Public Environment Report

Technical Appendix B: Groundwater

North East Link Project

North East Link Public Environment Report

Technical Appendix B – Groundwater technical report

Prepared for North East Link

September 2019

Executive summary

This technical report is an appendix to the North East Link Public Environment Report (PER). It has been used to inform preparation of the PER and the assessments required for the action under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) assessments.

Overview

North East Link ('the action') 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 proponent for North East Link is the State of Victoria through the Major Transport Infrastructure Authority (MTIA). 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 the division 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 13 April 2018, a delegate of the Australian Government Minister for the Environment and Energy determined that North East Link is a controlled action due to likely significant impacts on the following matters protected under Part 3 of the EPBC Act:

- Listed threatened species and communities (Sections 18 and 18A)
- Listed migratory species (Sections 20 and 20A)
- Environment on Commonwealth land (Sections 26 and 27A).

The delegate of the Minister also determined that North East Link requires assessment by a PER. The PER allows stakeholders to understand the likely impacts of North East Link on these Matters of National Environmental Significance (MNES) and on the environment on Commonwealth land and how they are proposed to be managed. The PER was developed in parallel with the reference project development and preparation of the North East Link Environment Effects Statement (EES). The reference project has been assessed in the PER.

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

Groundwater context

In accordance with the requirements of the PER Guidelines, this groundwater assessment informs the assessment of the following MNES that are protected under Part 3 of the EPBC Act:

- Listed threatened species and communities (Sections 18 and 18A of the EPBC Act)
- Listed migratory species (Sections 20 and 20A)
- The environment of Commonwealth land (Sections 26 and 27A).

Changes to groundwater have potential to affect the habitat of listed threatened species and communities and listed migratory species. The significance of these impacts is addressed in PER Technical Appendix A – Flora and fauna, but the changes to groundwater that could cause those impacts are described in this report.

Assessment approach

Groundwater processes occur over a range of scales (such as local and regional flow regimes), and so it is necessary to extend the study area beyond the project boundary to capture these broader-scale processes. The study area for this assessment includes all land within approximately two kilometres of the project boundary, including the Yarra River catchment. This study area covers a much broader area than the expected zone of impact, and the additional information captured has been used to provide context for regional ground water flow processes.

This report examines the impacts on groundwater resources (including those on which MNES are dependent and those that affect Commonwealth land) based on the assessment of the following key issues:

- Potential for the action to affect groundwater, including with respect to flooding and future climate change scenarios
- Potential for contaminated groundwater to be discharged into surface waters or groundwater environments
- Potential for migration or disturbance of anthropogenic contaminated soil or groundwater or naturally occurring acid forming materials.

In assessing groundwater impacts for this technical report, the following steps were followed:

- The existing groundwater environment that would influence impacts on MNES and Commonwealth land was described
- Groundwater impacts, either direct or indirect, resulting from construction and operation of North East Link that could directly or indirectly impact on MNES and Commonwealth land were identified
- Measures to avoid or mitigate groundwater impacts were considered
- The significance of residual groundwater impacts was assessed.

In assessing the impacts to groundwater, impact pathways are dependent upon changes in groundwater level, and changes in groundwater quality. Changes in groundwater level can influence access to the groundwater resource by humans and the environment (dependent ecosystems). Changes in groundwater levels can also change groundwater quality through the oxidation of acid-generating materials, or movement of contaminated groundwater plumes.

In terms of receptors, there are a number of considerations. Groundwater can be a receptor itself as it is a media that can support ecosystems (such as stygofauna; fauna found in groundwater or aquifers). Groundwater can also convey nutrients and flows to other dependent ecosystems such as swamps and waterways. In this instance, changes to groundwater quality or levels may indirectly impact down-gradient receiving environments or ecosystems accessing groundwater.

Groundwater may also have a number of beneficial uses which are determined by its base salinity. For example, a low salinity groundwater could possibly be used for many purposes including drinking and irrigation, whereas saline groundwater less so. Changes to groundwater level and or quality can influence these beneficial uses that directly effect a range of receptors including humans and abstractive benefit of the groundwater (such as the ability to pump groundwater to service stock watering, irrigation, commercial or industrial water requirements).

North East Link would involve dewatering to enable the construction of structures in the subsurface and so changes in groundwater levels would occur. To predict the changes to groundwater levels as part of North East Link's construction and operation, a numerical groundwater model was developed, calibrated and subject to sensitivity and uncertainty analyses.

Since the numerical groundwater modelling was undertaken for the preparation of the draft PER that was published under Section 98 of the EPBC Act, additional numerical groundwater modelling has been undertaken. The purpose of the further modelling was to incorporate additional groundwater data collected over a period of approximately 12 months to enable transient calibration to seasonal variations in groundwater levels and to assess whether or not the additional calibration efforts result in changes to the assessment of project-induced groundwater impacts.

Description of the environment

The existing conditions are summarised as follows:

- The hydrogeology of the study area can be broadly divided into two aquifer systems: an alluvial aquifer and a bedrock aquifer system. These are likely connected aquifer systems (where alluvials overlie the bedrock), with contrasting aquifer hydraulic properties. The bedrock aquifer system underlies Simpson Barracks. The alluvial aquifer is interpreted to be present in the far north-eastern corner of Simpson Barracks, associated with the Watsonia Drain.
- 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 generally falls within Beneficial Use Category, Segment C as outlined in State Environment Protection Policy (SEPP) (Waters). Higher salinity (Segment D) groundwater has been identified on Simpson Barracks. At such salinity concentrations, groundwater is too saline for irrigation and potable use without treatment. Groundwater could be used for stock and industrial applications, but with much of the study area being within residential land zoning types, there is limited likelihood of these uses being realised. Abstractive groundwater use is not present at Simpson Barracks.
- 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 A or Segment C. Abstractive development is limited by aquifer production capacities and restrictions under Victoria's *Water Act 1989* in terms of setbacks from waterways. Much of the floodplain where the bulk of the alluvial aquifer is located is not developed and is zoned as Public Conservation and Resource, or Public Park and Recreation.
- Water levels within the study area are variable. On the floodplains, groundwater levels can be within 5 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. At

Simpson Barracks, the depth to groundwater is variable. In the northern areas near Yallambie Road, groundwater is over 10 metres below the surface. South of Blamey Road the depth to groundwater can be between 5 and 10 metres below the surface.

- Groundwater levels fluctuate seasonally. Available monitoring data indicates fluctuations within the bedrock of <1 metre. Benchmarking with the numerical groundwater predicts seasonal groundwater level fluctuations around 0.5 to 2.5 metres.
- Much of the land within the project boundary is located within Public Use, Public Park and Recreation and General Residential zones, which limit the likelihood of having land use resulting in groundwater contamination. Commercial and Industrial land use zones exist within parts of the project boundary. Land uses surrounding the Commonwealth land are principally for residential housing, but a fuel service station is located at the corner of Yallambie Road and Greensborough Road, adjacent to Simpson Barracks.
- Within the study area, the identification of existing groundwater contamination is limited. Hydrocarbon impacted groundwater has been identified in the north-west corner of Simpson Barracks, 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 Simpson Barracks at Borlase Reserve (near Lower Plenty Road). Polyfluoroalkyl Substances (PFAS) contamination has been found at one location near the former Bulleen Drive-in.

Key findings

The primary control for minimising changes to groundwater levels (drawdowns) relating to construction dewatering is the design philosophy. The action proposes to adopt tanked or undrained structures; that is, a water tight lining system that minimises the change in groundwater levels during construction and operation. The Yarra River crossing would be achieved using a tunnel boring machine (TBM) which results in near immediate permanent lining being emplaced during construction. However, some dewatering and change to water levels is inevitable for cut and cover excavations and mined tunnels, the former occurring within Simpson Barracks.

Changes in groundwater levels are predicted in areas where structures wold be constructed below grade, specifically between Yallambie Road in the north, and Bulleen Road in the south. During both construction and operation:

- Groundwater level changes (drawdown) are predicted to occur:
  - Beneath Commonwealth land

    The implications of this drawdown on potential groundwater dependent ecosystems (GDEs) and MNES have been assessed in PER Technical Appendix A – Flora and fauna).
  - Beneath the Yarra River

    However, this is interpreted to cause a reduction in hydraulic gradient and groundwater flow into the Yarra River. The reduction in baseflow over the reach is several orders of magnitude less than the average daily flows and are considered to be of negligible significance.
  - Water level changes are predicted at Bolin Bolin Billabong

    A small (0.1 metre) reduction in water levels is predicted at Bolin Bolin Billabong. Conceptualisation of the billabong suggests that water topping from the Yarra River is more critical to maintaining the health of the billabong. Implementation of a monitoring plan and contingent topping/water supply to the billabong are recommended mitigation measures.

  - Water level changes adjacent Banyule Creek, within Simpson Barracks.

    The ephemeral nature of Banyule Creek over the reach within Simpson Barracks has resulted in the potential impact being ascribed as having a low significance.

- Groundwater mounding is predicted hydraulically up-gradient of structures associated within the Manningham Road interchange and southern portal. Groundwater mounding is not predicted beneath Simpson Barracks.
- There is a low risk that groundwater level changes would result in the generation of acidic groundwater quality and adverse impact to Commonwealth land (Simpson Barracks) or MNES. This is based upon a lack of positive identification of acid-generating materials, and much of the excavation occurring within Simpson Barracks occurs within weathered (oxidised) bedrock. The assessment suggests the aquifer has a low sensitivity to this impact, and the likelihood of an impact occurring is considered low. In addition to controls upon drawdowns, management of excavation spoil is an identified mitigation measure.
- There is a low risk that groundwater level changes would affect abstractive beneficial use of groundwater. There is no existing development of groundwater resources on Commonwealth land, limited groundwater use in the region, and limited likelihood of future groundwater development (based on salinity). Requirements under Victoria's *Water Act 1989* as part of extraction licensing mitigate the impact of pumping interference or resource depletion through dewatering.
- There is a low risk that groundwater level changes would result in the dislocation of groundwater plumes and adverse impact to MNES. Groundwater contamination has been identified at Simpson Barracks, likely associated with a fuel service station identified on the corner of Yallambie Road and Greensborough Road. Monitoring bores exist on Simpson Barracks to assess the integrity of diesel underground storage tanks and information provided by the Department of Defence indicates that no contamination has been identified. Similarly to the acidified groundwater risk pathway, there is no existing groundwater development on Commonwealth land, and limited groundwater use in the region. Management of the identified contamination prior to construction is an identified mitigation measure.
- Groundwater quality changes can result from the spillage of hazardous materials, or as a result of the injection of fluids into aquifer (either to mitigate against water level changes) or disposal of waste waters.

  This impact would most likely occur during construction, but could occur during operation. This impact could affect users of groundwater, beneficial uses of groundwater and groundwater receiving environments. Implementation of a Construction Environmental Management Plan (CEMP) would be required to mitigate this impact. Requirements under the Water Act 1989 as part of reinjection licensing would mitigate the impact of the contamination of groundwater via reinjection.
- Groundwater seepage into construction excavations, and 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, sewer disposal or disposal to waterways or groundwater. Regulatory approvals would be needed once the preferred method has been determined during detailed design and this is the primary mitigation measure to protect down-stream receiving environments.

- Groundwater level changes can influence effective stress conditions in compressible geological materials. Simpson Barracks is located upon the bedrock aquifer which is not a soft or compressible geological material. This potential impact has therefore not been assessed.

Conclusions

The groundwater environment within the study area is relatively sensitive to impacts and has historically had minimal disturbance:

- There is limited existing abstractive development regionally, and no extractive development on Commonwealth land.
- There is limited evidence of contamination of groundwater. However, some contamination has been identified on Simpson Barracks associated with an adjacent fuel service station site.
- Some minor changes to recharge may have occurred within the region due to changing land use overlying the aquifer systems (urbanisation of the catchment). This has occurred partly upon, and adjacent to Simpson Barracks.

The groundwater quality in the bedrock aquifer within the study area (and including Simpson Barracks) is generally saline. This has likely historically limited groundwater development for abstractive benefit, and given the largely residential land use, limits the likelihood of future development for such benefit.

Through adopting a design philosophy of incorporating tanked structures, and implementing the provided mitigation measures, the significance of identified impacts to groundwater receptors such as existing users (stock, commercial) and GDEs from the action are considered low to negligible as a result of changes to groundwater levels and groundwater quality. The same mitigation measures are also considered appropriate for reducing the risks associated with acid sulfate materials and contaminated groundwater, and the associated potential indirect impacts to down-gradient groundwater receiving environments.

This report is subject to, and must be read in conjunction with the assumptions and qualifications contained throughout the report.

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Abbreviations

Terms	Description
AHD	Australian Height Datum
AMG	Australian Map Grid
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS	Australian Standard
BCL	Bore Construction Licence
bgl	Below ground level
BOM	Bureau of Meteorology
BTEX	Benzene, Toluene, Ethyl benzene and Xylene
CEMP	Construction Environmental Management Plan
CRS	Chromium reducible sulfur
DELWP	Department of Environment, Land, Water and Planning
DoD	Department of Defence (Australian Government)
DoEE	Department of Environment and Energy (Australian Government)
DSEWPAC	Department of Sustainability, Environment, Water, Population and Communities, Australian Government.
Dxh	Humevale Siltstone
EC	Electrical conductivity
EMF	Environmental Management Framework
EMP	Environmental Management Plan
EPA	Environment Protection Authority (Victoria)
EPBC	Environment Protection and Biodiversity Conservation Act 1999
EPBM	Earth Pressure Balance Machine
EPHC	Environment Protection and Heritage Council
EPR	Environmental Performance Requirement
EVC	Ecological Vegetation Class
FFG	Flora and Fauna Guarantee Act 1988
GDE	Groundwater dependent ecosystem
GED	General environmental duty

Terms	Description
GIS	Geographic information system
GMA	Groundwater management area
GQRUZ	Groundwater Quality Restricted Use Zones
HA	Hydrogeological Assessment
HEPA	Heads of EPAs Australia and New Zealand
K	Hydraulic conductivity – see Glossary
km	Kilometres
LMP	Local Management Plan
m	Metre
m^2	Square metre
mbgl	Metres below ground level
mm	millimetre
mS/cm	Millisiemen per centimetre (measure of electrical conductivity) 1,000 µS/cm=1 mS/cm
Mya	Millions of years ago
MAH	Monocyclic Aromatic Hydrocarbons
MNES	Matters of National Environmental Significance
NAG	Net Acid Generation
NAPP	Net Acid Production Potential
NATA	National Association of Testing Authorities, Australia
NELP	North East Link Project
Neo (Neo2)	Newer Volcanics Group
Nbr	Red Bluff Sand (Brighton Group)
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRS	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NUDLC	National Uniform Drillers Licensing Committee
Nug	Older Volcanics
Nxp	Sub-basaltic sediments
OEMP	Operation Environmental Management Plan
PAH	Polycyclic Aromatic Hydrocarbons

Terms	Description
PCE	Tetrachloroethylene
PCV	Permissible Consumptive Volume
PER	Public Environment Report
PFAS	Polyfluoroalkyl Substances
PFHxS	Perfluorohexane sulfonate
PFOS	Perfluorooctanesulfonic Substances
PVC	Polyvinyl chloride
PPWCMA	Port Phillip and Westernport Catchment Management Authority
Qa1 (Qa2)	Alluvium and alluvial terrace deposits
Qc1	Colluvium (Quaternary)
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
SWL	Standing Water Level
Sxa	Anderson Creek Formation
Sxm	Melbourne Formation
Sy	Specific yield
TBM	Tunnel boring machine
TDS	Total Dissolved Solids
TPH	Total Petroleum Hydrocarbons
UXO	Unexploded Ordinance
VAF	Victorian Aquifer Framework
VVG	Visualising Victoria Groundwater (website/database)
WMIS	Water Measurement Information System
WSPA	Water Supply Protection Area
WSUD	Water sensitive urban design

Glossary

Term	Description
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.

Term	Description
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.
Groundwater pumping (production) bore	A bore installed with the primary purpose to extract groundwater from a particular hydrogeological formation by means of a pump.

Term	Description
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 proponent for the North East Link project is the State of Victoria through the Major Transport Infrastructure Authority (MTIA). 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 (NELP) is the division 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.

Term	Description
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.
Victorian 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.
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 action') 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 to the Eastern Freeway, and include works along the Eastern Freeway from near Hoddle Street to Springvale Road.

The proponent for the North East Link project is the State of Victoria through the Major Transport Infrastructure Authority (MTIA). 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 the division 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.

North East Link was referred to the Australian Government's Department of the Environment and Energy on 17 January 2018. On 13 April 2018, North East Link was declared a 'controlled action', requiring assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). The decision notice requires North East Link to be assessed through a Public Environment Report (PER).

The purpose of this report is to assess the potential groundwater impacts associated with North East Link to inform the preparation of the PER required for the action.

North East Link also requires assessment under Victoria's *Environment Effects Act 1978*. A separate report has been prepared for the purposes of the Environment Effects Statement (EES) required under the Environment Effects Act.

1.2 Why understanding groundwater is important

1.2.1 What is groundwater?

Groundwater is 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 of low permeability and have a tendency to limit the flow of groundwater (such as clays and silts).

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

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 (human) 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 or 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 are referred to throughout this report.

- **Local groundwater flow regimes** describe local variations in flow directions in response to local undulations in topography. Local flow 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. The images below provide 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 discharge and discharge zones. Regional flow 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.

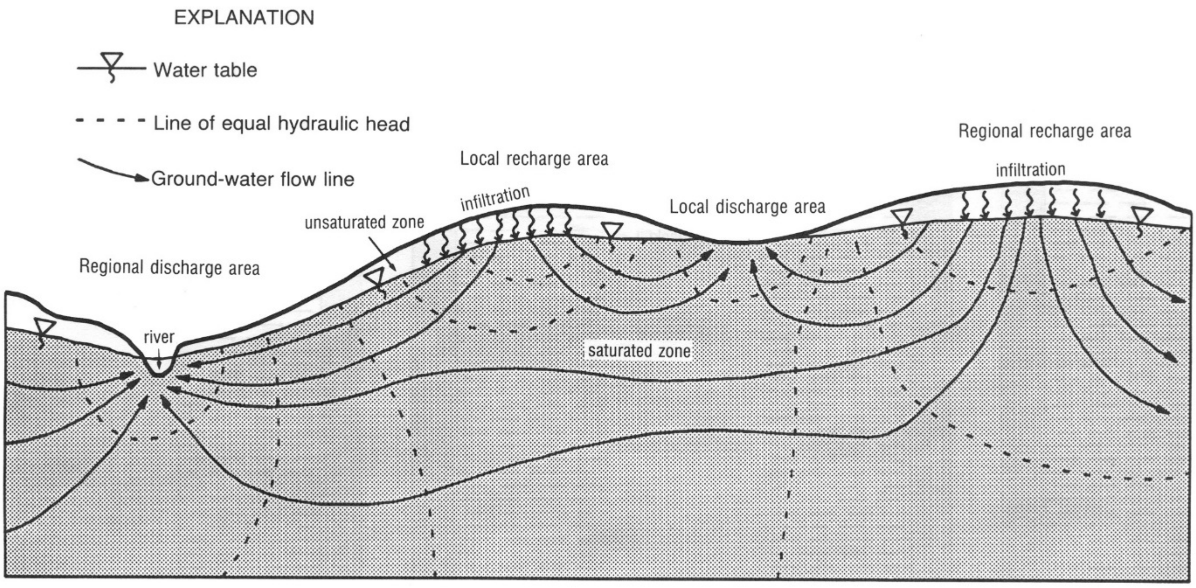


Figure 1-1 Local and regional groundwater flow regimes (Fleming, 1994)

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, the local regime that interacts with the project is of most relevance, while intermediate and regional regimes have been considered 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' or 'values'. The main beneficial uses of groundwater relevant to North East Link are outlined below. Consistent with relevant groundwater legislation and policies in Victoria (see Section 4), 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, with use typically being seasonal as irrigators generally 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 groundwater extraction bores).

At the national and state levels, Australian governments have policies to manage groundwater (see Section 4). These 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 upon 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 to maintain their communities of plants and animals, ecological processes and ecological 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.

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 riverbeds and banks.

Surface water flows in waterways are maintained by groundwater discharges known as baseflow. The degree of groundwater dependence is reliant on the location setting (including topography, geology, climate, surface water drainage, water table depth and vegetation rooting depth) and can be temporally variable. For instance, the groundwater dependence can be facultative (required occasionally) or obligatory (required all the time).

1.2.3 Potential impacts to groundwater

North East Link would involve the construction of structures such as tunnels and deep excavations and cuttings, which would in places be located below the water table. To maintain safe working conditions, and to enable construction, management of groundwater would be required during construction. During operation of North East Link, seepage into its structures would still occur (albeit at lower rates) depending upon 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 due to dewatering activities required to excavate structures below the water table, or groundwater seepage into structures located below the water table. Groundwater drawdown can also result from the extraction of groundwater to be used for construction activities.
- **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 groundwater disposal) or from structures that create a barrier to regional groundwater flow.

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

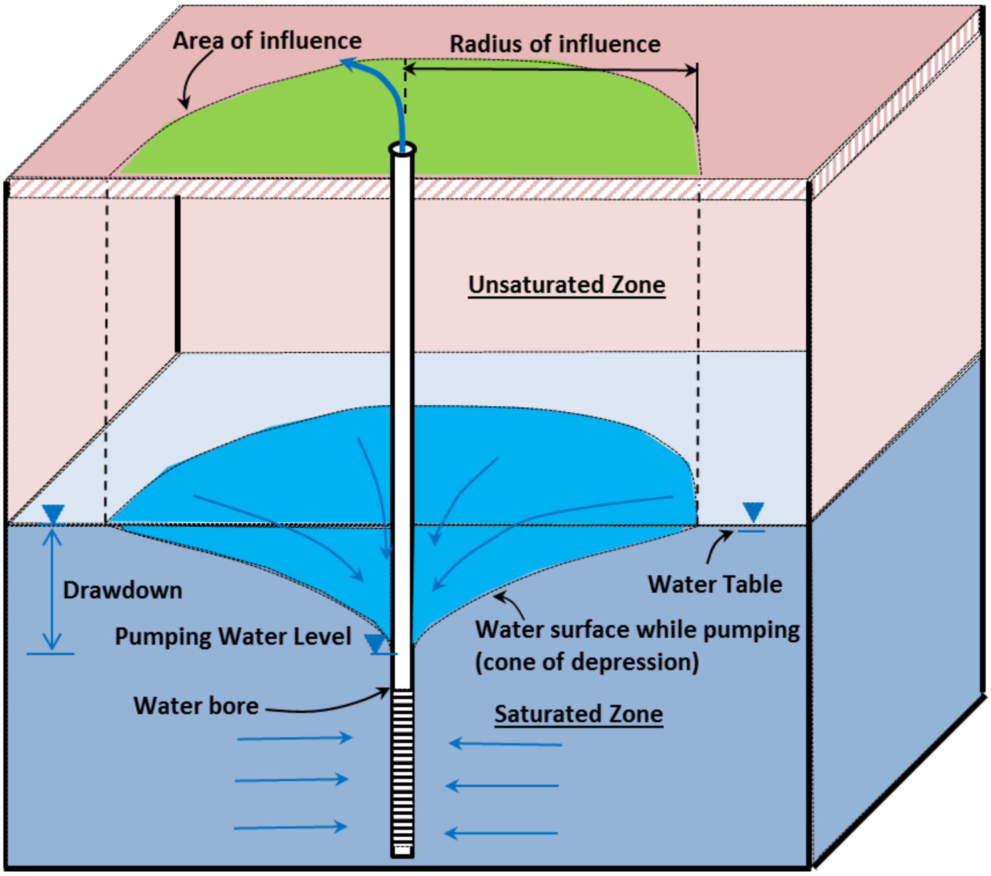


Figure 1-2 Drawdown from groundwater pumping

Changes in groundwater level affect flow regimes and this can have impacts without adequate controls in place. 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, as well as 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 as a result of construction and operation. This may result from the exposure and activation of potential acid-generating soils, movements of contaminated groundwater plumes, movement of native groundwaters of different water quality (saline intrusion), the storage and handling of hazardous materials, or incorporation of incompatible construction materials into the action.

1.2.4 Analysing groundwater drawdown

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 action would interact with it are required. 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, such as:

- Exclusion – grouting to prevent inflows, freezing, cut-offs (vertical barriers), slurries and shields. The methods are undertaken to enable construction of the waterproof structural lining system. In some cases the water proof lining system is installed during construction, such as the gasketted segments of a tunnel boring machine (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 (barrier), the level of the groundwater changes. The final form of the structure (its water tightness once completed) effects 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) creates 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. Excessive groundwater inflows can be an impediment to subsurface construction, and pose issues in terms of depletion of a resource, management of the volume of water 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 and intersects other bores or (in the case of unconfined aquifers) 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 change the groundwater movement from (or to) these features, thereby affecting water availability. Features such as rivers, or more permeable adjoining aquifers, 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. Monitoring is commonly prescribed to verify predicted water level changes.

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.

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

2. PER Guidelines

2.1 Controlling provisions

The controlling provisions are the matters protected under Part 3 of the EPBC Act which the proposed action may have a significant impact on. These are the focus of the PER assessment.

The controlling provisions relevant to groundwater are:

- Listed threatened species and communities (Sections 18 and 18A of the EPBC Act), including:
  - Matted Flax Lily (*Dianella amoena*) (endangered)
  - Grassy Eucalypt Woodland of the Victorian Volcanic Plain (critically endangered)
  - Swift Parrot (*Lathamus discolor*) (critically endangered)
  - Australian Painted Snipe (*Rostratula australis*) (endangered)
  - Australasian Bittern (*Botaurus poiciloptilus*) (endangered)
  - Macquarie Perch (*Macquaria australasica*) (endangered)
  - River Swamp Wallaby-grass (*Amphibromus fluitans*) (vulnerable)
  - Clover Glycine (*Glycine latrobeana*) (vulnerable)
  - Growling Grass Frog (*Litoria raniformis*) (vulnerable)
  - Australian Grayling (*Prototroctes maraena*) (vulnerable).
- Listed migratory species (Sections 20 and 20A of the EPBC Act), namely:
  - Latham's Snipe (*Gallinago hardwickii*).
- Environment on Commonwealth land (Sections 26 and 27A of the EPBC Act), namely:
  - Simpson Barracks and an unfenced strip of land immediately to the south, in Yallambie, which are collectively referred to in this report as 'Simpson Barracks'
  - A strip of land about one kilometre north of the barracks, to the rear of residential properties on Elder Street, Watsonia, which is referred to in this report as the 'War Services easement'.

Changes to groundwater have potential to affect the habitat of listed threatened species and communities, and listed migratory species. The significance of these impacts are addressed in PER Technical Appendix A – Flora and fauna but the changes to groundwater that could cause those impacts are described in this report.

2.2 PER Guideline requirements

The Australian Government's Department of Environment and Energy provided NELP with *Guidelines for the content of a draft Public Environment Report* (PER Guidelines) on 10 July 2018.

The content requirements from the PER Guidelines relevant to groundwater are shown in Table 2-1, as well as the location where these items have been addressed in this report.

Table 2-1 PER Guidelines content requirements relevant to groundwater

PER Guidelines section	Summary of PER Guidelines content requirements (1)	Application to this report
2.0 Specific content	Lists the matters to which the PER Guidelines apply.	The matters in this list that are relevant to this report are discussed in Sections 5 to 8.
2.2 Description of the action	Description of the construction and operational components of the action.	Chapter 3 of the PER describes the action. Section 3 of this report describes the specific components of the action relevant to groundwater impacts.
2.3 Feasible alternatives	Description and comparison of feasible alternatives	Chapter 4 of the PER describes the feasible alternatives.
2.4 Description of the environment	(a) A description of the abundance, distribution, and ecological relationships of threatened species and ecological communities in the study area (as defined in Section 5.2.2) including maps. A description of the known threats to, and assessment of quality and importance of, species or communities' habitats in the study area. A description of the scope, timing and methodology for studies or surveys including assessment of the adequacy of any surveys undertaken.	Section 6 of this report provides information relating to water resources and how these support ecology including groundwater dependent ecosystems.
	(b) A description of the surface and groundwater resources relevant to the action and listed threatened species or communities; and migratory species.	Section 6 of this report provides a detailed description of the surface water and groundwater resources potentially affected by the action.
	(c) A description of the Commonwealth land environment to be affected by the proposal	Section 6 of this report describes the groundwater features on and around Commonwealth land, potentially affected by the action.

PER Guidelines section	Summary of PER Guidelines content requirements (1)	Application to this report
2.5 Relevant impacts	(a) Requirements for the assessment of impacts on the specific content listed in Section 2 of the PER Guidelines. This includes assessment of: • Direct, indirect, cumulative and facilitated impacts • Long and short-term impacts and if they are reversible • Analysis of impact significance • If any impacts are unpredictable or unknown and any additional data that may be needed • Illustration of impacts using maps • Description of assessment methodology.	Section 5 of this report summarises the scope of the assessment and describes the impact assessment methodology and limitations. Section 7 of this report details the relevant impacts identified including maps where applicable.
	(b) Requirement to address cumulative impacts.	
	(c) Requirement to address 'facilitated' impacts at a local, regional, state and national scale.	
2.5.1 Listed threatened species and ecological communities; and migratory species	Specific requirements for assessment of the impacts on MNES (threatened species, ecological communities and migratory species). These include: • Number of individuals and area of occupancy affected. • Impacts on population and community • Loss, alteration or fragmentation of habitat and breeding sites.	PER Technical Appendix A – Flora and Fauna assesses impacts on MNES.
2.5.2 Water-related impacts	Requirement to assess impacts to waterways and groundwater that could potentially affect MNES or their habitat.	Section 7 of this report provides an assessment of potential changes to aquatic habitats and the availability of water for use by MNES. The impact of these changes on MNES is described in PER Technical Appendix A – Flora and fauna.
2.5.2.1 Groundwater	(b) Details of groundwater modelling including but not limited to:	
	• Hydrogeological conceptualisation(s) and geological investigations for the reference project	Section 6.14 documents the hydrogeological conceptualisation of the study area.

PER Guidelines section	Summary of PER Guidelines content requirements (1)	Application to this report
	• Predictive numerical groundwater modelling	Appendix A of this report contains a technical report on the numerical groundwater modelling. Appendix B of this report contains a supplementary report on further groundwater modelling.
	• Short-term and long-term impact assessments and analysis of modelling during construction and operation	Section 7 documents the assessment of significance of the impacts to groundwater.
	• Predictions of groundwater recovery and re-equilibration scenarios, including the influence on nearby groundwater dependent assets	Predicted water levels post construction have been documented in Appendix A, the supplementary report in Appendix B and Section 7.
	• Measures to manage groundwater encountered during the construction process	Section 7.3 and Section 9 document measures to manage groundwater during construction.
	• Any further data collection proposed to characterise groundwater chemistry and inform the installation of monitoring bores.	At the time of reporting, geotechnical investigations were ongoing. Additional information has been incorporated into the supplementary report on further groundwater modelling (Appendix B). Information applied to inform this report is discussed in Section 5.3. Additional groundwater sampling, and monitoring bore installations are proposed. Section 9 documents mitigation measures which include the development of a Groundwater Management Plan.
	(c) Groundwater characteristics across the proposed action area including depth to groundwater, piezometric surfaces of aquifers at the site, groundwater gradients and hydrogeological parameters.	Section 6 documents the hydrogeological conditions of the study area.
	d) An assessment of potential changes to groundwater baseflow contributions to the Yarra River and waterways within the project boundary.	Section 7.4.6 documents an assessment of potential changes in baseflow contributions.
	(e) Identification of any potential groundwater dependent ecosystems based on depth to groundwater.	Section 6.11 documents the potential groundwater dependent ecosystems in the study area. Further discussion is provided in PER Technical Appendix A – Flora and fauna.

PER Guidelines section	Summary of PER Guidelines content requirements (1)	Application to this report
	(f) Information on the impacts of dewatering, including an assessment of impacts to local aquifers including groundwater drawdown and the ongoing use of the developed site.	Sections 7.4.2 to 7.4.4 document the assessment of significance of the impacts to groundwater.
	(g) Details of dewatering techniques used – including information on the pre-drainage process, treatment and disposal of extracted groundwater.	Dewatering techniques are selected by the contractor. A discussion on potential options to control groundwater is provided in Section 7.
	(h) An assessment of the effects of groundwater extraction on groundwater dependent ecosystems and flows into the waterways listed above in the project boundary.	Groundwater modelling has been undertaken to predict drawdowns emanating from construction and operation. An assessment of the impacts to groundwater dependent ecosystems and waterways is provided in PER Technical Appendix A – Flora and fauna.
	(i) Identification of any other groundwater extraction in the area and an assessment of the potential impacts of the proposed project on these users. Detail of cumulative impacts from the removal and lowering of groundwater (such as groundwater recharge, changes to baseflows and downstream impacts on the receiving environments).	Sections 7.3.2 and 7.4.2 document the assessment of significance of impacts to existing groundwater users.

PER Guidelines section	Summary of PER Guidelines content requirements (1)	Application to this report
2.5.3 Commonwealth land – whole of the environment	Assessment of the whole of the environment on Commonwealth land (and the environment elsewhere that may be directly and indirectly affected by actions on Commonwealth land (see Significant Impact Guidelines 1.2 (DSEWPAC (2013b)). The requirements include a description of resources used for the assessment, description of the matters affected and assessment of: • Flora and fauna • People and communities (including the Defence estate as a distinct community) • Cultural and heritage values. • Landscapes and soils. • Water resources. • Pollutants, chemicals, and toxic substances.	Section 5 of this report describes the impact assessment methodology and limitations. Section 6 of this report describes the features potentially affected by North East Link. Section 7 of this report details the predicted groundwater impacts.
2.6 Proposed avoidance and mitigation measures	Description of safeguards and mitigation, including a consolidated list of measures, which include: • Details of the impacts to which measures relate. • Maps showing the measures' location. • The anticipated effectiveness of the measures and the expected environmental outcomes of their use. • Baseline data and/or proposed monitoring to demonstrate achievement of outcomes. • Description of habitat rehabilitation including management, methodology and timing • Statutory or policy basis and agency responsible for approval of measures • Cost of the mitigation measures • An overall framework for management, mitigation and monitoring including provision for independent auditing.	Section 9 of this report describes measures to avoid, mitigate and monitor groundwater impacts, including description of the likely residual impacts and environmental outcomes following the implementation of the mitigation measures. Section 9 provides a consolidated list of these measures.

PER Guidelines section	Summary of PER Guidelines content requirements (1)	Application to this report
2.7 Residual impacts/ environmenta l offsets	(a) Description of likely residual impacts (the 'Relevant impacts' referred to in Section 2.5 of the PER Guidelines following the implementation of mitigation measures referred to in Section 2.6.	Section 7 of this report describes the likely residual impacts and environmental outcomes following the implementation of the mitigation measures.
2.10 Consultation	Description of any consultation undertaken or proposed.	Section 6 of this report describes consultation that has informed the groundwater assessment.
2.13 Information sources provided in the PER	Information on the source, currency, reliability and uncertainty of data provided in the PER	Section 5.6 of this report describes assumptions including data sources and reliability. Parameter sensitivity and model uncertainty analyses were undertaken as part of the numerical groundwater modelling undertaken to predict changes in water levels as a result of North East Link. This analysis is documented in Appendix A.

Note:
1. A full copy of the guidelines can be found in PER Attachment I.

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
PER Technical Appendix C – Surface water	Provides a description and assessment of the action's effects on creeks and rivers.
PER Technical Appendix A – Flora and fauna	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 to groundwater level on terrestrial vegetation (including scarred trees) and groundwater dependent ecosystems are assessed by the ecological specialist discipline.
PER Technical Appendix D – Commonwealth land	Having regard to the assessment in this report, provides an assessment of the impacts of the action on Commonwealth land.

3. Description of the action

3.1 Overview

The North East Link alignment and its key elements assessed in the PER 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 provision of new dedicated bus lanes for the Doncaster Busway. There would also be a new interchange at Bulleen Road to connect North East Link to the Eastern Freeway.

These elements are illustrated in Figure 3-1.

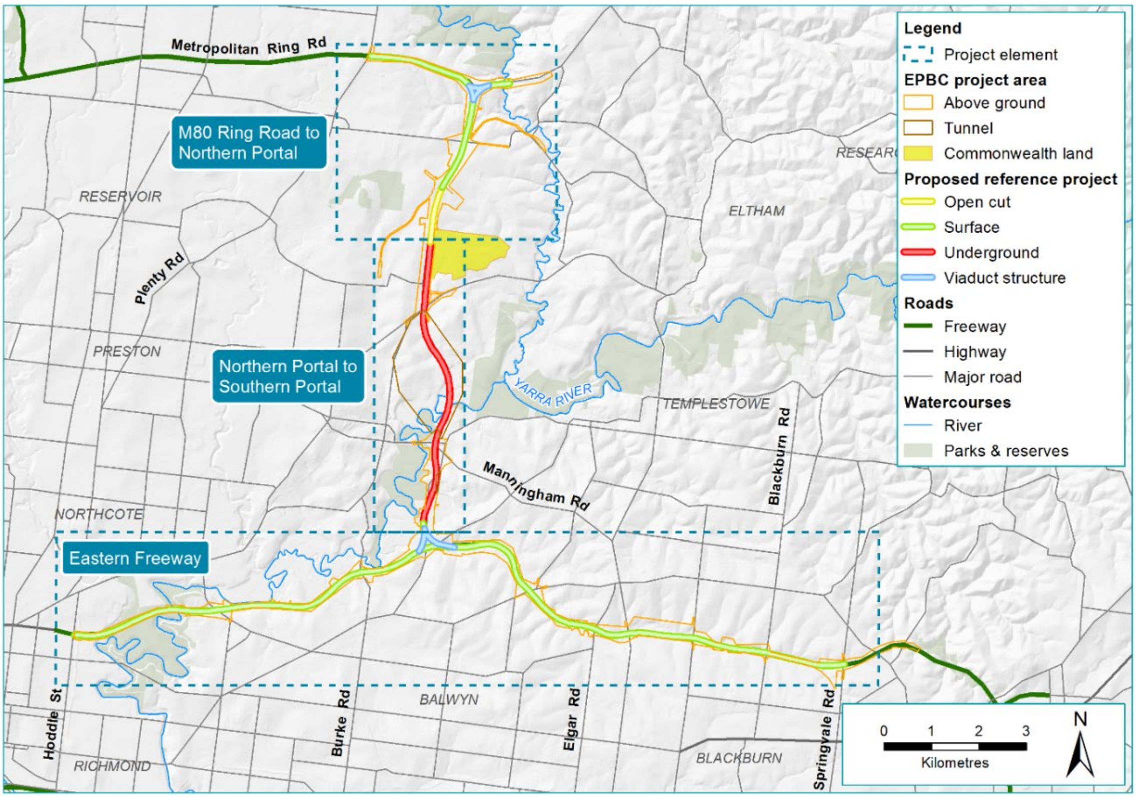


Figure 3-1 Overview of North East Link

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

For a detailed description of the project, refer to PER Chapter 3 – Description of the action.

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
- Tunnel construction using tunnel boring machines (TBM), mining and cut and cover techniques
- Construction of cross passages, ventilation structures and access shafts
- Installation of drainage and water quality treatment facilities
- Installation of a Freeway Management System
- Installation of noise walls
- Restoration of surface areas.

3.3 Operation

Following construction of North East Link, the key operation 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 on Commonwealth land

Commonwealth land that is potentially affected by the action includes:

- Simpson Barracks and the adjoining publicly accessible area immediately south-west of the fence line of the Barracks. This area is used for informal outdoor recreation purposes. All this land is referred to as ‘Simpson Barracks’ throughout this report.
- A strip of land located about one kilometre north of the barracks, to the rear of residential properties on Elder Street. This strip of land is an easement for electricity transmission lines, and is referred to in this report as the 'War Services easement'.

Key activities on Simpson Barracks include:

- Construction of North East Link carriageways in a trench between Yallambie Road to just north of Blamey Road, then as a cut and cover tunnel section between Blamey Road and Lower Plenty Road
- Construction of ramps for the Lower Plenty Road interchange
- Construction of a northern portal tunnel ventilation structure
- Construction compounds and laydown areas during construction.

Key activities on the War Services easement include:

- Construction of surface road components of North East Link, including a local road connection (Greensborough Road), an upgraded shared use path, new noise wall and stormwater drainage bioretention water treatment pond
- Relocation of electricity transmission lines
- Construction laydown areas and temporary car parking during construction.

3.5 Activities and design considerations relevant to groundwater

3.5.1 Interaction with groundwater

Within the three project elements described in Section 3.1, interaction with the groundwater environment would be greatest in the north 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. These areas are the focus of this report.

The construction of the Eastern Freeway has already altered the surface water and groundwater regimes and their dynamics. This is in addition to changes due to the urbanization of the catchment. Works within the Eastern Freeway element are at or above grade, and so there would be no direct interaction with the groundwater environment (that is, no requirement for dewatering during the construction or operation of North East Link).

The construction of retarding basins, wetlands, channelization/piping of waterways is proposed in the reference design within the Eastern Freeway element. These have the potential to create localized changes in surface water – groundwater dynamics, for example:

- Wetlands may spatially shift groundwater dynamics within the existing a narrow floodplain (but overall regional groundwater flow is not likely to change)
- Retarding basins create ponding of water (albeit for short time periods) and opportunities for groundwater recharge. Deeper basins that intersect underlying groundwater may require lining structures (for the basins to operate effectively)

- Significant changes to surface flow regimes are not proposed. Base levels of structures and waterway modification works are not to increase flood risk or changes to flow
- Channelisation/piping of flows may reduce interaction in the short term (where such presently exists), however, it is arguable that the longer term integrity of such structures, eg cracking, would lead to interaction
- The reduction in groundwater recharge from rainfall, as a result of the road widening is negligible to the overall intake area of the regional aquifer.

High risk areas are considered to be those elements of the project that include tunnels, cut and cover and portal structures that directly interact with groundwater. In such areas:

- Large, deep permanent structures are located below the groundwater table
- There is a need for significant long term construction dewatering
- There is a significant risk of long term change to water tables and water quality
- Geotechnical investigation and impact assessment effort has been reasonably proportionate to the level of risk.

Under these circumstances, reference to the Eastern Freeway element is therefore largely omitted from this report.

A design philosophy to minimise disturbance to groundwater was to adopt tanked conditions along the alignment where groundwater control was likely. Based on the project description, these locations of below grade (cut and cover, trench) and tunnelled sections are summarised in Table 3-1 and shown in Figure 3-1.

Table 3-1 Groundwater management along North East Link alignment

Location	Construction type	Construction		Operation	
		Drainage	Management[1]	Drainage	Management
Watsonia railway station to Blamey Road	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 3.5.6. Tanked conditions typically occur towards the end of the construction sequence as final lining systems are emplaced. Before tanked conditions are established, groundwater would need to be managed with 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 it to enable safe and stable working conditions.

A number of the groundwater risks are linked to changes in groundwater level, which occur during construction and longer-term operation of the project. Under these circumstances, design controls and mitigation measures that reduce groundwater level changes can address multiple risks.

3.5.2 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 or diaphragm) wall which could be supported by horizontal waling beams, props or ground anchors. Bored piles, including a capping beam exposed as part of excavations, are shown in Figure 3-2.

Figure 3-2 Bored piles, including a capping beam (as part of excavation)

Once the lateral pile support is in place, a 'roof' can be constructed. Ground beneath the roof or capping is then excavated to the desired elevations. During this period, groundwater can seep through the base of the excavation, but the piled wall generally minimises lateral movement of groundwater into the excavation. Dewatering can occur through sumps in the base of the excavation (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.

This type of system would be used to construct North East Link on, and adjacent to Commonwealth land between Yallambie Road and Lower Plenty Road.

3.5.3 TBM tunnelling description

There are different types of TBMs that can be used 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 3-3, 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.

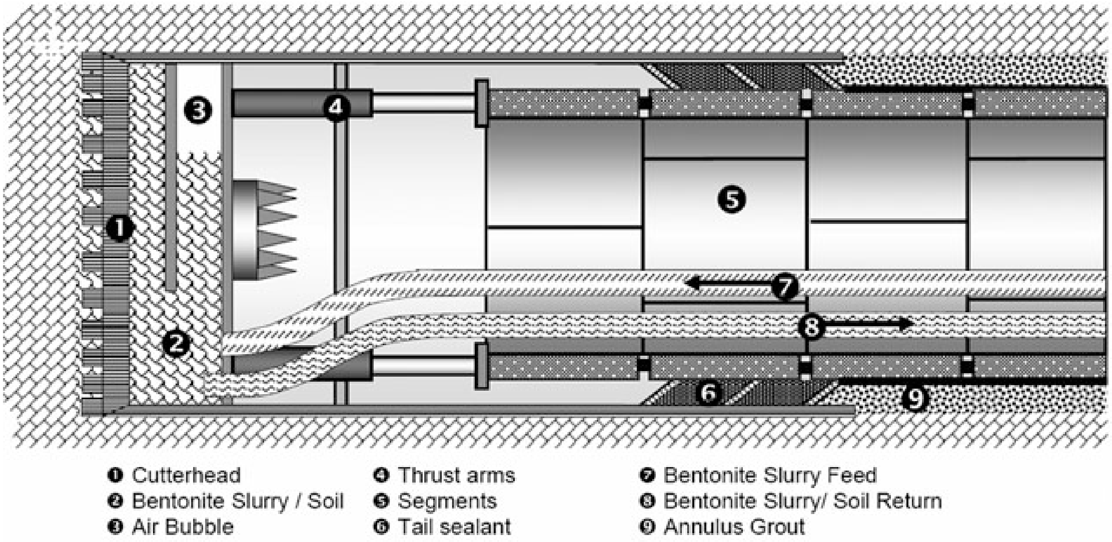


Figure 3-3 TBM slurry machine (section)

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 relocations of larger utilities that would be required for North East Link (such as sewers) would most likely to be constructed using open trenching and 'pipe jacking' methods. In simple terms, a pipe jack operates on a similar principle to a TBM, but at a smaller scale. Tunnelling is progressed using hydraulic rams to jack-off the sections of pipe previously laid.

3.5.4 Mined tunnelling description

A short section (approximately 420 metres) of North East Link would be tunnelled in Bulleen, and so 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, followed by the middle and lower parts.

A road header or continuous miner is used to excavate the geologic materials. An example of a road header is shown in Figure 3-4. Once excavated, temporary ground support is put in place 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 3-4 Road header

Excessive groundwater inflows can be assessed by probing in advance of tunnelling, and inflow controlled using grouting methods (to reduced 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.

3.5.5 Project dewatering risk areas

North East Link would involve construction below the water table, specifically:

- Tunnel (TBM as well as mined through conventional methods):
  - TBM tunnelling is proposed between Banksia Street/Manningham Road and Lower Plenty Road. Mined tunnelling would occur along a short section south of the Banksia Street portal. Other shafts, control rooms and cross passages would be required to support the tunnel ventilation, maintenance and emergency access. These would likely 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 could be limited by the selection of the ground support method. Grouting could 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 proposed cut and cover areas would be traversing sedimentary aquifers, the lateral cut-off of groundwater would also occur. The assessment has adopted diaphragm walls as lateral excavation supports.

3.5.6 Factors influencing water level disturbance

Factors influencing the estimates of drawdown during construction and operation are summarised in Table 3-2. Measures to control changes to the groundwater environment can be incorporated at detailed design, such as the water tightness proposed for structures, or methods of tunnelling to be used.

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 detailed design of North East Link.

Table 3-2 Factors influencing 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 tunnels is a key factor. Tanking (undrained lining conditions) that prevents groundwater ingress would minimise ongoing seepage into an operating tunnel and so 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. This type of 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 for North East Link have been assumed to be constructed as tanked structures. The TBM tunnels would be tanked almost instantaneously as they were constructed, although the mined tunnels would remain drained, with tanking occurring towards the end of construction.

Factor	Comment
Structure water tightness	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 tunnels. 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. The Haack Class 3 assumption is considered reasonable, based on its application to similar infrastructure projects completed or under construction in metropolitan Melbourne. It is further noted that the water tightness may be increased for specific parts of the project, eg cross passages and subterranean caverns, or where there are other engineering requirements such as frost risks. By assuming a Class 3 water tightness, the numerical modelling completed for the North East Link is conservative in the respect that more water tight structures would result in reduced groundwater seepage (and drawdown) during the operation of the project.
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). Slurry as well as 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 tunnels. 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 to stabilise ground conditions tunnel construction. 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 and ground stabilisation methods would reduce rock material permeability and so seepage inflow. Grouting in fractured rock conditions can be difficult to achieve a 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. Grouting is 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 or 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 tunnels, 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	A number of methods can be applied 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 reduce permeability 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 3.5.1.

3.5.7 Methods to manage captured groundwater

Groundwater that flows into excavations or the completed structures under operating conditions needs to be appropriately managed to minimise impacts on the environment.

During the construction of North East Link, groundwater would be captured in the various excavations. The management of this water would depend upon the water quality, and the site water requirements.

- Some of this groundwater may undergo treatment such as settling, and subsequently be reused in the 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 those relating to the State Environment Protection Policy (SEPP) (Waters) and the licensing requirements of Southern Rural Water. Treatment of the water before disposal may also be required to facilitate to the reinjection, such as to prevent mechanical, chemical and biological clogging.
- Captured groundwater could also be discharged to sewer, or to surface waterways. Disposal to sewer would requires wastewater to meet trade waste acceptability guidelines of Yarra Valley Water (or City West Water in the far west of the project boundary). 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 on the reference project, a number of North East Link structures have been designed as being tanked which would limit the volumes of groundwater to be managed. Once North East Link is operating, tanked structures may still be subject to minor seepage inflows, but at magnitudes expected to be significantly less than that during construction. The inflow rates entering a tanked structure would be based on the specified structure tightness (Haack) classification.

Water could also enter the tunnels as stormwater run-off and vehicle run-off. The two water treatment trains (groundwater inflow, and vehicle/storm run-off) are commonly separated within a tunnel to facilitate the treatment process. Disposal to sewer or waterways are potential wastewater management options that could be considered for North East Link.

4. Legislation, policy, guidelines and criteria

4.1 Legislation

Numerous legislative, policy and guidance documents are relevant to this groundwater impact assessment and are discussed further in this report. The key legislation, policy and guidelines that apply to the groundwater impact assessment for North East Link are summarised in Table 4-1.

Victorian legislation and guidance has been considered as part of this assessment and where appropriate has been used to provide criteria for valuing receptors and assessing and evaluating impacts.

Table 4-1 Key legislation and policy

Legislation/policy/ guideline	Relevance to this impact assessment
Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) (EPBC Act)	The EPBC Act is administered by the Australian Government's Department of Environment and Energy. The EPBC Act focuses on the protection of the environment, with emphasis on matters of national environmental significance. The EPBC Act also applies to actions that have a significant impact on the environment where the actions affect, or are taken on Commonwealth land, or are carried out by an Australian Government department or agency As discussed in Section 2.1, North East Link has been determined as a 'controlled action' that requires assessment and approval under the EPBC Act (EPBC 2018/8142).
National Environment Protection Council Act 1994 (Commonwealth)	The National Environment Protection Act Council 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 particular 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 during the construction of North East Link. No approvals for North East Link are required under the NEPM Act.

Legislation/policy/ guideline	Relevance to this impact assessment
Water Act 1989 (Victoria)	In the context of groundwater, the objective of the Water Act is for sustainable, efficient and equitable management and allocation of the resource. The Act also provides a means for the protection and enhancement of all elements of the terrestrial (surface) 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. 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 for North East Link, 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 changes groundwater levels, and these changes influence access to the resource which could interfere with existing groundwater users, reduce flows to waterways, or lower waters beyond the reach of roots. A rise of water levels can also create water logging issues. Water availability is regulated through the Water Act and so an assessment of North East Link's potential impact on existing abstractive users is relevant. For licensed groundwater works (dewatering or aquifer recharge), Section 40 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, effect on existing users and waterways.
Environment Protection Act 1970 (Victoria)	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 of 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 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. Victoria is proposing new environment protection laws, via the *Environment Protection Amendment Act 2018*. This Act is aimed at applying a new approach to 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). The Environment Protection Amendment Act is expected to take effect by mid-2020.

Legislation/policy/ guideline	Relevance to this impact assessment
Yarra River Protection (Willip-gin Birrarung Murron) Act 2017 (Victoria)	Legislation was introduced into the Victorian Parliament in 2017 to protect the Yarra River through the Yarra River Protection (Willip-gin Birrarung Murron) Act. The Act enables the identification of the Yarra River and the many parcels of public land that it flows through as a single living, integrated natural entity for protection and improvement. The Act provides for the preparation of the Yarra Strategic Plan to guide future use and development, and identify areas for protection within the Yarra corridor. Melbourne Water is leading the development of the Yarra Strategic Plan.
Environment Protection Amendment Act 2018 (Victoria)	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.
Climate Change Act 2017 (Victoria)	The Climate Change Act provides Victoria with a legislative foundation to manage climate change risks, maximise the opportunities from decisive action and to drive a transition to a climate resilient community and economy with net zero emissions by 2050.
Environment Effects Act 1978 (Victoria)	The Environment Effects Act provides for the assessment of proposed projects (works) that are capable of having a significant effect on the environment. The responsible Minister decides whether an Environmental 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.

4.2 State and local planning framework

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.

These SPPF clauses are specific to all councils across the state, although the planning schemes of local governments whose boundaries are within the North East Link project boundary may have additional clauses relating to groundwater and sustainable environmental practices.

4.3 Policies guidelines and standards

4.3.1 National guidelines and policies

A number of national guidelines are relevant to groundwater, which are summarised in Table 4-2.

Table 4-2 Summary of national guidelines

Policy/Guideline	Description
Australian Groundwater Modelling Guidelines (National Water Commission, 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 North East Link's potential impacts on groundwater has adopted these guidelines.
Minimum Construction Requirements for Water Bores in Australia (National Uniform Drillers Licensing Committee, 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 provide a consistent standard reference across Australia for the licensing of bores and drillers. Geotechnical investigations undertaken to characterise the groundwater environment of the North East Link project boundary 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 would assure safety at point of use. The guidelines have been development after consideration of the best available scientific evidence. The guidelines (updated in 2018) have been applied to assess groundwater quality in the North East Link project boundary.
Australian and New Zealand Guidelines for fresh and marine water quality, (ANZECC & ARMCANZ, 2018)	The guidelines outline the management framework recommended for applying the 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 applied to assess groundwater quality. It is acknowledged that a process of updating the guidelines is underway.
Guidelines for Managing Risks in Recreational Waters (NHMRC, 2008)	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.
Australian Guidelines for Water Recycling: Managed Aquifer Recharge (NRMMC, EPHC, NHMRC, 2009	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 are applied to aid the assessment and development of aquifer recharge schemes.
National Environmental Management Plan (HEPA PFAS, 2018)	The plan provides guidance to environmental regulators regarding the regulation of Polyfluoroalkyl Substances (PFAS) contaminated sites and materials.

4.3.2 State guidelines and policies

A number of Victorian guidelines are relevant to groundwater, which are summarised in Table 4-3.

Table 4-3 Summary of Victorian guidelines and policies

Policy/Guideline	Description
State Environment Protection Policy (SEPP) (Waters) 2018	The SEPP (Waters) formally commenced on 19 October 2019 and replaces the SEPP (Groundwaters of Victoria) and SEPP (Waters of Victoria). A subordinate instrument of Victoria's *Environment Protection Act 1970,* SEPP (Waters) 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. More information on the beneficial uses of groundwater is provided below this table. The objectives of SEPP (Waters) in respect of environmental quality are to: (a) Achieve the level of environmental quality required to protect the beneficial uses of waters (b) Ensure that pollution to waters from diffuse and point sources is managed in an integrated way to deliver the best outcome for the community as a whole (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). The SEPP (Waters) is relevant where construction activities may effect groundwater quality, or where changes in groundwater level results in the displacement of existing groundwater contamination. The identification of groundwater contamination during the construction of North East Link may trigger environmental investigations. Movement of groundwater contamination plumes to areas previously not polluted is an act of pollution under Victoria's *Environment Protection Act 1970.* Information on acceptable levels of groundwater drawdown is provided beneath this table. ***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.

Policy/Guideline	Description
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 sets a consistent approach for concluding whether a site is suitable for a particular use. In relation to groundwater, the SEPP (Land) sets out good practice to assess, clean-up and manage contaminated groundwater. The SEPP (Land) is relevant where the displacement of existing groundwater contamination by North East Link would result in the generation of vapours that degrade air quality. The SEPP (Land) describes the requirement to prevent the contamination of land, which is important for the protection of groundwater quality. Compliance with the SEPP (Land) is required, which is given effect under Victoria's *Environment Protection Act 1970*.
Ministerial Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems 2015	The Ministerial Guidelines are a supplement to a section of Victoria's *Water Act 1989* where a groundwater Take and Use application is made. The Ministerial Guidelines require applications to undergo a risk assessment and referral process.
Environment Protection (Industrial Waste Resource) Regulations 2009	These regulations (under Victoria's *Environment Protection Act 1970*) categorise industrial wastes (including groundwater) by risk profile so that each is appropriately handled, stored, treated, transported and disposed of. The regulations set a hierarchy of preference for waste management.
Water Industry Regulations 2006	These regulations (under Victoria's Environment Protection Act 1970) set out various trade waste policies and guidelines for Victoria's water authorities.
Groundwater Sampling Guidelines (EPA Victoria, 2000)	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 enable groundwater samples are representative of groundwater in the aquifer and will remain representative until analytical determinations or measurements are made
Guidelines for Hydrogeological Assessments (Water Quality) (EPA Victoria, 2006)	These guidelines describe the basics of groundwater contamination: how a site conceptual model is developed; the process of a hydrogeological assessment; the collection of groundwater data; and what a hydrogeological assessment report should contain.
The clean-up and management of polluted groundwater (EPA Victoria, 2014)	These guidelines provide details of EPA Victoria requirements and expectations for developing and implementing the clean-up and management of polluted groundwater for the protection of human health and the environment.
Construction techniques for sediment pollution control, (EPA Victoria, 1991)	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.
Environmental guidelines for Major Construction Sites (EPA Victoria, 1996)	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.

Policy/Guideline	Description
Publication 1287 2009 – Guidelines for risk assessment of wastewater discharges to waterways (EPA Victoria, 2009).	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.

Beneficial uses of groundwater, SEPP (Waters)

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

Table 4-4 Protected beneficial uses and groundwater segments (SEPP – Waters)

Beneficial use	Segment (mg/L TDS)						
	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:
  - The beneficial use for water dependent ecosystems and species is protected
  - There will be no risk to beneficial uses
  - Preferential flow through fractures or naturally formed cavities is not the dominant mode of permeability.

Groundwater drawdown

Acceptable levels of groundwater drawdown (or mounding) have not been defined by the Australian Government. However, in some cases, guidance on acceptable limits has been proposed in Victoria and these are summarised in Table 4-5.

Table 4-5 Acceptable levels of drawdown

Factor	Comment
Existing groundwater users	There is no formal guideline for the assessment of changes to groundwater levels on abstractive groundwater users. Acceptable interference limits between bores have been generally adopted from the guidelines recommended by the Rural Water Corporation (1993) that relate to assessment of impacts of groundwater take. Acceptable interference limits for existing bores are set out in guidelines 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. In terms of licensed groundwater use (such as irrigation, commercial and industrial uses), groundwater is managed based on the volume of take. Water level triggers have been applied in some Victorian groundwater management areas, but none are relevant to the study area.

<table>
<tr><th>Factor</th><th>Comment</th></tr>
<tr><td>Groundwater dependent ecosystems</td><td>
Acceptable limits of drawdown have been proposed by the DELWP Ministerial Guidelines for Groundwater Licensing and the Protection of High Value Groundwater Dependent Ecosystems (DELWP, 2015) using a risk-based approach relevant to the licensing of groundwater extractions, as follows:
<table>
<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>
</table>
These guidelines are applicable to a licensable quantum of groundwater. While active construction dewatering is a licensable action, drawdowns created by the deflection of groundwater around a structure are not licensable. Under these circumstances the approach of this assessment was to determine predicted drawdown magnitudes and extents and to refer these to PER Technical Appendix A – Flora and fauna to determine the ecological significance of the drawdown.
</td></tr>
<tr><td>Streamflow</td><td>
Acceptable limits of drawdown have been proposed by the DELWP (2015) Ministerial Guidelines using a risk-based approach relevant to the licensing of groundwater extractions, as follows:
<table>
<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="3">Moderate</td><td rowspan="3">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>The minimum recommended environmental flow remains above the Q90 flow rate.</td></tr>
<tr><td rowspan="3">Significant</td><td rowspan="3">Proposed extraction impacts significantly on natural or current streamflow.</td><td>Licence application is greater than 10% of lowest seasonal baseflow.</td></tr>
<tr><td>More than 10% reduction in the Q90 flow rate.</td></tr>
<tr><td>The minimum recommended environmental flow falls below the Q90 flow rate.</td></tr>
</table>
The approach of this assessment was to determine predicted drawdown magnitudes and extents and to refer these to PER Technical Appendix A – Flora and fauna.
</td></tr>
</table>

Factor	Comment
Settlement	Lowering the groundwater level has the potential to result in the 'effective stress' settlement of soft or compressible soil layers within the study area. This settlement could then lead to long-term damage effects to both structures and utilities within the study area. The current geological understanding of the Commonwealth land is that significant soft of compressible soil layers that are at risk of consolidation settlement effects due to groundwater drawdown have not been identified. No assessment of drawdown effects and consolidation settlement have been undertaken in this report.
Contamination migration	No acceptable level defined in this report. The SEPP (Waters) requires there not to be any detriment to beneficial uses (surface and groundwater) beyond the boundaries of a polluted groundwater zone. The approach of this assessment was to assess the risk of pollution being present, and potentially migrating towards a sensitive receptor.
Oxidation of acid sulfate soil materials	No acceptable level defined in this report. The SEPP (Waters) requires there not to be any detriment to beneficial uses (surface and groundwater) beyond the boundaries of a polluted groundwater zone. The approach of this assessment was to assess the risk of acid sulfate soil being present, oxidised and potentially migrating towards a sensitive receptor.

4.3.3 Australian standards

Australian standards that apply to groundwater are summarised in Table 4-6.

Table 4-6 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

4.3.4 Responsible authority

Groundwater licensing

A licence to take and use groundwater may be issued by the Minister under Section 51 of Victoria's *Water Act 1989*. Approvals under the Water Act, such as for bore construction, groundwater extraction (dewatering) or artificial groundwater recharge may also be required for North East Link from the relevant water corporation, which is Southern Rural Water in this part of the State.

Sewer discharge

As part of managing groundwater during the construction of North East Link, there may be a need for discharge to Melbourne's sewer networks. The study area (including Commonwealth land) mostly 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 would be responsible for the granting or licensing of trade waste agreements associated with sewer disposal for the project. 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 North East Link 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 (2009), via a risk-based approach. Approvals from Melbourne Water and the relevant local government and drainage authority would be required.

