and interdependencies and information requirements associated with obtaining approvals. Descriptions of all relevant legislation are contained in Appendix A of this report.

**Table 3-1 Primary legislation and associated information**

| Legislation / policy                                    | Key policies / strategies   | Implications for this project | Approvals required | Timing / interdependencies |
|---|---|-------------------------------|--------------------|----------------------------|
| <b>Commonwealth</b>                                     |   |                               |                    |                            |
| <b>National Environment Protection Council Act 1994</b> | NEPC 1999. The National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1) Amendment of the National Environment Protection (Assessment of Site Contamination) Measure 1999.<br><br>National Health and Medical Research Council (NHMRC) 2008. Guidelines for Managing Risks in Recreational Water.<br><br>Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ (2000).<br><br>Australian Drinking Water Guidelines (NHMRC/NRMMC (2011)), National Water Quality Management Strategy.<br><br>Minimum Construction Requirements for Water Bores in Australia (NUDLC, 2012).<br><br>National Water Quality Management Strategy, Guidelines for Groundwater Quality Protection in Australia (Australian Government 2013) | Project wide                  | NA                 | NA                         |
|   | National Health and Medical Research Council (NHMRC) 2008. Guidelines for Managing Risks in Recreational Water.   | Project wide                  | NA                 | NA                         |
| <b>Groundwater Modelling Guidelines 2012</b>            | Australian groundwater modelling guidelines - Waterlines Report Series No. 82, June 2012 (Sinclair Knight Merz and National Centre for Groundwater Research and Training  | Project wide                  | NA                 | NA                         |



| Legislation / policy   | Key policies / strategies  | Implications for this project  | Approvals required  | Timing / interdependencies  |
|--|--|--|---|---|
| <b>State</b>   |  |  |   |   |
| <b>Water Act 1989</b>  | <p>Allocating surface water and groundwater throughout Victoria – including for dewatering.</p> <p>Sections 67 and 72 – issuing bore licences.</p> <p>These licensing systems are administered by the rural water authorities (Southern Rural Water in southern Victoria).</p>   | <p>Groundwater dewatering and recharge through bores requires a licence from Southern Rural Water (for construction of bores and for pumping from/to bores).</p> | <p>Southern Rural Water – licence to construct bores for dewatering or recharge.</p> <p>Southern Rural Water – licence to pump from or inject to groundwater.</p> | <p>These licences require a hydrogeological assessment to be undertaken.</p>  |
| <b>Planning and Environment Act 1987</b>   | <p>No specific requirements but implies a general responsibility to planning authorities to consider the effects of ground movement.</p>   | <p>Should consider impacts of ground movement on environment as well as social and economic effects.</p>   | <p>No specific requirements.</p>  | <p>NA</p>   |
| <b>Environment Protection Act 1970</b>   | <p>State Environmental Protection Policy Groundwaters of Victoria, 1997.</p> <p>State Environmental Protection Policy Waters of Victoria, 2003.</p> <p>State Environmental Protection Policy Prevention and Management of Contaminated Land, 2002.</p> <p>Industrial Waste Management Policy Waste Acid Sulfate Soils, 1999.</p> <p>Environmental Guidelines for Major Construction Sites, EPA Publication 480 (1996).</p> | <p>Must consider the impacts to groundwater and surface water quality.</p>   | <p>NA</p>   | <p>NA</p>   |
| <b>State Environmental Protection Policy (Groundwaters of Victoria), Victoria Government Gazette No S160</b> | <p>EPA Victoria 2000. Groundwater Sampling Guidelines. Publication 669.</p> <p>EPA Victoria 2006. Guidelines for Hydrogeological (Groundwater Quality) Assessments. EPA Publication 668.</p> <p>EPA Victoria 2014. The cleanup and management of polluted groundwater. EPA Publication 840.1.</p>  | <p>Contaminated groundwater and pollution.</p>   | <p>Potential audit triggers.</p>  | <p>It has not been determined if EPA would require an Environmental Audit and if so what type (53V or 53X) and how long it would take – assume audit concurrent with works (eg 53V)</p> |



| Legislation / policy   | Key policies / strategies   | Implications for this project  | Approvals required   | Timing / interdependencies  |
|--|---|--|--|---|
|  | <p>National Health and Medical Research Council (NHMRC) 2008. Guidelines for Managing Risks in Recreational Water.</p> <p>Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ (2000).</p> <p>Australian Drinking Water Guidelines (NHMRC/NRMMC (2011)), National Water Quality Management Strategy.</p> <p>Minimum Construction Requirements for Water Bores in Australia (NUDLC, 2012).</p> <p>Australian Standard AS4482.1 - 2005 Guide to the investigation and sampling of sites with potentially contaminated soil Part 1: Non-volatile and semi-volatile compounds.</p> <p>Australian Standard AS4482.2 - 1999 Guide to the sampling and investigation of potentially contaminated soil Part 2: Volatile substances.</p> |  |  | <p>However EPA determination of audit requirement and approval of scope may take time – assume one - three months.</p>  |
| <p><b>State Environment Protection Policy (Prevention and Management of Contaminated of Land) No. S95</b></p> <p><b>State Environmental Protection Policy (Groundwaters of Victoria), Victoria Government Gazette No S160.</b></p> <p><b>Environment Protection (Industrial Waste Resource) Regulations 2009</b></p> | <p>DSE 2005. Potentially Contaminated Land. General Practice Note.</p> <p>Department of Transport, Planning and Local Infrastructure 2006. Victoria Planning Provisions (VPP) Environmental Audit Overlay. Clause 45.03 Sourced from <a href="http://planningschemes.dpcd.vic.gov.au/schemes/vpps">http://planningschemes.dpcd.vic.gov.au/schemes/vpps</a> - accessed 17/03/2015.</p>   | <p>Treatment or containment of soil and groundwater contamination.</p> | <p>Potentially:<br/>Audit triggers.</p>                                | <p>It has not been determined if EPA would require an Environmental Audit and if so what type (53V or 53X) and how long it would take – assume audit concurrent with works (e.g. 53V).</p> <p>However EPA determination of audit requirement and approval of scope may take time – assume one - three months.</p> |
| <p><b>Water Act. 1989.</b></p> <p><b>Water Industry Regulations 2006</b></p>   | <p>Various Trade Waste Policies and guidelines from the Water Authorities.</p>  | <p>Discharges</p>  | <p>Potentially:<br/>Audit triggers<br/>Water Authorities approvals</p> | <p>It has not been determined if EPA would require an Environmental Audit and if so what type (53V or 53X) and how long it would take – assume audit concurrent with</p>  |





| Legislation / policy   | Key policies / strategies  | Implications for this project   | Approvals required | Timing / interdependencies   |
|--|--|---|--------------------|--|
|  |  |   |                    | works (eg 53V).<br>However EPA determination of audit requirement and approval of scope may take time – assume one - three months. |
| <b>Water Industry Regulations 2006</b><br><br><b>Environment Protection (Prescribed Waste Resource) Regulations 2009</b> | EPA 1991. Construction techniques for sediment pollution control. EPA Publication 275.<br><br>EPA 1996. Environmental Guidelines for Major Construction Sites. Best Practice Environmental Practice. Publication 480.<br><br>EPA 2009. Guidelines for risk assessment of wastewater discharges to waterways. EPA Publication 1287. | Discharges.   | NA                 | Timing of EPA approvals process cannot be determined at this time – assume one – three months.                                     |
| <b>Public Health and Wellbeing Act 2008</b>  | Various policies for avoiding nuisance (contamination)   | May require action to avoid movement of groundwater contaminant plumes. | NA                 | NA   |



## 4 Methodology

### 4.1 Previous Investigations

A series of previous investigations undertaken for Melbourne Metro were relied upon for this impact assessment. These investigations are described in the Melbourne Metro Interpreted Hydrogeological Setting – EES Summary Report (Golder Associates, 2016a), which is included in Appendix G of this report. A summary of the previous investigations is provided below.

- Stage 1 – June to November 2010 – included drilling and installation of 17 groundwater monitoring bores, hydraulic testing (17 bores) and groundwater sampling (16 bores). This work was undertaken on an alignment consistent with the current Melbourne Metro design, and the interpretation of this data included tunnel inflow modelling (using analytical techniques) and drawdown estimations
- Stage 2 Phase 1 – 2011 – hydraulic testing and groundwater sampling of accessible Stage 1 bores
- Stage 2 Phase 2a – November 2011 to February 2012 – included drilling and installation of nine groundwater monitoring bores, hydraulic testing (nine bores) and groundwater sampling (nine bores). A groundwater numerical model was developed as part of this Stage/Phase. As with the Stage 1 investigations, this work was also undertaken on an alignment consistent with the Melbourne Metro design
- Stage 2 Phase 2b – October to December 2012 – included drilling and installation of six groundwater monitoring bores, hydraulic testing (two bores) and groundwater sampling (six bores)
- Stage 2 Phase 2c – May to August 2013 – included drilling and installation of nine groundwater monitoring bores, hydraulic testing (four bores) and groundwater sampling (six bores)
- Concept Design Phase – June to September 2015 – included drilling and installation of 29 groundwater monitoring bores, hydraulic testing (17 bores) and groundwater sampling (18 bores).

The field data collected during these investigations enabled the hydrogeological conditions along the alignment to be characterised. Specifically, this included delineating the geological units, particularly the complex aquifer sequences in the Moonee Ponds Creek and Yarra River palaeovalleys. Simple hydraulic tests (slug tests and packer tests) were performed on most bores to determine aquifer parameters for each unit, which is particularly important for understanding groundwater flow and therefore, for modelling impacts. In addition to these tests, a longer term (9 day) pumping test was undertaken near St Paul's Cathedral to test the permeability of the Melbourne Formation, and to assess the influence of drawdown in the Melbourne Formation on the adjacent Yarra River palaeovalley sediments.

Groundwater levels were measured for each bore, indicating existing groundwater levels in aquifers at tunnel depth, and the range of natural variation in levels where multiple monitoring phases were undertaken. Groundwater samples and analysis occurred at many bores to gain an understanding of existing groundwater quality. This information is important for determining the quality of groundwater inflows to Melbourne Metro structures, and therefore influences inflow disposal options. It is also necessary for defining existing beneficial uses of groundwater along the alignment which must be protected.

The relationship between EES Specialist Reports and the supporting Golder EES Summary Reports is shown in Table 4-1. The Golder EES Summary Reports directly relevant to this report are included in Appendix G (Interpreted Hydrogeological Setting, Golder, 2016a) and Appendix H (Regional Groundwater Numerical Modelling, Golder, 2016b). The appended reports were informed by the Golder Interpreted Geological Setting EES Summary Report and the Golder Contaminated Land Assessment EES Summary Report, as indicated in Table 4-1.



Table 4-1 Relationship between EES Specialist Reports and the supporting Golder EES Summary Reports

|                           |  | EES Specialist Reports             |                            |             |  |
|---------------------------|--|------------------------------------|----------------------------|-------------|--|
|                           |  | Ground movement and Land Stability | Future Development Loading | Groundwater | Contaminated Land and Spoil Management |
| Golder EES Summary Report | Ground Movement Assessment               |                                    |                            |             |  |
|                           | Interpreted Geological Setting           |                                    |                            |             |  |
|                           | Interpreted Hydrogeological Setting      |                                    |                            |             |  |
|                           | Regional Groundwater Numerical Modelling |                                    |                            |             |  |
|                           | Contaminated Land Assessment             |                                    |                            |             |  |

In addition, information for assessing the potential groundwater dependence of trees along the Melbourne Metro alignment was contained in Technical Appendices R and S *Arboriculture*.

The following online resources were also utilised:

- The Bureau of Meteorology (BoM) Groundwater Dependent Ecosystems Atlas (<http://www.bom.gov.au/water/groundwater/gde/>) for information on potentially groundwater dependent vegetation, rivers, creeks, lakes and wetlands
- The Victorian Water Measurement Information System (<http://data.water.vic.gov.au/monitoring.htm>) to identify existing groundwater bore locations.
- Visualising Victoria's Groundwater (<http://www.vvg.org.au/>) for information on the location of contaminated sites.

## 4.2 Peer Review

This assessment has been independently peer reviewed by Mr Hugh Middlemis of HydroGeoLogic Pty Ltd. The peer reviewer reviewed and provided feedback on drafts of this report. The peer reviewer's methodology is set out in their report, but in general terms it included a review of the assumptions, methodology, assessment criteria and scope applied in this report. It also addressed whether there were any additional matters which should be considered as part of the impact assessment in order to address the EES Scoping Requirements that are relevant to groundwater impacts or management. The peer reviewer was also required to consider whether there are any gaps or matters where they disagreed with this assessment. The final peer review report is attached at Appendix B of this report, which sets out the peer reviewer's conclusions in relation to this report, and whether or not all of their recommendations were adopted.

## 4.3 Risk Assessment

### 4.3.1 Overview

An Environmental Risk Assessment has been completed for impacts of Melbourne Metro. The risk-based approach is integral to the EES. Importantly, an environmental risk is different from an environmental impact. Risk is a function of the likelihood of a hazardous event occurring and the expected consequence if that



hazardous event occurred. Impact measures the extent to which the values of a resource or a receptor would be altered as a result of the hazardous event occurring. Impact assessments are important in order to better understand the likely outcome of hazardous events, while risk assessments are needed so that the level of effort committed to avoiding an impact is commensurate with the likelihood of that impact occurring.

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

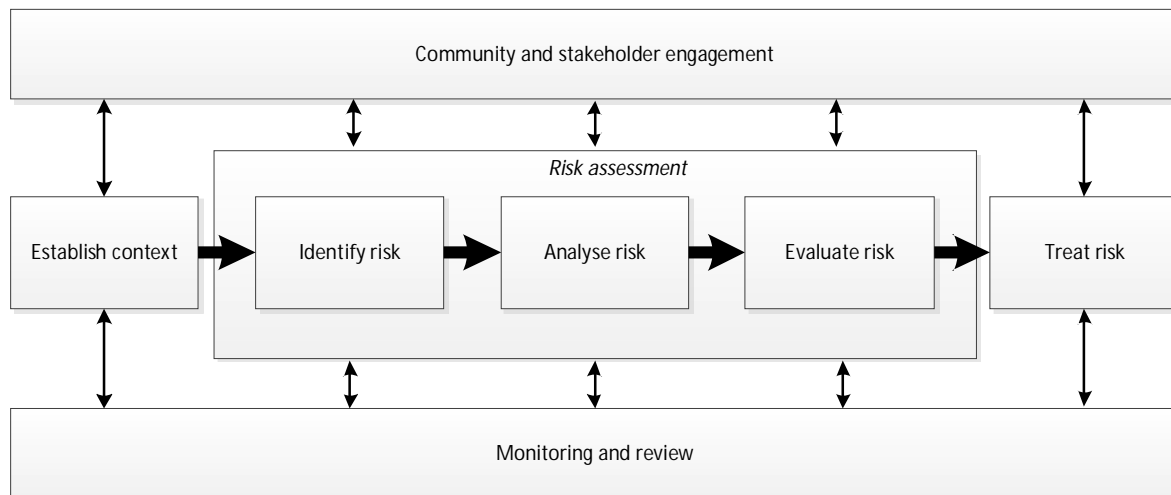


Figure 4-1 Overview of AS/NZS ISO 31000-2009 Risk Process

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

#### 4.3.2 Context

The overall context for the risk assessment and a specific context for each specialist study is described in Technical Appendix B *Environmental Risk Assessment Report*. The context describes the setting for evaluation of risks arising from Melbourne Metro. The specific context for the groundwater impact assessment is provided below:

*Groundwater can be a valuable resource with a wide range of beneficial uses as described in the SEPP (Groundwaters of Victoria). Due to one or a combination of high salinity or contamination from previous urban activities, the beneficial uses in the central Melbourne area are generally, dependent upon location, restricted to maintenance of ecosystems (if surface water bodies or vegetation is dependent upon groundwater, at least at some times), agriculture, parks and gardens (restricted), stock watering (restricted), industrial water use, primary contact recreation (restricted) and/or buildings and structures. Many Groundwater Quality Restricted Use Zone (GQRUZs) have been designated by the EPA at sites in the vicinity of the Melbourne Metro alignment, indicating that groundwater is contaminated to an extent that it is not suitable for certain beneficial uses. Disposal of groundwater would be in accordance with a Groundwater Disposal Strategy which would provide for treatment in accordance with the relevant statutory requirements, Water Industry Regulations 2006, SEPP (Waters of Victoria) and SEPP (Groundwaters of Victoria).*

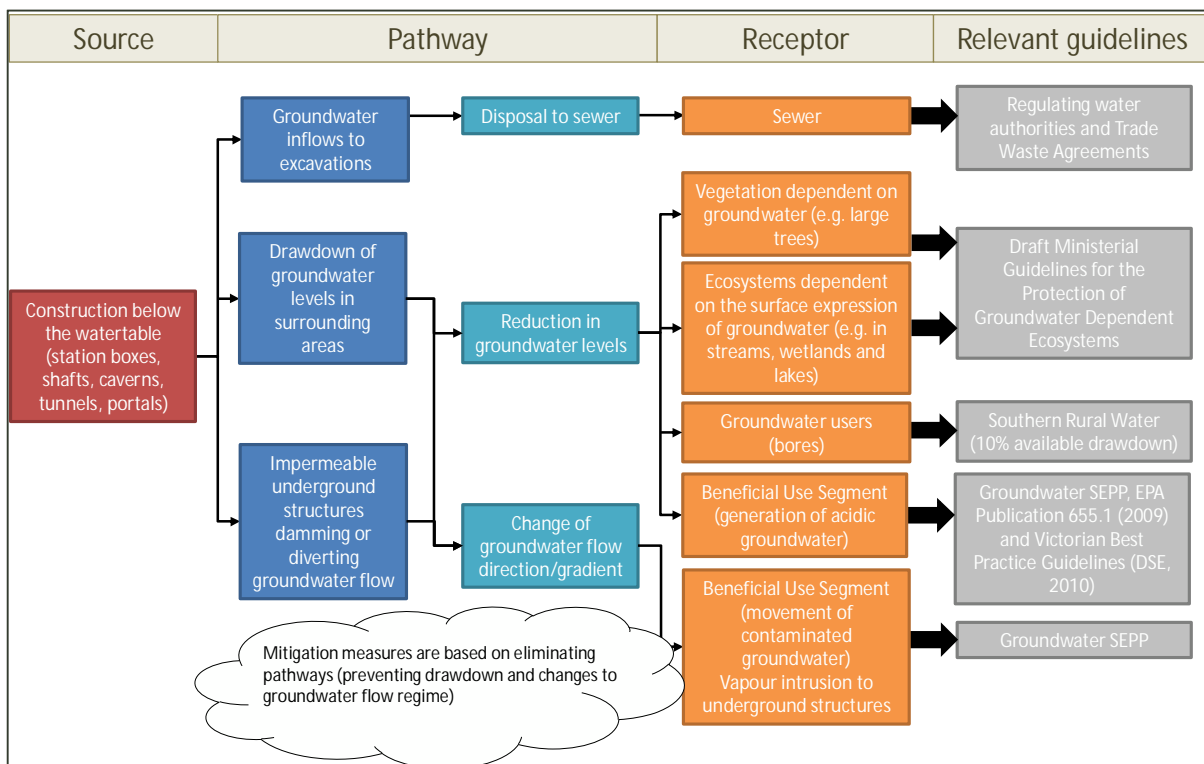
#### 4.3.3 Risk Assessment Methodology

The risk assessment methodology follows the source – pathway – receptor model for assessing the risk of impacts. This model assumes that for impacts to occur, there must be a source (or hazard), a set of receptors, and a pathway that connects the two. The source – pathway – receptor relationship for potential



groundwater impacts is summarised in the conceptual site model (CDM) in Figure 4-2. This approach is consistent with industry standards such as the Australian Groundwater Modelling Guidelines (SKM and NCGRT 2010), EPA Victoria Hydrogeological Assessment (Groundwater Quality) Guidelines (EPA, 2006) and the National Environment Protection (Assessment of Site Contamination) Measures (NEPC, 2013).

For Melbourne Metro, the source of groundwater impacts would be the construction and operation of stations, portals, shafts and tunnels. Hazardous activities in relation to groundwater that could occur during the construction and operation of Melbourne Metro include dewatering of excavations (and associated lowering of the watertable at and away from the excavation – referred to as groundwater drawdown), inflows to structures, and the blocking of natural groundwater flow paths. The source of impacts, and the hazardous activities that may occur during construction and operation of Melbourne Metro, have been identified using Chapter 6 *Project Description* of the EES and the assumptions stated in this document.



**Figure 4-2 Conceptual site model for the overall project relating to groundwater**

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

- Setting of the context for the environmental risk assessment
- Development of consequence and likelihood frameworks and the risk assessment matrix
- Review of project description and identification of impact assessment pathways by specialists in each relevant discipline area
- Allocation of consequence and likelihood ratings and determination of preliminary initial risks
- Further investigation of impact pathways and presence of receptors to confirm or revise initial risk rankings
- Development of Environmental Performance Requirements and mitigation measures to reduce initial risks ranked moderate (or higher), to achieve residual risk rankings.



The initial assessment of risk was undertaken by specialists using a workshop approach which assigned an initial risk ranking based on professional experience on similar projects and knowledge of the hydrogeological conditions along the alignment. The assessment of initial risk ratings was informed by:

- The design features and construction methodology of the Concept Design (discussed in more detail in Section 4.5.1); and
- Standard requirements that are typically incorporated into construction contracts for rail projects.

This initial assessment was then followed by an impact assessment, in which each potential impact pathway was further analysed, and the presence or absence of receptors was confirmed.

The receptors identified were:

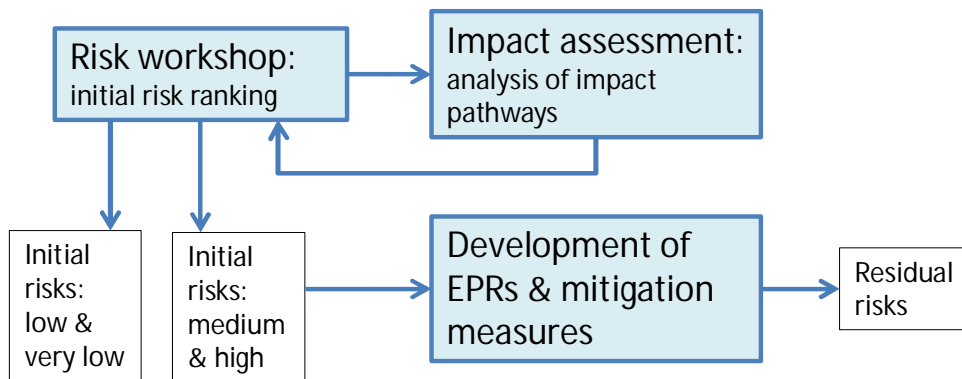
- Existing private bore users
- Surface water bodies and vegetation that interact with groundwater
- Existing contaminant plumes that may degrade groundwater quality at adjacent properties or cause vapour intrusion to underground structures
- PASS
- CityLink recharge bores.

The impact pathways analysed were:

- Groundwater drawdown which lowers the watertable and may reduce access to groundwater for receptors including bore users, groundwater dependent vegetation, rivers, creeks and lakes
- Groundwater drawdown which changes watertable gradients and may cause migration of contaminants
- Groundwater drawdown which exposes PASS leading to oxidation of sulfides and acidification of groundwater
- Groundwater drawdown which could result in ground settlement (impacts of settlement on infrastructure are discussed in Technical Appendix P *Ground Movement and Land Stability*)
- Aquifer damming which restricts flow within an aquifer.

Following the impact assessment, the initial risk rankings were reviewed to reflect the improved understanding of the likelihood and consequences of a particular impact pathway linking a source and receptor. Any risks that had an initial risk ranking of medium or high have been assigned Environmental Performance Requirements and mitigation measures have been identified which could achieve the recommended Environmental Performance Requirements in order to reduce risk to a residual risk ranking of very low or low. This process is described in Figure 4-3.

The Environmental Performance Requirements are outlined in the following sections of the impact assessment and collated in Table 18-1. All Environmental Performance Requirements are incorporated into Chapter 23 *Environmental Management Framework* of the EES.



**Figure 4-3 Process followed by groundwater specialists for assigning initial risk, analysing impact pathways, developing Environmental Performance Requirements and determining residual risk**

#### 4.3.4 Likelihood and Consequence Criteria

The likelihood rating criteria used in the risk assessment by all specialists is shown in Table 4-2. Where there is not enough information to assign a likelihood rating, a default rating of ‘possible’ has been assigned.

**Table 4-2 Likelihood rating criteria**

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

The consequence criteria framework used in the risk assessment is shown below (Table 4-3). Each specialist has used this framework to develop criteria specifically for their assessment.

**Table 4-3 Consequence framework**

| Level      | Qualitative description of biophysical / environmental consequence   | Qualitative description of socio-economic consequence   |
|------------|--|---|
| Negligible | No detectable change in a local environmental setting.   | No detectable impact on economic, cultural, recreational, aesthetic or social values.   |
| Minor      | Short term, reversible changes, within natural variability range, in a local environmental setting.                              | Short term, localised impact on economic, cultural, recreational, aesthetic or social values.   |
| Moderate   | Long term but limited changes to local environmental setting that are able to be managed.  | Significant and/or long-term change in quality of economic, cultural, recreational, aesthetic or social values in local setting. Limited impacts at regional level. |
| Major      | Long term, significant changes resulting in risks to human health and/or the environment beyond the local environmental setting. | Significant, long-term change in quality of economic, cultural, recreational, aesthetic or social values at local, regional and State levels. Limited               |



| Level  | Qualitative description of biophysical / environmental consequence   | Qualitative description of socio-economic consequence   |
|--------|--|---|
|        |  | impacts at national level.  |
| Severe | Irreversible, significant changes resulting in widespread risks to human health and/or the environment at a regional scale or broader. | Significant, permanent impact on regional economy and/or irreversible changes to cultural, recreational, aesthetic or social values at regional, State and national levels. |

The consequence rating criteria used in the risk assessment specifically for risks to groundwater values is shown in Table 4-4. Where there is not enough information to assign a consequence rating, a default rating of 'moderate' has been assigned.

**Table 4-4 Consequence rating criteria**

| Level of consequence | Consequence criteria |
|----------------------|----------------------|
|----------------------|----------------------|

**Groundwater drawdown impacts on surface waters**

Pumping groundwater from excavations may lead to stream flow depletion (either by decreasing baseflow or increasing streamflow losses to groundwater) and potentially adversely impact on health of aquatic ecosystems.

The consequence criteria are based on changes compared to background conditions, and potential for long term impacts. They are broadly consistent with the Ministerial Guidelines for Groundwater Licensing and the Protection of GDEs (2015), which describes a significant impact as a 10 per cent reduction in flow (at the 90<sup>th</sup> percentile flow rate). The Guidelines reference Copestake and Young (2008) who propose that at flows of between 70<sup>th</sup> to 95<sup>th</sup> percentile, 10-20 per cent of flow can be taken before breaching "good ecological status", and the criteria below are also consistent with that assessment.

|            |   |
|------------|---|
| Negligible | No detectable impact on river/creek flows.  |
| Minor      | Reduction in river/creek flows by up to ~ 5% compared with background). Likely to be difficult to differentiate impact from normal intra and inter-seasonal variability (e.g. climatic and other influences)<br>No detectable impact on river/creek ecosystems. |
| Moderate   | Reduction in river/creek flows by 5 – 20% compared with background<br>Decline in flow clearly measurable and differentiated from climatic and other influences<br>Long term local effects (i.e. immediately) on downstream river/creek ecosystems.              |
| Major      | Reduction in river/creek flows by 20 – 50% compared with background<br>Long term effects for local and downstream river/creek ecosystems.   |
| Severe     | Loss of majority of streamflow (50 – 100%) leading to major and irreversible changes in local and/or downstream aquatic ecosystems.   |

**Groundwater drawdown impacts on vegetation Groundwater Dependent Ecosystems (GDEs)**

Pumping groundwater from excavations leads to drawdown in the watertable, which can impact GDEs reliant on groundwater (the particular focus here is on groundwater dependent vegetation).

The criteria adopted here are consistent with the Ministerial Guidelines for Groundwater Licensing and the Protection of GDEs (2015). The Ministerial guidelines refer to depth to watertable as an appropriate management indicator for terrestrial vegetation and wetlands, and refer to drawdown numbers - minor (0.1 m), moderate (0.1 – 2 m) and significant impact (>2 m). The criteria below refer to changes compared to typical natural variation; however, based on typical natural variation for the study area, the two sets of criteria are broadly compatible.

|            |   |
|------------|---|
| Negligible | No / negligible drawdown at potential GDEs.                                       |
| Minor      | Minor groundwater drawdown at potential GDEs, but within range of typical natural |





| Level of consequence | Consequence criteria  |
|----------------------|---|
|                      | variation (i.e GDEs resilient to change).   |
| Moderate             | Drawdown is greater than typical natural variation of groundwater levels at GDEs - potential long term isolated impacts are possible (e.g. occasional tree death) if not managed, e.g. via watering or drawdown mitigation. |
| Major                | Drawdown is significantly greater than typical natural variation of GDEs - long term impacts are likely (e.g. many tree deaths) and ability to manage impacts is not certain.   |
| Severe               | GDEs cannot adapt to changed groundwater levels, widespread long term impacts are likely (e.g. tree deaths over wide area) and low likelihood of managing impacts.  |

#### Groundwater drawdown impacts on groundwater users

**Pumping groundwater from excavations leads to drawdown in the watertable, which can impact on other users of groundwater. The consequence criteria draw on Southern Rural Water bore interference guidelines, which indicate 10% of available drawdown in existing bores as an acceptable drawdown impact for new bores.**

|            |  |
|------------|--|
| Negligible | No / negligible drawdown at bores.   |
| Minor      | Decline in groundwater levels is less than 10% of available drawdown.  |
| Moderate   | Temporary decline in groundwater levels during construction of between 10% – 50% of available drawdown<br>Compensation (e.g. deepening bore, supplying water) easily implemented and not costly. |
| Major      | Permanent decline in groundwater levels of between 10% - 100% of available drawdown<br>Compensation (e.g. deepening bore, supplying water) is difficult and/or expensive.                        |
| Severe     | NA   |

#### Groundwater drawdown causing migration of contaminant plumes

**Groundwater drawdown causing existing contaminant plumes to migrate to areas previously unaffected by contamination, precluding the beneficial uses of groundwater for neighbouring properties and potentially causing vapour ingress to underground structures (e.g. basements) at those properties. Pumping groundwater from excavations leads to drawdown that could cause contaminated groundwater to migrate to third party properties, and reduce current and future beneficial uses of groundwater at those properties. If the contaminant plume consists of volatile substances, there is also the potential for vapour to enter structures on neighbouring properties as a result of the migration of contamination.**

|            |   |
|------------|---|
| Negligible | No / negligible drawdown and no / negligible plume movement.  |
| Minor      | Some movement of plume possible over long timeframes, enabling dispersion and natural attenuation to minimize impacts to beneficial uses of groundwater at neighbouring properties. Underground structures at neighbouring properties are not susceptible to vapour intrusion.  |
| Moderate   | Movement of plume which is likely to intersect third party properties and preclude some beneficial uses that would require management. Prevention of vapour intrusion into underground structures is possible without additional construction works (such as sealing basements).                                      |
| Major      | Plume would intersect third party properties and significantly reduce beneficial uses such that expensive management would be required.   |
| Severe     | Plume would intersect third party properties and preclude all current and future beneficial uses of groundwater at these properties. Vapour intrusion to underground structures results in permanent restrictions to use due to potential for major impacts to human health. Would require very expensive management. |

#### Groundwater drawdown oxidising Potential Acid Sulfate Soils (PASS) resulting in increased groundwater acidity

**Groundwater drawdown may expose PASS to air causing oxidation of sulfide minerals and impacts on groundwater quality, including increased acidity and heavy metal content.**



| Level of consequence | Consequence criteria   |
|----------------------|--|
| Negligible           | No detectable change in groundwater quality.   |
| Minor                | Some measurable change in groundwater quality but no impacts to beneficial uses of groundwater.  |
| Moderate             | Measurable change in groundwater quality that precludes some beneficial uses of groundwater in the area. Management is simple and inexpensive.               |
| Major                | Change in groundwater quality that significantly reduces beneficial uses such that expensive management would be required.                                   |
| Severe               | The change in groundwater quality would preclude all current and future beneficial uses of groundwater in the area. Would require very expensive management. |

#### Impacts of groundwater drawdown on CityLink recharge bores

##### Impact on CityLink Recharge wells (increased recharge required at CityLink wells due to drawdown)

|            |   |
|------------|---|
| Negligible | No discernible change in groundwater levels (near CityLink bores) compared to baseline / background levels.   |
| Minor      | Minor decline in groundwater levels (near CityLink bores) compared to baseline during and shortly after construction. Decline may be difficult to differentiate from climatic and other influences. |
| Moderate   | Moderate decline in groundwater levels (near CityLink bores) compared to baseline during construction phase and long term. Decline clearly differentiated from climatic and other influences.       |
| Major      | Large decline in groundwater levels (CityLink bores) compared to baseline during construction phase and long term.  |
| Severe     | Large decline in groundwater levels (near CityLink bores) compared to baseline during construction phase and long term leading to major settlement and associated infrastructure damage.            |

#### Melbourne Metro structures blocking aquifer flow and causing a groundwater 'damming' effect

**Where Melbourne Metro structures block groundwater flow through aquifers that are not laterally extensive (i.e. in palaeovalleys), groundwater levels may increase upstream, and decrease levels downstream of the structure. The change in groundwater levels as a result of aquifer damming can impact beneficial uses in those areas, such as bore owners and groundwater dependent vegetation and surface water features.**

|            |  |
|------------|--|
| Negligible | Change in groundwater levels upstream and downstream of structure is within the range of natural variation.  |
| Minor      | Upstream groundwater mounding and downstream fall in groundwater levels that is measurable, but impacts on CityLink injection bores, existing groundwater users, vegetation health and/or the water balance in rivers, creeks and lakes, and existing below ground infrastructure are within operational criteria.                                     |
| Moderate   | Upstream groundwater mounding that affects recharge bores and inflows to existing infrastructure. Downstream fall in groundwater levels that has a measurable effect on CityLink injection bores, existing groundwater users, vegetation health and/or the water balance in rivers, creeks and lakes. Management required.                             |
| Major      | Upstream groundwater mounding that affects recharge bores and inflows to existing infrastructure. Downstream fall in groundwater levels that has a measurable effect on CityLink injection bores, existing groundwater users, vegetation health and/or the water balance in rivers, creeks and lakes. Management is expensive. Significant legal risk. |
| Severe     | NA   |

The environmental risk assessment matrix used by all specialists to determine levels of risk from the likelihood and consequence ratings is shown below (Table 4-5). The initial risk rating has been used as a prioritization tool to focus the impact assessment on the medium and high risks. Following the impact



assessment, the initial risk rankings were reviewed to reflect the improved understanding of the likelihood and consequences of a particular impact pathway. Where the initial risk ranking is 'medium' or 'high', a set of performance requirements have been developed that when applied during construction and/or operation, would result in a residual risk rating of 'low' or 'very low'. Section 6 summarises the initial and residual risks for the groundwater impact assessment in the EES.

**Table 4-5 Risk Assessment Matrix**

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

## 4.4 Impact Assessment Methodology

The draft evaluation objective relevant to groundwater is included in Section 2 and Table 4-6. The draft evaluation objective and associated assessment criteria provide a framework to guide an integrated assessment of potential environmental impacts of the project, in accordance with the Ministerial guidelines for assessment of environmental effects under the *Environment Effects Act 1978*. The assessment criteria are evaluated for the impact assessment in each precinct section of this report (Sections 7 to 16) to identify potential impacts and appropriate mitigation measures.

**Table 4-6 Draft evaluation objectives, assessment criteria and indicators for assessing impacts for construction and operation of Melbourne Metro components**

| Draft EES evaluation objectives   | Assessment criteria  |
|---|--|
| <p><b>Hydrology, water quality and waste management:</b> To protect waterways and waterway function and surface water and groundwater quality in accordance with statutory objectives, to identify and prevent potential adverse environmental effects resulting from the disturbance of contaminated or acid-forming material and to manage excavation spoil and other waste in accordance with relevant best practice principles.</p> | <p>Criteria: Manage extraction of groundwater to avoid consequential impacts on natural (e.g. streamflows and GDEs) and built environment (subsidence, recharge wells and other groundwater bores) resulting from groundwater drawdown</p> <ul style="list-style-type: none"> <li>Indicator: Stream flow – changes in streamflow as a result of the project are predicted to be within range of natural intra and inter-seasonal variability</li> <li>Indicator: GDEs (vegetation) – if impacts cannot be easily managed (e.g. via watering), the magnitude and rate of change of groundwater drawdown predicted to be within range of natural intra and inter-seasonal variability</li> <li>Indicator: Subsidence – settlement predicted to be within tolerance of relevant infrastructure (addressed in Technical Appendix P <i>Ground Movement and Land Stability</i>)</li> <li>Indicator: CityLink recharge wells - No discernible change predicted in groundwater levels (near infrastructure of concern) compared to baseline / background levels</li> <li>Indicator: Other bores - Decline in groundwater levels is predicted to be less than 10 per cent of available drawdown (unless compensation can be easily implemented).</li> </ul> |



| Draft EES evaluation objectives | Assessment criteria   |
|---------------------------------|---|
|                                 | <p>Criteria: Manage extraction of groundwater to avoid consequential impacts on the natural environment resulting from groundwater disposal</p> <ul style="list-style-type: none"> <li>Indicator: Groundwater disposal must result in no detectable impact on river/creek water quality, i.e. within background and SEPP guidelines.</li> </ul> <hr/> <p>Criteria: Manage extraction of groundwater to avoid consequential impacts of moving known groundwater contamination to third party receptors</p> <ul style="list-style-type: none"> <li>Indicator: No reduction in beneficial uses of groundwater at third party properties as a result of contaminant migration in accordance with SEPP GoV</li> <li>Indicator: No human contact at third party properties with groundwater contaminant levels (including vapours) over relevant guideline values.</li> </ul> |

This impact assessment adopts a two-step process to identify potential impacts from the hazardous activities associated with Melbourne Metro on groundwater dependent values:

1. Identify groundwater dependent assets and values (receptors) that could potentially be impacted based on their anticipated sensitivity to changes in groundwater conditions
2. Estimate the magnitude of the pathway that connects the source to the receptors. Where these impact pathways intersect with groundwater dependent values, there is a risk of adverse consequences for the receptors. Mitigation measures can then be applied to reduce or avoid these impacts.

These steps of the methodology are described further in the following sections.

#### 4.4.1 Identifying Groundwater Dependent Values

The groundwater dependent values (groundwater related processes, functions and values) that were identified as potential receptors during the risk assessment included:

- Surface water bodies that receive groundwater inflows, which maintain flow regimes or water quality
- Deep-rooted vegetation that accesses and uses groundwater for at least part of its water requirements
- Existing groundwater users who access and use groundwater via groundwater bores
- Beneficial uses of groundwater beneath private and public properties that could be impacted by migration of groundwater contaminants, or acidification of groundwater by PASS.

To identify the location and sensitivity of these values to changes in groundwater conditions, a review of existing data and field inspections were undertaken.

Where the groundwater dependent values coincide with the estimated area of groundwater drawdown, impacts may occur. The impact assessment reviews the presence of these assets and values within the area of drawdown and discusses the expected sensitivity of the assets and values to the changes in groundwater conditions. There are generally no guidelines that indicate acceptable levels of drawdown for most groundwater dependent values, and different groundwater dependent values have different levels of sensitivity to drawdown. The consequence criteria developed for each risk covered in this impact assessment in Table 4-4 reference the available information on what is considered an acceptable level of impact. However, the relationship between drawdown and acceptable level of impact on receptors is often not well defined. Based on professional experience on projects of a similar nature, the levels of drawdown that would be expected to result in acceptable impacts for each receptor are:

- Drawdown that reduces the available head of water in a bore by less than 10 per cent (e.g. 1 m drawdown in a bore with 10 m of standing water)



- Drawdown that is within the range of natural variation in watertable elevation (approximately 0.5 m) for vegetation and surface water features that are dependent on groundwater
- CityLink recharge bores – acceptable criteria would need to be identified
- Drawdown of more than approximately 1 m would be considered to present a risk of:
  - Contaminant migration to third party properties, if the contaminant plume was already close to the boundaries of the contaminated site, and
  - Oxidation of PASS that increases the acidity and metal content of groundwater.

Ground subsidence as a result of groundwater drawdown (and other factors) is also a key impact that needs to be managed during construction and operation of Melbourne Metro. This risk is being assessed in Technical Appendix P *Ground Movement and Land Stability* of the EES, however for context, acceptable levels of groundwater drawdown are also relevant to this discussion. The amount of ground subsidence related to certain levels of groundwater drawdown depends on the thickness and physical properties of the sediments being dewatered. In the case of Coode Island Silt, for example, where it is 10 m thick, groundwater drawdown of 0.5 m would be considered to result in approximately 15 mm land settlement. For subsidence as well as the other potential receptors of groundwater drawdown impacts, small drawdowns of less than 0.5 m are expected to result in acceptable levels of impact, and are therefore considered to indicate a low risk of impact. As such, 0.5 m drawdown is used as the reporting cutoff for predicted drawdown in this impact assessment.

Sensitive assets and values that are likely to be impacted by drawdown have been identified and mitigation measures have been developed to reduce impacts on these features. The estimated groundwater drawdown, assets and values that may be impacted, and mitigation measures where required, are presented in each precinct section (Sections 7 to 16).

#### 4.4.1.1 Bore Inspections

A search of the Victorian Water Measurement Information System (VWMIS) was completed for the study area to identify bores registered for consumptive use (irrigation, stock and domestic). The list of bores was investigated to identify property details and attempts were made to contact all owners of property on which bores are listed.

Site inspections were undertaken on all properties where access could be gained in an attempt to identify whether the bores existed or were in use. The site inspection initially consisted of interviewing property owners/managers about the bore location and use. If the location of the bore was known, it was visited and photographs were taken. If the bore location was not known, attempts were made to determine where it might be located (i.e. looking at aerial images of coordinates, suggesting low lying areas of the site) and the property was searched in order to find the bore. Bore inspection findings are summarised in Appendix D.7 of this report. The majority of sites were able to be inspected. Three bores were located on properties where access could not be gained. These bores have been assumed to exist for the purposes of the EES.

#### 4.4.2 Quantifying Impact Pathways

The pathways that are associated with the risks identified in this report are related to changes in groundwater flow, which specifically includes:

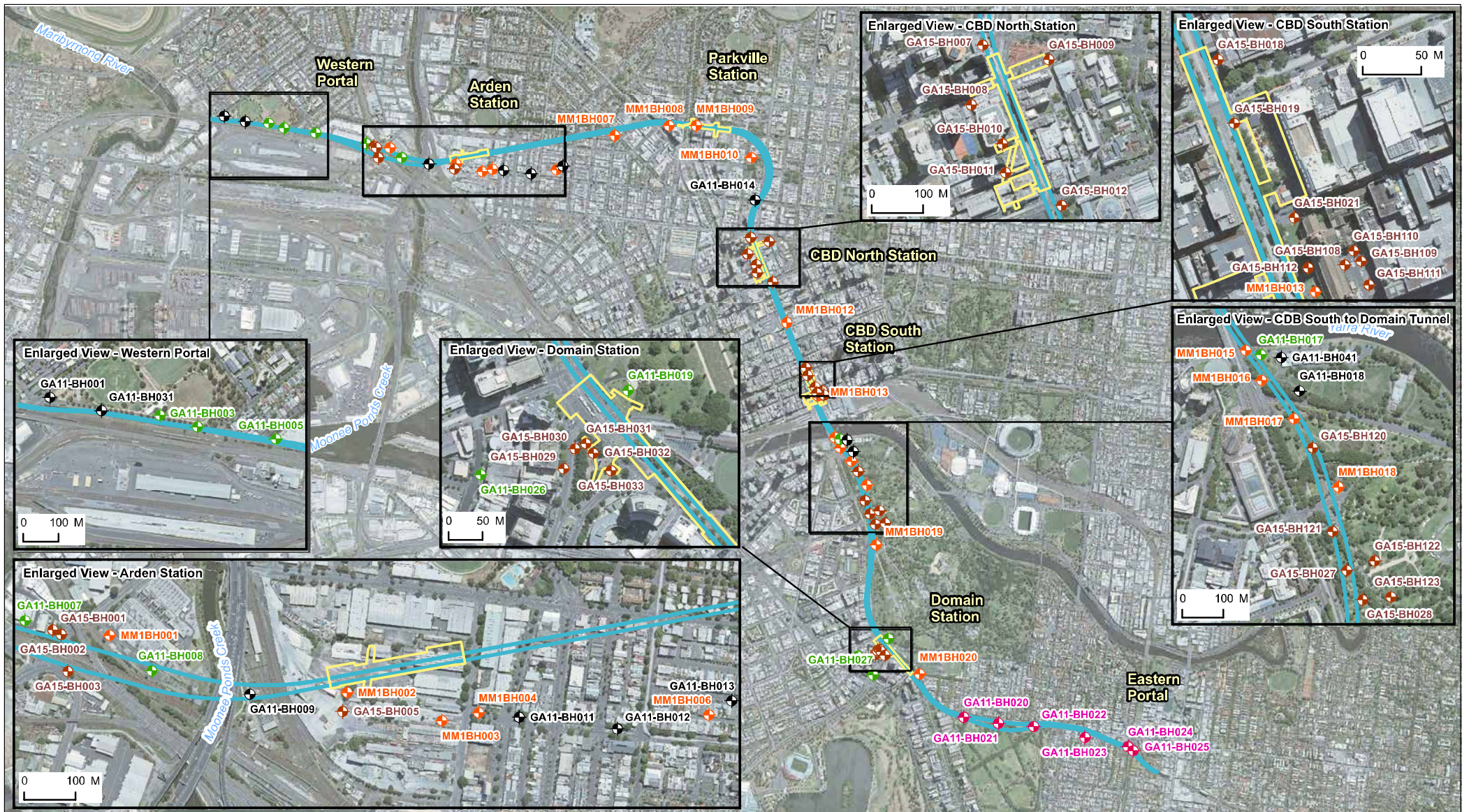
- Groundwater drawdown which lowers the watertable and may reduce access to groundwater for receptors including bore users, groundwater dependent vegetation, rivers, creeks and lakes
- Groundwater drawdown which changes watertable gradients and may cause migration of contaminants
- Groundwater drawdown which exposes PASS leading to oxidation of sulfides and acidification of groundwater
- Aquifer damming which restricts flow within an aquifer.



Groundwater drawdown can also cause ground settlement which can impact existing infrastructure. Technical Appendix P *Groundwater Movement and Land Stability* assesses the risks and potential impacts associated with settlement, however since groundwater drawdown is the key impact pathway, the mitigation measures to address ground settlement are discussed in this report. Hence, the mitigation measures in this report are key to achieving the relevant Environmental Performance Requirements in Technical Appendix P *Groundwater Movement and Land Stability*.

Quantifying impact pathways requires a good understanding of the hydrogeological conditions across the study area. This impact assessment relies on previous groundwater investigations for the Melbourne Metro that have been undertaken in a number of stages and phases, as described in Section 4.1.

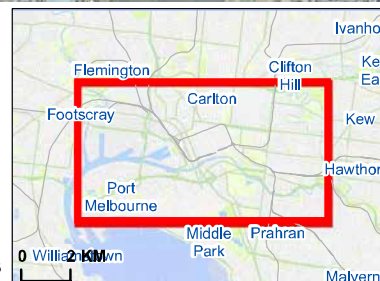
The groundwater monitoring bores from which data has been used for this study are shown in Figure 4-4 and summarised in Appendix B of this report. The hydrogeological conditions for the whole study area are summarised in the 'Regional context' chapter (Section 5) and the data is included in Appendix C of this report. The following sections describe how this data was used to quantify the impact pathways and estimate groundwater drawdown and damming effects.



**Legend**

- Groundwater Monitoring Wells**
- ◆ Stage 1
  - ◆ Stage 2 Phase 2A
  - ◆ Stage 2 Phase 2B
  - ◆ Stage 2 Phase 2C
  - ◆ RD (to 30 Sept 2015)
- Proposed Station Footprint
- Proposed Alignment

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



**Melbourne Metro Rail Project**

Title: MMR groundwater monitoring bore locations

Drawing Number: MMR-AJM-UGAA-MP-NK-500138

Revision: P1

|                   |                         |                 |              |
|-------------------|-------------------------|-----------------|--------------|
| Drawn By: A. Davy | Approved By: K. Dowsley | Date: 7/04/2016 | Map Size: A4 |
|-------------------|-------------------------|-----------------|--------------|

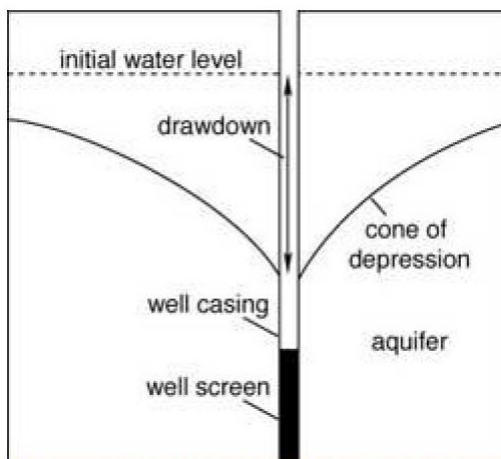
Scale: 0 500 1000 Metres

Figure 4-4 Melbourne Metro groundwater monitoring bore location map



#### 4.4.2.1 Groundwater Drawdown Estimates

Groundwater inflow can occur to Melbourne Metro infrastructure including station boxes, portals, shafts and tunnels where these structures are excavated below the groundwater level. These inflows can cause a lowering of groundwater levels in the aquifers around the infrastructure, which is known as 'drawdown'. Figure 4-5 demonstrates the concept of drawdown around a groundwater extraction bore. A similar process occurs when groundwater flows into an excavation and is pumped out. Drawdown is the primary impact pathway for groundwater related risks of construction and operation of Melbourne Metro. When referring to drawdown both the lateral extent of the area of drawdown and the vertical magnitude of the drawdown are important. The magnitude of drawdown is greatest closer to the excavation and reduces with distance away from the excavation.



**Figure 4-5 Example of drawdown as a result of groundwater extraction from a well**

The volume of inflows and the extent of drawdown (both lateral extent and vertical magnitude) around the infrastructure are controlled by the depth and size of the excavation below the groundwater level and the hydrogeological characteristics of the aquifers and aquitards surrounding the infrastructure. Inflows (and therefore drawdown) can occur during both the construction and operational phases of the project. If the lateral extent and/or vertical magnitude of drawdown are significant, it is more likely that assets and values that depend on groundwater would be impacted.

The prediction of groundwater drawdown is strongly influenced by the input parameters used to model drawdown. These inputs include excavation dimensions, and aquifer properties such as hydraulic conductivity. Hydraulic testing along the alignment has included packer and slug tests, which give hydraulic conductivity results for a small radius of the aquifer, and a pumping test that characterises more of the subsurface variation in aquifer properties. Despite many tests being carried out, subsurface variation is difficult to fully predict, and therefore the sensitivity of drawdown predictions to variations in hydraulic conductivity should be characterised. The methodology for the detailed design phase predictive model required by the Environmental Performance Requirements would need to assess the sensitivity of results to variations in hydraulic parameters.

##### 4.4.2.1.1 Drawdown During Construction

Drawdown was estimated using a combination of numerical modelling and analytical methods. Golder Associates developed a regional numerical model to simulate the effects of Melbourne Metro construction and operation on groundwater levels and flow paths. The model development, assumptions and results are reported in the Regional Groundwater Numerical Modelling Report (Golder Associates, 2016b, Appendix H). Modelling of drawdown associated with construction was undertaken for the western portal, Arden station, CBD North station, the mined tunnel between CBD North and CBD South, CBD South station, and Domain station. Regional modelling is sufficient for the assessment of risk that is required in this impact assessment.





Stochastic modelling can be undertaken for areas where the risk of ground settlement warrants further investigation, as it can provide a probability distribution of potential outcomes including the range of uncertainty of results. Stochastic modelling may be undertaken to inform the predictive modelling required by the Environmental Performance Requirements for the detailed design phase.

For the remaining structures that were not assessed with the Golder regional numerical model (Appendix H), analytical methods were used as set out in this report to estimate groundwater drawdown. This included Parkville station, the eastern portal, the Linlithgow Avenue emergency access shaft, shafts in Fawkner Park and cross passages between tunnels. These structures were not modelled using the numerical model as the relevant information was not available when the models were developed. These structures would be numerically modelled during detailed design as required by the Environmental Performance Requirements.

Two analytical methods have been used in this impact assessment to estimate the drawdown associated with construction of these structures:

- Theis (1935) drawdown method
- Armstrong (1996) excavation inflows method.

Analytical techniques generally assume a simplified hydrogeological model, which in some cases may not fully capture the hydrogeological complexity of the site or the interaction of the groundwater regime and associated infrastructure. Common assumptions for these methods include the homogenous, isotropic (uniform in all directions), uniform thickness and infinite nature of the aquifer. Where drawdown impacts are predicted to be restricted to a relatively small area within the one geological unit, these assumptions are reasonable. However, where drawdown occurs beyond the known aquifer extent, or within a unit that has expected anisotropic (not uniform in all directions) properties, these assumptions would not accurately represent the hydrogeological system. These methods and their associated assumptions and limitations are explained in detail in Appendix F of this report. Table 4-7 shows which methods were used for the analysis of drawdown at each precinct. These methods are commonly used for hydrogeological analysis.

Input parameters for the analysis regarding design and timing of the Melbourne Metro infrastructure were taken from Chapter 6 *Project Description* of the EES and advice from the design team where more detailed inputs were required.

Modelling to date has not considered cumulative impacts of drawdown during construction. Cumulative impacts occur where the drawdown surrounding a particular excavation overlaps with drawdown from a neighbouring excavation; for example, if construction occurs at the same time, drawdown associated with CBD North station and tunnels may intersect drawdown surrounding CBD South station. Cumulative impacts can increase the vertical magnitude of drawdown as well as the lateral extent of drawdown. The cumulative nature of drawdown may therefore exacerbate impacts on groundwater dependent values.

Although current modelling has not yet addressed this issue, the existing modelling and results are sufficient to model drawdown for each precinct and allow an assessment of risk to groundwater dependent values for the EES. The increased risk is confined to relatively small areas where drawdown cones intersect and additional impacts on groundwater dependent values are unlikely to be large. Based on experience on previous projects of a similar nature, cumulative impacts are relatively small, typically less than 10 per cent additional drawdown. Nevertheless, the future modelling during detailed design required by the Environmental Performance Requirements would provide confirmation that potential cumulative drawdown has been modelled and impacts mitigated to the extent required.

The drawdown estimated from the numerical modelling and analytical methods represent a 'base case' scenario, in which no mitigation measures to reduce drawdown have been modelled aside from the design features and assumed construction techniques in the Concept Design (e.g. TBM construction method and diaphragm walls). This means that the results presented represent the upper limit of possible groundwater impacts. In the areas of the alignment where drawdown is predicted to impact values and assets (e.g. the mined tunnels and CBD South station), mitigation measures would be employed to reduce inflows and



drawdown. Grouting of the mined tunnels and stations and injection of water into aquifers to maintain groundwater levels during construction are the key mitigation measures necessary to reduce drawdown for these precincts. These measures are described in Section 4.5 of this report.

#### 4.4.2.1.2 Drawdown During Operation

The regional numerical model (Golder Associates 2016b, Appendix H) was used to estimate cumulative drawdown associated with the long term operation of all Melbourne Metro structures. This assessment has assumed that during the operational lifetime of the Project, all underground structures would be tanked to minimise groundwater inflows (and consequent groundwater drawdowns). A tanked structure (station, shaft, tunnel, portal, adit or cross passage) is designed to withstand the full groundwater pressure which is applied to the structure. This means that the leakage rate into the structure is almost nil. This design is also called an undrained structure. This is in contrast to a drained structure which has an internal drainage system and which is designed to not resist any groundwater pressures.

The design tightness criteria used in the Concept Design for the tanking of Melbourne Metro structures are either Haack Class 3 or Haack Class 2 inflows (Haack, 1991), which assume inflow rates of:

- 0.1 L/m<sup>2</sup> over 100 m length (of tunnel) per day for Haack Class 3 structures
- 0.05 L/ m<sup>2</sup> over 100 m length per day) for Haack Class 2 structures.

Drawdowns away from the tunnels and other structures are controlled by these inflow rates. Table 4-7 shows the Haack tightness criteria adopted for each Melbourne Metro structure in the Concept Design.

The effects of long term climate change in the assessment of operational drawdown have been considered as follows:

- Recharge rates: recent analysis by CSIRO (Crosbie et al., 2013) on the impacts of climate change on groundwater recharge rates in south eastern Australia have shown a large scatter in projections of the possible change in recharge (both bigger and smaller) and consequently, it was decided not to specifically include this in the regional groundwater modelling. There is currently a low confidence in the understanding of the impact of climate change on groundwater recharge rates in most parts of Australia.
- Maximum flood height: the maximum flood heights under various flood scenarios with climate change has been assessed in the Technical Appendix N *Surface Water*. These floods represent extreme events and consequently, would only maintain the estimated heights for typically hours and at most a few days. In this case it is considered that this would not significantly affect groundwater levels. Note that 1 in 100 year flood levels without climate change have been allowed for in the assessment of maximum design groundwater levels.
- Sea level rise: long term sea level rise at the northern end of Port Phillip Bay of 0.98 m (IPCC 2013) over the life of the project due to climate change has been allowed for in the assessment of maximum design groundwater levels over the whole project.

It is noted that adopted anthropogenic induced changes to groundwater levels over the life of the project (e.g. sewer replacement, City Loop self-sealing) have a far bigger impact on groundwater levels than the climate change impacts.

**Table 4-7 Analytical methods used to estimate inflows and groundwater drawdown around Melbourne Metro structures**

| Structure                               | Construction   | Operation  |
|---|--|--|
| <b>TBM tunnels</b>                      | No analysis: assumed no inflow during construction as TBMs seal tunnel almost immediately. | Numerical modelling reported in Golder Associates (2016b), Appendix H: drawdown based on inflows for a Haack 3 tanking classification. |
| <b>Mined tunnels (CBD North to CBD)</b> | Numerical modelling reported in Golder Associates (2016b), Appendix H.                     |  |



| Structure   | Construction  | Operation   |
|---|---|---|
| <b>South)</b>   |   |   |
| <b>Western portal</b>   | Numerical modelling reported in Golder Associates (2016b), Appendix H.  |   |
| <b>Arden station</b>  | Numerical modelling reported in Golder Associates (2016b), Appendix H.  | Numerical modelling reported in Golder Associates (2016b), Appendix H: drawdown based on inflows for a Haack 2 tanking classification.  |
| <b>Parkville station</b>  | Theis (1935): used to calculate inflows and drawdown to base of the station for the construction period. Results were corroborated using the Armstrong (1996) method. | Numerical modelling reported in Golder Associates (2016b), Appendix H: drawdown based on inflows for a Haack 3 tanking classification.  |
| <b>CBD North station</b>  | Numerical modelling reported in Golder Associates (2016b), Appendix H.  | Numerical modelling reported in Golder Associates (2016b), Appendix H: drawdown based on inflows for a Haack 2 tanking classification.  |
| <b>CBD South station</b>  | Numerical modelling reported in Golder Associates (2016b), Appendix H.  |   |
| <b>Linlithgow access shaft</b>  | Theis (1935): used to calculate inflows and drawdown to base of the shaft for the construction period. Results were corroborated using the Armstrong (1996) method.   | Theis (1935): used to calculate inflows and drawdown to base of the cross passages for an operational lifetime of 100 years.  |
| <b>Tom's Block access shaft (alternative design option for Linlithgow access shaft)</b> | NA – above groundwater level  | NA – above groundwater level.   |
| <b>Domain station</b>   | Numerical modelling reported in Golder Associates (2016b), Appendix H.  | Numerical modelling reported in Golder Associates (2016b), Appendix H: drawdown based on inflows for a Haack 2 tanking classification.  |
| <b>TBM launch shaft in north-west of Fawkner Park</b>                                   | Theis (1935): used to calculate inflows and drawdown to base of the shaft for the construction period. Results were corroborated using the Armstrong (1996) method.   | Not applicable for Concept Design – not an operational structure<br>For alternative design option (emergency access shaft at this location)<br>Theis (1935): used to calculate inflows and drawdown to base of the cross passages for an operational lifetime of 100 years. |
| <b>Emergency access shaft in north-east of Fawkner Park</b>                             | Theis (1935): used to calculate inflows and drawdown to base of the shaft for the construction period. Results were corroborated using the Armstrong (1996) method.   | Theis (1935): used to calculate inflows and drawdown to base of the cross passages for an operational lifetime of 100 years.  |
| <b>Eastern portal</b>   | Theis (1935): used to calculate inflows and drawdown to base of the portal for the construction period. Results were corroborated using the Armstrong (1996) method.  | Numerical modelling reported in Golder Associates (2016b), Appendix H: drawdown based on inflows for a Haack 3 tanking classification.  |

#### 4.4.2.2 Aquifer Damming Assessment

Damming of an aquifer can occur when a structure (be it a tunnel, a station or other structure) cuts through an aquifer creating a physical barrier to groundwater flow and disrupting the flow through the aquifer. This may cause the groundwater level to increase on the upgradient side of the structure and decrease on the downgradient side of the structure. The increase on the upgradient side could theoretically cause water logging if the groundwater level is shallow. The decrease in groundwater level on the downgradient side



could cause unacceptable drawdown leading to settlement or impacts on groundwater dependent assets. Impacts from aquifer damming may occur if the structure cuts off a significant thickness of the aquifer, such that flow through the aquifer is restricted.

