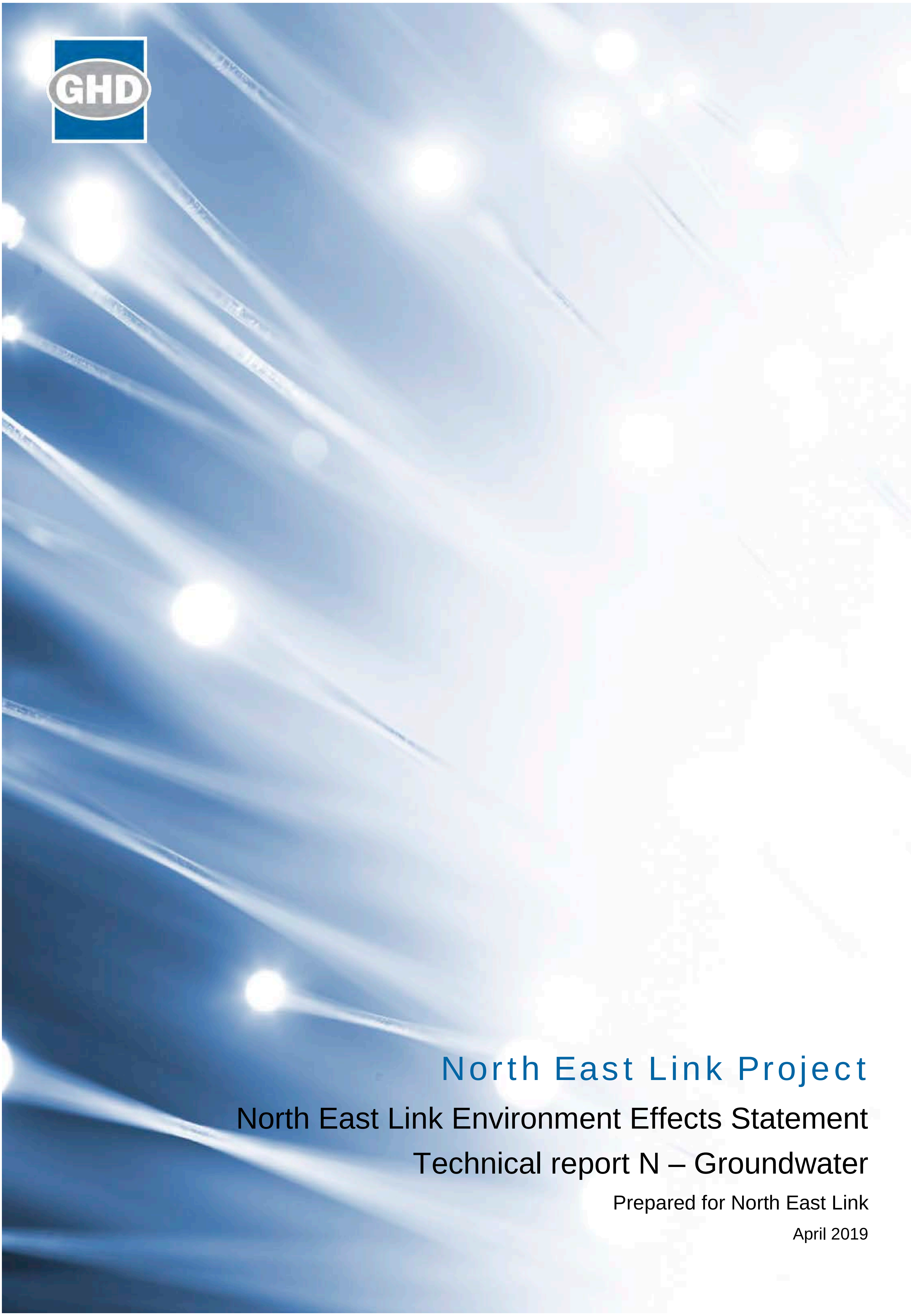
Environment
Effects Statement

Technical Report N
Groundwater



North East Link Project

North East Link Environment Effects Statement

Technical report N – Groundwater

Prepared for North East Link

April 2019

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Executive summary

This technical report is an attachment to the North East Link Environment Effects Statement (EES). It has been used to inform the EES required for the project and defines the Environmental Performance Requirements (EPRs) necessary to meet the EES objectives and set the groundwater quality outcomes for the project.

Overview

North East Link ('the project') is a proposed new freeway-standard road connection that would complete the missing link in Melbourne's ring road, giving the city a fully completed orbital connection for the first time. North East Link would connect the M80 Ring Road (otherwise known as the Metropolitan Ring Road) to the Eastern Freeway, and include works along the Eastern Freeway from near Hoddle Street, to Springvale Road.

The Major Transport Infrastructure Authority (MTIA) is the proponent for North East Link. The MTIA is an administrative office within the Victorian Department of Transport with responsibility for overseeing major transport projects.

North East Link Project (NELP) is an organisation within MTIA that is responsible for developing and delivering North East Link. NELP is responsible for developing the reference project and coordinating development of the technical reports, engaging and informing stakeholders and the wider community, obtaining key planning and environmental approvals and coordinating procurement for construction and operation.

On 2 February 2018, the Minister for Planning declared North East Link to be 'public works' under Section 3(1) of the *Environment Effects Act 1978,* which was published in the *Victorian Government Gazette* on 6 February 2018 (No. S 38 Tuesday 6 February 2018). This declaration triggered the requirement for the preparation of an EES to inform the Minister's assessment of the project and the subsequent determinations of other decision-makers.

The EES was developed in consultation with the community and stakeholders and in parallel with the reference project development. The reference project has been assessed in this EES. The EES allows stakeholders to understand the likely environmental impacts of North East Link and how they are proposed to be managed.

GHD was commissioned to undertake a groundwater impact assessment for the purposes of the EES.

Groundwater context

Groundwater forms an integral part of the water cycle and plays a role in the natural environment. In addition, it is a resource that has many uses. A reference project for North East Link has been prepared and this has been assessed in this EES. This report assesses the changes to groundwater levels (and quality) predicted to occur during construction of the project's tunnels, portals and shafts, as well as during its operation. These changes can influence:

- Existing groundwater users (private bores)
- Streamflow in connected waterways
- Groundwater availability to ecosystems
- Effective stress conditions in compressible geological materials
- The movement of contaminated groundwater (dissolved, vapour and separate phases)

- The stability of potential acid sulfate soils
- Regional groundwater flows.

Control of groundwater drawdown and control of groundwater mounding influences these risks and so mitigation is discussed in this report to ensure the environmental impacts of the project are managed.

The groundwater impact assessment in this report has been used to inform the following impact assessments for the EES:

- Arboriculture – refer Technical report G
- Human health impacts of contaminated groundwater and vapour migration – refer Technical report J
- Aboriginal cultural heritage – refer Technical report L
- Ground movement – refer Technical report M
- Contamination and soil – refer Technical report O
- Surface water – refer Technical report P
- Health of groundwater dependent ecosystems – refer Technical report Q.

Methodology

The scoping requirements for the EES issued by the Minister for Planning set out the specific environmental matters to be investigated and assessed in the EES for the project and to inform the scope of the EES technical studies. The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of constructing and operating the project.

The following evaluation objective is relevant to the groundwater assessment:

- Catchment Values – To avoid or minimise adverse effects on the interconnected surface water, groundwater and floodplain environments

To address the EES scoping requirements and to complete the impact assessment, the following methodology was applied:

- Identification of the study area and documentation of the existing conditions
- Identification of groundwater values in terms of existing and potential beneficial uses
- Conceptualisation of the hydrogeological conditions and potential impact pathways
- Risk assessment to identify the key impact assessment issues
- Numerical groundwater modelling to predict changes to groundwater associated with the project
- Evaluation of potential impacts arising from predicted groundwater changes
- Determination of residual risks and identification of EPRs.

Existing conditions

The existing conditions are summarised as follows:

- The hydrogeology of the project can be broadly divided into two aquifer systems: an alluvial aquifer and a bedrock aquifer system. These are likely to be connected aquifer systems (where alluvials overlie the bedrock) with contrasting aquifer hydraulic properties.
- Existing groundwater use in the region is limited. This is partly due to the urbanised setting, but low bore yields (generally <1 L/s) and saline groundwater tend to reduce abstractive potential.
- The bedrock aquifer groundwater is saline with salinities averaging 5,700 mg/L TDS, and falls within Beneficial Use Category, Segment C. Groundwater within this aquifer is too saline for irrigation and potable use without treatment. Groundwater from the bedrock aquifer could potentially be used for stock and industrial applications. However, because much of the project would be in an urban area there is limited likelihood of these uses being realised.
- The alluvial aquifer has an average groundwater salinity of 2,658 mg/L TDS which reflects its interaction with waterways, and shorter recharge pathways. Groundwater within the alluvial aquifer generally falls within Segment B, but can be within Segment A2 or Segment C. Abstractive development of the alluvial aquifer is limited by production capacities of the aquifer and the requirements of the Water Act 1989 (Vic)in respect of set-backs from waterways. Much of the floodplain where the bulk of the alluvial aquifer is located is not developed and is zoned for public conservation and resource, and public park and recreation purposes.
- Much of the project would be located within public use, public park and recreation and general residential planning zones, which limit the likelihood of having land uses resulting in groundwater contamination. Commercial and industrial land use zones exist within parts of the study area. PFAS contamination has been found at one location near the project and a number of areas where historical landfilling has occurred have been identified.
- Water levels within the study area are variable. On the floodplains, groundwater levels can be within five metres of the surface. As the topography rises above the floodplain, the depth to water increases and is generally 10 metres or greater below the surface.
- Long term groundwater level behaviour is not well understood due to an absence of historical data for the catchments and ongoing monitoring is underway to better understand the level of variability. Available monitoring information indicates seasonal fluctuations of around 1 metre in the bedrock aquifer. To address this data gap, sensitivity and uncertainty analysis has been used to inform the predictive groundwater numerical model.
- Within the study area, the identification of existing groundwater contamination is limited. Hydrocarbon impacted groundwater has been identified in the north-west corner of the Commonwealth land parcel, and is likely to be associated with the fuel service station located in this area. Areas of historical landfilling have been identified to the south of the Commonwealth land at Borlase Reserve (near Lower Plenty Road). PFAS contamination has been found at one location near the former Bulleen Drive-in.

Key findings

For reporting of existing conditions and groundwater impacts, the study area has been divided into three elements:

- M80 Ring Road to northern portal
- Northern portal to southern portal
- Eastern Freeway.

A large proportion of the works in the northern parts of the project's M80 Ring Road to northern portal element and the Eastern Freeway element are predominantly above ground surface and so would have limited interaction with the groundwater environment. Risks to groundwater in these sections are low. This report has therefore focused on the southern parts of the project's M80 Ring Road to northern portal and the northern portal to southern portal elements, where construction works would be below ground and where control of groundwater would be necessary for its construction.

Many of the project's structures within this element are proposed to be constructed using methods that tend to limit long-term groundwater inflow, such as tunnel boring machine (TBM) tunnels with segment lining systems, diaphragms and secant pile walls. As a consequence, the risk assessment concluded the majority of groundwater risks were low.

The majority of groundwater risks would occur during the project's construction, although there would be some risks during its operation as groundwater re-equilibrates after construction and installation of the structures within regional flow paths.

Risks to groundwater quality are most likely during the project's construction, although the implementation of a Construction Environmental Management Plan (CEMP) would address these risks. Groundwater monitoring programs implemented during construction would confirm the effectiveness of the environmental controls of the CEMP, or inform the need for additional controls.

The risk of adverse impacts on existing groundwater users due to drawdown during the project's construction and operation is considered to be low as there is a low density of existing groundwater use in the study area, and most identified bores are used for groundwater investigation or observation purposes.

Potentially acid generating rock has been identified in some parts of the Palaeozoic bedrock, but generally at depth within the lithological profile within fresher rock. Water level recovery from maximum drawdowns predicted to occur during the project's construction reduces the likelihood of long-term oxidation of these materials.

Land with potentially contaminating uses has been identified in local areas in the study area, and while contaminated groundwater has been identified in some of the North East Link groundwater monitoring network (such as one monitoring bore with PFAS), widespread plumes of groundwater contamination have not been identified. Particle tracking has been undertaken to determine the potential behaviour of hypothetical plumes under operating conditions as a conservative measure.

Drawdowns during the project's construction and operation are predicted to extend to sensitive areas such as the Bolin Bolin Billabong, and the Lower Plenty Road cut and cover trench. While some recovery would occur after construction, the structures would present an impediment to groundwater flow which would result in the permanent drawdowns down-gradient (west) of the alignment, and some rise or mounding of water levels up-gradient or east of the alignment. The implications of this drawdown on potential groundwater dependent ecosystems has been assessed in Technical report Q – Ecology.

Groundwater seepage into construction excavations as well as longer-term seepage, albeit at considerably lower volumes, into tanked structures is expected to be saline, based on native groundwater quality. A number of potential options exist for management of this wastewater, such as reuse and sewer disposal and regulatory approvals may be needed once the preferred method has been determined during the project's detailed design phase. In the case of sewer disposal, consideration of cumulative impacts with other infrastructure projects being constructed at the same time, and further discussion with regulators and water authorities would be required once the final design and construction methods were established.

Conclusions

Groundwater risks are associated with changes in groundwater quality and water level. Changes in water level may result in a number of implications to existing users, effective stress conditions of compressible substances as well as movement of groundwater contamination and acid forming materials, and water accessibility to waterways and dependent ecosystems.

These groundwater risks can be controlled or reduced through engineering design and construction methods. These principles have been previously applied to other tunnelling and road construction projects in Victoria. The project could therefore comply with the principles and objectives of the *Water Act 1989* (Vic) and *Environment Protection Act 1970* (Vic) and relevant State Environment Protection Policies (SEPPs).

The groundwater assessment has relied on the prediction of groundwater drawdowns through numerical groundwater modelling. While it is appreciated that modelling has limitations, it has identified key risk areas in terms of drawdown impacts (and mounding) and facilitated the development of Environmental Performance Requirements (EPRs) for the project.

The EPRs for North East Link would require groundwater monitoring, the refinement of the groundwater modelling and the use of construction methods to minimise groundwater inflows and longer-term changes to groundwater levels. Proper implementation of these EPRs should further reduce residual risks to the groundwater environment. It is therefore concluded the project meets the EES evaluation objectives.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 5.8 of this report, and the assumptions and qualifications contained throughout the report.

Structure of the EES

Summary Report

EES main report

1. Introduction
2. Project rationale
3. Legislative framework
4. EES assessment framework
5. Communications and engagement
6. Project development
7. Urban design
8. Project description
9. Traffic and transport
10. Air quality
11. Surface noise and vibration
12. Tunnel vibration
13. Land use planning
14. Business
15. Arboriculture
16. Landscape and visual
17. Social
18. Human health
19. Historical heritage
20. Aboriginal cultural heritage
21. Ground movement
22. Groundwater
23. Contamination and soil
24. Surface water
25. Ecology
26. Greenhouse gas
27. Environmental management framework
28. Conclusion

Technical reports

A. Traffic and transport
B. Air quality
C. Surface noise and vibration
D. Tunnel vibration
E. Land use planning
F. Business
G. Arboriculture
H. Landscape and visual
I. Social
J. Human health
K. Historical heritage
L. Aboriginal cultural heritage
M. Ground movement
N. Groundwater
O. Contamination and soil
P. Surface water
Q. Ecology
R. Greenhouse gas

Attachments

I. Sustainability approach
II. Urban design strategy
III. Risk report
IV. Stakeholder consultation report
V. Draft Planning Scheme Amendment
VI. Works Approval Application

EES Map Book

Abbreviations

Terms	Description
AHD	Australian Height Datum
AMG	Australian Map Grid
AS	Australian Standard
BCL	Bore Construction Licence
bgl	Below Ground Level
bTOC	below Top of Casing
BOM	Bureau of Meteorology
BTEX	Benzene, Toluene, Ethyl benzene and Xylene
CMA	Catchment Management Authority
CRS	Chromium Reducible Sulfur
DELWP	Department of Environment, Land, Water and Planning
DNRE	Department of Natural Resources and Environment
EC	Electrical Conductivity
EMF	Environmental Management Framework
EPA	Environment Protection Authority (Victoria)
EPBC	Environment Protection and Biodiversity Conservation Act 1999
EPR	Environmental Performance Requirement
EVC	Ecological Vegetation Class
FFG	Flora and Fauna Guarantee Act 1988
GDE	Groundwater Dependent Ecosystem
GED	General Environmental Duty
GIS	Geographic Information System
GMA	Groundwater Management Area
GMU	Groundwater Management Unit
HEPA	Heads of EPAs Australia and New Zealand
K	Hydraulic conductivity
km	kilometres
LMP	Local Management Plan
m	Metre
m^2	Square metre
mbgl	Metres below ground level
mm	millimetre

Terms	Description
mS/cm	Millisiemen per centimetre (measure of electrical conducitivity) 1,000 µS/cm=1 mS/cm
Mya	Millions of years ago
MAH	Monocyclic Aromatic Hydrocarbons
MNES	Matters of national environmental significance
MTIA	Major Transport Infrastructure Authority
NAG	Net Acid Generation
NAPP	Net Acid Production Potential
NATA	National Association of Testing Authorities, Australia
NELP	North East Link Project
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NRMMC	Natural Resource Management Ministerial Council
NUDLC	National Uniform Drillers Licensing Committee
PAH	Polycyclic Aromatic Hydrocarbons
PASS	Potential acid sulfate soil
PCE	Tetrachloroethylene
PFAS	Polyfluoroalkyl Substances
PVC	Polyvinyl chloride
PPWCMA	Port Phillip and Westernport Catchment Management Authority
SAFE	Secure Allocation Future Entitlement
SEC	State Electricity Commission
SEPP	State Environment Protection Policy
SON	State Observation Network
SPOCAS	Suspension Peroxide Oxidation Combined Activity and Sulfate
SPPF	State Planning Policy Framework
SRW	Southern Rural Water
SWL	Standing Water Level
Sy	Specific Yield
TBM	Tunnel Boring Machine
TDS	Total Dissolved Solids
TPH	Total Petroleum Hydrocarbons
UXO	Unexploded Ordinance
VAF	Victorian Aquifer Framework

Terms	Description
VVG	Visualising Victoria Groundwater (website/database)
WMIS	Water Measurement Information System
WSPA	Water Supply Protection Area
WWTP	Wastewater Treatment Plant
YVW	Yarra Valley Water

Glossary

Acronym	Definition
Aquifer	A geological formation, group of formations or part of a formation, which contains sufficient saturated permeable material to transmit and yield significant quantities of water.
Alluvial	Pertaining to, or composed of, alluvium or other deposits from streams and rivers.
Alluvium	A general term for unconsolidated material deposited during recent geological time by a stream or other body of running water. Typically forms a sorted or semi-sorted sediment in stream beds, floodplains, deltas or as fan at the base of a mountain slope.
Aquitard	A geological formation or group of formations that is saturated but does not allow water to flow freely to a pumping bore. However, aquitards may transmit appreciable amounts of water between adjacent aquifers.
Aquiclude	A geological formation, group of formations or part of a formation through which virtually no water moves.
Artesian	Pertaining to a confined aquifer in which the head level is above the surface of the ground.
Bedrock	A general term for rock, usually solid, that underlies soil or other unconsolidated material.
Bore screen	The intake portion of bore, which contains open area to permit the inflow of groundwater at a particular depth interval, while preventing sediment from entering with the water. Also serves as a structural retainer to support loose formation material.
Bore casing	Pipes (casing) that extend into the ground through which groundwater can be drawn from the aquifer to the surface. The casing supports the walls and prevents rocks and debris collapsing the bore and contamination by surface runoff.
Bore development	The vigorous agitation of water and air in the borehole to remove fine particles and other material introduced in the drilling process and to provide a good hydraulic connection between the bore and the aquifer.
Bore failure	The condition of a bore once it becomes unserviceable to the point of requiring refurbishment, replacement or decommissioning.
Capillary fringe	The zone above the saturated zone where capillary action can draw groundwater above the water table.
Catchment	The land area that drains into a stream, river, lake, estuary, or coastal zone.
Confined aquifer	An aquifer which is isolated from the atmosphere by an impermeable layer. Pressure in confined aquifers is generally greater than atmospheric pressure.
Contaminant	A substance, element, or compound that, if added to an aquifer, has an adverse effect on the quality of water in that aquifer.
Corrosion	The act or process of dissolving or wearing away a material.
Decommissioned bore	A bore, the purpose and use of which have been permanently discontinued.

Acronym	Definition
Department of Transport	The Victorian Department of Transport is responsible for delivering the government’s transport infrastructure agenda. It was formed on 1 January 2019 when the former Victorian Department of Economic Development, Jobs, Transport and Resources transitioned into the Department of Transport and the Department of Jobs, Precincts and Regions.
Dewatering	The lowering of static groundwater levels through extraction, usually by means of pumping from one or several groundwater bores.
Discharge	Any process by which water is removed from an aquifer. Includes water that flows to a surface feature, such as a spring, river or wetland, as well as water which flows to an adjacent aquifer.
Disinfection	A preventative measure against iron bacteria, potential encrustation and resulting decline in bore efficiency. Disinfection generally involves chemical treatment such as chlorination.
Dissolved oxygen	The amount of oxygen dissolved in water, such as groundwater or surface water. Usually measured in parts per million.
Drawdown	The change in groundwater head level that can be attributed to the operation of a pumping bore.
Ecosystem	A system that is made up of a community of animals, plants, and bacteria and its interrelated physical and chemical environment.
Electrical conductivity	The ability of a material to conduct electricity under an applied voltage. This is used to estimate the Total Dissolved Solids in a water sample.
Erosion	The process or group of processes whereby solids in the natural environment are relocated by moving water, glacial ice or wind.
Evaporation	The process by which liquid water becomes gaseous, or the volume lost from a body of water due to this process.
Evapotranspiration	Pertains to water lost to the atmosphere via evaporation and transpiration of plants.
Fault	A fracture or zone of fractures in a geological layer along which there has been displacement of the sides relative to one another.
Gravel Pack	Granular material introduced into the annulus between the borehole and casing/screen, to prevent or control the movement of finer particles from the aquifer to the bore.
Groundwater	Water occurring naturally below ground level or water pumped, diverted and released into a bore for storage underground.
Groundwater Dependent Ecosystem	An ecosystem that is partially or wholly reliant on groundwater for its survival. This can include terrestrial, subsurface and marine ecosystems.
Groundwater injection bore	A bore installed with the purpose to facilitate the injection of liquid or air into an aquifer. Commonly used in Managed Aquifer Recharge schemes or groundwater remediation.
Groundwater monitoring bore	A bore installed with the purpose to; determine the nature and properties of subsurface ground conditions; provide access to groundwater for measuring level, physical and chemical properties; and permit the collection of groundwater samples and conduct of aquifer testing.

Acronym	Definition
Groundwater pumping (production) bore	A bore installed with the primary purpose to extract groundwater from a particular hydrogeological formation by means of a pump.
Hardness	A measure of the mineral content of water, primarily calcium and magnesium ions. 'Hard' water causes an insoluble residue to form when water is used with soap.
Headworks	The part of a bore that protrudes at the ground surface. Usually entails a concrete collar and pad around the bore casing raised above the natural surface to prevent surface water entering the borehole.
Hydraulic conductivity	The volume of water that can flow through a given area of aquifer material under a given hydraulic head measured in $m^3/day/m^2$ (m/day) and usually assigned the symbol K.
Hydrogeochemistry	The chemical characteristics of water in hydrogeological formations.
Hydrostratigraphy	The identification and distinction of hydrogeological units based on their hydraulic properties.
Igneous rock	Rocks that solidified from molten material, that is, from magma.
Intrusive rock	Igneous rocks formed from magma injected beneath the Earth's surface. Generally these rocks have large crystals caused by slow cooling.
Lithology	The physical character of a rock or rock formation.
Major Transport Infrastructure Authority	The Major Transport Infrastructure Authority is the proponent for North East Link. The MTIA is an administrative office within the Victorian Department of Transport with responsibility for overseeing major transport projects.
North East Link Project	North East Link Project is an organisation within MTIA that is responsible for developing and delivering North East Link. NELP was formerly known as the North East Link Authority prior to 1 January 2019. NELP is responsible for developing the reference project and coordinating development of the technical reports, engaging and informing stakeholders and the wider community, obtaining key planning and environmental approvals and coordinating procurement for construction and operation.
Oxygen reduction potential	A measure of a water system's capacity to either release or gain electrons in chemical reactions. The process of oxidation involves losing electrons while reduction involves gaining electrons.
Permeability	The property or capacity of a porous rock, soil or sediment for transmitting a fluid; it is a measurement of the relative ease of fluid flow within a material.
pH	A measure of the acidity or alkalinity of a solution. Neutral solutions have a value of 7, this value increases for alkaline solutions and decreases for acidic solutions.
Porosity	The percentage of the bulk volume of a soil or rock that is occupied by interstices, whether isolated or connected. It is a measure of the void space in a material. Primary porosity is the originally porosity system in a rock or the interstices of a porous media (shape, arrangement, distribution, cementation, compaction). Secondary porosity can result from fracturing or chemical leaching.
Pumping test	A test that is conducted to determine aquifer or well characteristics.
Recharge	The process of adding water, or the amount of water added, to the volume of water stored in an aquifer.

Acronym	Definition
Reticulation	Refers to the network of piped-water, as opposed to water within a groundwater bore.
Salinity	A measure of the dissolved salt content of water or soil.
Scaling	Deposition of solid solutes from water on a surface.
Sedimentary rock	Rocks resulting from the consolidation of loose sediments that has accumulated in layers.
Standing water level	The level of water in a well or bore that is not being affected by pumping of groundwater.
Stratigraphy	The study of rock layers and layering, especially of their distribution, deposition and age.
Sub-Artesian	Conditions where groundwater rises naturally in a bore to a height appreciably above that of the surrounding water table, but not flowing out of the bore.
Surface water	Any water that collects as a surface features, including rivers, streams, lakes, wetlands and the ocean.
Sustainable yield	The groundwater extraction regime, measured over a specified planning timeframe that allows acceptable levels of stress on an aquifer system while still protecting the higher value uses associated with the total resource.
Total dissolved solids	The total mass of all solids dissolved in a water sample, measured in mg/L.
Transmissivity	The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.
Unconfined aquifer	An aquifer which has the upper surface exposed to the atmosphere.
Vadose zone	The subsurface zone between ground level and the saturated zone, that is, the water table.
Water table	The surface between the vadose zone and the saturated zone of unconfined groundwater. This can also be defined as the surface at which groundwater pressure is equal to atmospheric pressure.
Water Quality	The physical, chemical and biological characteristics of water, frequently used by reference to a set of standards against which compliance can be assessed.
Wetland	An area of land whose soil is saturated with moisture either permanently or seasonally. Such areas may also be covered partially or completely by shallow pools of water. Wetlands include swamps, marshes, and bogs, among others.
Yield	The rate at which water can be extracted from a pumping well, typically measured in L/sec or ML/day.

1. Introduction

1.1 Purpose of this report

North East Link ('the project') is a proposed new freeway-standard road connection that would complete the missing link in Melbourne's ring road, giving the city a fully completed orbital connection for the first time. North East Link would connect the M80 Ring Road (otherwise known as the Metropolitan Ring Road) to the Eastern Freeway, and include works along the Eastern Freeway from near Hoddle Street to Springvale Road.

The Major Transport Infrastructure Authority (MTIA) is the proponent for North East Link. The MTIA is an administrative office within the Victorian Department of Transport with responsibility for overseeing major transport projects.

North East Link Project (NELP) is an organisation within MTIA that is responsible for developing and delivering North East Link. NELP is responsible for developing the reference project and coordinating development of the technical reports, engaging and informing stakeholders and the wider community, obtaining key planning and environmental approvals and coordinating procurement for construction and operation.

On 2 February 2018, the Minister declared the works proposed for North East Link as Public Works and issued a decision confirming that an Environment Effects Statement (EES) is required for the project due to the potential for significant environmental effects.

Similarly, the project was referred to the Australian Government's Department of the Environment and Energy on 17 January 2018. On 13 April 2018 the project was declared a 'controlled action', requiring assessment and approval under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). Separate to this EES, a Public Environment Report (PER) is required to be prepared to satisfy the EPBC Act requirements, and assess the impacts of the project on Commonwealth land and matters of national environmental significance (MNES).

The purpose of this report is to assess the potential [technical area] impacts associated with North East Link and to define the Environmental Performance Requirements (EPRs) necessary to meet the EES objectives.

1.2 Why understanding groundwater is important

1.2.1 What is groundwater?

Groundwater is water located beneath the earth's surface and forms an integral part of the water cycle. Groundwater is stored and transmitted through the tiny pore spaces between soil and rock particles, or cracks, fractures, and crevices with the rock itself. These saturated (water filled) soils and rocks are classified into two basic types:

- **Aquifers** – which are geological materials such as unconsolidated sediments (gravel, sand or silt), permeable rock or fractured rock that can transmit large quantities of water
- **Aquitards** – which are geological materials are of low permeability and have a tendency to limit the flow of groundwater (such as clays and silts)

There are three phases of the groundwater cycle: recharge, storage and transmission, and discharge. Groundwater is sourced from water that originates above the ground from rainfall that has infiltrated into soil or rocks, or from surface water from rivers, streams and other waterways that has seeped into the subsurface.

The infiltrating waters progress through soils and rocks, which may not be completely filled with water (unsaturated zone), to the water table. The water table represents the upper surface of the zone of saturation within an aquifer. Within the aquifer, groundwater will flow under hydraulic gradients; that is, from high water pressure areas (hydraulic head) towards low water pressure zones, and ultimately towards a discharge zone.

In completing the water cycle, groundwater moves out of an aquifer and discharges to connected waterways such rivers, swamps, seeps and springs, or to the ocean. As it is part of a cycle, it is considered to be a finite resource.

Recharge and discharge could be considered as the ‘input’ and ‘output’ of an aquifer system and respectively, the start and end points of a groundwater flow regime. The nature of this flow process (geology, residence time) influences the groundwater quality, but it can also become contaminated by anthropogenic processes. Groundwater can be abstracted for human benefit (for example, for irrigation or drinking) or to support the environment (for example, by providing a flow component to waterways or water that is accessible by plants and their associated ecosystems).

Topography can influence groundwater flow regimes, and flow regimes have been characterised as being local, intermediate or regional (Tóth, 1963), based on the depth and length of flow paths, and the scale of investigation. These characterisations are shown in Figure 1-1 and referred to throughout this report:

- **Local groundwater flow regimes** describe local variations in flow directions in response to local undulations in topography. These local regimes occur close to the ground surface and are seasonally dynamic, responding to temporal variations in recharge processes. Local flow regimes are usually associated with shallow groundwater. Figure 1-1 provides a conceptual example of local flow through the shallow, short arrows.
- **Regional groundwater flow regimes** describe regional variations in flow directions driven by regional differences in topography and the location of regional recharge and discharge zones. These regional regimes typically occur on a catchment scale, with groundwater flowing over distances of several kilometres at depths greater than the local regimes. Since most parts of the regional flow regimes are deep and have longer flow paths, they are less responsive to seasonal variations in groundwater recharge.

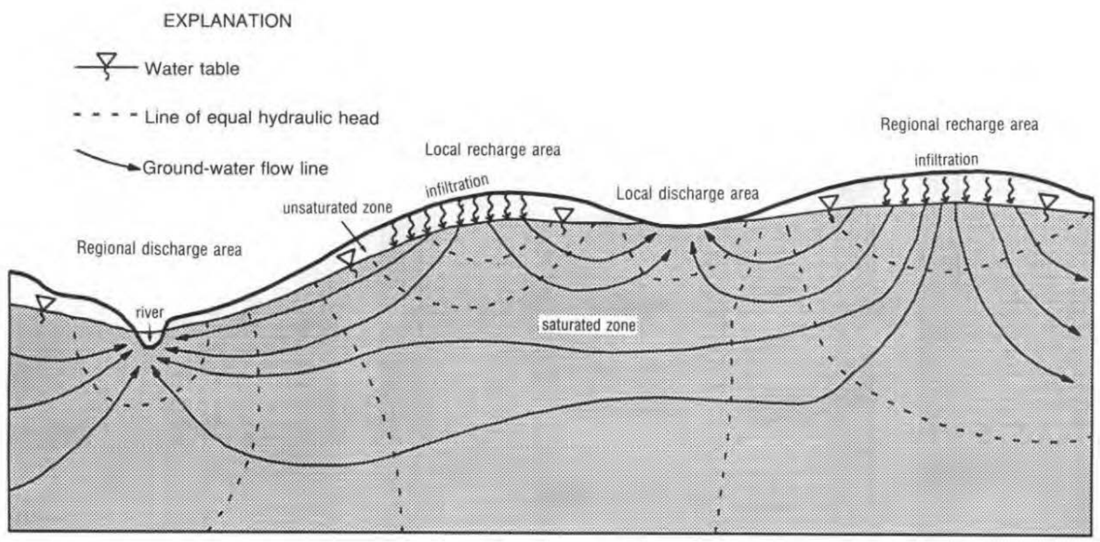

Figure 1-1 Local and regional groundwater flow regimes

Source: Fleming, 1994

An intermediate flow regime is sometimes used to subjectively describe flow that occurs between the local and regional regimes, depending on the size of the study area and processes of interest. In the context of this project, the local regime that interacts with the project is of most relevance, while intermediate and regional regimes have been considered collectively as a regional regime.

1.2.2 Who relies on groundwater?

Groundwater can have many and varied uses that may benefit people and the environment – these are generally referred to as 'beneficial uses'. The main beneficial users of groundwater relevant to this project are outlined below. Consistent with relevant groundwater legislation, existing as well as potential beneficial uses need to be considered.

Groundwater users

Groundwater has long been utilised as a water resource in Australia, a continent with historically low and unreliable surface water resources. In Victoria, groundwater resources are used primarily for agriculture irrigation purposes (DELWP, 2017[1]), with use generally being seasonal as irrigators typically pump groundwater in late Spring and Summer to address rainfall deficits. In addition, groundwater is used for industrial or commercial purposes, for municipal supply or for stock or domestic purposes. The use of groundwater for purposes other than stock and domestic use requires an extraction licence (such as for groundwater extraction bores).

At the national and state levels, Australian governments have policies to manage groundwater. These plans aim to achieve a balance between water use and the water needs of the environment, as well as controlling groundwater pollution and overuse.

Groundwater dependent ecosystems

In considering the role of groundwater in the study area, an understanding of the ecosystem dependence on groundwater is an important consideration.

A groundwater dependent ecosystem (GDE) is an ecosystem that has its species composition and natural ecological processes determined by groundwater. That is, GDEs are natural ecosystems that require access to groundwater to meet all, or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services.

GDE reliance on groundwater is shown in the study area via direct groundwater discharge to surface waters (such as baseflow to wetlands), and/or via evapotranspiration from the water table by vegetation. The degree of groundwater dependence typically varies temporally and or opportunistically, depending on the availability of other sources of water (for example, prevailing climate and runoff during wetter periods). Groundwater dependence is also spatially variable, as dictated by factors including topography, water table depth and vegetation rooting depth, soil types and groundwater quality.

The primary classes for categorising GDEs include (Eamus *et al.*, 2006):

a. **Ecosystems reliant on surface expressions of groundwater** – including baseflow rivers and streams, wetlands, some floodplains and mound springs and associated vegetation (where surface expressions of groundwater may penetrate to the root zone).

b. **Ecosystems reliant on subsurface presence of groundwater** – terrestrial vegetation that does not require surface expressions of groundwater.

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[1] https://www.water.vic.gov.au/groundwater/victorias-groundwater-resources

Within the study area, GDEs are most likely to occur as the following categories (Land and Water Australia, 2006):

- **Terrestrial vegetation** – vegetation communities (and dependent fauna) that obtain at least part of their water requirements from groundwater, but are not totally reliant on surface waters.
- **Wetlands** – aquatic communities and fringing vegetation in which groundwater provides at least seasonal water logging or inundation.
- **River base flow systems** – aquatic and riparian ecosystems that are dependent on groundwater-derived stream flow or bank storage for their baseflow. This category of GDE includes the hyporheic communities associated with river beds and banks.

Surface water levels in wetlands are maintained by groundwater discharges known as baseflow. Groundwater can flow (discharge) into a wetland, if the wetland water level is lower than the surrounding groundwater level. The degree of groundwater dependence is reliant on the location setting (such as topography, geology, climate, surface water drainage, water table depth and vegetation rooting depth) and can be temporally variable. For instance, some vegetation may rely on groundwater during drought periods.

1.2.3 Potential project impacts to groundwater

North East Link would involve the construction of structures such as tunnels and deep cuttings, which would in places be located below the water table. To main safe working conditions, and to enable construction, management of groundwater would be required during construction. During the project’s operation, seepage into structures would still occur (albeit at lower rates) depending on the water tightness of structures.

While fluctuations in the water table occur naturally (for example, the water table would become deeper during Summer due to less rainfall recharge), human-induced water table fluctuations could also occur. Water level fluctuations may be described as:

- **Groundwater ‘drawdown’** refers to the lowering of the water table from the existing groundwater level. In the context of this study, it relates to reduced (deeper) groundwater levels resulting from dewatering activities required to excavate structures below the water table, or groundwater seepage into structures located below the water table. It can also result from the extraction of groundwater for construction water supply purposes.
- **Groundwater ‘mounding’** refers to the raising of the water table from the existing groundwater level. In the context of this study, it relates to increased (shallower) groundwater levels that could result from recharge of aquifers (such as from groundwater disposal) or from structures that create a barrier to regional groundwater flow.

The drawdown due to the extraction of groundwater from a water bore is shown in Figure 1-2.

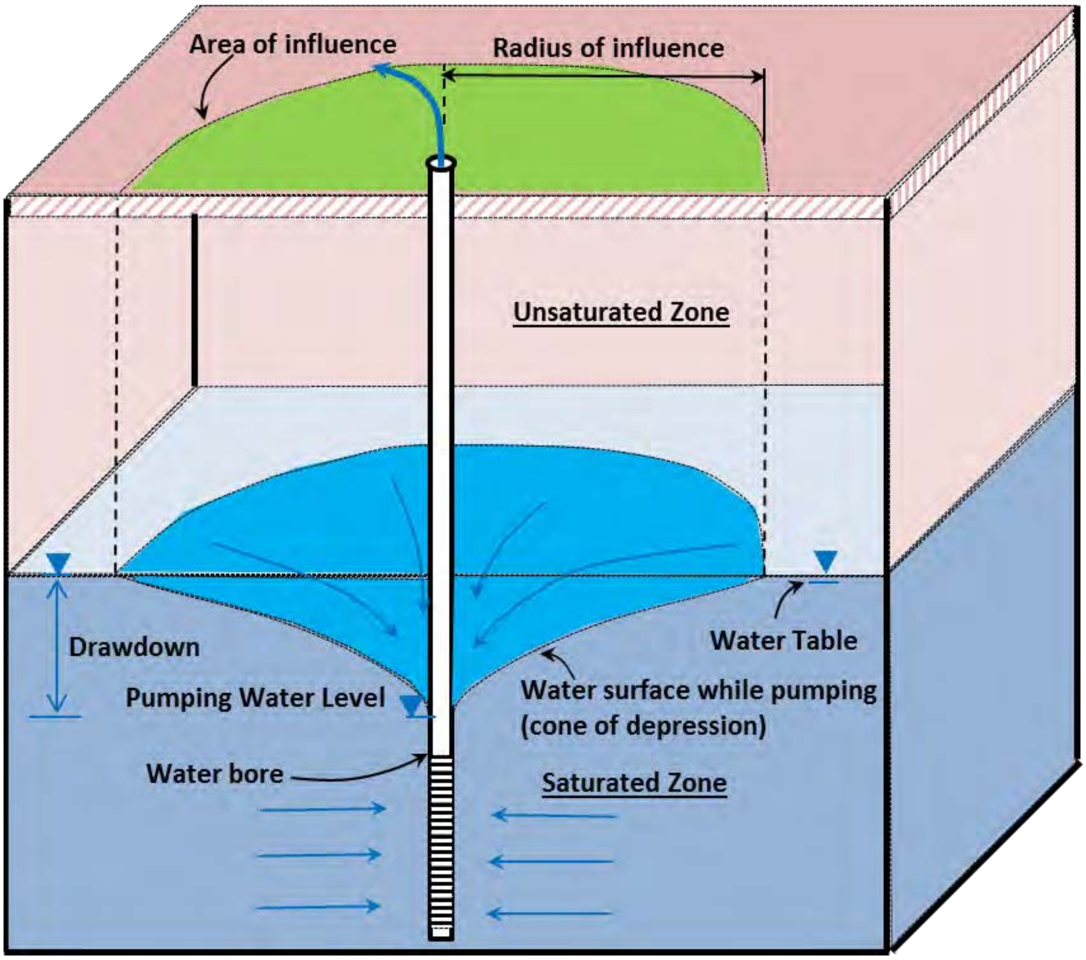


Figure 1-2 Drawdown from groundwater pumping

Changes in groundwater level affect flow regimes and without adequate controls, impacts may result. Drawdown of water levels has the potential to influence the stability of potential acid sulfate soils, effective stress changes and subsidence, water availability to ecosystems, and also the movement of contaminated groundwater plumes.

The potential for North East Link to cause the degradation of groundwater quality has also been considered, whereby:

Groundwater quality refers to changes to the native, or background groundwater quality due to the project's construction and operation. This may result from the exposure and activation of potential acid generating soils, movements of contaminated groundwater plums, the storage and handling of hazardous materials, or incorporation of incompatible construction materials into the project.

2. EES scoping requirements

2.1 EES evaluation objectives

The scoping requirements for the EES issued by the Minister for Planning set out the specific environmental matters to be investigated and assessed in the EES for the project and inform the scope of the EES technical studies. The scoping requirements include a set of evaluation objectives. These objectives identify the desired outcomes to be achieved in managing the potential impacts of constructing and operating the project.

The following evaluation objective is relevant to the Groundwater assessment:

- Catchment Values – To avoid or minimise adverse effects on the interconnected surface water groundwater and floodplain environments.

The groundwater assessment also informs the Ground Movement studies, which have a relatable objective of avoiding or minimising adverse effects on land stability from project activities, including tunnel construction and river and creek crossings.

2.2 EES scoping requirements

The aspects from the scoping requirements relevant to the groundwater evaluation objective are shown in Table 2-1, as well as the location where these items have been addressed in this report.

Table 2-1 Scoping requirements relevant to groundwater

Aspect	Scoping requirement	Section addressed
Key issues	Potential for project works to affect waterways, groundwater and hydrology, including with respect to flooding and future climate change scenarios.	Section 1.1
	Potential for contaminated run-off or other water, including groundwater, to be discharged into surface waters or groundwater environments.	Section 8.3 8.4 and 8.5
	Potential for migration or disturbance of anthropogenic contaminated soil or groundwater or naturally occurring acid forming materials.	Section 8.3 8.4 and 8.5
Priorities for characterising the existing environment	Document the key assumptions to be adopted in the surface and groundwater hydrological analysis with respect to future climate change scenarios.	Section 6 (6.1 to 6.16)
	Identify existing groundwater conditions and characteristics within the general area that might be affected by project works.	
	Identify known and potentially contaminated sites and ground conditions including acid forming materials.	
Design and mitigation measures	Describe measures to protect groundwater and aquifers, including with respect to the potential effects of constructing and operating the road tunnel.	Section 5.5 Section 8 (8.3.1 and 8.3.2)

Aspect	Scoping requirement	Section addressed
Assessment of likely effects	Assess residual effects on quality and availability of groundwater and water quality in receiving waters, having regard to existing water quality conditions, proposed mitigation measures and relevant SEPP standards.	Section 8 (8.3.1 and 8.3.2)
	Assess residual effects of short-term or longer-term changes to groundwater conditions, with particular regard to ground subsidence, tunnel drainage, groundwater availability and quality, relevant SEPP standards and beneficial uses.	
	Assess residual effects on surface and groundwater users or environmental values from changes in hydrology, contaminated soil, acid forming materials or contaminated groundwater.	
	Undertake sensitivity analysis, if required	
Approach to manage performance	Describe the environmental performance requirements to set surface water and groundwater quality outcomes as well as groundwater level or flood behaviour outcomes that the project must achieve.	Section 9

Note: Under habitat and biodiversity a priority for the characterising the existing environment is to 'Identify and characterise any groundwater dependant ecosystems that may be affected by altering the hydrogeological environment (particularly by dewatering)'. This is addressed in Technical report Q Ecology, which is informed by this assessment.

2.3 Linkages to other reports

This report relies on or informs the technical assessments as indicated in Table 2-2

Table 2-2 Linkages to other technical reports

Specialist report	Relevance to this impact assessment
Technical report M – *Ground Movement*	Groundwater numerical modelling provides an estimate of the predicted change in water levels from construction dewatering, and over the longer term operating conditions.
Technical report O –*Contamination and soil*	Characterises the presence of PASS materials and sites with potentially contaminating land use activities (historical and present). This informs risks of contaminated groundwater.
Technical report P – *Surface water*	Provides an assessment of the projects effects on creeks and rivers.
Technical report J – *Human health*	Provides an assessment of impacts of contaminated groundwater and vapour migration on human health
Technical report Q – *Ecology* Technical report L – *Aboriginal Cultural Heritage* Technical report G – *Arboriculture*	Groundwater numerical modelling provides an estimate of the predicted change in water levels from construction dewatering, and over the longer term operating conditions. The impact of these changes in groundwater level on terrestrial vegetation (including scarred trees) and groundwater dependent ecosystems are assessed by the ecological specialist discipline.

3. Project description

3.1 Overview

The North East Link alignment and its key elements assessed in the Environment Effects Statement (EES) include:

- **M80 Ring Road to the northern portal** – from the M80 Ring Road at Plenty Road, and the Greensborough Bypass at Plenty River Drive, North East Link would extend to the northern portal near Blamey Road utilising a mixture of above, below and at surface road sections. This would include new road interchanges at the M80 Ring Road and Grimshaw Street.
- **Northern portal to southern portal** – from the northern portal the road would transition into twin tunnels that would connect to Lower Plenty Road via a new interchange, before travelling under residential areas, Banyule Flats and the Yarra River to a new interchange at Manningham Road. The tunnels would then continue to the southern portal located south of the Veneto Club.
- **Eastern Freeway** – from around Hoddle Street in the west through to Springvale Road in the east, modifications to the Eastern Freeway would include widening to accommodate future traffic volumes and new dedicated bus lanes for the Doncaster Busway. There would be also a new interchange at Bulleen Road to connect North East Link to the Eastern Freeway.

These elements are illustrated in Figure 3-1.

The project would also improve existing bus services from Doncaster Road to Hoddle Street through the Doncaster Busway as well as pedestrian connections and the bicycle network with connected walking and cycling paths from the M80 Ring Road to the Eastern Freeway.

For a detailed description of the project, refer to EES Chapter 8 – Project description.

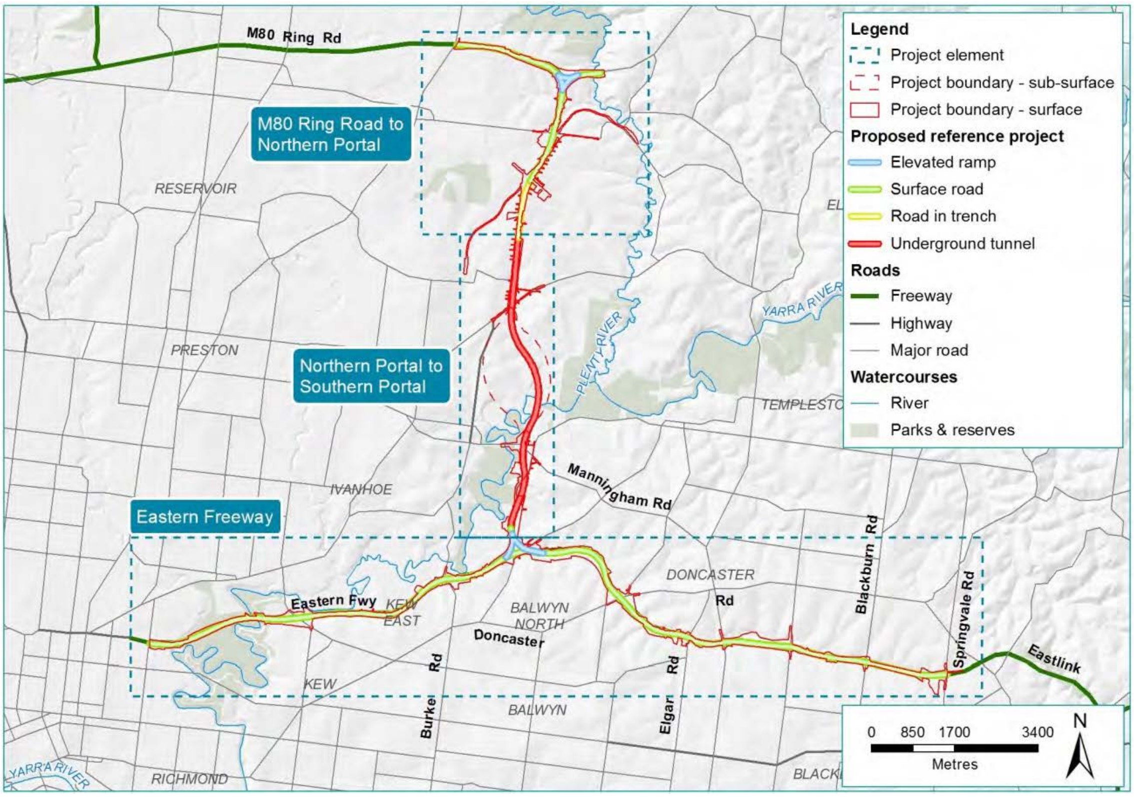


Figure 3-1 Overview of North East Link

3.2 Construction

Key construction activities for North East Link would include:

- General earthworks including topsoil removal, clearing and grubbing vegetation
- Relocation, adjustment or installation of new utility services
- Construction of retaining walls and diaphragm walls including piling
- Ground treatment to stabilise soils
- Tunnel portal and dive shaft construction
- Storage and removal of spoil
- Construction of cross passages, ventilation structures and access shafts
- Installation of drainage and water quality treatment facilities
- Installation of a Freeway Management System
- Tunnel construction using tunnel boring machines (TBMs), mining and cut and cover techniques
- Installation of noise barriers
- Restoration of surface areas.

3.3 Operation

Following construction of North East Link, the operation phase activities would include:

- Operation and maintenance of new road infrastructure
- Operation and maintenance of Freeway Management System
- Operation of North East Link motorway control centre
- Operation and maintenance of the tunnel ventilation system
- Operation and maintenance of water treatment facilities
- Operation and maintenance of the motorways power supply (substations)
- Maintenance of landscaping and Water Sensitive Urban Design (WSUD) features.

3.4 Activities and design considerations relevant to groundwater

Activities and design considerations relevant to groundwater, not included in the project description but which are particularly relevant to the groundwater studies include:

- The water tightness of underground structures and tanking conditions
- Specific detail of a potential construction program, including estimated timings on excavation activities.

Where this information is absent, a number of assumptions were made in the analysis and assessment of impacts, and these have been documented in the appropriate sections of this report.

4. Legislation, policy and guidelines

4.1 Commonwealth legislation

A summary of Australian Government legislation relevant to the project is provided in Table 4-1.

Table 4-1 Summary of Commonwealth legislation

Act	Description
National Environment Protection Council Act 1994 ('NEPC Act')	The NEPC Act resulted in the establishment of the National Environment Protection Council (NEPC) and National Environment Protection Measures (NEPMs). NEPMs are a set of national objectives designed to assist in protecting or managing particularly aspects of the environment. A NEPM was established for the Assessment of Site Contamination (ASC) (NEPC 1999) which was amended in 2013. The NEPM (ASC) provides a national approach to provide adequate protection of human health and the environment, where site contamination has occurred, through the development of an efficient and effective national approach to the assessment of site contamination. This is considered a relevant guideline as contaminated groundwater (and water, land, air) may be encountered by the project. *No approvals are required under the NEPM Act.*
Environment Protection and Biodiversity Conservation Act 1999 ('EPBC Act')	The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places – which are defined in the EPBC Act as Matters of National Environmental Significance (MNES). The EPBC Act has the following objectives: • Provide for the protection of the environment, especially matters of national environmental significance • Conserve Australian biodiversity • Provide a streamlined national environmental assessment and approvals process • Enhance the protection and management of important natural and cultural places • Control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife • Promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources • Recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity • Promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge. The Australian Department of Sustainability and Environment, People and Communities (DSEWPAC, 2013) provides for protection of environmental matters on Commonwealth land.

Act	Description
	Amendments made to the EPBC Act 1999 in 2013 made water resources a MNES, in relation to coal seam gas and large coal mining development. *Referral submitted to the Australian Government Minister for the Environment. Project determined to be a controlled action.* *Proposed action is to be assessed via a Public Environment Report (PER) and the accredited state process of an EES.*

4.2 State legislation

A summary of Victorian legislation relevant to the project is provided in Table 4-2.

Table 4-2 Summary of State legislation

Act	Description
Water Act 1989	In the context of groundwater, the Water Act principally deals with the sustainable, efficient and equitable management and allocation of the resource. It also provides a means for the protection and enhancement of all elements of the terrestrial phase of the water cycle. Under the Water Act, approvals are required for: • Construction of bores for monitoring, dewatering, or aquifer recharge. • Extraction of groundwater, or aquifer reinjection/recharge.
Environment Protection Act 1970	The Environment Protection Act empowers the Environment Protection Authority Victoria (EPA Victoria) to implement regulations, maintain State Environment Protection Policies (SEPPs) and protect the environment from pollution and the management of wastes. The Act regulates the discharge or emission of waste to water, land or air by a system of Works Approvals and licences. It has the objectives of preventing and managing pollution and environmental damage, and the setting of environmental quality goals and programs. No groundwater approvals are expected to be required under the Environment Protection Act. If aquifer reinjection involves brines, the volume proposed to be injected may trigger the need for a waste discharge licence.
Environmental Protection Amendment Act 2018	A key part of the Environment Protection Amendment Act is the general environmental duty (GED). This approach focuses on preventing waste and pollution impacts rather than managing those impacts after they have occurred. This duty requires people to undertake reasonably practicably steps to eliminate, or otherwise reduce risks of harm to human health and the environment from pollution and waste. A breach of GED could lead to criminal or civil penalties. This concept is analogous to Victoria's existing Occupational Health and Safety laws.
Yarra River Protection (Willip-gin Birrarung Murron) Act 2017	In 2017 legislation was introduced in Victorian Parliament to protect the Yarra River through the Yarra River Protection (Willip-gin Birrarung Murron) Act (Yarra River Protection (Willip-gin Birrarung Murron) Act) (Melbourne Water, 2018b). Melbourne Water is leading the development of the Yarra Strategic Plan which will underpin the Yarra River Protection (Willip-gin Birrarung Murron) Act.

Act	Description
Climate Change Act 2017	The Climate Change Act provides Victoria with a legislative foundation to manage climate change risks, maximise the opportunities from decisive action and drive a transition to a climate resilient community and economy with net zero emissions by 2050.
Environment Effects Act 1978	The Environment Effects Act provides for assessment of proposed projects (works) that are capable of having a significant effect on the environment. The responsible Minister decides whether an Environment Effects Statement (EES) should be prepared. The EES process involves: • Referral to the Minister for Planning • The Minister's decision on the need for an EES • Preparation of scoping requirements for the EES studies and reporting • Preparation of the EES report • Public review (exhibition and lodgement of submissions) • Ministerial assessment of environmental effects • Consideration of the assessment.

4.3 State and local planning schemes

The State Planning Policy Framework (SPPF) is common to all Victorian planning schemes, and contains policies in relation to various themes policies, guidelines and standards. The SPPF has specific provisions relating to the environment, specifically the protection of catchments, waterways and groundwater.

In terms of strategies within specific clauses:

- *Clause 12.03-1S River corridors, waterways, lakes and wetlands*
  To protect and enhance river corridors, waterways, lakes and wetlands.
- *Clause 12.03-1R Yarra River protection*
  To maintain and enhance the natural landscape character of the Yarra River corridor.

  Clause 13.01 – 1S Natural hazards and climate change
  To minimise the impacts of natural hazards and adapt to the impacts of climate change through risk-based planning
- *Clause 13.04-3S Salinity*
  To minimise the impact of salinity and rising water tables on land uses, buildings and infrastructure in rural and urban areas and areas of environmental significance and reduce salt load in rivers.
- *Clause 14.02 – 1S Catchment planning and management*
  To assist the protection and restoration of catchments, water bodies, groundwater, and the marine environment.
- *Clause 14.02-2S Water quality*
  To protect water quality
- *Clause 19.03-3S Integrated water management*
  To sustainably manage water supply, water resources, wastewater, drainage and stormwater through an integrated water management approach.

The above clauses apply across the state, but each local council within the North East Link project area may have additional clauses in its local planning scheme relating to groundwater and sustainable environmental practices.

4.4 Policies, guidelines and standards

4.4.1 National guidelines and policies

A number of national guidelines are relevant to groundwater and these are summarised in Table 4-3.

Table 4-3 Summary of national guidelines

Policy/Guideline	Description
Groundwater Modelling Guidelines 2012	The objective of the guidelines is to promote a consistent and sound approach to the development of groundwater flow and solute transport models in Australia. Modelling undertaken to assess impacts to groundwater has adopted these guidelines.
Minimum Construction Requirements for Water Bores in Australia 2012	The guidelines outline the minimum requirements for constructing, maintaining, rehabilitating, and decommissioning water bores in Australia. They are used extensively by regulators and the drilling industry, and provides a consistent standard reference across Australia for the licensing of bores and drillers. Geotechnical investigations undertaken to characterise the groundwater environment of the project have adopted these guidelines.
NHMRC, NRMMC 2011 Australian Drinking Water Guidelines 6	The guidelines are intended to provide a framework for good management of drinking water supplies that, if implemented, will assure safety at point of use. The ADWG have been developed after consideration of the best available scientific evidence. These guidelines have been applied to assess groundwater quality.
ANZECC, ARMCANZ 2000 Australian and New Zealand Guidelines for fresh and marine water quality.	The guidelines outline the management framework recommended for applying the water quality guidelines to the natural and semi-natural marine and fresh water resources in Australia and New Zealand. The guidelines provide a summary of the water quality objectives proposed to protect and manage the environmental values supported by the water resources, and advice on designing and implementing water quality monitoring and assessment programs. These guidelines have been updated in 2018 and applied to assess groundwater quality.
NHMRC 2008 Guidelines for Managing Risks in Recreational Waters	The primary aim of these guidelines is to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters. Threats may include natural hazards such as surf, rip currents and aquatic organisms, and those with an artificial aspect, such as discharges of wastewater. These guidelines have been applied to assess groundwater quality.
NRMMC, EPHC, NHMRC 2009 Australian Guidelines for Water Recycling: Managed Aquifer Recharge'	These guidelines provide a sound and consistent basis for protecting human health and the environment at managed aquifer recharge operations in all of Australia's states and territories. These guidelines have applied to aid the assessment and development of aquifer recharge schemes.
HEPA PFAS National Environmental Management Plan 2018	The plan has provided guidance to environmental regulators regarding the regulation of PFAS contaminated sites and materials.

4.4.2 State guidelines and policies

A number of Victoria guidelines are relevant to groundwater and these are summarised in Table 4-4.

Table 4-4 Summary of Victorian guidelines and policies

Policy/Guideline	Description
SEPP (Waters)	The SEPP (*Waters*) formally commenced on the 19 October 2018 and replaces the SEPP (*Groundwaters of Victoria*) and SEPP (*Waters of Victoria*). A subordinate instrument of the Environment Protection Act (1970) it describes the uses and values (beneficial uses) of water, and provides a frameworks for the protection (and improvement) and management of water quality in Victoria. The objectives of the SEPP (*Waters*) in respect of environmental quality are to: (a) achieve the level of environmental quality required to protect the beneficial uses of waters; and (b) ensure that pollution to waters from both diffuse and point sources is managed in an integrated way to deliver the best outcome for the community as a whole; and (c) protect and improve environmental quality through consistent, equitable and proportionate regulatory decisions that focus on outcomes and use the best available information. ***Groundwater*** Aims to maintain and where possible, improve groundwater quality sufficient to protect and enhance existing and potential beneficial uses. Groundwater with higher concentrations of salinity (measured as milligrams per litre of total dissolved solids (mg/L TDS) is deemed to have fewer beneficial uses. The goals and objectives specified focus on preventing detrimental changes to groundwater quality as a result of human interaction. The SEPP (*Waters*) does not intend to protect groundwater quantity (volume). ***Surface water*** Guides and supports the establishment of regional catchment and coastal planning processes, in which the community identifies the regional environmental, social and economic values of surface waters, and after careful consideration of their environmental, social and economic values and needs, sets appropriate goals, priorities and targets. Contains numerous schedules that address special environment protection measures needed for sensitive segments of the environment.
SEPP (Prevention and Management of Contaminated Land) 2002	The SEPP (Land) identifies the beneficial uses of land to be protected, how protection can be measured, and a consistent approach to concluding wither a site is suitable for a particular use. In relation to groundwater, this policy sets out good practice to assess, clean-up and manage contaminated groundwater. Compliance with the SEPP (PMCL) is required, which is given effect under the *Environment Protection Act 1970.*

Policy/Guideline	Description
Ministerial Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems 2015	These guidelines are a supplement to a section of the *Water Act 1989* where a groundwater Take and Use application is made. It requires applications to undergo a risk assessment and referral process.
Environment Protection (Industrial Waste Resource) Regulations 2009	These regulations (under the *Environment Protection Act 1970*) categorise industrial wastes (including groundwater) by risk profile to ensure that each is appropriately handled, stored, treated, transported and disposed of. This regulation sets a hierarchy of preference for waste management.
Water Industry Regulations 2006	These regulations (under the *Environment Protection Act 1970*) set out various trade waste policies and guidelines for Victoria's Water Authorities.
EPA Victoria 2000 Groundwater Sampling Guidelines	The key objective of this document is to foster practices that will assist with accurate and consistent determination of chemical and biological indicators of groundwater. Such practices will ensure that groundwater samples are representative of groundwater in the aquifer and will remain representative until analytical determinations or measurements are made
EPA Victoria 2006 Guidelines for Hydrogeological Assessments (Water Quality)	These guidelines describe the basics of groundwater contamination: how a site conceptual model is developed; the process of an HA; the collection of groundwater data; and what an HA report should contain.
EPA Victoria 2014 The clean-up and management of polluted groundwater.	These guidelines provide details of EPA Victoria requirements and expectations for developing and implementing the clean-up and management of polluted groundwater, to ensure the protection of human health and the environment.
EPA Victoria 1991 Construction techniques for sediment pollution control.	The publication documents techniques that can help protect the environment while increasing construction efficiencies and reducing land development costs. Legal requirements relating to water quality control are also documented.
EPA Victoria 1996 Environmental guidelines for Major Construction Sites.	The guidelines facilitate the preparation and implementation of environmental management plans for major construction sites. Information is provided on how to avoid and minimise environmental impact, the likely impact of construction activities on the environment and how this is assessed, guidelines for risk assessment and risk management, environmental performance objectives and best practice environmental measures to meet performance objectives.
EPA Victoria Publication 1287 2009 Guidelines for risk assessment of wastewater discharges to waterways.	These guideless outline what is expected from practitioners proposing to discharge wastewater to waterways and how this is to be assessed. A risk assessment framework and guidance on its application is provided.

4.4.3 Australian Standards

Australian Standards relevant to this groundwater impact assessment are listed in Table 4-5.

Table 4-5 Australian Standards

Standard	Title
AS1726 (2017)	Geotechnical site investigations
AS2368 (1990)	Test pumping of water wells (withdrawn)
AS2159 (2009)	Piling – Design and Installation
AS4482.1 (2005)	Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil – Non-volatile and Semi-Volatile Compounds
AS4482.2 (1999)	Guide to the sampling and investigation of potentially contaminated soil Volatile substances

4.4.4 Responsible authority

Groundwater licensing

A licence to take and use groundwater may be issued by the Minister under Section 51 of the *Water Act 1989.* Approvals under the Water Act, such as for bore construction, groundwater extraction (dewatering) or artificial groundwater recharge may also be required by the project from the relevant water corporation, Southern Rural Water.

Sewer discharge

As part of managing groundwater, there may be a need for discharge to Melbourne's sewer networks. The study area falls within the region serviced by Yarra Valley Water, one of Melbourne's three metropolitan retail water authorities that provide the essential services of water supply and sanitation.

Yarra Valley Water has Trade Waste Acceptance Criteria that set out wastewater quality objectives for disposal to sewer. Depending upon loads, Yarra Valley Water may refer applications to Melbourne Water. The Acceptance Criteria have been applied to assess whether groundwater could be disposed to sewer.

Disposal to surface water

Disposal of groundwater to surface systems would need to be assessed based on the EPA Victoria Publication 1287 (EPA Victoria, 2009), via a risk-based approach. Approvals from Melbourne Water and the relevant local council and drainage authority would be required.

4.5 Approach to application of legislation and policies

4.5.1 Water availability

From a resource perspective, groundwater availability is typically considered as the ability to access a particular volume of the overall resource for abstractive benefit, such as an irrigator is licensed to pump a specified volume each year. However, in the context of this impact assessment, a broader definition has been applied, as changes in groundwater storage are expressed as changes to groundwater levels and hydraulic gradients. Extraction (or replenishment) of groundwater alters groundwater levels, and changes in levels influence access to the resource which could interfere with existing groundwater users, reduce flows to waterways, or lower waters beyond the reach of roots. Also, rise in water levels can also create water logging issues.

Water availability is regulated through the *Water Act 1989* and so assessment of the project's potential impact to existing abstractive users is relevant. For licensed groundwater works (dewatering or aquifer recharge) Section 53 of the Water Act, requires the Minister to assess the impact of groundwater take amongst other things on the availability of water in the area, the water quality and the effect on existing users and waterways.

4.5.2 Water quality

Water quality is regulated through the *Environment Protection Act 1970* through the SEPP (*Waters*) which recently revoked the SEPP (*Waters of Victoria*) and SEPP (*Groundwaters of Victoria*). The SEPP (*Waters*) has been applied:

- To assess the potential for groundwater discharge to surface waterways, where such discharge regimes have been altered by the project.
- Where construction activities may affect groundwater quality, or where changes in groundwater level results in the displacement of existing groundwater contamination. Where groundwater contamination is identified by the project, it may trigger environmental audits. Movement of groundwater contamination plumes to areas previously not polluted is an act of pollution under the Environment Protect Act.

The SEPP (PMCL) is relevant where the displacement of existing groundwater contamination by the project would result in the generation of vapours that degrade air quality. The SEPP (PMCL) describes the requirement to prevent the contamination of land, which is important for the protection of groundwater quality.

4.5.3 Groundwater classification

The SEPP (*Waters*) aims to maintain and, where possible, improve water quality to protect beneficial uses. In respect to groundwater, groundwater with higher concentrations of salinity (measured as mg/L TDS) is deemed to have fewer beneficial uses.

SEPP (*Waters*) forms the primary guide to determining existing impacts and the risk of impacts to groundwater quality. The policy is based on a number of principles which include:

- Groundwater is an undervalued resource and all Victorians have a shared responsibility for its protection
- Protection of groundwater (and aquifers) is fundamental to the protection of connected surface waters
- Groundwater (and aquifers) should be protected to the greatest extent practicable from serious or irreversible damage arising from human activity

- Intergovernmental Agreement on the Environment (IGAE) principles (such as polluter pays, intergenerational equity and the precautionary principle).

The policy provides that groundwater is categorised into segments, with each segment having particular identified uses. The segments and their beneficial uses are summarised in Table 4-6.

Table 4-6 Protected beneficial uses and groundwater segments

	Segment (mg/L TDS)						
Beneficial use	**A1 (0-600)**	**A2 (601-1,200)**	**B (1,201-3,100)**	**C (3,101 – 5,400)**	**D (5,401 – 7,100)**	**E (7,101 – 10,000)**	**F >10,001**
Protection of water dependent ecosystems and species	✓	✓	✓	✓	✓	✓	✓
Potable water supply – desirable	✓						
Potable water supply – acceptable		✓					
Potable mineral water supply	✓	✓	✓	✓			
Agriculture and irrigation – irrigation	✓	✓	✓				
Agriculture and irrigation – stock watering	✓	✓	✓	✓	✓	✓	
Industrial and commercial	✓	✓	✓	✓	✓		
Water based recreation – primary contact recreation	✓	✓	✓	✓	✓	✓	✓
Buildings and structures	✓	✓	✓	✓	✓	✓	✓
Geothermal	✓	✓	✓	✓	✓	✓	✓
Cultural and spiritual values	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values	✓	✓	✓	✓	✓	✓	✓

Note: TDS – Total Dissolved Solids (mg/L). Source SEPP (Waters) 2018.

EPA Victoria may determine these beneficial uses do not apply to groundwater where:

- There is insufficient yield to sustain the beneficial use
- The application of groundwater, such as for irrigation, may be a risk to beneficial uses of land or the broader environment due to the soil properties
- The beneficial use specified in the definition of water dependent ecosystems and species relates to stygofauna and troglofauna
- The background level of an environmental quality indicator would not provide for the protection of the beneficial use.

In making a determination as to whether a beneficial use does not apply, EPA Victoria:

- May take into account possible variations within the aquifer and reasonable bore development techniques to improve yield
- Must be satisfied that
  – (i) the beneficial use for water dependent ecosystems and species is protected; and
  – (ii) there will be no risk to beneficial uses
  – (iii) preferential flow through fractures or naturally formed cavities is not the dominant mode of permeability.

4.5.4 Proposed amendment to the Environment Protection Act

Victoria is proposed new environment protection laws, via the *Environment Protection Amendment Act 2018*. This Act is aimed at managing environmental and human health risks, by identifying and managing them before they cause harm (that is, analogous to Victoria's Occupational Health and Safety laws which impose a duty of care to take reasonably practicable measures to reduce risk of harm).

Key implications of the new legislation on North East Link are summarised below:

- Permissions
  – Under the current Environment Protection Act, EPA Victoria can impose a licence on a high risk activity. With the amendment, a three-tiered approach is proposed with registrations, permits and licences being issued subject to the nature of the risks.
  – Licences will be issued for the most complex, high risk processes and can apply customised conditions. Licences will be subject to regular reviews, and will no longer be granted indefinitely.
  – This is relevant to the long-term management of tunnel waters.
- Waste management
  – Waste producers must identify and implement measures to minimise the risks associated with the management of wastes
  – This is relevant to the long-term management of tunnel waters.
- Contaminated land
  – The amendment introduces reforms to enable management or control of land to be more proportionate to the risks posed by the contaminated land (including groundwater). A 'duty to manage' obligation on the management or control of land to minimise the risk of harm to human health and the environment from the contamination. This includes:
    - Identifying contamination and assessment of the contamination
    - Managing the contamination by minimising the risks to human health and the environment
    - Notification of parties who may be affected by the contamination, and a duty to notify of contaminated land to EPA Victoria
  – Greater flexibility with the environment audit process, adopting a scalable approach depending upon the risk.
- Site management orders
  – To enable the establishment of long-term controls to ensure the safe ongoing management of sites that would otherwise pose ongoing risks to the community and environment.

- Better access to environmental information
  - Maintaining a public register of information such as licences, permits, registrations, environmental audits, site management orders, and environmental plans.

4.5.5 Regulatory changes and influence of the project

In summary, while the planning approvals process has been proceeding, changes to the Environment Protect Act and SEPPs have occurred. DELWP is the lead authority for co-ordinating the implementation of the SEPP (Waters) but EPA Victoria also has implementation responsibilities. The amendment Act is intended to take effect from 1 July 2020. When the amendment Act commences, the provisions of the SEPP (Waters) will be transitioned to new regulatory instruments.

Protection of water quality, and management of wastewater discharges are key areas relevant to the project. From a groundwater perspective, broadly, the new SEPP (Waters) requires consideration of additional beneficial uses such as for Traditional Owners, which were not previously considered under the superseded SEPP (Groundwaters of Victoria), and reclassification of groundwater segments. The groundwater study has considered these potential impacts to places including Bolin Bolin Billabong.

It is recognised by DELWP and EPA Victoria that wastewater management is a major source of potential pollutants. The previous SEPPs provided considerations for EPA Victoria and Southern Rural Water to take into account when licensing wastewater discharges, and extractions (and reinjection) respectively. The SEPP (Waters) and amendment Act provide further detail on these matters. These are matters that need to be considered with the design of structures and their water tightness, the management of groundwater inflows, and contamination (soil and groundwater) identified during the construction works.

It is further recognised there are some actions required to be undertaken by DELWP and EPA Victoria as part of the implementation of the SEPP (Waters) and Environment Protection Amendment Act, such as engagement with Traditional Owners to develop environmental indicators and objectives for the protection of this beneficial use. Engagement with and input from EPA Victoria and Southern Rural Water has been recognised in the development of the EPRs for North East Link.

5. Methodology

5.1 Overview of method

This section describes the method that was used to assess the potential impacts of North East Link. A risk-based approach was applied to prioritise the key issues for assessment and inform measures to avoid, minimise and offset potential effects. Figure 5-1 shows an overview of the assessment method.

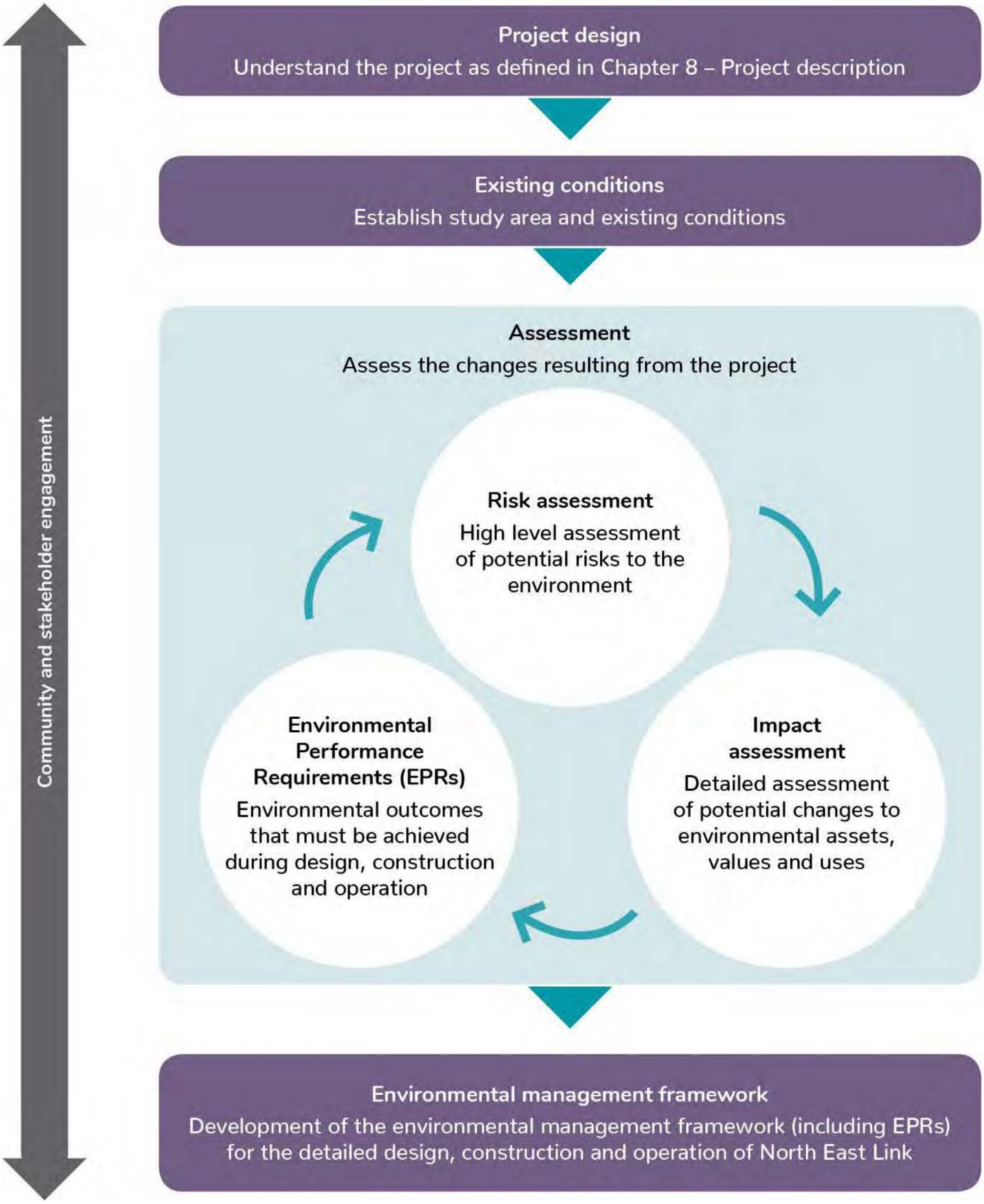


Figure 5-1 Overview of assessment method

The following sections outline the methodology for the groundwater impact assessment.

5.2 Study area

At a minimum, the study area encompasses the entire alignment of the North East Link reference project, and its project boundary in its entirety. However, groundwater processes occur over a range of scales such as local and regional flow regimes. It therefore necessary to extend the study area for the groundwater impact assessment beyond the project boundary to capture these broader processes. The approximate study area is shown in Figure 3-1.

Project boundary definition

The proposed **project boundary** established for the project defines the area in which the project elements and construction would be contained. It encompasses all areas that would be used for permanent structures and temporary construction areas (above and below ground). The geotechnical investigations undertaken to inform the groundwater conditions for the impact assessment were typically within or close to the project boundary.

Study area – whole project

The term **study area** for the groundwater impact assessment refers to a broader region surrounding the project boundary. The study area includes all land within approximately two kilometres of the project boundary, including the Yarra River catchment. This description covers a much broader area than the expected zone of impact, and the additional information captured has been used to provide context for regional groundwater flow processes. This broader study area was mostly assessed by desktop research.

No-go zones (adjacent to the project boundary within the study area)

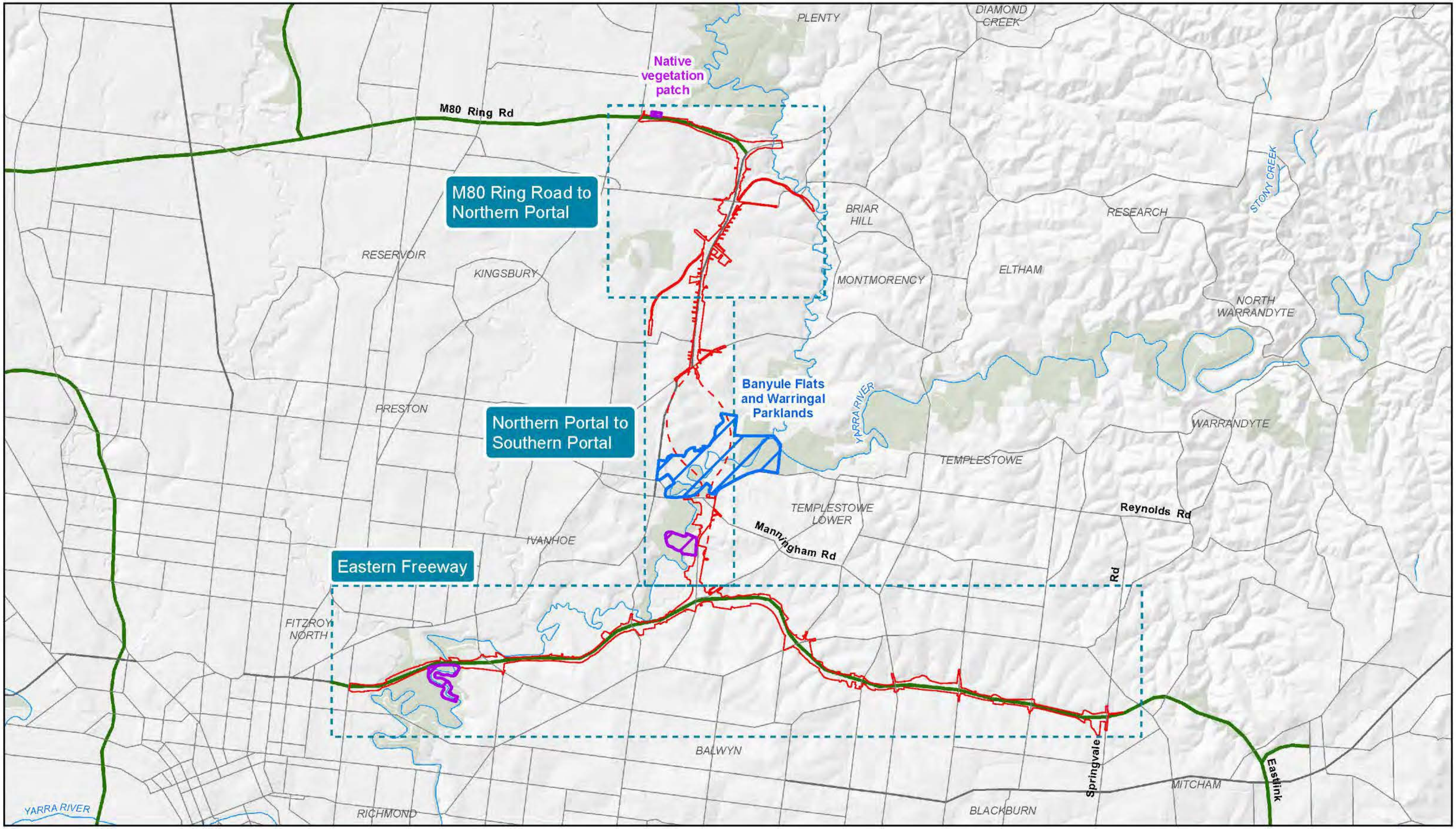
Direct impacts at a number of sensitive areas near the project would be avoided through the designation of no-go zones (adjacent to the project boundary), where surface works would not be permitted as part of the project. No-go zones have been designated for the following sensitive areas:

- A vegetated patch near the intersection of the M80 Ring Road and Plenty Road
- Bolin Bolin Billabong
- A portion of Yarra Bend Park (Eastern Freeway element).

Twin tunnels are proposed beneath the Banyule Flats, Warringal Parklands and the Yarra River and its associated floodplain, as well as the Heide Museum of Modern Art and sculpture park. This would avoid surface impacts at these locations. This area has been included within a designated ‘conditional no-go area’ where surface works for the project would not be permitted, with the possible exception of activities relating to site investigations, relocation of minor utilities, and ground improvement.

It is noted that while direct impacts would not occur, the potential for indirect impacts on sensitive areas within the no-go zones are considered in this assessment.

The project boundary and no go zones are shown in Figure 5-2.



Paper Size A4

0 700 1,400 2,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- Project element
- Project boundary - sub-surface
- Project boundary - surface
- Conditional no go zone area
- No go zone area

Roads

- Freeway
- Highway
- Major road

Watercourses

- River

- Parks & reserves

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Job Number	31-35006
Revision	E
Date	04/03/2019

Groundwater study area

Figure 5-2

G:\31\35006\GIS\Maps\Working\KBM\EES_PER_Technical_Report\EES_Technical_Reports_A4L_TR.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: CIP Imagery - DELWP - 2018 | roads, watercourses, parks, rail, localities, planning zones - Vicmap - 2019 | precinct, project infrastructure - GHD, AECOM - 2019 Created by: trighetti

5.3 Existing conditions

The existing conditions of the study area were determined by a desktop review of existing information as well as geotechnical investigations specifically for the North East Link EES.

5.3.1 Desktop hydrogeological investigations

Key elements of the desktop review include review of information from the following sources:

- Regional datasets including
  - DELWP Water Measurement Information System
  - Department of Jobs, Precincts and Regions boring data (GeoVic Version 3)
  - Geological mapping (Victorian geological survey)
  - Hydrogeological mapping (DELWP)
  - BOM Groundwater Atlas
  - Visualising Victoria Groundwater (VVG)
  - BOM GDE Atlas
- Published geological and hydrogeological reports
- VicRoads investigation reports.

5.3.2 Field hydrogeological investigation

NELP commissioned a geotechnical investigation program for the preparation of the North East Link EES. The program is ongoing and will continue during the detailed design of the project. The field data collected during these investigations provided site-specific hydrogeological information about the existing groundwater conditions in addition to the desktop literature review.

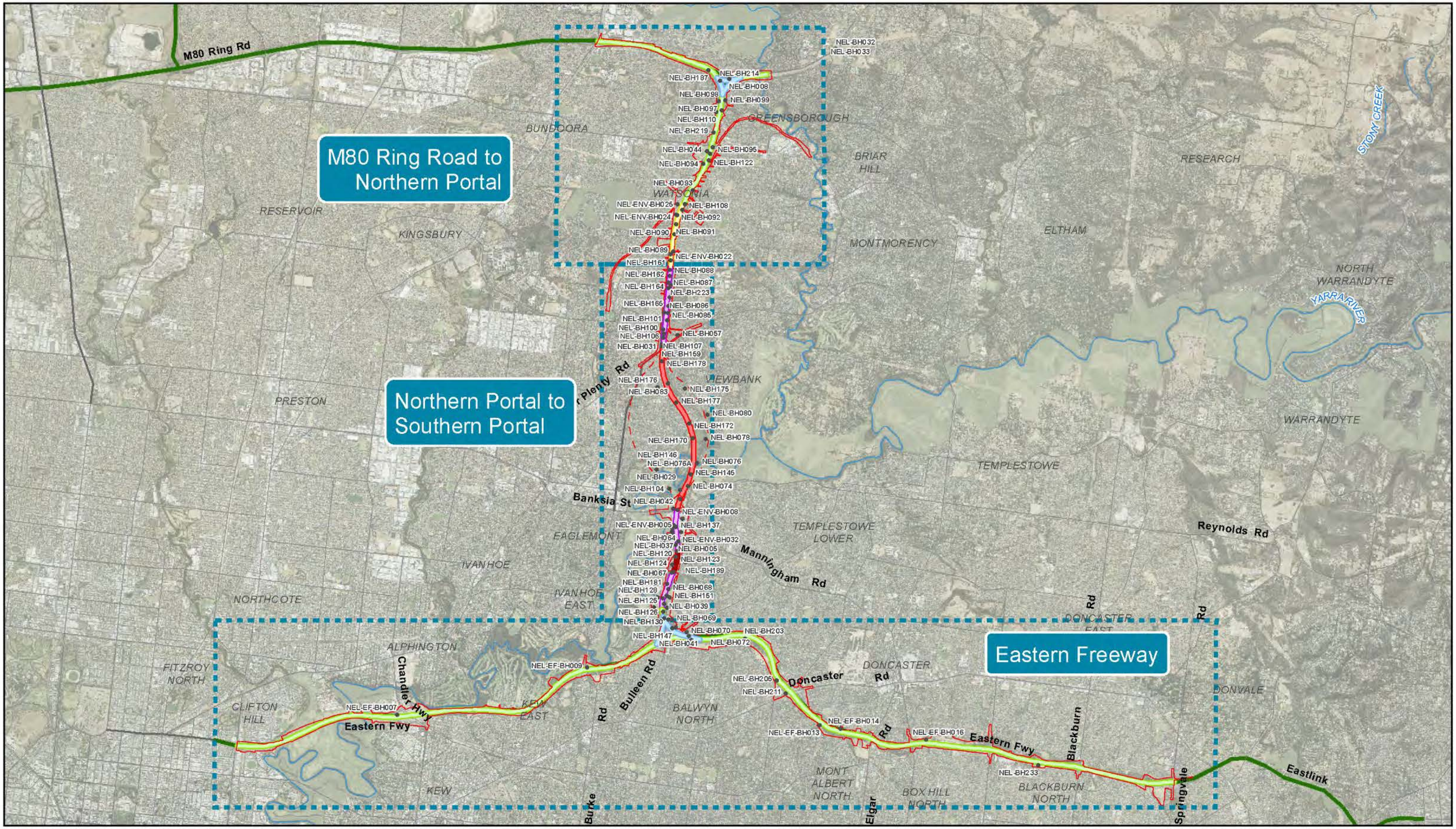
The geotechnical program comprised multiple investigation phases and was designed to supply multiple technical disciplines including geotechnical, tunnelling, contaminated land and hydrogeology. The investigations included:

- Core drilling and lithological sampling
- Core photography
- Lithological sampling and laboratory testing
- Geophysical assessment
  - Natural gamma, imaging (ultrasonic, optical)
- Packer testing (for the estimation of rock material hydraulic character)
- Groundwater monitoring bore construction and development
- Aquifer testing
  - Slug testing
  - Pumping test investigations
- Groundwater level gauging
- Groundwater sampling and laboratory analysis.

As of the end of June 2018 the following works had been completed:

- 110 geotechnical boreholes
- 70 monitoring bores
- 30 bores had undergone slug tests
- 62 bores had undergone packer testing
- 33 monitoring bores had been sampled.

The locations of the North East Link groundwater monitoring bores are shown in Figure 5-3.



Paper Size A4

0 0.5 1 2 3

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- Project Elements
- NEL Boreholes
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

- Elevated ramp
- Surface works
- Open Cut
- Cut and cover tunnel
- TBM bored tunnel
- Mined tunnel

Roads

- Freeway
- Highway
- Major road

Watercourses

- River
- Parks & reserves

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Job Number	31-35006
Revision	D
Date	01 Mar 2019

Groundwater monitoring network

Figure 5.3

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Vicmap: Roads, Watercourses 2018. Created by:trighetti

5.4 Risk assessment

An environmental risk assessment has been completed to identify environmental risks associated with construction and operation of North East Link. The risk-based approach is shown in Figure 5-4 and is integral to the EES as required by Sections 3.1 and 4.1 of the scoping requirements and the *Ministerial guidelines for assessment of the environmental effects under the Environment Effects Act 1978*.

Specifically the EES risk assessment aimed to:

- Systematically identify the interactions between project elements and activities and assets, values and uses
- Focus the impact assessment and enable differentiation of significant and high risks and impacts from lower risks and impacts
- Inform development of the reference project to avoid, mitigate and manage environmental impacts
- Inform development of EPRs that set the minimum outcomes necessary to avoid, mitigate or manage environmental impacts and reduce environmental risks during delivery of the project.

This section presents an overview of the EES risk assessment process. EES Attachment III Environmental risk report describes each step in the risk assessment process in more detail and contains a consolidated risk register.

This technical report describes the risks associated with the project on [technical discipline]. Wherever risks relating to this study are referred to, the terminology ‘risk XX01’ is used. Wherever EPRs relating to this study are referred to, the terminology ‘EPR XX1’ is used. The risk assessment completed for this study is provided as Appendix B.

5.4.1 Risk assessment process

The risk assessment process adopted for North East Link is consistent with AS/NZS ISO 31000:2009 Risk Management Process. The following tasks were undertaken to identify, analyse and evaluate risks:

- Use existing conditions and identify applicable legislation and policy to establish the context for the risk assessment
- Develop likelihood and consequence criteria and a risk matrix
- Consider construction and operational activities in the context of existing conditions to determine risk pathways
- Identify standard controls and requirements (Environmental Performance Requirements (EPRs)) to mitigate identified risks
- Assign likelihood and consequence ratings for each risk to determine risk ratings considering design, proposed activities and standard EPRs.

While there are clear steps in the risk process, it does not follow a linear progression and requires multiple iterations of risk ratings, pathways and EPRs as the technical assessments progress. Demonstrating this evolution, a set of initial and residual risk ratings and EPRs are produced for all technical reports. Figure 5-4 shows this process.

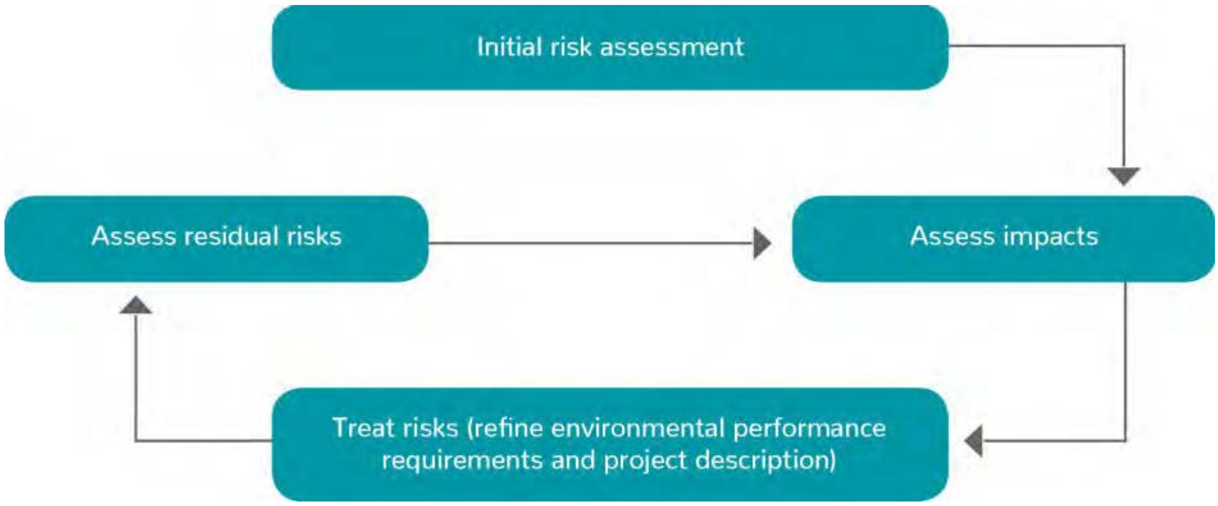


Figure 5-4 Risk analysis process

Rating risk

Risk ratings were assessed by considering the consequence and likelihood of an event occurring. In assessing the consequence, the extent, severity and duration of the risks were considered. These are discussed below.

Assigning the consequences of risks

'Consequence' refers to the maximum credible outcome of an event affecting an asset, value or use. Consequence criteria as presented in Chapter 4 – EES assessment framework, were developed for the North East Link EES to enable a consistent assessment of consequence across the range of potential environmental effects. Consequence criteria were assigned based on the maximum credible consequence of the risk pathway occurring. Where there was uncertainty or incomplete information, a conservative assessment was made on the basis of the maximum credible consequence.

Consequence criteria have been developed to consider the following characteristics:

- Extent of impact
- Severity of impact
- Duration of threat.

Severity has been assigned a greater weighting than extent and duration as this is considered the most important characteristic.

Each risk pathway was assigned a value for each of the three characteristics, which were added together to provide an overall consequence rating.

Further detail on the consequence criteria are provided Chapter 4 – EES assessment framework.

Assigning the likelihood of risk

'Likelihood' refers to the chance of an event happening and the maximum credible consequence occurring from that event. The likelihood criteria are presented in Table 5-1.

Table 5-1 Likelihood of an event occurring

Planned	The event is certain to occur
Almost certain	The event is almost certain to occur one or more times a year
Likely	The event is likely to occur several times within a five-year timeframe
Possible	The event may occur once within a five-year timeframe
Unlikely	The event may occur under unusual circumstances but is not expected (ie once within a 20-year timeframe)
Rare	The event is very unlikely to occur but may occur in exceptional circumstances (ie once within a 100-year timeframe)

Risk matrix and risk rating

Risk levels were assessed using the matrix presented in Table 5-2.

Table 5-2 Risk matrix

Likelihood	Consequence				
	Negligible	**Minor**	**Moderate**	**Major**	**Severe**
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
Planned	Planned	Planned	Planned	Planned	Planned

Planned events

North East Link would result in some planned events, being events with outcomes that are certain to occur (ie planned impacts such as land acquisition), as distinct from risk events where the chance of the event occurring and its consequence is uncertain. Although planned events are not risks, these were still documented in the risk register as part of Attachment III – Risk report for completeness and assigned a consequence level in order to enable issues requiring further assessment or treatment to be prioritised.

These planned events were assessed further through the impact assessment process.

Risk evaluation and treatment

The risk assessment process was used as a screening tool to prioritise potential impacts and the subsequent level of assessment undertaken as part of the impact assessment. For example, an issue that was given a risk level of medium or above, or was identified as a planned event with a consequence of minor or above, would go through a more thorough impact assessment process than a low risk.

Where initial risk ratings were found to be 'medium' or higher, or were planned events with a consequence of 'minor' or higher, options for additional or modified EPRs or design changes were considered where practicable. It should be noted that the consequence ratings presented in the risk register are solely based on the consequence criteria presented in Attachment III – Risk report. Further analysis and evaluation of the impacts potentially arising from both risks and planned events and information on how these would be managed is provided in Section 8.

5.5 Impact assessment

5.5.1 Overview

While approach to the impact assessment is multi-faceted, an underlying structure has been adopted which is summarised in the steps below.

1. Evaluation objectives
   The initial step is to recognise the evaluation objectives relevant to the groundwater environment and related aspects of the water cycle. These evaluation objectives are summarised in Section 2.

2. Existing conditions
   Before any analysis can be undertaken, an understanding of the existing groundwater conditions is required. This understanding, documented in Section 6, is formed from data obtained from published sources, stakeholder consultation, and geotechnical investigations.

3. Identify the values of groundwater
   As noted in Section 1.2, groundwater has different values and functions depending on the community, groundwater developers and the environment. This is discussed further in Section 5.5.2.

4. Proposed design
   A reference project is proposed to confirm the project can be constructed. With an understanding of the existing conditions and the proposed project, an assessment of potential impacts can be made. It has to be acknowledged the final project may deviate from the reference project, and so a broader perspective has to be applied when assessing the impacts. The proposed design is described in EES Chapter 8 – Project description.

5. Hydrogeological conceptualisation
   A conceptual understanding of the hydrogeology of the study area, the interactions with the project, and the other elements of the water cycle is required to enable analysis and predictions to be made about changes to the groundwater environment (groundwater levels and flows).

6. Understand the impact pathways
   Pathways that are associated with risks are linked to changes in groundwater flow or groundwater quality, for example:

   – Changes in groundwater level (reduction in water level or 'drawdown') may reduce the availability of groundwater to abstractive users, or access by groundwater dependent ecosystems, or alter interaction between groundwater and waterways and lakes.
   – Changes in groundwater level (increase in water level or 'mounding') may occur through the damming effects of an underground structure. This has implications to hydraulic gradients up and down-gradient of the structure.
   – Changes in groundwater levels can result in the exposure and activation of potential acid sulfate soil materials, which in turn can alter groundwater quality.

- Changes in groundwater levels can lead to changes in effective stress regimes of compressible sediments (subsidence)
- Changes in groundwater level can influence hydraulic gradients and the movement of and migration of contaminated groundwater plumes, generation of hazardous vapours, or mixing of groundwater with differing native quality
- Changes in groundwater quality can occur through spillage of hazardous materials, aquifer recharge processes, and altering of groundwater flow can lead to mixing of groundwaters

7. Evaluate the impacts
   Construction and operation impacts are analysed and evaluated both qualitatively based on hydrogeological understanding, but also qualitatively using tools such as analytical or numerical groundwater models. The assessment having regard to the existing legislative framework (refer Section 4). A risk-based approach is inherent to the evaluation of impacts (refer Section 5 and Section 7).
8. Controls
   Where potential exists for adverse impacts on the groundwater environment, control measures are to be developed. These measures can be incorporated into the (reference) design, which can eliminate risks, or be managed through Environmental Performance Requirements.

Further discussion of elements of the impact assessment approach are provided below.

5.5.2 Groundwater values

Groundwater, its functions, and related processes have various values:

- Abstractive benefit to users who access and use groundwater, such as industrial use, domestic use and irrigation use
- Provides a water supply (baseflow) as inflow to waterways, swamps and creeks, and in turn, associated ecosystems
- Provides a water supply to deep rooted vegetation, which in turn, creates habitats and associated ecosystems
- Functions to support loads within a compressible geologic medium
- Functions as a transport mechanism for contamination (dissolved, vapour and separate phases)
- Functions to maintain saturated conditions for potential acid sulfate soil materials.

Review of the existing conditions, data gathering and hydrogeological conceptualisation is undertaken to identify these values, and to assess the sensitivity of these values to change. A numerical groundwater model is applied to determine the extent of change to the water table (refer discussion below).

In general there are no guidelines that define the acceptable levels of groundwater drawdown for most groundwater values and functions. Acceptable levels of drawdown applied in this assessment have been summarised in Table 5-3.

Table 5-3 Acceptable levels of drawdown

<table>
<tr><th>Factor</th><th colspan="3">Comment</th></tr>
<tr><td>Existing groundwater users</td><td colspan="3">Acceptable interference limits for existing bores are set out in a strategy recommended by the Rural Water Corporation (1993). The acceptable limits are:
• Poorly defined aquifer system: Upper limit of acceptable interference is 10% of the available drawdown in the neighbouring bore
• Well defined aquifer system: Upper limit of acceptable interference is 20% of the available drawdown in the neighbouring bore.
The available drawdown is the depth of water above the intake of a pump under non pumping conditions. For example, if a bore has an available drawdown of 10 m, a 1 m decline in water level may be considered unacceptable.</td></tr>
<tr><td rowspan="9">Groundwater dependent ecosystems</td><td colspan="3">Acceptable limits of drawdown have been proposed by DELWP (2015) Ministerial guidelines using a risk based approach relevant to the licensing of groundwater extractions, as follows</td></tr>
<tr><th>Consequence</th><th>Description</th><th>Measure</th></tr>
<tr><td rowspan="2">Minor</td><td rowspan="2">Proposed extraction is small with respect to the aquifer’s ability to supply.</td><td>Water table decline of <0.1 m</td></tr>
<tr><td>Hydraulic gradient at wetland boundary remains positive.</td></tr>
<tr><td rowspan="2">Moderate</td><td rowspan="2">Proposed extraction impacts measurably with respect to the aquifer’s ability to supply.</td><td>Water table decline of 0.1 m to 2 m</td></tr>
<tr><td>Hydraulic gradient at wetland may fall to zero at boundary in dry conditions.</td></tr>
<tr><td rowspan="2">Significant</td><td rowspan="2">Proposed extraction is large with respect to the aquifer’s ability to supply.</td><td>Water table decline of >2 m at boundary</td></tr>
<tr><td>Hydraulic gradient at wetland reverses direction at boundary.</td></tr>
<tr><td colspan="3">These guidelines are applicable to a licensable quantum of groundwater. Active construction dewatering is a licensable action, however, drawdowns created by the deflection of groundwater around a structure are not licensable. Under these circumstances the approach of assessment was to determine predicted drawdown magnitudes and extents and to refer these to the Technical report Q – Ecology.</td></tr>
</table>

<table>
<tr><th>Factor</th><th colspan="3">Comment</th></tr>
<tr><td rowspan="9">Streamflow</td><td colspan="3">Acceptable limits of drawdown have been proposed by DELWP (2015) Ministerial guidelines using a risk based approach relevant to the licensing of groundwater extractions, as follows:</td></tr>
<tr><th>Consequence</th><th>Description</th><th>Measure</th></tr>
<tr><td rowspan="2">Minor</td><td rowspan="2">Proposed extraction on natural or current streamflow are small</td><td>Licence application is less than 1% of minimum average seasonal baseflow.</td></tr>
<tr><td>Less than 1% reduction in the Q90 flow rate.</td></tr>
<tr><td rowspan="2">Moderate</td><td rowspan="2">Proposed extraction impacts measurably on natural of current streamflow.</td><td>Licence application is between 1% and 10% of lowest seasonal baseflow.</td></tr>
<tr><td>Between 1% and 10% reduction in the Q90 flow rate.</td></tr>
<tr><td rowspan="2">Significant</td><td rowspan="2">Proposed extraction impacts significantly on natural or current streamflow.</td><td>The minimum recommended environmental flow remains above the Q90 flow rate.</td></tr>
<tr><td>Licence application is greater than 10% of lowest seasonal baseflow.</td></tr>
<tr><td colspan="3">Approach of assessment was to determine predicted drawdown magnitudes and extents and to refer these to the ecology assessment (Technical report Q – Ecology).</td></tr>
<tr><td>Subsidence</td><td colspan="3">No acceptable level defined in this report. Approach of assessment was to determine predicted drawdown magnitudes and extents and to refer these to the ground movement assessment (Technical report M – Ground movement assessment).</td></tr>
<tr><td>Contamination migration</td><td colspan="3">No acceptable level defined in this report. Approach of assessment was to determine predicted drawdown magnitudes and extents and to refer these to the contamination and soil assessment (Technical report O – Contamination and soil).</td></tr>
<tr><td>Oxidation of PASS materials</td><td colspan="3">No acceptable level defined in this report. Approach of assessment was to determine predicted drawdown magnitudes and extents and to refer these to the contamination and soil assessment (Technical report O – Contamination and soil).</td></tr>
</table>

5.5.3 Groundwater drawdown

Background

The majority of impacts to groundwater arise from altering groundwater levels, and to evaluate the impacts of change to groundwater levels, predictions need to be made. To make these predictions about the vertical and lateral extents of these changes, an understanding of the existing groundwater environment and how the project would interact with it are required, and this is discussed in this section.

To build a structure below groundwater, groundwater needs to be controlled during construction and this can be achieved via various construction methods, for example:

- Exclusion – grouting to prevent inflows, freezing, cut-offs (vertical barriers), slurries and shields. In some cases the water proof lining system is installed during the construction phase, such as the gasketted segments of a TBM
- Pumping – lowering water levels or pressures through the pumping of groundwater, or controlled seepage into excavations.

As groundwater flows into an excavation, or migrates around a cut-off, changes to groundwater levels occur. The final form of the structure (its water tightness upon completion) affects the longer-term (operation) water level conditions.

When an excavation is to occur below the groundwater table, the geologic materials need to be dewatered (become unsaturated). The lowering of the groundwater level (pressure) results in the creation of a hydraulic gradient towards the excavation or tunnel, and groundwater moves from high pressure to low pressure. This results in groundwater inflow, and a decline in groundwater levels remote from the seepage face (or dewatering point). The decline in water level is referred to as the ‘drawdown cone’ or ‘cone of depression’ around the pumping bore, or drawdown zone around an excavation. The concepts of drawdown and cone of depression are shown in Figure 1-2 in Section 1.2. Excessive groundwater inflows can be an impediment to subsurface construction, and pose issues in terms of depletion of a resource, management of the volume recovered and the effects of drawdown.

The extent of drawdown depends primarily on the nature of the aquifer, the pumping rate and pumping duration. If the aquifer system consists of fractured rock, or is of odd shape, the shape and extent of drawdown may vary in certain preferential directions. If the drawdown extends a certain distance from the extraction centre such that it intersects other bores or (in the case of unconfined aquifers) it intersects with environmental features such as creeks, rivers and dependent ecosystems, it is said to have interfered with these features.

The altering of the hydraulic gradient may result in changes to the groundwater movement from (or to) these features, thereby affecting water availability. Features such as rivers may stabilise the cone of depression (recharge boundaries) by inducing leakage from the surface water to groundwater. Aquifer thinning or permeability changes may result in increased drawdown as the cone expands to meet the dewatering rate (discharge boundaries).

It is important to understand the term drawdown (lowering of the water level in the aquifer due to removal of groundwater) and limitations in predicting drawdown. The extent of influence is time-dependent, and therefore dependent on construction depths and size, and construction progress (or excavation and ground support) rates/time periods considered.

The extent and magnitude of drawdown is not only dependent on the aquifer hydraulic parameters (principally transmissivity, storativity and homogeneity), but also factors such as leakage between adjoining aquifers and aquitards and interactions with hydraulically connected waterways/discharge features. Where hydrogeological systems become more complex, the accuracy of the drawdown predictions becomes increasingly problematic.