5. Assessment method

This section describes how relevant impacts of North East Link on Matters of National Environmental Significance (MNES) and the environment on Commonwealth land have been assessed. This section responds to Section 2.5 of the PER Guidelines.

5.1 Overview of method

Four technical reports were prepared to inform the PER and the assessment of impacts. This groundwater technical report is one of those four reports. Impacts and their significance were assessed taking into account relevant EPBC Act Significant Impact Guidelines. Figure 5-1 provides an overview of the assessment process.

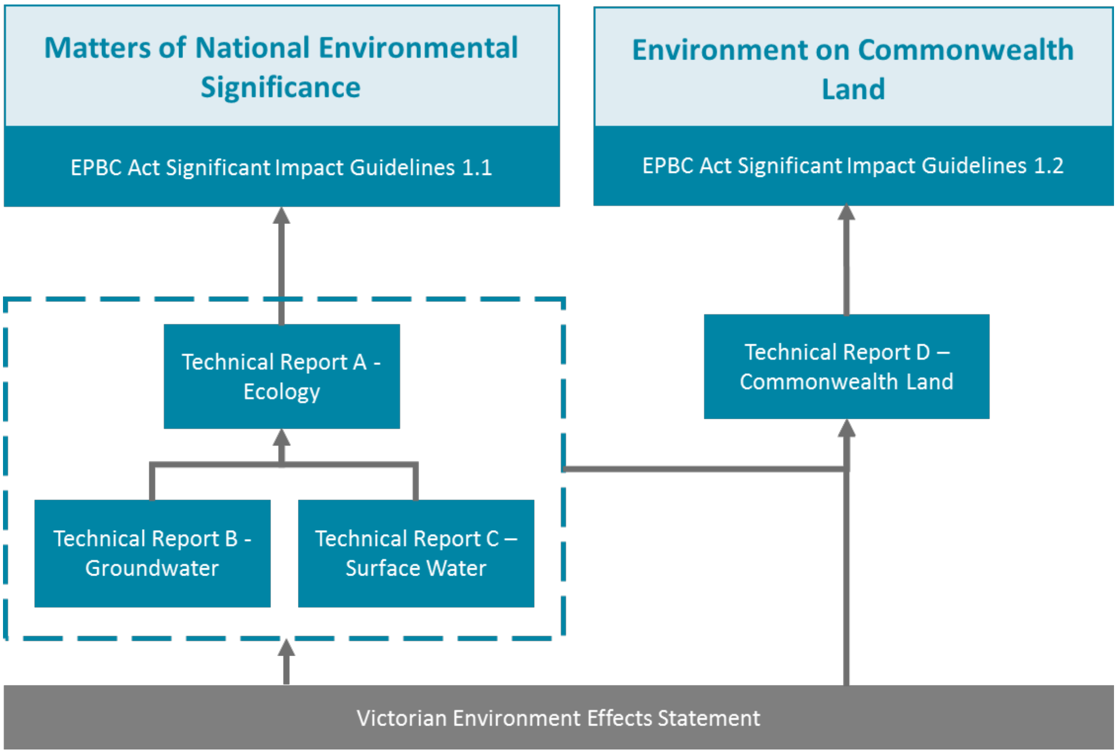


Figure 5-1 Assessment approach

In assessing groundwater impacts in this technical report, the following steps were followed:

- The existing groundwater environment that would influence impacts on MNES and Commonwealth land was described
- Groundwater impacts, either direct or indirect, resulting from construction and operation of North East Link that could directly or indirectly impact on MNES and Commonwealth land were identified
- Measures to avoid or mitigate groundwater impacts were considered
- The significance of residual groundwater impacts was assessed.

The impact assessment process has informed and been informed by community and stakeholder engagement (refer Chapter 14 – Consultation) and development of the reference project (refer Chapter 3 – Description of the action). Figure 5-2 shows this process.

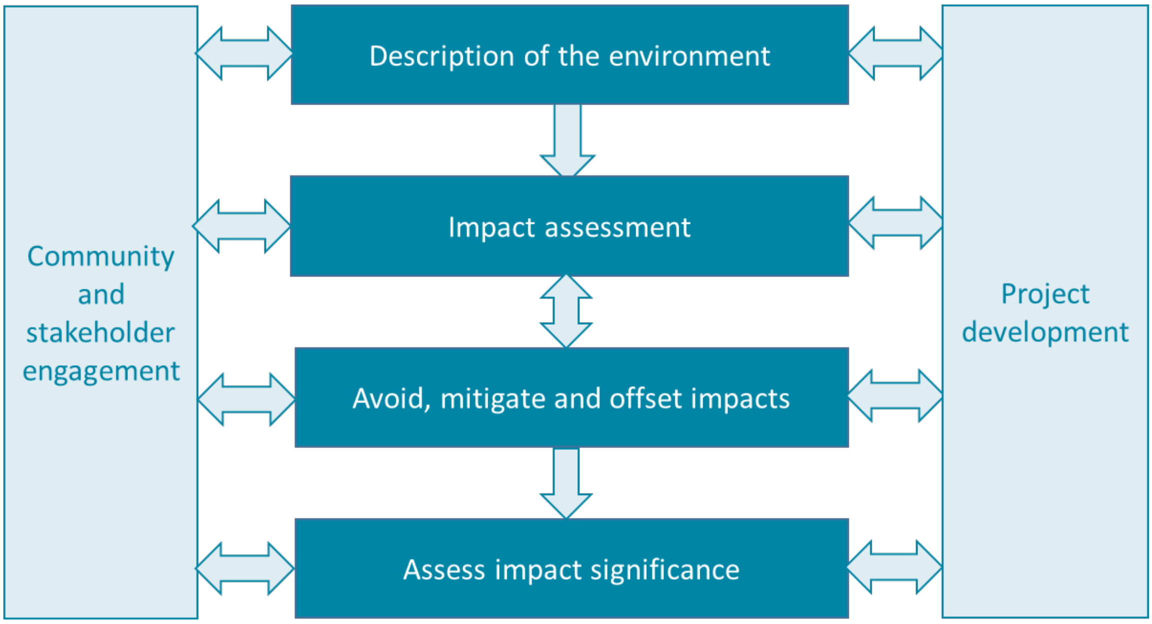


Figure 5-2 Impact assessment process

5.2 Study scope

5.2.1 Reference project

The action described in this report is based on a 'reference project' developed by the North East Link Project (NELP). This represents one feasible means by which the action could be developed within the EPBC boundary (as defined in Section 5.2.2) to achieve the objectives of North East Link and environmental outcomes set by the Environmental Performance Requirements (EPRs). The design of North East Link would be further refined and developed by the contractor appointed to construct it. However, any modifications to the reference project would need to be consistent with the objectives of North East Link, would need to meet the EPRs as finalised by the Victorian Minister for Planning, and must fall within the EPBC boundary for the action.

5.2.2 Study area

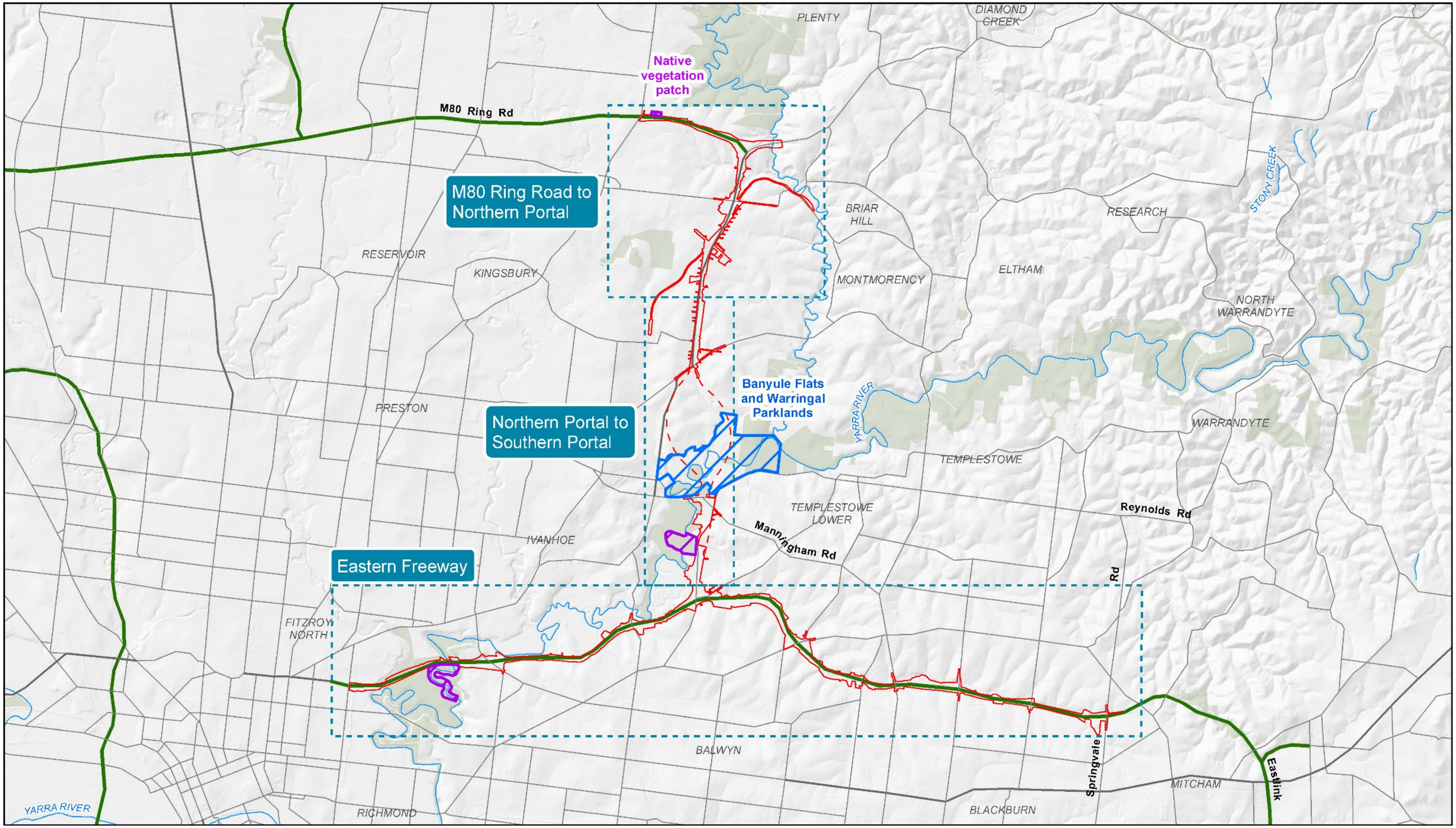
This report has assessed the impacts within the study area shown in Figure 5-3 and described below.

Study area

Groundwater processes occur over a range of scales, including local and regional flow regimes, which means it is necessary to extend the study area beyond the project boundary to capture these broader-scale processes.

The term 'study area' in this report refers to a broader region surrounding the alignment of North East Link, including permanent structures and temporary construction areas (above and below ground). The study area for this assessment includes all land within an approximate two kilometres of the project boundary, including the Yarra River catchment. This study area covers a much broader area than the expected zone of impact (within the project boundary), and the additional information captured has been used to provide context for regional ground water flow processes and associated impacts on MNES and Commonwealth land.

This broader study area was mostly assessed at a desktop level.



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
Public Environment Report

Groundwater study area

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

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

The potential for groundwater impacts within the study area shown in Figure 5-3 have been considered with respect to their potential to directly, or indirectly, impact the Commonwealth land environment or MNES. Where there is potential for these groundwater impacts to impact the Commonwealth land environment or MNES, they have been included in the assessment documented in this report.

EPBC boundary

The EPBC boundary is the area within which the action would take place, based on conservative assumptions made at the time of the referral variation (see ‘Request to accept a Variation of a proposal (EPBC 2018/8142) pursuant to Section 156A of the EPBC Act’ dated 30 May 2018 (NELA 2018)).

Project boundary

Contained within the EPBC boundary, the project boundary defines the maximum extent of the construction impacts of the reference project.

Groundwater resources within the project boundary were assessed at desktop level, supplemented with field investigations as described in Section 5.3.

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

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

- The Plains Grassy Woodland community between Enterprise Drive and the M80 Ring Road in Bundoora
- Bolin Bolin Billabong
- The Grey-headed Flying-fox campsite within Yarra Bend Park.

Twin tunnels have been proposed beneath the Banyule Flats, Warringal Parklands and the Yarra River and its associated flood plain, 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 would not be permitted, with the possible exemption 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 throughout this assessment.

Commonwealth land

Commonwealth land that is potentially affected by the action includes:

- Simpson Barracks and an adjoining publicly accessible area immediately south-west of the fence line of the Barracks. This area is used for informal outdoor recreation purposes. Throughout this report, all this land is referred to as ‘Simpson Barracks’
- A strip of land located about one kilometre north of Simpson Barracks, to the rear of residential properties on Elder Street. This strip of land is an easement for electricity transmission lines, and is referred to in this report as the 'War Services easement'.

5.2.3 Technical scope

The scope of this report examines the impacts on water resources (including those on which MNES are dependent and those that affect Commonwealth land) based on the assessment of the following key issues:

- Potential for the action to affect groundwater, including with respect to flooding and future climate change scenarios
- Potential for contaminated groundwater to be discharged into surface waters or groundwater environments
- Potential for migration or disturbance of anthropogenic contaminated soil or groundwater or naturally occurring acid forming materials.

To examine these issues the environment is characterised based on the following priorities:

- Document the key assumptions to be adopted in the surface and groundwater hydrological analysis with respect to future climate change scenarios – this was a consideration in any predictive numerical groundwater modelling undertaken
- 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 – this task had linkages with the water management specialists.

This impact assessment presents the results of a modelled assessment (see Section 7) of the residual impacts changes to groundwater levels including:

- Assessing 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 (Waters) standards
- Assessing 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 (Waters) standards and beneficial uses
- Assessing residual effects on surface and groundwater users or environmental values from changes in hydrology, contaminated soil, acid forming materials or contaminated groundwater
- Undertaking sensitivity analysis, if required
- Describing the design and mitigation measures to protect groundwater and aquifers.

The assessment provides the information on the changes to groundwater that could affect ecological receptors based in groundwater dependent ecosystems (GDEs) which could include EPBC Matters of National Environmental Significance. The description and evaluation of these impacts is described in PER Technical Appendix A – Flora and fauna.

5.3 Description of the environment

In describing the existing environment, the environmental assets, values and uses that may be affected by North East Link were characterised. This focused on the potential presence of or habitat for MNES, water resources that may support MNES and the environment on Commonwealth land.

This has considered:

- History, current use and condition of environmental assets, values and uses
- Significance of environmental assets, values and uses
- Sensitivity or vulnerability to impacts.

The existing environment of the study area was determined through a series of desktop and geotechnical investigations.

5.3.1 Desktop hydrogeological investigation

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

- Regional datasets including:
  - DELWP Water Measurement Information System
  - Victorian Department of Jobs, Precincts and Regions boring data (GeoVic Version 3)
  - Geological mapping (Victorian geological survey)
  - Hydrogeological mapping (DELWP)
  - Bureau of Meteorology (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 during the compilation of the PER. The program is ongoing and would continue with the detailed design of North East Link. The field data collected during these investigations provided site-specific hydrogeological investigation to enable improved characterisation of the existing conditions compared with that determined from the desktop literature review.

The geotechnical program comprised multiple investigation phases, and has been 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 have undergone packer testing
- 33 monitoring bores have been sampled.

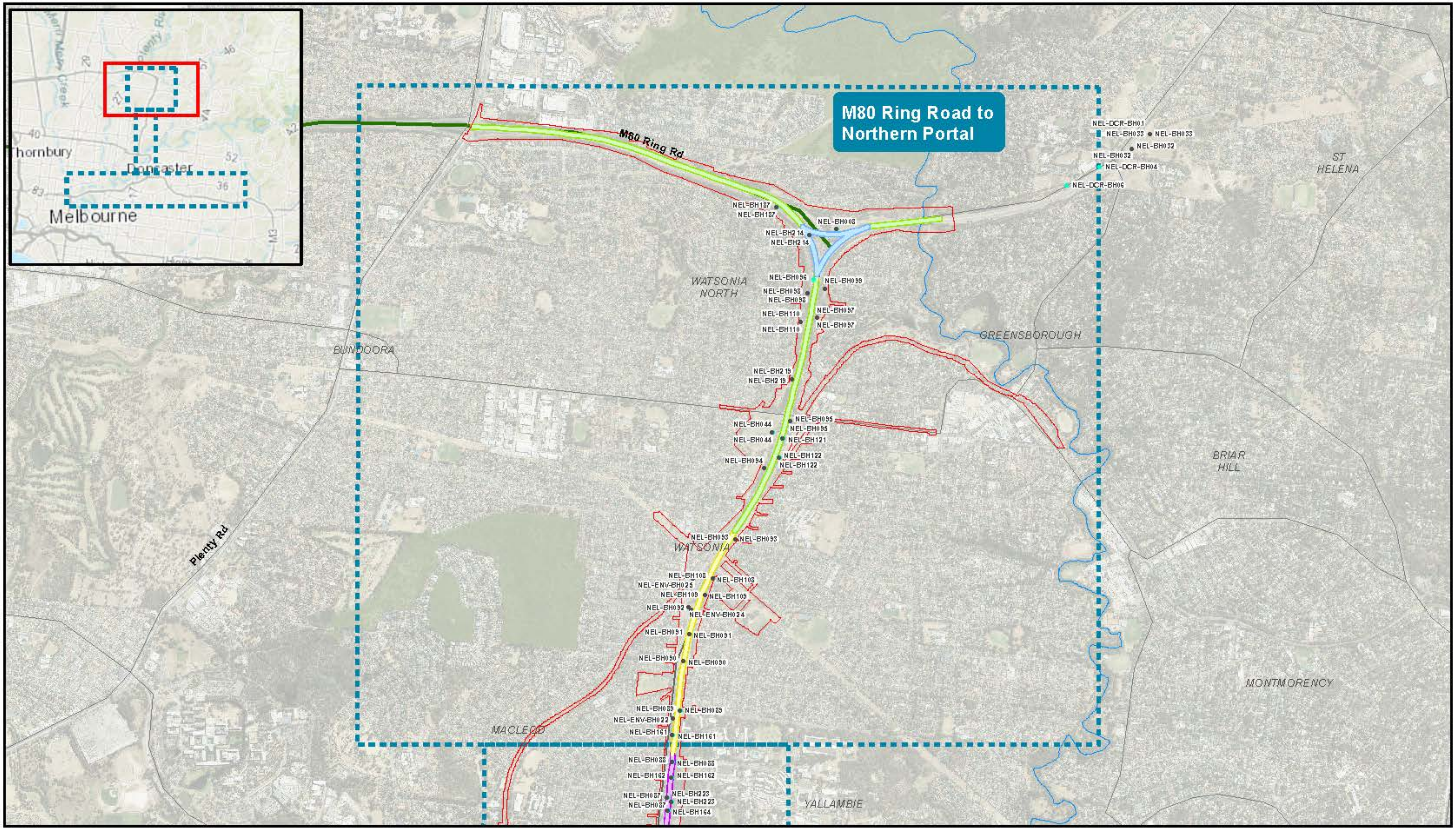
Since the publication of the draft PER, additional work was undertaken and as at the date of the finalisation of the PER, the following works had been completed:

- 141 constructed groundwater monitoring bores
- 10 targeted contamination monitoring bores
- 7 targeted pumping test bores
- 44 slug tests
- 89 monitoring bores have been sampled.

The location of North East Link groundwater monitoring bores is shown in Figure 5-4.

The geotechnical investigations undertaken on Commonwealth land have targeted the far western portion of Simpson Barracks, and are generally within 100 metres of Greensborough Road. Geotechnical boreholes were placed at approximate 100-metre intervals along the reference project alignment, although greater bore densities are present in areas identified as having elevated geotechnical risk.

As part of the finalisation of the PER, Section 6 has been updated, as appropriate, to reflect the results of the further groundwater investigations.



Paper Size A4

0 0.25 0.5 1

Kilometres

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

N

Legend

- NEL_Bore_Database_initial
- NEL_Bore_Database_further
- Project Elements
- 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
- River
- Parks & reserves

North East Link Project
Environment Effects Statement (EES)

NORTH EAST LINK PROJECT

Job Number 31-35006
Revision F
Date 23 Aug 2019

Groundwater monitoring network

Figure 5-4

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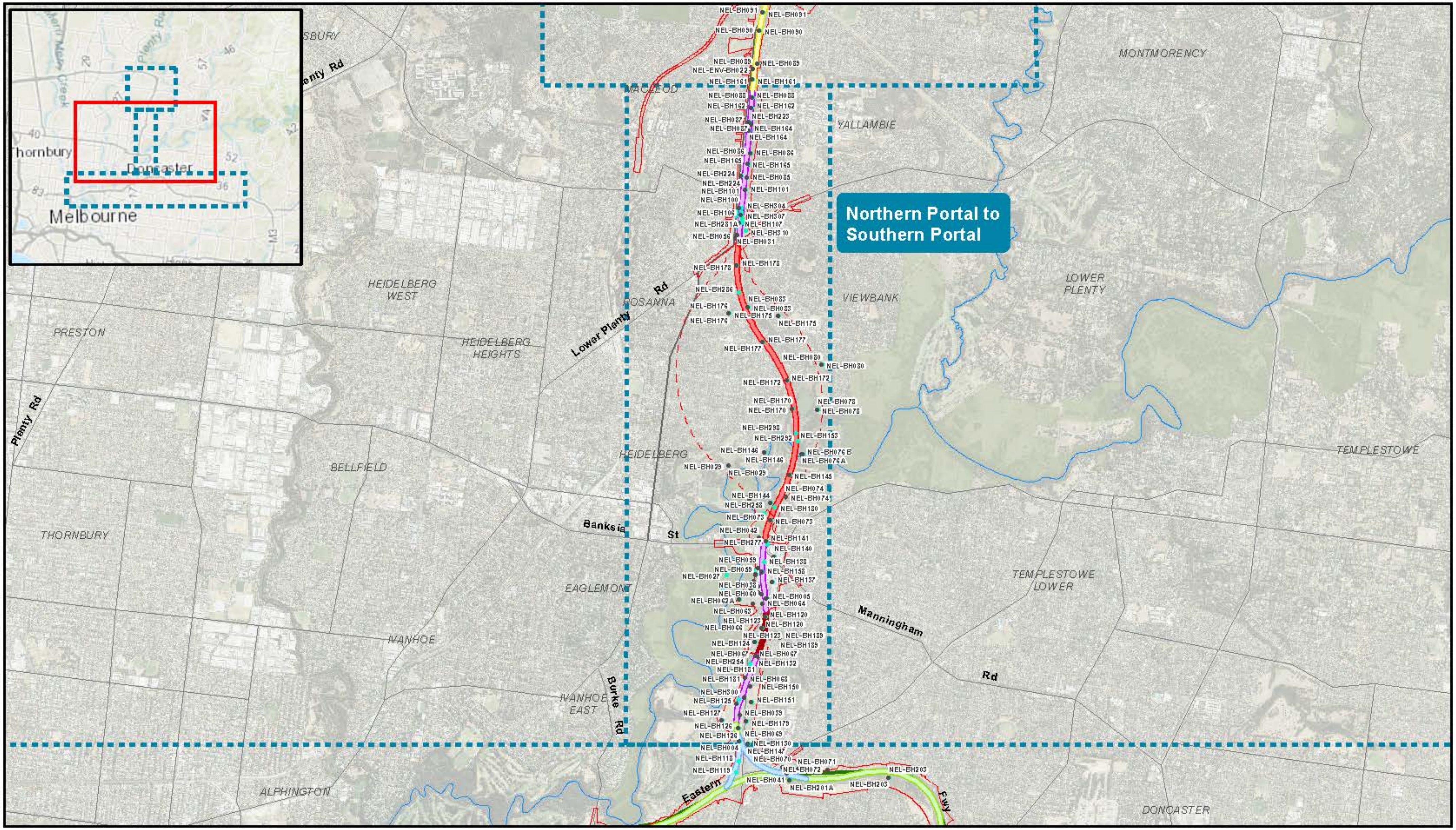
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community.



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Kilometres

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

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Legend

- NEL_Bore_Database_initial
- NEL_Bore_Database_further
- Project Elements
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

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North East Link Project
Environment Effects Statement (EES)

Job Number | 31-35006
Revision | F
Date | 23 Aug 2019

Groundwater monitoring network

Figure 5-4

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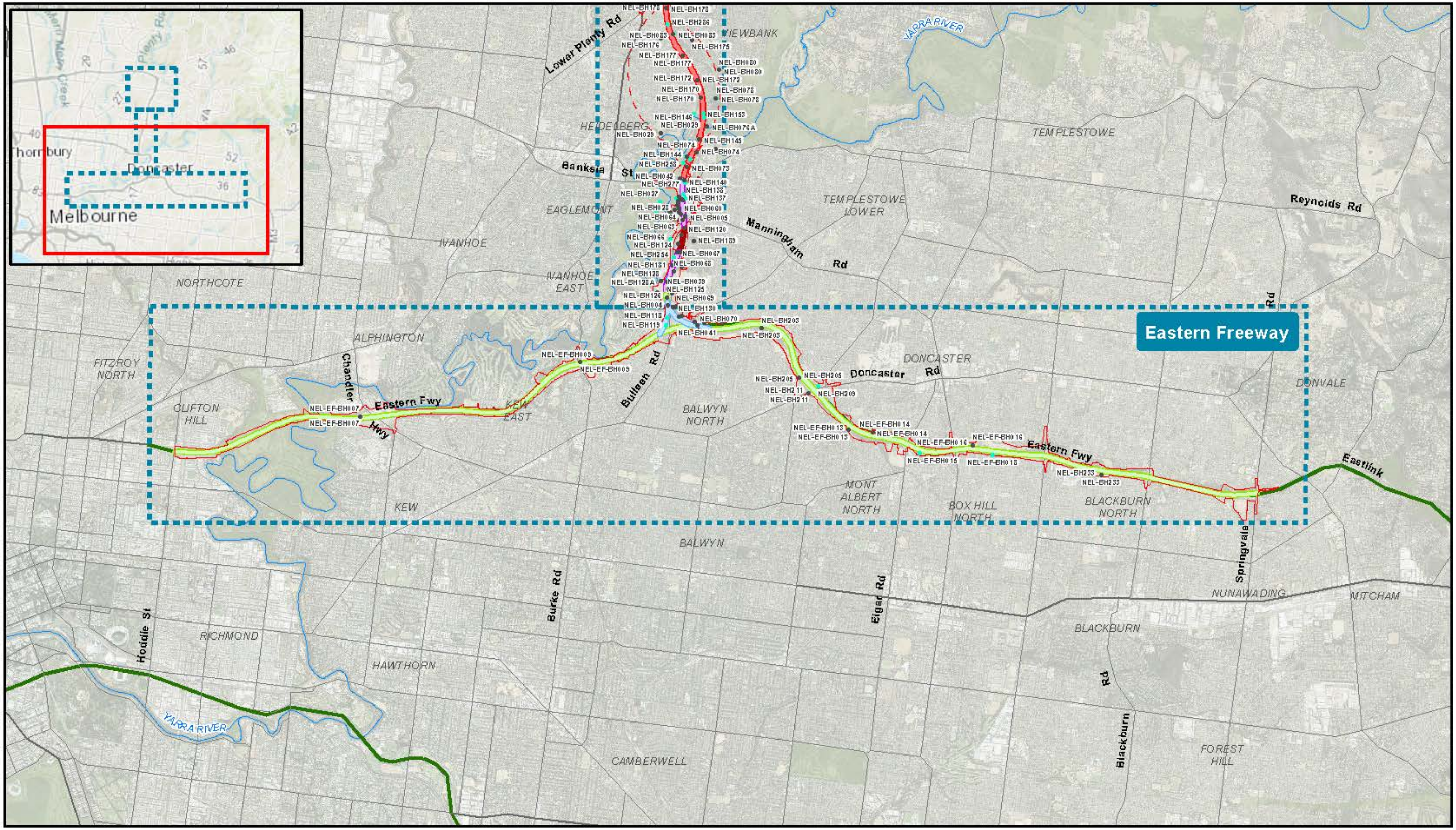
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com



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Kilometres

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

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Legend

- NEL_Bore_Database_initial
- NEL_Bore_Database_further
- Project Elements
- Project boundary - sub-surface
- Project boundary - surface

Proposed reference project

- Elevated ramp
- Surface works
- Open Cut
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- Parks & reserves

North East Link Project
Environment Effects Statement (EES)

Job Number	31-35006
Revision	F
Date	23 Aug 2019

NORTH EAST LINK PROJECT

Groundwater monitoring network

Figure 5-4

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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

5.4 Impact assessment

5.4.1 Impact assessment approach

Impact assessment

The change that would result from the implementation of North East Link is called an impact. Impacts can be positive or negative. Impacts can be a direct result of an action, or can occur indirectly. An example of an indirect impact is any impacts on habitat for MNES resulting from a change in groundwater conditions. The nature and extent of any impact is measured against the current environmental conditions, considering the differences between the 'with project' and 'no project' scenarios.

The following factors were considered when assessing potential impacts:

- Severity including the intensity, duration, timing and frequency, and scale or geographic extent of impacts
- The relationship between different impacts on the environment
- The likely effectiveness of measures to avoid and mitigate adverse impacts
- The likelihood that any given environmental impact would occur
- Whether any impacts are likely to be unknown, unpredictable or irreversible
- Benchmarks and requirements set by statutory requirements, policies and guidelines
- Community expectations
- The principles of ecologically sustainable development, and objectives and requirements of the EPBC Act.

Avoid, mitigate and offset impacts

Measures to avoid and mitigate impacts were developed in response to the impact assessment to reduce groundwater impacts and consequent impacts on MNES and the environment on Commonwealth land.

These have included refinements to the reference project design and specification of measures to avoid and mitigate environmental impacts during construction and operation of North East Link. The reference project is described in PER Chapter 3 – Description of the action.

Section 9 of this report describes the proposed groundwater avoidance and mitigation measures. PER Chapter 10 – Proposed avoidance and mitigation measures provides a consolidated list of avoidance and mitigation measures and the framework for implementing these.

Where impacts could not be reduced through avoidance and mitigation measures, environmental offsets have been proposed in accordance with the EPBC Act Environmental Offsets Policy (DSEWPAC, 2012). These are described in PER Chapter 11 – Offsets.

Assess impact significance

The significance of relevant impacts took into account the current environmental context and the likely effectiveness of measures to avoid, mitigate and offset potential impacts. Having regard to the assessment in this report, the significance of relevant impacts was also assessed against the EPBC Act Significant Impact Guidelines for each of MNES and the environment on Commonwealth land in PER Technical Appendix A – Flora and fauna and PER Technical Appendix D – Commonwealth land.

5.4.2 Impact identification

Hydrogeological conceptualisation

A conceptual understanding of the hydrogeology of the study area, the interactions with North East Link, 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, and groundwater quality).

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).

Understand the impact pathways

Pathways associated with impacts are linked to changes in groundwater flow or groundwater quality. For example:

- Changes in groundwater level (reduction in water level or ‘drawdown’) may reduce 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 can reduce 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 which can lead to mixing of groundwaters.

5.4.3 Construction assessment method

Disturbance to groundwater levels is expected to be greatest during construction when dewatering is generally at its greatest. For example, as tanked structures become sealed by placing 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. This is considered a reasonable approach as numerical groundwater models were also applied to assess drawdowns with other infrastructure projects such as CityLink, Metro Tunnel and the West Gate Tunnel Project. The development of the numerical model, construction, calibration, sensitivity analysis, uncertainty analysis, stress testing and climate change assessments are documented in Appendix A of this report.

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 A). Respectful of the limitations of numerical groundwater models, and noting that any proposed changes during detailed design of North East Link or alternative design proposals can have implications to the predicted groundwater impact, the predictive output nonetheless provides a tool to analyse impacts and determine mitigation measures.

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 PER Chapter 3 – Description of the action
- Consultation with mining and structural engineers
- Comparisons with constructability information.

It is acknowledged the construction of North East Link 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.

Since the numerical groundwater modelling was undertaken for the preparation of the draft PER, additional numerical groundwater modelling has been undertaken. The purpose of the further modelling was to incorporate additional groundwater data collected over a period of approximately 12 months to enable transient calibration to seasonal variations in groundwater levels and to assess whether or not the additional calibration efforts result in changes to the assessment of project-induced groundwater impacts. The further groundwater modelling is detailed in the *Report on Additional Groundwater Modelling, July 2019* which is attached as Appendix B.

5.4.4 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 northern portal to southern portal element). The final water tightness/drainage conditions of these structures is described in Table 3-2.

Climate change

As part of the assessment, and consistent with the PER Guidelines (refer Section 2), consideration of the effects of long-term climate change were included in the analysis. This approach is documented in Appendix A of this report.

Short-term climate extremes may occur during construction (such as drought) but the effects of climate change are generally relevant to the long-term operation of North East Link.

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 as a result of reduced aquifer through-flow – changes in water levels can effect flows to waterways, groundwater dependent ecosystems, or subsidence
- Differential loading upon the structure can occur.

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 tunnels and other long structures of North East Link located below the water table. The analysis was also informed by:

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

5.5 Rationale behind assessment method

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

- The approach is consistent with similar sized infrastructure projects completed in Victoria in recent times, 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).

5.6 Assumptions

The groundwater impact assessment made a number of assumptions which are summarised in Table 5-1.

Table 5-1 Groundwater impact assessment assumptions

Assumption	Relevance
Description of the action	The project infrastructure design and specification has been based upon a reference project documented in PER Chapter 3 – Description of the action. Where sufficient detail is not provided in Chapter 3, a number of assumptions have been made to support technical analysis and these are documented in this technical report.
Geotechnical field data	Field and laboratory data used in the impact assessment is based upon that collected up to 31 November 2018. Additional data collected after this date, was not included in this assessment. However, further groundwater modelling was completed to reflect this additional data. 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 for the groundwater impact assessment are constrained by the particular site conditions, such as the location of buildings, services and vegetation and access restrictions. 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. The geotechnical investigation program has multiple objectives, with the focus 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 and quality) remote from the key areas of interest (the tunnels) is limited. Furthermore, the sensitivity of some receptors (GDEs, contaminated groundwater plumes) and detailed assessment of them over larger area is not feasible. 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.

Assumption	Relevance
Groundwater monitoring	Some monitoring bores have been gauged at an approximate monthly frequency and have upwards of 12 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 metropolitan Melbourne. Only selected monitoring bores have been sampled and laboratory analysed. Few monitoring bores have been subjected to more the one groundwater monitoring (sampling) event. Groundwater monitoring bores have generally targeted a specific issue, such as the zone of tunnelling (that is, screened over the potential depth of the tunnels or 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. However, it is noted that nested monitoring bores have been installed where multiple aquifers have been obviously identified. • The vertical alignment of the tunnels evolved during the course of the reference project development and geotechnical investigations. As a result, the screen zone of some monitoring bores may be different to level of the tunnels. This is a noted data gap which is being addressed through further baseline condition monitoring before the construction of North East is proposed to start.
Numerical modelling	Numerical modelling has limitations and may produce a non-unique prediction which is discussed further in Appendix A of this report. While sensitivity analysis has been undertaken, ultimately the veracity of the numerical model predictions can be assessed through a monitoring program. This limitation is addressed by ongoing groundwater model development which is iterative with the design development and with emerging data from field investigations and ongoing monitoring. This is discussed further in Section 9. A minimum water level contour of 0.1 m has been used to inform the groundwater impact assessment. It should be noted that changes of less than 0.5 m are generally considered beyond the threshold of accuracy expected of a regional model of this kind.

Assumption	Relevance
Cumulative impact assessment	***Project scale*** A construction timeline is documented in PER Chapter 3 – Description of the action. 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. ***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 may interact with groundwater include the Metro Tunnel, the West Gate Tunnel Project 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 North East Link structures would need to consider the groundwater quality and its potential aggressive nature to materials. The durability of materials under these conditions has been assessed as part of the engineering design 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 is documented in this technical report. Any resultant implications to the built environment (such as buildings, roads and utilities) on Commonwealth land is documented in PER Technical Appendix D – Commonwealth land.
Groundwater impacts to dependent ecosystems	Changes in groundwater level can adversely affect the availability and supply of water to GDEs. Analysis of the predicted extent of groundwater drawdowns is documented in this technical report. The resultant implications for GDEs are documented and assessed in PER Technical Appendix A – Flora and fauna.
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 on Commonwealth land are documented and assessed in PER Technical Appendix D – Commonwealth land.

5.7 Stakeholder engagement

Stakeholders and the community were consulted to support the preparation of the North East Link EES and PER and to inform the development of the action and an understanding of potential impacts. Table 5-2 lists specific engagement activities that have occurred in relation to groundwater with more general engagement activities occurring at all stages of the action. For further detail relating to submissions received on the draft PER and associated responses, refer to PER Attachment VIII – Submissions report.

Table 5-2 Stakeholder engagement undertaken for groundwater

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 and other waterways within the project boundary.
Presentation to Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation (WWCHAC)	September 2018	Information session and briefing provided to WWCHAC primarily focused on Bolin Bolin Billabong	Opportunity for WWCHAC to engage with technical specialists regarding the works undertaken, and be informed of further studies in progress.
Presentation to WWCHAC	November 2018	Information session and briefing provided to WWCHAC, primarily focusing on Bolin Bolin Billabong.	Opportunity for WWCHAC to engage with technical specialists regarding the works undertaken, and be informed of outcomes of assessments to date.
Department of Defence (DoD)	December 2018	Request for information regarding bores identified on Commonwealth land.	Statement from DoD: 'These are testing holes to check for underground seepage from the nearby diesel fuel tank used to power a building generator. Most recent report from Golder (2013) recommended annual testing by maintenance contractor – will seek data noting that no seepage was evident in Golder assessments'. No further data received from DoD.
	May 2019	Impacts of drawdown on Commonwealth land	Opportunity for DoD to ask questions over extent of impact and potential impacts to Commonwealth land vegetation.

6. Description of the environment

This section describes the groundwater environment as relevant to MNES and the environment on Commonwealth land.

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 (mudstones and sandstones), which have been 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 (Cainozoic) marine sediments and periods of lava and pyroclastic flows. A summary of the hydrostratigraphy in the study area is provided in Table 6-1.

Table 6-1 Regional hydrostratigraphy

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 North East Link.
Tertiary	Pliocene			
		Brighton Group (Tpb)/Red Bluff Sands (equivalents)	Fine to coarse sands, gravels and clays. Marginal marine to fluvial deposition.	Porous media aquifer.
	Miocene			
	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. Principal aquifer underlying Commonwealth land.
Silurian	Middle	Melbourne Formation (Sxm)		
		Anderson Creek Formation (Sxa)		

6.1.1 Geological history

The oldest rocks forming the bedrock within the study area consist of the Silurian to Lower Devonian age meta-sediments which have been differentiated as the Anderson Creek (Sxa)[1] Formation, Melbourne Formation (Sxm) and Humevale Siltstone (Dxh). These rhythmically interbedded marine turbidite sediments are generally represented by mudstone, siltstone and sandstone and minor conglomerate.

During the 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 granite 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 lead to the creation of a majority 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.

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. 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).

6.1.2 Surface geology

A surface geological map of the study area is provided in Figure 6-1. A description of the key formations which occur within each element of the study area is summarised below.

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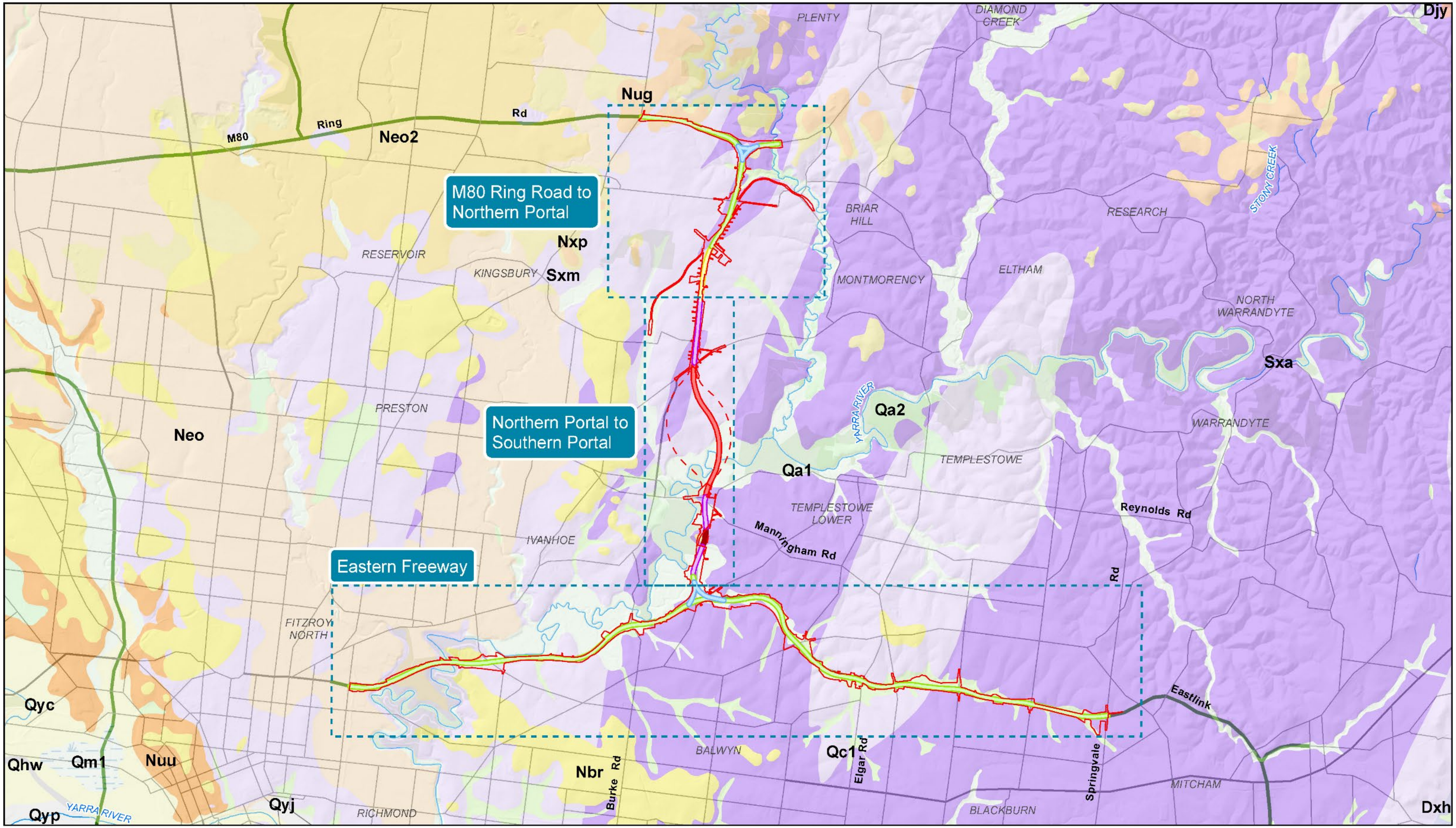
[1] Formation acronyms have been used on the geological map (Figure 6-1).



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

- Major road
- Freeway
- Highway

Watercourses

- River
- Parks & reserves

NORTH EAST LINK PROJECT

North East Link Project
Public Environment Report

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

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

M80 Ring Road to northern portal

In the western section of this 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.

Commonwealth land at Simpson Barracks

This land is principally situated upon Palaeozoic basement (indurated Silurian sediments). Drilling completed as part of the North East Link geotechnical investigation program indicates these rocks have a thin cover of residual soils, and can be extensively weathered.

It is noted there are small outcrops of Quaternary age alluvial sediments associated with Banyule Creek in the south-west part, and in the far-eastern part with the Watsonia Drain. The latter is approximately 1.5 kilometres from the North East Link project boundary.

Northern portal to southern portal

The surface geology of this 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/Manningham Road, the Palaeozoic bedrock outcrops. The bedrock rock is buried beneath Quaternary age alluvial sediments within the floodplain of the Yarra River, where the topography is flatter. South of Banksia Street/Manningham Road to the Eastern Freeway, the North East Link alignment is 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 element, near the intersection of the Eastern Freeway and North East Link, the alluvial sediments are of broader extent where the Koonung Creek floodplain joins the Yarra River floodplain.

Eastern Freeway

The geology along this element comprises mostly shallow Quaternary age alluvial sediments, as the Eastern 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 element. At the western end of the element (Yarra Bend Park and further west), the Eastern Freeway is located upon Newer Volcanic basalts. A small outcrop of Brighton Group sediments is mapped on the western side of Chandler Highway.

6.2 Geological long section

An interpreted geological long section has been developed as part of the geotechnical reporting and is reproduced as Figure 6-2. The vertical alignment of the 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 are to 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 North East Link would also be located within the bedrock. The approximate location of Commonwealth land is indicated on the section in Figure 6-2.

Proceeding from the north, as North East Link would begin to dive below grade from Watsonia railway station within a trench structure from here to Blamey Road. Within this section, North East Link 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 and then at Lower Plenty Road the construction method would shift to TBM tunnelling. TBM tunnelling would continue through the bedrock as it passed beneath the Yarra River floodplain, which starts south of Buckingham Drive (near Banyule Creek).

The southern portal 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. TBM construction crosses would therefore be oblique to the floodplain, although constructions in the portal and further south would occur on the margin and/or parallel to the floodplain. This is potentially fault controlled (refer 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 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.

A series of lineaments have been 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.

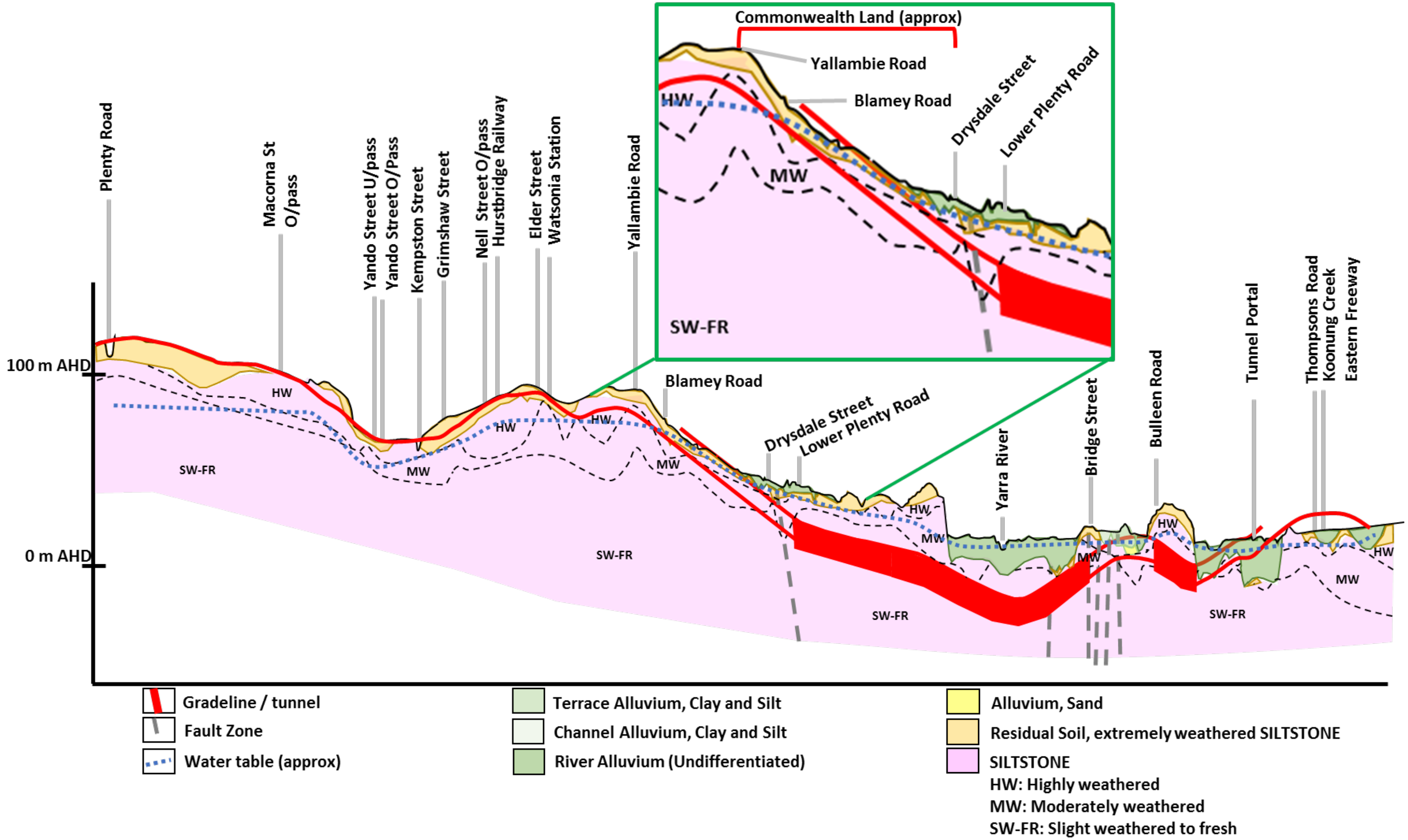


Figure 6-2 Geological long section

6.3 Topography and drainage

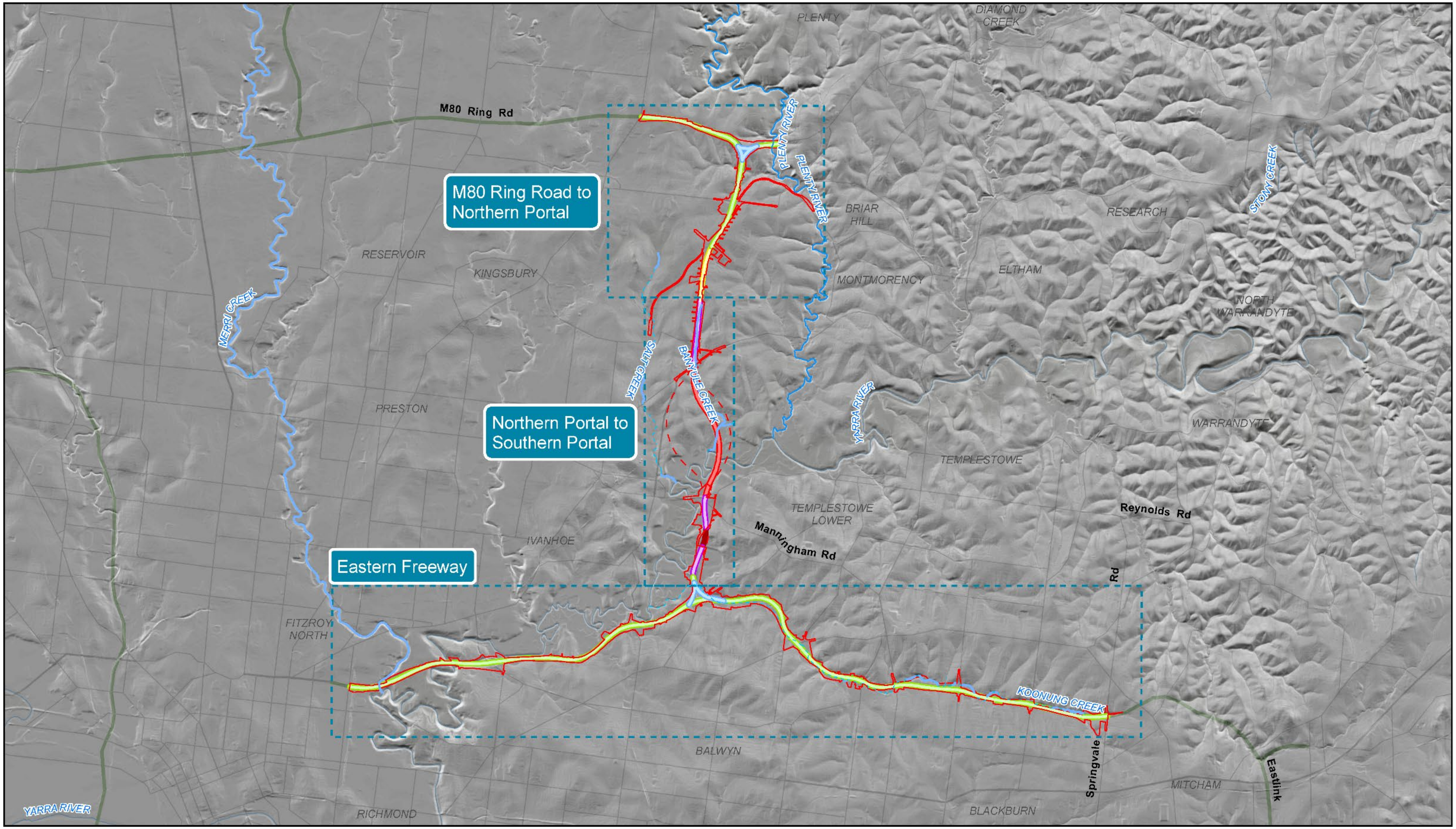
The study area topography, influenced by the Palaeozoic bedrock, forms undulating, rolling hills, which have been dissected by the Yarra River and its floodplain. The topography is highest around the M80 Ring Road to northern portal element, extending to over 100 metres above sea level (refer Figure 6-2).

On the Commonwealth land, the topography rises approximately 100 metres above sea level in the northern parts of the site. The topography falls at moderate grades southwards, and eastwards towards the floodplains of the Yarra River and Plenty River respectively.

The topography results in drainage towards the Yarra River floodplain, which generally lies between 10 to 20 metres above sea level in the 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 and shown in Figure 6-3.

Table 6-2 Study area drainage

Element	Waterway	Description
M80 Ring Road to northern portal	Plenty River	Eastern extent of element ends at Plenty River. The river parallels much of the element, but if offset to the east by typically 1 km or more.
Northern portal to southern portal	Salt Creek	Drainage line extends within the Palaeozoic bedrock, offset to the west of the alignment and drains southwards towards before its confluence with the Yarra River near Banksia Street.
	Banyule Creek	Drainage line extends within the Palaeozoic bedrock and drains southwards towards before its confluence with the Yarra River near Banyule Swamp. **The alignment of Banyule Creek in its upper reaches adjacent the Simpson Barracks falls within Commonwealth land.**
	Yarra River	TBM passes beneath Yarra River north Banksia Street/Manningham Road, and then parallels the southern extent of this element.
Eastern Freeway	Koonung Creek	Parallels much of the east of the Eastern Freeway element (south side of Eastern Freeway) before its confluence with the Yarra River near Bulleen Road.
	Yarra River	Parallels much of the western extent of the element and bridged near the western end of the element.



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

Roads

- Freeway
- Highway
- Major road

Watercourses

- River
- Parks & reserves

North East Link Project
Public Environment Report

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

Study Area
Topography and Waterways

Figure 6-3

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

6.4 Identified aquifers

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. These two systems 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).

  This aquifer underlies Commonwealth land.
- 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 (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 (dykes, karst, and contact metamorphism)
- Tectonic history
- Local variations in lithology.

The fractured rock aquifer occurs in each of the three North East Link 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.

While these porous media aquifers comprise various geologies (and geological periods), they have been collectively referred to as the 'Alluvial aquifer' throughout this report. Within porous media aquifers, groundwater is 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 of clays, sands, silts and gravels. In some areas, coarse grained sandy beds have been identified through geotechnical drilling (refer Figure 6-2), and these are likely to dominate flow processes in these aquifers.

6.5 Groundwater management

The study area does not fall within a defined groundwater management unit (it is unincorporated). A Permissible Consumptive Volume (PCV) (total volume of groundwater (and/or surface water) which may be taken in an area) has not been established and so there are no caps on water entitlements that can be issued under Victoria's *Water Act 1989*.

The Commonwealth land is also considered to be 'unincorporated'

Classified as an Unincorporated area, this is circumstantial evidence of limited abstractive development or development potential (low yields, poor quality). Due to these factors, DELWP has not implemented more rigorous resource management measures in this area compared with those in declared groundwater management areas (GMA) and Water Supply Protection Areas (WSPA) found elsewhere within the state.

6.6 Aquifer hydraulic parameters

6.6.1 Published information

Aquifer hydraulic parameters, specifically hydraulic conductivity, are important to understand the movement of groundwater and the influence that tunnels, cuttings and dewatering activities have on the groundwater environment. Hydraulic conductivity refers to 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 is usually assigned the symbol K.

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.

While a summary of hydraulic conductivity estimates is provided in Table 6-3, it is acknowledged the hydraulic conductivity of the bedrock aquifer can be highly variable owing to the nature of fractured rock aquifers (because hydraulic conductivity can span several orders of magnitude).

Table 6-3 Published hydraulic conductivities

Formation	Hydraulic conductivity (K)		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.

Storativity and specific yield

A summary of estimates is provided in Table 6-4, although 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)

6.6.2 Site-specific testing

Horizontal hydraulic conductivity

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 on the sections of North East Link that would be below grade as either a tunnel, or trench structure that intersected the water table. A summary of the hydraulic conductivity testing is provided in 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 (K)		
			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}

Notes:
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 (K)		
			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.

6.7 Groundwater quality

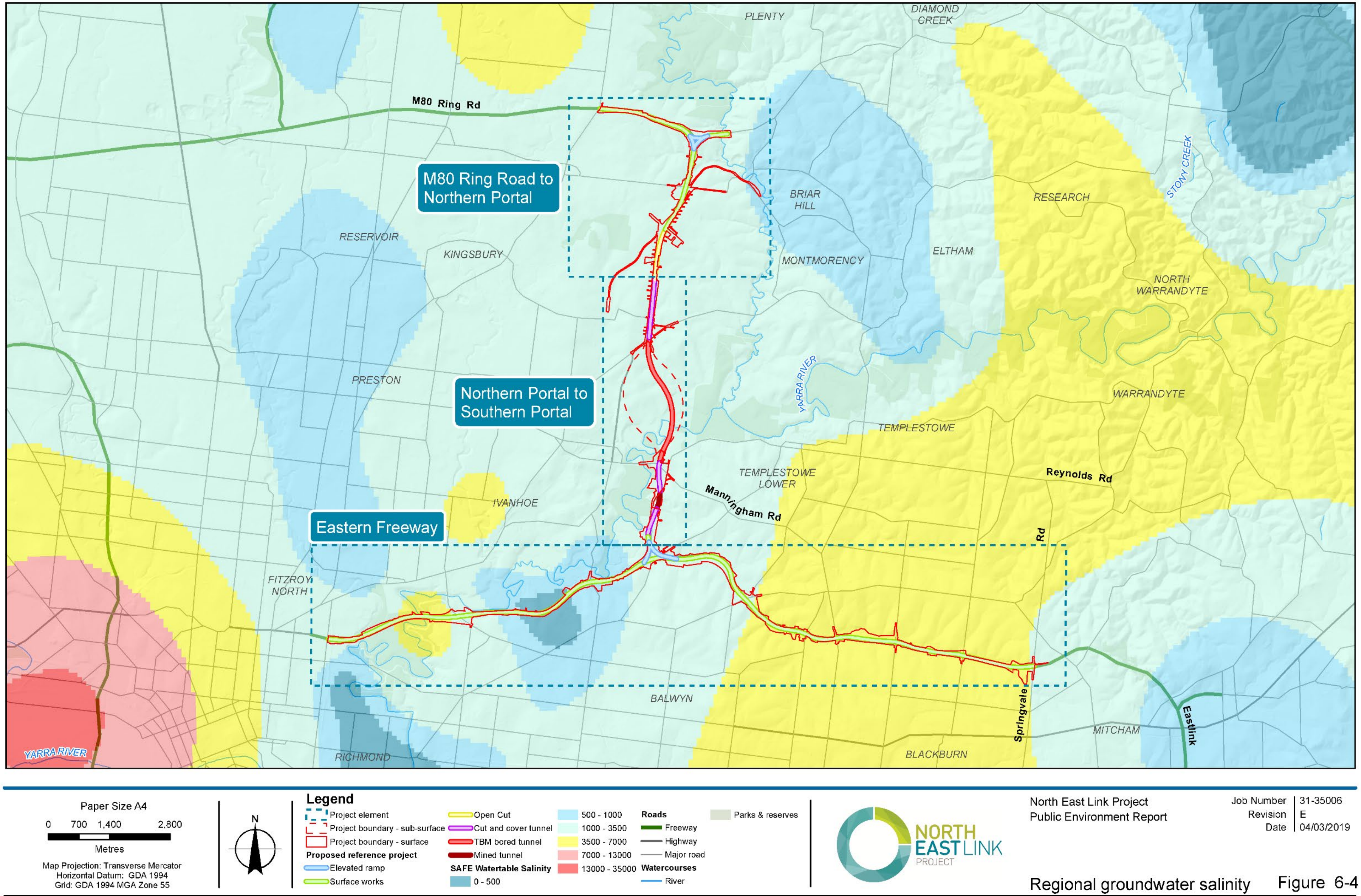
This section provides a general overview of the groundwater quality of the study area. This overview has been informed from regional mapping, and groundwater sampling undertaken as part of the geotechnical investigation program.

6.7.1 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 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 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 such is provided in Section 6.14. As discussed in Section 6.7.2, there are some inaccuracies with the regional mapping based on site-specific groundwater sampling. However, as this assessment covers a much wider area than the smaller area of the reference project, this broader-scale mapping is still important for discussions on the wider groundwater context.



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Regional groundwater salinity

Figure 6-4

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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

6.7.2 NEL monitoring network

Broader project area

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 as the environment studies, and future baseline monitoring for the action.

Following development, selected groundwater monitoring bores were sampled using low-flow sampling methods, in accordance with the EPA Victoria Groundwater Sampling Guidelines (EPA Victoria, 2000). Discussion of the spatial variability of groundwater quality is provided later in this report, but a summary of the salinity identified in the initial modelling data is provided in Table 6-7 and of the further work undertaken in Table 6-8.

Table 6-7 Study area groundwater salinity (initial data)

Area	Aquifer	Number of samples	Groundwater salinity (mg/L TDS)			
			Minimum	Maximum	Mean	Geometric mean
Whole of study area	Sediments (Alluvial)	7	910	6,100	2,658	2,235
	Bedrock (Palaeozoic)	26	730	9,900	5,720	5,099
Commonwealth land	Bedrock (Palaeozoic)	11	4,700	10,000	6,300	6,880

Notes:
1. At time of reporting, no North East Link bores were developed in the volcanics (Newer or Older).
2. Whole of study area excludes Commonwealth land.

Table 6-8 Study area groundwater salinity (further data)

Area	Aquifer	Number of samples	Groundwater salinity (mg/L TDS)			
			Minimum	Maximum	Mean	Geometric mean
Whole of study area	Sediments (Alluvial)	35	703	7,190	2,795	2,148
	Bedrock (Palaeozoic)	104	730	12,000	6,268	5,602
Commonwealth land	Bedrock (Palaeozoic)	24	5,220	10,800	7,061	6,835

Notes:
1. At time of reporting, no North East Link bores were developed in the volcanics (Newer or Older).
2. Whole of study area includes Commonwealth land.
3. Some bores have been sampled more than once.