Damming is only a risk where Melbourne Metro structures truncate major aquifers and is therefore only considered for preceptincts that intersect aquifers in the Moonee Ponds Creek and Yarra River palaeovalleys. Although the Melbourne Formation (which dominates of the alignment) can have high permeability zones, restricting flow is not considered as a risk due to its large lateral extent. Aquifer damming is therefore assessed for the tunnels between western portal and Arden station and CBD South station and Domain station.

In order to assess the effects of groundwater damming, a review of the thickness of the aquifer compared to the relatively impermeable underground structure was undertaken. Other factors that are key to assessing this effect are the hydraulic conductivity of the aquifer and the groundwater flow direction.

## 4.5 Measures for Minimising Groundwater Inflows and Drawdown Impacts

Several measures are available that can be used to mitigate impacts from groundwater drawdown during construction and operation of Melbourne Metro. Many measures have been included in the preliminary Concept Design of stations, tunnels and portals as set out in Table 4-8 and discussed below. Other measures have been specified as an outcome of the drawdown and impact predictions in this report (these are associated with Environmental Performance Requirements). Sections 4.5.1 and 4.5.2 describe the measures for reducing drawdown that are available to the contractor. During the detailed design phase, the contractor would be required to model the groundwater impacts of the proposed design and confirm that the proposed design features and construction techniques would achieve acceptable outcomes.

### 4.5.1 Design Features

Several design features have been selected in the Concept Design in order to limit inflows during construction and operation of Melbourne Metro. These design features are presented in Chapter 6 of the EES Main Report and additional detail has been established from discussions with the design team. These features have been included in the modelled predictions of drawdown and inform the initial risk rankings. The design features that limit groundwater inflows to Melbourne Metro include:

- Tanking structures to a certain Haack water tightness classification to limit groundwater inflow during operation
- TBM construction method for tunnels
- Diaphragm walls (sometimes with toe grouting) for station box construction
- Secant piling to limit groundwater inflows during construction.

#### 4.5.1.1 Construction Design Features

The selection of design features and construction methods that minimise groundwater inflows and drawdown during construction is controlled by both constructability considerations and the risk of impacts. Drained tunnels and stations are assumed during construction in locations where either the constructability of a tanked structure is not possible (e.g. for the mined tunnel between CBD North and CBD South stations) or where impacts are expected to be minor due to excavation being in low permeability formations.

Construction of most tunnels (from the western portal to CBD North, and from CBD South to the eastern portal) using a TBM minimises groundwater inflows during construction. The TBM can maintain a pressure front at the boring face as it proceeds, which temporarily establishes a groundwater flow gradient away from the tunnels. The walls of the tunnels are then installed immediately following tunnel excavation. As such, the excavated tunnels are constructed and sealed before significant groundwater inflows can occur.



Construction of station boxes can use diaphragm walls to prevent groundwater inflows during construction. These are currently planned in the Concept Design for construction of Arden station and Domain station. Diaphragm walls are constructed in panels using specialised equipment to cut a narrow trench to the appropriate depth. This trench would be kept open using bentonite slurry whilst a reinforcement cage is installed and concrete is pumped into the trench. This method is likely to result in very little groundwater inflow, which would be largely restricted to the floor of the excavation prior to installation of the concrete base slab.

Toe-grouting beneath the diaphragm wall into the Melbourne Formation underlying the station is currently planned in the Concept Design for Arden station to further reduce potential for inflows through the base of the station box during construction. The diaphragm wall at Domain station would be embedded into the Melbourne Formation to a depth of 5 m below the base of the excavation.

Secant piles are constructed so that adjacent piles intersect and create a wall that restricts groundwater inflows. The usual practice is to construct alternate piles along the line of the wall, then drill between these piles to construct the adjoining piles. Secant piling is a method to create a retaining wall which inhibits the passage of groundwater and consequently can be effective where groundwater control is required. Chapter 6 *Project Description* of the EES describes these construction methods in more detail.

These design features and construction methodology are part of the Concept Design, however any proposed alterations during the detailed design phase could have implications for groundwater related impacts. To ensure that any alternative design proposals sufficiently protect groundwater dependent values, an overarching requirement (included as an Environmental Performance Requirement) is to develop a detailed design phase groundwater model. This model would predict impacts associated with the detail design features and proposed construction methodology. If any additional impacts are predicted during detailed design modelling, mitigation measures would need to be developed to reduce these impacts. The model would also be used to optimise the design and implementation of the mitigation measures, and would be an input to the development of a Groundwater Management Plan (GMP).

#### 4.5.1.2 Operational Design Features

Structures can be designed and constructed to achieve a certain Haack water tightness, which limits the volume of groundwater flowing into the structures during operation, and therefore the extent of groundwater drawdown. All Melbourne Metro infrastructure that is below the watertable (including stations, portals, tunnels, shafts, adits and cross passages) would be built to a water tightness classification of at least Haack 3, which limits inflows to 0.1 L/m<sup>2</sup>/day for a 100m length of structure. These inflows are very small and generally result in a small extent of groundwater drawdown around the structure. The required water tightness classification would be achieved at the end of construction and would limit drawdown for the operational stage of Melbourne Metro.

Where the risks associated with groundwater drawdown are highest, more stringent design features have been adopted in the Concept Design to reduce inflows and drawdown during operation. The risk of ground settlement has been the primary risk influencing the selection of design features to minimise groundwater inflows and drawdown. Since ground settlement is a significant risk where the Coode Island Silt occurs (i.e. in the palaeovalleys), the precincts near the Moonee Ponds Creek and Yarra River palaeovalleys have the more stringent water tightness criteria (Haack 2 for Arden station, CBD South station and Domain station, as opposed to Haack 3 for Parkville station and the portals). CBD North station has possible contamination issues which also require inflows to be limited by Haack 2 water tightness. The precincts considered to present the highest risk of settlement or impacts to beneficial uses of groundwater have also been modelled in more detail, as described in Section 4.4.2.1.



Table 4-8 Summary of Concept Design and construction techniques modelled in this impact assessment

| Structure   | Construction technique   | Construction tanking | Operation water tightness  |
|---|--|----------------------|--|
| <b>Tunnels (except between CBD North and CBD South)</b> | TBM construction results in the tunnel being tanked (no groundwater inflow) during construction.   | Tanked               | Tanked: tightness classification of Haack 3 (0.1 L/m <sup>2</sup> per day over 100 m length of tunnel).  |
| <b>Tunnels between CBD North and CBD South</b>          | Mined tunnelling technique.  | Drained.             |  |
| <b>Western portal</b>                                   | Secant pile wall with toe grouting.  | Tanked               |  |
| <b>Arden station</b>                                    | Diaphragm walls with toe grouting.   | Tanked               | Tanked: tightness classification of Haack 2 (0.05 L/m <sup>2</sup> per day over 100 m length of tunnel). |
| <b>Parkville station</b>                                | King Post Piles or similar retaining walls.  | Drained              | Tanked: tightness classification of Haack 3 (0.1 L/m <sup>2</sup> per day over 100 m length of tunnel).  |
| <b>CBD North station</b>                                | Cavern construction<br>Access shafts King Post Piles or similar retaining walls.   | Drained              | Tanked: tightness classification of Haack 2 (0.05 L/m <sup>2</sup> per day over 100 m length of tunnel). |
| <b>CBD South station</b>                                | Cavern construction<br>Access shafts King Post Piles or similar retaining walls.   | Drained              |  |
| <b>Domain station</b>                                   | Diaphragm walls embedded into Melbourne Formation.   | Tanked               |  |
| <b>Eastern portal</b>                                   | King Post Piles or similar retaining walls.  | Drained              | Tanked: tightness classification of Haack 3 (0.1 L/m <sup>2</sup> per day over 100 m length of tunnel).  |
| <b>Emergency access shaft (Linlithgow Avenue)</b>       | King Post Piles or similar retaining walls.  | Drained              |  |
| <b>TBM launch shaft (north-west Fawkner Park)</b>       | King Post Piles or similar retaining walls.  | Drained              |  |
| <b>Emergency access shaft (north-east Fawkner Park)</b> | King Post Piles or similar retaining walls.  | Drained              |  |
| <b>Early works - all Precincts</b>                      | No information was available at the time of writing, but it is assumed that all services apart from the North Yarra Main Sewer and South Yarra Main Sewer are within the upper 3 m and are therefore above the watertable. Hence there is no risk of groundwater inflow. |                      |  |

#### 4.5.2 Mitigation Measures

Environmental Performance Requirements set the standards to be achieved during construction and operation to protect the beneficial uses of groundwater and minimise the impacts associated with groundwater drawdown. Where modelling predicts the risk of groundwater drawdown to be moderate or high even with the design features of the Concept Design discussed above, mitigation measures have been identified that could further reduce groundwater drawdown during construction, and enable the



recommended Environmental Performance Requirements to be achieved. There are two main mitigation measures that have been recommended to achieve the recommended Environmental Performance Requirements at individual precincts:

- Grouting of excavation walls to reduce inflows during construction, and
- Injection of water into aquifers to reduce drawdown during construction.

These measures have not been included in the current modelling of groundwater drawdown used in this impact assessment, but extensive previous experience on projects of a similar nature indicates that these measures can be very effective at reducing drawdown enough so that the risk to receptors is low in all cases. The measures would be modelled as part of the detailed design process as required by the Environmental Performance Requirements, to quantify their effectiveness and enable optimal design.

Other non-engineering mitigation measures are recommended in this impact assessment. Where deep-rooted trees exist in areas of shallow groundwater, they may be groundwater dependent for at least part of their life cycle. Drawdown in these areas may therefore impact the trees, and as such, monitoring of shallow groundwater levels where potentially groundwater dependent vegetation exists and watering of the trees (if drawdown occurs) is included as an Environmental Performance Requirement.

#### 4.5.2.1 Grouting

Where the planned construction method is a mined excavation (for example the CBD caverns and tunnel), grouting of the excavation walls would limit groundwater inflows during construction. For example this technique may be utilised at CBD North and CBD South stations, and the tunnels between CBD North and CBD South. Grouting is a commonly used technique for many excavations below the watertable. Texts including Gustafson (2012) and Stagg and Zienkiewicz (1968) give multiple examples of the process and successful use of grouting to reduce rock permeability around tunnels. The process is demonstrated in Figure 4-6.

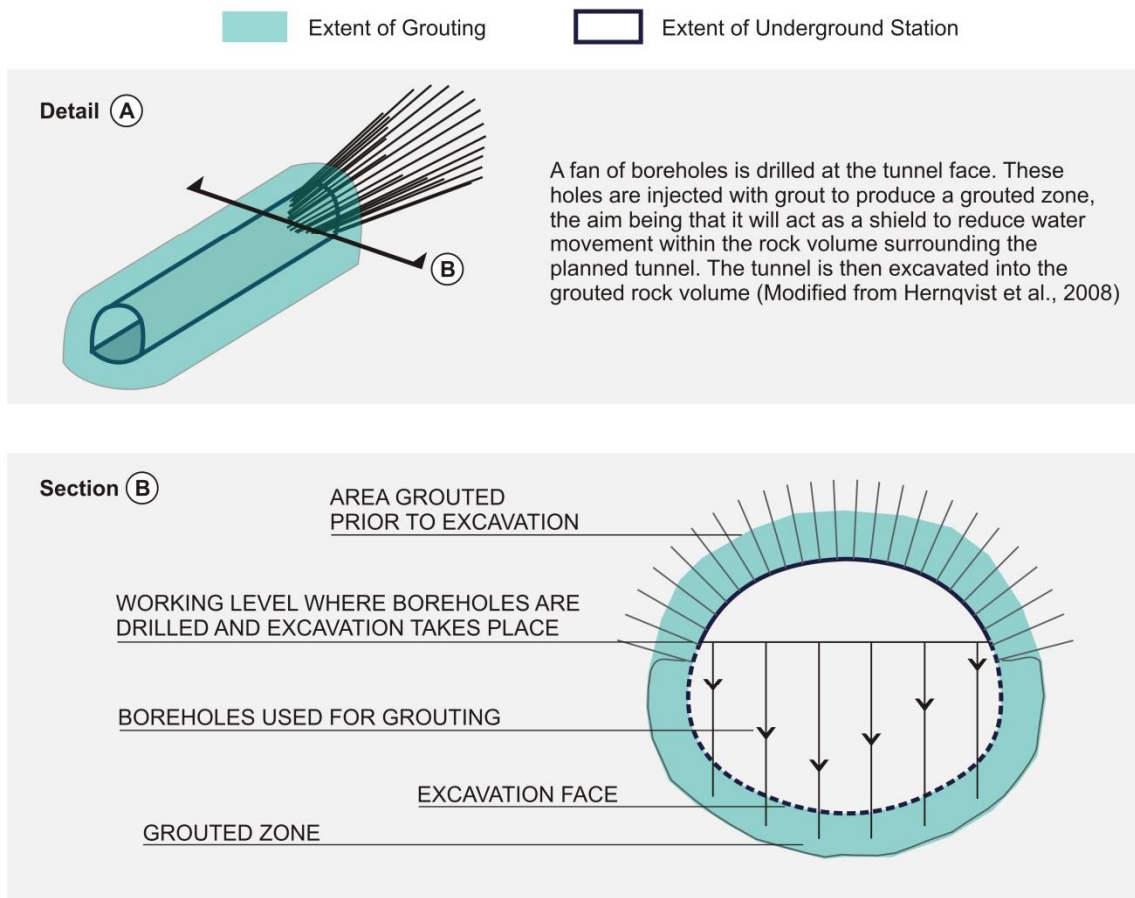


Figure 4-6 Example of grouting technique for limiting groundwater inflow to the mined excavation

#### 4.5.2.2 Temporary Injection Bores

As well as grouting, areas where drawdown is predicted to occur close to sensitive receptors or potentially cause high level of settlement could be protected by the installation of temporary groundwater injection bores. These bores inject water into confined aquifers so that water levels in overlying units (especially Coode Island Silt) are not significantly affected. This measure is commonly used to mitigate the risk of settlement, and has been successfully used for the last 20 years in the Yarra palaeovalley to prevent settlement associated with drawdown around the CityLink tunnels.

Drawdown occurring near sedimentary valleys such as the Yarra River palaeovalley and the Moonee Ponds Creek palaeovalley are more likely to require installation of temporary injection bores due to the risk of ground settlement associated with possible groundwater drawdown in these areas. As such, temporary injection bores have been identified as potential mitigation measures for the western portal, Arden station and CBD South station. The bores would be operated as needed during construction to keep groundwater levels within an acceptable range. Note that at the end of construction, the excavations would all be tanked (i.e. groundwater inflows reduced to very small values) and hence injection bores would no longer be required.

Conceptual bore locations are included in this report in the precinct sections of this report for western portal, Arden station and CBD South station, however further borefield design would occur during the detailed design phase of the Project. The design of the temporary injection borefields would confirm the number of bores required, injection depths and injection rates. As noted above, modelling would be undertaken to confirm optimal design and operation parameters for the borefields and monitoring during construction would confirm the effectiveness of the borefields. The use of injection bores would mitigate the risk of ground





settlement (Technical Appendix P *Ground Movement and Land Stability*), as well as risk to the receptors considered in this impact assessment. Discussion with relevant authorities would be required to gain approvals for injection.

The water source for injection bores would be subject to assessment during the detailed design phase, however the preference would be to use potable water because of:

- Water quality and clogging risks – the primary operational risk with injection bores is clogging of the bores (due to physical, chemical or biological clogging). The risk of clogging increases significantly if using a source of water other than potable water (e.g. groundwater, stormwater, river water) due to the constituents in that water. Clogging risk is particularly pertinent when injecting into relatively lower permeability formations. While these alternative sources of water can be treated, the water quality is still unlikely to equal that of potable water and hence, clogging risks would still be higher. Also, establishing treatment facilities for a short-term injection borefield is unlikely to be feasible
- Logistical constraints – the activity and space requirements of building a treatment plant for the alternate source of injection water, and more significantly the pipe distribution network to take the water to the injection bores, would potentially have major logistical constraints and public amenity impacts, including potentially significant disruption to various transport routes
- Reliability of supply – the alternate sources of water all have a low reliability of supply (unless large storages are built, and this is not feasible). It is not an acceptable risk to run-out of injection water.

The volumes of potable water required for injection are minor and would only be required for the duration of construction at each relevant precinct. Water requirements may be 1.5 L/sec (213 KL/day, based on estimated average inflow to the structures) which is a very minor proportion of the total water supply for Melbourne.

#### 4.5.3 Over-arching Environmental Performance Requirements

A key Environmental Performance Requirement is to develop a design phase groundwater model to assess groundwater drawdown and confirm that impacts are consistent with the impacts predicted in this report. All Environmental Performance Requirements have a monitoring component, where monitoring of potential changes in water levels near groundwater dependent values is required to confirm that mitigation measures are effective and that the risk of impact is low.

The development of a Groundwater Management Plan is included as an overarching Environmental Performance Requirement. The Groundwater Management Plan would be based on the impacts predicted in the detailed design phase groundwater model (discussed in Section 4.5.1), and would detail the management approaches, mitigation measures, and monitoring required to satisfy the Environmental Performance Requirements in this report. The Groundwater Management Plan would need to be approved by the relevant regulatory authorities.

## 4.6 Groundwater Disposal Strategy Development

A Groundwater Disposal Strategy has been developed by MMRA which considers the volume of groundwater that would require disposal during construction of the Melbourne Metro. The volume is based on the Concept Design features that minimise inflows to underground structures (e.g. TBM tunnel construction, diaphragm walls, piling) and construction sequencing to assess the timing of inflows. The volume and timing of groundwater inflows has been used to calculate both peak and average salt loads, which are the key criteria for determining appropriate collection, treatment and disposal options. AJM reviewed the Groundwater Disposal Strategy and have included it in Appendix I.

Section 17 summarises the Volumes determined in the Groundwater Disposal Strategy and establishes a preferred option for disposal. An Environmental Performance Requirements has been identified that



requires the groundwater disposal to be within agreed acceptable limits. Further discussion with Melbourne Water would be required to set these limits and confirm the approach to disposal.

## 4.7 Assumptions

Several assumptions have been made regarding the project in this impact assessment. These are listed in Table 4-9.

**Table 4-9 Assumptions of methodology**

| Assumptions  | Relevance  |
|--|--|
| <b>Project description</b>   | Infrastructure design and specifications have been taken from the MMRA Project Description (Chapter 6 <i>Project Description</i> of the EES) and assumptions stated in this document where the project description is not sufficiently detailed, including the Concept Design and construction assumptions in Table 4-8.   |
| <b>Melbourne Metro alignment</b>   | This impact assessment is based on the horizontal and vertical alignment shown on Melbourne Metro Geological Long Section (Golder Associates, 2016a), which the Concept Design version P2.3 for the rail alignment and P3.9 for stations.  |
| <b>Geology</b>   | The geological units intersected by the tunnels, stations and portals and used in the impact assessment were taken from Melbourne Metro Geological Long Section (Golder Associates, 2016a, Appendix G).  |
| <b>Chainages</b>   | The chainages used in this report were taken from Melbourne Metro Geological Long Section (Golder Associates, 2016a, Appendix G).  |
| <b>Golder field data</b>   | Golder field data (borelogs, water level monitoring, slug testing, packer testing, groundwater quality analysis) received on or before 30 September 2015 has been incorporated in this impact assessment (Golder Associates, 2016a, Appendix G). Any field data received after 30 September 2015 has not been specifically included in this EES, with the exception of the St Paul's Cathedral pumping test results (Golder Associates 2016a, Appendix H).   |
| <b>Potential impacts of groundwater contamination on human health</b>              | <p>Potential impacts of groundwater quality and contamination on different receptors has been assessed in different specialist reports, as follows:</p> <ul style="list-style-type: none"> <li>• Impacts of contaminated groundwater on human health (for example on construction workers due to tunnel inflows) are assessed in Technical Appendix Q <i>Contaminated Land and Spoil Management</i></li> <li>• Impacts on beneficial uses of groundwater caused by groundwater contaminant migration is assessed in this report.</li> </ul>  |
| <b>Potential impacts of drawdown on ground settlement</b>                          | Depressurisation of aquifers beneath the Coode Island Silt may cause depressurisation and settlement in the CIS, with potential impacts on overlying infrastructure. Drawdown is assessed in this report, but the likely settlement effects associated with drawdown are assessed in the Technical Appendix P <i>Ground Movement and Land Stability</i> .  |
| <b>Groundwater corrosivity and implications for Melbourne Metro infrastructure</b> | Design of any structures would need to take into account potential aggressive ground conditions in accordance with AS 2159-2009. A durability analysis has been undertaken and is included in Technical Appendix Q <i>Contaminated Land and Spoil Management</i> .   |
| <b>Cumulative impacts during construction</b>                                      | <p>Drawdown has been assessed individually for each precinct and each tunnel section, but in practice, drawdown would occur at the same time for adjacent precincts as construction progresses. Where significant drawdown occurs, the drawdown cone from one precinct (or tunnel section) may intersect with the drawdown cone from a neighbouring precinct. The cumulative effect where drawdown cones overlap is a greater total drawdown, which may increase impacts on groundwater dependent values in the areas of overlap.</p> <p>In the areas of the alignment where cumulative impacts would be most significant (e.g. the mined tunnels and CBD North and South stations), mitigation measures would be employed to manage drawdown. Based on professional experience on projects of a similar nature, this mitigated drawdown – even allowing for cumulative impacts – is</p> |



| Assumptions | Relevance   |
|-------------|---|
|             | expected to be significantly less than the unmitigated drawdown (not allowing for cumulative impacts) on which this assessment is based. Prediction of cumulative drawdown is therefore not critical for identifying risks in this assessment, but would be further analysed as part of the detailed design phase of the project. |

## 4.8 Stakeholder Engagement

The following specific engagement with stakeholders was undertaken as part of this assessment (Table 4-10). A draft of this impact assessment report was reviewed by the Technical Reference Group (TRG) and feedback is addressed in this report.

The Environment Protection Authority (EPA) provided detailed comments and requests for further information. These requests have been addressed where possible, but it was acknowledged that additional work would occur during the detailed design phase of Melbourne Metro to satisfy several of the issues raised by the EPA. While this detail would be available after the EES submission date, confirmation that this further material would be provided has been captured in this impact assessment through an Environmental Performance Requirement (discussed in Section 4.5.3) that requires development of a Groundwater Management Plan. It is expected that the GMP would provide the detail of groundwater management and mitigation measures requested by the EPA. Future consultation with Melbourne Water is also anticipated to further develop the groundwater disposal strategy, as discussed in Section 17.

**Table 4-10 Summary of stakeholder engagement**

| Activity   | When              | Matters discussed / issues raised   | Consultation outcomes  |
|--|-------------------|---|--|
| <b>Meeting with Southern Rural Water</b>   | 12 May 2015       | <p>Potential impacts on existing groundwater users.</p> <p>Potential impacts on CityLink recharge bores.</p> <p>Approaches to licensing groundwater extraction for dewatering associated with construction, and possible groundwater disposal options.</p> <p>Risks of subsidence and aquifer damming by the tunnels.</p> | <p>Process for future engagement with Southern Rural Water established.</p> <p>Issues to be discussed further identified.</p> <p>Further information on CityLink recharge bores requested.</p>   |
| <b>Stock and domestic bore inspections, involving site visits and discussions with site owners or operators where possible</b> | 13 – 14 July 2015 | <p>Investigation existence of stock and domestic bores registered on the Water Measurement Information System (WMIS).</p>   | <p>Site inspections were carried out to determine the existence of bores.</p> <p>Only two bores could be located during the site inspections. These bores were located at the Melbourne Market in West Melbourne and are not used as the groundwater is too saline.</p> <p>One bore was not visited because the site tenants could not be contacted, and two bores were not visited because they were considered far enough from the alignment not to be impacted.</p> |



| Activity                                 | When             | Matters discussed / issues raised  | Consultation outcomes  |
|--|------------------|--|--|
| <b>Meeting with Southern Rural Water</b> | 8 December 2015  | Existence of stock and domestic bores registered on the WMIS and inspected on 13/14 July 2015. | <p>Southern Rural Water agreed that the majority of bores no longer existed and did not need to be further considered in the impact assessment. It was agreed that six bores would continue to be considered in the EES and protected from impacts during construction and operation of Melbourne Metro. These were:</p> <ul style="list-style-type: none"> <li>• Two bores at the Melbourne Markets</li> <li>• One bore near Batman Avenue</li> <li>• Three bores that were unable to be visited in the site inspections (in Fitzroy, Richmond, North Melbourne).</li> </ul> <p>Outcomes of the bore user assessment are summarised in Appendix C of this report.</p> |
| <b>Meeting with the EPA</b>              | 11 January 2016  | Discussion of risks associated with movement of groundwater contaminant plumes                 | <p>General understanding of an approach to categorise this risk as high, moderate and low.</p> <p>Agreement to further discuss how risk of contaminant migration has been addressed in the groundwater impact assessment.</p>  |
| <b>Receipt of data from Transurban</b>   | June – July 2015 | Groundwater inflows to CityLink tunnels and operation of recharge bores                        | Data on steady state inflows to CityLink tunnels has been used in the calibration of numerical models.   |

In addition to the specific agency and TRG engagement listed in the table above, general engagement and consultation with the community was also conducted as part of this assessment. Written feedback was obtained through feedback forms and the online engagement platform, and face-to-face consultation occurred at the drop-in sessions (refer to Technical Appendix C *Community and Stakeholder Feedback Summary Report* for further information). Although the community was given the opportunity to offer feedback in regards to groundwater, no comments were provided or concerns identified.

## 4.9 Limitations

The limitations associated with this assessment are as follows:

- The groundwater dependent values that may be impacted by drawdown have been identified in a desktop analysis, with the exception of stock and domestic groundwater bores. There is limited site-specific field based knowledge of the sensitivity of vegetation and surface water bodies to changes in groundwater conditions. Potential for impacts on these assets is based on specialist knowledge and experience
- Groundwater bores have been screened at the depth of the tunnels along most of the alignment, rather than at the watertable. Deeper bores may not identify contamination, as it is often concentrated in the upper part of the watertable aquifer
- Groundwater bores have been screened at the depth of the tunnels along most of the alignment, rather than at the watertable. This means that the water levels measured for this assessment may not be representative of the watertable, but rather, of the potentiometric surface of deeper aquifers. This is likely to result in only small differences along most of the alignment (e.g. 1-2 m at most). One exception to this may be in any areas significantly affected by CityLink drawdown, where deeper units would have significantly lower water levels
- Some impacts on groundwater levels may occur over a large area. Since much of this area is outside the Project Boundary there has not been a detailed site assessment of existing conditions or the sensitivity



of receptors (e.g. contamination, vegetation dependence on groundwater) and such a detailed assessment over a large area is not feasible. The assessment of risk to receptors is instead based on a broader scale assessment of the existing conditions

- Some of the potential impacts described in this impact assessment are based on the results of analytical methods to assess drawdown associated with construction and operation of the stations, portals, shafts and tunnels (refer Section 4.3.2.1.1)
- Drawdown estimates for the western portal, Arden station, CBD North station, CBD South station, the tunnels between CBD North and CBD South station, and Domain station were derived from the regional numerical model developed by Golder Associates. These results are subject to the limitations described in Golder Associates (2016b), Appendix H.



## 5 Regional context

### 5.1 Geology and Hydrogeology

The geology of the study area has been described in Melbourne Metro EES Summary Report (Golder, 2016a, Appendix G). Golder developed a 3D geological model of the study area based on specific Project information as well as previous studies they have completed in the area. The cross sections produced by Golder based on this model have been used in this impact assessment to form precinct-specific hydrogeological conceptualisations.

The geology of Melbourne consists of Silurian bedrock overlain by Tertiary and Quaternary sediments and basalts. The Silurian bedrock in the area is the Melbourne Formation and consists of mudstone, sandstone and siltstone that has been folded, faulted and intruded with dykes, sills and granite bodies. These rocks have been weathered to varying depths, with fresh rock sometimes existing within the shallow profile, whereas in other areas bedrock is weathered to depths of up to 60 m (Hancock, 1992).

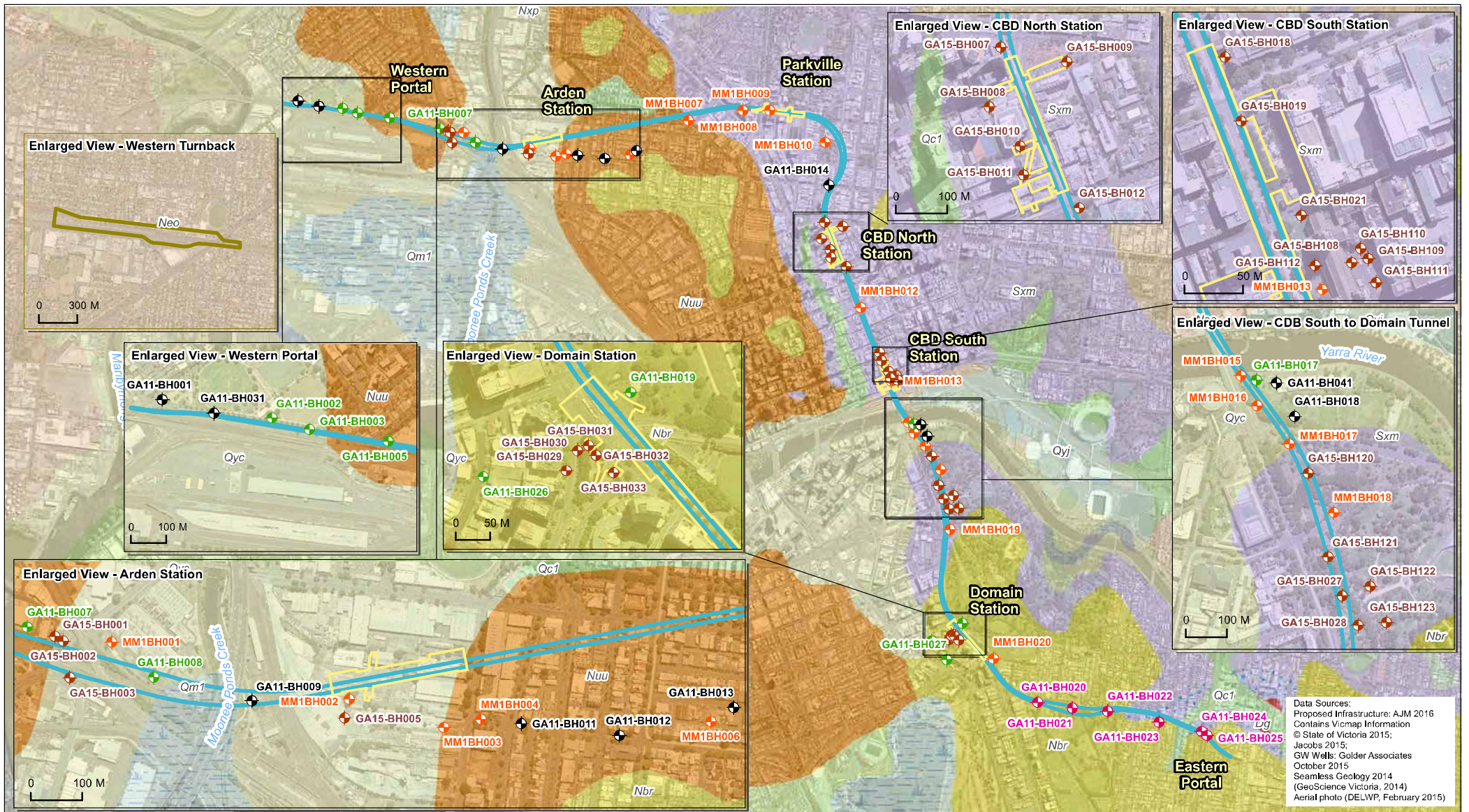
Where the Melbourne Formation occurs at the surface, it is unconfined to semi confined, depending on the extent of weathering in the upper portions of the unit. The upper portion of the bedrock weathers to form clay, which may locally confine the formation. Where the Melbourne Formation is overlain by the Tertiary and Quaternary sediments, it is likely to be semi to fully confined.

The nearest granite intrusion in the study area is near the eastern portal, where some minor metamorphosis of the Melbourne Formation siltstone has also occurred at the contact with the granite. It is not expected that metamorphosed rocks would be encountered by the tunnels. Volcanic dykes and sills are expected to be encountered across the study area. These intrusions have been moderately to extremely weathered to clay and range in thickness from <1 to 16 m.

The Melbourne Formation is overlain by Tertiary sediments and volcanics, including lake and swamp deposits (Werribee Formation), basalt flows and ash (Older Volcanics), marine sediments within eroded valleys (the Newport Formation) and sandy material (Brighton Group). Between the Maribyrnong River and Moonee Ponds Creek, the Werribee Formation and Older Volcanics are confined where they are overlain by the Coode Island Silt and unconfined or semi-confined elsewhere. At the southern end of the alignment near the eastern portal the Brighton Group is unconfined and unsaturated in many places. These formations are described in more detail in Appendix D of this report.

A series of sea level fluctuations in the Quaternary period then deposited gravels, sands, silts and clays over the Silurian and Tertiary units. These sediments cover much of Port Melbourne and South Melbourne and underlie the areas surrounding the Yarra River, the Maribyrnong River and the Moonee Ponds Creek. The Fishermans Bend Silt and Coode Island Silt act as confining layers to the other sediments in the palaeovalleys. The confined units below the Fishermans Bend Silt (Moray Street Gravels, Quaternary Fluvial Sediments and Lower Newer Volcanics Flow) are likely to have some degree of hydraulic connectivity. There may also be hydraulic connectivity between these units and the overlying Holocene Alluvium where the inferred overlying Holocene Alluvium valley intersects the older Jolimont clay.

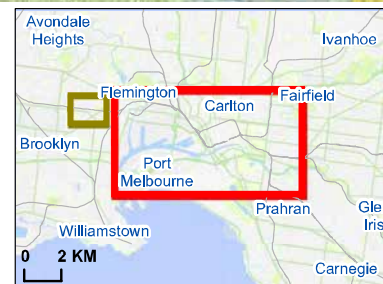
Figure 5-1 shows the geological units that outcrop at the surface of the study area. The main geological units in the study area, their occurrence, description and hydrogeological classification are included in Appendix D of this report. Appendix D.2 lists the hydrostratigraphy that would be encountered in each Melbourne Metro precinct, along with the hydraulic properties relevant to the area.



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Jacobs 2015;  
 GW Wells: Golder Associates  
 October 2015  
 Seamless Geology 2014  
 (GeoScience Victoria, 2014)  
 Aerial photo (DELWP, February 2015)

**Legend**

- |                                     |                         |                                     |
|-------------------------------------|-------------------------|-------------------------------------|
| <b>Groundwater Monitoring Wells</b> | <b>Geology 1:50,000</b> | Coastal Dune Deposits (Qd1)         |
| Stage 1                             | Devonian Granite (Dg)   | Waste Deposits (Qhw)                |
| Stage 2 Phase 2A                    | Brighton Group (Nbr)    | Swamp and Lake Deposits (Qm1)       |
| Stage 2 Phase 2B                    | Newer Volcanics (Neo)   | Coode Island Silt (Qyc)             |
| Stage 2 Phase 2C                    | Older Volcanics (Nuu)   | Jollimont Clay (Qyj)                |
| RD (to 30 Sept 2015)                | Nxp                     | Port Melbourne Sand (Qyp)           |
| Proposed Station Footprint          | Alluvium (Qa1)          | Melbourne Formation (Sxm): hornfels |
| Proposed Alignment                  | Colluvium (Qc1)         | Melbourne Formation (Sxm): generic  |
| Western Turnback                    |                         |                                     |



**Melbourne Metro Rail Project**

Title:  
EES Groundwater - Geology Overview

|  |                            |                    |                 |
|--|----------------------------|--------------------|-----------------|
| Drawing Number:<br>MMR-AJM-UGAA-MP-NK-500166 |                            | Revision:<br>P1    |                 |
| Drawn By:<br>A. Davy                         | Approved By:<br>K. Dowsley | Date:<br>7/04/2016 | Map Size:<br>A4 |

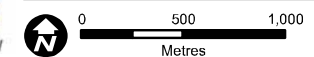


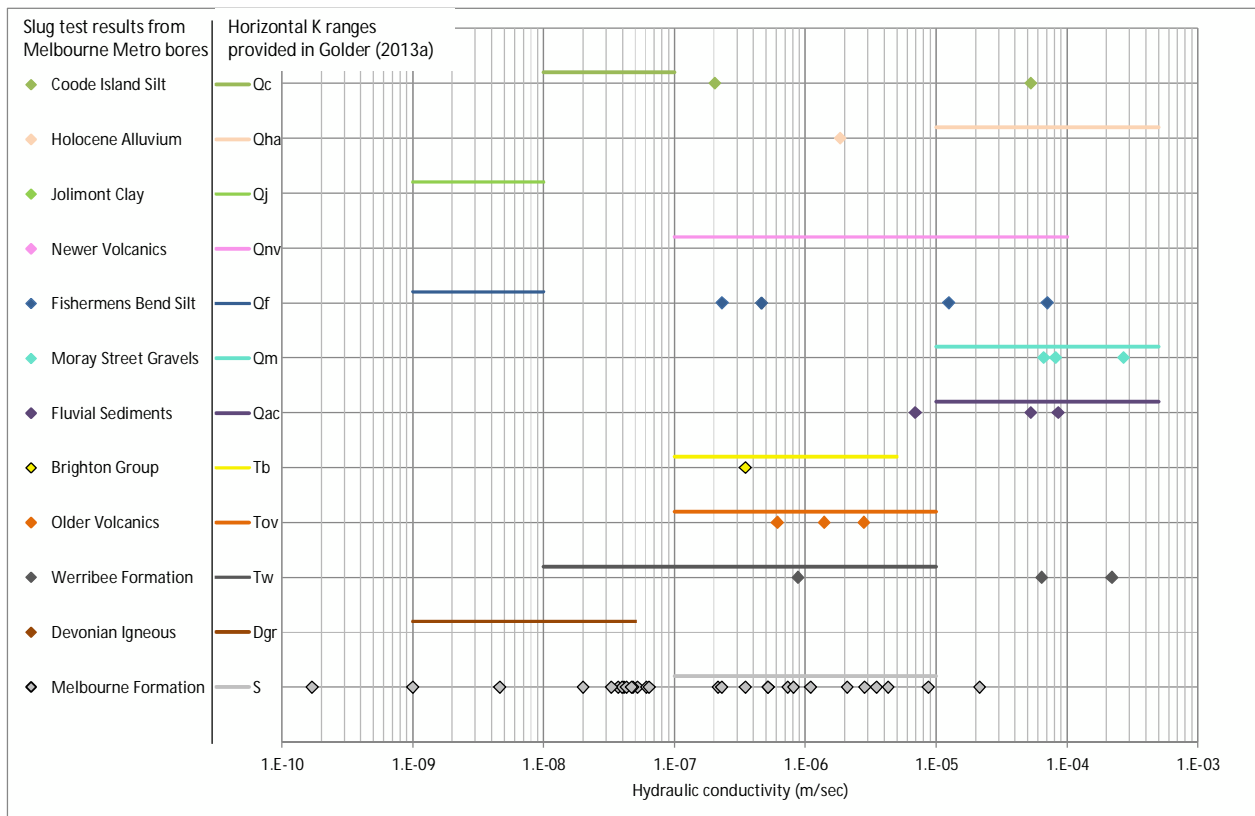
Figure 5-1 Surface geology



## 5.1.1 Hydraulic Properties

### 5.1.1.1 Horizontal Hydraulic Conductivity

Hydraulic conductivity is the key parameter that controls drawdown in response to tunnel inflows, which in turn may impact assets such as surface water, vegetation, built infrastructure and existing groundwater users. Single bore hydraulic tests (slug tests) have been undertaken in a number of bores along the alignment, and results are shown in Appendix D of this report. The range of hydraulic conductivity results for each geological formation is shown in Figure 5-2, which are based on slug tests conducted during Melbourne Metro, as well as on Golder’s experience and published literature as stated in Golder (2016a Appendix G, Section 5, and 2016b, Appendix H Section 4.4).



**Figure 5-2 Distribution of slug test results per formation with ranges from Golder’s previous experience (Golder 2016a, Appendix G, Golder 2016b, Appendix H)**

**Melbourne Formation:** The Melbourne Formation is expected to be encountered in the tunnels and stations for the majority of the alignment, from east of the Arden station to the Yarra River and from the south of the Yarra River to the eastern portal. Hydraulic conductivity is very variable in this unit, which results in significant uncertainties for estimating tunnel inflows. The results of the slug tests undertaken within the Melbourne Formation have the largest range and are spread over five orders of magnitude (Figure 5-2). Previous studies such as the Northern Sewage Project (NSP, SKM 2005), CityLink (Golders 1997), Peel Street North (EPA 2010), and East West Link (SKM 2013) have reported similarly variable hydraulic conductivity values.

**Devonian Igneous Rocks:** Although the tunnels are not expected to intersect any known igneous intrusions, it is possible that dykes exist in the Melbourne Formation that have not been identified. No tests have been done in the igneous rocks for this Project, but Golder’s previous experience (Golder, 2016b) suggests that previously encountered dykes have predominately acted as barriers to groundwater flow, probably because they are weathered to clay rather than fresh fractured rock units.





**Werribee Formation:** The tunnels are expected to intersect this unit at the western portal and to the east of the Arden station. The two tests undertaken in the Werribee Formation resulted in hydraulic conductivity values an order of magnitude higher than the top end of the relatively large range provided by Golder's from previous experience (Golder, 2016b) (Figure 5-2). Other previous projects support higher hydraulic conductivity results of  $6 \times 10^{-6}$  to  $2 \times 10^{-4}$  m/sec (Hancock 1992) and  $1.2 \times 10^{-5}$  to  $3.5 \times 10^{-4}$  m/sec (GHD 2011).

**Older Volcanics:** The tunnels are expected to intersect this unit at the western portal. All three tests completed for the Project are consistent with Golder's previous experience (Golder, 2016b) (Figure 5-2). Values from other projects are either generally consistent with these results (e.g. Westlink, SKM 2010) or higher (e.g.  $1.2 \times 10^{-7}$  to  $1.2 \times 10^{-4}$  m/sec, GHD 2011). This formation is fractured rock and the hydraulic conductivity would depend on the degree of fracturing and may vary greatly within a small area.

**Brighton Group:** The tunnels are likely to intersect this unit to the south of the Yarra River (above the CityLink tunnels), south of the Domain station and at the eastern portal. However, the Brighton Group is typically above the watertable across the alignment. The one test done in the Brighton Group falls within the relatively narrow range of previous experience stated by Golder (Golder, 2016b). Results from the WestLink investigation indicated slightly lower hydraulic conductivities, but within a similar order of magnitude ( $6 \times 10^{-8}$  to  $1 \times 10^{-7}$  m/sec, SKM 2010).

**Fluvial Sediments:** This unit is likely to be intersected by the tunnels west of Moonee Ponds Creek and potentially, to the east of Moonee Ponds Creek. The hydraulic conductivity of the two bores screened in the Quaternary Fluvial (and colluvial) sediments fall within or very close to the range of hydraulic conductivity values provided by Golder's previous experience (Golder, 2016b). However, there is potential for variation of hydraulic conductivity in this unit depending on the relative proportion of sand and clay present.

**Moray Street Gravels:** The tunnels are not expected to encounter the Moray Street Gravels, however the section of tunnels beneath the Yarra River would be located just above (within 5 m of) this formation. In addition, the Moray Street Gravels are an important unit in the geological and numerical groundwater models as they are the primary pathway for propagating drawdown beneath the Coode Island Silt, which can result in subsidence. Melbourne Metro's results are consistent with the range of hydraulic conductivity values provided by Golder's previous experience (Golder, 2016b).

**Fishermans Bend Silt:** The vertical alignment indicates that this unit is likely to be intersected at the Yarra River, at Moonee Ponds Creek and at the Arden station. Results of testing for Melbourne Metro and from previous experience (Golder, 2016b) indicate high variability. Golder (2016a) describes this unit as sandier towards the base and at the edges of the unit with more clay material towards the top. Consequently, they have designated the upper clayey material as the Upper Fishermans Bend Silt and the lower sandier material as the Lower Fishermans Bend Silt. Previous studies within the Yarra River area (CityLink (Golder, 1996), Power Street Interchange (Ervin et al., 2006a) and Crown Casino (Ervin et al., 2006b)) fall within the range provided by Golder. The Westlink project (SKM, 2010) reported hydraulic conductivity values four orders of magnitude higher than the range provided by Golder, although the authors note the formation is quite sandy at this point. The above indicates that the ranges of hydraulic conductivity for the Fishermans Bend Silt may be large and dependent on the proportion of sandy material present.

**Newer Volcanics:** The vertical alignment indicates that this unit is likely to be intersected to the north of the Yarra River. No tests were undertaken in the Newer Volcanics. The large range of values from past experience provided by Golder is largely due to the fractured nature of this unit (Golder, 2016b). Previous testing of this unit confirms that the range of possible hydraulic conductivity values is large ( $5 \times 10^{-9}$  to  $1 \times 10^{-4}$  m/sec) (SKM 2013, SKM 2010, SKM 2006).

**Jolimont Clay:** The current vertical alignment indicates that this unit is likely to be intersected to the north of the Yarra River. No tests were undertaken in the Jolimont Clay. The narrow range provided by Golder from their past experience (Golder, 2016b) is indicative of the predominately clayey material within this unit.



**Holocene Alluvium:** The current vertical alignment of the tunnels indicates that this unit is not likely to be intersected. The test from one bore screened in the Holocene Alluvium (GA11-BH018) is an order of magnitude lower than the range provided by Golder's previous experience (Golder, 2016b). The expected range of hydraulic conductivity for this unit is therefore relatively large ( $1 \times 10^{-6}$  m/sec to  $5 \times 10^{-4}$  m/sec, SKM 2013) and is dependent on the degree of clay bounding within the deposits.

**Coode Island Silt:** The current vertical alignment indicates that the tunnels are likely to intersect this unit south of the Yarra River, at the western portal, under Moonee Ponds Creek and at the Arden station. Results from the Melbourne Metro testing, Golder's previous experience (Golder, 2016b), and other previous projects indicate a narrow range of expected horizontal hydraulic conductivity values within the Coode Island Silt ( $1 \times 10^{-8}$  to  $5 \times 10^{-7}$  m/sec).

### 5.1.1.2 Vertical Hydraulic Conductivity

Golder (2016b, Appendix H) give values of vertical hydraulic conductivity based on previous experience and published literature as follows:

- Coode Island Silt:  $1 \times 10^{-9}$  to  $1 \times 10^{-8}$  m/sec (i.e. ratio of 0.1 to horizontal hydraulic conductivity)
- Fishermans Bend Silt:  $1 \times 10^{-8}$  m/sec (i.e. ratio of 0.1 to 1 to horizontal hydraulic conductivity).

For the majority of units within the Golder groundwater model, a ratio of 1:1 was used for horizontal and vertical hydraulic conductivity (with the exception of the above units).

Pumping tests during the Westlink investigation (SKM, 2010) estimated the following vertical hydraulic conductivities:

- Fishermans Bend Silt:  $7 \times 10^{-8}$  m/sec (from a pumping test undertaken in the underlying Moray Street Gravels)
- Brighton Group:  $5 \times 10^{-11}$  m/sec (from a pumping test undertaken in the underlying Older Volcanics).

The results from the Fishermans Bend Silt are within the range provided by Golder but the results for the Brighton Group indicate that a 1:1 ratio of vertical and horizontal hydraulic conductivity for this unit may not be valid. An alternative interpretation is that the test mentioned for the Brighton Group was in an area of particularly low vertical hydraulic conductivity and that regional values would be higher.

### 5.1.2 Storativity and Specific Storage

A 9 day pumping test has been completed at St Paul's Cathedral which gives a specific storage of the Melbourne Formation of  $4 \times 10^{-6} \text{ m}^{-1}$ , which is consistent with what would be expected for a slightly weathered, sedimentary fractured rock. During the Stage 1 preliminary groundwater investigations undertaken by Aurecon et al. (2010b), other storage estimates were listed for some units based on previous studies. Table 5-1 shows the range of storativity values available from previous research. For a detailed discussion of storativity and specific storage values refer to Appendix D of this report.

**Table 5-1 Storativity (S) and specific storage (S<sub>s</sub>) (S = S<sub>s</sub> × b)**

|                            | Melbourne Metro pumping test            | Stage 1 analytical modelling (Aurecon et al., 2010b)) | Golder transient modelling (Golder, 2016b) | Other values  | Reference                          |
|----------------------------|---|---|--|---|------------------------------------|
| <b>Melbourne Formation</b> | $S_s = 4 \times 10^{-6} \text{ m}^{-1}$ | S = 0.01  | S = 0.05                                   | S = < 0.05 (unconfined)   | Department of Water Resources 1992 |
|                            |   |   |  | S = $4 \times 10^{-4}$ and $3 \times 10^{-4}$ (unconfined, but considered very low) | RWC 1992                           |



|                             | Melbourne Metro pumping test | Stage 1 analytical modelling (Aurecon et al., 2010b)) | Golder transient modelling (Golder, 2016b) | Other values  | Reference             |
|-----------------------------|------------------------------|---|--|---|-----------------------|
|                             |                              |   |  | S = 0.007 and 0.02 (unconfined)   | SKM 2005              |
| <b>Brighton Group</b>       |                              | S = 0.05  | S = 0.08                                   | S = $1.5 \times 10^{-1}$ (in high K material, expected to be above average for this unit) | SKM 2005              |
| <b>Moray Street Gravels</b> |                              | S = 0.0005 (semi-confined)                            | S = 0.1                                    | S = $1.5 \times 10^{-4}$ (confined)   | HydroTechnology 1994  |
|                             |                              |   |  | S = $2.4 \times 10^{-5}$ (confined)   | SKM 2004              |
|                             |                              |   |  | S = $1.2 \times 10^{-4}$  | SKM 2010              |
| <b>Coode Island Silt</b>    |                              | $S_s = 0.005 \text{ m}^{-1}$                          | S = 0.15                                   | $S_s = 5 \times 10^{-3} \text{ m}^{-1*}$  | Ervine et al. (2006b) |
|                             |                              |   |  | S = 0.001 to 0.01 (unconfined)  | Aurecon et al., 2010a |

\* Measured from laboratory testing rather than pumping test

## 5.2 Potential Acid Sulfate Soils

Acid sulfate soils (or rock) are naturally occurring and can be found in both inland and coastal areas. Acid sulfate soils contain elevated concentrations of iron sulfides, which form when the soil is waterlogged and organic-rich. Under conditions where there is no air available, and where soils are below the watertable, the sulfides in the soil remain stable and do not present any environmental concerns.

If the watertable is lowered, or soil is excavated and exposed to air, a chemical reaction between the iron sulfides and oxygen produces acid. This can also lead to the release of heavy metals from the soils. When the watertable rises, the acidic groundwater and heavy metals can mobilise, causing potential impacts on aquatic ecosystems and deep rooted vegetation, as well as the corrosion of underground concrete or steel structures, foundations or services.

Acid sulfate soils can be present in the form of:

- Potential acid sulfate soils (PASS) - Soils that contain sulfidic materials that have not been oxidised, but that would generate acidity if exposed to air
- Actual acid sulfate soils (AASS) - Soils that have already become acidified are a result of exposure to air.

Impacts related to excavation of PASS soils and their management (e.g. acid run-off from stockpiles) are addressed in Technical Appendix Q *Contaminated Land and Spoil Management*. This assessment considers the potential impacts resulting from dewatering required during construction of features below the watertable.

Melbourne Metro investigations have included assessment of the acid generation potential and corrosivity of man-made fill, river sediments and natural soils and rock (refer to Appendix B of Technical Appendix Q *Contaminated Land and Spoil Management* for details of ASS/ASR analytical methods). For the purposes of assessing risks of dewatering associated with PASS, the difference between ASS and ASR is minimal.

A review of various data sources of information on potential ASS/ASR along the alignment was conducted



(Appendix B of Technical Appendix Q Contaminated Land and Spoil Management) and noted the potential for acid generating materials at the following locations or associated with the following geological units:

- Western portal area. This is consistent with local geology which includes Yarra Delta Sediments including the Coode Island Silt, which have a moderate to high potential to generate acidity
- Tunnels: CBD South to Domain Station. The tunnelling activities beneath the Yarra River area are also likely to encounter Coode Island Silt
- The geology along the remainder of the project alignment, which comprises Silurian-aged siltstones (the Melbourne Formation) through the North Melbourne, Carlton and CBD areas. Acid leaching tests on Melbourne Formation rock cores were conducted to assess the potential for short to long term acid generation. These static and kinetic tests, along with standard acid sulfate rock tests, indicate that moderately weathered to fresh Melbourne Formation rock has the potential to generate acid when oxidised
- Brighton Group sands and clays through the South Melbourne and South Yarra areas, are also known to have potential acid sulfate properties.

Regarding the potential for various geological materials to generate acidity, based on project testing to date, Golders (2016a, Appendix G) concluded the following:

- Coode Island Silt – Moderate to high potential to generate acidity
- Brighton Group – Low potential to generate acidity
- Werribee Formation – Low potential to generate acidity (but based on a small data set)
- Fishermans Bend Silt – Low potential to generate acidity (but based on a small data set)
- Melbourne Formation – Deep fresh to slightly weathered rock, typically present at depths greater than 24 m, has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered material is typically non-acid forming and hence low risk.

In summary, the highest risk units for activation of PASS through lowering of the watertable are the Coode Island Silt and fresh to slightly weathered Melbourne Formation. In areas of Coode Island Silt where this risk is present, there would be also the risk of subsidence – the mitigation measures proposed to deal with subsidence (grouting and injection bores) would minimise drawdown and hence the risk of any significant PASS activation is low. For the Melbourne Formation, the watertable generally resides in highly weathered material where the risk of PASS is low, and hence the risk of any significant PASS activation in the Melbourne Formation is generally low.

### 5.3 Groundwater Levels and Variability

In the wider project area, the highest groundwater levels are in the north and north-east and groundwater generally flows south and south west towards the Yarra River and Port Phillip Bay. The highest groundwater elevations along the alignment occur in the Parkville area at 25 m AHD and the lowest groundwater levels occur in the area of the CityLink tunnels at around -10 m AHD. Based on the current vertical alignment (Concept Design and alternative design options) and measured groundwater elevations the maximum height of groundwater above the tunnels is 34 m. In some areas, the measured groundwater level is below the base of the tunnels.

Figure 5-3 shows most recent water level monitoring results for each bore along the alignment. Regional groundwater flow is influenced by features such as the Moonee Ponds Creek, North and South Yarra Main Sewers, the City Loop tunnels and the CityLink Tunnels. This can be seen on Figure 5-3 where the watertable level is below 0 m AHD:

- In the west of the alignment near the western portal and Arden, where the North Yarra Main Sewer is lowering groundwater



- In the south-west of the alignment near Domain, where the South Yarra Main Sewer is lowering groundwater
- In the CBD, where the City Loop tunnels are lowering groundwater (Golder 2016b, Appendix H)
- To the south of the Yarra River, where the CityLink tunnels are lowering groundwater
- Around deep basements in the CBD and Southbank where inflows to basements are lowering groundwater.

The groundwater level monitoring to date for the Project has been sporadic and no bores have enough data to be able to assess seasonal or long term trends. Groundwater level loggers were installed between August 2013 and May 2014 in 12 bores and between August and September 2015 in 6 bores. The resultant hydrographs are shown in the relevant precinct chapters in Appendix D of this report. For the 9 month monitoring period (rather than the 12 months usually assessed for annual variations), the hydrographs indicate a possible seasonal variation of between 0.15 m and 0.5 m. Two bores (GA11-BH022 and GA11-BH027) have had loggers installed between August 2013 and August/September 2015 with a continuous logging record. Both of these bores are screened in the Melbourne Formation and are located in the southern end of the alignment. These bores show an annual seasonal variation of between 0.2 m and 0.5 m.

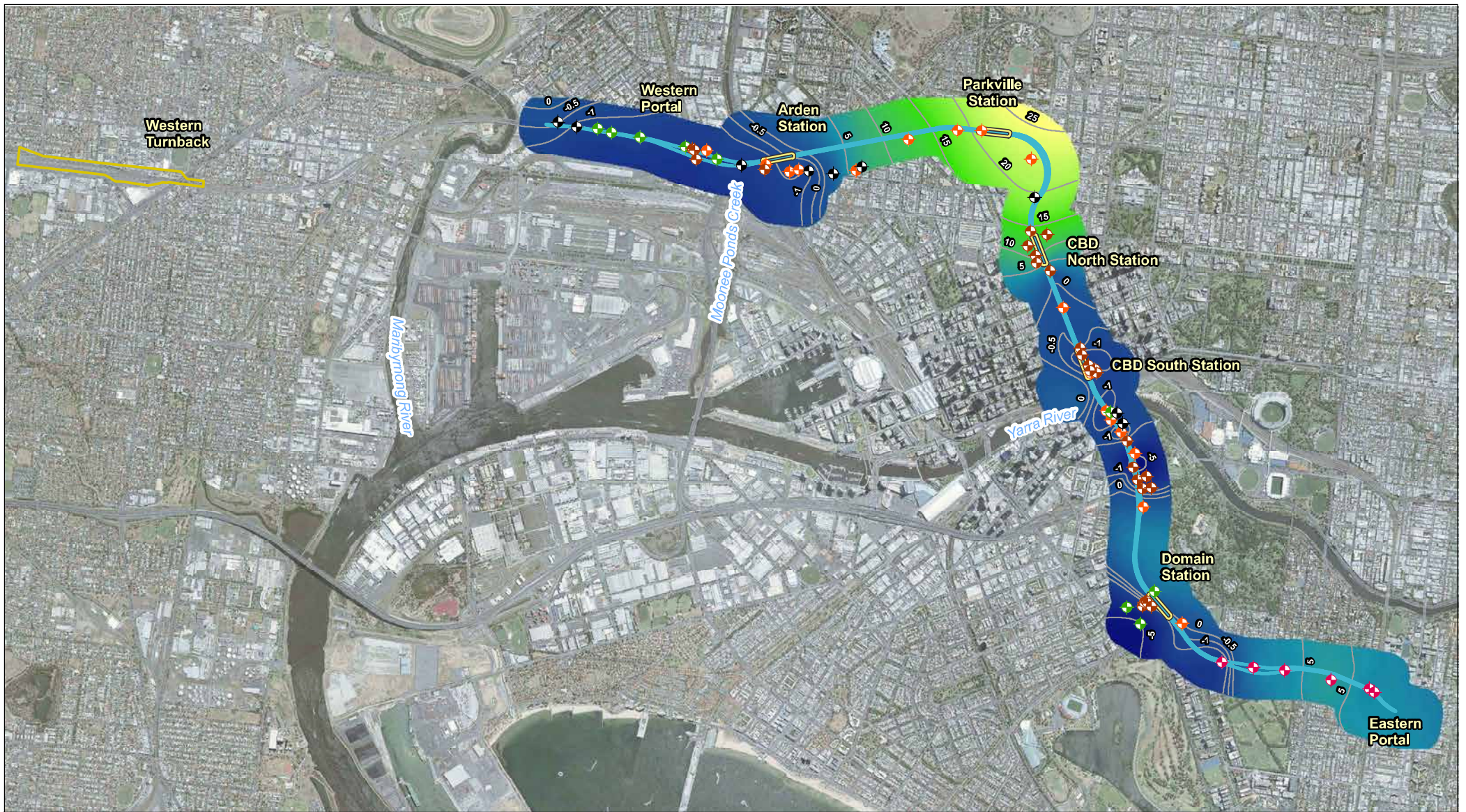
Bores in the State Observation Bore Network monitor long-term groundwater levels and chemistry. The nearest SOBN bores to the tunnels alignment are at Spotswood (57922 and 57923) and monitor the Newer Volcanics, which is the watertable aquifer at this location. The data from these bores indicate that annual seasonal groundwater variations are also within the order of 0.5 m (Appendix C of this report), although some years show groundwater level fluctuations of up to 1 m.