Groundwater levels would recover after construction, although the magnitude of recovery would depend upon the water tightness design of the structure. A tanked or undrained structure is one that has been constructed in such a manner that leakage of groundwater into the structure is very low (almost nil), and that is able to withstand the full loads imposed upon it by hydrostatic pressures.

An undrained structure is designed to enable on-going inflow of groundwater into it, thus creating a permanent drainage effect imposed upon the groundwater table. Not needing to withstand significant hydrostatic pressures, undrained structures are often considerably more economical to construct compared with drained structures.

Project dewatering risk areas

The project would involve constructions below the water table, specifically:

- Tunnel (TBM tunnels as well as and mined using conventional methods)
  TBM tunnelling is proposed between Banskia Street/Manningham Road and Lower Plenty Road. Mined tunnelling is a short section south of the Banksia Street portal. Other shafts, control rooms and cross passages are required to support the tunnel ventilation, maintenance and emergency access. These are likely to be excavated using road header or more traditional mining methods.
- TBM launch and retrieval portals.
  Portals at Banskia Street/Manningham Road and Lower Plenty Road would involve cut and cover tunnelling. Potential construction methods to support excavation faces may include secant piles, soldier piles and diaphragm walls. Rock bolting, shotcreting and mesh may also be applied. Water inflow into these excavations can be limited by the selection of the ground support method. Grouting can be used as an additional control measure.
- Cut and cover tunnelling
  Cut and cover tunnelling is proposed between the mined tunnel and the Eastern Freeway. The reference project indicates this structure would be drained during construction, but tanked once completed. Various ground control methods could be applied similar to those at the portals, such as grouting. As the cut and cover areas are traversing sedimentary aquifers, the lateral cut-off of groundwater would also occur. The assessment has adopted diaphragm walls as lateral excavation supports.

5.5.4 Construction assessment method

Disturbance to groundwater levels is expected to be greatest during the project's construction when dewatering was generally at its greatest. As structures become sealed, such as by the placement of the floor slab at the base of an excavation, groundwater seepage rates are reduced. Numerical groundwater modelling has been applied to predict the extent of impact to groundwater levels during construction and an overview of the modelling is presented in Section 5.6.

Factors influencing the estimates of drawdown during construction and operation are summarised in Table 5-4. These factors ignore the effects of ground conditions being different from that identified from the geotechnical investigations, and it is acknowledged that further geotechnical information would be available to a contractor during the project's detailed design phase.

Table 5-4 Factors influence dewatering risks and drawdown estimates

Factor	Comment
Tunnel design	In terms of the long-term performance and minimising long-term impact on groundwater levels, the drainage condition of the tunnel is a key factor. Tanking (undrained lining conditions) that prevents groundwater ingress would minimise ongoing seepage into an operating tunnel and thus mitigate the effects of changes to groundwater levels. Note that failure of seals, membranes, caulked joints and cracking (over time) results in some seepage. Drained tunnels deflect groundwater using a water-tight membrane (behind the lining segments) around the perimeter of the tunnel to the invert, where it can be removed. Such a lining system alleviates hydrostatic pressures acting on the tunnel. In low seepage conditions, they can be effective, although they create significant dewatering. The TBM and mined tunnels have both been assumed to be constructed as tanked structures. The TBM tunnel would be tanked almost instantaneously as it was constructed, but the mined tunnel would remain drained, with tanking occurring towards the end of its construction.
Tunnel perviousness	The design tightness criteria in the reference project has been assumed to meet Haack Class 3 (Haack 1991); that is, permissible daily leakage rates over either of two reference lengths (that are not linearly related): • 0.2 L/m^2 within a 10 m reference length, or • 0.1 L/m^2 within a 100 m reference length. Haack 3 describes conditions of the wall of the lining to be so tight that only isolated, locally restricted patches of moisture occur. No trickling water is evident. The 10 m reference length considered peak flow or flows over cross passages, and the inflow over an extended reference length of 100 m is more like the average inflow for the section of tunnel. The adoption of the 0.1 L/m^2 per 100 m expresses the quantity of daily leakage or water per unit area of the tunnel lining over the reference length. It enables a description of the allowable inflow into a tanked structure and supports hydrogeological analysis through numerical groundwater modelling.
Tunnelling construction method	TBMs with earth pressure balance/slurry face methods reduce groundwater inflow, and thus the extent and magnitude of dewatering (relative to other conventional tunnelling methods). Both slurry and earth pressure balance machines (EPBM) have a bulkhead located behind their cutting face to form a pressure chamber which can be pressurised to equalise ground pressure. Under these conditions there is minimal disturbance to the groundwater. Segmental lining systems and grouting occur as TBM tunnelling progresses, providing almost immediate sealing and minimising further disturbance to groundwater. Conventional drill and blast, or road header excavation methods require a working face. Groundwater is less easily controlled and requires either sump pumping, active dewatering or grouting (refer below) to reduce seepage into the tunnel. Predictions of drawdown were obtained using numerical groundwater modelling, which assumed that a TBM with earth pressure balance or slurry face was applied between Banksia Street/Manningham Road to Lower Plenty Road. Mined tunnel methods were assumed to be drained until the final base slab was constructed.
Treatments in advance of tunnelling	Freezing and compressed air are other tunnelling methods that can be undertaken to exclude groundwater from an excavation, and stabilise ground conditions, while a tunnel is being constructed. Probing and grouting (refer below) can be undertaken in advance of tunnelling, such as lancing, canopy, or tubes á manchettes approaches. The numerical groundwater modelling used to predict drawdowns did not assume that any pre-treatments were applied during the mining of tunnels.

Factor	Comment
Grouting	Grout/sealant/ground stabilisation methods would reduce rock material permeability and thus seepage inflow. Grouting in fractured rock conditions can be difficult to achieve complete seal. It can be undertaken ahead of tunnelling, from the ground surface. Chemical additives (resins, polymers) to cementitious grouts can improve water proofing and sealing properties. A useful method for stabilising groundwater by sealing/exclusion during the excavation of cross passages. In relatively stable ground conditions, shotcreting (a sprayed concrete with/without admixtures) can be used to control water ingress from a face. The numerical groundwater modelling used to predict drawdowns did not assume that any pre-treatments were applied during the mining of tunnels.
Remedial grouting	Grouting post-installation of lining segments to remediate seepage (either undertaken from within the tunnel, or from the surface). Grouting can also be undertaken to compensate for settlement. The numerical groundwater modelling used to predict drawdowns did not assume that any pre-treatments were applied during the mining of tunnels. It assumed that construction to the Haack 3 class would be achieved.
Cut and cover tunnelling	There are a number of methods to support an excavation face, although secant and diaphragm walls are most commonly used to provide a permanent means of excluding groundwater entry. Secant walls: Overlapping pile walls can form an effective barrier to groundwater flow. Where piles are displaced (that is, gaps form as piles are differing depths or not overlapping), remedial jet grouting can be undertaken (or shotcreting of exposed walls). Diaphragm walls: Diaphragm walls are constructed by excavating panels which are keyed into each other. Bentonite or polymer slurries are used to support the sides of the excavation. The wall is created by installing reinforcing and cement (which displaces the slurry during installation). The toe of the wall is typically keyed into a low permeability strata. Grout curtains can be established around the perimeter of excavations to exclude groundwater. Grouting into the base of excavations can also be undertaken to reduced permeabilities to groundwater flow. Numerical groundwater modelling was used to predict inflows into, and drawdowns extending from structures extending below the groundwater table. Further discussion on the design approach to water proofing of structures is provided in Section 8.1.1.

As noted in Table 5-4, prediction of drawdown requires an understanding of construction staging and progress rates. In a temporal sense, as construction progresses, groundwater inflows are expected to decrease as tunnel lining materials are installed, grouting completed to aid sealing, and ground support constructed and maintained at the portals. Construction staging and progress were informed by:

- Schedules documented in the project description
- Consultation with mining and structural engineers
- Comparisons with constructability information.

It is acknowledged the project could be staged in many ways, but the construction durations are considered a reasonable estimate. A conservative approach was applied in predictive modelling by assuming that base slabs were not progressively placed, but sealed at the end of the realistic construction duration.

It is noted that utility relocations, such as the Bulleen Road Sewer, were not included in the numerical groundwater model. The Bulleen Road Sewer is a DN1755 main sewer owned and operated by Melbourne Water and requires relocation to avoid conflicts with the project. It has been assumed the sewer would be relocated using a combination of micro-tunnelling (pipe-jacking) and open trenching. Pipe jacking would require approximate nine-metre diameter shafts to be installed.

Omission of this component from the numerical groundwater model was based upon the following rationale:

- Commonly utility relocations are completed in-advance of the project construction
- The tunnelling methods are analogous to TBM tunnelling described in Table 5-4
- Launch portals (where below groundwater level) are commonly completed using tanked retaining structures such as secant pile shafts
- Relatively short construction time frame of 10 months
- The EPRs that have been developed are considered appropriate for micro-tunnelling type works or trench excavations.

5.5.5 Operation assessment method

Operational drawdown

The regional numerical groundwater model was also applied to estimate the drawdowns associated with the long-term operation of North East Link, focusing specifically on the structures intersecting the groundwater table (that is, within the project's northern portal to southern portal element). The final water tightness/drainage conditions of these structures is as described in Table 5-4.

Climate change

As part of the assessment, and consistent with the EES scoping requirements (refer Section 2.2) consideration of the effects of long-term climate change were included in the analysis. This approach is documented in Appendix C.

Short-term climate extremes may occur during construction such as drought but in general terms, the effects of climate change are relevant to the long-term operation of the project.

Damming or impediments to regional flow

When a structure is placed below the water table and lies normal to or oblique to regional groundwater flow, it creates a physical barrier that obstructs or impedes groundwater flow. This can have a significant effect where the structure is near perpendicular to groundwater flow, or physically large relative to the flow sectional area of aquifer, or blocks/severs or truncates an aquifer. A number of implications can result:

- Water levels can rise up-gradient of the flow barrier – Water level rises that result in the water table being within two metres of the ground surface can result in water logging and ground salinization
- Water levels can fall down-gradient of the flow barrier – Changes in water levels can effect flows to waterways, groundwater dependent ecosystems, or subsidence
- Differential loading upon the structure.

This risk is generally assessed based on the long-term groundwater behaviour, as water levels may not have re-equilibrated in the timeframes typically taken for construction. The long-term prediction of the groundwater level response derived from the numerical groundwater model was applied to assess the risk of damming effects by the tunnel and other long, below water table structures forming the project. The analysis was also informed by:

- The mapped extents and thicknesses of aquifers
- Water table mapping of the study area.

5.6 Numerical modelling

5.6.1 Rationale

The prediction of groundwater level changes using a numerical groundwater model was considered a reasonable approach for North East Link. Numerical groundwater models were also applied to assess drawdowns with other infrastructure projects such as the CityLink tunnels, West Gate Tunnel project, and Metro Tunnel.

Numerical groundwater modelling was broadly consistent with Australian Guidelines (Barnett et *al*., 2012), with the development of the hydrogeological conceptual model, and numerical groundwater model involving several iterations informed by concurrent geotechnical investigations and data collection.

It is recognised that groundwater numerical models have their limitations (see Appendix C). Respectful of the limitations of numerical groundwater models, and noting that any proposed changes during detailed design of the project or alternative design proposals can have implications on the predicted groundwater impact, the predictive output nonetheless provides a tool with which EPRs can be developed.

5.6.2 Development

The groundwater model developed for the project is of regional scale, with model design and parametrisation guided by data obtained from drill holes and monitoring bores distributed along some 10 kilometres of the proposed alignment. The target confidence level of the model in accordance with the Australian Groundwater Modelling guidelines (Barnett et *al*., 2012) is class 1 (and some aspects of class 2) with a moderate level complexity that is commensurate with the intended model use and currently available data.

An unstructured grid version of the industry standard MODFLOW code, called MODFLOW-USG (Panday et *al*, 2013), was selected as the most appropriate groundwater modelling software for this study. This software has a number of advantages including the ability to closely represent the geometry of the project, efficient mesh refinement around features of interest, and robust handling of de-saturation and re-saturation of model cells.

The model domain was based on regional topography (groundwater divides) and surface water courses which made hydrogeological sense. The model domain and discretisation and the layering are shown in Figure 5-5 and Figure 5-6 respectively. Cell sizes were reduced around the tunnels and trench structures, to enable accurate placement of these features within the model domain.

The geological model constructed within LeapFrog® formed the basis for the numerical groundwater model. The bedrock was split into multiple layers to better represent the vertical alignment of the tunnels and cut and cover excavations. The midpoint of the tunnel was set in Layer 5 as shown in Figure 5-6.

Model calibration involves an iterative process to estimate parameters describing hydrogeological properties and boundary conditions so the model results closely match historical observations.

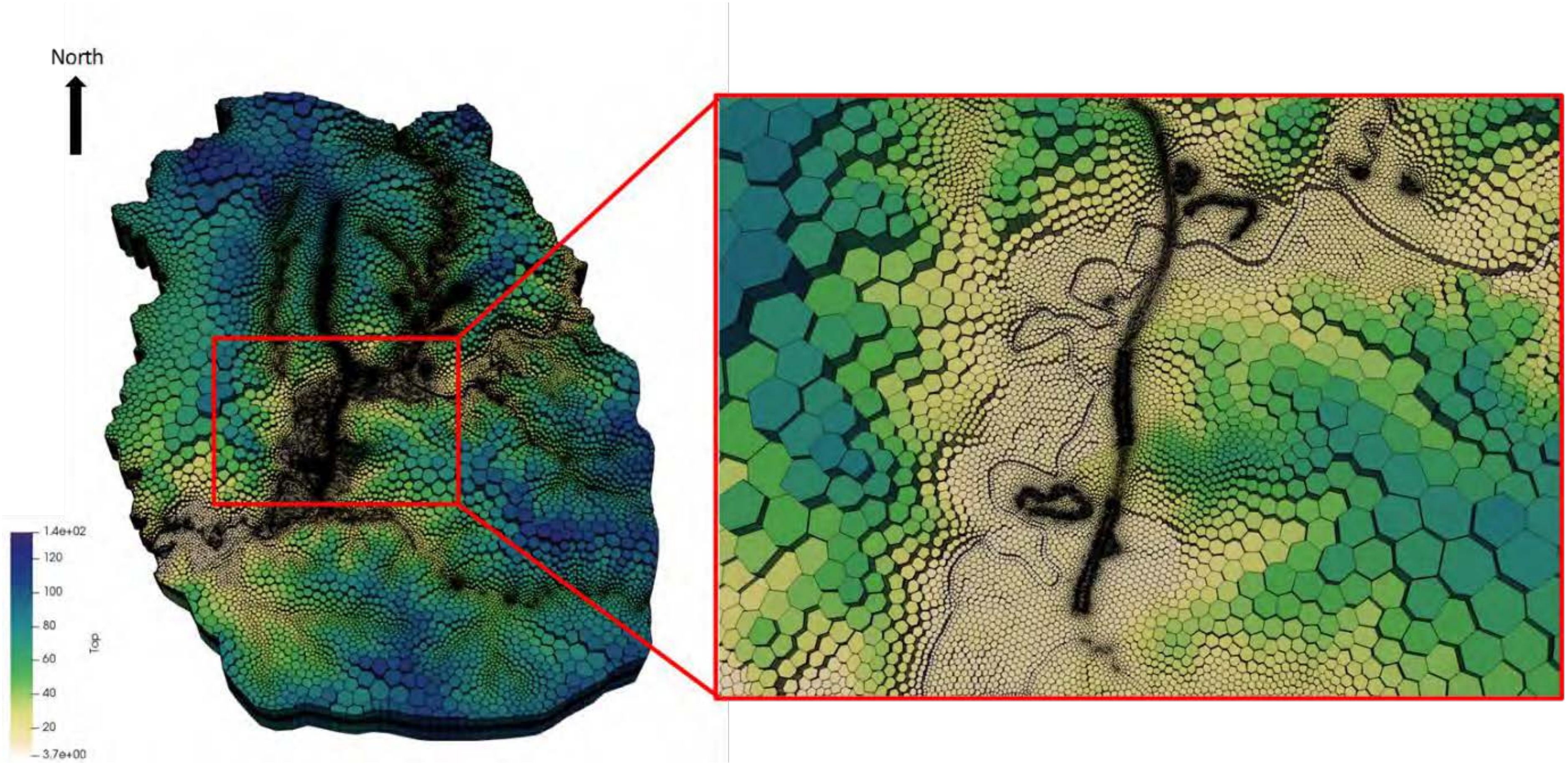


Figure 5-5 Numerical model domain and discretisation

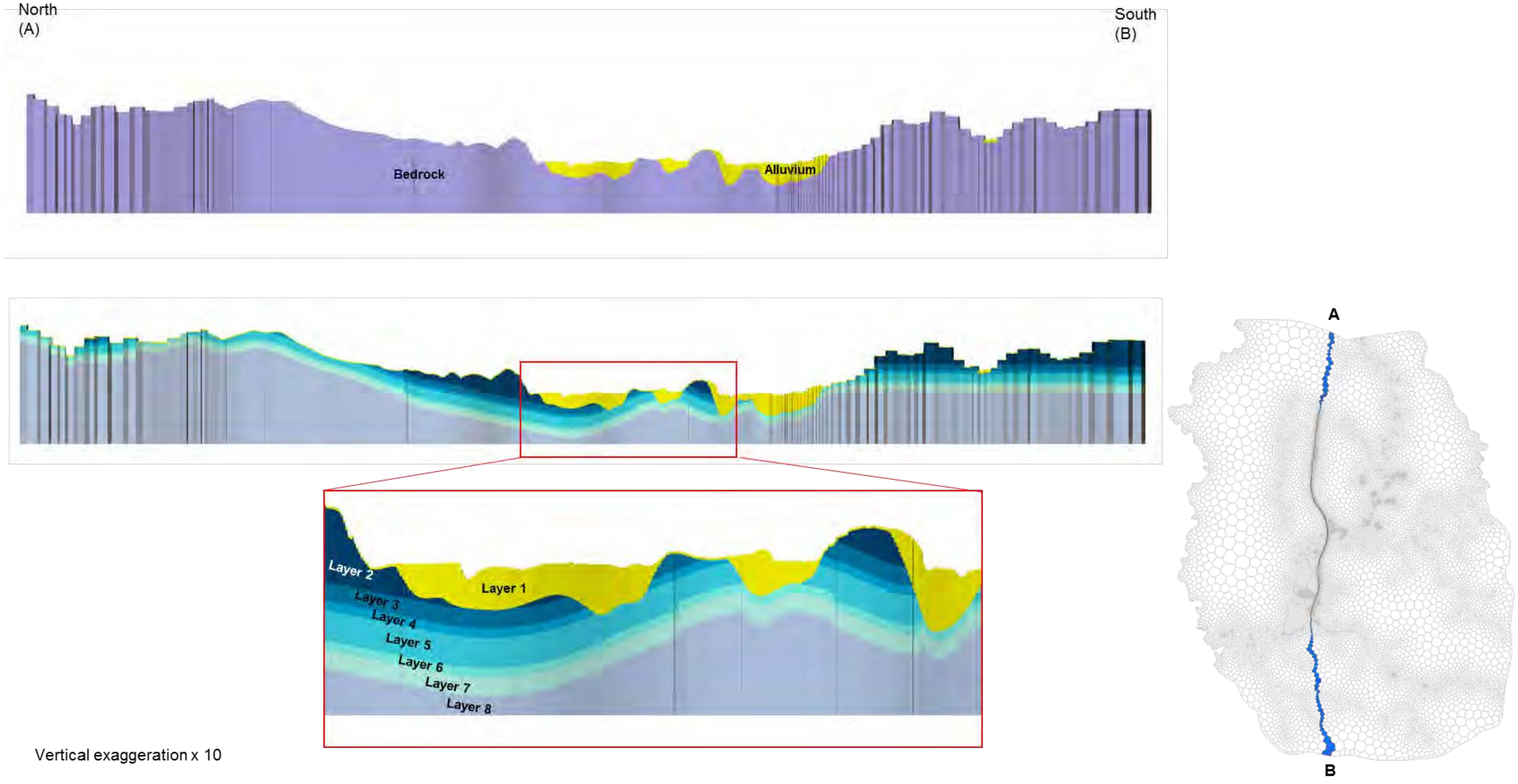


Figure 5-6 Numerical model cross section

Key observation data available for model calibration include:

- Groundwater levels measured in April 2018 in 69 monitoring bores, providing an approximately synchronous dataset representing the existing distribution of hydraulic heads along the project alignment.
- Drawdown of groundwater levels recorded during three constant rate pumping tests, capturing the response of aquifers to stresses imposed by extraction of groundwater.

There are currently no long-term monitoring data available within the model domain to enable meaningful transient calibration to seasonal variations in rainfall-derived recharge. In the absence of long-term transient data, recharge is only calibrated in steady state representing an approximately average recharge rate. This means the model's ability to replicate seasonal dynamics of the shallow groundwater system (and reasonableness of recharge) cannot be rigorously assessed through calibration to existing data.

When undertaking simulations to predict project-related impacts, the modelled groundwater levels would approximate a seasonally averaged response whereas in reality the groundwater levels would fluctuate about these modelled levels, potentially by around one to two metres.

5.6.3 Modelling scenarios

Using a construction schedule as per the reference project, modelling assumed the following:

- The three cut and cover structures would be excavated after the diaphragm walls are placed. Therefore, the majority of groundwater inflow would occur vertically from below until the base slabs are placed. The toe of the diaphragm walls would extend below the design floor level (model layer 5) into model layer 6 and seal off the (alluvial) sediments where it would be encountered at the Manningham Interchange and southern portal cut and covers.
- The tanking (base slab) of the northern portal (northwards from Lower Plenty Road) cut and cover would occur over a length of around 650 metres. A freely draining section called the 'trench' would be constructed further to the north along the alignment, which would drain groundwater (horizontally and vertically) where the floor of the trench penetrates the water table. This would maintain the water table adjacent to the trench at elevations approximately equal to its design levels.
- The TBM tunnels would leak at the design (maximum permissible) leakage rate, forming local sinks within the groundwater system.

The presence of cut-off walls such as diaphragm walls is simulated by reducing the hydraulic conductivity to a very low values (equivalent to a Haack Class 3 tightness). Excavation of the ground within the cut-offs is simulated as a drain. The placement of base slabs at the completion of excavation (and essentially forming the tanked structure) is simulated by reducing the vertical hydraulic conductivity of base cells.

5.6.4 Modelling results

Output from the numerical modelling (estimation of drawdowns during construction and under longer-term operation, particle tracking and groundwater inflows) are presented and discussed in the impact assessment section of this report (refer Section 8).

5.6.5 Modelling limitations

It is recognised the numerical model has limitations and may produce a non-unique prediction. While sensitivity analysis has been undertaken, ultimately the veracity of the numerical model predictions can be assessed through a monitoring program. EPR GW1 and EPR GW2 are proposed to address these limitations and are discussed in Section 9.

A minimum water level contour of 0.1 metres has been used to inform the groundwater impact assessment. It should be noted that changes of less than 0.5 metres are generally considered beyond the threshold of accuracy expected of a regional model of this kind.

5.7 Rationale

There is no single guideline for undertaking regional-scale hydrogeological assessments, but guidance on the methodology can be obtained from a number of sources:

- The approach is consistent with recent similar size infrastructure projects completed in Victoria, including the Victorian Desalination Plant, East West Link, West Gate Tunnel project and Metro Tunnel.
- The approach has relied upon content of relevant guidance documentation including:
  - EPA Victoria Publication No. 668 Hydrogeological Assessment (Groundwater Quality) Guidelines (2006)
  - DELWP Ministerial Guidelines for Licensing Groundwater for Urban Water Supply (2008)
  - DELWP Ministerial Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems (2015).

5.8 Limitations, uncertainties and assumptions

5.8.1 Assumptions

The groundwater environment impact assessment made a number of assumptions which are summarised in Table 5-5.

Table 5-5 Groundwater impact assessment assumptions

Assumption	Relevance
Project description	The project infrastructure design and specification has been based upon a reference project documented in EES Chapter 8 – Project description. Where sufficient detail has not been available in the project description, a number of assumptions have been made to support technical analysis and these have been documented in Appendix C.
Geotechnical field data	Field and laboratory data used in the impact assessment is based upon that collected up to 31st July 2018. Additional data may have been collected after this date, which has not have been included in this assessment.
Cumulative impact assessment	***Project scale*** A construction timeline has been documented in the project description. As part of the numerical groundwater modelling completed to support the impact assessment, this timeline was adopted, and assumed that dewatering may be occurring in multiple parts of the study area concurrently.

Assumption	Relevance
	Broad scale Nearby construction projects may also influence the groundwater environment. For example, when the effects of dewatering occurring simultaneously at multiple locations, the cones of depression in the water table overlap (superposition). A difficulty in undertaking a cumulative impact assessment is understanding the extent and magnitude of potential impacts arising from the neighbouring project, and the neighbouring project description. Other major infrastructure projects occurring in Melbourne which potentially interact with groundwater include the Westgate Freeway Project, Metro Tunnel and various Level Crossing Removal projects. These projects are considered too spatially distant from North East Link to result in cumulative groundwater impacts.
Groundwater corrosivity/ aggressive nature	Design of the project structures would need to consider the groundwater quality and its potential aggressive nature on materials. The durability of materials under these conditions has been assessed as part of the engineering of the reference project.
Groundwater drawdown impacts of settlement	Changes in groundwater levels can alter effective stress conditions and cause consolidation settlement in compressible materials. Analysis of the predicted extent of groundwater drawdowns has been documented in this technical report. The resultant implications to the built environment such as buildings, roads and utilities is documented and assessed in Technical report M – Ground movement
Groundwater impacts to dependent ecosystems	Changes in groundwater level can adversely affect the availability and supply of water to groundwater dependent ecosystems. Analysis of the predicted extent of groundwater drawdowns has been documented in this technical report. The resultant implications for groundwater dependent ecosystems is documented and assessed in Technical report Q – Ecology.
Groundwater impacts to human health	Potential impacts of groundwater quality and groundwater contamination on various receptors has been assessed in different specialist reports: • Impacts to groundwater beneficial uses caused by the dislocation or displacement of contaminated groundwater plumes are assessed in this technical report • Impacts to groundwater beneficial uses are documented and assessed in Technical report O – Contamination and soil.

5.8.2 Limitations

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the study area may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation and access restrictions (third-party limitations). As a result, not all relevant site features and conditions may have been identified in this report. Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

Other limitations identified with the groundwater impact assessment are as follows:

- There is limited understanding of the transient behaviour of groundwater levels and groundwater quality within the study area
  - Some monitoring bores have been gauged at an approximate monthly frequency and have upwards of 6 months of water level monitoring data. Inferences on groundwater level behaviour have been made based on the specialist experience, and behaviour in similar geological terrains elsewhere in Melbourne.
  - Only selected monitoring bores have been sampled and laboratory analysed. Few monitoring bores have been subjected to more than one groundwater monitoring (sampling) event.
  - This is a noted data gap which is being addressed through further baseline condition monitoring before construction started.
- The geotechnical investigation program has had multiple objectives, with the focus of the program to provide information to support the development of a reference project. As a result, groundwater monitoring bores have generally been located close to the reference project alignment, and few bores have been located offset from the alignment.

  Areas of change in groundwater level (drawdown extents) can extend distances from the project boundary. As a result, the characterisation of groundwater conditions, such as level, quality, remote from the key areas of interest in the project (the tunnels) is limited. Furthermore, the sensitivity of some receptors, such as groundwater dependent ecosystems, contaminated groundwater plumes and detailed assessment of them over larger area is not feasible.
- Groundwater monitoring bores have generally targeted a specific issue, such as the zone of tunnelling (screened over the potential depth of the tunnel/base of excavation). This has the following implications:
  - Some monitoring bores do not screen the first water intersection. Water quality information obtained from these bores may not be representative of conditions in the zone of water table fluctuation/shallow part of aquifer where contamination is most commonly identified. It is noted, however, that nested monitoring bores have been installed where multiple aquifers have been obviously identified.
  - The vertical alignment of the tunnel evolved during the course of the geotechnical investigations. As a result the screen zone of monitoring bores may be different to the tunnel level proposed as part of the reference project.

  Despite these limitations (that apply in selected areas only), the monitoring network is considered satisfactory in terms of providing a regional understanding of groundwater conditions in the vicinity of the reference project alignment.
- The limitations of the numerical groundwater modelling are discussed in Appendix C.

5.9 Stakeholder engagement

Stakeholders and the community were consulted to support the preparation of the North East Link EES and to inform the development of the project and understanding of potential impacts. Table 5-6 lists specific engagement activities that have occurred in relation to groundwater, with more general engagement activities occurring at all stages of the project. Feedback received during community consultation sessions is summarised in Section 5.10.

Table 5-6 Stakeholder engagement undertaken for hydrogeology

Activity	When	Matters discussed	Outcome
Meeting with Melbourne Water	May 2018	Information session between Melbourne Water and NELP to understand historical works completed by Melbourne Water at Bolin Bolin Billabong and elsewhere in the Yarra River floodplain.	Melbourne Water provided technical information including monitoring data, conceptual models and survey information for Bolin Bolin Billabong
Presentation to Wurundjeri Council	September 2018	Information session/briefing provided to Wurundjeri Council primarily focusing on Bolin Bolin Billabong.	Opportunity for Wurundjeri Council to engage with technical specialists regarding the works undertaken, and be informed of outcomes of assessments to date.
Presentation to Wurundjeri Board	November 2018	Information session/briefing provided to Wurundjeri Board primarily focusing on Bolin Bolin Billabong.	Opportunity for Wurundjeri Council to engage with technical specialists regarding the works undertaken, and be informed of outcomes of assessments to date.

5.10 Community feedback

In addition to consultation undertaken with specific stakeholders, consultation has been ongoing with the community throughout the design development and the EES process. Feedback relevant to the groundwater assessment is summarised in Table 5-7, along with where those topics are addressed in this report.

Table 5-7 Community consultation feedback addressed by groundwater

Issues raised during community consultation	How it's been addressed
Contamination of groundwater and changes in groundwater levels during tunnel construction.	These issues are discussed in Section 8.4.1 of this report. Generally speaking, the project is considered to have a low risk of intersecting contaminated groundwater because: • The project is not located within a highly contaminated area, due to the current and historic land uses • Based on investigations undertaken, including groundwater sampling, widespread groundwater quality issues have not been identified. In some areas groundwater contamination has been identified, and unexpected groundwater may still be encountered during project construction. To address these issues, EPRs have been established to minimise impacts.

Issues raised during community consultation	How it's been addressed
Contamination of groundwater or changes in levels during operation of the tunnels.	These issues are discussed in Section 8.4.2 of this report. If groundwater contamination is identified, it is expected that it would be assessed and managed as part of the construction works, reducing opportunity for issues during the project's operation. EPRs have been established to minimise impacts. Tunnel design philosophy and specifications to contractors require the tunnels are constructed to minimise the ingress of groundwater. Studies have been undertaken to determine the change to groundwater levels due to the tunnel construction. These studies have also factored in the effects of climate change. Groundwater levels would change due to the construction and operation of the tunnels. The groundwater studies undertaken have assessed the impact of groundwater level changes on existing groundwater users, and the environment. These issues are discussed in Section 8.4. The effects of changes in groundwater level on terrestrial vegetation are assessed in Technical report Q – Ecology.
Interaction between groundwater and surface water systems during construction and operation, particularly impacts to creeks, rivers and billabongs.	Geotechnical investigations have identified there is connectivity between surface water and groundwater within the Yarra River floodplain. This is not unexpected. Studies have been undertaken to determine the change to groundwater levels from construction of the tunnels. These studies have also factored in the effects of climate change. It is understood there is particular interest in some waterways, notably Banyule Creek, Banyule Swamp and the Bolin Bolin Billabong. It is also understood the billabong has significant cultural heritage values. Banyule Creek is ephemeral, flowing after rainfall events. In its lower reaches nearer the alluvial floodplain, drawdowns are predicted near this feature under operation conditions. This drawdown would be due to seepage into the constructed tunnels via the bedrock aquifer, based upon the maximum permitted seepage rate. The impact of the drawdown on vegetation is discussed in Technical report Q – Ecology.
	Drawdowns are not predicted to extend beneath Banyule Swamp. Recharge rates into the alluvial aquifer are greater than tunnel seepage rates. This is discussed in Section 8.4 of this report. Drawdowns are predicted to extend to Bolin Bolin Swamp. Water in the swamp is controlled by flow events in the Yarra River. The impact of the drawdown on the aquatic ecosystems of the swamp are discussed in Technical report Q – Ecology. Drawdowns are also predicted to extend beneath the Yarra River near the Manningham Road interchange. The predicted change in flows of the Yarra River is negligible.

5.11 Peer review

This assessment has been independently peer reviewed by Hugh Middlemis of HydroGeoLogic. The peer reviewer reviewed and provided feedback on drafts of this report, as well as the methodology, approach, assumptions and assessment criteria applied to the assessment. The peer reviewer's methodology is set out in his peer review report, which also included addressing whether there were any additional matters which should be considered as part of the impact assessment in order to address the EES scoping requirements, 'public works' Order or to otherwise adequately assess the likely impacts of the project relevant to this assessment or the management of those impacts. The peer reviewer also considered whether there were any gaps or matters in this assessment which they disagreed with. The final peer review report is attached as Appendix D of this report. This sets out the peer reviewer's conclusions, and whether all of their recommendations have been addressed in this report.

6. Existing conditions

This section describes the regional hydrogeological conditions of the study area.

6.1 Regional geological setting

6.1.1 Stratigraphy

The geology can be broadly summarised as comprising a basement of folded and faulted Palaeozoic marine sedimentary rocks comprising mudstones and sandstones. These rocks were subsequently uplifted and eroded over time into a system of river valleys. These valleys have been periodically filled and re-eroded by fluvial and near shore marine sediments and periods of lava and pyroclastic flows. Some erosion has also occurred after the deposition of some lava flows and younger fluvial sediments resulting in the presence of younger 'capping' of some hills and ridgelines in the study area.

A summary of the hydrostratigraphy in the study area is provided in Table 6-1.

6.1.2 Geological history

The oldest rocks forming the bedrock within the study area consist of the Silurian age (410 to 434 Mya) Anderson Creek Formation (Sxa) and Melbourne Formation (Sxm) meta-sediments which comprise of a generally uninterrupted sequence of rhythmically interbedded marine turbidite sediments. These sediments are generally represented by mudstone, siltstone and sandstone and minor conglomerate with the sequence gradually coarsening during the Silurian and on into the Lower Devonian. During the Lower Devonian (410 to 400 Mya) continued deposition of turbidite sediments occurred, with a change to mostly massively bedded siltstone, comprising the Humevale Formation (Dxh).

During their deposition, these sediments were subject to ongoing subsidence and folding, with subsequent multi-phase folding, uplift and erosion occurring during the Mid to Upper Devonian. The folding was generally on a north-south trending axes giving rise to complex structures.

During the Upper Devonian Period (354 to 382 Mya), intrusions of granitic bodies and felsic dykes took place resulting in associated contact metamorphism of adjacent basement rocks. These Devonian age igneous rocks have not been mapped at the surface in the study area.

A period of faulting, uplift and erosion took place over an extended period between the Permo-Triassic and Lower Cretaceous and on into the Palaeocene (from 250 Mya to approx. 66 Mya). The prolonged period of erosion was accompanied by deep chemical weathering, which led to the creation of a major unconformity in the stratigraphic sequence.

In the Eocene era a series of clays, silts and gravels were deposited as valley infill sediments in the maturely dissected terrain. These are termed sub-basaltic sediments (Nxp), located stratigraphically below the extensive basaltic flows of the Older Volcanics – Greensborough Basalt (Nug). The volcanic activity was accompanied by the intrusion of basic (dolerite/diorite) dykes into the basement Silurian and Devonian sequences.

Table 6-1 Regional hydrostratigraphy and their role in the groundwater flow

Epoch	Era	Formation	Lithological description	Comment
Quaternary	Recent (Holocene) to Pleistocene	Undifferentiated (Qrm, Qra)	Mostly alluvial deposits comprising sands, silts, clays, swamp deposits	Porous media aquifer. Mostly associated to Yarra River floodplain and waterways in study area.
		Newer Volcanics (Tvn)	Olivine basalts, vesicular. Multiple flows superimposed upon each other. Highly variable weathering profile.	Fractured rock aquifer. Identified in limited areas of project.
Tertiary	Pliocene			
	Miocene	Brighton Group (Tpb)/Red Bluff Sands (equivalents)	Fine to coarse sands, gravels and clays. Marginal marine to fluvial deposition.	Porous media aquifer.
	Oligocene	Older Volcanics (Tvo)	Greensborough Basalt Olivine basalt, often highly weathered	Fractured rock aquifer. Identified in limited areas, but also as dykes within basement rocks.
	Eocene	Werribee Formation (equivalents) (Tew)	Sands, clays, silts and gravels.	Not identified in the study area
Unconformity				
Devonian	Upper	Coldstream Rhyolite Yellingbo Porphyry	Porphyry, granodiorites	Not mapped in the study area
Unconformity				
Devonian	Lower	Humevale Siltstone	Massive siltstones with interbedded sandstones, conglomerate and greywacke beds. Upper parts may have well developed saprolitic zones.	Fracture rock aquifer. Geological basement, underlying entire study area. Outcrops widely throughout area.
Silurian	Middle	Melbourne Formation (Sxm)		
		Anderson Creek Formation (Sxa)		

Multiple marine transgressions and regressions during the Miocene to Pliocene led to deposition of shallow marine sediments (Red Bluff Sand (Nbr) of the Brighton Group) and non-marine sands and clays onto the dissected terrain. The Red Bluff Sands consist of poorly consolidated fine to coarse sand, grit and gravel, with occasional hard bands caused by iron cementation (limonite) due to surface weathering processes. This period also included deep weathering of the exposed Silurian terrain with extensive ferruginisation associated with prolonged weathering in temperate but wet climatic conditions. Following the deposition of the Brighton Group, a subsequent period of uplift and erosion resulted in renewed formation of palaeo-valleys and the ‘stranding’ of caps of Miocene age deposits in elevated locations.

During the Pleistocene Epoch (1.8 to 0.01 Mya) eruption of a series of basalt flows primarily in the north and west of the study area (Newer Volcanic Group, Neo and Neo2) led to infilling of the ancestral Darebin Creek valley and displacement of streams to the margins of the basalt flows. Regression of sea levels led to renewed valley erosion and ‘inversion’ of the topography around the basalt flows. Some alluvial and lake sediments are documented to be present within the Yarra valley upstream of Alphington. These sediments are associated with a lake, which formed in the valley after damming by a basalt lava flow at Alphington.

During the Holocene (0.01 Mya to present) following the Pleistocene, a series of laterally restricted sediments were laid down within the river valleys including alluvium and alluvial terrace deposits (Qa1, Qa2). Associated colluvium is also present (Qc1).

6.2 Surface geology

A surface geological map of the study area is shown in Figure 6-1 and the key formations which occur in each element of the project study area are summarised below.

M80 Ring Road to northern portal

In the western section of the project’s M80 Ring Road to northern portal element, Older Volcanic basalt (Greensborough Basalt) has been mapped in outcrop. Smaller outcrops of Older Volcanic and Newer Volcanic basalt have also been mapped in the eastern part of this element near the intersection of the Greensborough Bypass and Diamond Creek Road. Sub-basaltic sediments (Brighton Group equivalents) have also been mapped in isolated areas where North East Link would intersect with the M80 Ring Road and Greensborough Bypass, and further east near Diamond Creek Road.

These basalts and sediments form a thin cover over the Palaeozoic bedrock, which outcrops over much of this element, particularly near the M80 Ring Road, and south towards Yallambie Road and the junction with the project’s northern portal to southern portal element. Alluvial and colluvial sediments have been mapped along the Plenty River, although these tend to be laterally restricted and in close association with the river.

Northern portal to southern portal

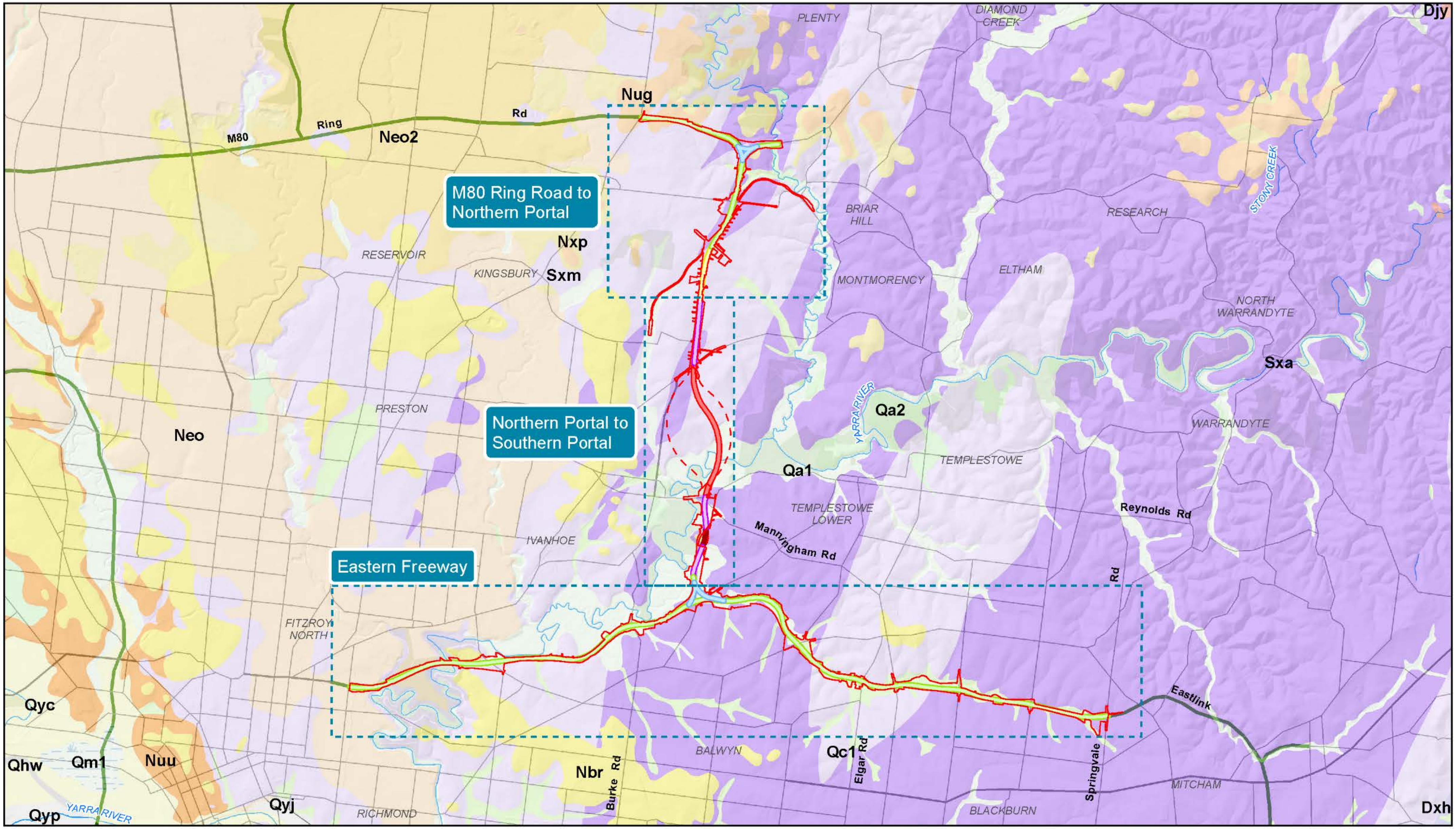
The surface geology of the project’s northern portal to southern portal element is mostly within the Palaeozoic bedrock, except in those areas near the Yarra River floodplain where alluvial sediments rest upon the bedrock.

South of Yallambie Road towards Banksia Street and Manningham Road, the Palaeozoic bedrock outcrops. The bedrock rock is buried beneath Quaternary alluvial sediments within the floodplain of the Yarra River, where the topography is flatter. South of Banksia Street and Manningham Road to the Eastern Freeway, North East Link would be aligned approximately parallel to the Yarra River floodplain. The Palaeozoic bedrock is exposed in higher elevations, otherwise it is buried beneath the sediments.

At the southern end of this project element, near the intersection of North East Link and the Eastern Freeway, the alluvial sediments are of broader extent where the Koonung Creek floodplain joins the Yarra River floodplain.

Eastern Freeway

The geology along the project's Eastern Freeway element comprises mostly of shallow Quaternary alluvial sediments, as the freeway is generally located within, or on the margins of the floodplain of the Yarra River or Koonung Creek. These alluvial sediments form a thin cover over the Palaeozoic bedrock although where absent, the bedrock outcrops in some sections of the project's Eastern Freeway element. At the western end of the element (Yarra Bend Park and further west) the freeway is located upon Newer Volcanic basalts. A small outcrop of Brighton Group sediments is mapped on the western side of the Chandler Highway.



Paper Size A4

0 700 1,400 2,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- Project element
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

- Elevated ramp
- Surface works
- Open Cut
- Cut and cover tunnel
- TBM bored tunnel
- Mined tunnel

Geographic Feature ID

- Djy
- Dxh
- Nbr
- Neo
- Neo2
- Nug
- Nuu
- Nxp
- Qa1
- Qa2
- Qc1
- Qhw
- Qm1
- Qyc
- Sxa
- Sxm

Roads

- Freeway
- Highway
- Major road

Watercourses

- River
- Parks & reserves

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

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Study Area
Surface geology

Figure 6-1

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: CIP Imagery - DELWP - 2018 | roads, watercourses, parks, rail, localities, planning zones - Vicmap - 2019 | precinct, project infrastructure - GHD, AECOM - 2019 Created by: trighetti

6.3 Geological long section

An interpreted geological long section has been developed as part of the geotechnical reporting. This section has been developed using regional geological information as well as data obtained from the North East Link geotechnical drilling program.

The geological long section is shown in Figure 6-2. The vertical alignment of the North East Link reference project is superimposed upon the section. The North East Link section extends from the intersection with the M80 Ring Road to the intersection with the Eastern Freeway. The section does not include the sections of upgrade along the M80 Ring Road and Eastern Freeway, although it is noted these sections would be constructed at or above grade.

As shown in the long section (refer Figure 6-2), the northern part of North East Link would be located within the Palaeozoic bedrock, and much of the below grade sections of the project would also located within the bedrock.

Proceeding from the north, North East Link would begin to dive below grade from Watsonia railway station and be within a road trench southwards from here to Blamey Road. Within this section, the project would be within Palaeozoic bedrock. Various grades of weathering of the bedrock have been differentiated on the long section. From Blamey Road North East Link would dip into cut and cover-constructed tunnels. At Lower Plenty Road the construction method would shift to tunnelling using a tunnel boring machine (TBM). TBM tunnelling continues through the bedrock as it passes beneath the Yarra River floodplain, which starts south of Buckingham Drive (near Banyule Creek). The southern portal of the tunnel would be located at Banksia Street/Manningham Road (the Manningham Road interchange), which coincides closely with the margin of the floodplain.

In this part of the study area, there is a change in the alignment of the floodplain extents. North of the Manningham Road interchange, the Yarra River floodplain trends in an east-west alignment, although south of here, the floodplain trends north-south. Construction of the North East Link tunnels using TBM would there cross oblique to the floodplain, although construction works in the portal and further south would occur on the margin and/or parallel to the floodplain. This is potentially fault controlled (see below). Areas of older terrace alluvial deposits, and filling have also been interpreted in the long section south of Banksia Street/Manningham Road.

The southern extent of the project's northern portal to southern portal element is shown on the long section to be within alluvial sediments of the Yarra River and Koonung Creek floodplains.

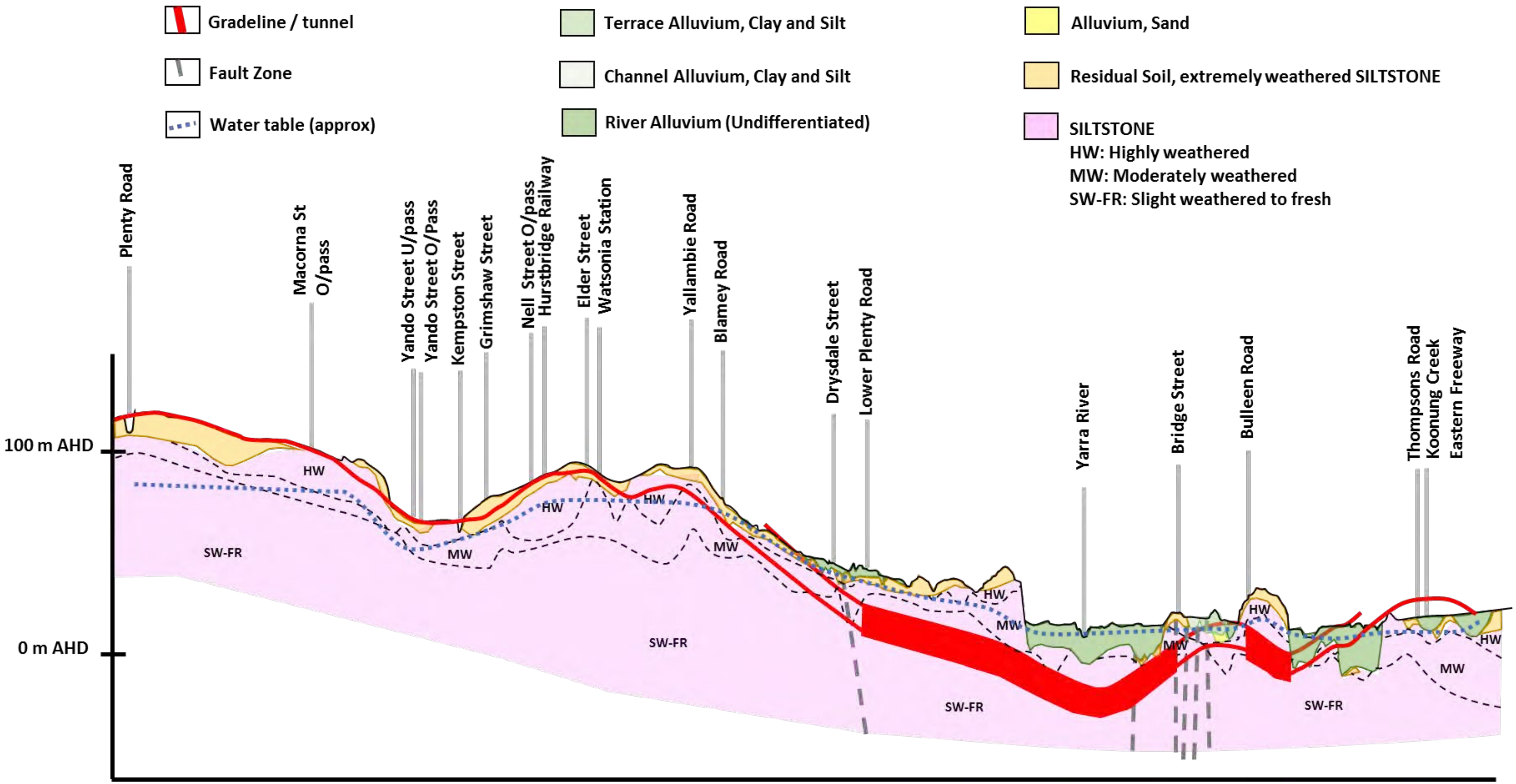


Figure 6-2 Geological long section

6.4 Geological structures

A series of lineaments are shown on the surface geological plan in Figure 6-1 and the geological long section in Figure 6-2. The lineaments represent the approximate north-south trending axes of anticlinal and synclinal folding within the Palaeozoic bedrock.

Fault zones are interpreted in the following locations:

- Lower Plenty Road
- Banksia Street/Manningham Road
- Bulleen Park.

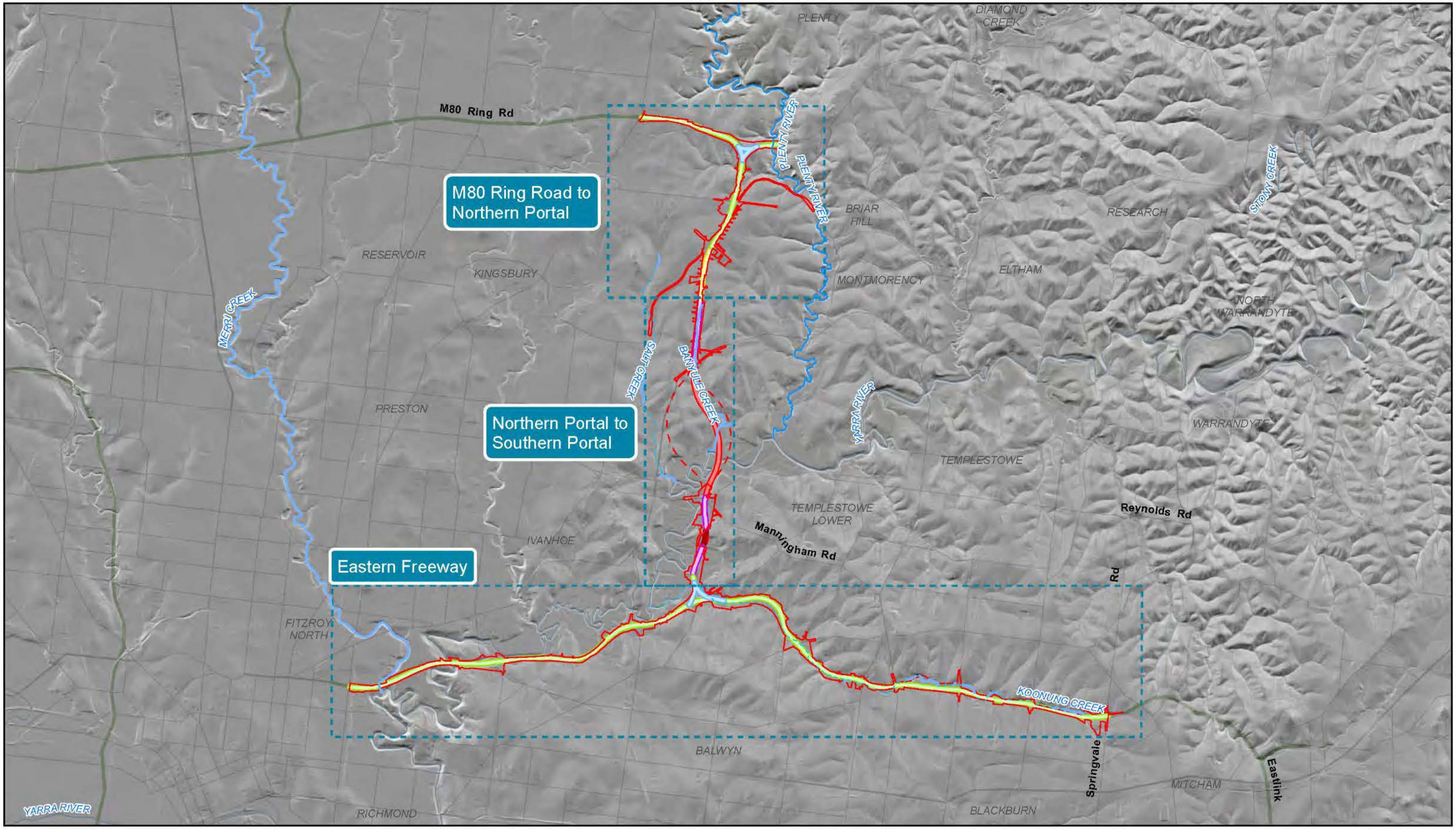
6.5 Topography and drainage

The study area topography is shown in Figure 6-3. The Palaeozoic bedrock forms undulating, rolling hills, which have been dissected by the Yarra River and its floodplain. The topography is highest around the project's M80 Ring Road to northern portal element, extending to over 100 metres above sea level.

The topography results in drainage towards the Yarra River floodplain, which generally lies 10 to 20 metres above sea level in the project's northern portal to southern portal element. Some of the larger drainage lines form permanent or ephemeral waterways, and these waterways are summarised in Table 6-2. Further information on waterways is provided in Technical report P – Surface water.

Table 6-2 Study area drainage

Element	Waterway	Description
M80 Ring Road to northern portal	Plenty River	The eastern extent of this project element ends at the Plenty River. The river parallels much of the element but is offset to the east by typically 1 km or more.
Northern portal to southern portal	Salt Creek	The drainage line extends within the Palaeozoic bedrock, offset to the west of the alignment and drains southwards before its confluence with the Yarra River near Banksia Street.
	Banyule Creek	The drainage line extends within the Palaeozoic bedrock and drains southwards before its confluence with the Yarra River near Banyule Swamp.
	Yarra River	The TBM would pass beneath Yarra River north Banksia Street/Manningham Road and then parallel the southern extent of this project element.
Eastern Freeway	Koonung Creek	This is parallel to much of the east of the Eastern Freeway element (south side of the Eastern Freeway) before its confluence with the Yarra River near Bulleen Road.
	Yarra River	This is parallel much of the western extent of the element and bridged near the western end of the element.



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Legend

- Project element
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

- Elevated ramp
- Surface works
- Open Cut
- Cut and cover tunnel
- TBM bored tunnel
- Mined tunnel

Roads

- Freeway
- Highway
- Major road

Watercourses

- River
- Parks & reserves

North East Link Project
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NORTH EAST LINK PROJECT

Study Area
Topography and Waterways

Figure 6-3

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6.6 Identified aquifers

6.6.1 Aquifer systems

All the geological formations mentioned in Section 6.1 constitute aquifers to varying degrees where they are saturated. From a high level hydrogeological perspective it is possible to simplify the various formations into two basic aquifer systems which are described below.

Fractured rock aquifers (bedrock aquifer)

The fractured rock aquifers include:

- Silurian – Devonian indurated sediments such as Anderson Creek, Melbourne and Humevale Formations (and including limestone); that is, Palaeozoic bedrock
- Basalts of the Newer (Quaternary/Upper Tertiary) and Older (lower Tertiary) Volcanics.

From a regional perspective, grouping these formations into a single aquifer system is considered a reasonable approach based on the following rationale:

- The various formations differentiated in the Palaeozoic bedrock are expected to have similar hydrogeological flow properties
- The Victorian Aquifer Framework (VAF) has collectively grouped all the Palaeozoic aquifers into a single 'basement' system
- Newer Volcanic basalts are limited in spatial extent and have only been identified in areas where at, or above grade construction is proposed.

Within these aquifers, groundwater is (mostly) transmitted by secondary porosity flow mechanisms in these rocks such as fractures, joints and other discontinuities within the rock mass. Primary porosity flow (that is, movement between grains) is mostly negligible in these materials except where the original matrix has been altered by weathering. Under these conditions, in a regional context, these rocks have hydrogeological similarities. On a local scale, the hydraulic character of the aquifers may vary because of:

- Weathering
- Nature of fracturing (size, density, persistence, infilling)
- Nature of their formation, such as dykes, karst, and contact metamorphism
- Tectonic history
- Local variations in lithology.

The fractured rock aquifer occurs in each of the three North East Link project elements. The aquifer is generally referred to in this report as the 'Bedrock' or 'Palaeozoic' aquifer.

Porous media aquifer (alluvial aquifer)

The porous media formations include the Tertiary Brighton Group, and the Quaternary (alluvial and colluvial) sediments:

- The Brighton Group sediments are suspected as underlying the Newer Volcanic basalt and are identified in the western parts of the study area.
- Quaternary sediments constitute a key aquifer in the study area. The alluvials are laterally restricted to the present day drainage lines and waterways, and in some cases can have high degree of interaction with waterways. Under these conditions, disturbance of groundwater in these sediments has potential environmental implications.

- Areas of filling have been identified within the study area, and where saturated, may behave analogous to porous media flow. Areas of filling are described in Technical report O – Contamination and soil.

While these porous media aquifers comprise various geologies, they have been collectively referred to as the 'Alluvial aquifer' throughout this report. Within porous media aquifers groundwater stored and transmitted by primary porosity flow (flow between the interstices and pore spaces of the sedimentary grains).

The alluvial sequences identified within the Yarra River and Koonung Creek floodplains comprises multiple stacked beds for clays, sands, silts and gravels. In some areas, coarse grained sandy beds have been identified through geotechnical drilling. These are shown in Figure 6-2 above and are likely to dominate flow processes in these aquifers.

6.7 Groundwater management

6.7.1 Definitions

The principle management unit for groundwater resources in Victoria is the Groundwater Management Unit or GMU. A GMU may be a Groundwater Management Area (GMA), a Water Supply Protection Area (WSPA) or an Unincorporated Area. An Unincorporated Area is a region falling outside a GMA or WSPA.

Under the *Water Act 1989* (Vic), the Minister for Water may declare the total volume of groundwater (and/or surface water) which may be taken in an area. This is termed the Permissible Consumptive Volume (PCV). The total volume of water allocated under the PCV became a trigger for declaration of a GMA (or WSPA).

The Water Act requires that all persons who wish to extract groundwater (except domestic and stock users) apply for a groundwater licence. Groundwater licences are issued to protect the rights of licence holders, to ensure that water is shared amongst users and that environmental requirements are protected. The Victorian Water Register was established as a public register of all water-related entitlements.

Within WSPAs, caps or moratoriums on the issue of additional extraction licences are often present. Owing to the implications on groundwater development, Ministerial approval, including the development of management plans, were required to convert a GMA to a WSPA. In the late 1990s approximately 50 GMAs were established across Victoria.

DELWP delegates the management of the Water Act to Southern Rural Water in the region where North East Link would be constructed. This means that Southern Rural Water is the licensing authority responsible for allocation of the region's groundwater (and surface water) resources. There has been continued water resource reform in Victoria and Southern Rural Water has been releasing Local Management Plans (LMPs) in response. LMPs are incorporating smaller GMUs into larger groundwater catchments for management purposes, but local rules have been retained to address specific issues and water trading arrangements. LMPs are considered to be more responsive than statutory management plans as they can be revised and updated with changing (local) groundwater conditions.

6.7.2 Review of mapping

The study area for the North East Link groundwater impact assessment does not fall within a defined groundwater management unit (which means it is unincorporated). A PCV has not been established and so there are no caps on water entitlements that can be issued under the Water Act.

Classification as an unincorporated area indicates there has been limited abstractive development or development potential (low yields, poor quality) in the region. Due to these factors, DELWP has not implemented more rigorous resource management measures in this area compared with those in declared GMAs and WSPAs.

6.8 Aquifer hydraulic parameters

6.8.1 Published information

Aquifer hydraulic parameters, specifically hydraulic conductivity, are important to understand the movement of groundwater and the influence the project's tunnels, cuttings and dewatering activities would have on the groundwater environment.

Horizontal hydraulic conductivity

In this region of metropolitan Melbourne, primarily due to the saline groundwater qualities (refer Section 6.7) and limited groundwater abstractive development, there have been limited opportunities to characterise aquifer hydraulic conductivities. However, correlations can be drawn from other parts of metropolitan Melbourne, and particularly from more recent infrastructure investigations where similar geological settings are found.

A summary of hydraulic conductivity estimates is provided in Table 6-3. It is acknowledged that the hydraulic conductivity of the bedrock aquifer can be highly variable owing the nature of fractured rock aquifers as hydraulic conductivity can span several orders of magnitude.

Table 6-3 Published hydraulic conductivities

Formation	Hydraulic conductivity (k_h)		Reference
	m/day	m/sec	
Melbourne Formation	8.6×10^{-6} to 1.8	1×10^{-10} to 2×10^{-5}	Melbourne Metro AJM (2016)
Palaeozoic Basement (generic)	0.02 to 1	2×10^{-7} to 1×10^{-5}	Leonard (1992)
Palaeozoic Basement (generic)	0.001 to 0.3	1.1×10^{-8} to 3.4×10^{-6}	Leonard (2006)
Palaeozoic Basement (generic)	1×10^{-5} to 1	1×10^{-10} to 1×10^{-5}	Dahlhaus *et al.*(2004)
Quaternary Alluvials	1	1.1×10^{-5}	GHD (2010)
Palaeozoic Basement (generic)	8×10^{-7} to 0.03	9.2×10^{-12} to 3.4×10^{-7}	GHD (2010)

Note: 1 m/day = 1.16×10^{-5} m/s

Vertical hydraulic conductivity

Information about vertical hydraulic conductivities of the alluvial sediments (or equivalents found elsewhere in the Yarra River floodplain) or the Palaeozoic bedrock aquifer was not identified.

GHD (2010) documents the following values based on calibrated regional modelling:

- Alluvials: 0.001 m/day
- Palaeozoic bedrock: 8×10^{-8} to 3×10^{-3} m/day.

Storativity and specific yield

A summary of estimates is provided in Table 6-4. It is acknowledged that specific yield and storativity can be difficult to quantify.

Table 6-4 Published storativities

Formation	Specific yield (Sy)	Storativity (S)	Reference
Alluvials	0.075	-	GHD (2010)
	0.05 to 0.3	-	Dahlhaus *et al* (2004)
Palaeozoic Basement (generic)	0.02 to 0.1	1×10^{-5}	Leonard (1992)
	0.02 to 0.05	-	Dahlhaus *et al* (2004)

6.8.2 Site-specific testing

Horizontal hydraulic conductivity

Hydraulic conductivity (K) is defined as the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

To characterise material permeabilities, three approaches were applied during site investigation activities to characterise aquifer hydraulic conductivity:

- Packer testing of geotechnical boreholes
- Single bore slug testing of monitoring bores
- Aquifer pumping tests.

The testing was mostly focused to those areas of the project that would be below grade in tunnels or road trenches that intersected the water table.

Slug tests are most commonly applied in situations where groundwater flow to a bore is not sufficient to allow pumping or where bore diameters are narrow (less than 100 millimetres). In addition, this approach is useful when only an order of magnitude of aquifer transmissivity is desired. The method estimates the hydraulic conductivity within close proximity or limited radius of influence (that is, metres) of the bore. Slug tests are, however, vulnerable to poor monitoring bore design or development. Features of the bore construction, such as a small open area, a too fine filter pack and/or remnants of the drilling process such as a residual mud cake or smearing of clays, may be a controlling factor in permitting the flow of water into the monitoring bore. These factors are not considered to have influenced the results due to the drilling method, bore construction and development procedures adopted. Falling and/or rising head hydraulic conductivity tests (or slug tests) were carried out on most installed groundwater monitoring bores to estimate the hydraulic conductivity around the screened section of the existing groundwater monitoring bores at the multiple sites.

The solutions developed by Bouwer and Rice (1976) and Hvorslev (1951) were primarily used to match the water level response in an unconfined aquifer due to the instantaneous injection (falling head) or withdrawal (rising head) of a ‘slug’ from a bore. The Hvorslev (1951) solution was originally intended for confined aquifers, although it can be used to approximate unconfined conditions when the bore screen is below the water table (that is, fully saturated).

Packer tests are completed on boreholes before the installation of monitoring well casing. A packer in an inflatable device is lowered into a borehole and is used to seal off a section of the borehole. Testing can be completed using a single packer (that is, isolation between the base of the hole and the packer or two packers (straddle)) where testing of the zone between the two packers is completed. Following inflation of the packer(s), water is injected into the test zone and the volume of water recorded. A lugeon is calculated from the packer test which can be approximated to a hydraulic conductivity.

A summary of the hydraulic conductivity testing is provided Table 6-5 and Table 6-6 for the packer testing and single bore slug testing respectively.

Table 6-5 Hydraulic conductivity estimates – packer testing

Aquifer	No. of Tests	Unit	Hydraulic conductivity (Kh)		
			Minimum	Maximum	Geometric mean
Bedrock	62 bores (342 tests)	Lugeons(1)	0(2)	198.3	1.12
		m/sec (by conversion)	0	2.3×10^{-5}	1.2×10^{-7}
		m/day (by conversion)	0	2	1.2×10^{-2}

Note:
1. 1 Lugeon ≅ 1.3×10^{-7} m/sec or ≅0.01 m/day
2. No water uptake during testing.

Table 6-6 Hydraulic conductivity estimates – slug testing

Aquifer	No. of Tests	Unit	Hydraulic conductivity (Kh)		
			Minimum	Maximum	Geometric mean
Bedrock	22	Lugeon (by conversion) (1)	0.8	123	8.4
		m/sec	1.1×10^{-7}	1.6×10^{-5}	1.1×10^{-6}
		m/day	9.2×10^{-3}	1.4	1×10^{-1}
Alluvials	8	m/sec	8.9×10^{-6}	2.8×10^{-4}	3.8×10^{-5}
		m/day	7.7×10^{-1}	24	3.3

Note:
1. 1 Lugeon ≅ 1.3×10^{-7} m/sec. Lugeon value is for comparative purposes only – slug tests are not used to determine lugeons.

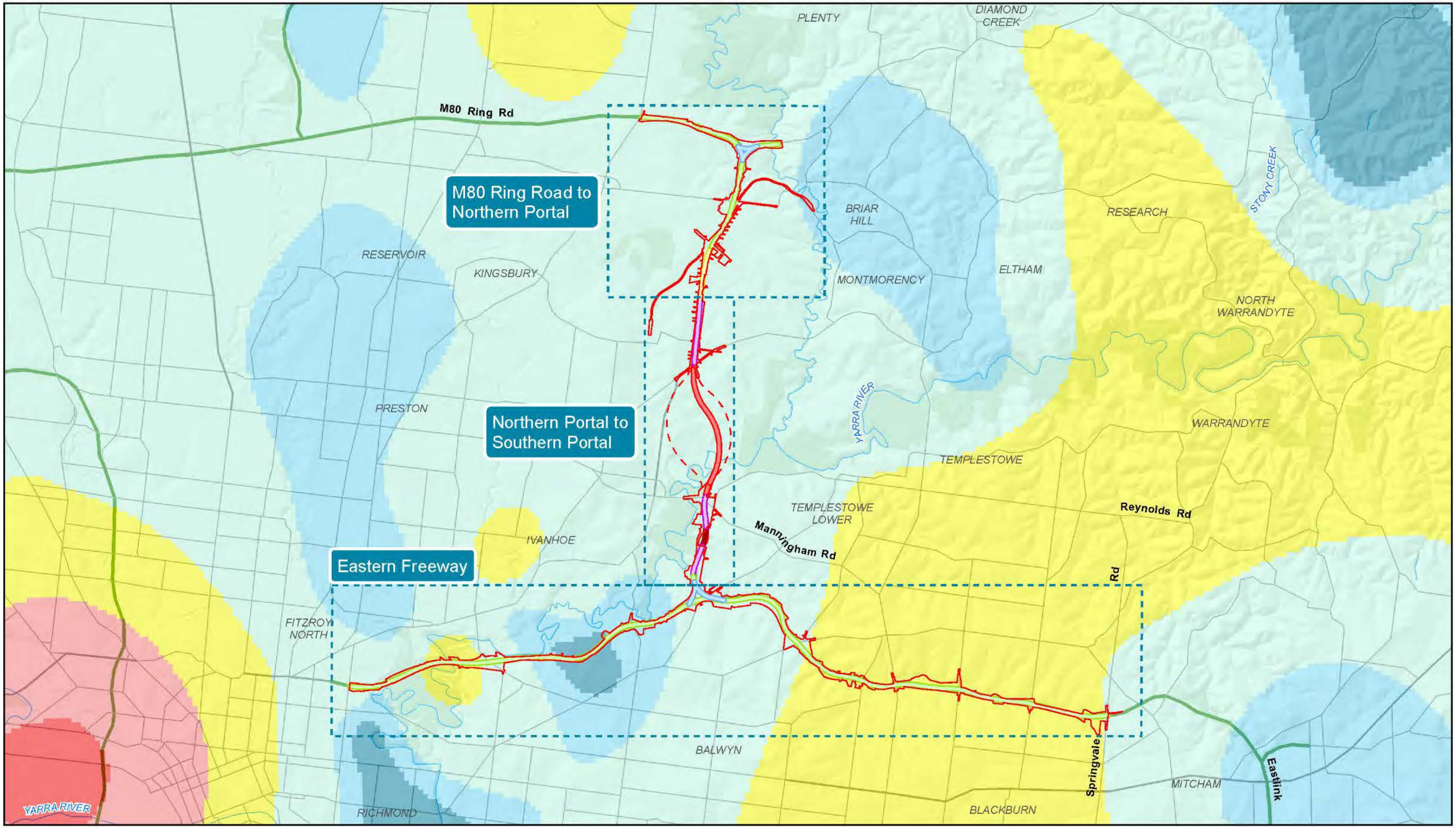
6.9 Groundwater quality

This section provides a general overview of the groundwater quality of the study area. This overview has been informed from the regional mapping and groundwater sampling undertaken as part of the geotechnical investigation program. Specific information about potentially contaminating land uses is provided in Technical report O – Contamination and soil.

6.9.1 Regional mapping

Broad-scale mapping of groundwater salinity, reported as Total Dissolved Solids (TDS) was completed by GHD (2012) and DCNR (1995) and is shown in Figure 6-4. From this mapping, the regional groundwater salinity is interpreted to be between 1,000 mg/L TDS and 3,500 mg/L TDS. It is noted that within the project's Eastern Freeway element, high salinity groundwater with salinities ranging between 3,000 mg/L to 7,000 mg/L TDS has been interpreted west of the Chandler Highway and east of Doncaster Road.

In general terms the groundwater salinity in the alluvial sediments is considered to be fresher (lower salinity) compared with that within the Palaeozoic bedrock, as the former have potential interaction with fresh surface water and a greater likelihood of shorter groundwater flow paths and residence times within the aquifer. Further conceptualisation of this is provided in Section 6.16. As discussed in Section 1.1.1, there are some inaccuracies with the regional mapping based on site-specific groundwater sampling.



Paper Size A4

0 700 1,400 2,800 Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- Project element
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

- Elevated ramp
- Surface works
- Open Cut
- Cut and cover tunnel
- TBM bored tunnel
- Mined tunnel

SAFE Watertable Salinity

- 0 - 500
- 500 - 1000
- 1000 - 3500
- 3500 - 7000
- 7000 - 13000
- 13000 - 35000

Roads

- Freeway
- Highway
- Major road

Watercourses

- River
- Parks & reserves

NORTH EAST LINK PROJECT

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Environment Effects Statement (EES)

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Regional groundwater salinity — Figure 6-4

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Data source: CIP Imagery - DELWP - 2018 | roads, watercourses, parks, rail, localities, planning zones - Vicmap - 2019 | precinct, project infrastructure - GHD, AECOM - 2019 Created by: trighetti

6.9.2 North East Link monitoring network

Selected geotechnical boreholes have been converted to groundwater monitoring bores and so a North East Link groundwater monitoring network has been established to support the engineering design and environment studies as well as and future baseline monitoring for the project.

Following their development, selected groundwater monitoring bores were sampled using low-flow sampling methods in accordance with EPA Victoria's Groundwater Sampling Guidelines (EPA Victoria, 2000). A summary of the salinity is provided in Table 6-7 and the spatial variability of groundwater quality is discussed in Section 6.9.3.

Table 6-7 Study area groundwater salinity

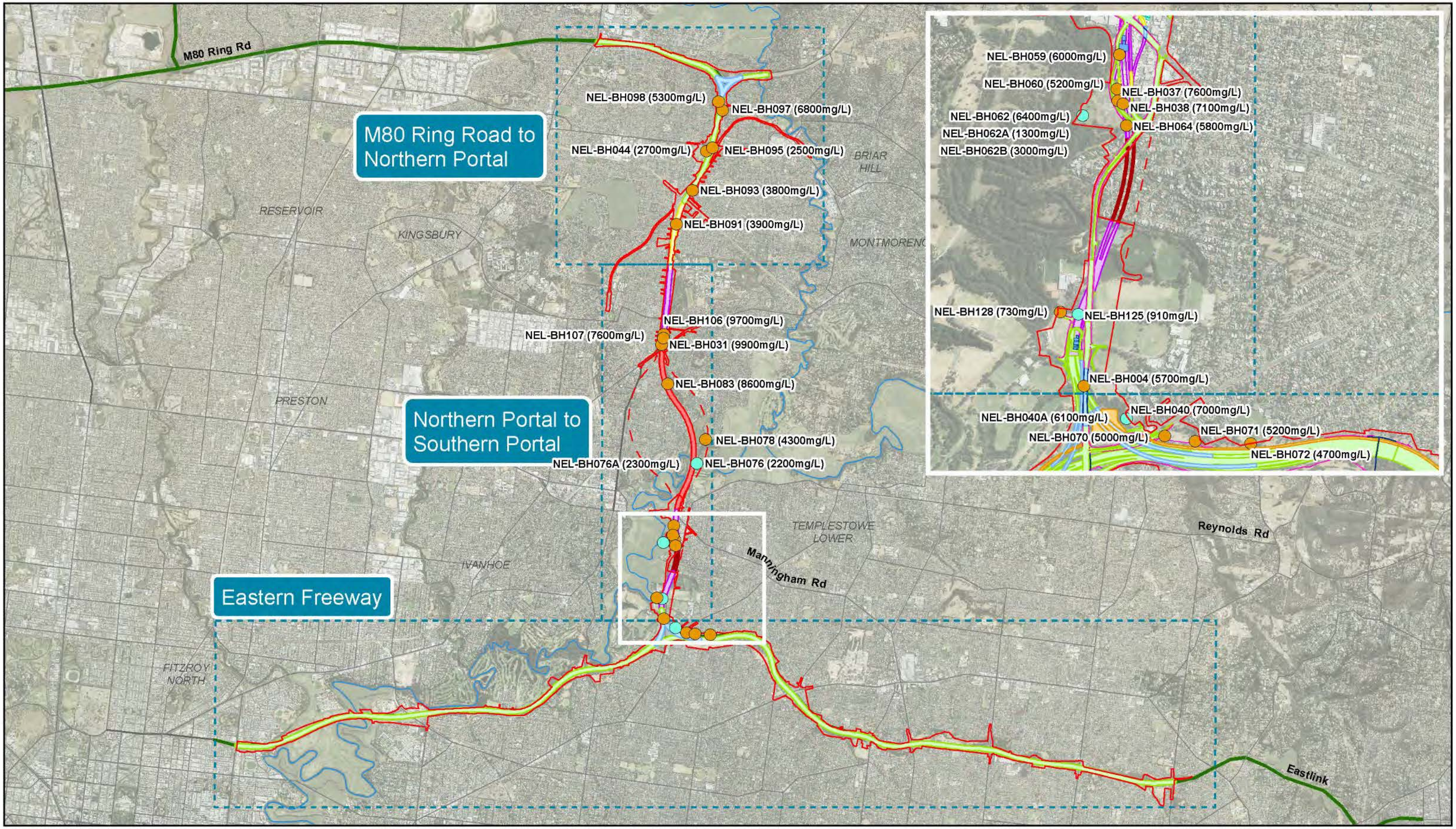
Aquifer	Number of samples	Groundwater salinity (mg/L TDS)			
		Minimum	Maximum	Mean	Geometric mean
Sediments (Alluvial)	7	910	6,100	2,658	2,235
Bedrock (Palaeozoic)	26	730	9,900	5,720	5,099

Note:
1. At time of reporting, no North East Link bores were developed in the volcanics (Newer or Older).
2. SEPP (Waters): Segment C = 3,101 – 5,400 mg/L TDS, Segment D = 5,401 – 7,100 mg/L TDS

The salinity as characterised by the North East Link monitoring network is shown in Figure 6-5. Based on these samples, groundwater within the alluvial sediments can range between Segments A2 to B but generally falls within Segment B. Groundwater within the Palaeozoic bedrock ranges from Segment A2 to E, although the lower salinity groundwater is identified generally close to waterways. Regionally, the bedrock aquifer groundwater typically falls within Segments C to E.

Some groundwater beneficial uses may not be applicable due to low yields of an aquifer which make extraction uneconomic, land use zoning (mostly residential zoning would suggest limited stock watering) and the elevated groundwater salinity (at higher salinities stock watering applications become limited depending on species). Under the SEPP (Waters), EPA Victoria determines which beneficial uses do not apply. The beneficial uses for each aquifer are summarised in Table 6-8 and the following comments are made:

- As inferred from the low density of existing private bores, the regional salinity mapping (DCNR 1995) is inaccurate. Groundwater quality over much of the project area, as characterised from the geotechnical investigation program, is more saline than indicated by the regional mapping.
- Although groundwater salinities fall within that suitable for potable mineral water supply, this beneficial use of groundwater has limited likelihood of being realised. The study area is not within a designed mineral water province and observations from sampling undertaken during the geotechnical investigation program indicated no obvious evidence of desirable mineral water properties such as effervescence.
- Geothermal use of groundwater is highly unlikely as elevated geothermal gradients have not been identified in the study area.



Paper Size A4

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Project element
Project boundary - sub-surface
Project boundary - surface

Aquifer
Alluvials
Bedrock

Proposed reference project
Elevated ramp
Surface works
Open Cut
Cut and cover tunnel
TBM bored tunnel
Mined tunnel

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Geotechnical program groundwater salinity

Job Number 31-35006
Revision C
Date 04 Mar 2019

Figure 6-5

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Data source: Vicmap: Roads, Watercourses 2018. Created by:sacevedo

Table 6-8 Beneficial uses of groundwater for aquifer systems in study area

Beneficial use	Aquifer		Comment
	Bedrock (Palaeozoic)	Alluvial	
Protection of water dependent ecosystems and species	✓	✓	Groundwater from around the study area discharges into the Yarra River (and tributaries)
Potable water supply – desirable			Such a beneficial use is unlikely to be realised in the study area. At the lower end of the salinity range, the alluvial aquifer may support potable use applications. Lower salinity water in the bedrock has been identified only in bores located close to Yarra River. Regionally, this potential beneficial use is not relevant to the bedrock aquifer.
Potable water supply – acceptable	✓	✓	
Potable mineral water supply	✓	✓	Groundwater is not in a designated mineral water province nor does it exhibit properties desirable in a mineral water, such as spritzig or effervescence.
Agriculture and irrigation – irrigation	✓	✓	Groundwater is generally too saline in the bedrock aquifer for irrigation use. Segment B salinity water in the bedrock aquifer has only been identified near to the Yarra River. The ability to develop the alluvial (and bedrock) aquifer for irrigation use would be dependent upon a) yield, and b) impact to waterways. For the bedrock aquifer, this beneficial use has only been included as it is noted that a bore with a designated irrigation use has been identified in the study area (refer Table 6-14), that intersects the bedrock aquifer. However, use of the bore for these purposes has not been confirmed.
Agriculture and irrigation – stock watering	✓	✓	Use of groundwater in the bedrock aquifer for stock watering would depend on livestock tolerances. At salinities above 6,000 mg/L (~mean salinity), the groundwater is suitable only for sheep and goats. This use is also unlikely to be realised in the metropolitan setting, although stock and domestic bores have been identified in the study area (refer Table 6-14).
Industrial and commercial	✓	✓	Could possibly be used but elevated salinities, low bore yields, and availability of potable reticulated supply suggest use of groundwater for these purposes is unlikely, given the largely residential land use of the study area. However, a commercial use bore has been identified in the study area (refer Table 6-14).

Beneficial use	Aquifer		Comment
	Bedrock (Palaeozoic)	Alluvial	
Water based recreation – primary contact recreation	✓	✓	Groundwater discharges to waterways such as the Yarra River. This could potentially be used for swimming pool top-up.
Buildings and structures	✓	✓	Water levels are generally too deep to impact current building configurations (off floodplain).
Geothermal (refer note)	✓	✓	This beneficial use is unlikely to be realised in the study area – the groundwater is not of elevated temperature within the upper 100 m of the surface.
Cultural and spiritual values (refer note)	✓	✓	Relevant where groundwater is discharging to creeks, billabongs and sustaining GDEs.
Traditional Owner cultural values	✓	✓	Bolin Bolin and the Yarra River are recognised as having significant traditional owner cultural values.

Note:
Yarra River is used for canoeing and boating (secondary contact).t

6.9.3 Known groundwater quality impacts

North East Link monitoring network

Groundwater samples were collected from the North East Link monitoring bore network consistent with EPA Victoria guidelines (2000) and analysed for a range of analytical parameters. A summary of water quality from the North East Link groundwater monitoring network is provided in Table 6-9.

Table 6-9 Summary of groundwater quality

Aquifer	Analyte	Unit	Count	Minimum	Maximum	Average	Geo. mean
Alluvials	pH	pH unit	7	6.3	8.3	7.37	7.33
	EC	µS/cm	6	1600	12000	4650	3637
	TDS	mg/L	7	910	6100	2658	2235
Bedrock	pH	pH unit	26	6	8.6	7.60	7.57
	EC	µS/cm	23	5500	19000	11117	10518
	TDS	mg/L	26	730	9900	5720	5099

The following general comments are made regarding the groundwater quality:

- There is a sampling bias in terms that most investigation bores have targeted the Palaeozoic bedrock aquifer. Regardless of this, sampling has supported the hydrogeological conceptualisation (refer Section 6.16) of fresher groundwater being present near waterways.
- Salinity of bores developed in the alluvial sediments ranged from 910 mg/L TDS to 6,000 mg/L TDS, with an average of 2,658 mg/L TDS. The highest salinity of 6,000 mg/L was identified in bore NEL-BH40A which is a shallow bore near Koonung Creek. This potentially suggests interaction with the underlying saline bedrock aquifer as the deeper bore constructed into the bedrock at this nested site recorded a salinity of 7,000 mg/L TDS. Salinities in the bedrock aquifer are much higher, and ranged from 5,500 mg/L to 9,900 mg/L TDS.
- Groundwater pH in both aquifer systems was between 6 and 9, and averaging 7.4 and 7.6 for the alluvial and bedrock aquifers respectively.
- Total Petroleum Hydrocarbons (TPH) were identified in bore NEL-BH062A (alluvials), located at the former Bulleen Drive-In, and NEL-BH191 (bedrock) within the Watsonia Station Car Park, above the laboratory limits of reporting.
- Concentrations PFHxS+PFOS and PFOS were reported above the adopted criteria NEMP (2018) Ecosystems Fresh Water (99 per cent), Stock watering and Primary Contact Recreation in groundwater sample obtained from NEL-BH062A (alluvial aquifer) located at the former Bulleen Drive-In. The source of PFAS in groundwater in this area is unclear and at this stage there is insufficient information to identify a likely source nor define the extent of the issue. PFAS may be migrating from the adjacent industrial area or may be associated with an activity undertaken at the former drive In. Compounds were also identified in bore NEL-ENV-BH009 (Manningham Road) and NEL-ENV-BH024 (near the Watsonia railway station car park).
- Concentrations of heavy metals have been identified above the limits of laboratory reporting, although in most cases concentrations are considered to be within the natural background ranges.

The groundwater quality based on its major ion chemistry is presented on Piper and Modified Durov plots as shown in Figure 6-6. These are visual aids for assessing the relative abundance of common ions in groundwater. The Modified Durov plot is similar to the Piper plot, although it differentiates a groundwater on salinity and pH.

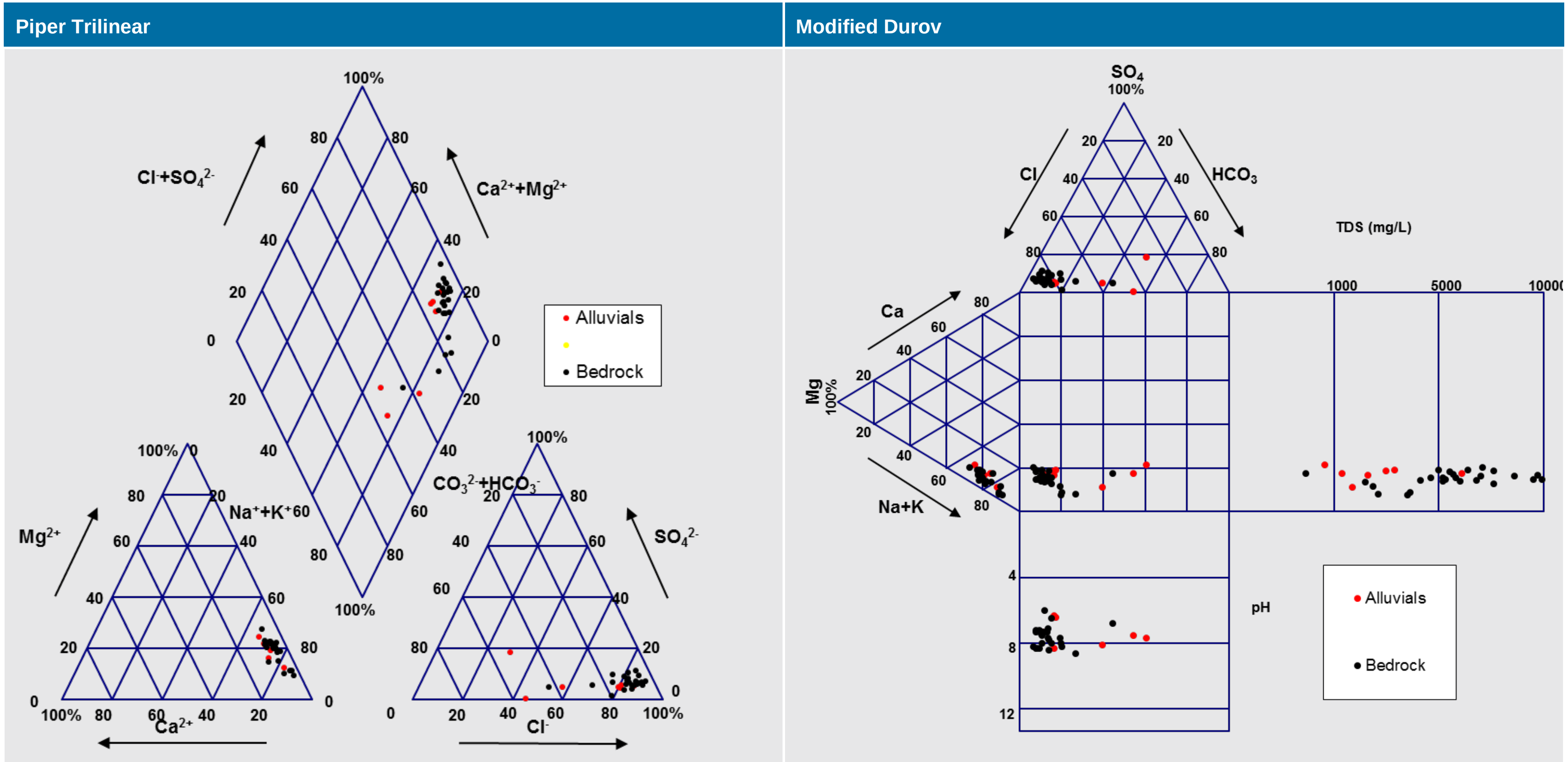


Figure 6-6 Hydrochemical analysis of major ion chemistry

The plots in Figure 6-6 confirm the bedrock groundwater is more saline and tends towards a sodium-chloride type water, based on the relatively dense clustering of the bedrock samples. Albeit a lower number of samples from the alluvial aquifer have been collected, the anion type is not able to be discerned. This suggests that the alluvial waters mix with other waters such as water from surface waters.

Historical landfilling

Landfilling has been identified in eight locations within the study area. These landfills are described in Technical report O – Contamination and soil. Of particular note from a groundwater perspective is the historical landfilling that occurred at Borlase Reserve (near the project's northern portal) and Bulleen Park (near the project's southern portal and cut and cover sections). Both these sites are in areas where potential changes in groundwater levels are expected and a summary of these areas is provided in Table 6-10.

Table 6-10 Landfills (northern portal to southern portal)

Landfill	Waste type	Description
Borlase Reserve	Solid inert waste and possible putrescible waste	Filling occurred during the early to mid-1960s. The geotechnical investigations for the project identified minor amounts of construction and demolition wastes, at depths generally less than 3 m (that is, above the groundwater table).
Bulleen Park	Solid inert waste and possible putrescible waste	Filling occurred during the early to late 1960s. Landfilling extended over the current day oval at Bulleen Park extending to the Yarra River in the west, the current day Veneto club in the north and the Bulleen Park entrance road in the south. Bores drilled in this area such as NEL-BH128 intersected 3 m of filling and groundwater levels were 6 m below surface (that is, filling occurring above the water table).

Groundwater Quality Restricted Use Zones (GQRUZ)

A GQRUZ is an area where historic groundwater pollution has been identified, that is subject to clean-up, and where restrictions exist as to what water can be used for if extracted via a groundwater bore. The locations of identified GQRUZ within one kilometre of the project are provided in Table 6-11 and shown in Figure 6-4. The identified GQRUZ are in areas remote from where North East Link would be constructed and so disturbance of any groundwater contamination in these places is highly unlikely.

Table 6-11 Study area GQRUZ

Element	Number	Description
M80 Ring Road to northern portal	1	Located 0.9 km south of western end of this project element, on Plenty Road.
Northern portal to southern portal	0	No GQRUZ identified.
Eastern Freeway	8	Located 0.7 km south of the eastern end of this project element on Doncaster Road. Located 1 km north of the eastern end of this project element on Doncaster Road (east of Tram Road). Located 0.8 km north of the western end of this project element, on Heidelberg Road, east of Yarra Bend Road. Five sites located at the western end of this project element near Hoddle Street. These are located north and south of the Eastern Freeway.

EPA Victoria audit sites

Statutory environmental audits are undertaken by an EPA Victoria-appointed independent environmental auditor, typically at the request of a site owner. The fact that an audit has been undertaken on a site is not an indicator of contamination, although it is likely to be an indicator of historic industrial and commercial land use with potential for contamination.

Audits completed in the project area are discussed and described in Technical report O – Contamination and soil. Audit sites located close to below grade works, including a description of available groundwater information are summarised in Table 6-12. In general terms, the audits provided little information to inform the understanding of groundwater quality.

Table 6-12 Study area audits (groundwater)

Audit	Description
Corner Bulleen Road and Austin Street EPA 27621-2	Former Bulleen Service Station (Axis Environmental 1996) Groundwater was not intersected as part of investigations. Hydrocarbon impacted soils were identified.
233 Bulleen Road EPA 42804-1	Former Burgess Waste Site, Bulleen (PPK, 2001) Groundwater was not intersected (depths to 12 m) as part of the investigations. Hydrocarbon impacted soils were identified.
Corner Yallambie Rd and Lower Plenty Road	Fuel storage area, Simpson Barracks (Golder, 1992) The environmental auditor could not determine from the available data if the groundwater below the site was contaminated. However, as contamination of the soils was not identified, any contamination must originate from off-site.

6.9.4 Aggressive or corrosive groundwater

The chemistry of groundwater has the potential to impact the integrity and lifespan of materials that would be used to construct North East Link if it comes into contact with features such as the project's tunnels, piles used in foundations, retaining walls and floor slabs.

Groundwater in the bedrock aquifer can have elevated salinity, chloride, sulfate and hardness. Selected groundwater monitoring bores were sampled for a suite of analytes specifically targeting its propensity to be aggressive. This information would be used during the design process to inform the selection of construction materials based on a consideration of their durability.

6.10 Groundwater levels and potentiometry

6.10.1 Regional mapping

Regional depth to water mapping was available from DELWP, and the mapping relating to the study area is shown in Figure 6-7. Mapping that is relevant to each of the project's element is summarised in Table 6-13.

Table 6-13 Project element depth to water from regional mapping

Element	Description
M80 Ring Road to northern portal	This project element is within an area considered to have water table depths greater than 10 m below surface. Exceptions are noted in the following lower lying areas: • Plenty River floodplain • North of Grimshaw Street and along the Hurstbridge rail corridor.
Northern portal to southern portal	At the northern end of this project element, groundwater levels are interpreted to be <5 m to 10 m deep. Within the Yarra River and Koonung Creek floodplains, water levels are potentially less than 5 m.
Eastern Freeway	In this project element, water levels are generally 5 m to 10 m below the surface to the west of Bulleen Road, and potentially less than 5 m to the east of Bulleen Road. Shallower groundwater levels are likely within the floodplains of the Yarra River and Koonung Creek. Where the Eastern Freeway is located above the floodplain (on outcropping bedrock) groundwater levels could be deeper.

6.10.2 Alignment mapping

The geotechnical program involved the construction of 70 monitoring bores throughout the study area. While the majority of the bores are located close to the alignment of the reference project, groundwater levels were mapped. Water levels from these bores were used to aid the steady state calibration of the numerical groundwater model.

The subsequent water table mapping is shown in Figure 6-8 below. Water levels have also been attached to the geological long section shown in Figure 6-2 above. In general, water levels are forming a subdued reflection of the topography, with groundwater flows towards the alluvial floodplains of the Yarra River.

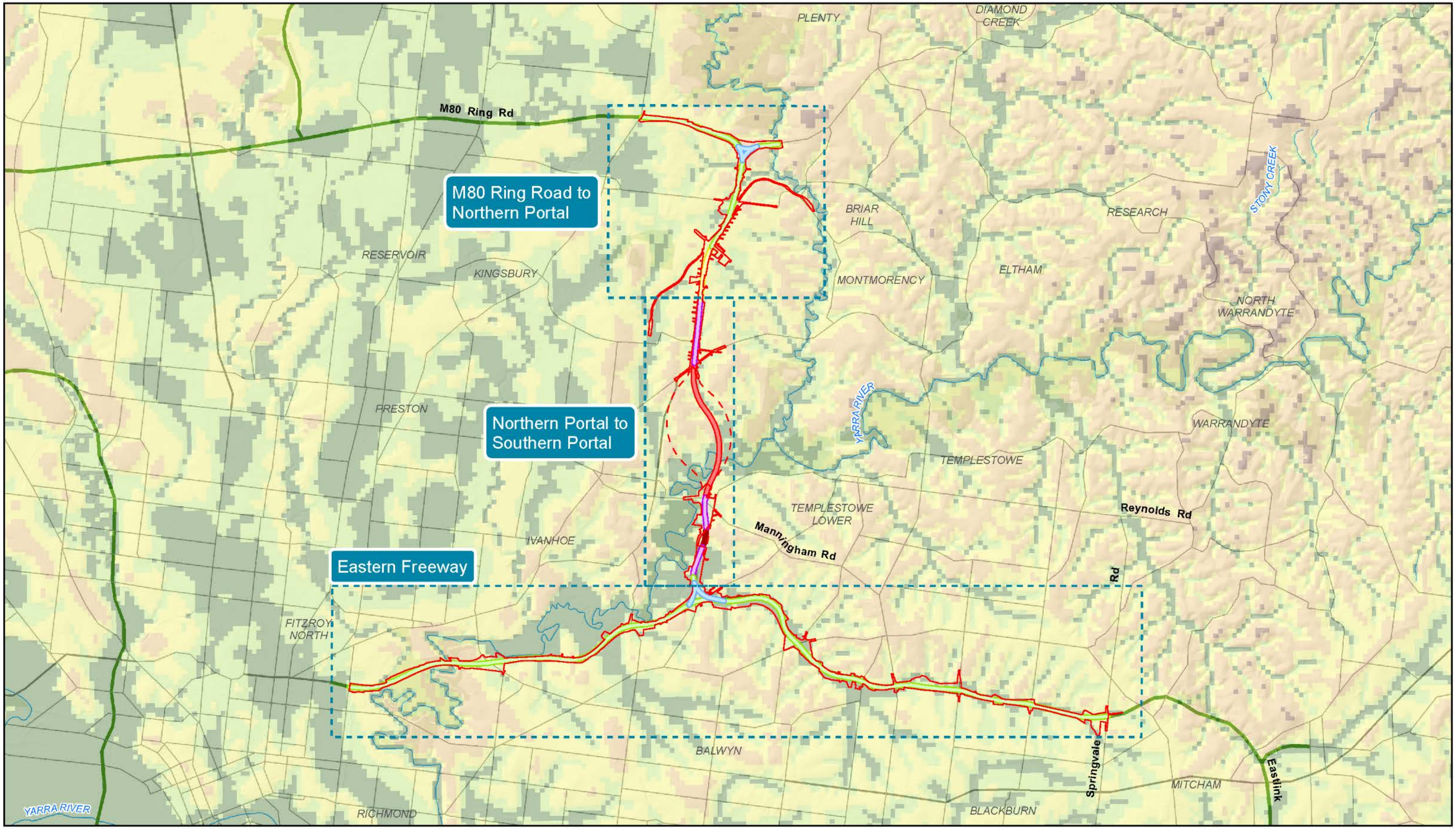
6.10.3 State observation bores

A search of the groundwater management system was undertaken to identify the presence of any active State Observation Network (SON) bores. The SON bores are used by DELWP to facilitate groundwater resource management, and can provide valuable information for a region as they provide a water level monitoring record, and at some sites, water quality monitoring data. Most SON bores are monitored every quarter, although monthly monitoring frequencies are adopted in some WSPAs. There are no SON bores located within a five-kilometre radius of the North East Link alignment.

6.10.4 Other monitoring

Other identified bores within two kilometres of the North East Link alignment are noted as having an observation use, but these are typically associated with contaminated land investigations and data is generally not publicly available for these sites.

Monitoring data was available from Melbourne Water associated with the Bolin Bolin Billabong. This information is discussed in Section 6.10.6.



Paper Size A4

0 700 1,400 2,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

Project element
Project boundary - sub-surface
Project boundary - surface

Proposed reference project

Elevated ramp
Surface works
Open Cut
Cut and cover tunnel
TBM bored tunnel
Mined tunnel

SAFE Watertable Depth (m)

5
10
20
50
100

Roads

Freeway
Highway
Major road

Watercourses

River
Parks & reserves

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Job Number	31-35006
Revision	E
Date	05/03/2019

Regional depth to water table

Figure 6-7

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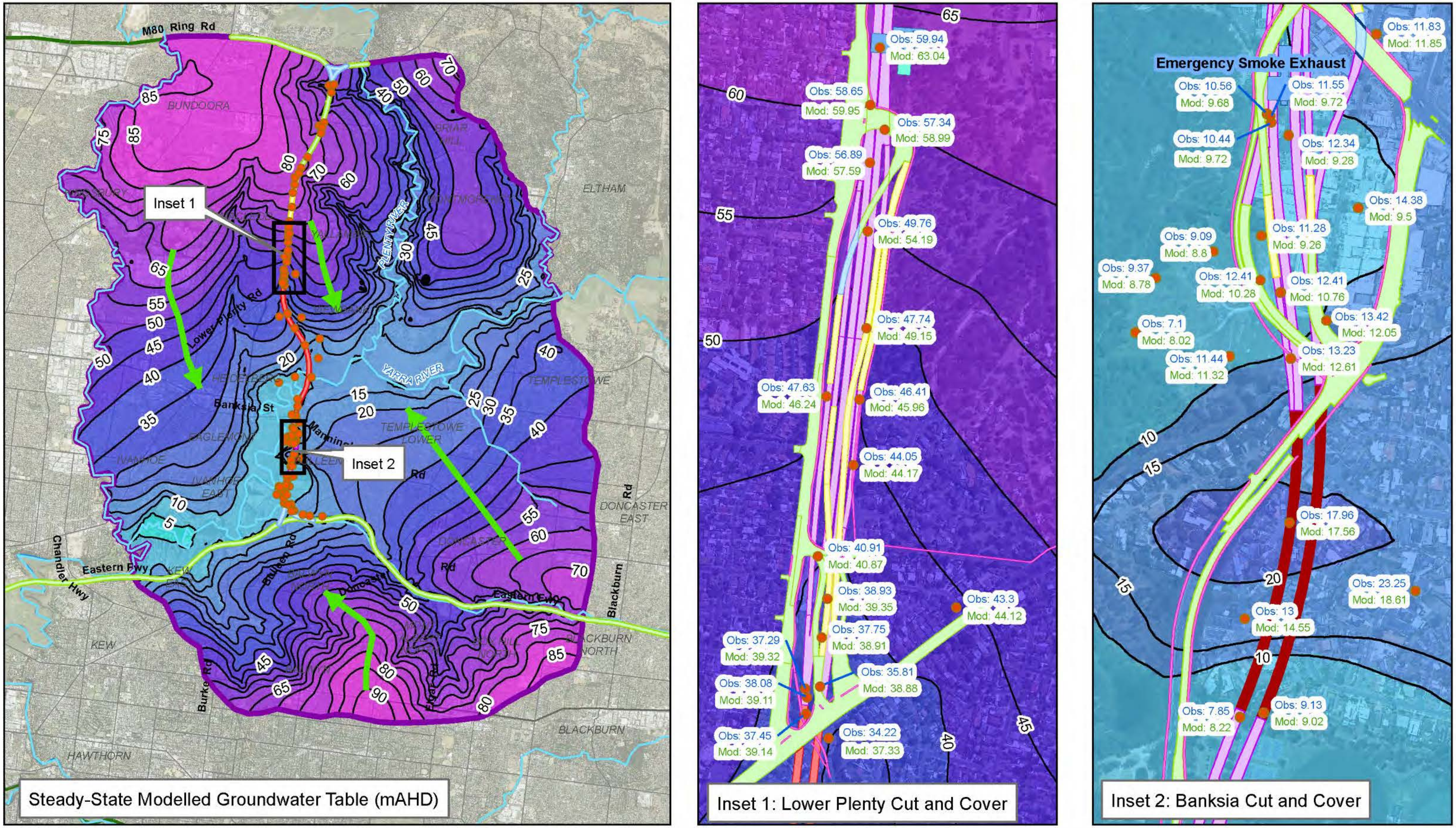
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: CIP Imagery - DELWP - 2018 | roads, watercourses, parks, rail, localities, planning zones - Vicmap - 2019 | precinct, project infrastructure - GHD, AECOM - 2019 Created by: sacevedo



Paper Size A4

0 400 800 1,600 2,400 3,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Groundwater Flow Direction
Calibration Bore
Proposed reference project
Elevated ramp
Surface works
Open Cut
Cut and cover tunnel
TBM bored tunnel
Mined tunnel
River
GW Model Domain
Modelled GW Table Contour
Modelled Gw Table (mAHD)
4 - 5
5.1 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 92.3
Proposed reference project (insets)
Ventilation system
Area for substation
Shared use path overpass
Shared use path
Shared use path underpass
Elevated ramp
Surface works
Open cut
Cut and cover tunnel
TBM bored tunnel

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Date 27 Feb 2019

Modelled water table elevation

Figure 6.8

G:\31\35006\GIS\Maps\Deliverables\20180625_NEv3_GWModel_Figures\20190227\3135006_NEv3_A4L_GWModel_Fig6.8_SSWTContours_Rev02.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: BaseMaps / DTM, VicMaps, 2018; Image Basemaps, CIP, 2017; GW Model Layers, GHD, 2018. Created by:sacevedo

6.10.5 Influences on water levels

There is insufficient time-series water level data available to characterise the seasonal response of groundwater levels.

Groundwater development

Groundwater extraction can locally influence groundwater levels, although this extraction is often seasonally dependent (for example, irrigation typically occurs predominantly through late Spring to early Autumn).

The groundwater quality (refer Section 6.9) indicates that the Palaeozoic aquifer is saline which limits the likelihood for wide-scale abstractive development, and thus the influence on groundwater levels regionally.

Continuous (all year round) groundwater pumping has the potential to occur as part of contaminated land remediation, although contaminated sites with active remediation involving groundwater pumping have not been identified. Under these circumstances, groundwater pumping would not likely affect groundwater flows.

Man-made structures

Groundwater levels can be influenced by leaking water mains, or perhaps more commonly, by leaking sewers or stormwater drainage where these items are constructed below the water table. The interaction between groundwater and these man-made structures can locally influence groundwater levels. The main sewers in the study area that are potentially below the water table are:

- Melbourne Water's Yarra East Main – this is a 1,750-millimetre diameter reinforced concrete sewer that follows the alignment of Bulleen Road and Templestowe Road (paralleling the alignment of the Yarra River and Plenty River).