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
- The elevated groundwater salinity (at higher salinities stock watering applications become limited depending upon species).

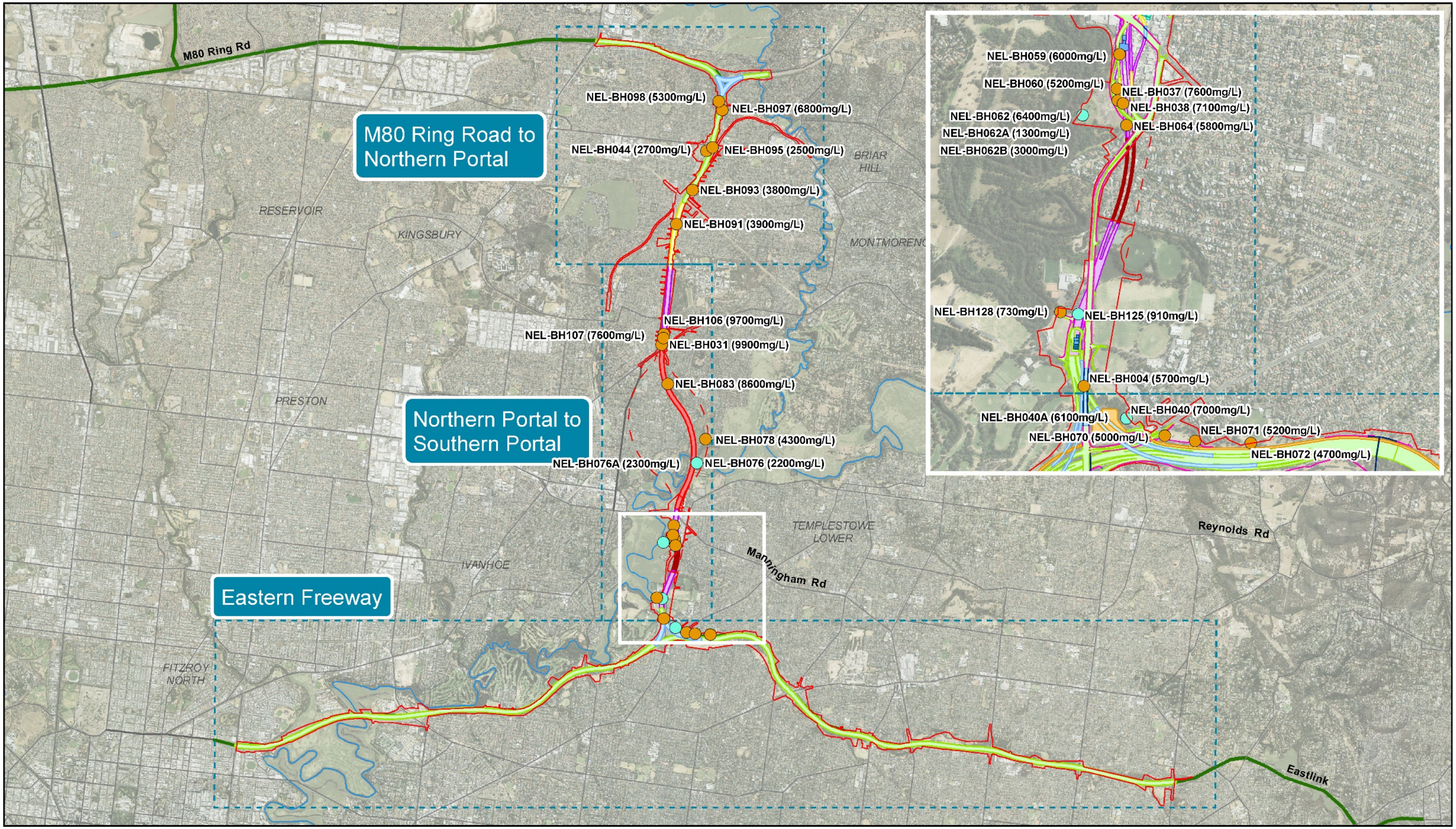
Under the SEPP (Waters), the EPA determines which beneficial uses do not apply.

The beneficial uses for each aquifer are summarised in Table 6-9 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 boundary, as characterised from the geotechnical investigation program, is more saline than indicated by the regional mapping (refer Section 6.7.1).
- 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.

Commonwealth land

Selected monitoring bores on Commonwealth land have undergone groundwater sampling. Groundwater salinity information was characterised by 24 samples and ranges between 5,220 mg/L TDS to 10,800 mg/L TDS with a mean of 7,061 mg/L TDS. These bores indicate the bedrock aquifer falls within Segment D (and confirms that regional salinity mapping shown in Figure 6-4 is inaccurate).



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

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

Aquifer
- Alluvials
- Bedrock

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

NORTH EAST LINK PROJECT

North East Link Project
Public Environment Report

Geotechnical program groundwater salinity

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Revision C
Date 04 Mar 2019

Figure 6-5

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

Table 6-9 Beneficial uses of groundwater for aquifer systems in study area

Beneficial use	Aquifer		Relevant to Commonwealth land	Comment
	Bedrock (Palaeozoic)	Alluvial		
Protection of water dependent ecosystems and species	✓	✓	Yes	Groundwater from around the study area would discharge into the Yarra River (and tributaries).
Potable water supply – desirable			No	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. Low salinity groundwater has been identified in the bedrock aquifer close to the Yarra River. Regionally, this potential beneficial use is not relevant to the bedrock aquifer.
Potable water supply – acceptable	✓	✓	No	
Potable mineral water supply	✓	✓	No	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	✓	✓	No. Based upon available salinity information groundwater in the bedrock aquifer is too saline.	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 Section 6.9), that intersects the bedrock aquifer. However, use of the bore for such purposes has not been confirmed.

Beneficial use	Aquifer		Relevant to Commonwealth land	Comment
	Bedrock (Palaeozoic)	Alluvial		
Agriculture and irrigation – stock watering	✓	✓	Yes. But use unlikely to be realised.	Use of groundwater in the bedrock aquifer for stockwatering would depend upon livestock tolerances. At salinities above 6,000 mg/L (~mean salinity), the groundwater is suitable only for sheep and goats. Such use is also unlikely to be realised in the metropolitan setting, however, stock and domestic bores have been identified in the study area (refer Section 6.9).
Industrial and commercial	✓	✓	Yes. But use unlikely to be realised.	Groundwater could possibly be used but elevated salinities, low bore yields, and availability of potable reticulated supply suggest use of groundwater for such 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 Section 6.9).
Water based recreation – primary contact recreation	✓	✓	Yes. But use unlikely to be realised.	Groundwater discharges to waterways, such as the Yarra River. Groundwater could potentially be used for swimming pool top-up.
Buildings and structures	✓	✓	Yes. But water levels generally too deep.	Water levels are generally too deep to impact current building configurations (off floodplain).
Geothermal	✓	✓	Yes. Refer comment.	Such a 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	✓	✓	Yes	Relevant where groundwater is discharging to creeks, billabongs and sustaining GDEs.
Traditional owner cultural values.	✓	✓	No	Bolin Bolin Billabong and the Yarra River are recognised as having significant Traditional Owner cultural values.

Notes:
1. Yarra River is used for canoeing and boating (secondary contact).
2. Alluvial aquifers not present on Commonwealth land.

6.7.3 Known groundwater quality impacts

North East Link monitoring network

Groundwater samples were collected from the North East Link monitoring bore network consistent with the EPA Victoria *Groundwater Sampling Guidelines* (2000), and analysed for a range of analytical parameters. A summary of water quality from the North East Link groundwater monitoring network identified in the initial modelling data is provided in Table 6-10 and of the further modelling data in Table 6-11.

Table 6-10 Summary of groundwater quality (initial data)

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	1,600	12,000	4,650	3,637
	TDS	mg/L	7	910	6,100	2,658	2,235
Bedrock	pH	pH unit	26	6	8.6	7.60	7.57
	EC	µS/cm	23	5,500	19,000	11,117	10,518
	TDS	mg/L	26	730	9,900	5,720	5,099

Table 6-11 Summary of groundwater quality (further data)

Aquifer		Analyte	Unit	Count	Minimum	Maximum	Average	Geo. Mean
Alluvials	Whole of project	pH	pH unit	39	6.24	8.3	7.08	7.07
		EC	µS/cm	38	1,180	13,000	5,315	3,898
		TDS	mg/L	35	703	7,190	2,795	2,148
	Commonwealth land	pH	pH unit	Not present on Commonwealth land (west side of Barracks)				
		EC	µS/cm					
		TDS	mg/L					
Bedrock	Whole of project	pH	pH unit					
		EC	µS/cm					
		TDS	mg/L	104	730	12,000	6,268	5,602
	Commonwealth land	pH	pH unit	24	6.7	7.8	7.4	7.4
		EC	µS/cm	24	8,380	18,300	12,095	11,768
		TDS	mg/L	24	5,220	10,800	7,061	6,835

Notes:
1. At time of reporting, no North East Link bores were developed in the volcanics (Newer or Older).
2. Whole of study area includes Commonwealth land.
3. Some bores have been sampled more than once.

The following general comments are made regarding the groundwater quality identified in Table 6-11 above:

- 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 6.14) of fresher groundwater being present near waterways.
- Salinity of bores developed in the alluvial sediments ranged from 910 mg/L TDS to 7,190 mg/L TDS, with an average of 2,95 mg/L TDS. The highest salinity of 7,190 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 730 mg/L to 12,000 mg/L TDS.
- Groundwater pH in both aquifer systems was between 6 and 9, and averaging 7.1 and 7.4 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 railway station car park, above the laboratory limits of reporting.

  TPH and BTEX was also identified in bore NEL-BH089 and NEL-ENV-BH022, both located near Yallambie Road. ***Both these bores are located on Commonwealth land.***
- Concentrations PFHxS+PFOS and PFOS were reported above the adopted criteria NEPM (2018) Ecosystems Fresh Water (99%), 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 Polyfluoroalkyl Substances (PFAS) in groundwater in this area is unclear and at this stage there is insufficient information to either identify a likely source or 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 Bulleen 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.

  Copper, nickel and zinc exceeded the ANZECC (2000) guidelines for the protection of freshwater aquatic ecosystems in bores NEL-BH089 and NEL-ENV-BH022. ***Both these bores are located on Commonwealth land.*** There is no obvious anthropogenic source of these heavy metals are so the concentrations are considered to represent naturally elevated background concentrations of these metals.

Historical landfilling

Landfilling has been identified in eight locations within the study area. Of particular note from a groundwater perspective is the historical landfilling that occurred at Borlase Reserve (near the northern portal) and Bulleen Park (near the 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 6-12.

Table 6-12 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. North East Link geotechnical investigations identified minor amounts of construction and demolition wastes, at depths generally less than 3 m (above the groundwater table). ***This former landfill is located south of, and within 500 m of Commonwealth land.***
Bulleen Park	Solid inert waste and possible putrescible waste	Filling occurred during the early to late 1960s. Landfilling extended over the current day football oval extending to the Yarra River in the west, the current day Veneto Club in the north, and the to 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 (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.

While GQRUZ have been identified within one kilometre of the North East Link project boundary, the majority are located at the western end of the Eastern Freeway element where the action is at, or above grade. This means that disturbance of any groundwater contamination in these places is highly unlikely.

There are no GQRUZ identified on Commonwealth land.

Environmental Audits

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.

A number of environmental audit sites were identified in the study area, with most located within the Eastern Freeway element. An audit was undertaken on the fuel storage area at 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.

6.8 Groundwater levels and potentiometry

6.8.1 Regional mapping

Regional depth to water mapping was available from DELWP and the mapping pertaining to the study area is presented in Figure 6-6. Water levels on the alluvial flood plains and near existing waterways tends to be less than five metres below the surface. Remote from the floodplain, on the bedrock areas, waters levels tend to be greater than 10 metres below the surface.

Water levels on Commonwealth land are interpreted to be between 10 and 20 metres below the surface based on regional mapping. Groundwater flow in the western part of Simpson Barracks (nearest the Greensborough Road) is interpreted to be southwards.

6.8.2 Alignment mapping

The geotechnical program involved the construction of 141 monitoring bores throughout the study area. While the majority of these bores are located close to the alignment of the reference project, mapping of groundwater levels has occurred. Water levels from these bores were used to aid the steady state calibration of the numerical groundwater model. Time series water level monitoring information obtained from this network was used to undertake a transient calibration update to the numerical groundwater model (refer Appendix B).

Resultant water table mapping is provided in Figure 6-7 and Appendix A of this report. In general, water levels are forming a subdued reflection of the topography, with groundwater flows towards the alluvial floodplains of the Yarra River.

6.8.3 State observation bores

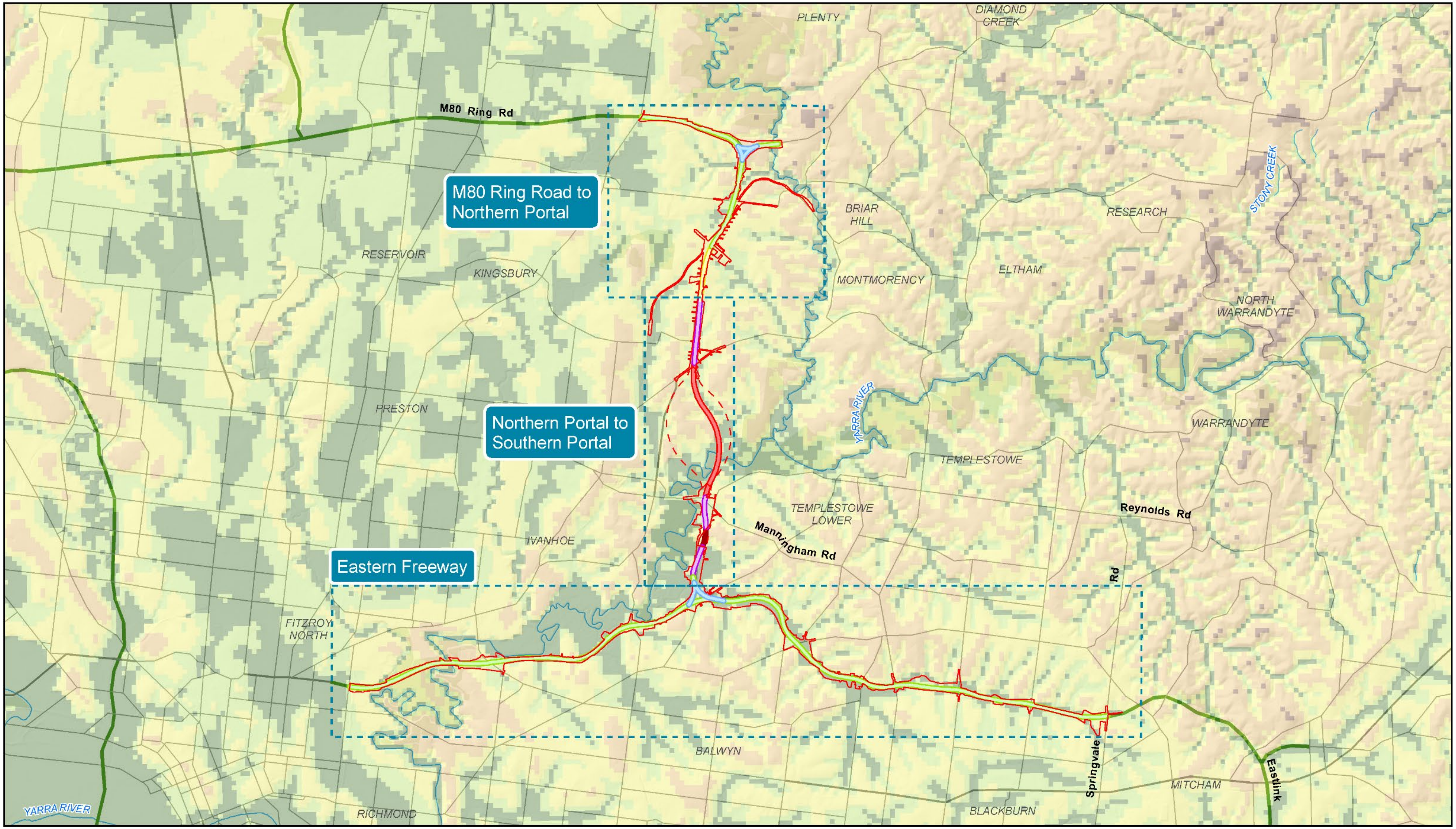
A search of the groundwater management system was undertaken to identify the presence of any active State Observation Network (SON) bores. The SON bores are used by DELWP to facilitate groundwater resource management, and can provide valuable information for a region as they provide a water level monitoring record, and at some sites, water quality monitoring data. Most SON bores are monitored at a quarterly frequency, although monthly monitoring frequencies are adopted in some Water Supply Protection Areas (WSPAs).

There are no SON bores located within a five-kilometre radius of the reference project alignment. None were identified on Commonwealth land.

6.8.4 Other monitoring

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

Monitoring bores were identified on Commonwealth land, although no monitoring information was available at the time of reporting. Information provided by the Department of Defence indicated these two bores were installed to monitor groundwater quality near diesel underground storage tanks.



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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Regional depth to water table

Figure 6-6

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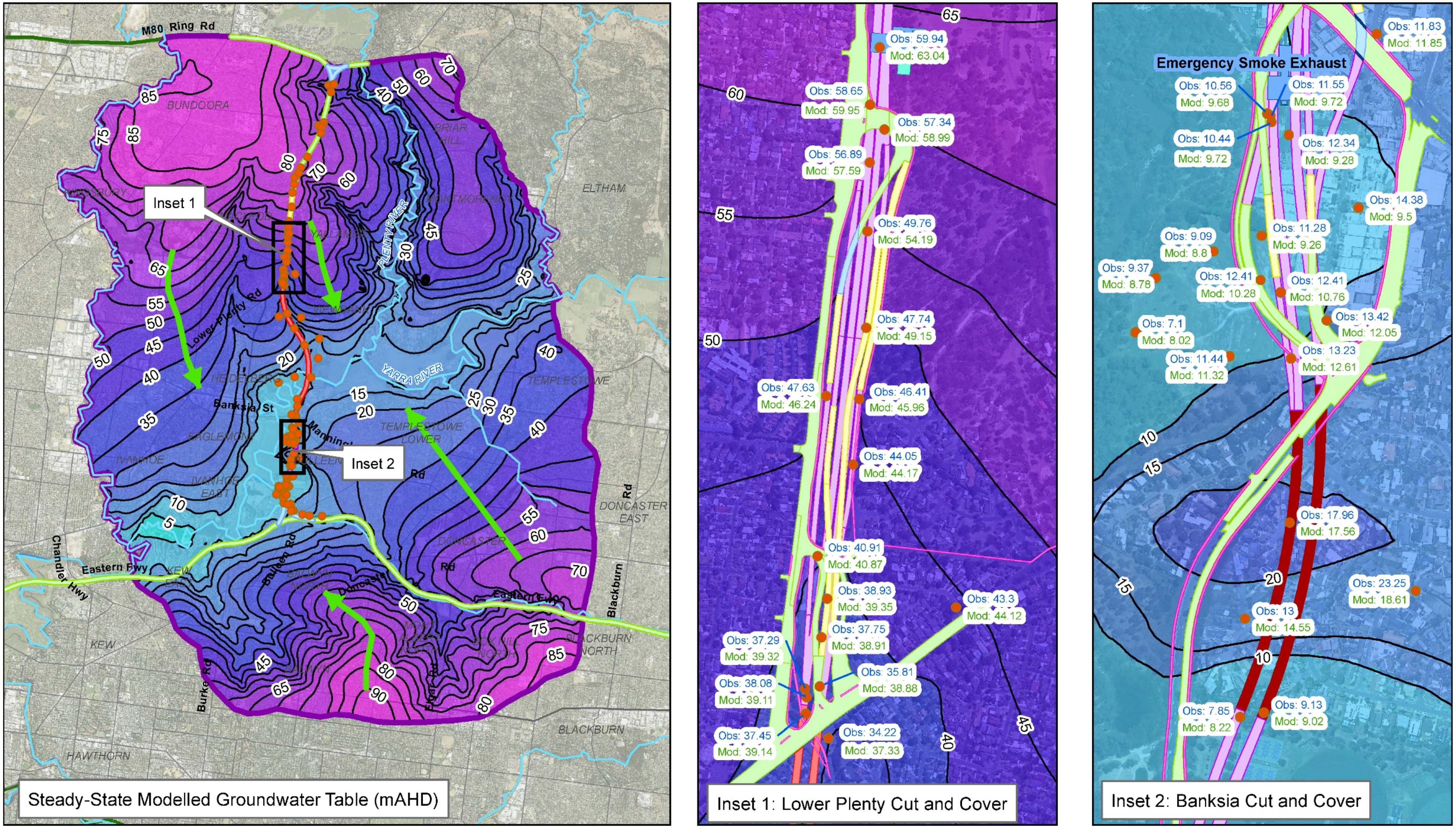
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: 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

N

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

NORTH EAST LINK PROJECT

Modelled water table elevation

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

6.8.5 Influences on water levels

Groundwater abstraction can locally influence groundwater levels, although this extraction is often seasonally dependent (irrigation occurs predominantly through late spring to early autumn). The groundwater quality (refer Section 6.7) indicates the Palaeozoic aquifer is saline which limits the likelihood for wide-scale abstractive development, and thus the influence on groundwater levels regionally.

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 such man-made structures can locally influence groundwater levels, although no obvious evidence of sewers locally influencing groundwater levels has been identified.

There are no obvious anthropogenic influences on groundwater levels in the western part of Simpson Barrack (Commonwealth land).

Review of time-series water level monitoring data from the North East Link groundwater monitoring network, which incorporates the 2018/19 summer (irrigation season), has not identified any obvious evidence of abstractive groundwater development.

6.8.6 Seasonal water level response

Groundwater levels often show a seasonal response that reflects recharge. That is, groundwater levels are expected to be lowest in the summer months, and highest in the winter and spring when greater rainfall tends to occur.

Time-series water level data available to characterise the seasonal response of groundwater levels and selected information is described in this section.

Melbourne Water monitoring

Melbourne Water provided monitoring data available for monitoring bores (bores BH02[2] and BH06) located marginally south of Bolin Bolin Billabong (between the billabong and the Veneto Social Club). This data ranged from August 2017 to June 2019 and is shown in Figure 6-8. The figure also includes:

- Yarra River levels (relative to m AHD), as measured at the Banskia Street Gauge (229135A)
- Water level in the deep pool (elevation datum not known). This shows a rise from an artificial filling event completed by Melbourne Water in late 2017, and second filling event from a flood event of the Yarra River (also in late 2017).

[2] Melbourne Water bore identification (not part of the North East Link geotechnical investigation groundwater monitoring network).

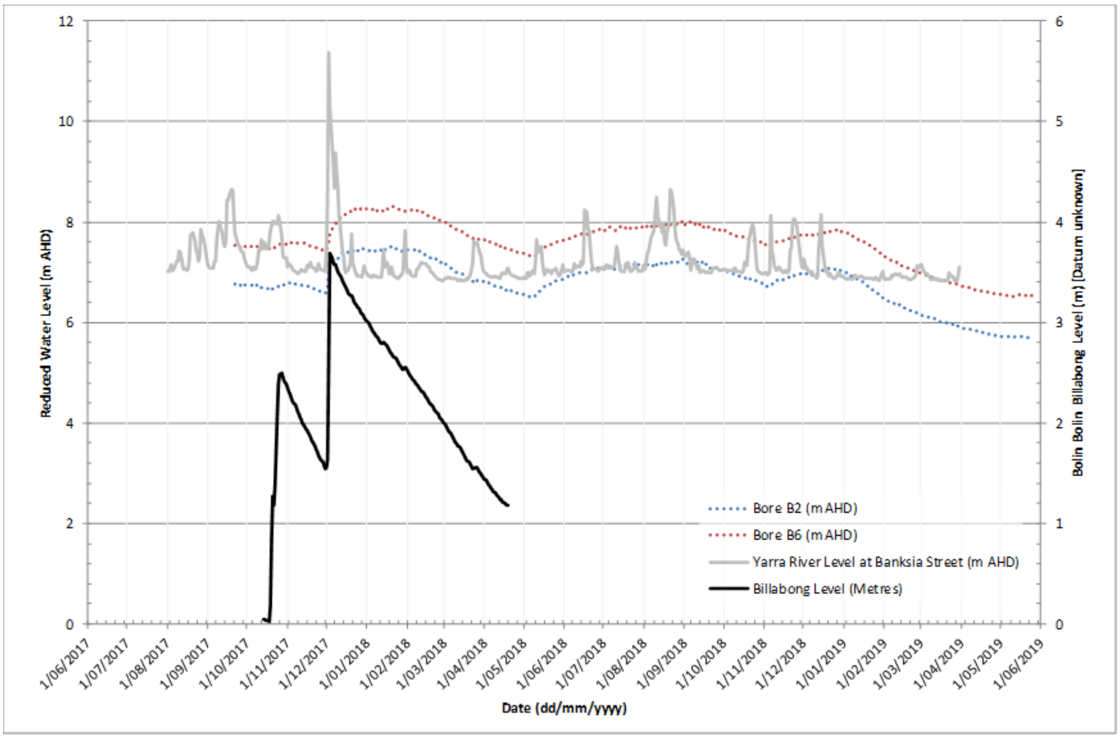


Figure 6-8 Time series water level data – Bolin Bolin Billabong

Groundwater levels have been recorded at an elevation of six to eight metres AHD with the water level in both bores rising sharply by approximately one metre after a flood on the Yarra River in early December 2017. A complete year of monitoring data is available for review and water levels have shown a one metre variation across the available monitoring record. Groundwater levels tend to be marginally higher than the Yarra River, consistent with regional flow towards the Yarra River.

NEL monitoring

An ongoing groundwater monitoring program implemented as part of the North East Link geotechnical investigations has, and continues to, inform this groundwater impact 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 6-9. The pressure head has been corrected to a standing water level on the hydrograph. Groundwater levels have exhibited an approximate one metre to 1.2-metre variation across the available monitoring record. The water pressure declines measured in June 2018 are due to drilling and pumping test investigations.

6.8.7 Drought response

Droughts, such as the Millennium Drought (1996 – 2010) can have a significant influence on groundwater levels. As noted in Section 6.8.3, there are no nearby State Observation Network (SON) bores within 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 and therefore review of other SON bores located around Melbourne, was undertaken. This review indicated the Millennium Drought saw a decline in water levels of two to three metres, with an approximate 50 per cent recovery following the drought.

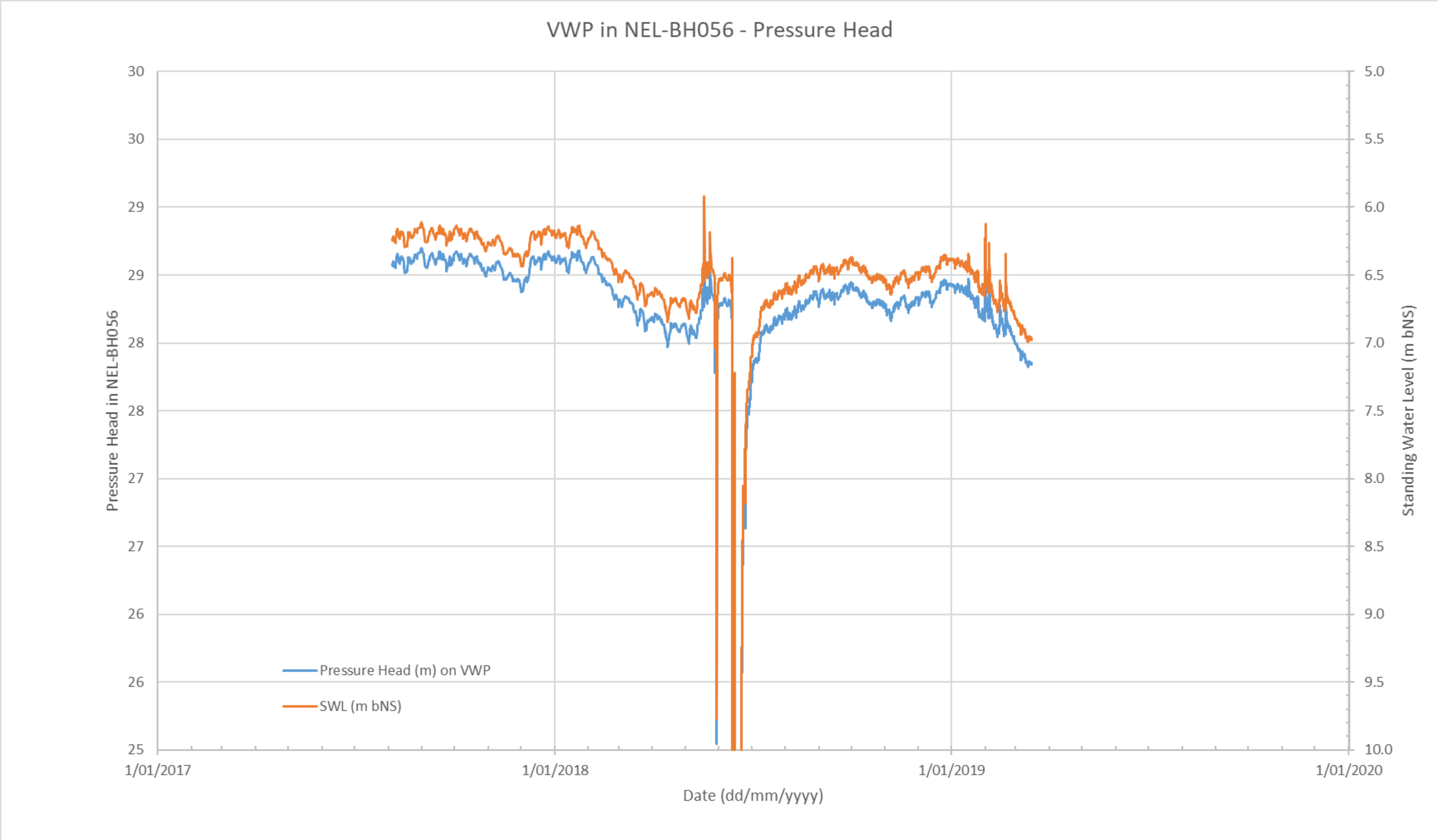


Figure 6-9 Time series water level data – NEL-BH056 (VWP)

6.9 Neighbouring groundwater use

Broader project area

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

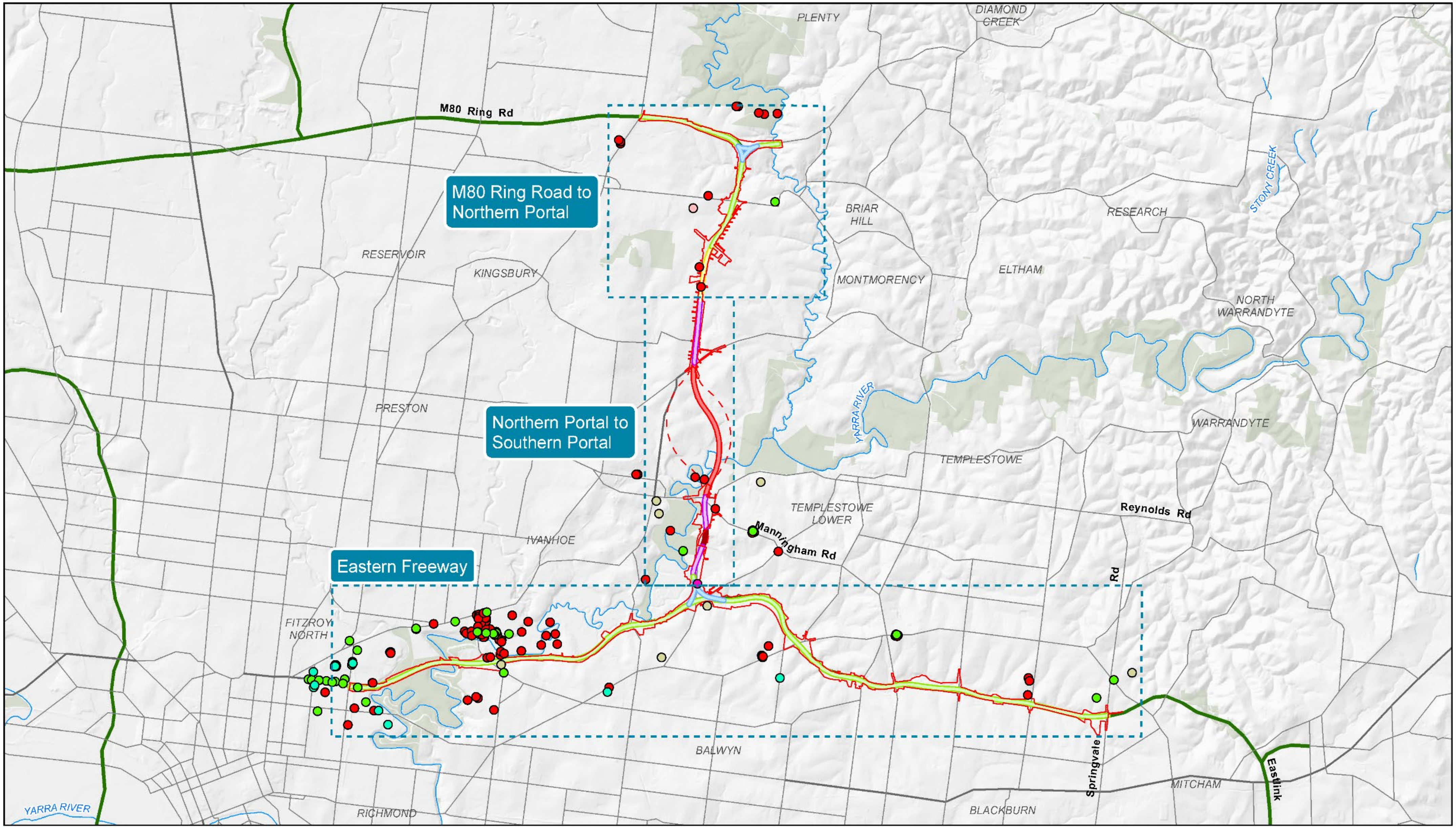
- Urbanised, mostly residential setting, where potable water is readily available through a widespread reticulation network operated by Yarra Valley Water.
- There is a minimum set back distance of 200 metres from a waterway or lake for bores, as stipulated by Victoria's *Water Act 1989*.
- The groundwater quality in the bedrock aquifer is brackish to saline, which generally limits its abstractive benefits (it 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 within the urbanised land setting. It is noted that fresher groundwater occurs nearer to the floodplains, but 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.

The following comments are made regarding the WMIS data:

- Bores installed prior to the proclamation of Victoria's original *Water Act 1989* may not be registered as there was no mandatory requirement to licence bores before this date
- The WMIS does not provide information regarding 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 (including water level information, pump setting depth and 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 reference project alignment and the bore numbers by use type are summarised in Table 6-13. The bore locations are shown in Figure 6-10.



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

NORTH EAST LINK PROJECT

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Date 28/02/2019

Study Area
WMIS groundwater bores

Figure 6-10

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

Table 6-13 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 the operational status has not been undertaken and such information is not available in publicly available records such as the WMIS.

The majority of bores identified in the study area have been installed for either groundwater investigation or 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 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 undertaken as part of North East Link geotechnical investigations were low, with rates of 0.5 L/s at Borlase Reserve, and <0.2 L/s at both Kim Close and Bulleen Park. However, pumping test bores were targeting the potential 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 being sited 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. It is questionable whether this bore is used for irrigation purposes based on the groundwater salinity of the bedrock aquifer,

and the relatively narrow casing diameter which limits the size of submersible pump that could be installed in the bore. The North East Link groundwater monitoring network has an automated water level datalogger in bore NEL-BH098 which is within 500 metres of this location, and there is no obvious evidence of any groundwater pumping identified. North East Link monitoring bores nearer to the college (with monthly monitoring data) also have no evidence of pumping.

- 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). Nearby North East Link monitoring bores do not show obvious evidence of use.
- 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 reference project alignment.

Commonwealth land

Two groundwater bores (monitoring bores) were identified on the Commonwealth land based on a site inspection by North East Link project officers undertaken on the western part of the land parcel only. These monitoring bores are not registered on the WMIS (and are not accounted for in Table 6-13).

6.10 Acid sulfate soils

6.10.1 Definitions

Acid sulfate 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 sulfide). 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 sulfides oxidise to sulphate, with resultant soils having low pH and potentially high concentrations of the heavy metals. These materials may be exposed during construction dewatering activities.

Groundwater levels may rise as a result of recovery from construction dewatering activities, or the leaching of infiltrating rainfall through the sulphate rich zones. This can cause 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 cause 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 – soil that contains unoxidised metal (iron) sulphides, usually in oxygen free or waterlogged conditions; when exposed to oxygen through drainage or disturbance, these soils produce sulfuric acid
- Actual Acid Sulfate Soil – 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 potential acid-generating materials above the water table and their management, such as acid run-off from stockpiles and treatment areas, filling, handing of spoil from tunnels – this is commonly managed through a Construction Environmental Management Plan (CEMP) and is not discussed further in this report
- Dewatering required as part of the construction of features below the water table, such as the TBM tunnels and cut and cover section.

The assessment of acid-generating materials arising from the dewatering required to construct North East Link structures below the water table is documented in Section 7.

6.10.2 Occurrence within study area

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

- Typically geologically young sediments (Holocene age) deposited 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.

The latter (Palaeozoic bedrock) has been mapped throughout the study area and underlies the Commonwealth land. In parts of metropolitan Melbourne it 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 North East Link geotechnical investigation program. Soil and rock samples were analysed in accordance with EPA Victoria Publication 655.1 – Acid Sulfate Soil and Rock (2009), which assessed:

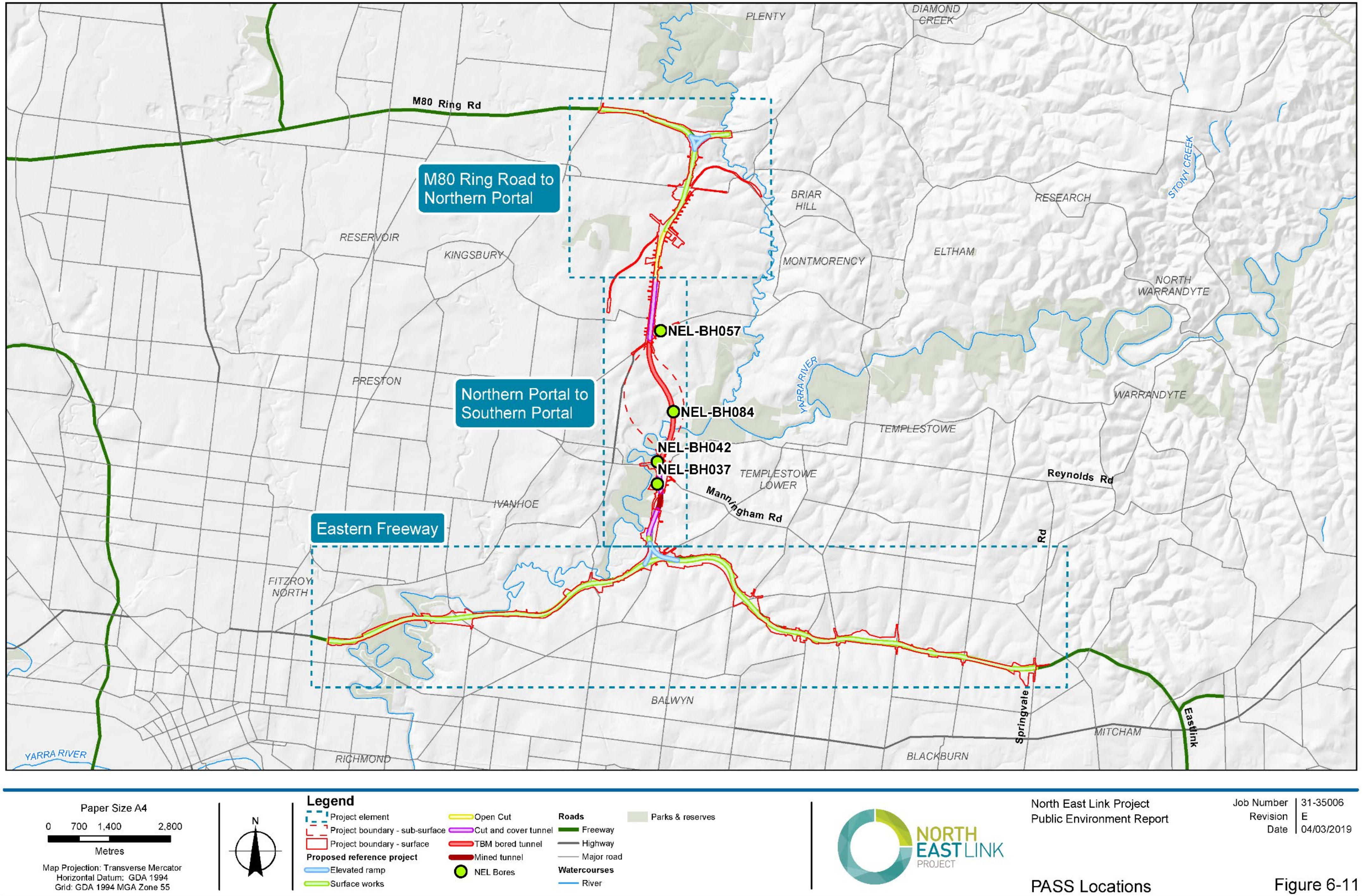
- Net Acid Production Potential (NAPP)
- Net Acid Generation Potential (NAGP)
- Suspension peroxide oxidation combined acidity and sulphur (SPOCAS) suite
- Chromium reducible sulphur (CRS) suite.

Applying the criteria in EPA (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'. The potential acid sulfate soil locations are shown in Figure 6-11.

An assessment of the significant of these materials is provided in Section 7. None of these sites are within Commonwealth land, although NEL-BH057 is within 300 metres of Commonwealth land.

6.11 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are discussed in PER Technical Appendix A – Flora and fauna. A discussion of groundwater interactions with waterways is provided in the next sections.



North East Link Project
Public Environment Report

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

PASS Locations

Figure 6-11

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

6.12 Relationships between aquifers

6.12.1 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.

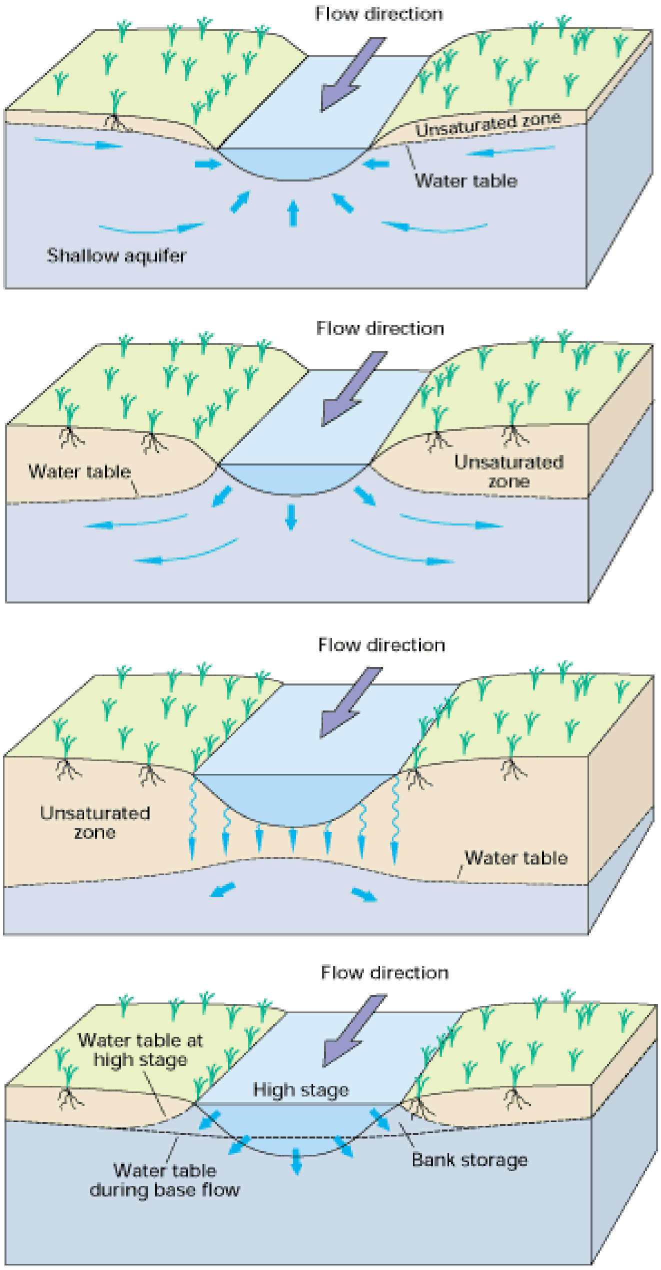
On Commonwealth land the aquifers are considered unconfined. There is potential for perching to occur where permeability contrasts exist or where vertical migration of infiltrating water may be impeded by low permeability beds. For example, water may perch in thin, permeable, soil horizons that overlie the Palaeozoic bedrock where a permeability contrast exists.

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. However, no nested sites have been installed on, or near Commonwealth land.

6.13 Groundwater and surface water interaction

6.13.1 Definitions

There are four different ways in which waterways and groundwater interact and these are shown in Figure 6-12. 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.

Source: Harvey *et al*., 1998.

Figure 6-12 Surface and groundwater interaction

6.13.2 Discussion

It is recognised that there is generally a limited quantitative understanding of connectivity between surface and groundwater throughout the study area, and the following comments are made:

- Numerical groundwater models (initial modelling and further modelling) are both calibrated against Yarra River baseflows.
- 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 is being undertaken at nested monitoring bores throughout the alignment. This information indicates hydraulic connection between waterways (Yarra River, Koonung Creek), alluvial and Palaeozoic bedrock aquifers.
- 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, such as the stabilisation of water levels as a result of 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 how they interact with groundwater is provided below.

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 an ephemeral stream with no permanent baseflow. The creek over much of 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 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.

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 describes 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, but 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. Connections between Banyule Swamp and Banyule Billabong with groundwater are not known (Melbourne Water conceptualisation, *date unknown*).

At the time of reporting, North East Link monitoring bores NEL-BH070 (bedrock), NEL-BH078 (bedrock) and NEL-BH080 (bedrock) are the only monitoring bores in this area of the action and these bores indicate groundwater levels between four and ten metres below the natural surface within the Palaeozoic basement. These bores intersected between six and twelve metres of alluvial sediments (mostly fine grained clays and silts) overlying the bedrock aquifer. Over 12 months of monitoring data is now available from these bores, which indicates an approximate one metre seasonal variation in water levels. Data for the alluvial sediments is not available in this area of the action.

Yarra River

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

Regional groundwater mapping (refer Figure 6-6) 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 was modified for construction of the Eastern Freeway. The creek has been re-aligned or placed within concrete channels in some places.

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 (PER Technical Appendix C – Surface water). Monitoring bore responses, such as the nested site at NEL-BH40 (and NEL-BH40A) show close correlations between levels in the bedrock and alluvial aquifer.

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-metre depth at a frequency less than the wet-dry arms.

The location of these zones and conceptualisation is shown in Figure 6-13.

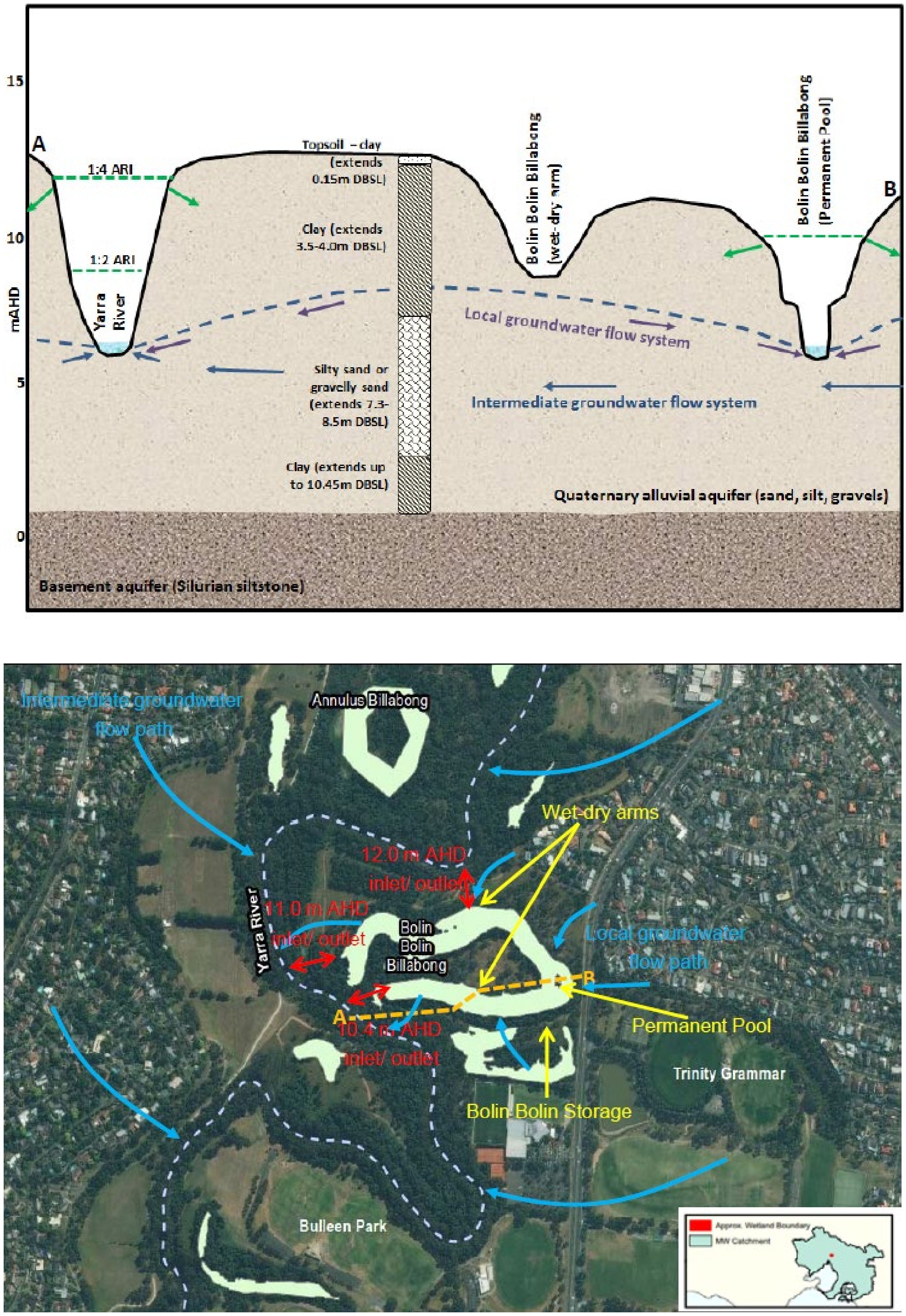


Figure 6-13 Conceptualisation of Bolin Bolin Billabong

Up to the 1990s, the billabong was frequently inundated (at least annually), but inundation has been less frequent more recently. 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. Available monitoring data (Melbourne Water) has been shown in Figure 6-8.

6.14 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 the subsequent groundwater impact assessment.

6.14.1 Banyule Creek and Koonung Creek

The conceptualisation of groundwater at Banyule Creek is shown in Figure 6-14.
The conceptualisation could also be applied to Koonung Creek, although it is recognised that while the hydrogeological setting of Banyule Creek and Koonung Creek share some 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 these 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 (for example, bank storage becomes negligible). However, over time, defects in channels, such as cracks, can reinstate some of the hydraulic connection
- 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
- Constructed wetlands or retarding basins within these areas may spatially shift groundwater dynamics within the existing floodplain. Retarding basins create ponding of water (albeit for short time periods) and opportunities for groundwater recharge. Deeper basins that intersect underlying groundwater may require lining structures (for the basins to operate effectively).

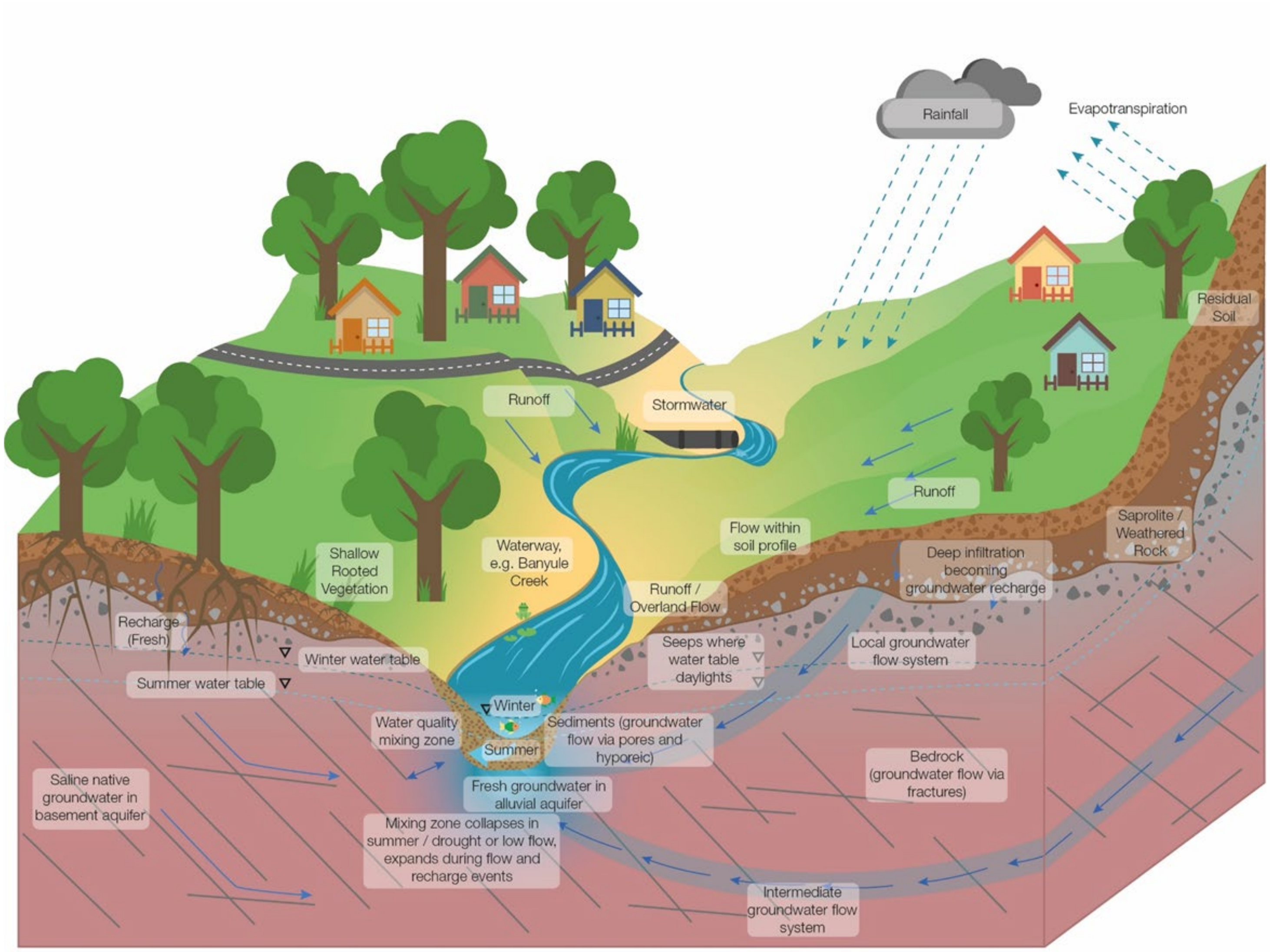


Figure 6-14 Conceptualisation of Banyule Creek

The geology in the conceptualisation has been divided into a two-aquifer system. 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 (in 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, although it 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 for the North East Link geotechnical investigation program. Residence times within the alluvial system are short, and owing to a strong interaction between surface water and groundwater and shorter flow paths, groundwater qualities can be 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 6-14 shows groundwater levels gaining stream conditions, although the nature of interaction between the waterway and groundwater may vary seasonally and along the reach of the both creeks.

For example, in the Simpson Barrack 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 (<1,000 µS/cm) which is significantly fresher than native bedrock groundwater (>6,000 µS/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 nearer to the floodplain.

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 metres) in bore NEL-BH170 and so may interact with the water table.

In regard to Koonung Creek, while there are few groundwater monitoring sites available along its reaches, 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.

6.14.2 Yarra River

The conceptualisation of groundwater within a generalised Yarra River floodplain is shown in Figure 6-15. There is a relatively broad floodplain associated with the Yarra River, which is occupied by mostly Public Use, Public Conservation and Resource, and Public Park and Recreation planning zones. 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 for the North East Link geotechnical investigation program indicates that 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, although 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. Rainfall recharge into the alluvials is expected to be greater relative to the bedrock aquifer.

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 upon the depth of these depressions.

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

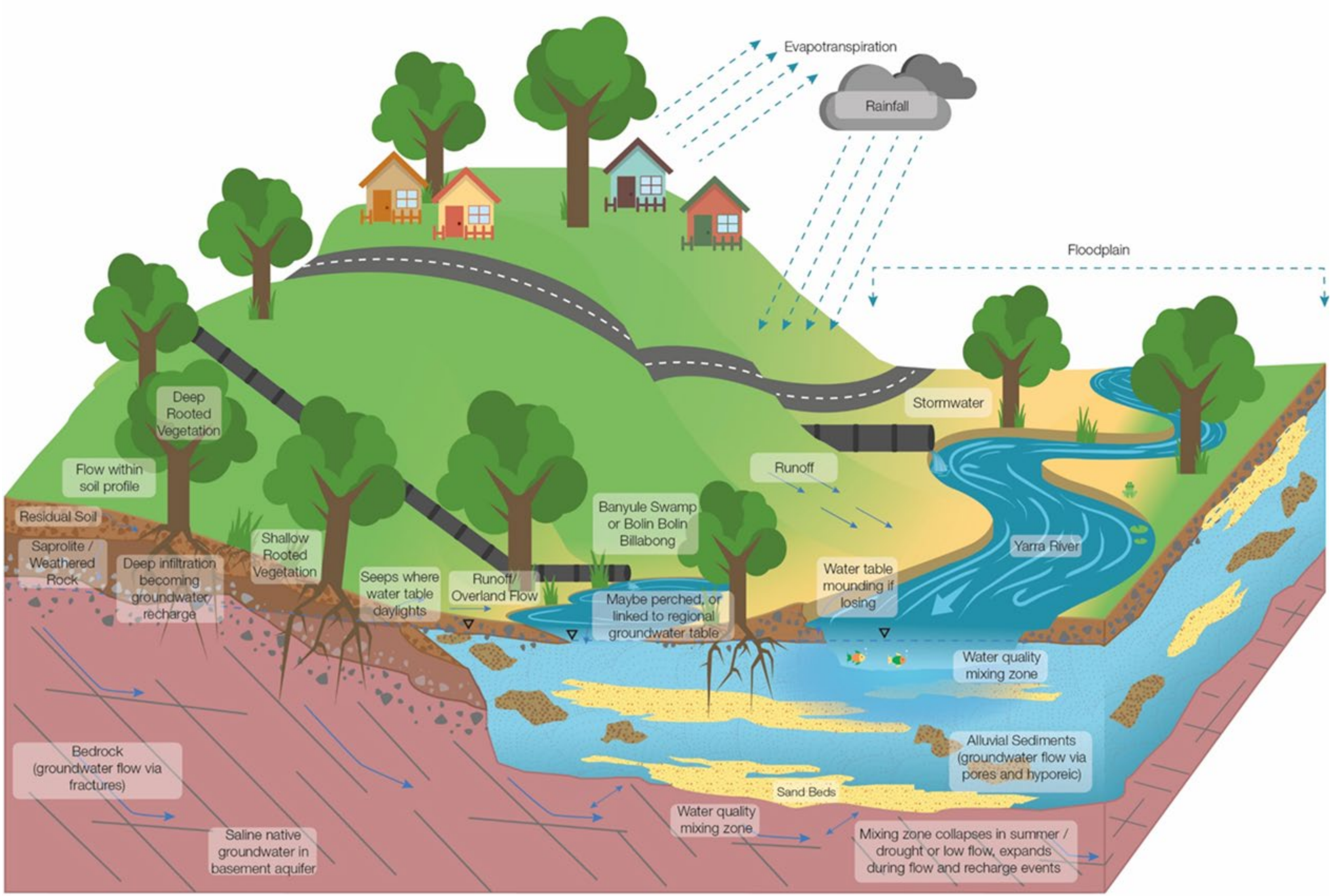


Figure 6-15 Conceptualisation of the Yarra River floodplain

7. Relevant project-wide impacts

7.1 Overview

This section describes the potential for construction and operation of North East Link to impact groundwater assets, values and uses.

The impact assessment has considered the potential for significant impacts on the environment as described by the criteria outlined in the EPBC Act Significant Impact Guidelines:

- Impacts upon listed threatened species and communities, and listed migratory species (MNES): Matters of National Environmental Significance – Significant Impact Guidelines 1.1 (Department of Environment, 2009).

  Changes to the groundwater environment, particularly groundwater levels, has the potential to impact indirectly upon MNES. This could take the form of reduced baseflow to waterways, or access to groundwater by vegetation.

  While the PER is required to assess these impacts, the assessment of impacts is discussed in PER Technical Appendix A – Flora and fauna.

- Actions on, or impacting upon, Commonwealth land, and actions by Commonwealth agencies – Significant impact guidelines 1.2 (DSEWPAC, 2013).

Groundwater can be a receptor itself, as it is a media that can support ecosystems such as stygofauna (fauna that live in groundwater systems or aquifers). Groundwater can also convey nutrients and flows to other dependent ecosystems such as swamps and waterways. In this instance, changes to groundwater quality or levels may indirectly impact down-gradient receiving environments or ecosystems accessing groundwater. Through these pathways there may be indirect impacts on MNES.

Groundwater may also have a number of beneficial uses which are determined by its base salinity. For example, a low salinity groundwater could possibly be used for many purposes including drinking and irrigation, whereas saline groundwater less so (refer Table 4-4). Changes to groundwater level and or quality can influence these beneficial uses that directly relate to humans and abstractive benefit of the groundwater (that is, the ability to pump groundwater to service stock watering, irrigation, commercial or industrial water requirements).

Some of the beneficial uses of groundwater relate to the built environment (such as the requirement to maintain groundwater quality so it does not cause the degradation of buildings and structures). This end use requirement to protect groundwater quality is not considered relevant to the PER assessment on the assumption that no heritage buildings or sites would be impacted (no deep foundations) in relation to Commonwealth land.

Since the publication of the draft PER, further work has been undertaken to provide more information for this report. As part of finalising the PER, the findings presented in the following section have been updated as relevant to reflect the additional outcomes of this further work.

7.2 Estimates of groundwater inflows

7.2.1 Calculation method

An understanding of the volume of groundwater inflows generated during construction and operation provides an insight into the magnitude of disturbance. Numerical groundwater modelling provides a coarse estimate of the groundwater inflows during and after construction, which have been summarised in Table 7-1.