It is reasonable to assume that groundwater levels along the alignment follow similar patterns to those seen in the State Observation Bore Network bores and therefore, groundwater levels may have historically been 2 to 3 m lower than they are presently and up to 1 m higher. Therefore, natural variability in groundwater levels could be 3 to 4 m along the alignment.

In the urban environment, groundwater levels can be altered substantially by infrastructure. Man-made features that have an impact on current groundwater levels also have the potential to impact long-term groundwater levels. For instance, if infrastructure that is currently acting as a groundwater sink was replaced or repaired groundwater levels could rise to reflect the more natural regional levels. Examples of where this could occur include around the South Yarra Main Sewer and the North Yarra Main Sewer, and the City Loop and CityLink tunnels. In some parts of the alignment, these anthropogenic influences on long-term groundwater levels could be far more significant than climate related variability.

There are currently 70 project-specific groundwater monitoring bores along the alignment and groundwater levels have been measured on a number of occasions by Golder. A summary of bore locations and groundwater level monitoring undertaken to date is provided in Appendix D of this report. Melbourne Metro bores were designed to assess conditions at tunnel depth and have not been designed to (necessarily) measure the watertable. Therefore, it is not always clear whether the watertable or a potentiometric surface is being measured. For the purpose of this impact assessment, it is assumed that the watertable and the potentiometric surfaces of most aquifers are very similar because there is some connection between aquifers overlying the tunnels. This would allow vertical interaction between aquifers that results in similar groundwater levels at equilibrium. In the Melbourne Formation a high degree of weathering can restrict vertical interaction between groundwater at different depths within the siltstone, however there is expected to be some degree of connectivity that results in similar groundwater levels at equilibrium.

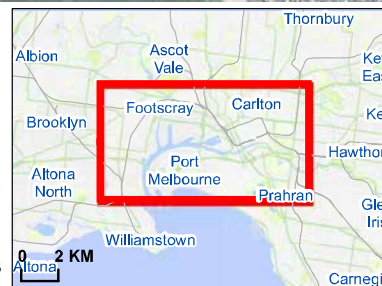
An estimate of the aquifer's degree of confinement at each bore location is made in Appendix D of this report based on the Golder geological model. However, in most areas of the alignment the confining condition is not known.



**Legend**

- Groundwater Monitoring Well Stage 1
- Groundwater Monitoring Well Stage 2 Phase 2A
- Groundwater Monitoring Well Stage 2 Phase 2B
- Groundwater Monitoring Well Stage 2 Phase 2C
- RD (to 30 Sept 2015)
- Watertable (Jacobs, 2015)  
High : 26.4m  
Low : -6.2m
- Watertable Contours
- Proposed Alignment
- Proposed Station
- Western Turnback Precinct

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Jacobs 2015;  
 GW Wells: Golder Associates October 2015  
 Aerial photo (DELWP, February 2015)



**Melbourne Metro Rail Project**

Title:  
 EES Groundwater - Watertable Overview

Drawing Number: MMR-AJM-UGAA-MP-NK-500168  
 Revision: P1

Drawn By: A. Davy  
 Approved By: K. Dowsley  
 Date: 7/04/2016  
 Map Size: A4

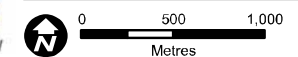


Figure 5-3 Potentiometric surface (assumed to be watertable) from bores on Melbourne Metro alignment



## 5.4 Groundwater Quality

This section sets out the groundwater quality regional context based on groundwater samples taken along the alignment and contaminated sites identified by the EPA.

Groundwater samples have been collected for laboratory analysis from a total of 58 bores. Full groundwater sampling results are included in Appendix E of this report. Drawdown caused by dewatering during construction and long-term operation has the potential to mobilise and transport groundwater contaminants in the vicinity of the alignment. Contaminant migration may also cause volatile contaminants to come into contact with underground structures, creating a risk of vapour intrusion to underground structures. Both of these risks may impact on groundwater users, the health and safety of construction workers, groundwater disposal options and potentially, other drained structures in the areas (e.g. basements).

In Victoria, groundwater quality objectives are designated by the SEPP (GoV) as described in Appendix A of this report. The National Environmental Protection Measures (NEPM) Groundwater investigation levels (GILs) are defined as the concentrations of a contaminant in the groundwater above which further investigation or a response is required. The GILs are based on Australian water quality guidelines.

Salinity data from regional mapping (DSE, 2012) and from samples collected from boreholes during this study is presented in Figure 5-4. Not all the bores sampled during this study are representative of the watertable aquifer and therefore, direct comparison is not appropriate in all cases.

Total dissolved solids (TDS) is a measure of salinity. The TDS of the groundwater ranges from 1,300 mg/L to 38,000 mg/L, with highest salinity in the west of the study area. Where the alignment crosses waterways (Maribyrnong River, Moonee Ponds Creek and Yarra River) salinity is higher than indicated by the regional watertable map. These high salinities are within the deeper confined aquifers.

Salinity is used to identify the beneficial uses of groundwater that must be protected under the SEPP (GoV) (1997). The salinity segments and their beneficial uses are shown in Table 5-2. The high salinity west of Parkville station means that in a broad sense, the groundwater is not suitable for beneficial uses associated with segments A1, A2, B or C. Only uses associated with segment D must be protected in this area, however there may be some local areas of lower salinity groundwater that require protection for more sensitive uses. This is discussed in each precinct chapter of this report.

Depending on the aquifer, several of the beneficial uses identified in Segment D may not be applicable due to existing contamination (e.g. where the EPA has designated GQRUZs), or due to low yields of an aquifer that make extraction of groundwater uneconomic. In particular, low permeability aquifers such as the Melbourne Formation may not yield suitable quantities of groundwater to enable irrigation or industrial water use. Stock watering is unlikely to be a feasible use in the urban setting of the Melbourne Metro.

East of Parkville station the groundwater is still too saline for drinking water, but may be suitable for irrigation, stock watering and primary contact recreational, such as for filling swimming pools. These uses require protection in this part of the study area, although if there are reasons that preclude some of these uses (such as low yields), then the beneficial use may not apply.

**Table 5-2 Salinity segments and beneficial uses (SEPP GoV 1997)**

| Segment                 | A1                        | A2                         | B                         | C                          | D                         |
|-------------------------|---------------------------|----------------------------|---------------------------|----------------------------|---------------------------|
| <b>TDS range (mg/L)</b> | 0 - 500                   | 500 – 1,000                | 1,001 – 3,500             | 3,501 – 13,000             | > 13,000                  |
| <b>Beneficial uses</b>  | Maintenance of ecosystems | Maintenance of ecosystems  | Maintenance of ecosystems | Maintenance of ecosystems  | Maintenance of ecosystems |
|                         | Potable water (desirable) | Potable water (acceptable) | Potable mineral water     | Primary contact recreation | Industrial water use      |



| Segment | A1                         | A2                         | B                          | C                        | D                        |
|---------|----------------------------|----------------------------|----------------------------|--------------------------|--------------------------|
|         | Potable mineral water      | Potable mineral water      | Irrigation                 | Stock watering           | Buildings and structures |
|         | Irrigation                 | Irrigation                 | Primary contact recreation | Industrial water use     |                          |
|         | Primary contact recreation | Primary contact recreation | Stock watering             | Buildings and structures |                          |
|         | Stock watering             | Stock watering             | Industrial water use       |                          |                          |
|         | Industrial water use       | Industrial water use       | Buildings and structures   |                          |                          |
|         | Buildings and structures   | Buildings and structures   |                            |                          |                          |

### 5.4.1 Known Groundwater Contamination

Groundwater quality sampling of Melbourne Metro bores gives an indication of the contamination status of groundwater along the alignment. The presence of organic compounds is discussed here as an indicator of anthropogenic contamination, but other contaminants may also be present. Full groundwater quality results are included in Appendix E of this report.

The majority of bores recorded organic compounds below laboratory detection levels. Organic contaminants above groundwater investigation levels were detected in the following bores:

- GA11-BH002 and GA11-BH007 in the western portal precinct
- GA11-BH041 in the Tunnels precinct between CBD South station and Domain station
- GA11-BH022 in the Tunnels precinct between Domain station and eastern portal
- GA15-BH007 in CBD North station precinct
- GA15-BH021 in CBD South station precinct.

These contaminants may be indicative of larger contaminant plumes, and therefore indicate that if drawdown occurs, there is a risk of contaminant migration to neighbouring properties that may preclude beneficial uses. Volatile contaminants were also detected in these bores and therefore there is a risk of vapour migration into underground structures. The potential for these risks to occur depends on whether there would be drawdown in the area of contamination. This potential for impact is assessed in each precinct chapter of this report.

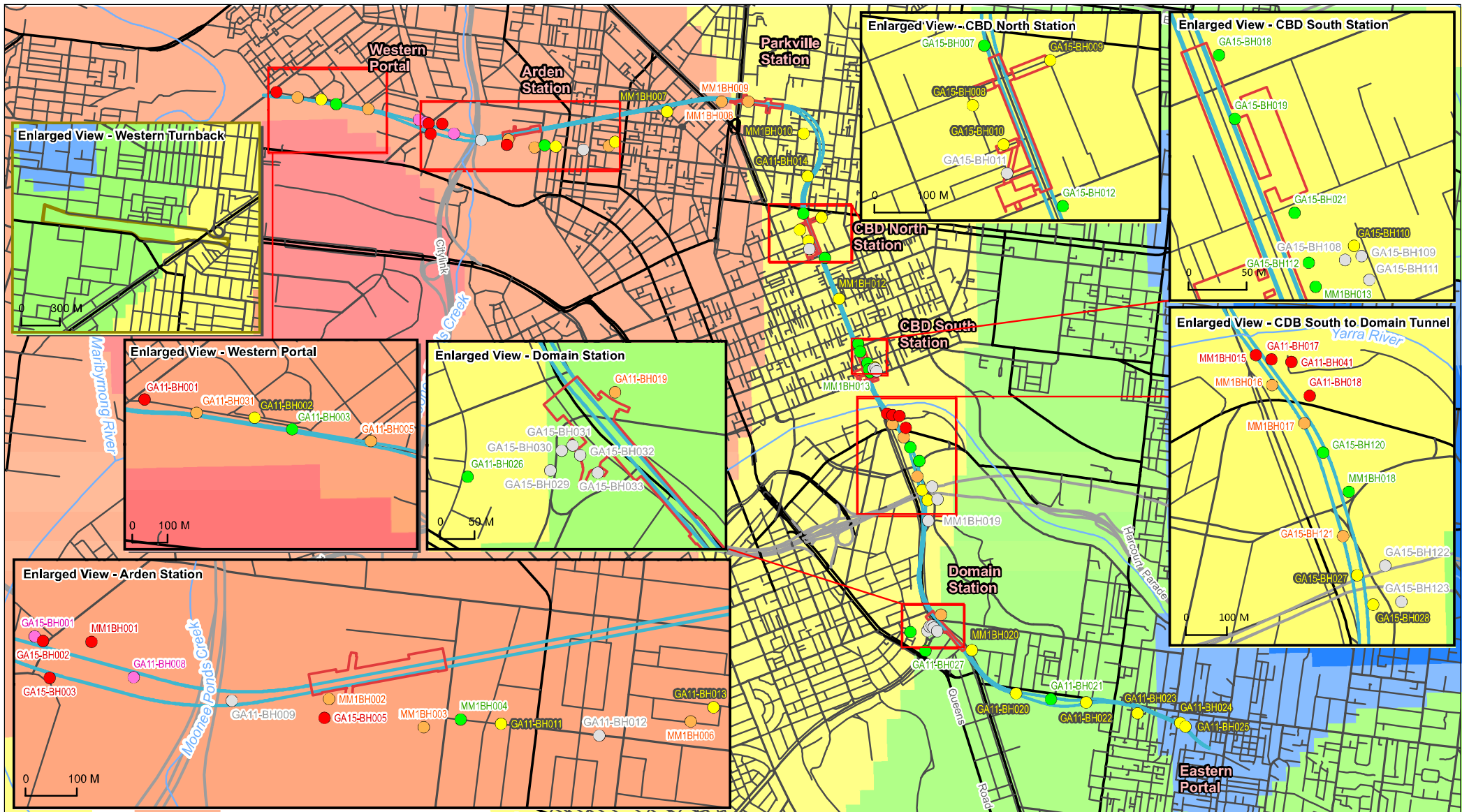
The bores along the alignment have generally been designed to monitor the groundwater at the depth of the tunnels. As such, the bores have not been designed to monitor potential contamination (e.g. shallow bores with screens intersecting the watertable). Therefore, it is possible that there would be some organic contamination of the groundwater that has not been identified by the groundwater investigations to date. Although such unknowns may exist across the study area, a holistic understanding of existing conditions coupled with likely project impacts allows the risk of groundwater contaminant migration to be understood. The combination of deeper groundwater samples, knowledge of historical land uses and modelling drawdown extents allows the risk of contaminant migration to neighbouring properties and preclusion of beneficial uses of groundwater at those properties to be adequately assessed.

In an urban setting such as this, there are expected to be low levels of contamination from general historical land uses. In some areas, past industrial land use may have resulted in areas of contamination that exceed groundwater investigation levels, and is therefore unsuitable for some beneficial uses. Unknown areas of contamination that may migrate if drawdown occurs is assessed in each precinct chapter based on historical landuses.





Many GQRUZs have been designated at sites along the alignment which indicate that groundwater is contaminated to an extent that it is not currently suitable for certain beneficial uses. These are identified for each precinct in the following impact assessment.



**Legend**

- No Value for TDS (mg/L)
- 0 - 3500
- 3500 - 7000
- 7000 - 13000
- 13000 - 35000
- 35000 - 50000

**TDS (mg/L)**

- 0 - 3500
- 3500 - 7000
- 7000 - 13000
- 13000 - 35000
- 35000 - 50000

**Watertable Salinity**

- <500
- 500- 1,000
- 1000 - 3,500
- 3,500 - 7,000
- 7,000 - 13,000
- 13,000 - 35,000
- >35,000

- Proposed Station Footprint
- Proposed Alignment
- Watercourse
- Western Turnback

Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Bores: Golder Associates October 2015



**Melbourne Metro Rail Project**

Title: Groundwater salinity

Drawing Number: MMR-AJM-UGAA-MP-NK-500139

Revision: P1

Drawn By: A. Davy

Approved By: K. Dowsley

Date: 7/04/2016

Map Size: A4

Scale: 0 500 1,000 Metres

MELBOURNE METRO RAIL AUTHORITY

gurecon JACOBS

AJM Mott MacDonald

Joint Venture GRIMSHAW

Figure 5-4 TDS concentrations from regional mapping and from bores along the alignment



#### 5.4.2 Potential for Corrosion

The condition of the groundwater has the potential to impact on the structural integrity and lifespan of materials used to construct the tunnels, portals, shafts and station boxes. The majority of the TBM constructed tunnels and at least a portion of each portal, shaft and station box would be exposed to the groundwater. In addition, many piles and supporting structures would also be in contact with groundwater. Golder (2016a, Appendix G) state that the overall groundwater composition suggests potential impacts on material structural durability due to:

- Elevated concentrations of TDS, chloride, sulfate and some metal (iron)
- Water hardness
- Reduced in-situ conditions
- Presence of sulfate reducing bacteria).

To assess the magnitude of potential impacts from the above parameters, the following guidelines can be used:

- Australian Standard AS2159 2009 – Piling – design and installation guidelines (parameters associated with the corrosion of steel and concrete – pH, chloride and sulfate)
- Langelier Index and Ryznar Stability Index (indicators of water ability to dissolve or deposit calcium carbonate).

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in the Technical Appendix Q *Contaminated Land and Spoil Management*.

### 5.5 Groundwater Use

There are 20 active registered (and five decommissioned) groundwater bores in the study area. An investigation into the ownership and status of these bores was completed as part of this assessment. Only two bores could be located and these were not currently being used by the owners (no pump infrastructure was installed) as the groundwater was too saline. Details of bore investigations are included in Appendix D of this report.

Discussions with Southern Rural Water confirmed that the majority of bores which could not be found were unlikely to exist and could therefore be disregarded from further consideration in the EES. It was agreed that six bores within the study area may still be in use and should continue to be included in the EES and protected from groundwater level impacts during construction and operation of Melbourne Metro. These were:

- Two of WRK979557, WRK979561 and/or WRK979652, located at the Melbourne Markets in Footscray (only two of these bores were found but it is not clear what their numbers are)
- WRK972626 near Batman Avenue
- WRK968523, 2 km east of the tunnels in Richmond
- WRK965942, 1 km north of Arden station
- WRK989150, 1 km east of the tunnels in Fitzroy.

Potential impacts on these bores is considered in the relevant precinct section of this report. There are nine bores registered as active licenced irrigation bores located at Flemington Racecourse (two are registered as dual use irrigation and/or disposal). These bores are outside the Golder model boundary and are 1.7 km north-west of the start of the western portal dive structure (i.e. the nearest point to the bores where groundwater is likely to be intersected by the tunnelling operations). Since the tunnels and the Flemington racecourse bores occur within different aquifers, hydraulic connection between the two locations is likely to



be limited. This reduces the likelihood of impacts on the bores from groundwater drawdown around the tunnels, however impacts are assessed in Section 6.

## 5.6 Groundwater-Surface Water Interaction

The main watercourses in the study area are the Maribyrnong River, the Yarra River and Moonee Ponds Creek. The groundwater flow direction generally tends to be towards these features and under natural conditions these may be the primary groundwater discharge features. However, the influence of urban infrastructure such as sewers, drained basements and tunnels has lowered groundwater levels such that groundwater discharge to surface water features is unlikely.

Golder (2016a, Appendix G) cite information from the CityLink tunnelling project that showed groundwater drawdown in the Silurian and basalt aquifers was transmitted rapidly under and beyond the Yarra River away from the tunnel excavation. Drawdown to the CityLink tunnels is still occurring and the drawdown cone is indicated in the groundwater contour map shown in Golder 2016b (Appendix H, Figure 7). This drawdown cone has been in existence since construction of the CityLink tunnels and has not been recharged by the Yarra River, suggesting a weak connection between the river and the groundwater. This is probably due to low permeability sediments on the riverbed which limit interaction between groundwater and the river. This weak connection suggests that impacts on the river from drawdown associated with construction and operation of Melbourne Metro is unlikely.

Groundwater levels near the Moonee Ponds Creek appear to be artificially lowered by the North Yarra Main Sewer. This feature is draining groundwater in the area and reducing groundwater elevation to below 0 m AHD, which is below the level of the Moonee Ponds Creek. Water levels measured for a previous project (SKM, 2013) suggest that less than 1 km upstream of the Melbourne Metro crossing on the Moonee Ponds Creek the groundwater levels are higher than the creek and groundwater is therefore likely to be contributing to creek flows.

Where the alignment crosses the Maribyrnong River it is likely that groundwater levels are above 0 m AHD. However, 300 m downstream (near the North Yarra Main Sewer), levels are known to be below 0 m AHD and below the level of the river (SKM, 2010), suggesting that the river changes from a gaining to a losing stream between the Melbourne Metro alignment and 300 m downstream.

The above information suggests that there is relatively weak connectivity between the groundwater and the rivers, which is interpreted to be due to the presence of low permeability riverbed sediments. Impacts on the river and creeks in the study area from drawdown associated with construction and operation of Melbourne Metro are therefore unlikely.

Albert Park Lake is approximately 600 m south-west of the Domain station and under natural conditions this low lying feature is likely to receive groundwater as it is a former swamp. However, the South Yarra Main Sewer runs along the northern edge of the lake and appears to be diverting some groundwater flow away from the lake. Any interaction between the lake and groundwater at the northern end (near Domain) is likely to be from the lake to the groundwater, with some losses of lake water to the sewer possible. Because the sewer has already lowered groundwater levels at the northern end of Albert Park Lake, dewatering at Domain station is not expected to have a significant additional impact on water levels near the Albert Park Lake. Therefore, additional losses from the Albert Park Lake to the groundwater as a result of construction and operation of Domain station are considered unlikely.

The lake in the Royal Botanic Gardens is approximately 700 m east of the tunnels between the CBD South and Domain stations. The lake is considered to be strongly connected to the watertable, as during CityLink construction water levels in the lake dropped at the same time as groundwater levels dropped because of inflows to the CityLink tunnels. As such, this lake should be considered to be groundwater dependent.



## 5.7 Groundwater Dependent Ecosystems

The Australian Groundwater Dependent Ecosystem (GDE) Atlas (BoM, 2012) comprises maps that show the location of potential GDEs across Australia, as well as ecological and hydrogeological information for each GDE.

Potential GDEs within the study area are shown in Figure 5-5. Groundwater vegetation is shown as 'ecosystems that rely on the subsurface presence of groundwater', while surface water bodies are shown as 'ecosystems that rely on the surface expression of groundwater'. The GDE Atlas (BoM, 2012) shows the main potential GDEs in the vicinity of the Project are the three main water courses (Moonee Ponds Creek, Maribyrnong River and the Yarra River) and riparian vegetation associated with these watercourses. Other surface water bodies such as the Albert Park Lake and the lake within the Royal Botanic Gardens are also shown to support groundwater dependent vegetation. These features are classed as having a high potential for groundwater interaction, most likely due to their low elevation and resulting close proximity to the watertable. As the GDE Atlas identifies potential GDEs based on regional analysis, the impact assessment in this report relies on more detailed site assessments of each potential GDE where available. There is evidence (as discussed above) that indicates the Yarra River, Moonee Ponds Creek, the Maribyrnong River and the northern part of Albert Park Lake are not groundwater dependent in Melbourne Metro study area.

Although all surface water bodies (with the exception of the lake in the Royal Botanic Gardens) are not considered groundwater dependent in the study area, the vegetation surrounding the surface water features may be using groundwater. It is common for older large trees with deep root systems to tap into groundwater resources. Many European species such as elms and plane trees have shallow root systems (<1.5 m) and typically rely on rainfall, leaking pipes or soil moisture for their water requirements, rather than groundwater. Other species with deeper roots may access groundwater, particularly during drought when there are few other water sources available.

Drawdown due to tunnelling has the potential to impact trees with deeper root systems that rely on groundwater. A comparison of tree rooting depth and groundwater levels has been undertaken for trees within the project boundary, to assess whether vegetation could be using groundwater. This review concluded that the rooting depth of trees in all precincts was shallower than groundwater, and therefore that the trees along the alignment are not groundwater dependent (Technical Appendix R and S *Agriculture*).

Potential groundwater impacts from construction and operation are likely to expand beyond the project boundary, and as such, the potential impacts on trees away from the alignment must also be considered. The groundwater dependence of large trees outside Melbourne Metro project Boundary has not been specifically assessed, however the likelihood of vegetation being highly reliant on groundwater in this area is low. Vegetation would preferentially use shallower water sources such as soil moisture, surface runoff, and leakage from drains. Therefore, groundwater use probably only occurs when these other water sources are unavailable, and as such, would be limited to longer-term dry periods such as droughts. Also, high salinity groundwater in the western part of the study area suggests that vegetation primarily relies on other water sources in preference to groundwater.

However, where groundwater levels are shallow, alternative water sources may not be available to trees and the trees may therefore have greater dependence on groundwater. This is possible where deep rooted trees exist in areas where the groundwater levels are shallow, such as around the Moonee Ponds Creek and Yarra River, the lake in the Royal Botanic Gardens and Albert Park Lake. Mitigation measures are recommended for deep rooted trees in areas of shallow groundwater where drawdown is predicted to occur. Groundwater dependence of vegetation is generally interpreted to be low across the majority of the alignment and surrounds, and largely confined to occasional dry periods. The risk of impacts from short term groundwater drawdown associated with construction is therefore considered to be low. The risk of impacts to vegetation is higher if longer term impacts to groundwater levels occur. The potential for such impacts is assessed further for each precinct in Sections 7 to 16.



|  |  |   |  |   |  |  |  |  |  |  |  |
|--|--|---|--|---|--|--|--|--|--|--|--|
| <b>Legend</b><br><b>Ecosystems that rely on subsurface presence of groundwater</b><br>■ High potential for GW interaction<br>■ Moderate potential for GW interaction<br>■ Low potential for GW interaction |  | <b>Ecosystems that rely on the surface expression of groundwater</b><br>■ High potential for GW interaction<br>■ Moderate potential for GW interaction<br>■ Low potential for GW interaction<br>■ Identified in previous study: fieldwork |  | — Proposed Alignment<br>□ Proposed Station<br>□ Western Turnback Precinct |  |  |  | <b>Melbourne Metro Rail Project</b><br>Title: EES Groundwater - GDE Overview<br>Drawing Number: MMR-AJM-UGAA-MP-NO-500165<br>Revision: P1<br>Drawn By: A. Davy<br>Approved By: K. Dowsley<br>Date: 7/04/2016<br>Map Size: A4 |  |  |  |
| Data Sources:<br>Proposed Infrastructure: AJM 2016<br>Contains Viemap Information<br>© State of Victoria 2015;<br>GDEs © BOM 2015<br>Aerial photo (DELWP, February 2015)                                   |  |   |  |   |  |  |  |  |  |  |  |

Figure 5-5 Potential GDEs identified in the GDE Atlas (BoM, 2012)



## 6 Risk assessment

Table 6-1 summarises the groundwater risks associated with the Project. The environmental risk assessment methodology is outlined in Section 4.1. The full risk register is provided in Appendix B of the EES, and shows the initial risk, Environmental Performance Requirements, and residual risk rankings.



Table 6-1 Risk Register for Impact Assessment

| Impact pathway   |   | Project Phase              | Precinct   | Initial risk |          |          | Residual risk |          |          | Risk no. |
|--|---|----------------------------|--|--------------|----------|----------|---------------|----------|----------|----------|
| Category   | Event   |                            |  | C            | L        | Risk     | C             | L        | Risk     |          |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users. | Construction and operation | 1 - Tunnels ( <i>Arden station to Parkville station</i> ) ( <i>Domain station to Eastern portal</i> )<br>3 - Arden station<br>4 - Parkville station<br>5 - CBD North station<br>7 - Domain station<br>8 - Eastern portal                                 | Negligible   | Rare     | Very low | Negligible    | Rare     | Very low | GW001    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users. | Operation                  | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> ) ( <i>CBD South station to Domain station</i> )<br>2 - Western portal<br>6 - CBD South station | Minor        | Unlikely | Low      | Minor         | Unlikely | Low      | GW002    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users. | Construction               | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD South station to Domain station</i> )  | Negligible   | Unlikely | Very low | Negligible    | Unlikely | Very low | GW003    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users. | Construction               | 1 - Tunnels ( <i>Western portal to Arden station</i> ) - Cross passage 2, 3  | Moderate     | Unlikely | Low      | Moderate      | Unlikely | Low      | GW004    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users. | Construction               | 1 - Tunnels ( <i>CBD South station to Domain station</i> ) - <i>alternative design option</i> - shaft  | Minor        | Possible | Low      | Minor         | Possible | Low      | GW005    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users. | Construction               | 1 - Tunnels ( <i>CBD North station to CBD South station</i> )  | Minor        | Possible | Low      | Minor         | Possible | Low      | GW006    |





| Impact pathway   |  | Project Phase              | Precinct  | Initial risk |          |          | Residual risk |          |          | Risk no. |
|--|--|----------------------------|---|--------------|----------|----------|---------------|----------|----------|----------|
| Category   | Event  |                            |   | C            | L        | Risk     | C             | L        | Risk     |          |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users.                                | Construction               | 2 - Western portal  | Minor        | Possible | Low      | Minor         | Possible | Low      | GW007    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on existing private bore users.                                | Construction               | 6 - CBD South station   | Minor        | Possible | Low      | Minor         | Possible | Low      | GW008    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on surface water features and the potential GDEs they support. | Construction and operation | 1 - Tunnels ( <i>Arden station to Parkville station</i> )<br>4 - Parkville station  | Negligible   | Rare     | Very low | Negligible    | Rare     | Very low | GW009    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on surface water features and the potential GDEs they support. | Construction and operation | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> )<br>2 - Western portal<br>3 - Arden station<br>5 - CBD North station<br>6 - CBD South station<br>7 - Domain station<br>8 - Eastern portal | Minor        | Unlikely | Low      | Minor         | Unlikely | Low      | GW010    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on surface water features and the potential GDEs they support. | Construction and operation | 1 - Tunnels ( <i>CBD South station to Domain station</i> ), <i>cross passage 11</i> , ( <i>Domain station to Eastern portal</i> )   | Minor        | Possible | Low      | Minor         | Possible | Low      | GW011    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on surface water features and the potential GDEs they support. | Construction               | 1 - Tunnels ( <i>CBD South station to Domain station - alternative design option - shaft</i> )  | Moderate     | Unlikely | Low      | Moderate      | Unlikely | Low      | GW012    |



| Impact pathway   |  | Project Phase              | Precinct  | Initial risk |          |        | Residual risk |          |      | Risk no. |
|--|--|----------------------------|---|--------------|----------|--------|---------------|----------|------|----------|
| Category   | Event  |                            |   | C            | L        | Risk   | C             | L        | Risk |          |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater). | Construction and operation | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> )<br>2 - Western portal<br>3 - Arden station<br>4 - Parkville station    | Minor        | Unlikely | Low    | Minor         | Unlikely | Low  | GW013    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater). | Construction and operation | 1 - Tunnels ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> )<br>5 - CBD North station                                    | Minor        | Unlikely | Low    | Minor         | Unlikely | Low  | GW014    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater). | Operation                  | 1 - Tunnels ( <i>CBD South station to Domain station</i> ) ( <i>Domain station to Eastern portal</i> )<br>6 - CBD South station<br>7 - Domain station<br>8 - Eastern portal | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW015    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater). | Construction               | 1 - Tunnels ( <i>CBD South station to Domain station</i> ), <i>cross passage 11</i>   | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW016    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater). | Construction               | 1 - Tunnels ( <i>CBD South station to Domain station - alternative design option - shaft</i> )  | Moderate     | Possible | Medium | Moderate      | Unlikely | Low  | GW017    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater). | Construction               | 1 - Tunnels ( <i>Domain station to Eastern portal</i> ) ( <i>CBD South station to Domain station</i> )  | Minor        | Unlikely | Low    | Minor         | Unlikely | Low  | GW018    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater). | Construction               | 6 - CBD South station   | Moderate     | Possible | Medium | Moderate      | Unlikely | Low  | GW019    |



| Impact pathway  |   | Project Phase | Precinct  | Initial risk |          |        | Residual risk |          |      | Risk no. |
|---|---|---------------|---|--------------|----------|--------|---------------|----------|------|----------|
| Category  | Event   |               |   | C            | L        | Risk   | C             | L        | Risk |          |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater).  | Construction  | 7 - Domain station  | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW020    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Regional drawdown impacting on potential groundwater dependent vegetation (such as large trees that may be using groundwater).  | Construction  | 8 - Eastern portal  | Moderate     | Possible | Medium | Moderate      | Unlikely | Low  | GW021    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction  | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD South station to Domain station</i> )   | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW022    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Operation     | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> ) ( <i>CBD South station to Domain station</i> ) ( <i>Domain to Eastern portal</i> )<br>2 - Western portal<br>3 - Arden station<br>5 - CBD North station<br>7 - Domain station<br>8 - Eastern portal | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW023    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction  | 1 - Tunnels ( <i>Western portal to Arden station, cross passages 2, 3</i> ) ( <i>CBD South station to Domain station, cross passage 11</i> )  | Minor        | Unlikely | Low    | Minor         | Unlikely | Low  | GW024    |



| Impact pathway  |   | Project Phase              | Precinct   | Initial risk |          |        | Residual risk |          |      | Risk no. |
|---|---|----------------------------|--|--------------|----------|--------|---------------|----------|------|----------|
| Category  | Event   |                            |  | C            | L        | Risk   | C             | L        | Risk |          |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 1 - Tunnels ( <i>CBD North station to CBD South station</i> )                                  | Moderate     | Possible | Medium | Moderate      | Unlikely | Low  | GW025    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 1 - Tunnels ( <i>CBD South station to Domain station - alternative design option - shaft</i> ) | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW026    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 1 - Tunnels ( <i>Domain station to Eastern portal - shaft</i> )                                | Moderate     | Possible | Medium | Moderate      | Unlikely | Low  | GW027    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 2 - Western portal<br>3 - Arden station  | Moderate     | Possible | Medium | Moderate      | Unlikely | Low  | GW028    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction and operation | 4 - Parkville station  | Minor        | Likely   | Medium | Minor         | Unlikely | Low  | GW029    |



| Impact pathway  |   | Project Phase              | Precinct   | Initial risk |          |        | Residual risk |          |        | Risk no. |
|---|---|----------------------------|--|--------------|----------|--------|---------------|----------|--------|----------|
| Category  | Event   |                            |  | C            | L        | Risk   | C             | L        | Risk   |          |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 5 - CBD North station  | Major        | Likely   | High   | Moderate      | Possible | Medium | GW030    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 5 - CBD South station  | Minor        | Possible | Low    | Minor         | Possible | Low    | GW031    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 7 - Domain station   | Minor        | Possible | Low    | Minor         | Possible | Low    | GW032    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Changing groundwater gradients results in movement of groundwater contaminant plumes onto third party properties with potential impacts to beneficial uses of groundwater, and potential for vapour intrusion to existing underground structures. | Construction               | 8 - Eastern portal   | Moderate     | Possible | Medium | Moderate      | Unlikely | Low    | GW033    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Generation of acidic groundwater due to dewatering of acid sulfate soils and/or rock.   | Construction and operation | 1 - Tunnels (CBD South station to Domain station - alternative design option - shaft) (Domain station to Eastern portal - shafts)<br>2 - Western portal<br>4 - Parkville station<br>7 - Domain station<br>8 - Eastern Portal | Minor        | Unlikely | Low    | Minor         | Unlikely | Low    | GW034    |



| Impact pathway   |   | Project Phase | Precinct   | Initial risk |          |        | Residual risk |          |      | Risk no. |
|--|---|---------------|--|--------------|----------|--------|---------------|----------|------|----------|
| Category   | Event   |               |  | C            | L        | Risk   | C             | L        | Risk |          |
| Potential groundwater inflows to structures causing drawdown | Generation of acidic groundwater due to dewatering of acid sulfate soils and/or rock. | Construction  | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD South station to Domain station</i> )  | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW035    |
| Potential groundwater inflows to structures causing drawdown | Generation of acidic groundwater due to dewatering of acid sulfate soils and/or rock. | Operation     | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> ) ( <i>CBD South station to Domain station</i> ) ( <i>Domain station to Eastern portal</i> )<br>3 - Arden station<br>5 - CBD North station<br>6 - CBD South station | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW036    |
| Potential groundwater inflows to structures causing drawdown | Generation of acidic groundwater due to dewatering of acid sulfate soils and/or rock. | Construction  | 1 - Tunnels ( <i>Western portal to Arden station, cross passages 2, 3</i> ) ( <i>CBD South station to Domain station, cross passage 11</i> )   | Minor        | Unlikely | Low    | Minor         | Unlikely | Low  | GW037    |
| Potential groundwater inflows to structures causing drawdown | Generation of acidic groundwater due to dewatering of acid sulfate soils and/or rock. | Construction  | 1 - Tunnels ( <i>CBD North station to CBD South station</i> )  | Moderate     | Possible | Medium | Moderate      | Unlikely | Low  | GW038    |
| Potential groundwater inflows to structures causing drawdown | Generation of acidic groundwater due to dewatering of acid sulfate soils and/or rock. | Construction  | 3 - Arden station  | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW039    |
| Potential groundwater inflows to structures causing drawdown | Generation of acidic groundwater due to dewatering of acid sulfate soils and/or rock. | Construction  | 5 - CBD North station<br>6 - CBD South station   | Moderate     | Unlikely | Low    | Moderate      | Unlikely | Low  | GW040    |



| Impact pathway   |  | Project Phase              | Precinct  | Initial risk |          |          | Residual risk |          |          | Risk no. |
|--|--|----------------------------|---|--------------|----------|----------|---------------|----------|----------|----------|
| Category   | Event  |                            |   | C            | L        | Risk     | C             | L        | Risk     |          |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on CityLink recharge scheme. | Construction and operation | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> ) ( <i>Domain station to Eastern portal</i> )<br>2 - Western portal<br>3 - Arden station<br>4 - Parkville station<br>5 - CBD North station<br>7 - Domain station<br>8 - Eastern portal | Negligible   | Rare     | Very low | Negligible    | Rare     | Very low | GW041    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on CityLink recharge scheme. |                            | 1 - Tunnels ( <i>CBD South station to Domain station, cross passage 11</i> )  | Minor        | Unlikely | Low      | Minor         | Unlikely | Low      | GW042    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on CityLink recharge scheme. | Construction               | 1 - Tunnels ( <i>CBD South station to Domain station</i> )  | Minor        | Unlikely | Low      | Minor         | Unlikely | Low      | GW043    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on CityLink recharge scheme. | Operation                  | 1 - Tunnels ( <i>CBD South station to Domain station</i> )<br>6 - CBD South station   | Minor        | Unlikely | Low      | Minor         | Unlikely | Low      | GW044    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on CityLink recharge scheme. | Construction               | 1 - Tunnels ( <i>CBD South station to Domain station - alternative design option - shaft</i> )  | Moderate     | Possible | Medium   | Moderate      | Unlikely | Low      | GW045    |
| Potential groundwater inflows to structures causing drawdown | Regional drawdown impacting on CityLink recharge scheme. | Construction               | 6 - CBD South station   | Moderate     | Possible | Medium   | Moderate      | Unlikely | Low      | GW046    |



| Impact pathway  |  | Project Phase              | Precinct   | Initial risk |          |          | Residual risk   |          |          | Risk no. |
|---|--|----------------------------|--|--------------|----------|----------|---|----------|----------|----------|
| Category  | Event  |                            |  | C            | L        | Risk     | C   | L        | Risk     |          |
| <b>Stations/tunnels damming groundwater flow</b>                    | The tunnel/station height spanning an aquifer could potentially dam the flow of groundwater through that aquifer, causing settlement on the downstream side and waterlogging on the upstream side. | Construction and operation | 1 - Tunnels ( <i>Arden station to Parkville station</i> ) ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> ) ( <i>Domain station to Eastern portal</i> )<br>2 - Western portal<br>4 - Parkville station<br>5 - CBD North station<br>6 - CBD South station<br>7 - Domain station<br>8 - Eastern portal | Negligible   | Rare     | Very low | Negligible  | Rare     | Very low | GW047    |
| <b>Stations/tunnels damming groundwater flow</b>                    | The tunnel/station height spanning an aquifer could potentially dam the flow of groundwater through that aquifer, causing settlement on the downstream side and waterlogging on the upstream side. | Construction and operation | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>CBD South station to Domain station - alternative design option</i> )<br>3 - Arden station   | Minor        | Possible | Low      | Minor   | Possible | Low      | GW048    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Drawdown in aquifers beneath the Coode Island Silt causes settlement.  | Construction and operation | 1 - Tunnels ( <i>Parkville station to CBD North station</i> ) ( <i>CBD North station to CBD South station</i> ) ( <i>Domain station to Eastern portal</i> )<br>4 - Parkville station<br>5 - CBD North station<br>6 - CBD South station<br>8 - Eastern portal   | Minor        | Unlikely | Low      | Addressed in Ground Movement & Land Stability Impact Assessment: risks GM015, GM016, GM018, GM024 |          | #N/A     | GW049    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Drawdown in aquifers beneath the Coode Island Silt causes settlement.  | Construction               | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> ) ( <i>CBD South station to Domain station</i> )  | Minor        | Likely   | Medium   | Addressed in Ground Movement & Land Stability Impact Assessment: risks GM015, GM016, GM018, GM024 |          | #N/A     | GW050    |
| <b>Potential groundwater inflows to structures causing drawdown</b> | Drawdown in aquifers beneath the Coode Island Silt causes settlement.  | Operation                  | 1 - Tunnels ( <i>Western portal to Arden station</i> ) ( <i>Arden station to Parkville station</i> ) ( <i>CBD South station to Domain station</i> )<br>2 - Western portal<br>3 - Arden station<br>7 - Domain station   | Major        | Possible | High     | Addressed in Ground Movement & Land Stability Impact Assessment: risks GM015, GM016, GM018, GM024 |          | #N/A     | GW051    |





| Impact pathway   |   | Project Phase              | Precinct   | Initial risk |          |        | Residual risk   |          |      | Risk no. |
|--|---|----------------------------|--|--------------|----------|--------|---|----------|------|----------|
| Category   | Event   |                            |  | C            | L        | Risk   | C   | L        | Risk |          |
| <b>Potential groundwater inflows to structures causing drawdown</b>  | Drawdown in aquifers beneath the Coode Island Silt causes settlement.   | Construction               | 1 - Tunnels ( <i>Western portal to Arden station, cross passages 2, 3</i> ) ( <i>CBD South station to Domain station, cross passage 11</i> ) | Minor        | Unlikely | Low    | Minor   | Unlikely | Low  | GW052    |
| <b>Potential groundwater inflows to structures causing drawdown</b>  | Drawdown in aquifers beneath the Coode Island Silt causes settlement.   | Construction               | 2 - Western portal<br>3 - Arden station<br>7 - Domain station  | Minor        | Likely   | Medium | Addressed in Ground Movement & Land Stability Impact Assessment: risks GM015, GM016, GM018, GM024                         |          | #N/A | GW053    |
| <b>Potential inflows to structures - health</b>                      | Contaminated groundwater inflows into tunnel and stations come into contact with train users and workers potentially impacting human health.  | Construction and operation | All  | Minor        | Unlikely | Low    | Addressed in Contaminated Land & Spoil Management Impact Assessment: risks CL007 to CL012, CL022 to CL031, CL044 to CL052 |          | #N/A | GW054    |
| <b>Potential inflows to structures - disposal</b>                    | Unexpected contaminated groundwater flowing into the tunnel and stations is not treated by the water treatment plant and results in untreated contaminated groundwater being released to the receiving environment (sewer, surface waters). | Construction and operation | All  | Moderate     | Possible | Medium | Moderate  | Unlikely | Low  | GW055    |
| <b>Potential inflows to structures - disposal</b>                    | Disposal of groundwater inflows causes impacts on receiving environment.  | Construction and operation | All  | Moderate     | Possible | Medium | Moderate  | Unlikely | Low  | GW056    |
| <b>Groundwater quality impacting on the durability of structures</b> | Structures are degraded by the aggressive groundwater quality resulting in structure breakdown. This may result in damage to nearby third party structures as well as the economic and social impacts on the transport system.              | Operation                  | All  | Major        | Rare     | Medium | Addressed in Contaminated Land & Spoil Management Impact Assessment: risks CL032, CL033, CL053, CL054                     |          | #N/A | GW057    |



| Impact pathway                            |  | Project Phase              | Precinct           | Initial risk |          |      | Residual risk |          |      | Risk no. |
|---|--|----------------------------|--------------------|--------------|----------|------|---------------|----------|------|----------|
| Category                                  | Event  |                            |                    | C            | L        | Risk | C             | L        | Risk |          |
| <b>Cumulative impact</b>                  | Cumulative drawdown results in unexpected impacts to groundwater dependent values. | Construction and operation | All                | Minor        | Possible | Low  | Minor         | Possible | Low  | GW058    |
| <b>South Yarra Main Sewer replacement</b> | Change in groundwater levels may impact groundwater dependent values.              | Construction and operation | 7 - Domain station | Minor        | Unlikely | Low  | Minor         | Unlikely | Low  | GW059    |



## 7 Precinct 1: Tunnels

### 7.1 Project Components

This precinct is located between the portals and stations and has been divided into six sections for the impact assessment:

- Between the western portal and Arden station (CH95+350 to CH96+230)
- Between Arden station and Parkville station (CH96+760 to CH97+760)
- Between Parkville station and CBD North station (CH98+330 to CH99+190)
- Between CBD North station and CBD South station (CH99+650 to CH100+120)
- Between CBD South station and Domain station (CH100+560 to CH102+150)
- Between Domain station and the eastern portal (CH102+750 to CH104+060).

This section describes the relevant components and construction activities that could result in impacts to existing conditions in this precinct, based on the Concept Design and the design assumptions stated in Section 4.7 of this report. Where the risk of impacts is predicted to be unacceptable (i.e. medium, high or very high), mitigation measures are recommended during construction and operation to reduce the risk of impact to an acceptable level (low or very low).

The tunnels precinct consists of two tunnels across the entire alignment. Other infrastructure within this precinct includes cross passages (23 in total, 20 in the Tunnels precinct) and shafts where these components are not already covered in other precincts. The components in each section of the tunnels precinct as presented on the geological long section (Golder, 2016a) are detailed in the following sections.

#### 7.1.1 Construction

The sections of tunnels between the western portal and CBD North station, and CBD South station to the eastern portal would be constructed by TBM. During construction, the TBM would maintain a pressure at its face (to counter groundwater pressure) that prevents groundwater inflow. The tunnels would be constructed almost immediately after boring by installation of tunnel lining segments behind the TBM as it progresses and therefore these sections of tunnel lining would be tanked almost immediately.

The tunnels section between CBD North station and CBD South station would be constructed using road headers, which would excavate through the Melbourne Formation siltstone. This method results in an interval between excavation and installation of tunnel lining, and can therefore allow greater groundwater inflows than the TBM method. The mined tunnels are assumed to be drained during construction. Where groundwater inflows and drawdown are predicted to impact receptors, additional mitigation measures have been identified that could achieve the Environmental Performance Requirements. The key mitigation measures that can be used to reduce drawdown during construction are grouting of the mined surfaces, such as between CBD North and CBD South stations, as well as a system of injection bores that can inject water to maintain groundwater levels. Together, these mitigation measures can be designed to reduce drawdown to levels that present a low risk of impact to receptors.

Cross passages and shafts may also act as drained structures during construction where they are below the watertable. For constructability reasons, techniques which prevent groundwater inflow would be adopted as part of the Concept Design. These construction techniques and the short construction timeframes for cross passages mean groundwater inflow would be minimal. The following sections summarise the analysis of the potential impact pathways that may result in potential impacts to groundwater dependent values associated with construction of each section of the Tunnels precinct of Melbourne Metro.



## 7.1.2 Operation

During operation, it is planned that all tunnels, shafts, cross passages and adits below the watertable would be tanked to a tightness classification of Haack 3. These construction standards largely prevent groundwater inflows to structures, and as such drawdown is minor in most cases. Therefore, the potential for impacts on surrounding groundwater dependent values is also generally low. The following sections summarise the predicted drawdown and outline the potential impacts on groundwater dependent values associated with operation of the Tunnels precinct of Melbourne Metro.

## 7.1.3 Alternative Design Options

### 7.1.3.1 Infrastructure

The potential alternative design options for the Tunnels precinct include:

- Between CBD South station and Domain station:
  - An alternative design option is for the alignment to go below the CityLink tunnels (with deeper emergency access requirements), rather than above the CityLink tunnels
  - An alternative design option is for the emergency access shaft to be located 150 m south of Concept Design location (Tom's Block)
- Between Domain Station and the eastern portal:
  - An alternative design option for the emergency access shaft to be located in the north-west corner of Fawkner Park (at the TBM launch/retrieval shaft site).

These alternative design options do not alter the construction methodology and operational assumptions outlined above.

## 7.2 Tunnels: Western Portal to Arden Station

### 7.2.1 Existing Conditions

#### 7.2.1.1 Hydrostratigraphy

The tunnels between the western portal and Arden station (driven tunnel 970 m total length, including cross passages 2 and 3) encounters various geological units, including the sediments of the Moonee Ponds Creek palaeovalley.

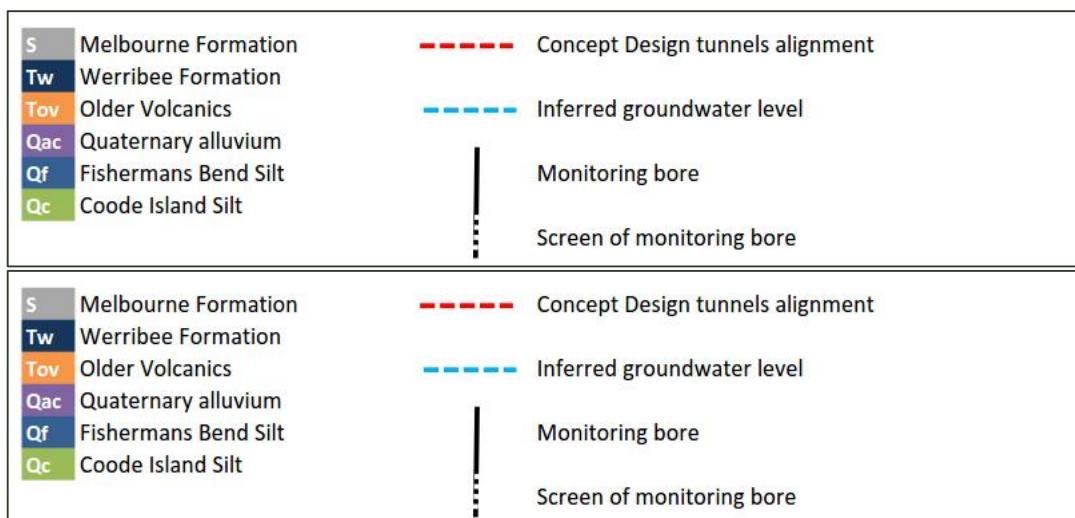


Figure 7-1 shows the hydrogeological conditions that this section of tunnels is expected to encounter.



The Coode Island Silt has moderate to high potential to generate acidity (Golder 2016a, Appendix G). More detail about the hydrogeological units expected to be encountered in this section of tunnels is included in Appendix D of this report.

### 7.2.1.1 Groundwater Levels

There are six groundwater monitoring bores along this section of tunnels and groundwater levels have been measured at least once in five of these bores (Appendix D of this report). In addition, longer term monitoring has occurred in GA11-BH009 (Fishermans Bend Silt bore) between August 2013 and May 2014. Note that Melbourne Metro bores were designed to assess conditions at tunnel depth and have not been designed to (necessarily) measure the watertable. Therefore, it is not always clear whether the watertable or a potentiometric surface is being measured. For the purpose of this impact assessment, it is assumed that the watertable and the potentiometric surfaces of most aquifers are very similar because there is some connection between aquifers overlying the tunnels. This would allow vertical interaction between aquifers that results in similar groundwater levels at equilibrium.

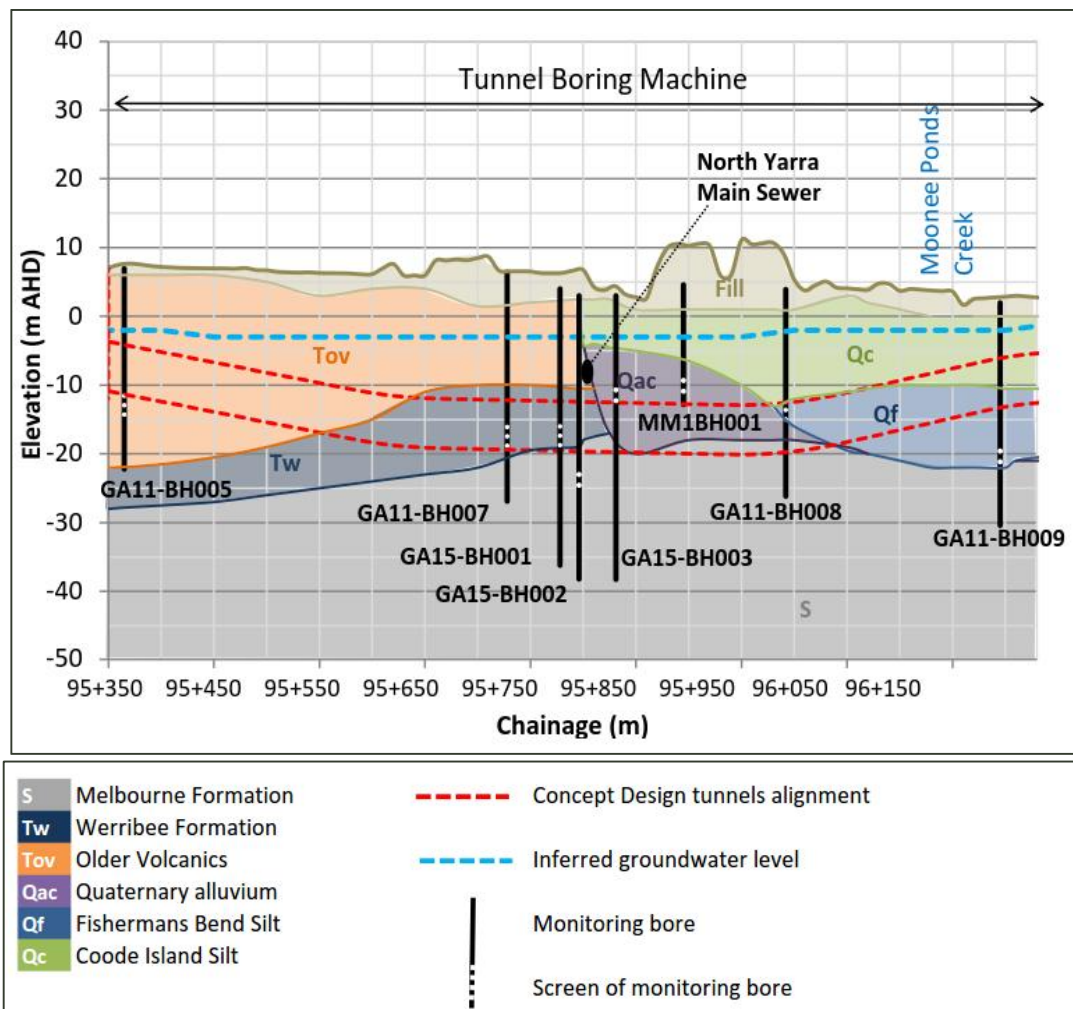


Figure 7-1: Conceptual site model for the area of tunnels between the western portal and Arden station

The Fishermans Bend Silt bore showed a variation of 0.4 m. The seasonal variation (measured in GA11-BH009) is similar to the wider Study Area. As discussed in Section 5.2, long term variations may be up to 3 – 4 m.

Groundwater levels in this precinct are below 0 m AHD (between -1.48 m AHD and -2.54 m AHD) and below the levels of the Moonee Ponds Creek. Under natural conditions, groundwater levels in this area would be



expected to be at or slightly above sea level (given the low lying ground elevations) and the watercourse would have acted as a groundwater discharge feature. The reason for the lower groundwater levels is likely to be the North Yarra Main Sewer, which crosses above the alignment and runs roughly parallel to the north and south of the alignment. The lowest groundwater levels in this area are where the sewer crosses the alignment.

The North Yarra Main Sewer is 3.2 m in diameter and the base of the tunnels is around -9 m AHD at the point it crosses above the alignment. The sewer is more than 100 years old and constructed of concrete and brick in parts. Therefore, the structural integrity of the sewer is almost certainly highly compromised. The sewer is known from previous project experience to be a major groundwater drainage feature in this area of Melbourne (SKM, 2013 and SKM, 2010). Given that the sewer is pulling groundwater levels below the base of the Moonee Ponds Creek, it is possible that some creek losses to the sewer are occurring.

The volume of groundwater leaking into this sewer across northern Melbourne is likely to be having an impact at the Western Treatment Plant in relation to salt load. Therefore, in the future it is likely that this sewer would be replaced. If this were to occur, groundwater levels in the area are likely to rise to above 0 m AHD, and possibly to around 2 to 3 m AHD.

The depth to groundwater in this area of the Tunnels precinct ranges between approximately 3 m below ground level near the Moonee Ponds Creek to 13 m below ground level at the western edge of the Moonee Ponds palaeovalley.

#### 7.2.1.2 Groundwater Quality

The six monitoring bores in this area have high salinity (measured as Total Dissolved Solids (TDS)), with results of between 22,000 and 43,000 mg/L TDS. Although these higher TDS results coincide with proximity to the tidal (saline) Moonee Ponds Creek, these bores are monitoring aquifers that are confined beneath the low permeability CIS.

The groundwater salinity in this precinct is above the range that would be expected from the regional mapping which designates this area as 7,000 to 13,000 mg/L TDS. The regional mapping refers to watertable TDS, whereas the results from bores in this section are from deeper confined aquifers that are typically more saline than the watertable. Groundwater of this salinity is within Segment C of the SEPP Gov (EPA Victoria 1997), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation.

Ammonia in GA11-BH008 is high, which normally indicates leaking sewers, or infiltrated fertilisers, however these concentrations are in confined aquifers which are not expected to be impacted from near surface activities. In this case, the high ammonia results are unexplained. Full groundwater quality analysis results are included in Appendix E of this report.

Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bores:

- GA11-BH007 (Werribee Formation) – TPH fraction C<sub>15</sub>-C<sub>28</sub> (0.22 mg/L)
- GA15-BH001 (Werribee Formation) - Methyl Ethyl Ketone (0.15 mg/L)
- GA15-BH003 (Quaternary Fluvial Sediments) – Methyl Ethyl Ketone (0.19 mg/L).



The concentrations of TPH fractions detected are below relevant guideline values (see Appendix E of this report) and are therefore not considered to be of concern. This area has a history of industrial land use and widespread low-level contamination of soil and groundwater is expected. However, Melbourne Metro bores were designed to assess conditions at the tunnels depth and do not specifically target groundwater contaminants. Therefore, while these hydrocarbon concentrations may be diffuse contamination resulting from the intensive land use in the area, they could also indicate contaminant plumes above the depth of the tunnels. The contaminants detected include volatile compounds.

There are no sites within 1 km of the area of tunnels between the western portal and Arden station that have been identified as GQRUZs. As such, it is assumed that all beneficial uses of groundwater within Segment C of the SEPP would apply within this area.

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q (*Contaminated Land and Spoil Management*).

#### 7.2.1.3 Groundwater Use

The nearest active stock and domestic bores to this area of tunnel are a small cluster of three bores located 750 m to the south-west of the tunnels (WRK979557, WRK979561 and WRK979562). These bores range in depth from 66 m to 79 m and are screened within the Melbourne Formation (screen lengths of 6 m). The bores are constructed of 110 mm diameter PVC and were drilled in June 2007.

Two of the three bores were found at the Melbourne Market, which is located 500 m to the south of the alignment, during a site inspection undertaken for Melbourne Metro in July 2015. The two bores found have not been utilised for water supply due to high salinity. It is not clear which bore numbers apply to the two bores that were found. The third bore is likely to not exist or has been destroyed. Discussions with Southern Rural Water confirmed that the two bores found at the market need to be considered in the impact assessment because of the potential for future use of the groundwater. The outcomes of the bore site inspections are summarised in Appendix D of this report.

#### 7.2.1.4 Groundwater-Surface Water Interaction

The Moonee Ponds Creek crosses above the alignment in this area. As discussed above, it is likely that groundwater levels in this area are being artificially lowered by the North Yarra Main Sewer. Groundwater levels are currently below 0 m AHD and below the level of the Moonee Ponds Creek.

Currently, any flow between the groundwater and the Moonee Ponds Creek is likely to be from the creek to the groundwater. However, given that the groundwater levels around the Moonee Ponds Creek are below 0 m AHD, it would appear that the flux from the watercourse to the groundwater is less than the flux of groundwater to the sewer at these locations.

Water levels measured for a previous project (SKM, 2013) suggest that less than 1 km upstream on the Moonee Ponds Creek the groundwater levels are higher than the creek and are likely to be contributing to creek flows.

#### 7.2.1.5 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. There are some large trees in the vicinity of the tunnel alignment (outside the Project Boundary) that were not assessed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*), for example on the existing railway sidings and along Ormond Street and Arden Street. There is no specific information on the type of trees and their water requirements, although groundwater dependence is expected to be low, as groundwater in the area is



saline and other water sources such as soil moisture, surface runoff and leaking drains are likely to constitute a preferable water source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

## 7.2.2 Potential Issues

Potential issues associated with the Concept Design are identified in Table 7-1. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 7-1 Potential issues associated with the Concept Design**

| Concept Design   | Issue   | Risk #  |
|--|---|---|
| <b>Tunnels<br/>(western portal<br/>to Arden station)</b> | <p>The tunnels are below the watertable, therefore the potential exists for inflows to the tunnels and associated drawdown during construction and operation. During construction it is assumed that the tunnels would be tanked almost immediately, which would prevent inflows and drawdown in the construction phase. For operation, the tunnels would be tanked to Haack 3 classification. Minor inflows would occur over the longer term which may result in drawdown. Potential operational impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>• Reduced available drawdown in the two bores at the Melbourne Market (WRK979557, WRK979561/WRK979562)</li> <li>• Migration of existing contaminants to third party properties. No GQRUZs exist in the area, but anthropogenic contamination has been detected which may be indicative of larger contaminant plumes, given the industrial history of the area. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> <li>• Potential acid generation from exposure of Coode Island Silt</li> <li>• Aquifer damming caused by tunnels restricting groundwater flow in the Fishermans Bend Silt.</li> </ul> | <p>GW002<br/>GW003<br/>GW004</p> <p>GW022<br/>GW023<br/>GW024</p> <p>GW035<br/>GW036<br/>GW037</p> <p>GW048</p> |
|  | <p>It is assumed that groundwater is not contributing to flow in the Moonee Ponds Creek and therefore drawdown impacts are considered unlikely and are not assessed. Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not considered further.</p>   |   |

## 7.2.3 Impact Assessment

Potential impacts of the Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where a medium, high or very high risk of impact has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

### 7.2.3.1 Construction

The tunnels that are constructed using the TBM would be tanked almost immediately after they have been excavated. This is expected to prevent inflows and associated drawdown during construction. No analysis of drawdown has therefore been undertaken for the tunnels between the western portal and Arden station precinct during the construction phase.