No obvious evidence of sewers locally influencing groundwater levels has been identified.

6.10.6 Seasonal water level response

Groundwater levels often show a seasonal response that reflects recharge. Groundwater levels are expected to be lowest in Summer and highest in Winter and Spring, when greater rainfall tends to occur.

There is a poor understanding of the seasonal groundwater responses as there is limited time-series water level information for the study area, although some data sources that are available are described below.

Melbourne Water monitoring

Melbourne Water provided monitoring data available for monitoring bores (bores BH02 and BH06) located at Bolin Bolin Billabong. This data ranged from August 2017 to the present (May 2018) and is shown in Figure 6-9.

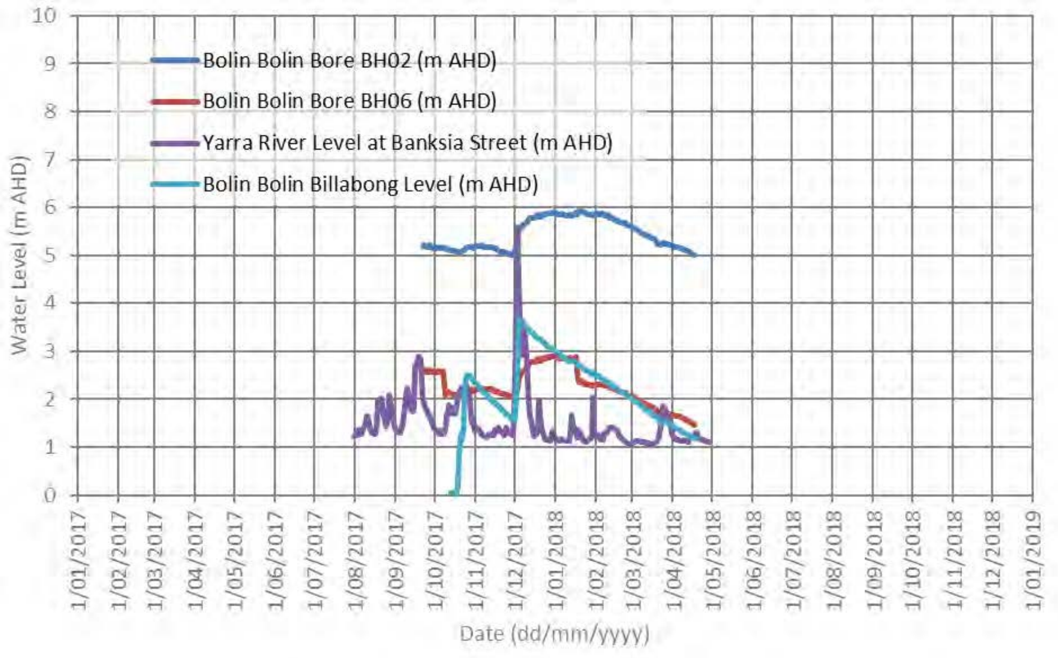


Figure 6-9 Time series water level data – Bolin Bolin Billabong

Groundwater levels have been recorded at an elevation of two to six metres AHD with the water level in both bores rising sharply by approximately one metre after a flood event on the Yarra River in early December 2017. Although a complete year of monitoring data is not available for review, water levels have shown a one metre variation across the available monitoring record. Groundwater levels are marginally higher than the Yarra River. Water levels in the billabong rose sharply in late 2017 in response to a high flow event in the Yarra River.

North East Link monitoring

An on-going groundwater monitoring program implemented as part of the geotechnical investigations for North East Link has and continues to inform this assessment. The longest time series data available is from August 2017 to present from NEL-BH056, located at Borlase Reserve (corner Lower Plenty Road and Greensborough Road) where a vibrating wire piezometer (VWP) has been installed.

The time series water pressure information is summarised in Figure 6-10 and rainfall information has also been appended to the hydrograph. The pressure head has been corrected to a standing water level on the hydrograph. Groundwater levels have exhibited an approximate 1 to 1.2-metre variation across the available monitoring record. The recent water pressure declines measured in June are due to drilling and pumping test investigations.

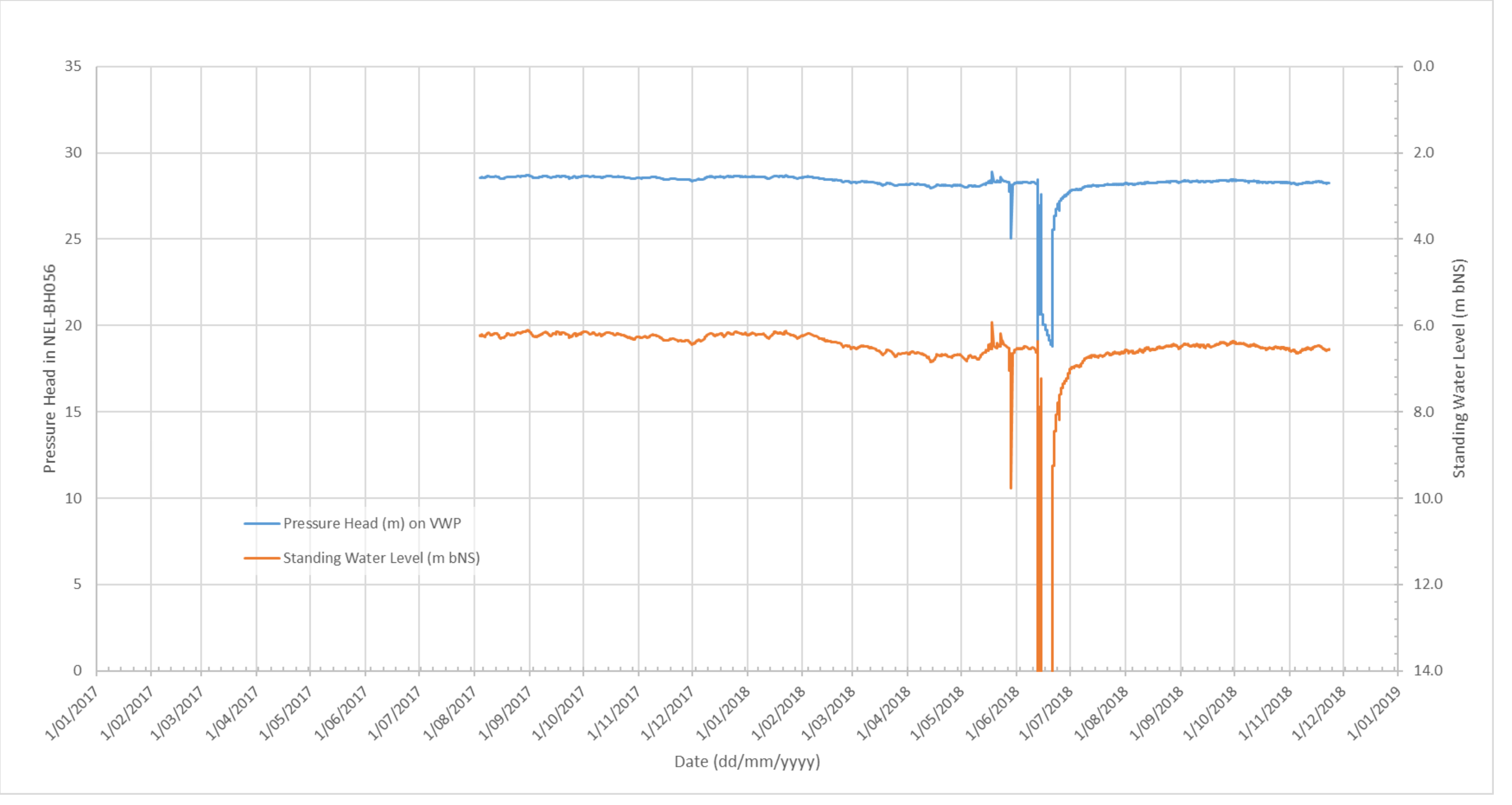


Figure 6-10 Time series water level data – NEL-BH056 (VWP)

6.10.7 Drought response

Droughts, such as the Millennium Drought (1996 – 2010) can have a significant influence on groundwater levels. As noted in Section 6.10.3, there are no nearby state observation bores in the study area that can be used to assess the longer term water level behaviour, and the historical influence of a stressed condition of groundwater. Correlations have to be drawn from further afield as discussed below.

A monthly residual mass curve of rainfall has been prepared and presented in Figure 6-11. This has been undertaken to characterise the influence of climate on groundwater levels. Rainfall data was reviewed from climate stations at Viewbank (086068) and Heidelberg (086053) which indicated similar rainfall trends. The deviation plot has been estimated based on the long-term average monthly rainfall, and monthly rainfall data since 2000.

The absolute value of the residual mass curve is not important, but rather the slope:

- A positive slope indicates a wetter than average period
- A negative slope indicates a drier than average period
- A section of both negative and positive indicates a period of generally average rainfall
- The grade of the slope indicates how much wetter or drier than average the climate is.

The plot indicates that over the period the data was collected, rainfall conditions were relatively average.

Kinglake (Upper Goulburn GMA)

Groundwater is developed in the Kinglake region for irrigation purposes and a number of state observation bores that develop the Palaeozoic bedrock have been established in the region. These bores are approximately 30 kilometres to the north of the project. While this region has similar geology to the study area, land use and groundwater use is different and the mean annual rainfall is higher than metropolitan Melbourne.

Unfortunately the state observation bores in the Kinglake/Pheasant Creek/Castella region have records generally only extending from 2010 and so do not capture the drawdown effect of the Millennium Drought, but rather the recovery response. Bore WRK0952886 has records extending from 2005 and is shown in Figure 6-11 with the cumulative monthly rainfall deviation. The seasonal water level variation in this bore is approximately 1 to 1.5 metres, with higher rainfall years (2010, 2016) resulting in more than a three-metre variation in groundwater levels.

Basalt plains (western suburbs, Unincorporated)

The basalts in the western suburbs of Melbourne are a water table aquifer, although saline groundwater has resulted in limited abstractive development. This is therefore considered to be representative of general water table conditions in Melbourne in the absence of abstractive development.

A nested monitoring site at Tarneit (bores 109684, 109683 and 93705) has groundwater monitoring levels extending as far back as 1970 and bore 109684 is shown in Figure 6-11. The Millennium Drought results a decline of three-metre decline in water levels at this location. Although water levels recovered approximately 70to 80 per cent with the breaking of the drought in 2010, since 2014 they have shown a declining trend and are currently 1.5 metres above the deepest water level recorded during the drought.

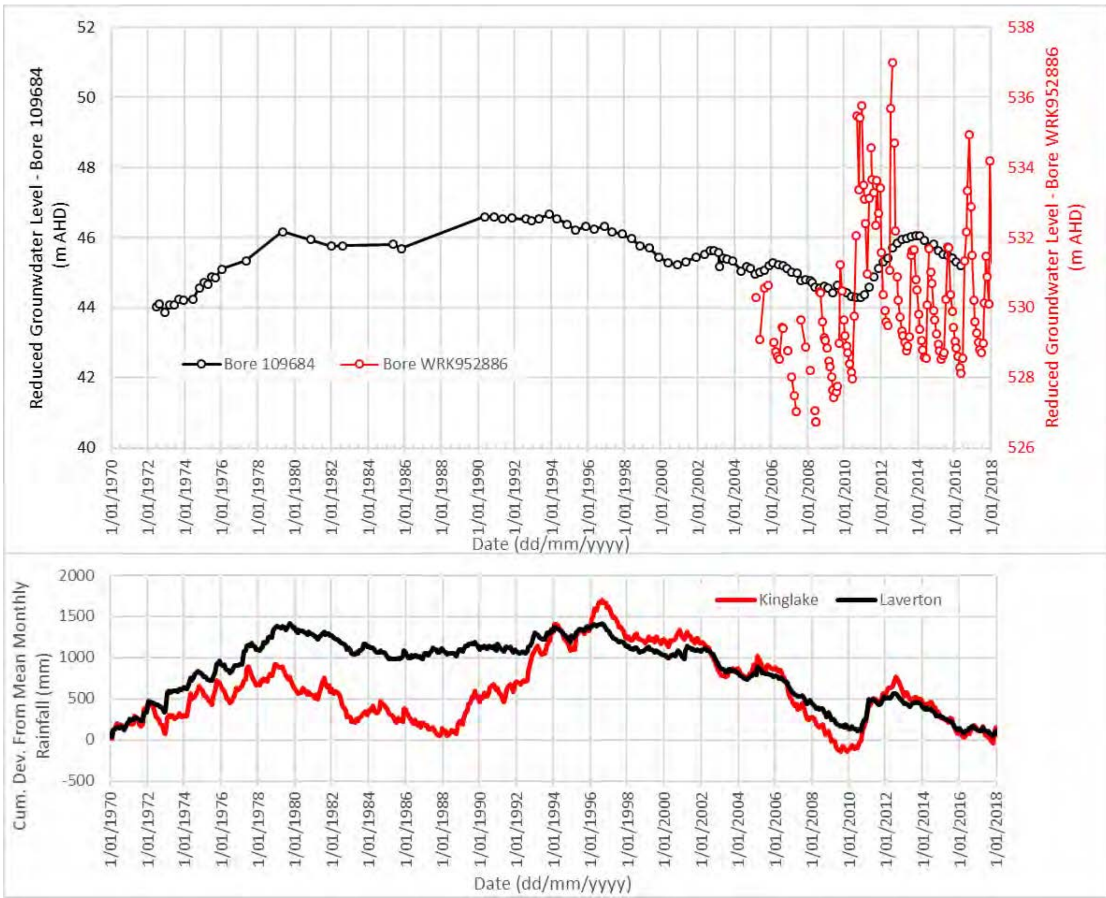


Figure 6-11 Regional state observation bore response

6.11 Neighbouring groundwater use

A number of factors limit the use of groundwater within the study area:

- Urbanised, mostly residential setting, where potable water is readily available through a widespread reticulation network operated by Yarra Valley Water
- There is a minimum set back distance of 200 metres from a waterway or lake for bores, as stipulated by the Water Act 1989 (Vic)
- The groundwater quality in the bedrock aquifer is brackish to saline, which generally limits its abstractive benefits (that is, too saline for irrigation or domestic garden supply). While groundwater of elevated salinity could be used for stock watering and industrial applications, these land uses are limited in the urbanised land setting. It is noted that fresher groundwater occurs nearer to the floodplains, although minimum set back distances and land use zoning (such as public open space) limit opportunities for groundwater development.

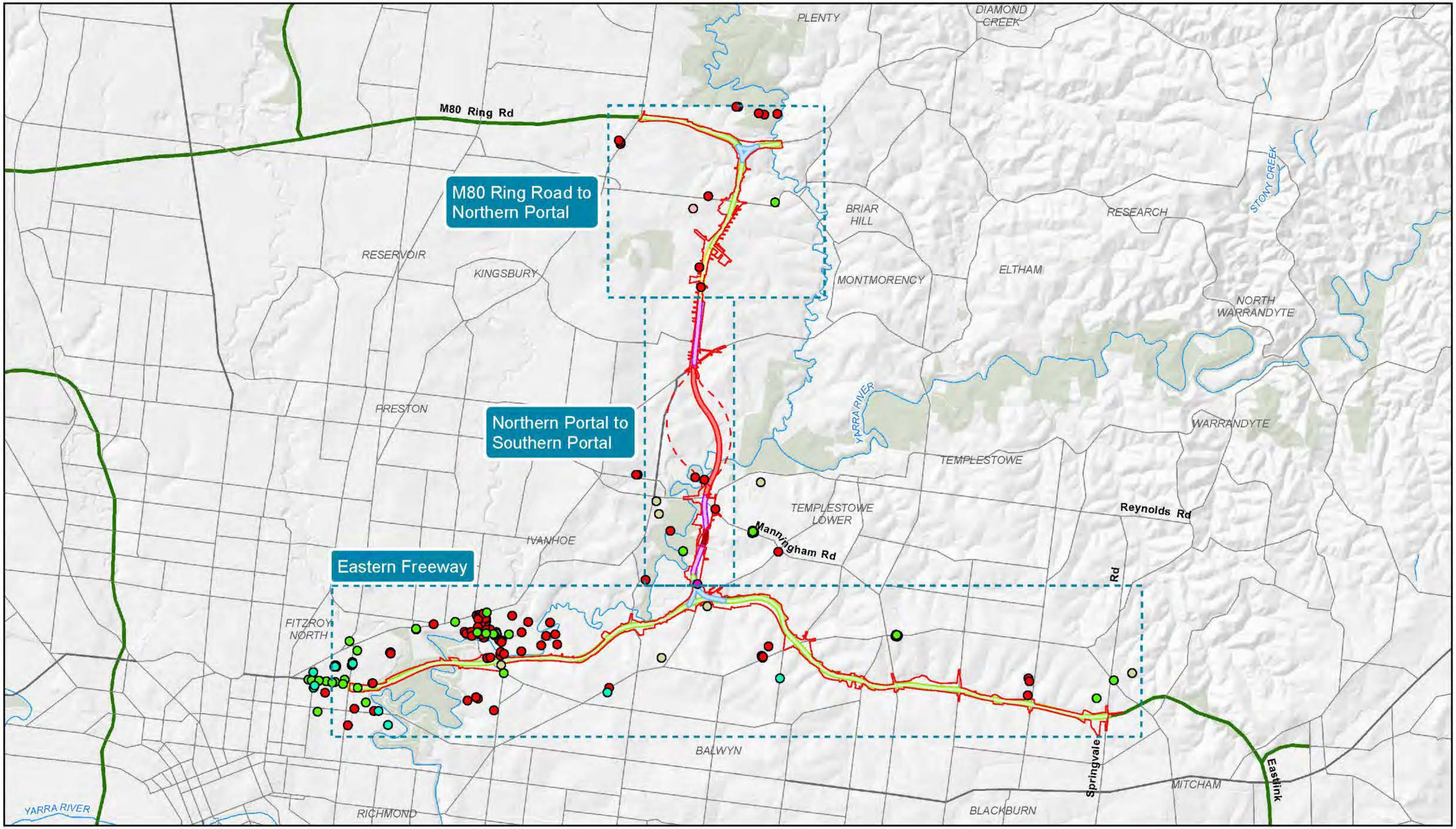
A search of the DELWP Water Management Information System (WMIS) was undertaken to identify and characterise groundwater use in the region. A search was undertaken of the study area to facilitate characterisation of the local and regional groundwater settings.

The following comments are made about the WMIS data:

- Bores installed before the proclamation of the Water Act in 1989 may not be registered as there was no mandatory requirement to licence bores before this date.
- The WMIS does not provide information about the operational status of groundwater bores.

- Bores installed without a bore construction licence are unlikely to be registered on the WMIS (unless detected by later audits).
- Many bores have not been surveyed for location. Bore locations as registered were often those initially proposed on the bore construction licence application. In many instances drilling contractors could not gain access to these sites and final locations often have a positional accuracy greater than ± 250 metres.
- The information registered on the WMIS is subject to the accuracy of bore completion reports submitted by drilling contractors.
- Information registered on the WMIS is subject to change since the completion of the bore (such as water level information, pump setting depth, groundwater quality).
- Some information is not available on the WMIS (such as pump setting depth, bore ownership).

There are 207 bores registered within one kilometre of the North East Link alignment and the bore numbers by use type are summarised in Table 6-14. The bore locations are shown in Figure 6-12.



Paper Size A4

0 700 1,400 2,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- Project element
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

- Elevated ramp
- Surface works
- Open Cut
- Cut and cover tunnel
- TBM bored tunnel
- Mined tunnel

WMIS Bores within 1km

- Not Known
- Commercial
- Domestic and/or Stock
- Groundwater Investigation
- Irrigation
- Observation

Roads

- Freeway
- Highway
- Major road

Watercourses

- River
- Parks & reserves

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Date 28/02/2019

Study Area
WMIS groundwater bores

Figure 6-12

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: CIP Imagery - DELWP - 2018 | roads, watercourses, parks, rail, localities, planning zones - Vicmap - 2019 | precinct, project infrastructure - GHD, AECOM - 2019 Created by: trighetti

Table 6-14 Study area groundwater use

Registered use	Element			Total
	M80 Ring Road to northern portal	Northern portal to southern portal	Eastern Freeway	
Groundwater investigation	0	0	37	37
Stock and domestic	0	3	4	7
Use not known	11	9	52	72
Miscellaneous	0	1	0	1
Irrigation	1	0	0	1
Commercial	0	1	0	1
Observation	1	8	79	88
Total	13	22	172	207

Note: Bores with Non-Groundwater or SEC use classification omitted.

An investigation into the ownership of the bores or their operational status has not been undertaken and so information is not available in publicly available records such as the WMIS.

The majority of bores identified in the study area were installed for groundwater investigation or for groundwater observation purposes and the majority of these are suspected to be for environmental or contaminated land investigation purposes. Most bores have been identified within the project's Eastern Freeway element and at the western end of the element, where a number of GQRUZs have been declared.

Some comments on the groundwater use data are noted below:

- No time series water level information was available for the bores identified.
- Limited groundwater salinity information was available. Of the salinity information available, salinities ranged between <1,000 µS/cm to 9,500 µS/cm with an average of 2,270 µS/cm. Using an EC to TDS conversion factor of 0.65, salinities range from <650 mg/L to 6,175 mg/L TDS, with an average of 1,475 mg/L TDS.
- Limited groundwater bore yield information was available. Of the yield information available, bore yields ranged from 0.1 L/s to 2 L/s with an average of 0.4 L/s. It is noted that flows during the pumping tests were low, with rates of 0.5 L/s at Borlase Reserve and <0.2 L/s at Kim Close and Bulleen Park. However, pumping test bores were targeting the zone of construction whereas yield could potentially improve with greater aquifer penetration.
- Bore WRK078524 is the only irrigation bore identified and is a 125-millimetre diameter bore drilled in 2015 to 113 metres. The bore location is plotted as at Loyola College, off Grimshaw Street, Watsonia. There is no salinity information for the bore. The bedrock aquifer that it develops is expected to be saline in this area based on the nearest North East Link monitoring bore information.

- Bore WRK958500 is the only bore with a Commercial use. It is a 25-metre deep bore drilled in 2007 and is located close to the Bulleen Swim Centre (located between Marcellin College sports fields and the Boroondara Tennis Centre).
- Bore 52618 has a Miscellaneous use. It is eight metres deep and located within Banksia Park. It is unlikely to have a licensable use given its location.
- There are seven stock and domestic bores identified within one kilometre of the alignment.

6.12 Acid sulfate soils

6.12.1 Definitions

Acid sulpfate soils are soils, sediments, unconsolidated geological material or disturbed consolidated rock mass that contain elevated concentrations of the metal sulfide. It occurs principally in the form of pyrite (iron sulphide). These soils can be rich in organics and were formed in low oxygen or anaerobic depositional environments.

The soils are stable when undisturbed or located below the water table. However, when oxygen is introduced, the sulphides oxidise to sulphate, with resultant soils having low pH and potentially high concentrations of the heavy metals.

Groundwater levels may rise as a result of recovery from construction dewatering activities, or leaching of infiltrating rainfall through the sulphate rich zones. This can result in oxidisation of materials and the mobilisation of pH and heavy metals into the environment where they can potentially impact deep-rooted vegetation, aquatic flora and fauna, and can be aggressive to reactive materials (such as concrete, steel) of foundations, underground structures (such as piles, pipes, basements) or buried services in contact with groundwater. It can also result in the discharge of acid groundwater to receiving surface water systems.

The occurrence of acid sulfate soil can be present in the form of:

- Potential Acid Sulfate Soil (PASS) – Soil that contains unoxidised metal (iron) sulfides. This is usually in oxygen free or waterlogged conditions. When exposed to oxygen through drainage or disturbance, these soils produce sulfuric acid.
- Actual Acid Sulfate Soil (AASS) – Potential acid sulfate soil that has been exposed to oxygen and water, and has generated acidity.

There are two main pathways for the activation of acid sulfate soil to form groundwater impacts:

- Excavation of PASS soils above the water table and their management, such as acid run-off from stockpiles and treatment areas, filling, handing of spoil from the tunnels
- Dewatering required as part of the construction of features below the water table, such as for the cut and cover construction of the tunnels.

The assessment PASS soils and their management is discussed in Technical report O – Contamination and soil. The assessment of acid sulfate soil arising from the dewatering required to construct North East Link structures below the water table is provided in Section 8.

6.12.2 Occurrence in study area

Acid-generating materials in Victoria are commonly found in a number of broad settings:

- Typically geologically young sediments (Holocene age) near sea level
- Sediments and tidal lakes of marine origin, and estuarine sediments
- Coastal wetlands, mangroves and swamps
- Ligneous rich deposits
- Indurated sediments that may contain elevated concentrations of metal sulphides (Cambrian to Middle Devonian age).

The latter (the bedrock geology that has been mapped throughout the study area) has been known to have had sulphide enrichment in places.

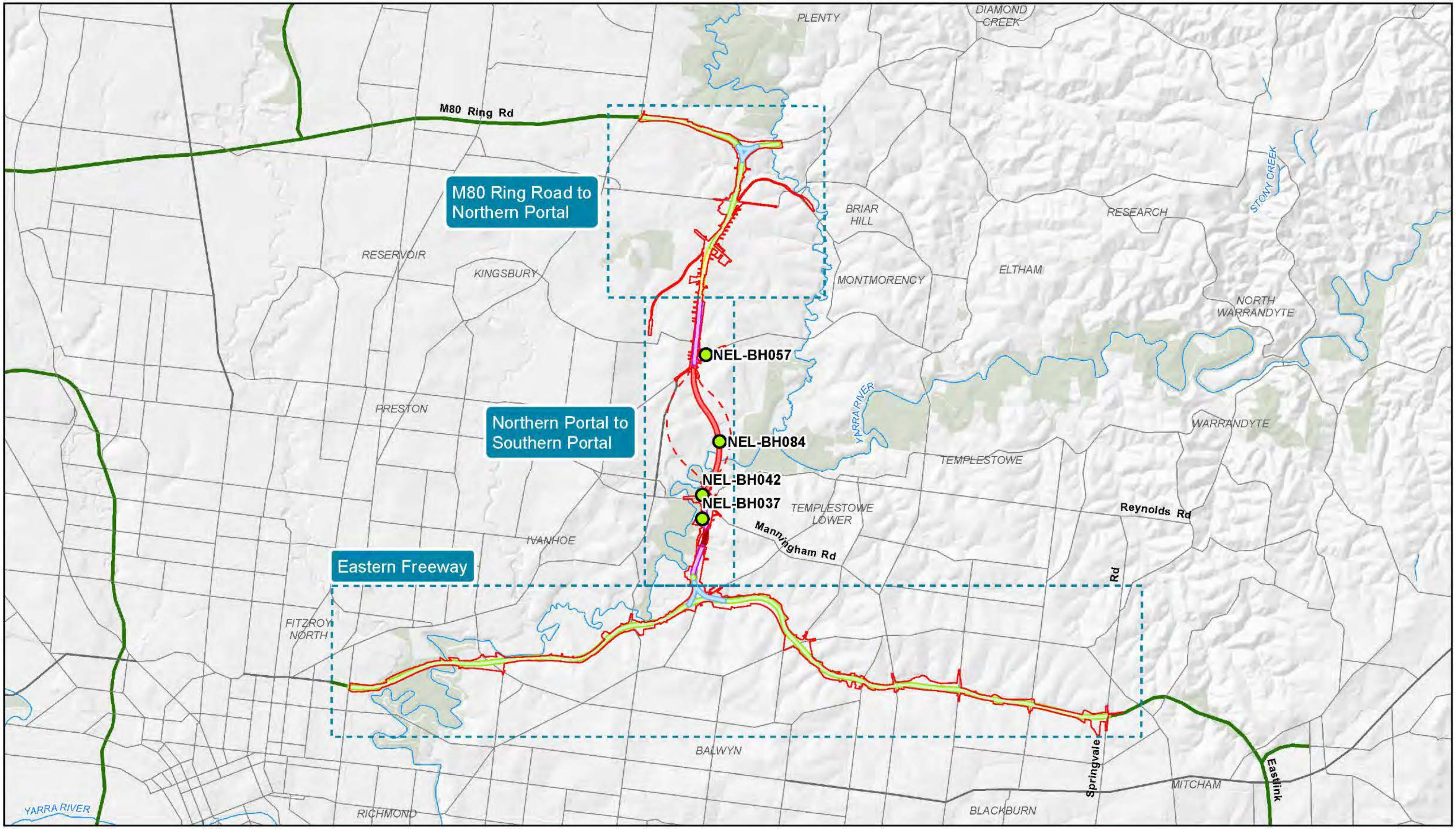
The potential for geological units to generate acids has been determined through laboratory testing undertaken as part of the geotechnical investigation program. Soil and rock samples were analysed in accordance with EPA Victoria Publication 655.1 Acid Sulfate Soil and Rock (2009), which include the following:

- Net Acid Production Potential (NAPP)
- Net Acid Generation Potential (NAGP)
- Suspension peroxide oxidation combined acidity and sulphur (SPOCAS) suite
- Chromium reducible sulphur (CRS) suite.

Applying the criteria of EPA Victoria (2009), four samples (NEL-BH037_25.0-25.08m, NEL-BH042 (45.75m), NEL-BH057 (21.0m) and NEL-BH084_37.95-38.05m) of the 71 in total that were assessed, are classified as rocks with potential to generate acid. Eleven samples were classified as ‘Uncertain’. Additional discussion of the testing program is provided in Technical report O – Contamination and soil.

Based on the testing undertaken, some parts of the Palaeozoic bedrock aquifer contain disseminated sulphides that have the potential to generate acid. It is noted, however, that the water table generally resides in the upper parts of these materials, where the rocks have been subject to oxygenation and chemical weathering. The risk of significant PASS activation in these areas is therefore reduced.

Locations with PASS are shown in Figure 6-13.



Paper Size A4

0 700 1,400 2,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

Project element
Project boundary - sub-surface
Project boundary - surface
Proposed reference project
Elevated ramp
Surface works
Open Cut
Cut and cover tunnel
TBM bored tunnel
Mined tunnel
NEL Bores
Roads
Freeway
Highway
Major road
Watercourses
River
Parks & reserves

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Job Number 31-35006
Revision E
Date 04/03/2019

PASS Locations

Figure 6-13

G:\31\35006\GIS\Maps\Working\KBM\EES_PER_Technical_Report\EES_Technical_Reports_A4L_TR.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: CIP Imagery - DELWP - 2018 | roads, watercourses, parks, rail, localities, planning zones - Vicmap - 2019 | precinct, project infrastructure - GHD, AECOM - 2019 Created by: trighetti

6.13 Groundwater dependent ecosystems

6.13.1 Definitions

A groundwater dependent ecosystem (GDE) is an ecosystem which has its species composition and natural ecological processes determined by groundwater. That is, GDEs are natural ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services. If the availability of groundwater to GDEs is reduced, or if the quality is allowed to deteriorate, these ecosystems are impacted.

It is widely acknowledged that a poor understanding exists in recognising GDEs, or understanding the hydrogeological processes affecting GDEs, or their environmental water requirements. GDEs within the study area include:

- Ecosystems that depend on the surface expression of groundwater:
  - Swamps and wetlands can be sites of groundwater discharge and may represent GDEs. The sites may be permanent or ephemeral systems that receive seasonal or continuous groundwater contribution to water ponding or shallow water tables. Tidal flats and inshore waters may also be sites of groundwater discharge. Wetlands can include ecosystems on potential acid sulfate soils and in these cases maintenance of high water levels may be required to prevent waters from becoming acidic.
  - Permanent or ephemeral stream systems may receive seasonal or continuous groundwater contribution to flow as baseflow. Interaction would depend upon the nature of stream bed and underlying aquifer material and the relative water level heads in the aquifer and the stream.
- Ecosystems that depend on the subsurface presence of groundwater. Terrestrial vegetation such as trees and woodlands may be supported either seasonally or permanently by groundwater. These may comprise shallow or deep rooted communities that use groundwater to meet some or all of their water requirements. Animals may depend upon such vegetation and therefore indirectly depend upon groundwater. Groundwater quality generally needs to be high to sustain vegetation growth.

6.13.2 Review of regional mapping

Given the topography, it is highly likely that local groundwater flow systems occur within the catchment as groundwater flows from the topographic highs to the low points within the landscape, emerging as seeps and springflow.

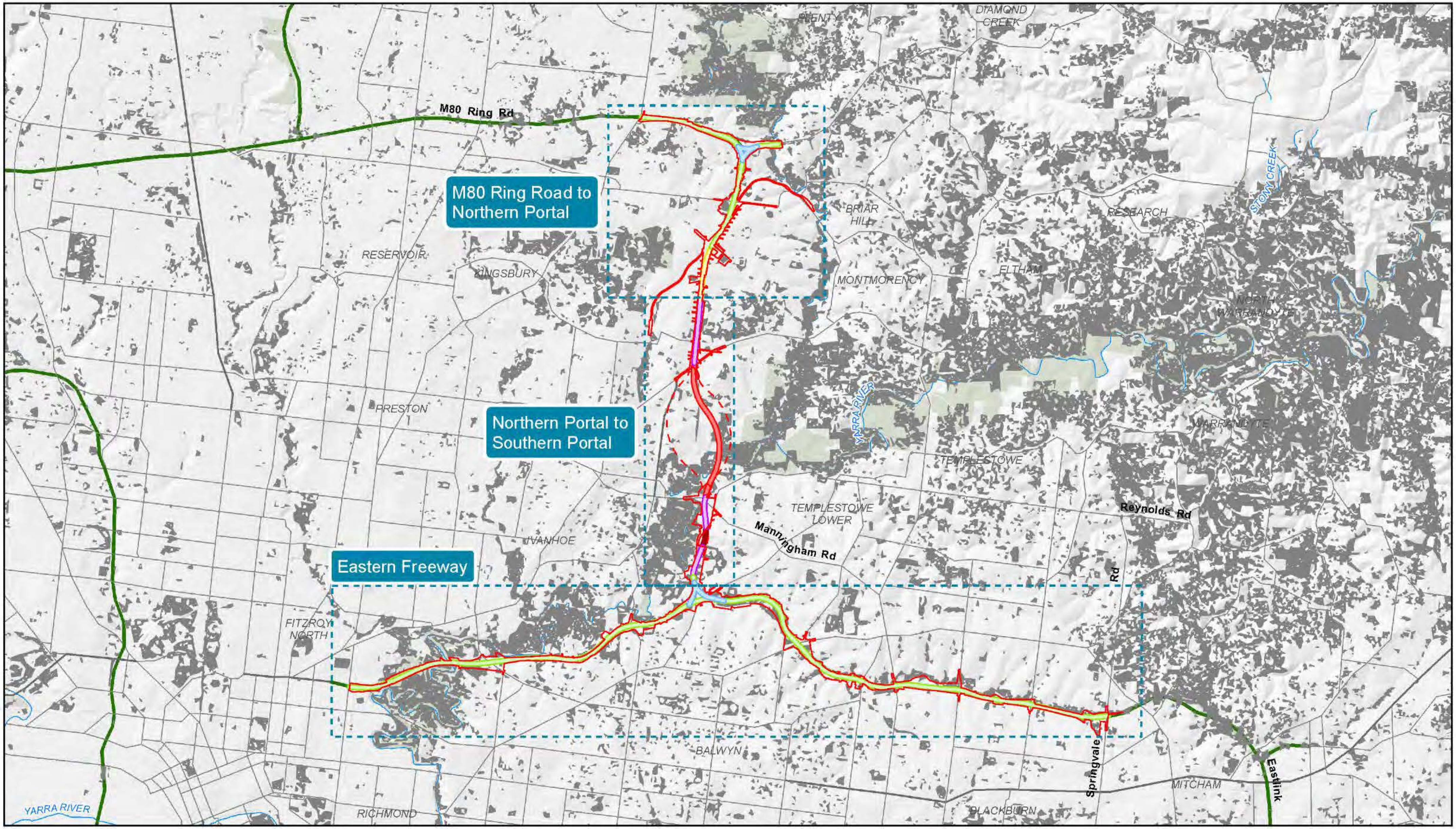
Mapping of potential GDEs completed by the former Victorian Department of Primary Industries (DPI) is provided in Figure 6-14. The following GDEs are noted, based on DPI and Bureau of Meteorology (BOM) data sources:

- GDEs dependent upon the surface expression of water, notably:
  - Yarra River floodplain, incorporating areas such as Banyule Swamp, Bolin Bolin Billabong, Kew Billabong.
  - Koonung Creek floodplain
  - Plenty River floodplain
  - Banyule Creek
  - Salt Creek.

- Terrestrial vegetation, including swampy and grassy woodlands, and riparian vegetation in association with the waterways noted above.

These features are classified as being potential GDEs possibly due to their location close to waterways and in areas where groundwater levels are interpreted to be near the surface. It is noted the BOM mapping has been based on regional analysis and so the local scale impact assessment has been undertaken for those areas in close proximity to the project.

Drawdown as a result of tunnelling and deep excavations has the potential to impact trees with deeper root systems that rely on groundwater. An assessment of rooting depths and salinity tolerances is provided in Technical report Q – Ecology.



Paper Size A4

0 700 1,400 2,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

- Project element
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

- Elevated ramp
- Surface works
- Open Cut
- Cut and cover tunnel
- TBM bored tunnel
- Mined tunnel
- Groundwater Dependant Ecosystems (GDE)

Roads

- Freeway
- Highway
- Major road

Watercourses

- River

- Parks & reserves

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Job Number	31-35006
Revision	E
Date	04/03/2019

Study Area
GDE (DPI) mapping

Figure 6-14

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: CIP Imagery - DELWP - 2018 | roads, watercourses, parks, rail, localities, planning zones - Vicmap - 2019 | precinct, project infrastructure - GHD, AECOM - 2019 Created by: trighetti

6.14 Relationships between aquifers

6.14.1 Nature of confinement

The Palaeozoic bedrock and alluvial aquifers are generally considered to be unconfined or water table aquifers from a regional perspective.

However, at a local scale some degree of confinement can occur and there are many parts of the study area where the confining conditions are not known, such as where the bedrock aquifer is overlain by younger fine grained sediments.

There are parts of the study area where geological conditions may retard the vertical migration of groundwater, for example:

- Deep (20 metres below surface) coarse grained beds buried beneath fine grained silt and clay have been identified in the alluvial aquifer in the Banksia Street/Manningham Road area, at the former Bulleen Drive-in. It was not possible to undertake pumping test investigations to characterise the presence or nature of confinement of these beds owing to access restrictions. However, nested monitoring bore hydrographs at the former Bulleen Drive-in (NEL-BH061, NEL-BH061A and NEL-BH061B) indicates hydraulic connection between alluvial beds and the bedrock aquifer with the Yarra River (refer Appendix A).

  Similar conditions where sand beds are located between intervening clays beds were noted elsewhere within the floodplain, such as at Bulleen Park. Given the alluvial setting, it is suspected that such beds:

  – May behave as a leaky aquifer system when subject to water level changes
  – May have a greater likelihood for groundwater to move in the horizontal direction.
- Potential for perching of groundwater exists in parts of the study areas where vertical migration of infiltrating water may be impeded by low permeability beds. For example, water may perch in thin, permeable, soil horizons that overlie the Palaeozoic bedrock where a permeability contrast exists.
- Where the upper parts of the Palaeozoic bedrock have been deeply weathered and the resulting saprolitic horizon is rich in clay.
- The nature of fracturing and fracture sets within the Palaeozoic bedrock. Where the rock mass has a low fracture density, the vertical and horizontal movement of groundwater may be restricted. Folds and deformations, and areas of greater fracture density may create preferential flow paths relative to more massive rock.

In some areas near the proposed North East Link alignment, monitoring bores screening different aquifers have been installed close together in what are referred as ‘nested’ sites. Examples of nested monitoring sites are summarised in Table 6-15. At each nested site there are bores in the alluvial sediments and the underlying bedrock, and so the water level response can provide insight into how the aquifers respond and interact.

Selected monitoring sites with automated water level logging are shown in Appendix A.

Table 6-15 Nested monitoring sites

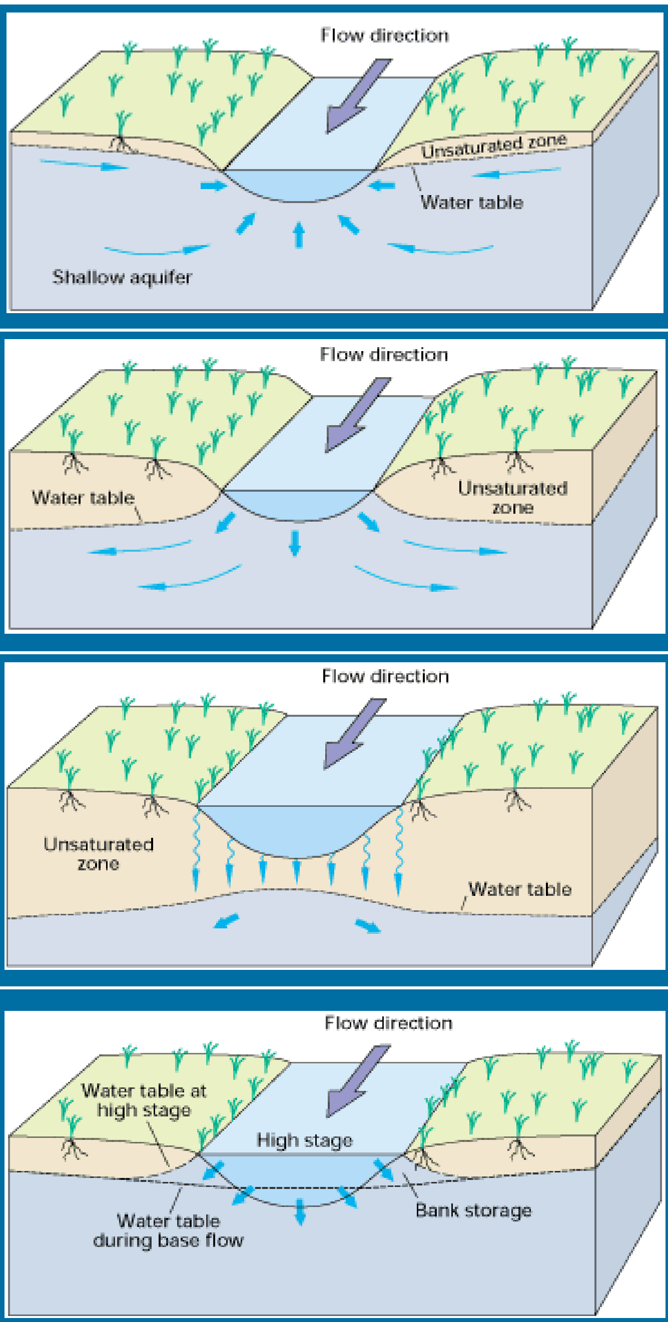
Location	Aquifer		Comment
	Alluvial	Bedrock	
NEL-BH004	NEL-BH004A	NEL-BH004	Site is near Koonung Creek.
NEL-BH040	NEL-BH040A	NEL-BH040	Site is near Koonung Creek, Manningham Hotel.
NEL-BH061	NEL-BH061A	NEL-BH061	Northern part of the former Bulleen Drive-in. Water levels are deeper in the alluvial aquifer relative to the bedrock and therefore indicate upwards hydraulic gradient.
NEL-BH062	NEL-BH062A, NEL-BH062B	NEL-BH062	South-west part of former Bulleen Drive-in. Hydrograph response between monitoring bores in the alluvials similar or near coincident. The peaks in water level (for example in mid-June 2018) are consistent with high flow events on the Yarra River (as per Station No. 229135A).
NEL-BH076	NEL-BH076A	NEL-BH076	North side of Yarra River.
NEL-BH128	NEL-BH128A	NEL-BH128	Bulleen Park near Veneto Club. Water levels indicate upwards hydraulic gradient. Hydrograph response between monitoring bores is similar or coincident.
NEL-BH140	NEL-ENV-BH008	NEL-BH140	Manningham Road near Greenaway Street (north extent).
NEL-BH158	NEL-ENV-BH014	NEL-BH158	Kim Close, southern end. Insufficient data to make a determination.
NEL-BH137	NEL-ENV-BH006	NEL-BH137	Greenaway Street, southern end.

Note: At the time of reporting many monitoring bores on the North East Link monitoring network had not been surveyed for relative level. Under these conditions, estimates of elevations have been based on LiDAR data, however, relationships between bores at nested sites and vertical flow directions are considered estimates only.

6.15 Groundwater and surface water interaction

6.15.1 Definitions

There are four different ways in which waterways and groundwater interact and these are shown in Figure 6-15. These flow conditions can vary along the length or reach of a waterway.



Gaining stream
When the groundwater table is higher than the surface water stage, groundwater can flow into the stream.

Losing stream
For losing conditions, the elevation of the waterway is greater than that of the surrounding groundwater.

Disconnected stream
This is a form of losing stream where an unsaturated zone exists between the waterway and groundwater.

Streambank storage
When a waterway is in flood following high rainfall events, water can shift and be stored within geological materials adjacent the waterway. Water in bank storage can take days or weeks to return to the waterway as streamflow.

Figure 6-15 Surface and groundwater interaction

Source: Harvey et al., 1998

In general, there is a limited understanding of connectivity between surface and groundwater throughout the study area. The following comments are made:

- Based upon groundwater level monitoring undertaken throughout the study area, there exists a hydraulic gradient from the higher elevations towards the lower elevations and alluvial floodplains (groundwater flows towards waterways).
- Data logging of water levels was undertaken at nested monitoring bores throughout the alignment, including at NEL-BH128 (Yarra River at Bulleen Park), NEL-BH004 (Koonung Creek at the Thompsons Road). The limited monitoring information is summarised in Table 6-15.
- Flow in Salt Creek and Banyule Creeks is ephemeral, suggesting that flows in these systems flows are derived from run-off harvested within their catchments. If groundwater inflows were substantive to these systems, higher salinities, reflective of the Palaeozoic bedrock aquifer would be expected and the streams potentially flowing all year round.
- Water level observations from the pumping test investigations completed at Borlase Reserve (near intersection of the Lower Plenty Road and Greensborough Bypass) included monitoring bores located near Banyule Creek. No recharge boundary conditions were identified in the monitoring data—stabilisation of water levels due to leakage from recharge sources such as Banyule Creek were not observed. This would suggest that obvious interaction between surface and groundwater does not occur at this location.

A discussion on some of the key waterways and surface water features is provided below. Further information regarding the existing conditions of these features is provided in Technical report P – Surface water.

Banyule Creek

Banyule Creek is a small waterway with its origin near Simpson Barracks. It outfalls into the Yarra River further to the south. It is considered to be an ephemeral steam with no permanent baseflow in its upper reaches. Much of the creek over its northern extent is located upon the bedrock aquifer system. When the creek enters the floodplain of the Yarra River, it flows across alluvial sediments. Water quality gauging (see Technical report P – Surface water) indicates that creek flows are typically fresh (<500 µS/cm). Groundwater in the bedrock aquifer is saline and so if groundwater was influent into the creek, it is a reasonable expectation that its salinity would be significantly higher.

Groundwater levels gauged in the Lower Plenty Road area indicate water levels are between four to six metres below the surface which puts them close to the base of Banyule Creek. In the lower elevations nearer to the Yarra River floodplain, water levels are around four to five metres below the surface, placing groundwater levels below the base of the creek.

Regional groundwater flow is southwards in the Banyule Creek region. In the upper reaches of Banyule Creek the water table is expected to be below the creek bed. However, in the downstream reaches, nearer to the alluvial floodplain, groundwater levels are shallow and are more likely to interact with the creek.

Banyule Swamp and Banyule Billabong

Banyule Swamp is a wetland located on the margins of the Yarra River floodplain, near Banyule Creek. Banyule Billabong is located marginally south of the swamp. Melbourne Water describe the billabong as being a freshwater marsh of less than two metres depth, which while mostly remaining flooded, can dry out every four to five years.

Historically annual flooding would have topped the billabong and swamp. However, extractions from the Yarra River have reduced flooding frequencies and filling events. Bankfull and overbank flows of the Yarra River are interpreted to be the primary sources of water for these wetlands, with other water sourced from local catchment run-off. Connection between Banyule Swamp and Banyule Billabong with groundwater is not known (Melbourne Water *date unknown*).

At the time of reporting, North East Link monitoring bores NEL-BH078 and NEL-BH080 are the only monitoring bores in this area of the project and these bores indicate groundwater levels between 4 to 5.5 metres below the natural surface within the Palaeozoic basement. Both bores intersected between six to eight metres of alluvial sediments (mostly fine grained clays and silts) overlying the bedrock aquifer. Long-term monitoring data is not available from these bores, nor for the alluvial sediments in this area of the project.

Yarra River

Previous studies of the Yarra River (SKM, 2011) suggest that gaining/losing conditions in the Yarra River are neutral between Heidelberg and the Chandler Highway across the year. This is largely a result of low to flat hydraulic gradients and lower recharge rates occurring in the urbanised area. Water quality is generally less than 300 µS/cm (see Technical report P – Surface water).

Regional groundwater mapping (refer) indicates groundwater flow is predominantly towards the Yarra River. Monitoring bore responses, such as the nested site at NEL-BH62 (located at the former Bulleen Drive-in) indicates that groundwater levels show a correlation with Yarra River flows.

Koonung Creek

Koonung Creek is a heavily modified creek which runs generally parallel to the Eastern Freeway from Springvale Road to its outfall into the Yarra River downstream of Bulleen Road. It is understood the creek has been modified through construction of the Eastern Freeway. In places the creek has been re-aligned or placed within concrete channels.

The creek flows through a thin sequence of Quaternary age alluvial sediments, which are laterally restricted to the present day course of the creek. Palaeozoic bedrock underlies these sediments, but also outcrops on the margins of the floodplains. In some areas, flow is directly upon a Palaeozoic bedrock streambed. Water quality is generally less than 1,000 µS/cm (see Technical Report P – Surface water).

Bolin Bolin Billabong

Bolin Bolin Billabong is located in Bulleen and is considered to have significant cultural and ecological value. The billabong has been conceptualised (Melbourne *Water date unknown*) as having three zones:

- A deep pool, typically inundated with up to two metres of water
- Wet-dry arms, which are elevated higher than the deep pool and intermittently inundated to 0.5 metres of water
- Floodplain, elevated above the wet-dry zone and inundated to 0.1 metres depth at a frequency less than the wet-dry arms.

The locations of these zones and conceptualisation are shown in Figure 6-16.

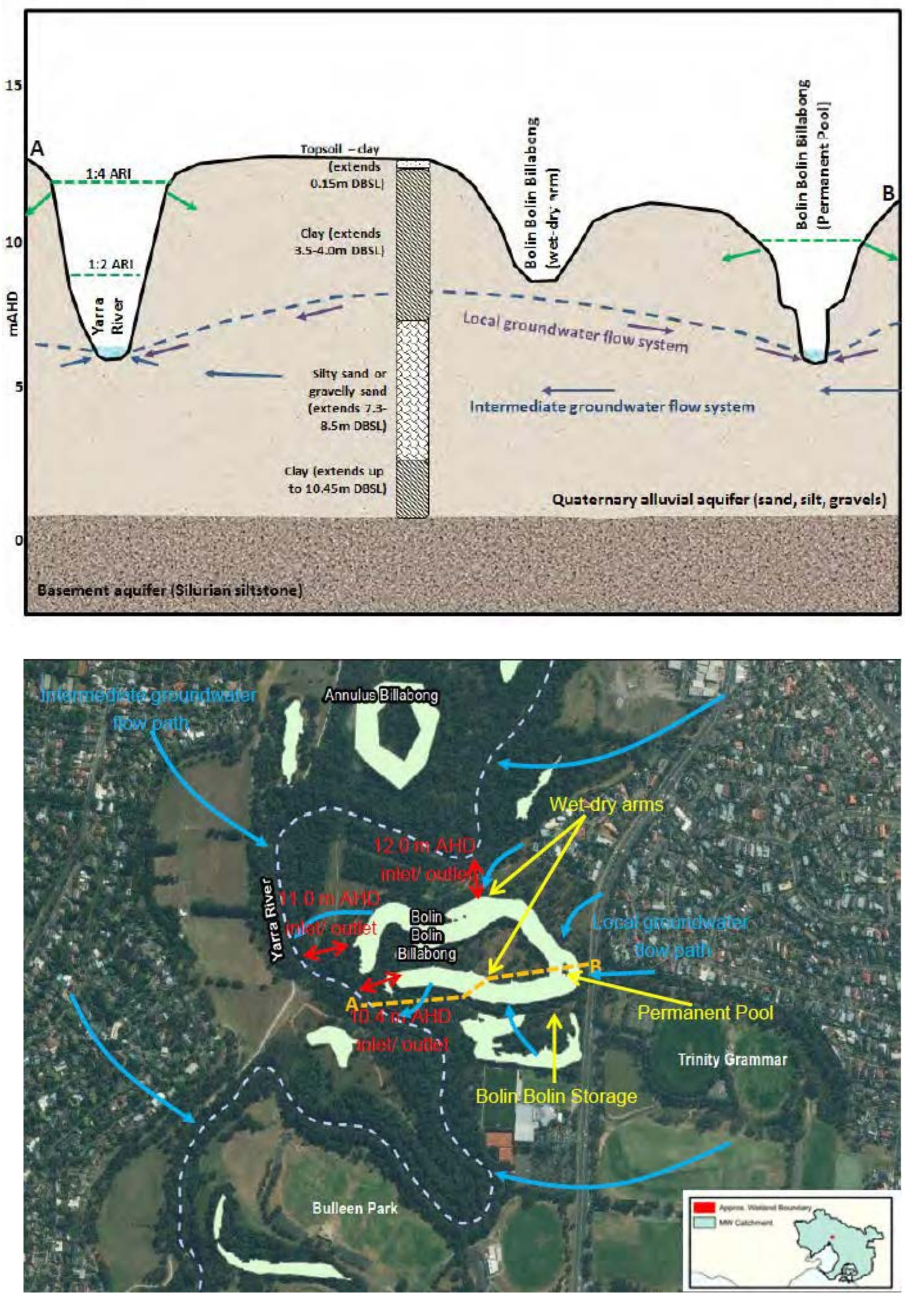


Figure 6-16 Conceptualisation of Bolin Bolin Billabong

Source: Melbourne Water (*date unknown*)

Geotechnical investigations were completed by Coffey (2012) and resulted in the construction of two groundwater monitoring bores (BH1 and B2). Drilling indicated the lithological profile comprises of approximately four metres of fine grained sediments (silts, clays) overlying sand, clayey sand and gravelly sand. GHD (2012) also completed test pitting and boring and confirmed a predominantly fine grained lithological profile in the upper four metres.

Up to the 1990s the billabong was frequently inundated (at least annually), however in inundation more recently has been less frequent. Water supply to the billabong is primarily from overbank and bankfull flows of the Yarra River. Floodplain inundation requires bankfull flows. The permanent pool is suspected as being sustained by groundwater and may be hydraulically connected to the Yarra River via the alluvium.

Water level mapping suggests region flow directions are westwards, from the elevated bedrock east of Bulleen Road towards the billabong.

6.16 Hydrogeological conceptualisations

A diagrammatical representation of the hydrogeological conceptualisation of two waterways in the study area is provided and discussed in this section. The conceptualisation is a way of describing the groundwater flow processes occurring, and the interactions with other elements of water cycle. The diagrams have been based on the geological setting, inputs from the geotechnical investigation program and experience of groundwater specialists. Some aspects of each conceptualisation may be uncertain, but they provide context to subsequent risk assessment and groundwater environmental impact assessment.

6.16.1 Banyule Creek and Koonung Creek

The conceptualisation of groundwater at Banyule Creek is shown in Figure 6-17. The conceptualisation could also be applied to Koonung Creek, although it is recognised that although the hydrogeological setting of Banyule and Koonung Creeks have a number of similarities, their catchments have differences. Banyule Creek flows through a mostly urbanised catchment, with little modification to the creek having occurred. Koonung Creek has undergone significant modification in terms or erosion control, re-alignment, and channelisation of flow. Its catchment is considerably more modified with the presence of the Eastern Freeway, and so its features are not shown on the schematic.

These modifications can influence the hydrogeology. For example:

- The channelisation of flow can reduce inputs from groundwater inflows into the waterway, so the bank storage becomes negligible
- The water quality and overall river ecological health can be influenced by channelisation, and run-off from urban landscapes

Riparian vegetation or lack thereof can alter groundwater fluxes entering the waterways.

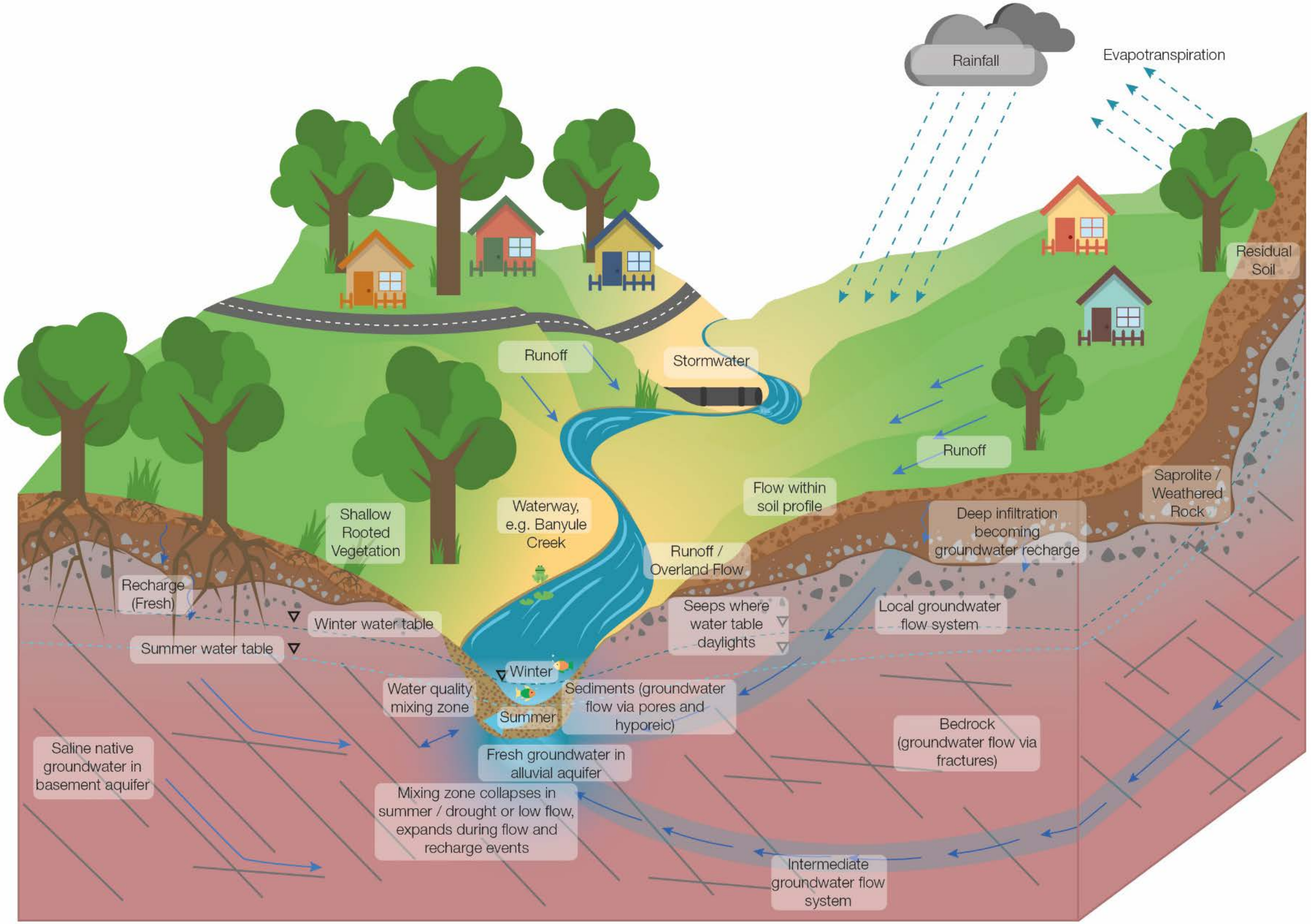


Figure 6-17 Conceptualisation of Banyule Creek

The geology in the conceptualisation has been divided into two aquifer systems. Both creeks are located within a narrow, thin Quaternary alluvial sequence which has accumulated within a topographic low in the Palaeozoic basement. The Palaeozoic basement is shown as having a thin soil cover, and over much of the northern parts of the alignment such as at Simpson Barracks, soils are generally one to three metres in thickness. In these areas, the alluvial sediments can be absent and the streambed is mostly founded upon weathered basement rocks, although downstream in the flatter grades, the alluvial sediments may form the streambed materials.

Rainfall run-off within the catchment forms flow within the ephemeral creeks. Some rainfall (and groundwater) is removed by evapotranspiration effects (water use by trees and evaporative effects). Rainfall infiltrating the ground surface can move laterally within the permeable soils overlying the bedrock. Deeper infiltration of rainfall results in accessions to groundwater. Here, within the bedrock, groundwater would migrate under topographic gradients towards areas of lower elevation. Hydraulic gradients can be steep in undulating and elevated topographies, but can become flatter near lower lying areas and alluvial floodplains nearer the Yarra River. Groundwater is stored and transmitted by the secondary porous features of the bedrock such as cracks, joints and factures. Groundwater ultimately emerges as springflow or seepage to waterways or the floodplain sediments.

The diagram shows groundwater flow towards the waterway but does not clearly indicate the hyporheic zone. The hyporheic zone is that part of the system where flow of the waterway occurs within the river bed. The size and geometry of hyporheic zones surrounding streams vary greatly in time and space.

Owing to the slow rates of groundwater movement in the Palaeozoic bedrock aquifer, and long residence times, groundwater can become mineralised and saline. Native groundwater qualities in the bedrock are therefore saline which has been confirmed by sampling completed as part of the geotechnical investigation program. Residence times within the alluvial system are short and owing to a strong interaction between surface water and groundwater, either as bank storage, or hyporheic flows, groundwater qualities are fresher, although a mixing zone may exist. Because of mixing between groundwater and surface water in the hyporheic zone, the chemical and biological character of the hyporheic zone may differ markedly from adjacent surface water and ground water.

As shown in the schematic, contributions to flow in the creek are from:

- Rainfall within the catchment
- Stormwater and urban run-off
- Interactions with the groundwater.

Figure 6-17 shows groundwater levels gaining stream conditions, although the nature of interaction between the waterway and groundwater may vary seasonally and along the reach of both creeks.

For example, in the Simpson Barracks area, stream flows are ephemeral and mostly related to stormwater run-off in the upper catchment areas. Banyule Creek water quality is generally of low salinity (<1 mS/cm) which is significantly fresher than native bedrock groundwater (>6 mS/cm in nearby bores). This suggests the creek would be losing during flow events. However, water quality monitoring undertaken by ecological specialists in Autumn 2018, in some deeper pools in Banyule Creek downstream of where it diverges from River Gum Walk area, identified localised, higher salinities, suggesting that influent or gaining conditions are present in places.

Further downstream within its catchment, on the alluvial floodplain south of Banyule Road, Banyule Creek is shallow and typically <1.5 metres deep and not greatly incised into the floodplain. Preliminary information from the geotechnical program has identified shallow groundwater levels (<1.5 m) in bore NEL-BH170 and therefore there may be interaction with the water table in these areas.

With regards to Koonung Creek, there are few groundwater monitoring sites available along its reaches, although nested bore site NEL-BH040 (bedrock) and NEL-BH040A (alluvials) are near coincident with the creek. Groundwater recharge is likely during flood events on Koonung Creek.

6.16.2 Yarra River

The conceptualisation of groundwater within a generalised Yarra River floodplain is shown in Figure 6-18. There is a relatively broad floodplain associated with the Yarra River, which is predominantly zoned for public use, public conservation and resource and public park and recreation purposes. The margins of the floodplain can be inferred from the topography of the region.

The conceptualisation of the Yarra River floodplain is also shown as a two aquifer system, with alluvial sediments overlying the bedrock. The alluvials comprise variable mixtures of sands, clays, silts and gravels. Drilling completed as part of the geotechnical investigation program indicates that the alluvial sediments can be upwards of 20 metres in thickness, and may contain discrete coarse grained beds, and fine grained beds within the sequence. Elsewhere the Yarra River streambed may rest directly upon the Palaeozoic bedrock. The streambed conditions of the Yarra River are not well understood as drilling has not been completed close to, or within the streambed.

Owing to the porosity of the alluvial aquifer, it is likely to store larger quantities of groundwater relative to the low porosity bedrock. The component of hyporheic flows within the alluvials may be significant, but it has not been quantified. Recharge to the alluvials can occur through interaction with the Yarra River, or directly through infiltration of rainfall or flood overbanking over the floodplain catchment.

Within the floodplain there are a number of swamps and billabongs such as Banyule Swamp and Bolin Bolin Billabong. These may or may not interact with groundwater depending on the depth of the depression in each case.

The groundwater in the bedrock is more saline relative to that within the floodplain sediments, although a mixing zone or interface is likely to exist between of the two aquifers.

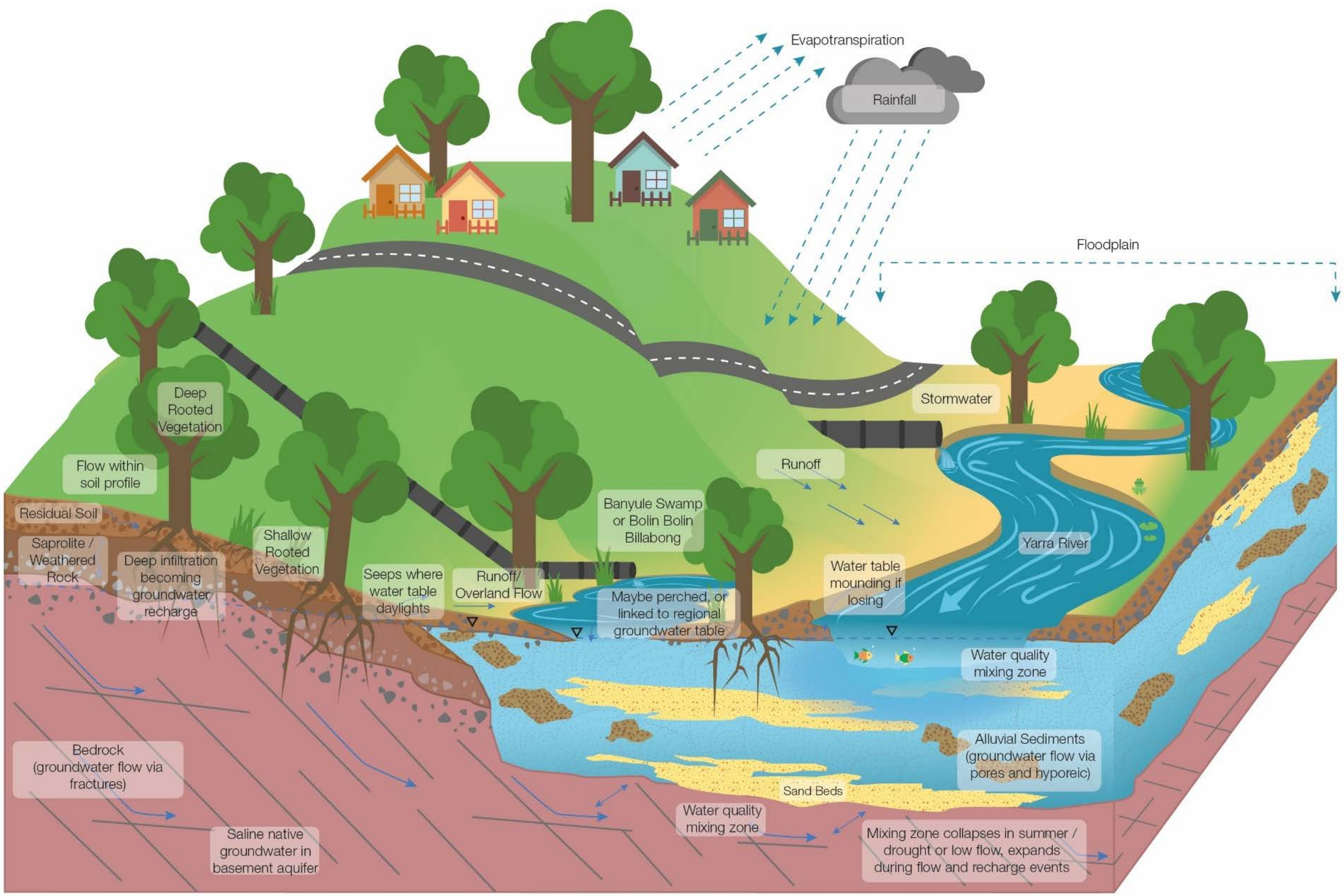


Figure 6-18 Conceptualisation of the Yarra River floodplain

7. Risk assessment

A risk assessment of project activities was performed in accordance with the methodology described in Section 5. The risk assessment has been used as a screening tool to prioritise the focus of the impact assessments and development of the Environmental Performance Requirements (EPRs) for the project. The risk pathways link project activities (causes) to their potential effects on the environmental assets, values or uses that are considered in more detail in the impact assessment. Risks were assessed for the construction and operation phases of the project.

The identified risks and associated residual risk ratings are listed in Table 7-1. The likelihood and consequence ratings determined during the risk assessment process and the adopted EPRs are provided in Appendix A. There are no planned events within the groundwater impact assessment.

Table 7-1 Groundwater risks

Risk ID	Potential threat and effect on the environment	Risk rating
Construction		
Risk GW01	Construction activities that result in the degradation of groundwater quality via spills, storage and handling of hazardous materials, such as fuels.	Low
Risk GW02	Construction activities including dewatering (or extraction of groundwater for construction water supply) result in loss of operational capacity of existing, registered, groundwater users.	Low
Risk GW03	Construction activities including dewatering (and water supply) result in a water level drawdown of a magnitude in areas having in situ sulfidic sediments or rock that results in generation of acidic groundwater conditions.	Low
Risk GW04	Construction activities including dewatering (or extraction of groundwater for construction water supply) result in the dislocation of delineated, contaminated groundwater plumes.	Low
Risk GW05	Management of groundwater seepage into construction excavations results in unacceptable impacts at the point of discharge.	Low
Operation		
Risk GW06	Traffic accidents, spillage of hazardous materials, or events resulting in generation of contaminated stormwater runoff result in the degradation of groundwater quality.	Low
Risk GW07	Long term groundwater seepage into drained structures results in loss of operational capacity of existing, registered, groundwater users.	Low
Risk GW08	Long term groundwater seepage into drained structures results in a groundwater drawdown in areas of in situ sulfidic sediments or rock and generates acidic conditions.	Low
Risk GW09	Long term groundwater seepage into drained structures results in the dislocation of delineated, contaminated groundwater plumes.	Low

Risk ID	Potential threat and effect on the environment	Risk rating
Risk GW10	Buried structures such as tunnels and long cut-off walls, results in the creation of a barrier to groundwater flow and changes to groundwater levels.	Low
Risk GW11	Management (disposal) of groundwater seepage entering into tunnels/portals, results in the unacceptable impacts (such as salt loads, contamination) to point of discharge (waterway, sewer, groundwater).	Low
Risk GW12	Unexpected contaminated groundwater seepage is not treated by the tunnel wastewater treatment plant resulting in groundwater being released to receiving environments (sewer, surface waters) or hazards to maintenance staff.	Low

It is noted that the risks associated with impacts on GDEs are assessed in Technical report Q – Ecology.

8. Impact assessment

8.1 Description of construction

8.1.1 Interaction with groundwater

Within the three project elements, interaction with the groundwater environment is greatest in the northern portal to southern portal element, and the southern part of the M80 Ring Road to northern portal element where construction would occur below the ground surface, and in places, below the groundwater table.

A design philosophy to minimise disturbance to groundwater was to adopt tanked conditions in areas within the alignment where groundwater control was likely. Based on the project description, these locations of below grade (cut and cover, trench) and tunnel sections areas are summarised in Table 8-1 and shown in Table 8-1.

Table 8-1 Groundwater management for along the project alignment

Location	Construction type	During construction		During operation	
		Drainage	Management[1]	Drainage	Management
Blamey Road to Watsonia railway station	Open trench	Drained	Monitoring	Drained	Monitoring
Blamey Road (Simpson Barracks) to Lower Plenty Road	Cut and cover	Partially drained	Recharge bores	Tanked	Monitoring
Lower Plenty Road to Banksia St/Manningham Road	Bored tunnel	Tanked	Monitoring	Tanked	Monitoring
Banksia St/Manningham Road to Bulleen Road	Cut and cover/Open trench	Partially drained	Recharge bores	Tanked	Monitoring
Bulleen Road to Trinity Grammar School Sporting Complex	Mined	Drained	Recharge bores	Tanked	Monitoring
Trinity Grammar School Sporting Complex to Bulleen Swim Centre	Cut and cover/ Open trench	Partially drained	Recharge bores	Tanked	Monitoring

Note: 1. Temporary methods to manage groundwater are described in Table 5-4.

However, before the establishment of tanked conditions, groundwater would need to be managed through temporary solutions such as dewatering using bores, or sumps within excavated areas. Excessive groundwater inflows into construction are undesirable and contractors take reasonable measures to minimise inflows to enable safe and stable working conditions. It is recognised the final project may differ from the reference project, and therefore EPRs have been linked to the groundwater risks and impacts discussed in the sections below.

A number of the groundwater risks are linked to changes in groundwater level which would occur during construction and the longer term operation of the project. Under these circumstances, design controls and the project's EPRs can address multiple risks.

8.1.2 Cut and cover tunnelling description

Where battered (sloped) excavations are not possible due to space constraints, a retaining wall system would be required. The retaining wall could comprise a bore pile (such as soldiers, contiguous/secant and diaphragm) wall which could be supported by horizontal waling beams, props or ground anchors, as shown in Figure 8-1.

Once the lateral pile support is emplaced, a 'roof' is constructed, and then ground beneath the roof or capping is excavated to the desired elevations. During this period, groundwater can seep through the base of the excavation, but lateral movement of groundwater into the excavation is generally minimised by the piled wall type. Dewatering can occur through sumps in the base of the excavation (that is, where seepage water is collected and removed from the excavation) or through the installation of dewatering bores (which can enable dewatering well in advance of the excavation face).

The structure becomes waterproof or tanked when the floor or base slab is laid, towards the end of the construction. This floor slab is typically laid sequentially as the excavation progresses with depth along the alignment.

Figure 8-1 Lateral wall construction

(Airport Link, Brisbane, 2011)

8.1.3 TBM tunnelling description

As noted in Section 5.5.4, there are different types of TBMs that can be used on the project and machines are selected based upon many factors such as the anticipated ground conditions, surface conditions, tunnel alignment and length, and geologic material strengths.

TBMs can be operated in ‘closed’ or ‘open’ modes. In ‘closed’ mode, groundwater is controlled using shields, compressed air, rock or soil debris or slurries. Segmental linings are progressively placed behind the cutting head, and grouted. A slurry machine is shown in Figure 8-2, which shows a cross section through a machine, extending from the cutting face, through to the completed lining system. The TBM advances by using hydraulic rams (thrust arms) that jack-off the previously installed segmental lining.

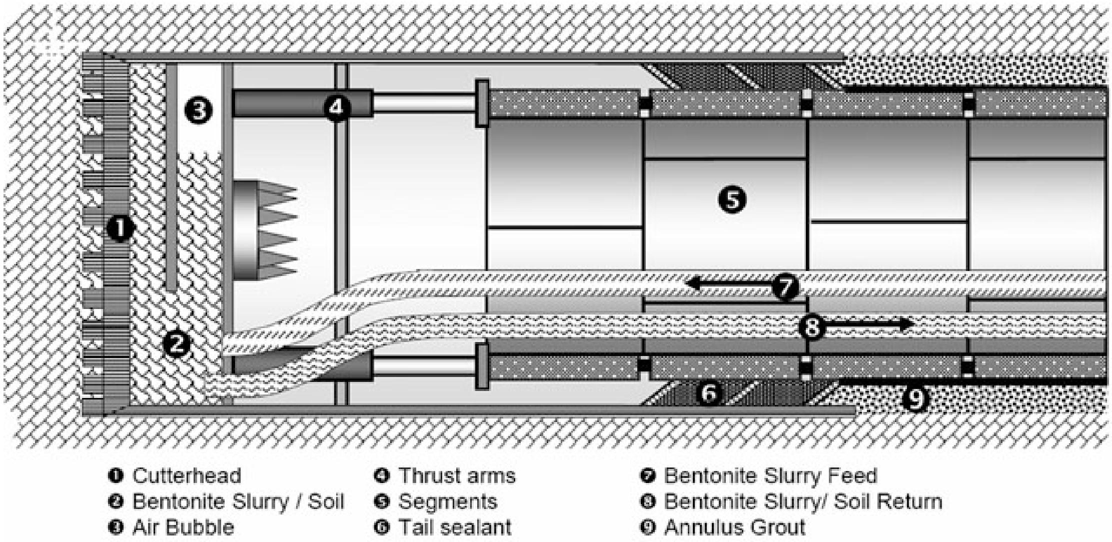


Figure 8-2 TBM slurry machine (section)

Changes in groundwater levels during TBM tunnelling can be minimal. Waterproof gaskets used between segments and grouting ports manufactured into the pre-cast concrete segments enables grout to be injected into the annulus between the drilled tunnel and exterior of the segments. Unlike the more conventional mining methods and cut and cover tunnelling, sealing of the tunnel from groundwater occurs as the tunnelling progresses.

Some of the larger utility relocations are most likely to be constructed using open trenching and ‘pipe jacking’ methods. In simple terms, a pipe jack is a similar principle to a TBM, but at a smaller scale. Tunnelling is progressed as using hydraulic rams to jack-off the sections of pipe that have previously been laid. Mined tunnelling description

Owing to a short section (approximately 420 metres) of the project to be tunnelled in Bulleen, more traditional open-face mining techniques may be applied. These techniques typically have a ‘heading’ and ‘bench’ or sequential approach, where the upper part of the tunnel face or heading is excavated, and then the middle and lower parts.

A road header or continuous miner as shown in Figure 8-3 is used to excavate the geologic materials. Once excavated, temporary ground support is emplaced to provide a safe excavation. At some distance behind the excavation face, the permanent or secondary lining system is applied. Under these conditions, groundwater may freely drain into the tunnel for some time until the secondary (final) lining system is applied.

Figure 8-3 Road header

Excessive groundwater inflows can be assessed by probing in advance of tunnelling, and inflow controlled using grouting methods (to reduce rock permeability) or dewatering. Dewatering may occur through bores installed external to the tunnel, or from drainage holes drilled into the excavation face in advance of tunnelling.

Cross passages, plant and maintenance rooms and sumps within the TBM tunnel would also be constructed using similar mining methods.

8.2 Management of captured groundwater

Groundwater that flows into excavations or the completed structures under operating conditions, needs to be appropriately managed. This has been recognised as groundwater risk GW05 (construction) and risk GW11 and risk GW12 (operation).

8.2.1 Methods

During the project's construction, groundwater would be captured in the various excavations. The management of this water would depend on the water quality and the site water requirements.

- Some of this groundwater may undergo treatment such as settling and subsequently be reused in construction activities such as for dust suppression or to make up water for slurries.
- Captured groundwater could be reinjected into aquifers to provide hydraulic control on drawdowns. Disposal to groundwater must meet regulatory requirements, such as SEPP (Waters) and Southern Rural Water licensing requirements. Treatment of the water before disposal may also be required to facilitate the reinjection, such as to prevent mechanical, chemical and biological clogging.

- Captured groundwater could also be discharged to sewer or surface waterways. Disposal to sewer would require wastewater to meet trade waste acceptability guidelines of Yarra Valley Water. Disposal to waterways must meet regulatory requirements, such as SEPP (*Waters*), in terms of water quality (physical and chemical). Treatment may be required to achieve regulatory requirements, and monitoring may be required to ensure compliance.

Based upon the North East Link reference project, a number of structures have been designed as being tanked and would therefore limit the volumes of groundwater that need to be managed. Under operating conditions, tanked structures may be subject to minor seepage inflows, but at magnitudes expected to be significantly less than during the project's construction (for example, inflow rates based on Haack Class 3 tightness classification).

Water could also enter the tunnels as stormwater run-off and vehicle run-off. Commonly the two water treatment trains (groundwater inflow, and vehicle/storm run-off) are separated within a tunnel to facilitate the treatment process. Disposal to sewer or waterways are potential wastewater management options that could be considered. Risk GW12 is a slight variant of risk GW11 and is applied to where contaminated groundwater plumes intersect the operating tunnel. EPR GW5 and EPR SW3 have been proposed to address the risks associated with managing seepage inflows.

8.2.2 Estimate of volumes

Numerical groundwater modelling provides a coarse estimate of the groundwater inflows which is summarised in Table 8-2.

Sensitivity and uncertainty analyses were undertaken on the numerical groundwater model (refer Appendix C) which resulted in the development of 200 alternative models with predictions that are equally plausible based on the calibration dataset. Under these conditions, inflows are reported as both 95th percentile and 5th percentile in Table 8-2; that is, the 95th percentile indicates that 95 per cent of the 200 calibrated models inflows are less than this amount. The modelled inflows therefore consider plausible maximum and plausible minimum potential volumes.

Inflow rates are indicative only as:

- Construction scheduling has an influence on construction inflows, such as the time between excavation and tanking and the size of excavation opened
- The numerical model activates dewatering instantaneously and simplifies excavation activities and construction scheduling.

Note that inflow estimates for the TBM tunnel are not documented in Table 8-2 as the permanent lining is installed during construction. Based on a Haack Class 3, maximum permitted inflow rates would be 30.7 m^3/day for the twin tunnels.

Table 8-2 Groundwater inflow estimates

Excavation/cut and cover	Percentile	Average inflow during construction (m^3/day)	Maximum inflow during construction (m^3/day)	Average inflow post-construction (m^3/day)
Trench (~Blamey Road to Watsonia railway station)	95th	22	105	16
	5th	16	86	10
Lower Plenty (Lower Plenty Road to ~Blamey Road)	95th	123	330	14
	5th	98	282	12
Banksia (Manningham Road to mined tunnel)	95th	78	255	11
	5th	55	181	9
Southern (Mined tunnel to Bulleen Swim Centre)	95th	76	620	13
	5th	48	389	10

Note:
1. 10 m^3/day = 0.12 L/s
2. Does not include volumes that may be lost through evaporation
3. 95^{th} percentile: upper bound estimate, 5^{th} percentile: lower bound

The numerical groundwater model estimates inflows may peak during the project's construction at around 3.8 L/s (620 m^3/day). However, average inflows during the project's operation are estimated at less than 0.18 L/s (16 m^3/day) based on achieving a Haack Class 3 tightness of tanked structures.

The salinity of the groundwater would be a key consideration in how it is disposed. The average salinity of the Palaeozoic bedrock aquifer of 5,100 mg/L. Structures located in, or adjacent the alluvial floodplain (such as in the southern cut and cover sections) may receive lower salinity inflows. Ultimately, the salt load would be a blend of waters entering the structures and disposal to sewer would need to meet agreed waste acceptance criteria. Treatment may be required to achieve regulatory requirements, and monitoring may be required to ensure compliance.

8.3 M80 Ring Road to northern portal

8.3.1 Assessment of construction impacts

In most of the project's M80 Ring Road to northern portal element, construction works would occur either at or above grade and so risks of adverse impact to the groundwater environment are low due to the low likelihood of direct interaction.

In the southern portion of this project element, between Watsonia railway station to Erskine Road (to the south of Simpson Barracks) a trench structure is proposed. Over the northern half of this trench section, excavations would be above the water table but below the water table approximately south of Blamey Road.

8.3.1.1 Impact to groundwater quality (risk GW01)

Under the *Environment Protection Act 1970* (Vic) and the SEPP (*Waters*), groundwater has defined beneficial uses depending on its salinity and groundwater quality which must be protected to preserve these identified beneficial uses. Potential groundwater quality changes may arise during construction and operation phases of the project from:

- Spillage, improper handling, storage and application of hazardous materials
- Reinjection of groundwater seepage
- Incompatibilities with construction materials, such as leaching from imported backfill, chemical additives to grouts and sealing resins
- Fluids used during artificial recharge activities
- Saline intrusion/mixing of native groundwaters of different salinity.

Assessment

It is possible that construction activities generate local groundwater quality impacts from spillage or improper handling and application of hazardous materials, such as the refuelling and maintenance of construction plant and equipment. The likelihood of these environment incidents is low because it would be a requirement to implement controls to manage chemicals, fuels and hazardous materials to manage these risks (EPR SCC4).

Furthermore, a hazardous material (pollutant) needs sufficient time and a pathway to access the groundwater environment—it must be able to migrate vertically from the surface through the soil profile to the water table. It is a reasonable expectation that if a release of hazardous material occurred to the environment, incident response procedures would likely occur promptly, such as the use of spill kits/containment and reduce the severity of the consequence.

Artificial recharge (reinjection) may be applied to mitigate the effects of construction dewatering. This involves the deliberate injection of fluids (commonly potable or treated water) into a groundwater aquifer to control hydraulic gradients and stabilise water levels. It can be used to impart hydraulic controls on existing groundwater plumes, but also realises a potential risk of introduction of contaminants into an aquifer via the injection waters. In some cases, groundwater seepage captured from excavations is disposed via aquifer reinjection.
Aquifer reinjection is a licensable act under the *Water Act 1989* (Vic) and so the water quality of the injection fluids would need to be consistent with the SEPP (*Waters*). Water quality also needs to be of a standard that makes recharge technically achievable and practicable; that is, it minimises clogging (mechanical, biological, chemical) and is compatible with native groundwater quality. As part of the recharge licensing process, and making its determination, the licensing authority Southern Rural Water may seek an assessment of the proposed impacts to groundwater from the proponent seeking the reinjection licence, and may use EPA Victoria as a referral agency.

Changes to groundwater quality due to saline intrusion or the mixing of native groundwater of differing salinity has parallels with contamination, and is discussed in Section 8.3.1.

EPR GW2 has been proposed to ensure the baseline condition of the groundwater environment has been characterised pre-construction. The implementation of a Construction Environmental Management Plan and on-going monitoring during construction would be required to identify whether groundwater has been adversely impacted and an appropriate management response is required.

8.3.1.2 Impact to existing users and depletion of groundwater resources (risk GW02)

There are two aspects to this impact. Groundwater resources may be developed for a water supply to service construction effort—groundwater bores are installed to obtain a construction water supply source as an alternative to mains supply. The second aspect is that existing groundwater users may have their bore operation affected by drawdowns emanating from construction dewatering works. The latter aspect would extend into the operation of the project. In either case, water levels are reduced and the operation of existing groundwater abstractive bores may be affected.

This potential impact is shown schematically in Figure 8-4. A bore is located near the project (in this case a cut and cover trench section). Once the project was constructed, water levels would be drawndown due to construction dewatering or inflow into a drained or un-tanked structure. The change in water levels at the private bore can affect bore operation. While the schematic shows a section near the northern portal, the concept is the same for the tunnel sections (TBM and mined) and the southern portal.

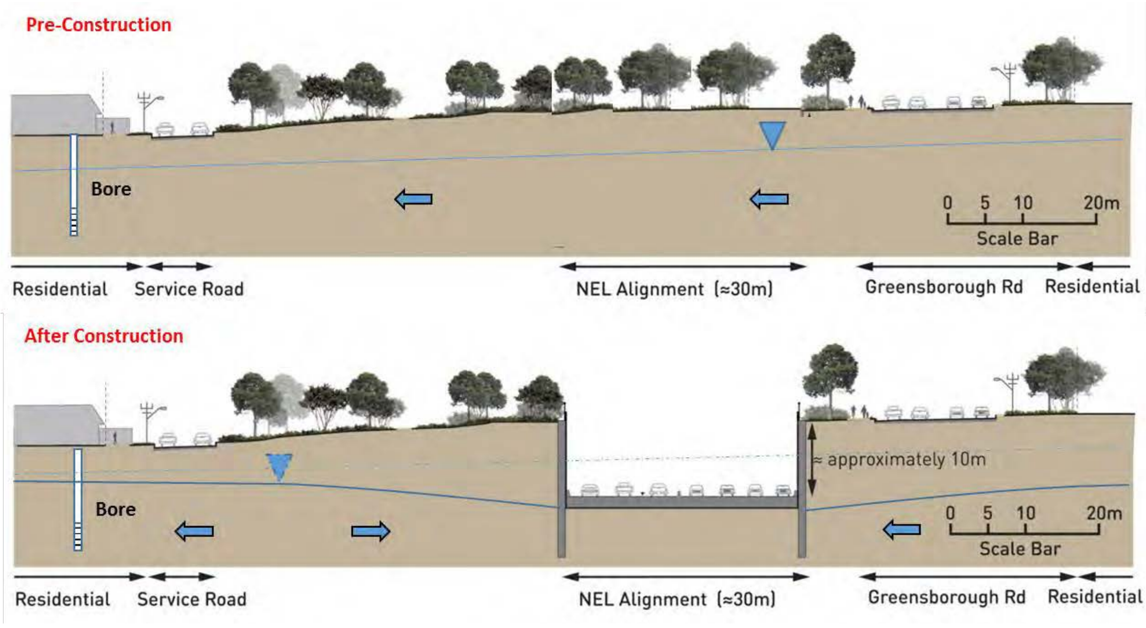


Figure 8-4 Impact to existing users

Assessment

There is increasing pressure for contractors to use alternative supplies of water for construction purposes to reduce stress on potable drinking water supplies (EPR SCC4). In some cases, contractors do not specifically install groundwater bores, but rather harvest groundwater seepage intersected during excavation activities occurring below the groundwater table. Reuse of groundwater, provided its quality is suitable for the intended use, can be an appropriate means of managing groundwater inflows.

Any groundwater bores installed for construction water supply or permanent water supply would need to be licensed by Southern Rural Water in accordance with the Water Act*,* and would be subject to its licensing determinations. As part of any licensing determination, a proponent would be required to complete a technical hydrogeological assessment to support the groundwater licensing. This would include an assessment of impact to existing users, surface water flows and water availability. A groundwater supply would not be licensed unless the risks of extraction on groundwater (other users, the environment) are deemed acceptable by Southern Rural Water. Note also that groundwater inflows into excavations and structures during the project's construction (and operation) may also be subject to Southern Rural Water licensing requirements.

Given the low bore yields of the bedrock aquifer, and generally poor groundwater quality, development of groundwater as a construction water supply is possibly limited. The same factors have generally resulted in limited existing abstractive development of the resource (refer Section 6.10.7).

The drawdown created by dewatering, either during construction or longer-term operation, may interfere with the operation of nearby existing groundwater users. The drawdown from dewatering decreases with distance from the tunnels or excavations, and expands in size while pumping occurs until steady state conditions are reached.

Based on the understanding of groundwater levels in relation to the grade line, the trench structure would start near Watsonia railway station and dive towards the south and Lower Plenty Road. Water level information collected from the geotechnical investigation program indicates the grade line would likely intersect the water table to the south of Blamey Road (at Simpson Barracks).

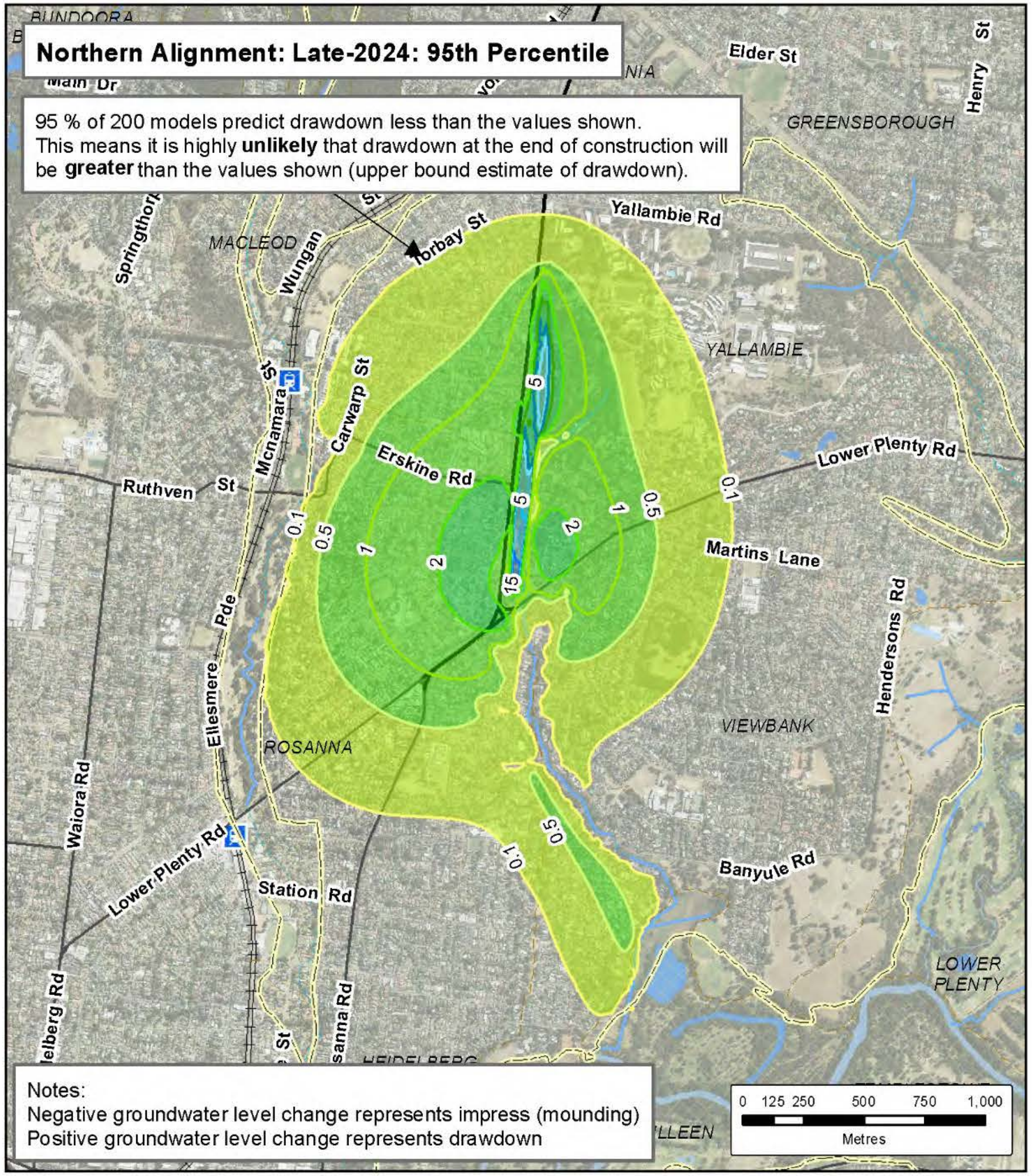
The predicted extent of drawdowns during the project's construction is shown in Figure 8-5 and Figure 8-6 for the 95th and 5th percentiles respectively. The reporting of percentiles is due to the uncertainty of analysis completed as part of the numerical groundwater modelling to address non-uniqueness issues. The uncertainty analysis identifies a range of alternative models (with different combinations of parameter values) and the predictions of the alternative models can be regarded as equally plausible based on the existing calibration dataset. A 95th percentile drawdown means that of the 200 plausible models, 95 per cent predict water level drawdowns to be less than shown in Figure 8-5.

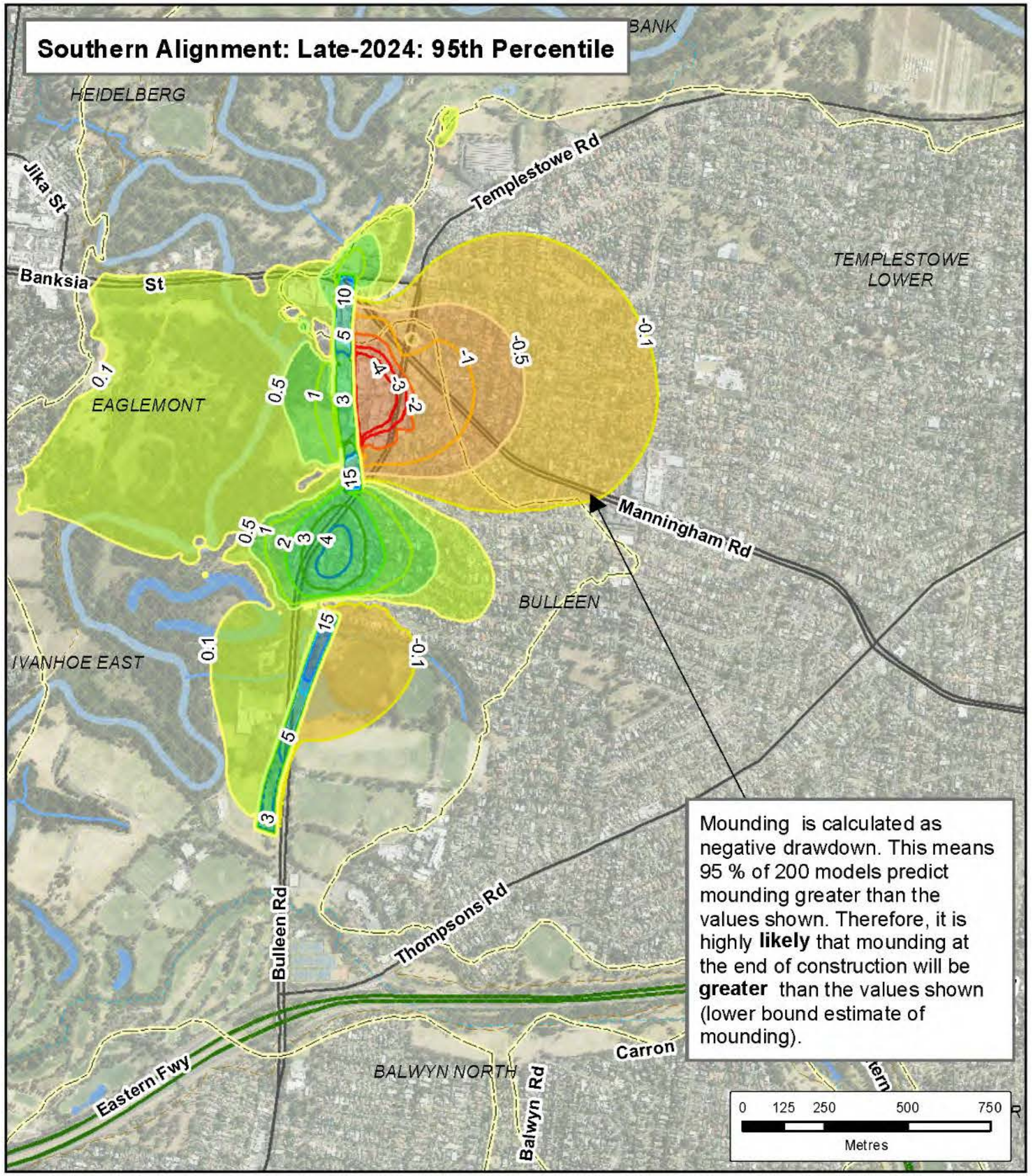
In reviewing the drawdown data the 95th percentile should be used, whereas the highest mounded water levels are most conservatively represented within the 5th percentile (refer Appendix C). The numerical model treats drawdowns as positive numbers, and mounding as negative numbers—the greater the mounding (more negative) the lower the percentile.

Bores identified in the predicted extent of construction drawdown are summarised in Table 8.3.

Table 8.3 Bores within predicted drawdown extent (construction) – M80 Ring Road to northern portal

Bore ID	Comment	Predicted drawdown impact
WRK98205 S9032243/1	A 25 m deep bore located at fuel service station at Yallambie Road. Assumed to be used for environmental investigation purposes. This bore is located within the Project boundary.	0.1 m to 0.5m
Unknown bores (2)	Identified at Simpson Barracks. Depth unknown. Assumed to be used for environmental investigation purposes.	0.5 m to 2 m





Paper Size A4

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

-5, -4, -3, -2, -1, -0.5, -0.1, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20

Modelled GWL Change (m)

< -5, -4.99 - -2, -1.99 - -0.5, -0.49 - -0.1, -0.09 - 0.1, 0.11 - 0.5, 0.51 - 2, 2.01 - 5, 5.01 - 10, 10.01 - 15, 15.01 - 20, > 20, Alluvium

North East Link Project
Environment Effects Statement (EES)

Job Number	31-35006
Revision	E
Date	05 Mar 2019

NORTH EAST LINK PROJECT

Predicted drawdowns:
95th Percentile (construction phase)

Figure 8-5

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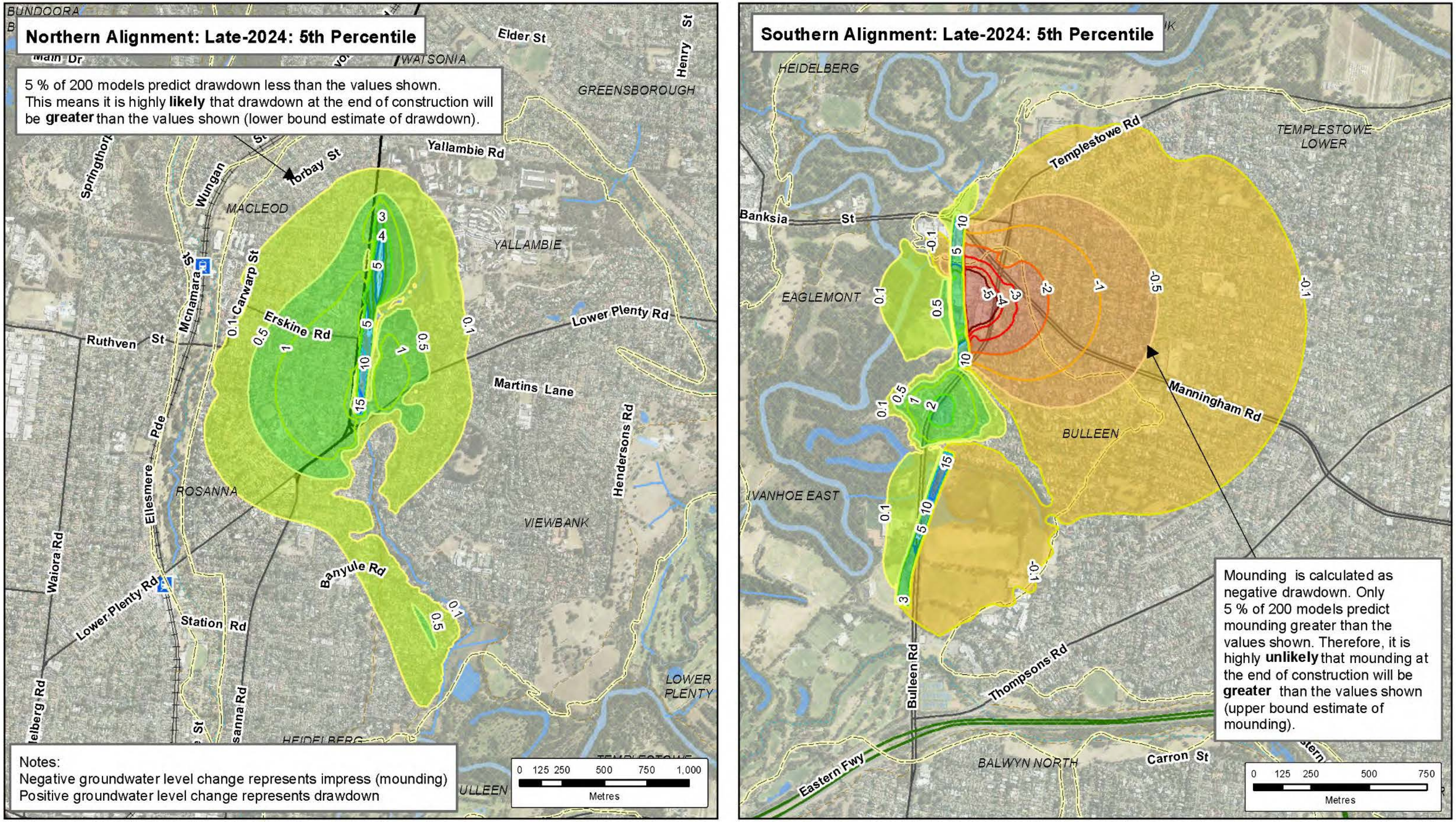
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti



Paper Size A4

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Modelled GWL Change (m)

-5, -4, -3, -2, -1, -0.5, -0.1, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20

Modelled GWL Change (m)

< -5
-4.99 - -2
-1.99 - -0.5
-0.49 - -0.1
-0.09 - 0.1
0.11 - 0.5
0.51 - 2
2.01 - 5
5.01 - 10
10.01 - 15
15.01 - 20
> 20
Alluvium

North East Link Project
Environment Effects Statement (EES)

Job Number 31-35006
Revision E
Date 05 Mar 2019

Predicted drawdowns:
5th Percentile (construction phase)

Figure 8-6

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti

Private groundwater bores with an abstractive beneficial use have not been identified within the predicted drawdown extent, only monitoring bores. Furthermore, the magnitude of drawdowns at distances greater than 500 metres from the trench are less than 0.5 metres. As noted in Section 6.10.7, seasonal water level fluctuations of 1 metre could be reasonably expected and the predicted drawdown is within the magnitude of drawdown (1 to 2 metres) change experienced during the Millennium Drought (1996 to 2010).

The primary control for minimising groundwater drawdowns relating to construction dewatering is the design philosophy (EPR GW3). Adopting structures that have tanked lining systems would minimise the change in groundwater levels during the project's construction.

A number of other mitigation measures are available to reduce impacts to existing groundwater users such as lowering pumps, drilling deeper bores, provision of alternative supplies during construction, or implementing recharge. The numerical groundwater model has not been applied to assess the extraction of groundwater for a construction water supply, nor the use of recharge bores to mitigate against drawdowns. These may be required to support licensing of a production bore, or the design of a recharge scheme.

This risk could be managed through managing the impacts of groundwater drawdown, but also through existing regulations, such as licensing requirements under the Water Act. Supplementing the existing regulations, EPR GW2, EPR GW3 and EPR GW4 require identification of potentially impacted parties, monitoring and implementation of mitigation measurements should adverse impacts to existing bores be identified.

Existing groundwater uses may also be impacted by changes in groundwater quality. As no private groundwater bores were identified within the predicted drawdown extent, this is not considered an issue. There is a single aquifer in this area (the bedrock system) and so mixing and saline intrusion issues are not expected.

Existing groundwater bores may be users of the resource, but there may be environments that may also rely upon groundwater, such as ecosystems that depend on groundwater, and drawdowns during construction could reduce accessibility. This risk is assessed in Technical report Q – Ecology. If drawdowns during construction are considered unacceptable by this assessment, a potential management measure is groundwater recharge (water recovered from excavations is recharged using injection bores to control hydraulic gradients). Grouting could also be undertaken to reduce the permeability of the ground, although this can still result in drawdowns.

8.3.1.3 Impact arising from drawdowns on PASS materials (risk GW03)

The reduction in water levels may expose PASS materials and generate acid plumes. This process is shown in Figure 8-7. The schematic shows PASS materials below the water table which are saturated and therefore stable. During a project's construction (or during its operation if a drained structure), PASS materials could oxidise if exposed by reduced water levels, and a leached plume would subsequently migrate under the prevailing hydraulic gradient. This plume can adversely affect infrastructure foundations in contact with groundwater as well as other buried structures that are hydraulically down-gradient of the plume, ecological receptors and groundwater receiving environments. While Figure 8-7 shows a section near the project's northern portal, the concept is the same for the tunnel sections (TBM and mined) and cut and cover section in the southern portal.