At the time of numerical model development there was insufficient data to enable transient calibration. Furthermore, it is acknowledged that groundwater models produce non-unique answers. To address such issues, sensitivity and uncertainty analyses were undertaken on the numerical groundwater model (refer Appendix A) which resulted in the development of 200 alternative models whose predictions are equally plausible based on the calibration dataset. Under these conditions, inflows are reported as 95th percentile as well as 5th percentile in Table 7-1 (that is, the 95th percentile indicates that 95 per cent of the 200 calibrated models inflows are less than this amount).

Further numerical groundwater modelling was undertaken following the publication of the draft PER. The purpose of further modelling was to incorporate additional groundwater data collected over a period of approximately 12 months to enable transient calibration to seasonal variations in groundwater levels and to assess whether or not the additional calibration efforts result in changes to the assessment of project-induced groundwater impacts.

The additional modelling (refer Appendix B) included a transient calibration, and the additional data generally resulted in an improved model performance. Whilst the model performance had improved, the overall findings of the model were generally similar to the original. An uncertainty analysis has not been completed as part of the further modelling, however, predicted drawdowns tend to be less based upon the further modelling undertaken.

Inflow rates are indicative only as:

- Construction scheduling – factors such as the time between excavation and tanking or the size of excavation opened can influence construction inflows. Estimated construction timeframes adopted by the numerical modelling have been included in Appendix A. These were based on construction program estimates provided for the reference project.
- The numerical model activates dewatering instantaneously and simplifies excavation activities and construction scheduling:
  - Specifically, simplification of the construction assumes that:
    - The base slab for the cut and cover sections of the excavation is placed over the entire footprint of the cut and cover structures at the end of construction, rather than incrementally. This means that the model assumes a longer time span of dewatering, making the model conservative in its estimates of groundwater inflow
    - The bored pile walls (see Section 3.5.2) for the cut and cover sections are placed first, which would prevent the majority of horizontal groundwater inflows
  - The model included the below construction schedule excavation timeframes:
    - Lower Plenty area (cut and cover): April 2022 – April 2024 (placement of base slab)
    - Southern area (cut and cover): July 2022 – July 2023 (placement of base slab)
    - Banksia area (cut and cover): July 2022 – April 2024 (placement of base slab)
    - TBM tunnel: July 2023 – September 2024 (lining installed during construction).
- The water tightness of structures achieved at the completion of construction may be better than Haack Class 3.

Note that inflow estimates for the TBM tunnel are not documented in Table 7-1 as the permanent lining would be 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 7-1 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

Notes:
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 construction at around 3.8 L/s (620 m^3/day). However, average inflows during 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.

With the exception of temporary spikes in the modelled inflow rates caused by the instantaneous activation of drain cells, the further modelling predicts groundwater inflow rates generally similar to the initial modelling. The main difference is predicted to occur in the northern portion of the alignment, due to higher recharge applied over the Bedrock (increased from 10 mm/year to 20 mm/year). This results in almost twice as much temporary inflow during construction of the Lower Plenty cut and cover (approximately 200 m^3/day) and twice as much long term inflow over the free draining trench (approximately 30 m^3/day). Once the structures are tanked, the long term inflow rates into the fully tanked sections are effectively identical, and are approximately equal to Haack Class 3 water tightness.

7.2.2 Note regarding inflows

The contractor would build North East Link according to the specifications, and this assessment has assumed the minimum water tightness specified would be Haack Class 3. Although the tunnels (or other structures) would be undrained, a small amount of seepage could still enter. The Haack Class 3 tightness describes the *'wall of the lining must be so tight that only isolated, locally restricted patches of moisture occur. Restricted patches of moisture reveal that the wall is wet, leading to a discolouration of a piece of blotting paper or newspaper if placed upon it – but no trickling water is evident'*.

In aiming to achieve this water tightness objective, the contractor may attain a better water tightness. However, for the purposes of assessment of impacts, adopting a maximum of Haack 3 classification is conservative as it assumes that inflows will be at a maximum (as per the assumed water tightness specification). As part of the construction, leakage tests may be required to assess compliance with the contract and where specifications are not met, approved sealing methods and retesting may be required. As noted in Table 3-2, the final water tightness of the project would depend upon the specification.

The total volume of leakage into the tunnels under these conditions may be upwards of 10 ML per annum. This is considered a small volume in terms of the overall resource in the bedrock aquifer. By comparison, from a groundwater resource perspective, a single stock and domestic bore developing the same aquifer would be allocated 2 ML per annum. Groundwater inflows into North East Link structures may be subject to Southern Rural Water licensing requirements.

7.2.3 Disposal

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 assess and, where required, take action to ensure compliance.

The loss of groundwater from the bedrock aquifer system is not considered significant in terms of the overall abstractive resource. The bedrock aquifer is regionally extensive in size and the annual volumes of water take as part of the action would be small compared with the overall recharge. Notwithstanding, the salinity of the aquifer limits its capacity for abstractive benefit.

7.3 Construction impacts

This section describes the potential groundwater construction impacts on the environment with a focus on those aspects of the action affecting Commonwealth land. Groundwater can impact MNES indirectly and such effects are discussed in PER Technical Appendix A – Flora and fauna. However, mitigation measures that minimise groundwater impact pathways, and thus indirectly influence impacts to flora and fauna are discussed in this section.

7.3.1 Impact to groundwater quality

Resource or receptors affected

Under Victoria's *Environment Protection Act 1970* and the SEPP (Waters), groundwater has defined beneficial uses depending on its salinity and the groundwater quality, which must be protected to preserve these identified beneficial uses. Potential groundwater quality changes may arise during construction of North East Link 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.

The value of the groundwater resource varies according to the beneficial uses. The bedrock aquifer is generally saline, which has perhaps been a deterrent to its development and limits its abstractive beneficial uses. Owing to the elevated salinity (within Commonwealth land), the bedrock aquifer is considered to have a low sensitivity to impact.

The alluvial aquifers tend to be much fresher, owing to greater recharge rates and interaction with waterways. However, existing abstractive development is limited, and future development of the resource is unlikely owing to licensing limitations (eg offsets from waterways). Owing to its limited extent in, or close to the western part of the Commonwealth land (nearest to North East Link) it is not considered to have development potential for abstractive purposes. A sensitivity of groundwater in the alluvial aquifer to impacts is also ascribed as being low.

Impact description and evaluation

It is possible that construction activities may result in localised groundwater quality impacts as a result of spillage or improper handling and application of hazardous materials, such as the refuelling and maintenance of construction plant and equipment. This type of impact has the potential to occur anywhere within the project boundary.

The likelihood of these environment incidents is low because the construction would be required to implement controls to manage chemicals, fuels and hazardous materials to manage these risks (see below). 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 should a release of hazardous material occur to the environment, incident response procedures are likely to occur promptly, such as the use of spill kits/containment, or to reduce the severity of the consequence though source removal. Within the Commonwealth land the unsaturated zone can be large (over 10 metres in places), making groundwater less vulnerable to surface spills of hazardous materials.

A second pathway where groundwater quality could be effected is through artificial recharge activities (where contaminated water is introduced into the aquifer via injection). This activity may be undertaken to dispose of surplus waters inflowing into excavations, or to impart hydraulic controls to mitigate the migration of contaminated groundwater or water level changes.

Through these two risk pathways, the volume of aquifer potentially impacted would likely be small as water quality changes would likely be highly localised (spills tend to be metres in size). In addition, groundwater travel times are slow requiring years for groundwater to travel tens of metres.

Proposed avoidance and mitigation measures

Implementation of management measures during construction is the primary means of avoidance and mitigation to control this impact and is assumed in the impact evaluation above. These avoidance and mitigation measures would include:

- Implementation of a Construction Environmental Management Plan (CEMP), including controls to manage chemicals, fuels and hazardous materials
- Where appropriate, reinjection of groundwater to mitigate the effects of construction dewatering (licensing process is regulatory controlled under Victoria’s *Water Act 1989.*

While not strictly a mitigation measure, additional groundwater monitoring would be required to identify whether this impact was unexpectedly occurring, and to assess groundwater quality throughout the construction. Monitoring would include:

- Establishment of baseline condition to characterise the groundwater environment pre-construction
- Ongoing groundwater monitoring during construction.

Aquifer recharge is a licensable act under the Water Act and so the water quality of the injection fluids would need to be consistent with the SEPP (Waters). Water quality would also need to be of a standard that makes recharge technically achievable and practicable (minimises mechanical, biological or chemical clogging) and is compatible with native groundwater quality. As part of the licensing process the licensing authority Southern Rural Water may seek an assessment of the proposed impacts to groundwater from the proponent seeking the aquifer recharge licence, and may use EPA Victoria as a referral agency. It is noted however that opportunities for artificial recharge within the project area are possibly constrained by the geological setting, and access to available land to establish such a scheme.

Residual impact

With the proposed control measures, the likelihood of impacts being realised is further reduced. The aquifer recharge licensing systems effectively eliminates the risk of contaminated materials being introduced into aquifers.

Should an incident occur and groundwater quality impacts be identified through the monitoring program, legislative controls for breaches of the SEPP (Waters) could include groundwater clean-up and restoration of water quality. With the proposed control measures, the residual impact significant is considered low, and not significant.

7.3.2 Impact to existing groundwater users from water level decline

Resource or receptors affected

Water level changes can affect the following receptors:

- Existing (and future) groundwater users (bores used for stock and domestic, irrigation, commercial and industrial purposes)
- There may be environments that may also rely upon groundwater, such as GDEs. Ecological receptors are addressed in PER Technical Appendix A – Flora and fauna.

Limited existing abstractive groundwater development has been identified in the project boundary (and none on Commonwealth land). It is suspected this is due to the mostly urbanised land setting, saline groundwater quality and low bore yields. No evidence of groundwater pumping has been identified in the water level responses of North East Link groundwater monitoring bores. Groundwater investigation (and monitoring) bores have been identified. However, these are typically used for the measurement of groundwater level and groundwater quality and are not used as a water resource.

Because alternative water supply options are available (such as reticulated supply) these abstractive receptors are considered to have a low sensitivity to impact.

Impact description and evaluation

A change in groundwater levels arising from North East Link could result from:

- Dewatering of excavations to enable construction below the water table
- Seepage into structures during construction, limited by the water tightness of the completed structures
- Use of groundwater by the construction contractor as water supply to service construction requirements, as an alternative to using potable drinking water supplies.

This potential impact is shown schematically in Figure 7-1. A bore is located near to the North East (in this case a cut and cover trench section). Once North East was constructed, water levels would be drawdown due to construction dewatering or inflow into a drained or un-tanked structure. The change in water levels at the private bore can effect bore operation.

The predicted scale of impact (the extent of water levels changes) would depend upon the causal mechanism. For example, the drawdown from a construction water supply bore intermittently operated may be different to dewatering of a large excavation. In general, as dewatering effects would be occurring across a large area of the action (several hundred metres of trench adjacent Commonwealth land) the scale of impact would be high.

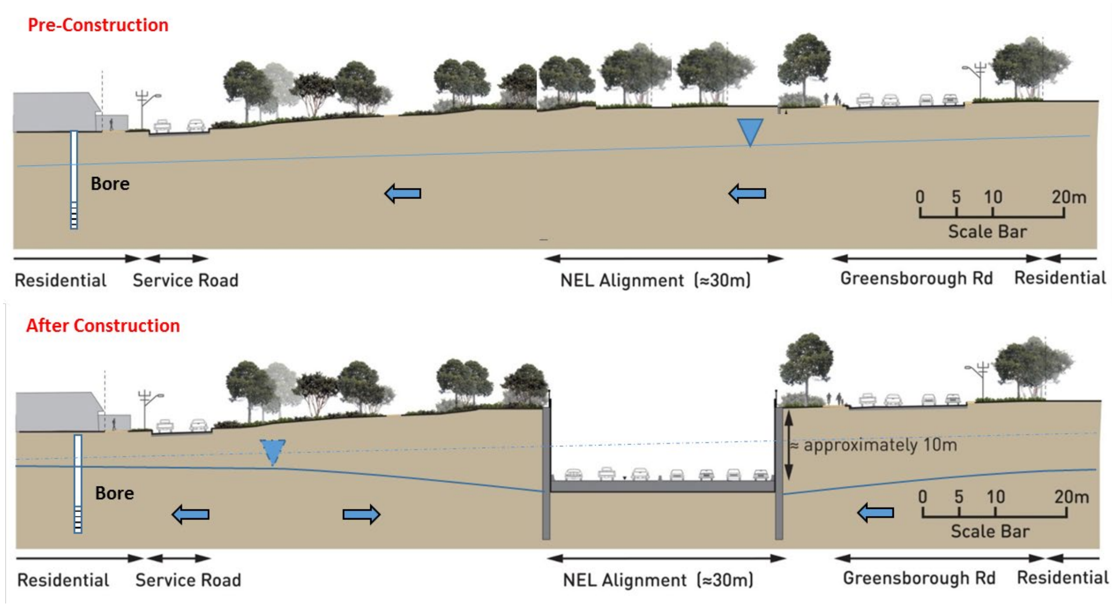


Figure 7-1 Impact to existing users

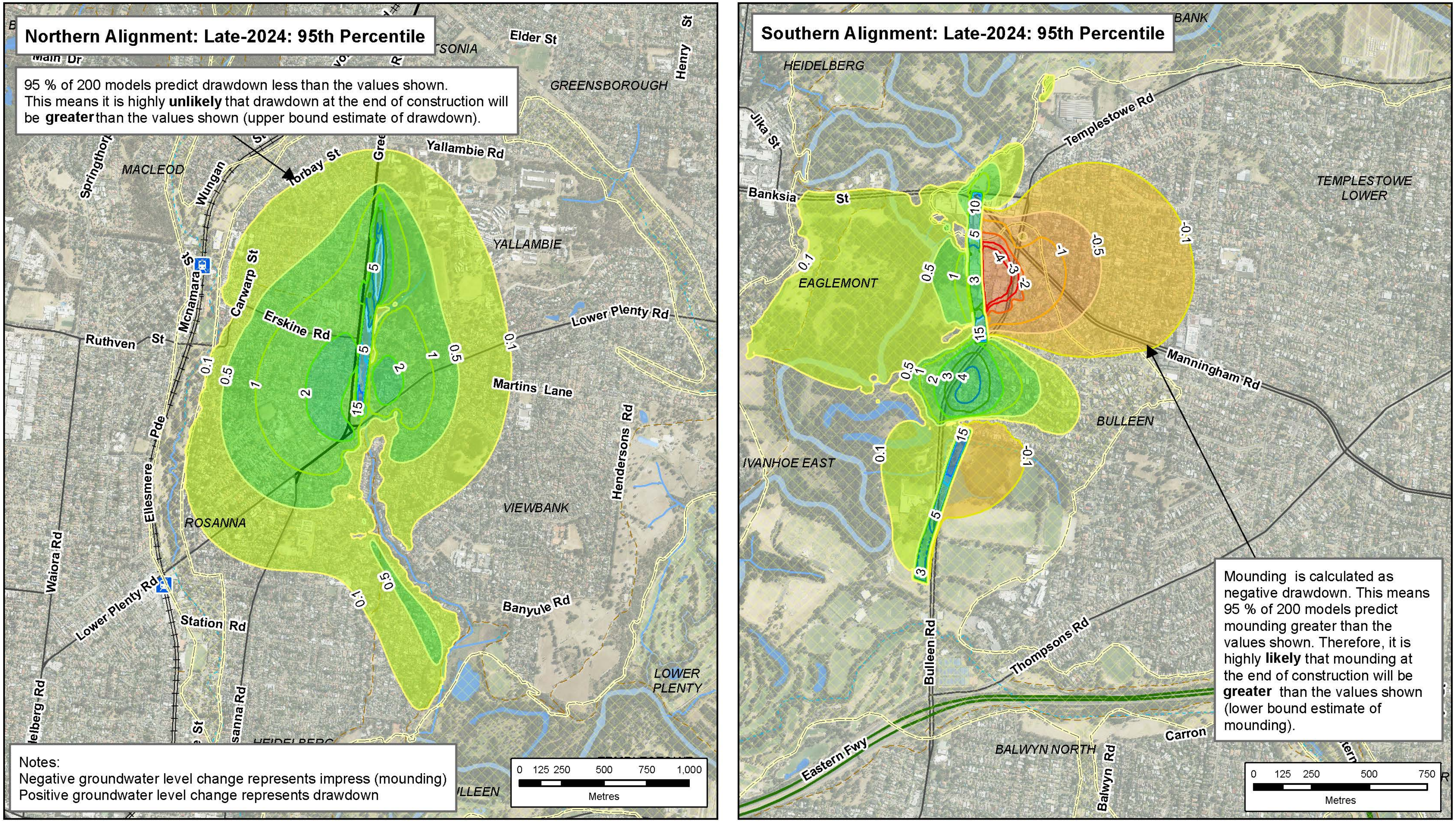
There is increasing pressure for contractors to use alternative supplies of water for construction purposes to reduce stress on potable drinking water supplies. A contractor could place production bores on available land to suit their construction requirements. In some cases, contractors do not specifically install groundwater bores, but 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. This industrial use of groundwater is a licensable act under Victoria's *Water Act 1989* (refer discussion on mitigation measures above) and so this aspect of the impact is not discussed further.

Numerical groundwater modelling has been undertaken to estimate the extent of drawdown arising from the construction of North East Link. The modelling has incorporated an uncertainty analysis (refer Appendix A) to address model non-uniqueness issues. This has resulted in the reporting of water level changes as 95th and 5th confidence intervals. The 95th percentile is relevant to areas of drawdown and denotes the drawdown extent where 95 per cent of the 200 calibrated model results are predicted. The 5th percentile, which is relevant to water table mounding, presents an area where 95 per cent of calibrated model results predicted mounding to be less than values shown. The predicted water levels are based on the reference project and the extent of tanking proposed in the trench section north of the northern portal.

The predicted extent of drawdowns towards the close of the construction period, when dewatering rates are greatest, based on the original data, are shown in Figure 7-2 and Figure 7-3 for the 95th and 5th percentiles respectively. The uncertainty analysis completed as part of the initial numerical modelling shows the contours of drawdown percentiles based on over 200 models of equivalent calibration.

As noted previously (refer Section 7.2), further groundwater modelling has been undertaken based on additional site works including incorporation of groundwater level monitoring information. The further modelling (refer Appendix B) has resulted in an improved calibration, and predicted drawdowns (or impressed heads) have reduced in size and magnitude.

Figure 7-4 shows the predicted impacts on groundwater levels based on the further groundwater modelling, noting this data does not include an uncertainty analysis as conducted as part of the initial numerical groundwater modelling. As such, Figure 7-4 is not directly comparable to Figure 7-2 or Figure 7-3.



Paper Size A4

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

N

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

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

North East Link Project
Environment Effects Statement (EES)

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Predicted drawdowns:
95th Percentile
(construction, initial modelling)

Figure 7-2

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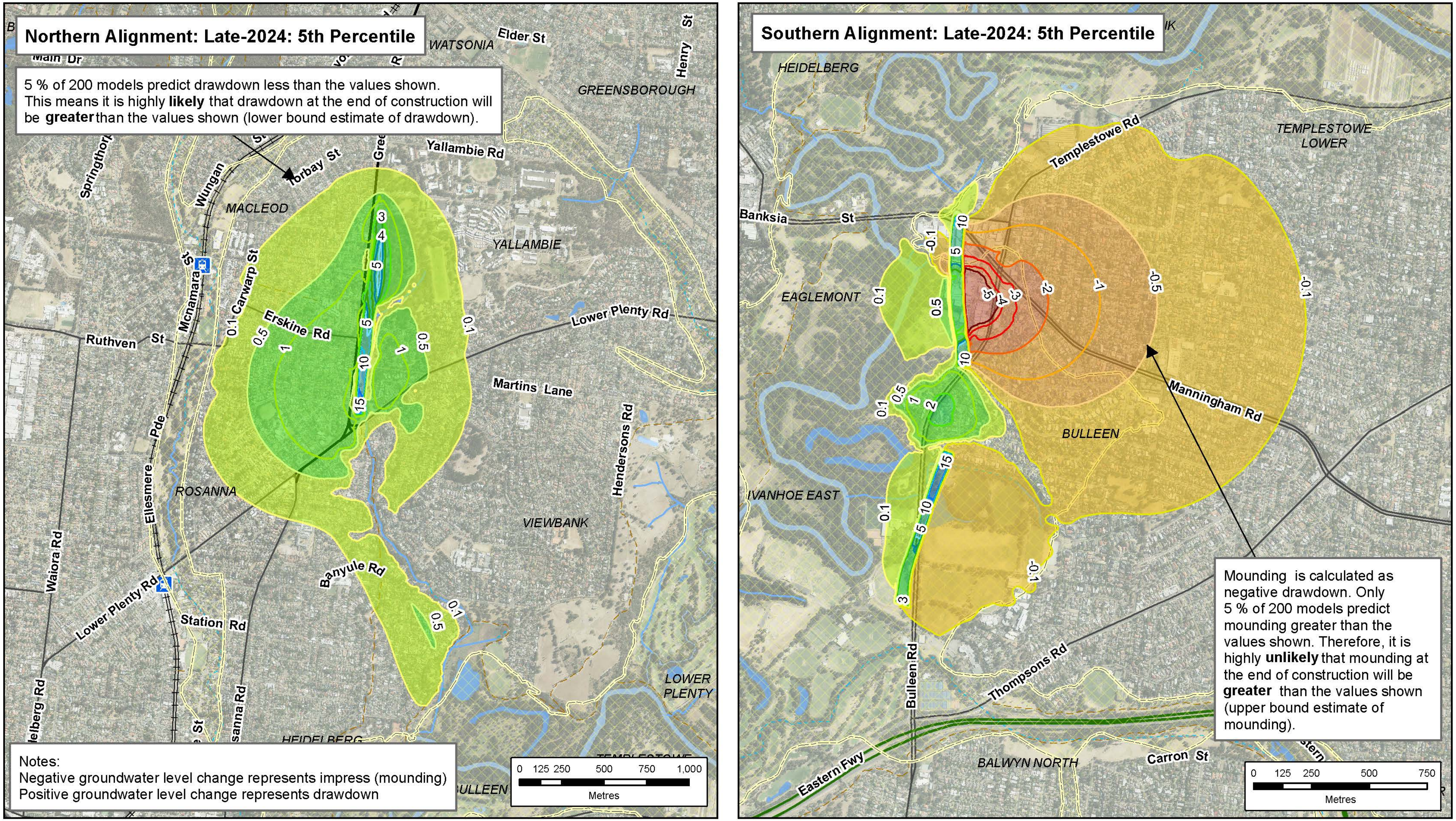
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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



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 G
Date 22 Aug 2019

Predicted drawdowns:
5th Percentile
(construction, initial modelling)

Figure 7-3

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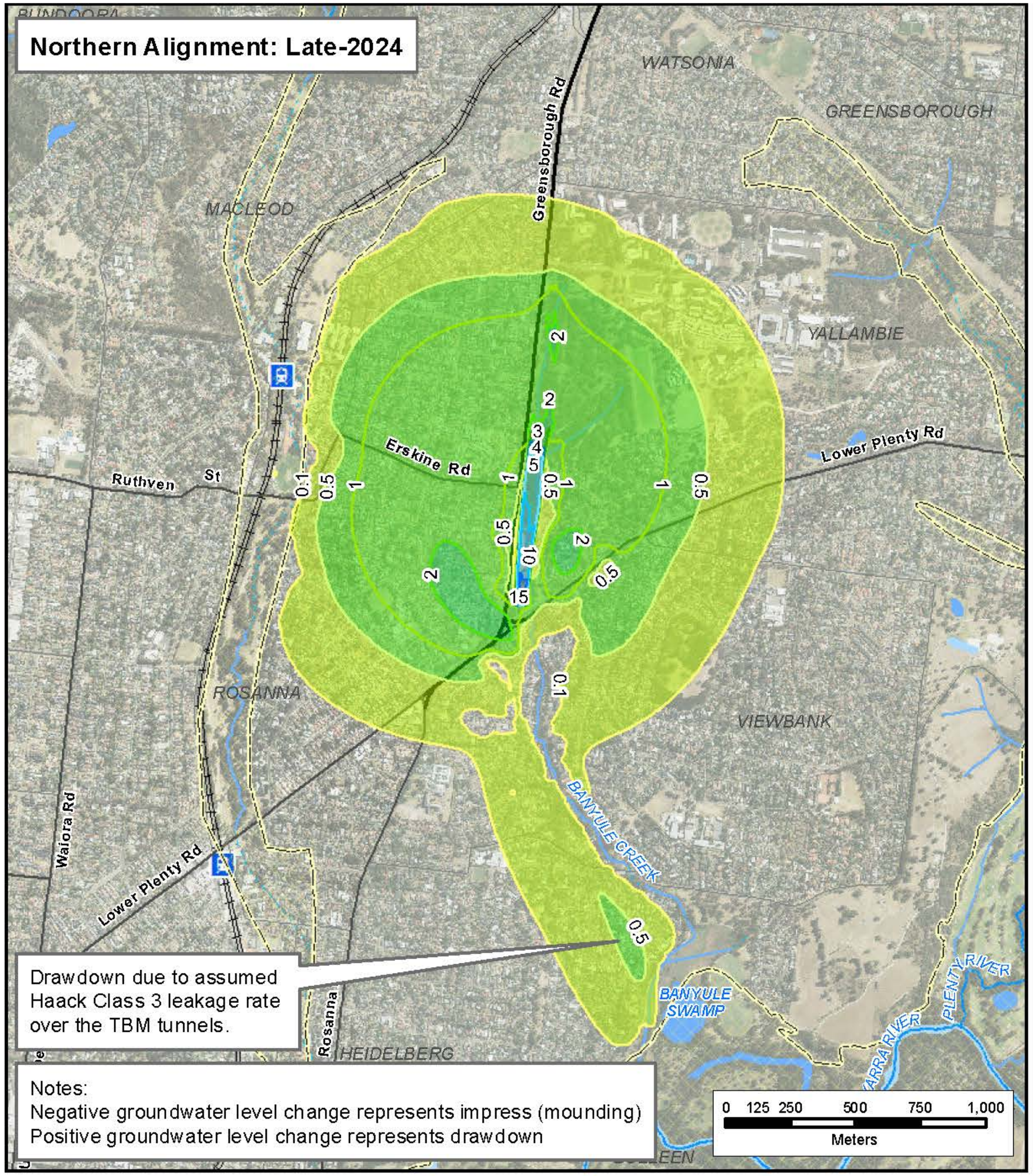
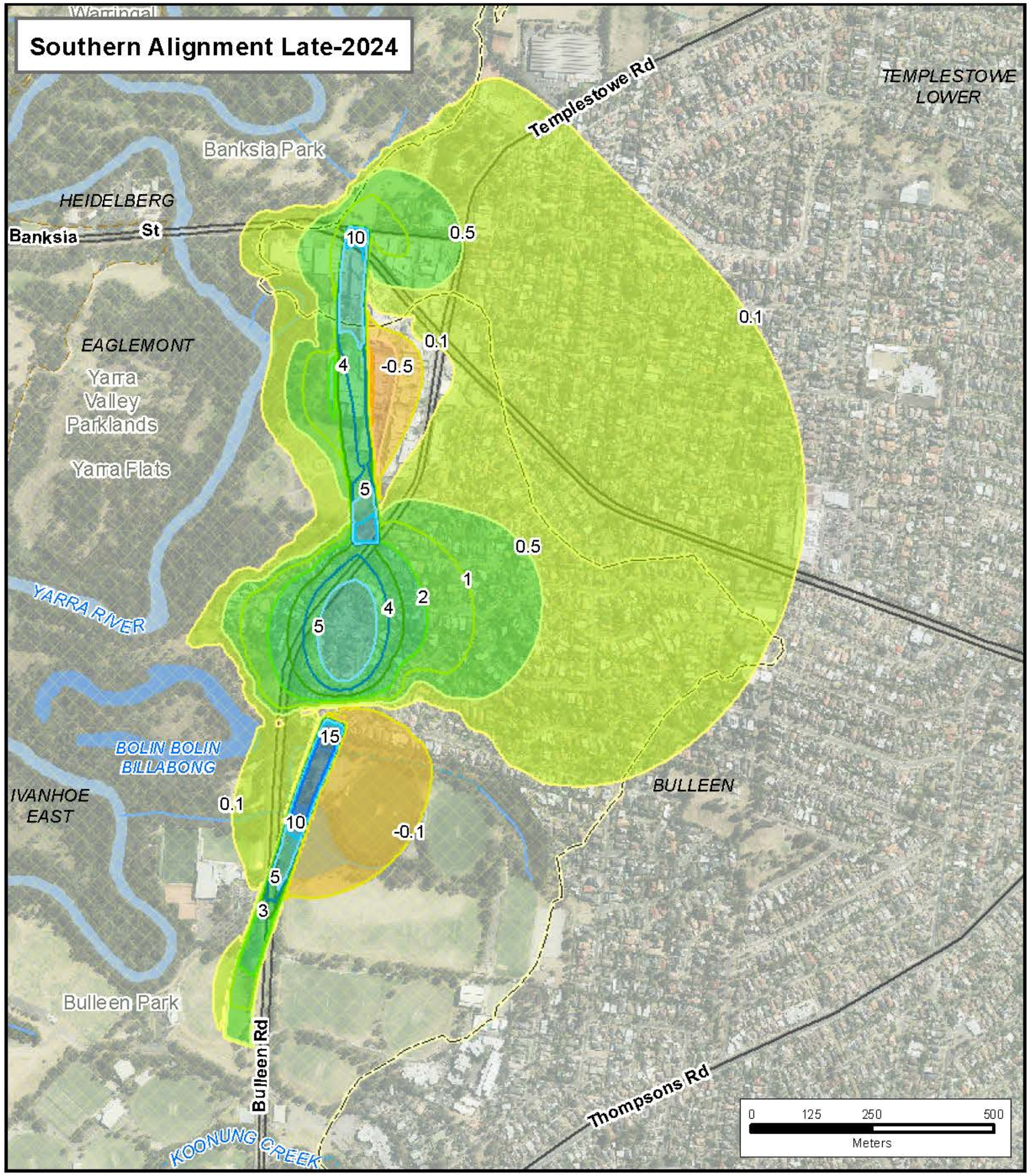
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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





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)

- -0.49 - -0.1
- 0.11 - 0.5
- 0.51 - 2
- 2.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- Alluvium

North East Link Project

Job Number	31-35006
Revision	E
Date	23 Aug 2019

Predicted groundwater level changes (construction, further modelling)

Figure 7-4

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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:mjshrives

Large areas of North East Link works would be undertaken at, or above ground level and so lowering of the groundwater table would not be required, such as for the interchange and upgrade works associated with the M80 Ring Road and the Eastern Freeway. As noted in Section 6.13, construction in the floodplains (channelization of flows, wetland and retarding basin creation) tend to locally shift groundwater dynamics within the floodplain itself and are considered to be of low risk in terms of groundwater effects. The assessment of impacts is focused on the area of North East Link where drawdowns are predicted to occur— the stretch extending between Watsonia railway station (north) to near Koonung Creek (south). Within this reach, drawdowns are predicted during construction to extend beneath Commonwealth land.

Greatest drawdowns would occur nearest the excavation faces and the drawdown would decrease with increasing distance from the tunnels or excavations, and expand while pumping occurs until steady state conditions are reached. Based on the understanding of groundwater levels in relation to the grade line, as the trench structure dives from Watsonia railway station towards the south and Lower Plenty Road, it would likely intersect the water table to the south of Blamey Road (Commonwealth land). The greatest magnitude of dewatering would occur at the northern portal/TBM tunnel entrance (near the Greensborough Road and Lower Plenty Road intersection) where the structure would be at its deepest below the water table.

It is noted that the further numerical modelling undertaken (refer Appendix B) predicts less drawdown in this area, but greater inflows, which is a result of assigning increased recharge to the bedrock aquifer in this area.

South of Lower Plenty Road, TBMs would be used for constructing the twin tunnels. Drawdowns beneath the TBM areas, between Lower Plenty Road and the Manningham Road interchange, are not predicted as the permanent lining would be installed as part of the construction activities.

A summary of bores identified within the predicted extent of construction drawdown is provided in Table 7-2. Both bores are located within Commonwealth land, although changes in water levels in these two monitoring bores would not likely significantly affect their operation.

Table 7-2 Bores within predicted drawdown extent (construction)

Bore ID	Comment	Bore Depth (m)	Predicted drawdown impact
Commonwealth land			
Unknown bores (2)	Identified on Simpson Barracks. Depth unknown. Assumed to be used for environmental investigation purposes.	Not known	0.5 m to 1 m for initial modelling[1] 0.1 m to 0.5 m for further modelling[2]

Notes:
1. Based on uncertainty analysis incorporated as part of the initial modelling.
2. Based on single model run only, no incorporated uncertainty analysis, further modelling.

As noted in Section 6.8.7, seasonal water level fluctuations of 0.5 to 1 metres could be reasonably expected, with potentially a greater fluctuation during decadal influences such as droughts. Southern Rural Water typically applies a 10 to 20 per cent loss in available drawdown in a production bore as being a significant impact, although this is based on the bores having an abstractive use.

Proposed avoidance and mitigation measures

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

Mitigations can also be applied to the receptors themselves. For example:

- Lowering pumps within bores
- Drilling deeper bores
- Providing alternative supplies during construction
- Implementing recharge (between the structure and receptors) to impart controls on water level change.

If the monitoring bores on Commonwealth land become fully dewatered, bore replacement costs would be low.

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. This numerical modelling may be required to support licensing of a production bore, or the design of a recharge scheme and would be completed during detailed design.

Any groundwater bores installed for construction water supply or permanent water supply would need to be licensed by Southern Rural Water in accordance with Victoria's *Water Act 1989* 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. This legislative requirement is considered to form an effective mitigation measure.

Residual impact

With the proposed mitigation measures, residual impact significance is considered to be low.

7.3.3 Impact arising from drawdowns on acid sulfate geological materials

Resources or receptors affected

Changes to water levels which result in the generation of acidic groundwater can impact the following receptors:

- Existing (and future) groundwater users (bores used for stock and domestic, irrigation, commercial and industrial purposes). The Palaeozoic bedrock aquifer is undeveloped aquifer on the Commonwealth land (no bores with abstractive use). Some, albeit small numbers of groundwater bores have been identified outside Commonwealth land.
- Waterways receiving groundwater, or ecosystems that can access groundwater (GDEs). Ecological receptors are addressed in PER Technical Appendix A – Flora and fauna.
- Buried structures, or structures with foundations, or basements that are below the water table, and hydraulically down-gradient of the acid plume. Based on the depth to water on Commonwealth land, and a resulting gradient from drawdowns towards the west and away from Commonwealth land, adverse impact to buildings is considered unlikely. Impact to this receptor is not discussed further.

The groundwater system has been disturbed (contamination identified in some areas) and the salinity results in the bedrock aquifer having limited abstractive benefit. The receptors are considered to have a low sensitivity to this potential impact.

Impact description and evaluation

The reduction in water levels may exposed potential acid sulfate geological materials and generate acid plumes. This is shown schematically in Figure 7-5. The schematic shows potential acid-generating materials below the water table which are saturated.
During construction (or during operation if a drained structure), the acid-generating materials could oxidise with a reduction in water level, and a leached plume would subsequently migrate under the prevailing hydraulic gradient. The plume can adversely affect foundations in contact with groundwater, other buried structures that are hydraulically down-gradient of the plume, ecological receptors and groundwater receiving environments.

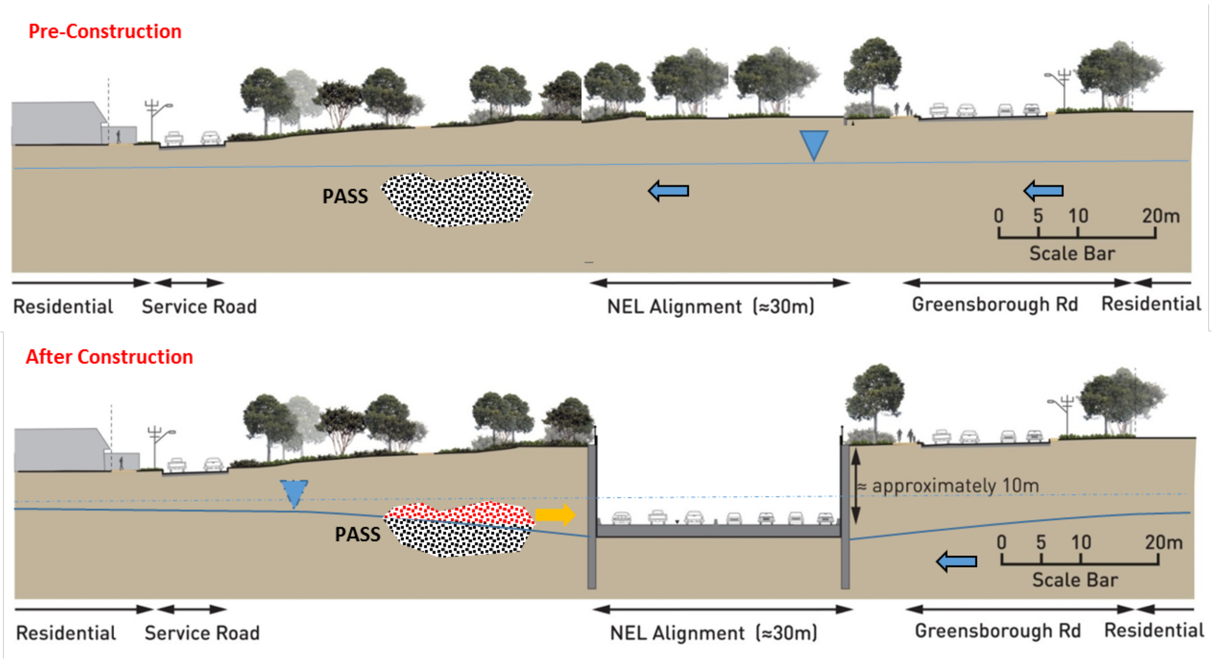


Figure 7-5 Groundwater changes and acid sulfate soil oxidation

Sampling undertaken during the North East Link geotechnical investigation program identified parts of the Palaeozoic bedrock as being potential acid-generating materials (refer Section 6.10). These bedrock samples were collected near the Manningham Road interchange, beneath the Yarra River floodplain, and near the northern portal (within 500 metres of Commonwealth land). Further evidence of potential acid sulfate soil materials may be identified with additional geotechnical investigations required to support the detailed design.

A number of factors suggest the generation of acidic groundwater conditions during construction would be low:

- Laboratory analysis of over 80 rock samples identified only four samples that were potential acid sulfate soils (no confirmed acid-generating soil or rock materials were identified). The four samples identified as potential acid sulfate soils were identified at depths greater than 20 metres below the surface in fresh bedrock.

- As the potential acid sulfate soil materials identified were associated with the deeper, fresher bedrock, this means that dewatering extents (and magnitudes) must coincide with these depths, which eliminates much of the drawdown extents except those close to the excavation face.

  The predicted extent of drawdowns towards the close of construction are shown in Figure 7-2 and Figure 7-3 for the 95th (drawdown) and 5th (mounding) percentiles respectively.

  – 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. Under these circumstances, although dewatering would extend beneath Commonwealth land, it would not expose fresh geologic material. Maximum dewatering occurs outside Commonwealth land at the Lower Plenty Road end where excavation is deepest.
  – 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 northern as well as southern portal excavations, potential acid sulfate soil materials inside the excavation extents would be removed, removing a potential source of acid-generating materials.
- At the northern as well as 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 would be 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 7-2, Figure 7-3, and Figure 7-4). The lateral extent would be controlled by the geological setting. Where alluvial sediments overlie the bedrock, drawdowns would tend to be highly constrained to close proximity to the cut-off wall. This is because the alluvial sediments are recharged at higher rates relative to the underlying bedrock and can reduce drawdown extents in the bedrock through leakage. Greater drawdowns occur within the bedrock aquifer owing to its lower permeability and lower storage, although predictive numerical modelling indicates these too are highly constrained to close proximity to the excavation.

  If acid-generating geological materials were identified as 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 upon the water tightness achieved).
- With increasing distance from the cut-offs at the northern or the southern portals, the drawdowns decline. Typically at distances greater than a few hundred metres from the cut-off walls, the drawdowns are between 0.1 to 0.5 metre (for both the initial and further modelling). These drawdowns are within the range of seasonal fluctuation and so geological materials are likely to have already been oxidised, or drawdowns are too small to result in the unsaturation and oxidation of fresh bedrock.
- The duration of construction would likely be short (two to three years) so provides limited opportunity for rainfall recharge to infiltrate and generate a flux of leaching water, which has to 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 (in both the initial and further modelling). No abstractive groundwater use has been identified on Commonwealth land and the elevated groundwater salinity suggests that future groundwater development either on or adjacent to Commonwealth land would be unlikely.
- 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 suitable pH levels in the future.
- Geotechnical investigations (Geotesta, 2016) indicated that potential acid sulfate soils were unlikely to be present in the Bolin Bolin region. Soil pH analysis did not identify low pH. Coffey (2012) borehole logs indicated that sediments tended to be coarser grained (sands) with no obvious evidence of potential acid sulfate materials or indicators recorded on lithological logs.

Proposed avoidance and mitigation measures

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 construction. Designers would also need to consider the water chemistry and potentially aggressive nature of groundwater on foundation materials.

Notwithstanding the unlikely nature of the impact, a monitoring program would be implemented to determine the magnitude of change in groundwater levels and assess the reliability of the predicted drawdown estimates. A Construction Environmental Management Plan (CEMP) would need to include measures to manage spoil recovered from excavations identified to be acid-generating, and provide contingency actions if monitoring indicated pH changes in groundwater.

Residual impact

With the proposed mitigation measures, the significance of residual impacts is considered to be low.

7.3.4 Impact arising from drawdowns on contaminated groundwater plumes

Resources or receptors affected

Changes to water levels can dislocate contaminated groundwater plumes, or cause native groundwaters of differing quality to mix (saline intrusion). This can impact the following receptors:

- Existing (and future) groundwater users (bores used for stock and domestic, irrigation, commercial and industrial purposes)
- Waterways receiving groundwater, or ecosystems that can access groundwater (GDEs). Ecological receptors are addressed in PER Technical Appendix A – Flora and fauna
- Generate vapour hazards for overlying residential properties overlying the contaminated groundwater plume.

The groundwater system has been disturbed (contamination identified in some areas) and the salinity results in the bedrock aquifer having limited abstractive benefit. The receptors are considered to have a low sensitivity to this potential impact.

Impact description and evaluation

The reduction in water levels may influence the migration of contaminated groundwater plumes. This is shown schematically in Figure 7-6. The schematic shows 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 densities contrast between native groundwater and the contamination constituents). During construction (or during 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 action. While the schematic shows a section near the northern portal, the concept is the same for the tunnel sections (TBM and mined) and southern portal.

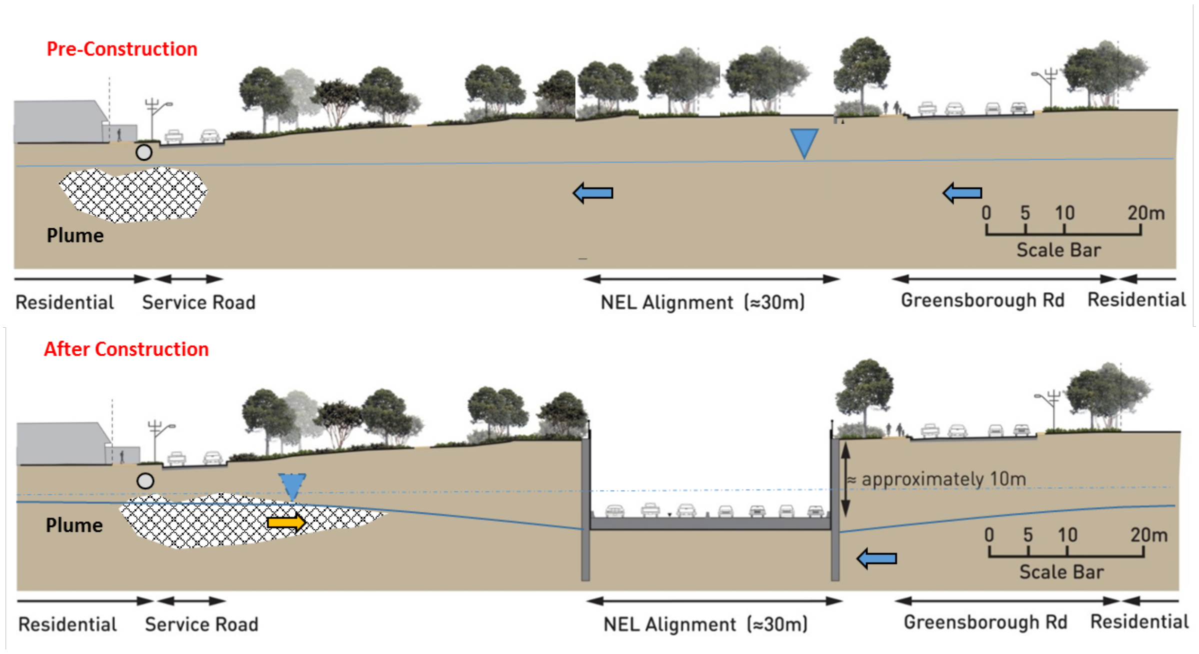


Figure 7-6 Groundwater changes and contaminated groundwater movement

The geotechnical investigation program included a groundwater sampling program that had the objective of characterising groundwater quality from a broad project wide perspective. Groundwater quality impacts have been identified within the project boundary, including Commonwealth land (refer discussion below), and contaminated groundwater has been identified. This subsequently identified potential risk areas, however, delineating the extent of groundwater plumes was outside the scope of the investigation program.

As noted previously, North East Link would be below the groundwater surface in an area extending between Watsonia railway station (north) to Koonung Creek (south), and this forms the focus of the discussion of impacts. Within this reach, which includes Simpson Barracks and Commonwealth land, there are a number of potentially contaminating land uses which are summarised in Table 7-3. The presence of contaminated soils and groundwater at Simpson Barracks is not known and no information has been disclosed by the Department of Defence.

For this impact discussion, only the initial groundwater modelling results are used, as the minor changes from the further modelling, which reflect an improved model calibration, do not significantly add to the quantitative understanding of the impact.

Table 7-3 Potentially contaminating land uses (northern portal to southern portal, from north to south)

Location	Potential source of contamination	Potential impact pathway	Potential contaminants of concern (soil and groundwater)
Nearby to Simpson Barracks			
Watsonia Road, near Watsonia railway station **(>500 m north from Simpson Barracks)**	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 perchlorethylene 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.
Yallambie Road (cnr Greensborough Road) **(north west corner of Simpson Barracks)**	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.
Simpson Barracks	Defence information from their website confirmed 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.

Location	Potential source of contamination	Potential impact pathway	Potential contaminants of concern (soil and groundwater)
Borlase Reserve, Yallambie **(<500 m from Simpson Barracks)**	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.
Greater than 3 km away from Simpson Barracks			
Bulleen Industrial Precinct, 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 Industrial Precinct 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 Industrial Precinct on Bulleen Road	Four active and one former fuel service stations – 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 Industrial Precinct, 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 Industrial Precinct, Manningham Road	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 Industrial Precinct, 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 Industrial Precinct, 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 Industrial Precinct, 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 Industrial Precinct, 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.
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 Public 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.

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 changes to groundwater levels during construction is shown in Figure 7-2 and Figure 7-3 for the 95th percentile (drawdown) and 5th percentile (mounding) respectively.

While it is recognised there are a number of potentially contaminating land uses within the project boundary, groundwater sampling undertaken as part of the geotechnical investigation program has generally not identified obvious evidence of widespread contamination. However, groundwater quality impacts have been identified in the following areas where water levels changes are predicted:

- The fuel service station (located within the project boundary) and Simpson Barracks are nearest to the proposed areas requiring construction dewatering, and the predicted extents of dewatering during construction do extend as far as the service station. Recent findings from the geotechnical investigation have identified hydrocarbons in bore NEL-ENV-BH022, which is south of the service station at the intersection of Yallambie and Greensborough Roads. This is located on Commonwealth land.
- Near Lower Plenty Road, the northern portal trench would intersect sediments of the Borlase Reserve Landfill. Construction of the northern portal itself would also result in the intersection and removal of fill materials. This area is located within 500 metres of Commonwealth land.
- Polyfluoroalkyl Substances (PFAS) contamination (bore NEL-BH062) at the former Bulleen Drive-in. This is remote from Commonwealth land, but the site abuts the Yarra River. PFAS has also been identified near Watsonia railway station, although this is outside the predicted extent of construction dewatering.

As there are no existing abstractive groundwater use near any of these locations, the significance of the changes in water levels and the resulting impact to groundwater quality (plume movement) is considered to be low. In the case of the northern portal areas (including Commonwealth land), groundwater salinity would limit future development of groundwater resources for abstractive benefit. The former Bulleen Drive-in is mostly within 300 metres of the Yarra River, which is within the offset distance for licensing purposes.

It is noted there are a number of potentially contaminating land uses in the commercial precinct near the Manningham Road interchange, such as multiple fuel service stations, cement works and dry cleaners. Without North East Link, the Yarra River is a likely receiving environment for groundwater discharge. Construction of North East Link may assist in mitigating impacts to groundwater receiving environments:

- North East Link would influence groundwater levels, and create a depression in the groundwater table with localised flow towards excavations during construction (refer Figure 7-2 and Figure 7-3 for the 95th percentile (drawdown) and 5th percentile (mounding) respectively). A component of contaminated groundwater flow discharging to the Yarra River may be intercepted by North East Link structures and disposed elsewhere (after treatment)
- The short construction timeframe (estimated two to three years) does not provide time for migration of a groundwater plume over significant distances
- Excavation activities within the project boundary may remove contaminated spoil and aid source removal.

Proposed avoidance and mitigation measures

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 construction. While this controls drawdowns and the influences upon the movement of contamination, addition controls are required to those areas where contaminated groundwater has been identified. This is to prevent adverse health risks to construction works and the public, but also to prevent the project from displacing, mobilising or spreading the existing contamination.

Managing the migration of contaminants would be achieved by:

- Ongoing groundwater monitoring during construction
- Measures to minimise changes to groundwater levels through tunnel construction methods
- Implementing contingency measures and/or controls as required to manage, mitigate and minimise to the extent practicable any movement of contamination that is identified (source removal, clean-up or hydraulic controls)

  For example, the contamination identified associated with the fuel service station near the intersection of Yallambie Road and the Greensborough Bypass would need to be assessed and the plume delineated, particularly as the reference project alignment is through this region. Where risks to the groundwater are unacceptable, in terms of impact to beneficial uses, groundwater clean-up may be required before construction of North East Link started, or procedures put in place during construction to manage the interception of contaminated groundwater and the risks to construction worker health and safety. A similar approach would be required for the PFAS contamination identified at the former Bulleen Drive-in, at the site of the proposed Manningham Road interchange
- A Groundwater Management Plan would be developed and implemented to protect groundwater quality and manage interception of groundwater. If appropriate, the plan would contain measures to manage contaminated spoil, 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 would address vapour risks associated with soil, groundwater and landfill conditions as well as measures to manage odour
- Contaminated groundwater that is captured by the project would be appropriately managed and disposed.

Residual impact

With the implementation of the mitigation measures described above, the impact could be reduced and the residual impact upon Commonwealth land, and potential groundwater receiving environments, is considered to be low.

7.4 Operational impacts

This section describes the potential groundwater operational impacts on the environment with a focus on those aspects of North East Link affecting Commonwealth land. Groundwater can impact MNES indirectly and so effects are discussed in PER Technical Appendix A – Flora and fauna. Mitigation measures that minimise groundwater impact pathways, and thus indirectly influence ecological impacts are, however, discussed in this section.

7.4.1 Impact to groundwater quality

Resources or receptors affected

The receptors that could be affected are as per the construction phase.

As per discussions in Section 7.3.1, groundwater is not currently developed for extractive benefit on Commonwealth land, and limited development occurs in the greater region.

Owing to the elevated salinity of groundwater in the bedrock aquifer, and limited likelihood of future development, it has a low sensitivity to impact.

Receptors would also include groundwater receiving environments and GDEs. Assessment of impact to GDEs is documented in PER Technical Appendix A – Flora and fauna.

Impact description and evaluation

During operation of North East Link, groundwater quality changes have the potential to occur through two pathways:

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

Without mitigation, release of contaminants from traffic accidents has the potential to result in major impacts to groundwater quality, but this risk is possible across all the state's road networks. As noted for during North East Link's construction, the pathway of the groundwater contamination process is complex. Vehicle accidents are generally localised and an emergency services response would likely be rapid, reducing the potential for migration of contaminants from the surface to the underlying groundwater system.

Once operational, 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 need to pond and then vertically infiltrate the water table, before it could be 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 has included a number of water treatment features along the alignment that would filter and treat the stormwater captured from the new road surfaces.

Spillage or the more deliberate management of stormwater would generally be confined to localised areas of North East Link. The scale of impact is considered to be small.

Proposed avoidance and mitigation measures

Mitigation measures would include:

- Prepare and implement an Operation Environmental Management Plan (OEMP) for the management, monitoring, reuse and disposal of groundwater inflows during operation that comply with relevant legislation and guidelines, specifically SEPP (Waters).

  Water sensitive urban design (WSUD) principles would be applied to the stormwater management regime and landscaping. This could result in features such as grass swales, wetlands and bioretention ponds being incorporated into North East Link's design to naturally treat run-off or stormwater from the local stormwater drainage system. These WSUD features could range from approximately 45 m^2 to 3,000 m^2 in size. Drainage design and stormwater management is discussed further in PER Technical Appendix C – Surface water.

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.

- To minimise the potential of spilled liquids ending up in waterways, North East Link would include spill containment features on freeway pavements (including ramps) designed in accordance with AusRoads Guidelines.

A post-construction groundwater quality monitoring program would monitor during the first two years of operation. Long-term groundwater monitoring post construction (beyond two years) is not proposed provided that a review of groundwater condition at North East Link's completion (end of construction) confirmed that no adverse impacts had 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.

Residual impact

As the controls are included in the initial assessment, the residual significance of impact remains low.

7.4.2 Impact to existing users and depletion of groundwater resources

Resources or receptors affected

The receptors that could be affected are as per the construction phase.

As per discussions in Section 7.3.1, groundwater is not currently developed for extractive benefit on Commonwealth land, and limited development occurs in the greater region. Owing to the elevated salinity of groundwater in the bedrock aquifer, and limited likelihood of future development, it has a low sensitivity to impact.

Receptors would also include groundwater receiving environments and GDEs (a reduction in water levels may make groundwater harder access by vegetation). Assessment of potential impacts on GDEs is documented in PER Technical Appendix A – Flora and fauna.

Impact description and evaluation

This impact has been previously described in Section 7.3.2.

There is a low density of groundwater use in the region, and availability of alternative water supplies such as mains supply. Although changes in groundwater levels during operation of North East Link are predicted to occur across a large area, the magnitude of drawdown would not be significant as it would generally be within the range of seasonal fluctuation. A worst case arises when drawdowns are imposed upon a decadal-type water level response, such as during a severe drought.

Predicted drawdowns during operation are shown in Figure 7-7 and Figure 7-8 for the 95th percentile (drawdown) and 5th percentile (mounding) respectively. In some areas, particularly those nearest the excavation, full recovery of water levels would occur following construction. In other areas, water levels would only partially recover to pre-construction conditions. The extent of drawdown during operation would be larger in extent compared with that determined for the construction, although the magnitude of drawdown would be a lot less.

It should be noted that the further modelling (refer Appendix B) indicates that groundwater drawdowns are less than that originally predicted, however, the original predictions from the initial modelling are shown as they incorporate the uncertainty analysis, and show the contours of drawdown percentiles based on over 200 models of equivalent calibration.

Figure 7-9 shows the predicted impacts on operational groundwater levels based on the further groundwater modelling undertaken, noting this data does not include an uncertainty analysis as conducted for the initial modelling results. As such, Figure 7-9 is not directly comparable to Figure 7-7 or Figure 7-8.

Following construction, the depressed water tables would begin to recover and, after 50 years, the water levels would approach a steady state condition. The extent of drawdown shown in Figure 7-7, Figure 7-8, and Figure 7-9 for the further modelling results, is influenced by a number of factors:

- The limit of tanking adopted at the northern portal. During operation, the only water that would be discharged into the structure would occur through:
  - Seepage through lining systems (refer below)
  - Seepage into structures that are below the water table but not tanked. Based on the reference project, tanking would extend approximately 600 metres north from Lower Plenty Road (start of TBM tunnelling). There would be a length of North East Link (approximately 600 metres in length) south of Blamey Road where the structure would be below groundwater level and has been assessed as not having a lining water tightness of Haack 3 classification.
- The cone of depression would expand until an area outside of the completed structure is reached where groundwater recharge is equal to the water being discharged into the structure. Recharge to the bedrock aquifer would be very low and therefore a large area (cone of depression) of bedrock aquifer would be required to supply water that seeps into structures.
- It has been assumed the water tightness of structures intersecting the water table would achieve a maximum leakage rate equivalent to a Haack 3 classification. In aiming to achieve such a water tightness objective, the constructor may attain a better water tightness. Adopting a maximum of Haack 3 classification adds some conservatism to the model.
- The drawdown figures show the extent of drawdown to 0.1 metre. Referring to Figure 1-2, the extent of drawdown continually decreases with increasing distance from the point of pressure reduction (the structure).

As noted previously the existing two bores on Commonwealth land are used for monitoring purposes and therefore their use is not affected by water level change. Bores neighbouring Simpson Barracks, in other areas where dewatering extends, are summarised in Table 7-4.

Table 7-4 Bores within predicted drawdown extent (operation)

Bore ID	Comment	Predicted drawdown impact
Within 500 m of Simpson Barracks		
Unknown bores (2)	Identified at Simpson Barracks. Depth unknown. Assumed to be used for environmental investigation purposes. **(Within Commonwealth land)**	1 m to 1.5 m for initial modelling 0.1 m to 0.5 m for further modelling
WRK98205 S9032243/1	25 metre deep bore located at fuel service station at Yallambie Road. Assumed to be used for environmental investigation purposes.	0.1 m to 0.5 m for initial modelling 0.1 m to 0.5 m for further modelling

Bore ID	Comment	Predicted drawdown impact
WRK982752 S9032219/1	Located near the intersection of Powley Parade and Greensborough Road, the bore was drilled to a nominal depth of 150 metres.	0.1 m to 0.5 m for initial modelling Not predicted to be impacted for further modelling.
Greater than 500 m from Simpson Barracks		
WRK980589 S9030648/1	Hendersons Road, bore was drilled in 2007 to a depth of 63 metres. Registered as a stock and domestic bore.	Not predicted to be impacted for both initial and further modelling
WRK983584 S9032802/1	25 metre deep bore located at fuel service station (Caltex Woolworths) on Manningham Road. Assumed to be used for environmental investigation purposes.	0.5 m to 1 m (mounding) for initial modelling 0.5 m to 1 m (mounding) for further modelling
WRK061580 WRK061579	10 metre 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 for initial modelling 0.1 m to 0.5 m for further modelling

Note: Predicted impact has been reported for both the initial and further numerical groundwater modelling undertaken. The initial numerical modelling includes an uncertainty analysis. The updated modelling (Appendix B) predicts impacts to be reduced in magnitude based on improved performance of the model. The updated findings from the further modelling are based on one model run only, and as such provide context, but are not directly comparable to the initial modelling impact predictions.

North of the tunnel portal at Blamey Road, a single private bore, bore WRK982752 (S9032219/1) was identified near the intersection of Powley Parade 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 Water Management Information System (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 0.1 to 0.5 metre loss of available drawdown for the initial modelling (no impact predicted for the further modelling). 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 would be less than 10 per cent. Based on this assessment, the impact of dewatering during operation of North East Link on existing groundwater users is considered to be low. Nearby North East Link monitoring bores (eg NEL-BH091) have not identified any obvious evidence of groundwater pumping.

As noted in the discussion of the construction impacts, seasonal water level fluctuations of one to two metres could be reasonably expected and the predicted drawdown is within the magnitude of drawdown change experienced during the Millennium Drought (refer Section 6.8.7).

In other parts of the study area where water level changes are predicted such as near the Manningham Road interchange, other bores have been identified. As noted previously, with increasing distance from excavations, the drawdowns reduce. At distances typically greater than a few hundred metres, the predicted drawdown is 0.1 to 0.5 metres for both the initial and further modelling. Such drawdowns are not considered to significantly affect operation and is within the 10 per cent licensing guidelines recommended by Southern Rural Water. Based on this assessment, the impact of 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 identify all existing groundwater users. Existing groundwater users can also be impacted if there are water quality changes.