### 7.2.3.2 Operation

It is assumed that the tunnels would be tanked to Haack 3 tightness, which results in inflows of 0.0046 L/sec per 100 m of two tunnels, based on an internal tunnel diameter of 6.3 m at the location of the tunnel liner and Haack 3 daily inflow criterion of 0.1 L/m<sup>2</sup> over 100 m length of tunnel. Drawdown of groundwater levels as a





result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b), which is included as Appendix H of this report.

#### 7.2.3.2.1 Potential Impacts

The estimated groundwater drawdown as a result of the minor inflows to the tunnels is predicted to be less than 0.2 m immediately above the tunnels at steady state. This minimal drawdown means that no impacts on groundwater dependent values are anticipated along the tunnels section between the western portal and Arden station. If there is any change in construction technique or detailed design that may cause greater inflows, potential drawdown impacts should be assessed for the following receptors:

- Two bores at the Melbourne Market (WRK979557, WRK979561/WRK979562) (**Risk #GW002**)
- Migration of potential existing contaminants to third party properties, although there is currently no information on the presence of contaminants that exceed assessment criteria in this area (**Risk #GW023**)
- Groundwater acidification due to potentially acid forming sediments. The highest risk areas are where the tunnel passes through the Moonee Ponds Creek paleovalley, where the watertable sits within the Coode Island Silt (**Risk #GW036**).

#### 7.2.3.2.2 Aquifer Damming Assessment

Damming of an aquifer can occur when a structure (be it a tunnel, a station or other structure) cuts through an aquifer creating a physical barrier to groundwater flow and disrupting the flow through the aquifer. This may cause the groundwater level to increase on the upgradient side of the structure and decrease on the downgradient side of the structure.

In this segment the tunnel intercepts up to approximately 50 per cent of the cross sectional area of the Fisherman's Bend Silt (FBS) unit. The FBS would usually be conceptualised as an aquitard, however investigations undertaken for Melbourne Metro suggest that the lower FBS in this area has significant permeability, and would act as an aquifer. The overlying Coode Island Silt has relatively low permeability and hence most of the regional groundwater flow would be transmitted in the FBS. Regional groundwater flow is conceptualised as being approximately north to south and hence orthogonal to the tunnel.

Since the tunnels would leave most of the lower FBS unobstructed to groundwater flow, and the aquifer is quite transmissive, aquifer damming is unlikely to occur. There may be a minor increase in the hydraulic gradient immediately around the structure to compensate for the minor decrease in the cross sectional area of the lower FBS. The distance 'down aquifer' where the groundwater pressure would be affected would be short, typically in the order of several tunnel diameters (i.e. tens of metres at most). Hence the risk of any adverse effects, such as subsidence, is considered to be very low.

#### 7.2.4 Environmental Performance Requirements

Since the minimal drawdown and low risk of aquifer damming means the risk of impacts to groundwater dependent values is low, no specific Environmental Performance Requirements have been recommended for this section of tunnels. However the project-wide Environmental Performance Requirements of developing a detailed design phase model and a groundwater management plan to assess and manage impacts associated with the detailed design still apply.



## 7.3 Tunnels: Arden Station to Parkville Station

### 7.3.1 Existing Conditions

#### 7.3.1.1 Hydrostratigraphy

The expected geology encountered in this section of the Tunnels precinct is Werribee Formation in the west and Melbourne Formation in the east. This section includes TBM driven tunnels (1,500 m in total length) and cross passages. Figure 7-2 shows the hydrogeological conditions that this section of tunnels is expected to encounter.

Deep, fresh to slightly weathered rock of the Melbourne Formation, typically present at depths greater than 24 m, has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered material is typically non-acid forming and hence low risk. The Werribee Formation has low potential to generate acidity. More detail about the hydrogeological units expected to be encountered in the section of tunnels from Arden station to Parkville station is included in Appendix C of this report.

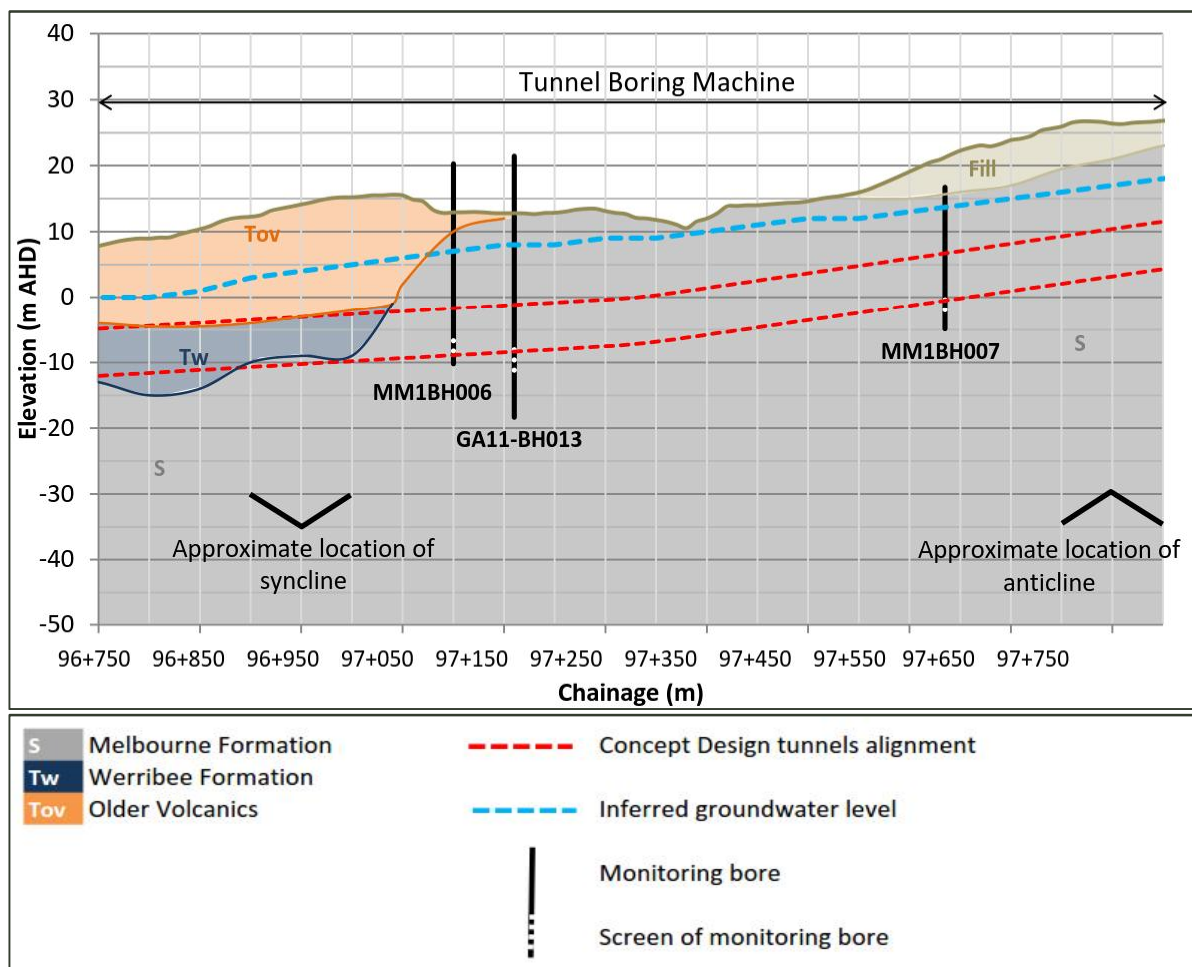


Figure 7-2: Conceptual site model for the tunnels area between the Arden and Parkville stations

#### 7.3.1.2 Groundwater Levels

There are three bores in this area monitoring groundwater levels in the Melbourne Formation siltstone. Groundwater level results are included in Appendix C of this report.

The water levels in MM1BH006 and MM1BH007 rose by 1 m between July 2010 and June 2011 which reflects the above average rainfall experienced during this period. Over the following year, the rise of water



levels was around 0.3 m in MM1BH006, coinciding with a period of more typical annual rainfall (Appendix C of this report). A logger installed in nearby GA11-BH011 (50 m west of the western end of this area of tunnels) shows an annual seasonal variation of 0.5 m. Groundwater flow in this area appears to be towards the west.

The depth to groundwater in this area ranges between approximately 5 m below ground level to 12 m below ground level. The shallowest groundwater levels are near the Arden station and at Courtney Street in the east of the area. The deepest groundwater levels are expected to be near Abbotsford Street.

### 7.3.1.3 Groundwater Quality

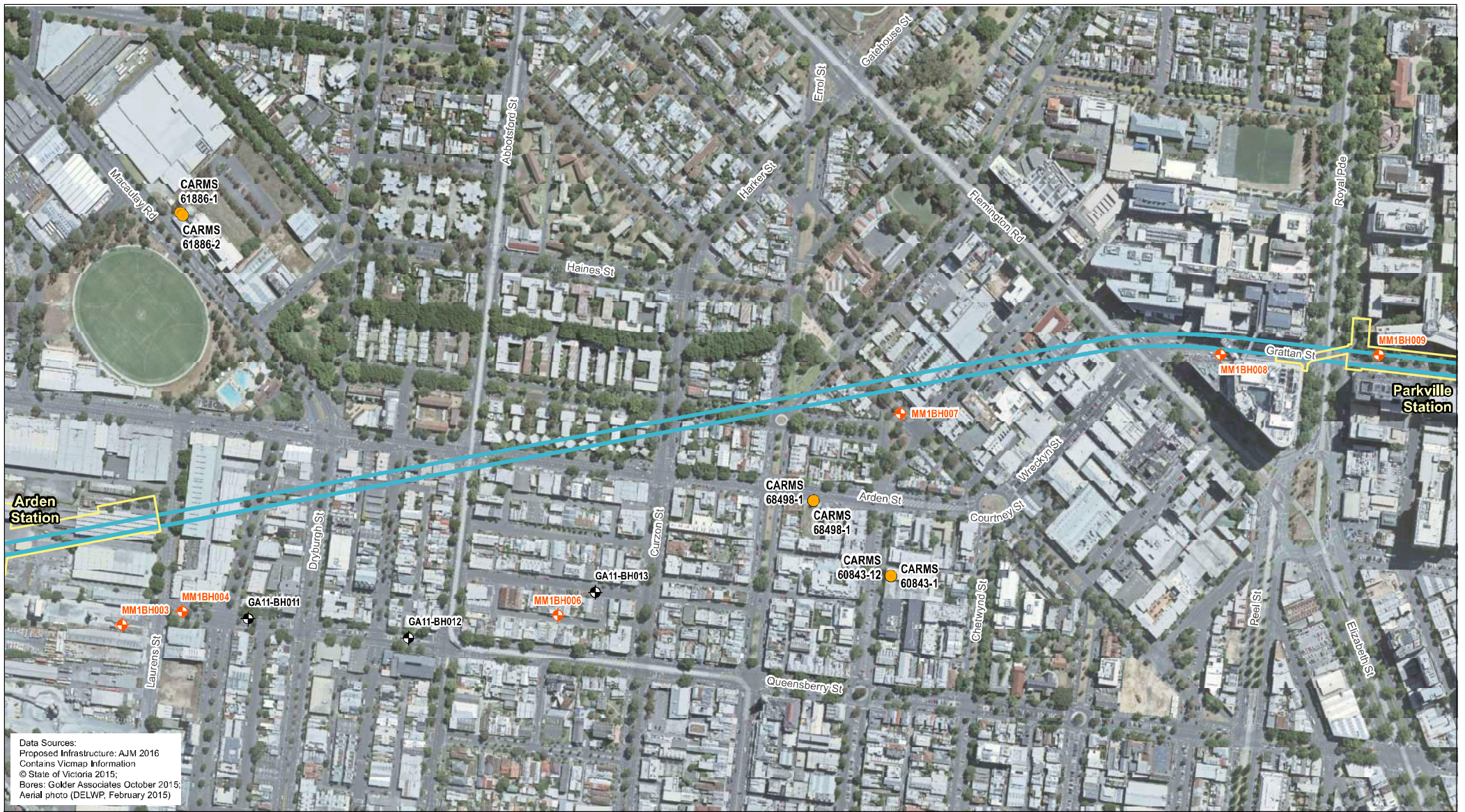
The three monitoring bores in this area of the Tunnels precinct have TDS concentrations in the Melbourne Formation of between 4,000 and 10,000 mg/L TDS. The groundwater in this area is slightly fresher (less saline) than would be expected from the regional mapping which designates this area as 7,000 to 13,000 mg/L TDS. The regional mapping refers to watertable salinity, whereas the results from Melbourne Metro bores are from deeper parts of the Melbourne Formation which may be more saline. Groundwater of this salinity is within Segment C of the SEPP (GoV) (EPA Victoria 1997), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation. Full groundwater quality analysis results are included in Appendix E of this report.

Organic compounds can be an indication of anthropogenic contamination, however none were detected in the samples. This is generally an industrial area and widespread low-level contamination of soil and groundwater is expected. However, Melbourne Metro bores were designed to assess conditions at tunnel depth and do not specifically target groundwater contaminants.

Three GQRUZs are located within a 1 km radius of the Arden station to Parkville station tunnels (Figure 7-3). These are sites where groundwater contamination restricts certain uses of the groundwater (including many Segment C uses), as shown in Table 7-2. Volatile contaminants are present in these GQRUZs. If inflow to the tunnels was to occur, associated drawdown may change hydraulic gradients in the area, causing movement of these contaminants towards the tunnels.



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

**Legend**

**EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations**

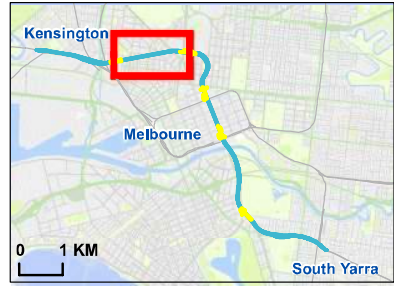
- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- ◆ Stage 2 Phase 2A
- ◆ Stage 2 Phase 2B
- ◆ Stage 2 Phase 2C
- ◆ Procurement Phase
- ◆ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 3 of 10



**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment - Arden to Parkville Tunnel

Drawing Number: MMR-AJM-UGAA-MP-NK-500222 Revision: P1

|                      |                         |                    |                 |
|----------------------|-------------------------|--------------------|-----------------|
| Drawn By:<br>A. Davy | Approved By:<br>F. Dean | Date:<br>8/04/2016 | Map Size:<br>A4 |
|----------------------|-------------------------|--------------------|-----------------|

0 140 280 Metres

Figure 7-3 GQRUZs within 1 km of the tunnels area between the proposed Arden and Parkville stations



Table 7-2 Contaminants and restricted uses for GQRUZs within 1 km of the tunnels area between Arden and Parkville stations

| Reference  | Main groundwater contaminants   | Restricted / excluded uses of groundwater   |
|--|---|---|
| <b>CARMS 61886-1. Cardno Lane Piper, 2012. Environmental Audit report and statement of Environmental Audit - 60-96 Macaulay Road, North Melbourne.</b> | Heavy metals, TPH, naphthalene, fluoride, ammonia, cyanide, benzene, xylene, ethyl benzene, toluene, styrene, bis(2-ethylhexyl) phthalate and benzo(a)pyrene. | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Industrial water use<br>Primary contact recreation    |
| <b>CARMS 68498-1. Coffey Environments, 2013. Environmental Audit report – 33-35 Arden Street, North Melbourne.</b>                                     | NAPL.   | Potable water supply<br>Agriculture, parks and gardens.<br>Stock watering.<br>Industrial water use.<br>Primary contact recreation |
| <b>CARMS 60843-12: Chadwick T&amp;T Pty Ltd, 2009. Environmental Audit report (53X) - 90-96 Leveson and 15-25 Byron Street, North Melbourne.</b>       | Antimony, boron, Cadmium, Chromium VI, Copper, Manganese, Mercury, Selenium, Tin, Zinc, Cis-1, 2 DCE, Nitrate, Sulfate.                                       | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Primary contact recreation                            |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

#### 7.3.1.4 Groundwater Use

The nearest stock and domestic bore to this area of the tunnels is located approximately 100 m to the west (WRK962001). This bore was not located during the site inspection undertaken for Melbourne Metro in July 2015 and it is expected that it no longer exists. Outcomes of the site inspections are summarised in Appendix D of this report. Discussions with Southern Rural Water confirmed that the bore is not likely to be used and that it can be excluded from further consideration in the EES.

#### 7.3.1.5 Groundwater-Surface Water Interaction

There are no surface water bodies or major watercourses within this part of the Tunnels precinct.

#### 7.3.1.6 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in the Technical Appendix R and S *Arboriculture* and are considered not to be groundwater dependent. There are some large trees in the vicinity of the tunnels (outside the project boundary) that were not assessed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*), for example on Plane Tree Way and Flemington Road. Some of these are plane trees, which have shallow root systems (<1.5 m), and are therefore not expected to access groundwater. There is no specific information on the other types of trees or their water requirements, however groundwater dependence is expected to be low, as groundwater in the area is saline and other water sources such as soil moisture, surface runoff and leaking drains would constitute a preferable water



source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

### 7.3.2 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 7-3. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 7-3 Potential issues associated with the Concept Design for the tunnels between Arden and Parkville stations**

| Concept Design                                      | Issue  | Risk #  |
|---|--|---|
| <b>Tunnels (Arden station to Parkville station)</b> | <p>The tunnels would be below the watertable, therefore the potential exists for inflows to the tunnels and associated drawdown during construction and operation. During construction the tunnels would be tanked almost immediately, which would prevent inflows and drawdown in the construction phase. For operation, the tunnels would be tanked to Haack 3 classification. Minor inflows would occur over the longer term, which may result in drawdown. Potential operational impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>• Migration of existing contaminants to third party properties. There are three GQRUZs in the area. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> <li>• Potential acid generation from exposure of Melbourne Formation.</li> </ul> <p>No bore users or surface water bodies exist in this section of this part of the Tunnels precinct. Vegetation is not expected to be dependent on groundwater, so impacts are not considered further.</p> | <p>GW022<br/>GW023</p> <p>GW035<br/>GW036</p> |

### 7.3.3 Impact Assessment

Potential impacts of Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where a medium, high or very high risk of impact has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

#### 7.3.3.1 Construction

The tunnels constructed using the TBM would be tanked almost immediately after they have been excavated. This is expected to prevent inflows and associated drawdown during construction. No analysis of drawdown has therefore been undertaken for the tunnels between the Arden station and Parkville station precinct during the construction phase.

#### 7.3.3.2 Operation

The tunnels would be tanked to Haack 3 tightness, which results in inflows of 0.0046 L/sec per 100 m of two tunnels, based on an internal tunnel diameter of 6.3 m at the location of the tunnel liner and Haack 3 daily inflow criterion of 0.1 L/m<sup>2</sup> over 100 m length of tunnel. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b), which is included as Appendix H of this report.

##### 7.3.3.2.1 Potential Impacts

The estimated groundwater drawdown as a result of the minor inflows to the tunnels is predicted to be less than 0.2 m immediately above the tunnels at steady state. This minimal drawdown means that no impacts on groundwater dependent values are anticipated along the tunnels section between the Arden station and



Parkville station. If there is any change in construction technique or detailed design that may cause greater inflows, potential drawdown impacts should be assessed for the following receptors:

- Migration of existing contaminants to third party properties. There are three GQRUZs within 1 km of the tunnels (**Risk #GW023**)
- Groundwater acidification due to exposure of potentially acid forming Melbourne Formation (**Risk #GW036**).

#### 7.3.4 Environmental Performance Requirements

Since the minimal drawdown means the risk of impacts to groundwater dependent values is low, no specific Environmental Performance Requirements have been recommended for this section of tunnels. However the project-wide Environmental Performance Requirements of developing a detailed design phase model and a groundwater management plan to assess and manage impacts associated with the detailed design still apply.

## 7.4 Tunnels: Parkville Station to CBD North Station

### 7.4.1 Existing Conditions

#### 7.4.1.1 Hydrostratigraphy

The expected geology across this part of the Tunnels precinct is Melbourne Formation siltstone. This section includes TBM driven tunnels (960 m in length) and cross passages. Figure 7-4 shows the hydrogeological conditions that this section of tunnel is expected to encounter.

Deep, fresh to slightly weathered rock of the Melbourne Formation, typically present at depths greater than 24m, has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered Melbourne Formation is typically non-acid forming and hence low risk. More detail about the hydrogeological units expected to be encountered in the section of tunnels from Parkville station to CBD North station is included in Appendix C of this report.

There are two groundwater monitoring bores in this area. MM1BH010 has undergone hydraulic testing on two occasions with an average hydraulic conductivity value of  $7.4 \times 10^{-7}$  m/sec. This is within the expected range of hydraulic conductivity for the Melbourne Formation testing across the Study Area, and close to the median of  $5.5 \times 10^{-7}$  m/sec.

#### 7.4.1.2 Groundwater Levels

Groundwater levels have been monitored at least once in each bore between 2010 and 2013. Over these dates the groundwater levels varied by 0.5 m, which is broadly consistent with rainfall trends for the period. A groundwater level logger installed in nearby MM1BH009 (275 m west of the western edge of this part of the precinct) between August 2013 and May 2014 shows an annual seasonal variation of 0.35 m. Groundwater flow in this area appears to be towards the south or south west. Groundwater level monitoring results are included in Appendix C of this report.

The depth to groundwater in this area ranges between approximately 6 m below ground level to 14 m below ground level. The shallowest groundwater levels are near Bouverie Street in the north of the area and towards Victoria Street in the south of the area.

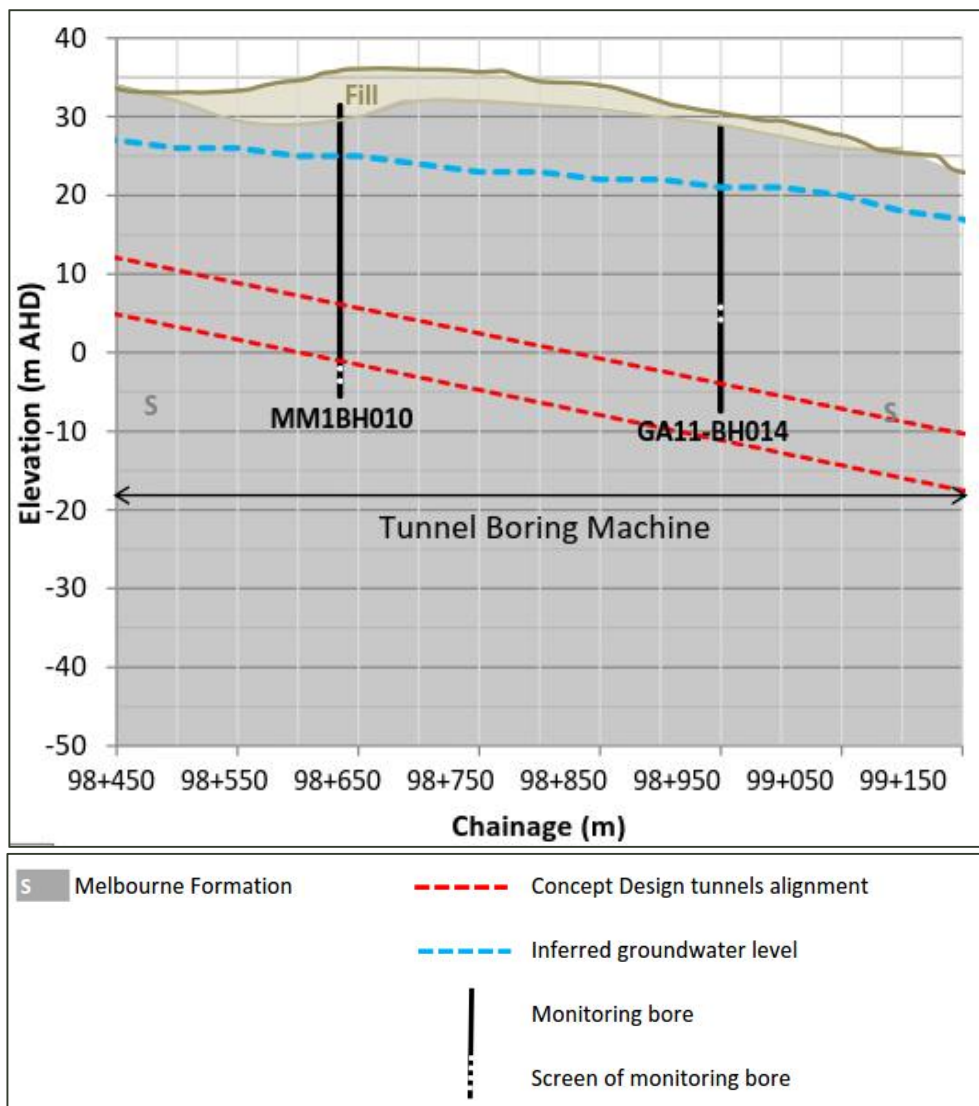


Figure 7-4: Conceptual site model for the tunnels area between Parkville and CBD North stations

#### 7.4.1.3 Groundwater Quality

Both monitoring bores in this part of the Tunnels precinct have TDS concentrations of between 4,000 and 6,000 mg/L TDS. The groundwater salinity in this area is consistent with the regional watertable mapping which indicates a salinity of 3,500 to 7,000 mg/L TDS. Groundwater of this salinity is within Segment C of the SEPP (GoV), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation.

High nitrate concentrations were detected in GA11-BH014, which may indicate the groundwater is affected by leakage from a sewer or infiltrated fertiliser. Full groundwater quality analysis results are included in Appendix E of this report.





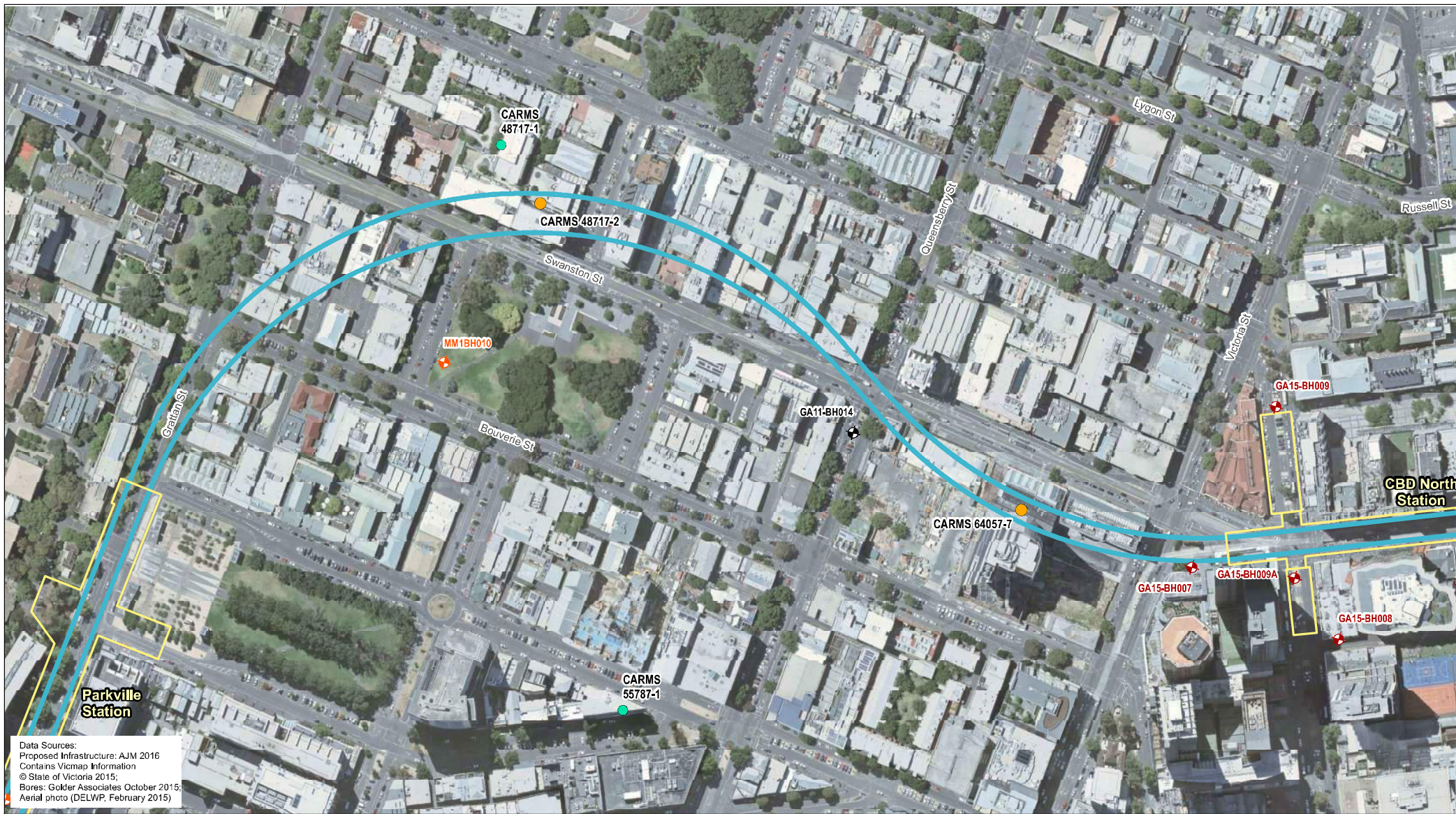
Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bores:

- GA11-BH014 (Melbourne Formation) – Cis-1,2-Dichloroethene (0.007 mg/L) and tetrachloroethene (0.012 mg/L)
- MM1BH010 (Melbourne Formation) – 1,1-Dichloroethane (0.013 mg/L) and 1,1-Dichloroethene (0.084 mg/L).

These concentrations are relatively low and generally below the relevant guideline values for the protection of ecosystems and drinking water (ANZECC, 2000, NHMRC/NRMCC, 2011 and USEPA, 2014). The exception to this is the drinking water standard for 1,1-Dichloroethane (0.0027 mg/L – USEPA, 2014) and 1,1-Dichloroethene (0.03 mg/L – NHMRC/NRMCC, 2011), which are exceeded. Drinking water is not a protected Beneficial Use in this area due to the high groundwater salinity, however these standards are also often used to indicate suitability for the Beneficial Use 'Preliminary contact – recreation'. As such, existing contamination may mean groundwater in the area is not suitable for this Beneficial Use. These compounds are common industrial solvents and may be expected in low levels in areas with a history of industrial land uses.

There are three GQRUZs within a 1 km radius of the tunnels area between the Parkville and CBD North stations (Figure 7-5). These are sites where groundwater contamination restricts certain uses of the groundwater, as shown in Table 7-4. Two of these are known pollution plumes on this part of the tunnels precinct: at the former brewery site between Victoria and Queensbury Streets (CARMS 64057-7), and on the corner of Swanston Street and Pelham Street (CARMS 48717-2). These plumes are described further in Section 11.2.3.

Volatile contaminants are present in these GQRUZs. Drawdown associated with inflows at the tunnels may change hydraulic gradients in the area, causing movement of these contaminants towards the tunnels.



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

**Legend**

**EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations**

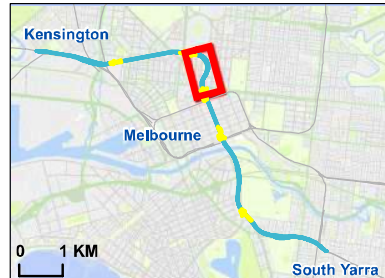
- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- Stage 2 Phase 2A
- Stage 2 Phase 2B
- Stage 2 Phase 2C
- Procurement Phase
- ◆ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 5 of 10



**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment - Parkville to CBD North Tunnel

Drawing Number: MMR-AJM-UGAA-MP-NK-500222  
 Revision: P1

|                      |                         |                    |                 |
|----------------------|-------------------------|--------------------|-----------------|
| Drawn By:<br>A. Davy | Approved By:<br>F. Dean | Date:<br>8/04/2016 | Map Size:<br>A4 |
|----------------------|-------------------------|--------------------|-----------------|

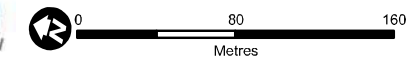


Figure 7-5 GQRUZ within 1 km of the tunnels area between Parkville and CBD North stations



**Table 7-4 Contaminants and restricted uses for GQRUZs within 1 km of the tunnels area between Parkville and CBD North stations**

| Reference   | Main groundwater contaminants                               | Restricted / excluded uses of groundwater   |
|---|---|---|
| CARMS 48717-2. GHD Pty Ltd, 2004. Environmental Audit report (53X) - CNR Swanston, Pelham Street, Carlton.        | BTEX (especially benzene and xylene) TPHs.                  | Potable water supply<br>Stock watering<br>Primary contact recreation                                    |
| CARMS 51419-2. 116-128 Leicester Street, Carlton. No report available.  | No information available                                    | Potable water supply<br>Stock watering<br>Primary contact recreation                                    |
| CARMS 64057-7. Peter J Ramsay and Associates, 2015. Environmental Audit report: 539-553 Swanston Street, Carlton. | Dissolved petroleum hydrocarbons, chlorinated hydrocarbons. | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering.<br>Primary contact recreation |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

#### 7.4.1.4 Groundwater Use

There are three registered bores within 1 km of this section of the tunnels:

- Two stock and domestic bores located approximately 250 m to the north-west (WRK981453 and WRK981452). The bores were not located during the site inspection undertaken for Melbourne Metro in July 2015, and it is likely that they no longer exist. Discussion with Southern Rural Water confirmed that they are no longer used and can be excluded from further consideration in this impact assessment
- One groundwater bore is located approximately 850 m to the north-east (WRK989150), which is 20 m deep and was drilled in 2007. This bore was not visited in the site inspections and its current status could not be confirmed. As this bore may still be in use, it is considered as a potential receptor in this impact assessment. The outcomes of the site inspections are summarised in Appendix D of this report.

#### 7.4.1.5 Groundwater-Surface Water Interaction

There are no surface water bodies or major watercourses that are likely to interact with groundwater within this part of the Tunnels precinct. There are two artificial ponds in the Carlton Gardens, approximately 300 m south-east and 500 m east of the tunnel alignment respectively. These ponds are in an elevated landscape



and are not likely to be connected to the watertable. For this impact assessment they are not considered to be interacting with groundwater.

#### 7.4.1.6 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in Technical Appendix R and S *Arboriculture* and are considered not to be groundwater dependent. There are some large trees in the vicinity of the tunnels alignment (outside the project boundary) that were not assessed in the arboriculture impact assessments. There is no specific information on the type of these trees and their water requirements, however groundwater dependence is expected to be low, as other water sources such as soil moisture, surface runoff and leaking drains would constitute a preferable water source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

#### 7.4.2 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 7-5 below. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 7-5 Potential issues associated with the Concept Design for the tunnels between Parkville station and CBD North station**

| Concept Design  | Issue  | Risk #         |
|---|--|----------------|
| <b>Tunnels (Parkville station to CBD North station)</b> | The tunnels are below the watertable, therefore the potential exists for inflows to the tunnels and associated drawdown during construction and operation. During construction the tunnels would be effectively tanked almost immediately, which is assumed to prevent inflows and drawdown in the construction phase. For operation, the tunnels would be tanked to Haack 3 classification. Minor inflows would occur over the longer term, which may result in drawdown. Potential operational impacts of drawdown in this area include: | GW002, GW003   |
|   | <ul style="list-style-type: none"> <li>• Reduced available drawdown in one bore (WRK989150)</li> <li>• Migration of existing contaminants to third party properties. Three GQRUZs exist in the area. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> </ul>  | GW022<br>GW023 |
|   | <ul style="list-style-type: none"> <li>• Potential acid generation from exposure of Melbourne Formation.</li> </ul> <p>No groundwater dependent surface water bodies exist in this section of the Tunnels precinct. Vegetation is not expected to be dependent on groundwater, so impacts are not considered further.</p>  | GW035<br>GW036 |

#### 7.4.3 Impact Assessment

Potential impacts of the Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where a medium, high or very high risk of impact has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

##### 7.4.3.1 Construction

The tunnels constructed using the TBM would be tanked almost immediately after they have been excavated. This is expected to prevent inflows and associated drawdown during construction. No analysis of drawdown has therefore been undertaken for the tunnels between the Parkville station and CBD North station during the construction phase.



### 7.4.3.2 Operation

It is assumed that the tunnels would be tanked to Haack 3 tightness, which results in inflows of 0.0046 L/sec per 100 m of two tunnels, based on an internal tunnel diameter of 6.3 m at the location of the tunnel liner and Haack 3 inflow criterion of 0.1 L/m<sup>2</sup>/day. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder (2016b), which is included as Appendix H of this report.

#### 7.4.3.2.1 Potential Impacts

The estimated groundwater drawdown as a result of the minor inflows to the tunnels is predicted to be less than 0.2 m immediately above the tunnels at steady state. This minimal drawdown means that no impacts on groundwater dependent values are anticipated along the tunnels section between the Parkville station and CBD North station. If there is any change in construction technique or detailed design that may cause greater inflows, potential drawdown impacts should be assessed for the following receptors:

- One bore (WRK989150) (**Risk #GW002**)
- Migration of existing contaminants to third party properties. Three GQRUZ exist in the area which could migrate if drawdown occurred (**Risk #GW023**)
- Groundwater acidification due to exposure of potentially acid forming Melbourne Formation (**Risk #GW036**).

### 7.4.4 Environmental Performance Requirements

Since the minimal drawdown predicted means the risk of impacts to groundwater dependent values is low, no specific Environmental Performance Requirements have been recommended for this section of tunnels. However the project-wide Environmental Performance Requirements of developing a detailed design phase model and a groundwater management plan to assess and manage impacts associated with the detailed design still apply.

## 7.5 Tunnels: CBD North Station to CBD South Station

### 7.5.1 Existing Conditions

#### 7.5.1.1 Hydrostratigraphy

The expected geology across this part of the Tunnels precinct is Melbourne Formation siltstone. This area includes mined tunnels (680 m in length) and a cross passage. Figure 7-6 shows the hydrogeological conditions that this section of tunnels is expected to encounter.

Deep, fresh to slightly weathered rock of the Melbourne Formation, typically present at depths greater than 24m, has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered Melbourne Formation is typically non-acid forming and hence low risk. More detail about the hydrogeological units expected to be encountered in the section of tunnels from CBD North station to CBD South station is included in Appendix C of this report.

There is one groundwater monitoring bore in this part of the precinct (MM1BH012) and this bore has undergone hydraulic testing. This bore shows a hydraulic conductivity of  $1.1 \times 10^{-6}$  m/sec which is similar to the average for the Melbourne Formation testing across the Study Area of  $2.6 \times 10^{-6}$  m/sec.

#### 7.5.1.1 Groundwater Levels

Groundwater levels have been monitored in MM1BH12 on four occasions: June 2010, August 2010, July 2011 and June 2012. Over this period the groundwater levels have risen from June 2010 to July 2011 and



then fallen again in June 2012. The rise in groundwater levels between 2010 and 2011 corresponds with a higher than average rainfall over the period. However, rainfall was also above average between 2011 and 2012 and groundwater levels over this period fell. This varied response to rainfall may be due to the limited recharge over this area due to the prevalence of low permeability surfaces that prevent infiltration, or the influence of below ground urban infrastructure (such as tunnels and basements) on groundwater levels. The groundwater levels monitored in this part of the precinct and the bore hydrograph are included in Appendix C of this report.

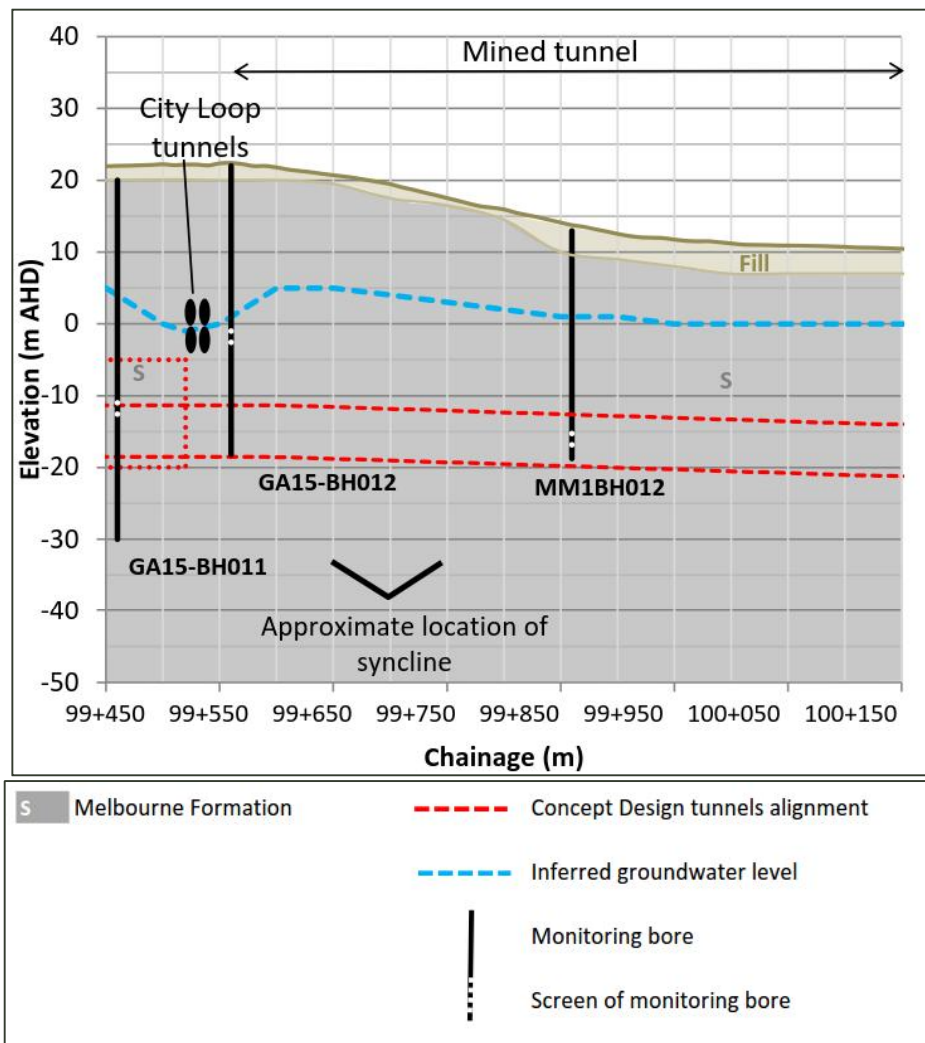


Figure 7-6: Conceptual site model for the tunnels area between CBD North and CBD South stations

Groundwater levels in this area are likely to be controlled by manmade structures such as the City Loop tunnels, which cross under the alignment near CBD North station. The City Loop tunnels were designed to drain groundwater and are lowering water levels in the northern CBD area to below 0 m AHD in some areas. The drawdown towards these tunnels may also be responsible for the limited variation in groundwater during higher rainfall events (i.e. recharge to the aquifer in this area may be less than inflow to the tunnels and therefore recharge events are not the main influence on groundwater variation). Groundwater flow in this area is generally to the west and south except in the very north of the area where groundwater may be flowing north towards the City Loop tunnels.

The depth to groundwater in this area of the Tunnels precinct ranges between approximately 10 m below ground level to 20 m below ground level. The shallowest groundwater levels are in the south of the area towards the CBD South station.



The lack of bore data in this tunnels section would be addressed by additional drilling and monitoring in the next phase of the Project. Because there is limited geological variation in this tunnels section (i.e. the tunnels are entirely within the Melbourne Formation), the current level of information is sufficient for the assessment of risk required for this EES.

#### 7.5.1.2 Groundwater Quality

The one monitoring bore in this part of the Tunnels precinct has a salinity of 5,100 mg/L TDS. The groundwater salinity in this area is consistent with the regional mapping which designates this area as 3,500 to 7,000 mg/L TDS. Groundwater of this salinity is within Segment C of the SEPP (GoV), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

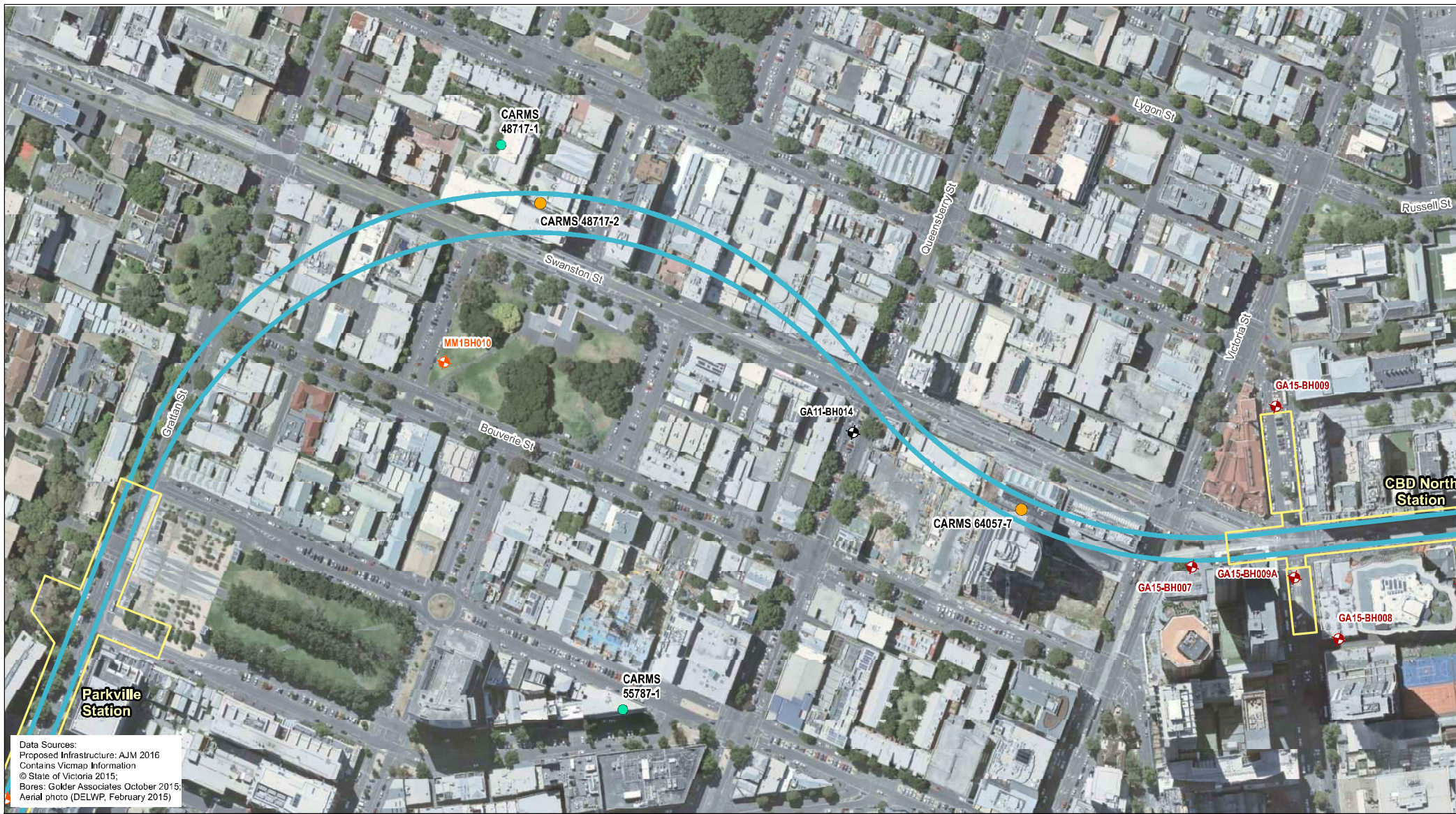
Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation. Full groundwater quality analysis results are included in Appendix E of this report.

Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bore:

- MM1BH012 (Melbourne Formation) – Toluene (0.002 mg/L)

The concentrations of toluene detected are below relevant guidelines for the protection of ecosystems and drinking water (ANZECC, 2000 and NHMRC/NRMCC, 2011). Therefore they are not considered to be of concern. This is an intensively developed area and widespread low-level contamination of soil and groundwater is expected. However, Melbourne Metro bores were designed to assess conditions at tunnel depth and do not specifically target groundwater contaminants. Therefore, while these hydrocarbon concentrations may be diffuse contamination resulting from the intensive land use in the area, they could also indicate contaminant plumes at depths above the tunnels.

There are three GQRUZs within 1 km of these tunnels, as shown on Figure 7-7 and described in Table 7-6. These are sites where groundwater contamination restricts certain uses of the groundwater. Volatile contaminants are present in these GQRUZs. Drawdown associated with inflows at the tunnels may change hydraulic gradients in the area, causing movement of these contaminants towards the tunnels.



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

**Legend**

**EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations**

- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- ◆ Stage 2 Phase 2A
- ◆ Stage 2 Phase 2B
- ◆ Stage 2 Phase 2C
- ◆ Procurement Phase
- ◆ Reference Design Phase

**Infrastructure**

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 5 of 10



**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment - Parkville to CBD North Tunnel

Drawing Number: MMR-AJM-UGAA-MP-NK-500222 Revision: P1

Drawn By: A. Davy Approved By: F. Dean Date: 8/04/2016 Map Size: A4

0 80 160 Metres

Figure 7-7 GQRUZ within 1 km of the tunnels area between CBD North and CBD South stations





**Table 7-6 Contaminants and restricted uses for GQRUZ within 1 km of the tunnels area between Parkville and CBD North stations**

| Reference   | Main groundwater contaminants                               | Restricted / excluded uses of groundwater   |
|---|---|---|
| CARMS 48717-2. GHD Pty Ltd, 2004. Environmental Audit report (53X) - CNR Swanston, Pelham Street, Carlton.        | BTEX (especially benzene and xylene) TPHs.                  | Potable water supply<br>Stock watering<br>Primary contact recreation                                    |
| CARMS 55787-1. Sinclair Knight Merz, 2005. Environmental Audit report: 97-113 Leicester Street, Carlton.          | Benzene (and other MAH), TPH.                               | Potable water supply<br>Stock watering<br>Primary contact recreation                                    |
| CARMS 64057-7. Peter J Ramsay and Associates, 2015. Environmental Audit report: 539-553 Swanston Street, Carlton. | Dissolved petroleum hydrocarbons, chlorinated hydrocarbons. | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering.<br>Primary contact recreation |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

### 7.5.1.3 Groundwater Use

There are four registered bores within approximately 1 km of this section of tunnels, but none were found during a site inspection undertaken for Melbourne Metro in July 2015. The outcomes of the site inspections are summarised in Appendix D of this report. Discussions with Southern Rural Water agreed on an approach for considering potential impacts to these bores, which is:

- For three of the bores which could not be located during site inspections (WRK968690, WRK975062, WRK975063), it was agreed that the bores are not used and probably no longer exist. Therefore they do not need to be considered any further in this impact assessment
- One bore could not be located during the site inspection (WRK972626), but its large diameter construction and expected location suggest that it may be a CityLink recharge bore that has been mislabelled in the WMIS database. On this basis, it should be considered further in this impact assessment.

### 7.5.1.4 Groundwater-Surface Water Interaction

There are no surface water bodies or watercourses within this part of the Tunnels precinct. The closest water body is the Yarra River approximately 400 m south, although previous tunnelling work suggests there is limited interaction between groundwater and the Yarra River. Groundwater investigations for the CityLink project observed that drawdown propagated quickly under and beyond the river during construction (Golder 2016b, Appendix H). This suggests a relatively weak connection between the river and the groundwater, which is interpreted to be due to low permeability sediments in the riverbed. This limited degree of interaction means that drawdown impacts on the Yarra River are not anticipated.



### 7.5.1.5 Groundwater Dependent Vegetation

Trees along the alignment have been reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. There are some large trees in the vicinity of the tunnel alignment (outside the project boundary) that were not assessed in the arboriculture impact assessments, for example on Collins Street and Bourke Street. Most of these trees appear to be plane trees, which have shallow roots systems (<1.5 m) and are not expected to access groundwater. As such, these trees are not assessed for impacts associated with tunnel construction or operation.

Outside the CBD there are several large trees that could potentially be using groundwater. There is no specific information on the type of trees and their water requirements, although groundwater dependence is expected to be low, as other water sources such as soil moisture, surface runoff and leaking drains would constitute a preferable water source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

### 7.5.2 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 7-7. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 7-7 Potential issues associated with the Concept Design for tunnels between CBD North and CBD South stations**

| Concept Design  | Issue   | Risk #   |
|---|---|--|
| <b>Tunnels (CBD North station to CBD South station)</b> | <p>The tunnels are below the watertable, therefore the potential exists for inflows to the tunnels and associated drawdown during construction and operation.</p> <p>During construction the tunnels would be mined using road headers, and would remain open (untanked) for a period of time (assumed 18 months in total). Inflows and associated drawdown can therefore occur during this period. For operation, the tunnels would be tanked to Haack 3 classification. Minor inflows would occur over the longer term which may result in drawdown.</p> <p>Potential impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>• Reduced available drawdown in one groundwater bore (WRK972626)</li> <li>• Migration of existing contaminants to third party properties. No GQRUZs exist in the area, but anthropogenic contamination has been detected which may be indicative of larger contaminant plumes, given the intensive development in the area. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> <li>• Potential acid generation from exposure of Melbourne Formation.</li> </ul> <p>No groundwater dependent surface water bodies are expected to exist in this section of the Tunnels precinct. Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not considered further.</p> | <p>GW002<br/>GW006</p> <p>GW023<br/>GW025</p> <p>GW036<br/>GW038</p> |

### 7.5.3 Impact Assessment

Potential impacts of the Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where a medium, high or very high risk of impact has been predicted, additional mitigation measures are recommended to reduce the risk of impact.



### 7.5.3.1 Construction

For the majority of the tunnels, the inflows (and drawdown of surrounding groundwater levels) are considered to be minimal due to the TBM construction method. However, between CBD North and CBD South stations the tunnels would be excavated using mined methods (road header machine) and this section of tunnels would be drained during construction. This section of tunnels is below the watertable and therefore groundwater inflows are likely to occur, resulting in drawdown around the tunnels. It is recommended that mitigation measures such as grouting of tunnel walls be implemented to prevent inflows in this section of tunnels, but the following analysis assumes the base construction case without mitigation measures.

#### 7.5.3.1.1 Groundwater Drawdown Estimate

Inflow volumes and associated drawdown of groundwater levels were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b), which is included as Appendix H of this report. If no mitigation measures are implemented to prevent inflows, drawdown is predicted to extend several hundred metres to the east and west of the tunnels by the end of construction. Groundwater dependent values within this area of drawdown may be impacted by reduced groundwater availability as a result of deeper groundwater levels. Although this unmitigated drawdown is expected to extend beyond the north and south ends of the tunnel, the primary influence on drawdown in these locations is from construction of the CBD North and CBD South stations. Impacts in these areas are discussed in Sections 11.4 and 12.4 of this report respectively.

#### 7.5.3.1.2 Potential Impacts

If no mitigation measures are implemented, drawdown is predicted to occur within several hundred metres of this section of tunnels as a result of the construction techniques (i.e. drained tunnels). Based on these results, a series of mitigation measures (e.g. forward grouting at the tunnel face) are recommended to limit inflows to the tunnels, and therefore limit drawdown.

Groundwater dependent assets within the area of drawdown are susceptible to impacts. As a result of the predicted level of drawdown in the unmitigated scenario, potential impact receptors include:

- Third parties with properties close to possible contaminant plumes (**Risk #GW025**). Three GQRUZs are within the predicted area of drawdown to the north of this tunnels section, although these would be primarily influenced by drawdown from CBD North station as discussed in Section 11.4 of this report
- Groundwater acidification due to potentially acid forming Melbourne Formation (**Risk #GW038**).

However, with appropriate mitigation measures (principally forward grouting at the tunnel face) it is considered that drawdown around the tunnels would be limited, and groundwater dependent values in the area would not be impacted.

There are no active groundwater users within the predicted area of drawdown for this section of the Tunnels precinct. Similarly, the surface water bodies and vegetation within the area of drawdown are not expected to be dependent on groundwater, so impacts are not considered further. The following sections present the analysis of impacts of this level of drawdown on each potential receptor.

#### *Contamination Migration to Third Party Properties*

Anthropogenic contamination has been detected along the tunnels alignment between CBD North and CBD South stations. Given the intensive development in the area this could reflect diffuse contamination of the aquifer, or could be indicative of particular contaminant plumes. The extent of the predicted drawdown cone would intersect these areas of contamination and could cause migration of contaminants towards the tunnels. If contaminant plumes do exist in this area, the predicted drawdown could cause migration to third party properties, and threaten beneficial uses of the groundwater at those properties. Beneficial uses that need to be protected are:



- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Drinking water and irrigation are not protected beneficial uses because of the high salinity of the groundwater in this area (SEPP GoV 1997). Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct.

Due to the uncertainty about whether contaminant plumes exist, there is considered to be a medium risk of migration of contaminants and associated vapour migration in the area of drawdown. Mitigation measures and complementary monitoring would be implemented during construction to reduce this risk to low. The predicted level of drawdown would be significantly reduced provided mitigation strategies such as ahead of face probing and pre/post-excavation grouting are effectively employed during construction to limit inflows and drawdown. These are described in Section 12.4.1.3 of this report.

#### *Potential Acidification of Groundwater due to PASS Activation*

The mined construction technique would result in groundwater drawdown. This may expose Melbourne Formation siltstones to oxygen, and hence there is a risk of PASS activation. There has been limited PASS testing along this segment to date, and hence the real risk of PASS is uncertain. Testing at CBD North station indicates the presence of PASS at the station cavern (Golder 2016a, Appendix G). The majority of testing at CBD South station indicates the absence of PASS at the station cavern, but this is based on a small number of samples (Golder 2016a, Appendix G).

The risk of any significant offsite impacts at the northern end of this section is considered low, as groundwater levels in this area are controlled by the City Loop and are therefore have already been drawn down. The risk of any significant offsite impacts from PASS at the southern end of this section is also considered low as mitigation measures including grouting and injection bores would limit drawdown in this area.

### **7.5.3.2 Operation**

It is assumed that the tunnels would be tanked to Haack 3 tightness, which results in inflows of 0.0046 L/sec per 100 m of two tunnels, based on an internal tunnel diameter of 6.3 m at the location of the tunnel liner and Haack 3 daily inflow criterion of 0.1 L/m<sup>2</sup> over 100 m length of tunnel. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b), which is included as Appendix H of this report.

#### **7.5.3.2.1 Potential Impacts**

The estimated steady state groundwater drawdown as a result of the minor inflows to the tunnels is predicted to be less than 1 m immediately above the tunnels. The influence of the drawdown cone is limited to within a few hundred metres either side of the tunnel. There are no known groundwater dependent assets or values within this area of drawdown, and therefore, no impacts on groundwater dependent values are anticipated during operation. If there is any change in construction technique that may cause greater inflows, potential drawdown impacts should be assessed for groundwater bore WRK972626 (**Risk #GW002**), migration of existing contaminants to third party properties (**Risk #GW023**), and potential acidification of groundwater due to exposure of Melbourne Formation (**Risk #GW036**).



## 7.5.4 Environmental Performance Requirements

Table 7-8 provides the recommended Environmental Performance Requirements and proposed mitigation measures for the precinct. In addition to the precinct specific Environmental Performance Requirements below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a groundwater management plan to assess and manage impacts associated with the detailed design also apply.