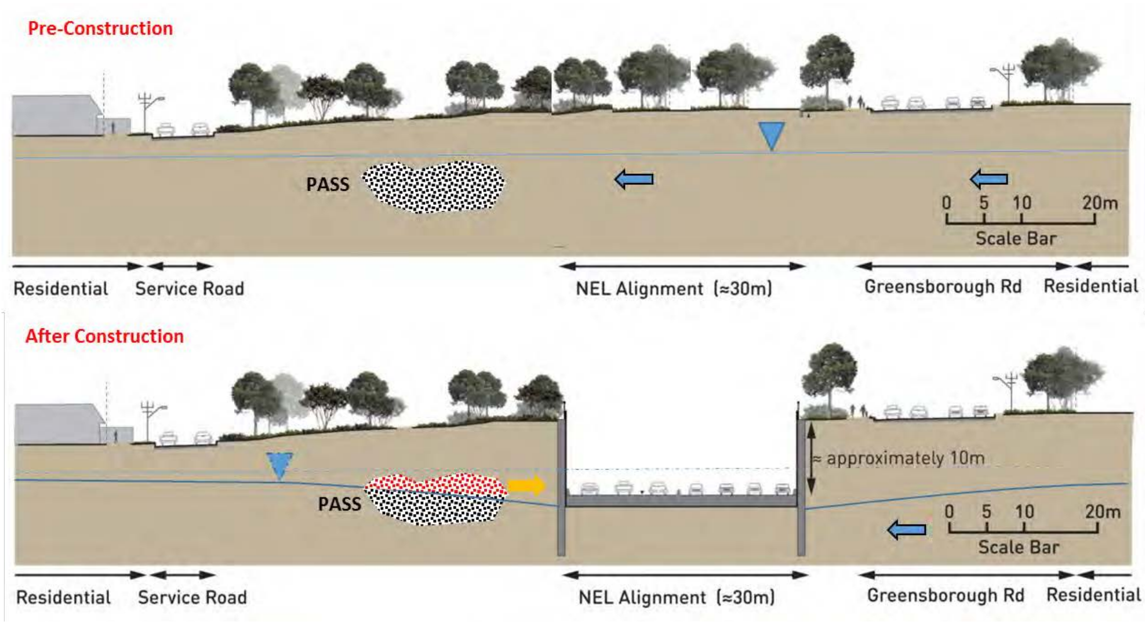


Figure 8-7 Groundwater changes and PASS oxidation

Assessment

PASS materials above the water table have the potential to be exposed through excavations, such as by foundation earthworks. This impact is assessed in Technical report O – Contamination and soil. EPR CL2 is proposed to address PASS-related risks identified in that assessment. The following discussion is based on PASS oxidation processes catalysed through changes in groundwater level by construction or longer-term dewatering.

In the project's M80 Ring Road to northern portal element, the trench structure extending from Watsonia railway station to Erskine Road and the northern portal would intersect groundwater south of Blamey Road. The predicted extent and magnitude of construction drawdown which occurs within the Palaeozoic bedrock aquifer is shown in Figure 8-5 (95th percentile) and Figure 8-6 (5th percentile) above.

There are a number of bases upon which to concluded there is a low risk of encountering acid generating geological materials within this section of the M80 Ring Road to northern portal element:

- Laboratory analysis of over 80 rock samples identified only four samples that were PASS; no confirmed acid generating soil or rock materials were identified. The four samples identified as PASS were identified at depths greater than 20 metres below the surface in fresh bedrock and not located within this project element.
- Review of the interpreted weathering profile of the bedrock (refer Figure 6-2 above) indicates the trench excavation would predominantly be within weathered bedrock.
- The magnitude of drawdown predicted to occur within this project element is similar to the magnitude of what could be reasonably assigned to seasonal fluctuation, or a drought response, so would unlikely expose materials that have not been previously unsaturated.

In addition, EPR GW2 and EPR GW3 would require the implementation of a monitoring program and design and construction methods that minimise groundwater impacts to acceptable levels.

8.3.1.4 *Impact arising from drawdowns on contaminated groundwater plumes (risk GW04)*

A reduction in water levels may influence the migration of contaminated groundwater plumes. This process is shown in Figure 8-8, which depicts a hypothetical contaminated groundwater plume emanating from an underground storage tank (representing a contaminated site). The plume would migrate in the direction of regional groundwater flow (with the exception being where there are density contrasts between native groundwater and the contamination constituents). During a project's construction (or during its operation if a drained structure), the plume would migrate under the prevailing hydraulic gradient, which could be different to that existing pre-construction of the project. While Figure 8-8 shows a section near the project's northern portal, the concept is the same for the tunnel sections (TBM and mined) and the southern portal.

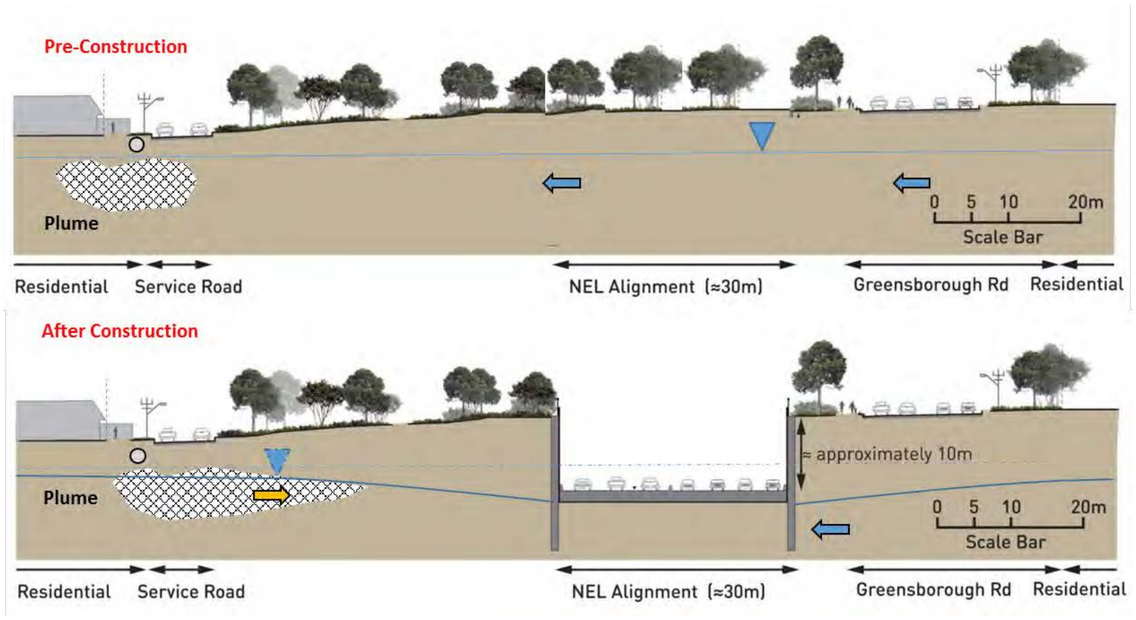


Figure 8-8 Groundwater changes and contaminated groundwater movement

Assessment

In the project's M80 Ring Road to northern portal element, the trench structure extending from Watsonia railway station to Erskine Road and the northern portal would intersect groundwater south of Blamey Road. For an impact to occur to groundwater receptors via this pathway, a plume needs to be present and its migration influenced by changes in the hydraulic gradient. The predicted extent and magnitude of construction drawdown is shown in Figure 8-5 (95^{th} percentile) and Figure 8-6 (5^{th} percentile) above. Other parts of the element are above grade and would not require groundwater control.

Potentially contaminating land uses in the trench area are summarised in Table 8.4.

Table 8.4 Potentially contaminating land uses (M80 Ring Road to northern portal)

Location	Potential source of contamination	Potential impact pathway	Potential contaminants of concern (soil and groundwater)
Yallambie Road (cnr Greensborough Road)	Fuel service station – loss of fuels from the fuel delivery system including the underground and above ground tanks, and fuels/oils/solvents from possible workshop use on site.	Excavation of soil/rock, vapour inhalation and abstraction of groundwater	Metals (such as copper, chromium, lead, zinc), solvents (including chlorinated hydrocarbons), total petroleum hydrocarbons (TPHs), BTEX, PAHs, phenol, chlorofluorocarbons, acids, alkalis, asbestos from brake replacement activities and antifreeze (ethyl-alcohol, ethylene glycol, isopropyl alcohol, methyl alcohol). Asbestos containing materials.
Watsonia Road, near Watsonia railway station	Dry cleaners – leaks and spills from storage, use and disposal of dry cleaning chemicals	Excavation of soil/rock, vapour inhalation and abstraction of groundwater	Chlorinated hydrocarbons (such as [PCE] tetrachloroethene and daughter products, trichloroethylene, 1,1,1 – trichloroethane, carbon tetrachloride,), volatile organic compounds, surfactants, waterproofing, petroleum hydrocarbons (white spirits).
	Automotive service/repair centre and car rental facilities – leaks and spills from use and storage of fuels and chemicals	Excavation of soil/rock, vapour inhalation and abstraction of groundwater	Metals (such as copper, chromium, lead, zinc), solvents (including chlorinated hydrocarbons), total petroleum hydrocarbons (TPHs), BTEX, PAHs, phenol, chlorofluorocarbons, acids, alkalis, asbestos from brake replacement activities and antifreeze (ethyl-alcohol, ethylene glycol, isopropyl alcohol, methyl alcohol). Asbestos containing materials.
	Timber and hardware	Vapour inhalation and abstraction of groundwater	Chlorinated hydrocarbons, pentachlorophenol, PAHs, organochlorine pesticides, metals (such as arsenic, copper, chromium) and ammonia.
Simpson Barracks	Defence information from their website confirmed that the property contains several historic landfills, containing waste from Defence operations and potentially asbestos containing materials. Potential for underground storage tanks (USTs); storing diesel, petroleum and waste oil. Storage/use explosive ordnance	Excavation of soil and abstraction of groundwater, vapour migration	Potential asbestos, heavy metals, TPHs, BTEX, PAHs, MAHs, UXO.

Whilst it is recognised that there are a number of potentially contaminating land uses within this element, groundwater sampling undertaken as part of the geotechnical investigation program has generally not identified obvious evidence of contamination. Groundwater contamination (PFAS) has been identified near the Watsonia Station commercial precinct, however, construction grades are above the water table. Hydrocarbons have been identified in bore NEL-ENV-BH022, which is south of the service station at the intersection of Yallambie Road and Greensborough Road.

The fuel service station (located within the project boundary) and Simpson Barracks are nearest the proposed areas requiring construction dewatering. The extents of dewatering during the project's construction are not predicted further north of Yallambie Road (and the service station).

The primary control for minimising groundwater drawdowns relating to construction dewatering is the design philosophy. Adopting structures that have tanked lining systems would minimise the change in groundwater levels during the construction phase

EPR GW2, EPR GW3 and EPR GW4 have been proposed to minimise groundwater drawdowns through design and construction, monitoring actual water level conditions (pre- and during construction) as well as the consideration of the impact of contamination on project structures, and to have contingency measures should unexpected contamination be encountered, such as source removal, clean-up, or containment.

In terms of the identified groundwater impact at Yallambie Road, construction would occur above the groundwater table. EPR CL4 is also relevant as a reduction in groundwater levels could lead to volatilisation of petroleum hydrocarbons identified near Yallambie Road, and EPR CL1 and EPR CL3 are pertinent to the management of excavated spoil. It is noted that the predicted drawdown near the service station is estimated between 0.1 metre and 0.5 metres (95^{th} percentile) as shown in Figure 8-5 above. Regional groundwater flow is estimated to be southwards and therefore dewatering won't significantly dislocate contaminated groundwater. Under EPR GW3, actions must be taken to manage contaminated groundwater identified in this area. It is noted the trench structure occupies the bulk of the footprint of the service station, implying that the source (tanks and associated hydrocarbon impact soils) would be removed.

The construction timeframe (an estimated two to three years) does not provide time for migration of a groundwater plume over significant distances. A quantitative estimate of groundwater travel times can be determined from a Darcian analysis of the advective transport of a conservative water species using the Ogata (1970) method (Fetter, 2001):

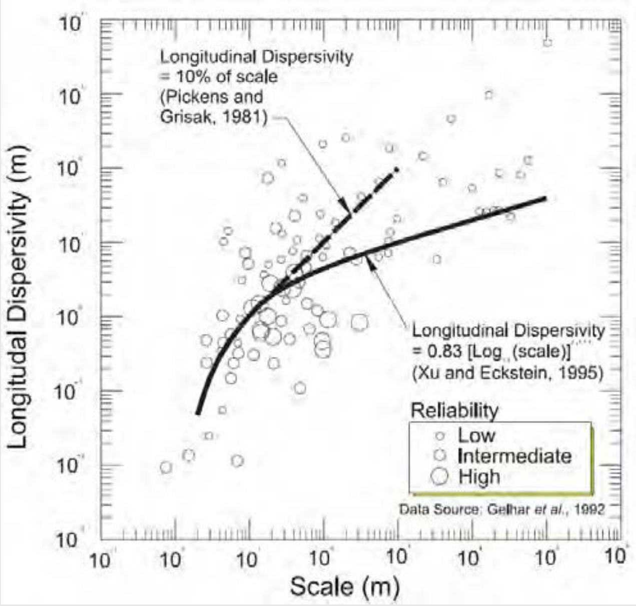
$$C = \frac{C_0}{2}\left[\mathrm{erfc}\left(\frac{L - v_x t}{2\sqrt{D_L t}}\right) + \exp\left(\frac{v_x L}{D_L}\right) erfc\left(\frac{L + v_x t}{2\sqrt{D_L t}}\right)\right]$$

As groundwater advection transports a mass of contaminant, it also results in the mass being spread and dispersed. Dispersion processes occur as a result of non-uniform water velocities within an aquifer. Dispersion of plumes varies both in space and time, such as from local pore and fracture scale, to regional scale of the depositional environment. Analytical inputs are summarised in Table 8.5.

Table 8.5 Groundwater travel time

Input	Description	Value
C_o	Initial concentration: It is assumed the plume constituents behave as a conservative species that is stable and does not attenuate in the groundwater environment via mechanisms such as biodegradation, adsorption, chemical fixation and dissociation. Some common contaminants such as hydrocarbons are not stable in the groundwater environment. As an example, a concentration of 100 mg/L has been assumed.	100 mg/L
L	Distance between the source and receptor. For this example, Bolin Bolin Billabong is approximately 120 m from the southern portal of the mined tunnel, or the centre of the former Bullen Drive-in is approximately 150 m from the Yarra River.	100 m
v_x	Average linear groundwater flow velocity. $\bar{v} = \frac{k\frac{dh}{dl}}{n_e}$ Where $\bar{v} = average\ linear\ velocity,$ $k = hydraulic\ conductivity,$ $n_e = effective\ porosity, and$ $\frac{dh}{dl} = hydraulic\ gradient.$ Monitoring bore slug testing was undertaken to estimate hydraulic conductivity and a mean of 0.1 m/day was derived for the bedrock aquifer. Hydraulic gradients are extremely flat near the alluvial floodplain. A gradient of 0.005 has been adopted assuming some disturbance from construction. Effective porosity range of 0.05 for the bedrock.	0.002 m/day
t	Time since the release of the wastewater.	365 days

Input	Description	Value
D_L	Longitudinal dispersivity: Estimation of dispersivity values in an aquifer is problematic given that it is impracticable to measure dispersion in the field. It is generally understood that dispersion is a scale-dependent variable, so that it can be estimated based on the contaminant plume length (which in this case is unknown), otherwise they can be informed through column scale laboratory tests. A number of empirical relationships, based on scale have been determined based on the length of the flow path (L) and estimated using an empirical relationship ($a_L = 0.83(\log L)^{2.414}$ provided by Xu and Eckstein (1995).	8.9×10^{-3} m/day



Output from the analytical approach is summarised in Figure 8-9 for three distances from the source and applying hydraulic conductivities of 0.05 m/day, 0.1 m/day and 0.2 m/day. Adopting the mean hydraulic conductivity of the bedrock, it takes more than 10 years before breakthrough 100 metres from the source. Note the analysis assumes the contaminants are stable. Hydrocarbons (organics), nutrients, and heavy metals are constituents that can attenuate along groundwater flow paths.

Due to these factors, the risk that construction dewatering affecting the migration of contaminated groundwater is considered to be low in this project element. However, risks still persist into the project's operation and these are discussed in the sections below.

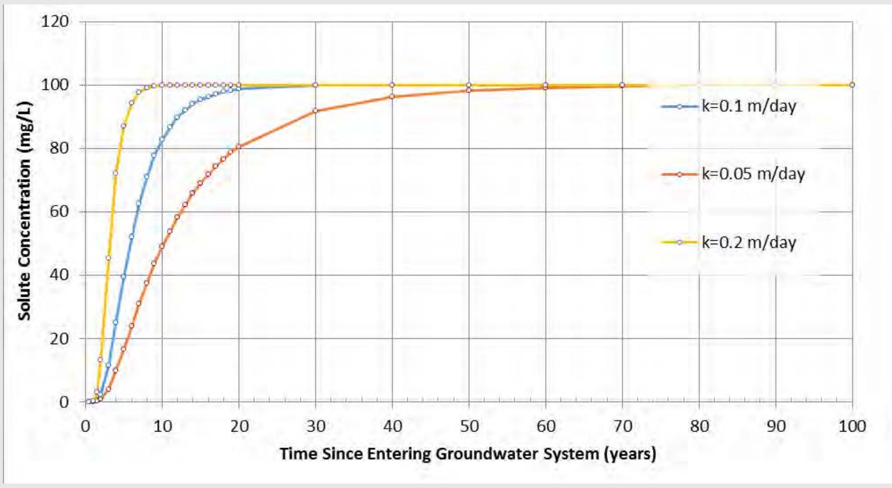
Groundwater drawdowns can result in the mixing of natural groundwaters of different native quality. There is a low risk of saline intrusion occurring based on the following lines of evidence:

- That part of the trench between Watsonia railway station and Blamey Road that requires dewatering is located within a single aquifer system; the bedrock aquifer. Groundwater quality, based on the geotechnical program is saline and ranges between 3,800 mg/L to over 9,000 mg/L TDS.
- The magnitude of drawdowns predicted in this area during construction of 0.1 to 0.5 metres (95th percentile); groundwater migration rates are low.

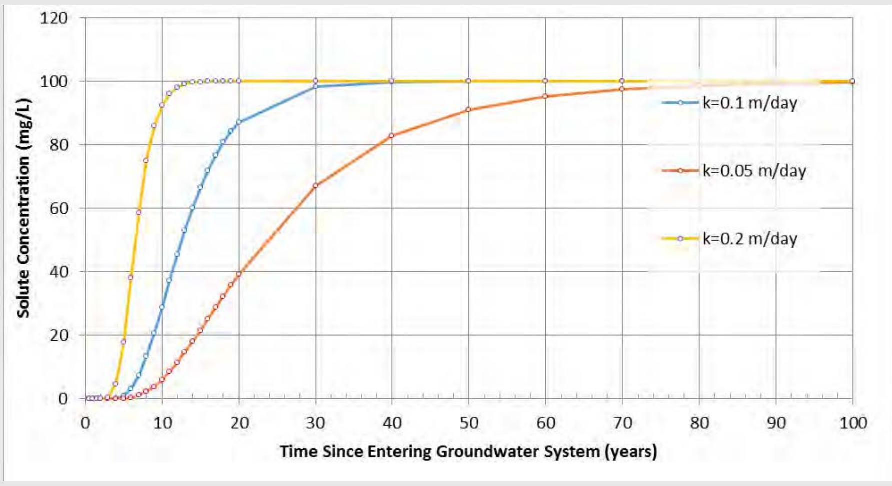
8.3.1.5 Management of construction groundwater seepage (risk GW05)

Refer to Section 8.2 for a discussion on the volumetric management of groundwater seepage. Based on groundwater level information obtained from the geotechnical investigation program, the vertical grade line of the project is above the water table north of Blamey Road.

At 25 metres from the source



At 50 metres from the source



At 100 metres from the source

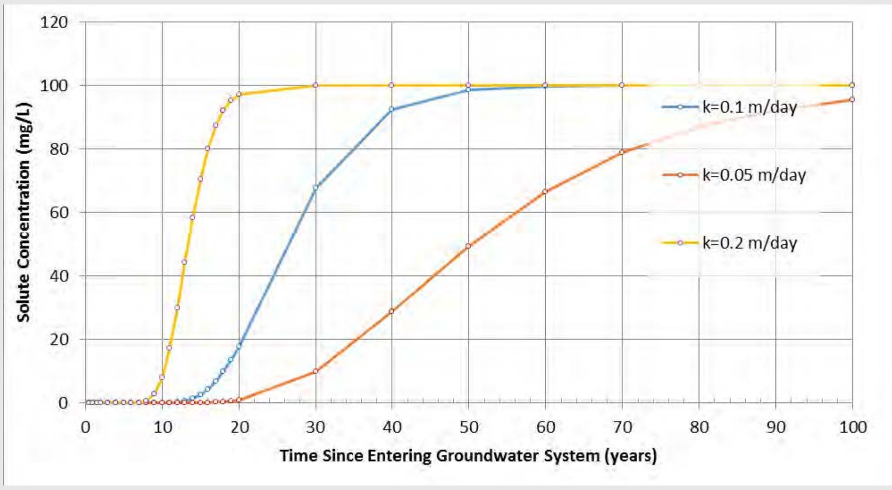


Figure 8-9 One dimensional analytical transport

8.3.2 Assessment of operation impacts

8.3.2.1 Impact to groundwater quality (risk GW06)

During the project's operation, groundwater quality changes have the potential to occur through:

- Spillage of hazardous materials
- Management of stormwater run-off.

Release of contaminants from traffic accidents cause major impacts to groundwater quality, but this risk applies across the state's road network. As noted for during the project's construction, the pathway of the groundwater contamination process is complex. These accidents are generally localised and a rapid emergency services response would be likely, thereby reducing the potential for migration of contaminants from the surface to the underlying groundwater system.

Once the project was operating, roadside water run-off from North East Link would contain oils, greases, heavy metals and other potential contaminants. This run-off would be associated with any major road in an urbanised setting and would be harvested by conventional roadside drainage. Owing to the migration pathways involved, risk to groundwater is considered to be low. That is, significant quantities of impacted run-off would have to pond and then vertically infiltrate the water table, before it either evaporated or was taken up (transpired) by roadside vegetation. To minimise the potential for pollutants to end up in the waterways (and groundwater), the reference project includes a number of water treatment features along the alignment that would filter and treat the stormwater captured from the new road surfaces.

Water Sensitive Urban Design (WSUD) principles would be applied to the stormwater management regime and landscaping of the project. Features such as grass swales would be incorporated into the project's design to naturally treat run-off or stormwater from the local stormwater drainage system. In addition, soils within the proposed alignment may have appreciable fine fractions (such as clays, silts or carbonaceous material). The low permeability of these soils would retard the vertical migration of contaminated waters, but also naturally attenuate some contaminants such as heavy metals through adsorption. These WSUD features include wetlands, bioretention ponds and storage dams which range from approximately 45 m^2 to 3,000 m^2 in size. Further information on drainage design and stormwater management is provided in Technical report P – Surface water, and EPR SW11 has been proposed to manage stormwater.

To minimise the potential of spilled liquids ending up in waterways, the project would include spill containment on freeway pavements (EPR SW2). This would contain the spill from the types of heavy vehicles expected to utilise North East Link.

EPR GW2 is proposed to address monitoring of groundwater condition. Long-term groundwater monitoring post construction (beyond two years) is not proposed provided that a review of groundwater condition at project completion confirms that no adverse impacts have occurred. If changes in groundwater condition were identified during construction, monitoring may be extended in these areas post-construction to verify restoration of the groundwater environment. EPR GW5 and EPR SW2 have also been proposed so that contingency measures are available to address risks to groundwater from spill events.

8.3.2.2 *Impact to existing users and depletion of groundwater resources (risk GW07)*

Predicted drawdowns during the operation period are shown in Figure 8-10 and Figure 8-11 for the 95th percentile and 5th percentile drawdowns for the northern portal area, and bores identified in the general area are summarised in Table 8.6. Three of the four bores were of unknown use, and although a stock and domestic bore was identified, it falls outside of the predicted drawdown extent (95 per cent confidence interval).

Table 8.6 Bores within predicted drawdown extent (operation) – M80 Ring Road to northern portal

Bore ID	Comment	Predicted drawdown impact
WRK982752 S9032219/1	Located near the intersection of Powley Avenue and Greensborough Road, the bore was drilled to a nominal depth of 150 m. Use not known.	0.1 m to 0.5 m
WRK980589 S9030648/1	Hendersons Road, bore was drilled in 2007 to a depth of 63 m. Registered as a stock and domestic bore.	Not predicted to be impacted.
WRK98205 S9032243/1	25 m deep bore located at Service Station at Yallambie Road. Assumed to be used for environmental investigation purposes.	0.1 m to 0.5 m
Unknown bores (2)	Identified at Simpson Barracks. Depth unknown. Assumed to be used for environmental investigation purposes.	1 m to 1.5 m

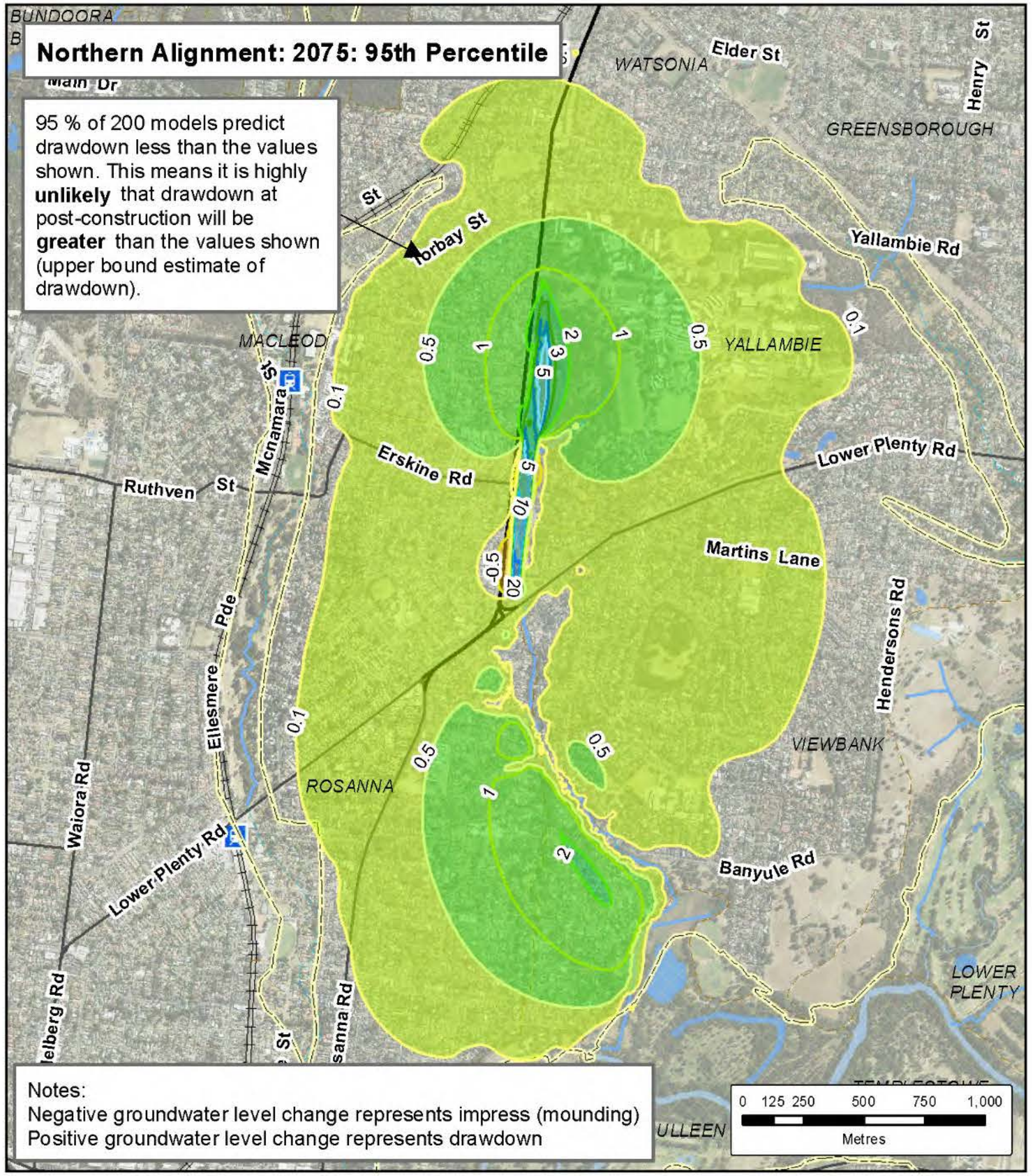
Within this area, a single private bore with an abstractive beneficial use, bore WRK982752 (S9032219/1) was identified near the intersection of Powley Avenue and Greensborough Road. The bore was drilled in 2013 with a nominal depth of 150 metres, although its status, use, and construction information is not known. The DELWP WMIS indicates the bore is not licensed.

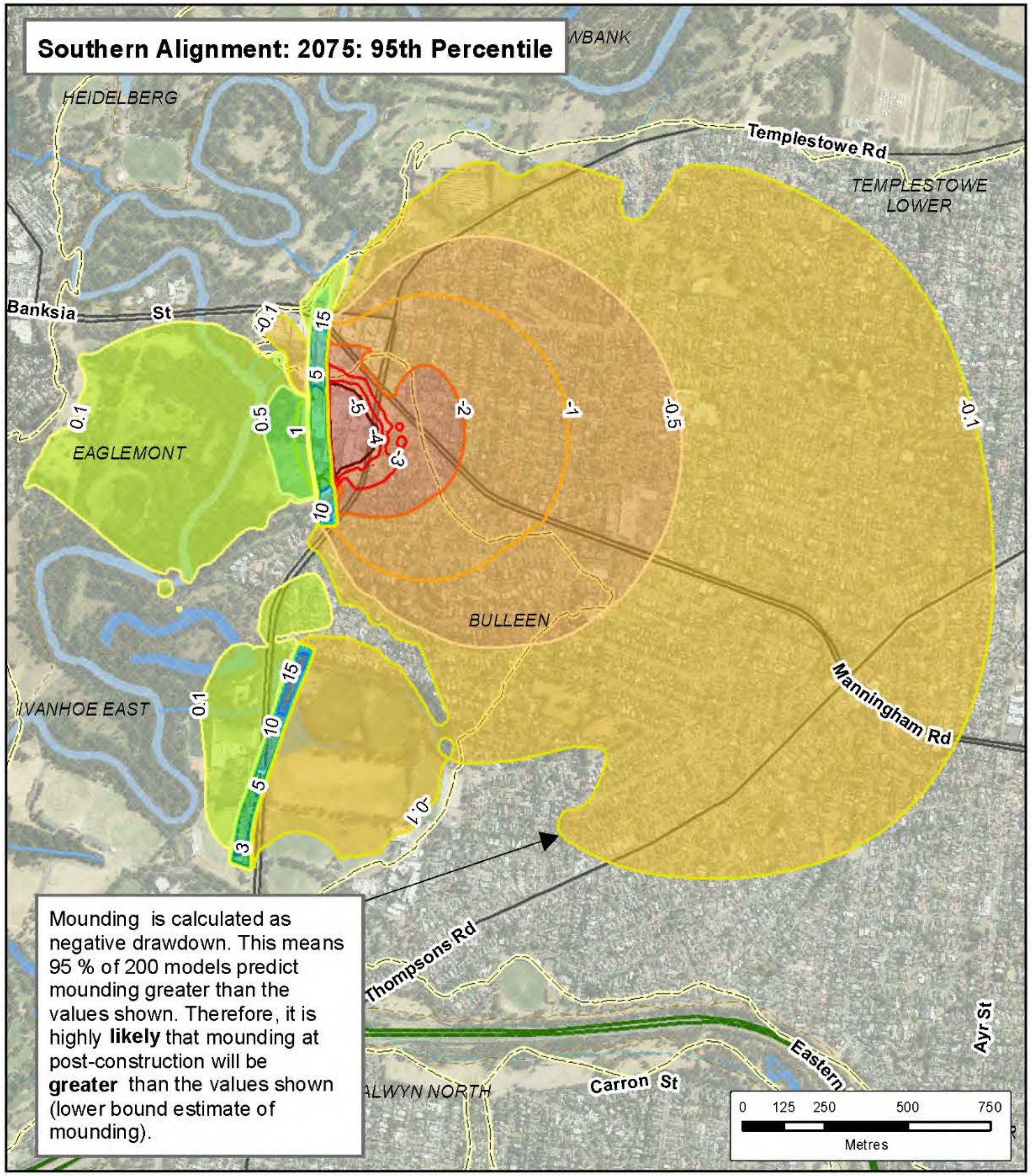
Based on the regional geology, this bore would intersect the Palaeozoic bedrock aquifer. It is subject to a predicted 0 to 0.5-metre loss of available groundwater as a result of drawdown. Assuming the bore is operational and a conservative, minimum pump installation depth of 30 metres (that is, 20 metres below groundwater) loss of available drawdown is less than 10 per cent. Based on this assessment, the impact of dewatering during the project's operation on existing groundwater users is considered to be low. The magnitude of drawdown is not expected to result in a change in groundwater quality at this bore.

As noted in the discussion of the project's construction impacts, seasonal water level fluctuations of over 1 metres could be reasonably expected and the predicted drawdown is within the magnitude of drawdown change experienced during the Millennium Drought (refer Section 6.10.7).

An EPR has not been specifically proposed to address longer-term impacts. It is considered reasonable that existing groundwater users would be identified and appropriately managed during the project's construction, as per EPR GW4 and that project monitoring would be undertaken in accordance with EPR GW2.

As the bores are all located within bedrock areas, it is a reasonable assumption that the magnitude in change of water levels would likely result in a change in native water quality at these sites.





Paper Size A4

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

- -5
- -4
- -3
- -2
- -1
- -0.5
- -0.1
- 0.1
- 0.5
- 1
- 2
- 3
- 4
- 5
- 10
- 15
- 20

Modelled GWL Change (m)

- < -5
- -4.99 - -2
- -1.99 - -0.5
- -0.49 - -0.1
- -0.09 - 0.1
- 0.11 - 0.5
- 0.51 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- > 20
- Alluvium

North East Link Project
Environment Effects Statement (EES)

Job Number	31-35006
Revision	E
Date	05 Mar 2019

Predicted drawdowns:
95th Percentile (operation phase)

Figure 8-10

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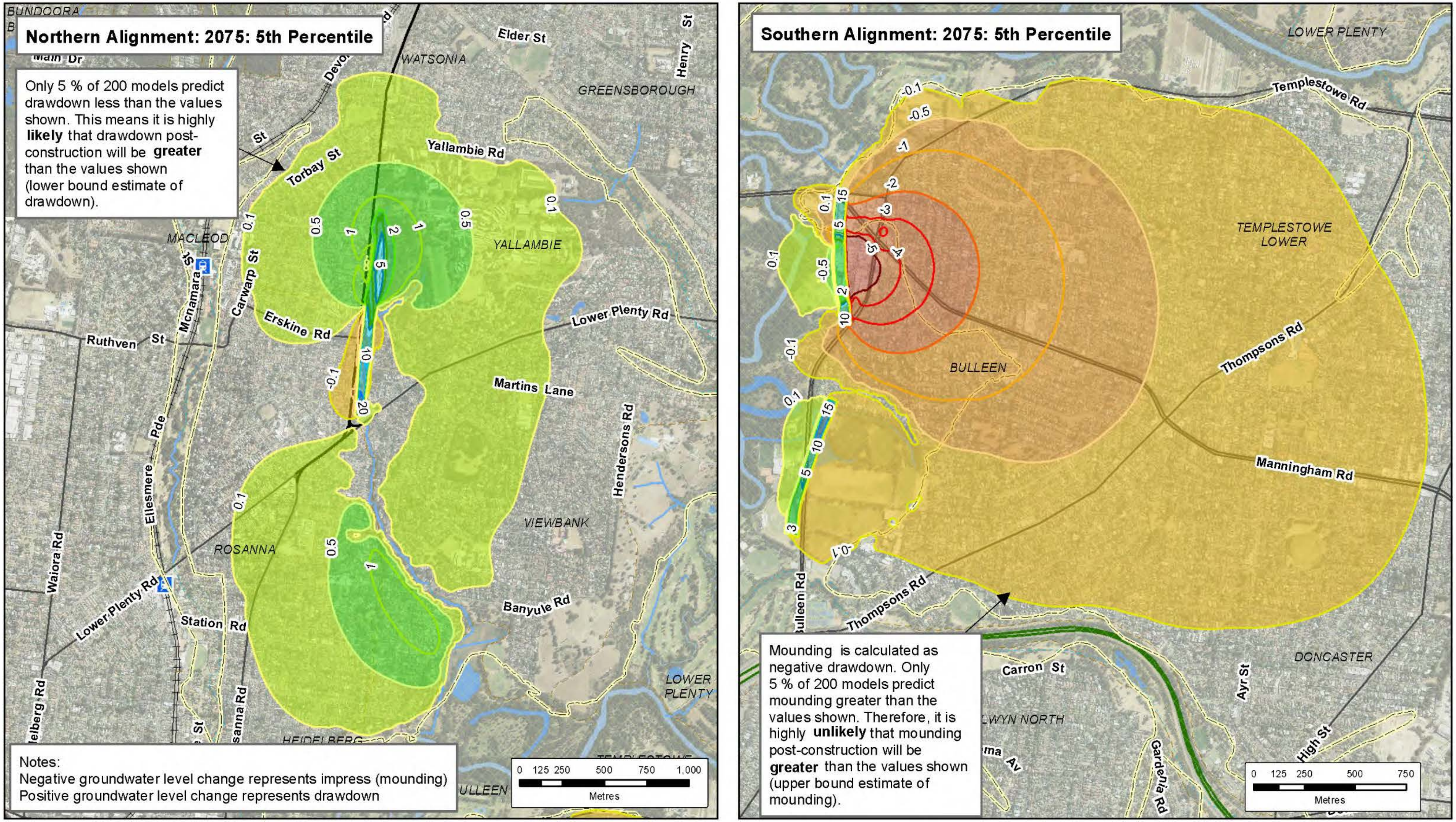
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti



Paper Size A4
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)
-5, -4, -3, -2, -1, -0.5, -0.1, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20

Modelled GWL Change (m)
< -5, -4.99 - -2, -1.99 - -0.5, -0.49 - -0.1, -0.09 - 0.1, 0.11 - 0.5, 0.51 - 2, 2.01 - 5, 5.01 - 10, 10.01 - 15, 15.01 - 20, > 20, Alluvium

North East Link Project
Environment Effects Statement (EES)

Job Number 31-35006
Revision E
Date 05 Mar 2019

Predicted drawdowns:
5th Percentile (operation phase)

Figure 8-11

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti

8.3.2.3 Impact arising from drawdowns on PASS materials (risk GW08)

In Section 8.3.1.3 it was noted there was a low risk of encountering PASS materials.
The greatest drawdowns occur during the project's construction, but groundwater levels do recover over the longer term.

Predicted drawdowns during the operation period have been shown in Figure 8-10 and Figure 8-11 for the 95th percentile and 5th percentile respectively. The magnitude of drawdown is predicted to be between 0.1 and 0.5 metres over the long term, which is within the range of seasonal groundwater level fluctuation. Under these conditions, only the upper parts of the water table would be affected, and these have already been subject to oxidation. Under these circumstances, the potential risk of the long-term operation of the project creating a PASS hazard through dewatering is considered to be low.

EPR GW2 has been proposed to address monitoring of groundwater condition. Long-term groundwater monitoring post-construction (beyond two years) is not proposed provided that a review of groundwater condition at the project's completion confirmed that no adverse impacts had occurred.

8.3.2.4 Impact arising from drawdowns on contaminated groundwater plumes (risk GW09)

As noted in Section 8.3.1.4, there are sites in the project's M80 Ring Road to northern portal element that have or had potentially contaminating land uses. Petroleum hydrocarbon contamination has been identified in monitoring bores near the service station on the corner of Greensborough Road and Yallambie Road. As per Technical report O – Contamination and soil, a better understanding of the contamination status of groundwater in this element would be obtained before excavation started (EPR CL1).

EPR GW2, EPR GW3 and EPR GW4 are proposed to minimise drawdowns and to ensure monitoring of groundwater before and during construction and to protect groundwater quality. These measures should result in further prevention of this risk.

Ongoing monitoring during the project's operation is not proposed as the presence and management of identified contamination should have occurred before construction started. If a plume was identified during construction, EPR GW4 requires appropriate measures are in place to manage this. Extending the monitoring beyond the project's construction may be required to assess whether management actions and restoration of groundwater has occurred.

8.3.2.5 Impact of project representing a barrier to regional groundwater flow (risk GW10)

The presence of a tunnel or cut and cover structure, whether it is drained or tanked, can provide an impediment to regional groundwater flow. This is most likely to occur when the impediment is aligned perpendicular or oblique to the regional groundwater flow direction.

A schematic of this concept is provided in Figure 8-12. In this schematic, groundwater flow is from right to left across the section. The construction of an impediment requires groundwater to migrate around the blockage. This results in mounding on the upstream side of the structure. Downstream of the structure, the aquifer receives less through flow from the aquifer, and therefore water levels have a tendency to decline. A small amount of decline on the downstream side may also occur depending on the structure's drainage conditions or water tightness.

Falling water levels on the down-stream side can influence accessibility to groundwater dependent ecosystems and existing groundwater bores. Mounding can create water logging issues which can affect vegetation, or underground structures such as cellars or buried services. While Figure 8-12 shows a section near the project's northern portal, the concept is the same for the tunnel sections (TBM and mined) and the southern portal.

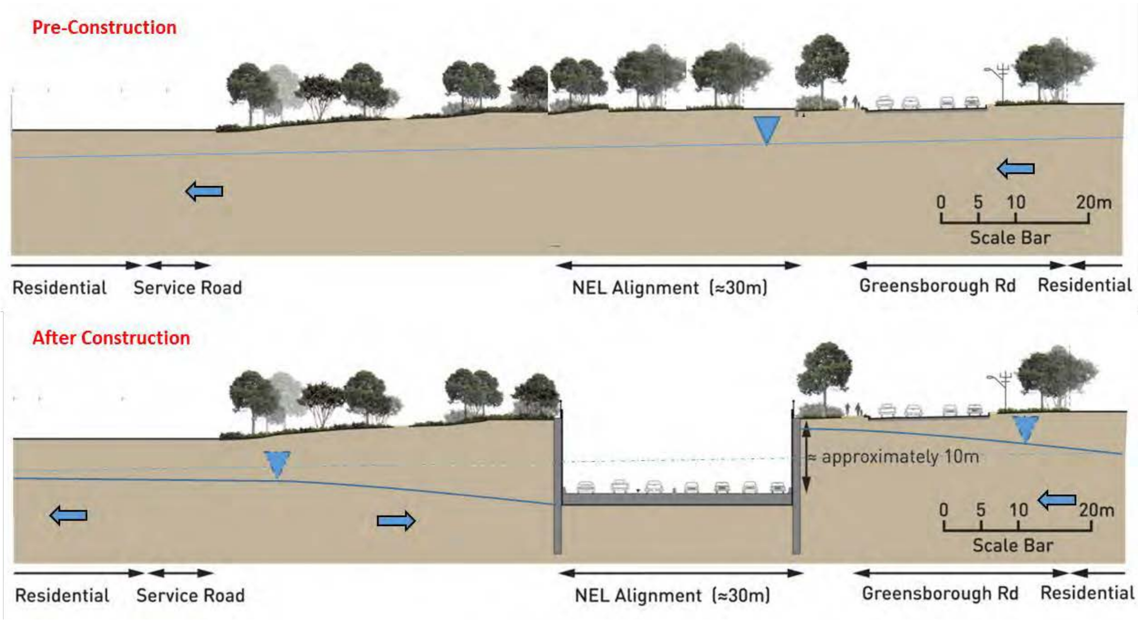

Figure 8-12 Barriers to groundwater flow

Assessment

In the M80 Ring Road to northern portal element, the trench structure extending from Watsonia railway station to Erskine Road and the northern portal would intersect groundwater south of Blamey Road.

The long-term drawdown effects predicted by the numerical groundwater (refer Figure 8-10 and Figure 8-11 above) do not indicate the presence of impediments to regional flow. In this area, groundwater flow is also southwards (refer Figure 6-8), towards the northern portal/Yarra River and aligned or parallel with the project and unlike that shown in the conceptual schematic in Figure 8-12). As flow largely migrates parallel to the structures, the risk of the project being an impediment to regional flow is low.

8.3.2.6 Impact of contaminated groundwater seepage (risk GW12)

Groundwater seepage into excavations during construction dewatering, or long-term drainage into the structure during the project's operation needs to be managed because it may be contaminated, may have elevated concentrations of suspended solids, or it could be naturally elevated in salinity.

Assessment

Groundwater recovered from the Palaeozoic bedrock aquifer is naturally elevated in salinity and this has been confirmed from groundwater monitoring and pumping test investigations completed as part of the geotechnical investigation program.

Under operation (risk GW12), tanked structures may get minor seepage inflows, but at magnitudes expected to be significantly less than that during the project's phase (refer Figure 8-2 above). Water can also enter the tunnels as stormwater run-off and vehicle run-off. EPR GW5 has been proposed so that wastewaters generated during operation of the tunnels are managed to prevent adverse impact to the environment. EPR SW3 is another relevant EPR.

8.4 Northern portal to southern portal

8.4.1 Assessment of construction impacts

8.4.1.1 Impact to groundwater quality (risk GW01)

The nature of risk GW01 has already been described in Section 8.3.1.1 above and that description also applies to the project's northern portal to southern portal element.

The same EPRs noted are relevant.

Assessment

Assessment of risk GW01 in Section 8.3.1.1 of this report concluded the risk would be managed by EPR GW2, EPR SCC4 and the Construction Environmental Management Plan.
That assessment applies equally to the project's northern portal to southern portal element.

8.4.1.2 Impact to existing users and depletion of groundwater resources (risk GW02)

The nature of risk GW02 has already been described in Section 8.3.1.2 of this report and that description also applies to the project's northern portal to southern portal element.

Assessment

Predicted drawdowns for the northern portal to southern portal element during the project's construction are shown in Figure 8-5 and Figure 8-6 above for the 95th percentile and 5th percentile respectively. These show the predicted drawdowns before achieving fully tanked conditions at each locality; that is, just before the placement of the base slab in the cut and cover tunnel sections and the final linings in the mined tunnel.

Bores identified in the predicted extent of construction drawdown are summarised in Table 8.7. All the bores identified are used for environmental investigation purposes; that is, measurement of groundwater level and groundwater quality. The predicted drawdown on these bores would therefore not affect the operation of the bores. Under these conditions, the risk of construction dewatering adversely impacting existing groundwater users is low.

Table 8.7 Bores within predicted drawdown extent (construction) – northern portal to southern portal

Bore ID	Comment	Predicted drawdown impact
WRK983584 S9032802/1	25-m deep bore located at fuel service station (Caltex Woolworths) on Manningham Road. Assumed to be used for environmental investigation purposes. This bore is located within the project boundary.	0.5 m to 1 m (mounding)
WRK061580 WRK061579	10-m deep observation bores located at Bolin Bolin Billabong (City of Manningham/Melbourne Water). Used for environmental investigation purposes.	0.1 m to 0.5 m

As noted previously, this risk could be managed by managing the impacts of groundwater drawdown and through existing regulations, such as licensing requirements under the Water Act. Supplementing the existing regulations, EPR GW2, EPR GW3 and EPR GW4 are relevant to this risk in this project element.

Changes in water level can change water quality as native groundwaters of differing salinity are mixed. Significant changes to the native groundwater quality at the bores identified in Table 8.7 are not expected to adversely impact bore use because:

- Identified bores are currently used for monitoring purposes (no abstractive use)
- Regional groundwater flow is towards the Yarra River (east to west). The groundwater level changes would not significantly disrupt this regional flow pattern. That is, the capture zone or water that contributes to the recharge of the bore would essentially remain the same.

8.4.1.3 Impact arising from drawdowns on PASS materials (risk GW03)

The nature of risk GW03 has already been described in Section 8.3.1.3 of this report and that description also applies to the project's northern portal to southern portal element.

Assessment

Sampling undertaken during the geotechnical investigation program identified parts of the Palaeozoic bedrock as being potential PASS (acid sulfate rock). Samples of bedrock collected near the Manningham Interchange TBM launch site, beneath the Yarra River floodplain and near the northern portal, confirm that PASS materials exist. Further evidence of PASS materials may be identified with additional geotechnical investigations required for the detailed design.

These PASS materials are generally associated with the deeper, fresher bedrock, and occur at depths greater than 20 metres below the surface. At the northern portal and Banksia Street/Manningham Road TBM launch site, dewatering to these depths would be required during construction. During this period, groundwater and any acidified groundwater generated during this short period would be draining toward the excavation (see Section 8.2 for disposal options).

There are a number of factors which result in the risk of PASS generation developing adverse impacts to groundwater being classified as low during the project's construction:

- Laboratory analysis of over 80 rock samples identified only four samples that were PASS; no confirmed acid-generating soil or rock materials were identified. The four samples identified as PASS were identified at depths greater than 20 metres below the surface in fresh bedrock.
  - Much of the northern portal area, apart from a section between Drysdale Street and Lower Plenty Road, would be located within slightly weathered to fresh bedrock.
  - Much of the southern portal area would be located within weathered bedrock, apart from portions of the Manningham Road interchange and southern portal (extending from the mined tunnel).
- In the excavations for the northern and southern portals, PASS materials inside the excavation extents would be removed, removing the potential source of acid-generating materials. EPR CL2 has been developed to manage this spoil.

- At the northern and southern portals, the greatest drawdown would occur in the deepest portions of the excavation which are adjacent the TBM tunnel (northern portal) and mined tunnel (southern portal). The bulk of groundwater inflows into these excavations is up through the floor of the excavation. Vertical cut-off walls are proposed to seal (minimise) lateral inflows from the bedrock aquifer (northern portal, southern portal) and the alluvial aquifer (southern portal).

  This results in predicted drawdowns being laterally restricted close to the excavation area only (refer Figure 8-5 and Figure 8-6 above). The lateral extent is controlled by the geological setting. Where alluvial sediments overlie the bedrock, drawdowns would tend to be highly constrained in close proximity to the cut-off wall. The alluvial sediments are recharged at higher rates relative to the underlying bedrock which can mitigate drawdowns. Greater drawdowns occur within the bedrock aquifer owing to its lower permeability and storage, although predictive numerical modelling indicates these too are highly constrained in close proximity to the excavation. This is shown schematically in Figure 8-13.

  If acid-generating geological materials are present within the excavation these would be removed. Some drawdown may occur external to the cut-off walls (noting that some seepage can be transmitted laterally through the cut-off depending on the water tightness achieved).
- The duration of construction would likely be two to three years which provides limited opportunity for rainfall recharge to infiltrate and generate a flux of leaching water, which would then migrate to a receptor (or seepage face).
- Existing groundwater bores with abstractive use have not been identified in those areas predicted as having over 15 metres of drawdown.
- Contamination hazards arise when naturally occurring metals are leached from aquifer geological materials due to the low pH conditions. Groundwater can have a natural capacity (alkalinity) to buffer against pH changes and provide protection against acidification. Based on groundwater sampling undertaken throughout the North East Link monitoring network, the geometric mean groundwater alkalinity of 520 mg/L (alluvial sediments) and 514 mg/L (bedrock aquifer) and pH >6.5 for both aquifer systems was determined. These waters are designated as being of very high alkalinity and considered by Shand et al. (2018) to be adequate to maintain acceptable pH level in the future.
- Geotechnical investigations (Geotesta, 2016) indicated that PASS were unlikely to be present. Soil pH analysis did not identify low pH. Coffey (2012) borehole logs indicated the sediments tended to be coarser grained (sands) with no obvious evidence of PASS materials or indicators recorded on lithological logs.

Designers would need to consider the water chemistry and potentially aggressive nature of groundwater on foundation materials. Seepage into construction would need to be monitored and appropriately managed. Acid waters can be damaging to sewers and waterways and so treatment may be required as part of the management of wastewater. EPR GW2, EPR GW3 and EPR GW4 are proposed to require consideration of designs that minimise construction dewatering as well as monitoring during construction, and to have appropriate measures in place to manage acidified groundwater.

8.4.1.4 Impact of groundwater drawdown on movement of contaminated groundwater (risk GW04)

The nature of risk GW04 has already been described in Section 8.3.1.4 of this report and that description also applies to the project's northern portal to southern portal element.

Assessment

There are a number of potentially contaminating land uses in the project's northern portal to southern portal element, including landfill sites at Borlase Reserve (northern portal), and Bulleen Park (southern portal) and commercial/industrial land zonings around the Banksia Street/ Manningham Road TBM launch site. Multiple fuel service stations, cement works and dry cleaners have been identified within this project element near the southern portal as summarised in Table 8.8.

Table 8.8 Potentially contaminating land uses (northern portal to southern portal)

Location	Potential source of contamination	Potential impact pathway	Potential contaminants of concern (soil and groundwater)
Bulleen commercial/industrial area, within North East Link	Dry cleaners – leaks and spills from storage, use and disposal of dry cleaning chemicals	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	Chlorinated hydrocarbons (such as perchlorethylene and daughter products, trichloroethylene, 1,1,1 – trichloroethane, carbon tetrachloride), volatile organic compounds, surfactants, waterproofing, petroleum hydrocarbons (white spirits).
Active – Two active service stations located within the Bulleen commercial/industrial area on Manningham Road W and two active on Bulleen Road immediately adjacent to the area Former – One former service station located to the south of the Bulleen commercial/industrial area on Bulleen Road	Four active and one former fuel service station – leaks and spills of fuels from filling vehicles and storing fuels	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	Metals (such as copper, chromium, lead, zinc), solvents (including chlorinated hydrocarbons), total petroleum hydrocarbons (TPHs), BTEX, PAHs, phenol, chlorofluorocarbons, acids, alkalis, asbestos from brake replacement activities and antifreeze (ethyl-alcohol, ethylene glycol, isopropyl alcohol, methyl alcohol). Asbestos containing materials.
Multiple locations within the Bulleen commercial/industrial area, within North East Link	Automotive service/repair centre and car rental facilities – leaks and spills from use and storage of fuels, oils and chemicals	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	Metals (such as copper, chromium, lead, zinc), solvents (including chlorinated hydrocarbons), total petroleum hydrocarbons (TPHs), BTEX, PAHs, phenol, chlorofluorocarbons, acids, alkalis, asbestos from brake replacement activities and antifreeze (ethyl-alcohol, ethylene glycol, isopropyl alcohol, methyl alcohol). Asbestos containing materials.

Location	Potential source of contamination	Potential impact pathway	Potential contaminants of concern (soil and groundwater)
Bulleen commercial/industrial area, Manningham Road W, within North East Link	Garden supplies – leaks and spills from use and storage of chemicals	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	Metals (such as cadmium, arsenic, copper, lead, mercury, magnesium, aluminium, iron), organochlorine pesticides, organophosphate pesticides, carbamates, TPHs, BTEX, nitrogen compounds, phosphorous.
Bulleen commercial/industrial area, within North East Link	Vehicle storage yard – leaks and spills from use and storage of fuels and chemicals	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	TPHs, BTEX, solvents, heavy metals, PAHs, waste oil.
Bulleen commercial/industrial area, within North East Link	Mower sales/service centre – leaks and spills from use and/or storage of chemicals and fuels	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	Metals (lead), PAHs, TPHs, acids, (including chlorinated hydrocarbons), alkalis and antifreeze (ethyl-alcohol, ethylene glycol, isopropyl alcohol, methyl alcohol).
Bulleen commercial/industrial area, Kim Close, within North East Link	Timber and hardware, demolition and salvage	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	Chlorinated hydrocarbons (such as pentachlorophenol), PAHs, organochlorine pesticides, metals (such as arsenic, copper, chromium) and ammonia, asbestos-containing materials.
Bulleen commercial/industrial area, Bulleen Road, within North East Link	Concrete supplier – bulk storage of fuels	Excavation of soil and rock, vapour inhalation and abstraction of groundwater	TPHs, BTEX, solvents, heavy metals, PAHs, waste oil, asbestos containing materials.
Borlase Reserve, Yallambie	Former landfill (solid inert waste and possible putrescible waste)	Disturbance of waste, abstraction of groundwater, gas migration	Landfill gases (methane, carbon dioxide, hydrogen sulphide and carbon monoxide), asbestos containing materials, heavy metals, nutrients (ammonia, nitrate, phosphorous), TPHs, BTEX, PAHs, MAHs.

Location	Potential source of contamination	Potential impact pathway	Potential contaminants of concern (soil and groundwater)
Bulleen Park, Bulleen	Former landfill (solid inert waste and possible putrescible waste)	Disturbance of waste, abstraction of groundwater, gas migration	Landfill gases (methane, carbon dioxide, hydrogen sulphide and carbon monoxide), asbestos containing materials, heavy metals, nutrients (ammonia, nitrate, phosphorous), TPHs, BTEX, PAHs, MAHs.
Located near Rocklea Road and Yarraleen Place, Bulleen	Former quarry, unclear whether it has been backfilled with potentially uncontrolled fill	Excavation of soil, abstraction of groundwater, gas migration	Landfill gases (methane, carbon dioxide, hydrogen sulphide and carbon monoxide), asbestos containing materials, heavy metals, nutrients (ammonia, nitrate, phosphorous), TPHs, BTEX, PAHs, MAHs.
Freeway Golf Course, Balwyn North (eastern section of golf course adjacent Bulleen Rd (former Camberwell Landfill)	Former landfill (putrescible waste and solid inert waste)	Disturbance of waste, abstraction of groundwater, gas migration	Landfill gases (methane, carbon dioxide, hydrogen sulphide and carbon monoxide), asbestos containing materials, heavy metals, nutrients (ammonia, nitrate, phosphorous), TPHs, BTEX, PAHs, MAHs.

In the northern part of the project's northern portal to southern portal element, the trench would intersect sediments of the Borlase Reserve landfilling. Construction of the northern portal itself would also result in the intersection and removal of filling material. In the southern parts of this project element, the cut and cover structures would be close to the former Bulleen Landfill. EPR CL1 and EPR CL2 have been proposed to address these risks.

Predicted drawdowns for the northern portal to southern portal element during the project's construction are shown in Figure 8-5 and Figure 8-6 above for the 95th percentile and 5th percentile respectively. In terms of the northern portal, groundwater quality monitoring has not identified groundwater contamination. Drawdowns extend into the M80 Ring Road to northern portal element and are relevant to the identified contamination near the intersection of Yallambie Road and Greensborough Road (refer to the discussion in Section 8.3.1.4). Dewatering would extend beneath the interpreted filling extents of the Borlase Reserve landfilling.

Predicted dewatering extents during construction works in the southern parts of the element associated with the Banksia Street/Manningham Road TBM launch site, mined tunnel and cut and cover sections encompass potentially contaminating land uses, but significant groundwater quality impacts, apart for a detection of PFAS at the former Bulleen Drive-in, have not been identified from the North East Link groundwater monitoring network. It is further noted that a number of these sites are located within the project boundary and excavation activities may remove contaminated spoil and aid source removal. EPR CL1 and EPR CL2 have been proposed to address these risks.

Existing groundwater users have not been identified in these locations within the predicted drawdown extents and so plume movement would not affect these users. Under prevailing groundwater flow directions, groundwater discharge is interpreted to be towards the Yarra River floodplain (noting the detection of PFAS at the former Bullen Drive-in) plume migration is likely to be towards the Yarra River as a receiving environment. Dewatering required to construct the Manningham Road interchange would result in localised modification to regional hydraulic gradients as groundwater is drained into the excavation areas (plume migration may be arrested during the project's construction).

In addition to these areas which have been highlighted based on land use, groundwater contamination may be unexpectedly encountered elsewhere within the project's northern portal to southern portal element, either as part of baseline monitoring, additional geotechnical investigations to inform design or as part of construction activities. Further investigations would be undertaken during the project's design phase to characterise the PFAS identified at the former Bulleen Drive-in.

EPR GW2, EPR GW3 and EPR GW4 are proposed to require consideration of designs that minimise construction dewatering as well as monitoring during construction, and to have appropriate measures in place to manage contaminated groundwater should it be encountered. EPR CL1 is required to include methods for treatment/remediation plan for contaminated land and groundwater.

Groundwater drawdowns can also cause the mixing of groundwaters of differing native quality, (saline groundwater could migrate into fresher groundwater), which is akin to saline intrusion. In this case, and under exceptional circumstances, groundwater beneficial uses may change, although the groundwater has not been contaminated by industrial activities. This can affect existing abstractive groundwater development (which is limited in this area), or groundwater dependent ecosystems (which include the Yarra River and associated terrestrial riparian vegetation).

For a change in water quality to occur, to affect GDEs, the mixing or interface between saline (bedrock) and fresher groundwater (alluvial aquifer) must shift westwards. Conceptually, it would be difficult for this to occur because of the nature of the project. The alluvial sediments are cut-off on the western side of the excavation. A cut-off also occurs on the east side, so seepage into the excavation is predominantly through the base of the excavation, which occurs within bedrock. Equipotentials of flow would develop beneath the excavation, with some regional flow (from the east) being intercepted by the excavation, and flows passing underneath at some depth below the excavation, and continuing westwards (see also Figure 8-14).
As mounding is predicted to occur on the upstream or eastern side of excavations, the project would restrict the westwards groundwater flow (where more saline waters may emanate from). EPR GW2 should ensure that groundwater qualities remain relatively stable.

8.4.1.5 Management of construction groundwater seepage (risk GW05)

Refer to Section 8.2 for a discussion on the volumetric management of groundwater seepage.

Assessment

A former landfill has been identified at Borlase Reserve near the northern portal. Leachate generated from this landfill may be captured by dewatering. EPR CL1 requires the development of a health, safety and environment management plan to protect workers and the public, as well as measures to ensure any contaminated or hazardous material exposed during construction would be made safe. EPR GW4 also requires methods for handling and managing groundwater intercepted during construction.

As part of the Construction Environmental Management Plan, a contractor would be required to undertake reasonable actions to appropriately manage this seepage. This would be in accordance with the EPA Victoria waste hierarchy (avoidance, reuse, recycling, recovery) of energy, treatment, containment and disposal. EPR GW3 is aimed at minimising construction inflows and EPR GW4 requires measures to be planned to deal with this water.

During the project's construction, groundwater seepage generated from dewatering activities could be handled by temporary sewer connections, off-site cartage by wastewater 'vacuum' trucks or disposal to groundwater or surface water. Disposal to sewer requires wastewater to meet trade waste acceptability guidelines of Yarra Valley Water and it is noted there is increasing pressure to minimise salt loads to sewer. Wastewater could be reused as a construction water supply, or disposed to waterways or groundwater provided in meets regulatory requirements, such as SEPP (*Waters*) in terms of water quality (physical and chemical). Treatment may be required to achieve regulatory requirements and monitoring to ensure compliance.

8.4.2 Assessment of operation impacts

8.4.2.1 Impact to groundwater quality (risk GW06)

The nature of risk GW06 has already been described in Section 8.3.2.1 of this report and that description also applies to the project's northern portal to southern portal element.

Assessment

Assessment of risk GW06 in Section 8.3.2.1 of this report was that the risk would be managed by WSUD features and EPR SW11, EPR SW2, EPR GW2 and EPR GW5. This assessment applies equally to the northern portal to southern portal element.

8.4.2.2 Impact to existing users and depletion of groundwater resources (risk GW07)

The nature of risk GW07 has already been described in Section 8.3.2.2 of this report and that description also applies to the northern portal to southern portal element.

Assessment

The predicted extent of drawdown during the project's operation is shown in Figure 8-10 and Figure 8-11 above for the 95th percentile and 5th percentile respectively. Bores identified within the predicted extent of long-term drawdown are summarised in Table 8.9.

Table 8.9 Bores within predicted drawdown extent (operation) – northern portal to southern portal

Bore ID	Comment	Predicted drawdown impact
WRK983584 S9032802/1	25-m deep bore located at fuel service station (Caltex Woolworths) on Manningham Road. Assumed to be used for environmental investigation purposes.	2 m to 3 m mounding
WRK061580 WRK061579	10-m deep observation bores located at Bolin Bolin Billabong (City of Manningham/Melbourne Water). Used for environmental investigation purposes.	0.1 m to 0.5 m

As these bores are not used for abstractive benefit, the change in water level is not considered to affect operation and is within the 10 per cent licensing guidelines recommended by Southern Rural Water. Based on this assessment, the impact of construction dewatering on existing groundwater users is considered to be low.

It is acknowledged that bores may exist that are not identified on the DELWP WMIS, such as older bores drilled pre-1969 or unregistered bores. Community consultation would be required to ensure that all existing groundwater users are identified and EPR GW4 is proposed to manage this risk. Existing groundwater users can also be impacted if there are water quality changes. EPR GW2 would require monitoring of groundwater to ensure changes to water levels and quality are acceptable.

8.4.2.3 Impact arising from drawdowns on PASS materials (risk GW08)

The nature of risk GW08 has already been described in Section 8.3.1.3 of this report and that description also applies to the northern portal to southern portal element.

Assessment

As noted for the assessment of the project's construction, PASS materials have been identified in the Palaeozoic bedrock but tend to occur in the deeper, fresher bedrock which is less likely to be dewatered, particularly in areas remote from the construction works.

Predicted extents of drawdown, as derived from the numerical groundwater model, under long-term conditions are shown in Figure 8-10 and Figure 8-11 above for the 95th percentile and 5th percentile respectively. The predicted drawdowns indicate that water levels would recover to generally within three metres of pre-construction water levels; that is, three to four metres of drawdown. PASS materials identified at depth (generally below 20 metres) would have been re-saturated and so ongoing generation of acid plumes would not occur.

To better illustrate the recovery of groundwater levels, some hydrogeological cross sections have been prepared and populated with data obtained from the geotechnical investigation program (existing water levels) and numerical groundwater model (predicted drawdowns). The cross sections are:

- Figure 8-13
  This cross section is oriented south-west to north-east, extending from Bolin Bolin Billabong to the southern portal. It has been prepared to show the change in groundwater levels over the long term.
  Water levels would be drawn down during construction but significantly recover post construction. A drawdown of 0.1 to 0.5 metres exists in the longer term near Bolin Bolin, which is not easily discerned on the section despite the vertical exaggeration. Mounding is evident upstream of the project, due to cut-off walls associated with the Manningham Road interchange.
- Figure 8-14
  This cross section is orientated south-west to north-east, extending through the Manningham Interchange. The cross section has been prepared to show the effect of water table mounding post-construction.

It should be noted that:

- The cross section construction orientation is oblique to the regional flow direction which is not ideal, but has been chosen based on the orientation of existing monitoring bores and to best show changes in water levels from the project.
- The vertical scale has been exaggerated to enable differentiation of the pre- and post-construction water level.

The cross section in Figure 8-13 shows that drawdowns would be greatest during the project's construction, but significant subsequent recovery in water levels would occur. This recovery could potentially result in re-saturating PASS geological materials that may have been exposed to oxygen during the construction's dewatering. With increasing distance from the excavation, the change in water levels is less than 0.5 metres and within the range of seasonal fluctuation. Similar to the assessment discussions in Section 8.4.1.3 (and Section 8.3.2.3), the potential exposure of PASS is considered unlikely due to:

- Confirmed acid sulfate soil materials not being identified
- Much of the excavations being located within weathered bedrock
- Potential source materials with the excavation being removed
- Limited time during the construction period for leaching fluxes to be generated should acid sulfate soil materials become exposed.

Long-term change in water levels (western side of the south portal and Manningham Road interchange) are of similar magnitude to seasonal water table fluctuations, and drought response water levels.

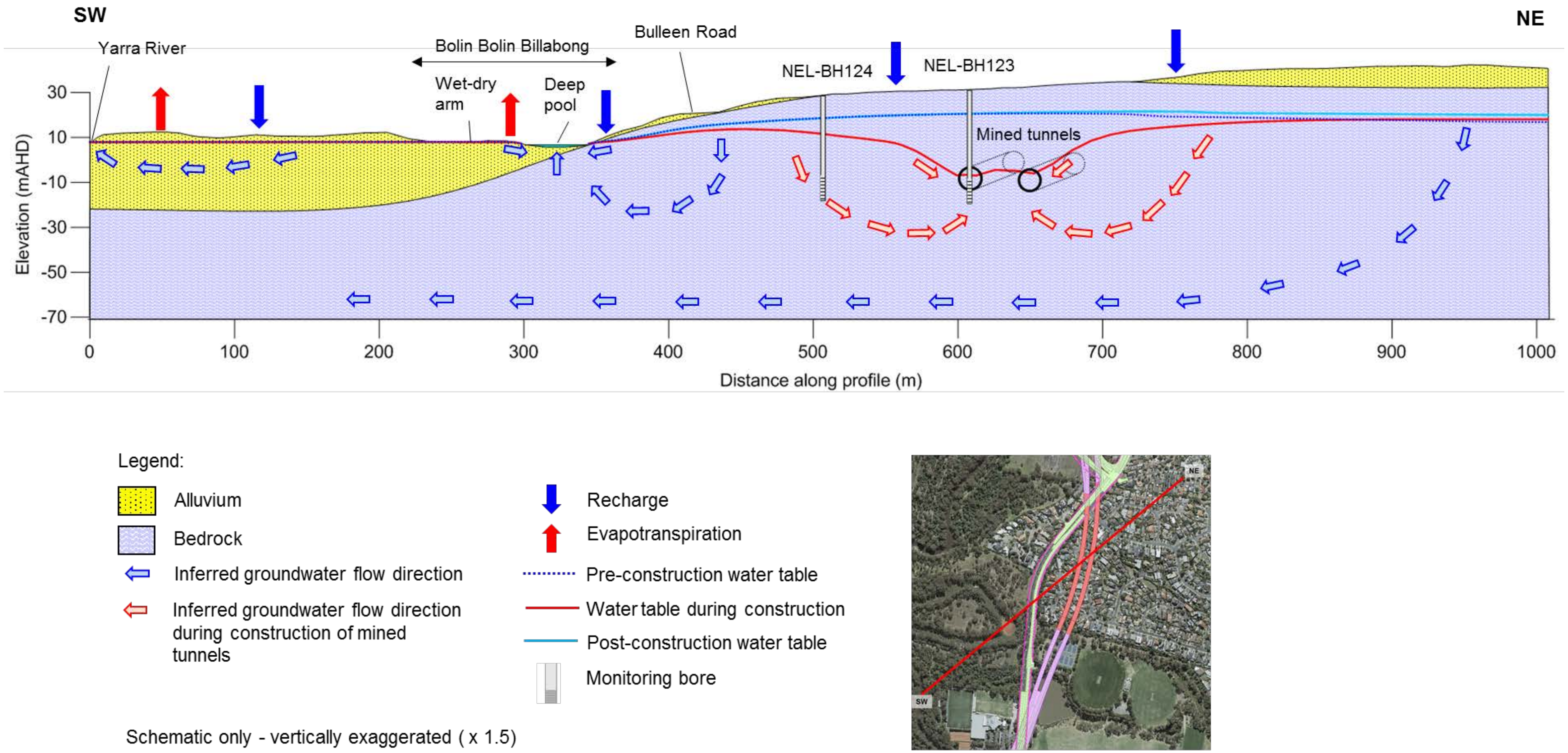

Figure 8-13 Cross section: Bolin Bolin Billabong

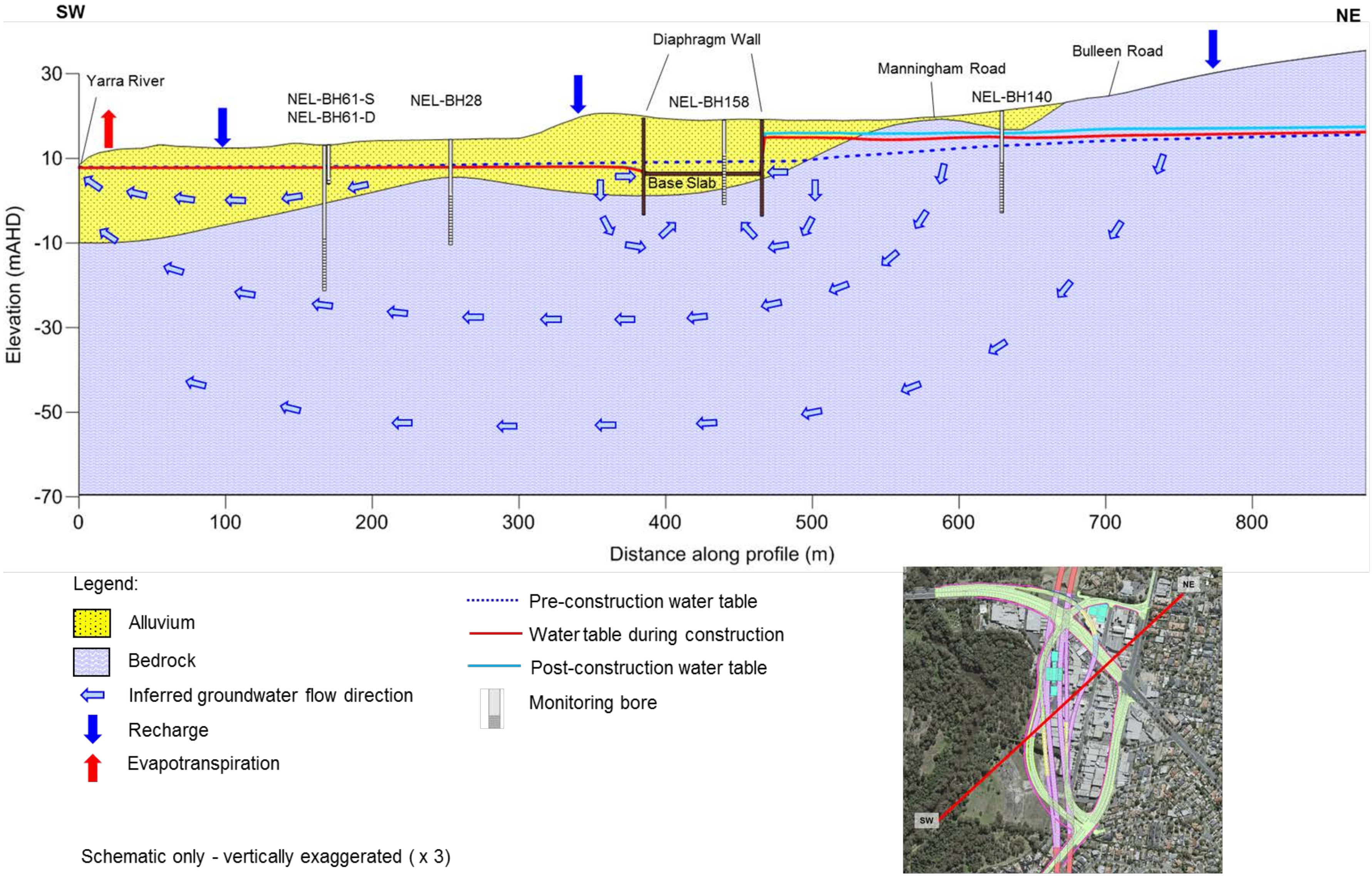

Figure 8-14 Cross section: Manningham Road interchange

8.4.2.4 Impact arising from drawdowns on contaminated groundwater plumes (risk GW09)

The nature of risk GW09 has already been described in Section 8.3.2.4 of this report and that description also applies to the project's northern portal to southern portal element.

Assessment

Predicted extents of drawdown, as derived from the numerical groundwater model, under long-term conditions are shown in Figure 8-10 and Figure 8-11 above for the 95th percentile and 5th percentile respectively.

At the northern portal, regional groundwater flow is southwards and therefore parallel with the structure. While no instances of contaminated groundwater have been identified in this area, the long-term drawdowns are predicted to extend beneath the service station at the intersection of Yallambie Road and Greensborough Road (discussed in Section 8.3.2.4) and the former Borlase Reserve landfill. A slight rise in water levels is predicted at the southern end of the northern portal. The magnitude of drawdown is predicted to be within the limits of seasonal variation and would not likely result in the saturation of the fill materials at Borlase Reserve.

South of the Yarra River at the Manningham Road interchange and mined tunnel, long-term water levels are predicted to mound as regional groundwater flow is impeded by the tanked structures. Groundwater sampling undertaken as part of geotechnical investigation has identified concentrations of PFAS in the southern area (former Bulleen Drive-in) and the presence of multiple fuel service stations implies a high of risk potentially encountering contaminated groundwater.

Drawdowns are predicted to extend over the northern part of the Bulleen Oval area where the former Bulleen Landfill was located. This drawdown has the potential to draw waters into the structure. EPR SW3 has been proposed to manage the potential that leachates are intercepted and captured by the longer-term drawdown extent (see also the discussion in Section 8.5.2.7).

As noted in Section 8.4.1.4 (Table 8.8) while there are number of potentially contaminating land uses, widespread contamination has not been identified or delineated. If groundwater contamination was identified, it is expected it would be capable of being assessed and managed as part of the project's construction. EPR GW2, EPR GW3 and EPR GW4 are proposed to require consideration of designs that minimise construction dewatering and for monitoring during construction, and to have appropriate measures in place to manage contaminated groundwater should it be encountered. Requirement EPR GW5 is proposed to address concerns of contaminated groundwater entering structures and presenting either a hazard to maintenance workers or issues for tunnel wastewater treatment and management. Ongoing monitoring of groundwater quality during the project's operation is not proposed as the presence and management of identified contamination should have occurred during the project's construction. If a plume was identified, monitoring beyond the project's construction may be required to assess whether management actions and restoration of groundwater has been effective.

8.4.2.5 *Impact of project representing a barrier to regional groundwater flow (risk GW10)*

The nature of risk GW10 has already been described in Section 8.3.2.5 of this report and that description also applies to the project's northern portal to southern portal element.

Assessment

In assessing impacts associated with the damming of regional groundwater flow, review of the long-term predicted drawdowns has been undertaken as this provides sufficient time for groundwater levels to re-equilibrate after construction disturbance. Predicted extents of drawdown, as derived from the numerical groundwater model, under long-term conditions are shown in Figure 8-10 and Figure 8-11 above for the 95th percentile and 5th percentile respectively.

At the northern portal, the structure is parallel to the regional groundwater flow and within the Palaeozoic aquifer. Tanking is proposed to extend approximately 670 metres north of Lower Plenty Road (refer Table 8-1 above). In this area of the project, mounding of 0.5 metres is predicted in association with the northern portal trench structure where the structure is tanked. This occurs in an area adjacent the alignment of the ephemeral waterway, Banyule Creek.

A 0.5-metre mounding is within the limits of seasonal groundwater fluctuation. Therefore a change in groundwater levels is unlikely to be identified or attributed to mounding and may not have a material effect on the environment in this region. Banyule Creek is ephemeral and does not have all year round flow. In the lower elevations, local groundwater flow may be towards the creek, however, widespread groundwater discharge to the creek is unlikely. This is based on the average salinity recorded in Banyule Creek being fresh (low), relative to the saline native groundwater. It is suspected that mixing would occur and that much seepage would be lost through evapotranspiration via riparian vegetation. It is understood that salinity profiling undertaken as part of aquatic studies of the waterway did identify brackish pools in reaches along the waterway.

Beneath the Yarra River, the TBM tunnel would pass through the bedrock aquifer. There is limited groundwater monitoring information within the Yarra River floodplain as access to install bores was not available at the time of reporting. However, available information from the North East Link groundwater monitoring network indicates water levels are generally less than five metres from the surface.

A numerical modelling scenario was undertaken to predict mounding beneath the floodplain as a result of the TBM tunnel. This modelling scenario assumed the tunnel was impermeable, where previous modelling assumes it leaks at a rate equivalent to the Haack Class 3 tightness. The results of this modelling did not predict that any mounding would occur beneath the floodplain; that is groundwater could flow above and below the tunnel within the bedrock aquifer without increasing water levels in the overlying alluvial sediments.

South of the Yarra River crossing, the project would be approximately aligned parallel to the Yarra River and with regional groundwater flow in the Palaeozoic aquifer interpreted to be towards the Yarra River, the tanked structures of the project would create an impediment to regional groundwater flow. The mounding extents are shown in Figure 8-11 above (5th percentile).

This creates two effects in the region:

- On the down-gradient or western side, drawdowns would extend westwards from the structure (refer Figure 8-10 above).
  These drawdowns would extend beneath the Yarra River, which implies that leakage rates from the Yarra River are insufficient to maintain recharge to groundwater to stem the influence of drawdown. The predicted magnitude of water level change may not be obviously differentiated from the natural seasonal groundwater level variation.

Some drawdown is predicted (0.1 to 0.5 metres) at Bolin Bolin Billabong (refer Figure 8-13). Conceptualisation of the billabong (refer Figure 6-16 in Section 6) notes that interaction between parts of the billabong and groundwater is uncertain. Irrespective of this uncertainty, potential exists for changes in groundwater accessibility existing in this area. The impact of this drawdown is assessed in Technical report Q – Ecology.

On the up-gradient or eastern side of North East Link structures, mounding of the groundwater is predicted to occur. In areas generally east of Bulleen Road, water level rises of up to six metres are predicted, and up to three metres in areas east of Manningham Road (refer Figure 8-11 and Figure 8-14).

The resulting depth to groundwater from the mounding (refer Figure 8-11) indicates that water levels may rise to within five metres of the ground surface in areas between the project structures and Bulleen and Manningham Roads.

If water levels rise to within two metres of the surface there is an elevated risk of water logging or salinity risk. Shallower water levels can also potentially lead to increased seepage into (leaky) basements and underground rooms, and buoyancy effects from hydrostatic uplift, such as from multi-level underground car parks, deep sewers and underground storage tanks.

A hydrograph for monitoring bore NEL-BH137 is shown in Figure 8-15. Bore NEL-BH137 is located within a car park between Greenway Street and Bulleen Road; that is, located within an area where mounding is predicted to be greatest. The 200 model runs undertaken as part of the uncertainty analysis indicate that water levels resulting from the mounding remain greater than 5 metres below the surface.

It is understood that much of this area may be acquired for the project. Assessment and requirements for the protection of utilities at risk in this area are discussed in Technical report M – Ground movement.

EPR GW1 and EPR GW2 have been proposed so that groundwater monitoring is undertaken to enable update and refinement of the predictive numerical groundwater model and mounding effects. It is not practicable to impose a long-term monitoring program post-construction to assess the recovery and re-equilibrium of groundwater levels and so control measures, if required, would need to be in place before the project was completed.

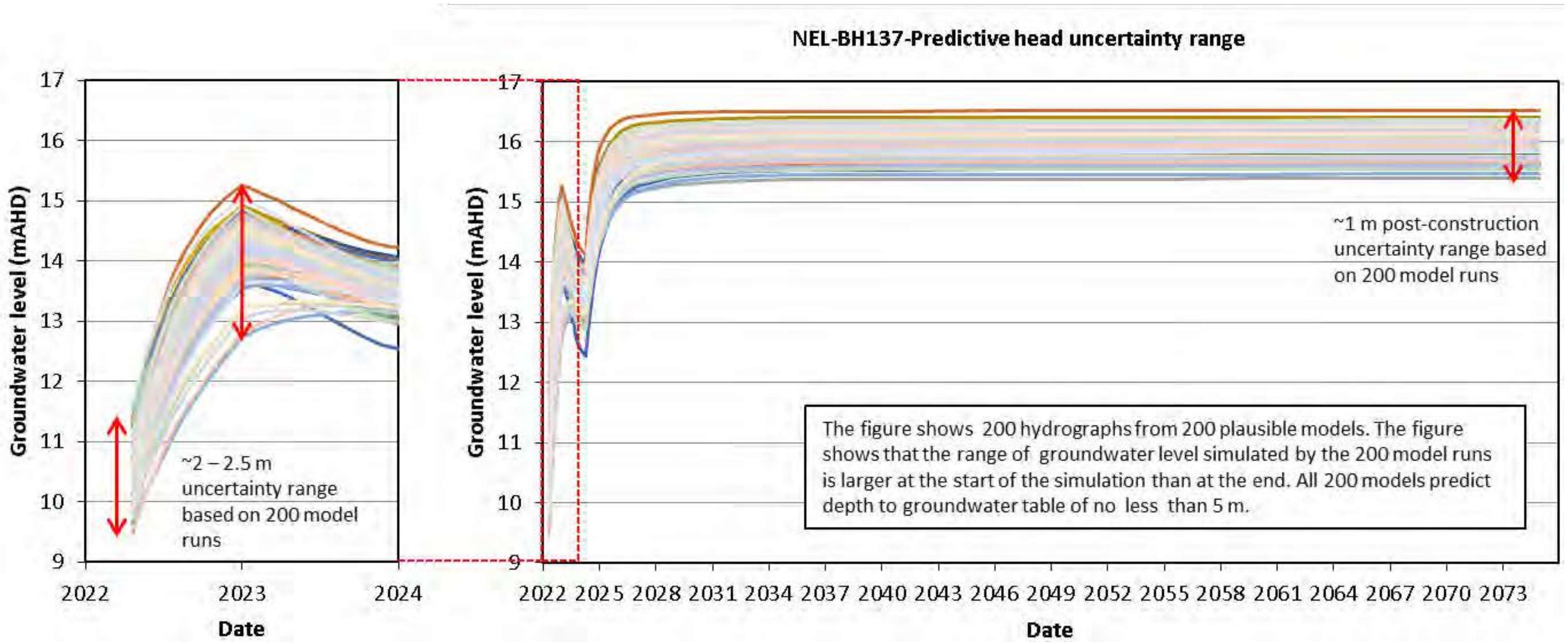

Figure 8-15 Hydrograph of Bore NEL-BH137 (Greenaway Street)

8.4.2.6 Impact to streamflows

This is not considered a significant risk, although it has been raised in feedback from community consultation and so further discussions is provided in this section.

As noted in Section 6.16, groundwater interacts with surface water, but the nature of this interaction can be variable. Within the project's alignment, groundwater is interpreted to flow towards, and potentially discharge to, waterways and floodplains. This is shown in Figure 8-16. A reduction in the regional gradient downstream of the structure occurs as through-flow is reduced. Further reduction may occur depending on the water tightness of the structure itself. When a structure is created below the water table, the regional hydraulic gradient may be changed, which can either prevent groundwater from recharging a waterway or cause streamflow to leak from the waterway to groundwater.

Figure 8-16 is for a section near the northern portal, but it also applies to excavations at the Banksia Street/Manningham Road TBM launch site, and the southern portal cut and cover sections.

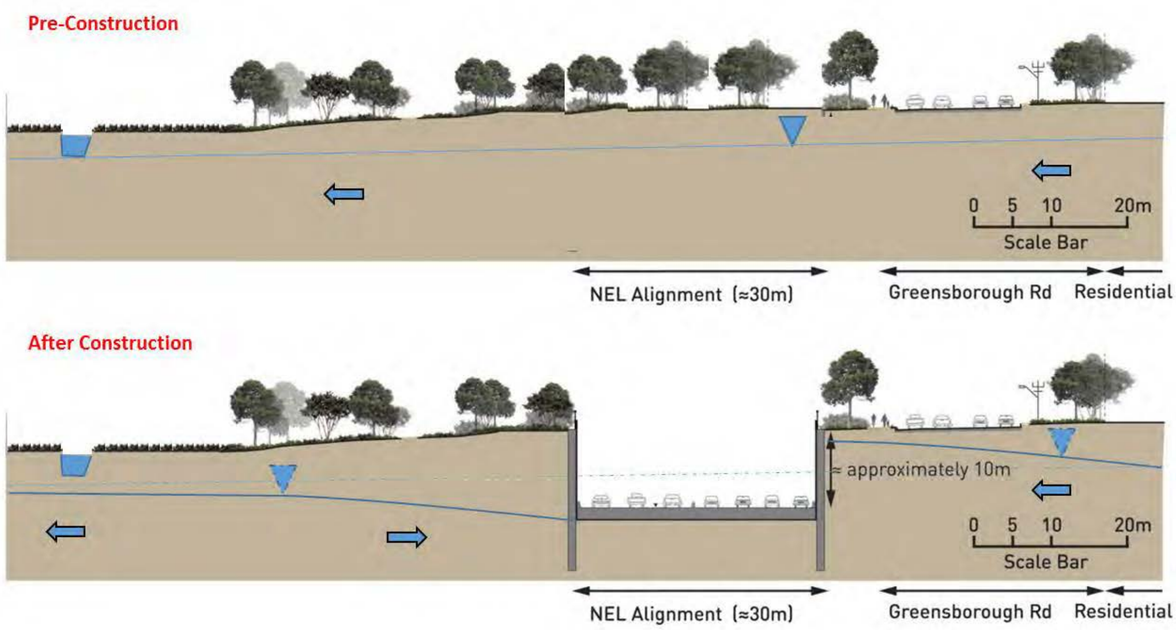

Figure 8-16 Groundwater influences on streamflow

Assessment

It is interpreted that the alluvial aquifer system is strongly hydraulically connected with the major waterways in the region. When working near waterways, there is an elevated risk when dewatering excavations that the drawdown extent would reach the nearby waterway which would then provide a supply of water, or recharge, back to groundwater and potentially complicate dewatering activities; that is, higher pumping rates would be required to cope with reduced drawdowns.

Discussion on some of these waterways has already been provided in this report, but impacts arising from dewatering are also summarised below.

Yarra River

Interaction between groundwater and the Yarra River is poorly understood in terms that the geotechnical investigations did not specifically target the streambed, and have not quantified interaction and leakage rates. Nested monitoring bores (see Appendix A for locations) that were installed as part of the geotechnical program confirmed that river flows influence water levels in the alluvium. Other studies such as SKM (2011) and GHD (2010) have attempted to quantify baseflow, which has been used to aid model calibration.

Environmental Performance Requirements such as EPR GW3 are proposed to minimise drawdown, although during the project's operation, drawdowns would occur a result of the tanked structured becoming an impediment to regional flow. Long-term groundwater level drawdowns are predicted to extend beyond the Yarra River, albeit at a low magnitude (0.1 metre). This drawdown beneath the Yarra River is considered to represent a reduction in the hydraulic gradient between the Yarra River and groundwater. It is not expected to result in a nett loss of flow or leakage from the Yarra River, as gradients would still result in discharge from groundwater to the waterway.

The daily volume of flow taken from aquifers adjacent the Yarra River is several orders of magnitude less than the daily flow of the Yarra River. Review of the Yarra River flow duration curve from gauging station 229135A (at Heidelberg) indicates that based on flow data between 2010 and 2018, flows over 4.3×10^{4} m^3/day (5 m^3/s) occur at a 90 per cent frequency.
The estimated total daily groundwater inflow volume into the structures (refer Table 8-2 above) is 50 m^3/day (6×10^{-4} m^3/s) under operational conditions, and 294 m^3/day (3×10^{-3} m^3/s) on average during construction.

With the proximity of construction at the Manningham Road interchange to the Yarra River, it is considered to be within the best interests of a contractor to minimise construction inflows through appropriate construction methods so that water volumes managed in this area are minimised.

Banyule Swamp and Banyule Billabong

Located within the Yarra River floodplain, it is acknowledged that uncertainty exists in respect of the conceptualisation of the features of Banyule Swamp and Banyule Billabong and connection with groundwater. However, North East Link would pass marginally to the west of these features as a TBM tunnel with tanked lining conditions. Disturbance to the groundwater environment through these construction methods is likely to be minimal and considered to be of low risk because:

a) Tunnelling is within the bedrock aquifer and does not 'cut-off' regional groundwater flow paths in this aquifer (groundwater can migrate above and below the TBM tunnels)

b) Drawdowns in the alluvial floodplain are likely to be negligible as leakage from the alluvial sediments would prop up water levels in the underlying bedrock aquifer.

Banyule Creek

The project's northern portal would be adjacent to Banyule Creek. The creek is interpreted as being ephemeral in the upper parts of its catchment. In the lower parts of the creek's catchment, particularly in deeper pools, groundwater contributions to flow are possible, but most likely minor based on the fresh groundwater quality of the creek (compared with the more saline native groundwater). Long-term drawdowns in this region are expected to be around 0.1 metres, which is within the range of seasonal fluctuation.

Koonung Creek

The location of this creek is removed from any dewatering activities (refer Figure 8-5 and Figure 8-6 above) associated with large structures. Some diversion or minor coffer dam works may be required with realignment, streambed modification, or pile cap/foundation works. These are expected to be of short duration and any changes to the groundwater environment are considered to be of low risk.

Bolin Bolin Billabong

Drawdowns from the project's construction (refer Figure 8-5 and Figure 8-6 above) are predicted to extend to the billabong. Some recovery of water levels is expected following construction (refer Figure 8-10 and Figure 8-11 above) but owing to the damming effect on regional groundwater flow lines, drawdowns are likely to occur down-gradient of the structure.

Environmental Performance Requirements such as EPR GW3 are proposed to minimise drawdown, although the predictive numerical groundwater modelling has identified that operation drawdown is likely to result from the tanked structure being an impediment to regional flow. Discussion on the impacts to the billabong is provided in Technical report Q – Ecology.

Environmental Performance Requirements such as EPR GW2 and EPR GW3 are proposed during the project's construction to manage potential impacts associated with drawdown and stream flow depletion. EPR FF6 is also proposed to specifically address the groundwater dependent ecosystems such as Bolin Bolin Billabong.

In terms of mitigating the impact to the billabong, potential options may include:

- Periodically filling of the deep pool by harvesting from the Yarra River
- Periodical topping with groundwater.

Melbourne Water is actively managing the hydrological regime of the billabong. Periodic topping with groundwater would involve the installation of groundwater production bores into the alluvial sediments (to increase the likelihood of harvesting fresher groundwater) and topping the billabong. Given the proximity of a groundwater bore to the Yarra River, Southern Rural Water would likely be interested in understanding the potential impacts of groundwater harvesting on the Yarra River. Negotiation with Southern Rural Water (and Melbourne Water) would be required to address this licensing issue.

It is considered a reasonable expectation that selection and design of appropriate mitigation measures to protect Bolin Bolin Billabong would be determined as part of EPR FF6.

8.4.2.7 Impact of contaminated groundwater seepage (risk GW12)

Groundwater seepage into excavations during construction dewatering, or long-term drainage into the structure under operating conditions needs to be managed because it may be contaminated, may have elevated concentrations of suspended solids or it could be naturally elevated in salinity.

Assessment

Groundwater recovered from the Palaeozoic bedrock aquifer is naturally elevated in salinity and this has been confirmed from groundwater monitoring and pumping test investigations completed as part of the geotechnical investigation program. Contaminated groundwater could also be recovered, such as PFAS has been identified at the former Bulleen Drive-In.

Under operating conditions (risk GW12), tanked structures may get minor seepage inflows, but at magnitudes are expected to be significantly less than during the project's construction (refer Table 8-2 above). Water can also enter the tunnel system as stormwater run-off and vehicle run-off. Environmental Performance Requirement EPR GW5 has been proposed so that wastewaters generated during operation of the tunnels are managed to prevent adverse impact to the environment.

8.4.2.7 Impact of drawdown on aquifers

This is not considered a significant risk, but it has been raised in feedback from community consultation so is discussed in this section.

Settlement occurs in subsurface, compressible geological materials due to changes in effective stress which can be induced by lowering groundwater pore pressures (dewatering). In this case, damage to the aquifer (the permeable formations storing and transmitting groundwater) and thus potential impacts to flow and down-gradient environments is not considered to be an issue. This is based upon the following:

- The magnitude of drawdown relative to the thickness of the compressible sediments.
- Predicted drawdowns near sensitive receptors, such as Bolin Bolin Billabong are within the range of seasonal fluctuation; that is, superimposed upon geological materials that have a recent history of wetting and drying.
- Clays and silts tend to be less stiff than the permeable sand beds. In permeable materials, pore water pressure reductions would occur effectively immediately at the same time as drawdown. In fine grained materials, which would tend to leak water vertically towards permeable beds, compression can be slower.

8.5 Eastern Freeway

Risks identified within the project's Eastern Freeway element are the same as for the M80 Ring Road to northern portal element. This is because construction works occur either at or above grade and so risks of adverse impact to the groundwater environment are low due to the low likelihood of direct interaction.

8.5.1 Assessment of construction impacts

8.5.1.1 Impact to groundwater quality (risk GW01)

The nature of risk GW01 has already been described in Section 8.3.1.1 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

Assessment of risk GW01 in Section 8.3.1.1 of this report concluded the risk would be managed by EPR GW2, EPR SCC4 and the Construction Environmental Management Plan.
That assessment applies equally to the project's Eastern Freeway element.

8.5.1.2 Impact to existing users and depletion of groundwater resources (risk GW02)

The nature of risk GW02 has already been described in Section 8.3.1.2 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

Dewatering is not required in this area as construction would be above grade. However, localised, short-term activities may be required within works near Koonung Creek.

A review of the extent of construction dewatering that would occur in the northern portal to southern portal element indicates that drawdowns are not predicted to occur within the Eastern Freeway element.

Therefore the risk of adverse impacts to existing users a result of drawdown of the water table during construction is low. The same EPRs noted in Section 8.3.1 are relevant.

8.5.1.3 Impact arising from drawdowns on PASS materials (risk GW03)

The nature of risk GW03 has already been described in Section 8.3.1.3 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

Dewatering is not required in this area as construction is above grade. A review of the extent of construction dewatering that would occur in the project's northern portal to southern portal element indicates that drawdowns are not predicted to occur within the Eastern Freeway element.

Therefore the risk of adverse impacts arising from the oxidation of PASS materials as a result of drawdown of the water table during construction is low. The same EPRs noted in Section 8.3.1 are relevant.

8.5.1.4 Impact arising from drawdowns on contaminated groundwater plumes (risk GW04)

The nature of risk GW04 has already been described in Section 8.3.1.4 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

A review of the extent of construction dewatering that would occur in the northern portal to southern portal element indicates that drawdowns are not predicted to occur within the Eastern Freeway element.

Therefore the risk of adverse impacts arising from dislocation or displacement of identified contaminated groundwater plumes as a result of drawdown of the water table during construction is low. The same EPRs noted previously in Section 8.3.1 are relevant.

8.5.2 Assessment of operation impacts

8.5.2.1 Impact to groundwater quality (risk GW06)

The nature of risk GW06 has already been described in Section 8.3.2.1 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

Dewatering is not required in this area as construction is above grade. The discussion in Section 8.3.2 is applicable to the Eastern Freeway element, and the same EPRs noted previously in Section 8.3.2 are previously are relevant.

8.5.2.2 Impact to existing users and depletion of groundwater resources (risk GW07)

The nature of risk GW07 has already been described in Section 8.3.2.2 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

The discussion in Section 8.3.2 is applicable to the Eastern Freeway element. Under long-term operation, drawdowns resulting from the project's construction and operation in the northern portal to southern portal element are not predicted to extend into the Eastern Freeway element. The same EPRs noted previously in Section 8.3.2 are relevant.

8.5.2.3 Impact arising from drawdowns on PASS materials (risk GW08)

The nature of risk GW08 has already been described in Section 8.3.2.3 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

The discussion in Section 8.3.2 is applicable to the Eastern Freeway element. Under long-term operation, drawdowns resulting from the project's construction and operation in the northern portal to southern portal element are not predicted to result in the oxidation of PASS materials within the Eastern Freeway element. The same EPRs noted previously in Section 8.3.2 are relevant.

8.5.2.4 Impact arising from drawdowns on contaminated groundwater plumes (risk GW09)

The nature of risk GW09 has already been described in Section 8.3.2.4 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

The discussion in Section 8.3.2 is applicable to the Eastern Freeway element. Under long-term operation, drawdowns resulting from the project's construction operation in the northern portal to southern portal element are not predicted to result in the movement of identified groundwater plumes. The same EPRs noted previously in Section 8.3.2 are relevant.

8.5.2.5 Impact of project representing a barrier to regional groundwater flow (risk GW10)

The nature of risk GW010 has already been described in Section 8.3.2.5 of this report and that description also applies to the project's Eastern Freeway element.

Assessment

The discussion in Section 8.3.2 is applicable to the Eastern Freeway element. The Eastern Freeway element is above grade and under long-term operation, drawdowns resulting from operation of the project in the northern portal to southern portal element are not predicted to extend into the Eastern Freeway element. The same EPRs noted previously in Section 8.3.2 are relevant.

8.6 Climate change

8.6.1 Approach

An EES scoping requirement was to assess the future climate change scenarios on the groundwater environment. Groundwater within the study area is primarily recharged by rainfall and so changes in the frequency and seasonality of rainfall may influence changes in groundwater recharge.

DELWP (2016) released guidelines for the assessment of climate change impacts on Victorian water supplies, and these provide climate change scenarios and associated projections of climate. For groundwater specifically, guidance has been provided on groundwater recharge to unconfined aquifers (refer Table 8.10) and this guidance has been applied to the predictive numerical groundwater modelling undertaken for the North East Link EES assessment. DELWP (2016) notes the majority of climate models project Victoria's climate to be hotter and drier.

Table 8.10 Yarra River basin projected change in recharge

Year 2040			Year 2065		
10th %	50th %	90th %	10th %	50th %	90th %
8.3%	-6.9%	-30.8%	5.6%	-11.2%	-74.2%

Source: DELWP (2016).
Note:
1. (+) increase, (-) reduction
2. 10th% = low impact, 50th% = medium, 90th% = high impact

To assess the influence of climate variability on the numerical groundwater model predictions, tasks completed included:

- Benchmarking of the calibrated model against long-term historical climate data
- Simulating the influence of short-term climate variability on model predictions during the project's construction
- Simulating the influence of long-term climate variability on model predictions during the project's operation.

The approach and results are documented in Appendix C and summarised below.

8.6.2 Benchmarking

Benchmarking was undertaken to determine whether the model:

- Can produce seasonal variations in water levels with trends and a range of fluctuations consistent with only term climate trends and bore hydrographs observed elsewhere in the Melbourne area
- Simulates the hydrogeological evolution of the groundwater system to the current condition, with groundwater levels simulated at the end of the benchmarking period matching those measured recently.

Benchmarking indicated the numerical model remains calibrated with time varying recharge. The numerical model was also able to simulate spatial variability in climate, generate responses that matched observed longer-term climate trends such as the Millennium Drought.

8.6.3 Short term climate variability

Time varying recharge from dry (Millennium Drought) to wet (post-Millennium Drought) was applied to the numerical groundwater model to asses influence. For each condition, the recharge was applied to the model without the project, and with the project, to characterise the difference in water levels.

Review of water level drawdowns indicated that short-term variability in climate (wet or dry) has only a small effect on the prediction of groundwater level changes during construction (refer Appendix C). The analysis also determined:

- Only small differences between calculated groundwater inflow rates (into excavations) were determined between the wet and dry scenarios.
- The impact of the project on groundwater fluxes is not strongly sensitive to short term climate variability.

8.6.4 Long-term climate variability

To assess the significance of longer term climate change, recharge and evapotranspiration were linearly scaled over the 53-year predictive simulation period using the dry (high impact/90th percentile) and wet (low impact/10th percentile) scaling factors proposed by DELWP (2016) (refer Table 8.10). With each climate change scenario, the numerical groundwater model was run with, and without the project to distinguish between the impact of climate from that of the project (a total of four runs).

It should be noted there is no certainty the future climate will resemble the historical climate or that it will vary in accordance with the climate change projections outlined in DELWP (2016). The purpose of the climate change scenarios is to stress test the model by utilising long-term historical data and two extreme bounds of climate change projections, so the significance of climate variability (and associated uncertainty) on prediction of long-term project impacts can be assessed.

For the wet climate change scenario, the period of the highest water table/baseflow is chosen to show the predicted impact of the project under the wettest possible condition. For the dry climate change scenario, the period of the lowest water table/baseflow is chosen to show the predicted impact of the project under the driest possible condition.

The dry (high impact) climate change scenario results in a significant overall lowering of groundwater levels. The reduction in groundwater levels (drawdown) is smaller over the free draining section in the northern portion of the project’s alignment. This is due to the decline in the elevation of the water table caused by reduced recharge, resulting in less interception of the water table by the free draining trench. Drawdown is slightly larger around the tanked section of the Lower Plenty cut and cover and TBM tunnels (within the basement aquifer), due to less recharge and groundwater through-flow to offset ongoing leakage into these structures. In the southern portion of the project’s alignment, drawdown and mounding are also subdued under the dry scenario due to the lower water table and reduced through-flow.

Water table mounding on the up-gradient side of the Manningham Interchange is significantly reduced under the dry (high impact) scenario due to an overall reduction in groundwater levels from reduced recharge. Under the wet (low impact) climate change scenario, changes in water levels are similar to those predicted under average (existing) conditions. When climate change effects are considered in conjunction with model uncertainty (non-uniqueness) there is limited potential for water tables under the wet scenario to mound to within 5 metres below the ground surface. Given the relatively narrow uncertainty range and the majority of climate change predictions in Victoria indicating drier future conditions, the likelihood of a shallow water table

(<5 metres below ground level) occurring as a result of mounding on the up-gradient side of the Banksia Street/Manningham Road interchange is considered low.

Reductions occurring in groundwater fluxes to Bolin Bolin Billabong are predicted to occur under both the wet (low impact) and dry (high impact) scenarios, which is a result of the reduced throughflow recharge to the wetland. The impact of the project is estimated at around 1 to 3 per cent under climate change (3 per cent – dry to 5.5 per cent – wet) compared with average climate conditions (3 per cent).

8.7 Cumulative impacts

The cumulative assessment of the project has been assessed from a local as well as regional scale.

8.7.1 Local-scale cumulative impacts

The first perspective is for local scale, where dewatering may be undertaken in multiple areas simultaneously during construction. For example, excavation of portals and interchanges at Banksia Street/Manningham Road is likely to be undertaken concurrently with excavations to construct the northern portal.

In predicting the drawdowns from the project, the numerical modelling assumed that construction dewatering may be occurring simultaneously in different parts of the project. This is considered to be a worst case or conservative scenario because drawdowns are maximised when the radii of influence from multiple areas of dewatering intersect.

It is recognised the project could be constructed in a variety of sequences. However, the timing of construction of the northern and southern portals would need to consider the launch and retrieval of the TBM. It is considered to be in the best interests of a contractor to minimise construction timeframes and thus dewatering durations to achieve an economic construction outcome.

8.7.2 Regional-scale cumulative impacts

Assessment of regional-scale impacts can be problematic because an understanding of other anthropogenic stresses on the groundwater environment is required from two perspectives; a local scale and a regional scale. It is understood a number of other infrastructure projects would potentially be underway at the same time North East Link, including works for the Level Crossing Removal Project (some of which include below grade or rail or road under options) and the Metro Tunnel (which includes a significant length of tunnelling and underground cavern excavation).

Predicted drawdowns are not interpreted to extend to the influence of the Metro Tunnel and so cumulative impacts to the groundwater environment from the two projects are not expected.

A potential consideration is the management of wastewater from the project, specifically inflows into drained and tanked structures. The native groundwater quality of the Palaeozoic bedrock is saline and so management options need to consider salt loads associated with this wastewater.

It has been assumed the TBM tunnels of North East Link and their associated tanked structures would be completed to a Haack Class 3 condition (refer Table 5-4 in Section 5) which renders the structures near impermeable, although some seepage occurs. Wastewater would also be captured by the tunnels from sources such as stormwater runoff and water carried on vehicles. To manage this wastewater, a possible option could be disposal to sewer. At Melbourne’s Eastern and Western Treatment Plants, treated effluent is a commodity for reuse such as for irrigation, and so the management of salt is important in the downstream sewage process.