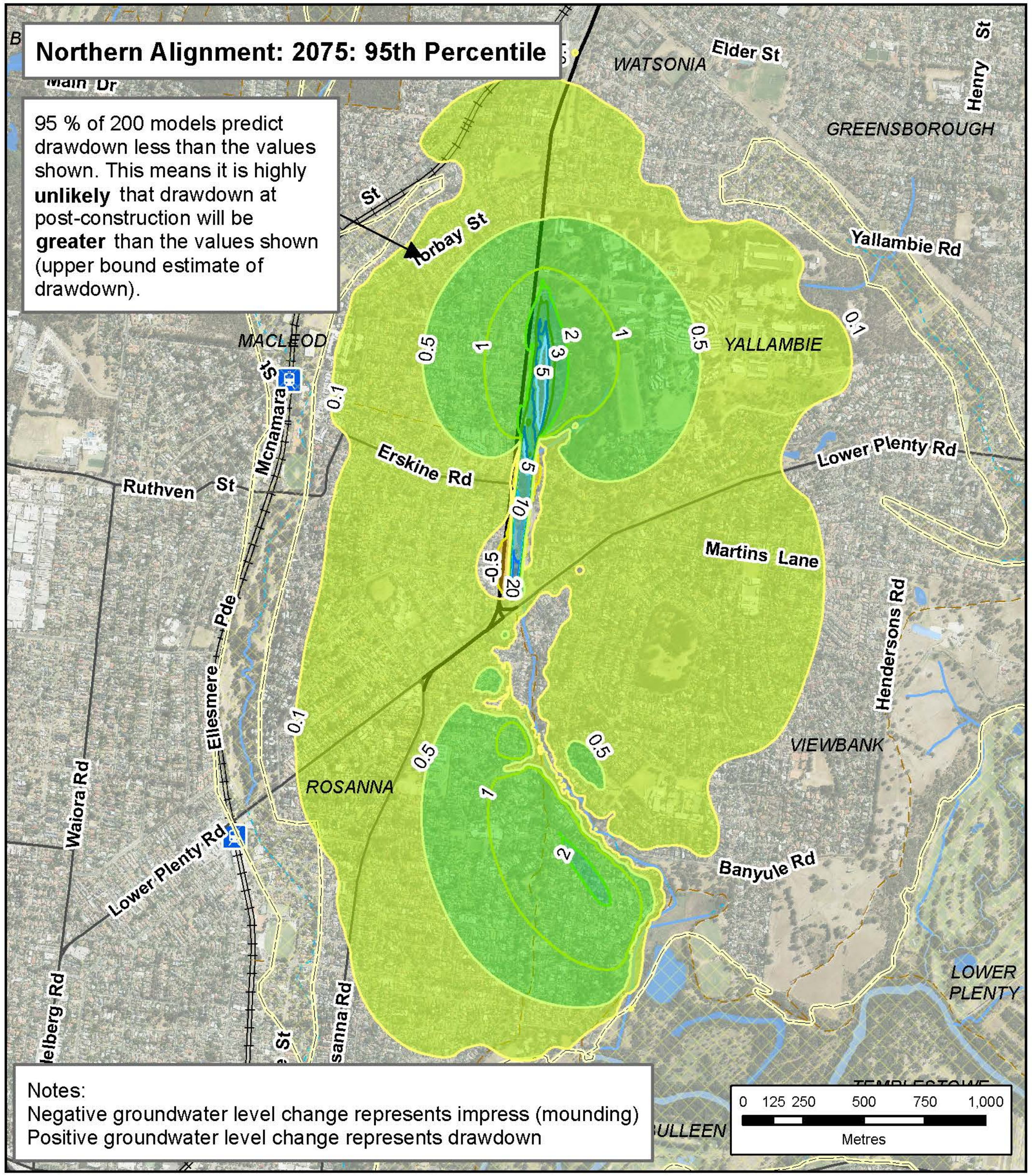
Proposed avoidance and mitigation measures

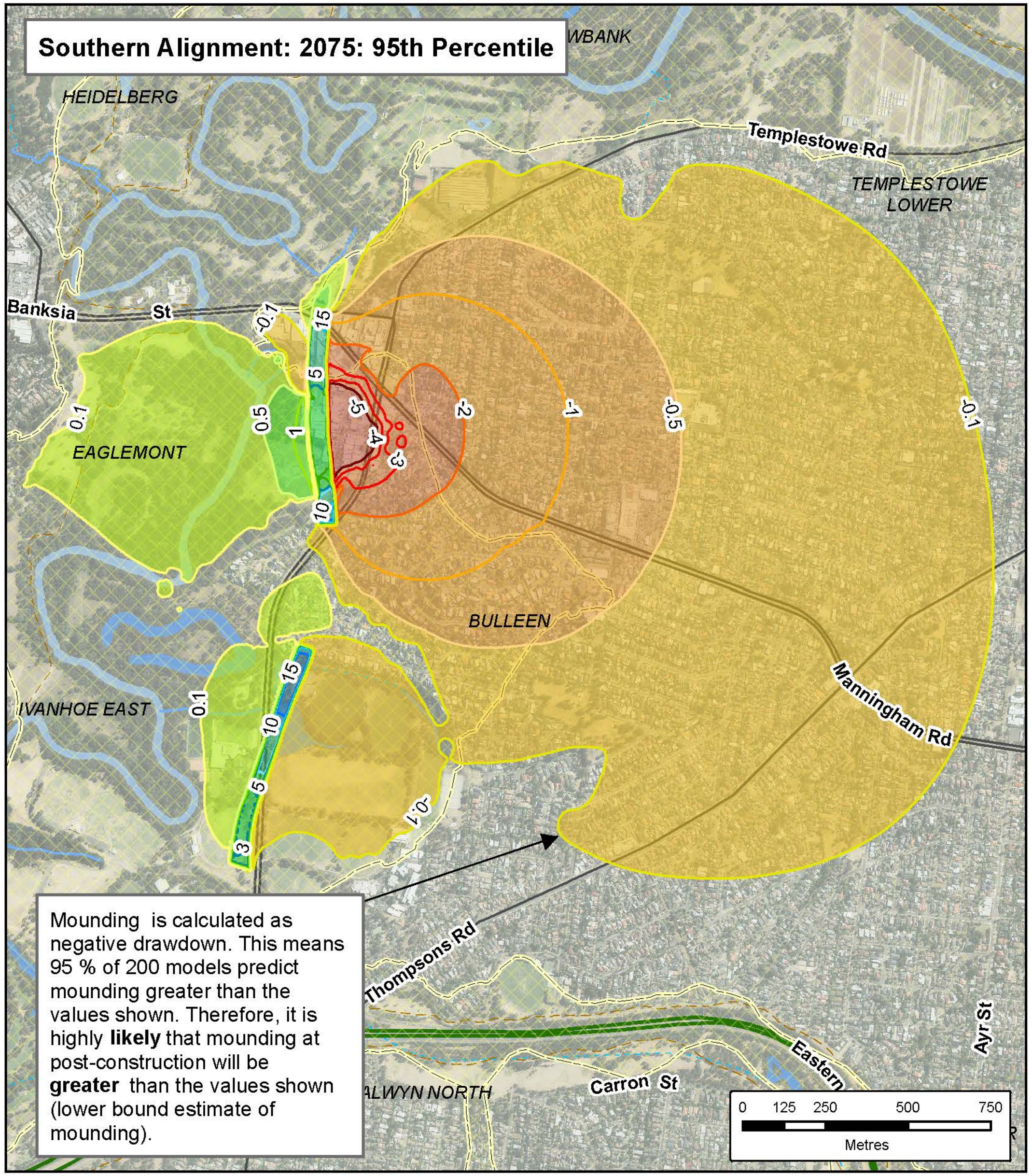
The avoidance and mitigation measures are the same as those proposed during construction. During construction, water supply to identified groundwater users would be maintained and so these controls would have been implemented before the completion of construction upon those assets identified to be at the greatest risk.

Ongoing monitoring of water levels would be required to confirm the adequacy of applied measures as identified in the Groundwater Management Plan. Private bores installed after the completion of construction would be expected to have been constructed to accommodate any longer-term water level changes.

Residual impact

With proposed avoidance and mitigation measures, the likelihood of impacts to the groundwater environment is considered limited.





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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

North East Link Project
Environment Effects Statement (EES)

Job Number 31-35006
Revision G
Date 22 Aug 2019

Predicted drawdowns:
95th Percentile
(operation, initial modelling)

Figure 7-7

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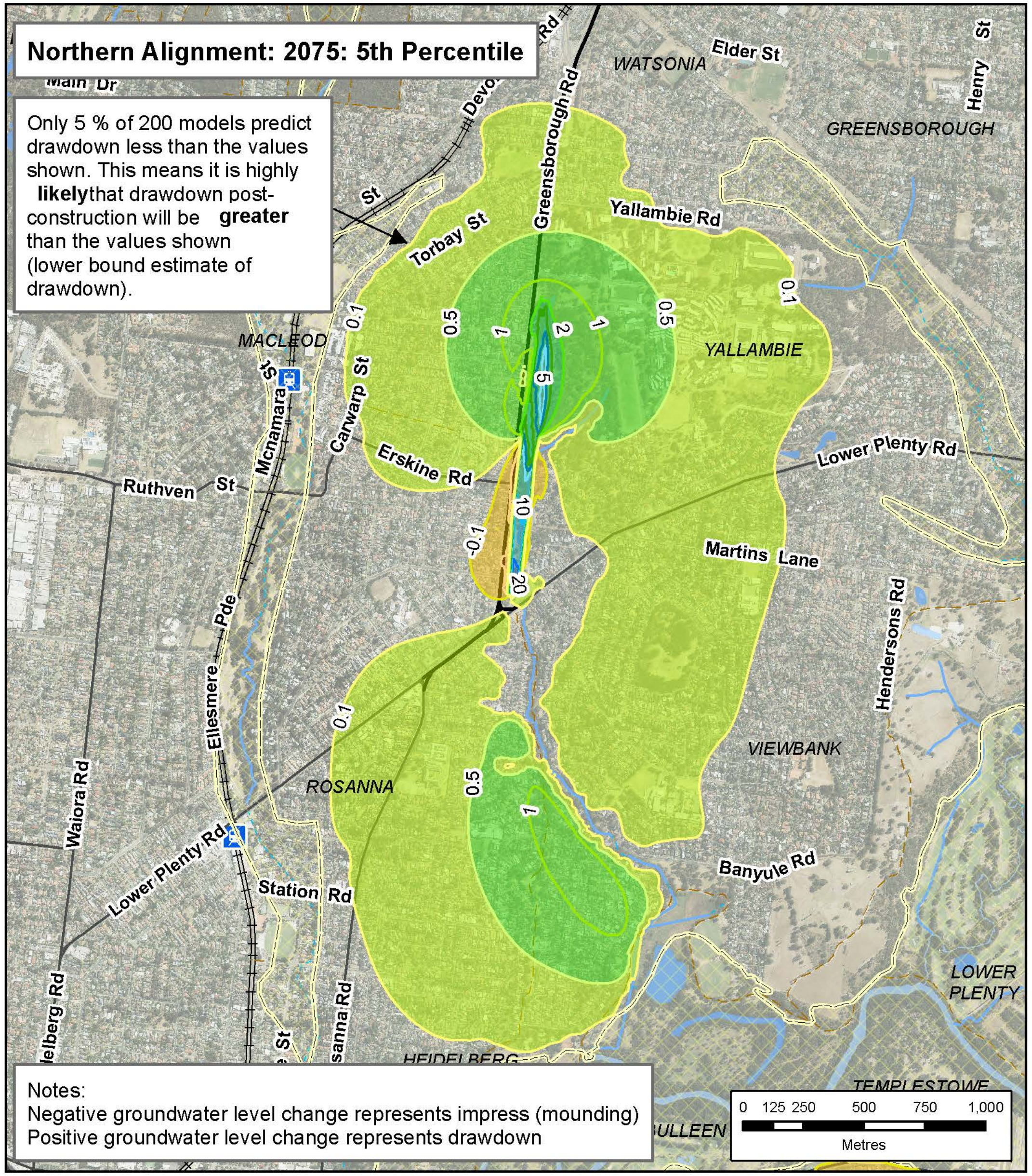
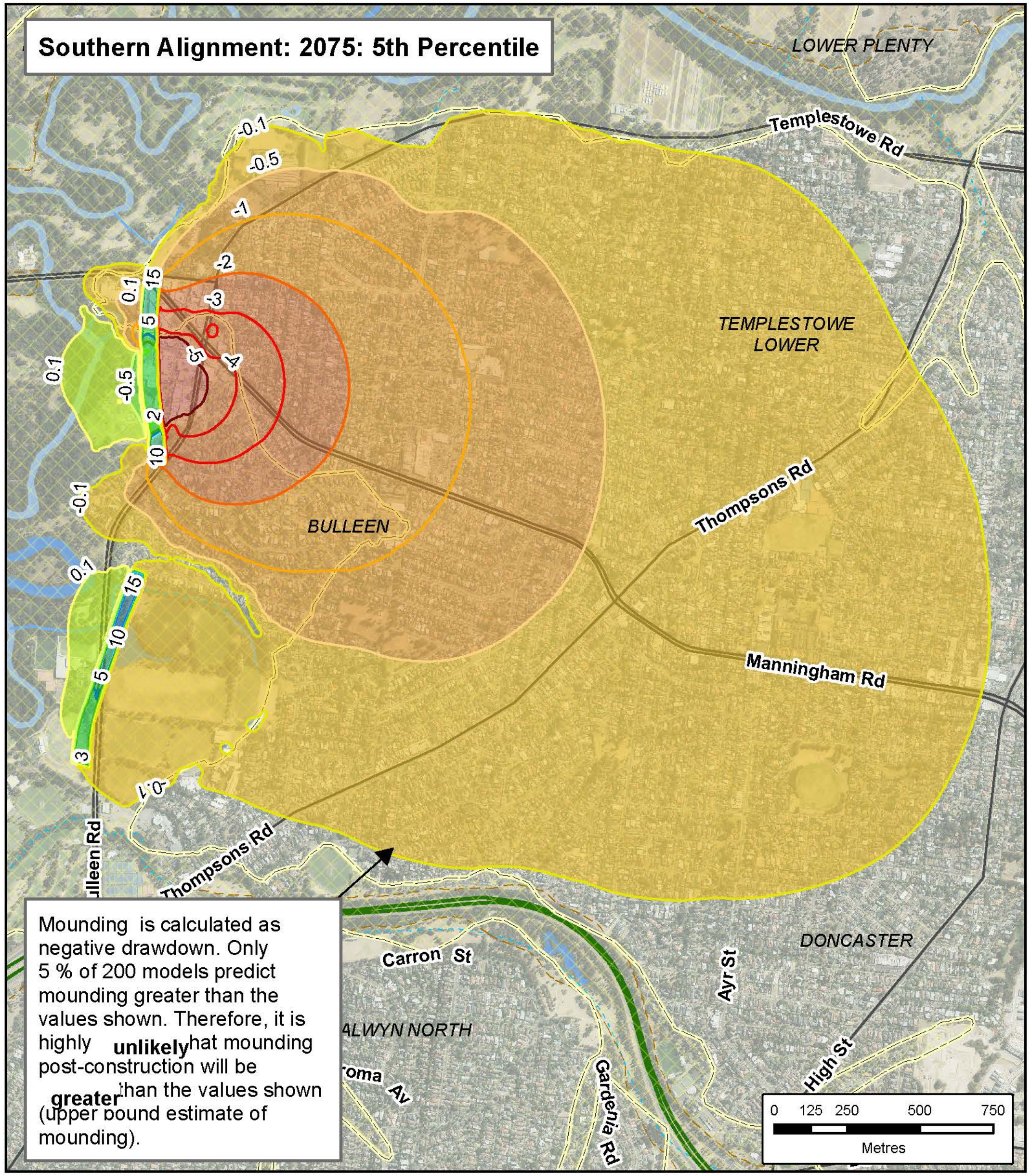
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo





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)

Predicted drawdowns:
5th Percentile
(operation, initial modelling)

Job Number 31-35006
Revision G
Date 22 Aug 2019

Figure 7-8

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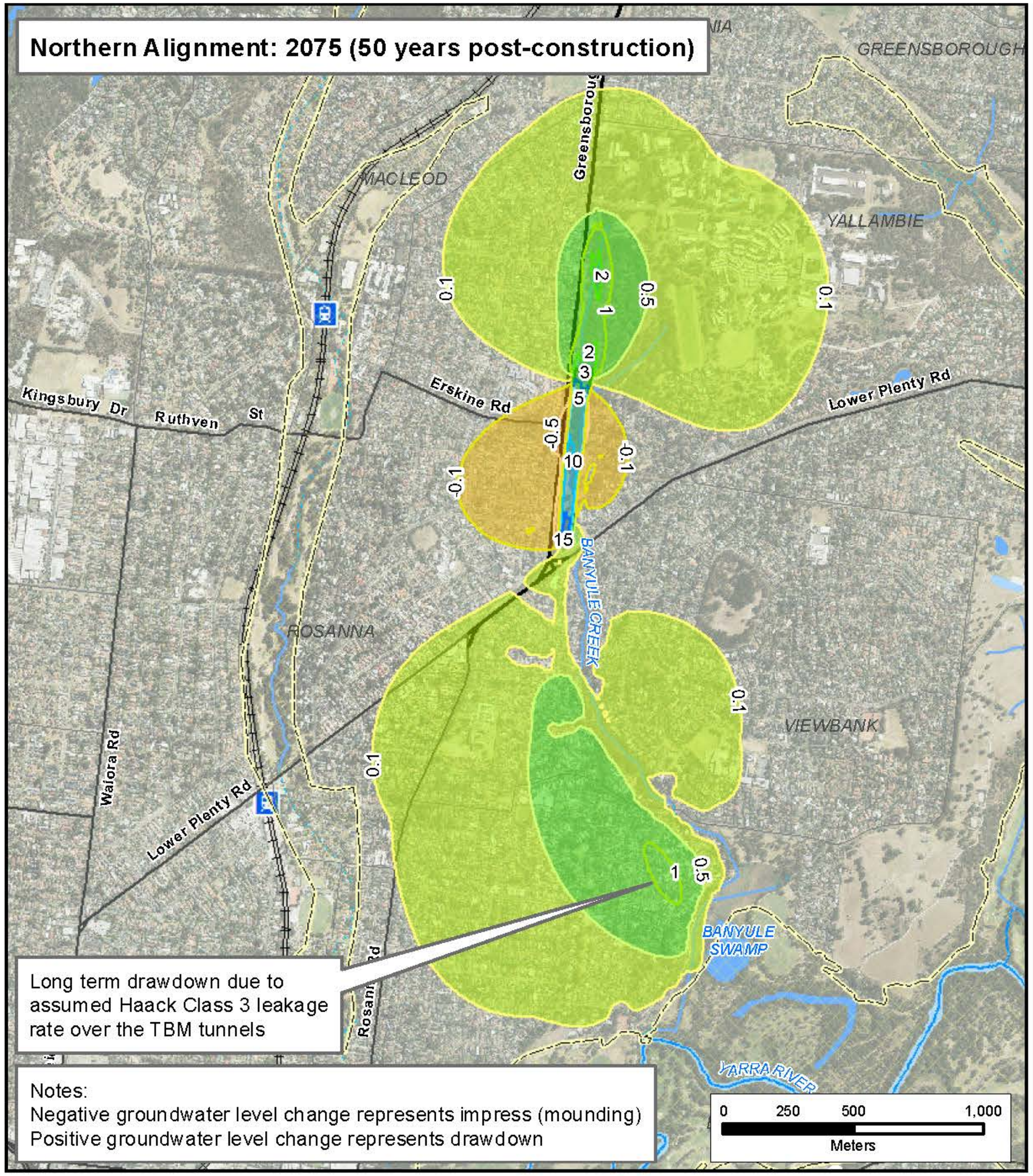
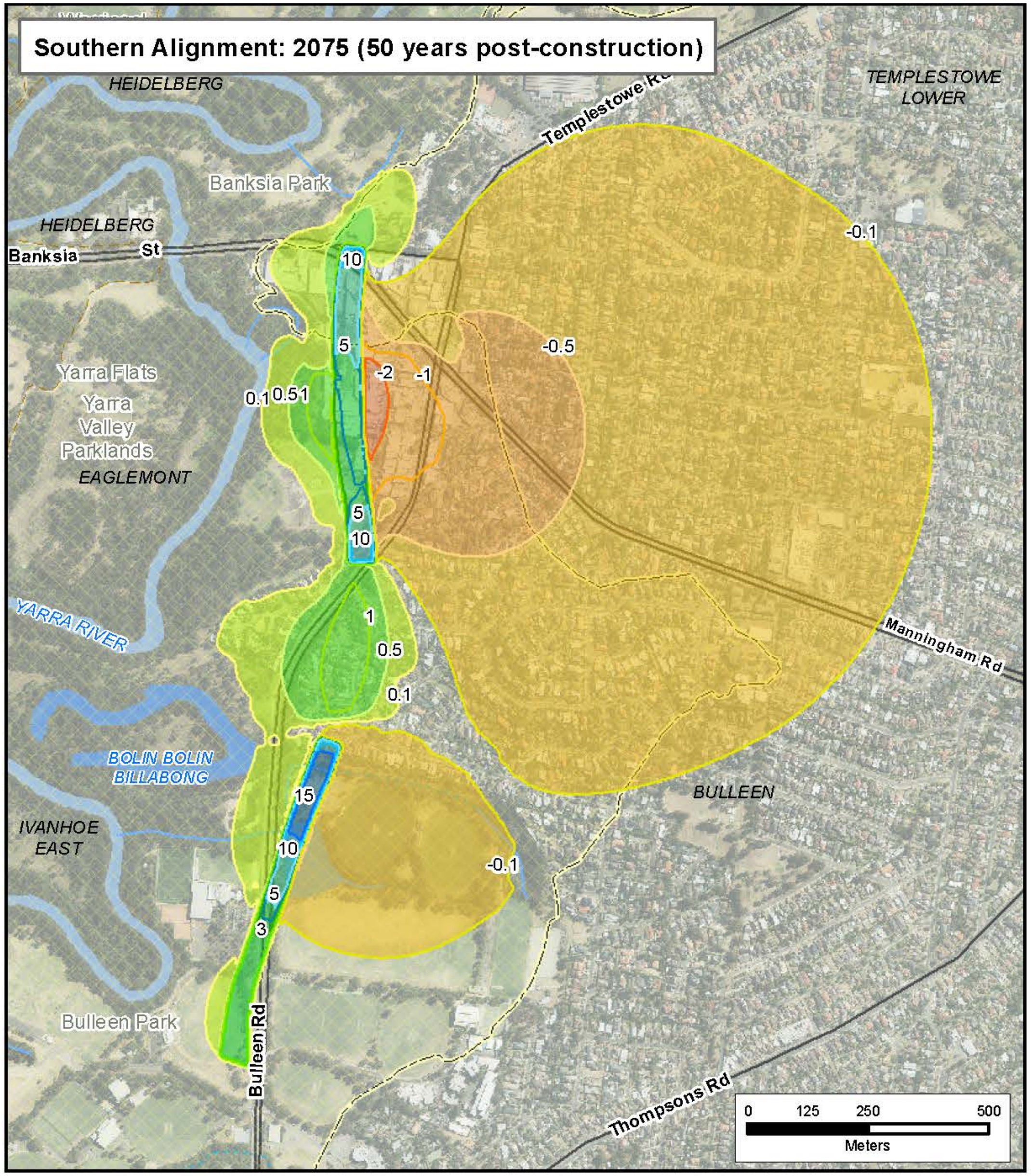
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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





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)

- < -5.81 - -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

North East Link Project

Job Number	31-35006
Revision	B
Date	23 Aug 2019

NORTH EAST LINK PROJECT

Predicted groundwater level changes (operation, further modelling)

Figure 7-9

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7.4.3 Impact arising from drawdowns on acid sulfate geological materials

Resources or receptors affected

The receptors that could be affected are as per the construction phase.

As per discussions in Section 7.3.1, groundwater is not currently developed for extractive benefit on Commonwealth land, and limited development occurs in the greater region. Owing to the elevated salinity of groundwater in the bedrock aquifer, and limited likelihood of future development, it is considered not sensitive to impact.

Receptors would also include groundwater receiving environments and GDEs. Assessment of impact to GDEs is documented in PER Technical Appendix A – Flora and fauna.

Impact description and evaluation

This impact has been previously described in Section 7.3.3.

As previously discussed, actual acid sulfate soil materials have not been identified based on the geotechnical sampling program completed to date. Water levels near excavations (where drawdowns would be greatest) would have partially recovered from construction maximums, which can resaturate acid-generating geologic materials.

Predicted water level changes during operation of North East Link are shown in Figure 7-7 and Figure 7-8 for the 95th percentile (drawdown) and 5th percentile (mounding) respectively. Figure 7-9 shows the results from the further modelling. Groundwater monitoring would be used to determine if potential acid sulfate soil materials have oxidised and generated acidic groundwater conditions during construction.

Under operating conditions, the magnitude of drawdown relative to the construction phase would be much less as dewatering effort is relaxed after construction, although the extent of drawdown that is ultimately developed during operation would be greater. Although the operating drawdown would be greater in area, the predicted magnitude of drawdown is typically within that of the seasonal water table fluctuation ranges. Worst case occurs when these drawdowns are superimposed upon water levels lows which can occur during a drought. However, geological mapping has indicated weathering depths upwards of 20 metres in the bedrock aquifer, and so exposure of fresh (unoxidised) geological material is highly unlikely, and increasingly unlikely with increasing distance from excavation areas.

Proposed avoidance and mitigation measures

Mitigation measures proposed as part of the design and construction are applicable to the operation of North East Link. The primary control is the tanking and water tightness of proposed structures. Water level drawdowns are expected to be at the maximum towards the end of construction. Partial, and in some areas, full recovery of water levels is predicted after construction is complete.

A key requirement is the monitoring of water levels and quality during construction. Further sampling for acid generating materials is expected to be undertaken as part of detailed design. Where the oxidation of acid sulfate soil materials has been identified as being a high risk (either from detailed design investigations, or from further numerical modelling), contingency measures as per the Groundwater Management Plan would be implemented to protect groundwater quality. Monitoring of groundwater would continue into operation for two years or until the groundwater quality has been acceptably restored.

Residual impact

With the proposed mitigation, residual impact significance is predicted to be low.

7.4.4 Impact arising from drawdowns on contaminated groundwater plumes

Resources or receptors affected

The receptors that could be affected are as per the construction phase.

As per discussions in Section 7.3.1, groundwater is not currently developed for extractive benefit on Commonwealth land, and limited development occurs in the greater region. Owing to the elevated salinity of groundwater in the bedrock aquifer, and limited likelihood of future development, it is considered to have a low sensitivity to impact.

Receptors would also include groundwater receiving environments and GDEs. Assessment of impact to GDEs is documented in PER Technical Appendix A – Flora and fauna.

Impact description and evaluation

The impact has been previously described in Section 7.3.4, which includes a summary table of potentially contaminating land uses that may have impacted groundwater quality.

Under operating conditions, the magnitude of drawdown relative to the construction of North East Link would be much less, although the extent of drawdown could be greater. It is noted that further numerical modelling (refer Appendix B) indicates reduced extents of operational drawdown compared to that of the initial numerical modelling (refer Appendix A), however, the further modelling does not include the uncertainty analysis, ie percentiles of drawdown. Although the operational drawdown would be greater in area, the magnitudes are typically within the seasonal water table fluctuation ranges. Therefore changes in water levels, and the resulting implications on contaminated groundwater plumes, are potentially localised.

Predicted drawdowns during operation of North East Link are shown in Figure 7-7 and Figure 7-8 for the 95th percentile (drawdown) and 5th percentile (mounding) respectively. Figure 7-9 shows the results of the further groundwater modelling. The long-term drawdowns are predicted to extend beneath the fuel service station at the intersection of Yallambie Road and Greensborough Road (Commonwealth land), and the former Borlase Reserve landfill. Groundwater contamination has been identified in the north-west corner of the Commonwealth land.

South of the Yarra River at the Manningham Road interchange and the mined tunnel, long-term water levels are predicted to mound east or hydraulically up-gradient of North East Link as regional groundwater flow is impeded by the tanked structures. Concentrations of Polyfluoroalkyl Substances (PFAS) in the southern area (former Bulleen Drive-in), and the presence of multiple fuel service stations implies as high risk potentially encountering contaminated groundwater.

Proposed avoidance and mitigation measures

Mitigation measures proposed as part of the design and construction are applicable to the operation of North East Link. The primary control is the tanking and water tightness of proposed structures. Water level drawdowns are expected to be at their maximum towards the end of construction. Partial, and in some areas, full recovery of water levels is predicted.

It is a considered a reasonable assumption that further investigations would be completed during detailed design to delineate the groundwater quality in these areas, particularly where groundwater quality impacts have been identified from the available geotechnical investigation program information to date.

Where the contaminated groundwater has been identified, contingency measures as per the Groundwater Management Plan would be implemented to manage the plume during construction. This would include monitoring of water levels and quality during construction.

Additional measures implemented during construction could include source removal, clean-up and/or hydraulic control of the plume. During operation, it is assumed that intensive management of the plume would no longer be required, or at least management regimes could be adapted to the new groundwater conditions post construction.

Monitoring of groundwater would extend into operation to confirm that groundwater quality has been acceptably restored.

Residual impact

With the proposed mitigation, residual impact significance is predicted to be low.

7.4.5 Discussion of impact of North East Link representing a barrier to regional groundwater flow

Resources or receptors affected

Impressed or raised water levels can affect the following receptors:

- Existing (and future) groundwater users (bores used for stock and domestic, irrigation, commercial and industrial purposes).

  The Palaeozoic bedrock aquifer is not developed on Commonwealth land (no bores with abstractive use). Some, albeit small numbers of groundwater bores have been identified outside Commonwealth land. A rise in water levels can be beneficial to pumping bores as it increases the available drawdown or water level above a pump. The groundwater system has been disturbed (contamination identified) and the salinity results in limited abstractive beneficial use. These impacts have a low sensitivity.
- Buildings and structures. No significant groundwater mounding is predicted to occur beneath Commonwealth land and so this is not discussed further.
- Waterways receiving groundwater, or ecosystems that can access groundwater (GDEs). Ecological receptors are addressed in PER Technical Appendix A – Flora and fauna. Some discussion of the process has been presented in this document owing to the potential for water level changes near waterways.

Impact description and evaluation

The presence of a tunnel or cut and cover structure, whether it is drained or tanked, can impede 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 7-10. 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 so water levels have a tendency to decline. A small amount of decline on the downstream side may also occur depending upon the structure’s drainage conditions or water tightness.

Mounding can create water logging issues which can affect vegetation, or underground structures such as cellars or buried services. Falling water levels on the down-stream side can influence accessibility to GDEs and existing groundwater bores. While the schematic shows a section near the northern portal, the concept is predicted to occur at the southern portal.

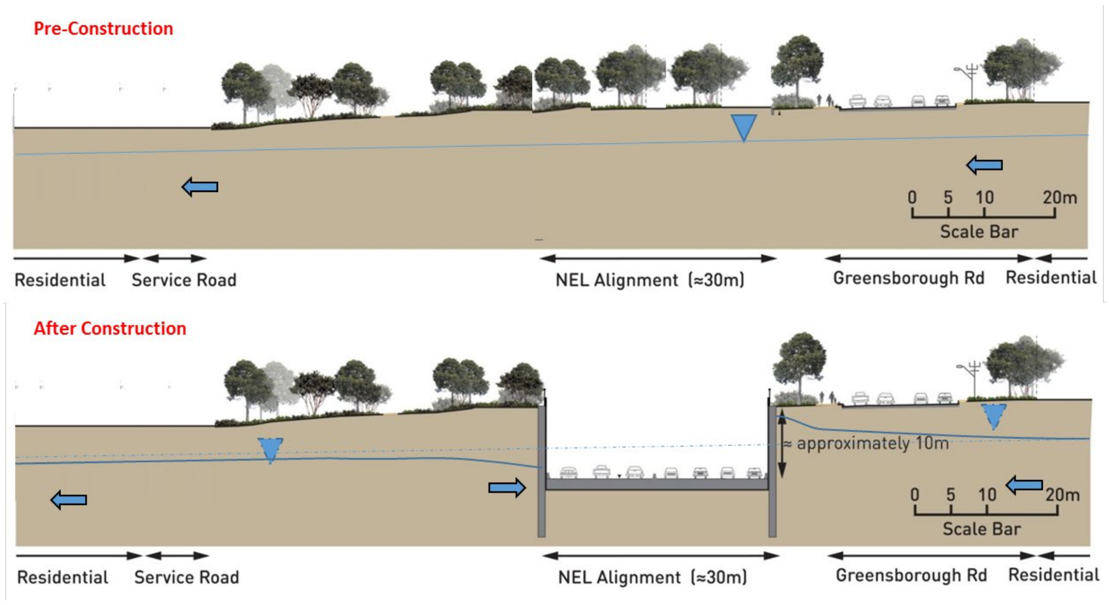

Figure 7-10 Barriers to groundwater flow

The impact would be created during operation of North East Link as water levels are recovering from construction dewatering. Mounding (and drawdown) would be greatest nearest the tanked structure, and would decrease with increasing distance from the structure.

Predicted drawdowns during operation of North East Link are shown in Figure 7-7 and Figure 7-8 for the 95th percentile (drawdown) and 5th percentile (mounding) respectively. The effect of structures being a barrier to regional flow is predicted to be negligible on Commonwealth land. The long-term drawdown effects predicted by the initial numerical groundwater do not indicate the presence of impediments to regional flow. In this area, groundwater flow is southward towards the northern portal/Yarra River and aligned or parallel with the action and unlike that shown in the conceptual schematic in Figure 7-10. As flow largely migrates parallel to the structures, the risk of North East Link impeding regional flow in this area is therefore low.

Small areas of mounding (<0.5 metre) are predicted in a small area on the western side of the structure at the northern portal, to the south of the Commonwealth land. This occurs in an area adjacent the alignment of the ephemeral waterway, Banyule Creek. A predicted 0.5 metres of mounding is within the limits of seasonal groundwater fluctuation. Water level monitoring in bores at Borlase Reserve indicates water levels are over five metres below the surface and therefore mounding may not have a material effect on the environment (creek flows in this region) and water logging, when superimposed upon seasonal water level highs.

South of the Yarra River crossing, North East Link 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 action would impede regional groundwater flow.

This would create two effects in the region:

- On the down-gradient or western side, drawdowns extend westwards from the structure (refer Figure 7-7). These drawdowns would extend beneath the Yarra River, which implies the hydraulic gradient and groundwater inflow rates into the Yarra River would be marginally reduced.
- Some drawdown is predicted (0.1 to 0.5 metres) at Bolin Bolin Billabong. Conceptualisation of the billabong (refer Section 6.13) 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 PER Technical Appendix A – Flora and fauna.
- On the up-gradient or eastern side of the 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 7-8).

A hydrograph for monitoring bore NEL-BH137 is shown in Figure 7-11 based on the initial groundwater modelling. Bore NEL-BH137 is located within a carpark between Greenway Street and Bulleen Road (it is located within an area where mounding is predicted to be greatest). The 200 model runs undertaken as part of the numerical groundwater model uncertainty analysis indicate that water levels resulting from the mounding remain greater than five metres below the surface. As water levels are not predicted to rise to within two metres of the surface, there is no elevated risk of salinity or water logging.

It is noted, that with the further numerical modelling (refer Appendix B), improved calibration between modelled and existing (pre-construction) piezometric heads was achieved in this area. This improvement occurred due to improved spatial representation of heads (based on the time-series water level monitoring information), and aquifer pumping tests completed in the former Bulleen Drive In (resulting in improved understanding of spatial variability in hydraulic conductivity). The model improvements indicate that the maximum extent of mounding is around 2.5 metres.

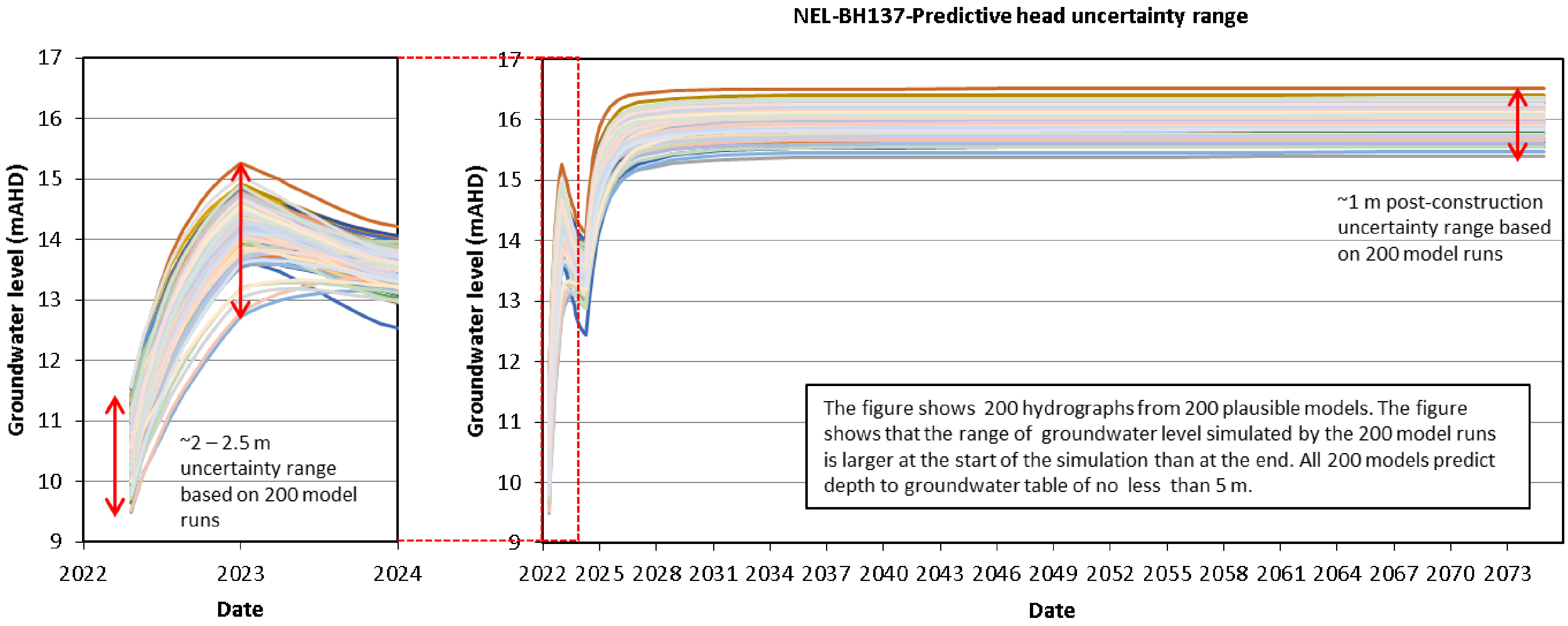

Figure 7-11 Hydrograph of Bore NEL-BH137 (Greenaway Street)

Proposed avoidance and mitigation measures

The construction of a water tight structure provides the benefit of minimising a number of potential impacts to groundwater by reducing groundwater drawdown. The disadvantage of this is the formation of a barrier to regional groundwater flow.

Analysis has indicated that mounding is unlikely to result in shallow water tables and groundwater logging (salinisation) and impacts to Commonwealth land. Mounding is predicted to occur east of the Manningham Road interchange in both the initial and further modelling. Monitoring in this region is required to verify the predicted changes in groundwater level. Ongoing monitoring during operation is undesirable and it is proposed that monitoring be undertaken over a duration that verifies the predictive numerical groundwater model.

Remote from Commonwealth land, drawdowns are predicted to extend beneath the deep pool of Bolin Bolin Billabong, adjacent to the Yarra River. Controls that could be implemented from a groundwater context to mitigate impacts to the billabong may include:

- Monitoring of water levels during construction
- Artificial topping

  Where required, identify and implement additional measures required to mitigate impacts from changes in groundwater levels, flow and quality at the billabong. As the billabong is filled via flood events in the Yarra River, additional fill events could be undertaken. This could involve pumping from the Yarra River, adjustment of levee bank elevations, or possibly the installation of groundwater production bores into the alluvial sediments (to increase the likelihood of harvesting fresher groundwater) and topping the billabong. Being a regulated waterway, a volume and licence may need to be traded to enable pumping from the Yarra River.

  Given the proximity of a groundwater bore to the Yarra River, Southern Rural Water would likely be interested with 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 as in making a determination of a groundwater extraction licence application, Southern Rural Water needs to consider waterway setback distances.

Other controls are recommended in PER Technical Appendix A – Flora and fauna.

Residual impact

The significance of the residual impact to the regional groundwater flow are expected to be low.

7.4.6 Discussion of impact to streamflows

Resources or receptors affected

Receptors affected are waterways and associated dependent ecosystems that are fed by groundwater discharge. Assessment of impact to ecological receptors is documented in PER Technical Appendix A – Flora and fauna.

While there would be no direct impacts to groundwater, a discussion of the impact and groundwater's role has been included in this report.

Impact description and evaluation

As noted in Section 6.14, groundwater interacts with surface water, although the nature of this interaction can be variable. Within the alignment, groundwater is interpreted to flow towards, and discharge to, waterways and floodplains. This is shown conceptually in Figure 7-12 below.

Groundwater flowing towards a waterway could be captured through construction dewatering and seepage into structures. Groundwater through-flows can also be reduced as a result of mounding and impediments being placed within regional flow paths – all processes that have been previously described.

The schematic below is for a section near the northern portal, although it is applicable to excavations at the Manningham Road interchange, and the southern portal cut and cover sections. At the northern portal and in its upper reaches, Banyule Creek is ephemeral and disconnected from groundwater.

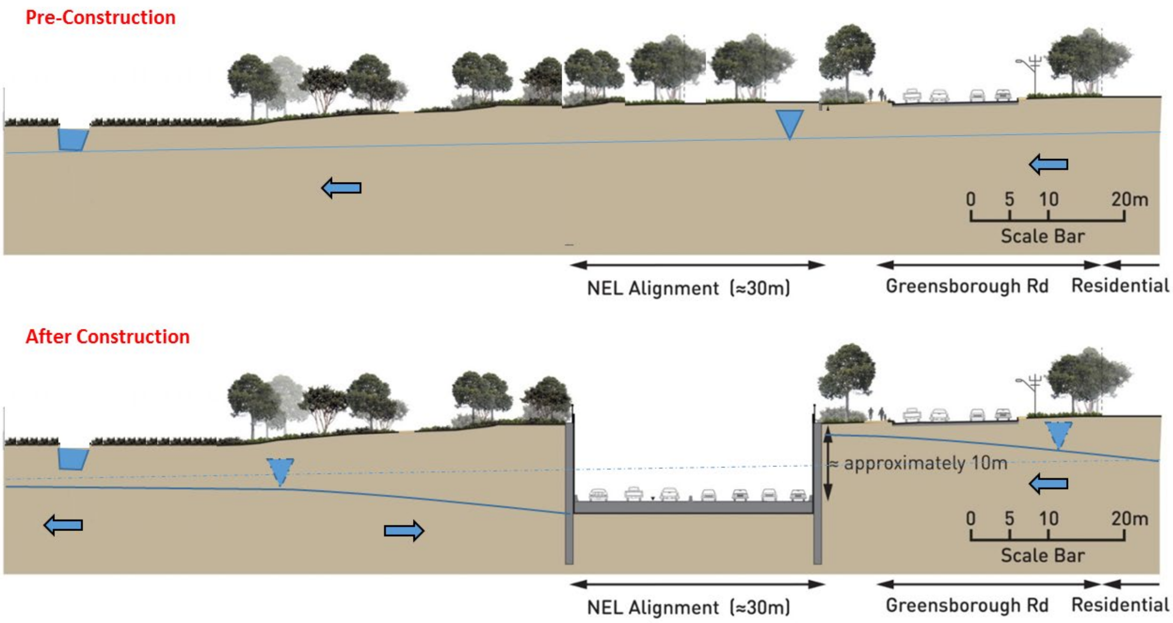

Figure 7-12 Groundwater influences on streamflow

It is interpreted that the alluvial aquifer system is 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 (higher pumping rates required to cope with recharge derived from waterways).

Discussion on some of these waterways have been previously undertaken (refer Section 6.13). However, a summary of impacts arising from dewatering is provided 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 (refer Appendix A) installed as part of the geotechnical program confirm 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, however, these studies have attached uncertainties.

Tunnelling beneath any waterway results in a risk of altering the hydraulic connection between the tunnel and the overlying water. This is an important construction consideration, as increased groundwater inflows can significantly affect safety of construction personnel, the stability of excavations, and the effort required to manage the groundwater. These factors create an increased risk of time delays and construction costs.

Based upon the reference project, the TBM tunnel passes approximately 25 m below the Yarra River. Within the floodplain, the cover of bedrock overlying the tunnel is variable and ranges between a few meters to around 15 m (refer Figure 6-2). As the TBM tunnel rises towards the surface towards Manningham Road interchange, the alluvial sediments may also be intersected by the tunnel.

Interaction between the Yarra River and the underlying aquifers has been confirmed by water level responses in groundwater monitoring bores. This interaction can be influenced by faulting and geological structures in the bedrock (refer Figure 6-2), the presence of coarse grained beds within the alluvial sequence, and weathering profiles in the bedrock.

Closed face TBM tunnelling methods typically adopt low face pressures and therefore the risk of hydraulic fracturing and enhancement of hydraulic connection is considered to be low.

Where the floodplain sediments are intersected, unstable geological conditions may result in void creation as these materials slough into the excavation. Grouting of segments (typically occurring at distances 1.5 x diameters behind the face), would reduce the likelihood of the TBM annulus creating pathways for water migration.

Groundwater level drawdowns are predicted to extend beyond the Yarra River for the initial modelling, albeit at a low magnitude (0.1 to 0.5 metres) (refer Figure 7-2 and Figure 7-8 for construction and operation respectively). 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 net loss of flow or leakage from the Yarra River, as gradients would still result in discharge from groundwater to the waterway.

The 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 x 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 7-1) is 50 m^3/day (6 x 10^{-4} m^3/s) under operational conditions, and 294 m^3/day (3 x 10^{-3} m^3/s) on average during construction. The further modelling predicts a less than one per cent reduction in Yarra River baseflow due to the structures (see Appendix B), which is smaller than the 5.5 per cent reduction predicted by the initial modelling.

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

- Banyule Swamp and Billabong

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

  a. Tunnelling would be within the bedrock aquifer and would not 'cut-off' regional groundwater flow paths in this aquifer (groundwater could migrate above and below the TBM tunnels)

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

- Banyule Creek

  The northern portal and trench structure would be adjacent to Banyule Creek. The creek is interpreted as being ephemeral in the upper parts of its catchment. In these parts the creek is situated upon Commonwealth land. In the lower parts of the creek's catchment, particularly in deeper pools, groundwater contributions to flow are possible, but are most likely minor based on the fresh groundwater quality of the creek.

  Predicted long-term drawdowns in this region are expected to be around 0.1 metres to 0.5 metres, which is within the range of seasonal fluctuation. In these reaches the creek is ephemeral, and so reductions in groundwater levels are not expected to alter flow regimes.

- Koonung Creek

  The location of Koonung Creek is removed from any dewatering activities associated with North East Link's 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 construction of North East Link (refer 7.4.5) are predicted to extend to Bolin Bolin Billabong. Some recovery of water levels is expected following construction, however, owing to the damming effect on regional groundwater flow lines, drawdown would occur down-gradient of the structure and extend to the billabong (refer Figure 7-8 for the initial modelling results).

  The further modelling predicts a marginally larger reduction in groundwater at the Bolin Bolin Billabong partly due to greater drawdown simulated over the mined tunnels to the northeast, although they are still very small). The extent of the 0.1 to 0.5 metre drawdown contour is localised at the deep pool and indicates a reduction in groundwater levels at the deep pool to be towards the lower end of this range over the long term (see Figure 7-9).

Proposed avoidance and mitigation measures

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 construction and operation of North East Link.

However, the predictive numerical groundwater modelling has identified that operation drawdown resulting from the tanked structured would impede regional flow and cause potential drawdowns that extend towards Bolin Bolin Billabong. Discussion on the impacts to the billabong is provided in PER Technical Appendix A – Flora and fauna.

The proximity of construction activities to waterways usually triggers a heightened risk awareness to construction contractors. This is because of a potential interaction between the waterway and groundwater and potential for increased excavation inflows and therefore construction risks (and costs to contractors). This may drive the need for further geotechnical investigations, or influence the selection of construction techniques to minimise the likelihood of greater inflows.

Notwithstanding these impacts, there are number of controls that could be implemented from a groundwater context to mitigate impacts to the billabong and may include:

- Monitoring of water levels during construction
- Periodical topping with water (as discussed in Section 7.4.5).

Residual impacts

Residual impact significance of groundwater impacts to streamflows is predicted to be low.

7.4.7 Discussion on a northern tunnel boring machine (TBM) launch site

The assessment assumed that TBM tunnelling would progress from the south (Manningham Road interchange) towards the north. The potential groundwater impacts of the alternative TBM launch site—a northern 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 North East Link, 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 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 mitigation measures developed for the launch site in the reference project would be equally applicable.

7.4.8 Discussion on southern tunnel boring machine (TBM) retrieval site

The northern TBM launch option assumes the TBMs would be retrieved from the Manningham Road interchange. However, the timing of property acquisition may mean the Manningham Road 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, and below the water table, it has been assumed the shafts would be excavated and supported using diaphragm walls or bored piles. Groundwater inflow to the excavation would be largely cut-off laterally, and principally occur upwards via the base of the shaft, until it was 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 10 metres below the ground surface. Retrieval shaft excavations would be predominantly within the bedrock aquifer system, but 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 base case (that is without the structure) by approximately 50 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 one 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.

8. Facilitated impacts and cumulative impacts

The cumulative assessment of North East Link has been assessed from two perspectives: a local scale and a regional scale.

8.1 Local-scale cumulative impacts

The first perspective is that of a 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 would likely to be undertaken concurrently with excavations to construct the northern portal.

In predicting the drawdowns from the action, the numerical modelling assumed that construction dewatering may be occurring simultaneously in different areas. 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 that North East Link could be constructed in a variety of sequences, although ultimately the timing of construction of the northern and southern portals 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.

8.2 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. It is understood are a number of infrastructure projects would potentially be under construction at the same time as North East Link, including railway level crossing removals, some of which include below grade or rail or road under options, as well as the West Gate Tunnel Project and the Metro Tunnel, which both include a significant length of tunnelling and underground cavern excavation.

Predicted drawdowns are not interpreted to extend to the influence of the West Gate Tunnel Project or the Metro Tunnel and so cumulative impacts to the groundwater environment from the three projects are not expected.

A potential consideration is the management of wastewater from North East Link, specifically inflows into drained and tanked structures. The native groundwater quality of the Palaeozoic bedrock is saline and so management options would need to consider salt loads associated with this wastewater.

It has been assumed the TBM tunnel and associated tanked structures would be completed to a Haack Class 3 condition (refer Table 3-2) which would render the structures near impermeable, although some seepage would occur. Wastewater would also be captured by the tunnels from stormwater runoff, and water carried upon 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 irrigation, and so management of salt would be important in the downstream sewage process.

Disposal of wastewater from North East Link to sewer represents a potential cumulative impact as wastewater would also be generated from other infrastructure projects, such as the Metro Tunnel, which may also consider disposal to sewer as a means to manage wastewater inflows.

9. Avoidance and mitigation measures

This section presents a consolidated list of the avoidance and mitigation measures proposed to address relevant impacts on MNES, Commonwealth land and groundwater. These include measures to mitigate impacts specifically relating to groundwater, as well as other measures to avoid and mitigate construction and operation impacts more generally. Sections 7 and 8 describe in detail measures for each relevant impact.

A range of environmental management plans would be developed and implemented for the construction and operation of North East Link and would support implementation of the measures described in this section. Plans would include Construction Environmental Management Plans (CEMPs) including sub plans for specific issues, Worksite Environmental Management Plans (WEMPs), and an Operation Environmental Management Plan (OEMP).

An independent environmental auditor would review the environmental management plans and proposed management measures prior to construction or operation works that are subject of the management plans commencing. The independent environmental auditor would conduct regular audits of compliance with the environmental management plans.

9.1 Groundwater-specific measures

Key measures to mitigate impacts on groundwater would include:

- Developing a predictive numerical model to predict changes to groundwater levels, flow and quality to inform decisions made for mitigation strategies. This model should be developed:
  - In consultation with the EPA Victoria
  - With reference to the Australian Groundwater Modelling Guidelines (June 2012)
  - And reviewed and verified by an Independent Environmental Auditor
- Minimising changes to groundwater levels through tunnel drainage design and construction methods through:
  - Adopting construction methods to avoid the mobilisation of contaminated groundwater and acid sulfate soils
  - Implementing engineering control measures and ground treatment to minimise to the extent practicable groundwater inflow during excavation, construction and operation of tunnels, cross passages and subsurface excavations
- Developing and implementing a Groundwater Management Plan detailing measures to avoid and mitigate construction impacts including through measures such as the following:
  - Selection and use of artificial recharge fluids that would not diminish groundwater quality
  - Measures to mitigate and minimise oxidation of acid sulfate soil materials and acidification of groundwater
  - Assessment of damming and barrier effects
  - Subsidence management
  - Protection of waterways and potential GDEs from unacceptable groundwater impacts
  - Protecting water supply for users of existing extraction bores

  - Identification, treatment, disposal and handling of contaminated groundwater plumes, groundwater seepage water and/or slurries including vapours in accordance with relevant legislation and guidelines
  - Treatment and disposal of groundwater consistent with EPA Victoria waste hierarchy and requirements

  A Groundwater Management Plan documents an approach that a contractor must undertake to monitor, assess, and mitigate adverse impact to groundwater. The minimum components of such a plan are noted above, however, this list is not exhaustive.

  A construction contractor would tailor the Groundwater Management Plan to the specific requirements of the project, consult with EPA Victoria (and other relevant authorities) in preparing the plan and develop the plan and requirements to a level that satisfies the independent environmental auditor.

- Developing and implementing a monitoring program before, during and after construction to:
  - Establish baseline water level and quality conditions
  - Calibrate the predictive model prior to commencement of construction
  - Assess the adequacy of proposed design and construction methods and inform the need for any additional measures or changes to mitigate impacts from changes in groundwater levels, flow and quality
  - Monitor and confirm restoration of the groundwater environment in terms of water level and water quality
- Managing captured groundwater seepage and disposal in accordance with the EPA Victoria waste hierarchy
- Managing groundwater during the operation of North East Link through preparation of measures for management, monitoring and disposal of groundwater inflows during operation to comply with all relevant legislation and guidelines. Any trade waste agreement from the relevant water authority would be obtained in accordance with regulatory requirements, where disposal to sewer is proposed. Approval from EPA and the relevant water authority (as required) would be obtained in accordance with regulatory requirements where discharge to waterways is proposed.

9.2 Other measures

Other measures that would be developed and implement to mitigate impacts to groundwater would include:

- A Groundwater Dependent Ecosystem Monitoring and Mitigation Plan
- A spoil management plan to minimise impacts from disturbance of acid sulfate soil
- Design and construct the spill containment capacity of the stormwater drainage system to manage the risk of hazardous spills from traffic accidents
- Measures to manage chemicals, fuels and hazardous materials during construction and operation, including for spill response
- Prepare and implement a Construction Environmental Management Plan (CEMP) and Operations Environmental Management Plan (OEMP).

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Appendices

Appendix A – Groundwater modelling report

North East Link Project

North East Link Public Environment Report

Appendix A – Numerical Groundwater Model Report

Prepared for North East Link

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.

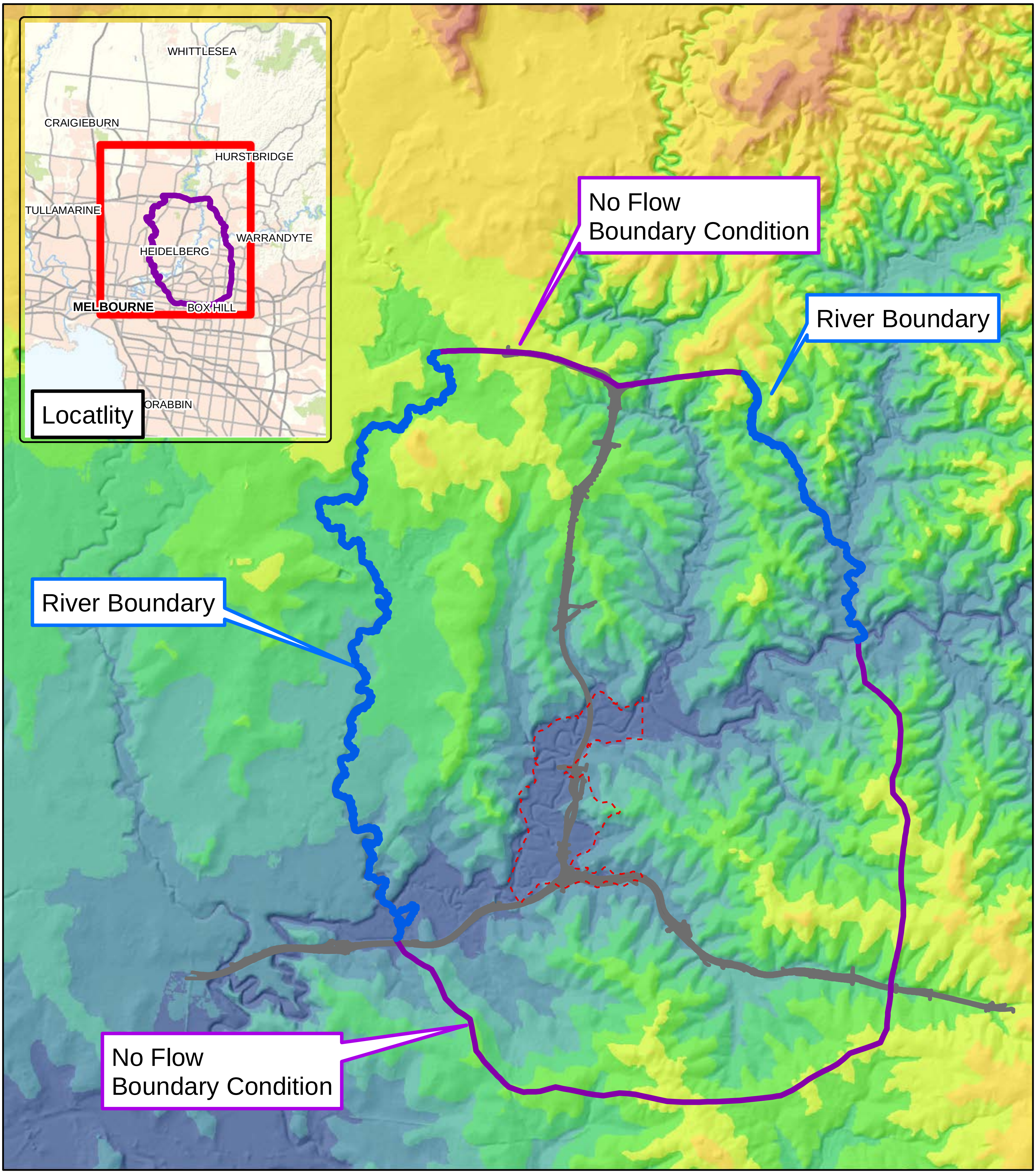
Figure 1 presents the model domain which encloses the project alignment, potential area of influence of project activities (as inferred from the preliminary 'proof of concept' modelling) and key hydrological features such as wetlands and rivers. A combination of regional topographical surface (VicMap 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
- 20.1 - 40
- 40.1 - 60
- 60.1 - 80
- 80.1 - 100
- 100.1 - 120
- 120.1 - 160
- 160.1 - 180
- 180.1 - 200
- 200.1 - 271.6

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
Public Environment Report

Job Number 31-35006
Revision A
Date 26 Feb 2019

Groundwater Model
Model Domain

Figure 1

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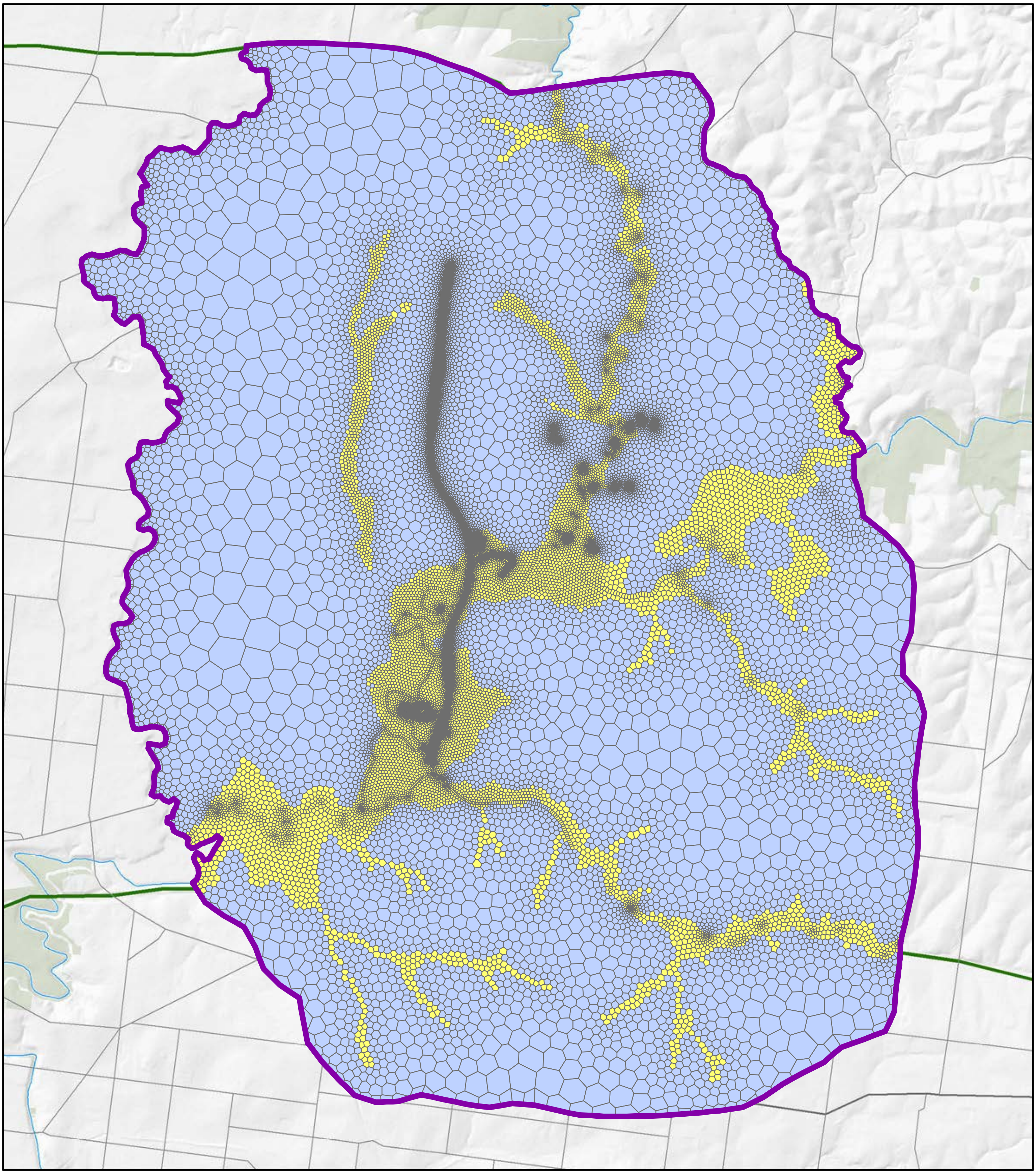
Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo

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

North East Link Project
Public Environment Report

Job Number 31-35006
Revision A
Date 26 Feb 2019

Model Mesh and
Hydrostratigraphic Units

Figure 2

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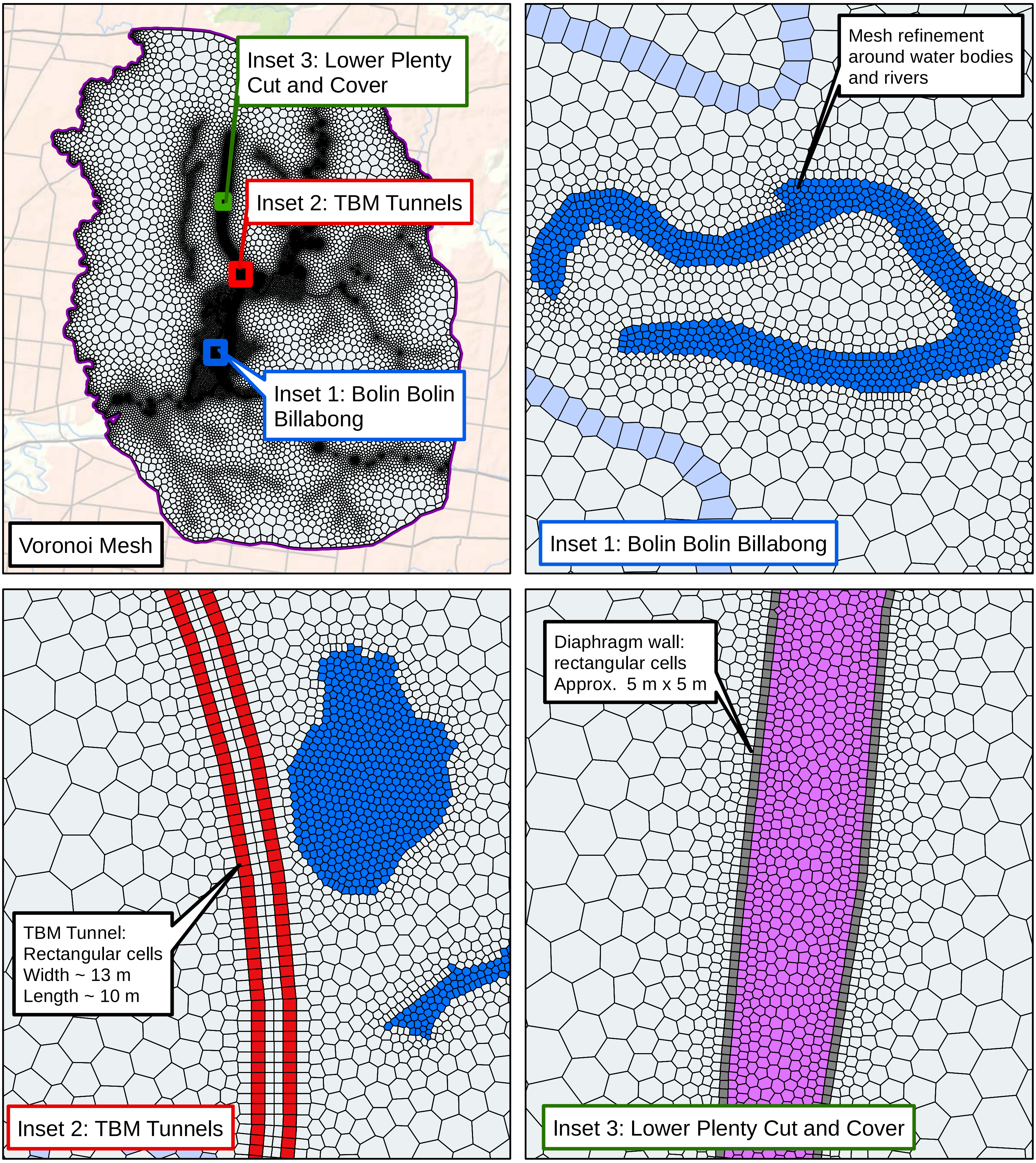
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data: BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



Legend

- GW Model Mesh
- GW Model Domain

Model Features

- River
- Water Body
- TBM Tunnel
- Diaphragm Wall
- Cut and Cover
- Mined Tunnel
- Trough (Free Draining)

Paper Size A4

0 950 1,900 3,800

Metres

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

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Public Environment Report

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Date	26 Feb 2019

Groundwater Model Mesh and Hydrogeological Features

Figure 3

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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.