**Table 7-8 Environmental Performance Requirements for section of tunnels precinct between CBD North and CBD South stations**

| Asset / value   | Impact  | Environmental Performance Requirements   | Proposed mitigation measures   | Risk no.       |
|---|---|--|--|----------------|
| <b>Beneficial uses of groundwater at third party properties</b> | Construction: Moderate risk of impact on third party properties based on landuse and expected presence of contaminants within predicted area of impact. Beneficial uses that need to be protected are: <ul style="list-style-type: none"> <li>• Stock watering</li> <li>• Industrial water use</li> <li>• Primary contact recreation</li> <li>• Buildings and structures.</li> </ul> Operation: none. | Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details: <ul style="list-style-type: none"> <li>• An approach identified in consultation with the EPA so that contaminant migration causes no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> | Likely to involve further investigation and/or mitigation measures, for example: <ul style="list-style-type: none"> <li>• Site specific risk assessment of contaminant location and concentrations</li> <li>• Use of injection or discharge bores to prevent contaminant migration</li> <li>• Minimisation of drawdown through construction techniques such as construction using a TBM or grouting of the tunnels.</li> </ul> | GW023<br>GW025 |
|   |   | Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential: <ul style="list-style-type: none"> <li>• Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures.</li> </ul>   |  |                |
| <b>Beneficial uses of</b>                                       | Construction: Moderate risk of impact on  | Develop and implement a GMP detailing  | Testing of rock cores to assess site specific  | GW036          |



| Asset / value                     | Impact  | Environmental Performance Requirements  | Proposed mitigation measures  | Risk no.     |
|-----------------------------------|---|---|---|--------------|
| <p><b>groundwater in area</b></p> | <p>Beneficial Uses of groundwater within predicted area of impact. Beneficial uses that need to be protected are:</p> <ul style="list-style-type: none"> <li>• Stock watering</li> <li>• Industrial water use</li> <li>• Primary contact recreation</li> <li>• Buildings and structures.</li> </ul> <p>Operation: none.</p> | <p>groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details:</p> <ul style="list-style-type: none"> <li>• Methods for minimising drawdown in areas of known PASS and establishing appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> <hr/> <p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"> <li>• Activation of PASS and groundwater acidification.</li> </ul> | <p>risk of PASS.</p> <p>Prevent acidification of groundwater by minimizing drawdown in the area through:</p> <ul style="list-style-type: none"> <li>• Use of injection or discharge bores to prevent drawdown and contaminant migration</li> <li>• Minimisation of drawdown through construction techniques such as construction using a TBM or grouting of the tunnels.</li> </ul> | <p>GW038</p> |



## 7.6 Tunnels: CBD South Station to Domain Station

### 7.6.1 Existing Conditions

#### 7.6.1.1 Hydrostratigraphy

The tunnels between the CBD South and Domain stations encounter various geological units, including the sediments of the Yarra River palaeovalley. This area includes TBM driven tunnels (1,780 m in length) for both the alignment option the CityLink tunnels as well as the variation below CityLink, cross passages, and the intervention shaft located a few metres to the north of Linlithgow Avenue. The hydrogeological units expected to be encountered over this section of tunnels include the Newer Volcanics, Coode Island Silt, Fishermans Bend Silt, Melbourne Formation and Brighton Group. The tunnels are predominantly below the watertable apart from in the vicinity of the CityLink tunnels where they are above the watertable in unsaturated Melbourne Formation and Brighton Group.

The Fishermans Bend Silt, Brighton Group and Newer Volcanics have a low potential to generate acidity. The Coode Island Silt has a moderate to high potential to generate acidity. Deep, fresh to slightly weathered Melbourne Formation siltstone, typically present at depths greater than 24 m, has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered Melbourne Formation is typically non-acid forming and hence low risk.

Figure 7-8 shows the hydrogeological conditions this section of the Tunnels precinct is expected to encounter. More detail about these hydrogeological units is included in Appendix C of this report.

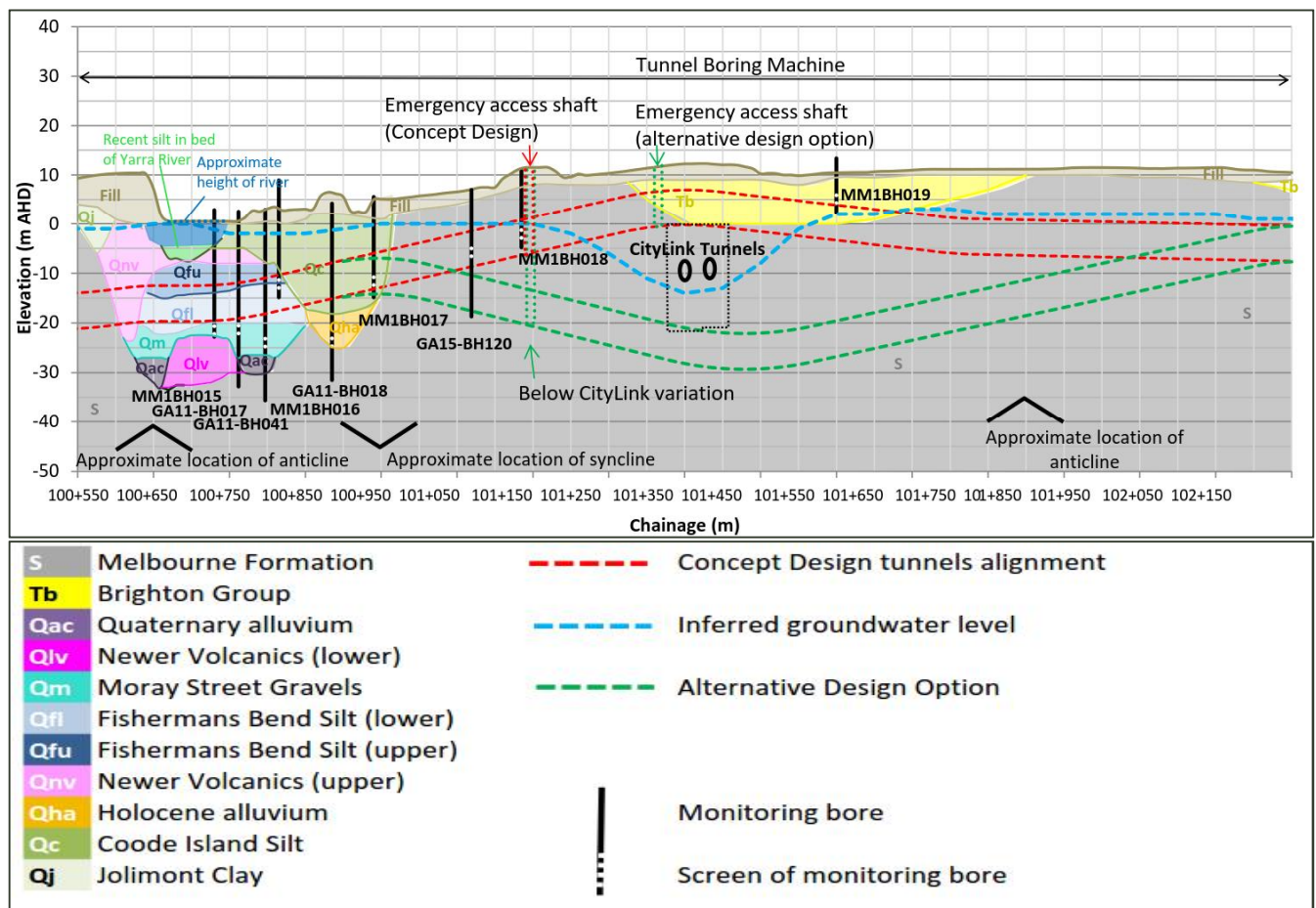


Figure 7-8: Conceptual site model for the tunnels area between CBD South and Domain stations



### 7.6.1.2 Groundwater Levels

There are 10 groundwater monitoring bores in this part of the Tunnels precinct and each has been monitored at least once. In addition, regular monitoring of groundwater levels occurred in four bores between August 2013 and May 2014. Of these four, two were monitoring the Moray Street Gravels (MM1-BH015 and GA11-BH017), one in the Fishermans Bend Silt (MM1BH016), and one in the Holocene Alluvium (GA11-BH018) and one in the Melbourne Formation (MM1BH018). Groundwater levels and the bore hydrographs are included in Appendix C of this report.

Note that Melbourne Metro bores were designed to assess conditions at tunnel depth and have not been designed to (necessarily) measure the watertable. Therefore, it is not always clear whether the watertable or a potentiometric surface is being measured. For the purpose of this report, however, it is assumed that the watertable and the potentiometric surfaces of most aquifers are very similar because there is some connection between aquifers overlying the tunnels. This would allow vertical interaction between aquifers that results in similar groundwater levels at equilibrium. In the Melbourne Formation a high degree of weathering can restrict vertical interaction, however there is expected to be some degree of connectivity that results in similar groundwater levels at equilibrium.

Both the seasonal and inter-annual variations observed in the confined aquifers are relatively small when compared to groundwater level variations in unconfined aquifers across the Study Area. Groundwater levels in all bores show a rise between 2010 and 2011, and then the confined bores (MM1BH015 and MM1BH016) show a fall in levels to 2012 whereas the unconfined bores (MM1BH017 and MM1BH018) continued to rise over the same period. Such variation indicates that rainfall variations are not the dominant influence on groundwater levels in the confined aquifer in this area.

The water levels in bores near the Yarra River show levels at or below 0 m AHD with some levels deeper than -2 m AHD. This is likely to be due to man-made structures which drain groundwater in the CBD (e.g. basements and sewers). The CityLink tunnels that cross the alignment in this part of the precinct act as groundwater drains and are lowering the watertable beneath Linlithgow Avenue. Because of this, the tunnels are above the watertable at this location.

Calculations of maximum potential groundwater levels at the CBD South station has been undertaken for Melbourne Metro design process and take into account the likely effect of climate change and flooding of the Yarra River. These calculations predict a potential maximum groundwater level at the CBD South Station of +3 m AHD. A similar rise in watertable could occur in the north of this part of the precinct based on the same principals, although any rise on the south bank of the Yarra River would be restricted by the low elevation of the ground level here.

Groundwater levels are recorded to be below the mean river level of 0.2 m AHD, although the majority of the measured bores in this area are screened in the deeper confined aquifers and therefore may not be representative of the watertable elevation. Bore MM1BH018 is screened within the watertable and shows a level up to 2.5 m lower than the river, as this bore is probably being influenced by the CityLink tunnels drawdown.

The depth to groundwater in this part of the precinct ranges between approximately 3 m below ground level to 23 m below ground level in the vicinity of the CityLink tunnels. The shallowest groundwater levels are in the low-lying areas on the south bank of the Yarra River.

### 7.6.1.3 Groundwater Quality

Eleven of the 14 monitoring bores in this part of the Tunnels precinct have been sampled and the results show a wide range of salinity. The lowest concentrations are from bores within the Melbourne Formation. MM1BH018 (1,300 mg/L) is the lowest recorded salinity along the alignment for this formation and may indicate nearby leaky water infrastructure such as water mains and irrigation pipes. Further, this bore is located in parklands and may receive irrigation recharge.





The CIS and FBS bores have reasonably high salinity but the highest values are within the deeper confined aquifers of the Moray Street Gravels and the Holocene Alluvium. The groundwater in this part of the precinct is more saline than the regional watertable mapping indicates, which designates this area as 3,500 to 7,000 mg/L TDS. The regional mapping refers to watertable salinity, whereas the salinity results from Melbourne Metro bores are from deeper confined aquifers that are typically more saline. Groundwater of this salinity is within Segment C of the SEPP Gov (EPA Victoria 1997), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation. Full groundwater quality analysis results are included in Appendix E of this report.

Elevated ammonia was detected in the Moray Street Gravels and the Holocene Alluvium in this tunnels section. Normally ammonia indicates leaking sewers, or infiltrated fertilisers, however these concentrations are in confined aquifers which are not expected to be impacted from near surface activities. In this case, the high ammonia results are unexplained.

Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bore:

- GA11-BH041 (Moray Street Gravels) – TPH fractions C<sub>10</sub>-C<sub>14</sub> (0.48 mg/L), C<sub>15</sub>-C<sub>28</sub> (0.66 mg/L), C<sub>10</sub>-C<sub>36</sub> (1.14 mg/L), C<sub>10</sub>-C<sub>40</sub> (1.09 mg/L) and C<sub>10</sub>-C<sub>16</sub> (1.09 mg/L).

The concentrations of TPH fractions are above the relevant guideline values for drinking water, recreational and irrigation uses (see Appendix E of this report). This bore is screened more than 20 m below ground level within a confined aquifer. Therefore, the source of these organic compounds is not likely to be local, but may have infiltrated where the aquifer outcrops further upstream.

There are three GQRUZ within a 1 km radius of the tunnel area between CBD South and Domain stations (Figure 7-9). These are sites where groundwater contamination restricts certain uses of the groundwater, as shown in Table 7-9. Volatile contaminants are present in these GQRUZ. Drawdown associated with inflows to the tunnel may change hydraulic gradients in the area, causing movement of these contaminants towards the tunnel.



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

**Legend**

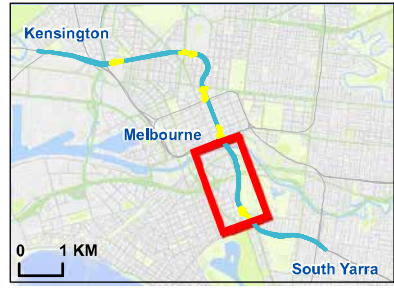
- Emergency Access Structure
- EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations**
- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- ◆ Stage 2 Phase 2A
- ◆ Stage 2 Phase 2B
- ◆ Stage 2 Phase 2C
- ◆ Procurement Phase
- ◆ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Station Footprint
- Proposed Alignment

Map 8 of 10



**MELBOURNE METRO RAIL AUTHORITY**

**ajm** **JACOBS**  
 Matt MacDonald  
 Joint Venture GRIMSHAW

**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment - CBD South to Domain Tunnel

Drawing Number: MMR-AJM-UGAA-MP-NK-500222 Revision: P1

|                      |                         |                     |                 |
|----------------------|-------------------------|---------------------|-----------------|
| Drawn By:<br>A. Davy | Approved By:<br>F. Dean | Date:<br>14/04/2016 | Map Size:<br>A4 |
|----------------------|-------------------------|---------------------|-----------------|

0 150 300 Metres

Figure 7-9 GQRUZ within 1 km of the tunnels area between CBD South and Domain stations



**Table 7-9 Contaminants and restricted uses for GQRUZ within 1 km of the tunnels area between CBD South and Domain stations**

| Reference  | Main groundwater contaminants  | Restricted / excluded uses of groundwater  |
|--|--|--|
| CARMS 47089-4. LanePiper, 2006. Environmental Audit report: Freshwater Place, Stage 2, Southbank.                          | Boron, Manganese, Nickel, Zinc, Naphthalene, Fluorene, Phenanthrene, Anthracene, Benzo(a)pyrene. | Maintenance of ecosystems.<br>Agriculture, parks and gardens.<br>Stock watering.   |
| CARMS 68727-1. Golder Associates Pty Ltd, 2011. Environmental Audit report (53X) - 63-75 Coventry Street, South Melbourne. | Cadmium, lead, nickel, zinc, PAHs, MAH, Chlorinated Ethenes.                                     | Potable water supply.<br>Agriculture, parks and gardens.<br>Stock watering.<br>Industrial water use<br>Primary contact recreation. |
| CARMS 73039-1. 102-118 Sturt Street, Southbank.  | Report not available.  | Potable water supply.<br>Agriculture, parks and gardens.<br>Stock watering.<br>Primary contact recreation.                         |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

#### 7.6.1.4 Groundwater Use

There are four bores listed as stock and domestic use within 1 km of this part of the Tunnels precinct, but none of them could be found during a site inspection undertaken for Melbourne Metro in July 2015. Outcomes of the site inspections are summarised in Appendix D of this report. Discussions with Southern Rural Water agreed on an approach for considering potential impacts to these bores, which is:

- For three of the bores which could not be located during site inspections (WRK975062, WRK975063, WRK968690), it was agreed that the bores are not used and probably no longer exist. Consequently they do not need to be considered any further in this impact assessment
- One bore could not be located during the site inspection (WRK972626), but its large diameter construction and expected location suggest that it may be a CityLink recharge bore that has been mislabelled in the WMIS database. On this basis, it should be considered further in this impact assessment.

Five CityLink recharge wells are located within 1.5 km of the tunnels alignment between CBD South and Domain stations. The wells inject water into the Moray Street Gravels to maintain saturation in the overlying Coode Island Silt and prevent ground settlement. Relative to this section of the tunnels, the wells are located:

- Two approximately 450 m west
- One well approximately 600 m east
- One well approximately 750 m east
- One well approximately 1250 m east.



#### 7.6.1.5 Groundwater-Surface Water Interaction

Watertable elevations are likely to be artificially low in the CBD due to manmade groundwater drains such as basements, sewers and tunnels. It is likely therefore that the watertable elevation is below the level of the river and therefore, groundwater flow to the river would not be occurring.

During groundwater investigations associated with the CityLink project, groundwater drawdown was shown to have propagated quickly under and beyond the river during tunnel construction (Golder 2016b, Appendix H). The lack of recharge from the river to mitigate this drawdown suggests a weak connection between the river and the groundwater. This is interpreted to be due to low permeability sediments in the river bed.

Under natural conditions, there may have been a component of groundwater flow towards Albert Park Lake, which is approximately 700 m to the south-west of the tunnels. However, the natural conditions in this area are disturbed by the South Yarra Main Sewer, which runs along the northern edge of the lake. The sewer acts as a drain for groundwater and has lowered groundwater levels in the area. Therefore the lake is now more likely to be losing water to groundwater in the area influenced by the sewer.

The lake in the Royal Botanic Gardens is located approximately 800 m to the east of this section of the alignment and may have some interaction with groundwater. There is anecdotal evidence to suggest that water levels in the lake in the Royal Botanic Gardens were lowered when groundwater drawdown occurred during CityLink construction. Because of this, the lakes are considered to be at least partially reliant on groundwater contributions to maintain inundation.

#### 7.6.1.6 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. Trees outside the project boundary have not been reviewed and therefore the groundwater dependence of these trees has not been assessed. Large trees in the gardens east of St Kilda Road, including the Royal Botanic Gardens, were not assessed in the arboriculture impact assessment as they are outside the project boundary. Where groundwater levels are shallow close to the Yarra River and the lake in the Royal Botanic Gardens, the trees may have some dependence on groundwater. Deep-rooted tree species in these areas have a greater potential for groundwater use, and hence, a greater sensitivity to impacts from drawdown. These trees should be identified and irrigated through the period of drawdown.

Other trees in the gardens and parklands are further away from surface water features in areas where groundwater is deeper. These trees are expected to preferentially use other sources of water such as soil moisture and surface runoff and are not considered to be at risk from drawdown of groundwater associated with the tunnels.

### 7.6.2 Alternative Design Options

#### 7.6.2.1 Below CityLink

The alternative design option in this area is for the alignment to go below the CityLink tunnels, which would necessitate deeper emergency access shaft requirements for the Linlithgow Avenue shaft.

##### 7.6.2.1.1 Existing Conditions

The majority of the encountered hydrogeology for this variation is the same as for the Concept Design. The alternative design tunnels (to go below the CityLink tunnels) diverge away from the Concept Design at CH100+910 and re-join the Concept Design alignment at CH102+140. The encountered geology for this alternative design is Coode Island Silt for 40 m followed by Melbourne Formation. The properties of these units in this precinct are described in Appendix D of this report.



Groundwater levels in this precinct are described in Section 7.6.1.2 of this report. The height of groundwater above the tunnels varies significantly from the Concept Design for this alternative design option. For the Concept Design, part of the tunnels are in the unsaturated aquifer above the CityLink tunnels. For this deeper alignment, the tunnels are below the groundwater level over the length of the alternative design option. The height of groundwater above the tunnels (based on the geological long section (Golder 2016a, Appendix G) is shown in Appendix D of this report.

The groundwater quality existing conditions for this variation are the same as for the Concept Design (Section 7.6.1.3).

#### 7.6.2.1.2 Potential Receptors

The groundwater use, groundwater-surface water interaction, and groundwater dependent ecosystems existing conditions for this alternative design option are the same as for the Concept Design (Section 7.6.1).

### 7.6.2.2 Emergency Access Shaft 150m Further South

The alternative design option in this area is for emergency access shaft to be located 150 m south of the Concept Design location (alternative design option within Tom's Block).

#### 7.6.2.2.1 Existing Conditions

The Concept Design shaft is located entirely within the Melbourne Formation, whereas for this alternative design option the shaft would intersect both Brighton Group and Melbourne Formation. However, as described below the shaft is likely to be in the unsaturated zone of these units. The properties of these units in this precinct are described in Appendix D of this report.

The groundwater levels in this precinct are described in Section 7.6.1.2. The location for the shaft alternative design option is above the CityLink tunnels in an unsaturated section of the aquifer (mostly Brighton Group and some Melbourne Formation). Based on the groundwater level information available, no dewatering would be necessary for this shaft alternative design option.

The groundwater quality existing conditions for this alternative design option are the same as for the Concept Design (Section 7.6.1.3).

#### 7.6.2.2.2 Potential Receptors

The groundwater use, groundwater-surface water interaction, and groundwater dependent ecosystems existing conditions for this alternative design option are the same as for the Concept Design (Section 7.6.1).

### 7.6.3 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 7-10. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 7-10 Potential issues associated with the Concept Design for the tunnels between CBD South and Domain stations**

| Concept Design                                       | Issue  | Risk #       |
|--|--|--------------|
| <b>Tunnels (CBD South station to Domain station)</b> | <p>The tunnels are partially below the watertable, therefore the potential exists for inflows to the tunnels and associated drawdown during construction and operation. During construction the tunnels would be tanked effectively immediately, which prevents inflows and drawdown in the construction phase. For operation, the tunnels would be tanked to Haack 3 classification. Minor inflows would occur over the longer term, which may result in drawdown. Potential operational impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>One potential groundwater bore (WRK972626)</li> </ul> | GW002, GW003 |



| Concept Design  | Issue   | Risk #   |
|---|---|--|
|   | <ul style="list-style-type: none"> <li>Lake in the Royal Botanic Gardens</li> <li>Migration of existing contaminants to third party properties. There are three GQRUZs in the area, and anthropogenic contamination has been detected which may be indicative of larger contaminant plumes. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> <li>Large trees that may be using groundwater where the watertable is shallow near the Yarra River and the lake in the Royal Botanic Gardens</li> <li>Impacts on CityLink recharge wells influencing operation of the wells</li> <li>Potential acid generation from exposure of Coode Island Silt and Melbourne Formation</li> <li>Aquifer damming caused by tunnels restricting groundwater flow in the Holocene Alluvium.</li> </ul> <p>It is considered that groundwater is not contributing to the Yarra River and Albert Park Lake, and therefore drawdown impacts are considered unlikely and are not assessed for these assets.</p> | GW011<br><br>GW022,<br>GW023<br>GW024<br><br>GW015,<br>GW016<br>GW018<br><br>GW042,<br>GW043<br>GW044<br><br>GW035,<br>GW036<br>GW037<br><br>GW057 |
| <b>Alternative Design Option: Below CityLink</b>                            | As for Concept Design, but the tunnels are fully below the watertable.  | GW005,<br>GW012,<br>GW026,<br>GW017,<br>GW045,<br>GW034,<br>GW048  |
| <b>Alternative Design Option: Emergency access shaft 150m further south</b> | As for Concept Design   |  |

#### 7.6.4 Alternative Design Option

The key issues associated with the potential alternative design options to the Concept Design for the tunnels alignment between CBD South and Domain stations are the same as for the Concept Design.

#### 7.6.5 Impact Assessment

Potential impacts of Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where a medium, high or very high impact has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

##### 7.6.5.1 Concept Design

###### 7.6.5.1.1 Construction

The tunnels constructed using the TBM would be tanked almost immediately after they have been excavated. This is expected to prevent inflows and associated drawdown during construction. No analysis of



drawdown has therefore been undertaken for the construction phase of tunnels between the CBD South station and Domain station precincts.

The shaft just north of Linlithgow Avenue is predominantly within the unsaturated zone. The tunnels at this location are below the watertable, but assuming the tunnels are constructed first and then the emergency access shaft is installed above the tunnels, dewatering would not be required and therefore no drawdown of groundwater levels would occur.

#### 7.6.5.1.2 Operation

It is assumed that the tunnels would be tanked to Haack 3 tightness, which results in inflows of 0.0046 L/sec per 100 m of two tunnels, based on an internal tunnel diameter of 6.3 m at the location of the tunnel liner and Haack 3 daily inflow criterion of 0.1 L/m<sup>2</sup> over 100 m length of tunnel. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b) which is included as Appendix H of this report. In the Concept Design, the Linlithgow shaft would be above the watertable, and therefore groundwater inflow and associated drawdown would not occur during operation.

#### *Potential Impacts*

The estimated groundwater drawdown as a result of the minor inflows to the tunnels is predicted to be less than 0.2 m immediately above the tunnels at steady state. This minimal drawdown means that no impacts on groundwater dependent values are anticipated along the tunnels section between the CBD South and Domain stations. If there is any change in construction technique or detailed design that may cause greater inflows, potential drawdown impacts should be assessed for:

- One potential groundwater bore 500 m east of the tunnels (WRK972626) (**Risk #GW002**)
- Lake in Royal Botanic Gardens (**Risk #GW011**)
- Groundwater acidification due to potentially acid forming Coode Island Silt and Melbourne Formation (**Risk #GW036**)
- Migration of existing contaminants to third party properties. There are three GQRUZs in the area, and anthropogenic contamination has been detected at depth (**Risk #GW023**)
- Large trees that may be using groundwater near the Yarra River and the lake in the Royal Botanic Gardens (**Risk #GW015**)
- CityLink recharge wells to the east and west of the alignment (**Risk #GW044**).

#### 7.6.5.2 Alternative Design Options

##### 7.6.5.2.1 Construction

As for the Concept Design, the tunnels in the alternative design option would be constructed using the TBM which is expected to prevent inflows and associated drawdown during construction. No analysis of drawdown has therefore been undertaken for the alternative design option for the tunnels between the CBD South station and Domain station precincts.

The alternative design option for the emergency access intervention shaft is located at Tom's Block. This structure is located above the watertable and therefore dewatering would not be required and no drawdown of groundwater levels would occur.

The alternative design option where the tunnels are below CityLink means that the Linlithgow emergency access shaft would need to be excavated deeper to reach the deeper tunnel alignment. The deeper shaft would extend below the watertable and therefore may need to be drained during construction. For this impact assessment, it is assumed that the shaft is not tanked during construction, and therefore groundwater



inflows to the shaft would occur if mitigation measures were not applied. This scenario is used to predict drawdown around the shaft.

Groundwater levels at the Linlithgow emergency access shaft deep alternative design option are approximately 0 m AHD and the base of the shaft is at -20 m AHD. Therefore, approximately 20 m of groundwater drawdown would be required to keep the excavation dry during shaft construction. Inflow volumes and associated drawdown of groundwater levels were estimated using an analytical approach that is described in Appendix F of this report. These methods are assumed to be accurate to the nearest 1 m.

#### Potential Impacts

During construction, if a drained construction approach was taken, approximately 20 m of drawdown would be required at the shaft, which is predicted to result in a cone of depression that extends several hundred metres from the shaft by the end of construction. Results of the analytical modelling are shown in Appendix F. Groundwater dependent values within this area of drawdown may be impacted by reduced groundwater availability if no mitigation measures are applied.

If this level of unmitigated drawdown occurred at Linlithgow shaft, potential receptors include:

- A possible groundwater bore (WRK972626) 450 m east of the intervention shaft (**Risk #GW005**)
- Large trees that may be using groundwater near the Yarra River (**Risk #GW017**)
- Migration of existing contaminants to third party properties. There is one GQRUZ within the area of drawdown, and anthropogenic contamination has been detected at depth (**Risk #GW026**)
- Groundwater acidification due to potentially acid forming Coode Island Silt and Melbourne Formation (**Risk #GW034**)
- CityLink recharge wells to the east and west of the shaft (**Risk #GW045**).

It is expected that groundwater is not contributing to the Yarra River and therefore drawdown impacts are considered unlikely and have not been assessed. Albert Park Lake and the lake in the Royal Botanic Gardens are outside the predicted area of drawdown associated with construction of the Linlithgow shaft (below CityLink alternative design option) and therefore no impact is predicted and no mitigation measures are required. The following sections further analyse impacts on each of these receptors.

#### Groundwater Users

A significant impact on existing groundwater users is considered to be a decline in groundwater levels that reduces the available drawdown in the bore by more than 10 per cent (RWC 1993). Groundwater level information is not available to calculate the available drawdown but a conservative estimate of 5 m below ground is used.

Table 7-11 shows the reduction in available drawdown at bore WRK972626 as a result of predicted drawdown associated with construction of the Linlithgow Avenue emergency access shaft (deep alternative design option). The predicted impact is within acceptable limits.

**Table 7-11 Predicted maximum impact on existing groundwater bores near the TBM launch shaft and emergency access shaft**

| Bore ID   | Bore depth | Water level         | Available drawdown | Estimated drawdown at bore at 540 days (Theis best estimate) | Reduction in available drawdown |
|-----------|------------|---------------------|--------------------|--|---------------------------------|
| WRK972626 | 34 m       | Unknown, assume 5 m | 29 m               | 2 m  | 7%                              |

1 – Percentage reduction in available drawdown calculated by:  $(\text{drawdown}/\text{available drawdown}) \times 100$





Unmitigated drawdown at the five CityLink recharge wells is predicted to be less than 1 m. This is a minor impact which is within the range of normal seasonal fluctuations. Lowering the watertable to this extent may slightly depressurise the Coode Island Silt, which increases the risk of ground settlement. The ground movement impact assessment (Technical Appendix P *Ground Movement and Land Stability*) reviews the potential for this impact to occur in detail. Mitigation measures such as grouting of the shaft and establishing a groundwater injection borefield in the Yarra River palaeovalley would reduce the predicted extent of drawdown so that the CityLink bores are unlikely to be affected.

#### *Impacts on Vegetation*

Vegetation in areas of shallow watertables within the area of predicted drawdown may be impacted during construction. Deep-rooted tree species should be identified and their dependence on groundwater should be assessed. If found to be groundwater dependent, the trees within the area of drawdown should be irrigated through the period of drawdown. This measure is expected to fully mitigate any potential impacts on trees caused by groundwater drawdown.

#### *Contaminant Migration to Third Party Properties*

The extent of the predicted drawdown cone would intersect one GQRUZ located 500 m to the south west of the shaft. The drawdown may cause migration of contaminants to previously uncontaminated areas, which may impact beneficial uses of groundwater at third party properties. Beneficial uses that need to be protected are:

- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Drinking water and irrigation are not protected beneficial uses because of the high salinity of the groundwater in this area. Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct.

Drawdown at the GQRUZ is predicted to be minor (1 m or less) and therefore significant migration of the contaminants is not likely during the short timeframes of construction. Hence the risk of these contaminants precluding beneficial uses at third party properties is considered to be low.

#### *Potential Acidification*

The shaft is mainly excavated through highly weathered to moderately weathered Melbourne Formation, and is dominantly above the 24 m suggested in Golder (2016a, Appendix G) as an indicator of lower PASS risk for the Melbourne Formation. Hence the risk of PASS is considered low.

### **7.6.5.2.2 Operation**

#### *Below CityLink Tunnels*

The deeper tunnel alignment means that the tunnels would be below the watertable for the entire length between CBD South and Domain stations. In a drained tunnel, this would result in greater inflows and a larger drawdown cone, with associated potential impacts on vegetation, surface water bodies and groundwater users. However it is assumed the tunnels and deeper Linlithgow shaft would be constructed to a Haack 3 tightness classification, which means inflows (and therefore drawdown) would be limited by the tunnel and shaft lining. Therefore, the extent of drawdown during operation is expected to be the same for the alternative design option as for the Concept Design, and no impacts to groundwater dependent vegetation, surface water bodies or groundwater users are anticipated.



#### *Emergency Access Shaft 150 m Further South*

The alternative design option for the emergency access shaft at Tom's Block is predominantly above the watertable. Therefore, no impacts to groundwater dependent vegetation, surface water bodies or groundwater users are anticipated.

#### **7.6.5.2.3 Aquifer Damming Assessment**

If the below CityLink alignment option is selected, there is potential for a portion of the Holocene Alluvium (HA) aquifer to be blocked. The HA is an aquifer with relatively high permeability, and regional groundwater flow is approximately orthogonal to the tunnel. It is unlikely that the 'below CityLink' alignment would result in more than 50 per cent of the cross sectional area of the Holocene Alluvium being intersected.

As the tunnels would still leave at least half of the HA unobstructed to groundwater flow, and the aquifer is transmissive, there is likely to be a slight increase in the hydraulic gradient across the tunnels to compensate for the decrease in the cross sectional area (i.e. an increase in pressure up-gradient of the tunnels and a decrease in pressure down-gradient of the tunnels). The distance up and down-gradient where the groundwater pressure would be affected would be short, typically in the order of several tunnel diameters (i.e. tens of metres at most). Hence the risk of any adverse effects, such as subsidence, is considered to be low.



## 7.6.6 Environmental Performance Requirements

Table 7-12 provides the recommended Environmental Performance Requirements and proposed mitigation measures for the precinct. In addition to the precinct specific Environmental Performance Requirements below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a Groundwater Management Plan to assess and manage impacts associated with the detailed design also apply.

**Table 7-12 Environmental Performance Requirements for the tunnels area between CBD South and Domain stations**

| Asset / value   | Impact   | Environmental Performance Requirements  | Proposed mitigation measures   | Risk no. |
|---|--|---|--|----------|
| Large trees that may access groundwater   | Construction of Linlithgow shaft alternative design option: uncertain due to lack of knowledge of tree species and their water requirements for large trees outside the Project Boundary, but possible since trees are within drawdown extent.   | <p>Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details:</p> <ul style="list-style-type: none"> <li>Identifying and if necessary, specifying mitigation measures to protect groundwater dependent vegetation during periods of drawdown.</li> </ul> | Deep-rooted tree species in areas of shallow groundwater should be identified and their dependence on groundwater should be assessed. If found to be groundwater dependent, the trees within the area of drawdown should be irrigated throughout the period of drawdown. | GW017    |
|   | <p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"> <li>Reduction in access to groundwater for trees.</li> </ul> |   |  |          |
| CityLink recharge wells. Impacts may cause depressurisation and potential settlement in overlying Coode Island Silt | <p>Construction of Linlithgow shaft alternative design option: some drawdown predicted at CityLink recharge bores.</p> <p>Operation: none.</p>   | <p>Develop and implement a GMP detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details:</p> <ul style="list-style-type: none"> <li>Methods for minimising drawdown at any existing recharge bores, and establishing appropriate monitoring networks to confirm effectiveness of mitigation.</li> </ul>           | Mitigation measures would include grouting, and temporary recharge bores located in the Yarra River palaeovalley.  | GW045    |



| Asset / value | Impact | Environmental Performance Requirements   | Proposed mitigation measures | Risk no. |
|---------------|--------|--|------------------------------|----------|
|               |        | <p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"><li>• Change in groundwater levels in any existing recharge bores that may be present in the area around the project.</li></ul> |                              |          |



## 7.7 Tunnels: Domain Station to Eastern Portal

### 7.7.1 Existing Conditions

#### 7.7.1.1 Hydrostratigraphy

The expected geology across this part of the Tunnels Precinct is Melbourne Formation which is overlain in the west and east of the tunnels section by the Brighton Group. This area includes TBM driven tunnels (1,690 m total length), cross passages, TBM launch / retrieval shaft located in the north-west corner of Fawkner Park, and an emergency access shaft located in the north-east corner of Fawkner Park.

The Brighton Group has a low potential to generate acidity. Deep, fresh to slightly weathered Melbourne Formation siltstone, typically present at depths greater than 24m, has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered Melbourne Formation is typically non-acid forming and hence low risk.

Figure 7-10 shows the hydrogeological conditions along this part of the Tunnels precinct. More detail about the hydrogeological units expected to be encountered in the section of tunnels from Domain station to eastern portal is included in Appendix C of this report.

There are four groundwater monitoring bores in this section of the tunnels but only one has undergone hydraulic testing (GA11-BH023 in the Melbourne Formation). The hydraulic conductivity measured in this bore was  $2.2 \times 10^{-5}$  m/sec which is an order of magnitude higher than the average for the Melbourne Formation testing across the Study Area of  $2.7 \times 10^{-6}$  m/sec, and is the highest measured hydraulic conductivity in this formation during this project. This high hydraulic conductivity may be due to the bore's close proximity to a syncline fold which can be responsible for increased fracturing of the rock.

#### 7.7.1.1 Groundwater Levels

There are four groundwater monitoring bores in this part of the Tunnels precinct and groundwater levels have been monitored at least once in all bores. In addition, regular groundwater monitoring occurred in GA11-BH022 between August 2013 and September 2015, which showed a groundwater level variation of 0.52 m over the monitoring period. The groundwater levels monitored in the bores and the bore hydrographs are included in Appendix C of this report.

Groundwater flow in this part of the precinct appears to be towards the west and the western most bore records a groundwater elevation below 0 m AHD. The below 0 m AHD groundwater level in this bore is likely to be due to the presence of the South Yarra Main Sewer. This structure appears to be acting as a drain and lowering groundwater levels in the area. Under natural conditions the groundwater is still likely to flow west or south-west towards Port Phillip Bay - groundwater levels under natural conditions would be expected to be around 5 m AHD this far from the coastline. The South Yarra Main Sewer is a major groundwater drain in the area and as such, may be replaced in the future. If full replacement of the sewer were to occur, then groundwater levels in the east of this part of the precinct may rise by around 2 to 3 m.

The depth to groundwater in this part of the precinct ranges between approximately 6 m below ground level to 17 m below ground level. The shallowest groundwater levels occur in the west of this area.

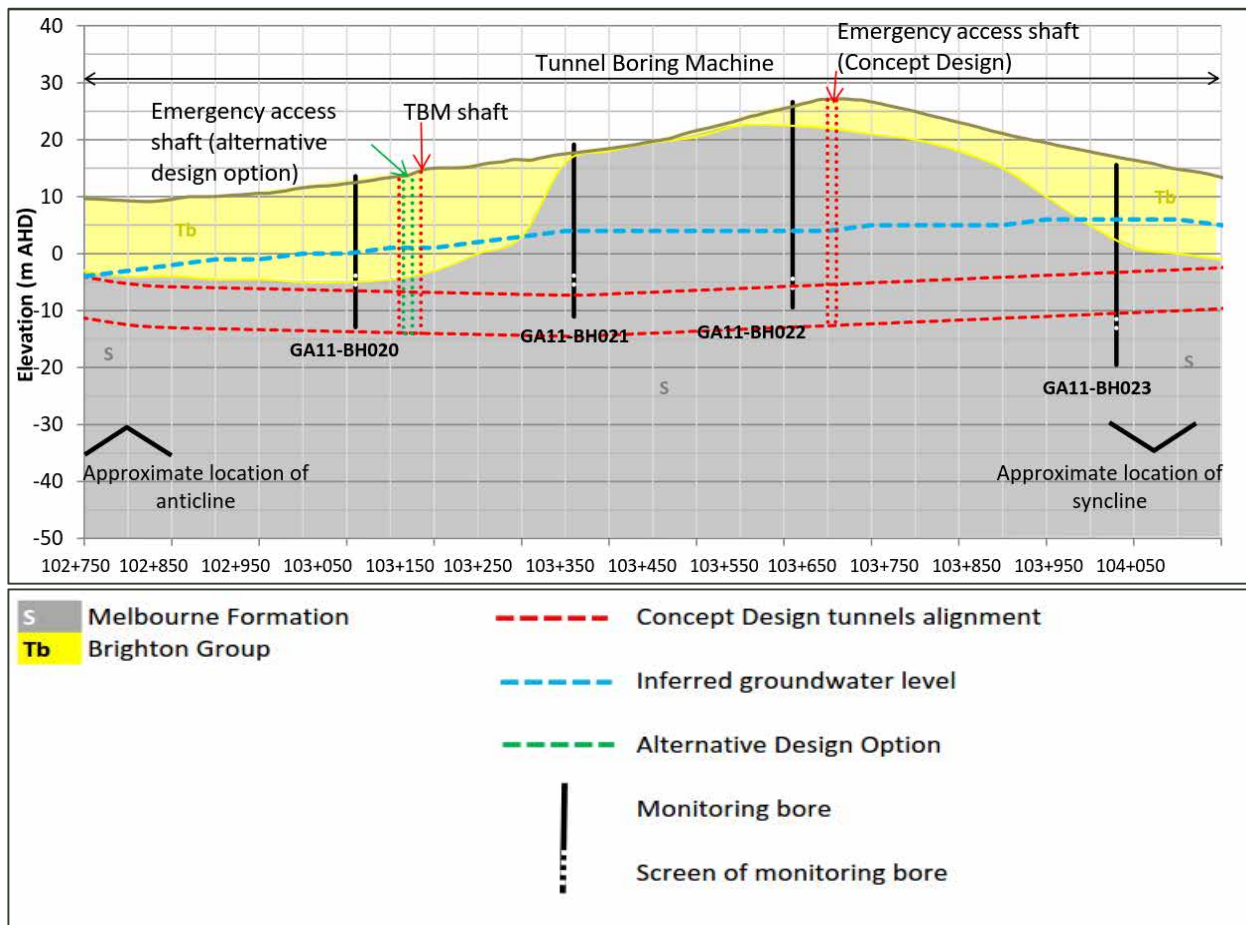


Figure 7-10: Conceptual site model for the tunnels area between Domain station and the eastern portal

### 7.7.1.2 Groundwater Quality

All four monitoring bores in this part of the precinct have been sampled and three of the four bores record salinity close to the alignment average for the Melbourne Formation (5,600 mg/L). The groundwater salinity in this area generally exceeds the range that would be expected from the regional watertable mapping which designates this area as 1,000 to 3,500 mg/L expected TDS. The exception to this is GA11-BH021 which records a comparatively low TDS. Groundwater of this salinity is within Segment B of the SEPP (GoV), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Irrigation
- Potable mineral water (no mineral water is expected in this area and this Beneficial Use is not considered further)
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water. Full groundwater quality analysis results are included in Appendix D of this report.



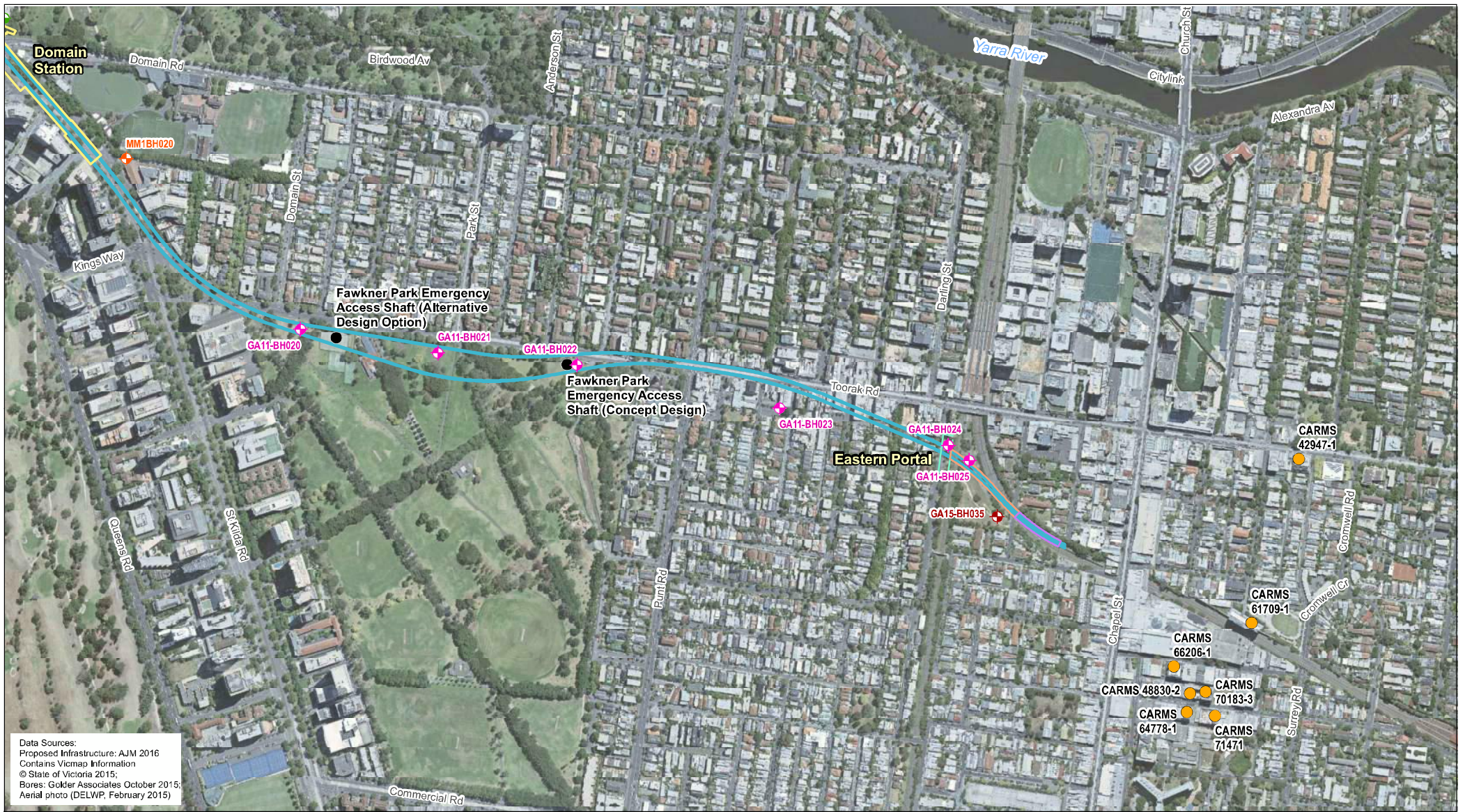
Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bores:

- GA11-BH022 (Melbourne Formation) – methyl ethyl ketone (0.15 mg/L)
- GA11-BH023 (Melbourne Formation) – TPH fractions C<sub>6</sub>-C<sub>9</sub> (0.02 mg/L), C<sub>10</sub>-C<sub>14</sub> (0.06 mg/L) and C<sub>15</sub>-C<sub>28</sub> (0.21 mg/L) as well as xylene isomers (0.01 mg/L in total).

The concentration of methyl ethyl ketone is below the USEPA drinking water standard (USEPA, 2014). Methyl ethyl ketone is a common industrial solvent and the detected concentrations may relate to surrounding industrial use areas. The concentrations of TPH and xylene detected are below relevant guideline values (refer to Appendix D of this report) and are therefore not considered to be of concern.

Melbourne Metro bores were designed to assess conditions at tunnel depth and do not specifically target groundwater contaminants. Therefore, while these analytes may be diffuse contamination resulting from the intensive land use in the area, they could also indicate contaminant plumes at other depths. Bores targeting the specific suspected contaminants may be required to confirm that no contaminant plume exists and therefore that groundwater beneath neighbouring properties is not at risk from potential migration of contaminants.

There are six GQRUZs within 1 km of the tunnels area between Domain station and the eastern portal (Figure 7-11). These are sites where groundwater contamination restricts certain uses of the groundwater, as shown in Table 7-13. Volatile contaminants are present in these GQRUZs. Drawdown associated with inflows at the eastern portal may change hydraulic gradients in the area, causing movement of these contaminants towards the eastern portal.



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

**Legend**

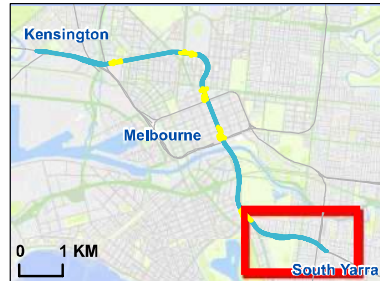
- Emergency Access Structure
- ◆ EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations
- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- ◆ Stage 2 Phase 2A
- ◆ Stage 2 Phase 2B
- ◆ Stage 2 Phase 2C
- ◆ Procurement Phase
- ◆ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 9 of 10



**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment - Domain to Eastern Portal Tunnel

Drawing Number: MMR-AJM-UGAA-MP-NK-500222 Revision: P1

Drawn By: A. Davy Approved By: F. Dean Date: 8/04/2016 Map Size: A4

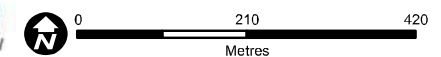


Figure 7-11 GQRUZ within 1 km of the tunnels area between Domain station and the eastern portal





**Table 7-13 Contaminants and restricted uses for GQRUZ within 1 km of the tunnels area between Domain Station and the eastern portal**

| Reference   | Main groundwater contaminants  | Restricted / excluded uses of groundwater  |
|---|--|--|
| CARMS 42947-1 & 2. Golder Associates Pty Ltd, 2002. Environmental Audit report (53X) - 332-336 Toorak Road, South Yarra.    | PAHs, TCE, PCE, Nickel, Zinc.  | Drinking water<br>Livestock water supply<br>Irrigation<br>Recreational (e.g. contact)<br>Industrial                              |
| CARMS 66206-1. Peter J Ramsay and Associates, 2011. Environmental Audit report - 20-24 Garden Street, South Yarra.          | Heavy metals, petroleum hydrocarbons and nitrate.  | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Industrial water use<br>Primary contact recreation   |
| CARMS 48830-2. Coffey Geosciences Pty Ltd, 2004. Statutory Environmental Audit report - 19 – 23 Wilson Street, South Yarra. | LNAPL, petroleum hydrocarbons (predominantly C6-C9 fraction).  | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Primary contact recreation                           |
| CARMS 70183-2. Environmental Auditors Pty Ltd, 2013. Environmental Audit report - 25-29 Wilson Street, South Yarra.         | Zinc, Benzene, petroleum hydrocarbons (predominantly C6-C10 fraction).                               | Potable water supply<br>Stock watering<br>Agriculture, parks and gardens   |
| CARMS 64778-1. Peter J Ramsay and Associates, 2010. Environmental Audit report - 26 – 28 Wilson Street, South Yarra.        | Benzene, Toulene, Xylene, Copper, Nickel, Zinc, 1,1-dichloroethene.                                  | Potable water supply<br>Stock watering<br>Agriculture, parks and gardens<br>Industrial water use.<br>Primary contact recreation. |
| CARMS 71471-1. Golder Associates, 2014. Statutory Environmental Audit: 42 Wilson Street, South Yarra.                       | 1,1,2-trichloroethane, trichloroethene<br>1,1-dichloroethene, cis-1,2-dichloroethene vinyl chloride. | Potable water supply.<br>Stock watering,<br>Agriculture, parks and gardens<br>Industrial water use<br>Primary contact recreation |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.



### 7.7.1.3 Groundwater Use

The nearest stock and domestic bores to this part of the tunnels precinct are:

- WRK990820, which is located approximately 375 m north of the tunnels
- Bore 89269, located approximately 400 m to the north.

Neither of the bores could be located during the site inspection undertaken for Melbourne Metro in July 2015. Outcomes of the site inspections are summarised in Appendix D of this report. In discussions with Southern Rural Water it was agreed that they are not used and probably no longer exist. They can therefore be excluded from further consideration in this impact assessment.

There is one other bore registered as domestic use to the north of the tunnels (350 m) from this part of the precinct but this is listed as having been decommissioned and would not be considered further.

### 7.7.1.4 Groundwater-Surface Water Interaction

The nearest surface water bodies to this part of the Tunnels precinct are Albert Park Lake (500 m west) and the pond at the Royal Botanic Gardens (750 m north). Under natural conditions, it is expected that groundwater would flow towards Albert Park Lake. However, the presence of the South Yarra Main Sewer along the northern edge of the lake is likely to be diverting some flow to the north of the lake. Any interaction between the lake and groundwater at the northern end (near Domain station) is likely to be from the lake to the groundwater. From this part of the precinct, there may still be some groundwater flow towards the eastern edge of the lake.

The lake in the Royal Botanic Gardens is located approximately 900 m north of this section of the alignment and may have some interaction with groundwater. Previous experience on similar projects suggests that water levels in the lake in the Royal Botanic Gardens were lowered when groundwater levels were lowered during CityLink construction. As such, the lake is considered to be at least partially reliant on groundwater contributions to maintain inundation.

### 7.7.1.5 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. Large trees within the Royal Botanic Gardens were not assessed in the arboriculture report as they are outside the project boundary. These trees may have some dependence on groundwater, particularly closer to the Yarra River and the lake in the Royal Botanic Gardens where groundwater levels are shallow. There is no information on the type of these trees and their water requirements, and therefore the groundwater dependence of these trees cannot be assessed. Where deep-rooted tree species exist, there is a greater potential for groundwater use, and hence, a greater sensitivity to impacts from drawdown. These trees should be identified and irrigated through the period of drawdown if necessary.

Other trees in the gardens and parklands are further away from surface water features in areas where groundwater is deeper. These trees are expected to preferentially use other sources of water such as soil moisture and surface runoff and are not considered to be at risk from drawdown of groundwater associated with the tunnels.

### 7.7.1.6 Alternative Design Option

A potential alternative design option in this area is for the emergency access shaft to be located in the north-west corner of Fawkner Park (at the TBM launch/retrieval shaft site). The shaft would encounter Brighton Group sediments and Melbourne Formation Siltstone.

Groundwater levels at this location are 14 m below the surface (1 m AHD). The lower 8 m of the shaft would be below the watertable and may therefore receive groundwater inflows, with associated drawdown of the watertable. The existing conditions for groundwater quality, groundwater use, groundwater-surface water



interaction, and groundwater dependent vegetation for this alternative design option are the same as for the Concept Design (Section 7.7.1).

### 7.7.2 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 7-14. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 7-14 Potential issues associated with the Concept Design for the tunnels area between Domain station and the eastern portal**

| Concept Design   | Issue   | Risk #   |
|--|---|--|
| <b>Tunnels and shafts between Domain station and eastern portal (Concept Design and alternative design option)</b> | <p>The tunnels are below the watertable, therefore the potential exists for inflows to the tunnels and associated drawdown during construction and operation. During construction they would be tanked immediately, which would prevent inflows and drawdown in the construction phase. Shafts would be drained during construction, which would allow groundwater inflows.</p> <p>For operation, the tunnels would be tanked to Haack 3 classification. Minor inflows would occur over the longer term which may result in drawdown. Potential operational impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>• The lake in the Royal Botanic Gardens and potentially Albert Park Lake</li> <li>• Migration of existing contaminants to third party properties. There are six GQRUZs in the area, and anthropogenic contamination has been detected which may be indicative of larger contaminant plumes. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> <li>• Large trees that may be using groundwater, particularly where the watertable is shallow near the Yarra River and around the lake in the Royal Botanic Gardens</li> <li>• Oxidation of potentially acid forming Melbourne Formation.</li> </ul> <p>There are no active groundwater users within 1 km of this section of tunnels. It is expected that groundwater is not contributing to the Yarra River and therefore drawdown impacts are considered unlikely and are not assessed.</p> | <p>GW011</p> <p>GW023, GW027</p> <p>GW015, GW018</p> <p>GW034, GW036</p> |

### 7.7.3 Impact Assessment

Potential impacts of Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where a medium, high or very high impact has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

#### 7.7.3.1 Concept Design

##### 7.7.3.1.1 Construction

The tunnels constructed using the TBM would be tanked almost immediately after they have been excavated. This is expected to prevent inflows and associated drawdown during construction. No analysis of



drawdown has therefore been undertaken for the tunnels between the Domain station to the eastern portal during the construction phase.

There are two shafts located within this section of the tunnels:

- A TBM launch shaft is located in the north-west corner of Fawkner Park
- An emergency access shaft is located in the north-east corner of Fawkner Park.

It is assumed these shafts would be drained during construction where they are below the watertable. Inflow volumes and associated drawdown of groundwater levels were estimated using an analytical approach that is described in Appendix F of this report.

Groundwater levels at the TBM launch shaft are approximately 1 m AHD and the base of the shaft is at -14 m AHD. Therefore, approximately 15 m of groundwater drawdown would be required to keep the excavation dry during shaft construction.

Groundwater levels at the emergency access shaft in the north east of Fawkner Park are approximately 4 m AHD, which means approximately 17 m of groundwater drawdown would be necessary to keep the excavation dry for construction.

#### *Groundwater Drawdown Estimates*

During construction, if no mitigation measures are applied, 14 m drawdown would be required at the shaft, which is predicted to result in a drawdown cone that extends several hundred metres from the shaft at the end of construction. Results of the analytical modelling are shown in Appendix F.

For the emergency access shaft in the north east of Fawkner Park, a drawdown cone that extends several hundred metres from the shaft is predicted in the unmitigated case. Groundwater dependent values within this area of drawdown may be impacted by reduced groundwater availability.

#### *Potential Impacts*

Mitigation measures such as grouting during construction of the shafts and/or the installation of temporary injection bores would be implemented to counteract drawdown and maintain groundwater levels close to current levels in this precinct. Unmitigated drawdown at the TBM launch shaft and the emergency access shaft would lead to potential environmental, economic and social receptors of changes in groundwater levels, flow or quality such as:

- Third parties with properties close to possible contaminant plumes. Although GQRUZs would not be affected by the predicted levels of drawdown, there may be other contaminant plumes given the historical industrial landuse (**Risk #GW027**)
- Groundwater acidification due to potentially acid forming Melbourne Formation (**Risk #GW034**).

There are no active groundwater users within 1 km of the tunnels and the area of impact does not intersect Albert Park Lake or the lake in the Royal Botanic Gardens. Therefore, impacts are unlikely for these values and are not considered further. Likewise, it is expected that groundwater is not contributing to the Yarra River and drawdown impacts are considered unlikely and are not assessed.

Groundwater is expected to be up to 14 m deep at the TBM launch shaft and 23 m deep at the intervention shaft, which is deeper than the range that is accessible to most large trees. Several large trees exist in the area of drawdown around the shafts, but they are likely to rely on sources of water that are closer to the surface. As such, drawdown is unlikely to impact vegetation health.

#### *Contaminant Migration to Third Party Properties*

Several areas of groundwater contamination have been identified. There are no GQRUZs within the predicted area of drawdown, but there are likely to be other areas with contaminated groundwater given the industrial land uses in the past. If contamination migrates to previously uncontaminated areas, beneficial uses of groundwater at third party properties may be precluded.



Beneficial uses that need to be protected are:

- Irrigation
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Drinking water is not a protected beneficial use because of the salinity of the groundwater in this area. Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct.

Because there is uncertainty around the presence of contaminated groundwater within the predicted area of impact, there is conservatively considered to be a moderate risk of contaminant and associated vapour migration impacting beneficial uses of groundwater at neighbouring properties. Mitigation and monitoring such as grouting of the shaft may be implemented to reduce this risk to low. The predicted level of drawdown would be significantly reduced provided mitigation strategies are implemented.

#### *Potential Acidification of Groundwater Due to PASS*

The shafts are mainly excavated through highly weathered to moderately weathered Melbourne Formation, and are dominantly above the 24m suggested in Golders (2016a) as an indicator of lower PASS risk for the Melbourne Formation. Hence the risk of PASS oxidising and causing groundwater acidification is considered low.

#### **7.7.3.1.2 Operation**

It is assumed that the tunnels would be tanked to Haack 3 tightness, which results in inflows of 0.0046 L/sec per 100 m of two tunnels, based on an internal tunnel diameter of 6.3m at the location of the tunnel liner and Haack 3 daily inflow criterion of 0.1L/m<sup>2</sup> over 100 m length of tunnel. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H).

#### *Potential Impacts*

The estimated groundwater drawdown as a result of the minor inflows to the tunnels is predicted to be less than 0.2 m immediately above the tunnels at steady state. This minimal drawdown means that no impacts on groundwater dependent values are anticipated along the tunnels section between the Domain station and the eastern portal, no impacts on groundwater dependent values are anticipated. Any change in construction technique or detailed design that may cause greater inflows should be assessed for potential drawdown impacts:

- The lake in the Royal Botanic Gardens and Albert Park Lake (**Risk #GW011**)
- Migration of existing contaminants to third party properties. There are six GQRUZs in the area, and anthropogenic contamination has been detected which may be indicative of larger contaminant plumes (**Risk #GW023**)
- Large trees that may be using shallow groundwater near the river and around the lake in the Royal Botanic Gardens (**Risk #GW015**).

#### **7.7.3.2 Alternative Design Option**

A potential alternative design option in this area is for the emergency access shaft to be located in the north-west corner of Fawkner Park (at the TBM launch/retrieval shaft site). The predicted impacts for this alternative design option are the same as the TBM launch/retrieval shaft, as discussed in Section 7.7.3.1.1.



## 7.7.4 Environmental Performance Requirements

Table 7-15 provides the recommended Environmental Performance Requirements and proposed mitigation measures for the precinct. In addition to the precinct specific Environmental Performance Requirement below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a groundwater management plan to assess and manage impacts associated with the detailed design also apply.

**Table 7-15 Environmental Performance Requirements for the tunnels area between Domain Station and the eastern portal**

| Asset / value   | Impact  | Environmental Performance Requirements   | Proposed mitigation measures   | Risk no. |
|---|---|--|--|----------|
| <b>Beneficial uses of groundwater at third party properties</b> | Tunnel construction: no impact.<br><br>Shaft construction: Moderate risk of impact on third party properties based on landuse and expected presence of contaminants within predicted area of impact. Beneficial uses that need to be protected are: <ul style="list-style-type: none"> <li>• Irrigation</li> <li>• Stock watering</li> <li>• Industrial water use</li> <li>• Primary contact recreation</li> <li>• Buildings and structures.</li> </ul> Operation: no impact. | Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details: <ul style="list-style-type: none"> <li>• An approach identified in consultation with the EPA so that contaminant migration causes no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> | Likely to involve further investigation and/or mitigation measures, for example: <ul style="list-style-type: none"> <li>• Site specific risk assessment of contaminant location and concentrations.</li> <li>• Use of injection or discharge bores to prevent contaminant migration.</li> <li>• Minimisation of drawdown through construction techniques such as grouting or ground freezing.</li> </ul> | GW027    |
|   |   | Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential: <ul style="list-style-type: none"> <li>• Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures.</li> </ul>   |  |          |



## 8 Precinct 2: Western Portal (Kensington)

### 8.1 Project Components

The western portal precinct is located from approximately 200 m west of the corner of Kensington Road and Hobsons Road to approximately 100 m east of the corner of Tennyson Street and Childers Street. This section describes the components and construction activities that could result in the impacts to existing conditions in this precinct, based on the Concept Design and the assumptions stated in Section 4.7 of this report. Where predicted impacts have moderate, major or severe consequences for groundwater dependent values, mitigation measures would be applied during construction and operation to reduce the risk associated with these impacts.