Disposal of wastewater from the project to sewer represents a potential cumulative impact as wastewater would also be generated from the Metro Tunnel, which may also consider disposal to sewer as a means to manage wastewater inflows.

8.8 Alternative options

Although the reference project for North East Link has largely been finalised, there are currently two design options being considered for the arrangement of the Manningham Road interchange, and two locations for the launch of the tunnel boring machine (TBM) being considered. For information on the design options, refer to EES Chapter 8 – Project description.

This section explains how the potential impacts associated with the alternative design options would differ from the impacts associated with the reference project assessed in the sections above.

8.8.1 Manningham Road interchange alternative design

The alternative design for the Manningham Road interchange involve changes in the configuration of the connections between the North East Link tunnels and adjoining roads, such as Banksia Street, Manningham Road and Bulleen Road.

The alternative option does not significantly alter the configuration of the ground support of the southern portal, and so it is concluded the numerical groundwater model's predicted estimates of water level change are reasonable for the reference project as well as the alternative design of the Manningham Road interchange.

8.8.2 Northern tunnel boring machine (TBM) launch site

The potential groundwater impacts of the alternative TBM launch site have been reviewed. In general terms, the TBM results in the permanent, tanked tunnel lining being placed during construction. Therefore over the TBM tunnel sections of the project, there would not likely be any change to the impact assessment based on tunnel drive direction.

On the assumption the portal structures (TBM launch and retrieval) remain a similar size, some variation in the drawdown during the project's construction may occur. This is because the portal construction timings (durations) may be altered—a drawdown at the northern portals may occur earlier than predicted by the numerical groundwater model. At the end of construction, the magnitude of drawdowns should be similar.

If the alternative option for the TBM launch site was selected, it would not alter the conclusions of the impact assessment and the EPRs developed for the launch site in the reference project would be equally applicable.

Tunnel boring machine (TBM) retrieval site

The Northern TBM launch option assumes that the TBMs would be retrieved from the Manningham Interchange structure. However, the timing of property acquisition may mean that the Manningham Interchange is not ready to retrieve the TBMs. Therefore, for the northern launch option, a TBM retrieval site would be required north of Banksia Street/Bridge Street.

The retrieval site would comprise either two shafts (for each TBM) or one larger shaft, that would be used to dismantle and remove the TBMs after they have completed their respective drives from north of the Yarra River. Similar to other structures that would extend below the subsurface, it has been assumed that the shafts would be excavated and supported using diaphragm walls or bored piles. Groundwater inflow to the excavation would principally occur upwards via the base of the shaft, until it is eventually sealed with a floor slab.

Geotechnical investigation boreholes drilled to the north of Bridge Street, such as NEL-BH141 and NEL-BH142 have intersected only a thin cover of sediments (approximately two metres), and water tables approximately ten metres below the ground surface. Retrieval shaft excavations would be predominantly within the bedrock aquifer system, but are situated close to the margin of the Yarra River floodplain.

The numerical groundwater model was applied to assess the potential impacts of shaft construction and dewatering on the groundwater environment. The radial extent of dewatering was larger than the reference project (that is without the structure) by approximately 50 metres to 70 metres. Long term drawdown estimates indicate that partial recovery of groundwater drawdown would occur and the spatial extent of drawdown would contract from that estimated at the close of construction. Long term drawdowns are estimated to be less than 1 metre at distances greater than 25 metres from the structure.

The dewatering extents were largely constrained somewhat by the interpreted extent of the alluvial floodplain. This is interpreted to be a result of the storage capacity of the alluvial sediments, which would provide recharge to the bedrock via leakage.

9. Environmental Performance Requirements

Table 9.1 lists the recommended Environmental Performance Requirements (EPRs) relevant to the groundwater assessment.

Table 9.1 Environmental Performance Requirements

EPR ID	Environmental Performance Requirement
EPR GW1	**Design and construction to be informed by a groundwater model** Develop a predictive and numerical groundwater model, informed by field investigations, to predict changes in groundwater levels and flow and quality, as they are affected by construction, and develop mitigation strategies, as per EPR GM1. The groundwater model must be updated to take account of any changes to construction techniques or operational design features.
EPR GW2	**Monitor groundwater** Develop and implement a pre-construction, and construction groundwater monitoring program to: • Establish baseline water level and quality conditions throughout the study area • Calibrate the predictive model prior to commencement of construction, manage construction activities, and verify the model predictions. • Assess the adequacy of proposed design and construction methods, and where required, identify and implement any additional measures required to mitigate impacts from changes in groundwater levels, flow and quality. A post-construction groundwater monitoring program must be developed and implemented to: • Confirm the acceptability of resultant water quality and water level recovery (and potential mounding) as predicted by the numerical groundwater model. Acceptability is to be assessed with consideration to the Groundwater Dependent Ecosystem Monitoring and Mitigation Plan (as required by EPR FF6) and other identified beneficial uses of groundwater • Confirm the effectiveness of applied measures as identified in the Groundwater Management Plan (refer EPR GW4) and if required, identify and implement contingency measures to restore groundwater to an acceptable level. The duration of post-construction monitoring must be a minimum of two years or until acceptable restoration of groundwater has been confirmed. The monitoring program must be developed in consultation with EPA Victoria and be consistent with EPA Victoria Publication 668 Hydrogeological assessment groundwater quality guidelines, EPA Victoria Publication 669 Groundwater Sampling Guidelines, and the State Environment Protection Policy (Waters).

EPR ID	Environmental Performance Requirement
EPR GW3	**Minimise changes to groundwater levels through tunnel and trench drainage design and construction methods** Design long term tunnel drainage and adopt construction methods which minimise changes to groundwater levels during construction and operation to manage, mitigate and/or minimise to the extent practicable: • Requirements for groundwater management and disposal • Mobilisation of contaminated groundwater • Dewatering and potential impacts of acid sulfate soils, including both unconsolidated sediments and lithified sedimentary rock • Potential impacts on waterways and potential groundwater dependent ecosystems, including terrestrial ecosystems • Any other adverse impacts of groundwater level changes such as subsidence. Design and implement engineering control measures and/or ground treatment to limit to the extent practicable groundwater inflow and groundwater drawdown during excavation, construction and operation of tunnels and trenches, cross passages and subsurface excavations. The Groundwater Management Plan (as required by EPR GW4) must contain measures and/or controls to minimise groundwater inflow during construction to excavations and groundwater drawdown, including contingency measures should monitoring indicate adverse impacts are occurring. These must include measures to: • Minimise to the extent practicable reduction or loss of groundwater discharge to waterways or loss of water availability for terrestrial ecosystems. • Manage, mitigate and minimise the oxidation of acid sulfate soil materials and acidification of groundwater • Manage, mitigate and minimise any movement of contamination that is identified. • Manage, mitigate and minimise impacts on beneficial uses and risk of vapour intrusion. • Ensure that groundwater seepage is collected, treated and disposed during construction in accordance with the Environment Protection Act 1970 waste management hierarchy and EPA Victoria requirements. Obtain a trade waste agreement from the relevant water authority where disposal to sewer is required or approval from EPA and the relevant water authority (as required) if discharge to waterways is determined to be appropriate.
EPR GW4	**Implement a Groundwater Management Plan to Protect groundwater quality and manage groundwater interception** A Groundwater Management Plan must be developed in consultation with EPA Victoria and implemented to protect groundwater quality and manage interception of groundwater including documenting the measures required to achieve EPR GW2 and EPR GW3. The Groundwater Management Plan must be informed by the groundwater modelling required by EPR GW1 and updated where required in response to modelling results and assessment of the adequacy or effectiveness of controls. The Groundwater Management Plan must include requirements and construction methods to protect groundwater quality including where appropriate, but not limited to: • Selection and use of sealing products, caulking products, lubricating products and chemical grouts during construction that will not diminish the groundwater quality • Selection and use of fluids for artificial recharge activities that will not diminish the groundwater quality • Requirements to ensure compatibility of construction material with groundwater quality to provide long term durability for infrastructure design lif

EPR ID	Environmental Performance Requirement
	• Design and development of drainage infrastructure that minimises clogging and maintenance risks from dissolved constituents in groundwater precipitating out of solution • Measures to assess, remove and dispose of contaminated groundwater and impacted soils associated with excavation and construction • Reinjection borefields for hydraulic control of drawdowns (or contaminated groundwater plumes). • Remedial grouting. The Groundwater Management Plan must include requirements and methods for management of groundwater interception during construction, including where appropriate, but not limited to: • Identification, treatment, disposal and handling of contaminated seepage water and/or slurries including vapours in accordance with relevant legislation and guidelines • Assessment of barrier/damming effects • Subsidence management • Dewatering and potential impacts on acid sulfate soils, including both unconsolidated sediments and lithified sedimentary rock • Protection of waterways and potential groundwater dependent ecosystems • Management of unexpected contaminated groundwater, eg using treatments, hydraulic controls, grouting and exclusion methods. • Contingency actions when interventions are required. The Groundwater Management Plan must also include a review to confirm the status of potential use of extraction bores within the estimated construction drawdown area. Where required, measures must be developed and implemented, to the satisfaction of Southern Rural Water, to maintain water supply to identified, impacted groundwater users.
EPR GW5	**Manage groundwater during operation** Prepare as part of the OEMP and implement measures for management, monitoring, reuse where possible and disposal of groundwater inflows during operation that comply with relevant legislation and guidelines, including but not limited to: • State Environment Protection Policy (Waters) • State Environment Protection Policy (Prevention and Management of Contaminated Land) • Water Industry Regulations 2006 • *Occupational Health and Safety Act* 2004 and Occupational Health and Safety Regulations 2017. The OEMP must include contingency measures and emergency response plans if unexpected groundwater contamination is encountered and requires disposal.
EPR SW2	**Design to include spill containment** Design and construct the spill containment capacity of the stormwater drainage system for all freeway pavements (including ramps) to manage the risk of hazardous spills from traffic accidents at or prior to every stormwater outlet, to meet AustRoads requirements. The design and location of spill containment must consider the risk and potential impact of a spill, as well as the effectiveness in reducing the risks associated with a spill on the environment. Develop procedures for freeway roads and ramps to be implemented in response to a hazardous spill.

EPR ID	Environmental Performance Requirement
EPR SW3	**Waste water discharges to be minimised and approved** The Surface Water Management Plan (refer EPR SW5) and OEMP must include requirements and methods for minimising, handling, classifying, treating, disposing and otherwise managing waste water. Any proposed discharge of waste water from the site must be approved by the relevant authority prior to discharges occurring and meet the State Environment Protection Policy (Waters) requirements.
EPR SW11	**Adopt Water Sensitive Urban and Road Design** Adopt and implement water sensitive urban design and integrated water management principles in the stormwater treatment design, in general accordance with the Urban Design Strategy, the specifications of the relevant local council as applicable, and VicRoads Integrated Water Management Guidelines (June 2013), the Victorian Stormwater Committee's Victoria Best Practice Environmental Management Guidelines for Urban Stormwater (as published by CSIRO in 1999 with assistance from EPA Victoria and others) and the DELWP Integrated Water Management Framework for Victoria (September 2017).
EPR CL1	**Implement a Spoil Management Plan** Prepare and implement a Spoil Management Plan (SMP) in accordance with relevant regulations, standards and best practice guidelines. The SMP must be developed in consultation with the EPA Victoria and include processes and measures to manage spoil. The SMP must define roles and responsibilities and include requirements and methods for: • Complying with applicable regulatory requirements • Completing a detailed site investigation (in accordance with Australian Standard AS 4482.1-2005Guide to the investigation and sampling of sites with potentially contaminated soil and the EPA Victoria Industrial Waste Resource Guidelines) prior to any excavation of potentially contaminated areas to identify location, types and extent of impacts and to characterise spoil to inform spoil and waste management. • Identifying the nature and extent of spoil (clean fill and contaminated spoil) • Storage, handling, transport and disposal of spoil in a manner that protects human health and the environment and is consistent with the transport management plan(s) required by EPR T2. This includes methods and requirements for the appropriate treatment/remediation of any contaminated excavated spoil and contaminated residual material left on site. • Design and management of temporary stockpile areas • Minimising impacts and risks from disturbance of acid sulfate soils (as per EPR CL2), odour (as per EPR CL3) and vapour and ground gas intrusion (as per EPR CL4) • Management of hazardous substances, including health, safety and environment procedures that address risks associated with exposure to hazardous substances for visitors and general public; contain measures to control exposure in accordance with relevant regulations, standards and best practice guidance and to the requirements of WorkSafe and EPA Victoria; and include method statements detailing monitoring and reporting requirements • Identifying where any contaminated or hazardous material is exposed during construction (notably through former landfills, service stations and industrial land) and how it will be made safe for the public and the environment. Beneficial uses of land and National Environment Protection (Assessment of Site Contamination) Measures 2013 guidance on criteria protective of those beneficial uses must be considered for the land uses in these areas. This must include methods for: o Construction of appropriate cover (soil, concrete, geofabric etc) such that no contamination is left exposed at the surface or where it may be readily accessed by the public and such that it cannot generate runoff or leachate during rain events

EPR ID	Environmental Performance Requirement
	o Maintenance of the cover o Identification of the nature and depth of the contaminants o Mitigating impacts during sub-surface works in those areas, such as drilling and excavation. • Monitoring and reporting • Identifying locations and extent of any prescribed industrial waste (PIW), other waste, and the method for characterising PIW and other waste prior to excavation • Identifying suitable sites for disposal of any waste. This includes identifying contingency arrangements for management of waste, where required, to address any capacity issues associated with the licensed landfills' ability to receive PIW and other waste.
EPR CL2	**Minimise impacts from disturbance of acid sulfate soil** The SMP referenced in EPR CL1 must include requirements and methods to minimise impacts from disturbance of acid sulfate soil, including but not limited to: • Characterise acid sulfate soil and rock prior to excavation • Develop appropriate stockpile areas including lining, covering and runoff collection to prevent release of acid to the environment • Identify suitable sites for re-use management or disposal of acid sulfate soil and rock • Prevent oxidation that could lead to acid formation if possible through cover and/or scheduling practices, ie ensuring acid sulfate soil and rock is not left in stockpiles for any length of time and/or addition of neutralising compounds Requirements and methods must be in accordance with the Industrial Waste Management Policy (Waste Acid Sulfate Soils), EPA Victoria Publication 655.1 Acid Sulfate Soil and Rock, and the Department of Sustainability and Environment's Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soil.
EPR CL3	**Minimise odour impacts during spoil management** The SMP referenced in EPR CL1 must include requirements and methods for odour management (in accordance with EPA Victoria requirements) during the excavation, stockpiling and transportation of contaminated material including: • Identifying the areas of contamination that may pose an odour risk • Monitoring of the excavated material for possible odour risk • Management measures to minimise odour.
EPR CL4	**Minimise risks from vapour and ground gas intrusion** Relevant North East Link sections must be designed to prevent ingress of vapours and gases associated with any construction that interfaces with landfill sites or contaminated areas. The SMP referenced in EPR CL1 must include requirements for assessment, monitoring and management of intrusive vapour including potentially flammable or explosive conditions in enclosed spaces or other impacts on human health and the environment. The plan must address vapour risks associated with excavation of impacted soils, extraction of impacted groundwater, open excavations and stockpiles and gases associated with landfills. This must include, where relevant: • Securing of the excavation and stockpile area from the public and signage warning of open excavations • Daily monitoring of vapours and odours while excavations are open and stockpiles remain onsite • Mitigation measures to prevent fugitive releases of vapours and gasses during construction.

EPR ID	Environmental Performance Requirement
EPR FF6	**Implement a groundwater dependent ecosystem monitoring and mitigation plan** Prepare and implement a Groundwater Dependent Ecosystem Monitoring and Mitigation Plan. The Groundwater Dependent Ecosystem Monitoring and Mitigation Plan must be informed by the groundwater modelling and groundwater monitoring required by EPR GW1 and EPR GW2. Where the survival of Groundwater Dependent Large Trees is predicted to be affected based on groundwater modelling outputs, offsets must be obtained in accordance with EPR FF2.
EPR SCC4	**Minimise and appropriately manage waste** Develop and implement management measures for waste (excluding soils) minimisation during construction and operation in accordance with the *Environment Protection Act 1970* waste management hierarchy and management options, to address: • Litter management • Construction and demolition wastes including, but not limited to, washing residues, slurries and contaminated water • Organic wastes • Inert solid wastes.
EPR CL5	**Manage chemicals, fuels and hazardous materials** The CEMP and OEMP must include requirements for management of chemicals, fuels and hazardous materials including: • Minimise chemical and fuel storage on site and store hazardous materials and dangerous goods in accordance with the relevant guidelines and requirements. • Comply with the Victorian WorkCover Authority and Australian Standard AS1940 Storage Handling of Flammable and Combustible Liquids and EPA Victoria publications 480 Environmental Guidelines for Major Construction Sites and 347 Bunding Guidelines • Develop and implement management measures for hazardous materials and dangerous substances, including: o Creating and maintaining a dangerous goods register o Disposing of any hazardous materials, including asbestos, in accordance with Industrial Waste Management Policies, regulation and relevant guidelines o Implementing requirements for the installation of bunds and precautions to reduce the risk of spills • Contingency and emergency response procedures to handle fuel and chemical spills, including availability of on-site hydrocarbon spill kits.

10. Conclusion

The purpose of this report is to provide groundwater impact assessments to inform the preparation of the EES required for the project. These assessments have focused on the risks associated with groundwater drawdown around below-grade structures, which can result in potential impacts to bore users, the movement of plumes of contaminated groundwater, and the oxidation of potentially acid sulfate soils and rock. Groundwater level changes as a result of structures forming an impediment to regional flow have also been considered.

Groundwater drawdown can also influence settlement, and the water supply to dependent ecosystems. Information from this report has been used for other EES technical reports to assess these impacts.

10.1 Relevant EES evaluation objectives

The following evaluation objective is relevant to the groundwater assessment is:

- Catchment values – To avoid or minimise adverse effects on the interconnected surface water, groundwater and floodplain environments.

The groundwater assessment has also informed the ground movement assessment (Technical report M), which have a relatable objective of avoiding or minimising adverse effects on land stability from project activities, including tunnel construction and river and creek crossings. The groundwater assessment has also informed the ecology assessment (Technical report Q) which assesses the potential impacts on groundwater dependent ecosystems due to changes to groundwater, and arboriculture and heritage assessments which consider the potential impacts to trees and their heritage values. The groundwater assessment has also informed the human health assessment (Technical report J), particularly with respect to impacts of contaminated groundwater and vapour migration on human health.

This groundwater assessment was informed by the contamination and soil assessment (Technical report O), which characterises the presence of PASS materials and sites with potentially contaminating land use activities.

Surface water quality and impacts to the floodplain are assessed in Technical report P – Surface water.

To address the EES objectives this groundwater assessment has documented the potential effects on beneficial uses of groundwater due to changes in flows, water quality, hydrology connectivity, mobilisation of existing groundwater contamination, or dewatering arising during the project's construction and operation.

10.2 Existing conditions summary

The following conclusions are made regarding the existing conditions:

- The hydrogeology of the project can be broadly divided into two aquifer systems; an alluvial aquifer and a bedrock aquifer system. These are likely to be connected aquifer systems (where the alluvials overlie the bedrock) with contrasting aquifer hydraulic properties.
- Existing groundwater development in the region is limited. This is partly due to the urbanised setting, but low bore yields (generally <1 L/s) and saline groundwater tend to reduce abstractive potential.

- The bedrock aquifer groundwater is saline with salinities averaging 5,700 mg/L TDS, and which results in a Segment D, Beneficial Use classification. Fresher groundwater (Segment A) has been identified near the Yarra River, and more saline groundwater (Segment E) in other parts of the alignment such as Simpson Barracks. Groundwater is too saline for irrigation and potable use without treatment. Groundwater could be used for stock and industrial applications, but because much of the project would be within residential land zoning types there is limited likelihood of these uses being realised.
- The alluvial aquifer has an average groundwater salinity of 2,658 mg/L TDS which reflects its interaction with waterways, and shorter recharge pathways. Groundwater within the alluvial aquifer generally falls within Segment B, but can be within Segment A2 or Segment C depending upon local flow paths. Abstractive development is limited by aquifer production capacities and restrictions under the Water Act 1989 (Vic) in terms of set-backs from waterways. Much of the floodplain where the bulk of the alluvial aquifer system is located is not developed and zoned as Public Conservation and Resource, or Public Park and Recreation.
- Much of the project would be located within public use, public park and recreation and general residential planning zones which limit the likelihood of having land uses resulting in groundwater contamination. Commercial and industrial land use zonings have been identified within parts of the study area, such as in the Manningham Road/Bulleen Road area. PFAS contamination has been identified within the project area.
- Water levels across the alignment are variable but typically 5 to over 12 metres below the surface. Shallower water levels (generally within 5 metres of the surface) have been identified within the floodplain/alluvial sediments. Deeper water levels occur within the bedrock aquifer, particularly in the topographically elevated parts of the study area.
- Available groundwater monitoring information indicates a seasonal variation in the bedrock of around one metre. The long term behaviour of groundwater levels are not well understood due to an absence of historic data for the catchment areas and ongoing monitoring is underway to better understand the level of variability. To address this data gap, sensitivity and uncertainty analysis has been used to inform the predictive groundwater numerical model. In addition, comparison of water level responses in similar bedrock terrains was undertaken, and benchmarking studies of recharge with the numerical model.

10.3 Impact assessment summary

For the purposes of this assessment, the project has been split into three elements but works in much of the M80 Ring Road to northern portal and the Eastern Freeway elements would be predominantly above grade and so would have limited interaction with the groundwater environment. Risks to groundwater in these two project elements are low. This report has therefore focused on the southern section of the project's M80 Ring Road to northern portal element where the road would be in a trench, as well as the northern portal to southern portal element where construction works would be below grade and control of groundwater would be necessary to enable construction works.

Cut and cover structures, TBM tunnelling and conventional mined tunnelling would occur int these areas. This tunnelling would intersect the water table in places, including the crossing below the Yarra River floodplain. The impact assessment relied upon a risk-based approach, and considered the project's construction and operation.

Where groundwater risks have been identified, EPRs have been proposed to eliminate or mitigate adverse impacts. The risk-based approach has aided the development of robust EPRs so that alternative construction methods and alignments can be accommodated.

In terms of the impacts to the groundwater environment:

- Groundwater risks have similar pathways for the project's construction and operation. Risks are mostly associated with changes to groundwater levels (either rises or falls) although risks are also attached to the preservation of groundwater quality.
- Groundwater drawdowns are greatest during the project's construction compared, as some recovery of water levels would occur once construction was completed when structures became tanked (sealed) and active dewatering was reduced. As a general rule, as the project's construction duration is relatively short (approximately 2 to 3 years of dewatering) and given the slow groundwater movement rates, some potential impacts during construction may not be fully developed until water levels re-equilibrate over the project's longer-term operation. Under these circumstances, operating conditions require greater consideration.
- Key groundwater risks investigated through this assessment include:
  - Changes in groundwater quality due to hazardous materials handling and aquifer recharge (risk GW01 and risk GW06)
  - Impacts to the operational capacity of existing groundwater users (risk GW02 and risk GW07)
  - The oxidation of PASS materials from dewatering activities (risk GW03 and risk GW08)
  - The displacement or dislocation of contaminated groundwater plumes – groundwater movement rates would suggest that risks during the project's operation are greater as water levels re-equilibrate over the long term (risk GW04 and risk GW09)
  - Damming of groundwater flow by the placement of 'impermeable' structures within regional flow paths – as water levels take time to re-equilibrate, this risk is associated with the project's longer-term operation (risk GW10).

With the implementation of the EPRs, the residual risks are expected to be low

Changes in groundwater can also effect the effective stress condition of compressible sediments, and can alter access for groundwater dependent ecosystems dependent. This report has predicted drawdowns and developed EPRs to address these issues. However, the assessment of impact is documented in Technical report Q – Ecology and Technical report M – Ground movement.

It is appreciated these potential impacts pose a risk to the groundwater environment but the EPRs would be effective in reducing and managing these risks.

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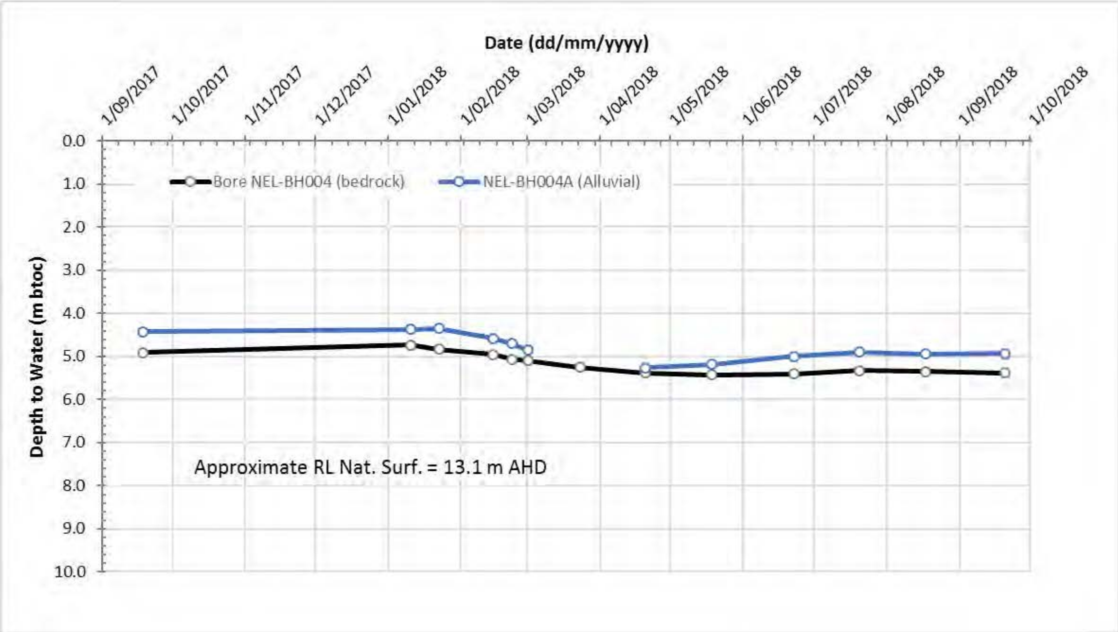
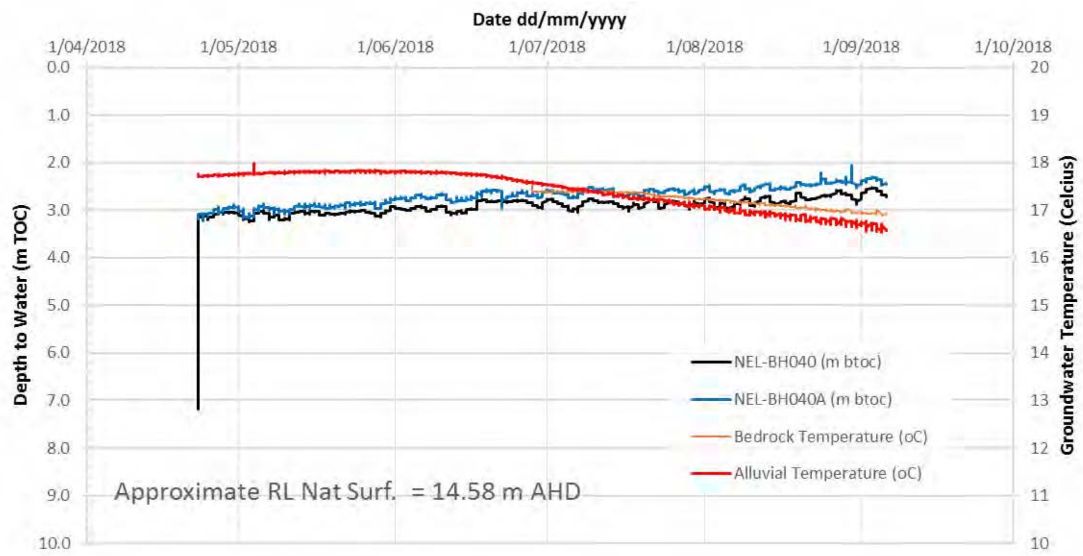
Appendices

Appendix A – Nested bore hydrographs

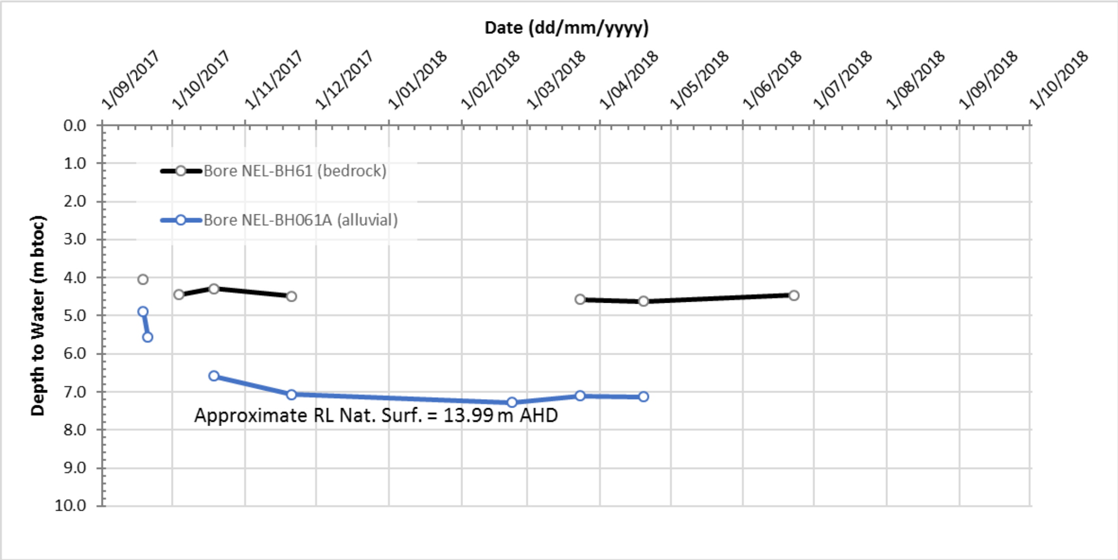
Nested Site NEL-BH004 (bedrock) and NEL-BH004A (alluvials) – near Koonung Creek



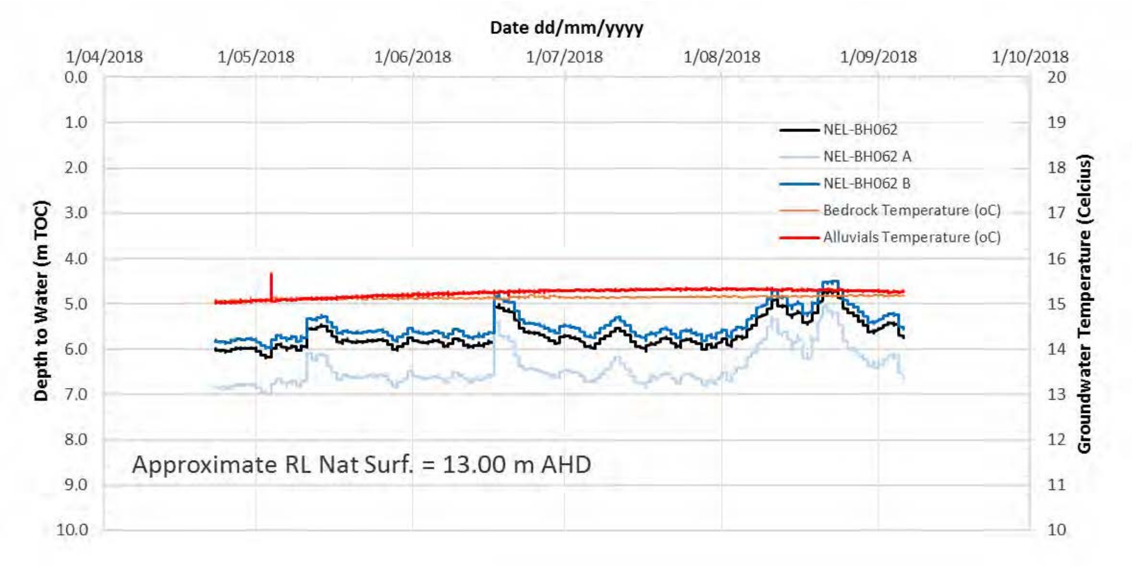
Nested Site NEL-BH040 (bedrock) and NEL-BH40A (alluvials) – near Koonung Creek



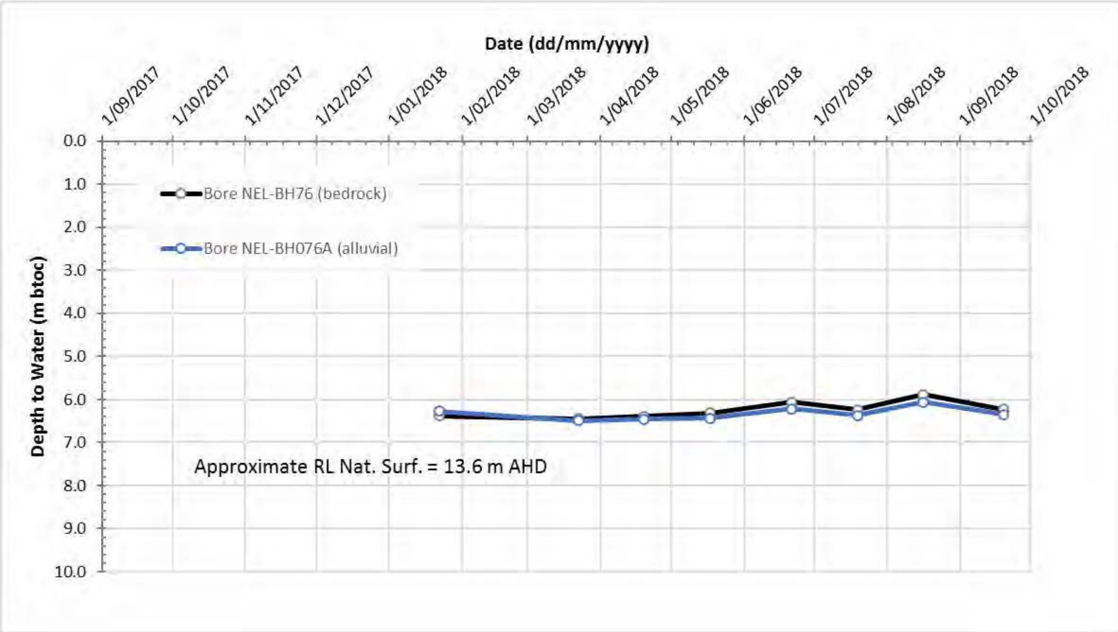
Nested Site NEL-BH061 (bedrock) and NEL-BH061A (alluvials)



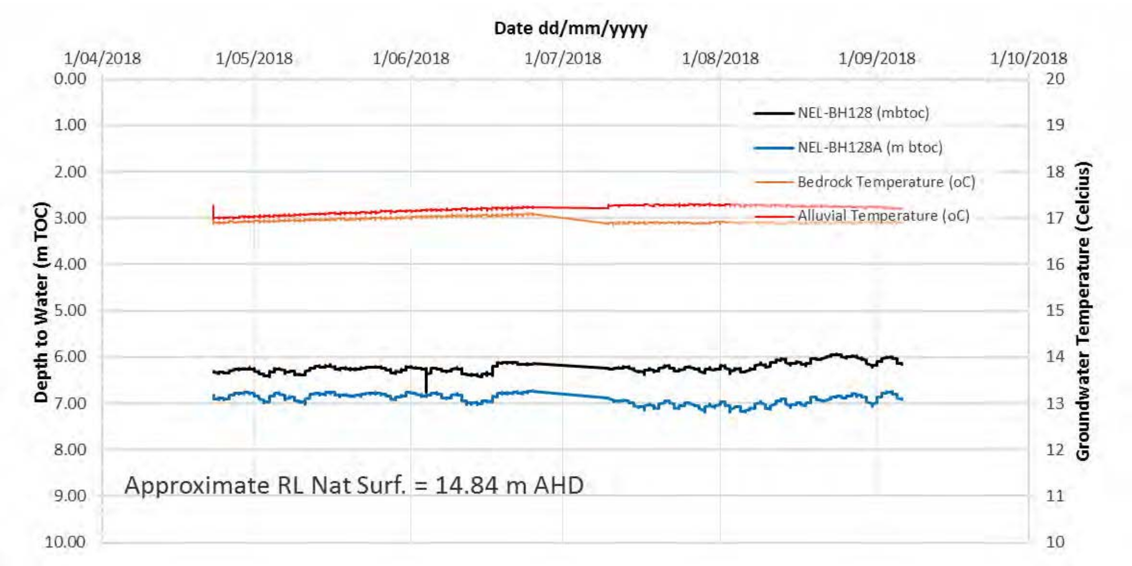
Nested Site NEL-BH62 (bedrock), NEL-BH62A and NEL-BH62B (alluvials) – near Yarra River



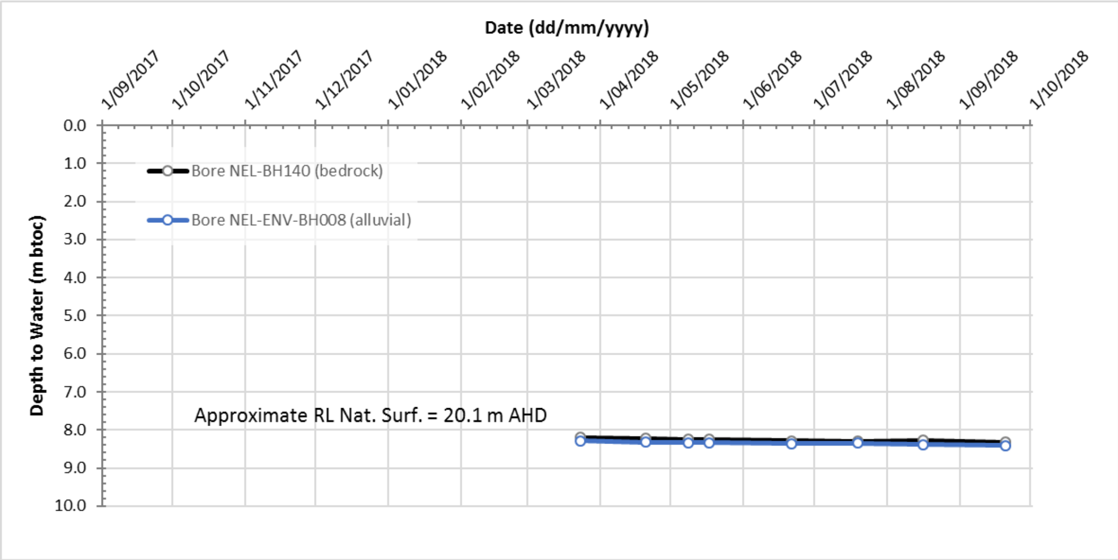
Nested Site NEL-BH076 (bedrock) and NEL-BH076A (alluvials)



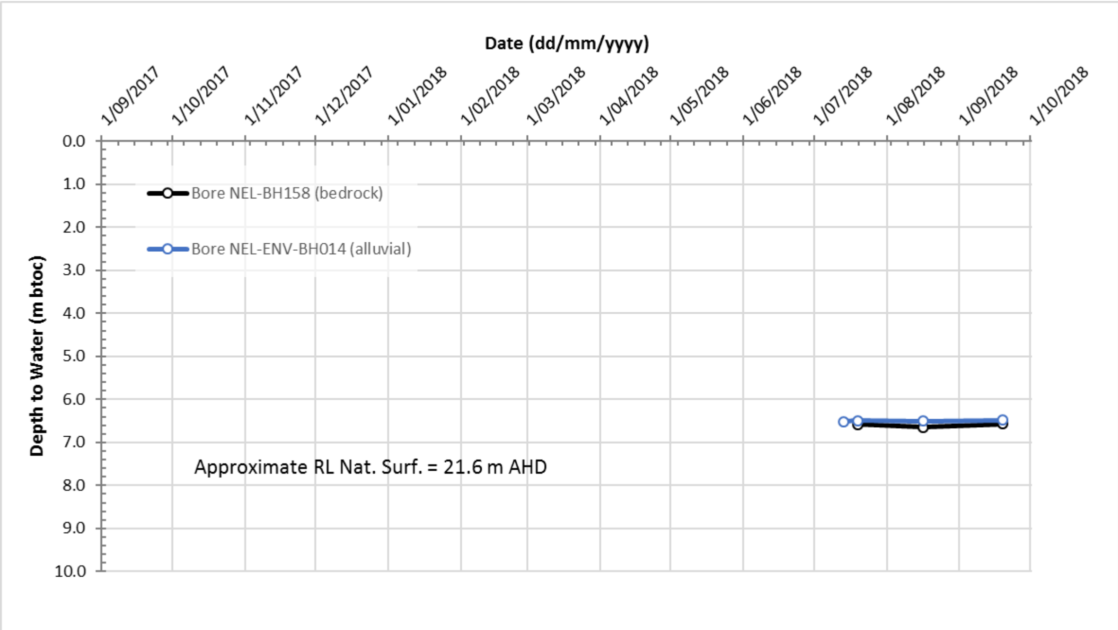
Nested Site NEL-BH128 (bedrock) and NEL-BH128A (alluvials) – near Yarra River



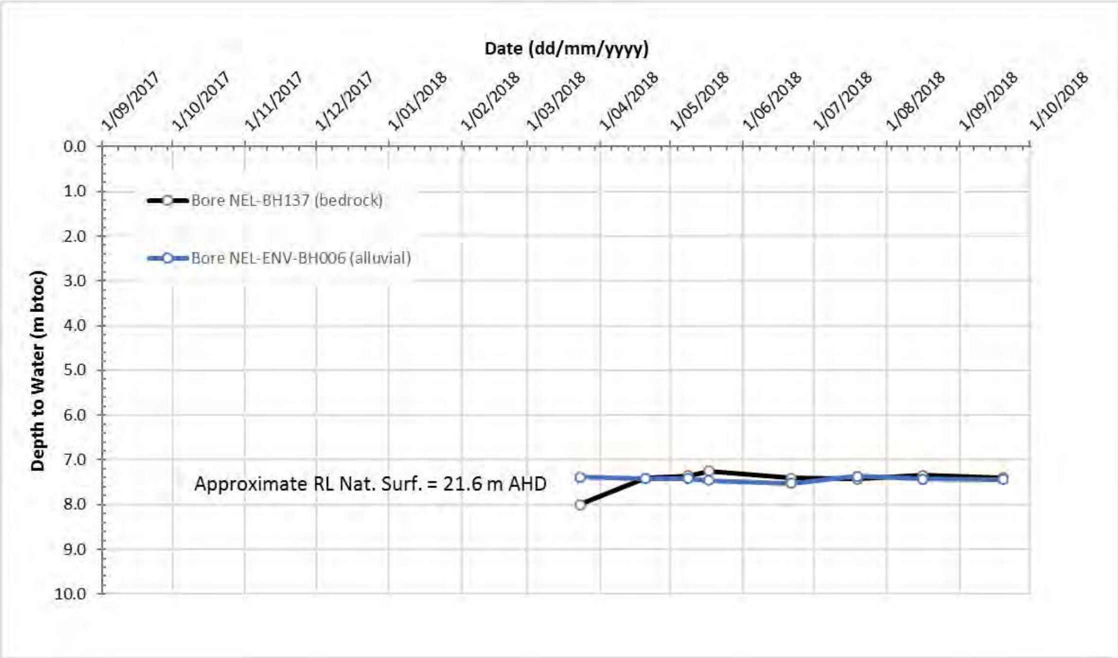
Nested Site NEL-BH140 (bedrock) and NEL-ENV-BH008 (sediments)



Nested Site NEL-BH158 (bedrock) and NEL-ENV-BH014 (sediments)



Nested Site NEL-BH137 (bedrock) and NEL-ENV-BH006 (sediments)



Note: Bores not surveyed.

Appendix B – Risk assessment

Consequence criteria

Characteristic	Factor	
Extent	Wider region Corridor Municipality Local	
Severity	Very high	A very high degree of impact on an environmental asset, value or use of moderate or higher significance, or A very high number of impacts on environmental assets, values or uses, or Impacts on environmental assets, values or uses of very high significance.
	High	A high degree of impact on an environmental asset, value or use of moderate or higher significance, or A high number of impacts on environmental assets, values or uses, or Impacts on environmental assets, values or uses of high significance.
	Medium	A moderate degree of impact on an environmental asset, value or use of moderate or higher significance, or A moderate number of impacts on environmental assets, values or uses, or Impacts on environmental assets, values or uses of moderate significance.
	Low	A low degree of impact on an environmental asset, value or use, or A low number of impacts on environmental assets, values or uses, or Impacts on environmental assets, values or uses of lower significance.
	Very low	A very low degree of impact on an environmental asset, value or use, or A very low number of impacts on environmental assets, values or uses, or Impacts on environmental assets, values or uses of very low significance
Duration	Permanent (>7 years)	
	Long term construction (>2 – 7 years)	
	Medium term construction (>3 months – 2 years)	
	Short term construction (0 – 3 months)	

Likelihood criteria

Planned	The event will occur
Almost certain	The event is almost certain to occur one or more times a year
Likely	The event is likely to occur several times within a five-year timeframe
Possible	The event may occur once within a five-year timeframe
Unlikely	The event may occur under unusual circumstances but is not expected (ie once within a 20-year timeframe)
Rare	The event is very unlikely to occur but may occur in exceptional circumstances (ie once within a 100-year timeframe)

Risk rating

Likelihood	Consequence				
	Negligible	**Minor**	**Moderate**	**Major**	**Severe**
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
Planned	Planned	Planned	Planned	Planned	Planned

Risk ID	Potential impact pathway	Environmental Performance Requirements	Initial risk rating						Reasoning	Residual risk rating						Reasoning
			Magnitude of consequence			Overall Consequence	Likelihood	Risk Level		Magnitude of consequence			Overall consequence	Likelihood	Risk level	
			Extent	Severity	Duration					Extent	Severity	Duration				
Risk GW01	Construction activities that result in the degradation of groundwater quality via spills, storage and handling of hazardous materials, such as fuels.	EPR EMF2 EPR CL5 EPR GW2, EPR GW4	Local	Medium	3 months to 2 years	Minor	Possible	Low	• Could occur in localised areas, anywhere throughout study area • CEMP expected to reduce the consequence of such happening, possible reduction in likelihood	Local	Medium	3 months to 2 years	Minor	Possible	Low	Low initial risk
Risk GW02	Construction activities including dewatering (or extraction of groundwater for construction water supply) result in loss of operational capacity of existing, registered, groundwater users	EPR SCC4 EPR GW1, EPR GW2, EPR GW3, EPR GW4	Municipality	Low	3 months to 2 years	Minor	Unlikely	Low	• Existing groundwater bores present in study area, but quality and yield expected to limit abstractive use. • Could occur in multiple parts of the study area • Bores would need to be located close to areas of large drawdowns to be impacted significantly. Multiple options available to mitigate effects (such as alternative water, lowering pumps)	Municipality	Low	3 months to 2 years	Minor	Unlikely	Low	Low initial risk

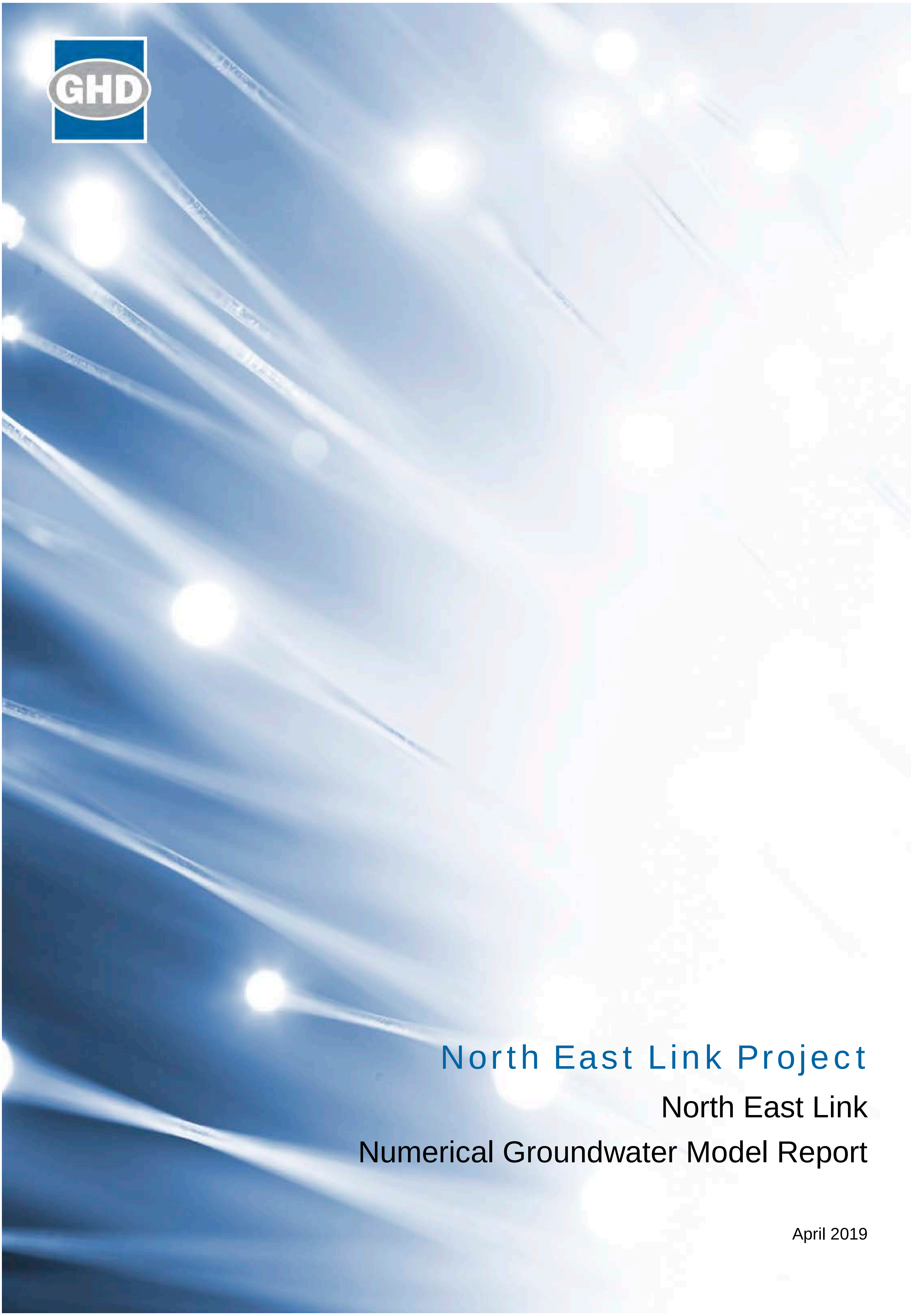
Risk ID	Potential impact pathway	Environmental Performance Requirements	Initial risk rating						Reasoning	Residual risk rating						Reasoning
			Magnitude of consequence			Overall Consequence	Likelihood	Risk Level		Magnitude of consequence			Overall consequence	Likelihood	Risk level	
			Extent	Severity	Duration					Extent	Severity	Duration				
Risk GW03	Construction activities including dewatering (and water supply) result in a water level drawdown of a magnitude in areas having in situ sulfidic sediments or rock that results in generation of acidic groundwater conditions.	EPR GW1, EPR GW2, EPR GW3, EPR GW4	Municipality	Low	3 months to 2 years	Minor	Possible	Low	• Multiple factors need to align for this risk to occur such as dewatering, presence of acid sulfate soil materials, a flux of recharge to generate plume, and a nearby receptor • Could occur in multiple parts of the study area • Sampling and further contamination characterisation may reduce this risk	Municipality	Low	3 months to 2 years	Minor	Possible	Low	Low initial risk
Risk GW04	Construction activities including dewatering (or extraction of groundwater for construction water supply) result in the dislocation of delineated, contaminated groundwater plumes.	EPR CL1 EPR GW1, EPR GW2, EPR GW3, EPR GW4	Local	Medium	3 months to 2 years	Minor	Possible	Low	• Potential to occur at multiple sites (but generally considered localised areas – multiple land parcels) within the study area • Split into two pathways (groundwater and vapour?) • Refer also Contamination and Soil Risk Register	Local	Medium	3 months to 2 years	Minor	Possible	Low	Low initial risk
Risk GW05	Management of groundwater seepage into construction excavations results in unacceptable impacts at the point of discharge.	EPR GW4 EPR SW1	Local	Medium	3 months to 2 years	Minor	Possible	Low	• May occur at multiple points along corridor. Reasonable expectation that any discharge to conform with requirements of relevant SEPP (*Waters*) or water utility • Refer also Surface Water Risk Register	Local	Medium	3 months to 2 years	Minor	Possible	Low	Low initial risk

Risk ID	Potential impact pathway	Environmental Performance Requirements	Initial risk rating						Reasoning	Residual risk rating						Reasoning
			Magnitude of consequence			Overall Consequence	Likelihood	Risk Level		Magnitude of consequence			Overall consequence	Likelihood	Risk level	
			Extent	Severity	Duration					Extent	Severity	Duration				
Risk GW06	Traffic accidents, spillage of hazardous materials, or events resulting in generation of contaminated stormwater runoff result in the degradation of groundwater quality.	EPR GW1, EPR GW5	Corridor	Low	3 months to 2 years	Moderate	Rare	Low	• Could occur anywhere. But emergency response practises expected to reduce consequence (severity) and likelihood	Corridor	Low	3 months to 2 years	Moderate	Rare	Low	Low initial risk
Risk GW07	Long term groundwater seepage into drained structures results in loss of operational capacity of existing, registered, groundwater users	EPR GW4, EPR GW5	Municipality	Low	7+ years	Moderate	Rare	Low	• Mitigation measures imposed during construction should reduce the likelihood of this occurring	Municipality	Low	7+ years	Moderate	Rare	Low	Low initial risk
Risk GW08	Long term groundwater seepage into drained structures results in a groundwater drawdown in areas of situ sulfidic sediments or rock and generates acidic conditions.	EPR GW5	Municipality	Very low	7+ years	Minor	Unlikely	Low	• Multiple factors need to align for this risk to occur such as dewatering, presence of acid sulfate soil materials, a flux of recharge to generate plume, and a nearby receptor • Sampling and further contamination characterisation may reduce this risk	Municipality	Very low	7+ years	Minor	Unlikely	Low	Low initial risk

Risk ID	Potential impact pathway	Environmental Performance Requirements	Initial risk rating						Reasoning	Residual risk rating						Reasoning
			Magnitude of consequence			Overall Consequence	Likelihood	Risk Level		Magnitude of consequence			Overall consequence	Likelihood	Risk level	
			Extent	Severity	Duration					Extent	Severity	Duration				
Risk GW09	Long term groundwater seepage into drained structures results in the dislocation of delineated, contaminated groundwater plumes.	EPR CL1 EPR GW1, EPR GW2, EPR GW3, EPR GW4, EPR GW5	Local	Medium	7+ years	Moderate	Unlikely	Low	• Size of impact could be larger which could increase the risk • Duration of clean-up influences risk • Unknown potential to occur at multiple sites within the study area • Split into two pathways (groundwater and vapour) • Refer also Contamination and Soil Risk Register	Local	Medium	7+ years	Moderate	Unlikely	Low	Low initial risk
Risk GW10	Buried structures such as tunnels and long cut-off walls, results in the creation of a barrier to groundwater flow and changes to groundwater levels.	EPR GW1, EPR GW5	Municipality	Low	7+ years	Moderate	Unlikely	Low	• Large proportion of below grade areas in same geology (bedrock). Noted that palaeochannels/ alluvials exist in areas that require further investigation	Municipality	Low	7+ years	Moderate	Unlikely	Low	Low initial risk Modelling indicates mounding would occur.
Risk GW11	Management (disposal) of groundwater seepage entering into tunnels/portals, results in the unacceptable impacts (such as salt loads, contamination) to point of discharge (such as waterway, sewer, groundwater)	EPR SCC4 EPR GW4, EPR GW5 EPR SW3	Local	Low	7+ years	Minor	Unlikely	Low	• May occur at multiple points along corridor. Reasonable expectation that any discharge to conform with requirements of relevant SEPP (*Waters*) or water utility • Refer also Surface Water Risk Register	Local	Low	7+ years	Minor	Unlikely	Low	Low initial risk

Risk ID	Potential impact pathway	Environmental Performance Requirements	Initial risk rating						Reasoning	Residual risk rating						Reasoning
			Magnitude of consequence			Overall Consequence	Likelihood	Risk Level		Magnitude of consequence			Overall consequence	Likelihood	Risk level	
			Extent	Severity	Duration					Extent	Severity	Duration				
Risk GW12	Unexpected contaminated groundwater seepage is not treated by the tunnel wastewater treatment plant resulting in groundwater being released to receiving environments (sewer, surface waters) or hazards to maintenance staff.	EPR GW2	Municipality	Low	7+ years	Moderate	Unlikely	Low	• Reasonable expectation that discharge from long term operation of the tunnel is managed (disposed) in accordance with relevant SEPP or water utility (sewer) requirements	Municipality	Low	7+ years	Moderate	Unlikely	Low	Low initial risk

Appendix C – Groundwater modelling report



North East Link Project

North East Link

Numerical Groundwater Model Report

April 2019

Table of contents

Table index

Figure index

1. Introduction

1.1 Purpose of this report

North East Link (‘the project’) is a proposed new freeway-standard road connection that would complete the missing link in Melbourne’s ring road, giving the city a fully completed orbital connection for the first time. North East Link would connect the M80 Ring Road (otherwise known as the Metropolitan Ring Road) to the Eastern Freeway, and include works along the Eastern Freeway from near Hoddle Street to Springvale Road.

North East Link was referred to the Minister for Planning on 12 January 2018. On 2 February 2018, the Minister issued a decision determining that an Environment Effects Statement (EES) is required for the project due to the potential for significant environmental effects. Similarly, the project was referred to the Australian Government’s Department of the Environment and Energy on 17 January 2018. On 13 April 2018 the project was declared a ‘controlled action’, requiring assessment and approval under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act).

This technical report describes numerical groundwater modelling undertaken to predict potential changes to groundwater caused by the project, specifically the cut and cover structures and tunnels that would be constructed below the existing water table. The report provides key inputs to the preparation of the EES and the Public Environment Report for assessment under the EPBC Act.

1.2 Study objective

The project is located adjacent to environmentally sensitive areas, with groundwater connected water bodies and groundwater-dependent ecosystems that are potentially sensitive to changes in the elevation of water table, groundwater fluxes and water quality. These include water bodies such as the Bolin Bolin Billabong, a high value ox-bow lake on the floodplain of the Yarra River in Bulleen, and vegetation that is potentially reliant on groundwater to meet some of its water requirements. The primary objective of numerical groundwater modelling is to inform potential impacts and risks of the project on these sensitive receptors.

To meet this objective, the groundwater model must be capable of predicting potential changes to existing groundwater levels and fluxes arising from interactions with the project. Outputs from the modelling are required in a format suitable to assist hydrogeologists, ecologists and other relevant specialists to evaluate risks of the projects to groundwater sensitive receptors and to inform measures necessary to mitigate and manage these impacts.

1.3 Modelling approach

1.3.1 Staged approach

The development of major projects is rarely undertaken in a linear fashion. Instead many assessments are typically carried out during the course of the project, with field investigations and data collection often occurring in parallel to conceptualisation and modelling. While the groundwater modelling described in this report has followed a staged approach broadly consistent with the recommendations of the Australian Groundwater Modelling guidelines (Barnett *et al.*, 2012), the development of the hydrogeological conceptual model and numerical groundwater model involved several iterations informed by concurrent hydrogeological investigations and data. This included simple ‘proof of concept’ numerical groundwater modelling undertaken prior to data collection, findings of which have provided inputs to the design and construction of the groundwater model described in this report.

1.3.2 Target confidence level and model complexity

The modelling effort required to meet the study objective is guided by the target confidence level and complexity of the model. Confidence in model predictions depends fundamentally on the availability of data, whether or not sufficient data are available to characterise the groundwater flow processes of interest and whether or not sufficient information is available to inform hydrogeological parameters that have the greatest influence on model predictions. Complexity of the model reflects the level of sophistication of modelling techniques such as mesh design, degree of parameterisation and choice of boundary conditions.

The groundwater model developed for the project is of regional scale, with model design and parametrisation guided by data obtained from drill holes and monitoring bores distributed along some 10 kilometres of the proposed alignment. The target confidence level of the model in accordance with the Australian Groundwater Modelling guidelines (Barnett *et al.,* 2012) is class 1 (and some aspects of class 2), with a moderate level complexity that is commensurate with the intended model use and currently available data. Section 4.4 discusses the model confidence level achieved within the context of data availability, calibration performance and predictive requirements.

1.3.3 Structure of this report

This report has been structured to align with the staged approach adopted for groundwater modelling, with findings described in each section of the report informing the subsequent sections in a progressive manner. The existing hydrogeological conditions and conceptualisation of groundwater systems that underpin the development of the numerical model are described in EES Technical report N – Groundwater and are not duplicated here, although key datasets are described where relevant in supporting the model design and choice of parameters:

- Section 2 describes the design and construction of the numerical groundwater model
- Section 3 describes model calibration and sensitivity analysis
- Section 4 describes model predictions
- Section 5 describes predictive uncertainty analysis.

2. Model design and construction

2.1 Software

An unstructured grid version of the industry standard MODFLOW code, called MODFLOW-USG (Panday *et al.*, 2013), has been selected as the most appropriate groundwater modelling software for this study. Features of MODFLOW-USG that are particularly suited to addressing the modelling needs and objectives include:

- Flexible meshing, utilising a range of cell shapes, that allows model cells to closely follow the geometry of structures (such as tunnel alignment and diaphragm walls) and hydrological features, enabling more accurate representation of the physical system.
- Efficient local mesh refinement around features of interest within a regional model domain while retaining larger cells elsewhere, minimising model size (total cell count) and run times without compromising resolution in critical areas. The model layers can also 'pinch out' where hydrostratigraphic units (HSUs) are not present and cells are not required throughout the model domain. This has flow-on benefits to the modern requirements of modelling projects such as run-intensive calibration and uncertainty analysis.
- Robust handling of de-saturation and re-saturation of model cells for tracking the water table across multiple model layers, based on the Upstream Weighting scheme of MODFLOW-NWT (Niswonger *et al*., 2011). In this case, all model layers are of the Upstream Weighting type.
- Capability of dynamically varying material properties during model simulation, such as to represent the placement of base slabs at different times during construction, using the Time-Variant Materials (TVM) package.
- Extraction of local water balance, such as in and out of group of cells, which can be implemented easily using the utility ZONEBUDGET.

The unstructured mesh of the MODFLOW-USG model has been generated using AlgoMesh 1.2 (HydroAlgorithmics, 2016) and model input files have been prepared using a combination of AlgoMesh, Geographic Information Systems (GIS) and a range of in-house and third-party utilities. The model runs have been undertaken using the beta version of MODFLOW-USG, distributed with Groundwater Vistas by Environmental Simulations Incorporated (ESI), which supports advanced capabilities such as adaptive time stepping and the TVM package.

2.2 Model domain and mesh

2.2.1 Model domain

The model domain should be large enough to capture the key stresses imposed on the groundwater system and their area of influence, both in the context of past and future activities (Barnett *et al.*, 2012). Defining the domain therefore necessitates an understanding of the regional groundwater flow behaviour and the influence of future project activities.

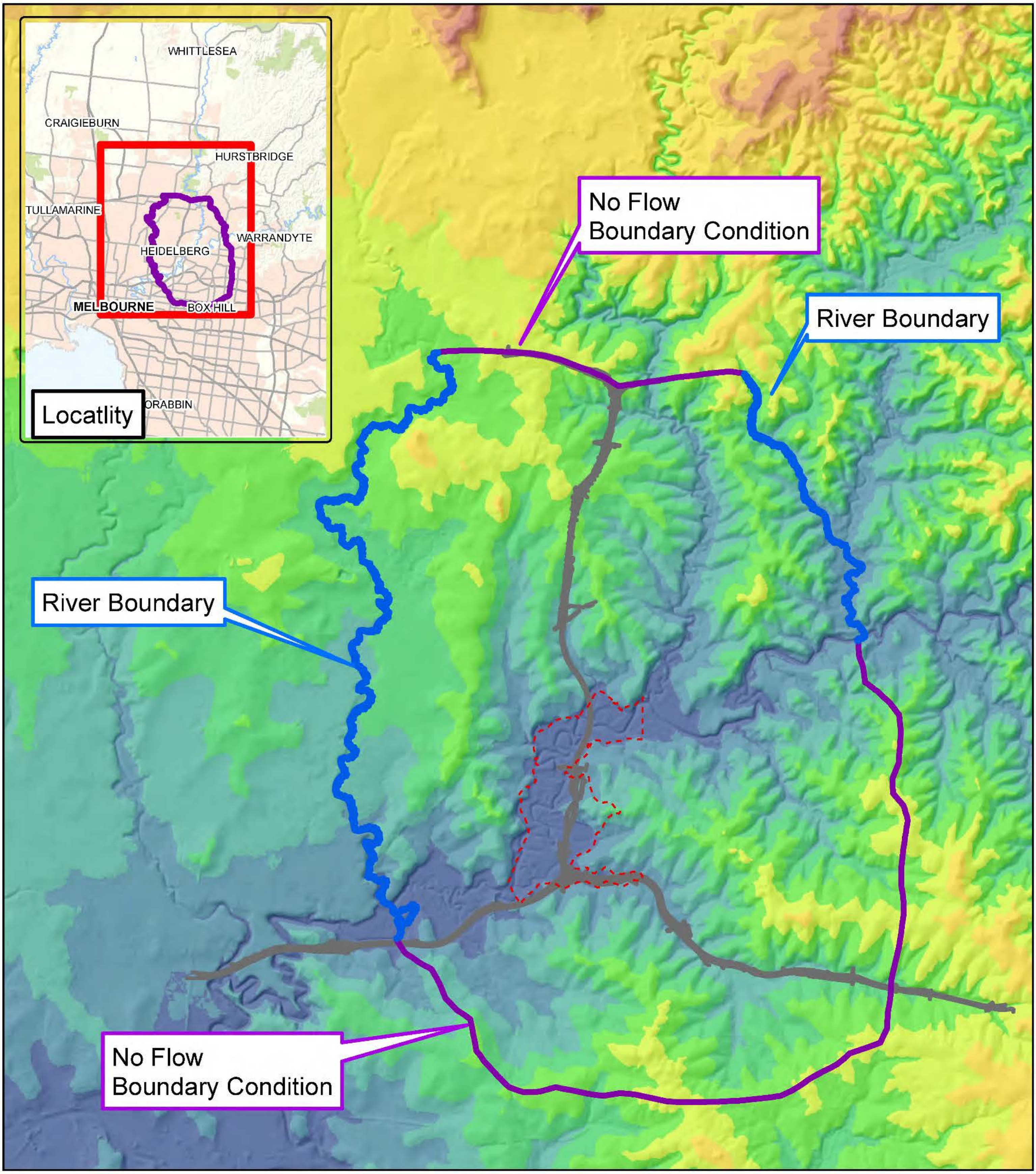
Figure 1 presents the model domain which encloses the project alignment, potential area of influence of project activities (as inferred from the preliminary 'proof of concept' modelling) and key hydrological features such as wetlands and rivers. A combination of regional topographical surface (VicMap 10 metre digital elevation model) and contours of the water table from regional datasets such as the Victorian Aquifer System (DELWP. 2017) and ecoMarkets Port Phillip model (GHD, 2010) have been used to define the location of hydrologically sensible boundaries. These follow regional flow lines along topographical ridges (inferred groundwater divides along the northern, southern and parts of eastern boundaries) and surface water courses (inferred groundwater discharge points along the western and eastern boundaries).

2.2.2 Model mesh

Figure 2 and Figure 3 present the model mesh, which uses voronoi-shaped (tessellated) cells (a shape considered numerically ideal for the control volume finite difference method employed by MODFLOW-USG). The mesh generation has carefully considered the following:

- Along the tunnelled (TBM and mined) sections of the alignment, the voronoi cells are approximately rectangular with cell width and length of around 10 metres and 13 metres respectively. A width of around 13 metres has been chosen as rectangular cells with a thickness of 13 metres has a cross-sectional area approximately equal to circular tunnels with an outer diameter of 15 metres (refer to Section 2.3 for descriptions of layer thickness). The cells closely follow the tunnel alignment, including where the alignment deviates from a straight line, enabling accurate representation of linear structures within the regional model domain.
- Along the perimeter of the tanked sections of Lower Plenty, Banksia and Southern (Bulleen) cut and cover excavations, the voronoi cells are approximately rectangular with cell width and length of around five metres to simulate the effect of diaphragm walls.
- Cell geometries follow hydrological features such as the Yarra River, Bolin Bolin Billabong, Banyule Billabong and other water bodies and minor drainage lines (based on VicMap stream and water body geometries). The cell lengths are around 5 –10 metres at the water bodies and around 20 – 30 metres along surface water courses.
- Cells are refined within the Alluvium, based on the mapped extent from project’s Leapfrog geological model and the Quaternary sediment extent from published geological maps.
- Nodes are centred on monitoring bores such that the centres of the voronoi cells coincide with the location of the bores.
- The mesh has been optimised to avoid poor cell shapes, retaining ‘ideal’ hexagonal cells within sub-areas where possible.

The model has eight layers with the same mesh refinement in plan. Pinch outs are enabled in selected layers where the layers are not continuous across the model domain (see Table 1). The model has a total of 251,613 cells.



Legend

Leapfrog geological model (Alluvium)	
GW Model Domain	
River Boundary Condition	
Proposed reference project	

Elevation (mAHD)

0.1 - 20	60.1 - 80	160.1 - 180
20.1 - 40	80.1 - 100	180.1 - 200
40.1 - 60	100.1 - 120	200.1 - 271.6
	120.1 - 160	

Paper Size A4

0 650 1,300 2,600

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Job Number 31-35006
Revision A
Date 26 Feb 2019

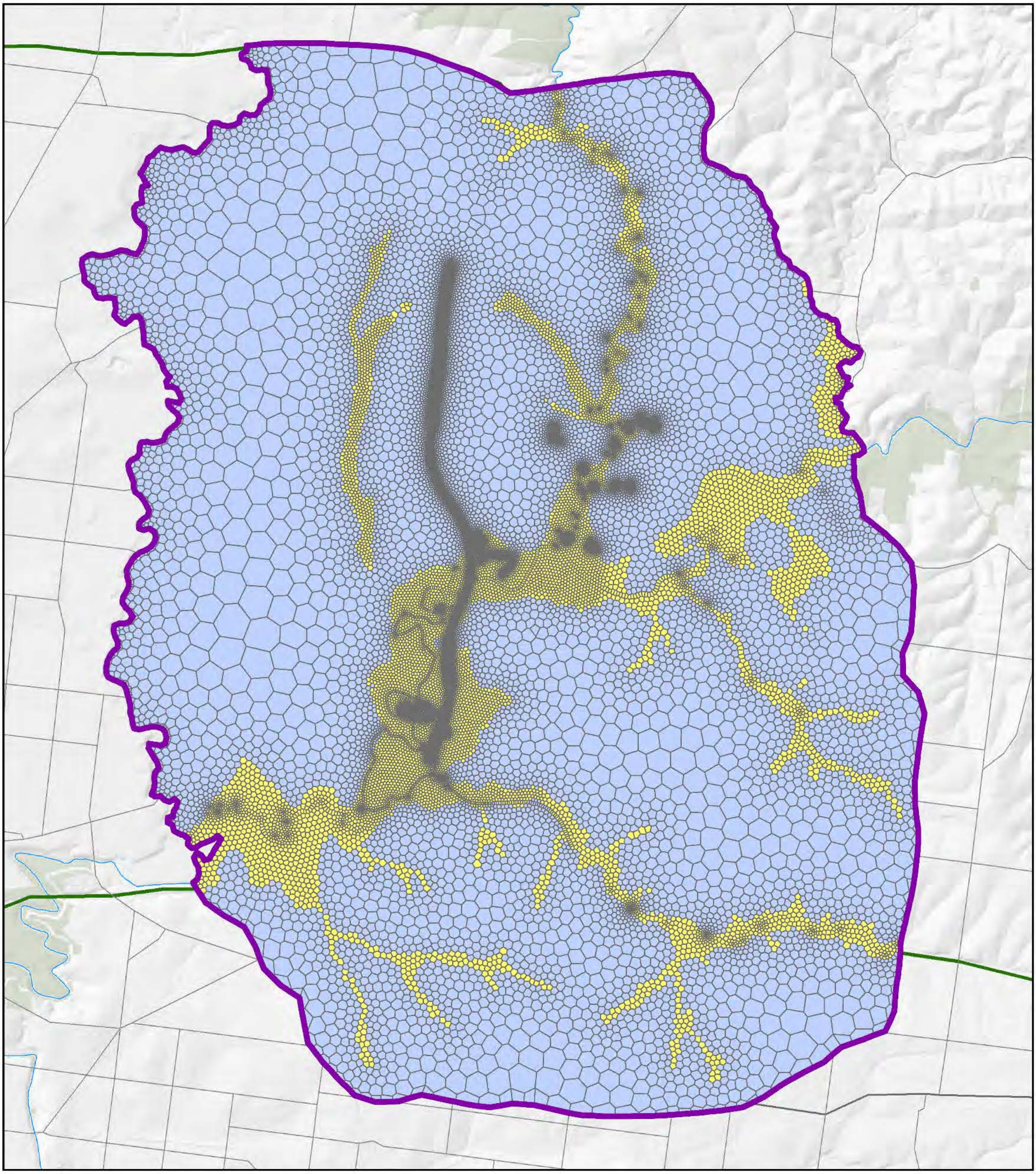
Groundwater Model
Model Domain

Figure 1

G:\31\35006\GIS\Maps\Deliverables\20180625_NEv3_GWModel_Figures\3135006_NEv3_A4P_GWModel_Fig01_Domain.mxd

Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com



Legend

GW Model Domain

Hydrostratigraphic Unit

Alluvium

Bedrock

Paper Size A4

0 460 920 1,840

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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North East Link Project
Environment Effects Statement (EES)

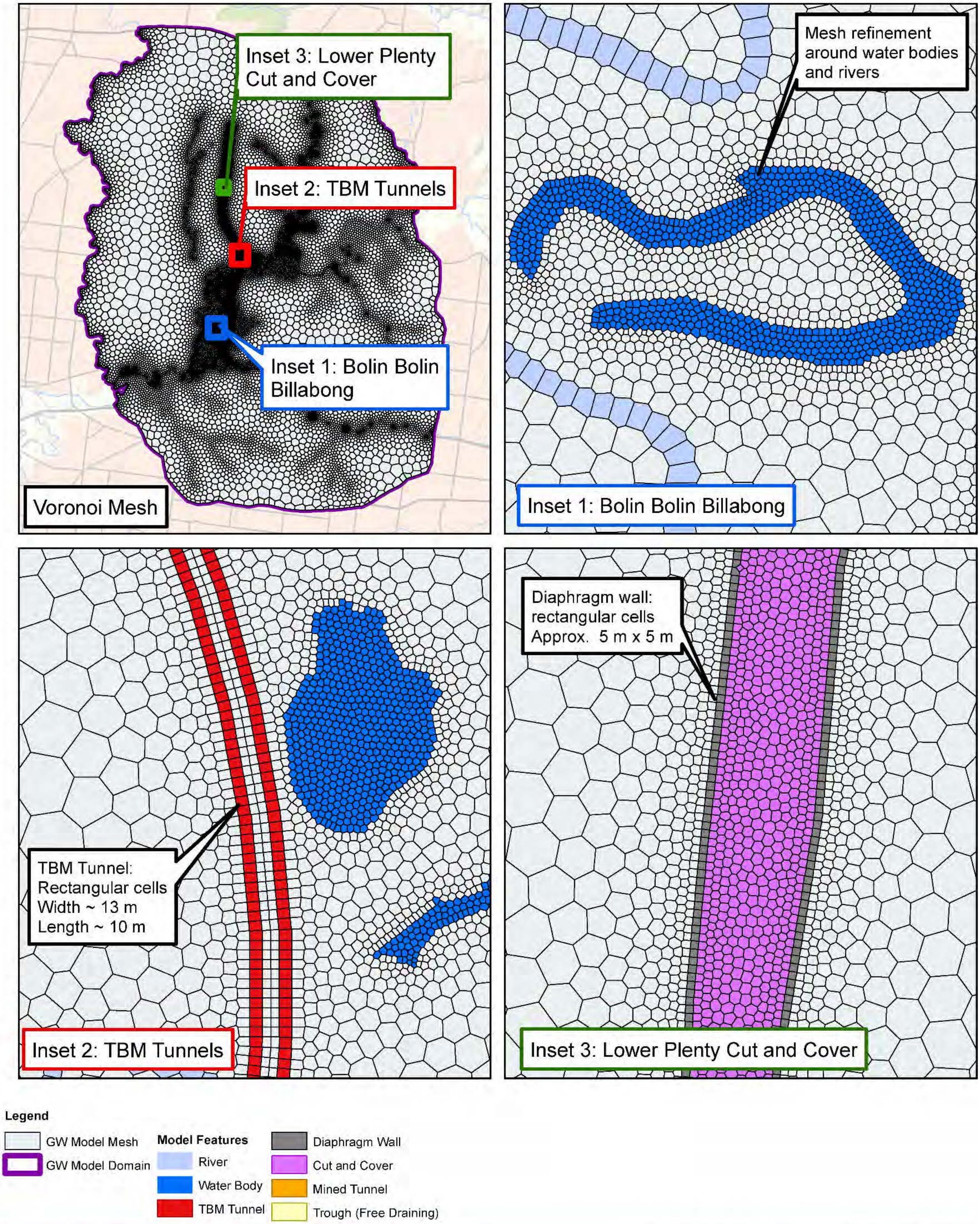
Job Number	31-35006
Revision	A
Date	26 Feb 2019

Model Mesh and
Hydrostratigraphic Units

Figure 2

G:\31\35006\GIS\Maps\Deliverables\20180625_NEv3_GWModel_Figures\3135006_NEv3_A4P_GWModel_Fig02_HydC… 180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Job Number 31-35006
Revision A
Date 26 Feb 2019

Groundwater Model Mesh and Hydrogeological Features

Figure 3

G:\31\35006\GIS\Maps\Working\20180627C_Groundwater_EES_Reports\20190226_NewUpdates\3135006_NEv3_A4P_GWModel_Fig03_ModelMeshAndHydrogeologycalFeatures.mxd

Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

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2.3 Model elevation and layering

The model top, representing land surface, has been sourced from the top of Leapfrog geological model (developed specifically for the project) and 10 by 10 metres VicMap digital elevation model (DEM). The top of the Leapfrog geological model has been derived from a LiDAR dataset except along the Yarra River where the model top represents the approximate bathymetry of the river (top of river bed) calculated from spot measurements provided by Melbourne Water.

Figure 4 shows the areas in the model domain where the two topographical datasets have been used (left inset) and the model top derived from these datasets (right inset). The area delineated as the Leapfrog model domain utilised the top of the Leapfrog geological model. As it can be seen in the figure, the transition from the Leapfrog geological model to VicMap DEM is smooth with no discernible differences in elevation across the boundary of the two datasets at the scale of the groundwater model. Along key surface water features such as the Bolin Bolin Billabong, higher resolution data derived from the top of the Leapfrog geological model provides greater vertical accuracy than the +/-5 metre accuracy of the VicMap DEM (refer to Section 2.4.2 for further details). Figure 5 is a 3D image of the model mesh and model top.

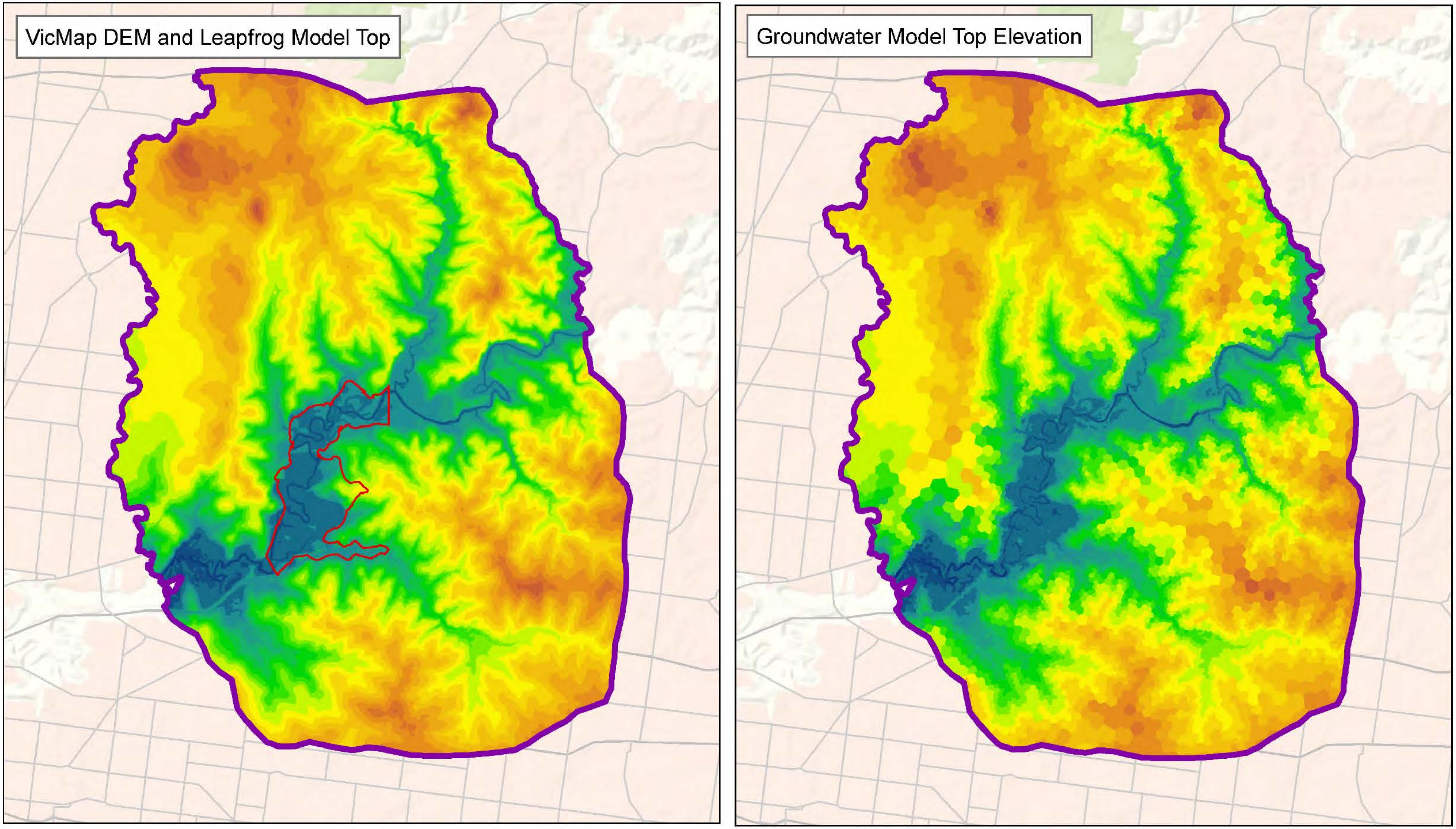
The base of model layer 1 corresponds to the bottom of the Alluvium, which is derived from the Leapfrog geological model and the Victorian Aquifer System (VAF). Although the lithology of the Alluvium can be variable on a local scale with interbedded lenses of sand and clay, this HSU is represented as one unit in the groundwater model. This level of simplification is considered appropriate for regional-scale modelling, as groundwater flow along the project alignment, over a distance of several kilometres, would depend more strongly on regional averages in aquifer properties. The geometry of the Alluvium in the Leapfrog geological model has been modelled using a combination of geological data including borehole logs and geophysical surveys. The thickness of the Alluvium outside the Leapfrog geological model domain is derived from the Quaternary Aquifer of the VAF.

The Bedrock unit underlying the Alluvium has been split into several model layers to accurately simulate the vertical alignment of the tunnels and cut and cover excavations, including the placement of the diaphragm walls. Figure 6 presents a north to south model cross-section taken along the project alignment, showing the relationship between the model layers and HSUs. The mid-point of model layer 5 follows the centreline of the tunnel alignment. The thickness of model layer 5 is set at 13 metres, as 13 by 13 metres square model cells have a cross-sectional area approximately equal to that of a circular tunnel with a diameter of around 15 metres. Along the cut and cover sections, the bottom of layer 5 corresponds to the base of the excavation except where the layer pinches out against the Alluvium (layer 1).

Model layers 3 and 7 are eight metres thick and layers 4 and 6 are four metres thick. These layers have been introduced into the Bedrock to provide the necessary vertical resolution for simulating the drainage of groundwater into the tunnels and excavations, in addition to enabling the toe of the diaphragm walls to penetrate below the base of the cut and cover excavations. The layers also allow accurate placement of observation and pumping bores within the Bedrock to assist with model calibration. These layer thicknesses are maintained along the project alignment except where the layers pinch out against the Alluvium. To minimise the total cell counts, pinch outs are also incorporated into model layers 2 to 5 some distance from the alignment where the same vertical resolution is not required in the Bedrock. To simplify the assignment of recharge and evapotranspiration, model layer 1 is maintained continuous throughout the model domain with the layer thickness reducing to one metre outside the Alluvium (properties from the underlying Bedrock are assigned where the layer 1 thickness is reduced to 1 metre).

Table 1 Model layers

Model layer	Cells	Purpose
1	42,641	Represents the full thickness of Alluvium (minimum thickness elsewhere).
2	11,520	Provides vertical resolution in the Bedrock above tunnels.
3	17,664	Provides vertical resolution in the Bedrock above tunnels.
4	21,648	Provides vertical resolution in the Bedrock above tunnels.
5	30,217	Represents the centreline of tunnel alignment and base of cut & covers.
6	42,641	Provides vertical resolution in Bedrock below tunnels and cut & covers. Allows the toe of diaphragm walls to penetrate below cut & cover base.
7	42,641	Provides vertical resolution in Bedrock below tunnels and cut & covers.
8	42,641	Base of the model (set at an elevation of -50 mAHD).



Paper Size A4

0 400 800 1,600 2,400 3,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

Leapfrog Domain

Topography (mAHD)

- 3.2 - 5.3
- 5.4 - 10
- 10.1 - 15.2
- 15.3 - 20
- 20.1 - 25.2
- 25.3 - 30
- 30.1 - 35.2
- 35.3 - 39.9
- 40 - 45.2
- 45.3 - 49.9
- 50 - 59.9
- 60 - 69.9
- 70 - 79.9
- 80 - 89.9
- 90 - 99.9
- 100 - 109.9
- 110 - 119.9
- 120 - 129.8
- 129.9 - 137.2

NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

Job Number | 31-35006
Revision | A
Date | 26 Feb 2019

Topographical datasets and groundwater model top

Figure 4

G:\31\35006\GIS\Maps\Working\20180627C_Groundwater_EES_Reports\20190226_NewUpdates\3135006_NEv3_A4L_GWModel_Fig04_Topography.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: BaseMaps / DTM, VicMaps, 2018; Image Basemaps, CIP, 2017; GW Model Layers, GHD, 2018. Created by:sacevedo

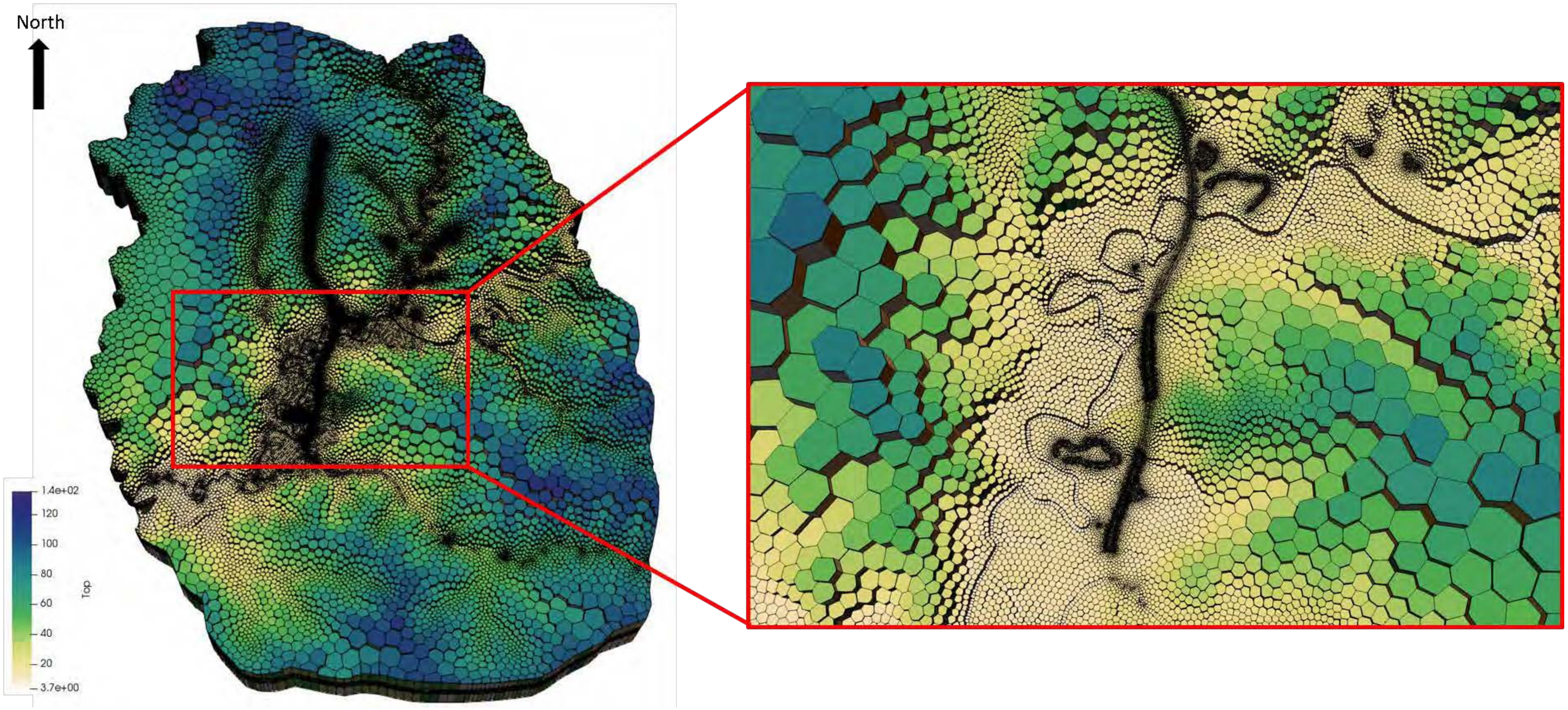


Figure 5 3D model view and model top

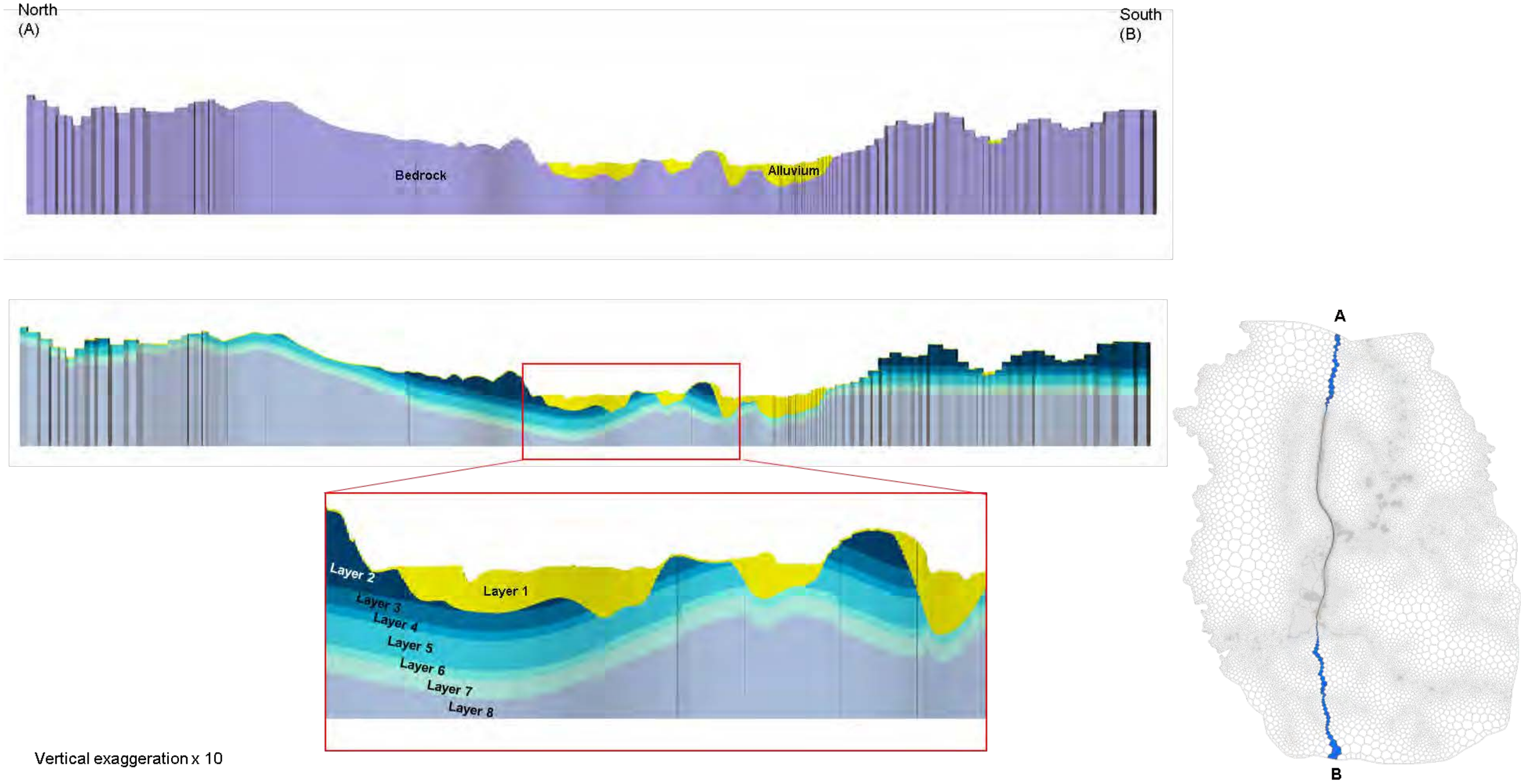


Figure 6 North to south model cross-section

2.4 Model boundary conditions

2.4.1 Recharge and evapotranspiration

Recharge is simulated using MODFLOW-USG's Recharge (RCH) package, applied to the uppermost active cells. A zone-based approach has been adopted, applying different recharge rates to the Alluvium (higher permeability sediments in low-lying areas within the floodplain) and Bedrock. Recharge rates have been estimated during model calibration.

Evapotranspiration in areas of shallow water table is simulated using MODFLOW-USG's Evapotranspiration (EVT) package. The EVT surface is set equal to model top (ground surface) and EVT rate and extinction depth, each as a single model-wide value, have been adjusted during model calibration.

Recharge and EVT rates are discussed further in Section 3.3.1. Recharge and EVT are both set to zero over the River cells.

2.4.2 River boundary conditions

MODFLOW-USG River (RIV) boundary conditions are used to simulate major surface water courses and wetlands. The location of RIV cells are shown in Figure 8.

The major surface water courses simulated include the Yarra River, Plenty River and other minor creeks based on the presence of surface water inferred from visual inspection of aerial images.

Major surface water courses

The model top along the Yarra River is approximately equal to the floor of the river within the Alluvium extent of the Leapfrog geological model. Along this reach of the river, the RIV stage is prescribed as 0.5 metres above the model cell top based on the long-term average river stages recorded at gauge 229200A (around 0.7 metres) and 229143A (around 0.4 metres), located around 5.9 kilometres and 1.3 kilometres east and west of the model domain respectively. For all other sections of water courses outside the Leapfrog geological model extent, the RIV stage is assumed to be equal to model top derived from VicMap DEM and water depth is assumed to be 0.5 metres, consistent with the ecoMarkets Port Phillip model (GHD, 2010). The RIV stage based on the VicMap DEM is approximate, with a vertical accuracy of +/- 5 metres or better (DSE, 2008). Figure 7 presents the configuration of RIV boundaries within and outside the Leapfrog model extent.

The conductance of each RIV cell is calculated based on a river width of 10 metres, river bed thickness of 0.5 metres and a single model wide river bed hydraulic conductivity value. The length of the river (also used in calculating conductance) has been calculated rigorously for each model cell based on the mapped stream geometries from VicMap. This means the conductance of every RIV cell along surface water courses varies to reflect different lengths of river traversing the voronoi cells of different edge lengths. While the water depth is expected to be variable, fluxes in and out of RIV cells are strongly influenced by a wide range of possible river bed hydraulic conductivity, which is not well understood. The river bed hydraulic conductivity has been estimated during model calibration and is discussed further in Section 3.3.1.

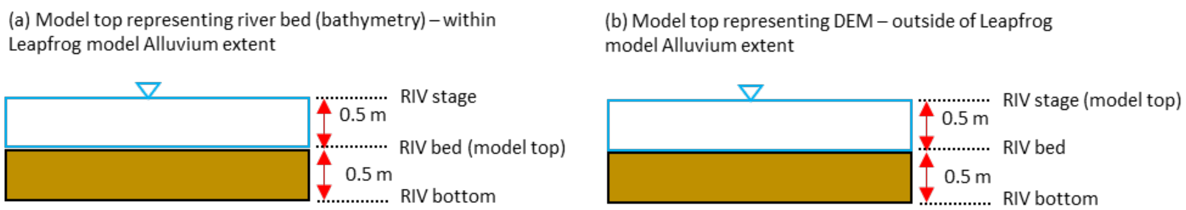
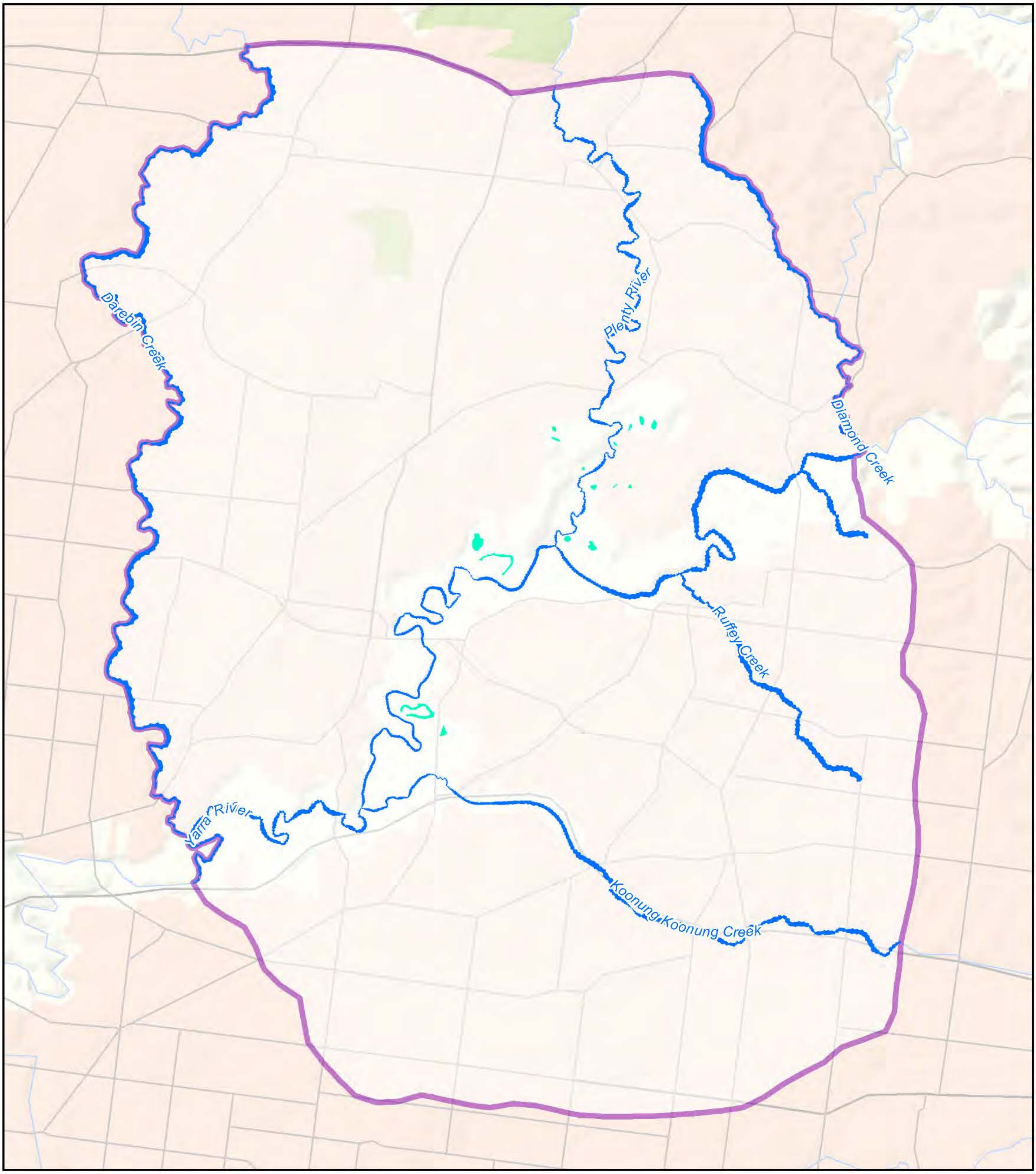


Figure 7 RIV boundary condition – surface water courses



Legend

GW Model Domain

RIV Boundary Condition

River

Water Body

Paper Size A4

0 460 920 1,840

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

North East Link Project
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Model Boundary Conditions - Existing Condition

Figure 8

G:\31\35006\GIS\Maps\Deliverables\20180625_NEv3_GWModel_Figures\3135006_NEv3_A4P_GWModel_Fig08_SS_BoundaryConditions.mxd

Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

Water bodies

Bolin Bolin Billabong is an ox-bow lake of high environmental value, located on the floodplain of the Yarra River in Bulleen and in close proximity to the project alignment. The billabong comprises a deep pool located in the south-east corner and wet-dry arms that are located on higher ground. According to Melbourne Water's conceptual model, the wet-dry arms are intermittently inundated primarily by overbank and bankfull flows from the Yarra River, with ponding of water to a depth of around 0.5 metres, whereas the deep pool is likely to be groundwater-fed and dries once every 10 years. Melbourne Water's survey data from October 2017 indicates the floor of the wet-dry arms typically ranges from around 7 mAHD to 8.5 mAHD in elevation and the water level in the deep pool is around 6 mAHD. This is consistent with the elevation of model top derived from the Leapfrog geological model (based on LiDAR data), which reflects the surface water level over the deep pool and dry floor elevation over the wet-dry arms, as shown in Figure 9.

A bathymetric survey of the deep pool has also been completed by Melbourne Water along five east to west transects. The survey data indicates the deep pool is up to 1.9 metres deep in the centre and has an average depth of around 1.5 metres, equating to an average floor elevation of around 4.5 metres AHD (based on a 6-metre AHD water level). The surface water and floor levels of the deep pool are lower than the groundwater levels measured in bores located 100 – 200 metres east of the billabong, which range from around 7.8 metres AHD to 13 metres AHD. This suggests the deep pool is a low point in the groundwater system with local groundwater flow towards it, consistent with Melbourne Water's conceptualisation that the deep pool represents a zone of groundwater discharge.

Figure 10 presents the RIV boundary condition assigned to the deep pool and wet-dry arms based on the existing data. For the wet-dry arms, a water depth of 0.25 metres, equal to 50 per cent of the typical water depth, has been used to account for the intermittent nature of this water body.

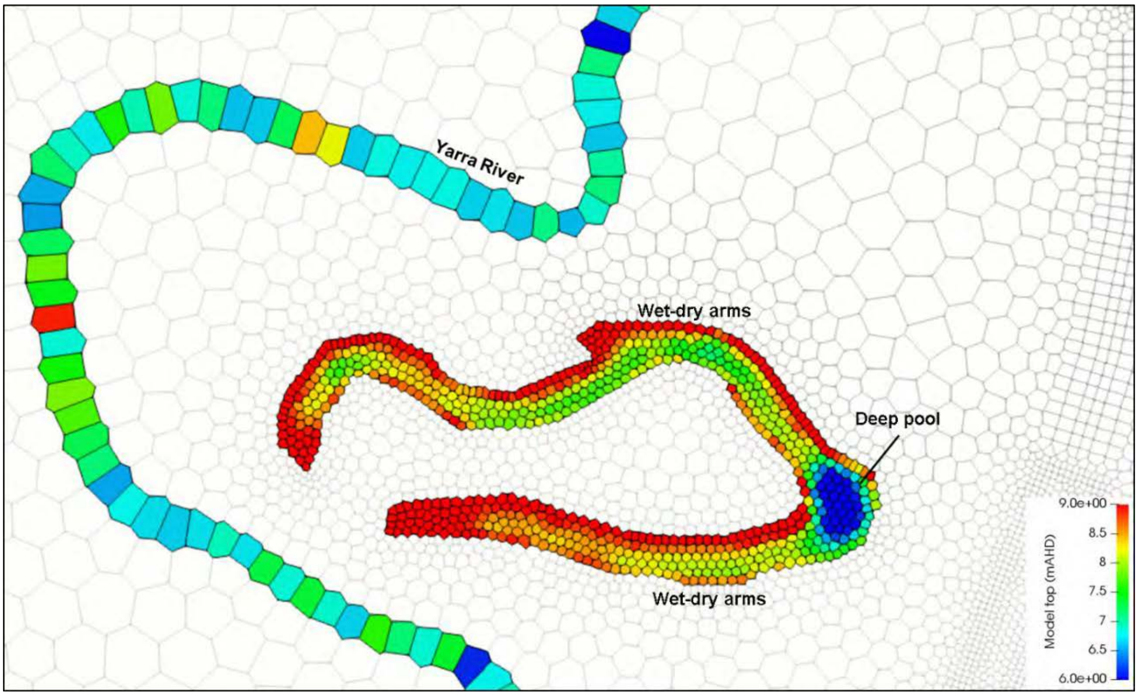


Figure 9 Model top at Bolin Bolin Billabong RIV cells

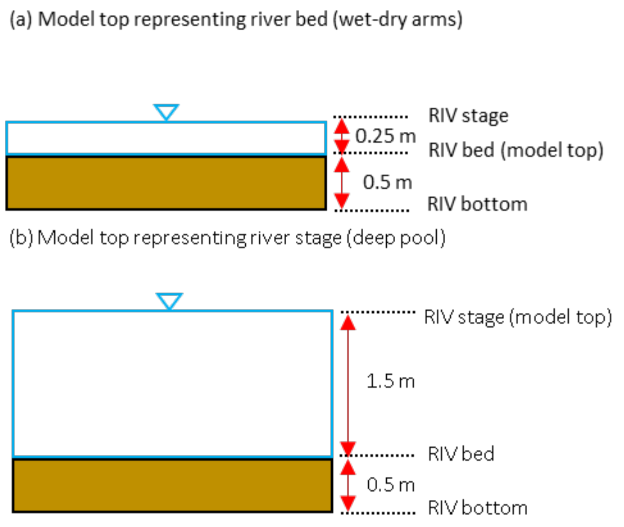


Figure 10 RIV boundary condition – Bolin Bolin Billabong

For Banyule Billabong, located on the northern side of the Yarra River in Heidelberg, the RIV stage is set equal to model top (DEM) with the top of RIV bed set at two metres below the model top based on a typical water depth of less than two metres in the deep freshwater marsh. The same configuration is assumed for Banyule Swamp, simulating these water bodies as a losing (recharge) feature in the groundwater system consistent with their elevated levels and the flow regime outlined in Melbourne Water's conceptual model. For all other water bodies, the RIV stage is assumed to be equal to model top (DEM) with the top of RIV bed set at 0.5 metres below model top.