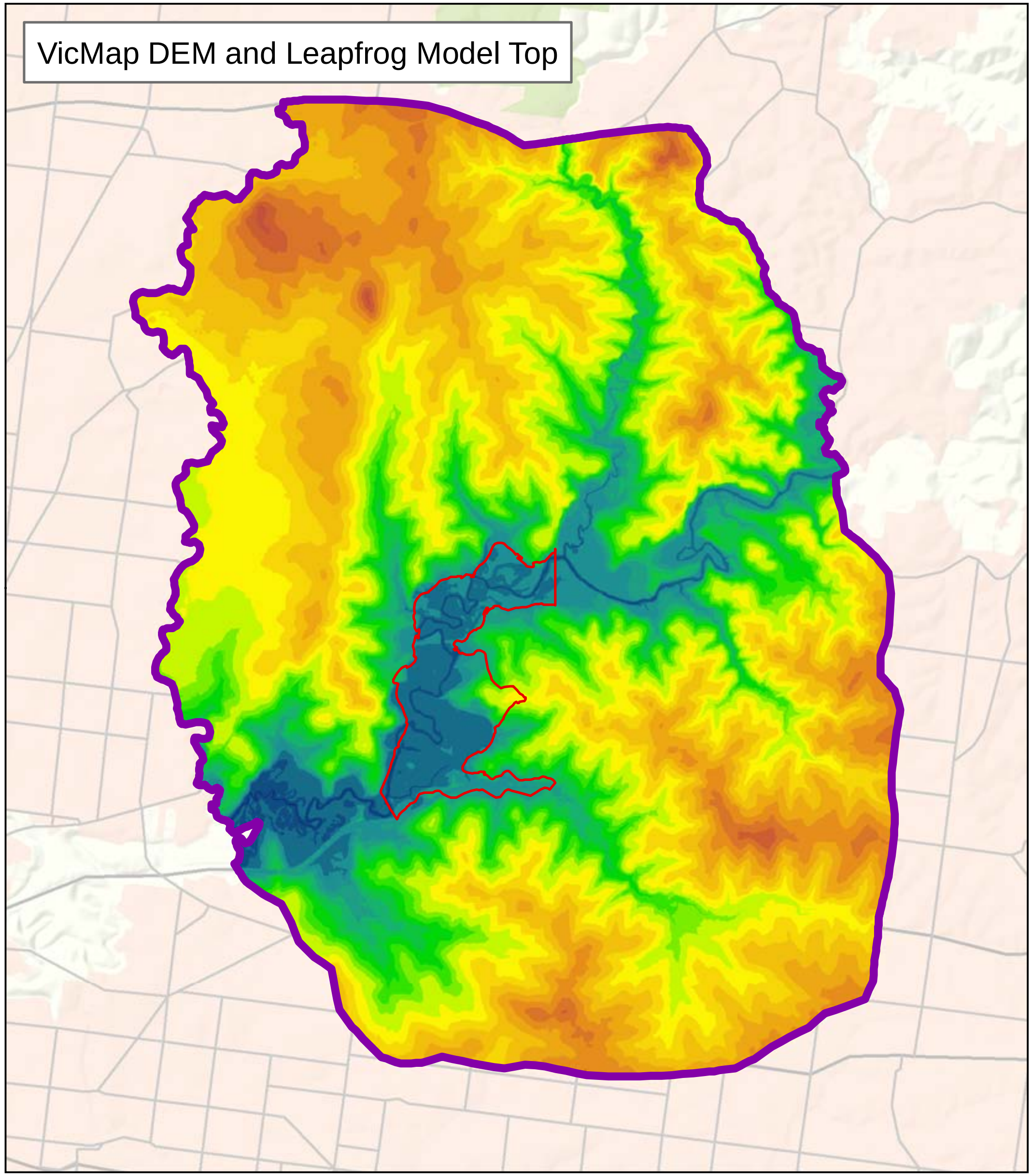
The base of model layer 1 corresponds to the bottom of the Alluvium, which is derived from the Leapfrog geological model and the Victorian Aquifer System (VAF). Although the lithology of the Alluvium can be variable on a local scale with interbedded lenses of sand and clay, this HSU is represented as 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.

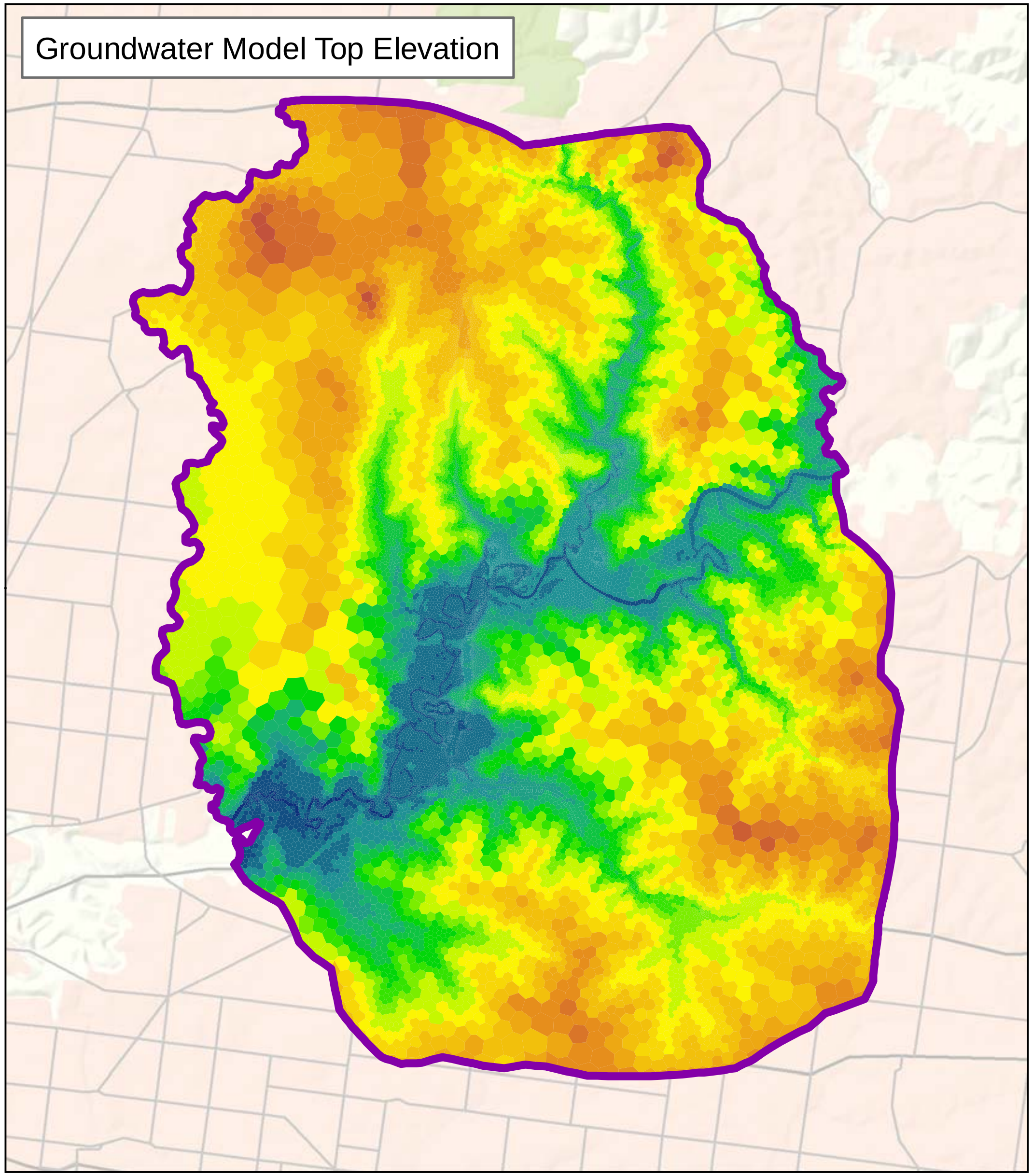
The Bedrock unit underlying the Alluvium has been split into several model layers to accurately simulate the vertical alignment of the tunnels and cut and cover excavations, including the placement of the diaphragm walls. Figure 6 presents a north to south model cross-section taken along the project 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

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Topographical datasets and groundwater model top

Figure 4

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

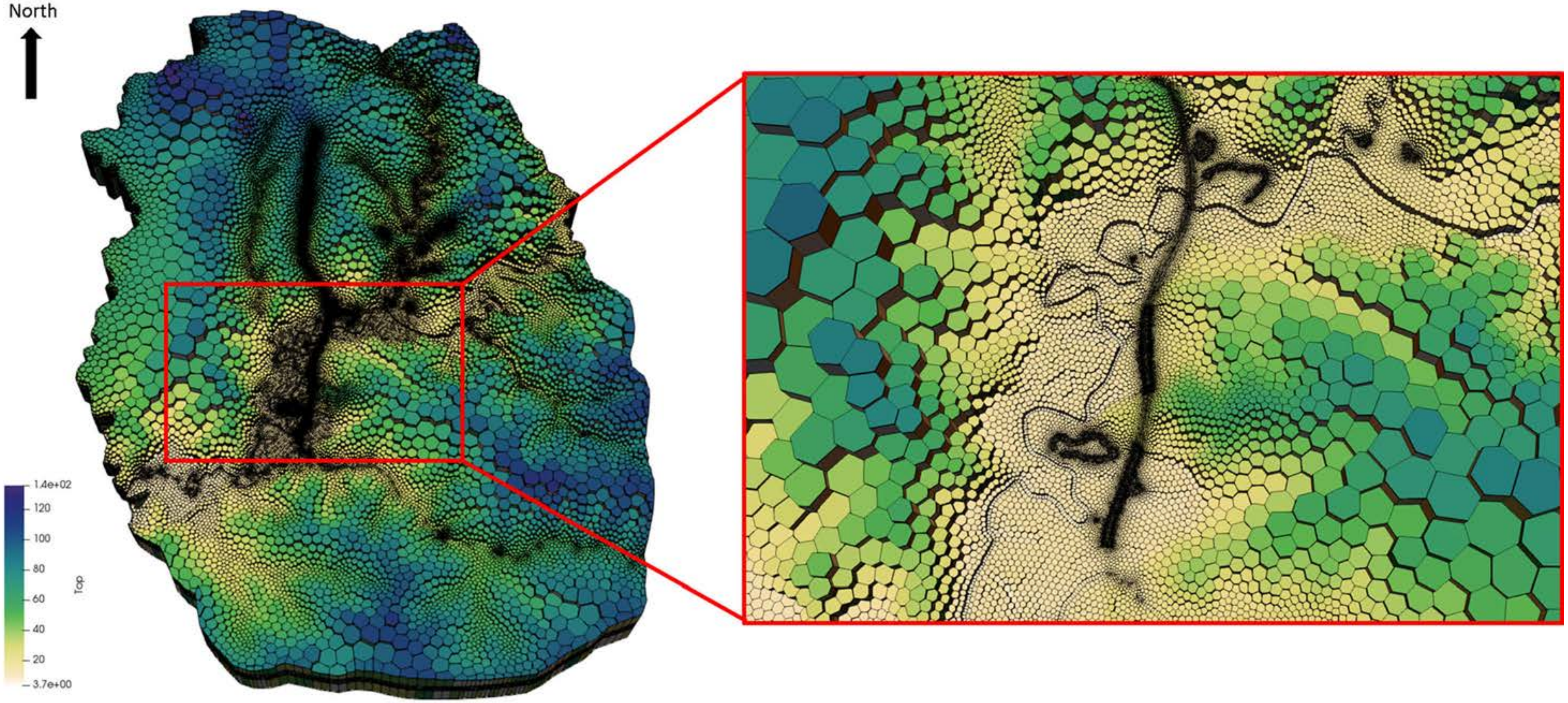


Figure 5 3D model view and model top

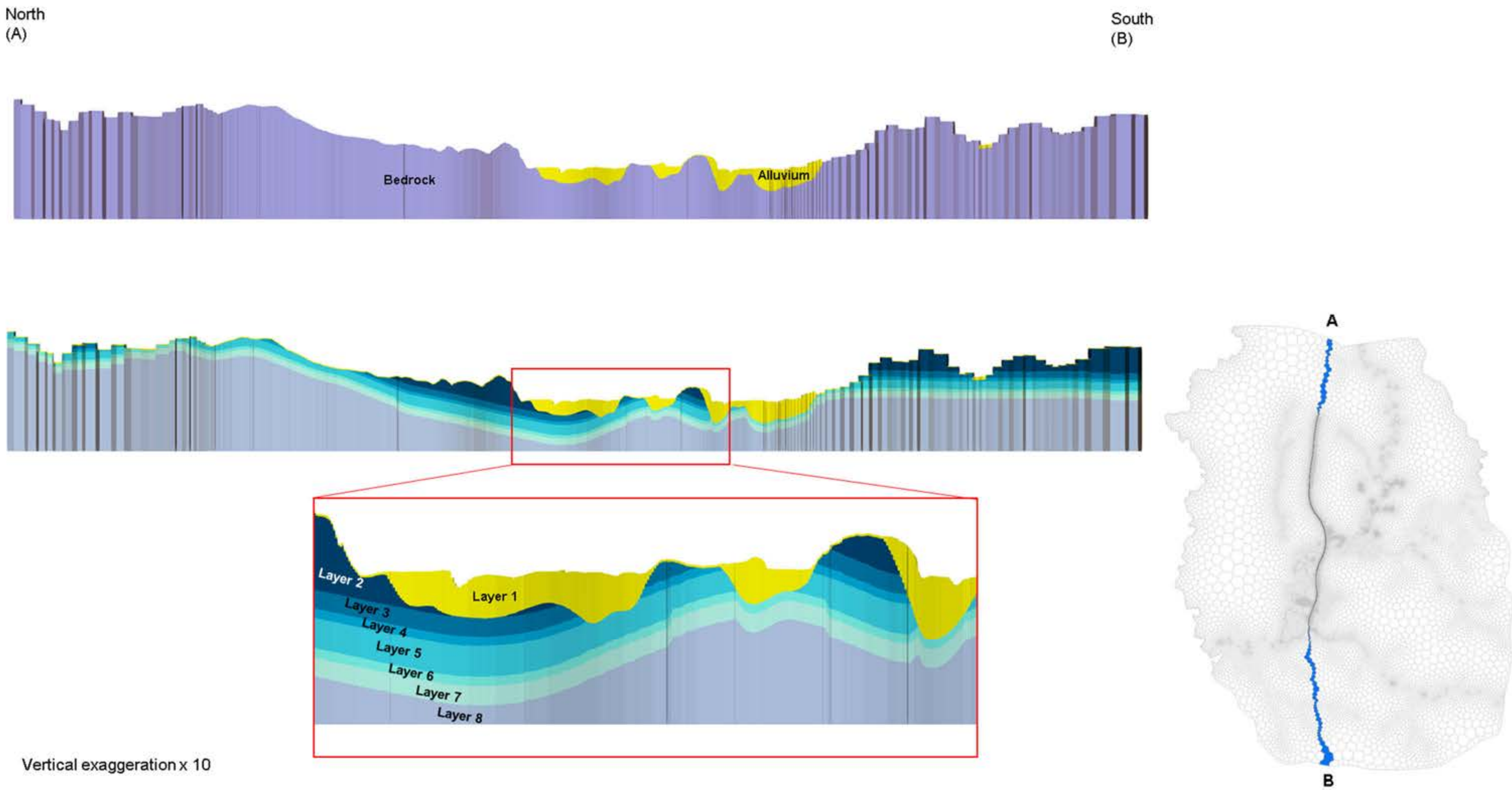


Figure 6 North to south model cross-section

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.

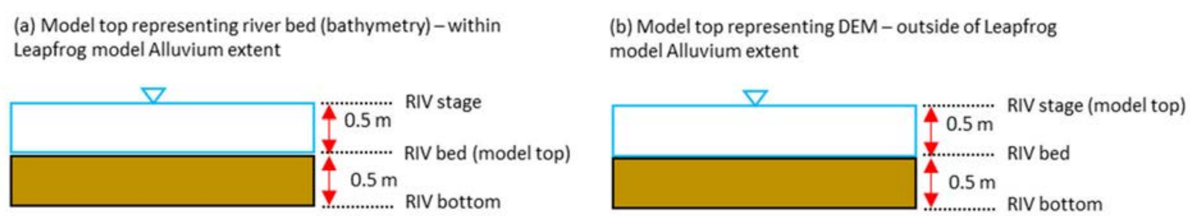
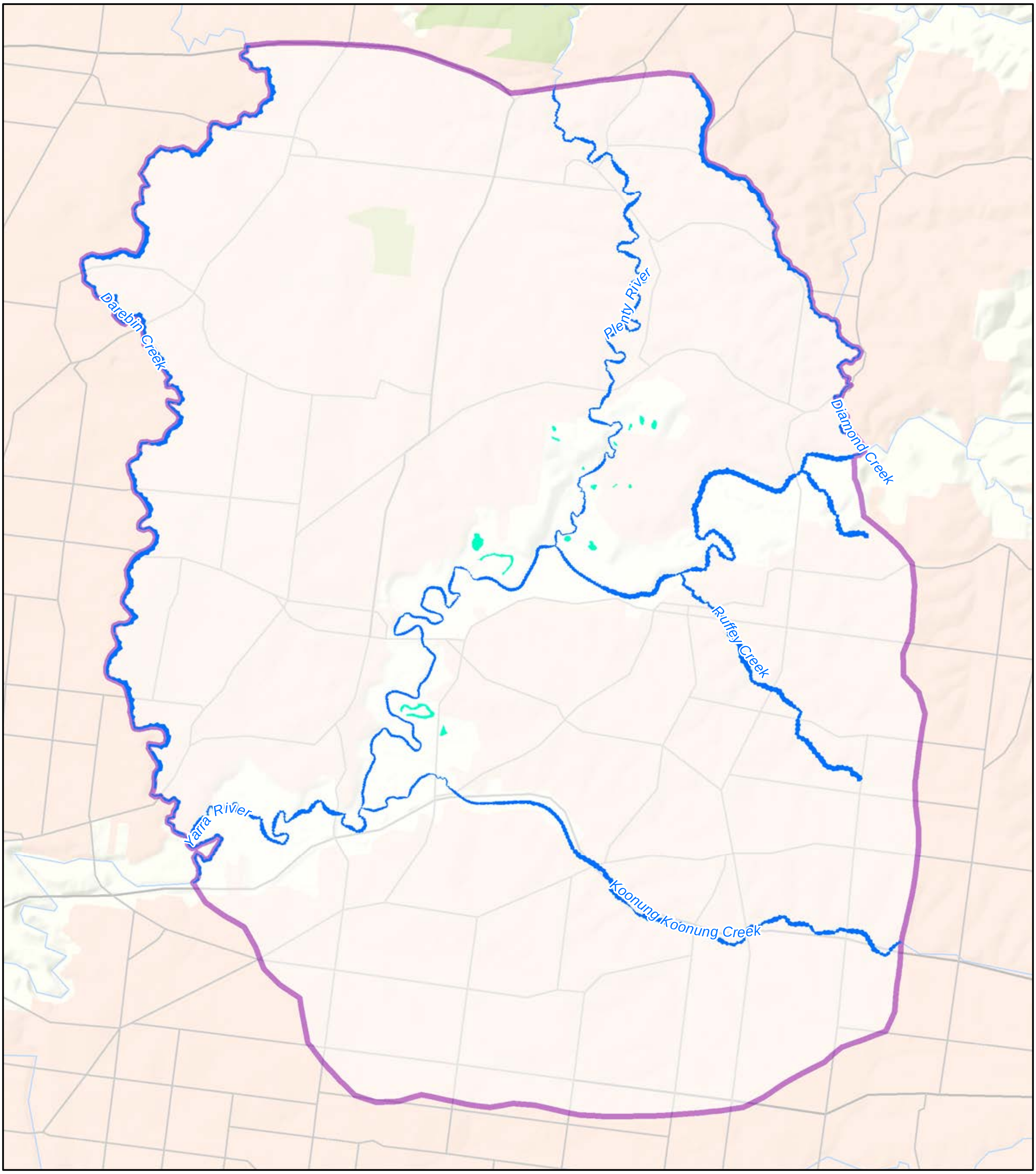


Figure 7 RIV boundary condition – surface water courses



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

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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

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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.

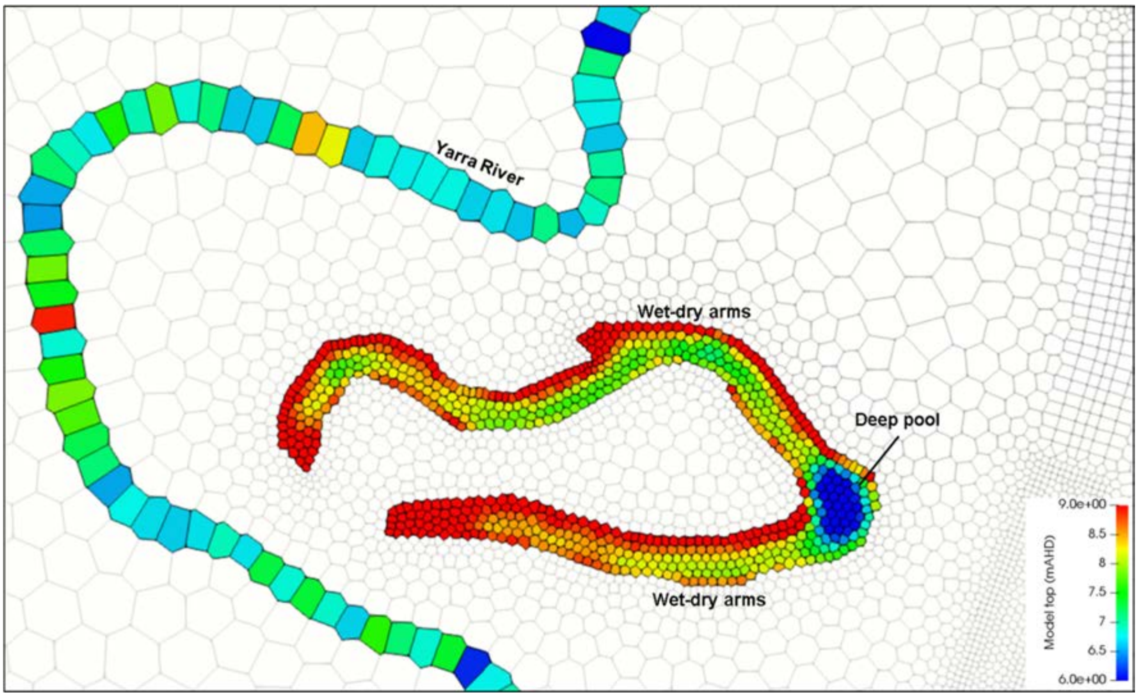


Figure 9 Model top at Bolin Bolin Billabong RIV cells

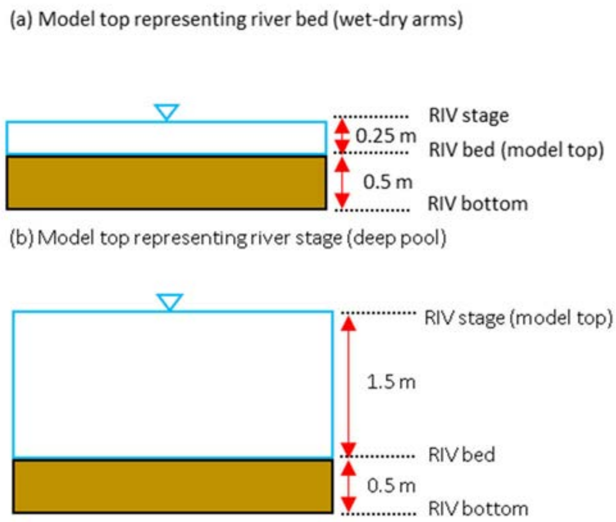


Figure 10 RIV boundary condition – Bolin Bolin Billabong

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.

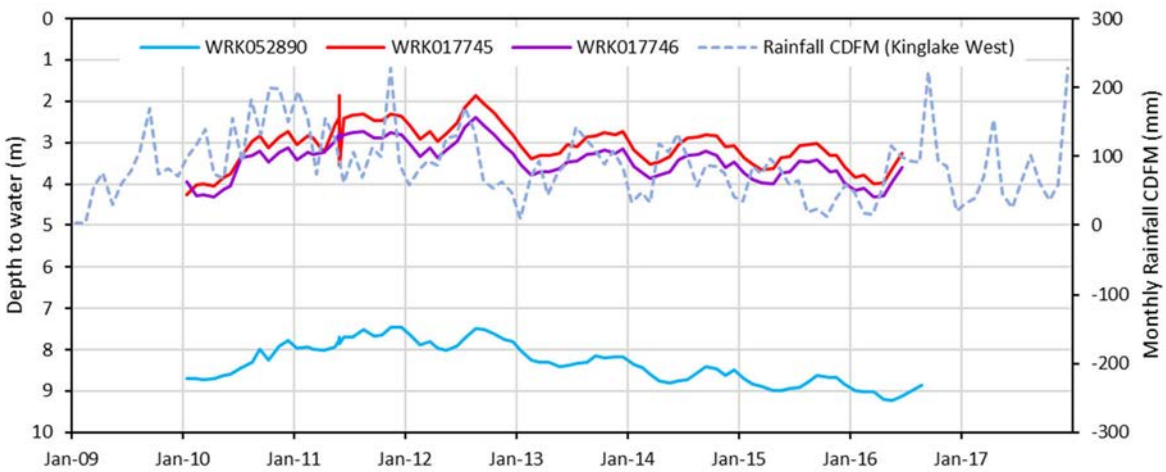


Figure 11 Regional bores (Kinglake) from state database

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.

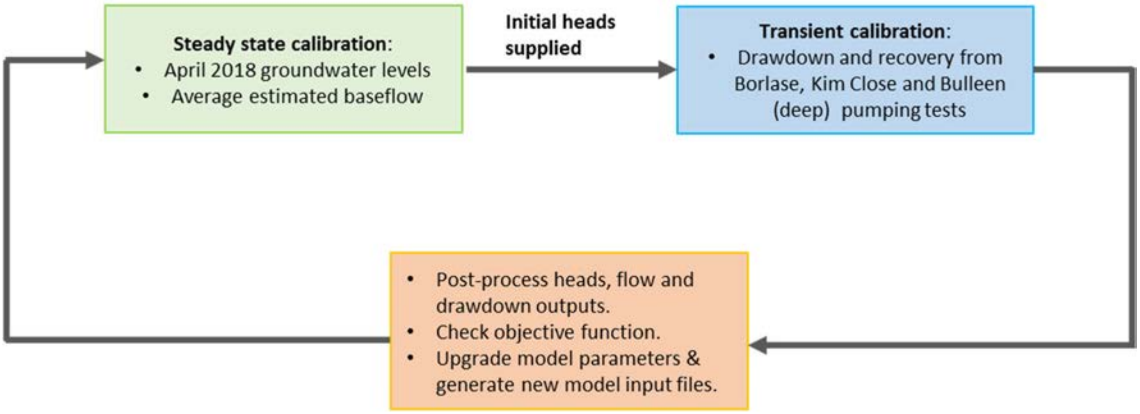


Figure 12 PEST calibration workflow

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.

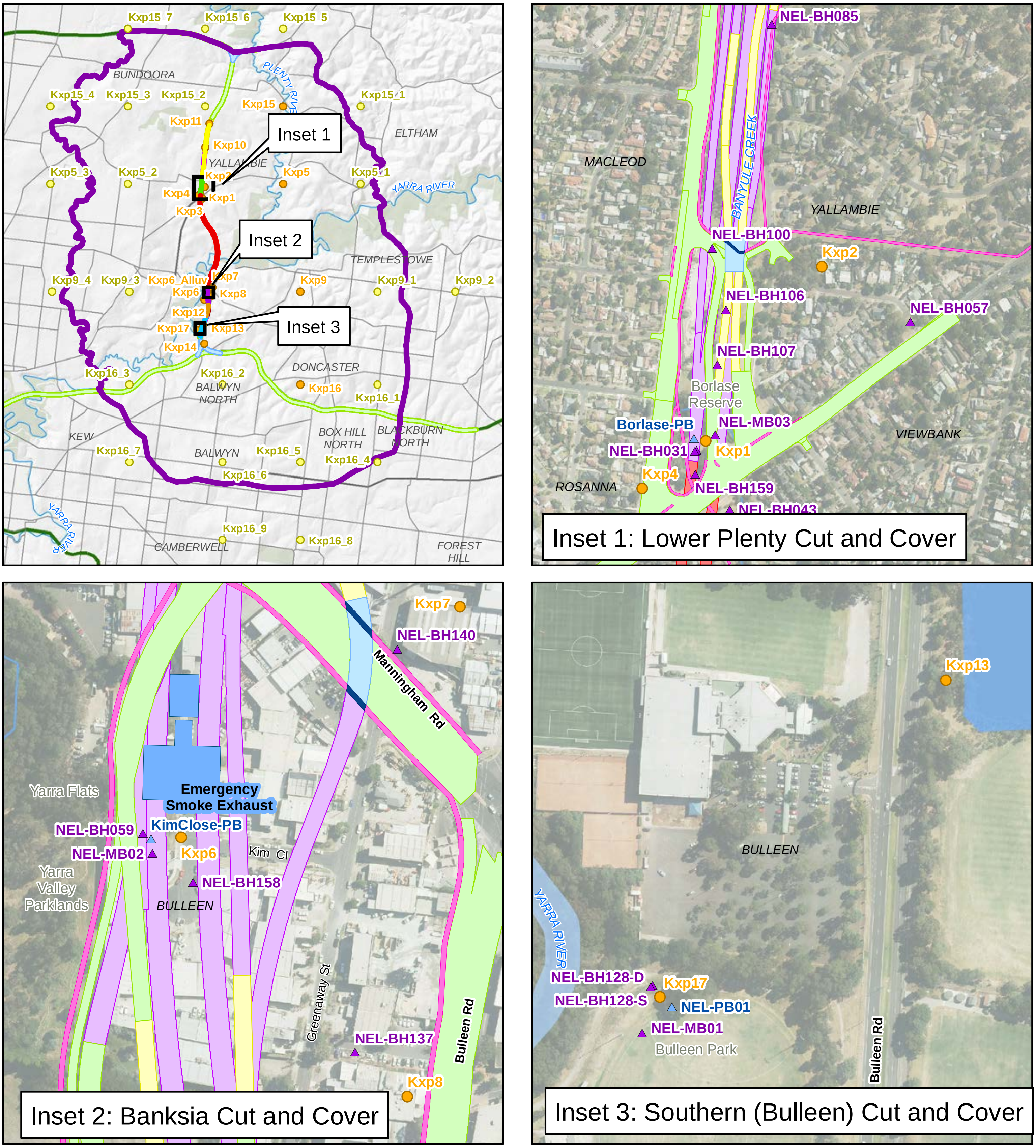
A single model wide RIV hydraulic conductivity is used to adjust RIV conductance, which is varied from 0.001 m/d to 1 m/d assuming a typical range of value for clayey/silty sands (Fetter, 2001). Recharge is varied from 10 mm/yr to 100 mm/yr. The maximum recharge is based on the long-term average recharge 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).



Legend

Pilot Point Type
- Adjustable
- Tied

Bore Type
- Observation Bore
- Pumping Test Bore

- GW Model Domain

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

Proposed reference project
- Ventilation system
- Area for substation
- Shared use path overpass
- Shared use path
- Shared use path underpass
- Multi-deck car park
- Public transport infrastructure upgrade
- Elevated ramp
- Surface works
- Open cut
- Cut and cover tunnel
- Rail tunnel
- TBM bored tunnel
- Mined Tunnel

Paper Size A4

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
Public Environment Report

Job Number	31-35006
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

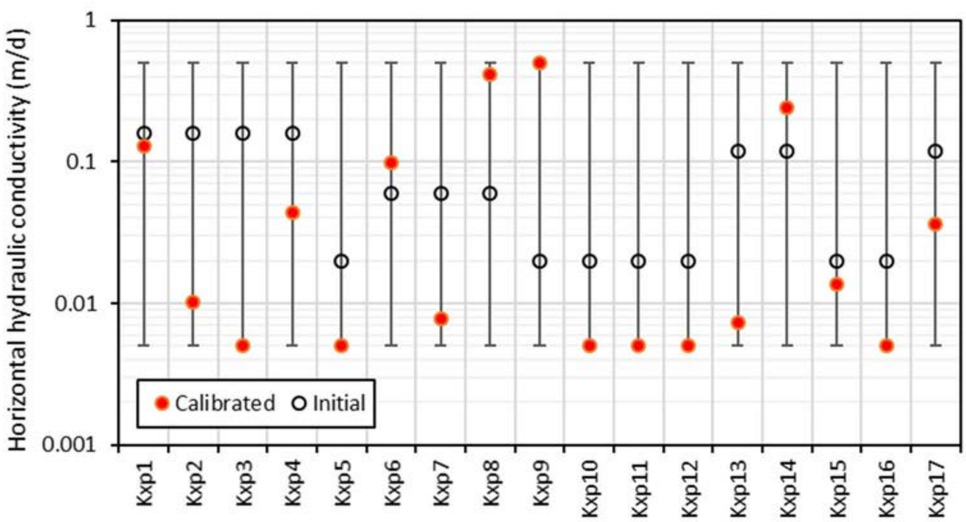
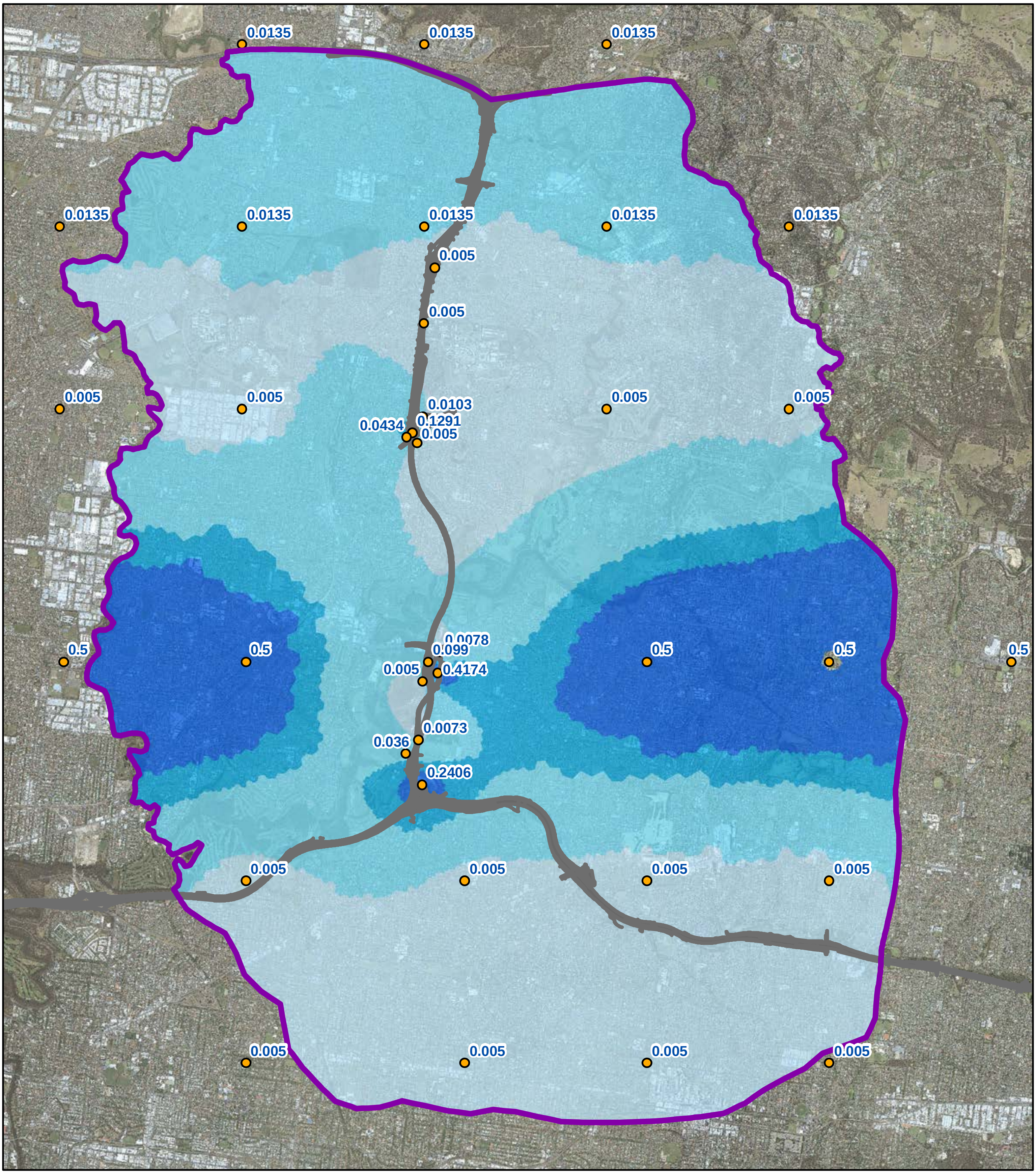


Figure 14 Calibrated pilot point horizontal hydraulic conductivity



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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Job Number 31-35006
Revision A
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

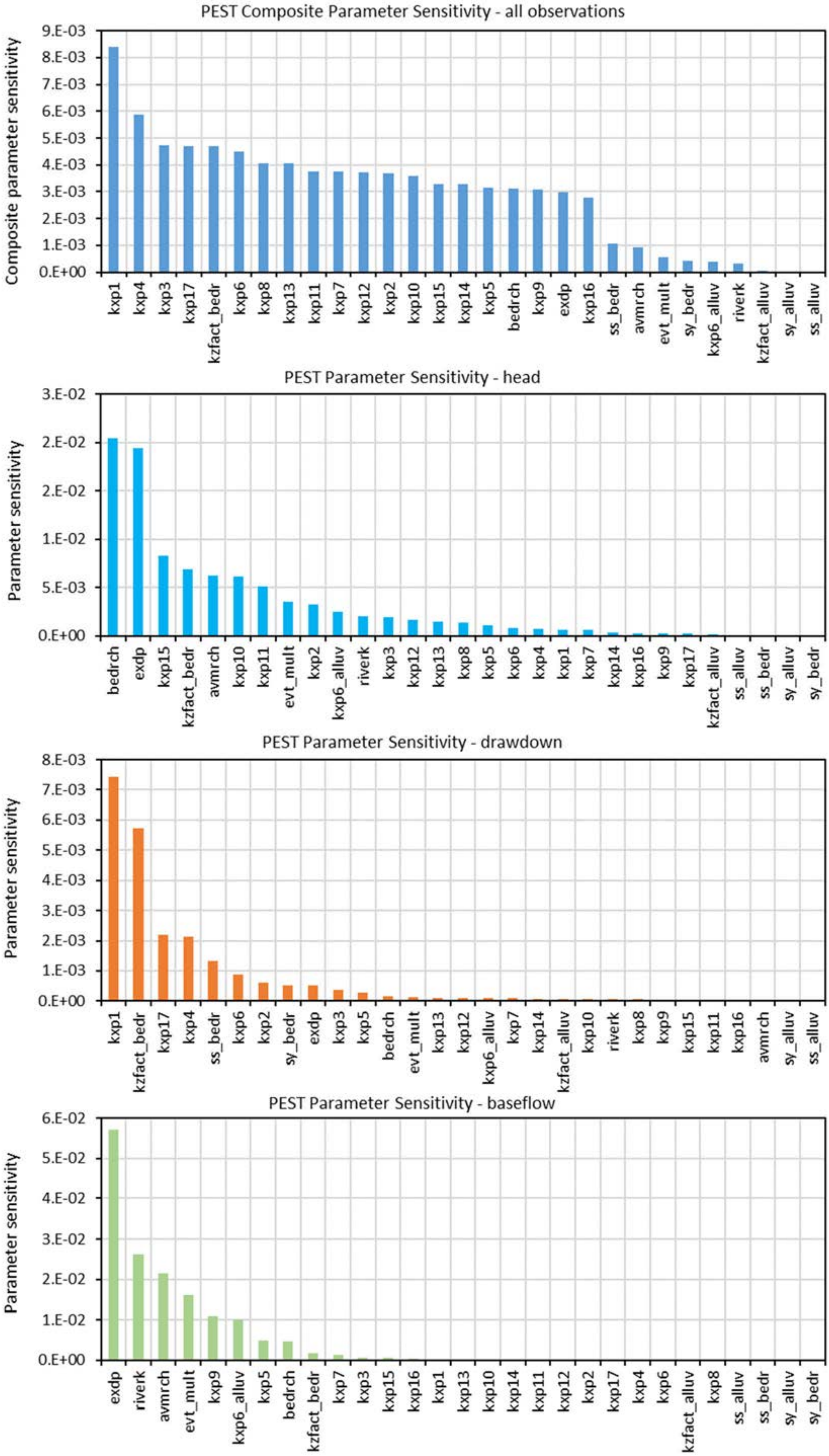
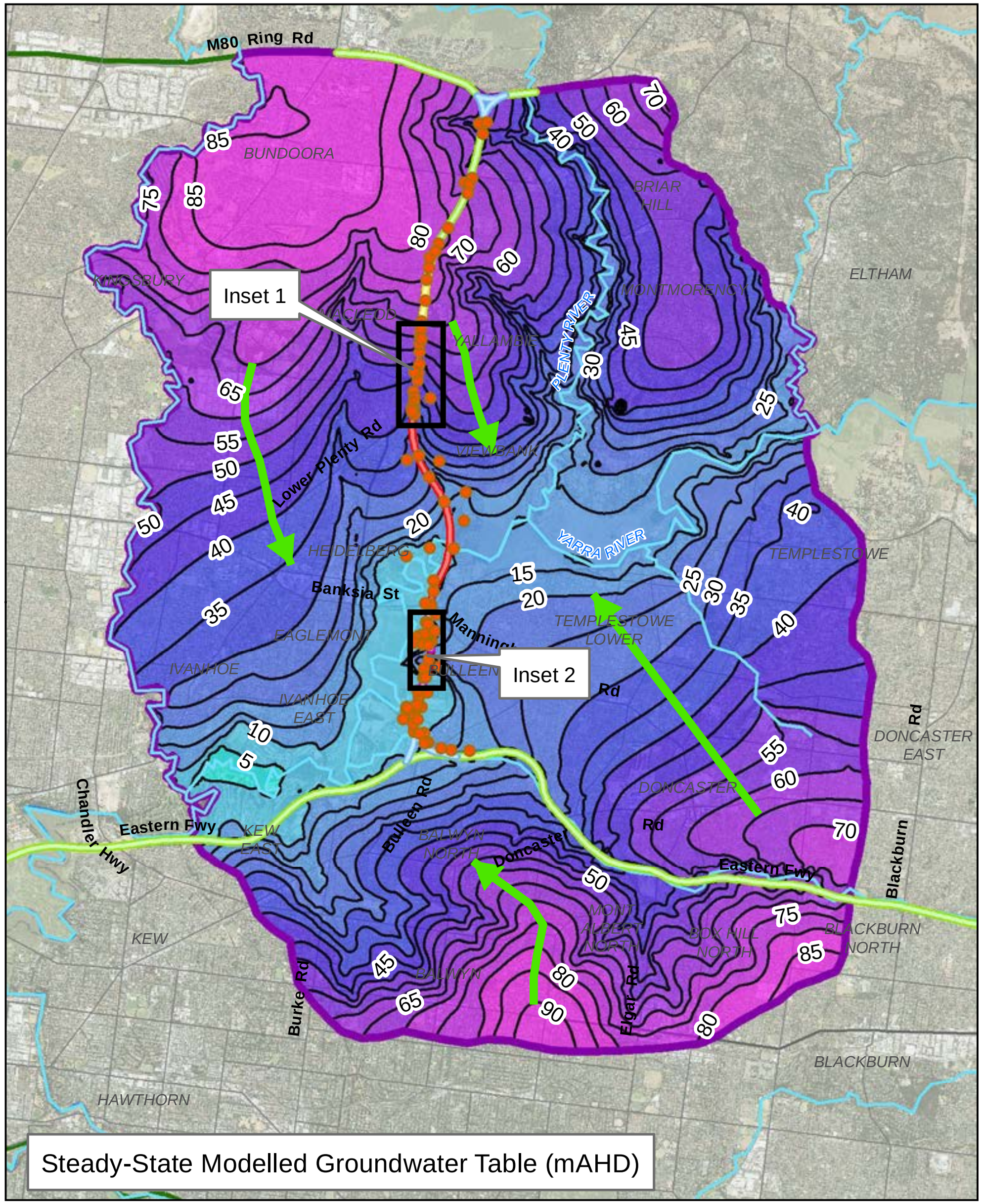
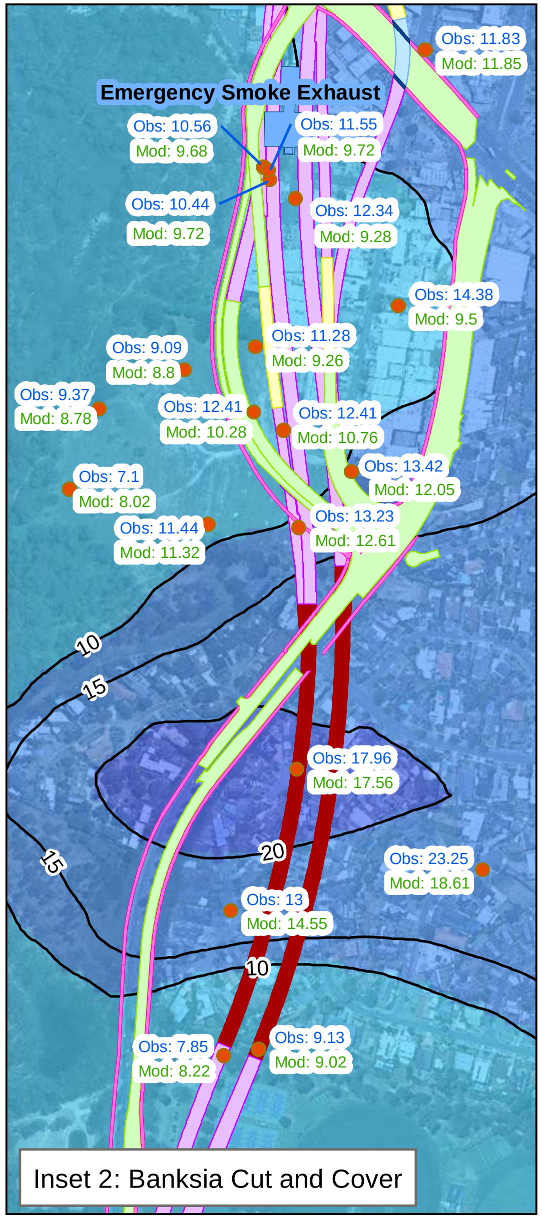


Figure 16 PEST composite parameter sensitivities



Steady-State Modelled Groundwater Table (mAHD)

Inset 1: Lower Plenty Cut and Cover



Inset 2: Banksia Cut and Cover

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

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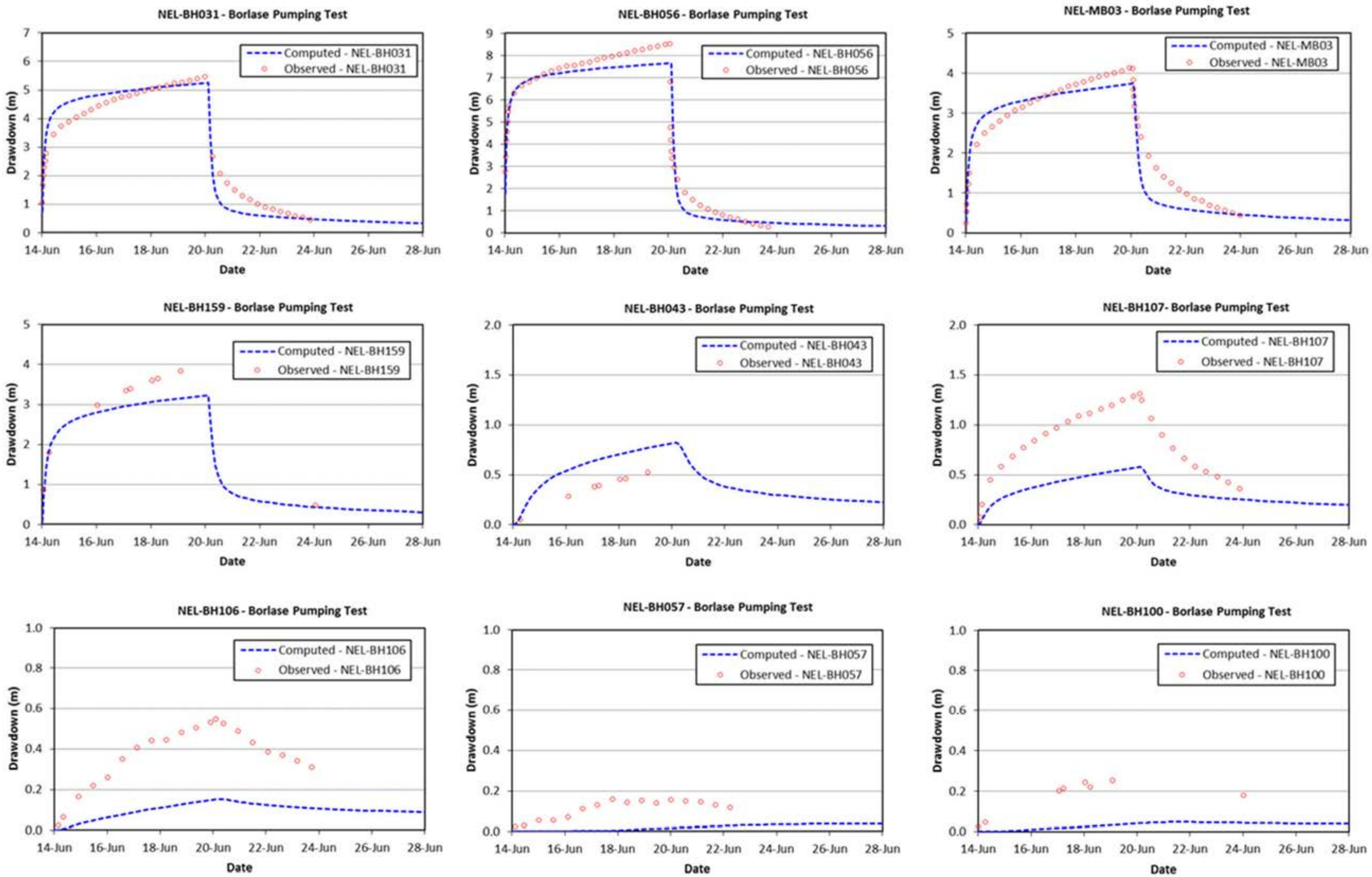
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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


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

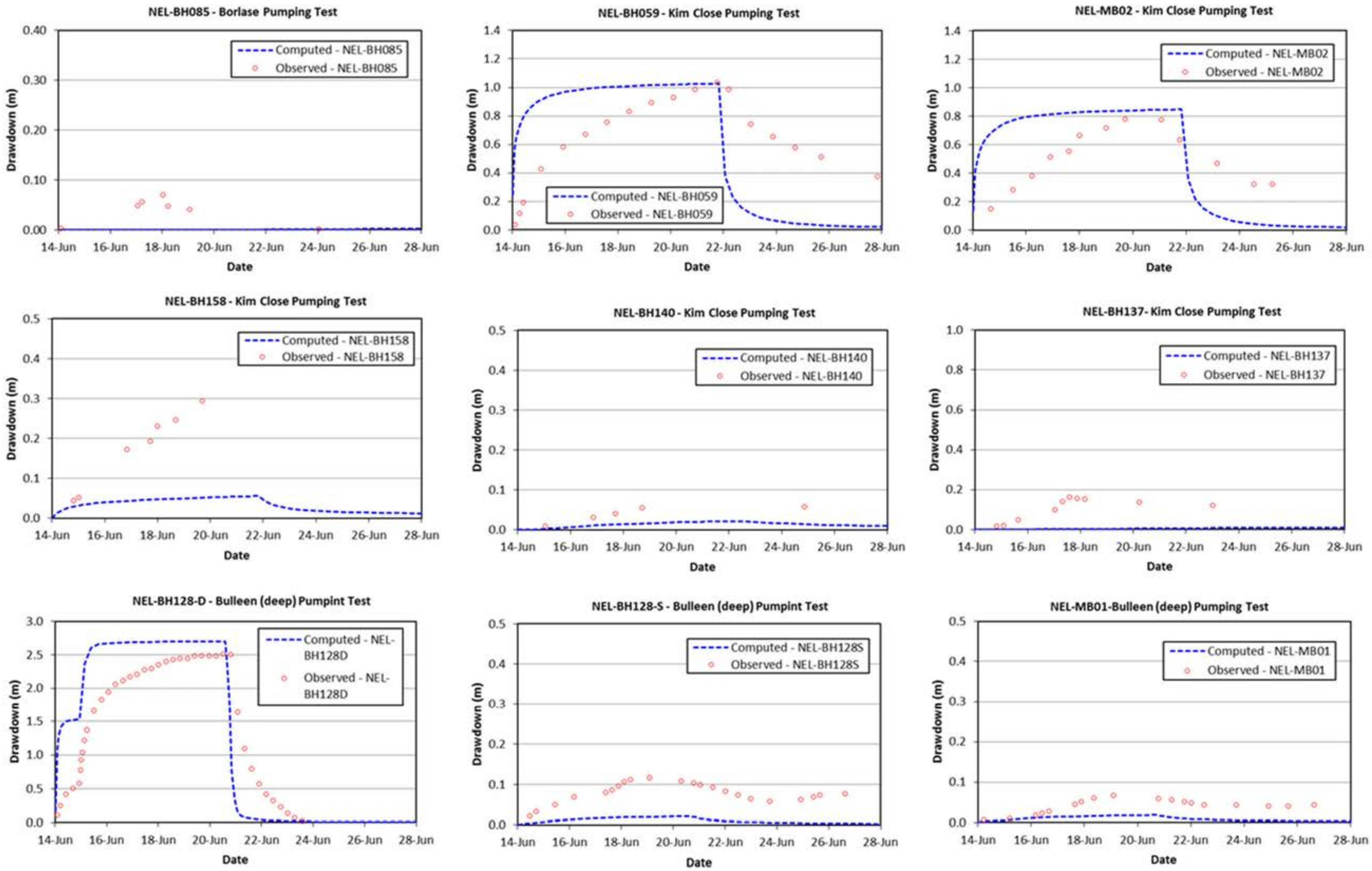
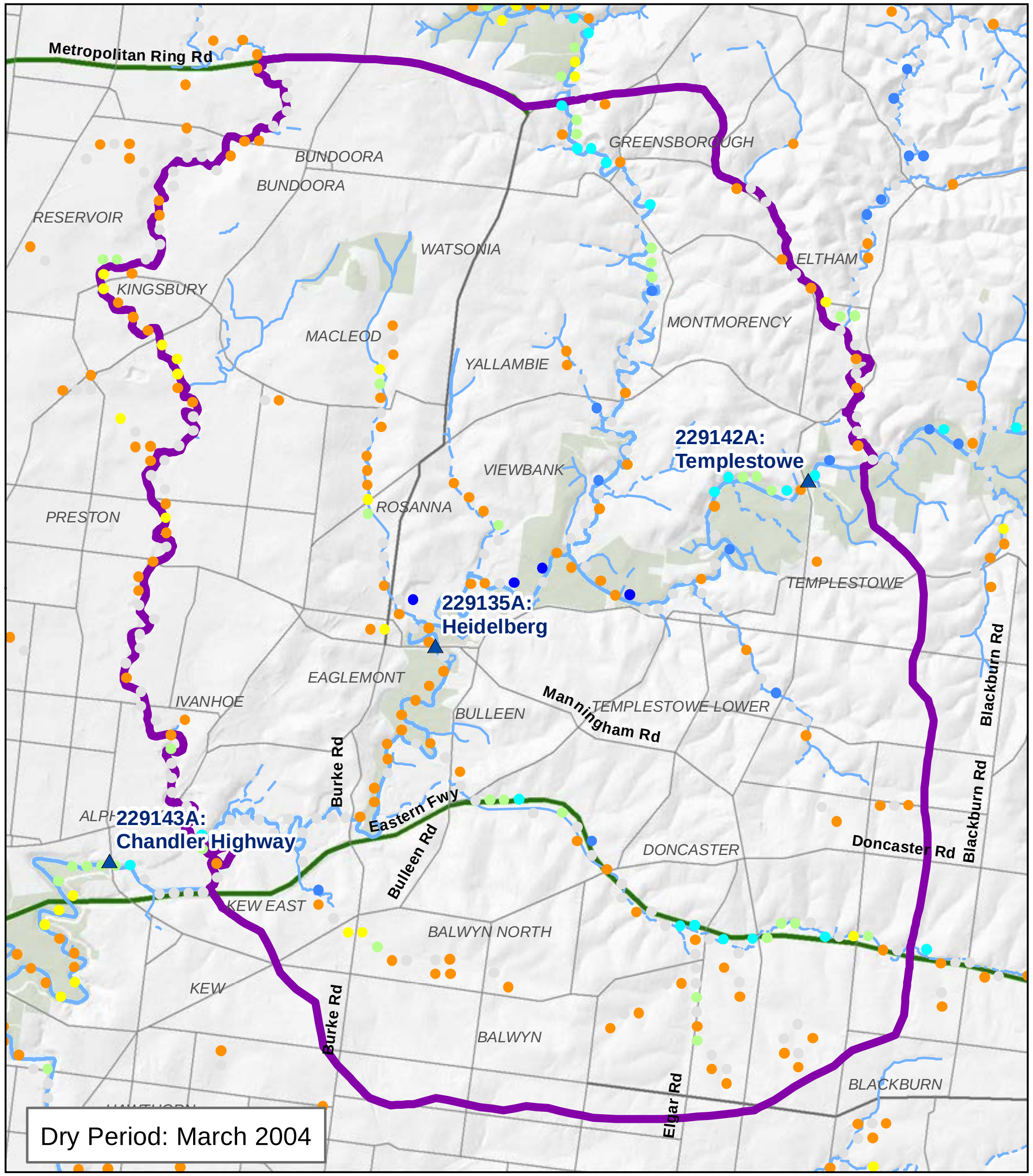
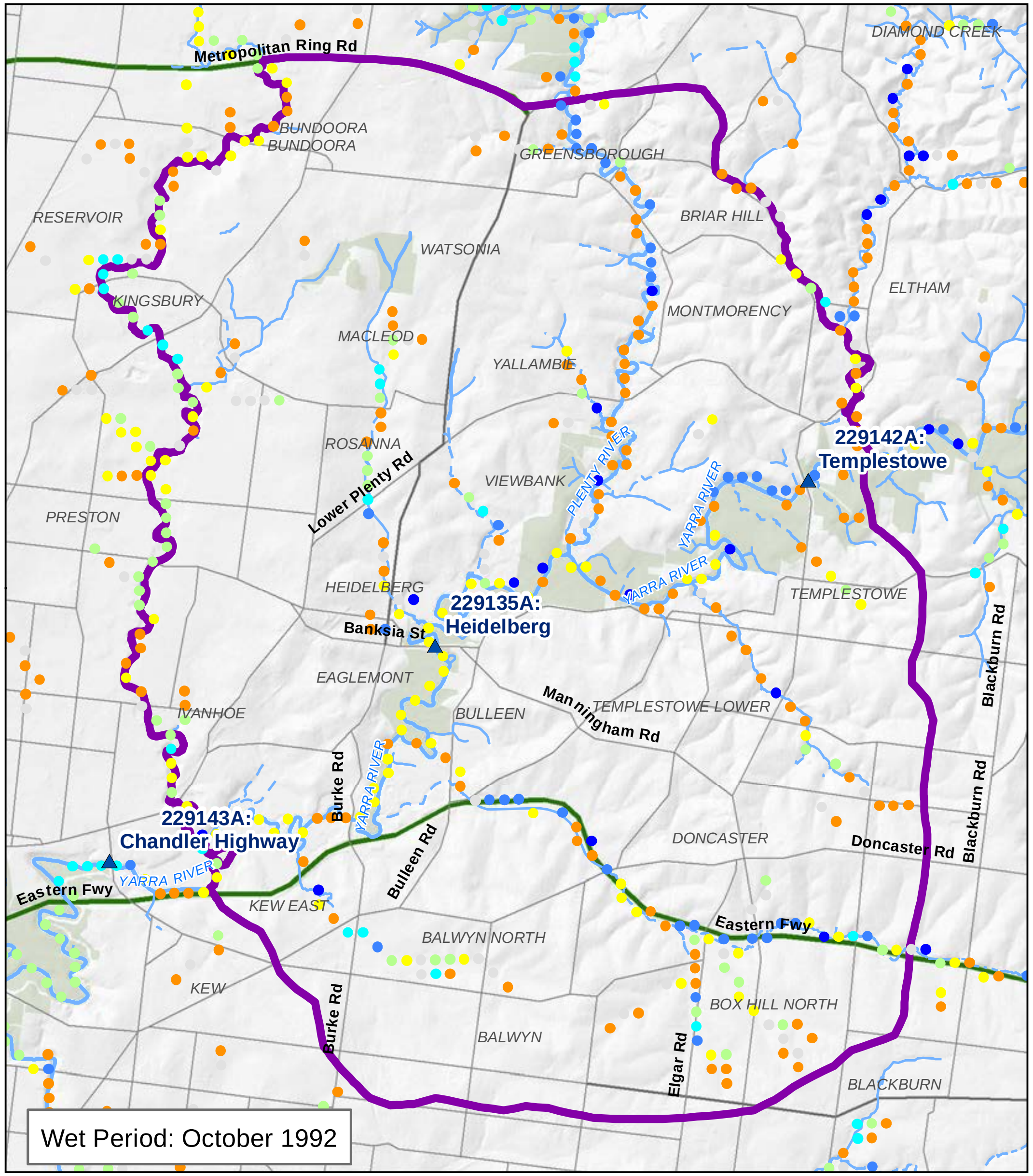


Figure 18 Calibrated drawdown hydrographs





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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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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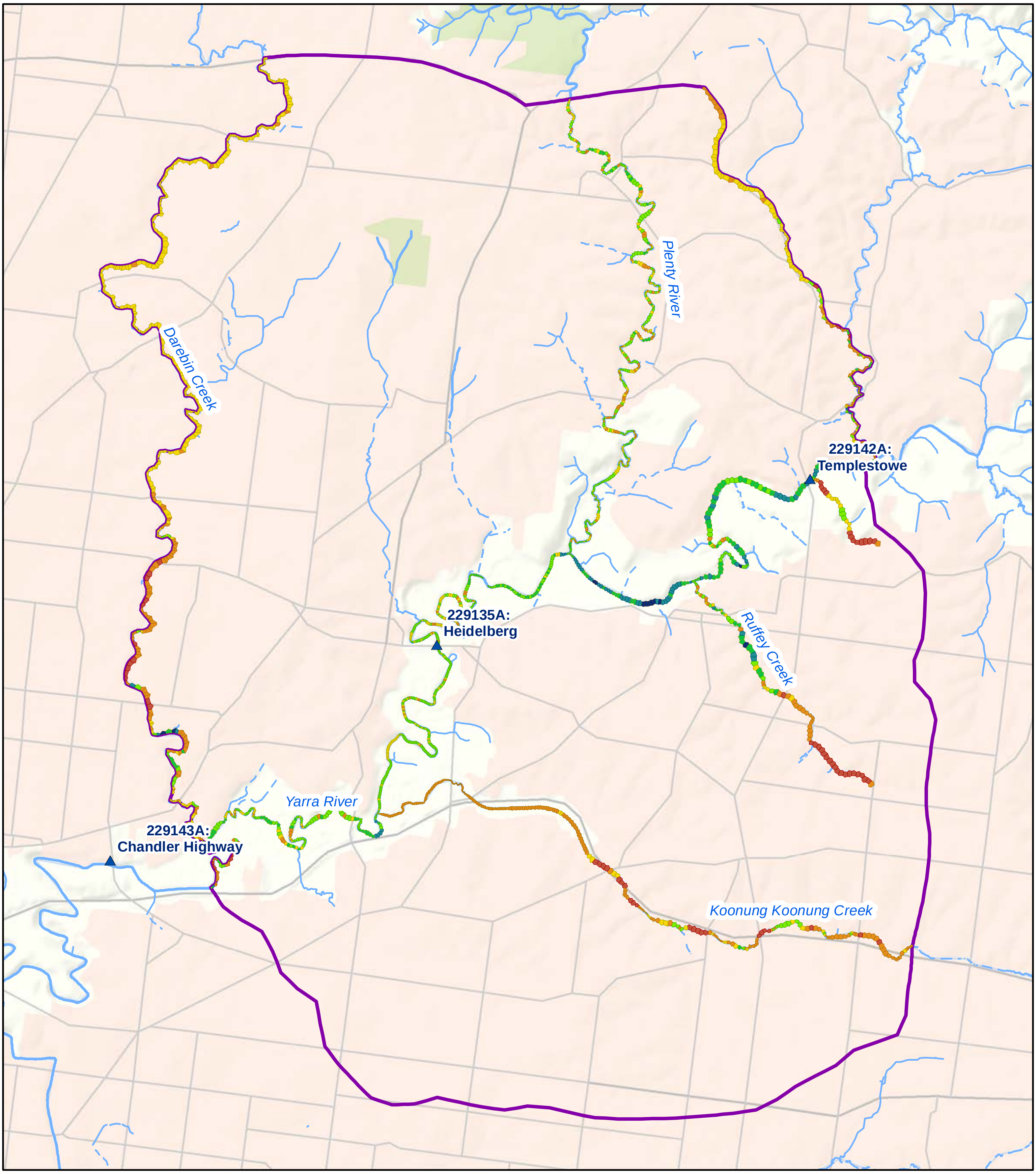
Data source: DELWP / GHD, EcoMarkets GW Model Results, 2010. BaseMaps / DTM, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



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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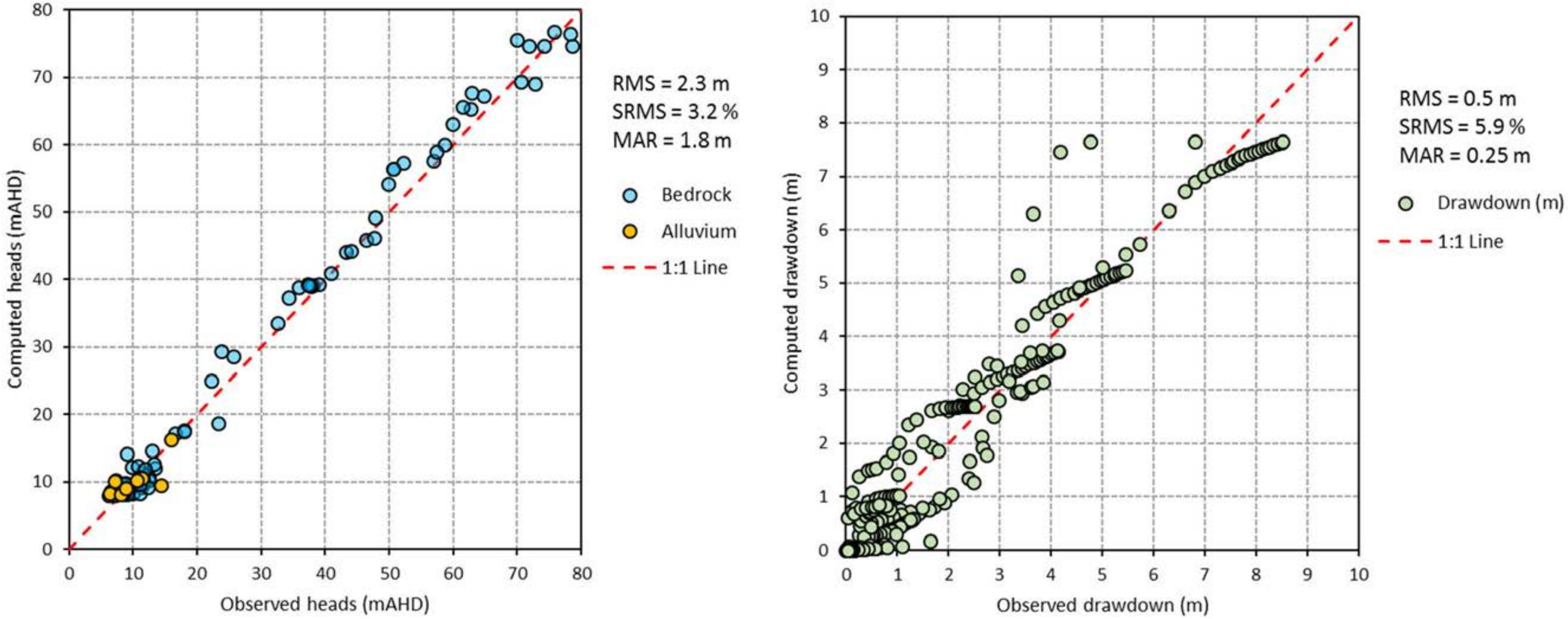


RMS = Root Mean Squared error

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).