#### 8.1.1 Infrastructure

The decline structure for the Concept Design begins at CH94+930 and continues to CH95+140. From CH95+140 the cut and cover tunnels begins and continues to the TBM retrieval box which is located between CH95+310 and CH95+350. The TBM box is likely to be approximately 40 m long by 18 to 23 m wide and up to 16 m below the existing ground level. Cross passage 1 is located within the TBM retrieval box.

#### 8.1.2 Construction

During construction of the decline structure, it is expected that open cut/embankment methods would be used. Once the decline structure is more than 6 m deep, a cut and cover tunnel would be constructed to the TBM retrieval shaft. Earth retaining structures may be used where geological conditions or space constraints dictate. These are likely to be in the form of a secant pile wall with toe grouting extending 5 m beneath the wall to limit groundwater inflows through the base of the excavation. Where underground components of the western portal are below the watertable, it is assumed that these components would be tanked during construction. This means that groundwater inflows through the excavation walls are largely prevented, although some inflows can still occur through the base of the excavation.

#### 8.1.3 Operation

During operation, it is planned that all underground structures in this precinct would be tanked to a tightness classification of Haack 3.

#### 8.1.4 Alternative Design Option

In the alternative design option the TBM retrieval shaft is approximately 200m further west than for the Concept Design, so that the TBM retrieval shaft and cross passage 1 are located at Ormond Road. The decline structure begins approximately 100 m further west than for the Concept Design, meaning that the decline structure is shorter in the alternative design option and the gradient is therefore steeper.

A similar construction approach to that described above for the Concept Design is expected. Similarly, this alternative design would have the same operational water tightness classification as the Concept Design (Haack 3).



## 8.2 Existing Conditions

### 8.2.1 Hydrostratigraphy

Figure 8-1 shows the hydrogeological units that the western portal construction works are expected to encounter. More detail about the hydrogeological units expected to be encountered in this precinct is included in Appendix C of this report.

The western portal excavations would be predominantly excavated through the Older Volcanics. The Portal excavations are east of the Maribyrnong palaeovalley, which contains Moray Street Gravels, Fishermans Bend Silt, Pleistocene Alluvium and Coode Island Silt. Apart from the Coode Island Silt, the units within the palaeovalley would not be intersected by the portal. Connection between aquifers within the palaeovalley to aquifers intersecting the alignment (i.e. the Older Volcanics) is not anticipated.

The Coode Island Silt in this area contains sandy layers within the clays, which allow drawdown to propagate through the unit, resulting in a higher potential rate of settlement. The hydraulic conductivity can therefore be expected to be variable within the unit, depending on whether sandy or clayey layers are intersected. The Coode Island Silt has moderate to high potential to generate acidity (Golder 2016a, Appendix G) and therefore if drawdown occurs in this unit, there is a risk of potential acidification of groundwater.

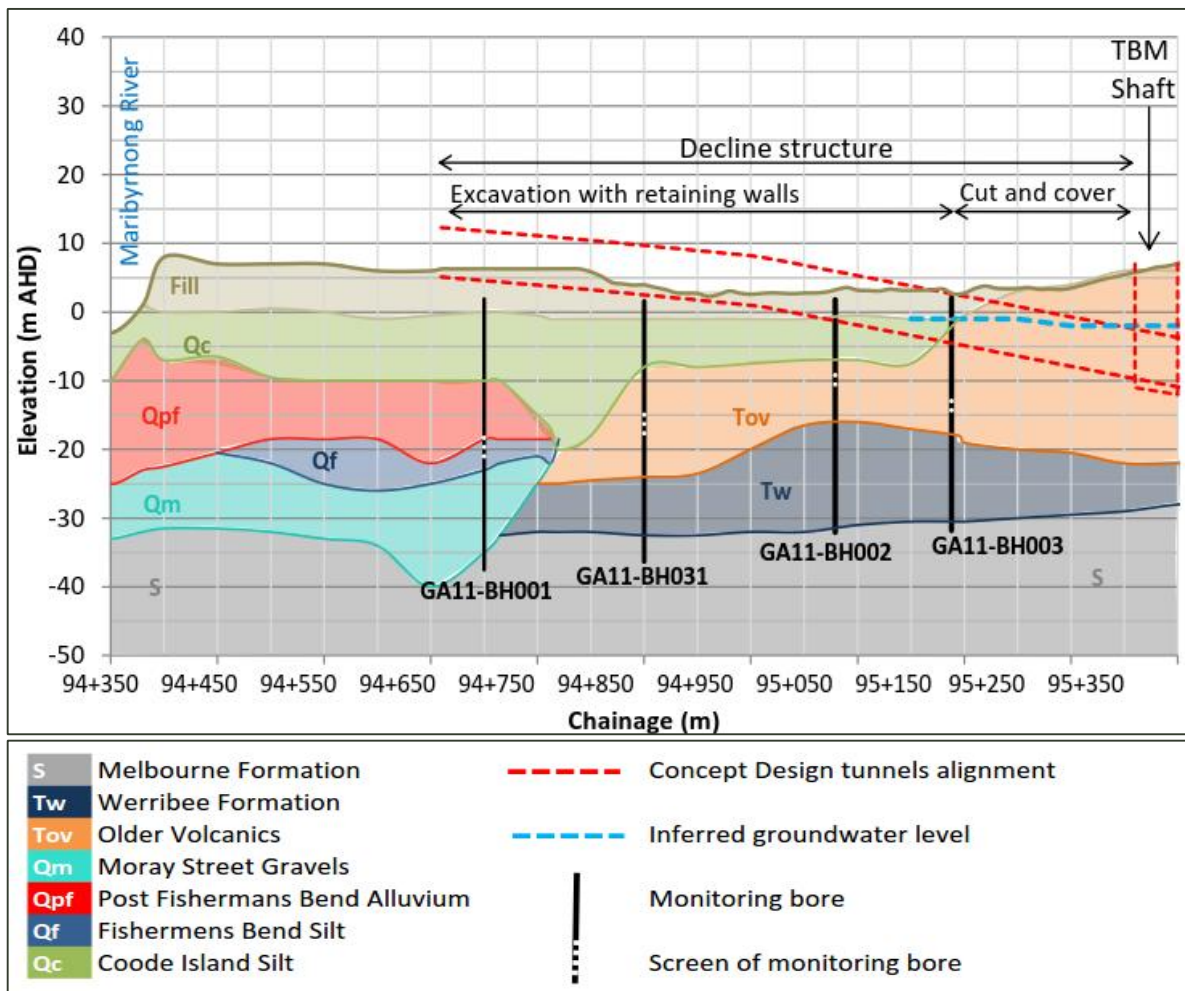


Figure 8-1: Conceptual site model for the western portal

### 8.2.2 Groundwater Levels

There are five groundwater monitoring bores in the western portal precinct and groundwater levels have been measured at least once in each bore (Appendix C of this report). In addition, a groundwater level logger





was installed in GA11-BH007 (Werribee Formation bore) located 350 m east of the eastern edge of the western portal between August 2013 and May 2014. The logger showed a groundwater variation of 0.35 m over the monitoring period. The seasonal variation (measured in GA11-BH007) is similar to the wider Study Area (as discussed in Section 5.2).

Groundwater levels in this precinct are below 0 m AHD and below the levels of the Moonee Ponds Creek 750 m to the east (and potentially the Maribyrnong River to the west). Under natural conditions, groundwater levels in this area would be expected to be at or slightly above sea level (given the low lying ground elevations) and the watercourses would act as groundwater discharge features. The reasons for the lower groundwater levels is likely to be the North Yarra Main Sewer, which crosses the alignment to the east of this precinct at around CH95+730 and runs parallel 400 m south of the alignment (west of CH95+730). The lowest groundwater levels in this precinct are at the eastern end of the alignment.

The North Yarra Main Sewer is 3.2 m in diameter and the base of the tunnels is around -9 m AHD at the point it crosses the alignment. The sewer is more than 100 years old and constructed of concrete and brick in parts. Therefore, the structural integrity of the sewer is almost certainly highly compromised and in this area it appears to be acting as a drain. The sewer is known from previous project experience to be a major groundwater drainage feature in this area of Melbourne (SKM, 2010 and SKM, 2013). Given that the sewer is pulling groundwater levels below the base of the Moonee Ponds Creek (-1.5 m AHD measured 150 m to the west of the creek and 45 m east of the creek), it is possible that some river losses to the sewer are occurring.

The nearest groundwater level data to the Maribyrnong River is 350 m from the watercourse at -0.43 m AHD. A study just south of the Melbourne Metro study area (SKM, 2010) shows that groundwater levels at the Maribyrnong River were above 0 m AHD and therefore some groundwater contribution to the watercourse to the south of Melbourne Metro is possible. However, where the North Yarra Main Sewer crosses the Maribyrnong River (300 m south of the western portal), the groundwater levels are as low as -1.5 m AHD. The SKM (2010) study suggests that, given the extent of below 0 m AHD groundwater levels on both banks of the watercourse, the river is relatively well sealed and not significantly leaky. Alternatively, the leakage rate to the sewer is very high compared to the leakage rate from the watercourse. This theory can also be applied to the Moonee Ponds Creek. In summary, these watercourses have limited connection to the watertable, and are more likely to be losing water into the aquifer, than be replenished by groundwater contributions.

The volume of groundwater leaking into the North Yarra Main Sewer across northern Melbourne is likely to be having an impact on salt loads at the Western Treatment Plant. Therefore, in the future it is likely that this sewer would be replaced. If this occurs, groundwater levels in the area are likely to rise to above 0 m AHD.

The depth to groundwater in the western portal precinct ranges between approximately 3 m below ground level to 9 m below ground level. The shallowest groundwater levels are near to the start of the dive structure.

### 8.2.3 Groundwater Quality

All five monitoring bores in this precinct have been sampled and the results show a wide range of TDS concentrations. The TDS concentrations in the Older Volcanics are between approximately 2,000 and 8,000 mg/L, which is significantly lower than for the Moray Street Gravels (in bore GA11-BH001). TDS results for Moray Street Gravels in other areas of the alignment are similarly high, and show consistent daily fluctuations in groundwater levels, suggesting a possible marine influence. However, the portal excavations would not intersect Moray Street Gravels.

Apart from the Moray Street Gravels, the groundwater in this precinct is mostly below or within the range that would be expected from the regional watertable mapping which designates this area as 7,000 to 13,000 mg/L TDS. Groundwater of this salinity is mostly within Segment C of the SEPP Gov (EPA Victoria 1997), which means the following beneficial uses must be protected:



- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health.
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation. Full groundwater quality analysis results are included in Appendix D of this report.

High ammonia was detected in the Moray Street Gravels. Normally ammonia indicates leaking sewers, or infiltrated fertilisers, however this concentration is in a confined aquifer, which is not expected to be impacted from near surface activities. In this case, the high ammonia result is unexplained.

Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bores:

- GA11-BH002 (Older Volcanics) – TPH fraction C<sub>15</sub>-C<sub>28</sub> (0.33 mg/L) and C<sub>29</sub>-C<sub>36</sub> (0.08 mg/L)

The concentrations of TPH fractions detected are below relevant guideline values (see Appendix E of this report) and are therefore not considered to be of concern. The low level of these contaminants also means that migration of volatiles is not a concern. There are no sites within 1km of the western portal that have been identified as GQRUZs. As such, it is assumed that the Segment C beneficial uses of groundwater listed above apply within this area.

This is a generally industrial area and widespread low-level contamination of soil and groundwater is expected. However, Melbourne Metro bores were designed to assess conditions at tunnel depth and do not specifically target groundwater contaminants. Therefore, while these hydrocarbon concentrations may be diffuse contamination resulting from the intensive land use in the area, they could also indicate contaminant plumes at depths above the tunnels.

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

#### 8.2.4 Groundwater Use

Three stock and domestic groundwater bores are registered within 1 km of the western portal. The three bores are located 750 m to the south (WRK979557, WRK979561 and WRK979562), range in depth from 66 m to 79 m and are screened within the Melbourne Formation.

Two of the three bores were found at the Melbourne Market during a site inspection undertaken for Melbourne Metro in July 2015. Outcomes of the site inspections are summarised in Appendix D.7 of this report. The two bores found have not been utilised for water supply due to high salinity. It is not clear which bores numbers apply to the two bores that were found. The third bore is likely to not exist or has been destroyed. Discussions with Southern Rural Water confirmed that the two bores found at the market need to be considered in the impact assessment because of the potential for future use of the groundwater.

There is one other bore (WRK988686) registered as domestic use to the north-east of the western portal precinct (750 m) but this is listed as having been decommissioned and would not be considered further.

There are also nine bores registered as active licenced irrigation bores located at Flemington Racecourse (two are registered as dual use irrigation and/or disposal) 1.7 km north-west of the start of the western portal dive structure. These bores are outside the Golder model boundary. The bores are between 26 and 36 m deep and appear to be screened in sands and gravels below silts and clays and above basalt. The surface



geology at Flemington Racecourse is Coode Island Silt and it is likely that these bores are screened in the Moray Street Gravels or the Post Fishermans Bend Alluvium, neither of which are likely to be intersected by the portals or tunnels in the Maribyrnong River valley. Since the tunnels and the Flemington racecourse bores occur within different aquifers, hydraulic connection between the two locations is likely to be limited. This reduces the likelihood of impacts on the bores from groundwater drawdown around the tunnels, however impacts are assessed in Section 8.4.

### 8.2.5 Groundwater- Surface Water Interaction

The Maribyrnong River is located approximately 50 m from the western boundary of the precinct and approximately 750 m from the decline structure. As discussed above, it is likely that water levels in this area are being artificially lowered by the North Yarra Main Sewer, such that in the area of the western portal groundwater levels are below the level of the river (SKM 2010). At the Maribyrnong River near the alignment, it is likely that groundwater levels are above 0 m (SKM 2010). The varying groundwater levels relative to the river indicate that flow directions may vary from flow from the river to the groundwater (south of the alignment) and flow from the groundwater to the river (nearer the western portal).

However, fine grained sediments and the presence of Coode Island Silts around the Maribyrnong River are likely to prevent significant interaction between the river and the groundwater. Although there is no pumping test data to confirm this conclusion, connectivity is considered to be low. The Maribyrnong River is conceptualised as not being groundwater dependent.

### 8.2.6 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. There are some large trees in the vicinity of the portal (outside the project boundary) that were not assessed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*), for example in JJ Holland Park and on Dynon Road. There is no specific information on the type of trees and their water requirements, however groundwater dependence is expected to be low, as groundwater in the area is saline and other water sources such as soil moisture, surface runoff and leaking drains would constitute a preferable water source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

## 8.3 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 8-1. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 8-1 Key issues associated with the Concept Design at the western portal**

| Concept Design  | Issue   | Risk #                                 |
|---|---|--|
| <b>Western portal: decline structure, cut and cover tunnel, TBM retrieval box</b> | Groundwater levels in the area could be up to approximately 0 m AHD, which would mean groundwater would have to be lowered by approximately 10 m to keep the excavation dry during construction.  |  |
|   | Potential impacts of drawdown in this area include: <ul style="list-style-type: none"> <li>Reduced available drawdown in two stock and domestic bores (WRK979557, WRK979561/WRK979562)</li> <li>Migration of existing contaminants to third party properties. There are no GQRUZs in the area, but anthropogenic contamination has been detected which may be indicative of larger contaminant plumes, given the intensive development in the area. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to</li> </ul> | GW002,<br>GW007<br><br>GW023,<br>GW028 |



| Concept Design   | Issue   | Risk # |
|--|---|--------|
|  | <p>underground structures.</p> <ul style="list-style-type: none"> <li>Potential acid generation from exposure of Coode Island Silt.</li> </ul> <p>It is assumed that the Maribyrnong River is not strongly connected to groundwater, and therefore drawdown impacts are considered unlikely and are not assessed.</p> <p>Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not considered further.</p> | GW034  |
| <p><b>Western portal alternative design option: decline structure, cut and cover tunnel, TBM retrieval box</b></p> | <p>All the above risks that apply to the Western Portal Concept Design also apply to the alternative design option.</p>   |        |

## 8.4 Impact Assessment

Potential impacts of Melbourne Metro construction and operation on the values associated with groundwater have been evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 of this report. In cases where an impact with moderate, major or severe consequences has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

### 8.4.1 Construction

Groundwater inflows and associated drawdown would be largely prevented during construction of the western portal due to the use of a secant piles retaining wall with toe grouting. It is expected that all infrastructure at the western portal would be tanked during construction, including the decline structure, the cut and cover tunnels, and the TBM retrieval shaft. However, some groundwater inflow may still occur through the base of the structure. Groundwater drawdown as a result of these inflows is assessed in this section.

Groundwater levels are approximately 0 m AHD at the western portal, and the base of the TBM shaft is at approximately -10 m AHD. Therefore, approximately 10 m of groundwater drawdown would be required to keep the excavation dry during construction. Inflow volumes and associated drawdown of groundwater levels were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H), which is included as Appendix H of this report.

#### 8.4.1.1 Groundwater Drawdown Estimate

In addition to the design features included in the Concept Design, it is likely that mitigation measures such as grouting of the excavation and the installation of temporary injection bores would be used by the contractor to counteract predicted drawdown at the western portal to manage the impacts of drawdown in this precinct.

If no mitigation measures were implemented, at the end of construction the drawdown cone around the western portal is predicted to propagate out from the cut and cover structure in a circular shape for several hundred metres. Groundwater dependent values within this area of drawdown may be impacted by reduced groundwater availability as a result of deeper groundwater levels.

#### 8.4.1.2 Potential Impacts

There are no active groundwater users within the predicted area of drawdown around the western portal. The predicted extent of the drawdown cone does not reach the groundwater bores used for irrigation at

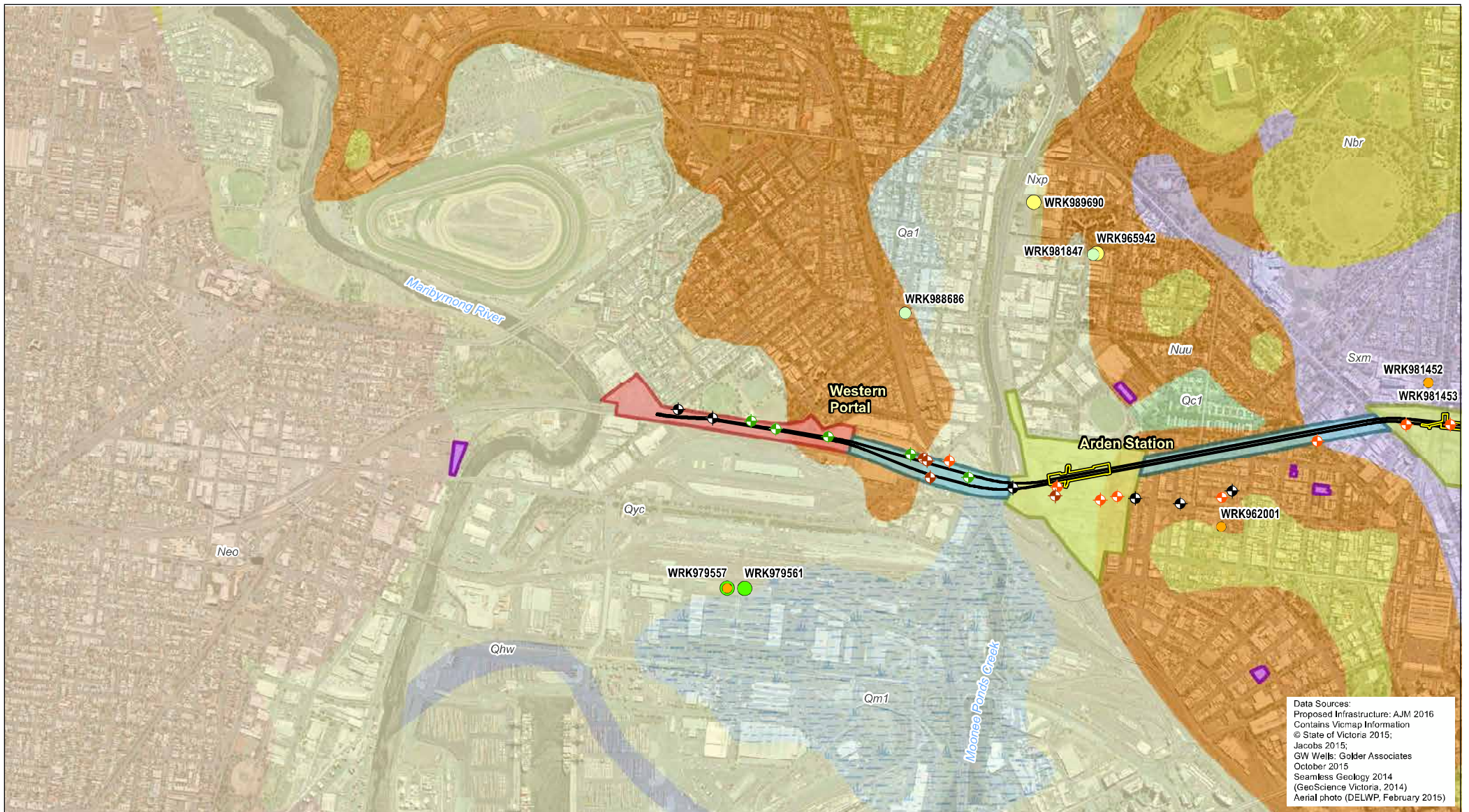


Flemington Racecourse, which are approximately 1.7 km to the north-west. Therefore, no impacts are expected on existing groundwater users. Similarly, the surface water bodies and vegetation within the area of drawdown are not expected to be dependent on groundwater, so impacts are not considered further.

If unmitigated, drawdown is predicted to occur within several hundred metres of the western portal. The impacts predicted are for a scenario in which no measures to mitigate inflows are considered. This conservative impact scenario has been used to develop Environmental Performance Requirements and recommend mitigation measures. The mitigation measures and their anticipated effectiveness is discussed in Section 8.4.1.3.

Groundwater dependent assets within the area of drawdown would be susceptible to impacts. Potential environmental, economic and social receptors of changes in groundwater levels, flow or quality include (Figure 8-2):

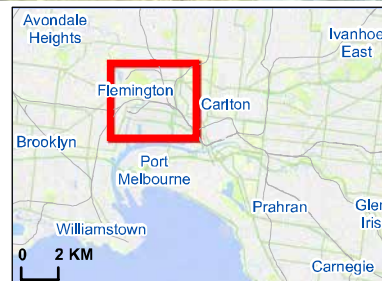
- Third parties with properties close to possible contaminant plumes. There are no GQRUZ in the predicted area of drawdown. However the industrial landuse of the area suggests that contaminant plumes may be present which may migrate if drawdown occurs. However, with appropriate mitigation measures (e.g. injection bores) it is considered that drawdown around the station would be minor, and groundwater dependent values in the area would not be impacted (**Risk #GW028**)
- Groundwater acidification due to potentially acid forming sediments (**Risk #GW034**).



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Jacobs 2015;  
 GW Wells: Goldier Associates  
 October 2015  
 Seamless Geology 2014  
 (GeoScience Victoria, 2014)  
 Aerial photo (DELWP, February 2015)

**Legend**

- Proposed Alignment
- Proposed Station Footprint
- GQRUZ Audit Sites
- Groundwater Monitoring Wells
  - Stage 1
  - Stage 2 Phase 2A
  - Stage 2 Phase 2B
  - Stage 2 Phase 2C
  - RD (to 30 Sept 2015)
- Geology 1:50,000
  - Brighton Group (Nbr)
  - Newer Volcanics (Neo)
  - Older Volcanics (Nuu)
  - Nxp
  - Alluvium (Qa1)
  - Colluvium (Qc1)
  - Waste Deposits (Qhw)
  - Swamp and Lake Deposits (Qm1)
  - Coode Island Silt (Qyc)
  - Melbourne Formation (Sxm): generic
- Station Precinct
  - Portal Precinct
  - Tunnel Precinct
- Existing stock and domestic bore locations
  - Could not be found
  - Decommissioned
  - Bore not visited
  - Bore located



**Melbourne Metro Rail Project**

|  |                         |                  |              |
|--|-------------------------|------------------|--------------|
| Title: EES Groundwater Precinct - Western Portal |                         |                  |              |
| Drawing Number: MMR-AJM-UGAA-MP-NK-500428        |                         | Revision: P1     |              |
| Drawn By: A. Berman                              | Approved By: K. Dowsley | Date: 26/04/2016 | Map Size: A4 |
|  |                         |                  |              |

Figure 8-2 Groundwater dependent assets and risks at the western portal



#### 8.4.1.2.1 Potential Acidification Due to PASS

Construction methods for the western portal and TBM shaft would minimise groundwater drawdown and the risk of PASS. Specifically, predicted drawdown is limited to the Older Volcanics and not expected to reach the Coode Island Silt, hence risk of PASS is low.

#### 8.4.1.2.2 Contaminant Migration to Third Party Properties

No areas of contaminated groundwater have been identified in the vicinity of the western portal, however since this is an industrial area, there may be undetected contamination in the groundwater. If contaminant plumes do exist in this area, the predicted drawdown could cause migration to third party properties, and threaten beneficial uses of the groundwater at those properties. Beneficial uses that need to be protected are:

- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Drinking water and irrigation are not protected beneficial uses because of the high salinity of the groundwater in this area. Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct.

Due to the uncertainty about whether such contamination exists, there is considered to be a moderate risk of migration of contaminants and associated vapour migration in the area of drawdown. Mitigation and monitoring would be implemented to reduce this risk to low.

#### 8.4.1.3 Mitigation Measures

In order to limit inflows and minimise groundwater drawdown, mitigation measures have been identified. A series of temporary groundwater injection wells may be installed, for example in the locations shown conceptually on Figure 8-3. These wells may be used to inject water to maintain groundwater levels in the Older Volcanics aquifer. The primary reason for establishing an injection borefield at the western portal would be to prevent drawdown leading to ground subsidence. However, the measures also reduce the risk of PASS activation and migration of groundwater contaminants.

The detailed design phase of the project would confirm the construction and operational requirements for these bores, including the number and location of bores, injection rates and schedules, and injection water source. Additional modelling would be undertaken during detailed design to confirm the optimal borefield configuration and operational requirements so that drawdown beneath the Coode Island Silt (the approximate horizontal extent of which is shown as 'CIS outlines' in Figure 8-3) is minimised to prevent damage from subsidence. Based on experience on other tunnelling and deep excavation projects, there is a high degree of confidence that injection bores would be fully effective. Monitoring during construction of the western portal would also be established to ensure the injection bores are effective at maintaining groundwater levels.

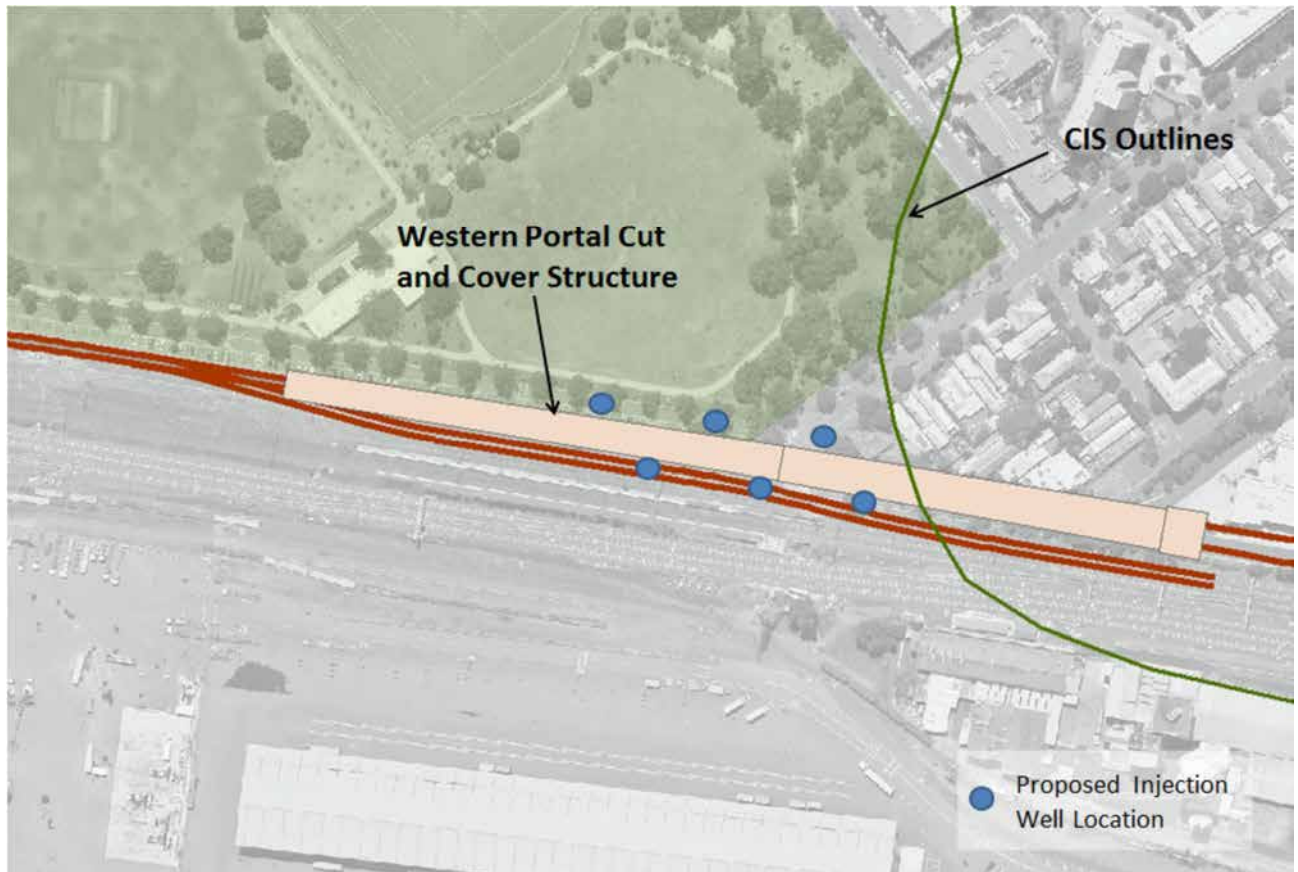
### 8.4.2 Operation

The western portal would be tanked for operation and therefore long term inflows are expected to be minor. The inflow rate is determined by the construction of the tanking and the aim for all underground structures for this project is Haack Tightness Class 3, which limits inflow to 0.1 L/m<sup>2</sup> per day per 100 m length. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H).



#### 8.4.2.1 Groundwater Drawdown Estimate

The estimated groundwater drawdown as a result of the minor inflows to the western portal would be minimal. At steady state, drawdown immediately above the tunnels is predicted to be less than 0.2 m.



**Figure 8-3 Conceptual location of temporary groundwater injection wells (through the Coode Island Silt [CIS] area)**

#### 8.4.2.2 Potential Impacts

Since minimal drawdown is expected at the western portal, no impacts on groundwater dependent values are anticipated. If there is any change in construction technique or detailed design that may cause greater inflows, potential drawdown impacts should be assessed for:

- Two unused stock and domestic groundwater bores 750 m to the south in the Melbourne Market grounds (WRK979557, WRK979561/WRK979562) (**Risk #GW002**)
- Third parties with properties close to possible contaminant plumes (**Risk #GW023**)
- Groundwater acidification due to potentially acid forming sediments (**Risk #GW034**).

No groundwater dependent surface water bodies or vegetation is expected to exist in this precinct.

#### 8.4.3 Alternative Design Option

Similar impacts to the concept design are expected for the alternative design option. The movement of the TBM retrieval box approximately 200 m to the west means that the TBM retrieval box would still be constructed in the Tertiary Older Volcanics, but would be closer to the edge of the Maribyrnong River palaeovalley sediments. Most of the decline structure would be excavated through Coode Island Silt, which





could mean that drawdown in the unmitigated case is slightly higher than for the Concept Design, particularly if there is interaction between the Coode Island Silt and the underlying Holocene Alluvium.

The unmitigated Concept Design case predicted drawdown propagating several hundred meters around the excavations. In the unmitigated alternative design option, these impacts would be similar, albeit slightly larger. The same impacts on groundwater dependent values apply as described above for the Concept Design.

The justification for temporary injection bores is slightly greater for the alternative design option. No detailed design of the injection bores has been undertaken at the EES stage. However the alternative design option may require more bores or a greater injection rate. There is a high confidence that injection bores would be able to negate any possible adverse impacts. The injection bores would be located further west than those shown for the Concept Design.

Operational impacts are expected to be as for the Concept Design as described in Section 8.4.2. The approximate 200 m westward movement for the alternative design is not expected to have any significant difference on possible impacts on the Maribyrnong River.



## 8.5 Environmental Performance Requirements

Table 8-2 provides the recommended Environmental Performance Requirements and proposed mitigation measures for the precinct. In addition to the precinct specific Environmental Performance Requirement below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a Groundwater Management Plan to assess and manage impacts associated with the detailed design also apply.

Table 8-2 Environmental Performance Requirements for the western portal

| Asset / value   | Impact   | Environmental Performance Requirements   | Proposed mitigation measures   | Risk no. |
|---|--|--|--|----------|
| <b>Beneficial uses of groundwater at third party properties</b> | Construction: Moderate risk of impact on third party properties based on landuse and expected presence of contaminants within predicted area of impact. Beneficial uses that need to be protected are: <ul style="list-style-type: none"> <li>• Stock watering</li> <li>• Industrial water use</li> <li>• Primary contact recreation</li> <li>• Buildings and structures</li> </ul> Operation: none. | Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details: <ul style="list-style-type: none"> <li>• An approach identified in consultation with the EPA so that contaminant migration causes no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> | Likely to involve further investigation and/or mitigation measures, for example: <ul style="list-style-type: none"> <li>• Site specific risk assessment of contaminant location and concentrations</li> <li>• Use of injection or discharge bores to prevent contaminant migration</li> <li>• Minimisation of drawdown through construction techniques such as grouting of the structure.</li> </ul> | GW028    |
|   |  | Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential: <ul style="list-style-type: none"> <li>• Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures.</li> </ul>   |  |          |



## 9 Precinct 3: Arden Station

### 9.1 Project Components

The Arden Station Precinct is located from the eastern edge of the Upfield Line to Munster Terrace. The precinct extends to Arden Street in the north and Dynon Road in the south. This section describes the components and construction activities that could result in hydrogeologically related impacts to existing conditions in this precinct, based on the Concept Design and the assumptions stated in Section 4.7 of this report. Where the risk of impact is predicted to be medium, high or very high, mitigation measures would be applied during construction and operation to reduce the risk of impacts to low.

#### 9.1.1 Infrastructure

The station box is located from CH96+310 and is 245 m long, approximately 25 m wide and 15 m deep orientated south west to north east. The area of excavation is approximately 6,250 m<sup>2</sup>.

#### 9.1.2 Construction

The proposed construction technique for this station is bottom up cut and cover, where the station box is fully excavated and built up from the base slab. Due to the sensitive geological conditions at this location diaphragm walls would be used as the retaining structures for this station, with toe grouting beneath the diaphragm wall. Diaphragm walls are constructed in panels using specialised equipment to cut a narrow trench to the appropriate depth. This trench would be kept open using bentonite slurry whilst a reinforcement cage is installed and concrete is pumped into the trench. This method is likely to result in very little groundwater inflow, which would be largely restricted to the floor of the excavation prior to installation of the concrete base slab.

Other infrastructure in the precinct that is relevant for groundwater processes and impacts is the North Yarra Main Sewer and a 1200 mm brick stormwater drain. There is no known relocation or upgrade work currently planned for these two pieces of infrastructure.

The tunnels in this precinct would be constructed using a TBM.

#### 9.1.3 Operation

During operation it is assumed that all underground structures in this precinct would be tanked to a tightness classification of Haack 2.

## 9.2 Existing Conditions

### 9.2.1 Hydrostratigraphy

The Arden station precinct is within the sediments of the Moonee Ponds Creek palaeovalley. Figure 9-1 shows the hydrogeological units that the Arden station precinct construction works would be expected to encounter.

The hydraulic conductivity values measured for the Coode Island Silt for this project are significantly higher than Golder's previous experience, and higher than what would generally be expected for a clayey aquitard. Bore GA15-BH005 is screened in a more sandy layer of the unit, as reflected by the high hydraulic conductivity results. The Coode Island Silt contains sandy layers within the clays, which allow drawdown to propagate through the unit, resulting in a greater potential area that may be affected by settlement and subsidence. The hydraulic conductivity can therefore be expected to be variable within the unit, depending on whether sandy or clayey layers are intersected. The vertical hydraulic conductivity is very low in the



Coode Island Silt with values of  $1 \times 10^{-9}$  to  $1 \times 10^{-8}$  m/sec expected.

The Coode Island Silt has moderate to high potential to generate acidity (Golder 2016a, Appendix G).

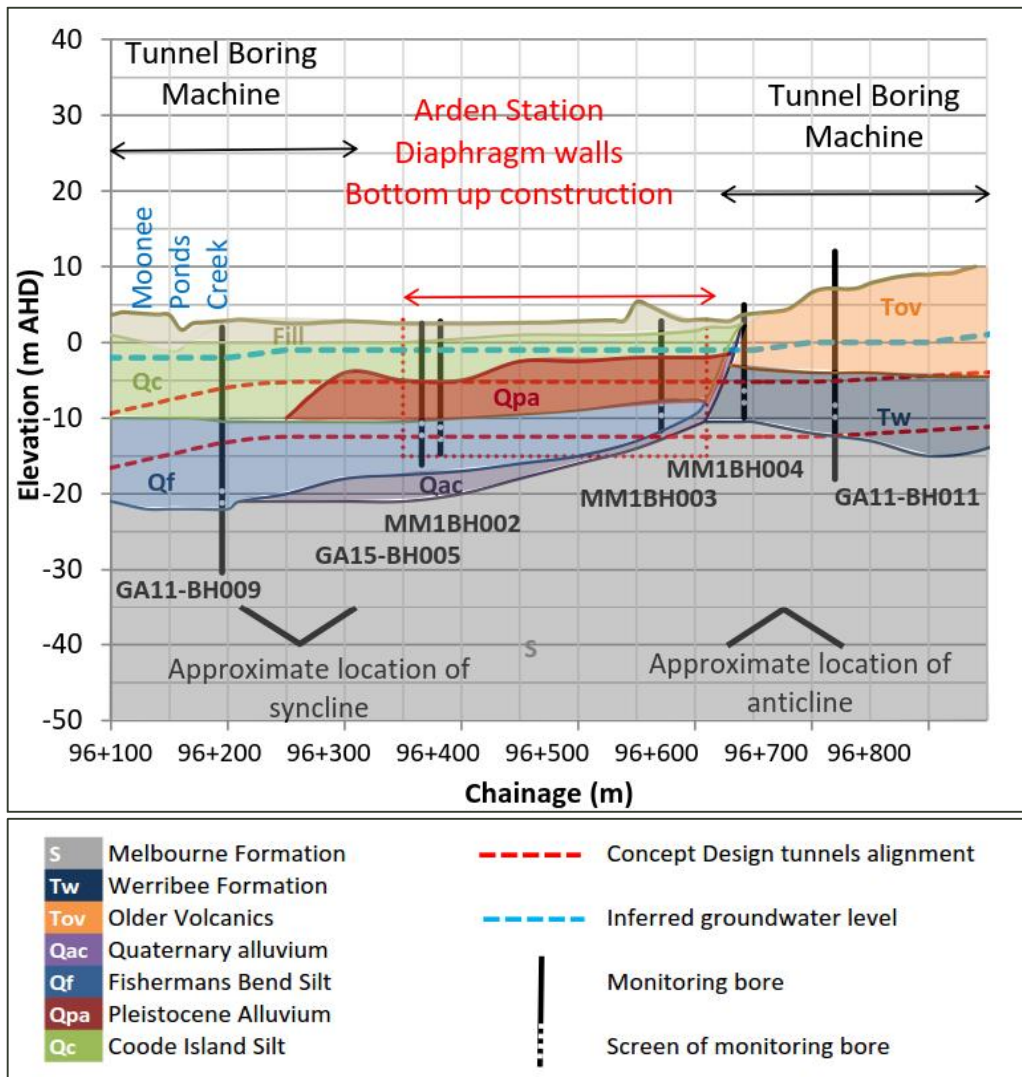


Figure 9-1: Conceptual site model for the Arden station precinct

### 9.2.2 Groundwater Levels

There are five groundwater monitoring bores in this precinct. The groundwater levels monitored in the bores and the bore hydrographs are included in Appendix C of this report. In addition to this manual monitoring, groundwater level loggers were installed in GA11-BH009 (Fishermans Bend Silt bore) and GA11-BH011 (Melbourne Formation bore) between August 2013 and May 2014. Note that Melbourne Metro bores were designed to assess conditions at tunnel depth and have not been designed to (necessarily) measure the watertable, but the watertable and the potentiometric surfaces of most aquifers in the area are likely to be similar because there is some connection between the aquifers overlying the tunnels. This would allow vertical interaction between aquifers that would result in similar groundwater levels at equilibrium.

The annual seasonal variations (as shown in the loggers) are as expected when compared to the wider study area. The year to year variations are relatively small but again, within what would be expected across the study area. The groundwater level variations generally correlate to rainfall patterns. Longer term variations may be up to 3 – 5 m (as discussed in Section 5.2).

Groundwater levels in this precinct are below 0 m AHD (between -0.78 m AHD and -1.75 m AHD) and below the levels of the Moonee Ponds Creek. Under natural conditions groundwater levels in this area would be



expected to be at or above sea level and the watercourses would be likely to act as groundwater discharge features. The reasons for the lower groundwater levels is likely to be the North Yarra Main Sewer, which runs parallel to the alignment approximately 250 m to the north. This feature is described in Section 8.2.2 (Western Portal Groundwater levels). Groundwater flow in this precinct would naturally be towards the west and south-west but there may be a northerly component to groundwater flow towards the sewer.

As a major drain of groundwater, the sewer may be replaced in the future. If this happens, groundwater levels in the area are likely to rise to above 0 m AHD. In this area groundwater levels may rise to 2 to 3 m AHD with further rise likely to be constrained by the ground elevation.

The depth to groundwater in this precinct ranges between approximately 4 m below ground level to 8 m below ground level. The shallowest groundwater levels are near the Moonee Ponds Creek and in the low lying area to the east of the creek.

### 9.2.3 Groundwater Quality

Four of the five monitoring bores in this precinct have been sampled and the results show a reasonably wide variation in TDS concentrations of between 3,000 and 25,000 mg/L. The highest TDS in vicinity of the station was measured from GA15-BH005, which monitors the Coode Island Silt. The Fishermans Bend Silt is confined beneath the more saline Coode Island Silt in this area and has moderate TDS concentrations. The deeper units (Werribee Formation and Melbourne Formation) have the lowest TDS concentrations in this area.

The groundwater in this precinct is typically within or below the range that would be expected from the regional watertable mapping which designates this area (7,000 to 13,000 mg/L TDS) with the exception of the Coode Island Silt (higher than range). Groundwater of this salinity is within Segment C of the SEPP Gov (EPA Victoria 1997), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation. Full groundwater quality analysis results are included in Appendix D of this report.

Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bore:

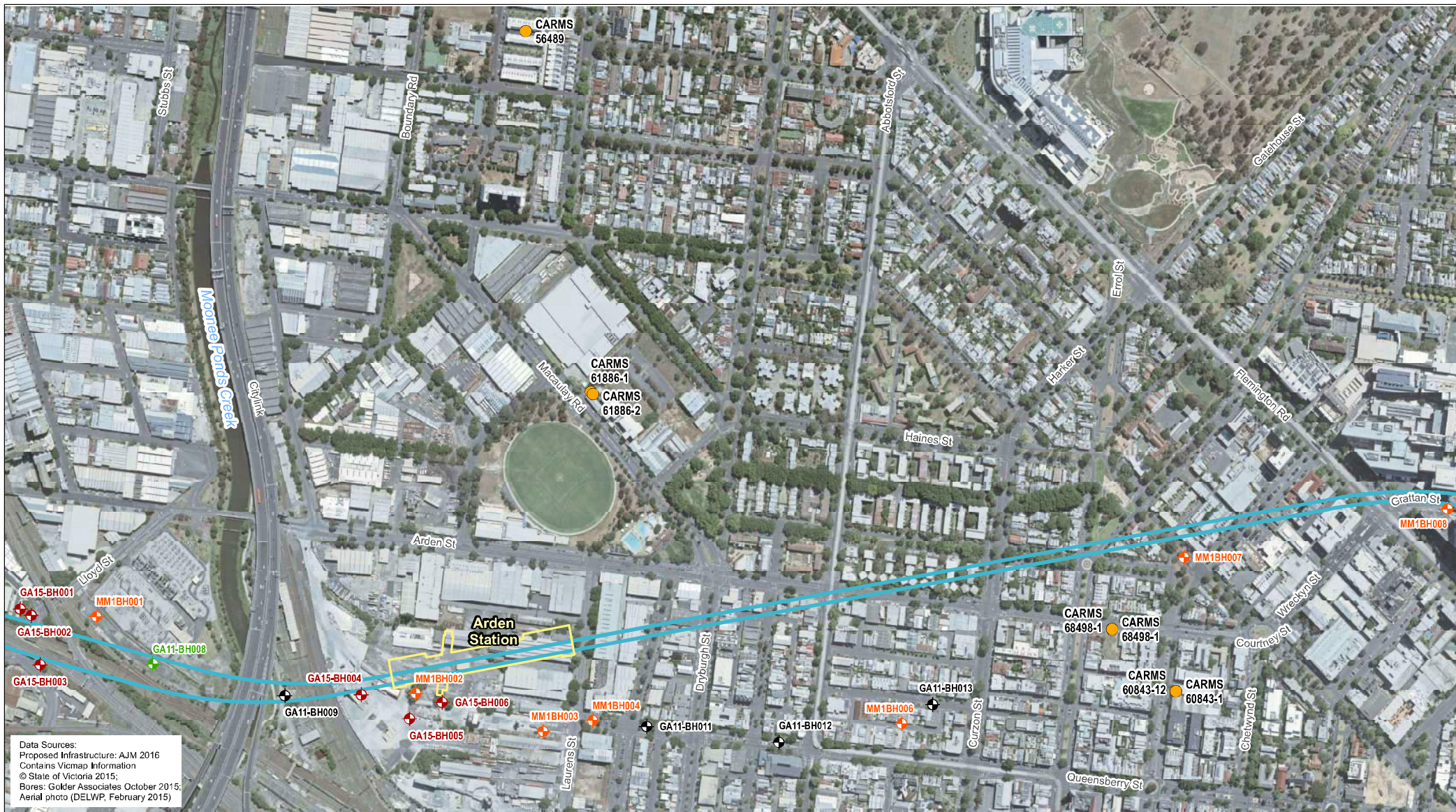
- MM1BH002 (Fishermans Bend Silt) – TPH fractions C<sub>10</sub>-C<sub>14</sub> (0.10 mg/L) and C<sub>15</sub>-C<sub>28</sub> (0.5 mg/L) as well as xylene (0.0003 mg/L).

The concentrations of TPH fractions and xylene detected are below relevant guideline values (see Appendix E of this report) and are therefore not considered to be of concern. This is a generally industrial area and widespread low-level contamination of soil and groundwater is expected. However, Melbourne Metro bores were designed to assess conditions at depth and do not specifically target groundwater contaminants. Therefore, while these hydrocarbon concentrations may be diffuse contamination resulting from the intensive land use in the area, they could also indicate contaminant plumes at depths above the station.

Four GQRUZ are located within a 1km radius of the Arden station (Figure 9-2). These are sites where groundwater contamination restricts certain uses of the groundwater, as shown in Table 9-1. Volatile



contaminants are present in these GQRUZ. Drawdown associated with inflows at the station may change hydraulic gradients in the area, causing movement of these contaminants towards the station.



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

**Legend**

**EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations**

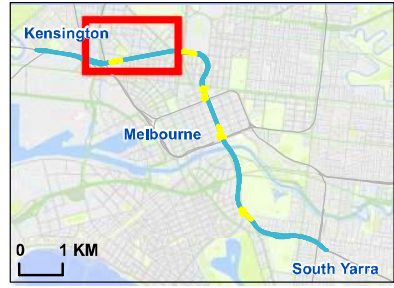
- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- ◆ Stage 2 Phase 2A
- ◆ Stage 2 Phase 2B
- ◆ Stage 2 Phase 2C
- ◆ Procurement Phase
- ◆ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 2 of 10



**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment - Arden Station

Drawing Number: MMR-AJM-UGAA-MP-NK-500222 Revision: P1

|                      |                         |                    |                 |
|----------------------|-------------------------|--------------------|-----------------|
| Drawn By:<br>A. Davy | Approved By:<br>F. Dean | Date:<br>8/04/2016 | Map Size:<br>A4 |
|----------------------|-------------------------|--------------------|-----------------|

0 170 340 Metres

Figure 9-2 GQRUZ within 1 km of the Arden station precinct



**Table 9-1 Contaminants and restricted uses for GQRUZ within 1 km of the Arden station precinct**

| Reference   | Main groundwater contaminants   | Restricted / excluded uses of groundwater  |
|---|---|--|
| CARMS 61886-1. Cardno Lane Piper, 2012. Environmental Audit report and Statement of Environmental Audit - 60-96 Macaulay Road, North Melbourne. | Heavy metals, TPH, naphthalene, fluoride, ammonia, cyanide, benzene, xylene, ethyl benzene, toluene, styrene, bis(2-ethylhexyl) phthalate and benzo(a)pyrene. | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Industrial water use<br>Primary contact recreation |
| CARMS 68498-1. Coffey Environments, 2013. Environmental Audit report – 33-35 Arden Street, North Melbourne.                                     | NAPL.   | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Industrial water use<br>Primary contact recreation |
| CARMS 60843-12: Chadwick T&T Pty Ltd, 2009. Environmental Audit report (53X) - 90-96 Leveson & 15-25 Byron Street, North Melbourne.             | Antimony, boron, Cadmium, Chromium VI, Copper, Manganese, Mercury, Selenium, Tin, Zinc, Cis-1, 2 DCE, Nitrate, Sulfate.                                       | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Primary contact recreation                         |
| CARMS 56489-1. Sinclair Knight Merz, 2009. Environmental Audit report: 52-76 Buncle Street, North Melbourne.                                    | TPH, BTEX, naphthalene, some metals/metalloids and nitrate.   | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Primary contact recreation                         |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

#### 9.2.4 Groundwater Use

Bore WRK962001 is registered for stock and domestic use and is located less than 100 m from the eastern section of the alignment in this precinct. This bore could not be located during the site inspection undertaken for Melbourne Metro in July 2015 and it is expected that this bore no longer exists. Outcomes of the site inspections are summarised in Appendix D.7 of this report. In discussions with Southern Rural Water, it was agreed that this bore is not used and can be excluded from further consideration in the EES.

#### 9.2.5 Groundwater-Surface Water Interaction

The Moonee Ponds Creek forms part of the western boundary of the Arden station precinct. As discussed above, it is likely that water levels in this area are being artificially lowered by the North Yarra Main Sewer. Water levels are currently below 0 m AHD and below the level of the Moonee Ponds Creek.

Currently, any flow between the groundwater and surface water is to the groundwater from the creek and it is possible that there are some creek losses to the sewer. However, given that the water levels around the Moonee Ponds Creek and south along the Maribyrnong River are below 0 m AHD, it would appear that the flux from the watercourse to the groundwater is less than the flux of groundwater to the sewer.





Water levels measured for a previous project (SKM, 2013) suggest that less than 1 km upstream on the Moonee Ponds Creek the groundwater levels are higher than the creek and are likely to be contributing to creek flows.

### 9.2.6 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. There are some large trees in the vicinity of the precinct (outside the Project Boundary) that were not assessed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*), for example in Arden Street Oval, Gardiners Reserve, Plane Tree Way, Green Street, Shiel Street and further north, in Royal Park. Many of these trees appear to be plane trees and elms, which are not expected to be groundwater dependent since they have shallow (<1.5 m) root systems. There is no specific information on the other tree species outside the Project Boundary and their water requirements, however groundwater dependence is expected to be low, as groundwater in the area is saline and other water sources such as soil moisture, surface runoff and leaking drains would constitute a preferable water source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

## 9.3 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 9-2. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 9-2 Key issues associated with the Concept Design for the Arden station precinct**

| Concept Design              | Issue  | Risk #   |
|-----------------------------|--|--|
| <p><b>Arden station</b></p> | <p>Inflows may occur through the base of the station box during construction (prior to laying of the concrete slab). This could result in groundwater drawdown, which may affect nearby groundwater users, surface water bodies, and vegetation. For operation the station would be tanked to Haack 2 classification. Minor inflows would occur over the longer term, which may result in drawdown.</p> <p>Potential impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>• Migration of existing contaminants to third party properties. There are four GQRUZS in the area, and anthropogenic contamination has been detected in sampling, indicative of low-level diffuse contamination. This is typical in an area with a long history of industrial use, and possibly related to contaminant plumes. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> <li>• Potential acid generation from exposure of Coode Island Silt</li> <li>• Aquifer damming caused by tunnels restricting groundwater flow in the Holocene Alluvium.</li> </ul> <p>It is assumed that the Moonee Ponds Creek is not strongly connected to groundwater, and therefore drawdown impacts are considered unlikely and are not assessed. Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not considered further. There are no active groundwater bores within 1 km of Arden station.</p> | <p>GW023,<br/>GW028</p> <p>GW036,<br/>GW039</p> <p>GW048</p> |



## 9.4 Impact Assessment

Potential impacts of Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where a medium, high or very high risk of impact has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

### 9.4.1 Construction

It is assumed that the station box would be partially tanked during construction using diaphragm walls installed through the Tertiary and Quaternary sediments, and into the siltstone basement. The diaphragm walls would prevent groundwater inflows into the station box through the retaining walls during construction, however, the base of the station box would not be tanked during construction. Therefore, some inflow to the station box from the Melbourne Formation through the base of the excavation is likely. Inflow volumes and associated drawdown of groundwater levels were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H), which is included as Appendix H of this report.

#### 9.4.1.1 Groundwater Drawdown Estimate

Measures such as grouting of the excavation and the installation of temporary injection bores would be implemented to counteract drawdown and maintain groundwater levels close to current levels in the Arden station precinct.

The drawdown cone for an unmitigated scenario at Arden station (after construction) is predicted to propagate out from the excavation for several hundred metres. The shape of the drawdown cone is likely to be irregular, as it is controlled by the variable geology around the station. Drawdown extends furthest towards the south-west and is restricted towards the east where it encounters the Melbourne Formation siltstone. Groundwater dependent values within this area of drawdown may be impacted by reduced groundwater availability as a result of deeper groundwater levels.

#### 9.4.1.2 Potential Impacts

Without mitigation measures, drawdown is predicted to occur within several hundred metres of Arden station. Groundwater dependent assets within the area of drawdown would be susceptible to impacts. There are no active groundwater users within the predicted area of drawdown around this station precinct. Moonee Ponds Creek is not expected to be strongly connected to groundwater and is unlikely to be impacted if drawdown occurred at Arden station precinct. Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not considered further.

Potential environmental, economic and social receptors of changes in groundwater levels, flow or quality include (Figure 9-3):

- Third parties with properties close to possible contaminant plumes. There are no GQRUZs in the predicted area of drawdown although the industrial landuse of the area suggests that contaminant plumes may be present which may migrate if drawdown occurs (**Risk #GW028**)
- Groundwater acidification due to potentially acid forming sediments (**Risk #GW039**).

##### 9.4.1.2.1 Potential Acidification Due to PASS

The station is excavated through Coode Island Silt sediments and hence there is a PASS risk. Station construction methods and mitigation measures (diaphragm wall, grouting and injection bores) would limit drawdown. This would mean the risk of any significant quantities of geological material being activated for PASS is also low.



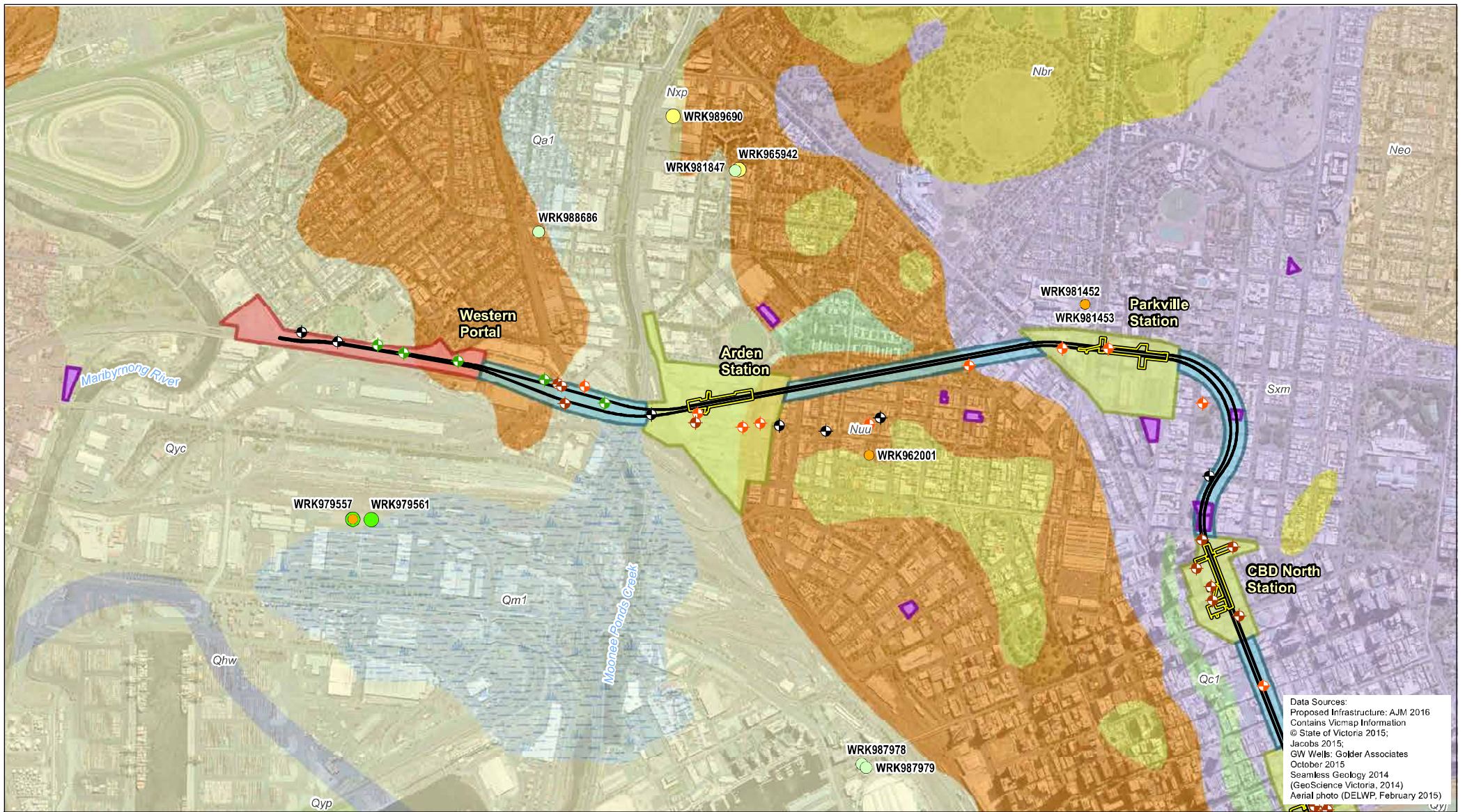
#### 9.4.1.2.2 Contaminant Migration to Third Party Properties

No areas of contaminated groundwater have been identified in the vicinity of Arden station, however since this is an industrial area, there may be undetected contamination in the groundwater. If contaminant plumes do exist in this area, the predicted drawdown could cause migration to third party properties, and threaten beneficial uses of the groundwater at those properties. Beneficial uses that need to be protected are:

- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Drinking water and irrigation are not protected beneficial uses because of the high salinity of the groundwater in this area. Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct.

Due to the uncertainty about whether such contamination exists, there is considered to be a moderate risk of migration of contaminants and associated vapour migration in the area of drawdown. However, mitigation measures (described in Section 9.4.1.3) would reduce drawdown and therefore reduce this risk to low. Monitoring would be implemented to confirm the effectiveness of the mitigation measures during construction.