The RIV conductance for all water bodies is calculated using a single model wide river bed hydraulic conductivity, a RIV bed thickness of 0.5 metres and the surface area of each RIV cell. A consistent approach is therefore applied to estimate RIV conductance for all water bodies, accounting for the differences in the surface area of voronoi cells.

2.4.3 Well boundary condition

MODFLOW-USG Well (WEL) boundary condition is used to simulate the effect of extracting groundwater via pumping wells, for calibrating the model to pumping test data. The WEL boundary condition is also used to simulate leakage of groundwater into the TBM and lined tunnels, which is described further in Section 4.1.

2.4.4 Drain boundary condition

MODFLOW-USG Drain (DRN) boundary condition is used to simulate the effect of construction dewatering in accordance with the proposed project construction schedule. Further details are provided in Section 4.1, describing the model configuration for predictive modelling.

2.5 Model parameterisation

Parameterisation involves making choices about how the spatial distribution of aquifer properties will be represented in the model (Barnett *et al.*, 2012). Models with the smallest number of parameters possible are described as parsimonious, whereas models with a large number of spatially varying parameters are described as highly parameterised. In modelling studies, a balance is sought between parsimony and complexity (highly parameterised spatial variability) that is consistent with the objective of modelling, the physical system of interest and supporting data.

In this study, the model has been parameterised on a HSU basis; however, hydraulic conductivities have been varied spatially within the Bedrock via interpolation of parameter values assigned to strategically positioned points called ‘pilot points’ (Doherty, 2003). Spatial variability in hydraulic conductivities, both horizontally and vertically, allows flexibility in the parametrisation of the heterogeneous fractured rock aquifer. This is particularly relevant where data obtained from pumping tests indicate spatial differences in groundwater behaviour along the project alignment, which cannot be appropriately replicated using a single model wide parameter. It should be noted that the model does not simulate flow along discrete fractures, which cannot be explicitly simulated without adequate supporting data. Instead, the model assumes a continuum approach whereby the aquifers are represented as zones of effective porous medium and the flow of groundwater through volumes of aquifers affected by the project is controlled by the bulk (albeit spatially varying) aquifer properties consistent with the regional scale of the impact assessment.

Specific yield and specific storage are assigned a constant value to each HSU, applying the principal of parsimony where appropriate and introducing complexity (spatial variability) as necessary to simulate the physical system of interest in a manner consistent with the data available.

Model parameterisation is discussed in further detail in Section 3.2.3, as part of model calibration.

3. Model calibration

3.1 Calibration performance criteria

Model calibration is a process by which model parameter values are altered within realistic bounds until the model outputs fit historical measurements, so that the model can be accepted as a reasonable representation of the physical system of interest (Barnett *et al*., 2012).
The quality of calibration is typically assessed against a predefined value of goodness of fit between simulated and observed values, using statistical measures such as the Scaled Root Mean Squared (SRMS) error. However, there are other criteria that can be used to assess the quality of model calibration and whether or not the model is fit for purpose. The following model calibration performance criteria have been adopted in this study:

- A target SRMS error of less than 10 per cent with respect to hydraulic heads, noting that SRMS error of <5 per cent is typically considered very well calibrated for a regional-scale model.
- The mass balance error of less than 1 per cent (Barnett *et al*., 2012).
- The model converges with an acceptably small convergence error and the model is numerically stable; that is, the simulated results are mathematically sound and the model is robust enough to be run multiple times during calibration and uncertainty analysis (Barnett *et al*., 2012).
- The model behaves in a manner consistent with the hydrogeological conceptual model and is capable of replicating key features of the hydrogeological system including:
  - Piezometric surface and groundwater flow directions consistent with the regional topography and those inferred from other studies such as the ecoMarkets Port Phillip model.
  - Drawdown of piezometric heads in response to pumping, as observed during pumping tests.

3.2 Calibration methodology

3.2.1 Calibration data

Key observation data available for model calibration include:

- Groundwater levels measured in April 2018 in 69 monitoring bores, providing an approximately synoptic dataset representing the existing distribution of hydraulic heads along the project alignment.
- Drawdown and recovery of groundwater levels recorded during three constant rate pumping tests, capturing the response of aquifers to stresses imposed by extraction of groundwater.

An estimate of long-term average baseflow to the Yarra River, between flow gauges 229142A and 229135A located within the model domain, is also available from SKM (2011). However, its baseflow estimate of around 23 megalitres (ML) per day, is derived from a method that accounts for surface water – groundwater interactions over the entire catchment represented between the gauges and baseflow contribution from sub-catchments (such as the Plenty River); not just that of the main river stem (SKM, 2011). As these catchment areas are significantly larger than the model domain (495 km^2 compared with around 60 km^2 between the flow gauges) and the reported baseflow value is an estimate only, it is applied as a loose calibration target representing the potential upper bound estimate of plausible baseflow.

To put into context, the dry and wet period baseflow to the Yarra River between the two flow gauges simulated by the ecoMarkets Port Phillip model is 3.3 ML/d to 6.85 ML/d respectively (GHD, 2010). Both the SKM (2011) and ecoMarkets (GHD, 2010) studies indicate that the Yarra River within the model domain is gaining more in the upstream section, becoming very low gaining to baseflow neutral in the downstream section. This provides a useful qualitative indicator of the nature of surface water – groundwater interaction expected within the model domain.

There are currently no long-term monitoring data available within the model domain to enable meaningful transient calibration to seasonal variations in rainfall-derived recharge. A search of the government database indicates that the nearest bores constructed in the Pre-Tertiary Bedrock aquifer with long-term monitoring data are located in Kinglake, 30 kilometres or more to the north-east of the project alignment. The majority of these bores are influenced by groundwater extraction, with data at only two locations (one nested bores) showing trends that are possibly representative of natural seasonal variations. Figure 11 presents the depth to water hydrograph of these bores, showing subtle seasonal variations of up to around two metres from 2010 to 2016, which generally mimics the monthly cumulative departure from mean (CDFM) rainfall.

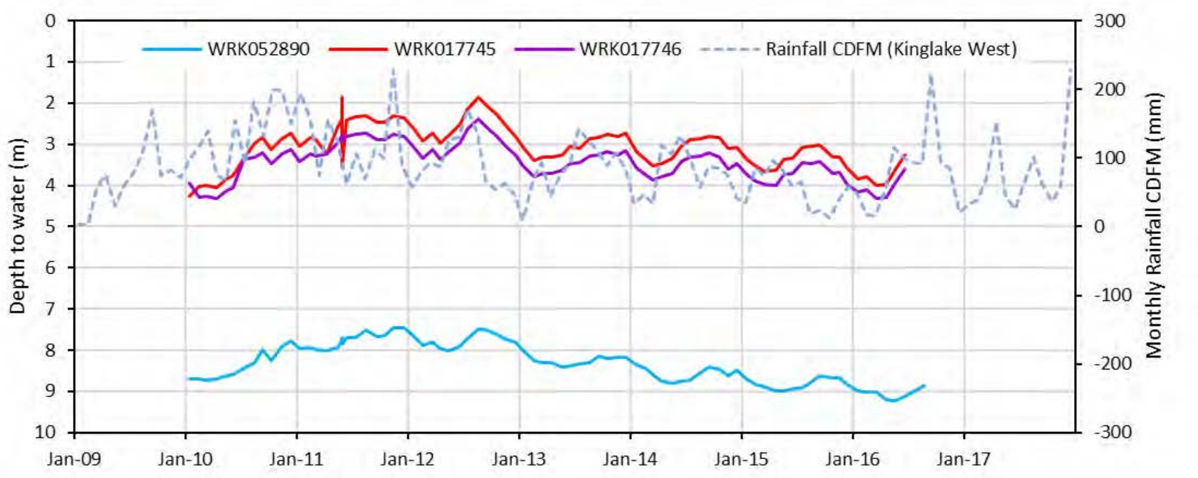


Figure 11 Regional bores (Kinglake) from state database

In the absence of long-term transient data, recharge is only calibrated in steady state representing an approximately average recharge rate. This means the model's ability to replicate seasonal dynamics of the shallow groundwater system (and reasonableness of recharge) cannot be rigorously assessed through calibration to existing data. When undertaking simulations to predict project-related impacts, the modelled groundwater levels would approximate a seasonally averaged response whereas in reality the groundwater levels will fluctuate about these modelled levels, potentially by around 1 – 2 metres.

Steady state calibration is also non-unique in the sense that only the ratio of recharge to hydraulic conductivity is identifiable. This limitation is partly addressed through transient calibration to pumping test data, ensuring that the model parameters are able to replicate, to some degree, the temporal effects of pumping as well as the spatial distribution of hydraulic heads.

The steady state modelled groundwater levels were verified against groundwater levels collected from additional 26 observation bores in August 2018, post-calibration.

3.2.2 Calibration approach

Calibration has been undertaken using a combination of manual (trial and error) and automated methods. The model has been run manually several times to test its stability and initial calibration performance, followed by a more rigorous automated parameter estimation using PEST(Doherty, 2016) and PEST_HP in a parallelized computing environment (Doherty, 2017).

Calibration consists of steady state calibration to April 2018 groundwater levels (heads) followed by transient calibration to drawdown observed during pumping tests, using the heads from the steady state calibration as initial heads. Both calibration runs have been integrated into a single PEST calibration workflow to ensure consistent parameters; that is, calibrated model parameters are able to simulate the distribution of hydraulic heads as well as drawdown due to pumping. This process is presented schematically in Figure 12. In addition to the heads, drawdown and flow observations, the total pumping rates have been included as calibration targets to minimise the potential for modelled pumping rates to fall below the actual pumping rates as MODFLOW-USG's autoflow correction adjusts the pumping rates.

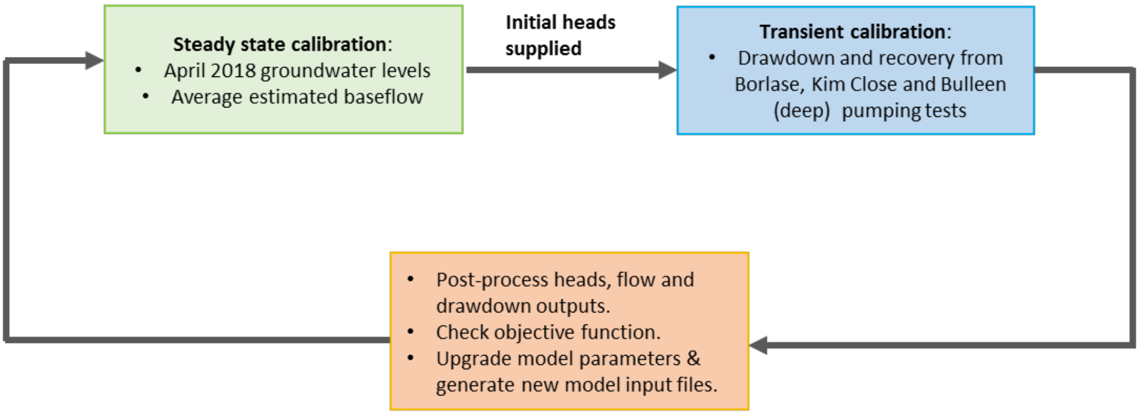


Figure 12 PEST calibration workflow

The automated calibration process has utilised a number of PEST utilities to facilitate pre- and post-processing efforts including:

- PAR2PAR (Doherty, 2016b) that converts the RIV hydraulic conductivity into a unique RIV conductance value for each RIV cell, taking into account the actual river length traversing each voronoi cell. This approach ensures that RIV conductance is consistent with the size of the voronoi cells, which is updated as PEST adjusts the single model wide RIV hydraulic conductivity during calibration.
- PLPROC (Doherty, 2016d) that undertakes spatial interpolation of horizontal hydraulic conductivities from pilot points to the model mesh, in this case to all model cells representing the Bedrock aquifer.
- USGMOD2OBS (Doherty, 2016c) that extracts computed hydraulic heads and drawdown at the time and location of observations.

In addition to the PEST utilities, an in-house utility has been used to convert horizontal hydraulic conductivities into vertical hydraulic conductivities from the calibrated vertical hydraulic conductivity factor (the ratio of horizontal to vertical hydraulic conductivities) and USGS ZONEBUDGET utility is used to extract baseflow (leakage out from the RIV cells) and pumping rates from the cell-by-cell flow file.

A single batch file has been prepared to run PEST and associated utilities in a sequential order and to process model outputs.

3.2.3 Calibration parameters

The horizontal hydraulic conductivities of the Bedrock aquifer are calibrated using pilot points. At each pumping test site, four pilot points are positioned one of which is located near the pumping bore and others located between the observation bores. Additional pilot points are positioned along the alignment where the observation bores are located outside the area of influence of pumping tests. A total of four regional pilot points are used outside the project alignment to facilitate the interpolation of hydraulic conductivity from the pilot points located along the project alignment. Additional 23 pilot points are positioned on a 2.5 by 2.5-kilometre grid and are ‘tied’ to these regional (parent) pilot points. These tied pilot points are varied along with their parent pilot point as a group, ensuring smooth spatial interpolation of hydraulic conductivity some distance from the alignment. The location of pilot points is shown in Figure 13.

At the pumping test sites, the pilot point is assigned an initial value derived from the analysis of the pumping test data. Elsewhere, an initial value of 0.02 m/d is assigned based on the analysis of slug and packer test data, taking into consideration data from other similar sites. The hydraulic conductivity of the Bedrock pilot points is allowed to vary from 0.005 m/d to 0.5 m/d, a range that is considered realistic for the bulk hydraulic conductivity at the scale of the model. For example, geometric mean hydraulic conductivity from slug and packer testing is around 0.1 m/d and 0.01 m/d respectively and data from other similar sites typically range from around 0.002 m/d to 0.5 m/d. Therefore, hydraulic conductivities of greater than 0.5 m/d derived from some test intervals are not considered representative of bulk averages.

The number of adjustable pilot points is kept as small as possible, to maintain hydraulic conductivity distribution consistent with the density of available data and to minimise risks of overfitting the data or introducing spurious heterogeneity. Prior information is included, using the hydraulic conductivity estimates derived from the analysis of pumping tests as preferred parameter values for pilot points located near the pumping bores. A pilot point covariance matrix is also used to account for spatial interdependence of each pilot point to surrounding pilot points. PEST is then run in the regularisation mode to minimise parameter variability unless deemed necessary during calibration.

The Alluvium is represented as a single zone, with the upper bound hydraulic conductivity set at 25 m/d based on the results of slug tests. The lower bound hydraulic conductivity is set at 0.1 m/d, which is lower than the range derived from slug testing and is intended to account for the presence of clay; that is, monitoring bores used in slug testing are generally screened in the sandier portions of the Alluvium whereas the presence of clay would be expected to reduce its bulk hydraulic conductivity.

The vertical hydraulic conductivities of the Alluvium and Bedrock are calculated by multiplying the horizontal hydraulic conductivities by vertical hydraulic conductivity factors, which are adjusted during calibration. A maximum value of 1 is used for this parameter so the horizontal hydraulic conductivities are not exceeded by the vertical hydraulic conductivities. Specific storage and specific yield are calibrated using a single model-wide parameter for each HSU, based on a typical literature-derived range of values for their lithologies and previous studies. Storativity derived from the analysis of pumping tests, while considered approximate, is generally towards the upper end of the calibration range.

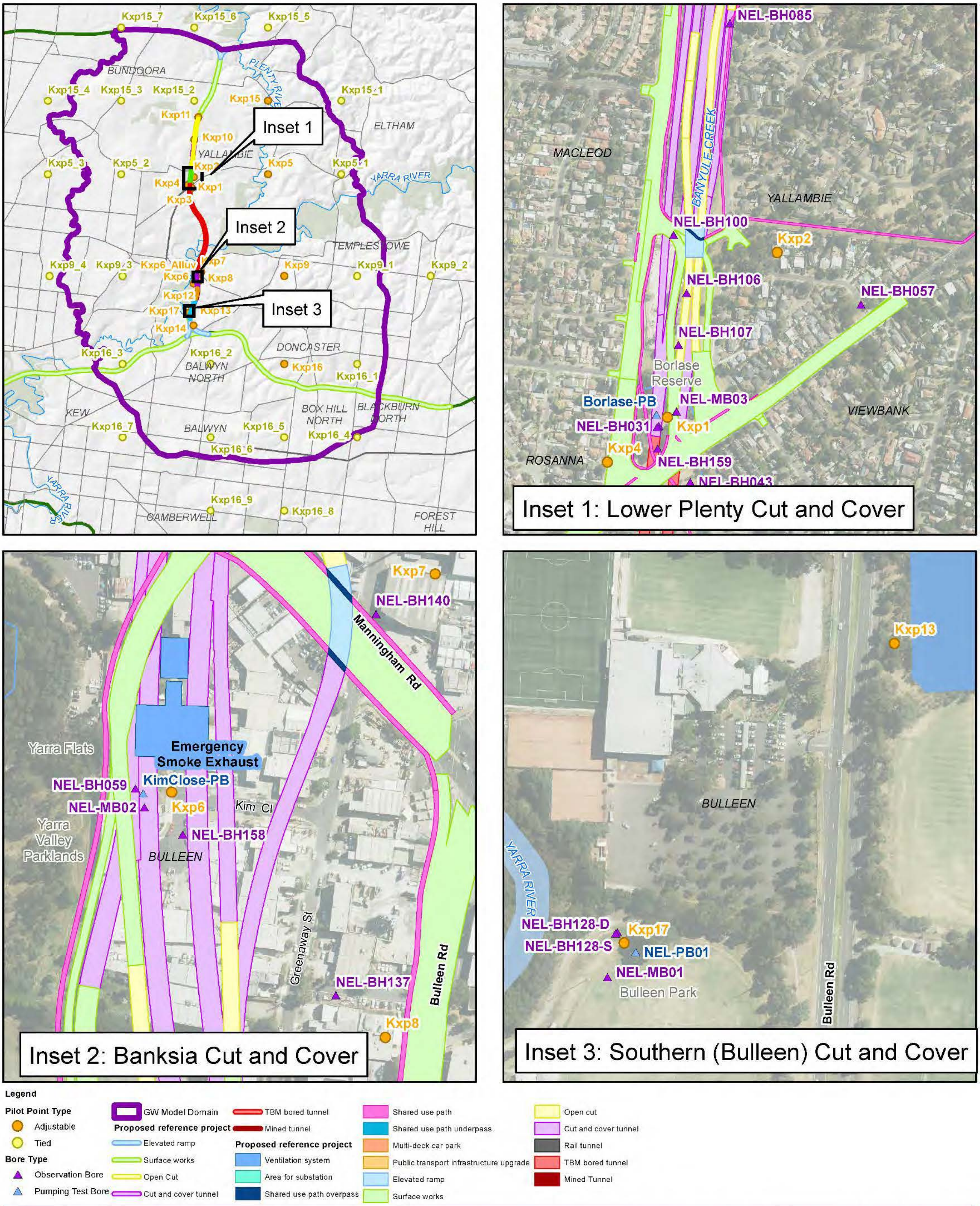
A single model wide RIV hydraulic conductivity is used to adjust RIV conductance, which is varied from 0.001 m/d to 1 m/d assuming a typical range of value for clayey/silty sands (Fetter, 2001). Recharge is varied from 10 mm/yr to 100 mm/yr. The maximum recharge is based on the long-term average recharge from the ecoMarkets Port Phillip model, which was derived from a recharge model called Ensym and is considered to represent the upper limit of plausible recharge, particularly over the Bedrock aquifer. Evapotranspiration (EVT) is varied from 500 mm/yr to 1300 mm/yr based on the Bureau of Meteorology (BoM) long-term average actual and potential EVT and calibrated using a single model wide multiplier. The EVT extinction depth is varied from 2 – 5 metres.

Table 2 Calibration parameters

PEST parameter ID	Parameter	Initial	Min	Max	Comment
kxp1 – 4	Bedrock Kx	0.16 m/d	0.005 m/d	0.5 m/d	Initial (preferred) value based on Borlase pumping test
kxp6 – 8	Bedrock Kx	0.06 m/d	0.005 m/d	0.5 m/d	Initial (preferred) value based on Kim Close pumping test
kxp13, 14 and 17	Bedrock Kx	0.125 m/d	0.005 m/d	0.5 m/d	Initial (preferred) value based on Bulleen (deep) pumping test
Kxp5, 9 - 12, 15-16*	Bedrock Kx	0.02 m/d	0.005 m/d	0.5 m/d	Range based on slug and packer tests and data from other similar sites
kxp6_alluv	Alluvium Kx	2 m/d	0.1 m/d	25 m/d	Range based on slug tests with lower min. to account for presence of clay
kzfact_alluv	Alluvium Kz factor	0.1	0.01	1	Maximum at 1 to prevent Kz>Kx
kzfact_bedr	Bedrock Kz factor	0.1	0.01	1	Maximum at 1 to prevent Kz>Kx
ss_alluv ^	Alluvium specific storage	5×10^{-5} /m	1×10^{-6} /m	1×10^{-3} /m	Range based on literature and other studies
ss_bedr ^	Bedrock specific storage	5×10^{-5} /m	1×10^{-6} /m	1×10^{-3} /m	Range based on pumping test, literature and other studies
sy_alluv	Alluvium specific yield	0.1	0.05	0.4	Range based on literature and other studies
sy_bedr	Bedrock specific yield	0.05	0.01	0.2	Range based on literature and other studies
avmrch	Alluvium recharge	50 mm/yr	10 mm/yr	100 mm/yr	Maximum based on ecoMarkets Port Phillip model
bedrch	Bedrock recharge	10 mm/yr	10 mm/yr	100 mm/yr	Maximum based on ecoMarkets Port Phillip model
evt_mult	EVT multiplier	1	0.9	2.36	Starting value 550 mm/yr, range 500 to 1300 mm/yr
exdp	EVT extinction depth	5 m	2 m	5 m	Range based on plausible rooting depths
riverk	RIV hydraulic conductivity	0.005 m/d	0.001 m/d	1 m/d	Typical range of values for clayey/silty sands

* Pilot points outside the area of influence of pumping tests

^Recent publication by Rau et al (2018) suggests a plausible upper threshold of specific storage for confined aquifers to be around 1.3 x 10-5 /m, much lower than the typical literature derived range of values (and those derived from the analysis of pumping tests). While the publication of this paper post-dates model calibration, the calibrated specific storage (see Section 3.3.1) and the range of values tested during uncertainty analysis (see Section 5.2) are within the range of plausible values proposed by Rau et al (2018).



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0 20 40 80

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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NORTH EAST LINK PROJECT

North East Link Project
Environment Effects Statement (EES)

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Revision	A
Date	26 Feb 2019

Pilot points and pumping test bore locations

Figure 13

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Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018; GW Bores, GHD, 2018. Created by:sacevedo

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3.3 Calibration performance

3.3.1 Calibrated parameters

Table 3 provides a summary of the calibrated model parameters and Figure 15 presents the calibrated horizontal hydraulic conductivities of the Bedrock based on the spatial interpolation of calibrated parameter values at the pilot points. The calibrated horizontal hydraulic conductivities at each pumping test site are generally consistent with those derived from the analysis of pumping tests, although local variability can be seen between some pilot points. The calibrated horizontal hydraulic conductivity of the Alluvium is towards the upper end of the range and reflects the effect of high recharge applied over this unit to simulate realistic baseflow (refer to Section 3.3.5). The calibrated Bedrock specific storage is within the plausible range of value suggested by Rau *et al.,* (2018).

Table 3 Calibrated model parameters

Parameter	Calibrated value
Bedrock Kx	0.005 – 0.5 m/d
Alluvium Kx	13 m/d
Alluvium Kz factor	0.01
Bedrock Kz factor	0.17
Alluvium specific storage*	3.1 x 10^{-5} /m
Bedrock specific storage	1 x 10^{-5} /m
Alluvium specific yield	0.05
Bedrock specific yield	0.01
Alluvium recharge	100 mm/yr
Bedrock recharge	10 mm/yr
EVT multiplier (EVT rate)	2.36 (1,298 mm/yr)
EVT extinction depth	5 m
RIV hydraulic conductivity	0.008 m/d

*Alluvium is unconfined and specific storage is not used by the model

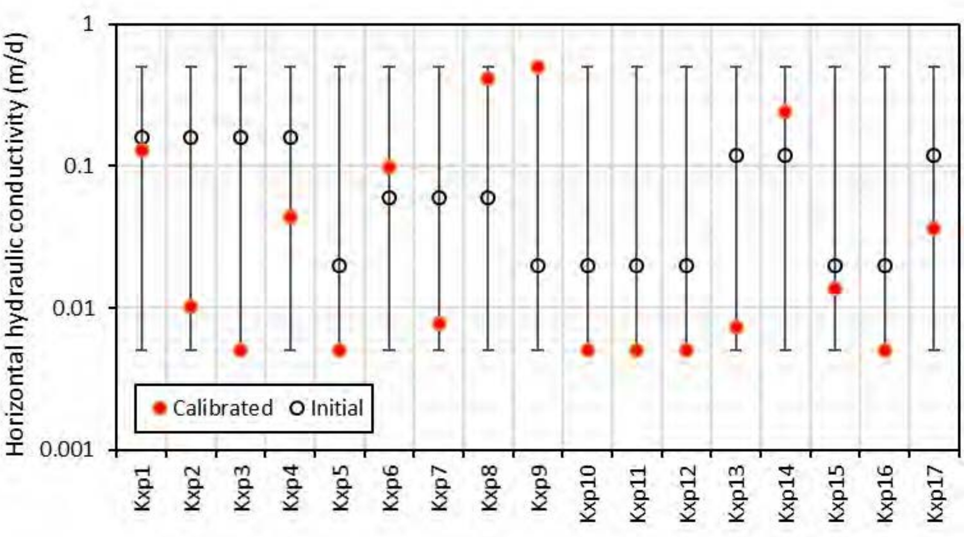
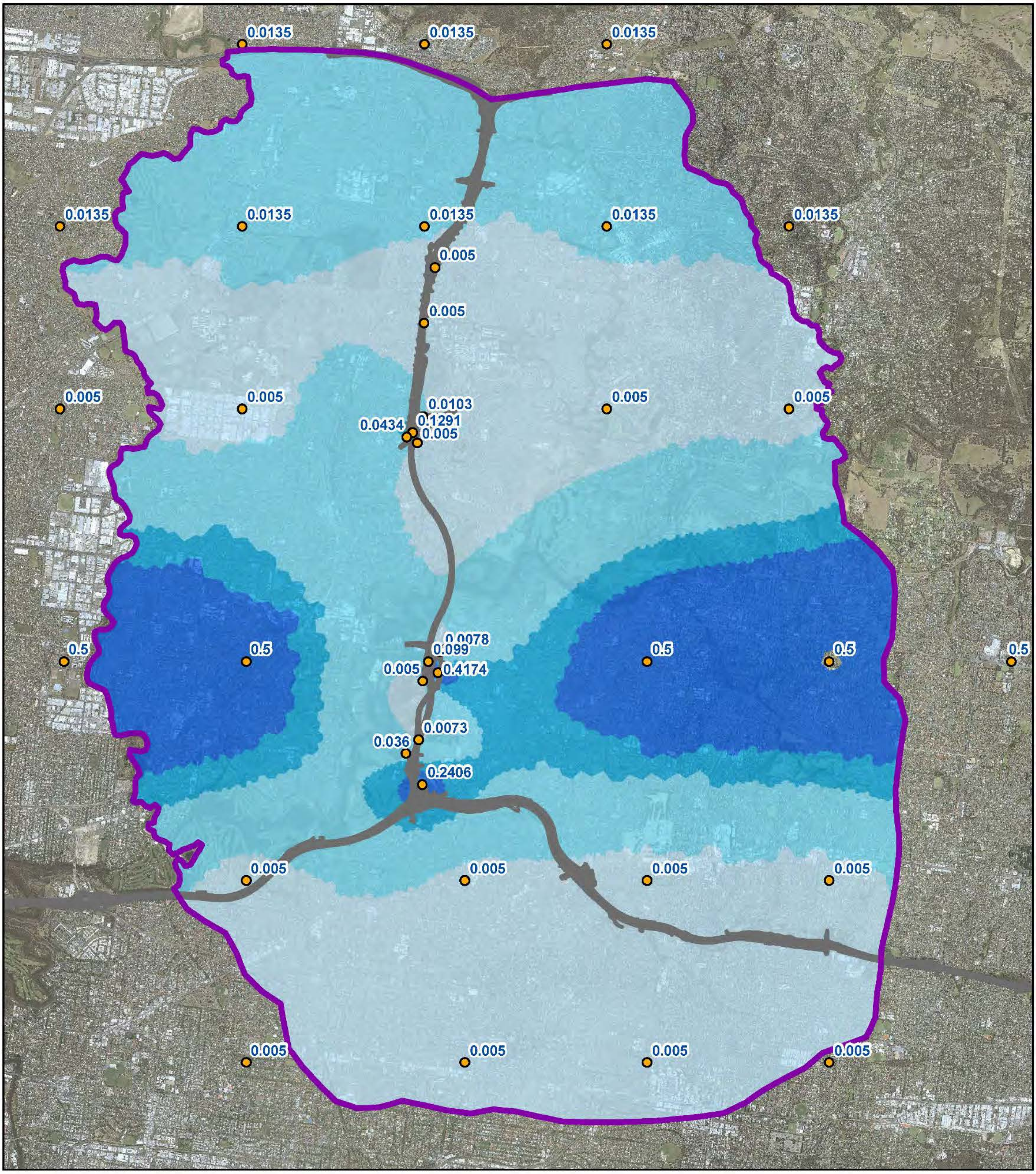


Figure 14 Calibrated pilot point horizontal hydraulic conductivity



Legend

GW Model Domain

Proposed reference project

Pilot Point

Calibrated Bedrock Kx (m/day)

Calibrated Hydralic Conductivity

Bedrock Kx (m/day)

0.004 - 0.010

0.011 - 0.050

0.051 - 0.100

0.101 - 0.483

Paper Size A4

0 460 920 1,840

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Environment Effects Statement (EES)

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Date 26 Feb 2019

Calibrated Bedrock
Horizontal Hydraulic Conductivity

Figure 15

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Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

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3.3.2 Parameter sensitivity

Automated calibration involves running the model many times, from which PEST calculates a figure related to the sensitivity of each parameter with respect to all observations. This information, referred to as composite parameter sensitivity, can be used to assess how sensitive each parameter is based on the information contained in the calibration dataset.

Figure 16 presents the PEST composite parameter sensitivity to all observations as well as sensitivity with respect to each observation group. The sensitivities computed by PEST are generally as expected, indicating high sensitivity of:

- Steady-state head calibration to recharge, hydraulic conductivity and evapotranspiration.
- Drawdown calibration to bedrock hydraulic conductivities and specific storage.
- Baseflow calibration to evapotranspiration, RIV conductance, recharge and hydraulic conductivity particularly over the Alluvium.

3.3.3 Calibrated water table contours

Figure 17 presents the simulated contours of the water table, derived from the uppermost active heads computed by the model. The figure also includes the observed and computed heads at the monitoring bores used in steady state calibration, providing indications of spatial differences in the quality of steady state calibration. The surface of the water table mimics the topography, with groundwater flowing towards discharge zones represented by water courses and drainage lines where groundwater discharges via baseflow and evapotranspiration. The deep pool within the Bolin Bolin Billabong is simulated as a zone of net groundwater discharge whereas the Banyule Swamp is simulated as a leaky feature, consistent with the existing conceptualisations and observed water levels.

3.3.4 Calibrated drawdown hydrographs

A series of hydrographs comparing the computed and observed drawdown are presented in Figure 18 (note the start of pumping test has been normalised to 14 June for all three tests). In general, drawdown and recovery are best calibrated to monitoring bores located within 50 – 100 metres of the pumping bores. The match between the computed and observed drawdown is poorer at bores located further away, as the magnitude of drawdown response decreases and starts to deviate from the ideal radial flow response.

The effect of local heterogeneity in fracture rock aquifers means achieving a high degree of match between the observed and computed drawdown at all locations is not always possible. The model is also of regional scale with a mesh that has not been optimised specifically for the simulation of pumping tests. Despite these limitations, the simulated responses are generally consistent with those expected from pumping and subsequent recovery, including a very small amount of drawdown induced in the Alluvium by the pumping (vertical leakage) in the underlying Bedrock (bores NEL-MB01 and NEL-BH128-S constructed within the Alluvium).

3.3.5 Calibrated baseflow

The simulated average baseflow to the Yarra River between flow gauges 229142A and 229135A is 1.77 ML/d. This is closer to the 3.3 ML/d to 6.85 ML/d range computed by the ecoMarkets Port Phillip model than the 23 ML/d estimate derived by SKM (2011) due to the size of the catchment (Section 3.2.1). The higher baseflows computed by the Port Phillip model are most likely due to high recharge applied equally to the Bedrock and Alluvium (around 100 mm/yr). This contrasts with lower calibrated recharge applied to the Bedrock in the project model, which is considered more consistent with the lower hydraulic conductivity of this aquifer and the ratio of recharge to hydraulic conductivity necessarily in matching the observed and computed heads.

With recharge at 100 mm/yr, the calibrated Alluvium hydraulic conductivity is 13 m/d which is considered to be at the high end of realistic average values (the majority of slug tests yielded values less than 5 m/d). Knowledge gained from model calibration indicates that it is possible to calibrate the model with lower recharge and hydraulic conductivity in the Alluvium; however, such modifications result in reductions in baseflows to values far below those estimated from previous studies (such as <1 ML/d). In this context, the calibrated parameters are considered to represent the best overall fit to the observed heads, drawdown and baseflow. Plausible alternative realisations of the model are discussed further as part of uncertainty analysis. Figure 19 presents the computed dry and wet season baseflows from the Port Phillip model and Figure 20 presents the computed baseflow from every RIV cells of the project model (excluding water bodies). Care is needed in comparing these figures, as baseflows computed on a cell-by-cell basis are not directly comparable between models of difference cell lengths (the Port Phillip model uses 200 by 200-metre cells). An important observation is that both models simulate higher baseflows in the upstream section of the Yarra River, where the river is classified as low gaining (SKM, 2011), and baseflow is generally lower downstream where the river is classified as baseflow neutral (SKM, 2011). Koonung Koonung Creek and the upstream section of Ruffey Creek are generally simulated as a losing system, which is more consistent with the dry period baseflow characteristics of the Port Phillip model (possibly reflecting the relatively dry recent conditions).

3.3.6 Calibration statistics

Figure 21 presents scatter plots of observed heads against computed heads and observed drawdown against computed drawdown. The scaled RMS error for the head observations is around 3.2 per cent, which includes the additional 26 post-calibration head observations. The scaled RMS for the drawdown observation is around 5.9 per cent. The scaled RMS errors for both observation groups are less than the target 10 per cent error. For the head observations, the scaled RMS is below the 5 per cent error that is generally considered good calibration for regional-scale groundwater models.

3.3.7 Water balance

The mass balance error is less than 0.05 per cent for the steady state calibration and for all time steps of the transient calibration. The mass balance errors are well below the target threshold of 1 per cent (Barnett *et al*., 2012). For both the steady state and transient models, the model required convergence in heads to within 0.001 metres.

Table 4 provides a breakdown of steady state water balance. The deep pool of the Bolin Bolin Billabong is simulated as a groundwater discharge feature, with a simulated discharge rate of 50 m^3/d.

Table 4 Steady state water balance

Component	Inflow (m^3/d_	Outflow (m^3/d)
Recharge	7,925	
Evapotranspiration		7,778
River	4,146	4,294
Total	12,071	12,072

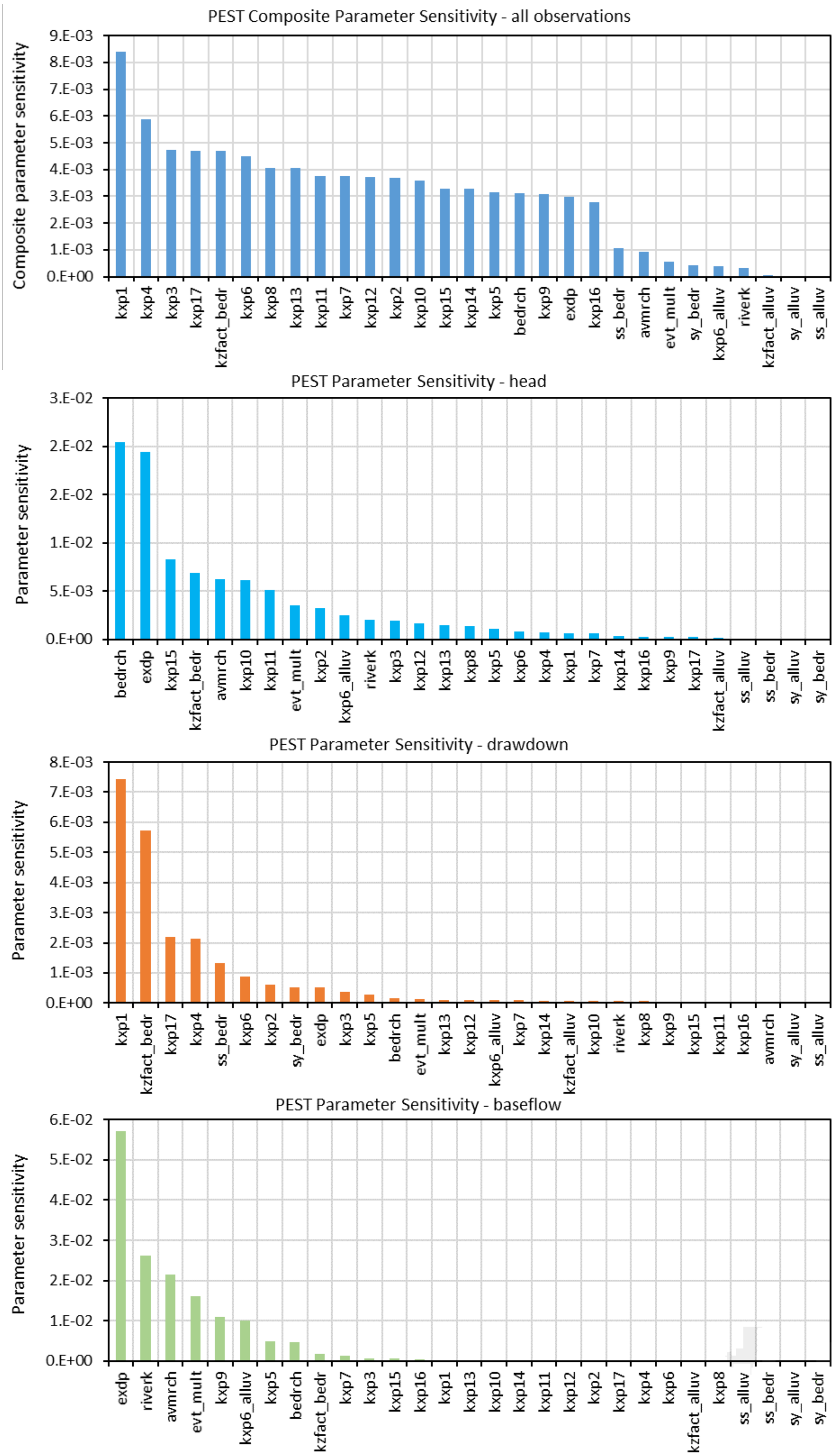
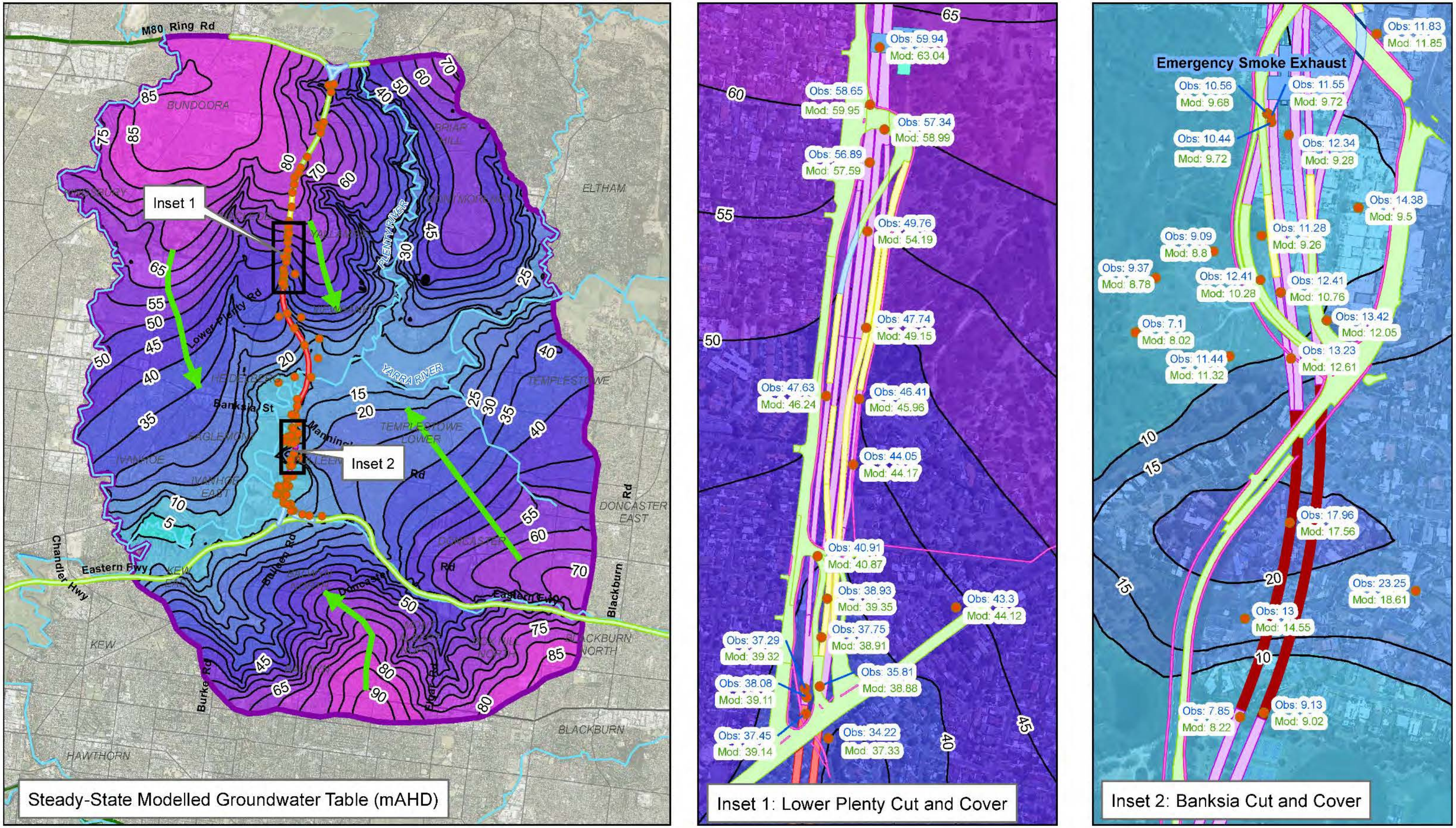


Figure 16 PEST composite parameter sensitivities



Paper Size A4

0 400 800 1,600 2,400 3,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Groundwater Flow Direction
Calibration Bore
Proposed reference project
Elevated ramp
Surface works
Open Cut
Cut and cover tunnel
TBM bored tunnel
Mined tunnel
River
GW Model Domain
Modelled GW Table Contour

Modelled Gw Table (mAHD)
4 - 5
5.1 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 92.3

Proposed reference project (insets)
Ventilation system
Area for substation
Shared use path overpass
Shared use path
Shared use path underpass
Elevated ramp
Surface works
Open cut
Cut and cover tunnel
TBM bored tunnel

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Calibrated Steady State Water Table Contours

Figure 17

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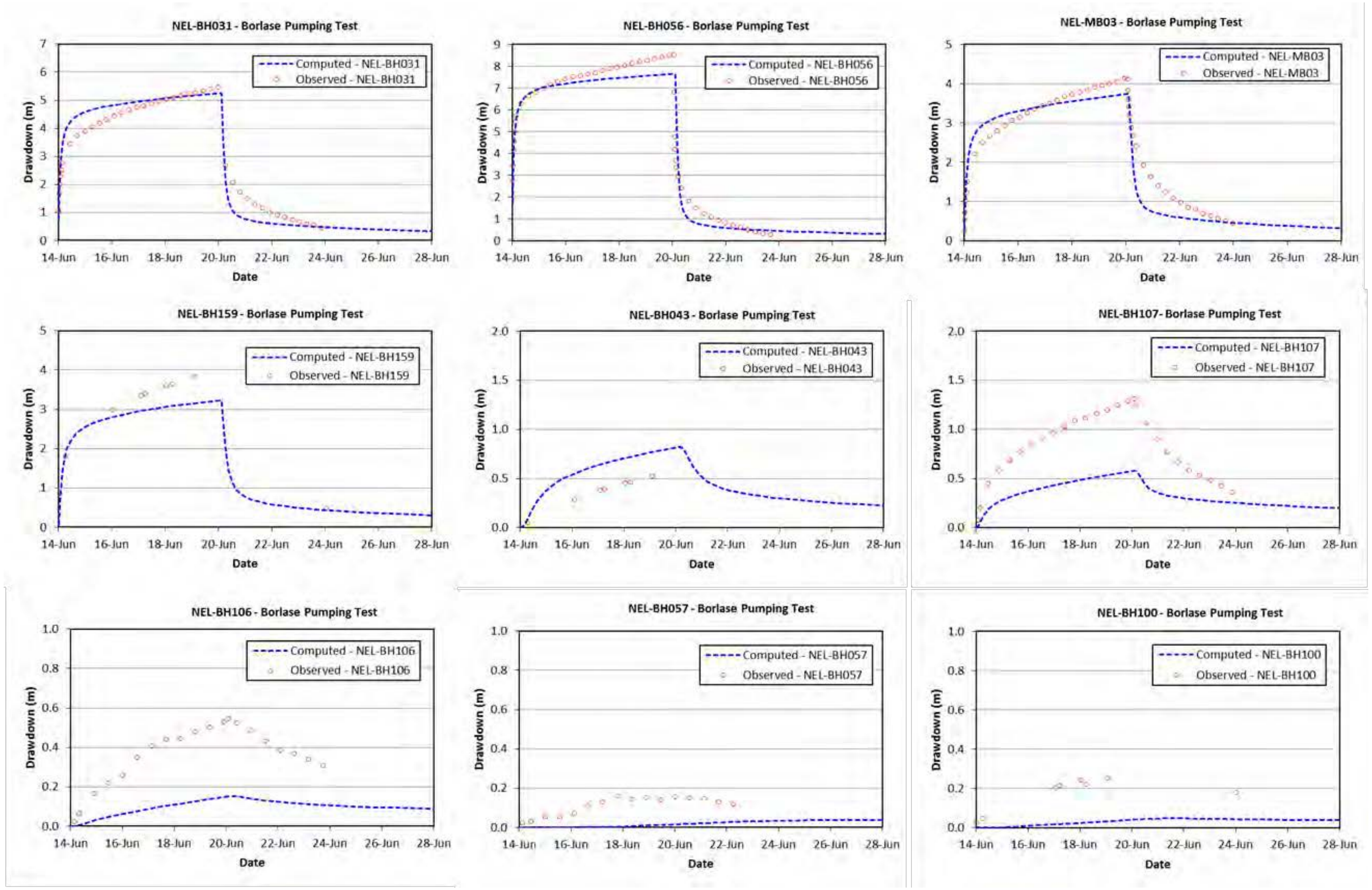
Data source: BaseMaps / DTM, VicMaps, 2018; Image Basemaps, CIP, 2017; GW Model Layers, GHD, 2018. Created by:sacevedo


NEL-BH031 - Borlase Pumping Test
Computed - NEL-BH031
Observed - NEL-BH031
NEL-BH056 - Borlase Pumping Test
Computed - NEL-BH056
Observed - NEL-BH056
NEL-MB03 - Borlase Pumping Test
Computed - NEL-MB03
Observed - NEL-MB03
NEL-BH159 - Borlase Pumping Test
Computed - NEL-BH159
Observed - NEL-BH159
NEL-BH043 - Borlase Pumping Test
Computed - NEL-BH043
Observed - NEL-BH043
NEL-BH107- Borlase Pumping Test
Computed - NEL-BH107
Observed - NEL-BH107
NEL-BH106 - Borlase Pumping Test
Computed - NEL-BH106
Observed - NEL-BH106
NEL-BH057 - Borlase Pumping Test
Computed - NEL-BH057
Observed - NEL-BH057
NEL-BH100 - Borlase Pumping Test
Computed - NEL-BH100
Observed - NEL-BH100
Drawdown (m)
Date
14-Jun 16-Jun 18-Jun 20-Jun 22-Jun 24-Jun 26-Jun 28-Jun

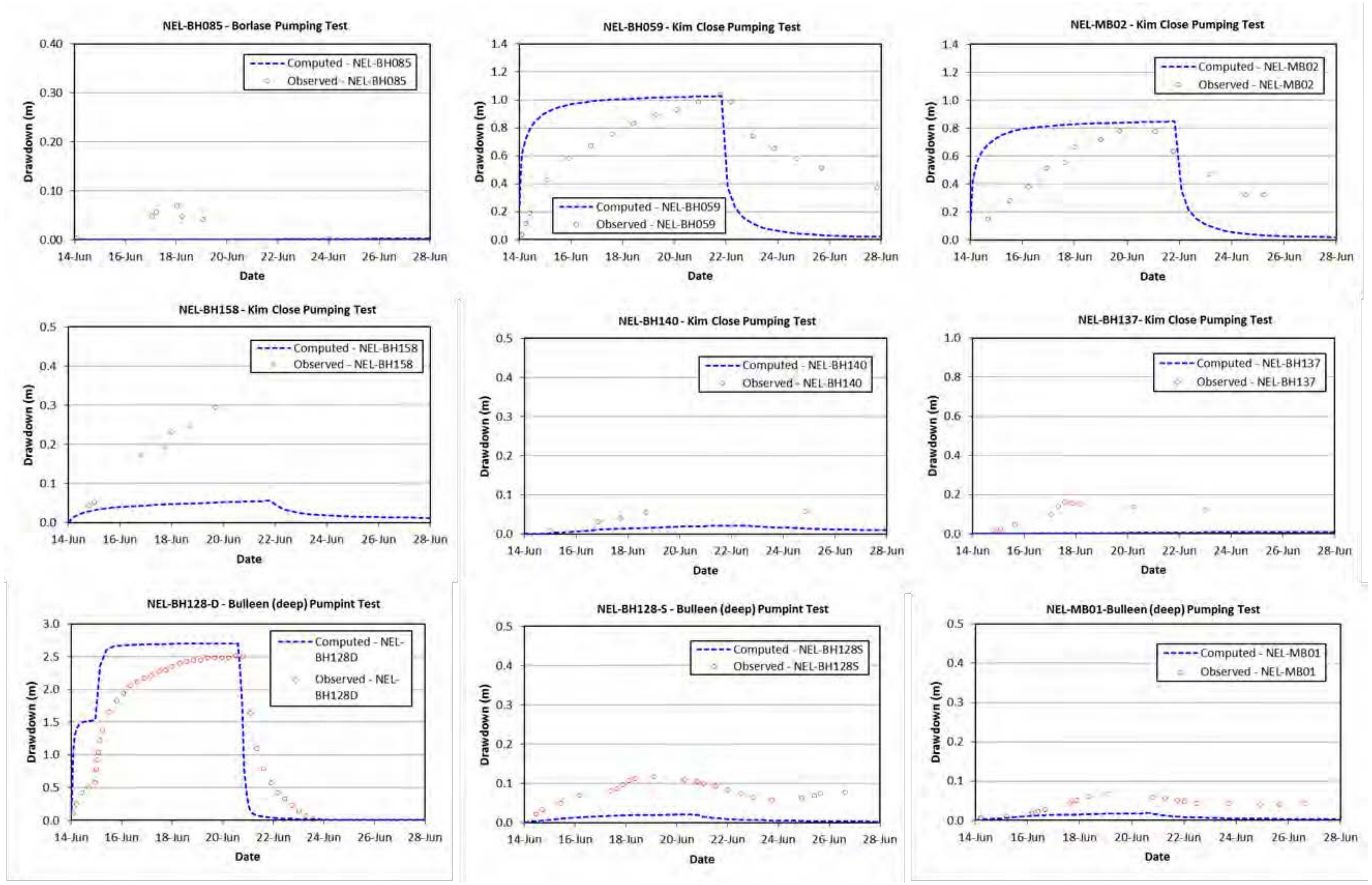
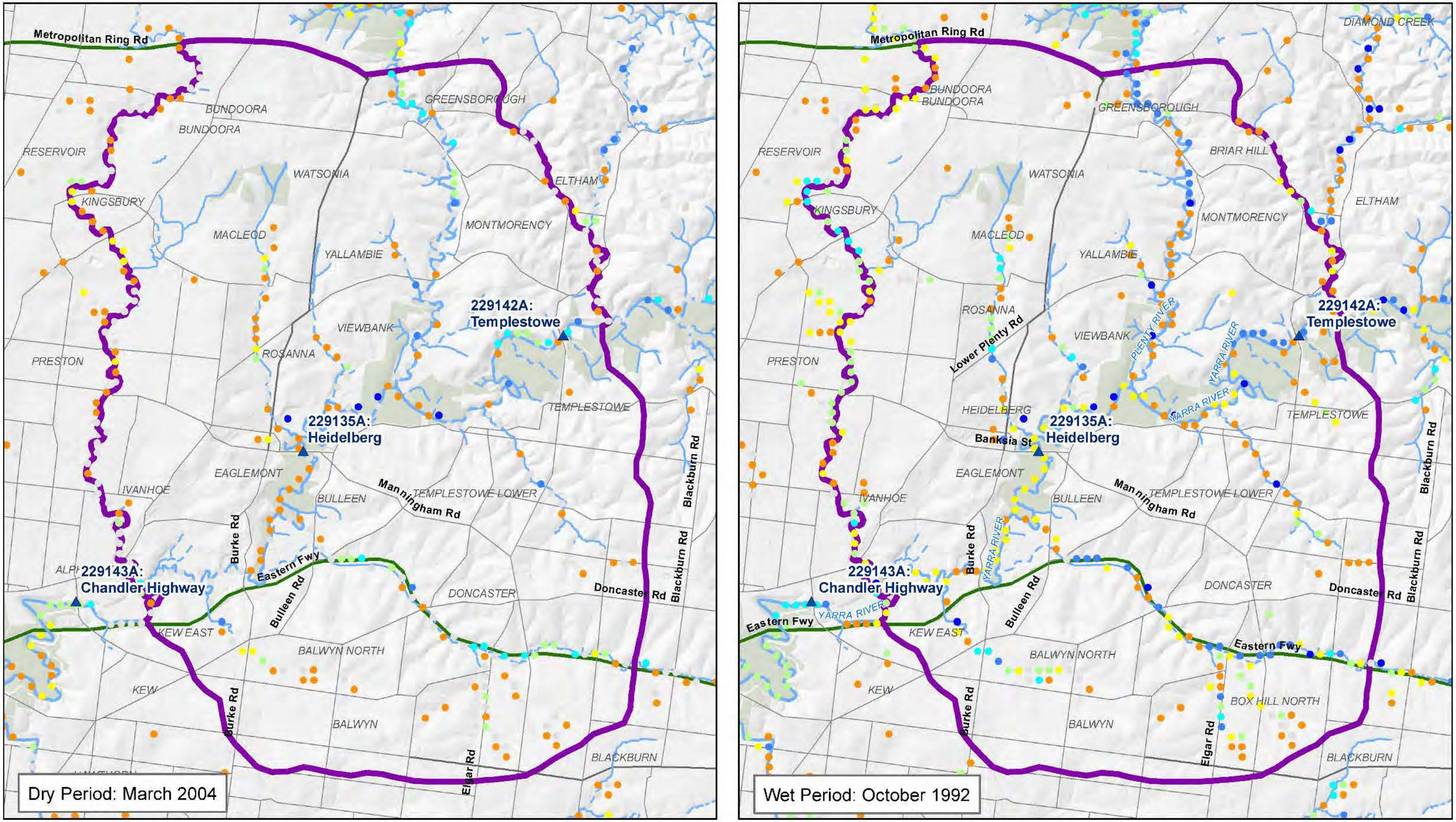


Figure 18 Calibrated drawdown hydrographs



Paper Size A4

0 375 750 1,500 2,250 3,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Legend

Modelled Flow Gain/Losses (ML/d)
- > 0.5 ML/d (Baseflow Gain)
- 0.4 - 0.3 ML/d (Baseflow Gain)
- 0.3 - 0.2 ML/d (Baseflow Gain)
- 0.2 - 0.1 ML/d (Baseflow Gain)
- 0.1 - 0.05 ML/d (Baseflow Gain)
- 0.05 - 0 ML/d (Baseflow Gain)
- 0 - 0.06 ML/d (Baseflow Loss)
- GW Model Domain
- River
- Stream
- Channel / drain
- Streamflow Gauge

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Date | 26 Feb 2019

EcoMarkets dry and wet period simulated baseflow

Figure 19

G:\31\35006\GIS\Maps\Deliverables\20180625_NEv3_GWModel_Figures\Working\3135006_NEv3_A4L_GWModel_EcoMarkets_WetDryBaseflow.mxd

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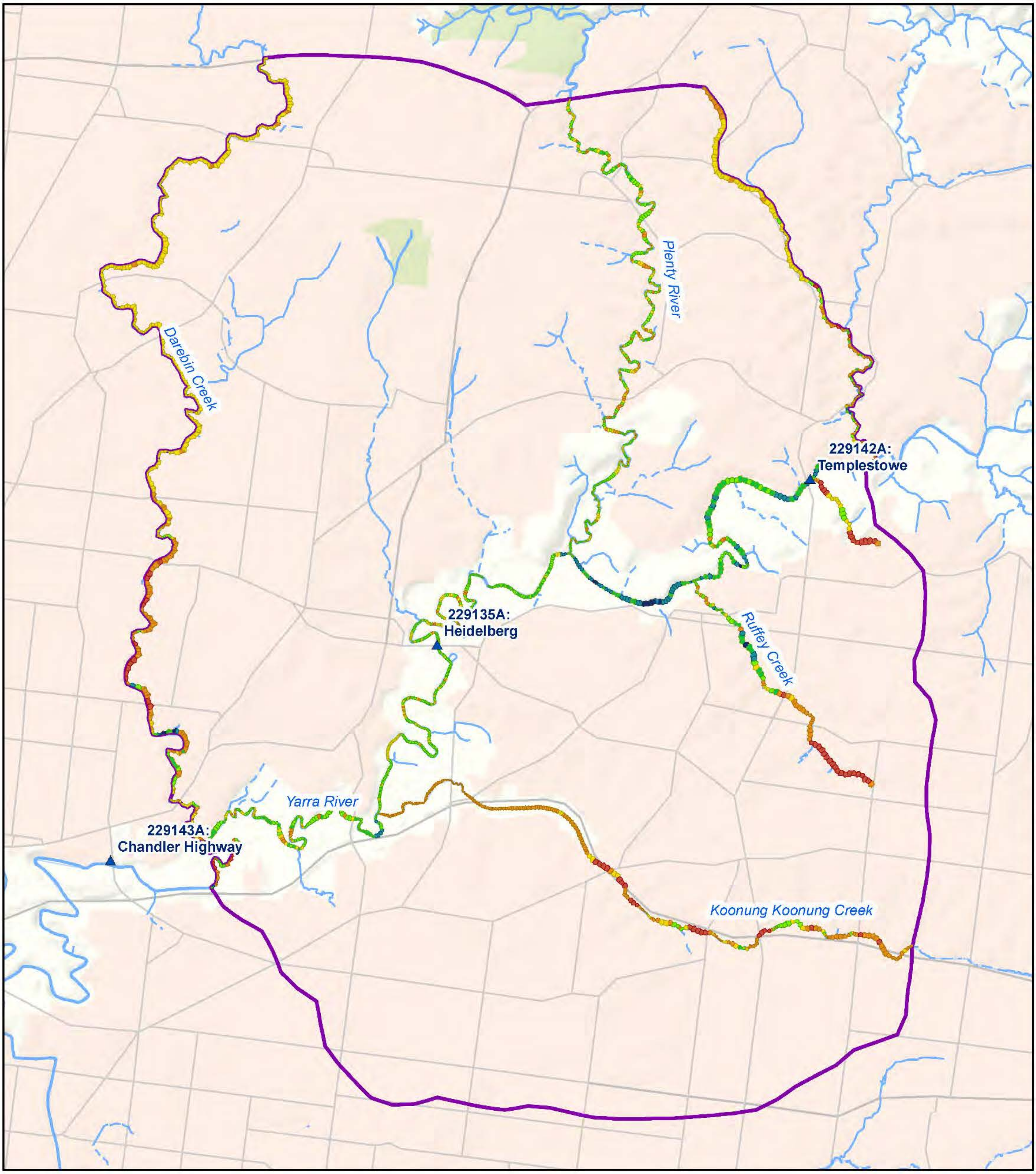
Data source: DELWP / GHD, EcoMarkets GW Model Results, 2010. BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



Legend

- ▲ Streamflow Gauge

Modelled Baseflow (ML/day)

- -0.012 - -0.007
- -0.006 - -0.001
- 0.000 - 0.001
- 0.002 - 0.005
- 0.006 - 0.010
- 0.011 - 0.015
- 0.016 - 0.022
- GW Model Domain

Note: Positive baseflow flux represents baseflow gains (from groundwater to river)

Paper Size A4

0 450 900 1,800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

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Calibrated Baseflow
(Surface Water Courses)

Figure 20

G:\31\35006\GIS\Maps\Deliverables\20180625_NEv3_GWModel_Figures\3135006_NEv3_A4P_GWModel_Fig20_CalibratedBaseflow.mxd

Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

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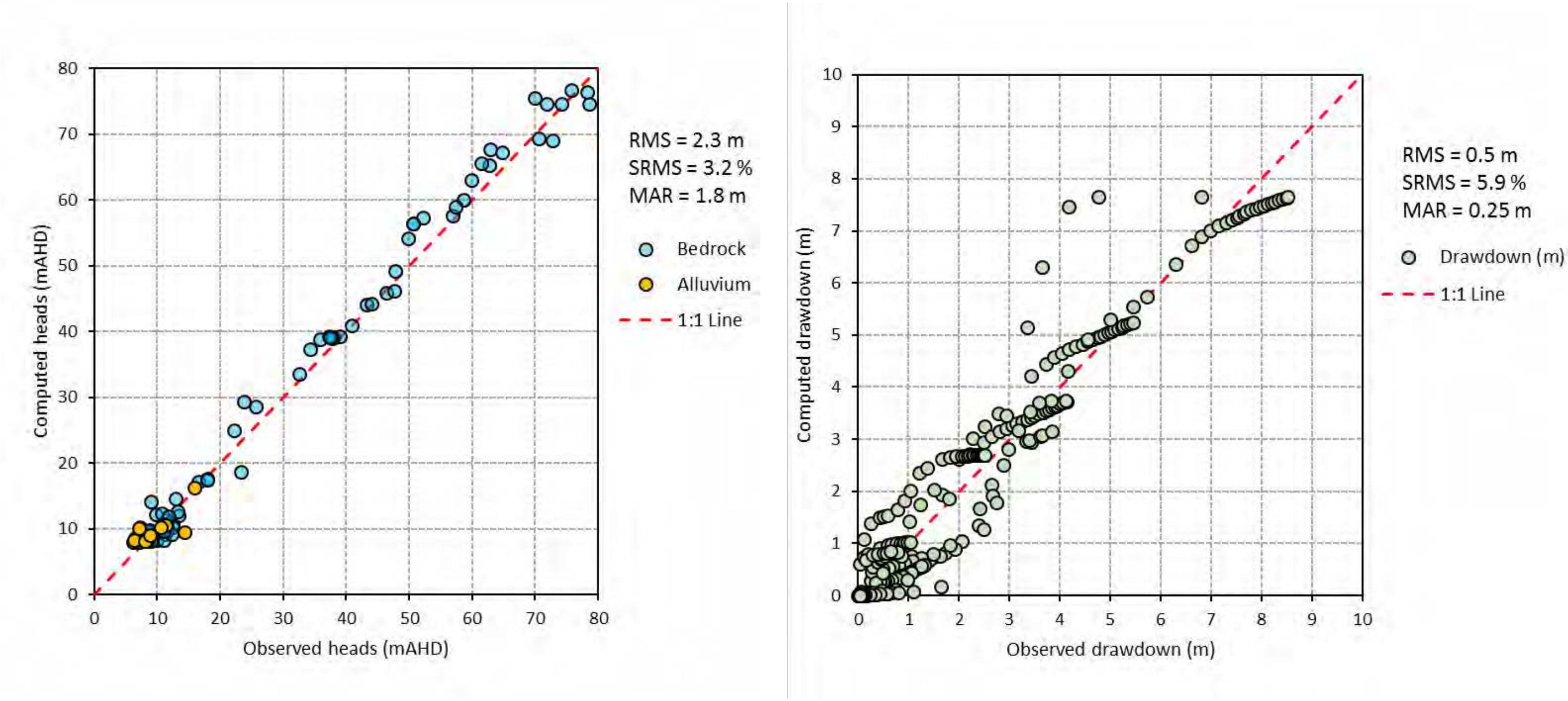


RMS = Root Mean Squared error

SRMS = Scaled Root Mean Squared error

MAR = Mean Absolute Residuals

Figure 21 Calibration scatter plots

4. Model prediction

4.1 Approach

4.1.1 Overview

The predictive modelling is designed to quantify the potential impacts of the cut and cover structures and tunnels constructed below the water table. Specifically, the modelling focuses on predicting potential impacts during:

- The construction of the project associated with:
  - Excavation of three cut and cover structures referred to as the Lower Plenty, Banksia and Southern (Bulleen) cut and covers (from north to south). This would involve placement of impermeable perimeter (diaphragm) walls that would limit lateral ingress of groundwater, although seepage of groundwater would occur from beneath until base slabs were placed, which would temporally depressurise the aquifers and create drawdown in the water table.
  - TBM (tunnel boring machine) tunnelling, which would result in minimal groundwater effects due to groundwater control and progressive placement of segmental linings.
  - Mined tunnelling between the Banksia and Southern (Bulleen) cut and covers, which would be freely drained until the tunnels were sealed and made watertight. This would result in temporary seepage of groundwater and depressurisation of aquifers.
- The operation of the project, when all structures with the exception of a free draining section, would be tanked (made watertight) which would permanently change the in-situ material properties.

Predictive scenarios are modelled to assess potential impacts of the project, as described below.

4.1.2 Reference project

The reference project is based on the existing construction schedule and assumes the following:

- The three cut and cover structures would be excavated after the diaphragm walls were placed. Therefore, the majority of groundwater inflow would occur vertically (upward) from below until the base slabs were placed. The toe of the diaphragm walls would extend below the design floor level (model layer 5), into model layer 6 (which is four metres thick), and would seal off the Alluvium where it is encountered along the Banksia and Southern cut and covers.
- The tanking (base slab) of the Lower Plenty cut and cover would occur over a length of around 650 metres. A freely draining section called the ‘trench’ would be constructed further to the north along the alignment, which would drain groundwater (horizontally and vertically) where the floor of the trench penetrates the water table. This would maintain the water table adjacent to the trench at elevations approximately equal to its design levels.
- The TBM tunnels would leak at the design (maximum permissible) leakage rate, forming local sinks within the groundwater system.

The presence of diaphragm walls is simulated by reducing the hydraulic conductivity of the perimeter cells to a value of 1 x 10^{-4} m/d. This is based on an equivalent hydraulic conductivity estimated from Haack Class 3 water tightness, consistent with values adopted for simulating diaphragm walls in other similar projects (such as the Metro Tunnel). The excavation of material is simulated using the DRN package, with DRN elevation set equal to the design level and DRN conductance set at 100 m^2/d, high enough to cause unrestricted flow. The placement of base slabs at the completion of excavation is simulated by reducing the vertical hydraulic conductivity of DRN cells to 1 x 10^{-4} m/d (Haack Class 3 water tightness), reducing the vertical flow and making the whole structure effectively watertight. This setup is shown schematically in Figure 22, based on a typical east to west section across the structures. The setup is designed to simulate the influence of low permeability structures and to achieve post-construction inflow rates consistent with Haack Class 3 water tightness (0.1 – 0.2 L/d/m^2).

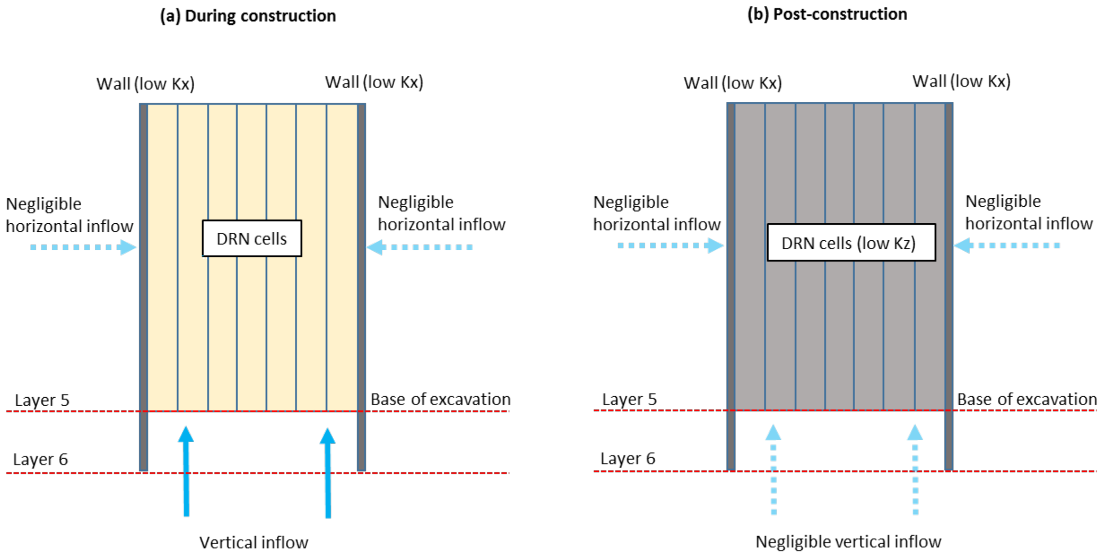


Figure 22 Cut and cover simulation

The effect of leaky TBM tunnels could be simulated in one of two ways:

- By specifying the flux (using a specified flux boundary such as the WEL boundary), or
- Specifying the head at the tunnels and computing the flux (using a head-dependent flux boundary such as the DRN boundary).

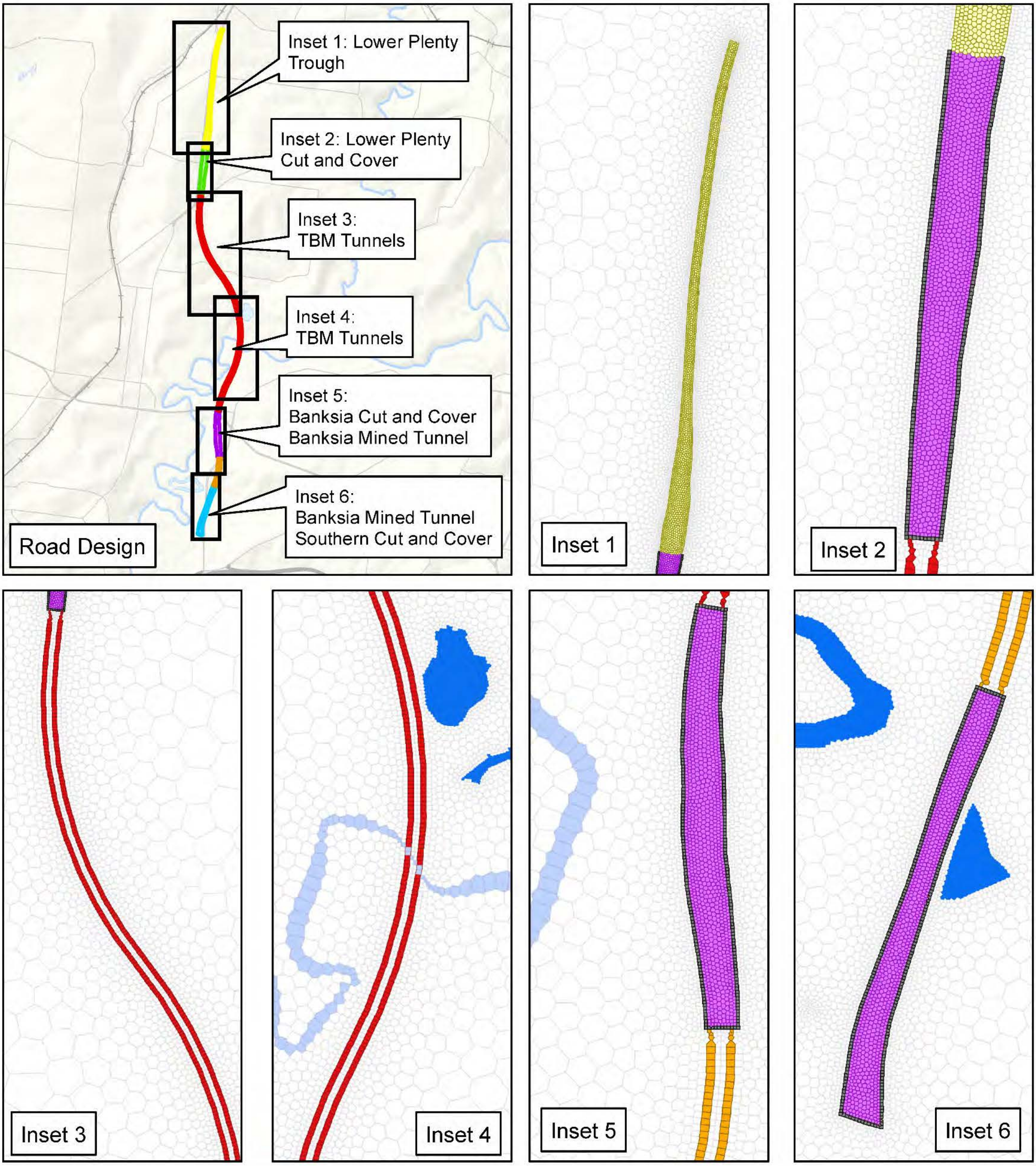
Because the TBM tunnels would not be free draining (seepage would be restricted to the design leakage rate through lining), the second option requires adjustments to the boundary conductance to ensure consistent design leakage rate along the whole length of the tunnel. A simpler approach with the WEL boundary is therefore used in this study to prescribe a design leakage rate based on Haack Class 3 water tightness. This equates to a daily leakage limit of 0.1 litres per square metre of tunnel surface area per 100 metres' length which, for a tunnel with a 14.1-metre inner diameter, equates to around 0.44 m^3/d average inflow over 100 metres length. While Haack Class 3 allows for a higher local peak inflow of 0.2 L/s/m^2 over a shorter reference length of 10 metres, the permissible inflow over the longer reference length of 100 metres is applied in this study to simulate average inflow along the entire length of the tunnels. This means 0.044 m^3/d is prescribed to every tunnel cell of 10 metres in length, resulting in an inflow of 0.44 m^3/d every 100 metres' length (or 0.88 m^3/d for the two tunnels combined). It should be noted that both the WEL and DRN boundaries would result in the same effect if they were configured to achieve the same leakage rate.

For the mined tunnels, the DRN boundary is used as the tunnels would drain freely based on the difference in hydraulic head along the perimeter of the tunnels and that of the surrounding aquifer. The DRN cells are assigned to model layer 5 with elevations equal to 0.1 metre above the layer bottom (approximately equal to the invert of the tunnels) and conductance of 100 m^2/d. In reality, piezometric head on the exterior surface of the tunnel varies to reflect the elevation head as the air pressure inside the tunnel is atmospheric. Using a single drain elevation equal to the tunnel invert is considered an appropriate level of simplification for regional-scale modelling, recognising that modelled inflow rates are far more sensitive to hydraulic conductivities that are known with much less certainty. Once the tunnels are lined, the DRN cells are deactivated and replaced by WEL cells with leakage (pumping) rates consistent with the design leakage rate.

Figure 23 shows the model boundary conditions used for the reference project and Figure 24 shows the relationship between the model layers and construction features on a north to south cross-section, including the vertical extent of diaphragm walls (shown in red). Figure 25 presents the proposed construction schedule as represented in the model. Quarterly stress periods are used to represent the progression of construction from stress period 1 to 10. Additional 6 stress periods are included to simulate the recovery of the groundwater system towards a new dynamic equilibrium over a post-construction period of 50 years (equal in length to the 50-year planning horizon for water strategies, as outlined in DELWP, 2016). The DRN and WEL boundaries are sequentially activated by breaking up the construction areas into quarterly increments. The base slab is assumed to be placed over the entire footprint of the cut and cover structures at the end of construction, rather than incrementally. This means the aquifers are depressurised over larger areas for longer periods and is considered conservative for the purpose of predicting temporary impacts. Changes in material properties are simulated dynamically using MODFLOW-USG’s TVM package.

The DRN cells remain active following the placement of the base slab to maintain the heads at the design level and to verify that the base slab is performing as intended (negligible DRN outflows following the lowering of vertical hydraulic conductivity). In the free draining trench area, the DRN cells continue depressurisation of the aquifer where the design level is below the water table. Recharge, EVT and RIV boundary conditions are assumed steady state, so that simulated changes caused by the project are easily discernible.

MODFLOW-USG’s adaptive time stepping algorithm is used to assist with model convergence, particularly when steep hydraulic conductivity contrasts are introduced into the model by the lowering of vertical hydraulic conductivity.



Legend

Road Alignment Sections
- Banksia - Mined Tunnel
- Banksia Cut and Cover
- Trough (Free Draining)
- Lower Plenty Cut and Cover
- Northern Tunnel - TBM
- Southern (Bulleen) Cut and Cover
- GW Model Mesh

WEL Cells
- TBM Tunnel

Reduced Conductivity
- Diaphragm Wall

DRN Cells
- Cut and Cover
- Trough (Free Draining)
- Mined Tunnel

RIV Cells
- River
- Water Body

Paper Size A4

0 460 920 1,840

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

NORTH EAST LINK PROJECT

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Model Boundary Conditions - Construction Period

Figure 23

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Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

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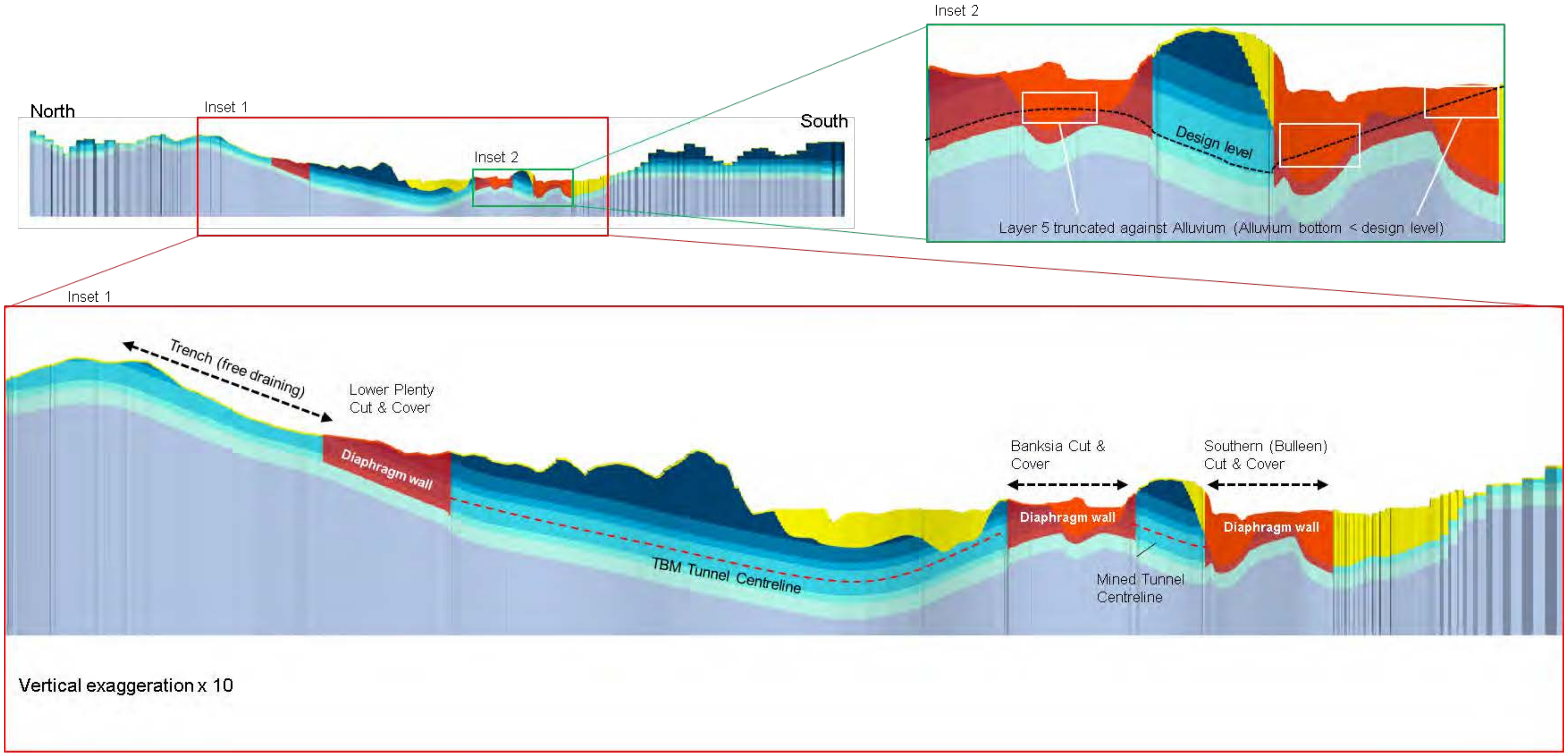


Figure 24 Model cross-section

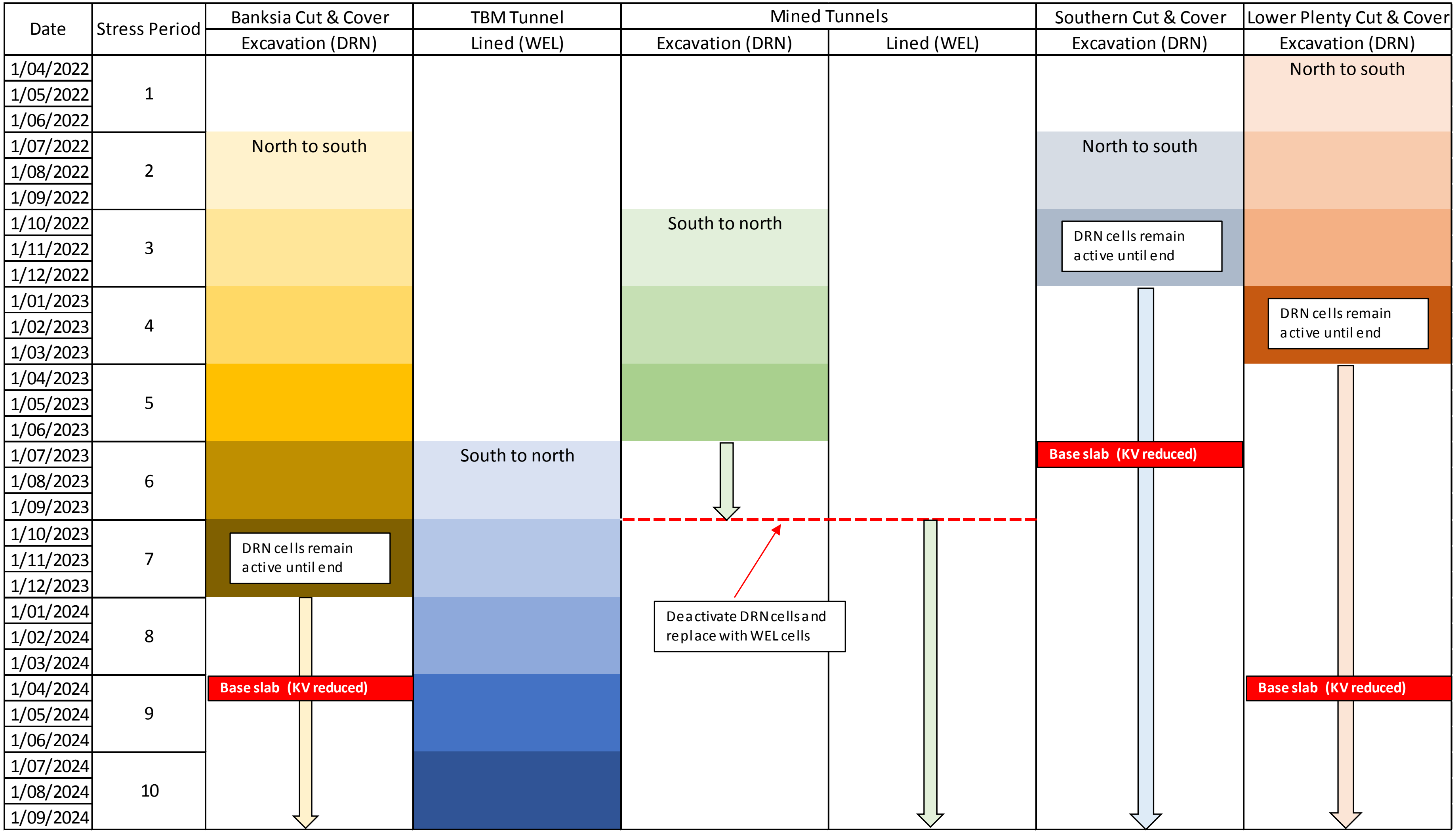


Figure 25 Model construction schedule and boundary conditions

4.2 Predicted impacts on groundwater levels

Predicted impacts on groundwater levels are described with reference to a series of contour maps of piezometric head (approximate water table) changes shown over the southern (Figure 26 and Figure 27) and northern (Figure 28 and Figure 29) portions of the alignment. The changes in piezometric heads are calculated relative to the calibrated steady-state heads, which are used as the initial heads for predictive modelling. Drawdown (lowering) of piezometric heads are presented with positive numbers and impress (rising) of piezometric heads are presented with negative numbers. A minimum contour of 0.1 metres is used to inform the Groundwater Impact Assessment; however, it should be noted that changes of less than 0.5 metres are generally considered beyond the threshold of accuracy expected of a regional model of this kind.

The contours are generated at four time slices to present the progression of construction. These include:

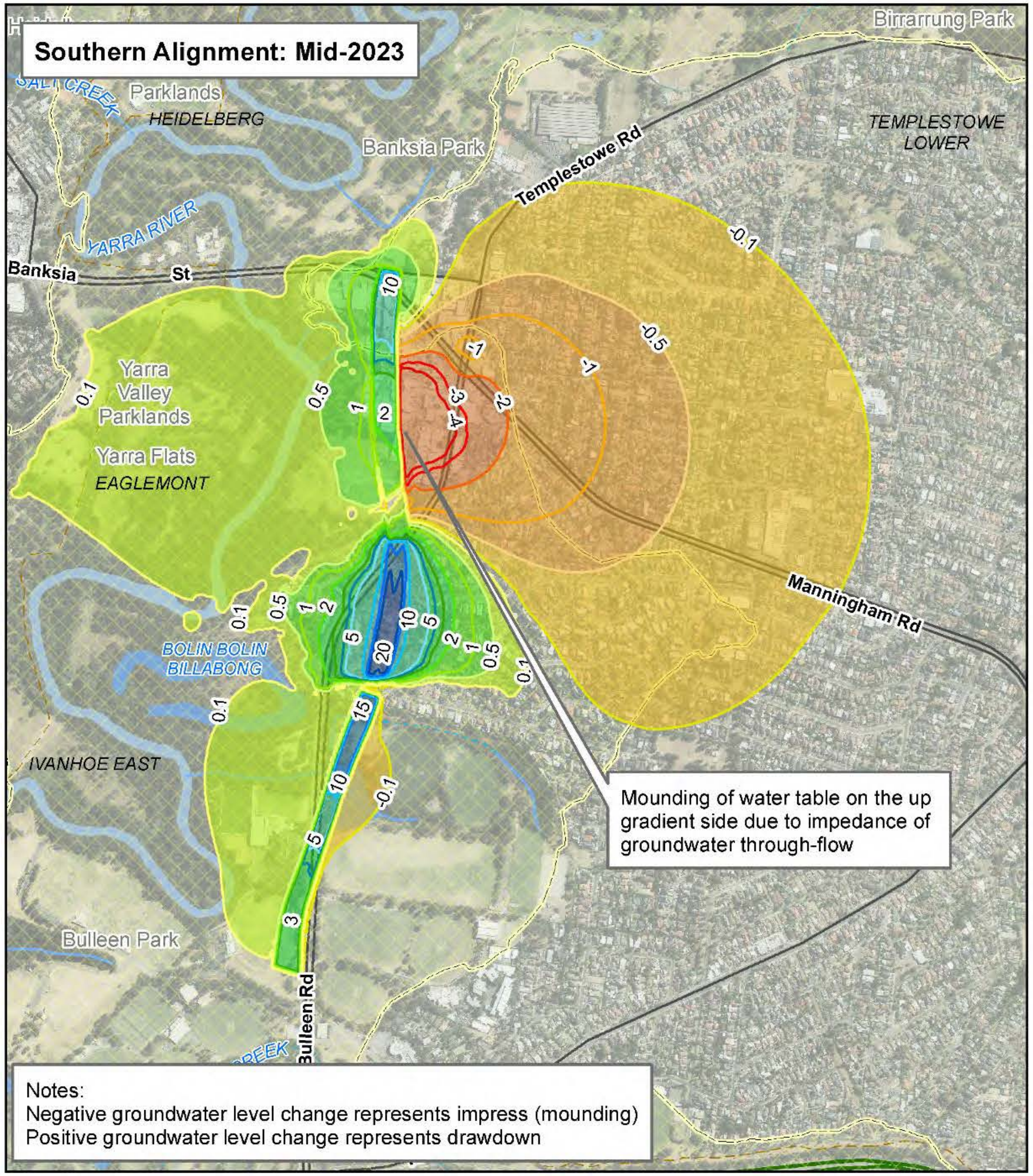
1. Mid 2023, corresponding to the end of excavation of mined tunnels and prior to the placement of base slabs at the Southern (Bulleen) cut and cover.
2. Early 2024, following the lining of the mined tunnels and placement of base slabs at the Southern (Bulleen) cut and cover, and prior to the placement of base slabs at the Banksia and Lower Plenty cut and covers.
3. Late 2024, corresponding to the end of construction.
4. 2075, corresponding to the end of the predictive timeframe, 50 years after construction.

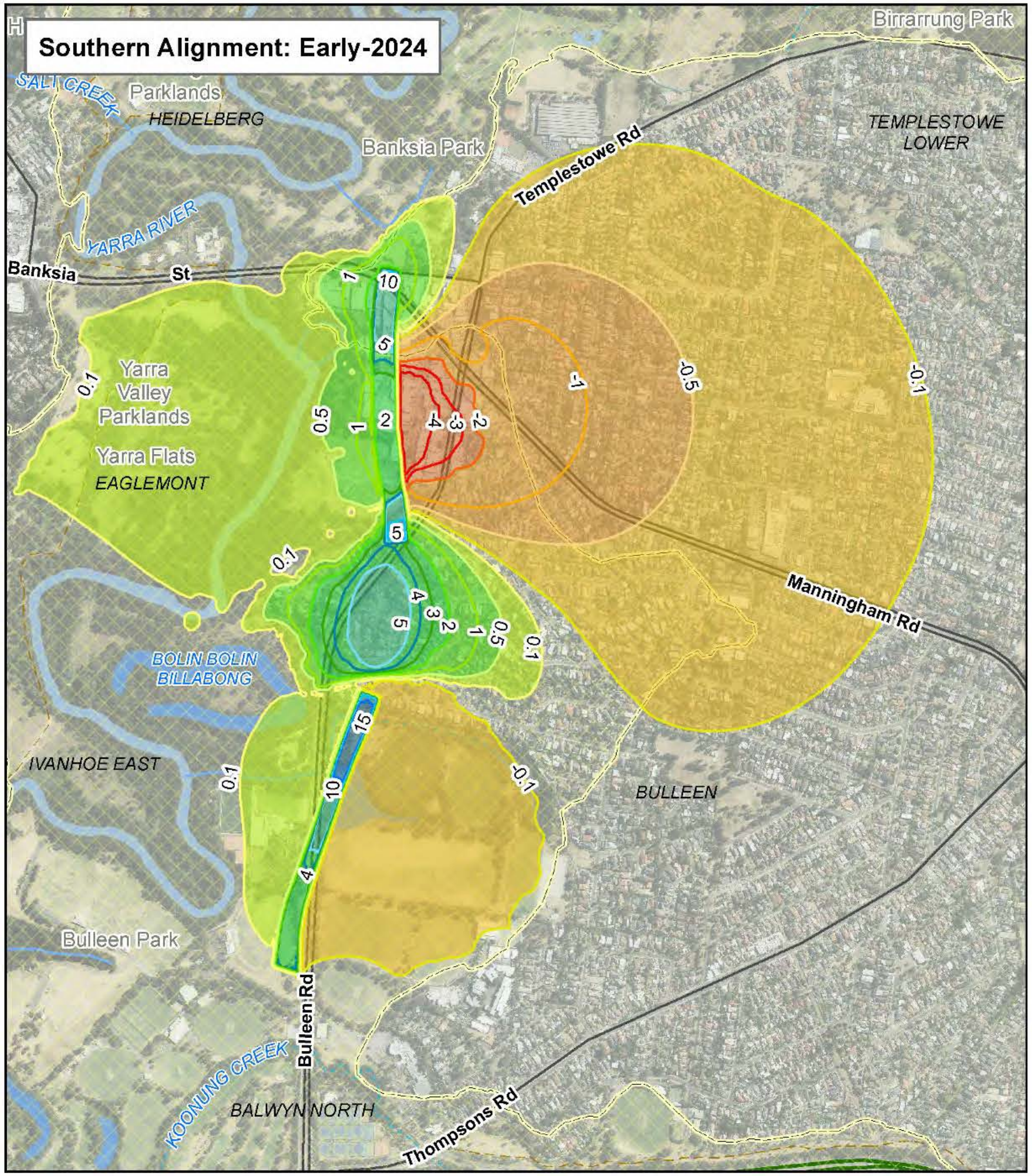
The contours of piezometric head changes indicate the following:

- The largest changes in piezometric heads occur within the footprint of the cut and cover excavations where the floor of the excavations penetrates the water table and groundwater is removed to maintain a dry condition. Drawdown in areas outside the cut and cover excavations is minimised by the presence of diaphragm walls. Large temporary drawdown is also predicted during excavation of the mined tunnels, forming a cone of depression in the water table/piezometric surface between the Banksia and Southern cut and covers in mid-2023.
- Following the lining of mined tunnels and placement of base slabs, the drawdown cone continues to expand by a very small amount due to the antecedent effect of depressurisation while the piezometric heads closer to the alignment begins recovery. This effect can be seen in the mid and late 2024 contours in the north (the Lower Plenty cut and cover), where the contour extents are marginally greater in late 2024 but the magnitude of drawdown is smaller within the vicinity of the alignment.
- In the southern portion of the alignment, mounding of the water table is simulated on the up gradient (eastern) side of the Banksia cut and cover and drawdown is simulated on the down gradient (western) side. This is due to the impedance of groundwater through-flow by the tanked cut and cover structure, which is oriented perpendicular to the direction of groundwater flow and truncates the Alluvium approximately at the centre of the structure. Several metres of mounding simulated on the up gradient side of the Banksia cut and cover is exaggerated by the modelled pre-construction water table that is locally underestimated in this area, as shown in Figure 17.

- In the Lower Plenty cut and cover area, permanent drawdown is simulated along the free draining trench where the trench floor penetrates the water table and drains the aquifer. (note drawdown is locally overestimated at the trench where the modelled pre-construction groundwater levels are higher than those observed). Drawdown simulated around the fully tanked section to the south is generally small (<0.5 metres) due to limited seepage of groundwater through diaphragm walls and base slabs of very low hydraulic conductivity. A small area of mounding is simulated in the south-west corner, caused by slight deflection of flow lines.
- Drawdown is predicted to occur above the TBM tunnels in the northern portion of the alignment. This occurs within the Bedrock, where drawdown along the alignment reflects the balance between the volume of water leaking into the tunnels and volume of water maintained by recharge and through-flow. For example, drawdown of up to around two metres is predicted above the TBM tunnels as a result of low recharge assigned to the Bedrock, which is insufficient to completely offset the assumed leakage into the tunnels. Minimal drawdown (<0.1 metre) is simulated along Banyule Creek, where groundwater is discharged via evapotranspiration; that is, drawdown is less pronounced in the zone of net groundwater discharge where flow lines converge. Drawdown is not predicted to occur at the water table where the TBM tunnels would be located below the Alluvium, as the water table is maintained by higher recharge and through-flow in this aquifer.

Figure 30 shows the contours of depth to groundwater predicted 50 years after construction. The depth to groundwater is calculated by subtracting the modelled water table (based on the uppermost active heads) from the VicMap DEM. The depth to groundwater on the up gradient side of the Banksia cut and cover is predicted to be around five metres below ground level due to mounding of the water table.