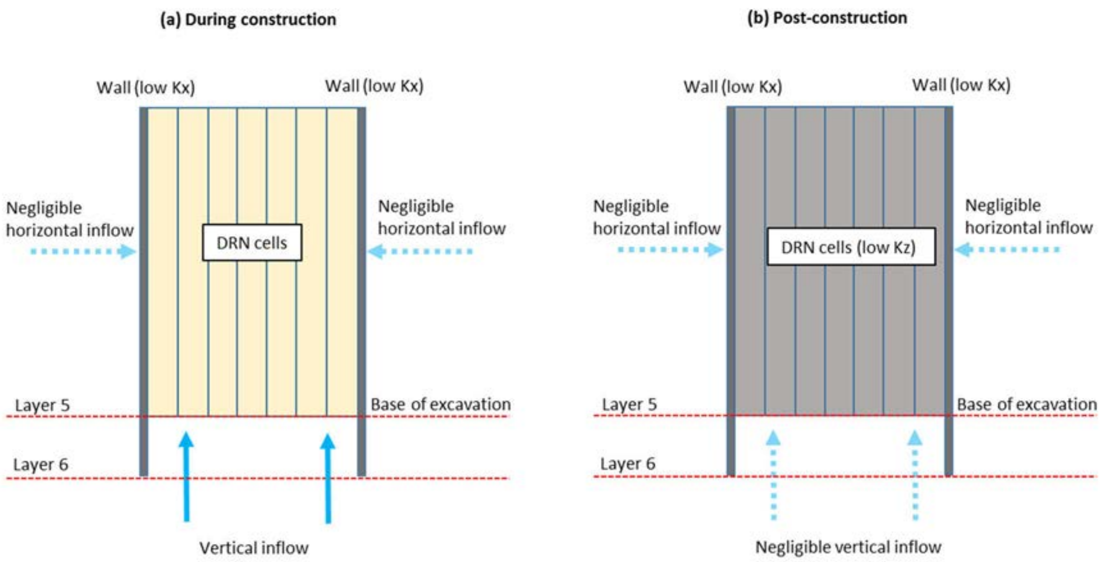


Figure 22 Cut and cover simulation

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).

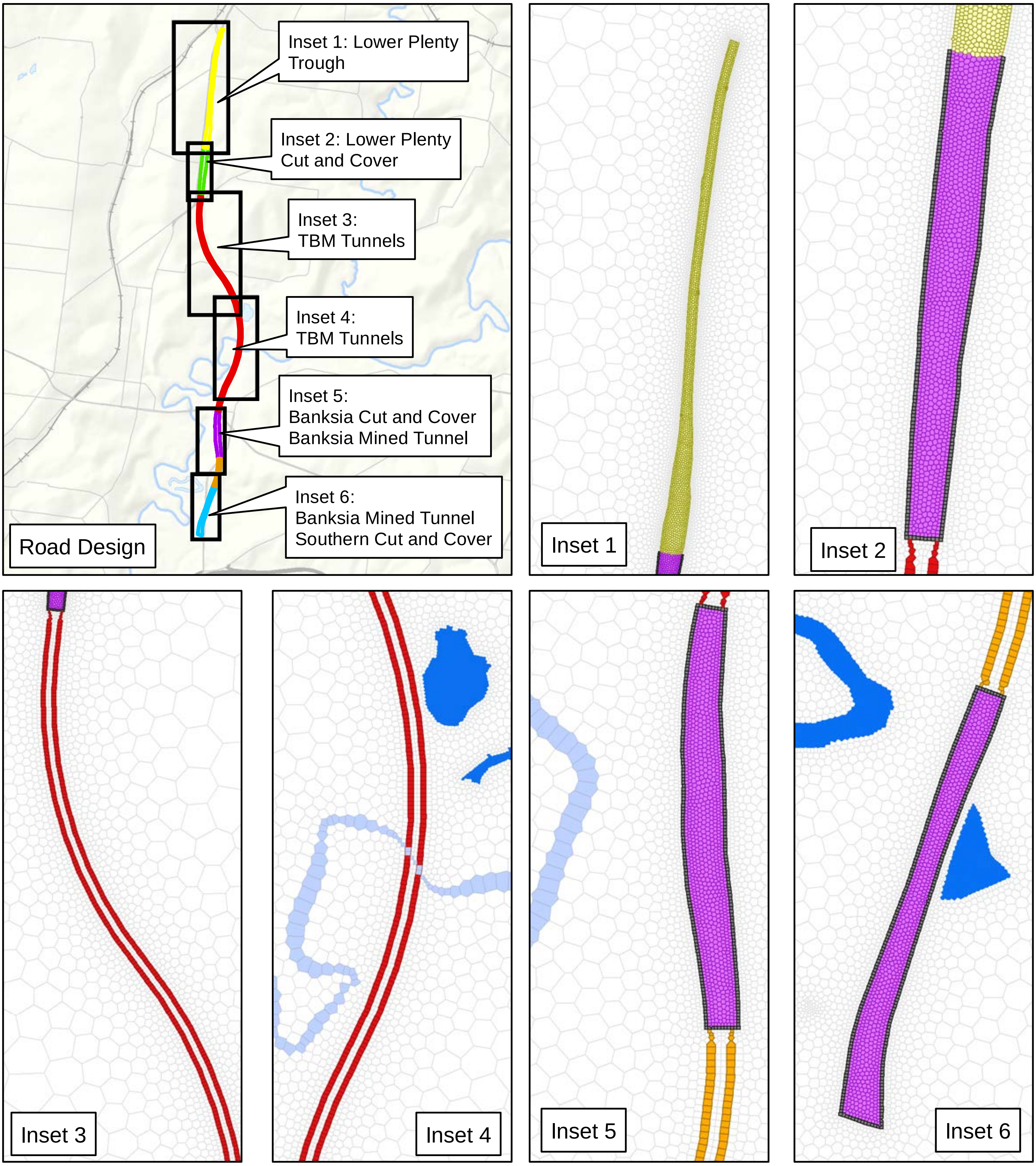
Because the TBM tunnels would not be free draining (seepage would be restricted to the design leakage rate through lining), the second option requires adjustments to the boundary conductance to ensure consistent design leakage rate along the whole length of the tunnel. A simpler approach with the WEL 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

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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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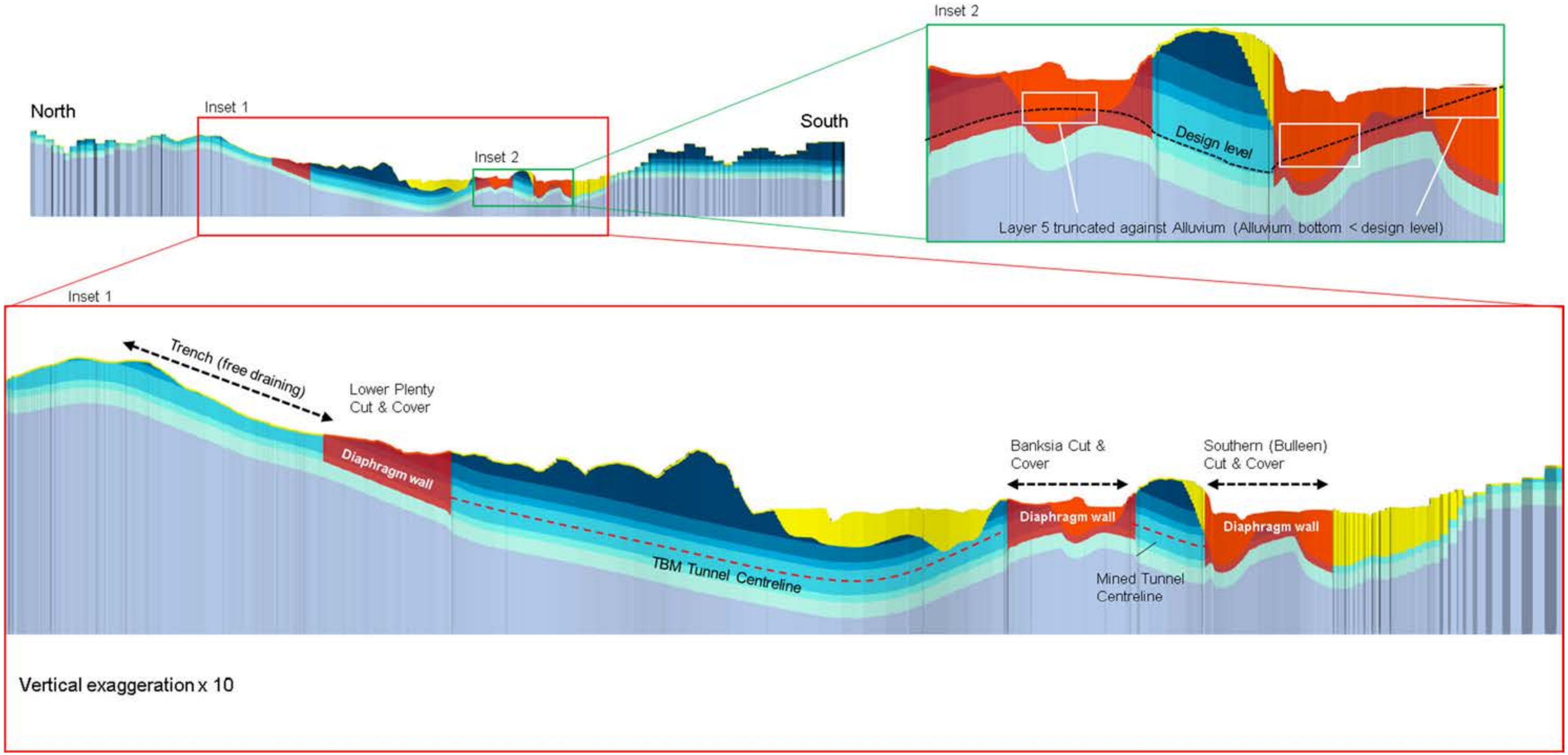


Figure 24 Model cross-section

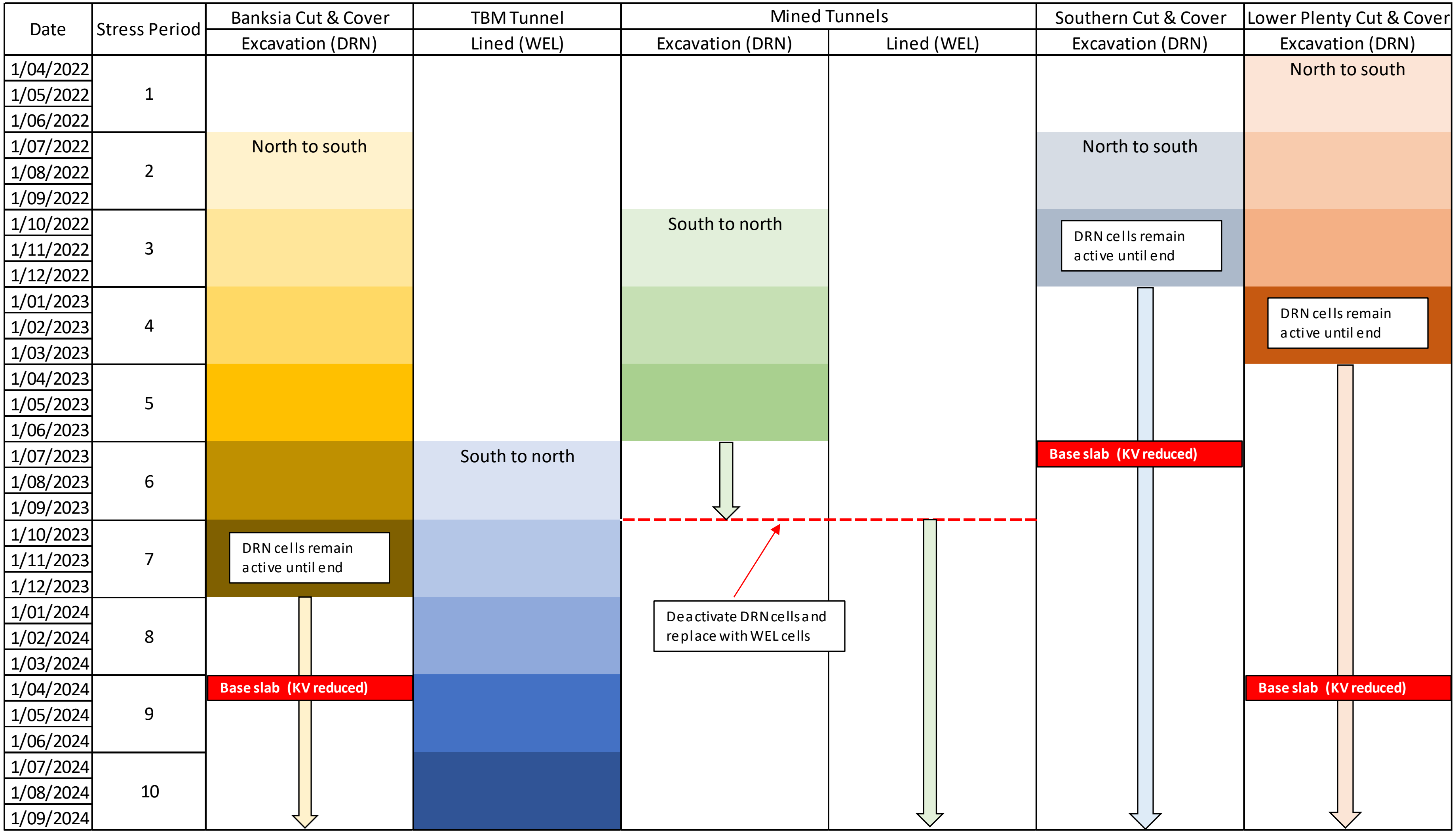


Figure 25 Model construction schedule and boundary conditions

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:

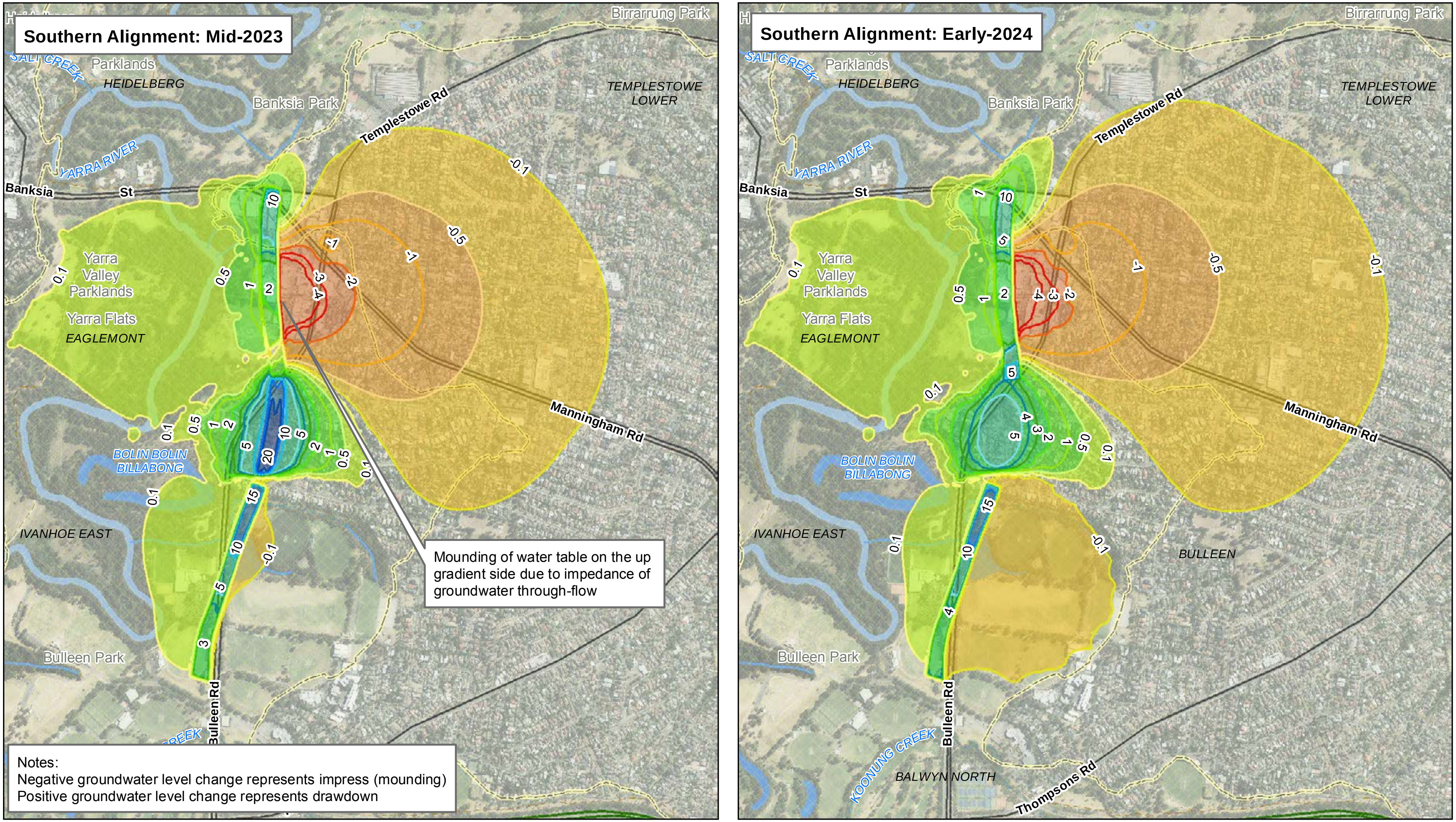
1. Mid 2023, corresponding to the end of excavation of mined tunnels and prior to the placement of base slabs at the Southern (Bulleen) cut and cover.
2. Early 2024, following the lining of the mined tunnels and placement of base slabs at the Southern (Bulleen) cut and cover, and prior to the placement 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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Predicted groundwater level changes –south (2023 – 2024)

Figure 26

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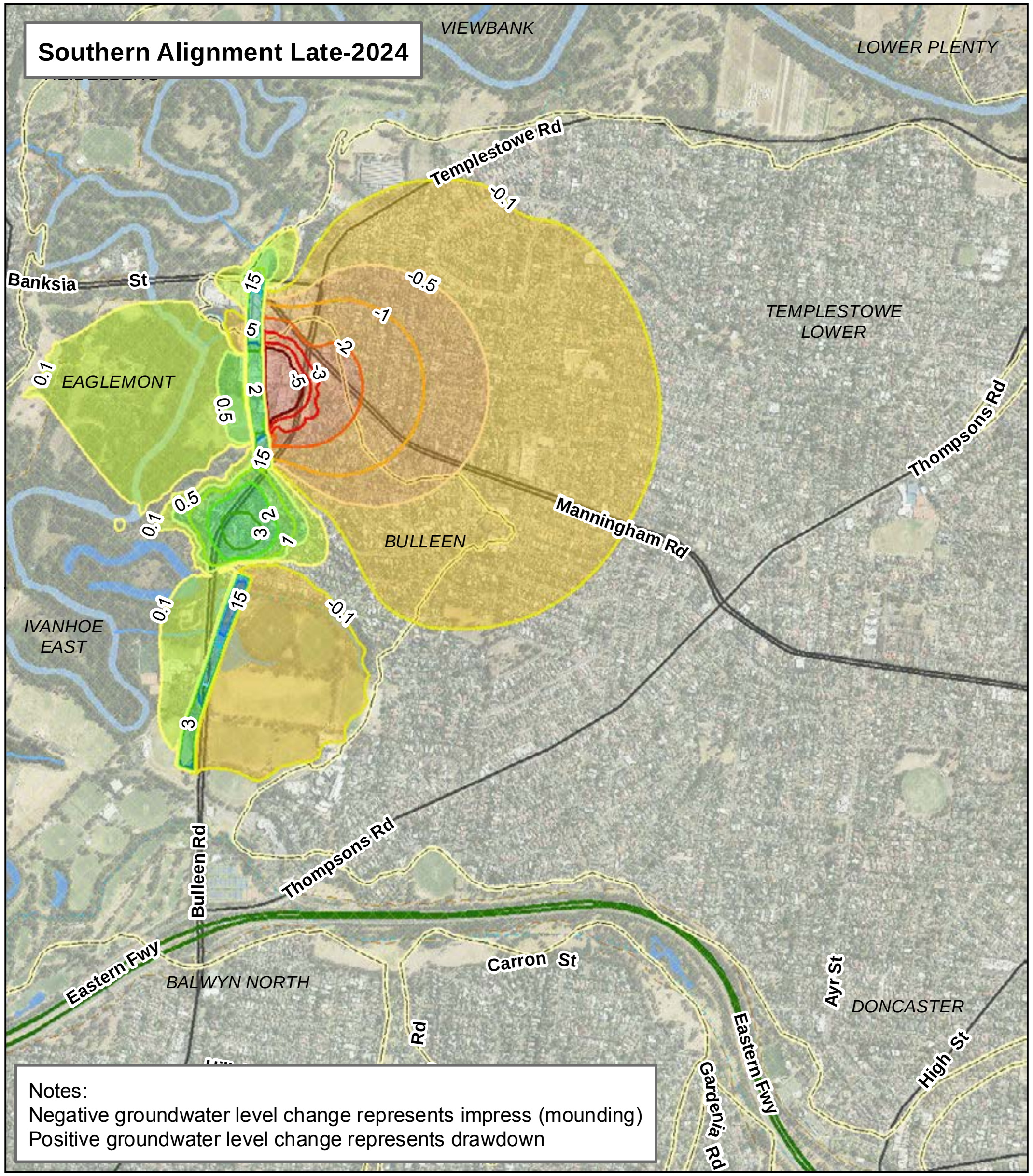
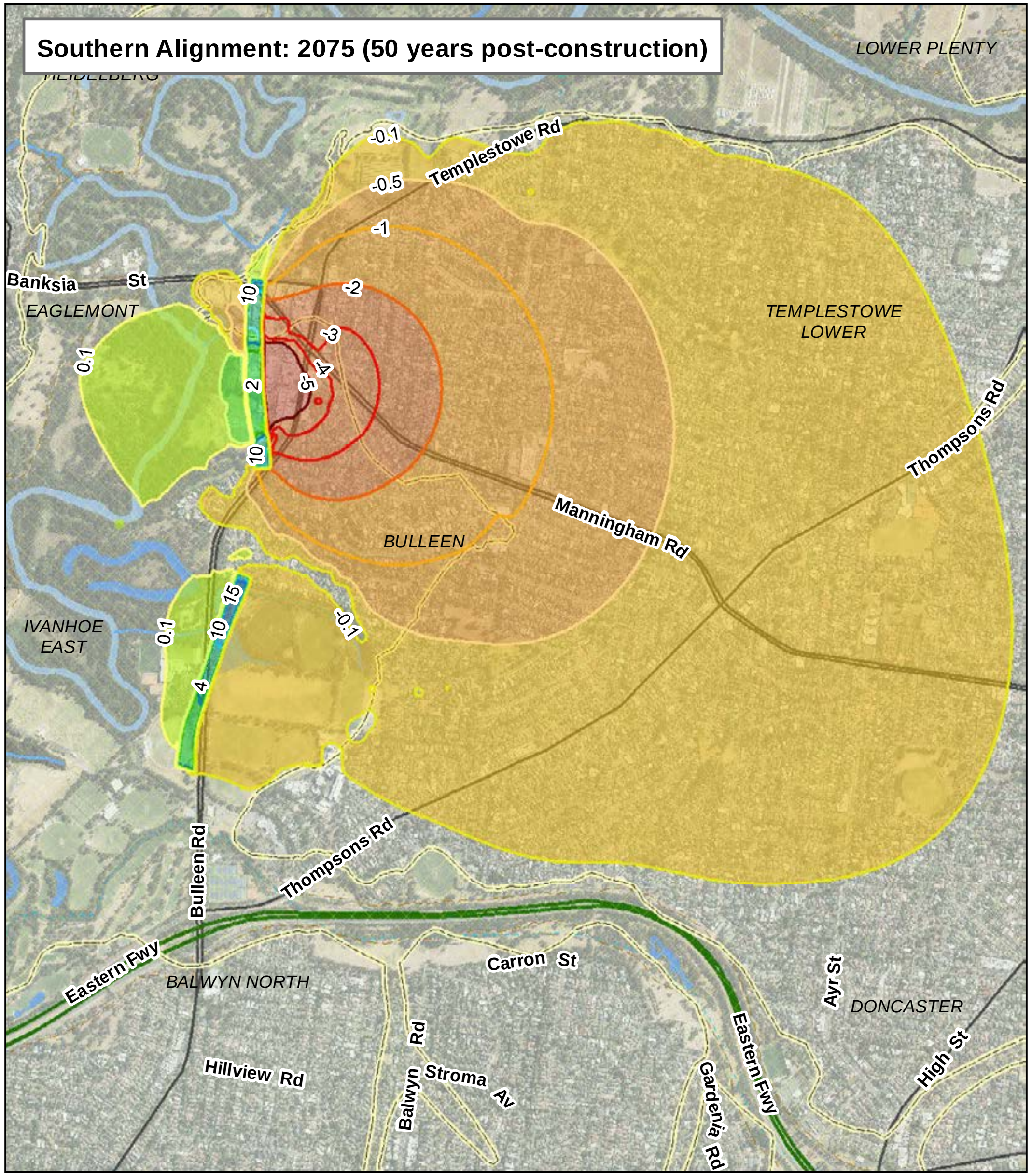
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti





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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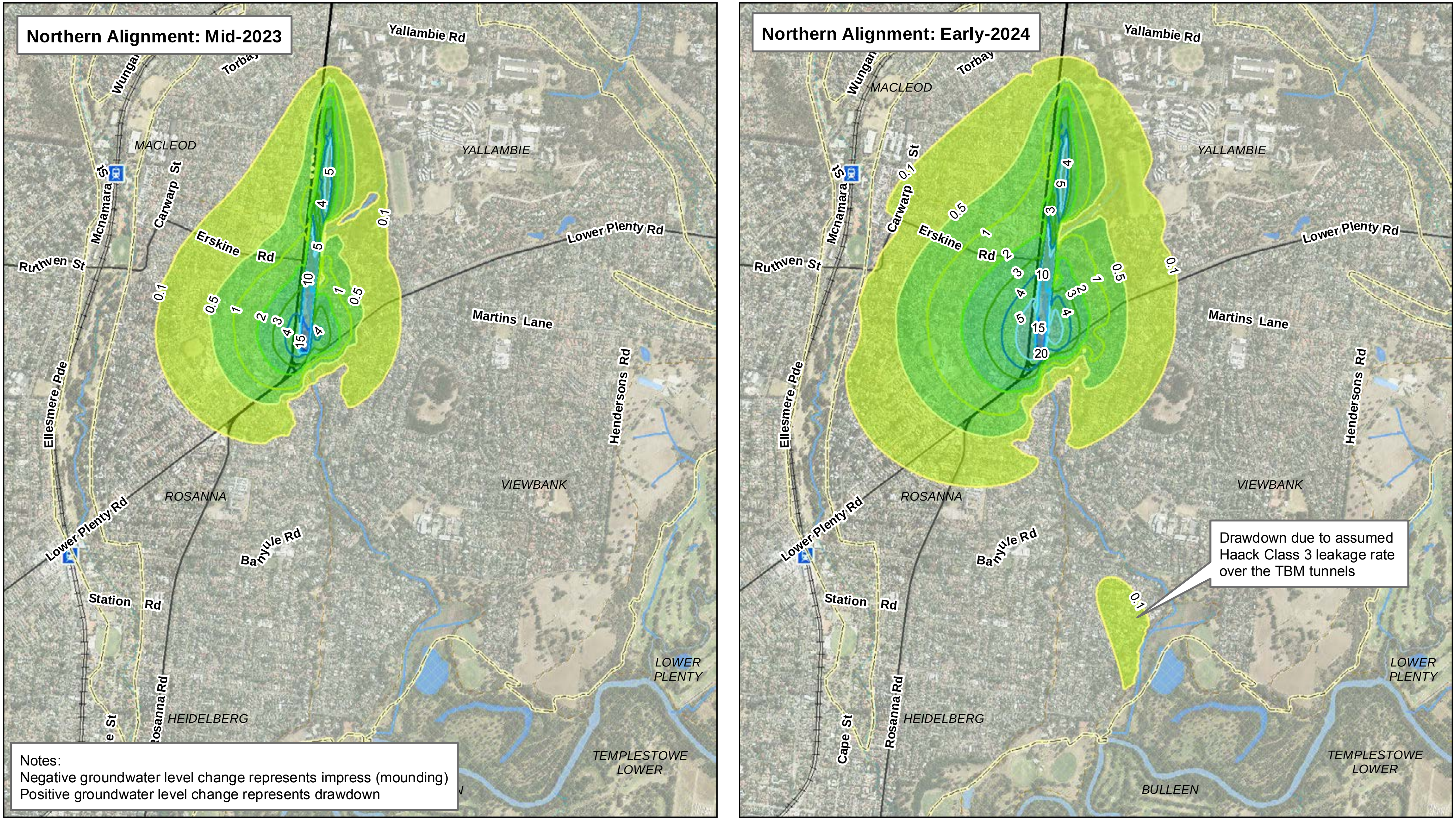

Paper Size A4

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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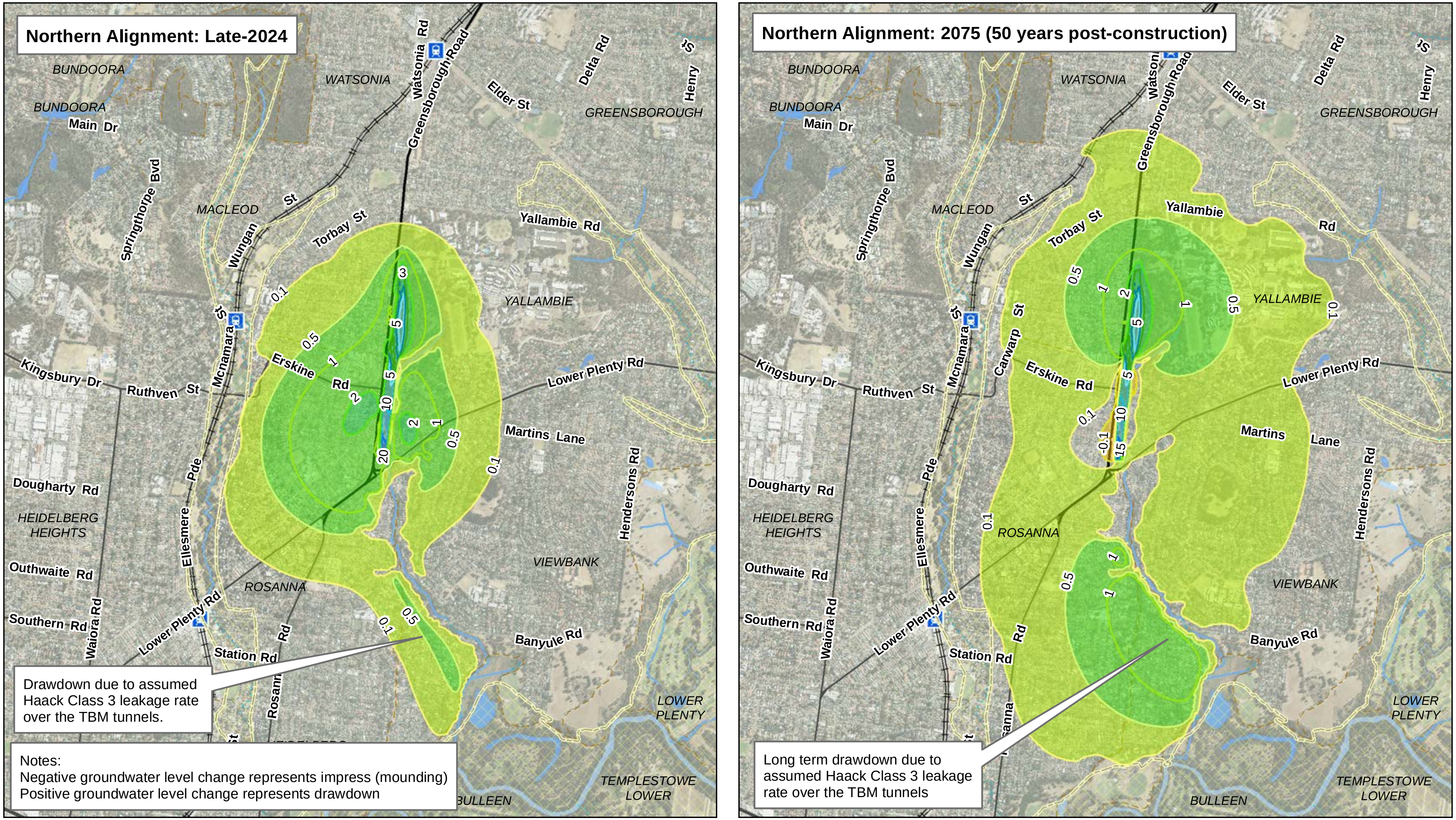
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti



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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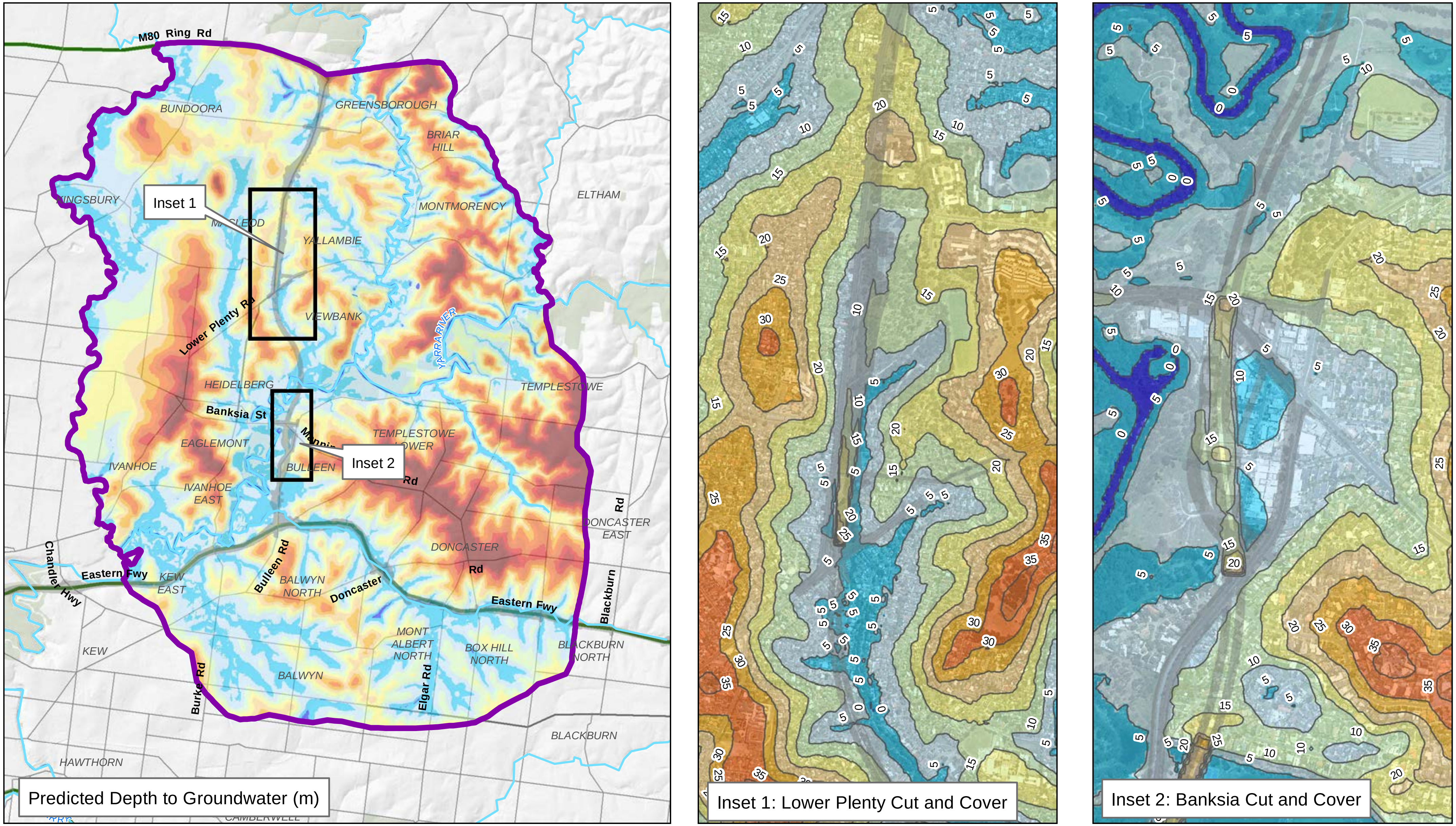
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



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
- 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

NORTH EAST LINK PROJECT

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Predicted Depth to Groundwater Post-Construction

Figure 30

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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.

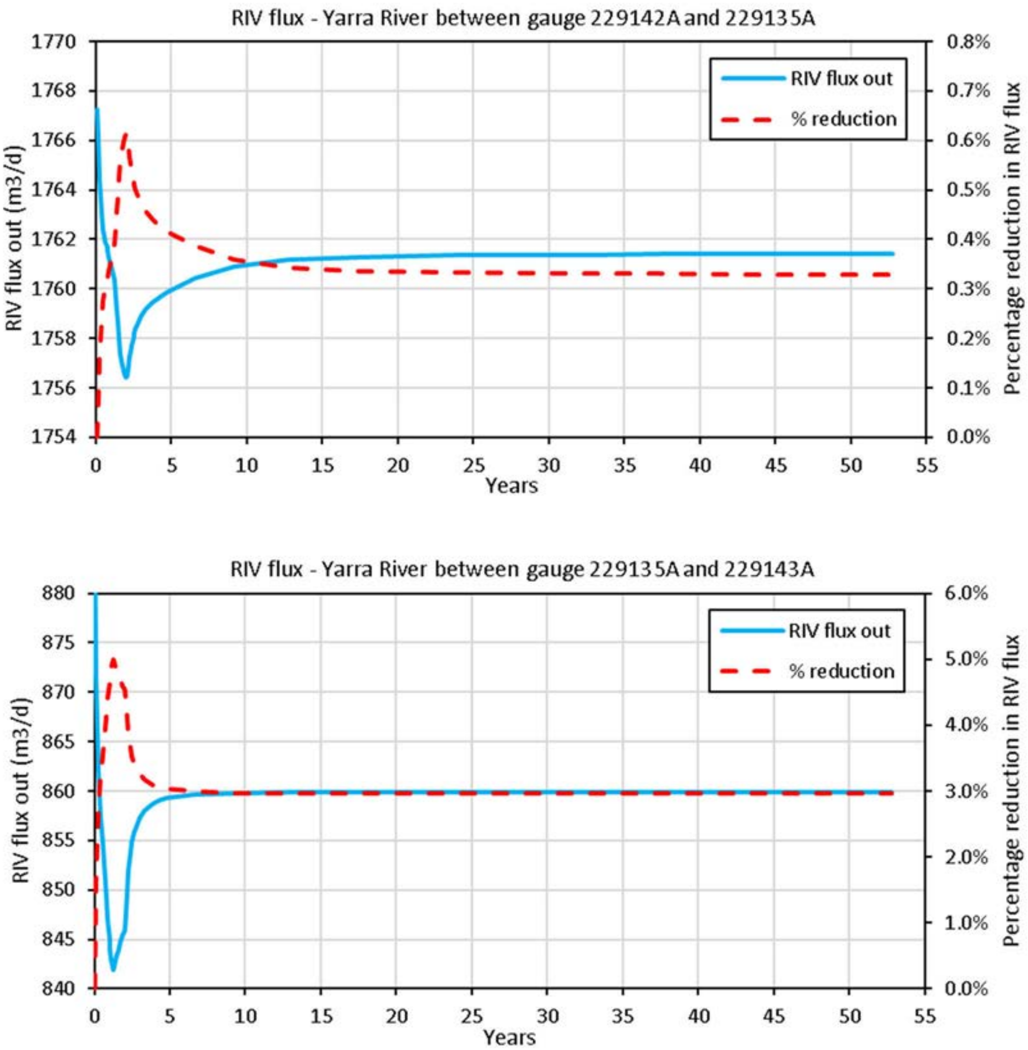


Figure 31 Predicted changes to Yarra River groundwater flux

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.

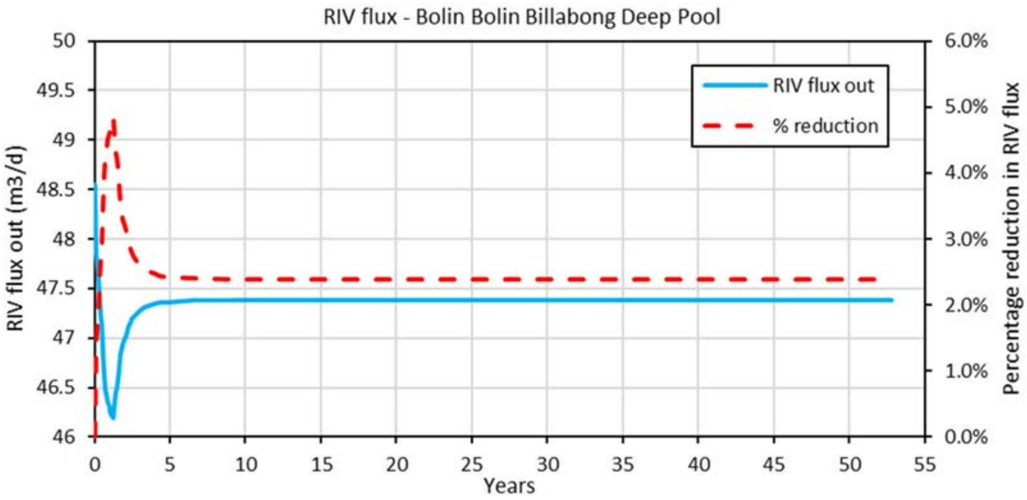


Figure 32 Predicted changes to Bolin Bolin Billabong groundwater flux

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.

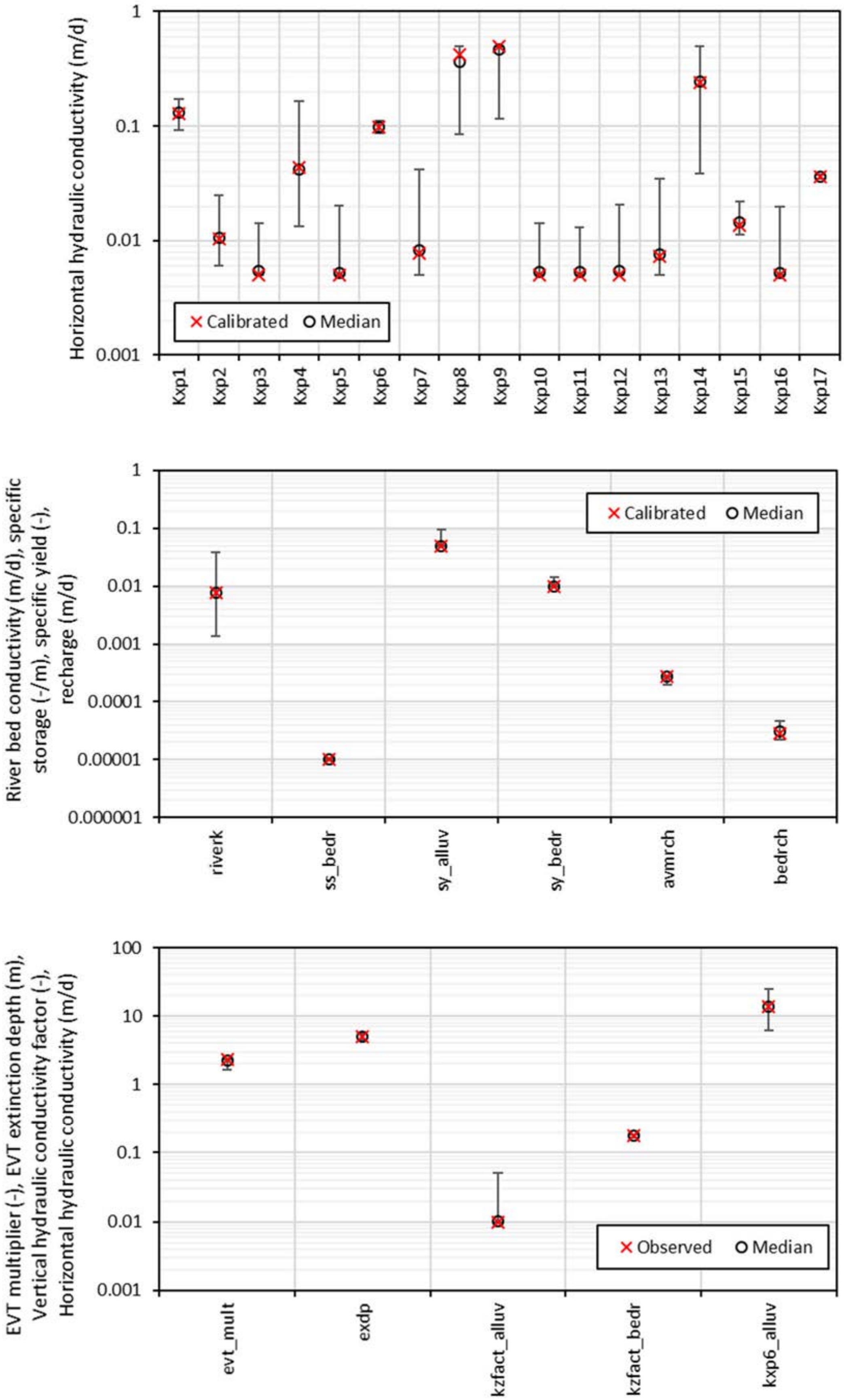


Figure 33 Uncertainty analysis parameter ranges

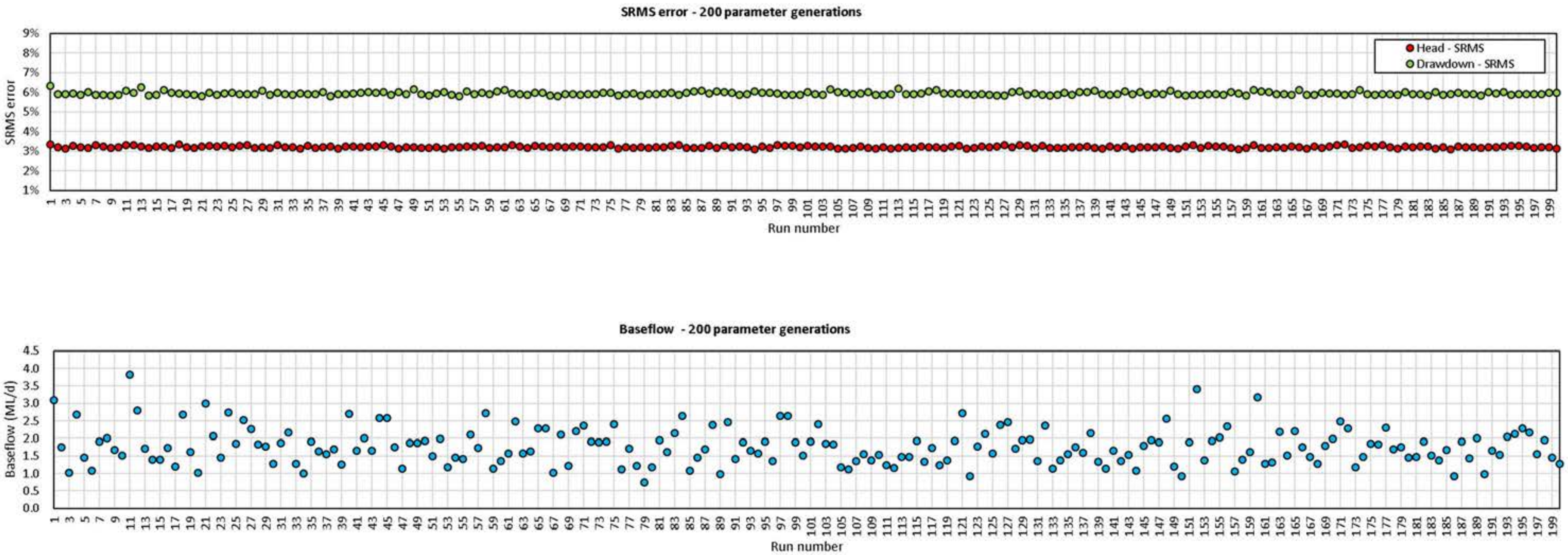


Figure 34 Uncertainty analysis - model calibration of 200 realisations

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.