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Jacobs 2015;  
 GW Wells: Golder Associates  
 October 2015  
 Seamless Geology 2014  
 (GeoScience Victoria, 2014)  
 Aerial photo (DELWP, February 2015)

|  |  |   |  |  |  |  |  |   |  |   |
|--|--|---|--|--|--|--|--|---|--|---|
| <b>Legend</b><br>Proposed Alignment<br>Proposed Station Footprint<br>GQRUZ Audit Sites<br><b>Groundwater Monitoring Wells</b><br>Stage 1<br>Stage 2 Phase 2A<br>Stage 2 Phase 2B<br>Stage 2 Phase 2C<br>RD (to 30 Sept 2015) |  | <b>Geology 1:50,000</b><br>Brighton Group (Nbr)<br>Newer Volcanics (Neo)<br>Older Volcanics (Nuu)<br>Nxp<br>Alluvium (Qa1)<br>Colluvium (Qc1) |  | Waste Deposits (Qhw)<br>Swamp and Lake Deposits (Qm1)<br>Cooze Island Silt (Qyc)<br>Jolimont Clay (Qyj)<br>Port Melbourne Sand (Qyp)<br>Melbourne Formation (Sxm): generic |  | <b>Station Precinct</b><br>Portal Precinct<br>Tunnel Precinct<br><b>Existing stock and domestic bore locations</b><br>Could not be found<br>Decommissioned<br>Bore not visited<br>Bore located |  | Avondale Heights<br>Brooklyn<br>Williamstown<br>Flemington<br>Port Melbourne<br>Carlton<br>Ivanhoe East<br>Prahran<br>Glen Iris<br>Carnegie | <br><b>MELBOURNE METRO RAIL AUTHORITY</b><br><br><b>Aurecon JACOBS</b><br><br><b>AJM</b><br>Joint Venture GRIMSHAW | <b>Melbourne Metro Rail Project</b><br>Title: EES Groundwater Precinct - Arden Station<br>Drawing Number: MMR-AJM-UGAA-MP-NK-500428<br>Revision: P1<br>Drawn By: A. Berman<br>Approved By: K. Dowsley<br>Date: 26/04/2016<br>Map Size: A4 |
|--|--|---|--|--|--|--|--|---|--|---|

Figure 9-3 Groundwater dependent assets and risks at Arden station



### 9.4.1.3 Mitigation Measures

In order to limit inflows and minimise groundwater drawdown, mitigation measures are planned. For example a series of temporary groundwater injection wells could be installed, in the locations shown conceptually on Figure 9-4. These wells would be used to inject water to maintain groundwater levels in the Early Pelistocene aquifer. The primary reason for establishing an injection borefield at Arden station would be to prevent drawdown leading to ground subsidence. However, the measures would also reduce the risk of PASS activation and migration of groundwater contaminants.

The detailed design phase of the project would confirm the construction and operational requirements for these bores, including the number and location of bores, injection rates and schedules, and injection water source. Additional modelling would be undertaken during detailed design to confirm the optimal borefield configuration and operational requirements so that drawdown beneath the Coode Island Silt (the approximate horizontal extent of which is shown as 'CIS outline' in Figure 9-4) is minimised to prevent damage from subsidence. Based on experience on other tunnelling and deep excavation projects, there is a high degree of confidence that injection bores would be fully effective. Monitoring during construction of Arden station would also be established to ensure the injection bores are effective at maintaining groundwater levels.

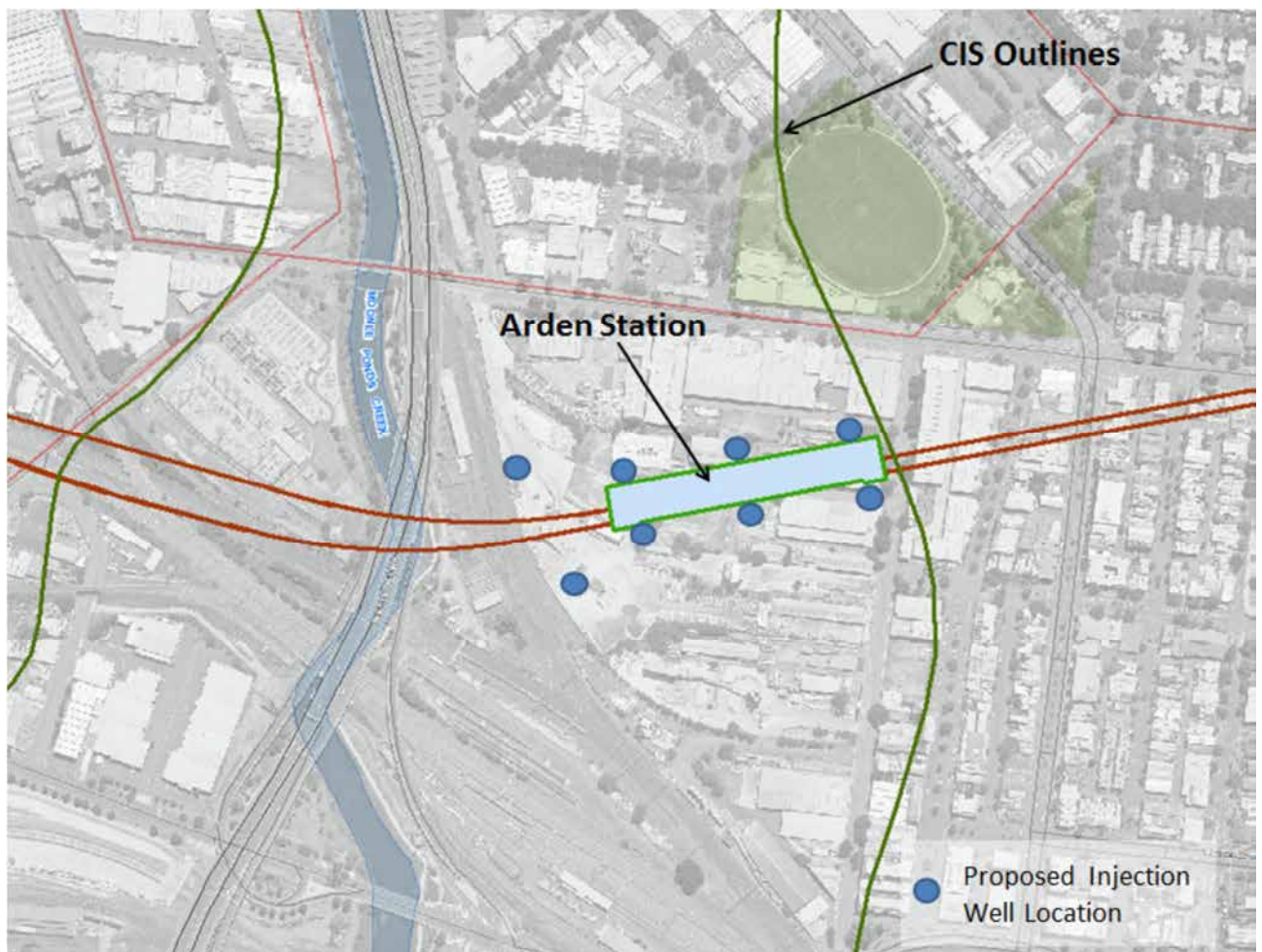


Figure 9-4 Conceptual location of groundwater injection wells at Arden station (located within the Coode Island Silt [CIS] area)



## 9.4.2 Operation

Arden Station would be tanked for operation and therefore long term inflows are expected to be minor. The inflow rate is determined by the construction of the tanking/lining and the aim for Arden station is Haack Tightness Class 2, which limits inflow to 0.05 L/m<sup>2</sup> per day per 100 m length. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H).

### 9.4.2.1 Groundwater Drawdown Estimate

The estimated groundwater drawdown as a result of the minor inflows to the station is minimal. At steady state, drawdown immediately above the tunnels is predicted to be less than 0.2 m.

### 9.4.2.2 Potential Impacts

Minimal drawdown is expected at the Arden station precinct during operation since it is assumed inflows are largely prevented by constructing the station to a Haack 2 tightness classification. Therefore, no impacts on groundwater dependent values are anticipated during operation. If there is any change in construction technique or detailed design that may cause greater inflows. Potential drawdown impacts should be assessed for:

- Migration of potential existing contaminants to third party properties (**Risk #GW023**)
- Groundwater acidification due to potentially acid forming sediments (**Risk #GW036**)
- Aquifer damming caused by tunnels restricting groundwater flow in the Holocene Alluvium (**Risk #GW048**).

Moonee Ponds Creek is not expected to be strongly connected to groundwater and is unlikely to be impacted if drawdown occurred at Arden station precinct. Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not considered further. There are no active groundwater bores within 1 km of Arden station.

### 9.4.2.3 Aquifer Damming Assessment

The impacts of damming on groundwater levels and flow in the Arden station are expected to be minor. In this precinct, assuming the D-wall is keyed into the bedrock, the station would intercept 100 per cent of the cross sectional area of the Quaternary alluvial aquifers. Regional groundwater flow is conceptualised as having some north to south component (i.e. orthogonal to the station), although the dominant flow direction is west to east (parallel to the station), towards major sewers west of the station apparently acting as groundwater drains. Investigations undertaken suggest that there are a number of units within the Quaternary sequence here that are quite permeable, including the Pleistocene alluvium and Upper and Lower Fisherman's Bend Silt (FBS) units. Hence there are units present expected to behave as aquifers and there is potential for damming of these units.

As the station is located on the eastern edge of the Moonee Ponds Creek paeleovalley, the existing flow would be diverted west of the station via the paeleovalley sediments and/or east of the station through Older Volcanics or Werribee Formation material. The Quaternary aquifers west of the station and units east of the station are also partially obstructed by the tunnels, which to some degree limits this route as a bypass flow. However, because the main groundwater flow direction is parallel to the station (west to east), and hence the largest surface area of the station does not intersect the dominant groundwater flow path and given the permeability of the aquifers, the increase in groundwater levels upgradient of Arden Station is likely to be fairly small and similarly the decrease in groundwater levels on the downgradient side of the station is also expected to be small. The distance up and down-gradient of the station where the groundwater level would be affected is expected to be short, in the order of tens of metres. The risk of any adverse effects, such as subsidence, is considered to be very small.



## 9.5 Environmental Performance Requirements

Table 9-3 provides the recommended Environmental Performance Requirements and proposed mitigation measures for the precinct. In addition to the precinct specific Environmental Performance Requirements below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a Groundwater Management Plan to assess and manage impacts associated with the detailed design also apply.

**Table 9-3 Environmental Performance Requirements for the Arden station**

| Asset / value   | Impact  | Environmental Performance Requirements  | Proposed mitigation measures  | Risk no. |
|---|---|---|---|----------|
| <b>Beneficial uses of groundwater at third party properties</b> | <p>Construction: Moderate risk of impact on third party properties based on landuse and expected presence of contaminants within predicted area of impact. Beneficial uses that need to be protected are:</p> <ul style="list-style-type: none"> <li>• Stock watering</li> <li>• Industrial water use</li> <li>• Primary contact recreation</li> <li>• Buildings and structures.</li> </ul> <p>Operation: none.</p> | <p>Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details:</p> <ul style="list-style-type: none"> <li>• An approach identified in consultation with the EPA so that contaminant migration causes no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> | <p>Likely to involve further investigation and/or mitigation measures, for example:</p> <ul style="list-style-type: none"> <li>• Site specific risk assessment of contaminant location and concentrations</li> <li>• Use of injection or discharge bores to prevent contaminant migration</li> <li>• Minimisation of drawdown through construction techniques such as grouting of the structure.</li> </ul> | GW028    |
|   |   | <p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"> <li>• Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures.</li> </ul>   |   |          |
| <b>Beneficial uses of</b>                                       | Construction: Moderate risk of impact on Beneficial Uses of groundwater within  | Develop and implement a GMP detailing groundwater management approaches to  | Testing of rock cores to assess site  | GW039    |



| Asset / value                     | Impact  | Environmental Performance Requirements   | Proposed mitigation measures  | Risk no. |
|-----------------------------------|---|--|---|----------|
| <p><b>groundwater in area</b></p> | <p>predicted area of impact. Beneficial uses that need to be protected are:</p> <ul style="list-style-type: none"> <li>• Stock watering</li> <li>• Industrial water use</li> <li>• Primary contact recreation</li> <li>• Buildings and structures.</li> </ul> <p>Operation: none.</p> | <p>address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details:</p> <ul style="list-style-type: none"> <li>• Methods for minimising drawdown in areas of known PASS and establishing appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> <hr/> <p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"> <li>• Activation of PASS and groundwater acidification.</li> </ul> | <p>specific risk of PASS.</p> <p>Prevent acidification of groundwater by minimizing drawdown in the area:</p> <ul style="list-style-type: none"> <li>• Use of injection or discharge bores to prevent drawdown and contaminant migration</li> <li>• Minimisation of drawdown through construction techniques such as grouting of the station cavern.</li> </ul> |          |





## 10 Precinct 4: Parkville Station

### 10.1 Project Components

The Parkville station precinct is located between CH97+760 m and CH98+330, from Flemington Road to 30 m east of Leicester Street. The precinct extends to 50m north of Grattan Street in the north and to Pelham Street in the south. This section describes the components and construction activities that could result in the impacts to existing conditions in this precinct, based on the Concept Design and the assumptions stated in Section 4.7 of this report. Where predicted impacts have moderate, major or severe consequences for groundwater dependent values, mitigation measures would be applied during construction and operation to reduce the risk associated with these impacts.

#### 10.1.1 Infrastructure

The station box is located beneath Grattan Street between Royal Parade and Leicester Street. There would be a below ground pedestrian connection across to the west side of Royal Parade.

#### 10.1.2 Construction

The proposed construction technique for this station is either bottom up cut and cover (where the station box is fully excavated and built up from the base slab), or top down cut and cover (where the station roof is installed and the station box is then excavated beneath the roof). Top down cut and cover allows for surface reinstatement whilst the excavation is completed beneath the roof slab.

The retaining structures for this station are assumed to be king post piles (KPP) due to the relatively non-sensitive geological surroundings. King post pile walls are typically reinforced piles spaced with shotcrete installed as the excavation proceeds. This method is likely to result in groundwater inflow to the excavation where the station box is below the watertable. Therefore, during construction, the station box would be fully drained.

Other construction works in this precinct include the potential relocation of electrical cables on Grattan Street. No information was available at the time of writing, but it is assumed that these services are within the upper 3 m and are therefore above the watertable.

#### 10.1.3 Operation

During operation, it is planned that all underground structures in this precinct would be tanked to a tightness classification of Haack 3. Parkville has been designed at Haack 3 as opposed to Haack 2 for all other stations because it would be constructed entirely in the Melbourne Formation siltstone and is far enough from palaeovalleys that there is no risk of drawdown causing subsidence.

### 10.2 Existing Conditions

#### 10.2.1 Hydrostratigraphy

The expected geology across this precinct is Melbourne Formation with a thin layer of overlying fill as shown in Figure 10-1. The Geology of Melbourne map (GSV, 1967) indicates that the Melbourne Formation across this precinct is dipping towards the south-east and there is an anticline structure just to the west of this precinct.

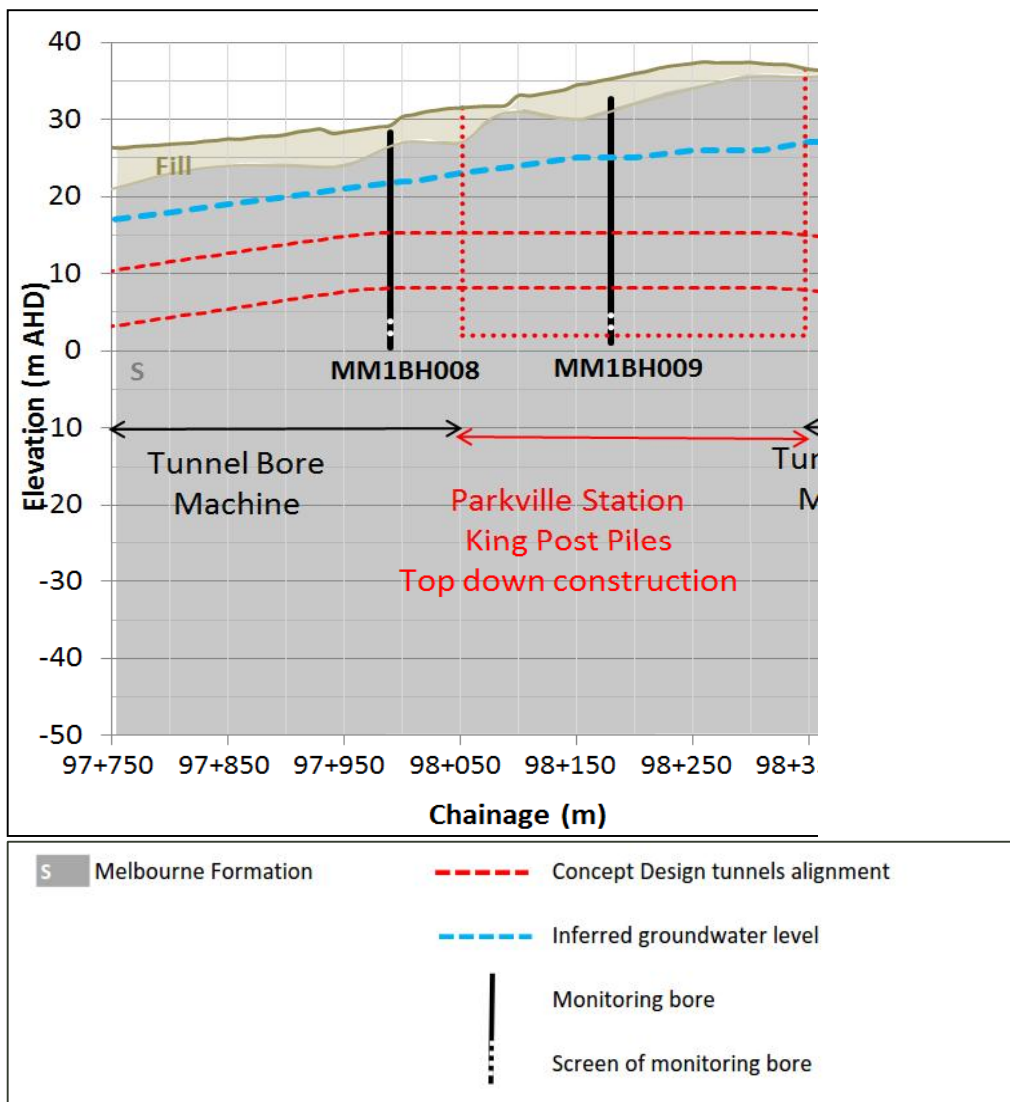


Figure 10-1: Conceptual site model for the Parkville station precinct

Geological features that may enhance bedrock permeability (synclines, anticlines, dykes) have been observed in basement excavations in this area. If these are encountered in station box excavations, higher hydraulic conductivity (and higher associated groundwater inflows) than described above may occur.

Where the Melbourne Formation is fresh to slightly weathered, which typically occurs at depths greater than 24 m, it has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered material is typically non-acid forming and hence low risk (Golder 2016a, Appendix G). The rock in the Parkville station excavation is highly to moderately weathered and is therefore a low risk for acid formation.

### 10.2.2 Groundwater Levels

There are two groundwater monitoring bores in this precinct and groundwater levels have been monitored multiple times. In addition, a groundwater level logger was installed in MM1BH009 between August 2013 and May 2014 and manual measurements were taken during this period. The groundwater levels monitored in the bores and the bore hydrographs are included in Appendix C of this report.

The levels in both bores rose between 2010 and 2011, which reflects rainfall patterns, but fell dramatically (around 3 m) in the following years. Construction of the Victorian Comprehensive Cancer Centre (VCCC) on the western side of Royal Parade occurred around this time (exact dates not available), which included a drained basement. Inflow data suggests that dewatering of the basement occurred during 2012 and 2013,



but it is possible that inflows were occurring before this time. This would explain the fall in groundwater levels, also as the fall in groundwater occurred earlier at MM1BH008 which is closer to the VCCC. Since early 2014 water levels have stabilised or risen in MM1BH009. MM1BH008 could not be located for monitoring.

The groundwater level logger shows an annual seasonal variation of 0.35 m. Groundwater flow in this precinct is towards the west and south west following topography, and influenced by drawdown around the VCCC basement. The University Square underground car park (completed in 2001) in the east of the precinct appears to extend slightly below the watertable. If this structure is drained and not tanked then it may be lowering groundwater, although levels are likely to have stabilised since construction.

The depth to groundwater in this precinct ranges between approximately 7 to 11 m below ground level.

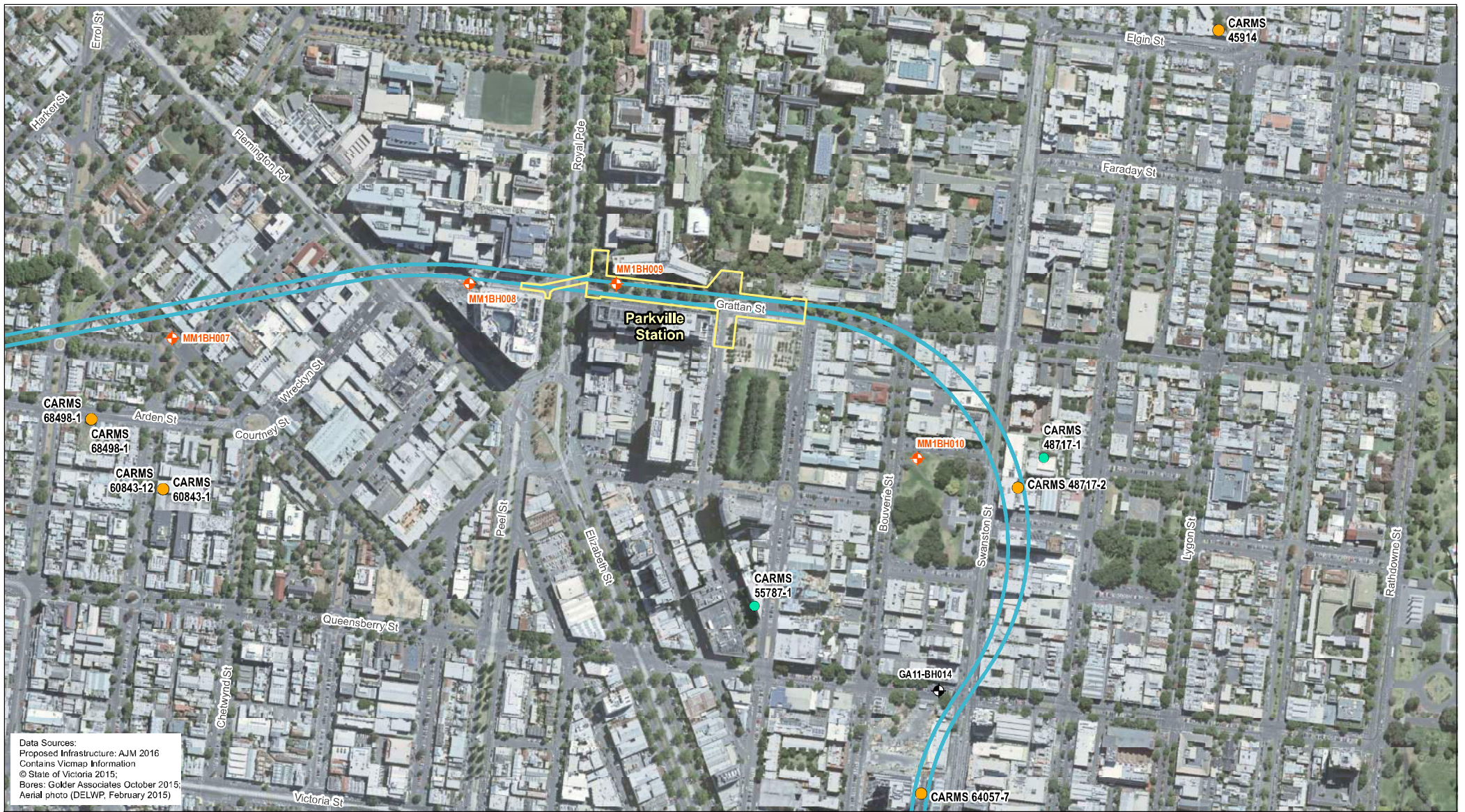
### 10.2.3 Groundwater Quality

Both monitoring bores in this precinct have been sampled and record TDS concentrations of 8,000 to 12,000 mg/L, which is at the upper end of the expected range for the Melbourne Formation. The groundwater in this precinct is higher than the range indicated in the regional watertable mapping which designates this area as 3,500 to 7,000 mg/L TDS. Groundwater of this salinity is within Segment C of the SEPP (GoV), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation. Low yields from the Melbourne Formation also limit other potential uses of groundwater in the area. Yields are unlikely to be sufficient for industrial water use or primary contact recreation, and stock watering is not a likely use in the urban setting of Melbourne Metro. The only relevant beneficial use is the issue of contaminated groundwater coming into contact with underground built structures. Full groundwater quality analysis results are included in Appendix D of this report.

Organic compounds can be used to indicate anthropogenic contamination, but none were detected in the sample analysis. Six GQRUZs are located within a 1 km radius of Parkville station (Figure 10-2). These are sites where groundwater contamination restricts certain uses of the groundwater, as shown in Table 10-1. Volatile contaminants are present in these GQRUZs. Drawdown associated with inflows at the station may change hydraulic gradients in the area, causing movement of these contaminants and volatiles towards the station.



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

**Legend**

**EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations**

- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ⊕ Stage 1
- ⊕ Stage 2 Phase 2A
- ⊕ Stage 2 Phase 2B
- ⊕ Stage 2 Phase 2C
- ⊕ Procurement Phase
- ⊕ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 4 of 10



**Melbourne Metro Rail Project**

Title:  
EPA audit sites in the vicinity of the alignment - Parkville Station

Drawing Number: MMR-AJM-UGAA-MP-NK-500222 Revision: P1

|                      |                         |                    |                 |
|----------------------|-------------------------|--------------------|-----------------|
| Drawn By:<br>A. Davy | Approved By:<br>F. Dean | Date:<br>8/04/2016 | Map Size:<br>A4 |
|----------------------|-------------------------|--------------------|-----------------|

0 150 300 Metres

Figure 10-2 GQRUZ within 1 km of Parkville station



**Table 10-1 Contaminants and restricted uses for GQRUZ within 1 km of Parkville station**

| Reference  | Main groundwater contaminants   | Restricted / excluded uses of groundwater   |
|--|---|---|
| CARMS 64057-7. Peter J Ramsay & Associates Pty Ltd, 2015. Environmental Audit report (53X) - 539-553 Swanston Street, Carlton.           | Trichloroethylene, TPH C10-C40, chloride, sulphate, TDS<br><br>(elevated heavy metals thought to be naturally occurring.  | Drinking water<br>Livestock water supply<br>Irrigation<br>Recreational (e.g. contact)   |
| CARMS 48717-2. GHD Pty Ltd, 2004. Environmental Audit report (53X) - Cnr Swanston and Pelham Street, Carlton.                            | BTEX (especially benzene and xylene) TPHs.  | Drinking water<br>Livestock water supply<br>Recreational (e.g. contact)   |
| CARMS 45914-1 & 2. Egis 2002. Environmental Audit report (53X): 216-228 Elgin Street, Carlton.   | Phase separated hydrocarbons (PSH) in south west corner of site.  | Drinking water<br>Livestock water supply<br>Recreational (e.g. contact)<br>Industrial   |
| CARMS 60843-1. Chadwick T&T Pty Ltd 2009. Environmental Audit report (53X): 90-96 Leveson Street and 15-25 Byron Street North Melbourne. | Antimony, boron, cadmium, chromium VI, copper, manganese, mercury, selenium, tin, cis-1,2 DCE, cyanide, nitrate, sulphate.  | Drinking water<br>Livestock water supply<br>Irrigation<br>Recreational (e.g. contact)   |
| CARMS 51419-2. – 116-128 Leicester Street, Carlton.  | No information, however the adjacent audit site (97-113 Leicester Street) records groundwater contaminants including: benzene and total petroleum hydrocarbons (TPH). | Drinking water<br>Livestock water supply<br>Recreational (e.g. contact)   |
| CARMS 68498-1. Coffey Environments, 2013. Environmental Audit report – 33-35 Arden Street, North Melbourne.                              | NAPL.   | Potable water supply<br>Agriculture, parks and gardens.<br>Stock watering.<br>Industrial water use.<br>Primary contact recreation |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

#### 10.2.4 Groundwater Use

There are three registered stock and domestic bores within 1 km of Parkville station (WRK962001, WRK981453 and WRK981452). These bores could not be located during the site inspection undertaken for Melbourne Metro in July 2015. . In discussions with Southern Rural Water, it was agreed that the bores probably no longer exist and are not used. As such, the bores can be excluded from further consideration in the EES. Outcomes of the site inspections are summarised in Appendix D.7 of this report.



## 10.2.5 Groundwater-Surface Water Interaction

There are no surface water bodies or watercourses within 2 km of this precinct.

## 10.2.6 Groundwater Dependent Vegetation

There are many large trees on Royal Parade, Grattan Street, in The University of Melbourne grounds and University Square that could potentially access the watertable. Many of the trees within The University of Melbourne are listed on the City of Melbourne's Exceptional Trees Register, and include elms, plane trees and eucalypts. The elms of Royal Parade are on the Victorian Heritage Register. Elms and plane trees have shallow roots systems (<1.5 m) and are not expected to access groundwater.

Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. Some of the other trees outside the proposed Project boundary that were not assessed in the arboriculture impact assessment, such as eucalypts, may have deeper root systems and may be using groundwater. There is no specific information on the type of trees and their water requirements, however groundwater dependence is expected to be low, as groundwater in the area is saline and other water sources such as soil moisture, surface runoff and leaking drains are likely to constitute a preferable water source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

## 10.3 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in the Table 10-2. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 10-2 Potential issues associated with the Concept Design**

| Concept Design           | Issue  | Risk # |
|--------------------------|--|--------|
| <b>Parkville station</b> | <p>Groundwater levels at the station are at approximately 22 m AHD, which would mean groundwater would have to be lowered by approximately 14m to keep the excavation dry during construction. This could result in groundwater drawdown, which may affect nearby groundwater users, and vegetation.</p> <p>Potential impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>Migration of existing contaminants to third party properties. There are four GQRUZs in the area. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures.</li> </ul> <p>No surface water bodies are present within 2 km of the Parkville station. Vegetation is not expected to be dependent on groundwater, so impacts are not considered further. There are no active groundwater bores within 1 km of the Parkville station.</p> | GW029  |

## 10.4 Impact Assessment

Potential impacts of Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where an impact with moderate, major or severe consequences has been predicted, additional mitigation measures are recommended to reduce the risk of impact.



## 10.4.1 Construction

It is assumed that Parkville station would be drained during construction. Where the station infrastructure is below the watertable groundwater inflows would occur, resulting in drawdown around the station.

Maximum measured groundwater levels are approximately 24.1 m AHD at Parkville station, and the base of the station is at approximately 8.1 m AHD. Therefore, approximately 16 m of groundwater drawdown would be required to keep the excavation dry during construction. Inflow volumes and associated drawdown of groundwater levels were estimated using an analytical approach that is described in Appendix F of this report.

### 10.4.1.1 Groundwater Drawdown Estimates

At the end of construction, the drawdown cone at Parkville station is predicted to propagate several hundred metres out from the station if no mitigation measures are implemented to prevent inflows. Results of the analytical modelling are shown in Appendix F. Groundwater dependent values within this area of drawdown may be impacted by reduced groundwater availability as a result of deeper groundwater levels.

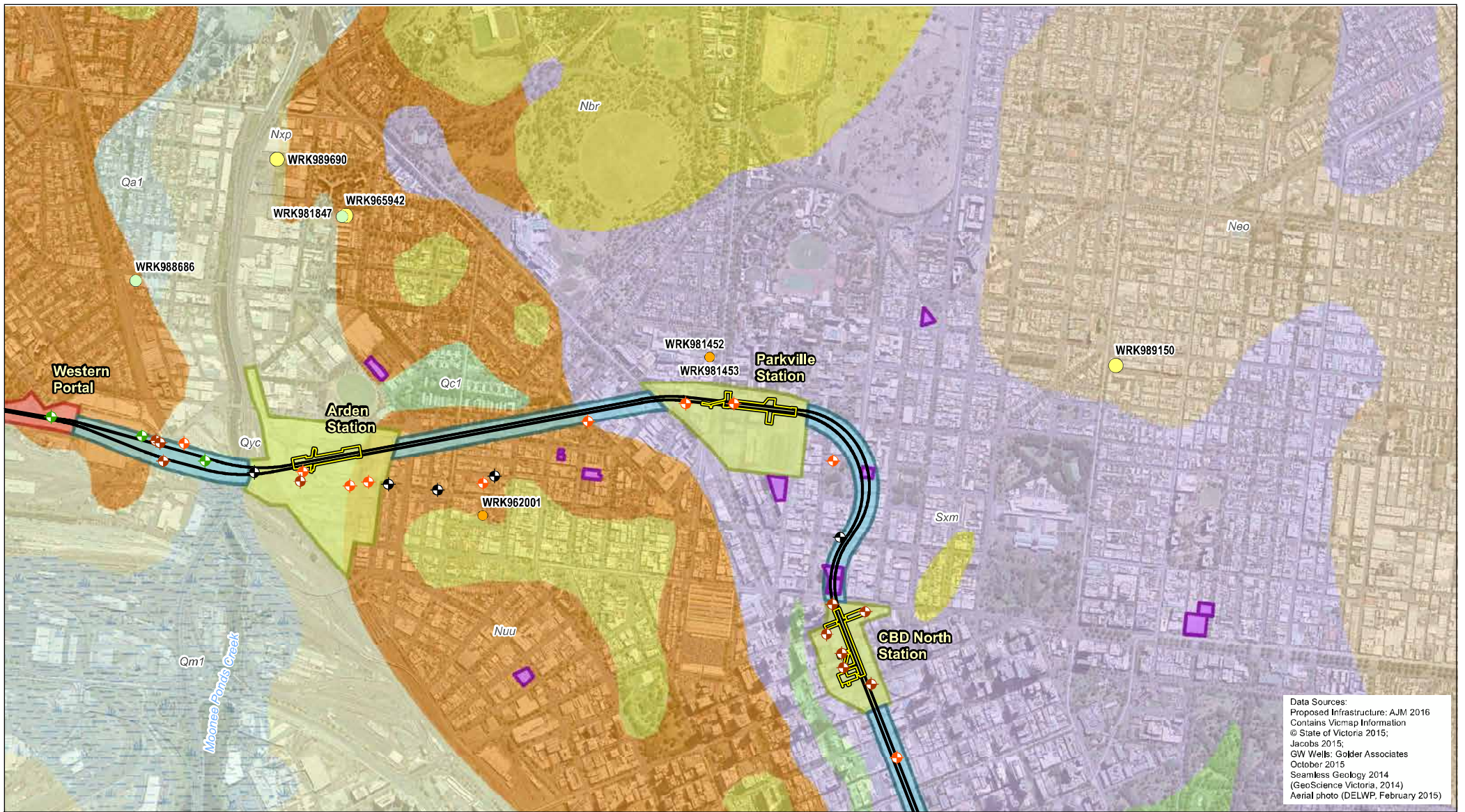
### 10.4.1.2 Potential Impacts

With appropriate mitigation measures (principally grouting of the station cavern during construction) it is considered that drawdown around the station would be minor, and groundwater dependent values in the area would not be impacted.

In the unmitigated case, groundwater dependent assets within the predicted area of drawdown are susceptible to impacts. Potential environmental, economic and social receptors of changes in groundwater levels, flow or quality include (Figure 10-3):

- Third parties with properties close to possible contaminant plumes. There is one GQRUZ in the predicted area of drawdown and migration to neighbouring properties may impact beneficial uses of groundwater at those properties. Vapour intrusion to underground structures is a risk associated with contaminant migration (**Risk #GW029**).

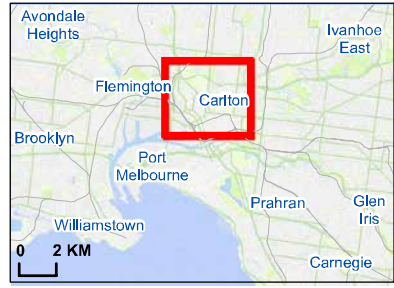
There are no active groundwater users within the predicted area of drawdown around this station precinct. There are no surface water bodies within 2 km of the Parkville station precinct, and vegetation is not expected to be dependent on groundwater. Therefore, impacts on groundwater dependent ecosystems are not considered further. The station would be excavated into Melbourne Formation that has already been moderately to highly weathered, and there is therefore a low risk of acid formation.



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Jacobs 2015;  
 GW Wells: Golder Associates  
 October 2015  
 Seamless Geology 2014  
 (GeoScience Victoria, 2014)  
 Aerial photo (DELWP, February 2015)

**Legend**

- Proposed Alignment
  - Proposed Station Footprint
  - GQRUZ Audit Sites
  - Groundwater Monitoring Wells
    - Stage 1
    - Stage 2 Phase 2A
    - Stage 2 Phase 2B
    - Stage 2 Phase 2C
    - RD (to 30 Sept 2015)
- Geology 1:50,000**
- Brighton Group (Nbr)
  - Newer Volcanics (Neo)
  - Older Volcanics (Nuu)
  - Nxp
  - Alluvium (Qa1)
  - Colluvium (Qc1)
  - Swamp and Lake Deposits (Qm1)
  - Coode Island Silt (Qyc)
  - Melbourne Formation (Sxm); generic
- Station Precinct**
- Station Precinct
  - Portal Precinct
  - Tunnel Precinct
- Existing stock and domestic bore locations**
- Could not be found
  - Decommissioned
  - Bore not visited
  - Bore located



**Melbourne Metro Rail Project**

Title: EES Groundwater Precinct - Parkville Station

|  |                            |
|--|----------------------------|
| Drawing Number:<br>MMR-AJM-UGAA-MP-NK-500428 | Revision:<br>P1            |
| Drawn By:<br>A. Berman                       | Approved By:<br>K. Dowsley |
| Date:<br>26/04/2016                          | Map Size:<br>A4            |

Scale: 0 280 560 Metres

Figure 10-3 Groundwater dependent assets and risks at Parkville station





#### 10.4.1.2.1 Contaminant Migration to Third Party Properties

Groundwater quality sampling in the immediate area of the station did not detect contamination. However, one GQRUZ is within the predicted extents of drawdown around Parkville station. Predicted drawdown at the GQRUZ is up to 7m, which could cause migration of contaminants towards neighbouring properties. If the contamination migrates to previously uncontaminated areas, beneficial uses of groundwater at third party properties may be precluded. The beneficial uses that may be considered in areas of high groundwater salinity are:

- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Drinking water and irrigation are not protected beneficial uses because of the high salinity of the groundwater in this area. Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct. Yields are unlikely to be sufficient for any of the other beneficial uses listed above. For this assessment, only buildings and structures need to be considered, since there is a risk that contaminated groundwater could come into contact with underground structures if it migrates. However, since none of the GQRUZs preclude this beneficial use (i.e. the groundwater quality is suitable for buildings and structures), migration would not affect buildings and structures at neighbouring properties. Hence, the risk of contaminant migration impacting beneficial uses at neighbouring properties is low.

#### 10.4.2 Operation

Parkville Station would be tanked for operation and therefore long-term inflows are expected to be minor. The inflow rate is determined by the construction of the tanking and the aim for all underground structures for this project is Haack Tightness Class 3, which limits inflow to 0.1 L/m<sup>2</sup> per day per 100 m length. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H of this report).

##### 10.4.2.1 Groundwater Drawdown Estimate

At steady state, a shallow drawdown cone is expected to extend out from the station. The level of drawdown across the area is minor, at less than 0.5 m in most locations.

##### 10.4.2.2 Potential Impacts

Minimal drawdown (<1 m) is expected at the Parkville station precinct during operation since it is assumed inflows are largely prevented by constructing the tunnels to a Haack 3 tightness criteria. However a shallow drawdown cone would extend out from the station due to inflows to the station over the long term.

Potential environmental, economic and social receptors of changes in groundwater levels, flow or quality include:

- Third parties with properties close to possible contaminant plumes. There are six GQRUZs in the predicted area of drawdown for this long term case (**Risk #GW029**).

The Melbourne Formation is highly saline and low-yielding, and because of this, the only beneficial use that is considered to apply is the avoidance of corrosion of buildings, as discussed in Section 10.4.1.2.1. None of the GQRUZs currently preclude the buildings and structures beneficial use (i.e. the groundwater quality is suitable for buildings and structures), and therefore migration would not affect buildings and structures at neighbouring properties. There are therefore not expected to be any impacts on beneficial uses if this contamination did migrate during operation.



In addition to this, the extent of migration would be minor. All six GQRUZs would experience less than 1 m drawdown over the long term and migration would therefore be limited. Over the long term the region would also be influenced by factors such as climate variability, leaking pipes, and other construction activities, which would influence groundwater gradients such that the effects of the station would be difficult to distinguish. Secondly, natural attenuation of several contaminants would occur over the long term, which would mean that lower concentrations migrate to neighbouring properties.

There are no active groundwater users within the predicted area of drawdown around this station precinct. Therefore, no impacts are expected on existing groundwater users. Similarly, there are no surface water bodies in the drawdown cone, and vegetation within the area of drawdown is not expected to be dependent on groundwater, so impacts are not considered further.



## 10.5 Environmental Performance Requirements

Table 10-3 provides the recommended Environmental Performance Requirements and proposed mitigation measures for the precinct. In addition to the precinct specific Environmental Performance Requirement below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a Groundwater Management Plan to assess and manage impacts associated with the detailed design also apply.

**Table 10-3 Environmental Performance Requirements for the Parkville station**

| Asset / value   | Impact  | Environmental Performance Requirements  | Proposed mitigation measures  | Risk no. |
|---|---|---|---|----------|
| <b>Beneficial uses of groundwater at third party properties</b> | Construction & operation: Low risk of impact on third party properties based on presence of GQRUZs within predicted area of impact. Beneficial uses that need to be protected are buildings and structures. | <p>Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details:</p> <ul style="list-style-type: none"> <li>An approach identified in consultation with the EPA so that contaminant migration causes no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> | <p>Likely to involve further investigation and/or mitigation measures, for example:</p> <ul style="list-style-type: none"> <li>Site specific risk assessment of contaminant location and concentrations</li> <li>Use of injection or discharge bores to prevent contaminant migration</li> <li>Minimisation of drawdown through construction techniques such as grouting of the structure.</li> </ul> | GW029    |
|   |   | <p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"> <li>Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures.</li> </ul>   |   |          |



# 11 Precinct 5: CBD North

## 11.1 Project Components

The CBD North station precinct is located from Victoria Street in the north to Little Lonsdale Street in the south. The precinct extends to the corner of Orr Street and Victoria Street in the east and to 150 m west of Swanston Street to the west. This section describes the components and construction activities that could result in hydrogeological impacts to existing conditions in the precinct, based on the Concept Design and the assumptions stated in Section 4.7 of this report. Where predicted impacts have moderate, major or severe consequences for groundwater dependent values, mitigation measures would be applied during construction and operation to reduce the risk associated with these impacts.

### 11.1.1 Infrastructure

The station cavern is located directly beneath Swanston Street, extending from La Trobe Street in the south to north of Franklin Street. The station cavern itself would be an approximate tube structure approximately 23 m in diameter (at the widest point) located at a maximum depth of 44 m.

In addition to the station cavern, there would be access shafts on the northern corners and south west corner of the station. These shafts would become pedestrian access points. The details of the shafts are:

- North shaft (Franklin Street entrance)
  - extends from the station to the east and west along Franklin Street
  - excavated to a maximum depth of 45 m
- South west shaft (La Trobe Street entrance)
  - extends from the station to the west just north of La Trobe Street
  - from the southern end of the shaft there would be a passenger underpass beneath La Trobe Street to Melbourne Central Station
  - excavated to a maximum depth of 45 m.

### 11.1.2 Construction

This station is proposed to be constructed using a mined cavern construction method. The shafts to the north-east and south-west are proposed to be used as access shafts to enable to construction of the cavern from underground. These shafts would be excavated using a retaining wall system such as king post piling.

Once excavated to the required depth, the shafts would be used as starting points for the cavern excavation, which would be excavated using the heading and bench method. This is a sequential technique, whereby the upper section (heading) is excavated first, followed by the middle section (bench) and finally the base. Roadheaders have a boom mounted cutting head mounted on a crawler travelling track and are used as the primary excavation equipment.

The ventilation adits from the northern end of Franklin Street entrance shaft to the northern end of the station box would be mined using the roadheader machines.

The caverns, adits and shafts would be expected to act as drained structures during construction.

### 11.1.3 Operation

During operation, it is planned that all underground structures in this precinct would be tanked to a tightness classification of Haack 2.



## 11.2 Existing Conditions

### 11.2.1 Hydrostratigraphy

The expected geology across this precinct is Melbourne Formation (and fill during surface excavations) as shown in Figure 11-1. The Geology of Melbourne map (GSV, 1967) indicates that the Melbourne Formation across this precinct is dipping towards the south-east and there is a syncline structure just to the south of this precinct.

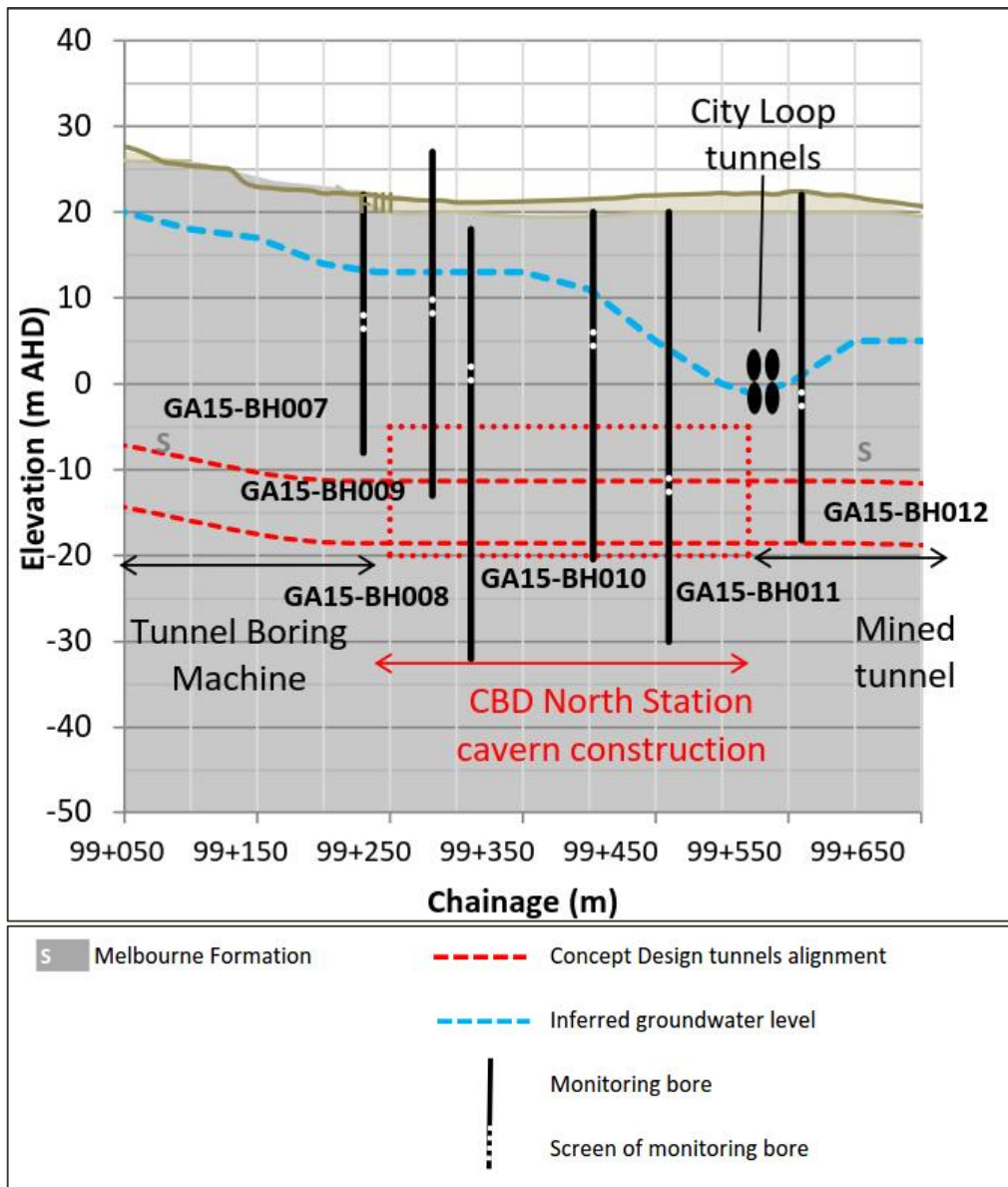


Figure 11-1 Conceptual site model for the CBD North station precinct

There are six groundwater monitoring bores in this precinct and five have undergone hydraulic conductivity testing. Results vary by two orders of magnitude within the precinct (refer to Appendix C of this report), which is typical of variation in the Melbourne Formation hydraulic conductivity.

The station box excavations would be constructed within 10 m of the existing City Loop tunnels. If these excavations are adjacent to areas where the rock profile has been previously fractured or stressed as a result of City Loop construction activities (which is likely), enhanced permeability may be present (compared to typical Melbourne Formation values).



Where the Melbourne Formation is fresh to slightly weathered, which typically occurs at depths greater than 24 m, it has moderate to high potential to generate acidity. Shallow highly weathered to extremely weathered material is typically non-acid forming and hence low risk (Golder 2016a, Appendix G). The degree of weathering of rock in the CBD North station excavation ranges from fresh to high weathered. The component of fresh rock presents a risk of acid formation.

### 11.2.2 Groundwater Levels

Groundwater level data was not available for bores in this precinct at the time of writing. However, interpreted groundwater levels have been shown on the Golder long section (2016a, Appendix G). This interpretation shows that groundwater levels in this precinct are being artificially lowered by the City Loop tunnels. Current groundwater levels are above the lower City Loop tunnels, which have self-sealed (i.e. they were once drained tunnels but are now largely sealed, probably due to geochemical reactions and associated precipitation near the tunnels and/or in the tunnels drainage system). It is expected that water levels are now controlled by the drains in the base of the upper tunnels, which are now experiencing groundwater ingress (levels are at approximately 0 m AHD) (Golder 2016a, Appendix G).

Groundwater levels are higher towards the north, generally reflecting topographical gradients. Groundwater flows from north to south, and is strongly influenced by drawdown around the City Loop tunnels.

Depth to groundwater is shallowest at the northern end of the CBD North station precinct, where groundwater levels are within approximately 10 m of the surface, and deepest at the southern end of the station where they are approximately 25 m below the surface.

### 11.2.3 Groundwater Quality

All monitoring bores in this precinct were sampled for water quality, which showed a narrow range of TDS of between 1,400 and 5,100 mg/L. This range is consistent with or below the TDS range derived from regional mapping (3,500 mg/L and 7,000 mg/L). Bores to the north and south of this precinct, which intersect the Melbourne Formation have TDS concentrations of 4,270 mg/L (GA11-BH014 to the north) and 5,100 mg/L (MM1BH012 to the south). Groundwater of this salinity is within Segments B and C of the SEPP Gov (EPA Victoria 1997), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Potable mineral water supply
- Irrigation
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Due to high salinity, the groundwater is not suitable for use as drinking water or for irrigation. Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct. This is not a potential mineral water supply area, and groundwater is not likely to be used for stock watering, so those beneficial uses also do not apply. Full groundwater quality analysis results are included in Appendix D of this report.

Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bore:

- GA15-BH007: Toluene (0.004 mg/L), Total BTEX (0.004 mg/L), Phenol (0.0017 mg/L), TPH fractions C<sub>10</sub>-C<sub>14</sub> (0.08 mg/L), C<sub>15</sub>-C<sub>28</sub> (0.56 mg/L), C<sub>10</sub>-C<sub>36</sub> (0.64 mg/L), C<sub>10</sub>-C<sub>40</sub> (0.66 mg/L), >C<sub>10</sub>-C<sub>16</sub> (0.11 mg/L), >C<sub>16</sub>-C<sub>34</sub> (0.55 mg/L) and Chloroform (0.01 mg/L).



The concentrations of TPH fractions C<sub>10</sub>-C<sub>36</sub> in this bore are above the relevant guideline values for drinking water and irrigation, but below levels considered safe for recreational uses of water. This is an intensively developed area and some low-level contamination of soil and groundwater is expected. Melbourne Metro bores were designed to assess conditions at tunnel depth and do not specifically target groundwater contaminants. Therefore, while these hydrocarbon concentrations may be diffuse contamination resulting from the intensive land use in the area, they could also indicate contaminant plumes at depths above the tunnels.

There is a known pollution plume at the former brewery site located on the north-west corner of this precinct.

The nitrate concentration at GA11-BH014 is high. High nitrate concentrations in urban environments are most likely due to leaking sewer or drainage infrastructure.

Three GQRUZs are located within a 1 km radius of the CBD North station precinct (Figure 11-2). These are sites where groundwater contamination restricts certain uses of the groundwater, as shown in Table 11-1. Volatile contaminants are present in these GQRUZs. The GQRUZs include the former brewery site immediately north of the precinct and a former service station site further north along Swanston Street. Drawdown associated with inflows at the station may change hydraulic gradients in the area, causing movement of these contaminants towards the station.



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

**Legend**

**EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations**

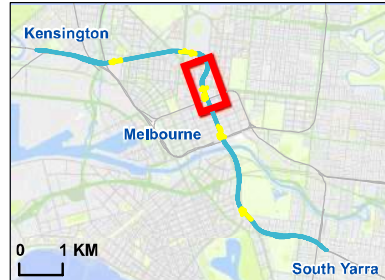
- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- ◆ Stage 2 Phase 2A
- ◆ Stage 2 Phase 2B
- ◆ Stage 2 Phase 2C
- ◆ Procurement Phase
- ◆ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 6 of 10



**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment -  
 CBD North Station

Drawing Number: MMR-AJM-UGAA-MP-NK-500222  
 Revision: P1

|                      |                         |                    |                 |
|----------------------|-------------------------|--------------------|-----------------|
| Drawn By:<br>A. Davy | Approved By:<br>F. Dean | Date:<br>8/04/2016 | Map Size:<br>A4 |
|----------------------|-------------------------|--------------------|-----------------|

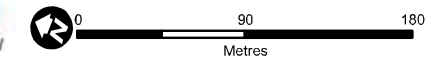


Figure 11-2 GQRUZ within 1 km of the proposed CBD North station precinct





**Table 11-1 Contaminants and restricted uses for GQRUZ within 1 km of the CBD North station precinct**

| Reference   | Main groundwater contaminants  | Restricted / excluded uses of groundwater  |
|---|--|--|
| CARMS 48717-2. GHD Pty Ltd, 2004. Environmental Audit report (53X): cnr Swanston and, Pelham Street, Carlton. | BTEX (especially benzene and xylene) TPHs.   | Potable water supply<br>Stock watering<br>Primary contact recreation                                   |
| CARMS 55787-1. Sinclair Knight Merz, 2005. Environmental Audit report: 97-113 Leicester Street, Carlton.      | Benzene (and other MAH), TPH.  | Potable water supply<br>Stock watering<br>Primary contact recreation                                   |
| CARMS 64057-7. Peter J Ramsay and Associates, 2015. Environmental Audit: 539-553 Swanston Street, Carlton.    | Chlorinated hydrocarbons (TCE, cis-1,2-dichloroethene, tetrachloroethene, vinyl chloride). | Potable water suppl.<br>Agriculture, parks and gardens<br>Stock watering<br>Primary contact recreation |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in Technical Appendix Q *Contaminated Land and Spoil Management*.

#### 11.2.4 Groundwater Use

There are no existing registered stock and/or domestic bores within 1 km of this precinct.

#### 11.2.5 Groundwater-Surface Water Interaction

There are no surface water bodies or watercourses within this precinct. The closest water body is the Yarra River approximately 1 km south. Groundwater levels near the river are at or below the level of the river and therefore groundwater is unlikely to contribute a large proportion to overall river flow. In addition, Golders (2016a, p30) reference groundwater investigations undertaken for the CityLink project, which show that groundwater drawdown propagated quickly underneath and beyond the river during construction, suggesting a relatively weak connection between the river and the groundwater. This is interpreted to be due to low permeability sediments in the riverbed. For this impact assessment, the Yarra River is considered to have limited interaction with groundwater.

There are two artificial ponds in the Carlton Gardens. These ponds are in an elevated landscape and are not expected to receive groundwater inflow. For this impact assessment they are not considered to be interacting with groundwater.

#### 11.2.6 Groundwater Dependent Vegetation

There are many large trees within 1 km of CBD North station that may be using groundwater, for example at Melbourne University, Carlton Gardens, Fitzroy Gardens and along street nature strips. Elms and plane trees have shallow roots systems (<1.5 m) and are not expected to access groundwater. Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are not considered to be groundwater dependent. There are some other large trees in the vicinity of the station (outside the Project Boundary) that were not assessed in the arboriculture impact assessment. There is no specific information on the type of trees and their water requirements, however



groundwater dependence is expected to be low, as other water sources such as soil moisture, surface runoff and leaking drains would constitute a preferable water source. Some groundwater use may occur in extended dry periods such as drought, but groundwater is not considered to be the primary water source for vegetation in the area.

### 11.3 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 11-2. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 11-2 Potential issues associated with the Concept Design for the CBD North station precinct**

| Concept Design           | Issue   | Risk #   |
|--------------------------|---|--|
| <b>CBD North station</b> | <p>Groundwater inflows to the station during construction, requiring dewatering. Groundwater levels in the area could be up to approximately 13 m AHD, which would mean groundwater would have to be lowered by approximately 33 m to keep the excavation dry during construction. Potential impacts of drawdown in this area include:</p> <ul style="list-style-type: none"> <li>• Reduced available drawdown in one groundwater bore (WRK972626)</li> <li>• Migration of existing contaminants to third party properties. Three GQRUZs exist in the area, and anthropogenic contamination has been detected in sampling, indicative of low-level diffuse contamination, typical in an area with a long history of industrial use, and possibly related to contaminant plumes. Migration may impact beneficial uses of groundwater at third party properties and/or cause vapour intrusion to underground structures</li> <li>• Potential acid generation from exposure of unweathered Melbourne Formation.</li> </ul> <p>It is assumed that the Yarra River is not strongly connected to groundwater, and therefore drawdown impacts on the River are considered to be negligible. Similarly, vegetation is not expected to be dependent on groundwater, so impacts are not considered further.</p> | <p>GW001</p> <p>GW023, GW030</p> <p>GW036, GW040</p> |

### 11.4 Impact Assessment

Potential impacts of Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where an impact with moderate, major or severe consequences has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

#### 11.4.1 Construction

CBD North station would be constructed as a cavern below ground using a road header machine or similar and would be drained during construction. The station cavern is below the watertable and inflows would occur, resulting in drawdown around the station.

Measured groundwater levels are approximately 0 m AHD at CBD North station (based on currently available information), and the base of the station would be at approximately -22 m AHD. Therefore, approximately 22 m of groundwater drawdown would be required to keep the excavation dry during construction. Inflow



volumes and associated drawdown of groundwater levels were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b), which is included as Appendix H of this report.

#### 11.4.1.1 Groundwater Drawdown Estimates

It is likely that additional measures such as grouting of the cavern during construction would be implemented in the CBD North precinct to limit inflows and drawdown in the surrounding aquifer.

If impacts were unmitigated, at the end of construction the drawdown cone at CBD North station is predicted to propagate out from the excavation for several hundred metres. Groundwater dependent values within this area of drawdown may be impacted by reduced groundwater availability as a result of deeper groundwater levels.