Paper Size A4

0 65 130 260 390 520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

-5
-4
-3
-2
-1
-0.5
-0.1
0.1
0.5
1
2
3
4
5
10
15
20

Modelled GWL Change (m)

-5.81 - -5
-4.99 - -2
-1.99 - -0.5
-0.49 - -0.1
-0.09 - 0.1
0.11 - 0.5
0.51 - 2
2.01 - 5
5.01 - 10
10.01 - 15
15.01 - 20
20.01 - 24
Alluvium

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Date | 27 Feb 2019

Predicted groundwater level changes –south (2023 – 2024)

Figure 26

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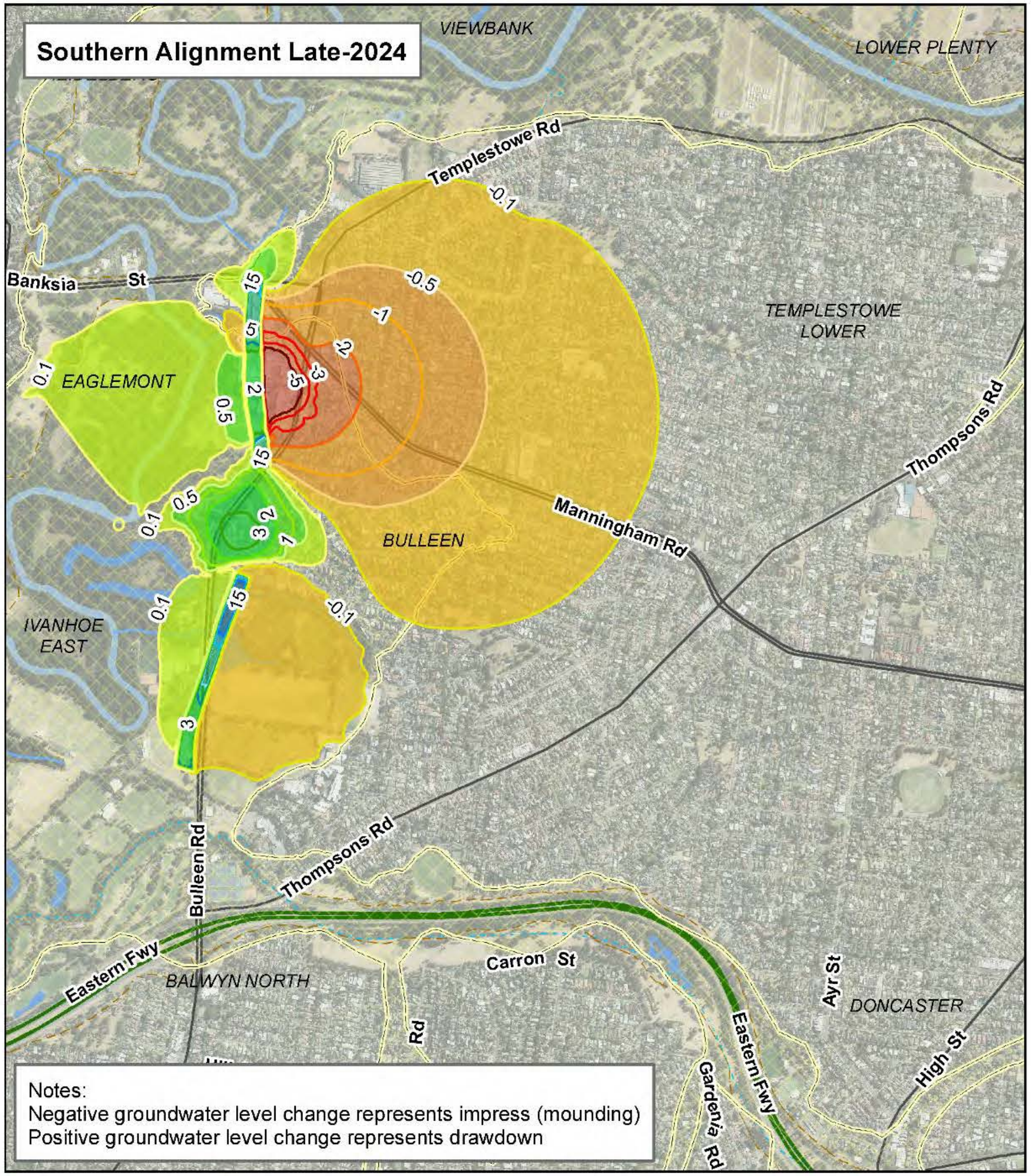
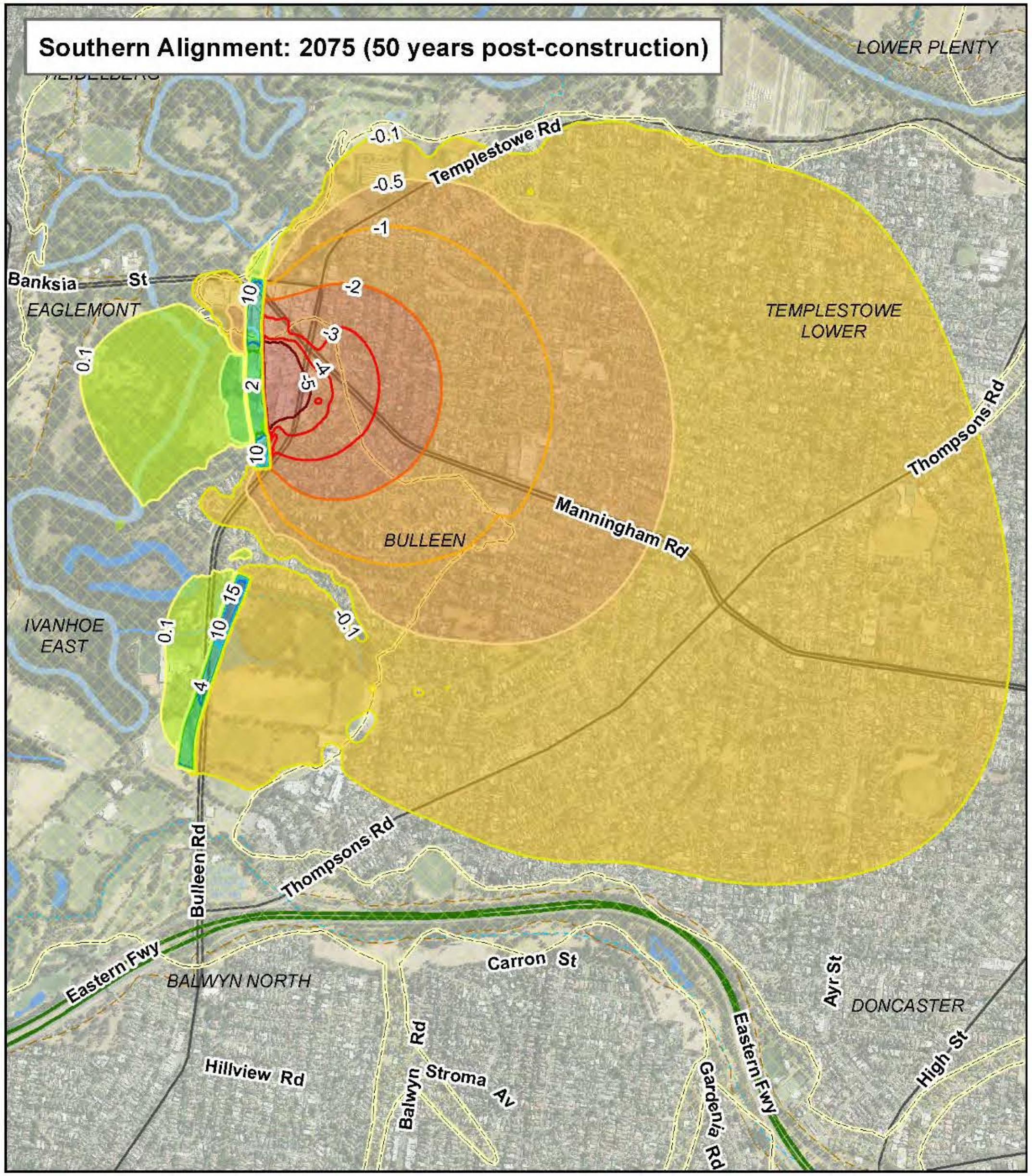
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo





Paper Size A4

0 90 180 360 540 720

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

- -5
- -4
- -3
- -2
- -1
- -0.5
- -0.1
- 0.1
- 0.5
- 1
- 2
- 3
- 4
- 5
- 10
- 15
- 20
- Alluvium

Modelled GWL Change (m)

- -5.81 - -5
- -4.99 - -2
- -1.99 - -0.5
- -0.49 - -0.1
- -0.09 - 0.1
- 0.11 - 0.5
- 0.51 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- 20.01 - 24

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Predicted groundwater level changes – south (2024, 2075)

Figure 27

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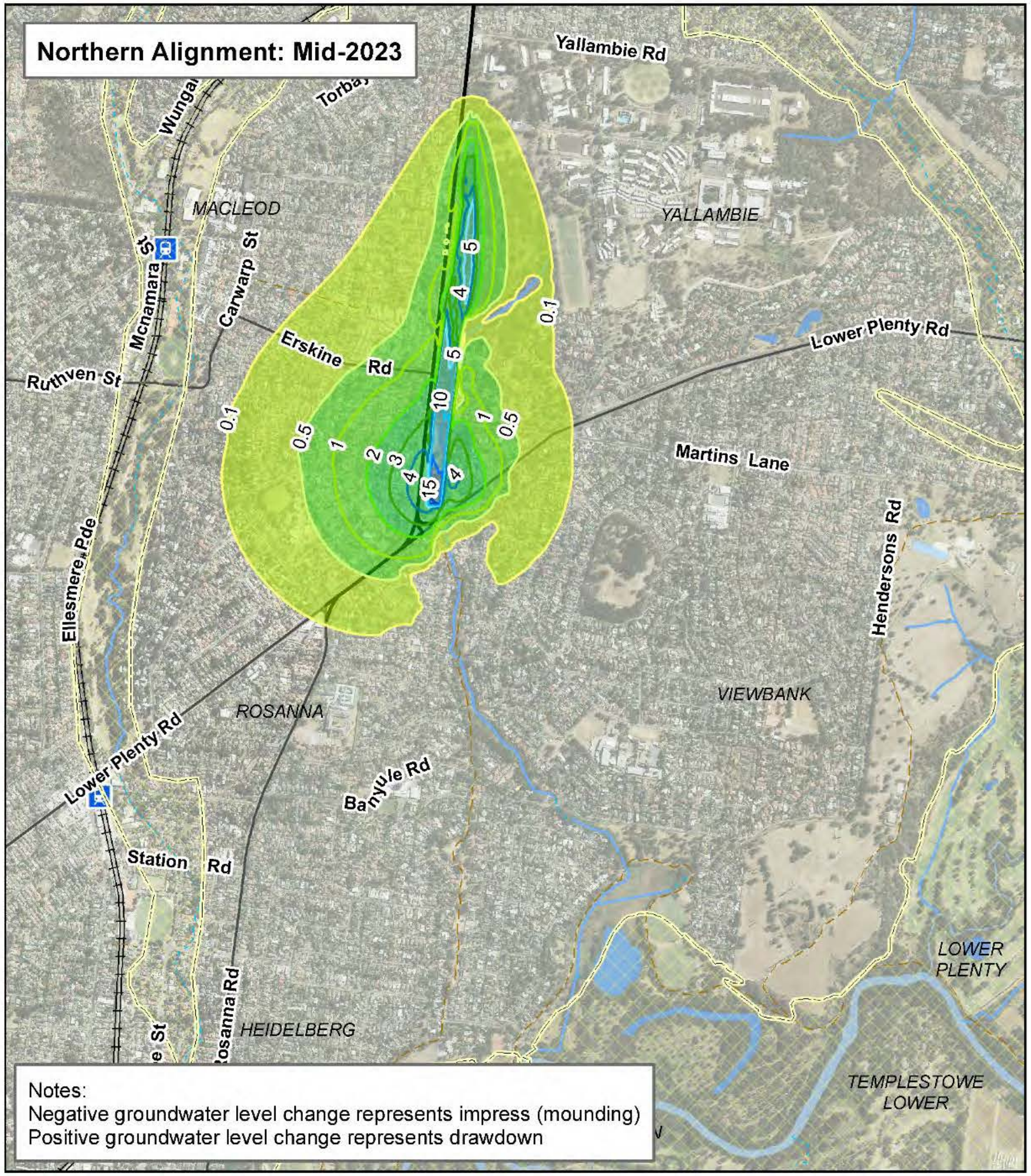
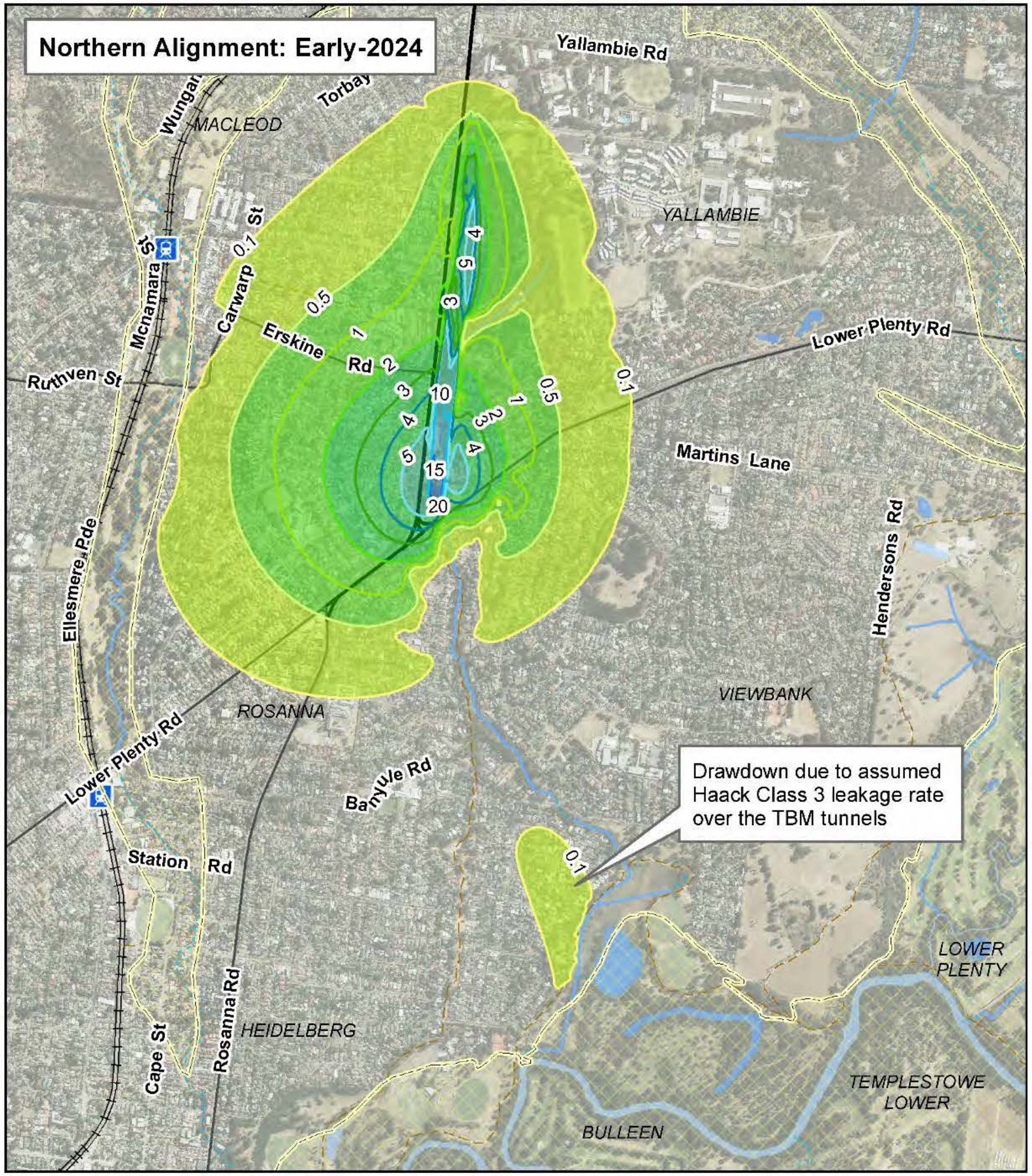
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo





Paper Size A4

0 90 180 360 540 720

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

-5, -4, -3, -2, -1, -0.5, -0.1, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20

Modelled GWL Change (m)

-5.81 - -5
-4.99 - -2
-1.99 - -0.5
-0.49 - -0.1
-0.09 - 0.1
0.11 - 0.5
0.51 - 2
2.01 - 5
5.01 - 10
10.01 - 15
15.01 - 20
20.01 - 24
Alluvium

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Predicted groundwater level changes – north (2023 – 2024)

Figure 28

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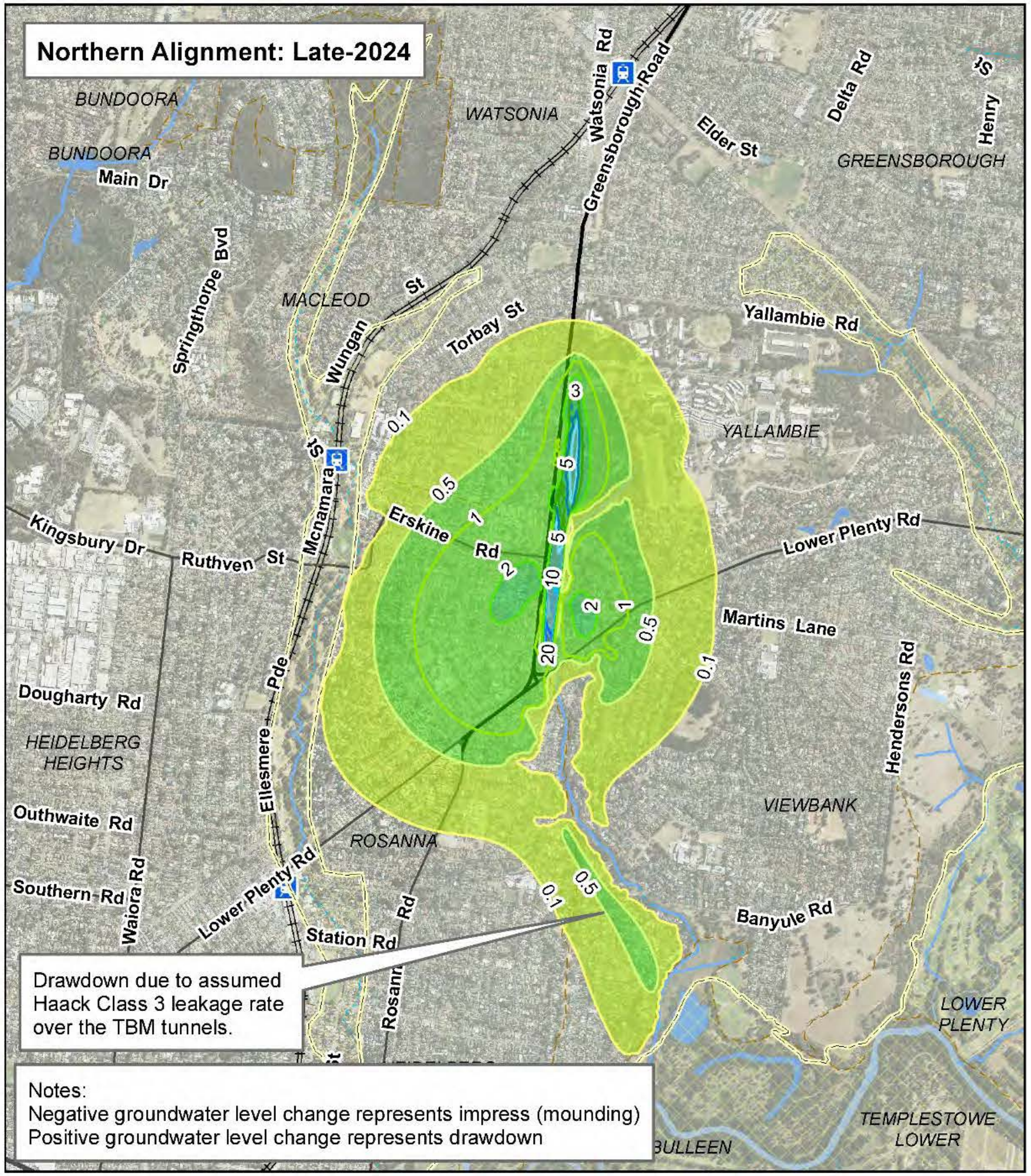
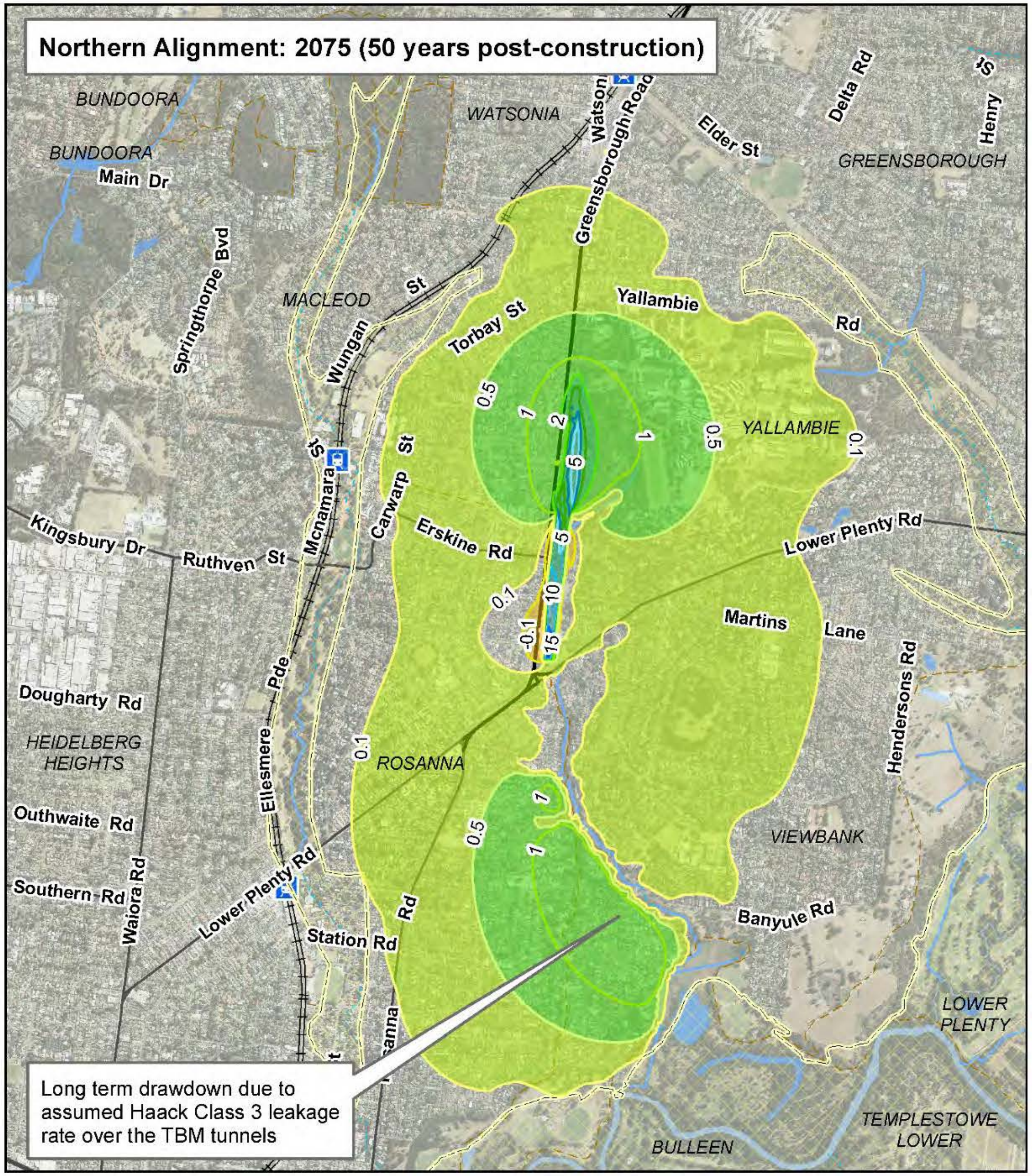
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo





Paper Size A4

0 115 230 460 690 920

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

-5, -4, -3, -2, -1, -0.5, -0.1, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20

Modelled GWL Change (m)

-5.81 - -5
-4.99 - -2
-1.99 - -0.5
-0.49 - -0.1
-0.09 - 0.1
0.11 - 0.5
0.51 - 2
2.01 - 5
5.01 - 10
10.01 - 15
15.01 - 20
20.01 - 24
Alluvium

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Predicted groundwater level changes - north (2024, 2075)

Figure 29

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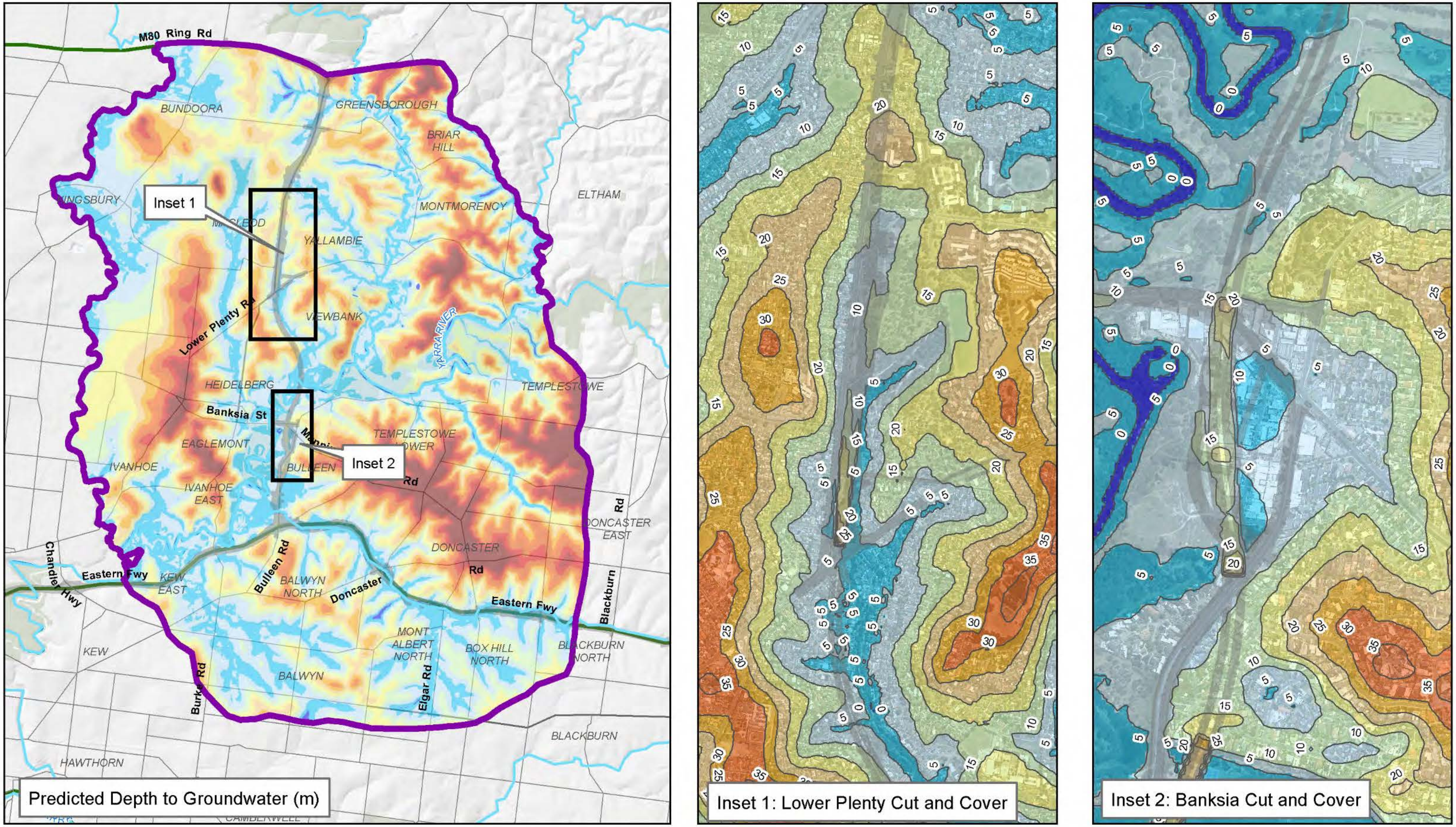
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



Paper Size A4

0 375 750 1,500 2,250 3,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GW Model Domain
Proposed reference project
Depth to groundwater (m)
River

Depth to groundwater (m)

< 0	15.1 - 20	35.1 - 40
0.1 - 5	20.1 - 25	40.1 - 45
5.1 - 10	25.1 - 30	45.1 - 50
10.1 - 15	30.1 - 35	> 50

NORTH EAST LINK PROJECT

North East Link Project
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Revision A
Date 27 Feb 2019

Predicted Depth to Groundwater
Post-Construction

Figure 30

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Data source: BaseMaps / DTM, VicMaps, 2018; Image Basemaps, CIP, 2017; GW Model Layers, GHD, 2018. Created by:sacevedo

4.3 Predicted impacts on groundwater fluxes

4.3.1 Predicted groundwater inflow rates

Groundwater inflow rates into the cut and cover excavations during and after construction are estimated using fluxes removed by the DRN cells. Initial DRN fluxes are typically high due to a combination of factors including high initial (heading) inflows and instantaneous activation of DRN boundary conditions over large areas. In reality, drainage of construction areas would be slower as dewatering occurs ahead of excavation faces, or as flows enter into excavations.

As such, average DRN fluxes are considered more reliable indicators of expected groundwater inflow rates during construction, with the maximum DRN fluxes indicating the potential for higher temporary inflows. Table 5 summarises the estimated inflows based on the DRN fluxes.

Table 5 Predicted groundwater inflow rates

Excavation / cut and cover	Average inflow during construction (m^3/d)	Maximum inflow during construction (m^3/d)	Average inflow post-construction (m^3/d)
Southern	86	404	11*
Banksia	70	225	10*
Lower Plenty	106	293	13*
Trench	17	90	11

*Equates to 0.1 – 0.2 $L/d/m^2$ of tanked sections (wall and base slab), approximately equal to Haack Class 3 tightness

4.3.2 Predicted impacts on river fluxes

Predicted changes to baseflow to the Yarra River are computed using fluxes from the RIV cells. The changes to baseflow are computed along the Yarra River in gaining sections between gauges 229142A and 229135A and gauges 229135A and 229143A.

A temporary reduction in baseflow of up to around 5.5 per cent is predicted between gauges 229135A and 229143A due to drawdown and reduced through-flow. A long-term (permanent) reduction in baseflow is predicted to be around 3 per cent. These equate to baseflow reductions of 25 to 45 m^3/d. To put into context, the flow duration curve at 229135A indicates a total flow of greater than 360,000 m^3/d for 90 per cent of the time based on long-term data. The predicted baseflow reductions equate to less than 0.01 per cent of this total flow. Predicted reductions in baseflow are smaller between gauges 229142A and 229135A, located further away from the predicted area of influence of the project.

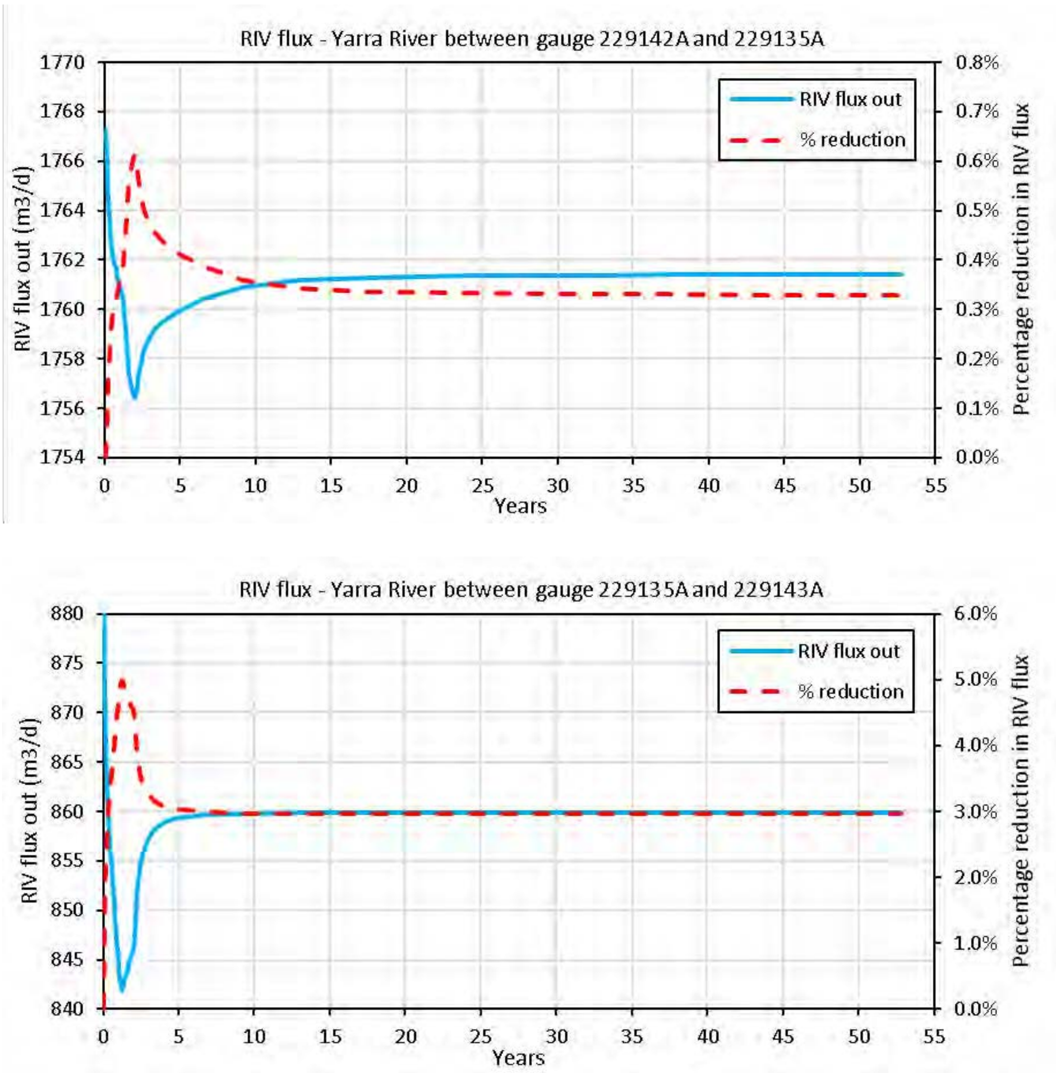


Figure 31 Predicted changes to Yarra River groundwater flux

Figure 32 presents the predicted changes to groundwater fluxes to the deep pool of Bolin Bolin Billabong, computed using the fluxes from the RIV cells. A temporary reduction of up to around 4.8 per cent is simulated during construction, followed by a permanent reduction of around 2.5 per cent post-construction. The reduction in groundwater flux is caused primarily by the small amount of drawdown predicted down gradient of the Southern (Bulleen) cut and cover (around 0.1 metres post-construction). This has the potential to cause a small reduction in the pool level during the dry season, which would be no greater than the 0.1 metres drawdown in the groundwater level.

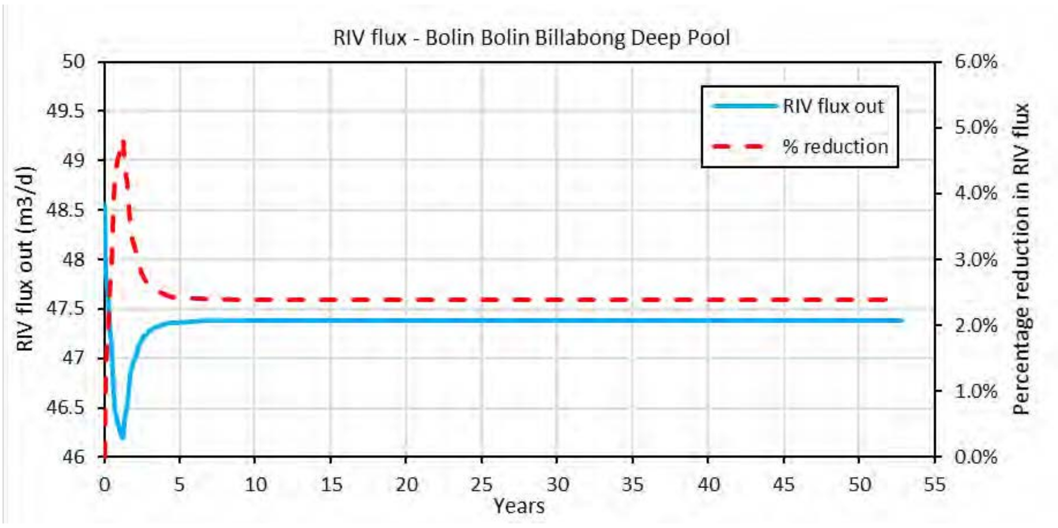


Figure 32 Predicted changes to Bolin Bolin Billabong groundwater flux

A very small increase in leakage from Banyule Swamp and Banyule Billabong (<0.25 per cent and <0.6 per cent respectively) is predicted due to <0.1 metres drawdown in the Alluvium caused by the leakage of groundwater into the underlying TBM tunnels.

4.4 Confidence level classification

The Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012) introduced the concept of confidence level classification. According to the Guidelines, the confidence in a model's ability to simulate potential future effects depends primarily on whether or not:

- Future stresses to be predicted by the model are similar to those of the past
- Predictions are required for a period of time similar to that of historical observations
- Available data sufficiently characterises hydrological features of most relevance to model predictions
- The model can be calibrated to available data.

While setting a target confidence level at the start of model development can be a useful way to align modelling expectations (refer to Section 1.3.2), the actual confidence level achieved by the model is not often known until the outcomes of predictions are considered within the context of model calibration performance, which in turn is informed by available data.

It is generally rare for a single model to satisfy all characteristics of a particular confidence level class outlined in the guidelines. Groundwater models developed for large construction projects are required to predict future changes to groundwater systems that are often large compared with those observed in the past, rendering low confidence in the cause and effect relationships simulated by the model. On the other hand, careful model design and sensible parameterisations ensures the model outputs are mathematically sound and provides an appropriate basis for informing potential project-related impacts on groundwater.

For the project, the key indicators of a low confidence level include the length of the predictive timeframe that exceeds the calibration timeframe and the magnitude of future stresses that is large compared with the past (such as stress imposed during pumping tests). Characteristics reflecting higher confidence levels include acceptable calibration statistics, low mass balance error (<0.05 per cent), sensible parameterisation consistent with the conceptual model and appropriate model design/spatial discretisation for the intended model use. Based on the consideration of the above, the groundwater model developed for the project is considered to have the characteristics of Class 1 to 2 confidence level; that is, a moderate confidence level, typically expected for a large-scale infrastructure project (Barnett *et al*., 2012).

5. Uncertainty analysis

5.1 Overview

Hydrogeological systems are complex natural systems whose properties cannot be measured at all spatial and temporal scales. Hydrogeological processes that have occurred in the past, and those that may occur in the future, can only be inferred from a finite number of measurements. Simplifications are therefore necessary in groundwater modelling and uncertainty is inherent in all model predictions.

In groundwater modelling, uncertainty in model parameters can lead to the problem of model non-uniqueness or identifiability (Barnett *et al*., 2012). This is when the behaviour of the groundwater system being modelled depends on a particular combination of parameters rather than a single parameter in isolation. Because model parameters are uncertain, with a plausible range of values, different combinations of parameter values could result in more than one plausible realisation of the same model. The predictive uncertainty analysis described in this section seeks to quantify the effect of this parameter uncertainty on model predictions, by identifying the range of alternative models whose predictions can be regarded as equally plausible based on the existing calibration dataset.

5.2 Approach

For the purposes of assessing uncertainty in the modelled groundwater level changes, a numerically efficient form of calibration-constrained Monte-Carlo analysis has been completed using PEST and its Null Space Monte Carlo methodology (Doherty, 2016). Monte Carlo analysis involves running many realisations of the model with a range of parameter values, and using the outputs from these models to estimate the uncertainty range of the outputs produced by the calibrated model. The term 'calibration-constrained' means only those model realisations that are sufficiently well calibrated are deemed plausible and used for the Monte Carlo runs. The Null Space Monte Carlo methodology is described in the Australian Groundwater Modelling guidelines as one of the methods available to explore model uncertainty (Barnett *et al.,* 2012).

The following PEST utilities have been utilised to undertake the uncertainty analysis:

- PREDUNC7 to generate posterior parameter uncertainty and covariance matrix files from the jacobian sensitivity matrix of the final calibrated model and parameter variability specified in the prior parameter uncertainty file. The parameter variability (plausible lower and upper bounds) is the same as the calibration ranges except for recharge and EVT extinction depth, which utilised wider parameter bounds of 5 –100 millimetres/yr and 2 – 8 metres respectively.
- RANDPAR to generate random parameter sets based on the posterior parameter covariance matrix. For highly parameterised models (>200 adjustable parameters), a large number of random parameter sets (around 1,000) are often used from which a sub-set of sufficiently calibrated models can be identified. As the number of adjustable parameters used in this project is only 28, the random combinations of parameters generated by RANDPAR are limited to 200.
- PNULPAR to undertake null-space projection of RANDPAR-generated parameter sets. This adjusts the 200 random parameter combinations so that each parameter set produces a model that can be considered reasonably calibrated.

Figure 33 presents the parameter ranges of the 200 parameter sets following null-space projection. Some parameters have narrower ranges than others because they are either constrained by the available pumping test data or the model could only be calibrated using a narrow range of values. For parameters with very wide range of values, the calibration was either very insensitive to those parameters, or the parameter could be varied in conjunction with other parameters as a ratio to maintain the calibration. For example:

- Kxp1, Kxp6 and Kxp17 have a narrow range of plausible values because they are constrained by drawdown measured in the vicinity of pumping bores. Similarly, ss_bedr has a narrow range of value (9.7 x 10^{-6} /m to 1.1 x 10^{-6} /m) because the Bedrock-specific storage is constrained by the observed drawdown response during pumping tests. The range of specific storage values tested is within the plausible range of value suggested by Rau *et al.,* (2018).
- Kxp3 is skewed towards the lower end of the range to simulate the subdued response to pumping test observed at bore NEL-BH043 (higher values overestimate drawdown observed in this bore).
- Kxp9 is skewed towards the upper end of the range to maintain sensible baseflow (> 1 Ml/d) between gauges 229142A and 229135A. Kxp9 below the median value is generally associated with baseflows below 1 ML/d.
- Kxp6_alluv (6 – 25 m/d) and avmrch (70 – 100 mm/yr) can be varied in conjunction to maintain a similar ratio of recharge to hydraulic conductivity without significantly affecting the calibration to observed heads.
- riverk has a wide plausible range (0.0014 – 0.038 m/d) as calibration is not strongly constrained by baseflow; as discussed in Section 3.2.1 and Section 3.3.5, the available baseflow data are estimates only, providing a sensible upper limit of plausible baseflow.

Figure 34 summarises the key calibration statistics for all 200 parameter sets as well as baseflows simulated between gauges 229142A and 229135A. Given the relatively small number of adjustable parameters, all 200 parameter combinations result in a similar degree of calibration with respect to observed heads and drawdown. Uncertainty associated with hydraulic conductivity (6 – 25 m/d) and recharge (70 – 100 mm/yr) of the Alluvium and hydraulic conductivity of river bed (0.0014 – 0.038 m/d) results in realisations of the model with a wide range of baseflows (0.75 – 3.8 ML/d) that are equally well calibrated to head and drawdown observations. This means there is a wide plausible range of baseflows that satisfy the measured heads and drawdown, reflecting the uncertain nature of baseflow estimation.

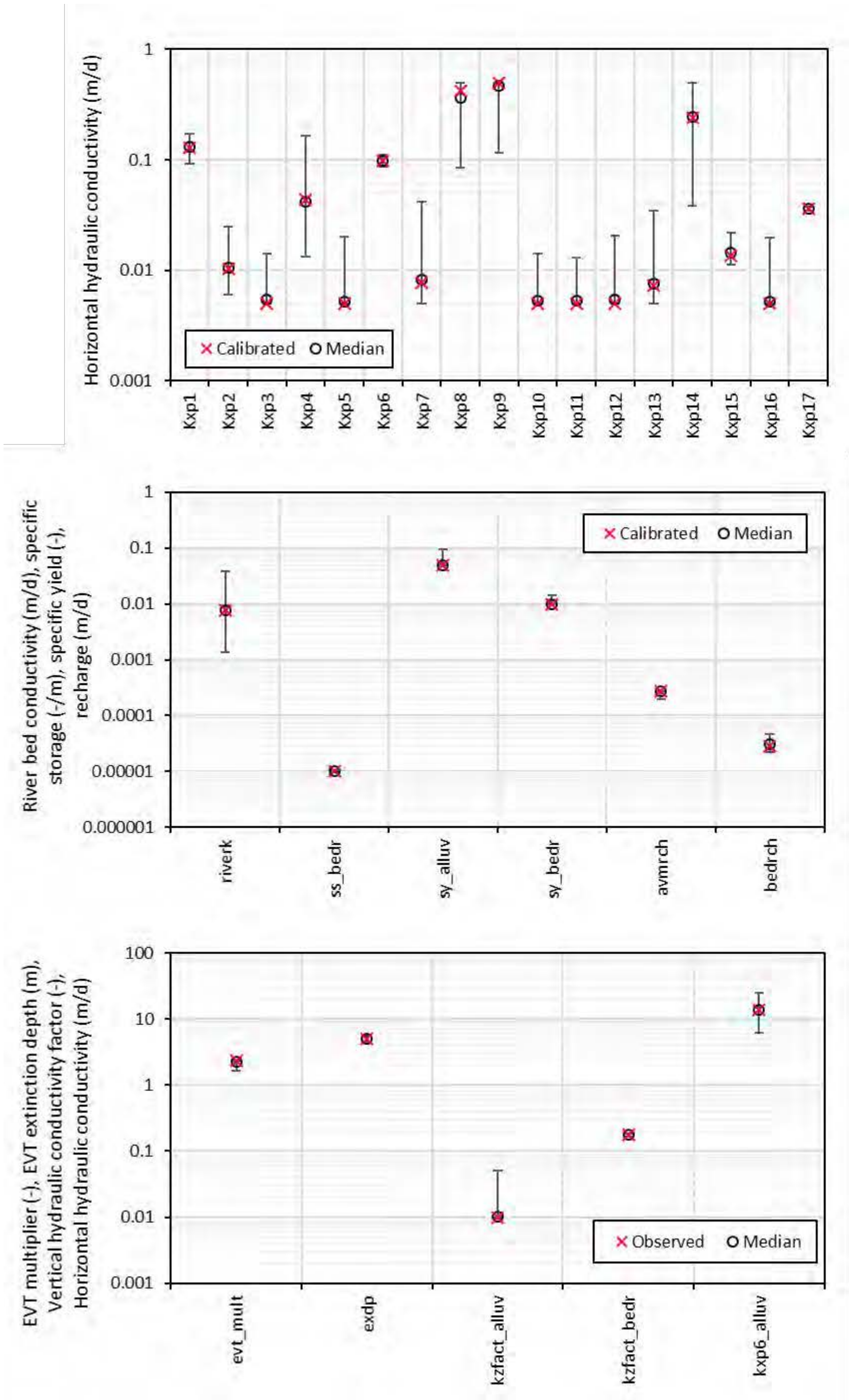
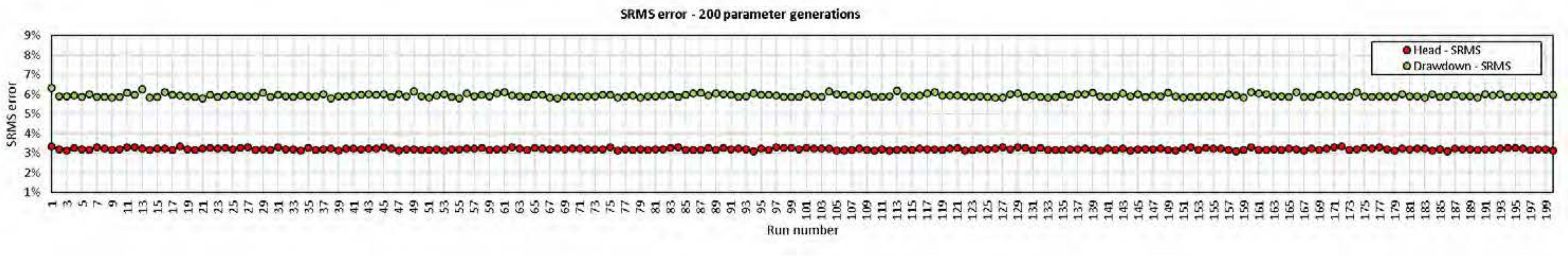


Figure 33 Uncertainty analysis parameter ranges



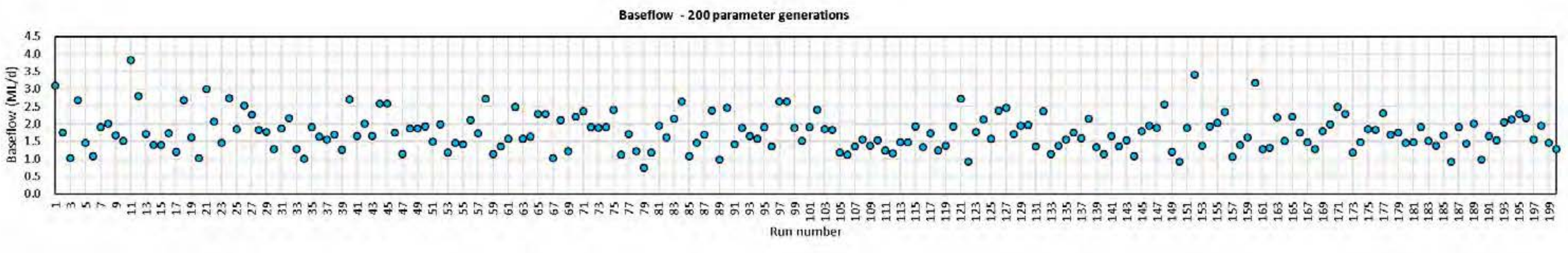


Figure 34 Uncertainty analysis - model calibration of 200 realisations

5.3 Predictive uncertainty results

5.3.1 Groundwater level changes

The estimated uncertainty in the extent and magnitude of drawdown and mounding (impress) is described using composite drawdown maps derived by aggregating the modelled change in head at each point in space across all 200 model runs. This means each map is not from any one of the 200 model runs; rather, it is a composite statistical image of the spatial drawdown and mounding characteristics across 200 maps.

Figure 36 to Figure 39 present the 95th and 5th percentile drawdown and mounding predictions for late 2024 (end of construction) and 2075 (50 years post-construction) based on 200 model runs. It should be noted the reduction in groundwater levels is calculated as positive drawdown whereas mounding is calculated as negative drawdown. This means:

- The 95th percentile is most conservative for drawdown prediction, implying that 95 per cent of the 200 alternative models predict drawdown that occurs within the ranges shown. This means it is unlikely the project would cause drawdown greater than the values shown in Figure 36 and Figure 37.
- The 5th percentile is most conservative for mounding (negative drawdown) prediction, implying that only 5 per cent of the 200 alternative models predict mounding greater than the ranges shown. This means it is unlikely the project would cause mounding greater (more negative) than the values shown in Figure 38 and Figure 39.

To place the drawdown and mounding uncertainty estimates into context, Figure 40 and Figure 41 show the range of change in groundwater levels between the 5th and 95th percentile estimates for late 2024 and 2075 respectively. These figures are derived by subtracting the 5th percentile contours from the 95th percentile contours, as shown schematically in Figure 35. The larger the difference between the 5th and 95th percentile contours, the greater the range of drawdown/mounding predicted by the 200 models and so the greater the uncertainty range in model predictions. The figures present the spatial and temporal differences in the magnitude of uncertainty associated with drawdown and mounding predictions, providing useful indications of areas where model predictions are most uncertain.

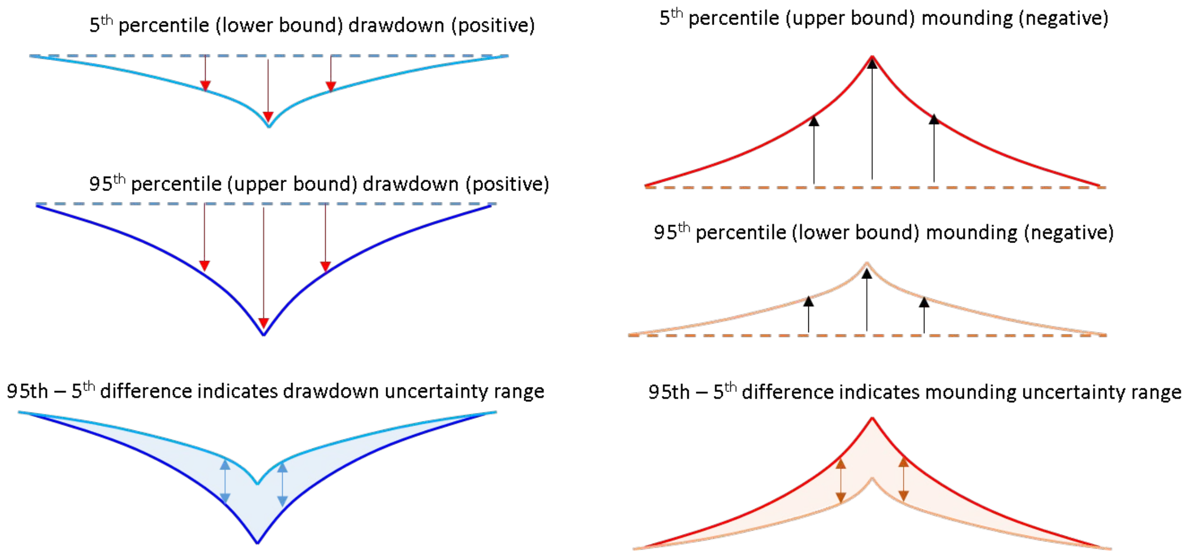
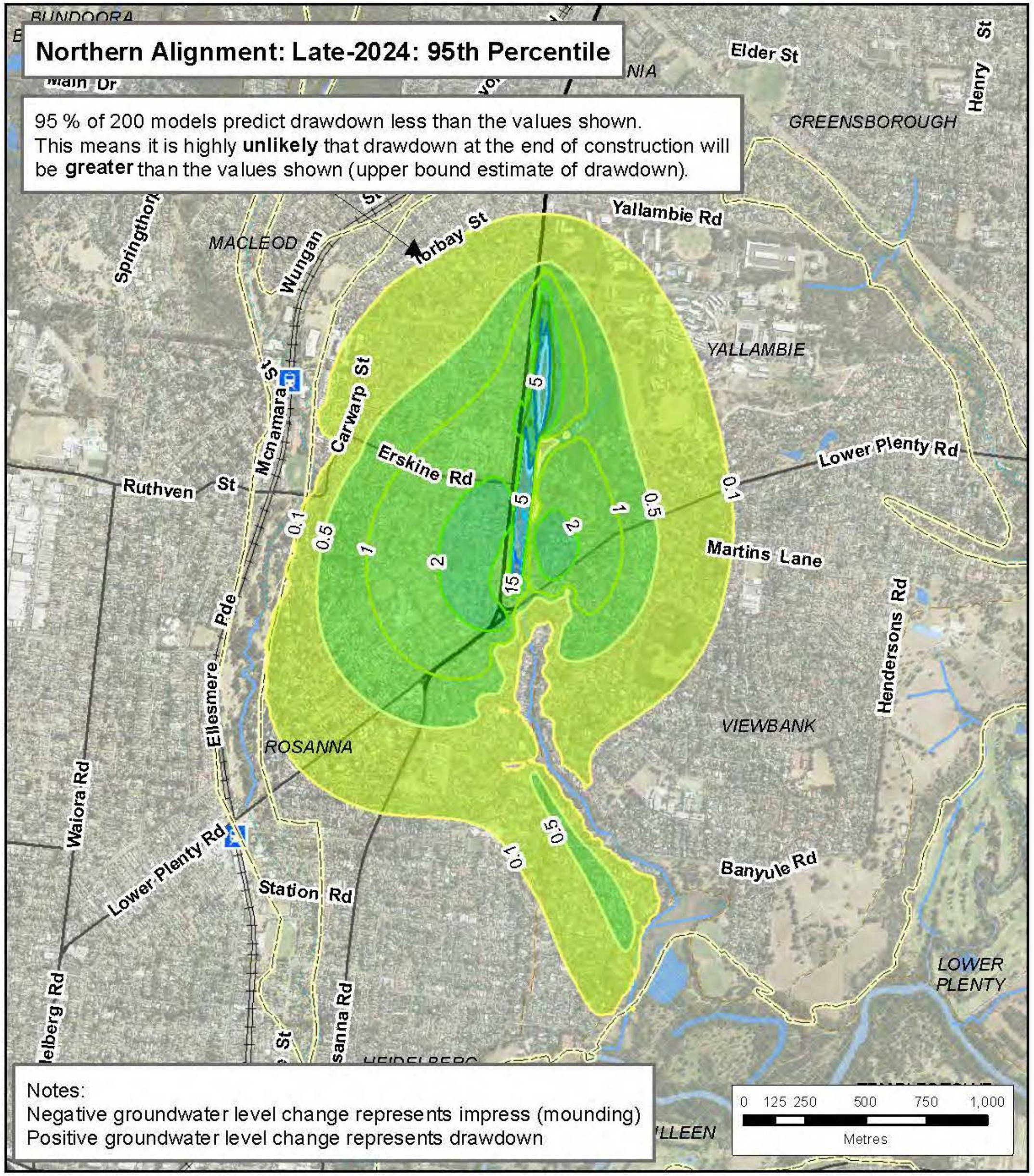
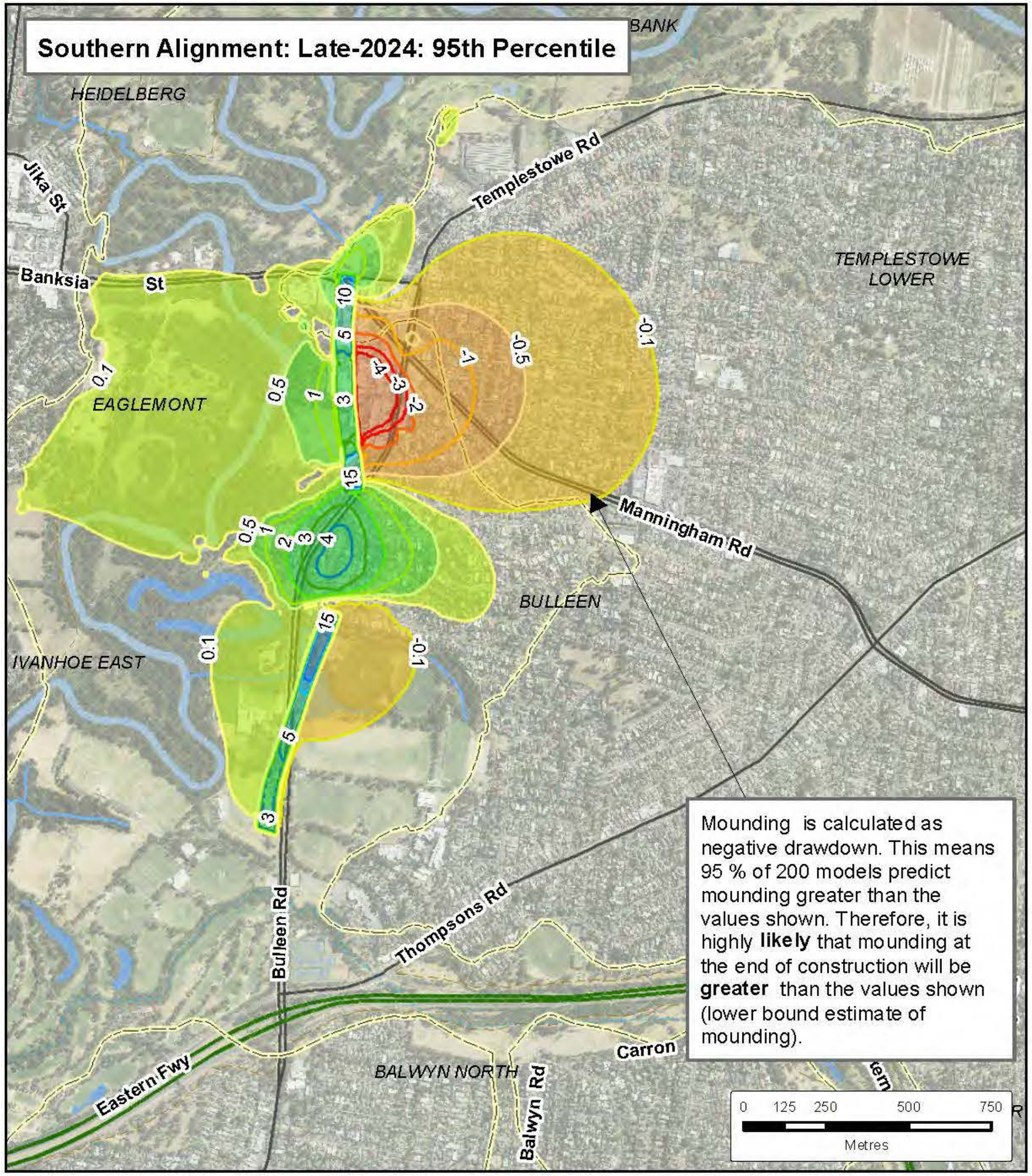


Figure 35 Computation of drawdown/mounding uncertainty range

In general, the uncertainty range within the vicinity of the cut and cover structures is larger at the end of construction following a period of active dewatering, especially above the mined tunnels where large temporary drawdown is predicted. In parts of the southern portion of the alignment, where groundwater level changes occur within the Alluvium, the uncertainty range at the end of construction is around 1 metre greater than in the northern portion. This is partly due to the presence of mined tunnels and partly due to the wider plausible range of Alluvium hydraulic conductivity and recharge compared to those of the Bedrock, which are less constrained by the available calibration datasets. The uncertainty in the spatial extent of drawdown is most discernible at the lower end of drawdown range, between 0.1 – 0.5 metres drawdown.

On the up gradient side of the Banksia cut and cover, the uncertainty range of mounding is greater at the start of the predictive simulation (before and during construction) than towards the end (post-construction). This is due to the uncertainty in the range of water table simulated at this location, the effect of which can be seen in the predicted hydrograph of bore NEL-BH137 located within the area of modelled mounding, as shown in Figure 42. The hydrograph from all 200 model runs show a wider range of heads (around two metres) at the start of the simulation than at the end of the simulation (around 1 metre). As discussed in Section 4.2, the calibrated model locally under-estimates the pre-construction water table in this area and it is possible to simulate higher water table by adjusting the ratio of recharge to hydraulic conductivity of the Alluvium (albeit also affecting the heads elsewhere). In contrast, the maximum post-construction water table is constrained by the regional water table and modelling indicates a smaller uncertainty range. An important outcome of the uncertainty analysis is that the depth to groundwater on the up gradient side of the Banksia cut and cover would unlikely reach less than five metres below ground level (bgl) post-construction.





Paper Size A4

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

-5, -4, -3, -2, -1, -0.5, -0.1, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20

Modelled GWL Change (m)

< -5, -4.99 - -2, -1.99 - -0.5, -0.49 - -0.1, -0.09 - 0.1, 0.11 - 0.5, 0.51 - 2, 2.01 - 5, 5.01 - 10, 10.01 - 15, 15.01 - 20, > 20, Alluvium

North East Link Project
Environment Effects Statement (EES)

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Revision C
Date 01 Mar 2019

Predicted groundwater level changes – late 2024 - 95th percentile (upper bound drawdown / lower bound mounding)

Figure 36

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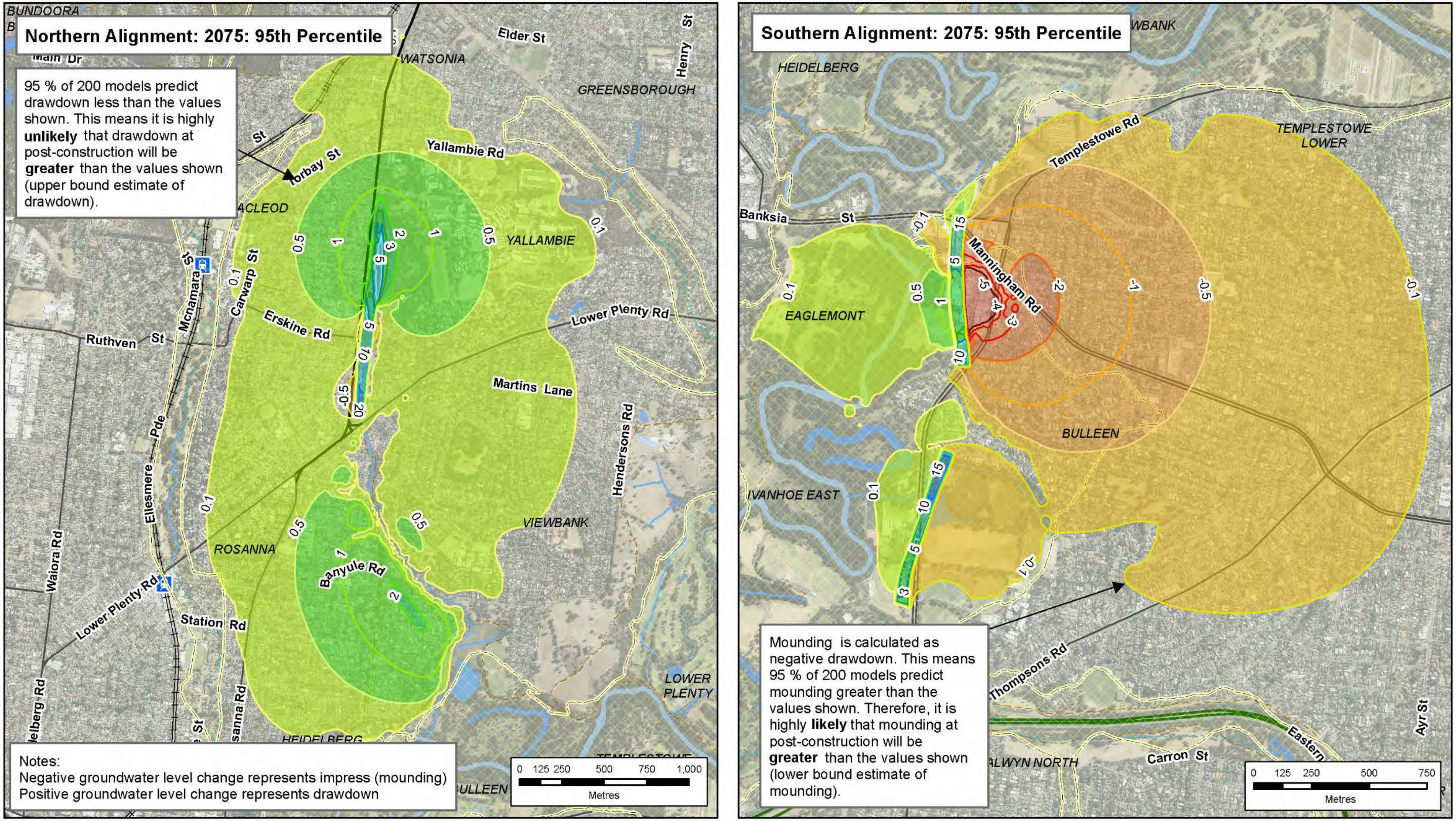
Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

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- -4
- -3
- -2
- -1
- -0.5
- -0.1
- 0.1
- 0.5
- 1
- 2
- 3
- 4
- 5
- 10
- 15
- 20

Modelled GWL Change (m)

- < -5
- -4.99 - -2
- -1.99 - -0.5
- -0.49 - -0.1
- -0.09 - 0.1
- 0.11 - 0.5
- 0.51 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- > 20
- Alluvium

NORTH EAST LINK PROJECT

North East Link Project
Environmnet Effects Statement (EES)

Job Number 31-35006
Revision A
Date 28 Feb 2019

Predicted groundwater level changes – 2075 - 95th percentile (upper bound drawdown / lower bound mounding)

Figure 37

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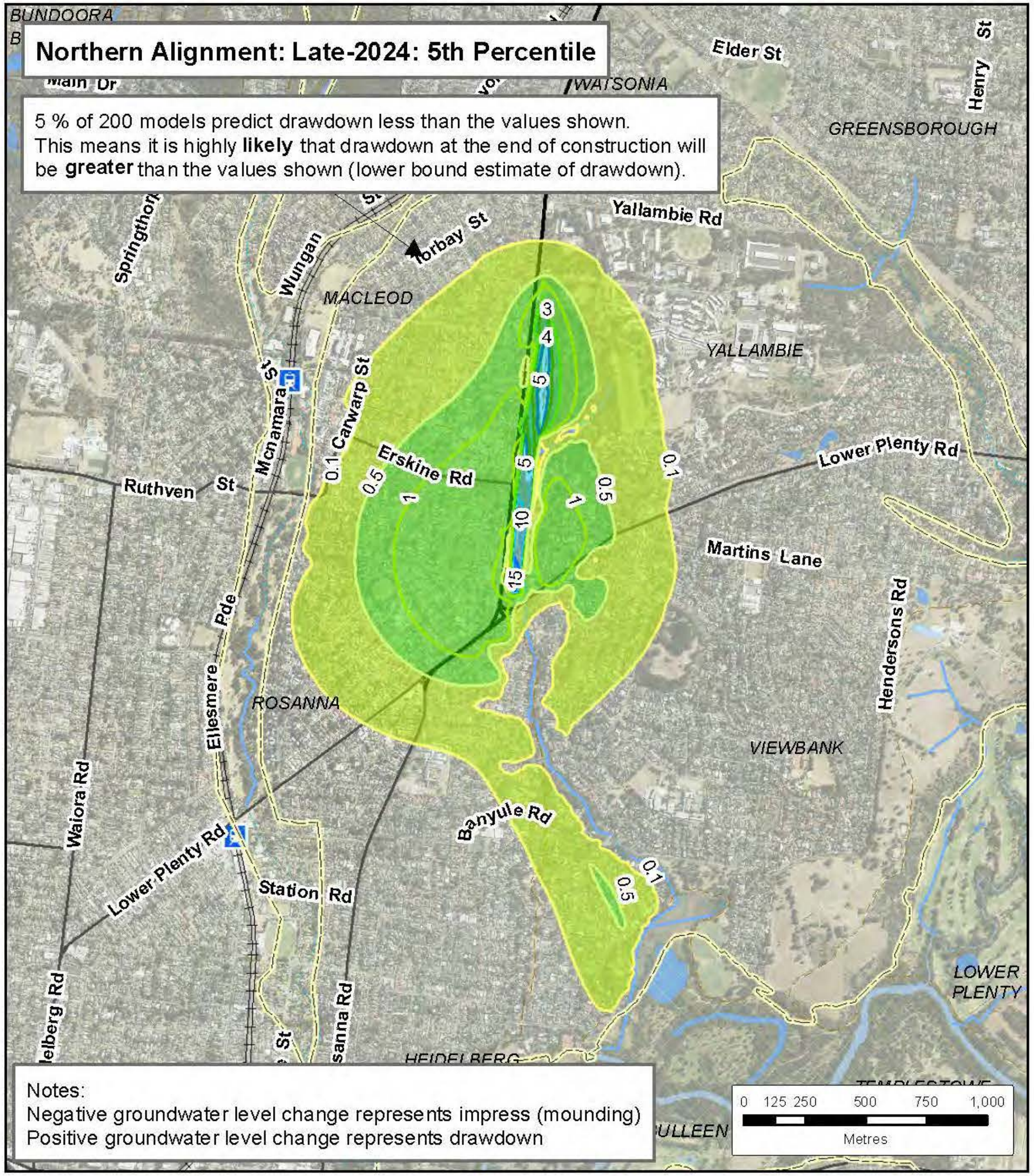

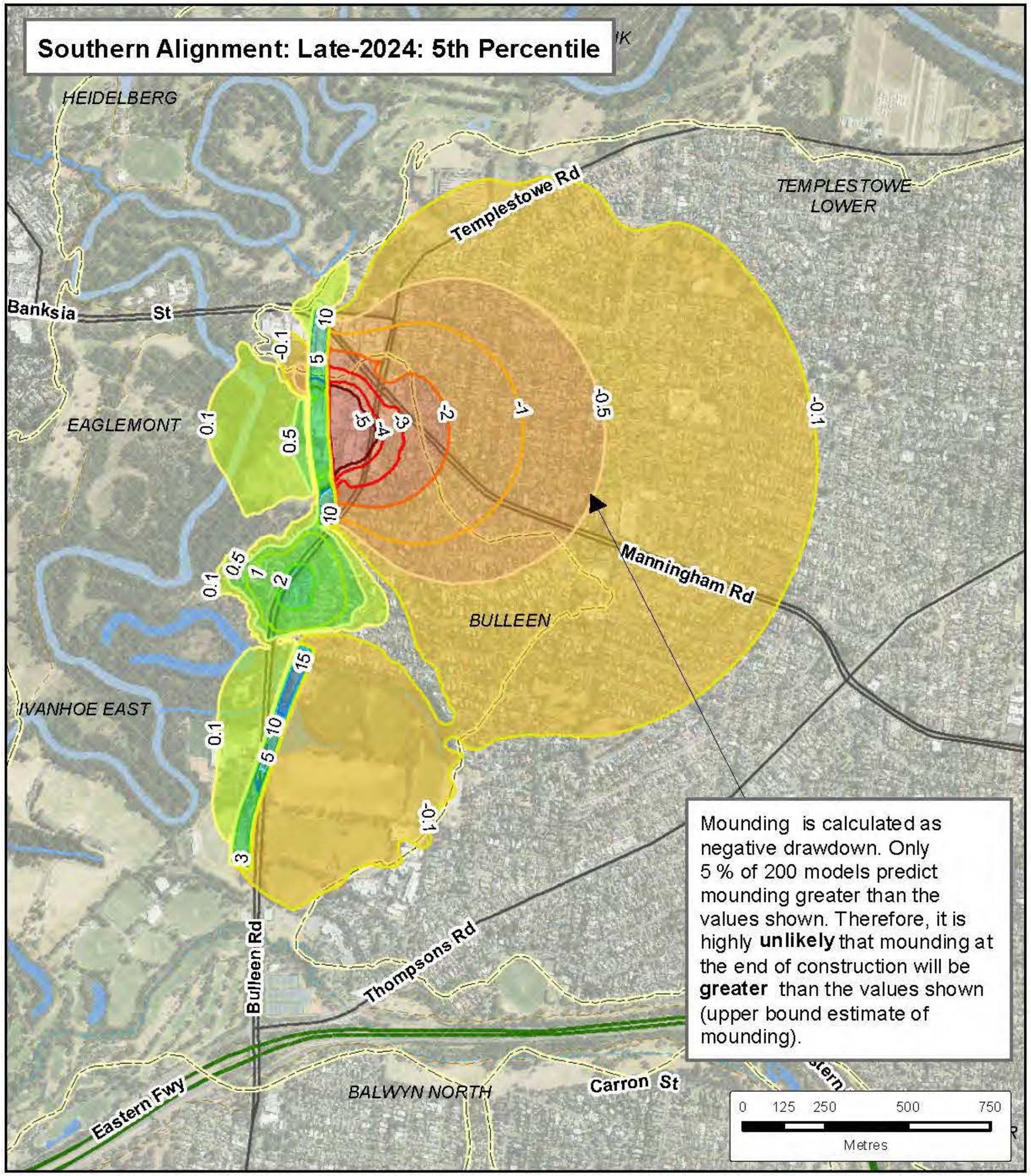

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Modelled GWL Change (m)

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- -3
- -2
- -1
- -0.5
- -0.1
- 0.1
- 0.5
- 1
- 2
- 3
- 4
- 5
- 10
- 15
- 20

Modelled GWL Change (m)

- < -5
- -4.99 - -2
- -1.99 - -0.5
- -0.49 - -0.1
- -0.09 - 0.1
- 0.11 - 0.5
- 0.51 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- > 20
- Alluvium

North East Link Project
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Job Number 31-35006
Revision B
Date 01 Mar 2019

Predicted groundwater level changes – late 2024 - 5th percentile (lower bound drawdown / upper bound mounding)

Figure 38

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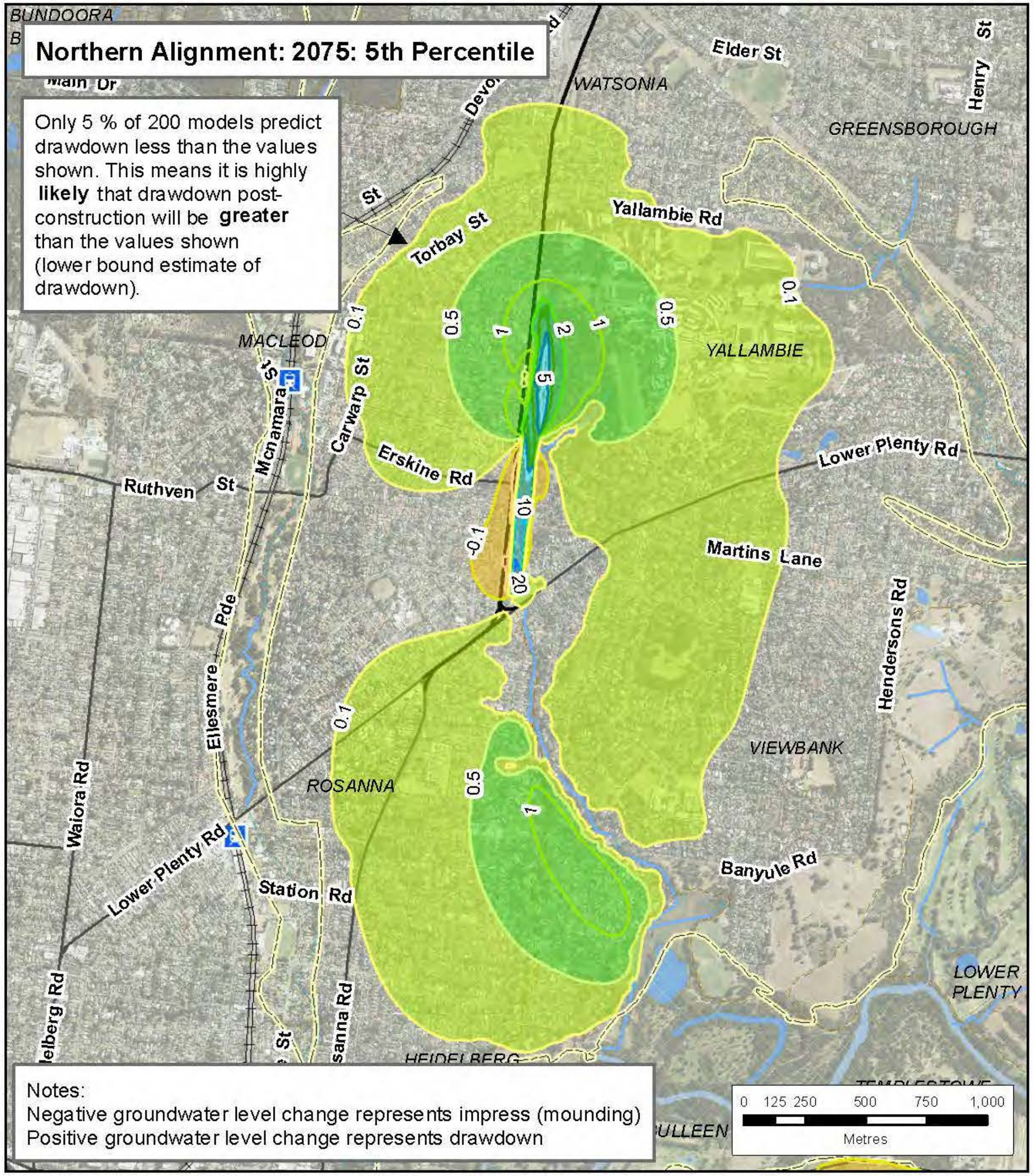
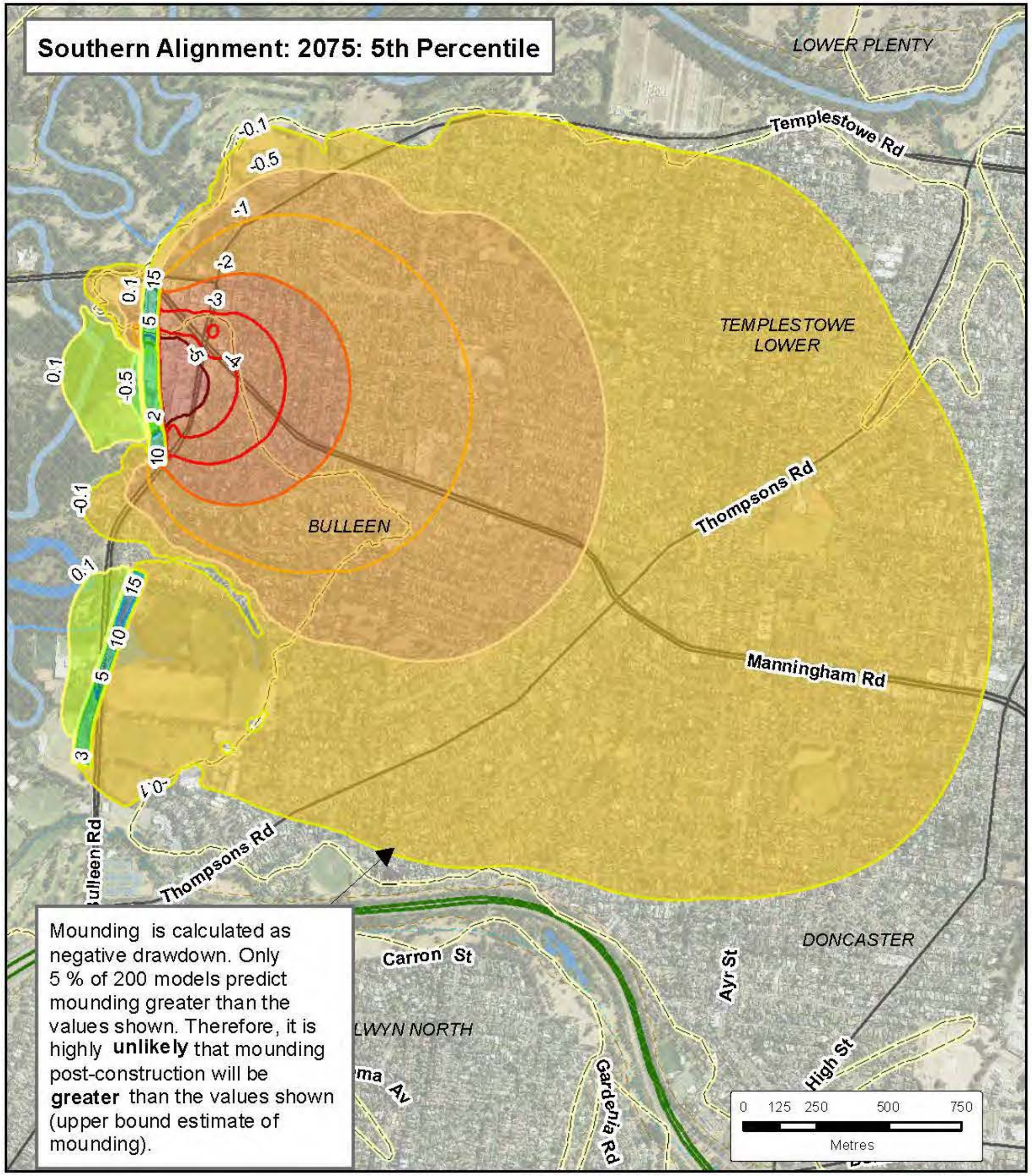
Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti





Paper Size A4

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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Modelled GWL Change (m)

-5, -4, -3, -2, -1, -0.5, -0.1, 0.1, 0.5, 1, 2, 3, 4, 5, 10, 15, 20

Modelled GWL Change (m)

< -5, -4.99 - -2, -1.99 - -0.5, -0.49 - -0.1, -0.09 - 0.1, 0.11 - 0.5, 0.51 - 2, 2.01 - 5, 5.01 - 10, 10.01 - 15, 15.01 - 20, > 20, Alluvium

North East Link Project
Environment Effects Statement (EES)

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Date	01 Mar 2019

Predicted groundwater level changes – 2075 - 5th percentile (lower bound drawdown / upper bound mounding)

Figure 39

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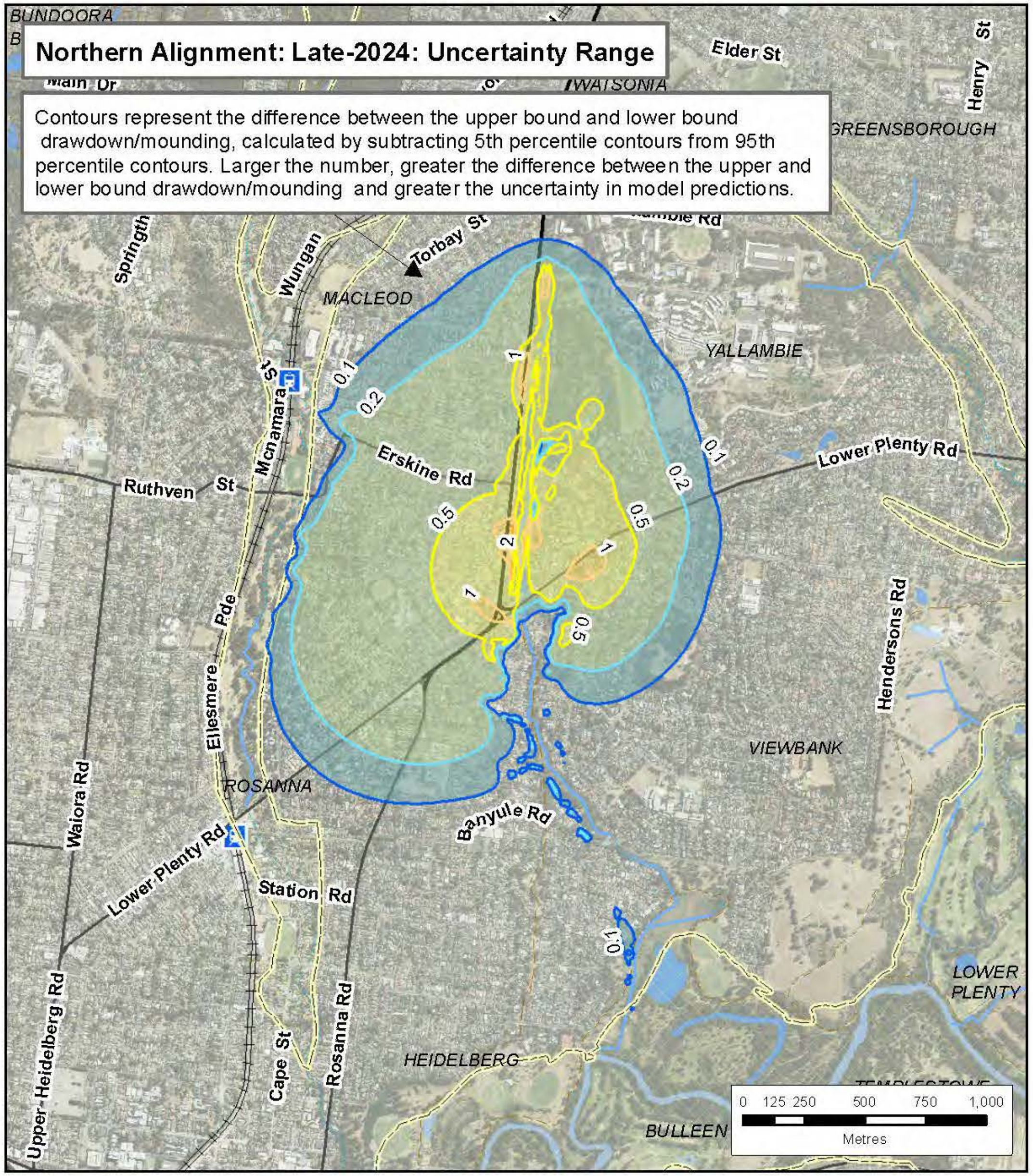

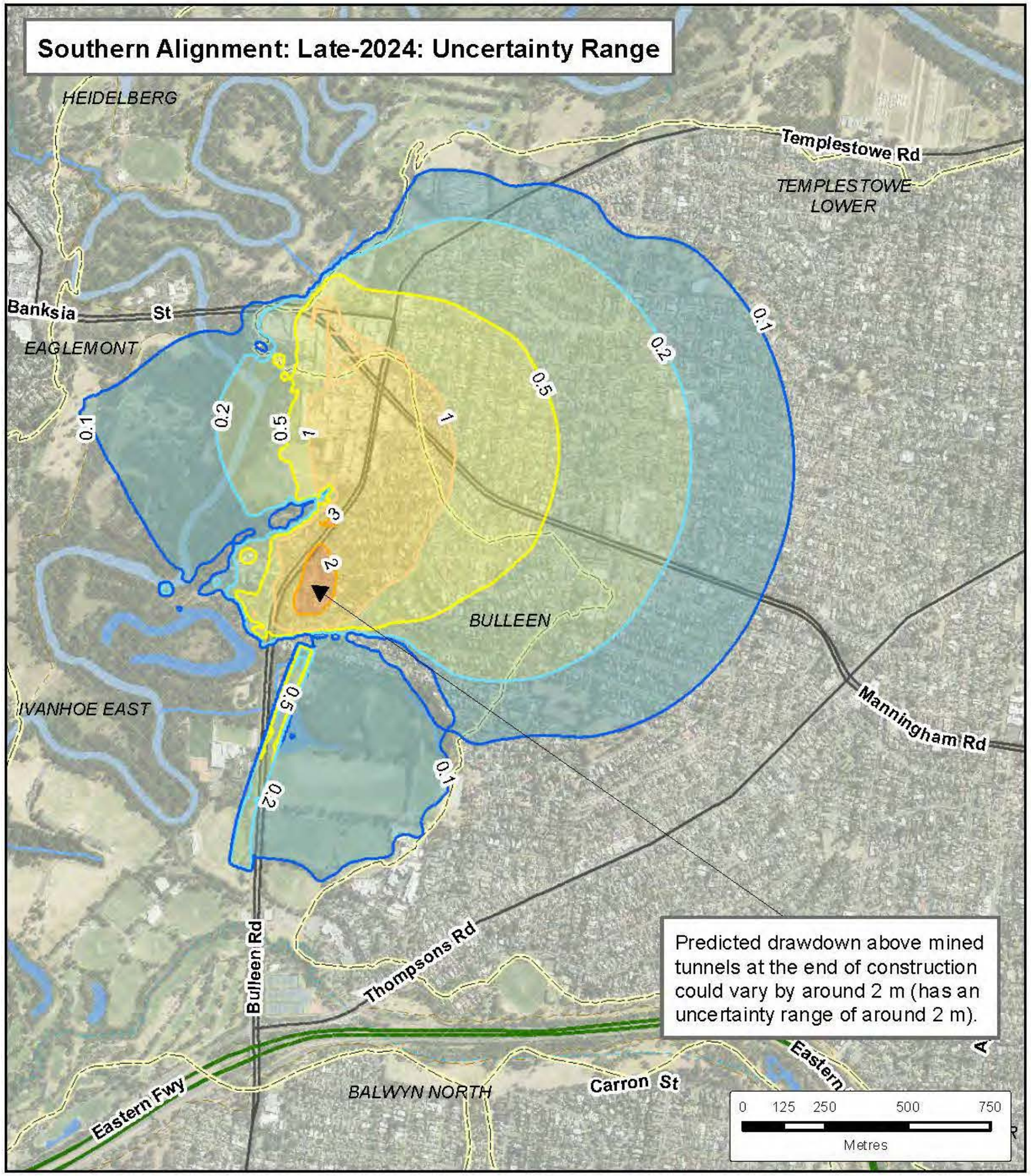

Paper Size A4

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Uncertainty Range in Modelled GWL Change (m)
- 0.1
- 0.2
- 0.5
- 1
- 2
- 3
- 4
- 5

Uncertainty Range in Modelled GWL Change (m)
- < -.1
- 0.11 - 0.2
- 0.21 - 0.5
- 0.51 - 1
- 1.01 - 2
- 2.01 - 3
- 3.01 - 4
- 4.01 - 5.11
- Alluvium

North East Link Project
Environment Effects Statement (EES)

Job Number 31-35006
Revision B
Date 01 Mar 2019

Predicted groundwater level changes uncertainty range – late 2024 (difference between upper and lower bound drawdown / mounding)

Figure 40

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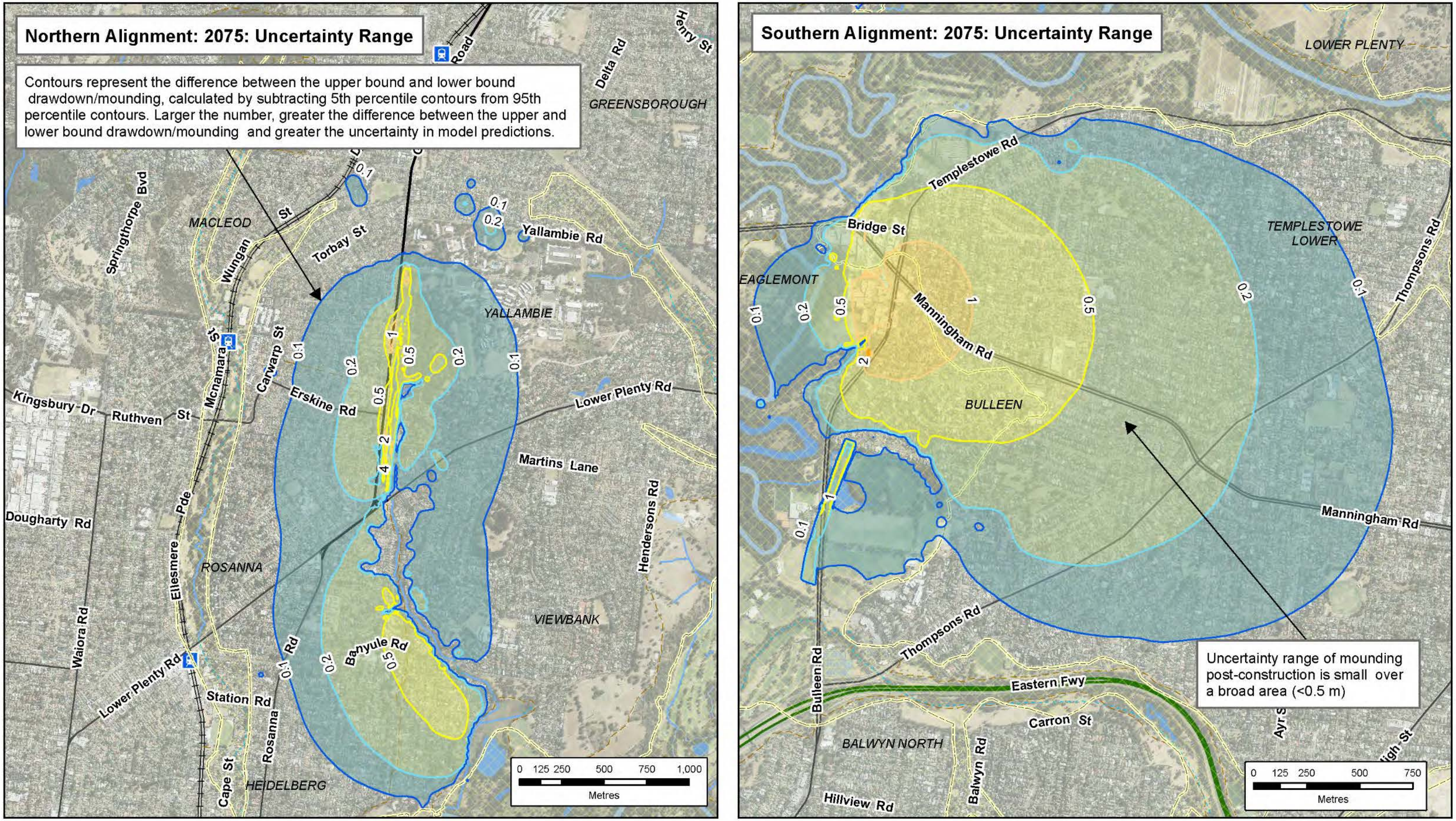

Paper Size A4

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Uncertainty Range in Modelled GWL Change (m)

- 0.1
- 0.2
- 0.5
- 1
- 2
- 3
- 4
- 5

Uncertainty Range in Modelled GWL Change (m)

- < -.1
- 0.11 - 0.2
- 0.21 - 0.5
- 0.51 - 1
- 1.01 - 2
- 2.01 - 3
- 3.01 - 4
- 4.01 - 5.11
- Alluvium

North East Link Project
Environmental Effects Statement (EES)

Job Number	31-35006
Revision	A
Date	27 Feb 2019

Predicted groundwater level changes uncertainty range - 2075 (difference between upper and lower bound drawdown / mounding)

Figure 41

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Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

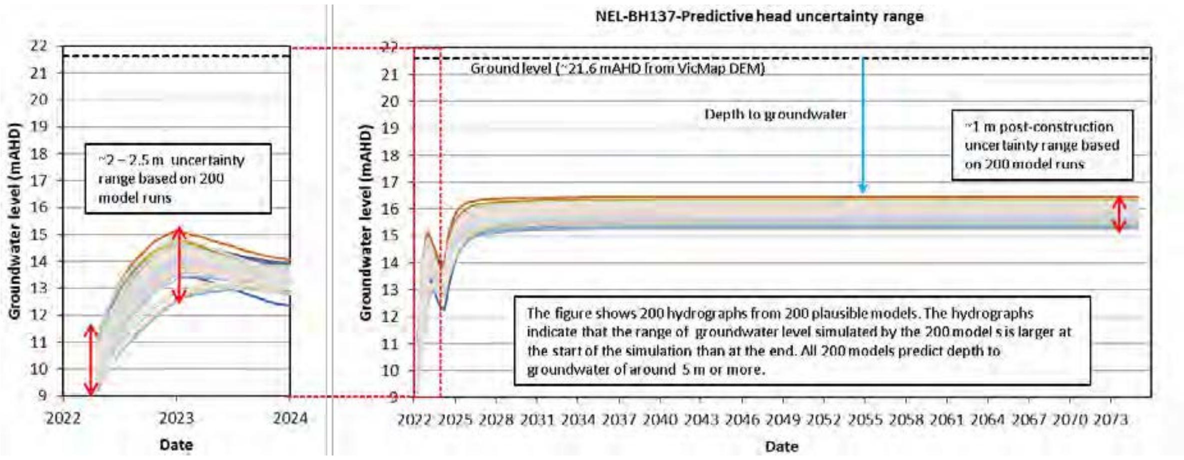


Figure 42 Predicted uncertainty range of mounding

5.3.2 Groundwater inflow rates

Table 6 and Table 7 provide a summary of the 5th and 95th percentile predicted groundwater inflow rates into the cut and cover excavations based on 200 model runs. The 95th percentile estimates represent the upper bound estimates, indicating the inflow rates would likely be less than those shown in Table 6. The differences in the post-construction inflow (seepage) rates between the 5th and 95th percentiles are small due to the effects of tanking, with small predicted differences resulting from the differences in modelled hydraulic heads (surface areas of tanked structures in contact with groundwater and hydraulic gradient across the structures).

Table 6 Predicted groundwater inflow rate – 95th percentile (upper bound)

Excavation / cut and cover	Average inflow during construction (m^3/d)	Maximum inflow during construction (m^3/d)	Average inflow post-construction (m^3/d)
Southern	123	620	13
Banksia	78	255	11
Lower Plenty	123	330	14
Trench	22	105	16

Table 7 Predicted groundwater inflow rate – 5th percentile (lower bound)

Excavation / cut and cover	Average inflow during construction (m^3/d)	Maximum inflow during construction (m^3/d)	Average inflow post-construction (m^3/d)
Southern	77	389	10
Banksia	55	181	9
Lower Plenty	98	282	12
Trench	16	86	10

5.3.1 Groundwater flux changes

The 5th and 95th percentile predicted river fluxes are computed to estimate the uncertainty in the predicted changes to groundwater fluxes to surface water bodies (baseflow). The percentage change in river fluxes also provide an indication of the relative impact of the project and are computed for each one of 200 model runs. These are aggregated and presented along with the river fluxes in Figure 43 to Figure 45.

Figure 43 indicates that 95 per cent of 200 model runs predict reduction in groundwater fluxes to Bolin Bolin Billabong by no greater than 4 per cent over the long term. Therefore, the modelling indicates a low likelihood of groundwater fluxes to the deep pool reducing by more than 4 per cent of the existing condition due to the project. Conversely, the 5th percentile reduction indicates that only 5 per cent of the 200 model runs predict percentage change in fluxes of less than 1.5 per cent post-construction, indicating a high likelihood that groundwater fluxes would be reduced by at least 1.5 per cent due to the project.

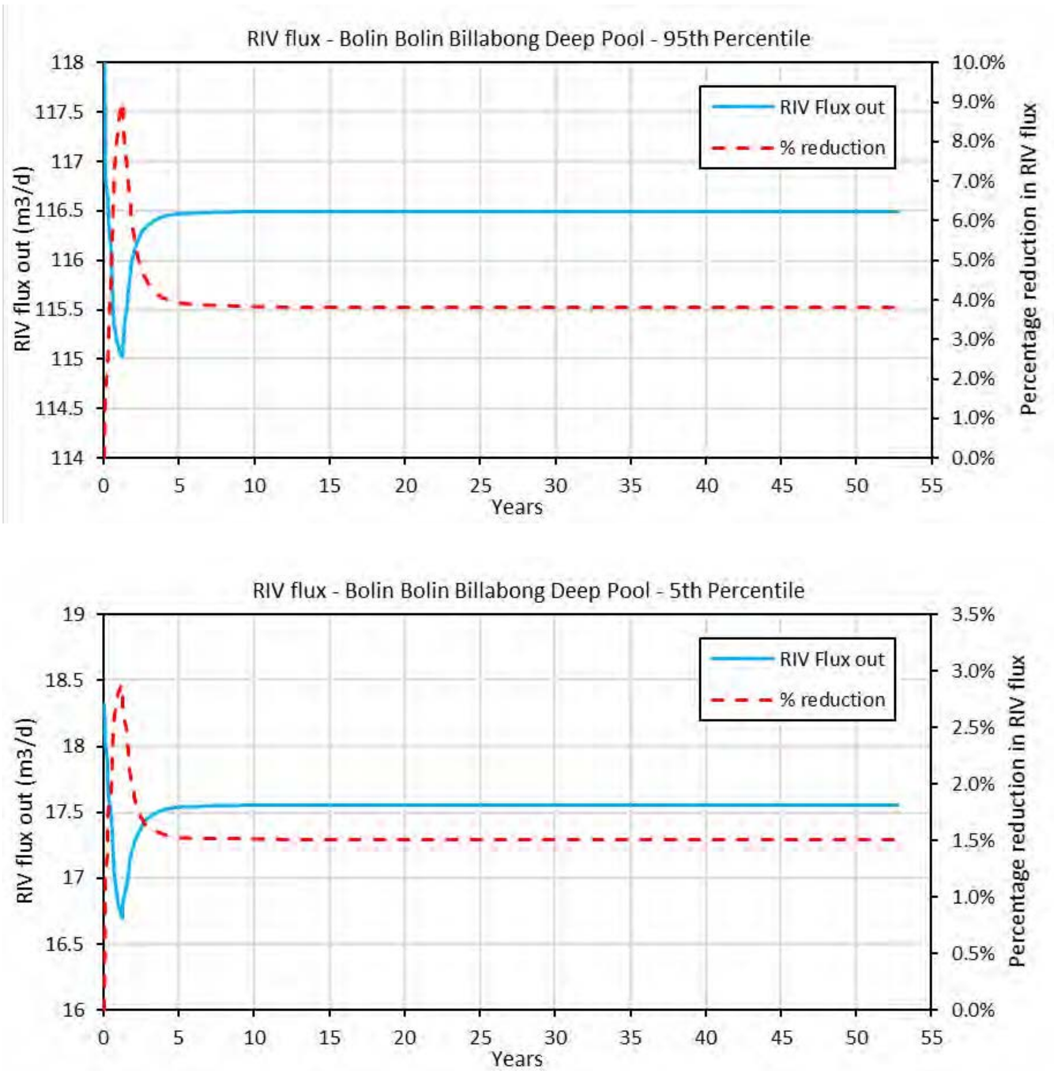


Figure 43 Uncertainty in predicted changes to Bolin Bolin Billabong groundwater flux (baseflow)

As discussed in Section 4.3.2, the largest reduction in groundwater fluxes (baseflow) to the Yarra River is predicted between gauges 229135A and 229143A, with 95 per cent of the 200 model runs predicting a temporary reduction of no greater than 60 m^3/d during construction and around 30 m^3/d post-construction. These equate to less than 0.02 per cent of the 360,000 m^3/d total flow recorded at 229135A for 90 per cent of the time.

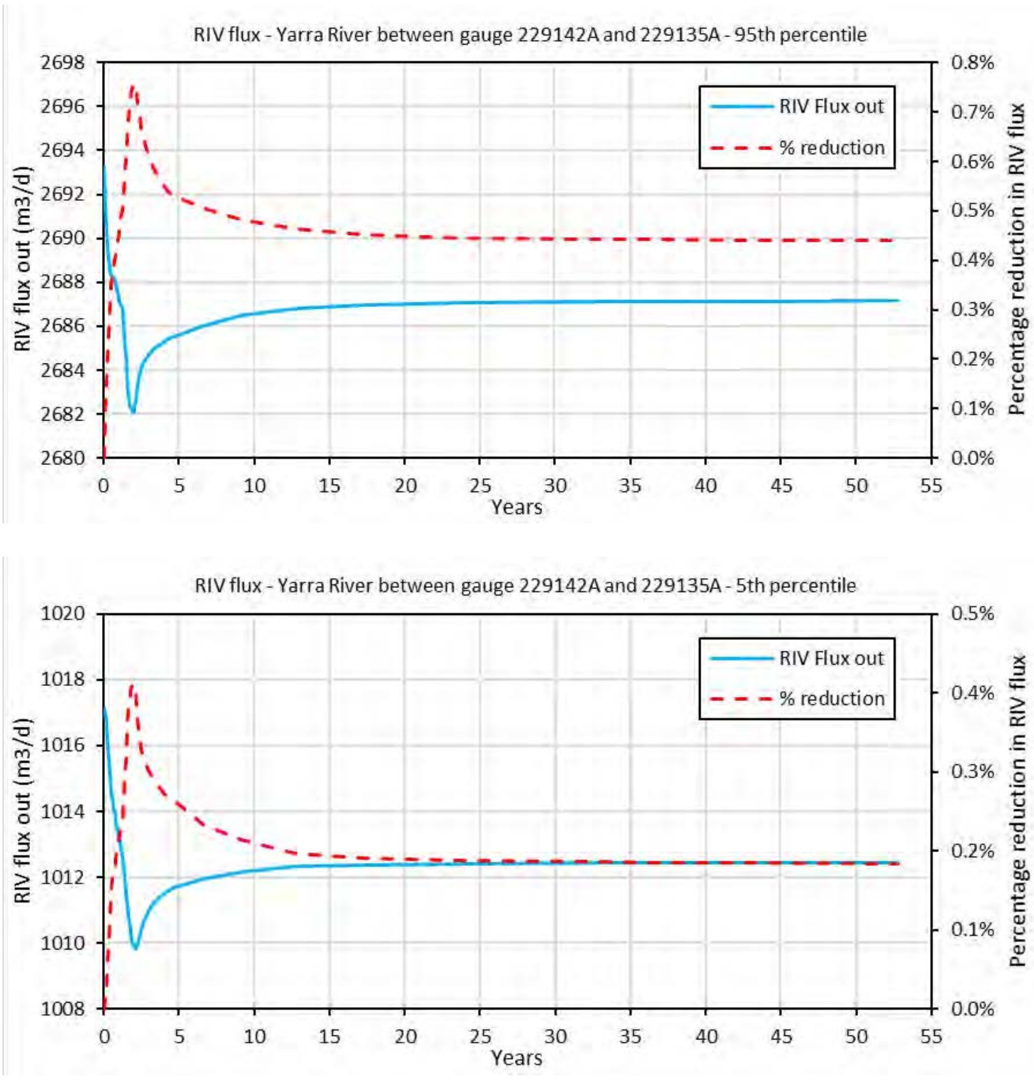


Figure 44 Uncertainty in predicted changes to Yarra River groundwater flux – 229142A to 229135A

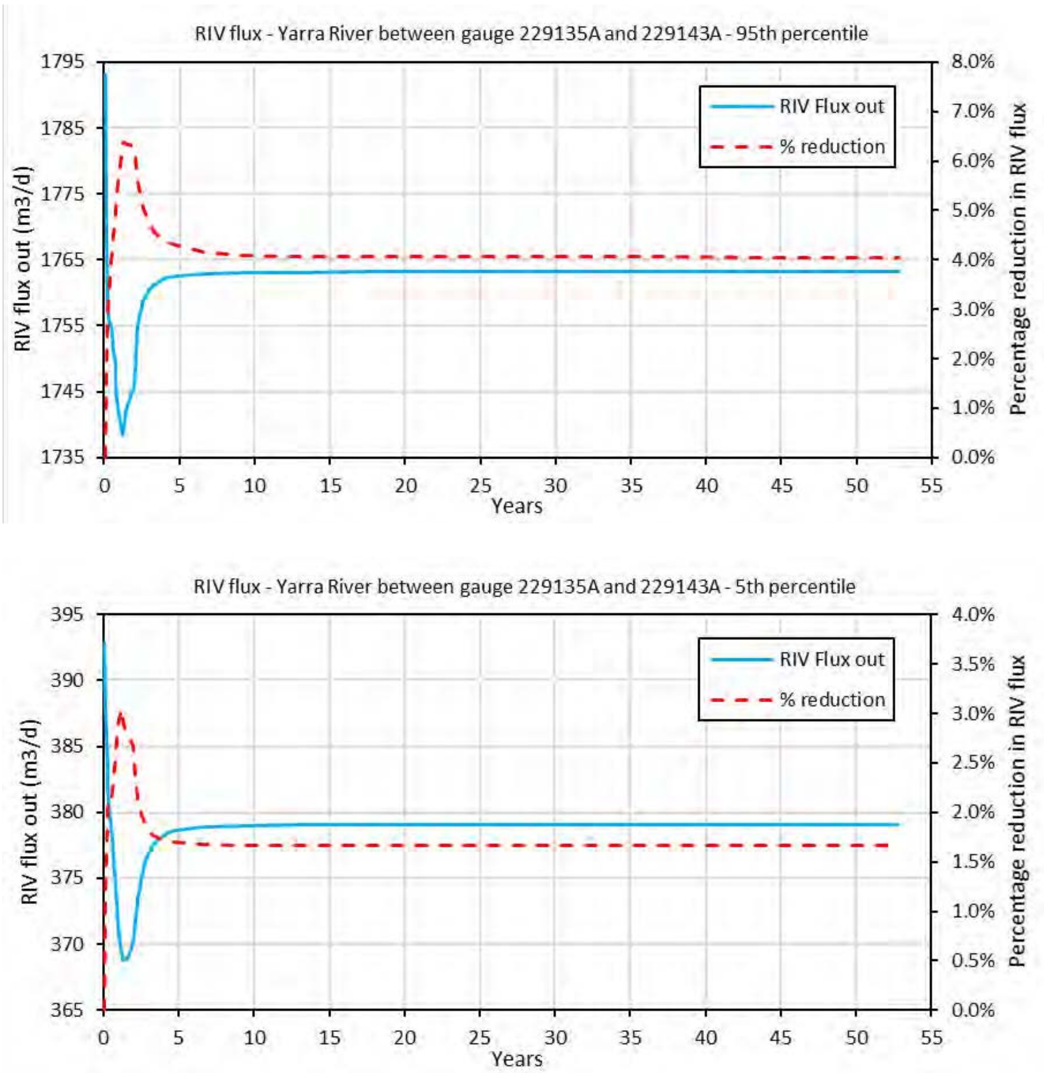


Figure 45 Uncertainty in predicted changes to Yarra River groundwater flux – 229135A to 229143A

6. Climate change effects

6.1 Overview

Changes in climate have the potential to affect the groundwater system, primarily by altering the dynamics of recharge and evapotranspiration. Predicting potential changes induced to these processes by future climate variations is challenging due to their dependence on multiple climate variables and complex interactions between vegetation, soil and climate (McCallum *et al.,* 2010). Some studies suggest that a warmer climate (higher temperature) may not necessarily imply reduced recharge if the same amount of rainfall were available because vegetation would have a lower leaf area index, leading to less rainfall interception (Crosbie *et al.,* 2010). Conversely, an increase in rainfall or rainfall intensity may not necessarily imply higher recharge if the seasonality of rainfall is altered in such a way that larger episodic rainfall events occur in generally dry months (summer) when the soil is not sufficiently wetted to facilitate infiltration of rainwater (DELWP, 2016).

Attempting to predict such complex processes in detail is beyond the scope of this study. Instead, the potential impacts of climate change is assessed with reference to the Victorian Government's *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria* (DELWP,2016), which reflect the most current knowledge of potential impacts of climate change on Victorian water resources. The guidelines state that most climate change predictions for Victoria indicate hotter and drier future conditions, with a combination of less rainfall and increased potential evapotranspiration expected to lead to reduced runoff and recharge (DEWLP, 2016). The potential impacts on groundwater resources are therefore presented in the guidelines as percentage changes in recharge to unconfined aquifers within each of the catchments. The percentage change in recharge is presented for low, medium and high impact scenarios and for two time periods (year 2040 and 2065). For the Yarra catchment, within which the study area lies, recharge is projected to reduce 30.8 per cent by year 2040 and 74.2 per cent by year 2065 under the high impact scenario (DELWP, 2016). However, under the low impact scenario, recharge is projected to increase by a small amount, with an 8.3 per cent and 5.6 per cent increase projected by year 2040 and 2065 respectively.

The reduction in recharge under the high impact scenario would result in regional lowering of the water table, leading to reduced groundwater contributions to surface water courses/water bodies and potentially reduced access to groundwater by vegetation. Changes to the groundwater system caused by the project over the long term would be expected to be most sensitive to this condition of reduced groundwater availability.

This section of the report details the assessment of potential impacts of climate variability on model predictions and includes:

1. Benchmarking of the calibrated model against long-term historical climate data.
2. Simulating the influence of short-term climate variability on model predictions during construction.
3. Simulating the influence of long-term climate variability (climate change) on model predictions post-construction.

6.2 Climate benchmarking

6.2.1 Approach

To provide a sensible basis for assessing the climate change effects, a benchmarking exercise has been undertaken by incorporating the long-term climatic variability into the calibrated model as time-varying recharge. While long-term measurements of groundwater levels are not available within the study area/model domain, the benchmarking exercise ensures that:

1. The model is capable of producing seasonal variations in groundwater levels with trends and range of fluctuations consistent with the long-term climate trends and bore hydrographs observed elsewhere in the Melbourne area.
2. The model appropriately simulates the hydrogeological evolution of the groundwater system to the current condition, with groundwater levels simulated at the end of the benchmarking period matching those measured recently; that is, the model remains calibrated at the end of the bench marking period.

The benchmarking exercise utilises the historical daily rainfall data from January 1965 to March 2018, sourced from the Scientific Information for Land Owners (SILO) database. The 53-year historical climate dataset covers the 53-year predictive period and includes the Millennium Drought and subsequent wet period. The data has been obtained from a point location near the confluence of the Yarra River and Plenty River, approximately in the middle of the model domain.

Quarterly stress periods are used to simulate the long-term climate variability to ensure a sensible number of stress periods (213) and model run time. Quarterly stress periods are also used to simulate the progression of construction which allow the predictive modelling scenario to be readily incorporated into the 53-year simulation with variable climate. The end of the final stress period coincides with the timing of the available recent groundwater level measurements used in steady state calibration (April 2018). Recharge for each stress period has been calculated from quarterly rainfall using recharge factors derived from the ratio of the calibrated steady state recharge rates and long-term average rainfall (around 710 mm/year) from 1965 to 2018. Recharge factors are 0.14 for the Alluvium and 0.014 for the Bedrock. The River (RIV) boundary condition and evapotranspiration (EVT) are assumed to be constant.

6.2.2 Benchmarking results

Figure 46 compares the scatter plot of observed and computed heads from the steady state calibration and heads computed at the end of the benchmarking run. The calibration is effectively identical, indicating that the model remains calibrated at the end of the 53-year simulation with time-varying recharge.