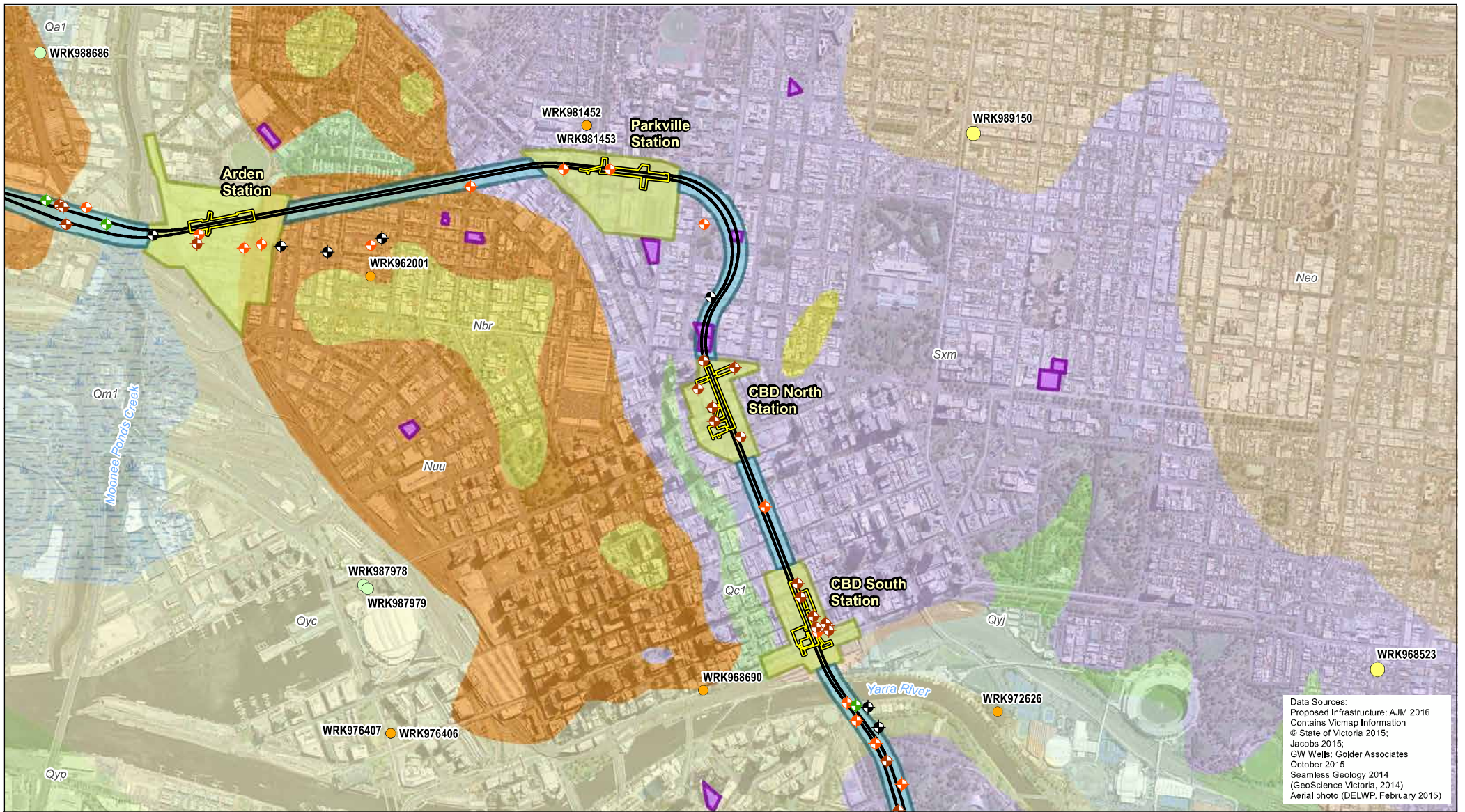
#### 11.4.1.2 Potential Impacts

Measures such as grouting of the excavation may be implemented to counteract drawdown and maintain groundwater levels close to current levels in the CBD North station precinct.

There are no active groundwater users within the predicted area of drawdown around the CBD North station precinct. It is expected that groundwater is not contributing to flow in the Yarra River and therefore drawdown impacts are considered unlikely and are not assessed. Similarly, vegetation is not expected to be dependent on groundwater, so these impacts are not considered further.

Drawdown is predicted to occur within several hundred metres of CBD North station as a result of the construction technique and draining of the tunnels for the unmitigated scenario. Groundwater dependent assets within the area of drawdown are susceptible to impacts. Potential environmental, economic and social receptors of changes in groundwater levels, flow or quality include:

- Third parties with properties close to possible contaminant plumes. There are three GQRUZs in the predicted area of drawdown and some low-level contamination in one Melbourne Metro bore (Figure 11-3) (**Risk #GW030**). An approach to managing the risk of migration of contaminant plumes is currently being developed with the relevant authorities.
- Groundwater acidification due to potentially acid forming sediments (**Risk #GW040**).



Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Jacobs 2015;  
 GW Wells: Goldier Associates  
 October 2015  
 Seamless Geology 2014  
 (GeoScience Victoria, 2014)  
 Aerial photo (DELWP, February 2015)

**Legend**

- Proposed Alignment
- Proposed Station Footprint
- GQRUZ Audit Sites
- Groundwater Monitoring Wells
  - Stage 1
  - Stage 2 Phase 2A
  - Stage 2 Phase 2B
  - Stage 2 Phase 2C
  - RD (to 30 Sept 2015)
- Geology 1:50,000**
  - Brighton Group (Nbr)
  - Newer Volcanics (Neo)
  - Older Volcanics (Nuu)
  - Alluvium (Qa1)
  - Colluvium (Qc1)
  - Swamp and Lake Deposits (Qm1)
  - Coope Island Silt (Qyc)
  - Jolimont Clay (Qyj)
  - Port Melbourne Sand (Qyp)
  - Melbourne Formation (Sxm); generic
- Station Precinct**
  - Station Precinct
  - Tunnel Precinct
- Existing stock and domestic bore locations**
  - Could not be found
  - Decommissioned
  - Bore not visited
  - Bore located



**Melbourne Metro Rail Project**

|   |                            |                     |                 |
|---|----------------------------|---------------------|-----------------|
| Title:<br>EES Groundwater Precinct -<br>CBD North Station |                            |                     |                 |
| Drawing Number:<br>MMR-AJM-UGAA-MP-NK-500428              |                            | Revision:<br>P1     |                 |
| Drawn By:<br>A. Berman                                    | Approved By:<br>K. Dowsley | Date:<br>26/04/2016 | Map Size:<br>A4 |
|   |                            |                     |                 |

Figure 11-3 Groundwater dependent assets and risks at CBD North station



#### 11.4.1.2.1 Potential Acidification Due to PASS

The station is partly excavated through highly weathered to moderately weathered Melbourne Formation. However approximately half of the station is to be excavated in slightly weathered to fresh Melbourne Formation. Testing to date indicates the presence of PASS at the station cavern (Golder 2016a, Appendix G). Hence in an unmitigated scenario, there is a risk of acid generation from rock exposed during construction of CBD North station. The risk of any significant offsite impacts is considered low, as regional groundwater gradients in this area are dominated by the City Loop tunnel. Mitigation measures such as grouting may be implemented to limit drawdown and reduce the risk of acid generation to low.

#### 11.4.1.2.2 Contaminant Migration to Third Party Properties

Several areas of groundwater contamination have been identified. In addition to the three GQRUZs, anthropogenic contamination has been identified in Project sampling, and it is possible that there are other areas with contaminated groundwater, given the intensive development in this area.

The extent of the predicted drawdown cone would intersect these GQRUZs and may cause migration of contaminants towards the station. If the contamination migrates to previously uncontaminated areas, beneficial uses of groundwater at third party properties may be precluded. Beneficial uses that need to be protected are:

- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

Drinking water and irrigation are not protected beneficial uses because of the high salinity of the groundwater in this area (SEPP GoV 1997). Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct. This is not a potential mineral water supply area, and groundwater is not likely to be used for stock watering, so those beneficial uses also do not apply.

There is considered to be a high risk of impacts on beneficial uses, and of vapour migration into underground structures, as the GQRUZ is immediately beside the station. Any drawdown would affect contaminant migration at the former brewery site. Various design and construction techniques are available which could reduce this risk.

The former brewery site (CARMS 64057) presents the highest risk of contaminant migration to neighbouring properties because drawdown at this GQRUZ is predicted to be several metres if no mitigation measures are applied. Over a construction period of two and half years, this level of drawdown would be likely to draw the former brewery site plume towards the south. Discussions with relevant authorities including the EPA are underway to establish an approach for managing this risk and to determine the most appropriate mitigation measures taking into account previous and ongoing environmental investigations by third parties. The Environmental Performance Requirements require the predictive modelling for the detailed design and Groundwater Management Plan to identify mitigation measures, confirm effectiveness, and set out monitoring requirements to address this risk.

The other two GQRUZs (CARMS 55787 and 48717) are further from the station precinct, in locations where between 0.2 and 0.5 m drawdown is predicted before the application of mitigation measures. Low levels of drawdown during the construction period would not cause contaminants to migrate far from their current location by the end of construction.

### 11.4.2 Operation

CBD North station would be tanked for operation and therefore long-term inflows are expected to be minor. The inflow rate is determined by the construction of the lining and the aim for all underground structures for this project is Haack Tightness Class 2, which limits inflow to 0.05 L/m<sup>2</sup> per day per 100 m length. Drawdown



of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H of this report).

#### 11.4.2.1 Groundwater Drawdown Estimate

The estimated groundwater drawdown as a result of the minor inflows to the station during operation is minimal. At steady state, drawdown immediately above the tunnels is predicted to be less than 0.2 m. Some of the drawdown impacts from Parkville station may be evident at CBD North station in the form of a shallow gradient toward Parkville station in the north. These are discussed in Section 10.4.2.

#### 11.4.2.2 Potential Impacts

Since minimal drawdown is expected in the vicinity of CBD North station, no impacts on groundwater dependent values are anticipated. If there is any change in construction technique or detailed design that may cause greater inflows, potential drawdown impacts should be assessed for:

- Third parties with properties close to possible contaminant plumes. There are three GQRUZs within 1 km of CBD North station which may migrate if drawdown occurs during operation (**Risk #GW023**)
- Acidification of potential acid sulfate rock (**Risk #GW036**)

No existing groundwater bores, groundwater dependent surface water bodies or vegetation exists within 1 km of CBD North station precinct.



## 11.5 Environmental Performance Requirements

Table 11-3 provides the recommended Environmental Performance Requirements and proposed mitigation measures for the precinct. In addition to the precinct specific Environmental Performance Requirement below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a Groundwater Management Plan to assess and manage impacts associated with the detailed design also apply.

Table 11-3 Environmental Performance Requirements for CBD North station

| Asset / value   | Impact  | Environmental Performance Requirements   | Proposed mitigation measures   | Risk no. |
|---|---|--|--|----------|
| <b>Beneficial uses of groundwater at third party properties</b> | Construction: High risk of impact on third party properties based on presence of GQRUZs and anthropogenic contamination within predicted area of impact. Beneficial uses that need to be protected are: <ul style="list-style-type: none"> <li>• Irrigation</li> <li>• Stock watering</li> <li>• Industrial water use</li> <li>• Primary contact recreation</li> <li>• Buildings and structures.</li> </ul> | Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details: <ul style="list-style-type: none"> <li>• An approach identified in consultation with the EPA so that contaminant migration causes no significant impacts on beneficial uses and vapour intrusion into underground structures, and establish appropriate monitoring networks to confirm effectiveness of approach.</li> </ul> | Prevent migration of contamination that degrades the beneficial uses of groundwater at third party properties. Approach to be accepted by the EPA. Likely to involve further investigation and/or mitigation measures, for example: <ul style="list-style-type: none"> <li>• Site specific risk assessment of contaminant location and concentrations</li> <li>• Use of injection or discharge bores to prevent contaminant migration</li> <li>• Minimisation of drawdown through construction techniques such as grouting of the station cavern.</li> </ul> | GW030    |
|   | Construction: Moderate risk of vapour migration impacts to underground structures.<br>Operation: none   | Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential: <ul style="list-style-type: none"> <li>• Contaminant migration on the beneficial uses of groundwater at third party properties caused by drawdown and vapour intrusion to underground structures.</li> </ul>   |  |          |



## 12 Precinct 6: CBD South Station

### 12.1 Project Components

The CBD South station precinct is located from Little Collins Street in the north to 60 m south of Flinders Street in the south. The precinct extends to Regent Place and Chapter House Lane in the east and to Flinders Way in the west. The southern end of the precinct extends to Hosier Lane in the east and Elizabeth Street in the west. This section describes the components and construction activities that could result in the impacts to existing conditions in this precinct, based on the Concept Design and the assumptions stated in Section 4.7 of this report. Where predicted impacts have moderate, major or severe consequences for groundwater dependent values, mitigation measures would be applied during construction and operation to reduce the risk associated with these impacts.

#### 12.1.1 Infrastructure

The station cavern is located directly beneath Swanston Street, extending from Flinders Street to just north of Collins Street. The station cavern itself would be an approximate tube structure approximately 24 m in diameter located to a maximum depth of 35 m.

In addition to the station box there would be access shafts on the north east corner and south-west corner of the station. These shafts would become pedestrian access points. The details of the shafts are:

- North-east shaft (City Square entrance)
  - extends across the northern end of City Square
  - excavated to a maximum depth of 35 m
  - a ventilation shaft connects the northern end of this shaft to the northern end of the station box
- South-west shaft (South entrance)
  - extends from the station to the west to Royston Place just north of Flinders Street
  - from the southern end of the shaft there would be a passenger underpass beneath Flinders Street to Flinders Street Station
  - excavated to a maximum depth of 35 m
  - a ventilation shaft connect the southern end of this shaft to the southern end of the station box.

An underground passenger entrance stretches from the south-eastern end of the station box to the visitor centre located in Federation Square.

#### 12.1.2 Construction

This station would be constructed using a mined cavern construction method. The shafts to the north-east and south-west would be used as access shafts to enable construction of the cavern from underground. These shafts would be excavated using a retaining wall system such as king post piling.

Once the shafts are excavated to the required depth they would be used as starting points for the cavern excavation, which would be excavated using the heading and bench method. This is a sequential technique, where the upper section (heading) is excavated first, followed by the middle section (bench) and finally the base. Roadheaders have a boom mounted cutting head mounted on a crawler travelling track and are used as the primary excavation equipment. The ventilation adits would be mined using the roadheader machines.

The Flinders Street underpass, and the Federation Square underpass, would be constructed as top down cut and cover excavations. Top down cut and cover involves constructing the permanent retaining structure from





the surface and excavating far enough to install the permanent roof before excavating beneath the roof. This method allows for surface reinstatement whilst the excavation is completed beneath the roof slab.

The caverns are expected to act as drained structures during construction. However, due to potential for significant impacts associated with groundwater drawdown during station construction (especially subsidence in Yarra River palaeovalley sediments), it is very likely that significant mitigation measures (e.g. pre-grouting ahead of the road cutter) would be required to minimise the amount of groundwater inflow to the station during construction.

### 12.1.3 Operation

During operation it is planned that all underground structures in this precinct would be tanked to a tightness classification of Haack 2.

## 12.2 Existing Conditions

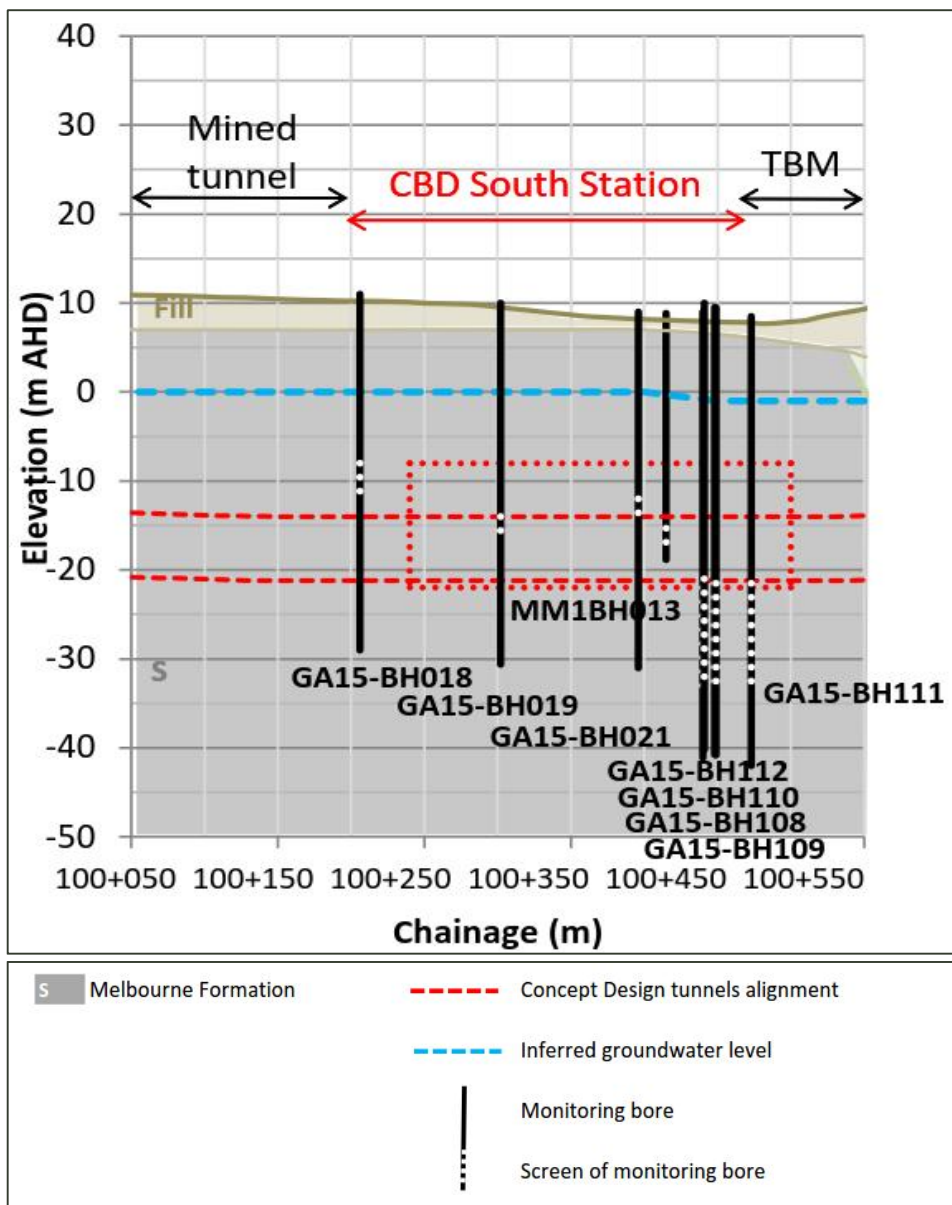
### 12.2.1 Hydrostratigraphy

The expected geology across this precinct is Melbourne Formation (and fill during surface excavations) – refer Figure 12-1. The Geology of Melbourne map (GSV, 1967) indicates that the Melbourne Formation across this precinct is dipping towards the north-west and there is an anticline structure just to the south of this precinct. The station is mainly excavated through highly weathered to moderately weathered Melbourne Formation. A small part of the station is to be excavated in slightly weathered to fresh Melbourne Formation. The majority of testing to date indicates the absence of PASS at the station cavern, but with a small number of samples indicating the presence of PASS (Golder, 2016a, Appendix G).

There are nine groundwater monitoring bores in this precinct, of which five have undergone hydraulic testing as shown in Appendix D of this report. These results are consistent with hydraulic conductivity results across the alignment and demonstrate the variability in hydraulic conductivity within the Melbourne Formation, with results spread across three orders of magnitude. A ten day aquifer pumping test was undertaken at the station (adjacent St Paul's Cathedral) in September 2015. Preliminary results from the test indicated hydraulic conductivity of the Melbourne Formation of 0.2 m/day ( $2 \times 10^{-6}$  m/s), which is higher permeability compared to the project wide median permeability.

### 12.2.1 Groundwater Levels

Three groundwater bores have been manually monitored in the CBD South station precinct and results are included in Appendix D of this report. In the year between June 2010 and July 2011 groundwater levels rose in MM1BH013 by over 1 m. In general, seasonal variations in the Melbourne Formation are likely to be within 0.5 m and longer-term variations are likely to be controlled by the manmade structures which drain groundwater in the CBD. Climate change is also expected to raise the average level of the Yarra River and in turn increase groundwater levels at the station.



**Figure 12-1: Conceptual site model for CBD South station precinct**

Calculations of maximum potential groundwater levels at this station have been undertaken for Melbourne Metro design process and take into account the likely effect of climate change and flooding of the Yarra River. These calculations predict a potential maximum groundwater level (for design purposes) at the CBD South station of 2.2 m AHD.

Groundwater levels in this precinct are likely to be controlled by dewatering of manmade features such as basements within the CBD. Local sewers (the Melbourne main sewer crosses the alignment in this precinct at approximately CH100+490) and the Telstra tunnel beneath Collins Street may also be influencing the groundwater levels. Groundwater appears to be flowing southwards towards the Yarra River.

The measured groundwater level in MM1BH013 may not be representative of the watertable, as this bore is screened relatively deeply within the Melbourne Formation. (However the difference between this level and the watertable is unlikely to be significant.) This formation may be semi-confined in this area due to the shallow weathering profile near the surface.

The depth to groundwater in this precinct ranges between approximately 7 m below ground level to 11.5 m below ground level. The shallowest groundwater levels are near the south of the precinct.



### 12.2.2 Groundwater Quality

Six of seven monitoring bores in this precinct have been sampled and record TDS concentrations between 1,400 and 5,300, which is low compared to the average over the entire alignment for the Melbourne Formation (5,600 mg/L). The groundwater in this precinct is also below the range that would be expected from the regional watertable mapping which designates this area as 3,500 to 7,000 mg/L TDS. Groundwater of this salinity is within Segment B to C of the SEPP GoV (EPA Victoria 1997), which means the following beneficial uses must be protected:

- Maintenance of ecosystems: groundwater discharging to surface water ecosystems must not alter ecosystem health
- Potable mineral water supply (there are no areas of mineral waters in the vicinity of the project and therefore this Beneficial Use is not considered further)
- Irrigation
- Stock watering
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

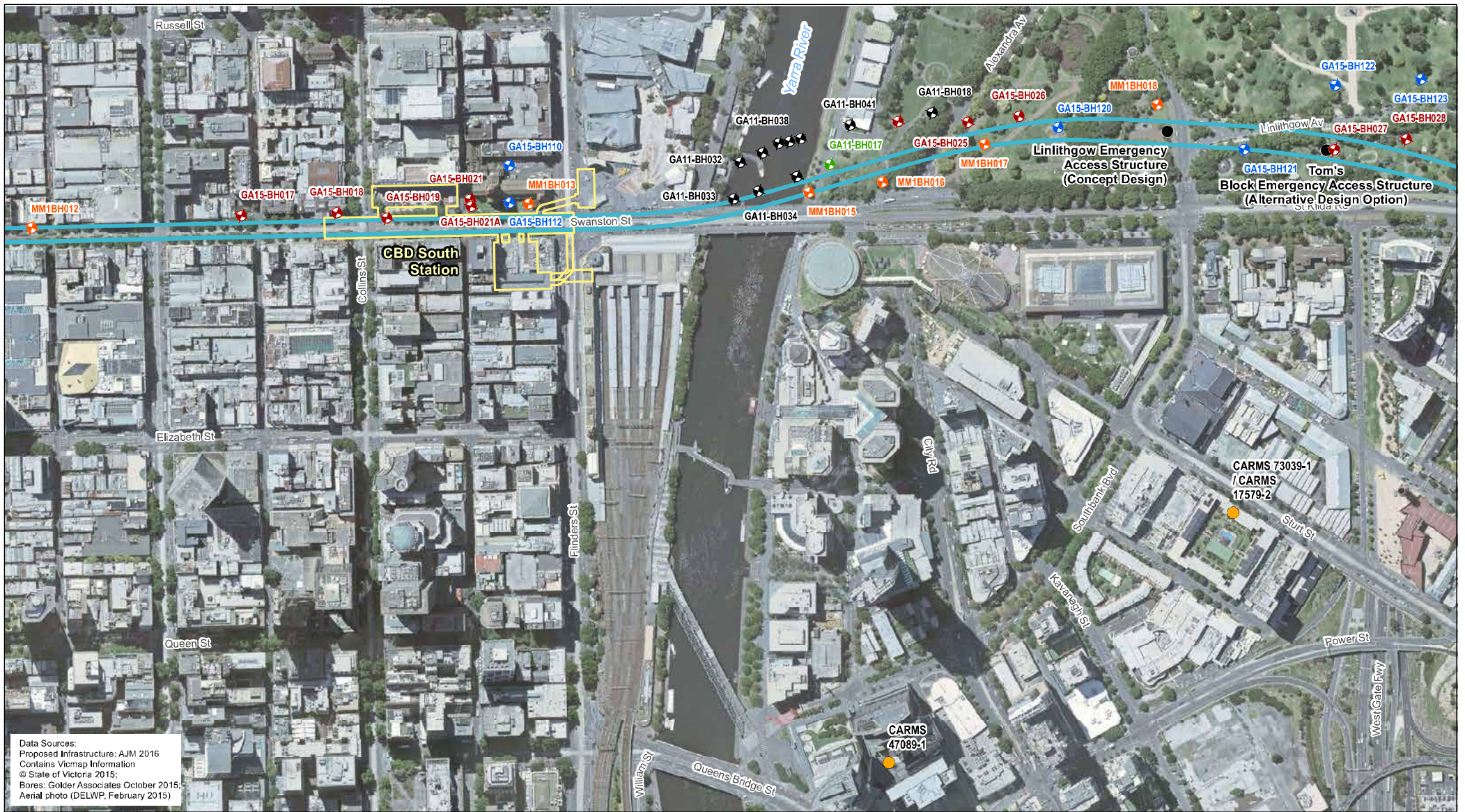
Due to high salinity, the groundwater is not suitable for use as drinking water. Maintenance of ecosystems is not protected because there are no ecosystems that are reliant on groundwater in this precinct. This is not a potential mineral water supply area, and groundwater is not likely to be used for stock watering, so those beneficial uses also do not apply. Full groundwater quality analysis results are included in Appendix D of this report.

Organic compounds can be an indication of anthropogenic contamination, and were detected in the following bore:

- GA15-BH021: TPH fractions C15-C28 (1.02 mg/L), C29-C36 (0.57 mg/L), C10-C36 (1.59 mg/L), C10-C40 (1.74 mg/L), >C16-C34 (1.5 mg/L), >C34-C40 (0.24 mg/L), Formaldehyde (0.2 mg/L) and Residual Chlorine (0.06 mg/L)
- GA15-BH110: Residual Chlorine (0.06 mg/L).

The concentrations of TPH fractions detected are above relevant guideline values for drinking water, recreational and irrigation uses (see Appendix D of this report). This bore is screened in the watertable aquifer, but at a level approximately 10m below the watertable. This is an intensively developed area and some low-level contamination of soil and groundwater is expected. Melbourne Metro bores were designed to assess conditions at station depth and do not specifically target groundwater contaminants. Therefore, while these hydrocarbon concentrations may be diffuse contamination resulting from the intensive land use in the area, they could also indicate contaminant plumes at depths above the station.

Two GQRUZs are located within a 1 km radius of the CBD South station precinct (Figure 12-2). These are sites where groundwater contamination restricts certain uses of the groundwater, as shown in Table 12-1. Volatile contaminants are present in these GQRUZs. Drawdown associated with inflows at the station may change hydraulic gradients in the area, causing migration of these contaminants towards the station.



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

**Legend**

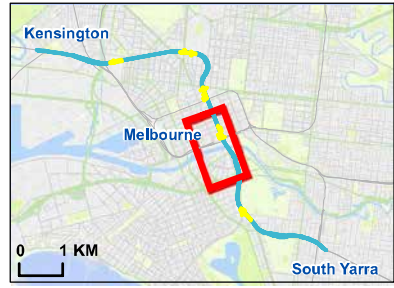
- Emergency Access Structure
- ◆ EPA Audit and Groundwater Restricted Use Zone (GWRUZ) Locations
- Audit report
- Audit report / GQRUZ

**Sampling Locations**

- ◆ Stage 1
- ◆ Stage 2 Phase 2A
- ◆ Stage 2 Phase 2B
- ◆ Stage 2 Phase 2C
- ◆ Procurement Phase
- ◆ Reference Design Phase

- Portal
- Tunnel - Cut and Cover
- Decline Structure
- Proposed Alignment
- Proposed Station Footprint

Map 7 of 10



**Melbourne Metro Rail Project**

Title:  
 EPA audit sites in the vicinity of the alignment -  
 CBD South Station

|  |                         |                     |                 |
|--|-------------------------|---------------------|-----------------|
| Drawing Number:<br>MMR-AJM-UGAA-MP-NK-500222 |                         | Revision:<br>P1     |                 |
| Drawn By:<br>A. Davy                         | Approved By:<br>F. Dean | Date:<br>14/04/2016 | Map Size:<br>A4 |

0 130 260 Metres

Figure 12-2 GQRUZ within 1 km of the CBD South station precinct



**Table 12-1 Contaminants and restricted uses for GQRUZ within 1 km of the CBD South station precinct**

| Reference   | Main groundwater contaminants  | Restricted / excluded uses of groundwater  |
|---|--|--|
| CARMS 47089-4. LanePiper, 2006. Environmental audit report: Freshwater Place, Stage 2, Southbank. | Boron, Manganese, Nickel, Zinc, Naphthalene, Fluorene, Phenanthrene, Anthracene, Benzo(a)pyrene. | Maintenance of ecosystems<br>Agriculture, parks and gardens<br>Stock watering                          |
| CARMS 73039-1. 102-118 Sturt Street, Southbank.   | Report not available.  | Potable water supply<br>Agriculture, parks and gardens<br>Stock watering<br>Primary contact recreation |

The design of any structures needs to take into account the potential aggressive groundwater conditions in accordance with AS 2159-2009. A durability assessment that reviews the potential for corrosion of Melbourne Metro structures is contained in the Contaminated Land and Waste Management impact assessment (Technical Appendix Q *Contaminated Land and Spoil Management*).

### 12.2.3 Groundwater Use

There are four registered bores within 1 km of CBD South station, but none of them could be located during a site inspection undertaken for Melbourne Metro in July 2015. Outcomes of the site inspections are summarised in Appendix D.7 of this report. Discussions with Southern Rural Water agreed on an approach for considering potential impacts to these bores, which is:

- For three of the bores which could not be located during site inspections (WRK968690, WRK975062, WRK975063), it was agreed that they probably no longer exist and are not used. Consequently they do not need to be considered any further in the EES
- One bore could not be located during the site inspection (WRK972626), but its large diameter construction and expected location suggest that it may be a CityLink recharge bore that has been mislabelled in the WMIS database. On this basis, it should be considered further in the EES.

Five CityLink recharge wells are also located within 1.2 km of CBD South station. The wells inject water into the Moray Street Gravels to maintain groundwater pressures in the overlying Coode Island Silt and prevent settlement. Relative to the station, the wells are approximately:

- 900 m east (one well)
- 1.2 km south (two wells)
- 1.5 km south-east (one well)
- 1.8 km south-east (one well).

### 12.2.4 Groundwater-Surface Water Interaction

The Yarra River is located 100 m to the south of the southern edge of this precinct. Groundwater levels are at or below the level of the river and therefore, groundwater is unlikely to contribute a large proportion to overall river flow. In addition, Golder (2016a, p30) reference groundwater investigations undertaken for the CityLink project which showed that groundwater drawdown propagated quickly underneath and beyond the river during construction, suggesting a relatively weak connection between the river and the groundwater. Golder attributes this to low permeability sediments in the river bed.

Despite differences between surface water and groundwater levels, there is anecdotal evidence to suggest that the lake in the Royal Botanic Gardens is connected to groundwater, as the lake level dropped when groundwater levels were lowered by CityLink construction.



## 12.2.5 Groundwater Dependent Vegetation

Trees along the alignment were reviewed in the arboriculture impact assessments (Technical Appendix R and S *Arboriculture*) and are considered not to be groundwater dependent. There are many other large trees within 2 km of CBD South station (outside the Project Boundary) that were not assessed in the Arboriculture Impact Assessments (Technical Appendix R and S *Arboriculture*), for example along city streets, St Kilda Road, Royal Botanic Gardens and Fitzroy Gardens. Elms and plane trees have shallow roots systems (<1.5 m) and are not expected to access groundwater.

Large trees within the Royal Botanic Gardens were not assessed in the arboriculture report as they are outside the Project Boundary. Where groundwater levels are shallow close to the Yarra River and the lake in the Royal Botanic Gardens, these trees may have some dependence on groundwater. There is no information on the type of these trees and their water requirements, and therefore the groundwater dependence of these trees cannot be assessed. Where deep-rooted tree species exist, there is a greater potential for groundwater use, and hence, a greater sensitivity to impacts from drawdown. These trees should be identified and irrigated through the period of drawdown.

Other trees in the gardens and parklands are further away from surface water features in areas where groundwater is deeper. These trees are expected to preferentially use other sources of water such as soil moisture and surface runoff and are not considered to be at risk from drawdown of groundwater associated with the station.

## 12.3 Potential Issues

As identified in the risk assessment (Table 6-1), the potential issues associated with the Concept Design are identified in Table 12-2. These are the potential receptors for which impacts must be specifically assessed during the impact assessment in the following sections.

**Table 12-2 Potential issues associated with Concept Design for the CBD South station precinct**

| Concept Design   | Issue  | Risk #       |
|--|--|--------------|
| <b>CBD South station cavern and entrances</b>  | Groundwater inflows to the station during construction, requiring dewatering.  |              |
|  | Groundwater levels in the area could be up to approximately 1 m AHD, which would mean groundwater would have to be lowered by approximately 21 m to keep the excavation dry during construction.   | GW002, GW008 |
|  | Potential impacts of drawdown in this area include:  |              |
|  | <ul style="list-style-type: none"> <li>Reduced available drawdown in one stock and domestic bores (WRK972626)</li> </ul>   | GW010        |
|  | <ul style="list-style-type: none"> <li>Reduced water levels in the lake in the Royal Botanic Gardens</li> </ul>  | GW015, GW019 |
|  | <ul style="list-style-type: none"> <li>Large trees that may be using groundwater near the Yarra River and the lake in the Royal Botanic Gardens</li> </ul>   |              |
|  | <ul style="list-style-type: none"> <li>Migration of existing contaminants to third party properties. Two GQRUZs exist in the area, and anthropogenic contamination has been detected in sampling, indicative of low-level diffuse contamination, typical in an area with a long history of industrial use, and possibly related to contaminant plumes</li> </ul> | GW023, GW031 |
| <ul style="list-style-type: none"> <li>Potential acid generation from exposure of unweathered Melbourne Formation</li> </ul> | GW036, GW040   |              |
| <ul style="list-style-type: none"> <li>Impacts on CityLink recharge wells influencing operation of the wells.</li> </ul>     | GW044, GW046   |              |
|  | It is assumed that the Yarra River is not strongly connected to groundwater, and therefore any drawdown impacts are considered to be negligible.   |              |



## 12.4 Impact Assessment

Potential impacts of the Melbourne Metro construction and operation on the values associated with groundwater are evaluated in accordance with the assessment criteria outlined in Section 2. The potential impacts outlined in this section are based on the design components specified in the Concept Design and the assumptions stated in Section 4.7 in this report. In cases where an impact with moderate, major or severe consequences has been predicted, additional mitigation measures are recommended to reduce the risk of impact.

### 12.4.1 Construction

CBD South station would be constructed as a cavern below ground using a road header machine or similar and would be drained during construction. The station cavern would be below the watertable consequently groundwater and inflows would occur, resulting in drawdown around the station. The assessment below considers an unmitigated scenario and a fully drained cavern. However, due to the predicted drawdown impacts, mitigation measures (e.g. grouting of the cavern) are recommended to significantly reduce drawdown.

Measured groundwater levels are approximately 1 m AHD at CBD South station (based on currently available information), and the base of the station is at approximately -25 m AHD. Therefore, approximately 26 m of groundwater drawdown would be required to keep the excavation dry during construction. Inflow volumes and associated drawdown of groundwater levels were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b), which is included as Appendix H of this report.

#### 12.4.1.1 Groundwater Drawdown Estimates

It is likely that mitigation measures would be implemented, including grouting of the station cavern to prevent inflows, and installation of temporary injection bores along the Yarra River to counteract drawdown. Together, these mitigation measures would maintain groundwater levels close to current levels and drawdown risks would be minimised. These measures are described in Section 12.4.1.3.

If no mitigation measures are applied, at the end of construction the drawdown cone at the CBD South station is predicted to propagate out from the excavated station in an irregular shape controlled by the variable geology surrounding the station. To the north the drawdown cone is within uniform geology (the Melbourne Formation) and is roughly circular in shape, extending several hundred metres out from the station cavern.

As shown in Golder (2016b, Figure 20, Appendix H of this report), at the northern edge of the Yarra River Palaeovalley and south of the CBD South Station, there is a rapid change in modelled drawdown contours. This relatively rapid change in the drawdown contours is due to the significant change in hydraulic properties (principally hydraulic conductivity and specific storage) from the Silurian mudstone as compared with the palaeovalley sediments. Minor drawdown of 0.2 m and 0.5 m extend south across the palaeovalley. This predicted drawdown is for a scenario where no additional measures to minimise groundwater inflows and/or drawdown have been modelled.

#### 12.4.1.2 Potential Impacts

It is expected that measures such as grouting of the excavation and the installation of temporary injection bores would be implemented to counteract drawdown and maintain groundwater levels close to current levels at the CBD South station precinct.

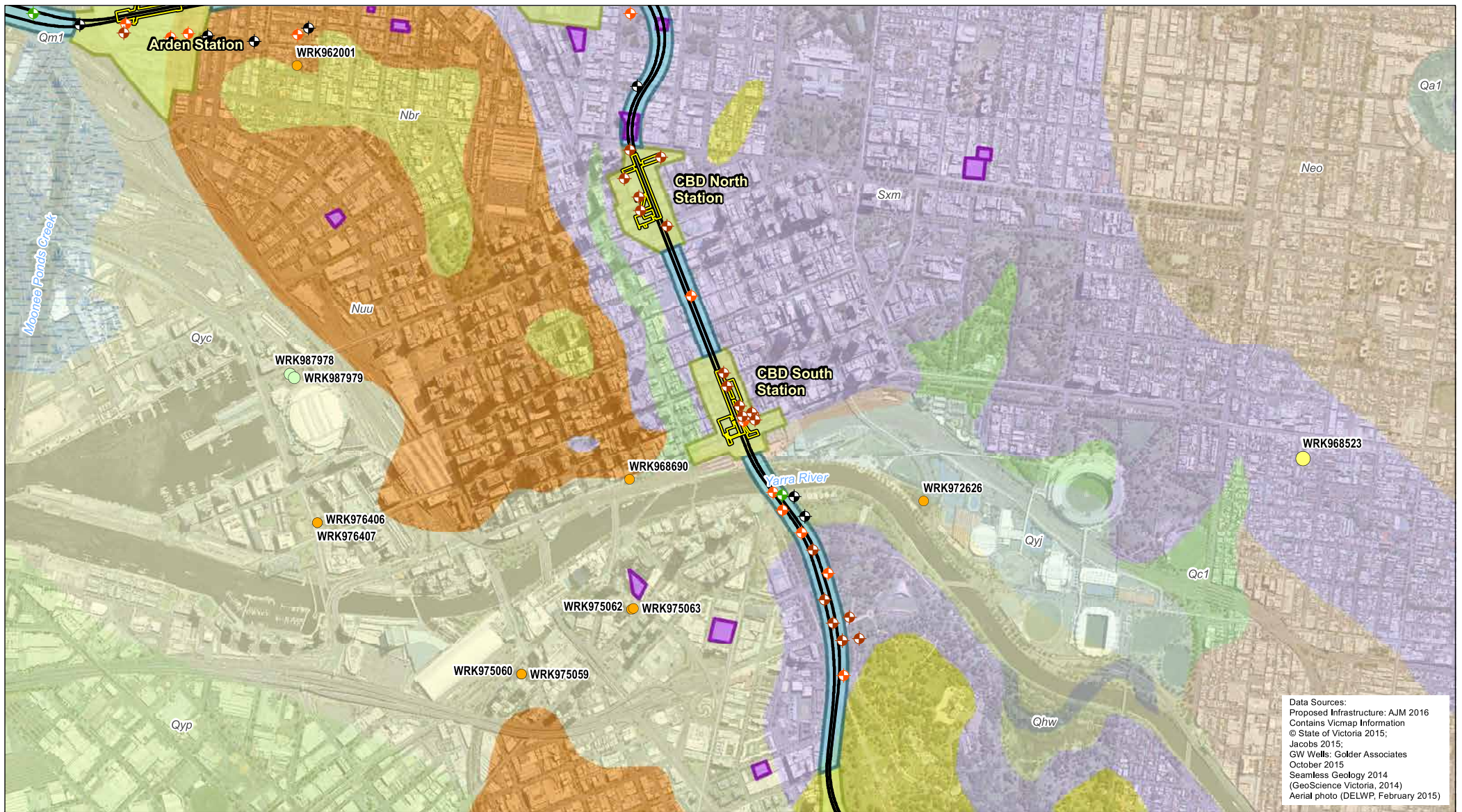
Groundwater dependent assets within the area of drawdown are susceptible to impacts. Potential environmental, economic and social receptors of changes in groundwater levels, flow or quality include (Figure 12-3):



- One possible stock and domestic groundwater bores (WRK972626) (**Risk #GW008**)
- Large trees that may be using groundwater near the Yarra River (**Risk #GW019**)
- Third parties with properties close to possible contaminant plumes. There are two GQRUZs within the predicted area of drawdown. An approach to managing the risk of migration of unknown contaminant plumes is currently being developed with the relevant authorities (**Risk #GW031**)
- Groundwater acidification due to potentially acid forming sediments (**Risk #GW040**)
- CityLink recharge wells, which may cause depressurisation and potential settlement in the overlying Coode Island Silt (**Risk #GW046**).

The surface water bodies within the area of drawdown are not expected to be dependent on groundwater, so impacts are not considered further. The lake in the Royal Botanic Gardens may be groundwater dependent, but is outside the predicted area of drawdown.





Data Sources:  
 Proposed Infrastructure: AJM 2016  
 Contains Vicmap Information  
 © State of Victoria 2015;  
 Jacobs 2015;  
 GW Wells: Golder Associates  
 October 2015  
 Seamless Geology 2014  
 (GeoScience Victoria, 2014)  
 Aerial photo (DELWP, February 2015)

**Legend**

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  - Stage 2 Phase 2B
  - Stage 2 Phase 2C
  - RD (to 30 Sept 2015)

**Geology 1:50,000**

- Brighton Group (Nbr)
- Newer Volcanics (Neo)
- Older Volcanics (Nuu)
- Alluvium (Qa1)
- Colluvium (Qc1)
- Waste Deposits (Qhw)
- Swamp and Lake Deposits (Qm1)
- Coode Island Silt (Qyc)
- Jolimont Clay (Qyj)
- Port Melbourne Sand (Qyp)
- Melbourne Formation (Sxm): generic

**Station Precinct**

- Station Precinct
- Tunnel Precinct

**Existing stock and domestic bore locations**

- Could not be found
- Decommissioned
- Bore not visited
- Bore located



**Melbourne Metro Rail Project**

**Title:** EES Groundwater Precinct - CBD South Station

**Drawing Number:** MMR-AJM-UGAA-MP-NK-500428

**Revision:** P1

|                               |                                   |                            |                        |
|-------------------------------|-----------------------------------|----------------------------|------------------------|
| <b>Drawn By:</b><br>A. Berman | <b>Approved By:</b><br>K. Dowsley | <b>Date:</b><br>26/04/2016 | <b>Map Size:</b><br>A4 |
|-------------------------------|-----------------------------------|----------------------------|------------------------|

**MELBOURNE METRO RAIL AUTHORITY**

**ajurecon JACOBS**

**AJM Mott MacDonald**

**Joint Venture GRIMSHAW**

0 300 600 Metres

Figure 12-3 Groundwater dependent assets and risks at CBD South station



#### 12.4.1.2.1 Groundwater Users

A significant impact on existing groundwater users is considered to be a decline in groundwater levels that reduces the available drawdown in the bore by more than 10 per cent (RWC 1993). The bore identified within 1 km of the station does not have groundwater level information to calculate the available drawdown, so a conservative estimate of depth to water has been assumed for each bore. The drawdown prediction from the Golder Associates (2016b, Appendix H of this report) numerical modelling has been used in Table 12-3 to assess impacts on the bore WRK972626.

Impacts for the unmitigated scenario are expected to be insignificant (< 10 per cent of available drawdown). As mitigation measures such as grouting of the station cavern are likely to be implemented during construction, drawdown and therefore the level of impact on this bore would be even less in the mitigated scenario.

Table 12-3 Predicted impact on existing groundwater bores within 2 km of CBD South station

|                  | Bore depth | Water level         | Available drawdown | Estimated unmitigated drawdown at bore at 660 days (Golder Associates 2016b) | Reduction in available drawdown <sup>1</sup> |
|------------------|------------|---------------------|--------------------|--|--|
| <b>WRK972626</b> | 34 m       | Unknown, assume 10m | 24 m               | 0.5 - 1 m  | 2 - 4%                                       |

1 – Reduction in available drawdown calculated by: (drawdown/available drawdown)\*100

Two of the five CityLink recharge wells are within the predicted unmitigated drawdown radius associated with construction at CBD South station. These two wells are near the Melbourne Park Tennis Centre and the northern side of the western entrance to the CityLink tunnels. The predicted unmitigated impact on these two wells is up to 1 m. This is a minor impact which is slightly above normal seasonal fluctuations. Lowering the watertable to this extent may slightly depressurise the Coode Island Silt, which increases the risk of ground settlement. The ground movement impact assessment (Technical Appendix P *Ground Movement and Land Stability*) reviews the potential for this impact to occur in detail. Mitigation measures including grouting of the station cavern and establishing a groundwater injection borefield in the Yarra palaeovalley during construction would further reduce the level of drawdown at these bores, so that the CityLink bores are unlikely to be affected.

#### 12.4.1.2.2 Impacts on Surface Water Bodies

Impacts of drawdown on the Yarra River are not assessed because there is expected to be little connection between groundwater and the river, based on the knowledge from CityLink construction, which did not significantly impact the river. The lake in the Royal Botanic Gardens may be groundwater dependent, but is outside the predicted area of drawdown.

#### 12.4.1.2.3 Impacts on Vegetation

Deep-rooted trees in areas where groundwater is expected to be shallow, such as along the Yarra River and near the lake in the Royal Botanic Gardens, may be dependent on groundwater. Many of these trees are within the area of predicted drawdown. Deep-rooted tree species should be identified and their dependence on groundwater should be assessed. If found to be groundwater dependent, the trees within the area of drawdown should be irrigated through the period of drawdown. This measure is expected to fully mitigate any potential impacts on trees caused by groundwater drawdown.

#### 12.4.1.2.4 Potential Acidification Due to PASS

The station is mainly excavated through highly weathered to moderately weathered Melbourne Formation. A small part of the station is to be excavated in slightly weathered to fresh Melbourne Formation. The majority of testing to date indicates the absence of PASS at the station cavern, however a small number of samples do indicate the presence of PASS (Golder 2016a, Appendix G). The risk of any significant offsite impacts



from PASS is considered low as mitigation measures (grouting and injection bores) would be required to limit drawdown to manage subsidence.

#### 12.4.1.2.5 Contaminant Migration to Third Party Properties

Several areas of groundwater contamination have been identified. In addition to the two GQRUZs, sampling of groundwater has identified anthropogenic contaminants that may be indicative of other contaminant plumes south of the Yarra River.

The extent of the unmitigated predicted drawdown cone would intersect these GQRUZs and contaminant locations and may cause migration of contaminants towards the station. Beneficial uses of the groundwater that must be protected are:

- Irrigation
- Industrial water use
- Primary contact recreation (e.g. swimming)
- Buildings and structures (groundwater contamination must not cause corrosion).

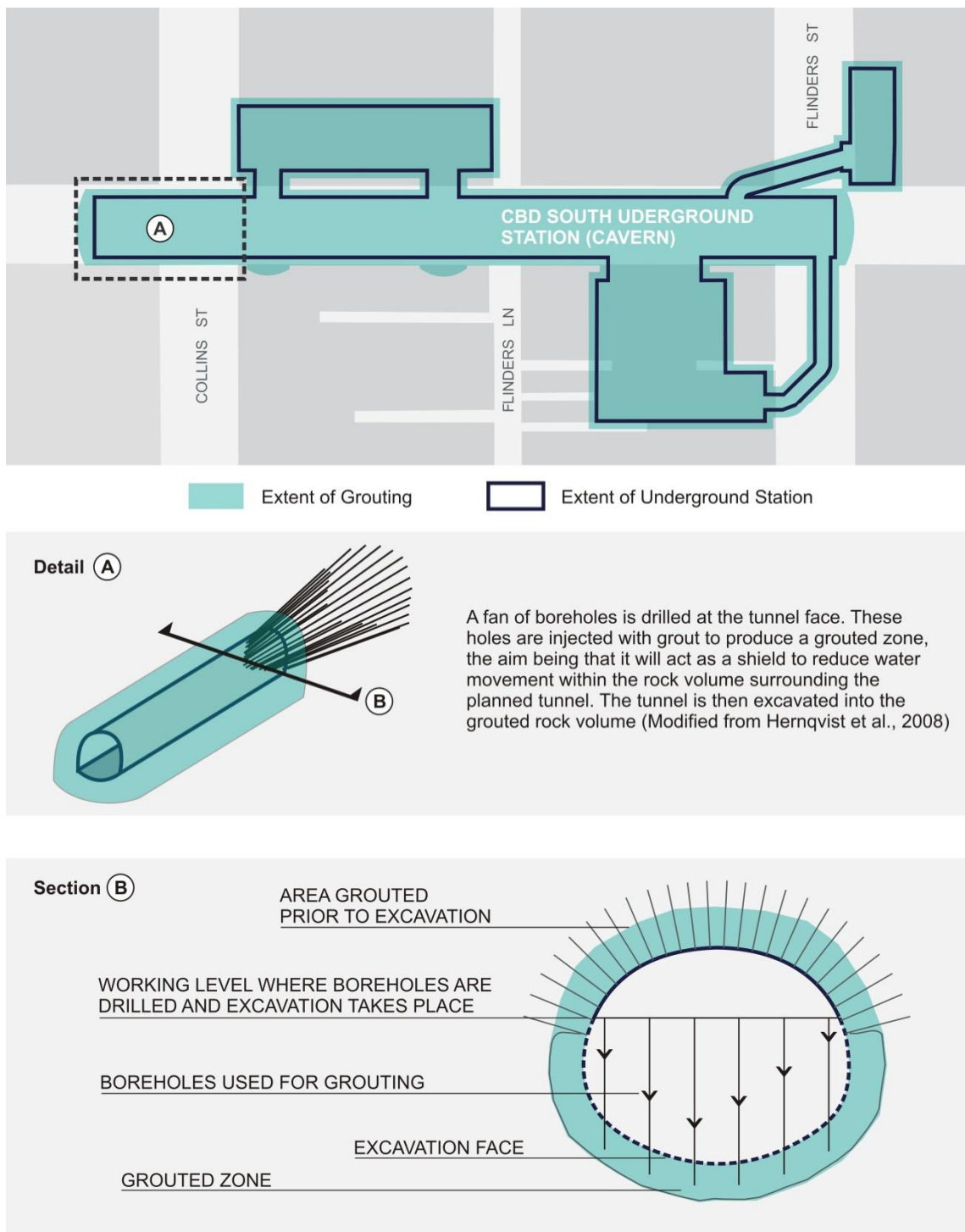
Due to high salinity, the groundwater is not suitable for use as drinking water. Maintenance of ecosystems also does not apply since groundwater does not contribute to the Yarra River. This is not a potential mineral water supply area, and groundwater is not likely to be used for stock watering, so those beneficial uses also do not apply.

The predicted drawdown at these contaminant locations is minor (approximately 0.2 m) and therefore little migration of this contaminated groundwater is likely within the duration of construction. Also, the additional mitigation measures that are likely to be implemented during station construction (e.g. grouting of the station cavern, and groundwater injection bores) would limit inflows and reduce the extent of drawdown. In this mitigated scenario, the GQRUZs are expected to be outside the predicted drawdown cone, and therefore the risk of contaminant migration is low.

#### 12.4.1.3 Mitigation Measures

In order to limit inflows and minimise groundwater drawdown, two mitigation measures have been identified. Grouting of the tunnel and station caverns would reduce groundwater inflows to the excavations. A typical approach to grouting is described in Figure 12-4. The use of temporary injection bores is also proposed. A series of temporary groundwater injection wells could be installed, for example in the locations shown conceptually on Figure 12-5. These wells would be used to inject water into the Moray Street Gravels (the approximate horizontal outline of which is shown as 'MSG outline' in Figure 12.5) during construction to maintain groundwater pressures in the overlying Coode Island Silts.

The detailed design phase of the Melbourne Metro would confirm the construction and operational requirements for these bores, including the number and location of bores, injection rates and schedules, and



**Figure 12-4 Grouting of mined tunnels and station excavation at CBD South station**

injection water source. At this time it is expected that 4 to 6 injection bores into the Moray Street Gravels would be required. Additional modelling would be undertaken during detailed design to confirm the optimal borefield configuration and operational requirements so that drawdown beneath the Coode Island Silt is minimised to prevent damage from subsidence. The Moray Street Gravels is a very permeable aquifer and is an excellent injection target. Based on previous experience on City Link and other projects, there is high confidence that temporary injection bores during construction can readily control groundwater drawdown. Monitoring during construction of CBD South station would also be established to ensure the injection bores are effective at maintaining groundwater levels.

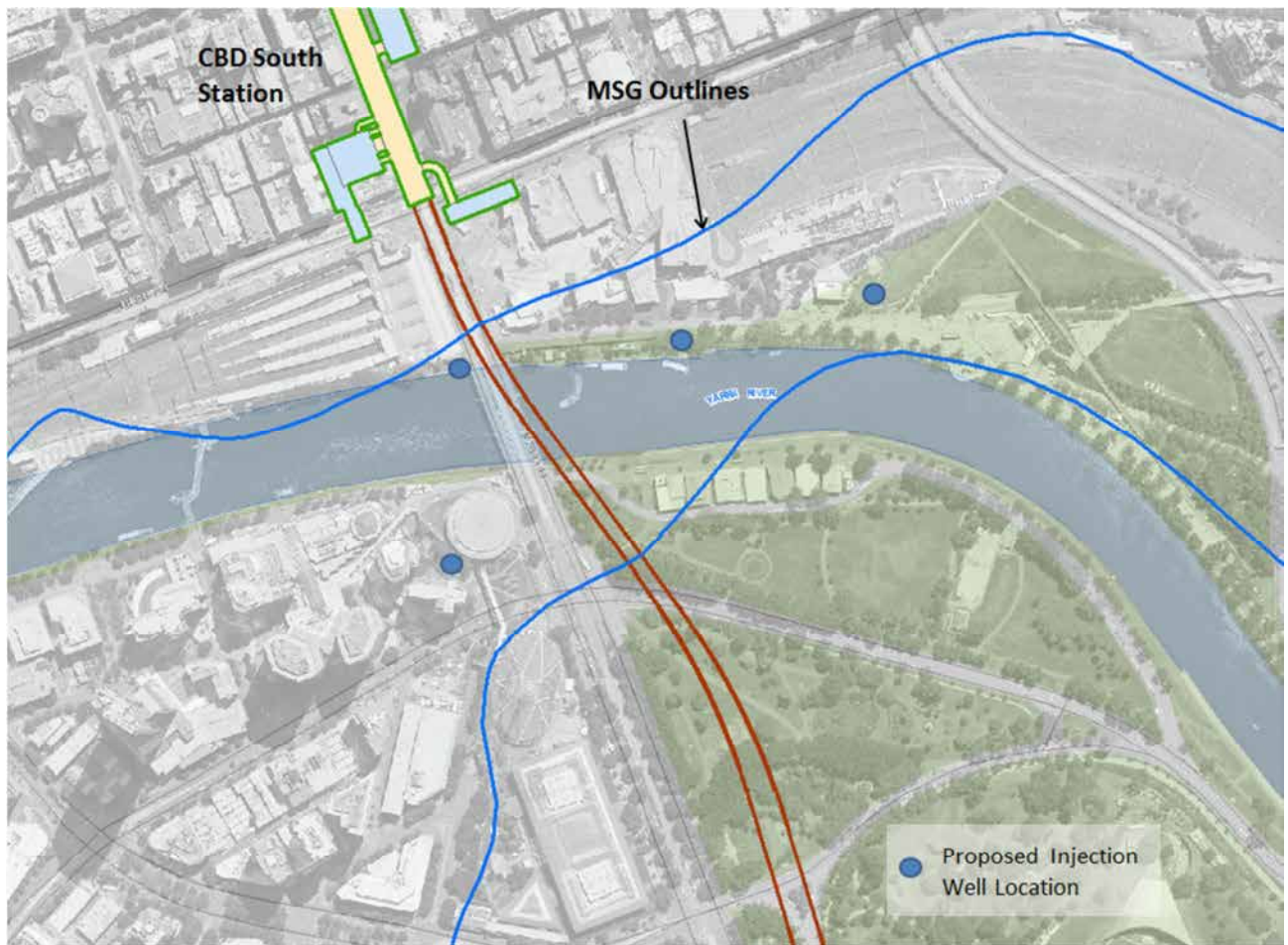


Figure 12-5 Conceptual location of temporary injection wells (MSG = Moray Street Gravels)

## 12.4.2 Operation

CBD South station would be tanked for operation and therefore long term inflows are expected to be minor. The inflow rate is determined by the construction of the tanking and the aim for the structures at CBD South station in the Concept Design is Haack Tightness Class 2, which limits inflow to  $0.05 \text{ L/m}^2$  per day per 100 m length. Drawdown of groundwater levels as a result of these inflows during operation were modelled using a regional groundwater model in FEFLOW. The method and accompanying inputs and assumptions of the numerical modelling are detailed in Golder Associates (2016b, Appendix H of this report).

### 12.4.2.1 Groundwater Drawdown Estimate

The estimated groundwater drawdown as a result of the minor inflows to the tunnels is minimal. At steady state, drawdown immediately above the tunnels is predicted to be less than 0.2 m.

### 12.4.2.2 Potential Impacts

Minimal drawdown is expected at the CBD South station precinct during operation since it is assumed inflows are largely prevented by constructing the station to a Haack 2 tightness classification. Therefore, no impacts on groundwater dependent values are anticipated during operation. If there is any change in construction technique or detailed design that may cause greater inflows, potential drawdown impacts should be assessed for:

- One possible stock and domestic groundwater bore (WRK972626) (**Risk #GW002**)
- Reduced water in the lake in the Royal Botanic Gardens (**Risk #GW010**)



- Large trees that may be using groundwater near the Yarra River and the lake in the Royal Botanic Gardens (**Risk #GW015**)
- Third parties with properties close to possible contaminant plumes (**Risk #GW023**)
- Groundwater acidification due to potentially acid forming sediments (**Risk #GW036**)
- CityLink recharge wells. Impacts may cause depressurisation and potential settlement in the overlying CIS (**Risk #GW044**).

No groundwater dependent surface water bodies are expected to exist in this station precinct.



## 12.5 Environmental Performance Requirements

Table 12-4 provides the recommended Environmental Performance Requirements and proposed mitigation measures for this precinct. In addition to the precinct specific Environmental Performance Requirements below, the project-wide Environmental Performance Requirements of developing a detailed design phase model and a Groundwater Management Plan to assess and manage impacts associated with the detailed design also apply.

**Table 12-4 Environmental Performance Requirements for CBD South precinct**

| Asset / value  | Impact   | Environmental Performance Requirements   | Proposed mitigation measures   | Risk no. |
|--|--|--|--|----------|
| <b>Large trees that may access groundwater</b>   | Construction: uncertain due to lack of knowledge of tree species and their water requirements for large trees outside the Project Boundary, but possible since trees are within drawdown extent. | Develop and implement a Groundwater Management Plan (GMP) detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details: <ul style="list-style-type: none"> <li>Identifying and if necessary, specifying mitigation measures to protect groundwater dependent vegetation during periods of drawdown.</li> </ul> | Deep-rooted tree species in areas of shallow groundwater should be identified and their dependence on groundwater should be assessed. If found to be groundwater dependent, the trees within the area of drawdown should be irrigated throughout the period of drawdown. | GW019    |
|  | Operation: none.   | Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential: <ul style="list-style-type: none"> <li>Reduction in access to groundwater for trees.</li> </ul>  |  |          |
| <b>CityLink recharge wells. Impacts may cause depressurisation and potential settlement in overlying Coode Island Silt</b> | Construction: some drawdown predicted at CityLink recharge bores.<br>Operation: none.  | Develop and implement a GMP detailing groundwater management approaches to address the predicted impacts to groundwater dependent values during construction. The GMP must be based on the detailed design phase groundwater model, and should include the following details: <ul style="list-style-type: none"> <li>Methods for minimising drawdown at any existing recharge bores, and establishing appropriate monitoring networks to confirm effectiveness of mitigation.</li> </ul>           | Mitigation measures would include grouting, and temporary injection bores located in the Yarra paleovalley.  | GW046    |



| Asset / value | Impact | Environmental Performance Requirements   | Proposed mitigation measures | Risk no. |
|---------------|--------|--|------------------------------|----------|
|               |        | <p>Develop and implement a groundwater monitoring plan as part of the GMP that details sufficient monitoring of drawdown to verify that no significant impacts occur from potential:</p> <ul style="list-style-type: none"><li>• Change in groundwater levels in any existing recharge bores that may be present in the area around the project.</li></ul> |                              |          |