Figure 47 presents the time series of computed heads (hydrographs) at key locations along the project alignment. Spatial differences in the response to climate variability can be seen in the hydrographs, reflecting the spatial differences in recharge applied to the Alluvium and Bedrock and the effect of the underlying geology. In general, the seasonality is most pronounced in areas where the Alluvium is thin, resulting in large portions of high recharge applied to the Alluvium forced into the underlying lower hydraulic conductivity Bedrock (see NEL-BH120 and NEL-BH124). Where the Alluvium is thicker, the larger storage capacity and higher transmissivity results in less spikes in the groundwater levels (such as NEL-BH132). Where the Bedrock aquifer is unconfined, the modelled seasonality is more subdued due to lower applied recharge. In all hydrographs, the long-term climate trends are easily discernible; such as the overall declining trend from around 1997 to 2009 coinciding with the Millennium Drought. The modelled seasonal variations range from around 0.5 – 2.5 metres and are similar to those observed in regional bores located outside the model domain (Figure 11).

Figure 48 presents time series of computed RIV fluxes to the deep pool of Bolin Bolin Billabong and the Yarra River between flow gauges 229142A and 229135A, and 229135A and 229143A. The temporal variability in the computed RIV fluxes reflects the influence of time-varying recharge. The wet period baseflows to the Yarra River are close to double the dry period baseflows, similar to the relative difference between the wet and dry period baseflows computed by the ecoMarkets Port Phillip model (3.3 and 6.85 ML/d respectively).

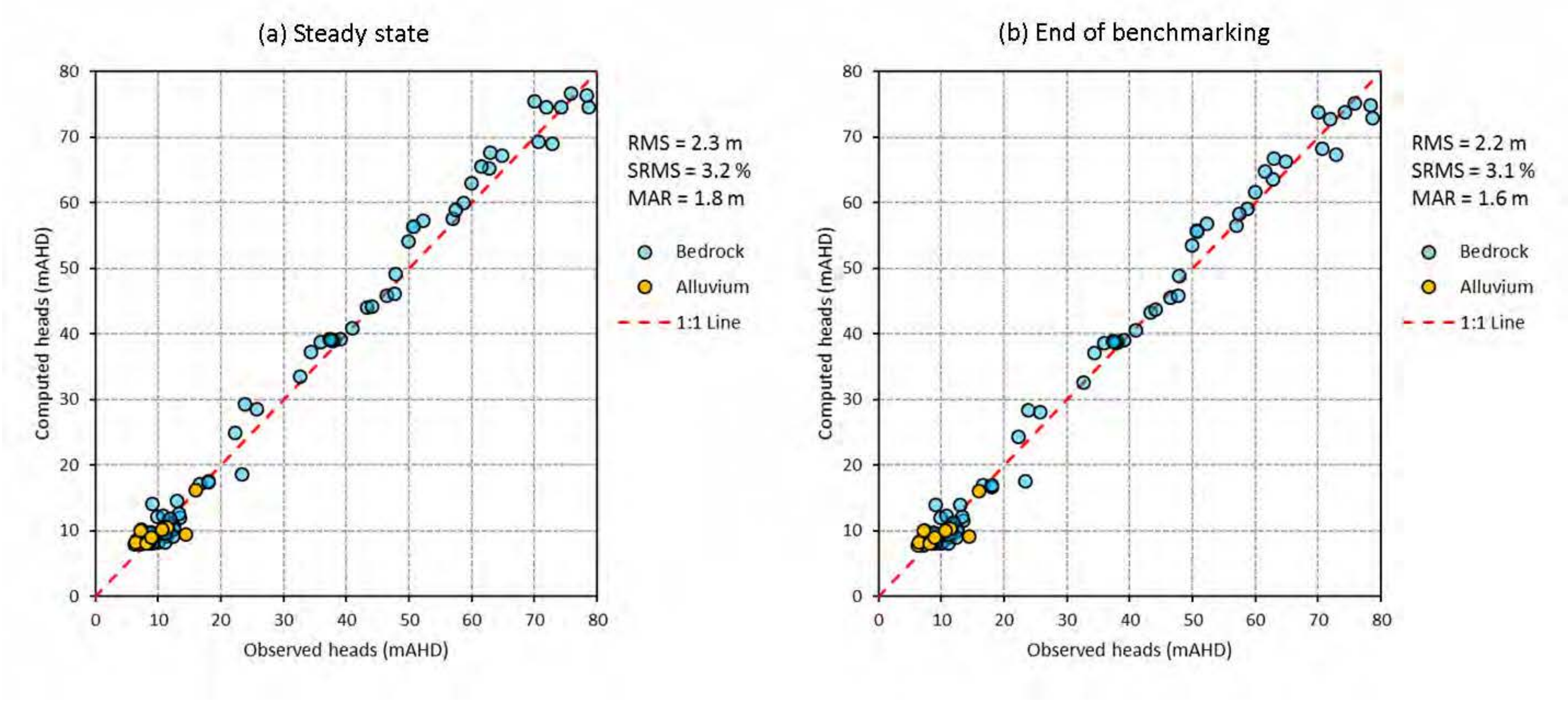


Figure 46 Calibration statistics of steady state and benchmarking models

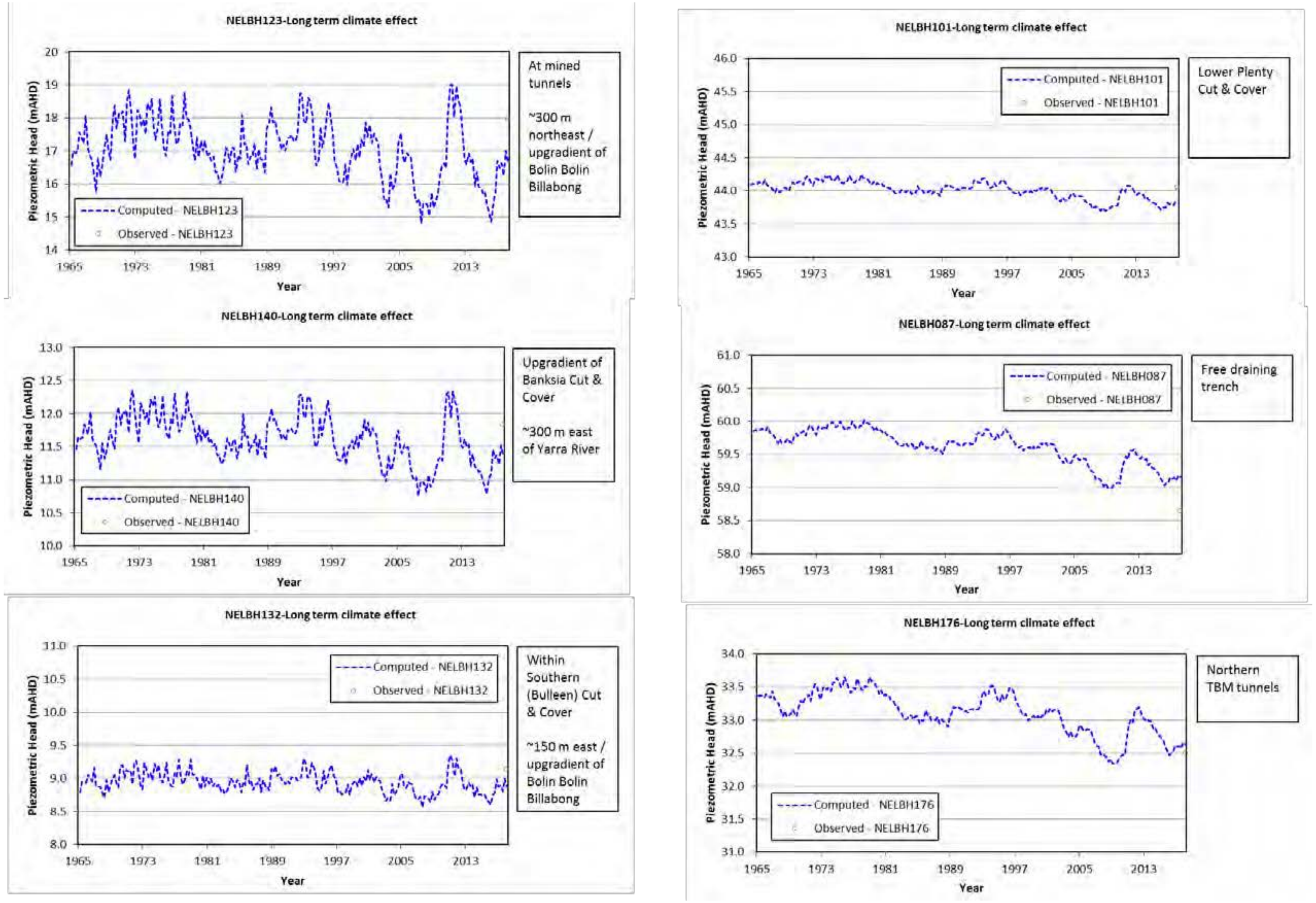
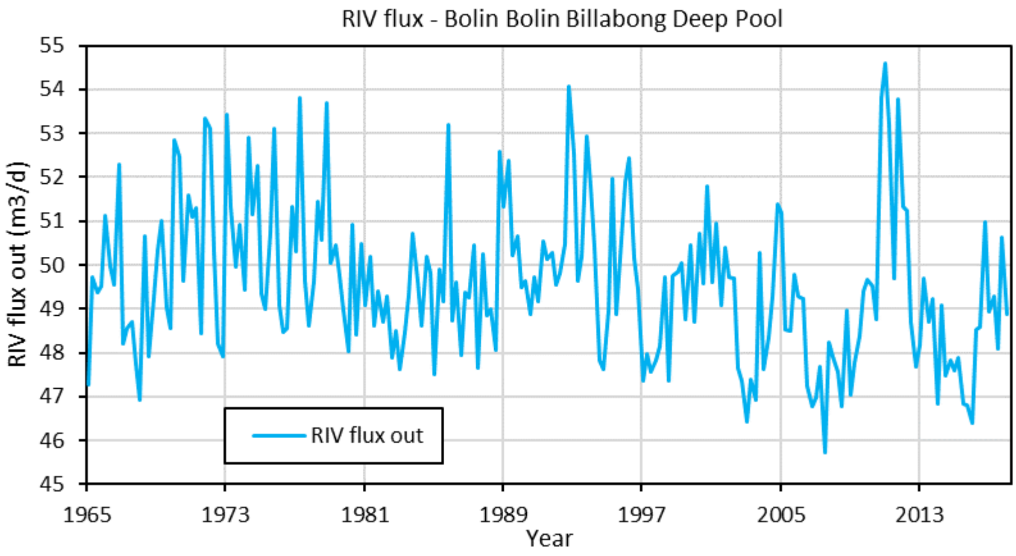
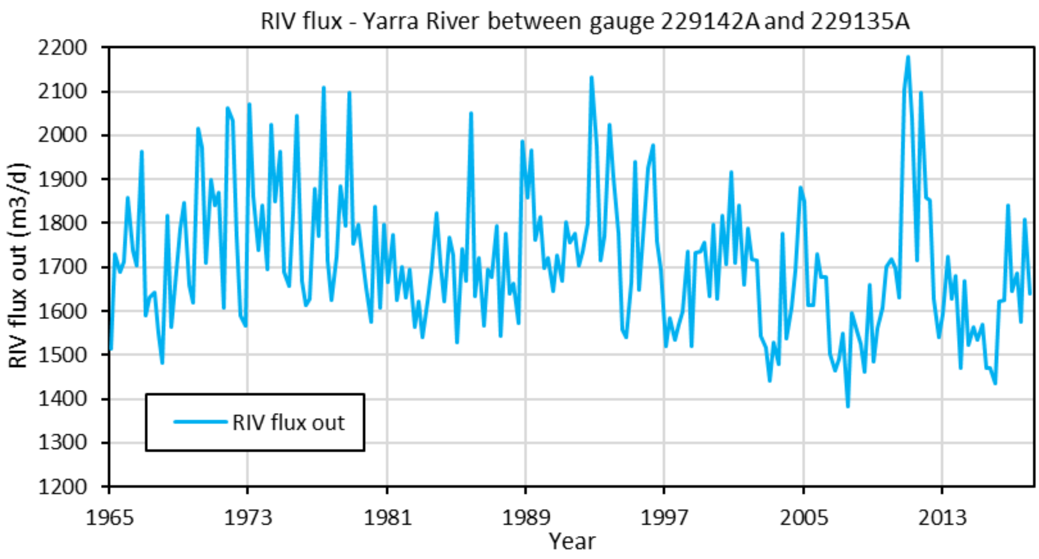


Figure 47 Simulated groundwater level variability





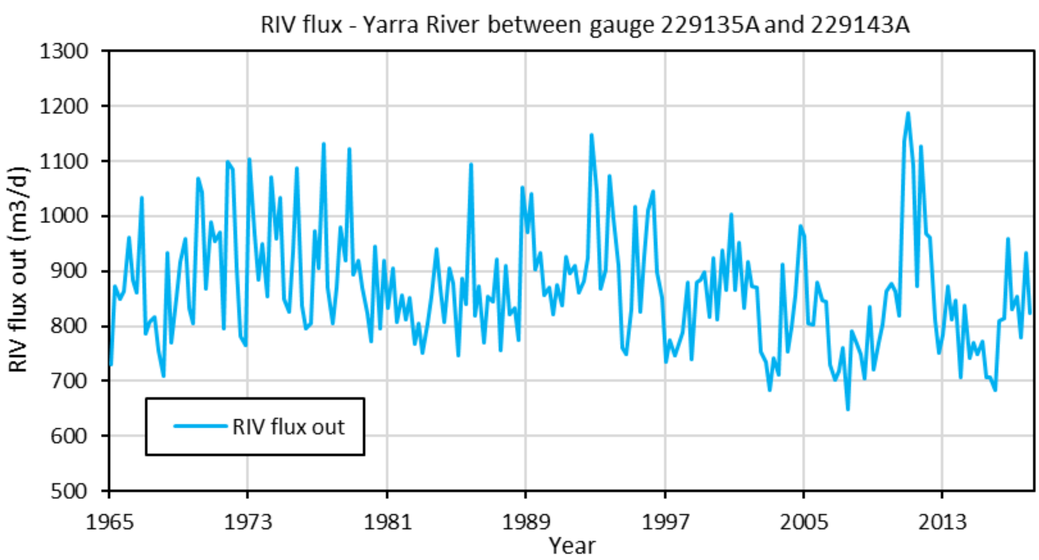


Figure 48 Simulated baseflow variability

6.3 Predicted effects of short-term climate variability

6.3.1 Approach

The effect of short-term climate variability on prediction of temporary dewatering impacts during construction is assessed using time-varying recharge from historical dry and wet periods.
The dry and wet periods chosen for this assessment are shown in Figure 49. The dry period encompasses the Millennium Drought, characterised by successive months of below average rainfall and the lowest modelled water table/baseflow. The wet period captures the subsequent wet months with above average rainfall (more than double at times) and the highest modelled water table/baseflow.

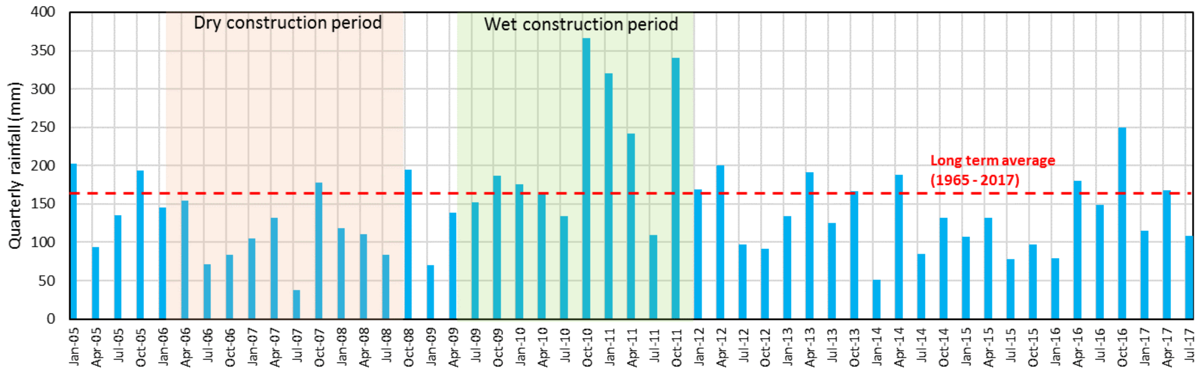
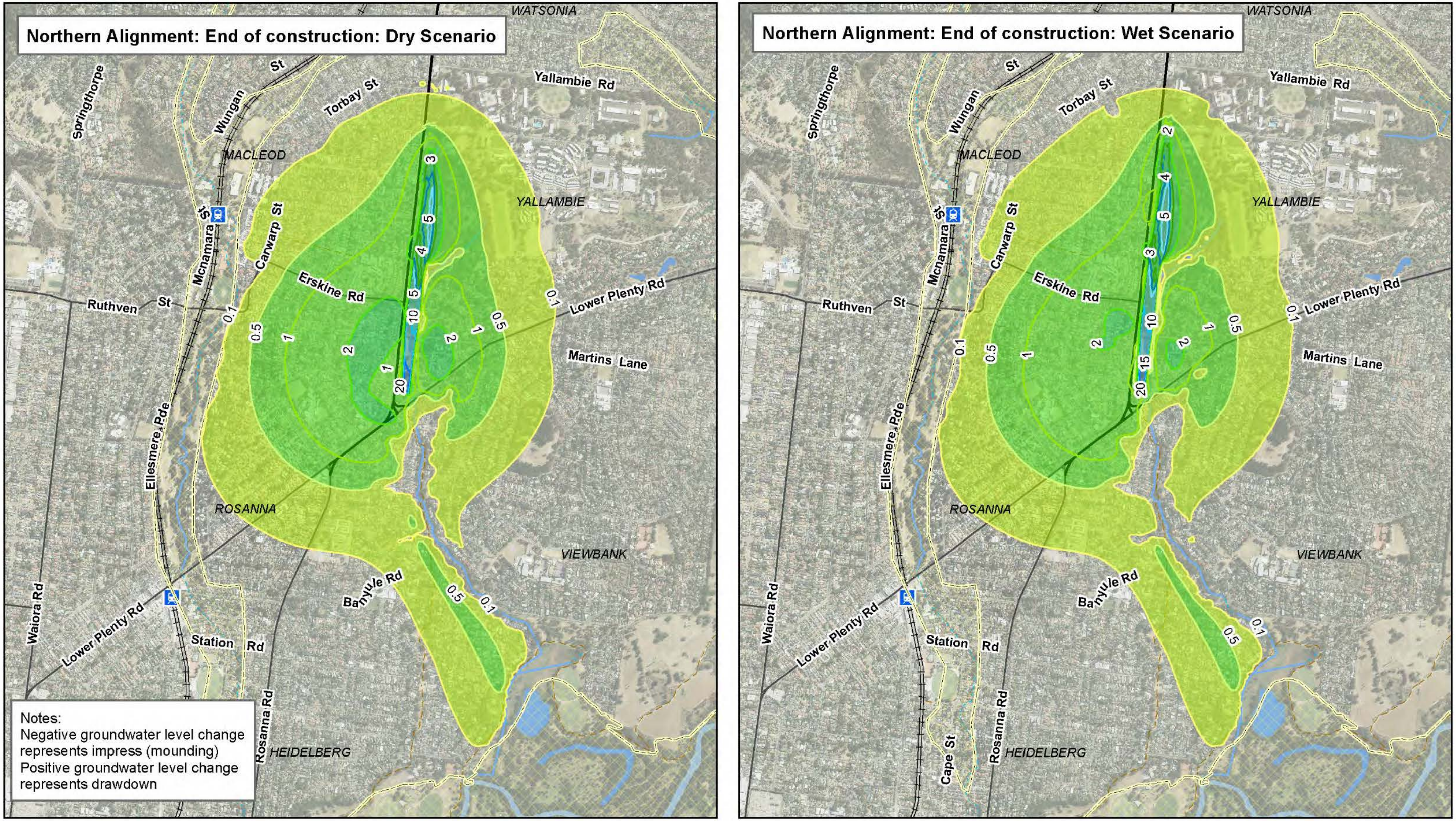


Figure 49 Dry and wet periods for modelling short-term climate variability

For both scenarios, the progression of the project's construction is simulated using quarterly stress periods identical to that described in Section 4.1.2 except for time-varying recharge derived from the benchmarking model for the corresponding (dry/wet) periods. To discern the changes to groundwater caused by the project from those due to climate, the model has been run with and without the project and differences between the two model runs calculated.

6.3.2 Predicted effects on groundwater levels

Figure 50 and Figure 51 compare the predicted groundwater level changes at the end of construction for the dry and wet construction scenarios. The contours of groundwater level changes are very similar, with dry and wet conditions resulting in subtle differences in contour extents; for example, the extent of 0.1 metre drawdown contour towards the Yarra River and Bolin Bolin Billabong. The short-term variability in climate has a small effect on the prediction of groundwater level changes during construction.



Paper Size A4

0 90 180 360 540 720

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

- -5
- -4
- -3
- -2
- -1
- -0.5
- -0.1
- 0.1
- 0.5
- 1
- 2
- 3
- 4
- 5
- 10
- 15
- 20

Modelled GWL Change (m)

- -5.81 - -5
- -4.99 - -2
- -1.99 - -0.5
- -0.49 - -0.1
- -0.09 - 0.1
- 0.11 - 0.5
- 0.51 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- 20.01 - 24
- Alluvium

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North East Link Project
Environment Effects Statement (EES)

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Revision A
Date 27 Feb 2019

Predicted groundwater level changes at end of construction for dry and wet climate scenarios - north

Figure 50

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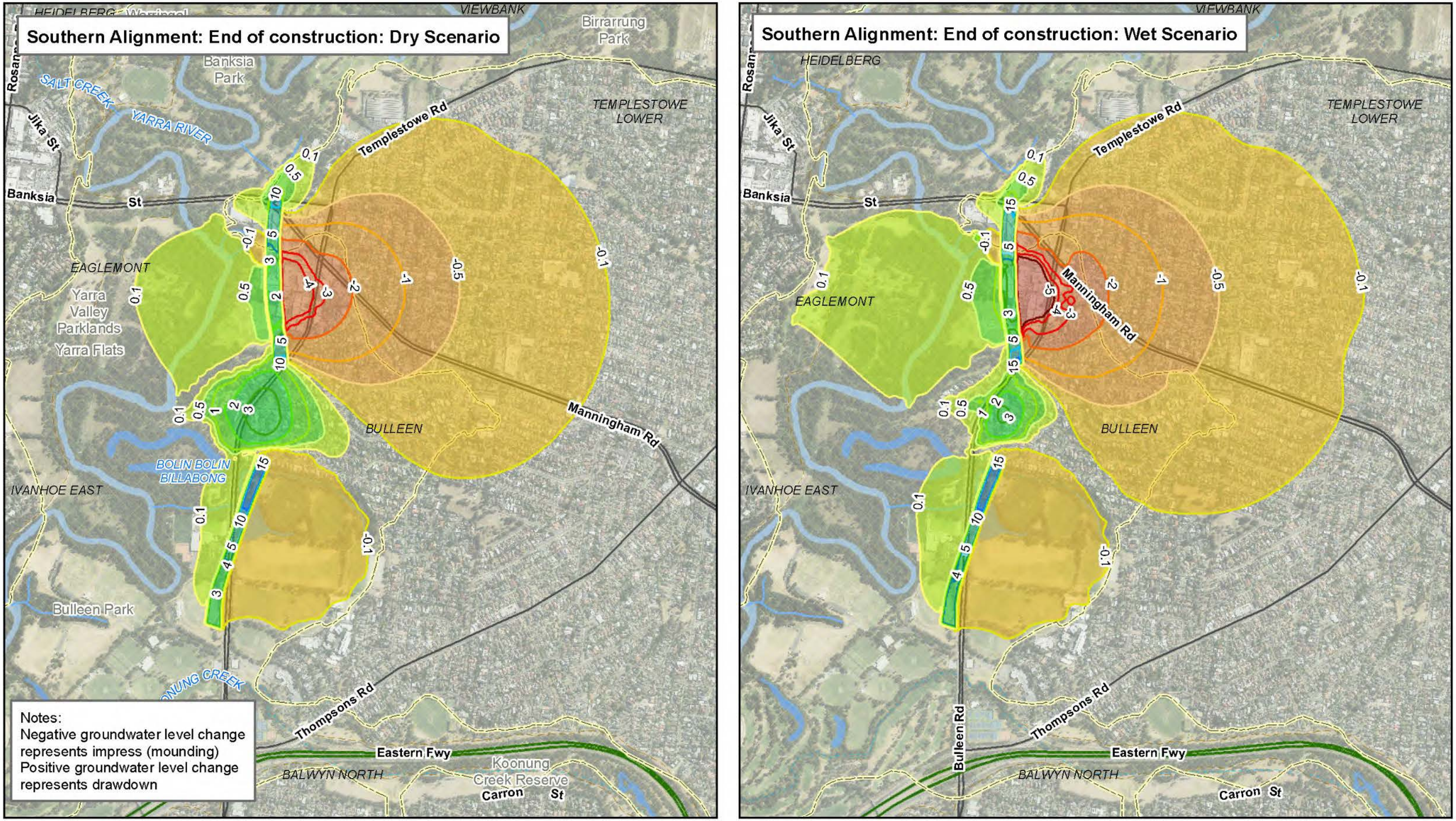
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



Paper Size A4

0 70 140 280 420 560

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

-5
-4
-3
-2
-1
-0.5
-0.1
0.1
0.5
1
2
3
4
5
10
15
20

Modelled GWL Change (m)

-5.81 - -5
-4.99 - -2
-1.99 - -0.5
-0.49 - -0.1
-0.09 - 0.1
0.11 - 0.5
0.51 - 2
2.01 - 5
5.01 - 10
10.01 - 15
15.01 - 20
20.01 - 24
Alluvium

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Environment Effects Statement (EES)

Predicted groundwater level changes at end of construction for dry and wet climate scenarios - south

Job Number 31-35006
Revision A
Date 28 Feb 2019

Figure 51

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Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti

6.3.3 Predicted effects on groundwater inflow rates

Table 8 summarises the predicted groundwater inflow rates into the cut and cover excavations for the dry and wet scenarios. The inflow rates are comparable to those predicted for the average (steady state) climatic condition in Section 4.3.1 (with small differences due to rounding to the nearest m^3/d) and the difference between the wet and dry scenarios is minor.

The short-term variability in climate has a small effect on the prediction of groundwater inflow rates during construction.

Table 8 Predicted dry and wet scenarios groundwater inflow rates

Excavation / cut and cover	Average inflow during construction (m^3/d)		Maximum inflow during construction (m^3/d)	
	Dry	Wet	Dry	Wet
Southern	81	84	400	403
Banksia	60	74	201	223
Lower Plenty	103	106	289	292
Trench	16	18	87	89

6.3.4 Predicted effects on groundwater fluxes

Figure 52 compares the dry and wet scenarios groundwater fluxes to Bolin Bolin Billabong and Yarra River during construction. While the magnitude and seasonality of groundwater fluxes are different, the percentage reductions in groundwater fluxes due to the project are comparable between the dry and wet scenarios (and to those predicted under the average climatic condition). In other words, the relative impact of the project on groundwater fluxes is not strongly sensitive to short-term climate variability (consistent with the minor differences in predicted groundwater level changes).

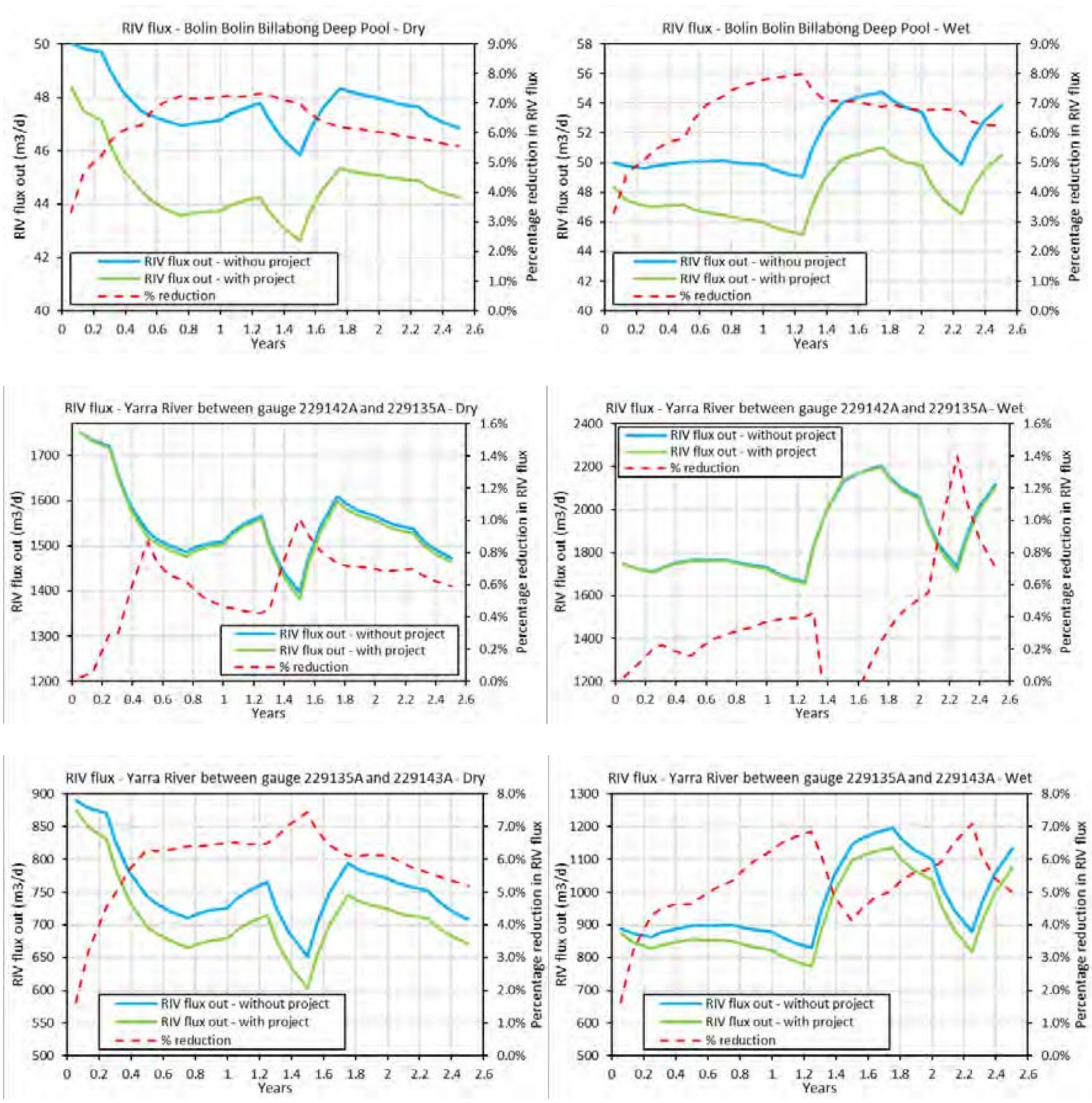


Figure 52 Predicted dry and wet scenarios groundwater fluxes (baseflow)

6.4 Predicted effects of long-term climate variability

6.4.1 Approach

The DELWP (2016) guidelines indicate the potential for the climate to vary over the long-term due to climate change, which has the potential to influence long-term impacts of the project post-construction. To assess the significance of climate change, recharge and evapotranspiration are linearly scaled over the 53-year predictive simulation period using the scaling factors from DELWP (2016). The dry (high impact / 90th percentile) and wet (low impact / 10th percentile) scenarios are modelled to capture the full range of projected climate change. Time varying recharge is based on the 53-year historical climate data as per the benchmarking model and is scaled linearly according to the climate change factors. The time varying recharge is based on the historical rainfall data from January 1965 to March 2018, which encompasses the climate data from July 1975 recommended by DELWP (2016).

The evapotranspiration is linearly scaled from the calibrated value of 1,298 mm/yr, noting that the actual volumes removed via evapotranspiration also depends on the position of the water table within the EVT extinction depth (which varies with time).

For each climate change scenario, the model is run with and without the project to discern the impact of climate from that of the project. This results in the following four model runs:

1. Wet (low impact) climate change scenario without the project. Recharge is linearly increased from 0 to 8.3 per cent over the first 25 years and from 8.3 per cent to 5.6 per cent over the remainder of simulation. Evapotranspiration is linearly increased from 0 to 3.1 per cent over the first 25 years and from 3.1 per cent to 5.9 per cent over the remainder of simulation (DELWP, 2016).
2. Wet (low impact) climate change scenario with the project. Recharge and evapotranspiration are as per above.
3. Dry (high impact) climate change scenario without the project. Recharge is linearly decreased from 0 to 30.8 per cent over the first 25 years and from 30.8 per cent to 74.2 per cent over the remainder of simulation. Evapotranspiration is linearly increased from 0 to 5.9 per cent over the first 25 years and from 5.9 per cent to 12 per cent over the remainder of simulation (DELWP, 2016).
4. Dry (high impact) climate change scenario with the project. Recharge and evapotranspiration are as per above.

It should be noted there is no certainty the future climate will resemble the historical climate nor that it will vary in accordance with the climate change projections outlined in DELWP (2016). The purpose of the climate change scenarios is to stress test the model by utilising long-term historical data and two extreme bounds of climate change projections, so the significance of climate variability (and associated uncertainty) on prediction of long-term project impacts can be assessed.

6.4.2 Predicted effects on groundwater levels

For the wet climate change scenario, the period of the highest water table/baseflow is chosen to show the predicted impact of the project under the wettest possible condition. For the dry climate change scenario, the period of the lowest water table/baseflow is chosen to show the predicted impact of the project under the driest possible condition. The timing of the modelled wettest and driest periods, representing the extreme range of potential climate change effects, can be seen in the modelled hydrographs in Figure 53. The reduction in recharge by 74 per cent under the dry scenario results in a significant overall lowering of the groundwater levels, much greater than the modelled historical variation.

Figure 54 and Figure 55 compare the predicted groundwater level changes for the dry and wet scenarios. For the dry scenario, the reduction in groundwater levels (drawdown) is smaller over the free draining section in the northern portion of the alignment. This is due to the decline in the elevation of the water table caused by reduced recharge, resulting in less interception of the water table by the free draining trench. Drawdown is slightly larger around the tanked section of the Lower Plenty cut and cover and TBM tunnels, due to less recharge and groundwater through-flow to offset ongoing leakage into these structures. In the southern portion of the alignment, drawdown and mounding are also subdued under the dry scenario due to the lower water table and reduced through-flow.

For the wet scenario, the predicted changes in groundwater levels are similar to those predicted based on the average condition (Section 4.2), The difference between the two hydrographs (red and blue lines) shown in Figure 53 indicates the effect of the project following construction is generally consistent over time under the wet scenario.

Figure 56 and Figure 57 compare the predicted depth to groundwater for the dry and wet scenarios. The depth to groundwater contours show that under the dry scenario, mounding on the up gradient side of the Banksia cut and cover no longer results in a condition of shallow water table due to the overall lowering of the water table. This effect can also be seen in Figure 58, which compares the hydrographs of the up gradient bore (NEL-BH137) for the dry and wet scenarios.

Figure 58 also shows the range of fluctuations in the water table under the wet scenario is similar to the uncertainty range resulting from model non-uniqueness. When the climate change effects are considered in conjunction with model uncertainty (non-uniqueness), the figure indicates the potential for the water table to reach less than five metres bgl albeit only temporarily and only under the condition of wetter than historical climate. Given the relatively narrow uncertainty range and that the majority of climate change projections in Victoria indicating drier future conditions (wet scenario equates to only 10th percentile climate change projection), the likelihood of a shallower water table (<5 metres bgl) occurring on the up gradient side of the Banksia cut and cover is considered low.

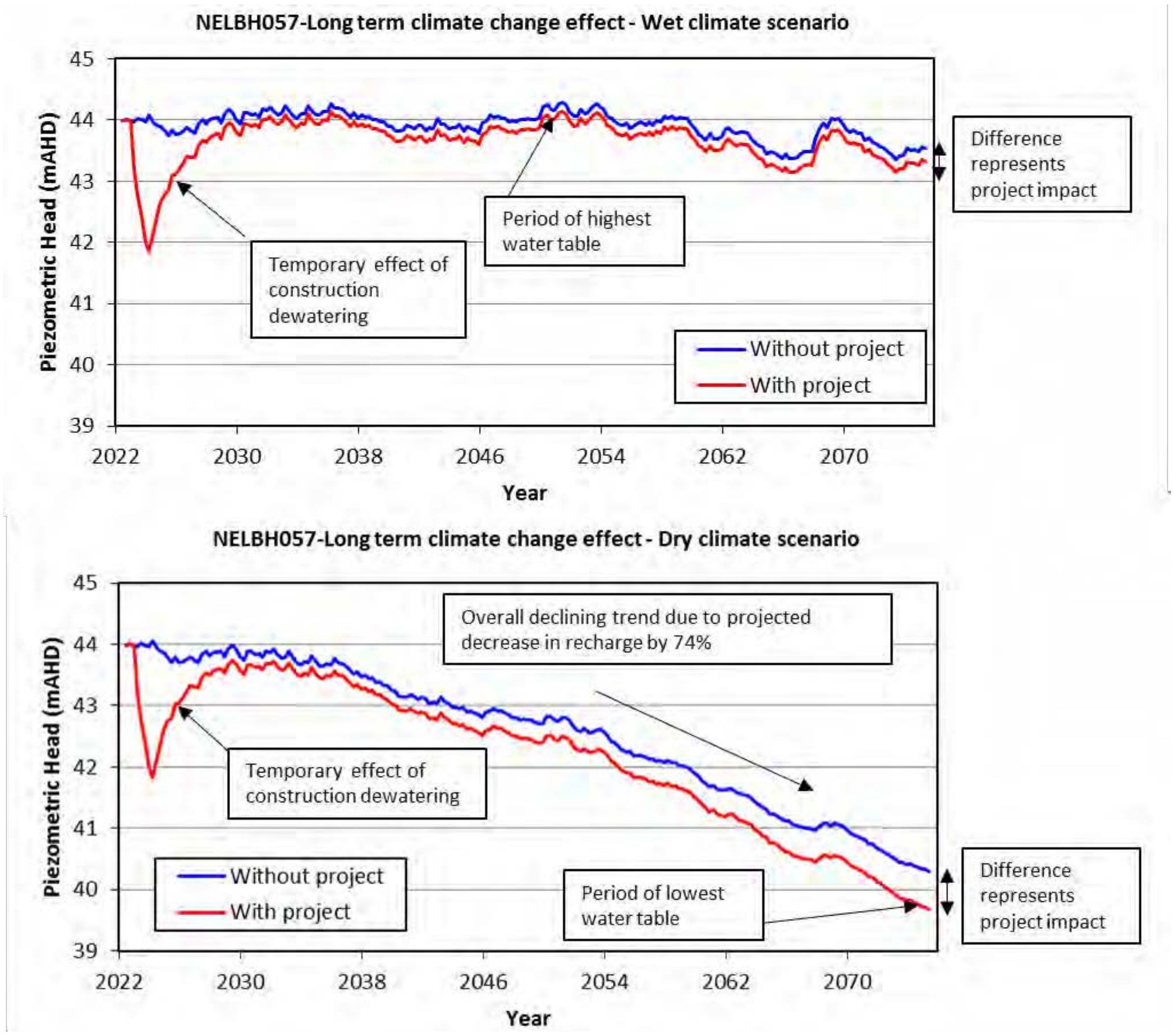
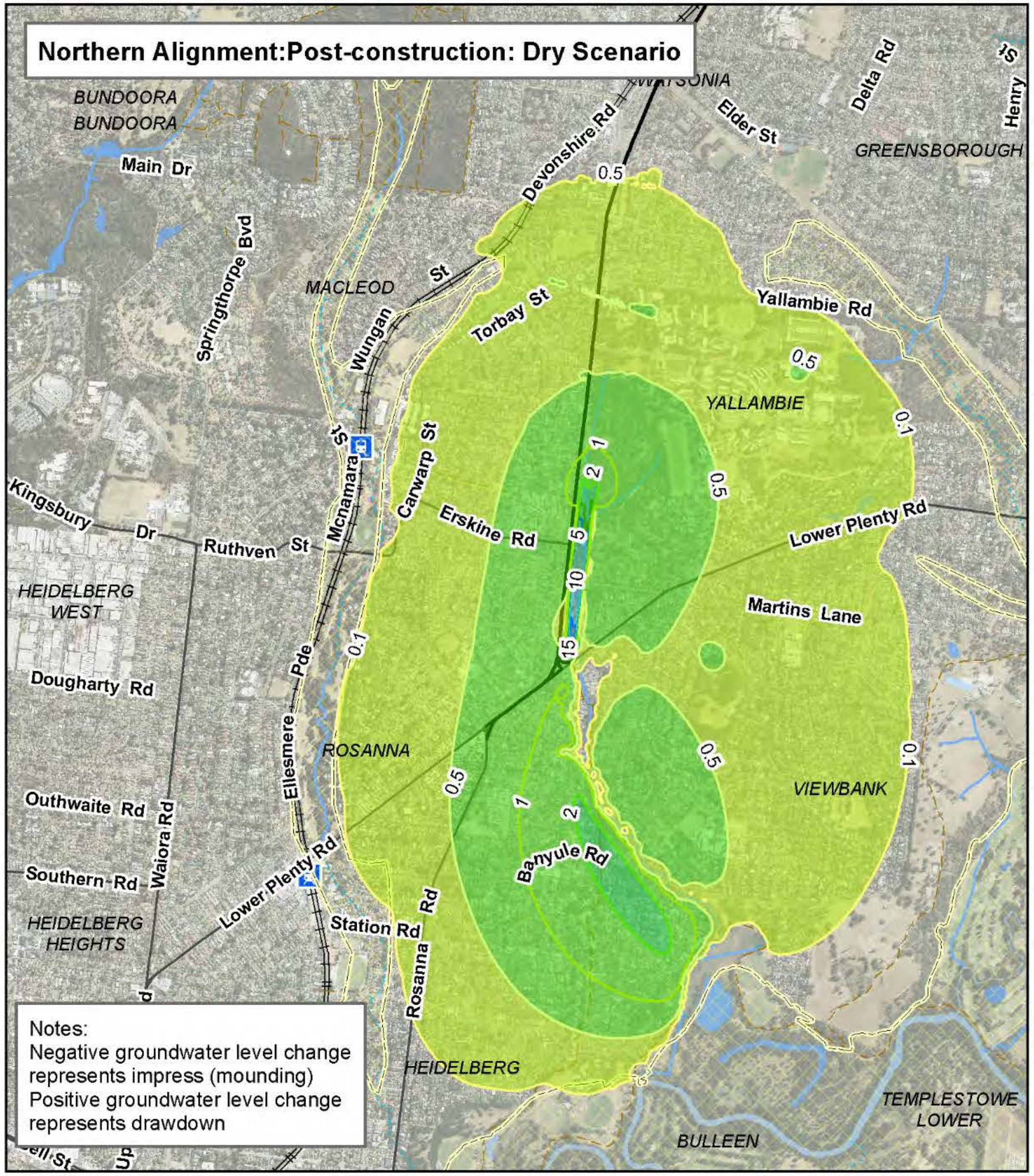
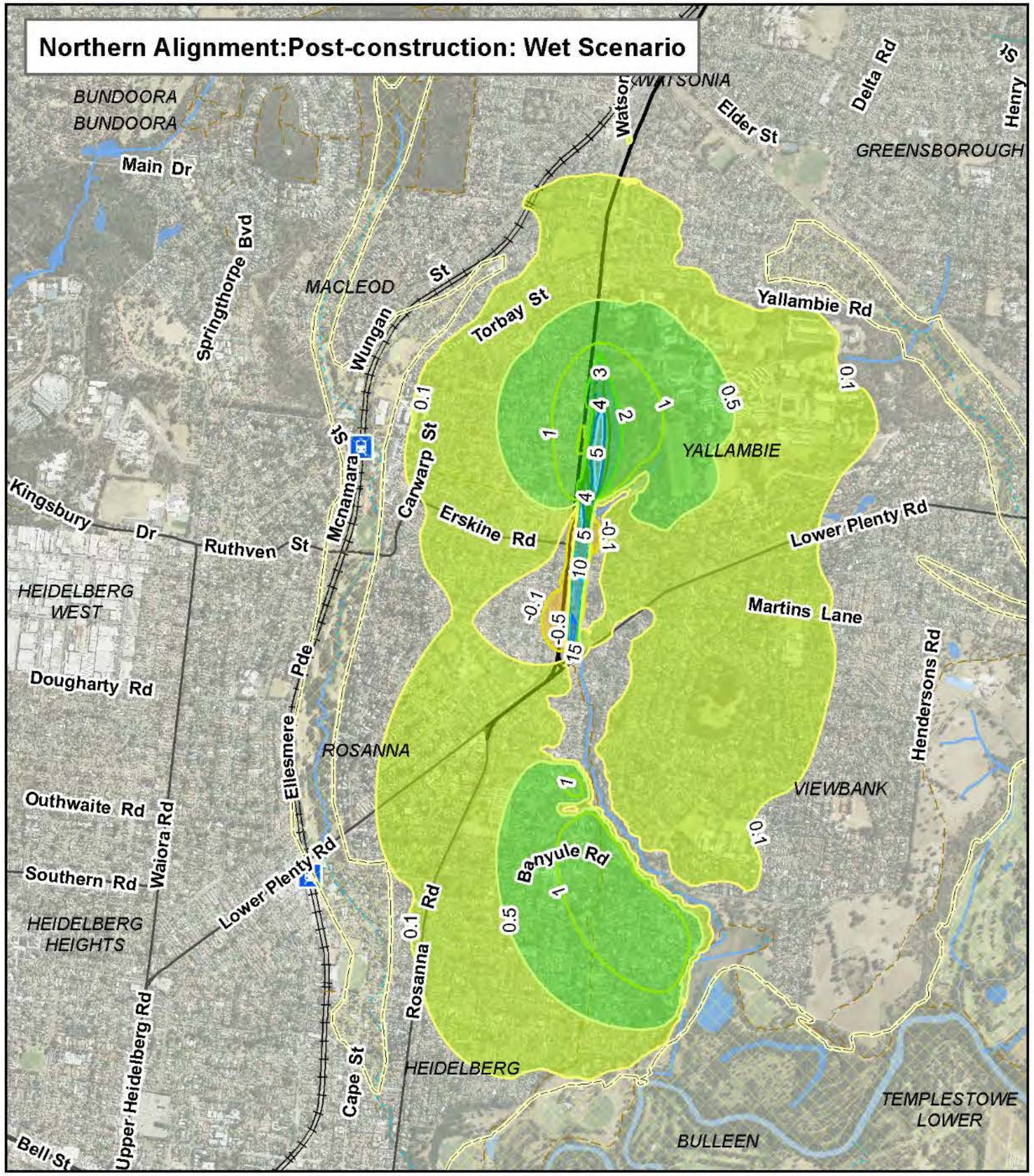


Figure 53 Wet and dry climate change scenario





Paper Size A4

0 115 230 460 690 920
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

- -5
- -4
- -3
- -2
- -1
- -0.5
- -0.1
- 0.1
- 0.5
- 1
- 2
- 3
- 4
- 5
- 10
- 15
- 20

Modelled GWL Change (m)

- -5.81 - -5
- -4.99 - -2
- -1.99 - -0.5
- -0.49 - -0.1
- -0.09 - 0.1
- 0.11 - 0.5
- 0.51 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- 20.01 - 24
- Alluvium

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Predicted post-construction groundwater level changes for dry and wet climate scenarios - north

Figure 54

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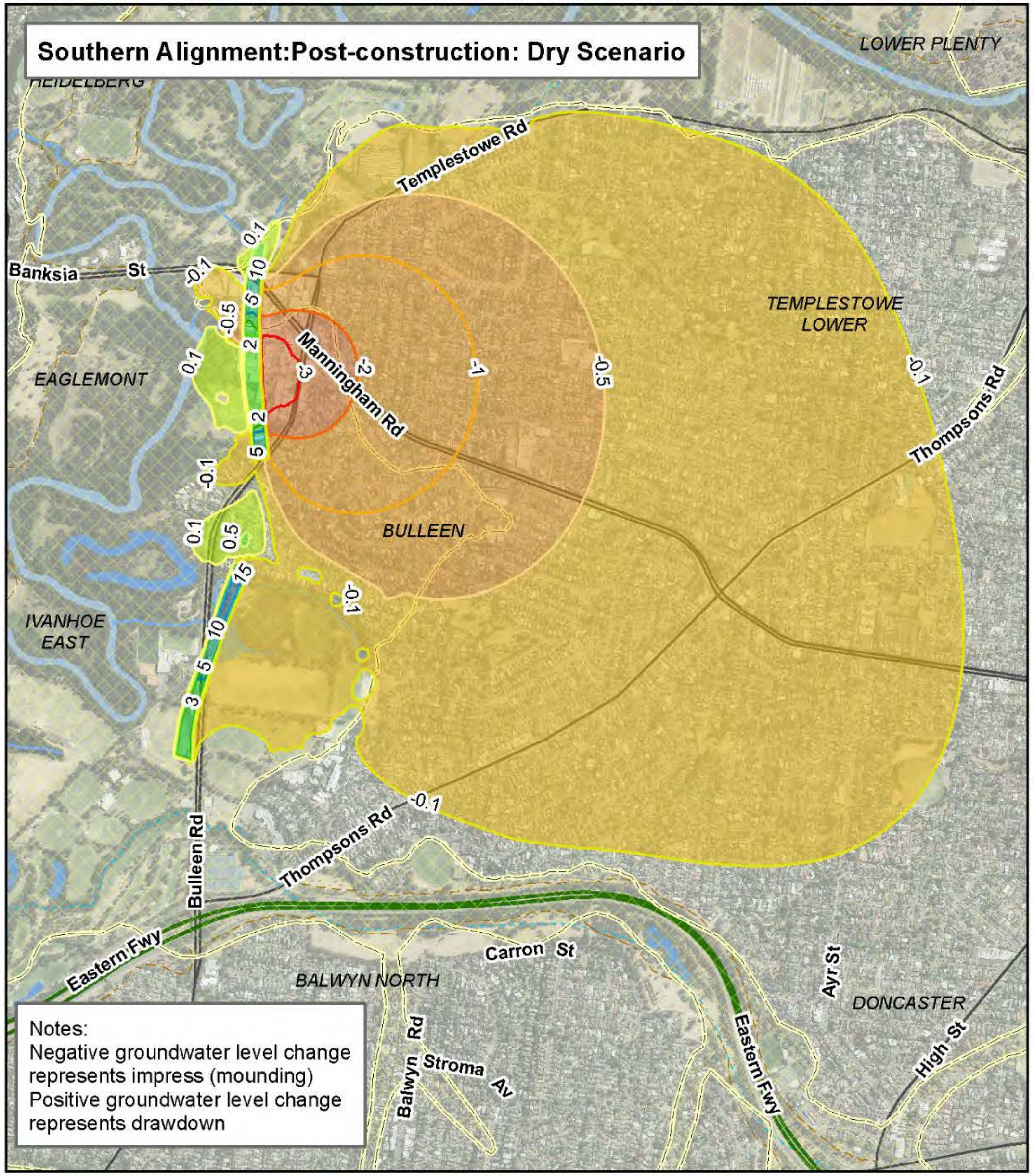
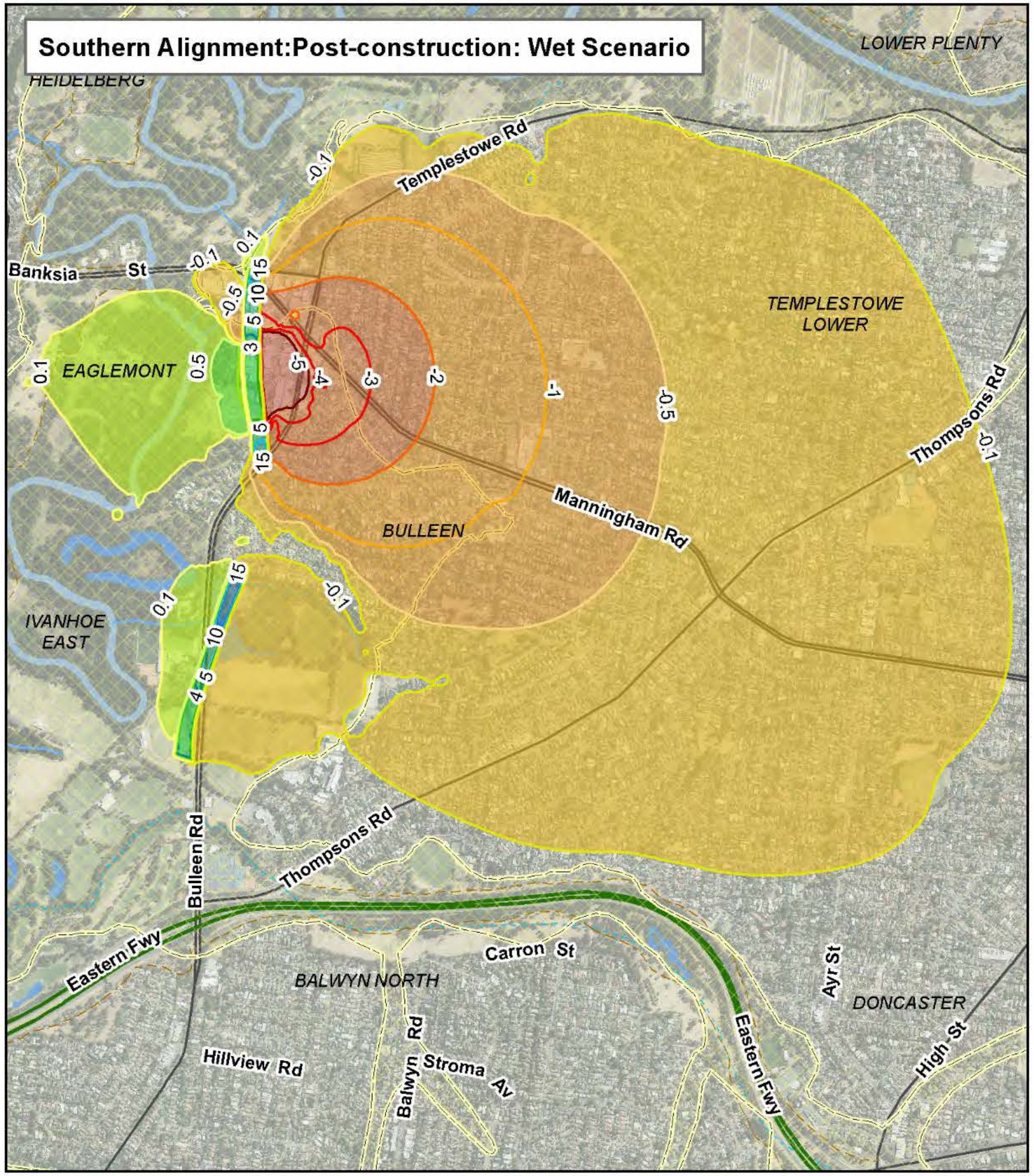
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo





Paper Size A4

0 90 180 360 540 720

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Modelled GWL Change (m)

-5
-4
-3
-2
-1
-0.5
-0.1
0.1
0.5
1
2
3
4
5
10
15
20

Modelled GWL Change (m)

-5.81 - -5
-4.99 - -2
-1.99 - -0.5
-0.49 - -0.1
-0.09 - 0.1
0.11 - 0.5
0.51 - 2
2.01 - 5
5.01 - 10
10.01 - 15
15.01 - 20
20.01 - 24
Alluvium

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Revision A
Date 27 Feb 2019

Predicted post-construction groundwater level for dry and wet climate scenarios - south

Figure 55

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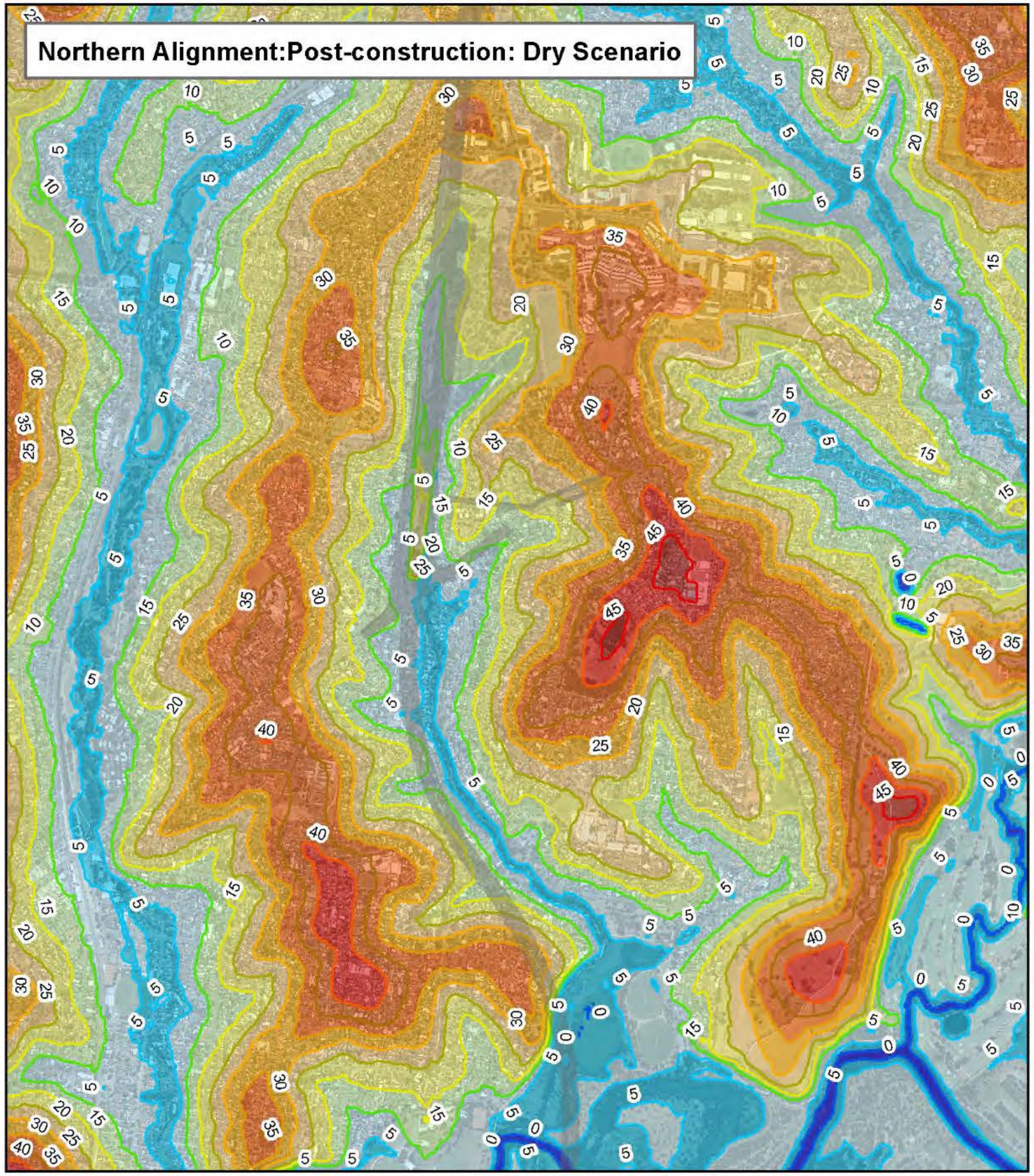
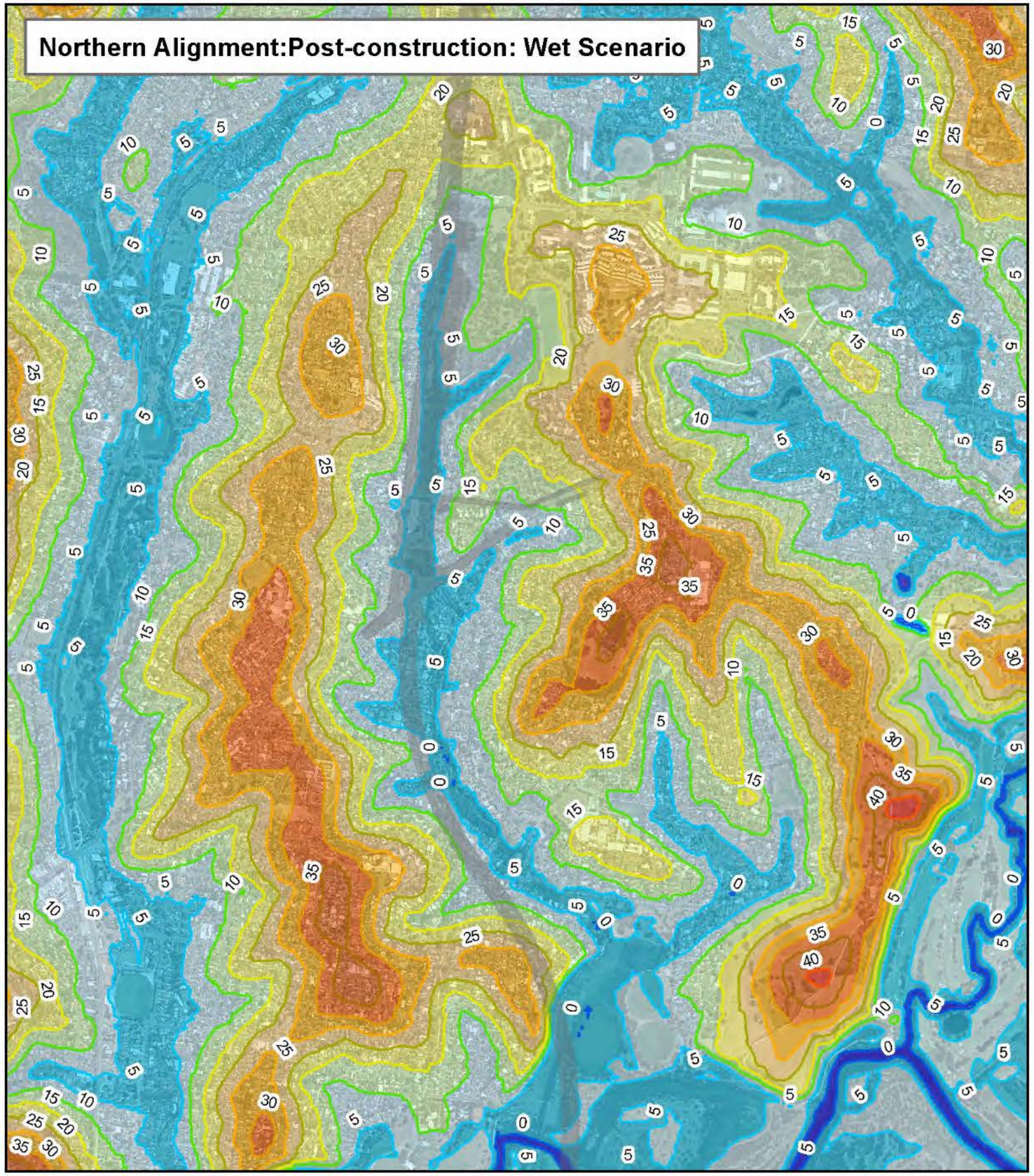
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo





Paper Size A4

0 90 180 360 540 720

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Depth to groundwater (m)

- < 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- > 50

Depth to groundwater (m)

- < 0
- 0.1 - 5
- 5.1 - 10
- 10.1 - 15
- 15.1 - 20
- 20.1 - 25
- 25.1 - 30
- 30.1 - 35
- 35.1 - 40
- 40.1 - 45
- 45.1 - 50
- > 50
- Proposed reference project

North East Link Project
Environment Effects Statement (EES)

NORTH EAST LINK PROJECT

Predicted post-construction depth to groundwater for dry and wet climate scenarios - north

Job Number	31-35006
Revision	A
Date	27 Feb 2019

Figure 56

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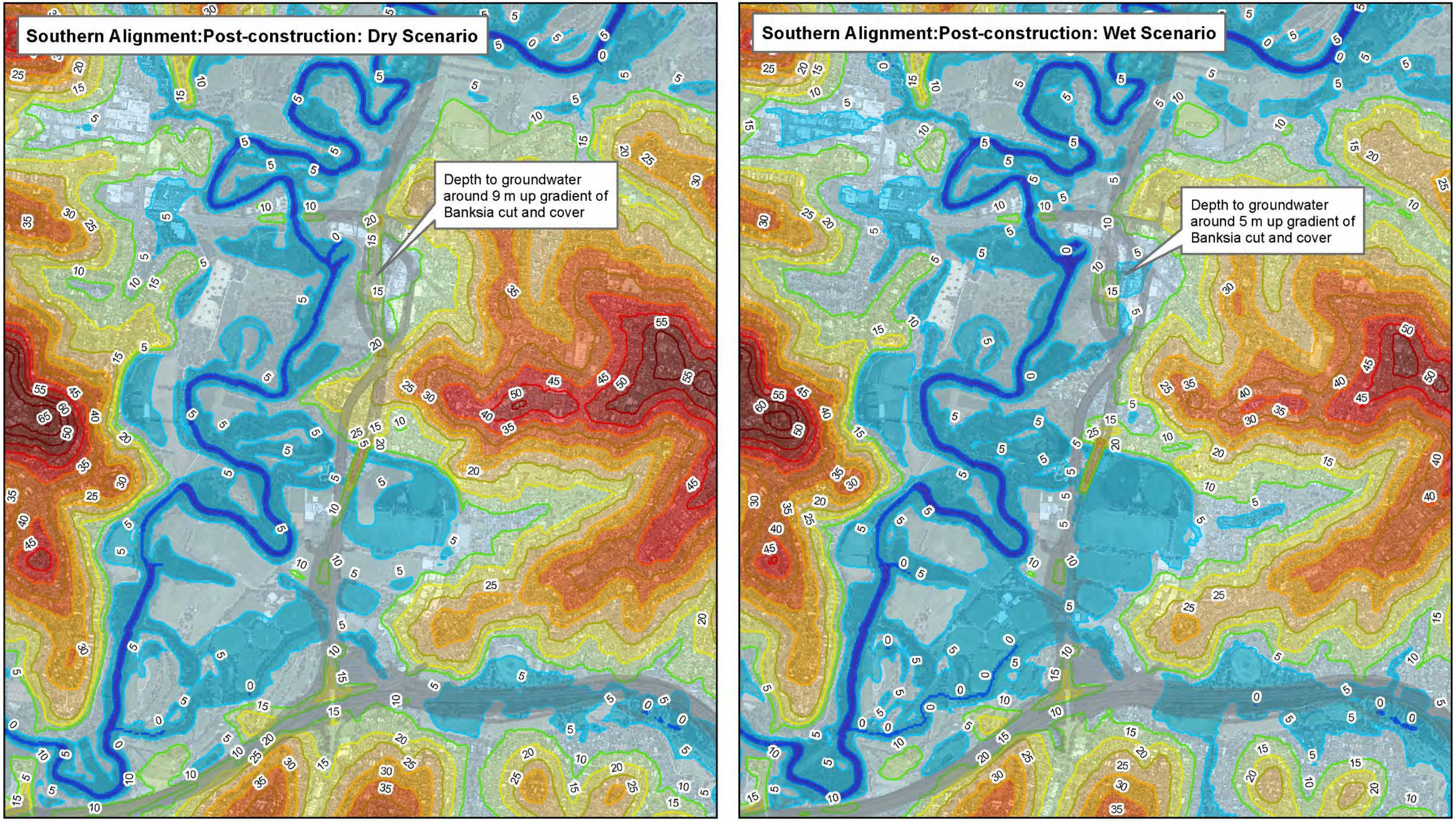
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



Paper Size A4

0 85 170 340 510 680

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Depth to groundwater (m)

- < 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- > 50

Depth to groundwater (m)

- < 0
- 0.1 - 5
- 5.1 - 10
- 10.1 - 15
- 15.1 - 20
- 20.1 - 25
- 25.1 - 30
- 30.1 - 35
- 35.1 - 40
- 40.1 - 45
- 45.1 - 50
- > 50
- Proposed reference project

North East Link Project
Environment Effects Statement (EES)

Predicted post-construction depth to groundwater for dry and wet climate scenarios - south

Job Number 31-35006
Revision A
Date 27 Feb 2019

Figure 57

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Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

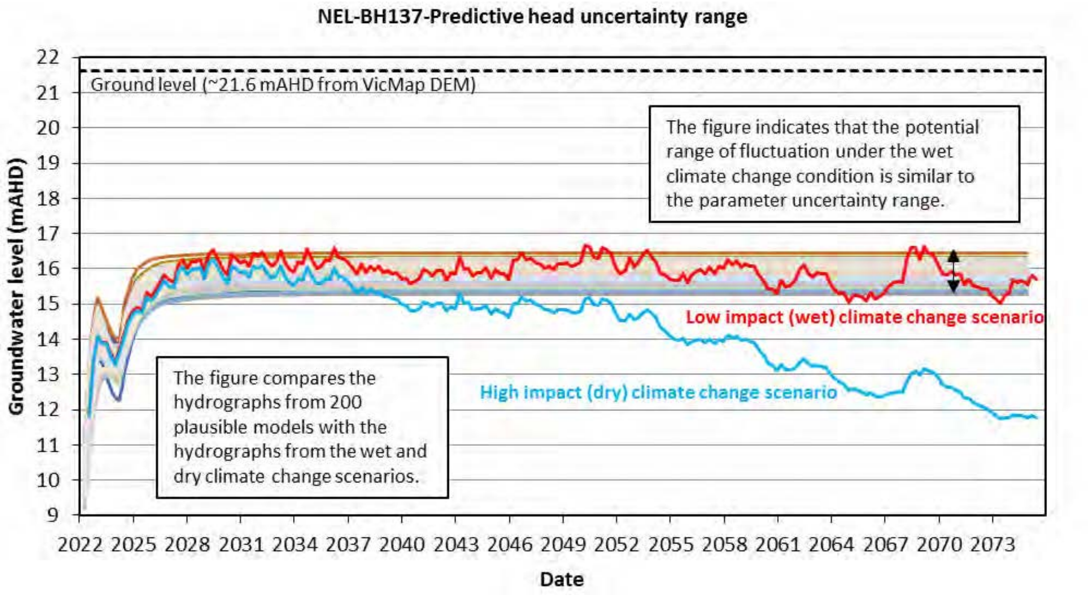

Figure 58 Predicted effects of climate change on mounding

6.4.3 Predicted effects on groundwater fluxes

Figure 59 and Figure 60 show the hydrographs of groundwater fluxes over the 53-year simulation period for the wet and dry climate change scenarios respectively. For the wet scenario, the predicted reductions in groundwater fluxes are slightly larger than those predicted for the average climatic condition (Section 4.2). For example, the predicted post-construction percentage reduction in groundwater fluxes to Bolin Bolin Billabong are 4.5 – 6 per cent for the wet scenario compared with around 3 per cent for the average condition. For the dry climate change scenario, the predicted reductions in groundwater fluxes are similar ranging from around 3 – 5.5 per cent for Bolin Bolin Billabong. The percentage reduction in groundwater fluxes becomes smaller towards the end of the dry climate change scenario, implying that the impact of the project becomes more subdued as groundwater fluxes to surface water bodies become smaller due to reduced recharge (consistent with generally smaller drawdown and mounding predicted under the dry condition).

The hydrographs indicate the effect of climate variability on prediction of reduction in groundwater fluxes is minor, equating to differences in percentage reduction of around 1 – 3 per cent compared with the average climatic condition.

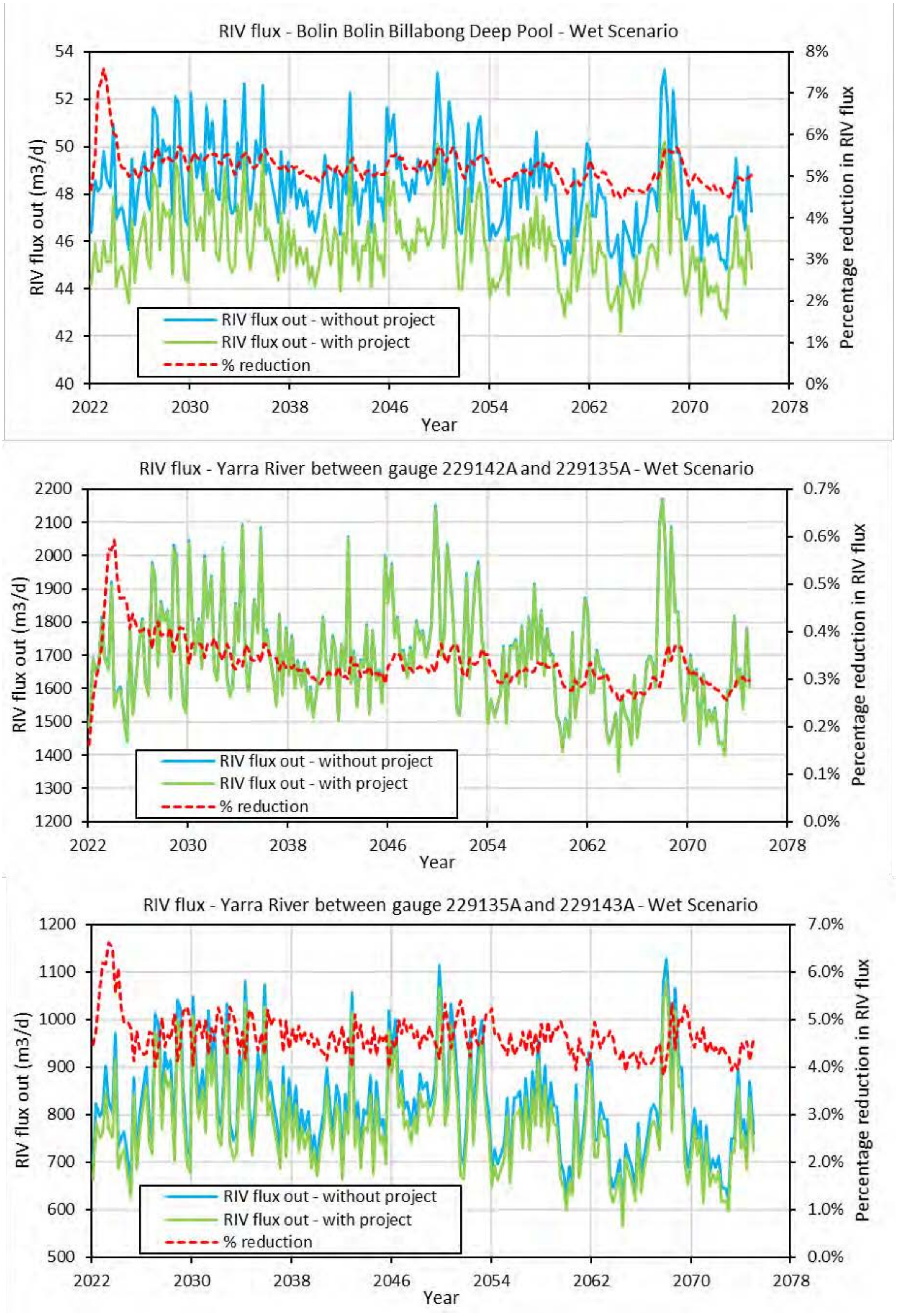

Figure 59 Predicted wet scenario groundwater fluxes (baseflow)

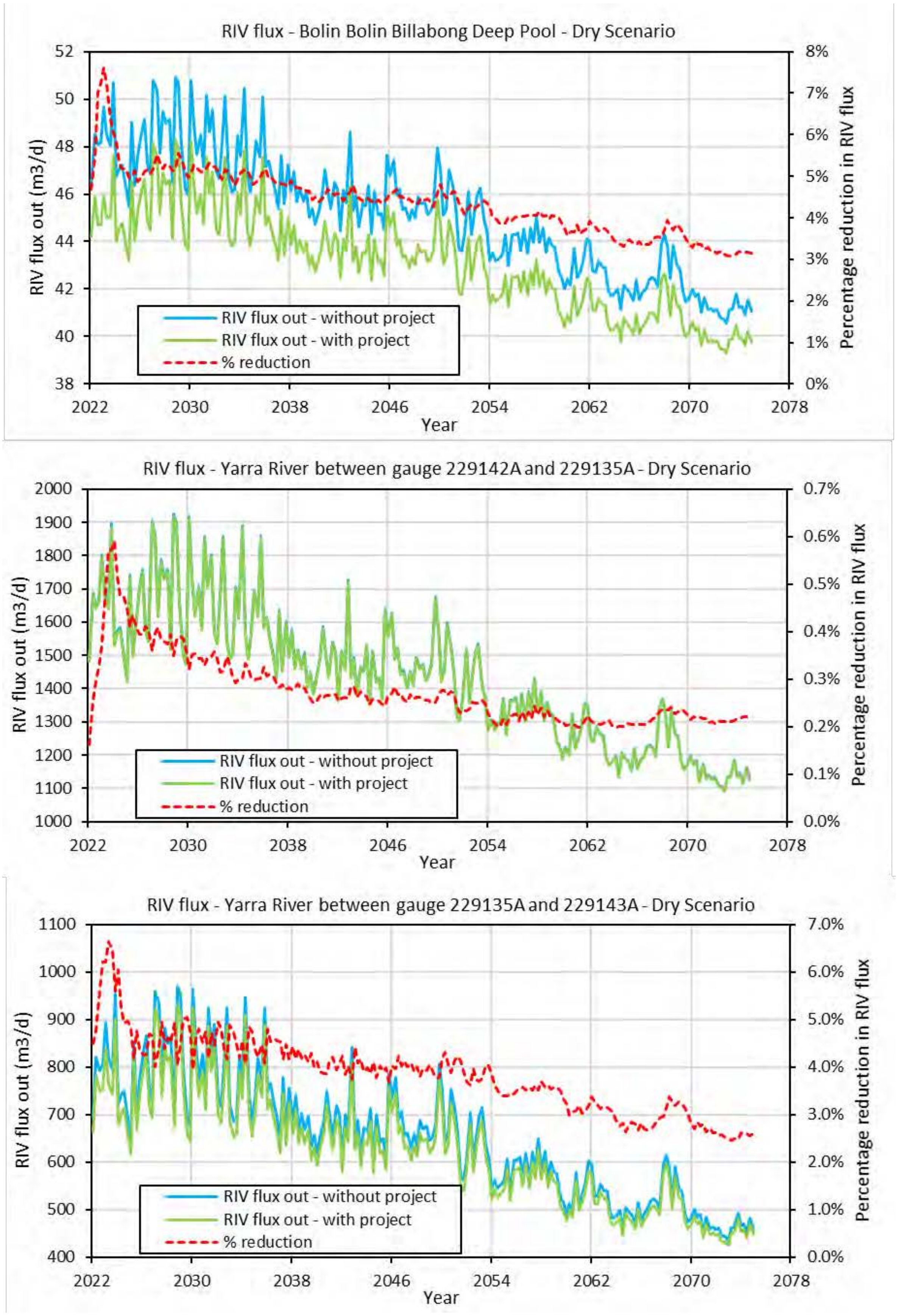

Figure 60 Predicted dry scenario groundwater fluxes (baseflow)

7. Conclusion

7.1 Summary of key findings

Key findings of numerical groundwater modelling are summarised below:

- During the project's construction, the piezometric heads would be lowered towards the floor of cut and cover excavations and mined tunnels, causing large temporary drawdown of up to around 25 metres at the sites of excavation. Drawdown in areas outside the cut and cover excavations would be minimised by the diaphragm walls. In the southern portion of the alignment, mounding of the water table is simulated on the up gradient (eastern) side of the Banksia cut and cover due to the impedance of groundwater through-flow by the diaphragm walls.
- Following the lining of mined tunnels and placement of base slabs, the piezometric heads would begin to recover although the antecedent effect of depressurisation is predicted to cause the drawdown cone to continue to expand temporarily (up to several months). The groundwater system is predicted to approach dynamic equilibrium with respect to the changed conditions 5 – 10 years post-construction.
- In the northern portion of the alignment, permanent drawdown is simulated along the free draining trench where the trench floor penetrates the water table whereas minimal permanent drawdown is simulated around the fully tanked section of the Lower Plenty cut and cover to the south (<0.5 metres). In the southern portion of the alignment, permanent drawdown of <1 – <0.2 metres is simulated on the down gradient of the Banksia and Southern (Bulleen) cut and covers respectively. Mounding of the water table on the up gradient side of the Banksia cut and cover is not predicted to result in depth to groundwater of less than five metres bgl.
- Drawdown of up to around two metres is predicted above the TBM tunnels in the northern portion of the alignment, where recharge and groundwater through-flow within the Bedrock are insufficient to completely offset seepage into the TBM tunnels. Drawdown is not predicted to occur at the water table where the TBM tunnels would be located below the Alluvium, as the water table would be maintained by higher recharge and through-flow in this aquifer.
- Seepage of groundwater into the cut and cover excavations would be minimised by the diaphragm walls, with the majority of seepage during construction occurring vertically via exposed floor of the excavations. Average groundwater inflow into cut and cover excavations during construction would range from 70 – 106 m^3/d (around 0.8 – 1.2 L/s). Following the placement of base slabs, the excavations would be fully tanked and seepage would occur at a limited rate. The model has been set up to enable seepages at a rate of 0.1 – 0.2 L/d/m^2, approximately equal to Haack Class 3 water tightness.

- Drawdown in the southern portion of the alignment is predicted to cause small reductions in groundwater fluxes (baseflow) to the deep pool of Bolin Bolin Billabong (2.5 – 4.8 per cent reduction) and Yarra River (3 – 5.5 per cent reduction between gauges 229135A and 229143A). The latter equates to baseflow reductions of 25 to 45 m^3/d, which are less than 0.01 per cent of the total stream flow of 360,000 m^3/d measured 90 per cent of the time. The small reduction in groundwater fluxes to Bolin Bolin Billabong post-construction is due to the small predicted drawdown of around 0.1 metres. This has the potential to cause a small reduction in the pool level during the dry season, which would be no greater than the 0.1 metre drawdown of groundwater level predicted in the underlying Alluvium. A very small increase in leakage from Banyule Swamp and Banyule Billabong (<0.25 per cent and <0.6 per cent respectively) is predicted due to <0.1 metres drawdown in the Alluvium caused by the leakage of groundwater into the underlying TBM tunnels.
- A Null Space Monte Carlo analysis based on 200 plausible alternative models indicates the largest uncertainty in predicted drawdown occurs within the vicinity of the cut and cover structures and mined tunnels and during periods of active dewatering (up to around four metres at the end of construction). The uncertainty in predicted drawdown and mounding is smaller post-construction (typically <1 metre) as tanking facilitates the recovery of piezometric heads and the groundwater system tends towards new dynamic equilibrium.
- While climate variability (and climate change over the long term) influences the groundwater levels and fluxes, the impact of the project predicted by the model is not particularly sensitive to the climate variability. The changes in groundwater levels (drawdown/mounding) and reduction in groundwater fluxes predicted under the average (steady state) climatic condition are generally comparable to those predicted under variable climatic conditions. The most notable effect of climate change is seen under the dry (high impact) scenario, where the lowering of the water table due to reduced recharge results in smaller drawdown (free draining trench) and mounding (up gradient of the Banksia cut and cover). The exception to this is over the TBM tunnels, which results in larger drawdown under the dry condition due to less recharge and groundwater through-flow to offset ongoing leakage into the TBM tunnels.
- Under the wet (low impact) climate change scenario, the water table up gradient of Banksia cut and cover may temporarily become less than five metres bgl if the effect of model uncertainty (non-uniqueness) is factored in. However, the likelihood of shallower water table is considered low based on the outcomes of uncertainty analysis and the low likelihood of wetter future climatic condition (equating to 10th percentile climate change projection).

7.2 Model limitations

Numerical groundwater models are a mathematical representation of complex real world systems. The physical domain of interest, comprising layers of rocks and sediments, is discretised into a number of cells and parameters that control the movement of groundwater through these layers are prescribed to each cell. The governing groundwater flow equations are solved by the code to compute hydraulic head and fluxes in and out of each cell.

This mathematical representation of a natural physical system, using a finite number of cells, is a necessary simplification that is inherent in all numerical modelling, the degree of which is influenced by factors including the availability of data, scale of the model, intended model use and computational demand of modelling techniques. The groundwater model described in this report is of regional scale, consistent with the scale of the project, with a level of detail commensurate with the intended model use and available data. It is not designed to simulate groundwater flow processes at all spatial scales (for example, the influence of individual fractures) which is neither necessary to inform the potential regional-scale impacts of the project nor possible with the data currently available.

Groundwater models constructed for major infrastructure projects are often required to make predictions of hydrological responses to stresses greater than those that have occurred in the past and for a period of time longer than the period of historical observations. While long-term monitoring data are not available in the project area to enable meaningful calibration to long-term seasonal variations, it should be noted that temporary dewatering activities will impose stresses to the system (up to around 25 metres drawdown) far greater than those associated with natural seasonal variations (1 – 2 metres). For temporary impacts during construction, pumping tests (while short-term and localised), have provided important indications of the system response to stresses larger than natural variations. For the post-construction period, long-term impacts of the project will depend to an extent on the future climatic condition which is not known and will be influenced by climate change.

This report describes several tasks undertaken to address recognised limitations of modelling. These include:

- Utilising unstructured gridding to enable accurate representation of the project within a regional model domain.
- Using available hydrological data to calibrate the model including pumping tests data collected at three key sites to simulate stress-response relationships.
- Undertaking a rigorous uncertainty analysis to explore the effect of model non-uniqueness that cannot be reduced by calibration to existing data.
- Stress testing of the model to assess the significance of climate variability using historical climate dataset and projected climate change factors based on the DELWP climate change guidelines.

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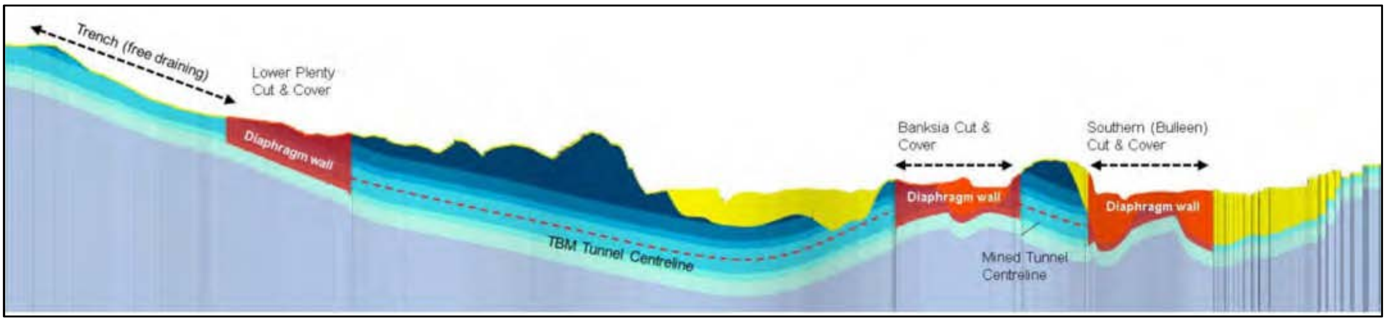
Appendix D – Peer review report

NORTH EAST LINK GROUNDWATER ASSESSMENT INDEPENDENT REVIEW

Prepared for:	Clayton Utz for the North East Link Project	20 February 2019



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Authors	Hugh Middlemis (HydroGeoLogic)

THIS REPORT SHOULD BE CITED/ATTRIBUTED AS:

Middlemis H (2019). North East Link Groundwater Assessment Independent Review. Prepared by HydroGeoLogic for Clayton Utz for the North East Link Project. 20 February 2019.

1. INTRODUCTION

The North East Link Project (NELP; within the Department of Transport) is responsible delivering North East Link on behalf of the State. North East Link is a new freeway-standard road connection between the M80 Ring Road to the Eastern Freeway (Figure 1). The project will involve the construction of surface road works as well as twin tunnels, deep cuttings and related structures that will extend below the water table in some areas. This will require groundwater management during construction and operation of the project.

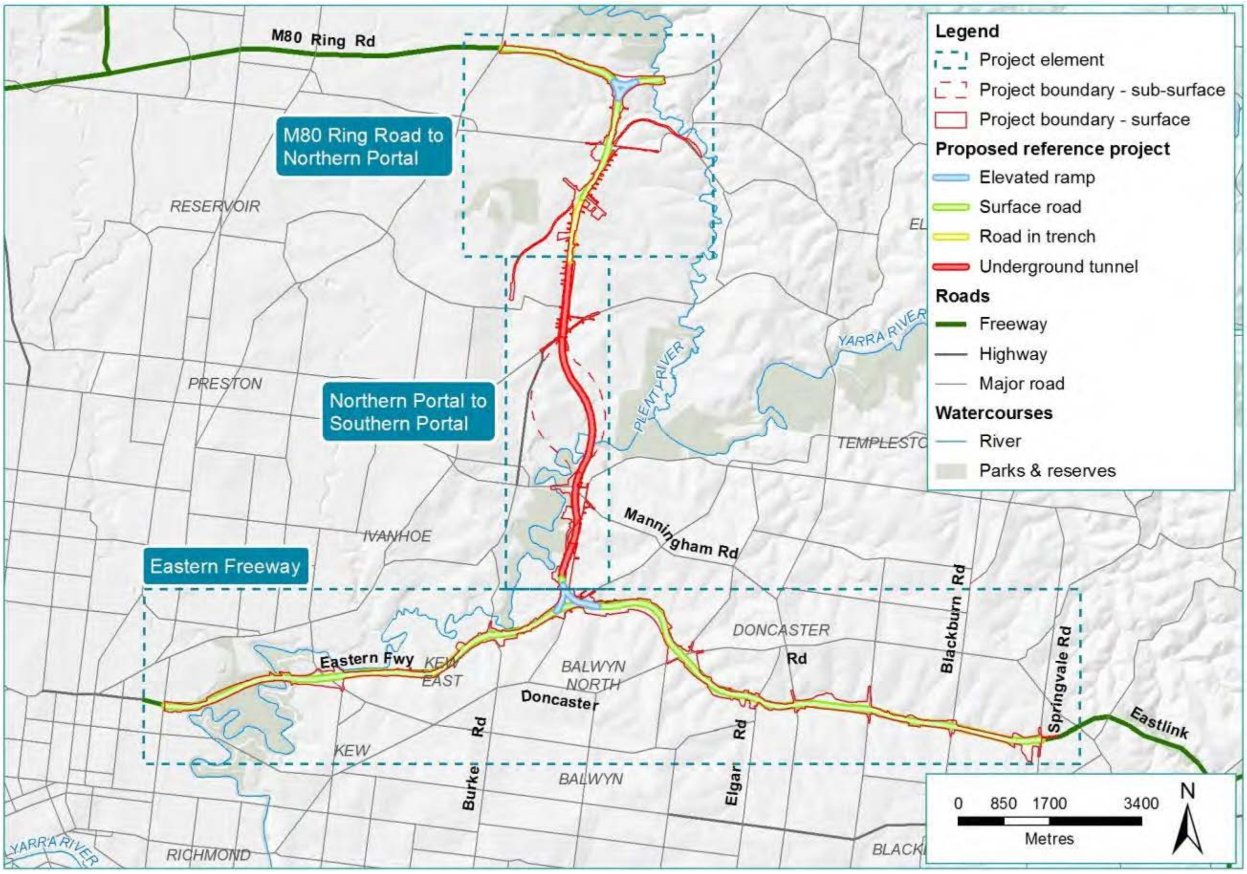

Figure 1 - Overview of North East Link (after GHD, 2019)

The Environment Effects Statement (EES) required for this project includes a Groundwater Technical Report (GHD, 2019), which includes an appendix with details on the numerical groundwater modelling. The Groundwater Technical Report defines the Environmental Performance Requirements (EPRs) to meet the groundwater-related EES objectives, and to set the groundwater quality outcomes for the project.

1.1 Peer Review Process and Criteria

This report summarises the outcomes of an independent peer review conducted by Hugh Middlemis (HydroGeoLogic) of the North East Link hydrogeological and groundwater modelling assessments conducted by GHD (2019). The purpose of the review is to assist in ensuring that the Groundwater Technical Report is prepared to a satisfactory standard, and that there is appropriate consideration of key issues relevant to groundwater in the

EES. The peer review considered whether the Groundwater Technical Report adequately addresses the relevant EES Scoping Requirements and the 'public works' declaration made by the Minister for Planning in respect of the Project, and is suitable to represent the groundwater impacts of the project.

In conducting this peer review, the reviewer has:

- assessed the process, methodology and assessment undertaken in preparation of the Groundwater Technical Report, including assessment criteria applied and assumptions relied upon;
- identified any additional matters which should be considered in order to address the EES Scoping Requirements, 'public works' Order or to otherwise adequately assess the likely impacts of the project; and
- assessed the adequacy of proposed Environmental Performance Requirements to manage potential adverse impacts arising from the Project relevant to groundwater.

The independent review was conducted over the period from June 2018 to January 2019. Draft version reports on the groundwater assessment studies undertaken by GHD were reviewed progressively. Issues logs and comment registers were prepared, discussed and updated as work proceeded and subsequent report versions were issued, until the final version 5 of the groundwater assessment report. During this process, the reviewer participated in several meetings and conference calls with GHD to discuss related technical matters.

This review report has a focus on the fitness for purpose of the final groundwater assessment report (GHD 2019) in meeting the EES scoping requirements for the North East Link Project. The groundwater modelling component (Appendix C to GHD 2019) is crucial, as the sensitivity and uncertainty analysis provided the consequence and likelihood (or impact and probability) data for the risk-based assessment methodology. The review of the modelling was conducted in accordance with the best practice principles of the Australian Groundwater Modelling Guideline (Barnett et al. 2012), augmented by the recent guidance on uncertainty analysis (Middlemis and Peeters, 2018).

Although there are no national best practice criteria for hydrogeological investigations as such, the 2006 EPA Guideline for Hydrogeological Assessment describes the basic guiding principles (in the context of environmental auditing and contaminated land investigations) including the need for a Conceptual Hydrogeological Model (CHM). The basic principles are common to most hydrogeological investigations; consider the data available and acquire more data if necessary to develop a hydrogeological understanding and a CHM. A CHM describes the physical framework, aquifer structure and flow system in terms of the key processes of natural and managed recharge, discharge and surface and groundwater interactions and related water quality characteristics. These principles are consistent with the data collation, analysis and conceptualisation principles outlined in the Australia Groundwater Modelling Guideline ("AGMG"; Barnett et al. 2012). The AGMG guided the development of the North East Link groundwater model that was used for the objective impact assessment, and has been applied to review it (noting that EPA 2006 cites Middlemis et al. 2001, which formed the basis for the 2012 AGMG).

This review also confirms that the groundwater assessment applied best practice to:

- considering potential pathways for impacts on water resources and dependent assets that could arise from the North East Link construction and operation, and
- developing EPRs that are fit for the EES purpose, with a hierarchy of measures to minimise, manage and mitigate adverse environmental effects.

1.2 Evidentiary Basis

The review was conducted by HydroGeoLogic under instructions from Clayton Utz acting as legal counsel to the North East Link Project. The main evidentiary basis is:

- GHD (2019). North East Link Project Environmental Effects Statement Groundwater Technical Report. Prepared for North East Link Project. January 2019.

2. REVIEW OUTCOME SUMMARY

Table 1 presents a summary of the findings of this peer review in relation to the groundwater modelling tool used for the impact assessment, based on the compliance checklist from the best practice modelling guidelines (Barnett et al. 2012).

Table 1 - Groundwater Model Compliance: 10-point essential summary - North East Link

Question	Y/N	Comments re North East Link groundwater model
1. Are the model objectives and model confidence level classification clearly stated?	Yes	Class 1-2 model confidence level is claimed, and is endorsed by this review.
2. Are the objectives satisfied?	Yes	Competent model design and calibration to groundwater levels, drawdown & baseflows, demonstrating fitness for purpose. Sensitivity and uncertainty analysis conducted, plus climate scenarios. Results presented in risk terms of consequence and likelihood (impacts and probability) for groundwater levels, drawdown and surface exchange fluxes. The results are integrated within a risk-based environmental impact assessment framework that carefully considers existing and future conditions, impact pathways and management measures, consistent with EES scoping requirements.
3. Is the conceptual model consistent with objectives and confidence level?	Yes	Hydrogeological analysis and conceptualisation is sound, and consistent with data and objectives. The Class 1-2 model confidence level is endorsed as suitable for EES purposes.
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	GHD 2019 report summarises previous studies, outlines new data acquired, all carefully combined to develop a sound conceptual model. Competent hydrogeologists and modellers have evaluated the data, conceptualisation, potential impact pathways, model design, execution, uncertainty assessments and outcomes.
5. Does the model design conform to best practice?	Yes	The model software, design, extent, layers, grid, boundaries, surface-groundwater interaction and parameters are consistent with best practice design and execution.

Question	Y/N	Comments re North East Link groundwater model
6. Is the model calibration satisfactory?	Yes	Model calibration performance is good (SRMS error 3.2% for steady state levels, 5.9% for pumping test drawdowns). 53-year benchmarking transient run 1965-2018 conducted (effectively a verification process) and 3.1% SRMS confirms sound calibration.
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Model parameter values are consistent with drilling, testing and previous modelling information. Comprehensive parameter sensitivity analysis identified key flux uncertainties as baseflow and evapotranspiration (ET). The calibration matches to flux estimates for ET and baseflows are reasonable, and data uncertainties are acknowledged. Uncertainty and climate scenario assessments predict low risk of materially significant changes/impacts to groundwater levels, ET or baseflows.
8. Do the model predictions conform to best practice?	Yes	Overall methodology is a good example of best practice in design and execution, notably including uncertainty & risk assessments.
9. Is the uncertainty associated with the simulations/predictions reported?	Yes	Composite parameter sensitivity analysis was run, and used in the calibration-constrained Null-Space Monte Carlo uncertainty analysis. Results estimate the predicted impacts in terms of spatial and temporal distributions of key criteria (groundwater levels, drawdown/mounding, and stream-aquifer flux exchanges), and the probability of occurrence. Short & long term climate variability scenarios also assessed. All consistent with best practice guidance, and the uncertainty implications are well documented.
10. Is the model fit for purpose?	Yes	My professional opinion is that the hydrogeological and groundwater modelling assessment is fit for the EES purpose and informing related management/mitigation strategies.

3. DISCUSSION

The groundwater assessment report (GHD 2019) is well-written and provides clear explanations of the hydrogeological setting and conceptual understanding (i.e. existing conditions), the numerical groundwater model design, implementation and uncertainty analysis (impact assessment), results and interpretations.

Changes to groundwater levels are identified as a key risk. This is warranted, as the changes can be due to either extraction (dewatering, seepage etc) or water table mounding due to structures (tunnels) impeding groundwater flows. These processes play a key role in potential impact pathways in relation to:

- existing groundwater users (low potential; saline groundwater & low bore yields)
- flux exchanges between groundwater and surface water systems (e.g. effects on groundwater-fed baseflows to streams);
- changes to depth-dependent evapotranspiration as a surrogate for effects on groundwater dependent ecosystems (GDEs; mostly on the floodplain);
- influences on potential settlement (e.g. on Commonwealth land);
- mobilising contaminated groundwater plumes;
- oxidation of potentially acid sulphide soils and rock.

The key performance indicators are thus clearly identified as groundwater level changes (drawdowns, mounding and depth to water table) and related groundwater flow system changes including river-aquifer exchange fluxes.

3.1 Model Design, Calibration and Prediction

The 3D MODFLOW-USG model domain, layer setup, grid design, boundary conditions and parameters applied are consistent with the available information and conceptualisation, with a bias towards conservative assumptions where warranted (e.g. over-estimating drainage through the base of excavations). The assumptions and limitations are well-described, and the sensitivity and uncertainty analysis is well-executed.

The conceptualisation is sound, based on a range of investigations in the area over many years, and has been executed aptly in the numerical model. The steady state model calibration performance achieved good matches to groundwater level monitoring data (statistical measures of scaled RMS are within the 5-10% guideline: 3.2% for groundwater levels and 5.9% for drawdowns). The simulated groundwater flow patterns reflect the hydrogeological conceptualisation. The time series matches to data from the three pumping tests are good, albeit short term.

A key acknowledged limitation is that that there is no long term monitoring data available on groundwater levels within the study area to undertake a meaningful transient model calibration (“history match”). This was addressed by a long term “benchmarking” simulation of applying to the model the climatic conditions over the period 1965 to 2018, a 53-year period of substantial hydrological variability. The result was a set of groundwater levels that achieved very good matches to measured groundwater levels at April 2018 (scaled RMS of 3.1%), confirming the sound model performance. This benchmarking methodology is consistent with best practice criteria (including DELWP 2016; see also section 3.3), and it confirms in principle the suitability of the model to investigate long term and seasonal variability effects. However, the “verification” of the reasonableness of the seasonal fluctuations simulated will have to wait until there is at least 6-12 months of monitoring data available.

The base case prediction scenario of the construction works schedule and post-construction operations was run with the calibrated model. The results are clearly presented in terms of groundwater inflows to excavations, groundwater level impacts, drawdown/mounding and depth to water table (helpful for assessments of groundwater-dependent ecosystems or GDEs). Groundwater flux exchanges with rivers, creeks and billabongs are also well-presented in volume and percentage change terms, and assessed in relation to the DELWP (2015) Ministerial guidelines on groundwater extraction effects on stream flows.

The presentation of the results and the interpretations and discussion is commendable.

3.2 Sensitivity and Uncertainty Assessments

A relative composite sensitivity (RCS) analysis was conducted using PEST routines, as recommended in the recent uncertainty analysis guidance (Middlemis and Peeters 2018). The results rank the parameter sensitivities:

- a high RCS value indicates that the model calibration is sensitive to that parameter, but that the measurements have provided enough information to adequately constrain the uncertainty
- a low RCS value indicates that the model calibration is not sensitive to the parameter because the measurements do not inform/constrain the calibration, and thus the effect on predictive uncertainty should be evaluated.

The composite parameter sensitivity was assessed in terms of the key performance indicators (groundwater levels, drawdowns and river-aquifer exchange fluxes or “baseflow”). It identified high model calibration sensitivity to factors including recharge, hydraulic conductivity, evapotranspiration, specific storage and river bed conductance, as is commonly found in modelling studies.

The sensitivity results were used to guide the subsequent calibration-constrained Null-Space Monte Carlo uncertainty analysis that was conducted consistent with best practice guidance (Barnett et al. 2012; Middlemis and Peeters, 2018). Such a comprehensive analysis is commendable, not least because it is not commonly undertaken in practice (Middlemis and Peeters, 2018). More importantly, the sensitivity and uncertainty assessment results provide estimates of the predicted impacts (consequences) in terms of spatial and temporal distributions of the key criteria (groundwater levels, drawdown/mounding, and stream-aquifer flux exchanges), along with the probability of occurrence (likelihood). There is also a clear presentation of the “uncertainty range” of impacts predicted (e.g. the difference between the upper and lower bounds in drawdown or mounding defined by the differences between the 95th and 5th percentile results).

The uncertainty assessment identified baseflow estimation (i.e. estimating groundwater inflows to streams from analysis of gauged stream flows) as a key uncertainty. This is fundamentally a data uncertainty that results in the groundwater model calibration being affected by non-uniqueness (i.e. there is a wide plausible range of baseflows, and the model calibration is not strongly constrained by the estimates of groundwater-stream flux exchanges). Having said that, the uncertainty analysis considered a wide range of parameter combinations, and the results indicate relatively low impact in percentage terms of groundwater inflows to the Yarra River or to the Bolin Bolin Billabong, with consideration of the DELWP (2015) Ministerial guidelines relating to groundwater extraction effects on stream flows.

The consequence and likelihood information provided by the groundwater uncertainty assessment is a good example of best practice, is very clearly presented and provides objective support to environmental effects and risk assessment and management tasks, and for related decision-making.

3.3 Climate Variability Scenarios

Guidance for modelling climate change scenarios is provided in DELWP (2016), which states at Recommendation 7 that "*recent climate is considered to be a better approximation of likely future conditions than GCM projections*." It recommends at Section 4.1 the use of a "*current climate baseline from July 1975*" to evaluate the effects of climate variability.

The North East Link Project groundwater assessment devised a 53-year run of the groundwater model over the period 1965-2018 as the climate baseline (or "benchmark run"), achieving a match to the recent short term groundwater level data available, but simulating hydrological variability since 1965.

Long term operational scenarios were then run with and without the tunnel works, with the differences used to quantify the incremental impacts of the tunnel. Short term climate variability that may affect construction conditions was also assessed by selecting a dry and a wet climate sequence from the climate baseline and running the model with and without the construction schedule. Such methods of scenario differencing are recommended in the best practice guidance to address predictive uncertainty (Barnett et al. 2012; guiding principle 6.2).

3.4 Model Confidence Level Classification

Although the "model confidence level classification" is identified as a key issue in the latest groundwater modelling guidelines (Barnett et al. 2012), there are identified limitations with the concept, as outlined in the IESC report on groundwater modelling uncertainty (Middlemis and Peeters, 2018), along with methods to address its limitations.

The groundwater assessment report claims a Class 1-2 model confidence level classification, as expected for the study purpose of impact assessment and management, and related licensing.

This review conducted an independent assessment of the model confidence level classification, consistent with the guidelines but based on the method outlined in Middlemis and Peeters (2018). This review finds that a Class 1-2 model confidence level is indeed justified, and confirms that the North East Link model is suitable for EES purposes.

4. ENVIRONMENTAL PERFORMANCE REQUIREMENTS

The impact assessments and interpretations are well-supported by the data available and the evidence presented. The groundwater assessments are integrated with a risk-based environmental impact assessment framework that carefully considers existing and future conditions, impact pathways and management measures. The overall approach provides quantification of the predicted impacts in terms of spatial and temporal distributions of the key criteria (groundwater level changes and related flow system effects and river-aquifer flux exchanges), along with the probability of occurrence.

This consequence and likelihood information is clearly presented and provides objective support to the development of EPRs that are well-designed to minimise, manage and/or mitigate adverse groundwater-related environmental effects. The EPRs for the North East Link Project require ongoing groundwater monitoring and groundwater model refinement tasks, and the use of design, construction and operational methods to minimise groundwater inflows and related long-term changes to groundwater levels and flow systems, consistent with the EES scoping requirements.

5. CONCLUSION

My professional opinion is that the North East Link Project hydrogeological and groundwater modelling assessment has been conducted with a high degree of professionalism and meets best practice criteria. It is fit for the EES purposes and to inform EPRs, management strategies and licensing. The assessments are integrated with a risk-based environmental impact assessment framework that carefully considered existing and future conditions, impact pathways and management measures. The assessment uses the results from the numerical groundwater model that is designed and executed using best practice methods, including sensitivity and uncertainty analysis, and short and long term climate variability scenarios. The approach provides quantification of the predicted impacts in terms of spatial and temporal distributions of the key criteria of groundwater level changes and related flow system effects and river-aquifer flux exchanges, along with the probability of occurrence. This consequence and likelihood information is clearly presented, providing objective support for the EPRs that are designed to minimise, manage and/or mitigate adverse groundwater-related environmental effects.

6. DECLARATIONS

For the record, the peer reviewer, Hugh Middlemis, is an independent consultant specialising in groundwater modelling. He is a civil engineer with a masters' degree in hydrology and hydrogeology and more than 38 years' experience. Hugh was principal author of the first Australian groundwater modelling guidelines (Middlemis et al. 2001) that formed the basis for the latest guidelines (Barnett et al. 2012) and was awarded a Churchill Fellowship in 2004 to benchmark groundwater modelling best practice. He is co-author of the 2018 guidance on modelling uncertainty (Middlemis and Peeters, 2018).

Hugh Middlemis has not worked on the North East Link Project nor for GHD consultants, and we assert no conflict of interest issues in relation to this work.

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
FINAL	T Anderson	K Aldous		M Roser		April 2019

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