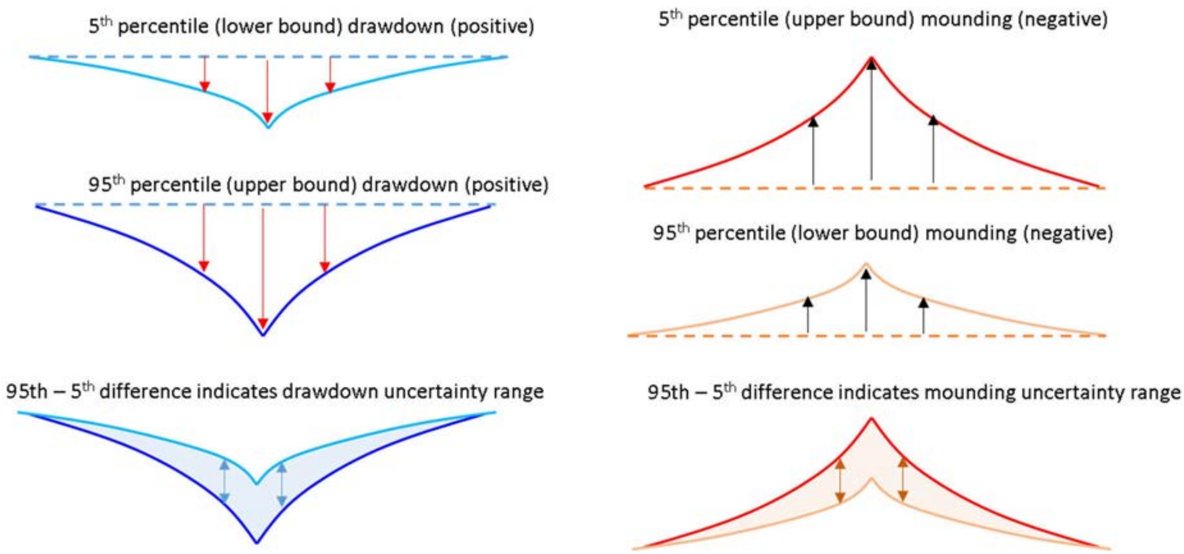
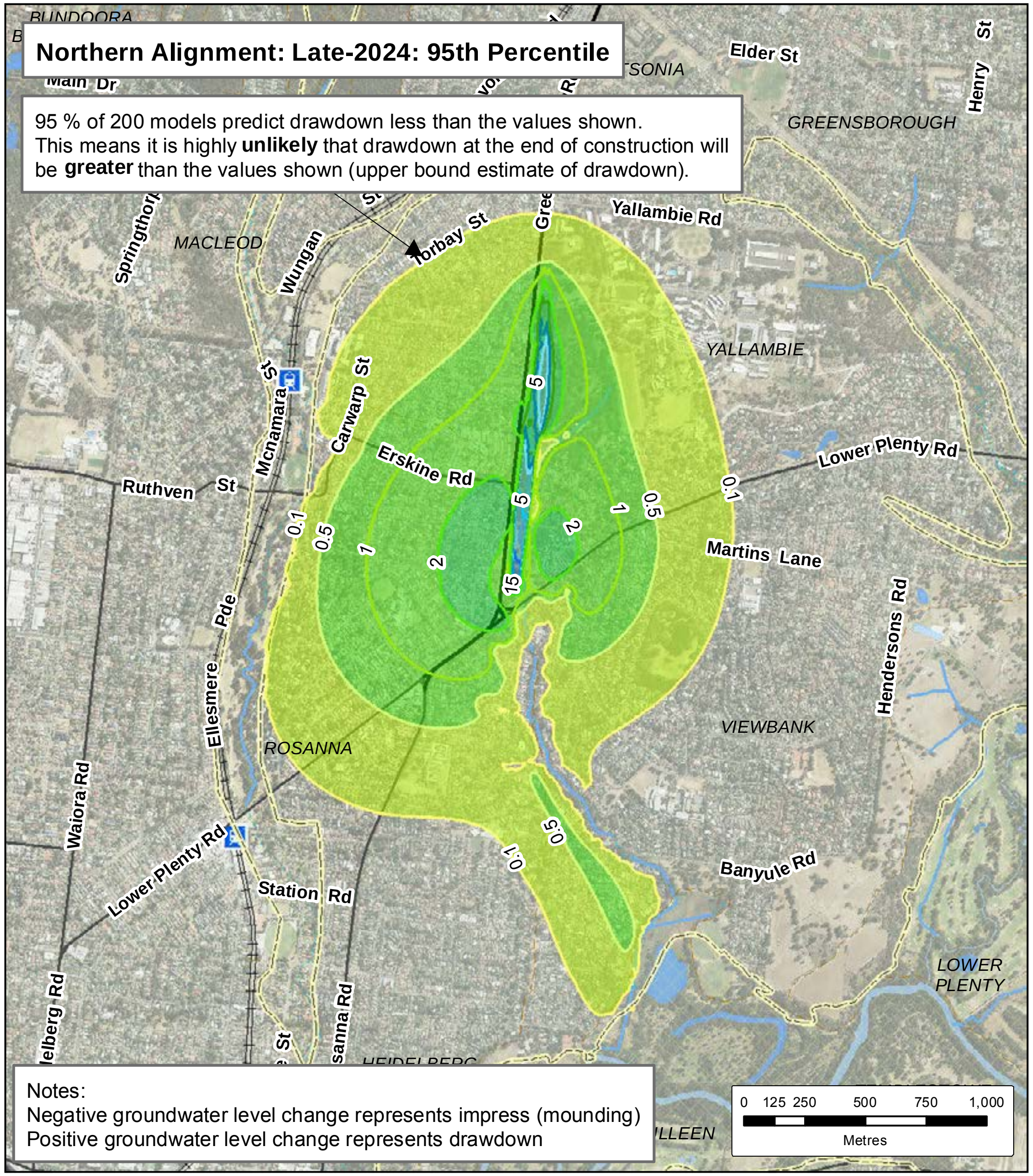
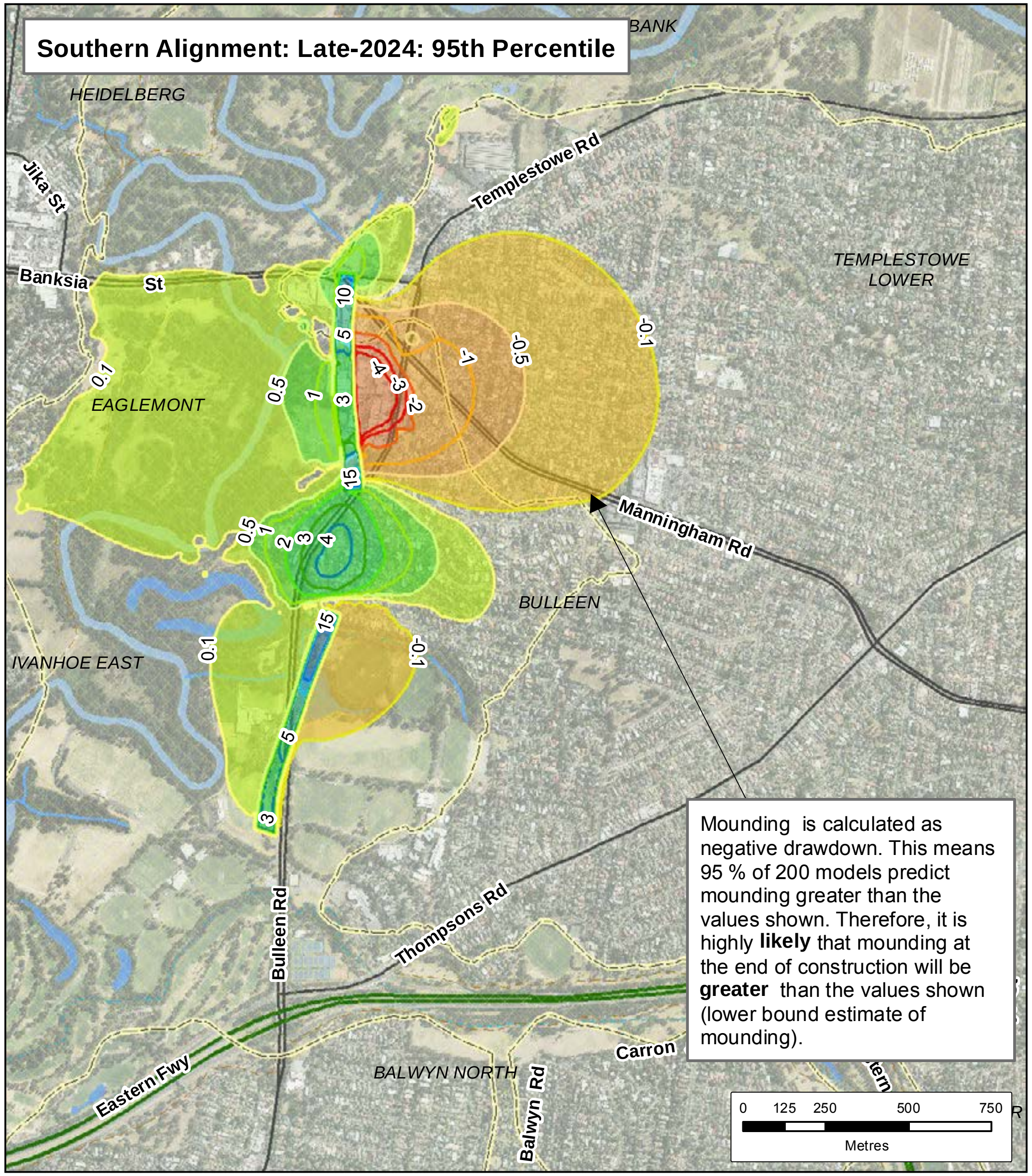


Figure 35 Computation of drawdown/mounding uncertainty range

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

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Predicted groundwater level changes – late 2024 - 95th percentile (upper bound drawdown / lower bound mounding)

Figure 36

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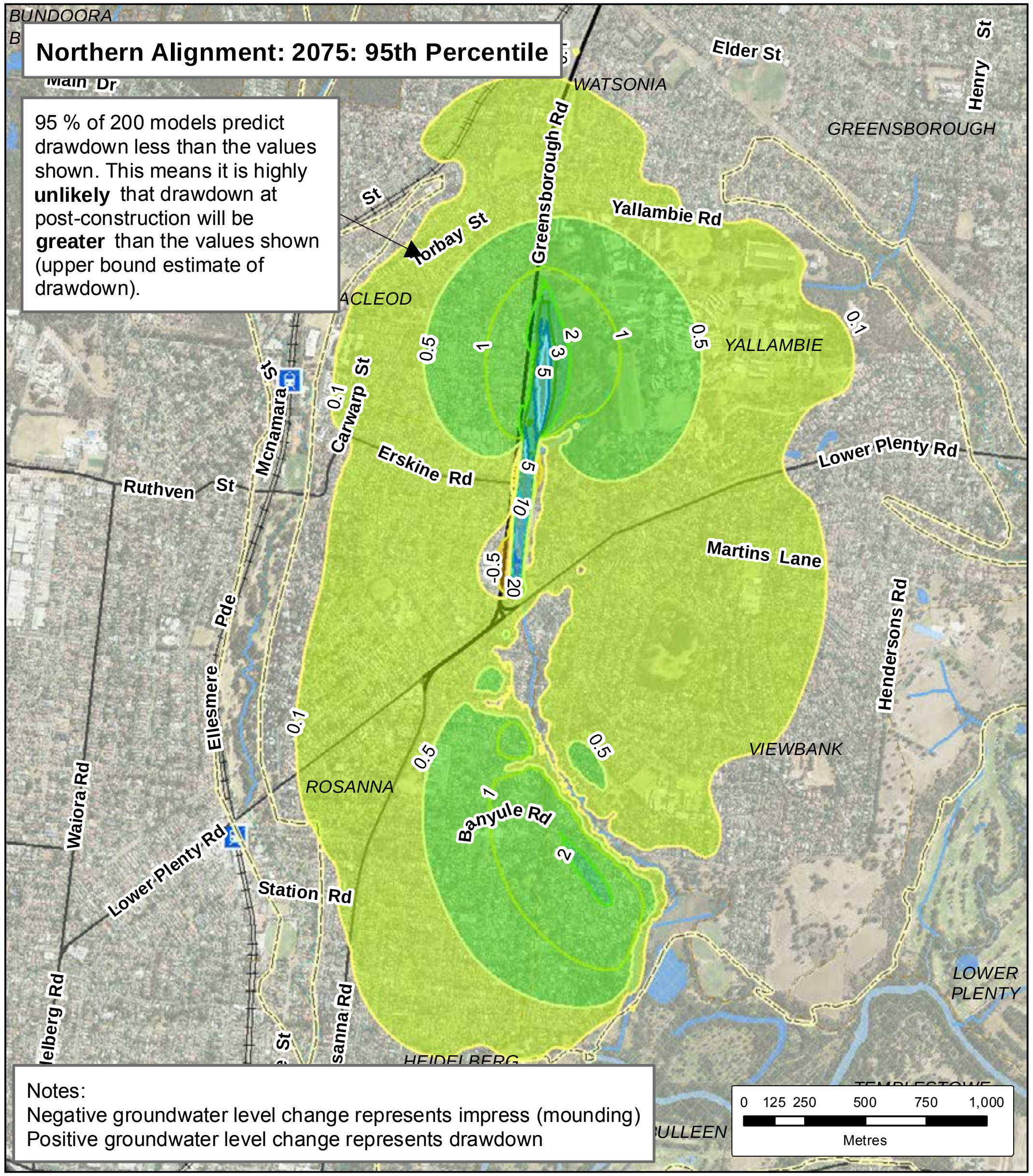

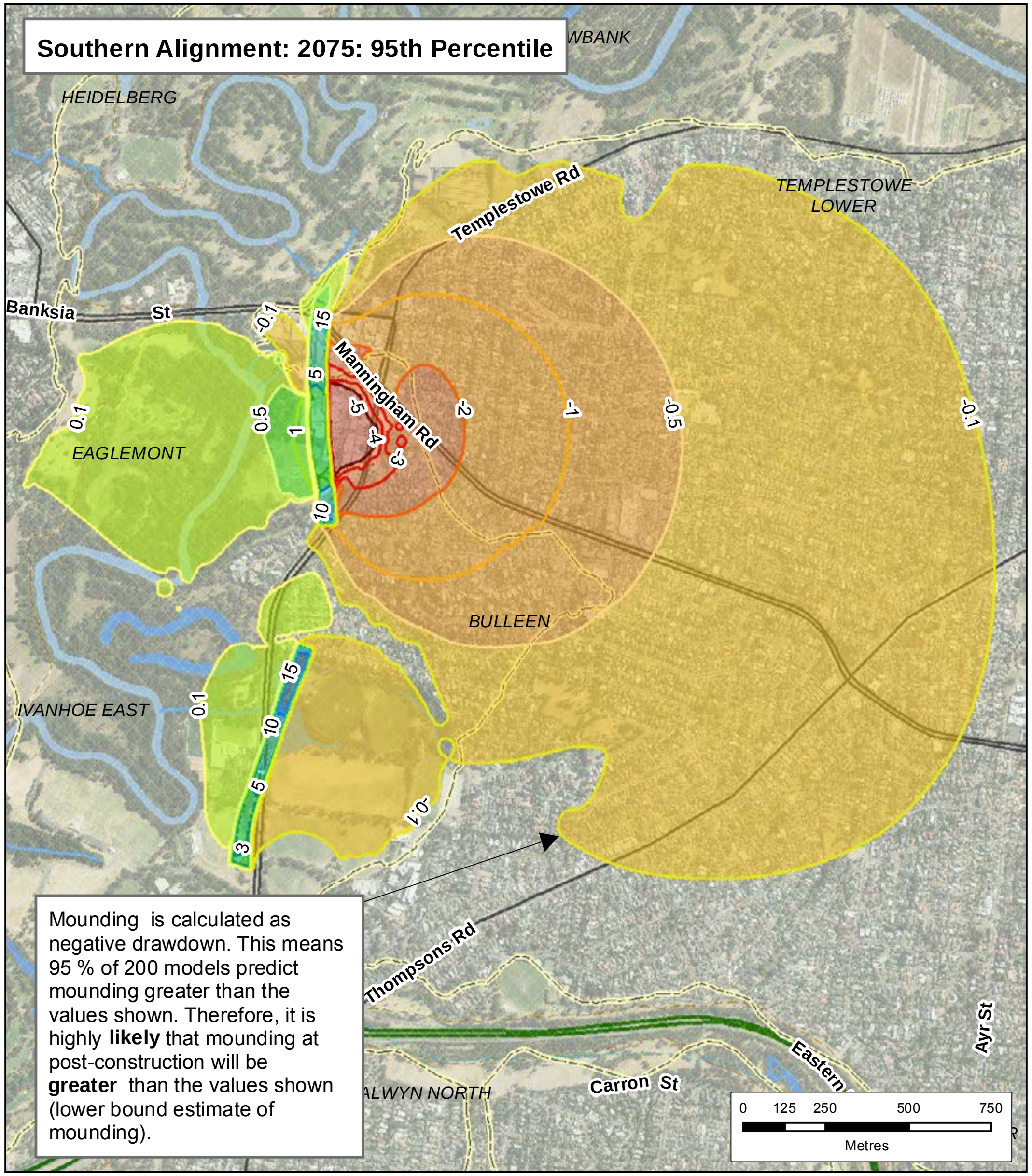

Paper Size A4

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

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Predicted groundwater level changes – 2075 - 95th percentile (upper bound drawdown / lower bound mounding)

Figure 37

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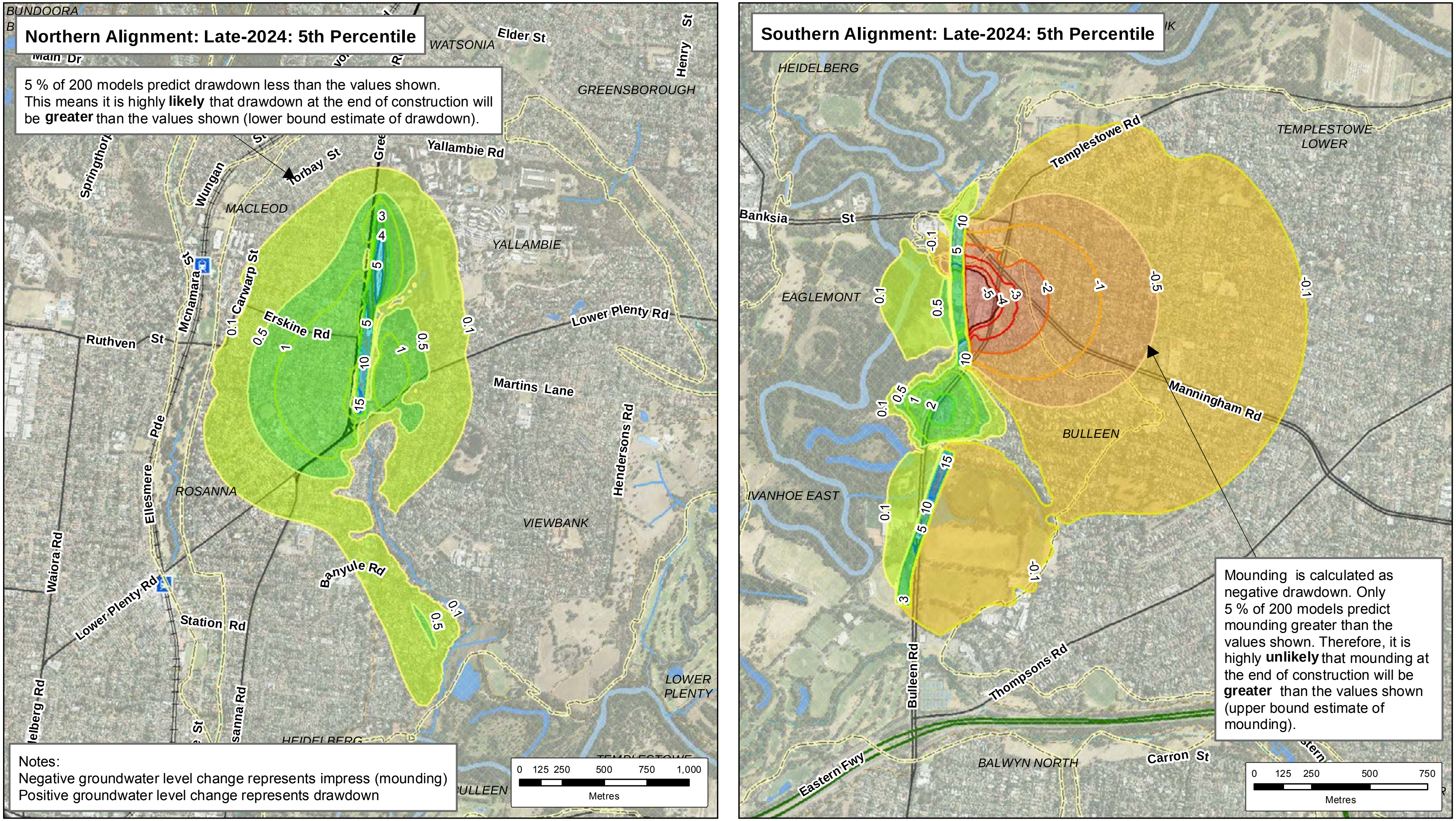

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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

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Predicted groundwater level changes – late 2024 - 5th percentile (lower bound drawdown / upper bound mounding)

Figure 38

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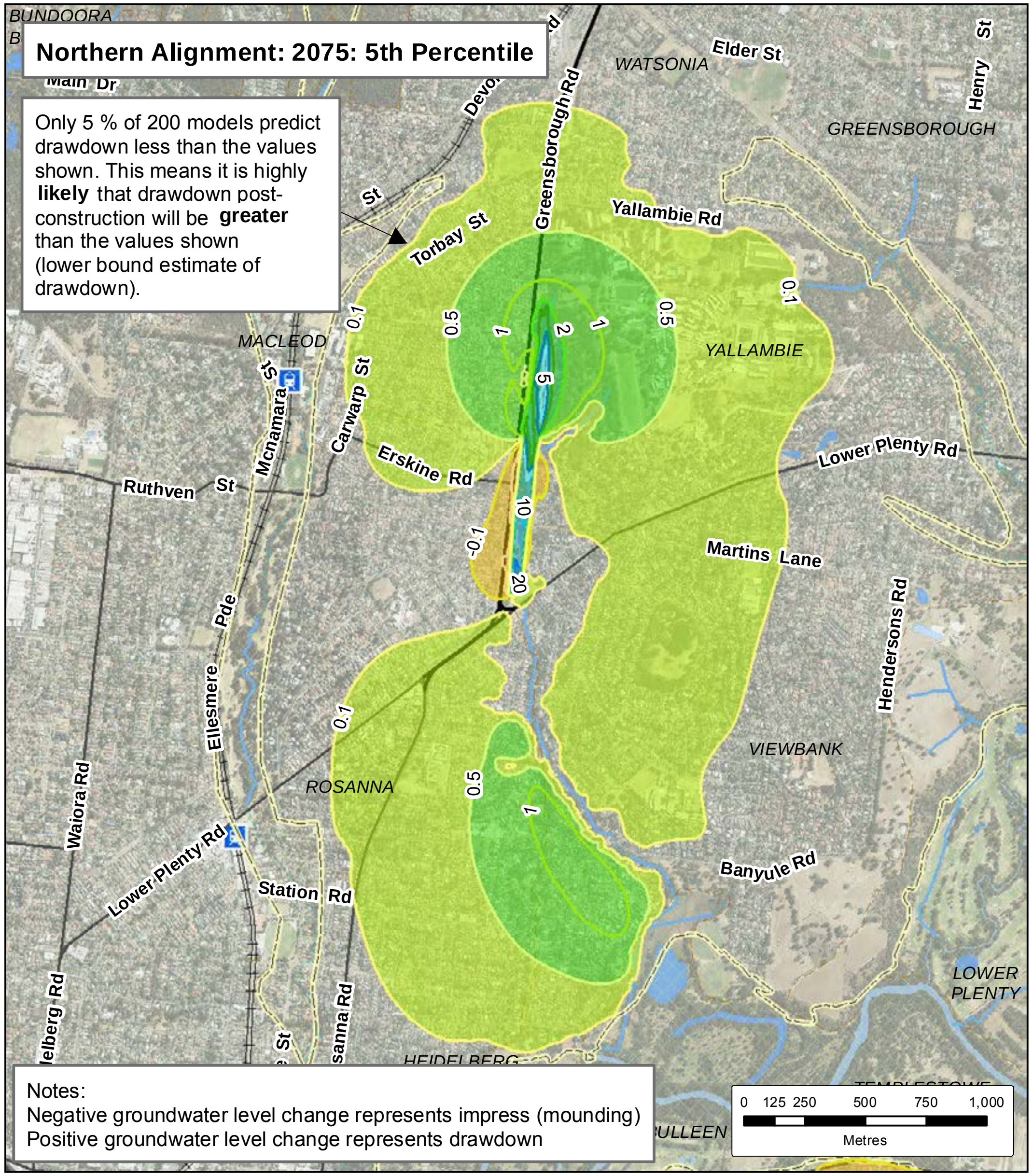
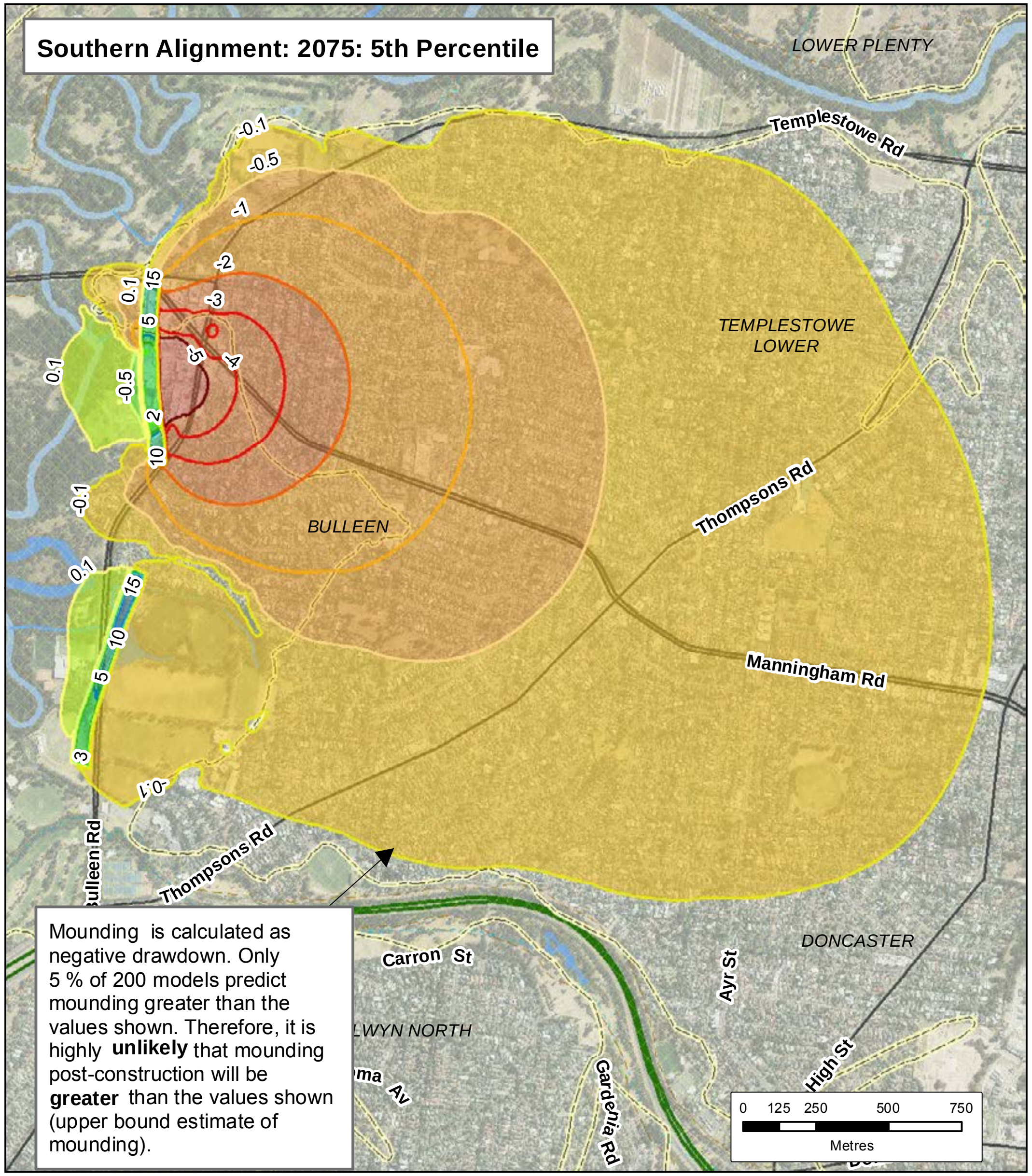
Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti





Paper Size A4

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

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Predicted groundwater level changes – 2075 - 5th percentile (lower bound drawdown / upper bound mounding)

Figure 39

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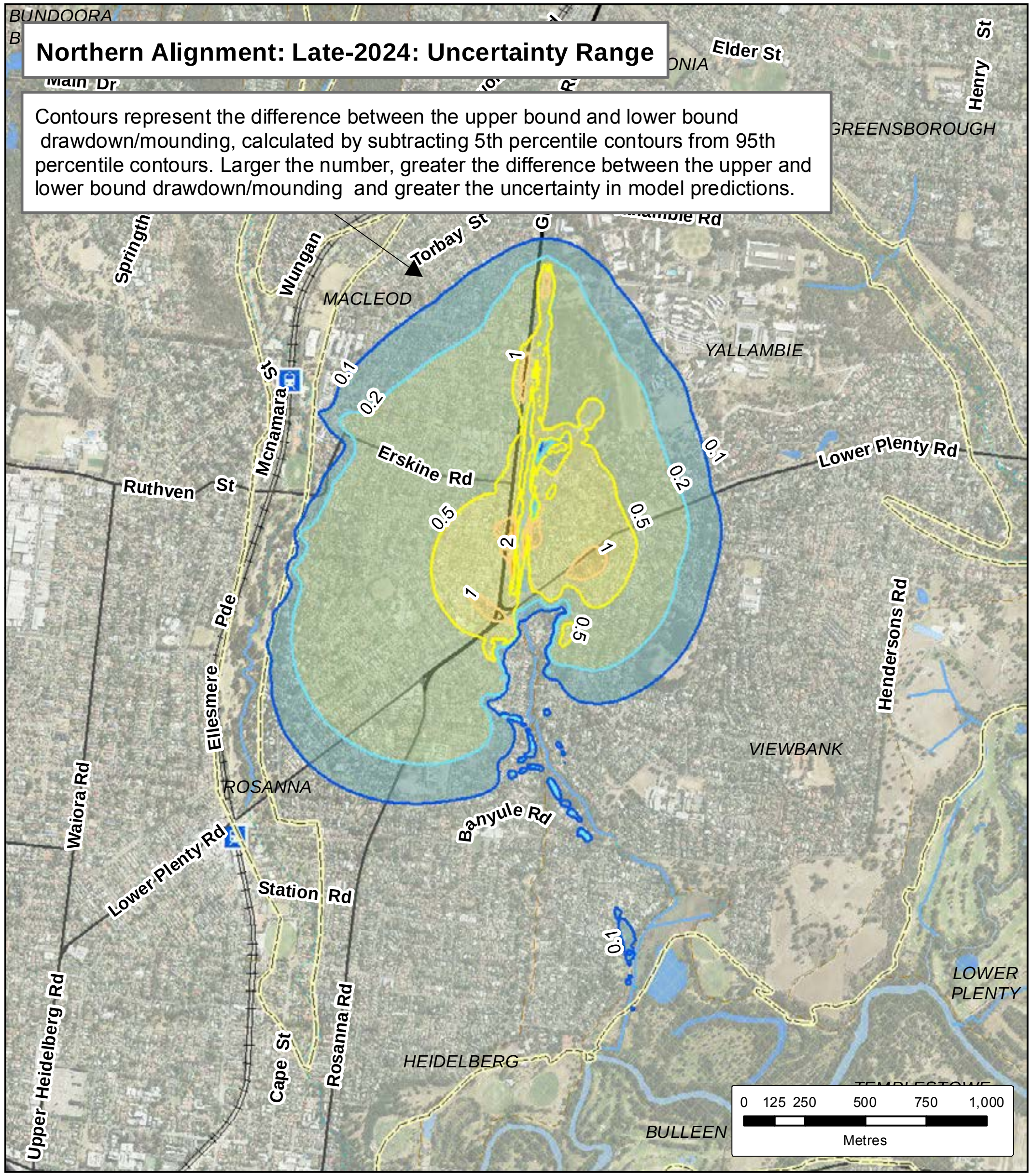
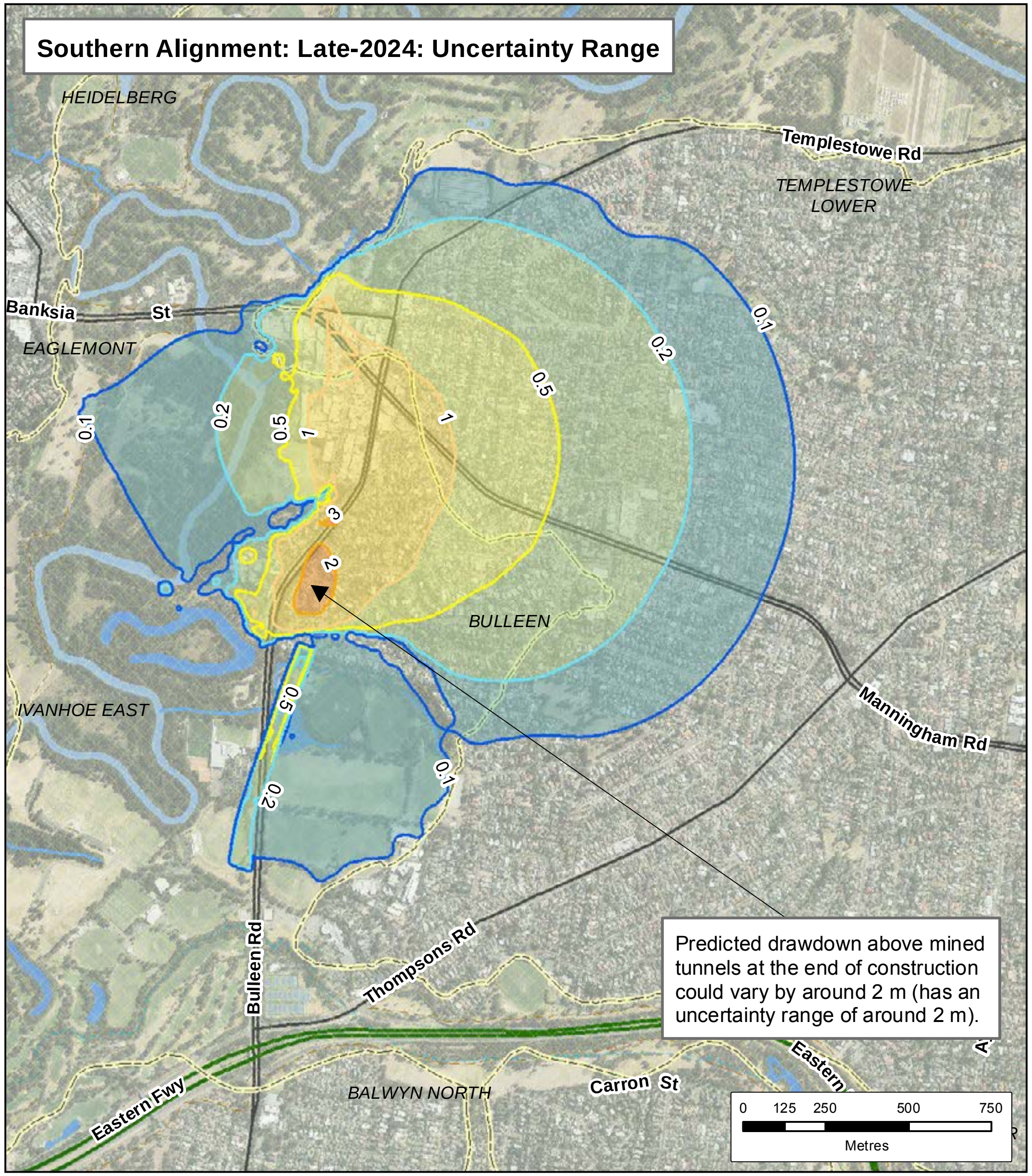
Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti





Paper Size A4

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

N

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

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Predicted groundwater level changes uncertainty range – late 2024 (difference between upper and lower bound drawdown / mounding)

Figure 40

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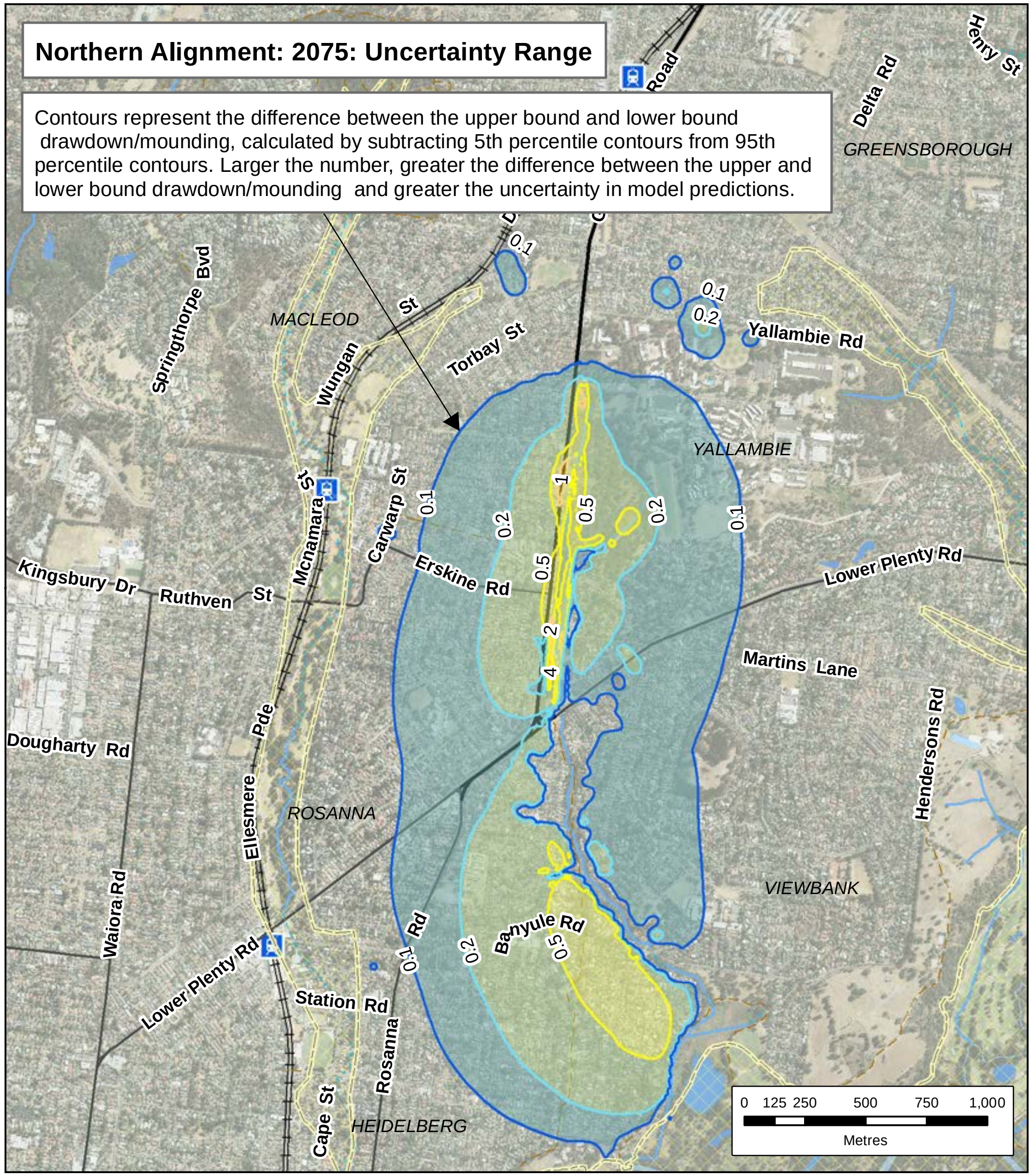
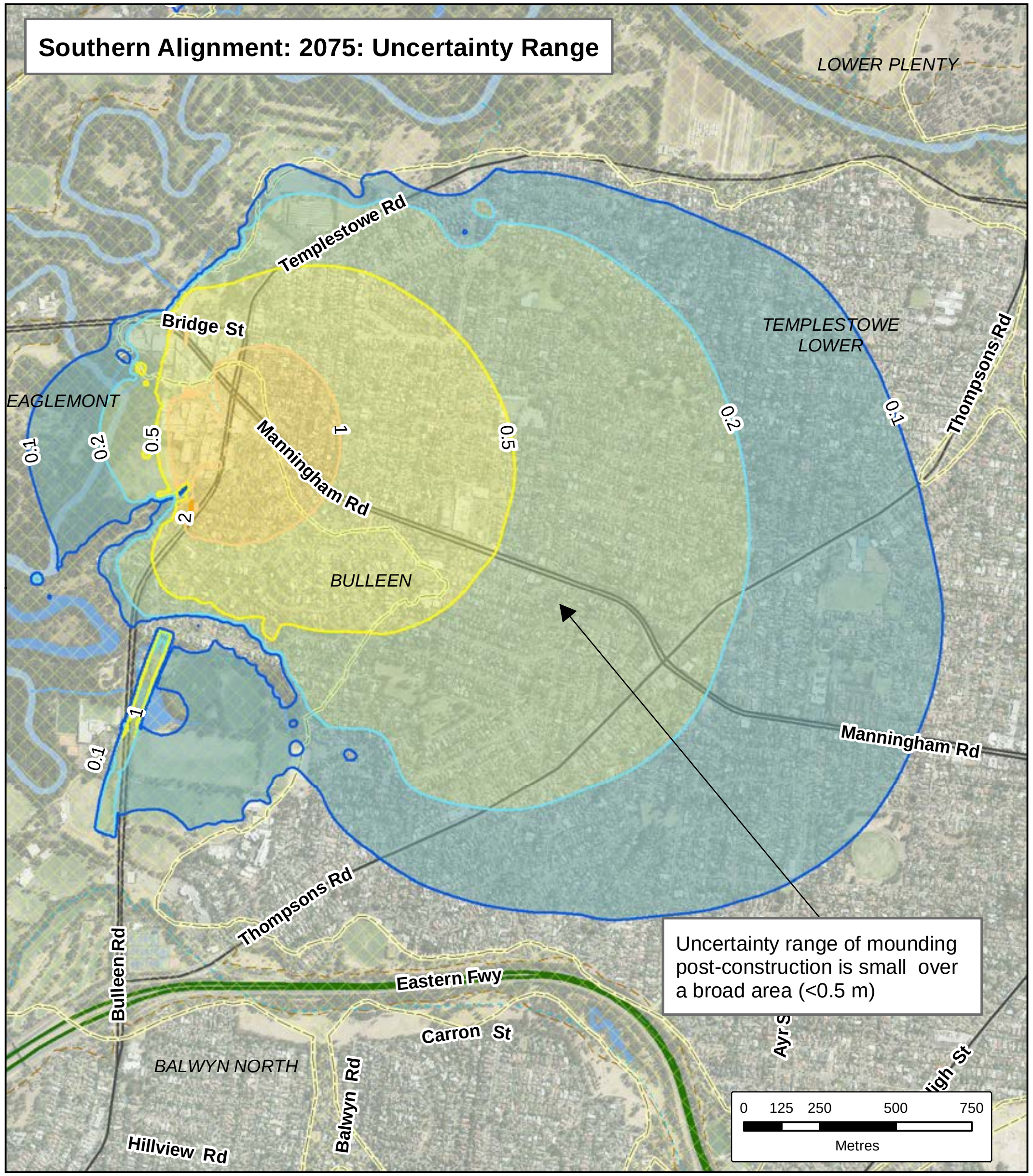
Data source: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti





Paper Size A4

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

N

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

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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

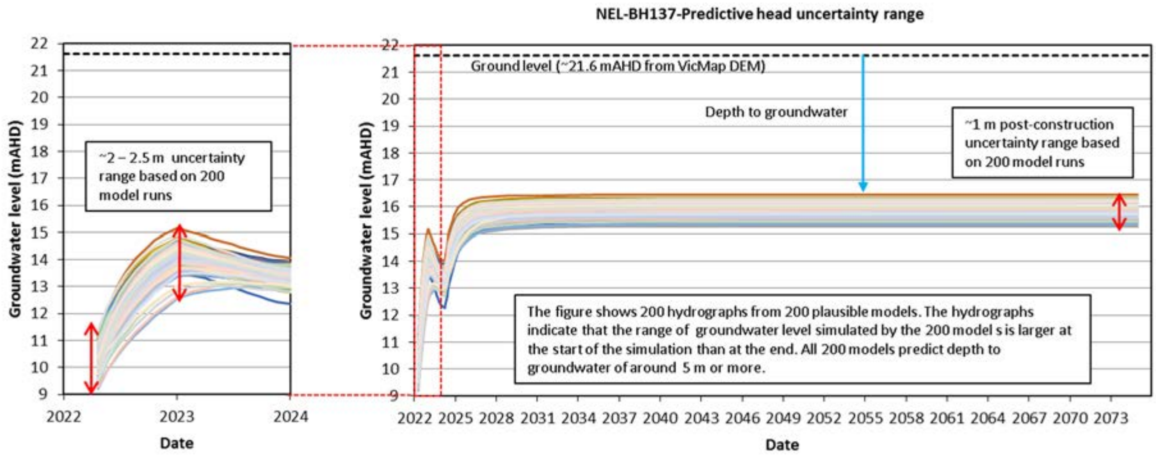


Figure 42 Predicted uncertainty range of mounding

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.

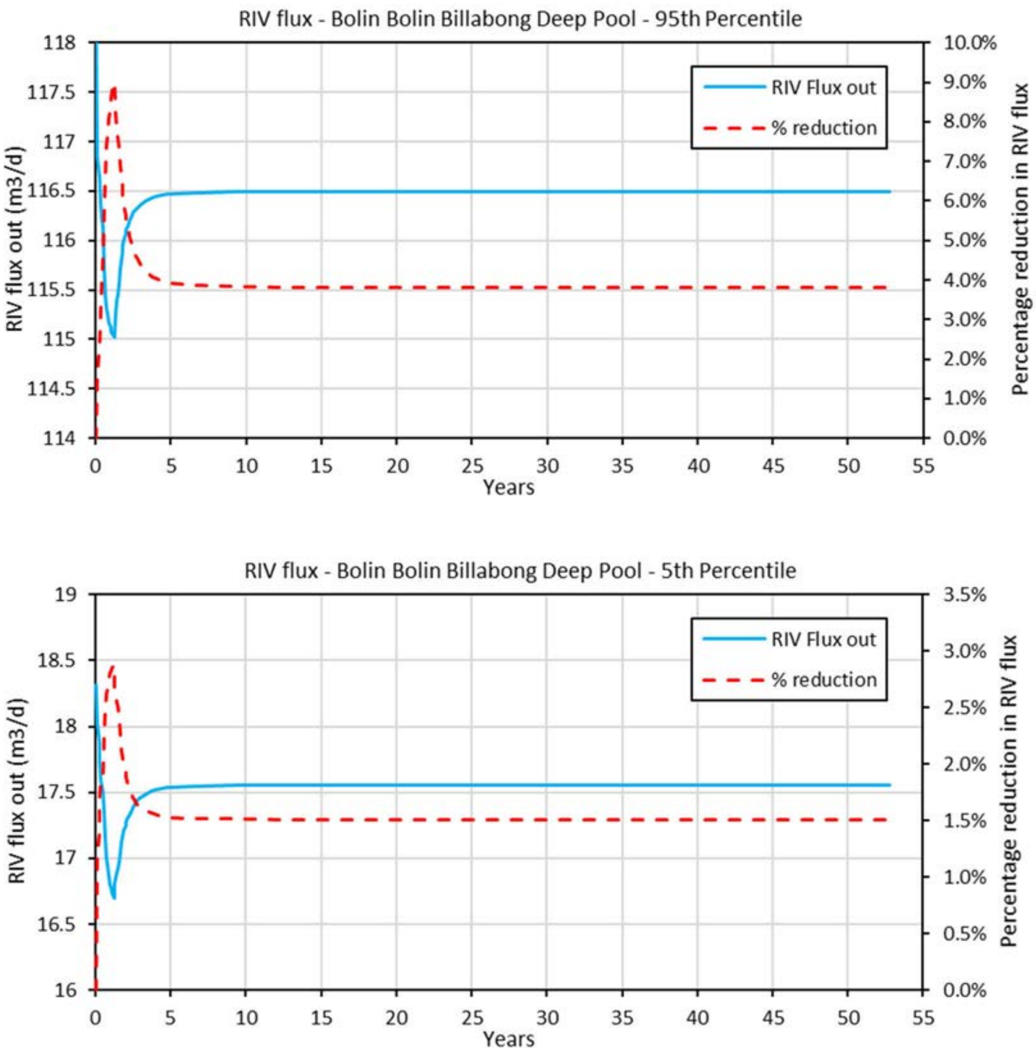
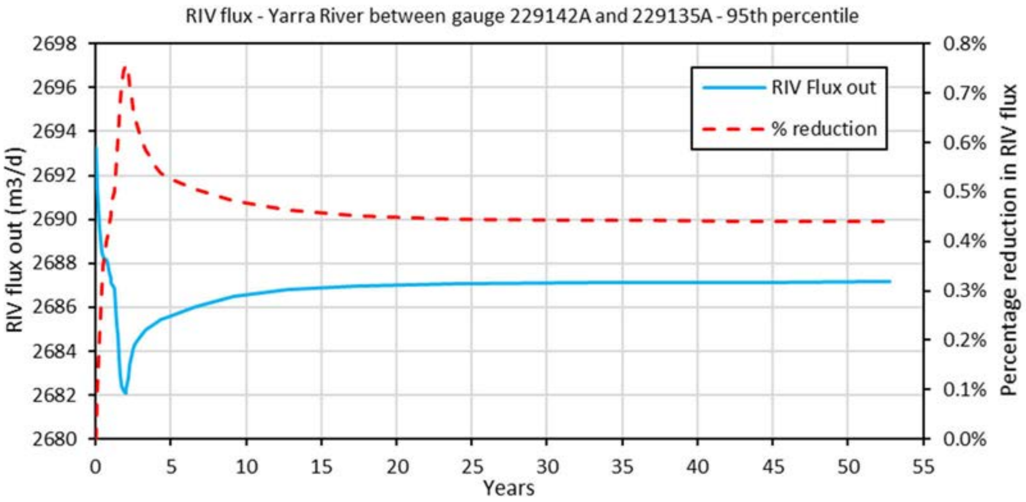


Figure 43 Uncertainty in predicted changes to Bolin Bolin Billabong groundwater flux (baseflow)

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.



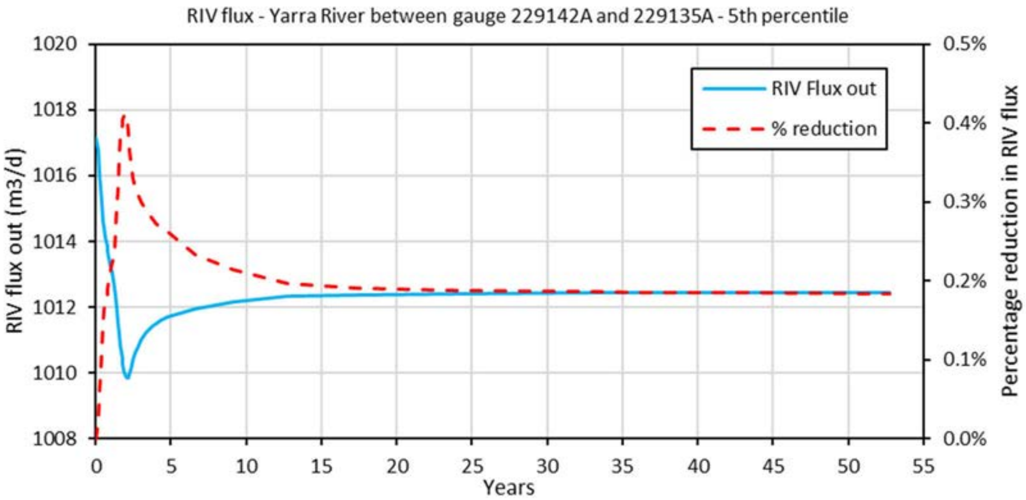
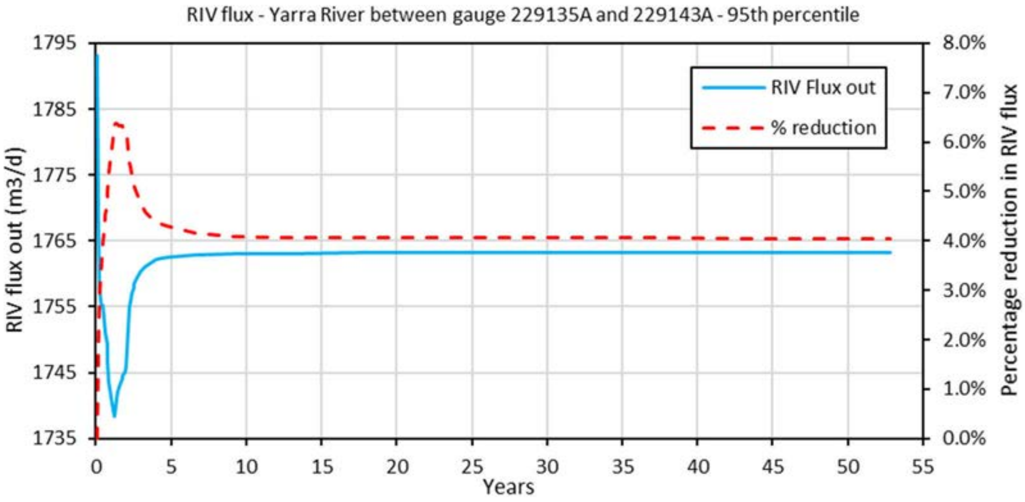


Figure 44 Uncertainty in predicted changes to Yarra River groundwater flux – 229142A to 229135A



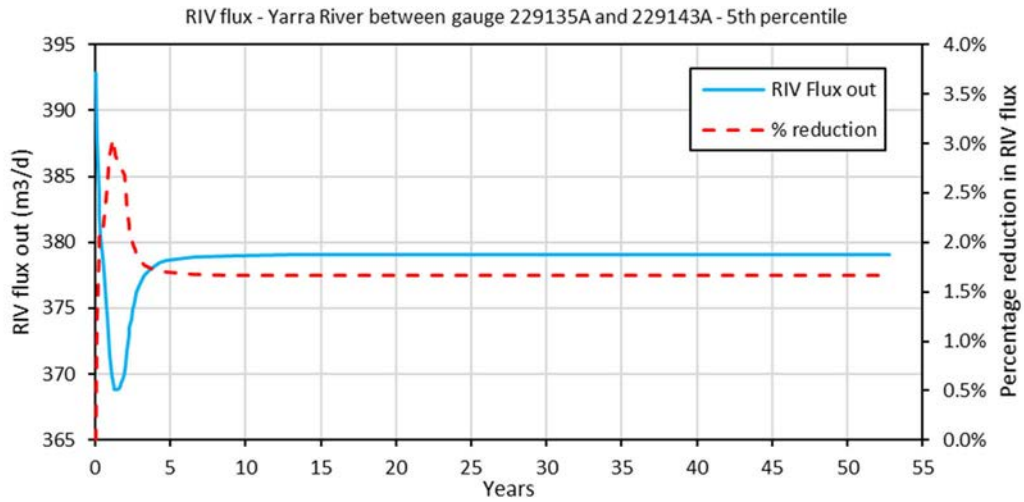


Figure 45 Uncertainty in predicted changes to Yarra River groundwater flux – 229135A to 229143A

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).

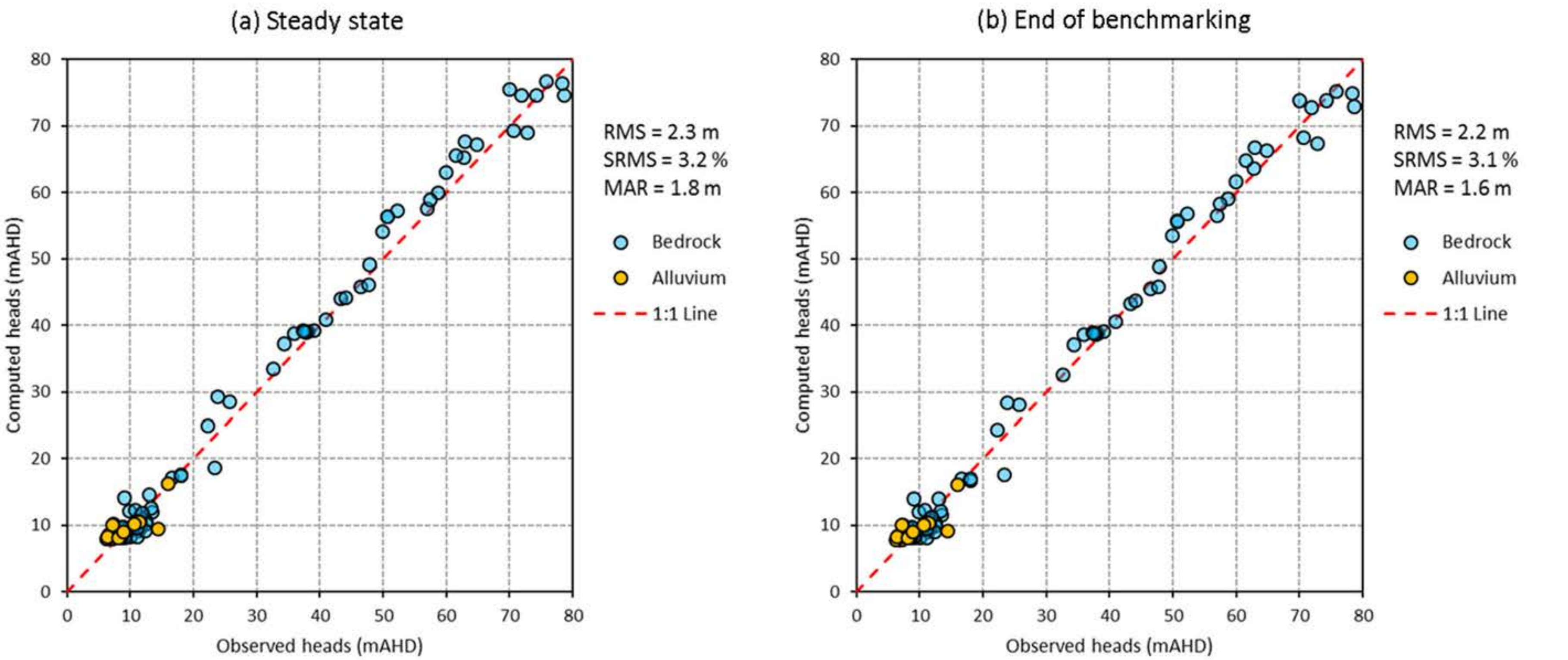


Figure 46 Calibration statistics of steady state and benchmarking models

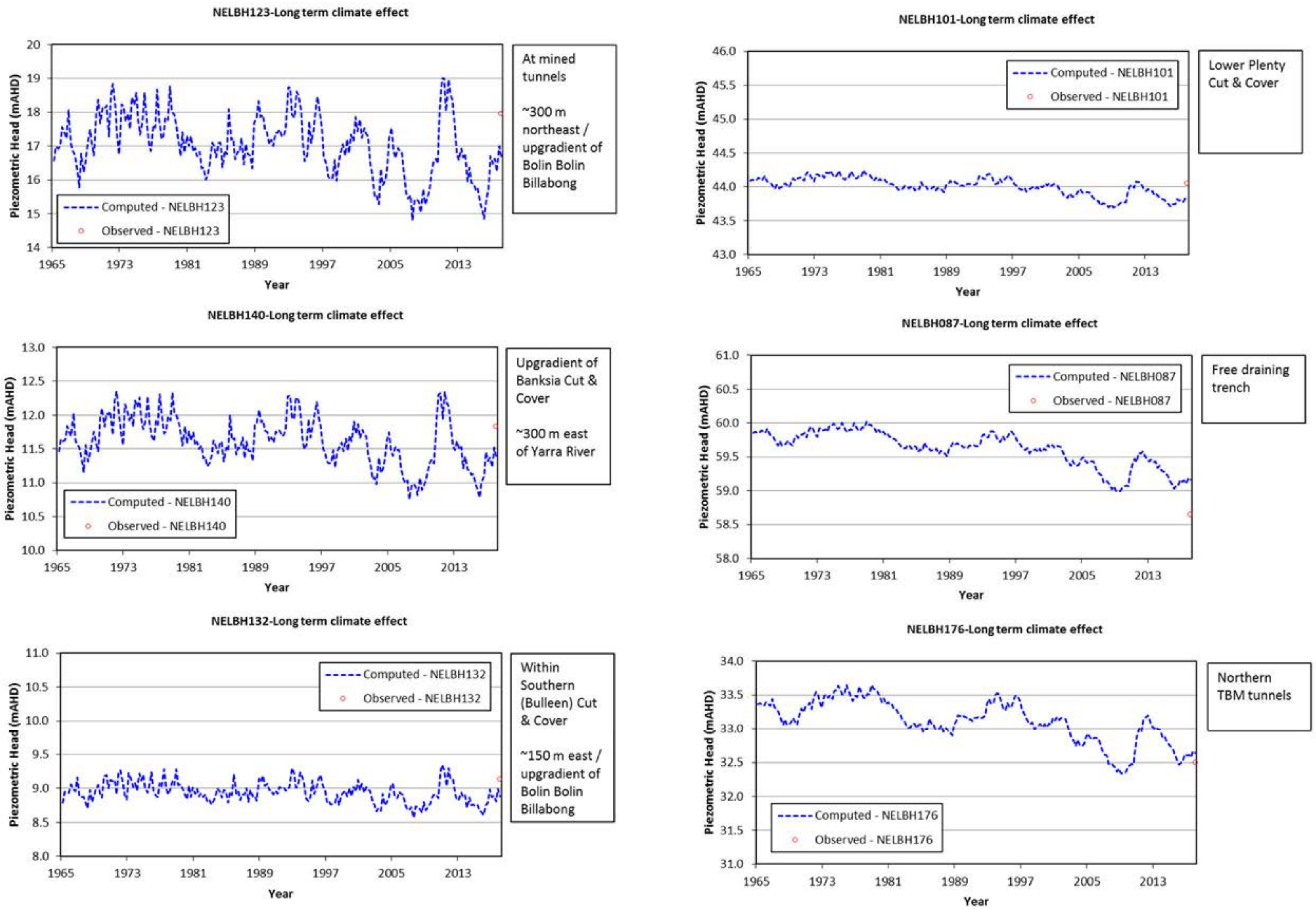
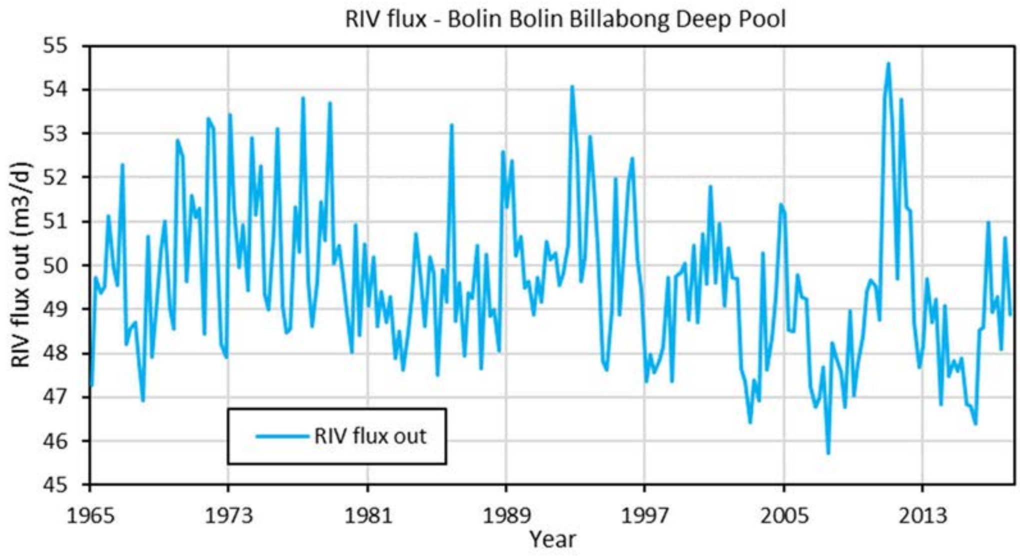
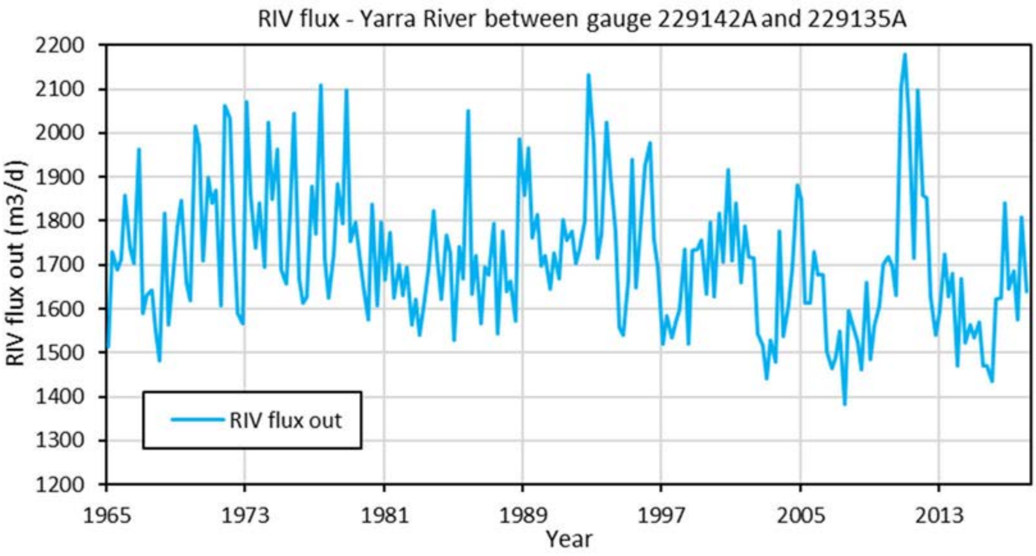


Figure 47 Simulated groundwater level variability





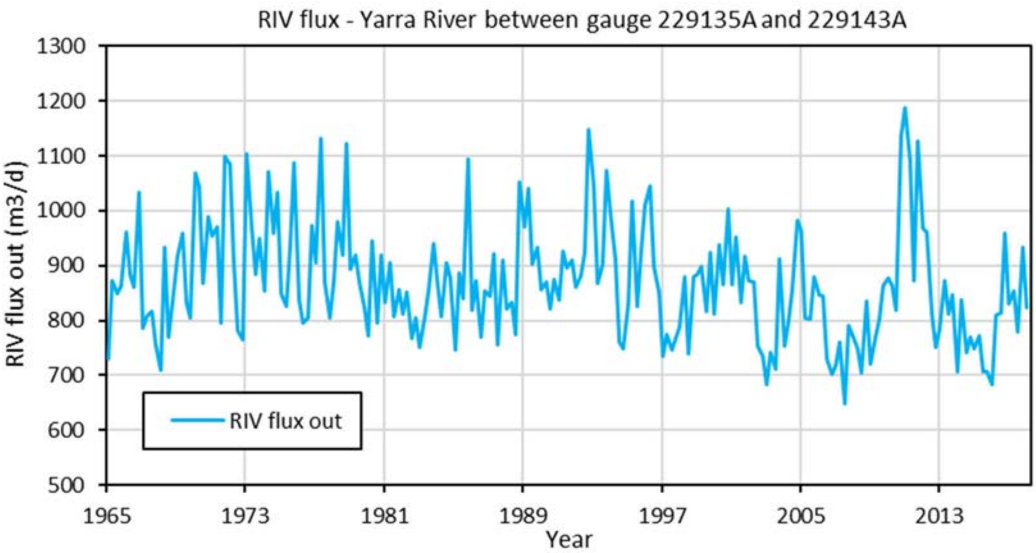


Figure 48 Simulated baseflow variability

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.

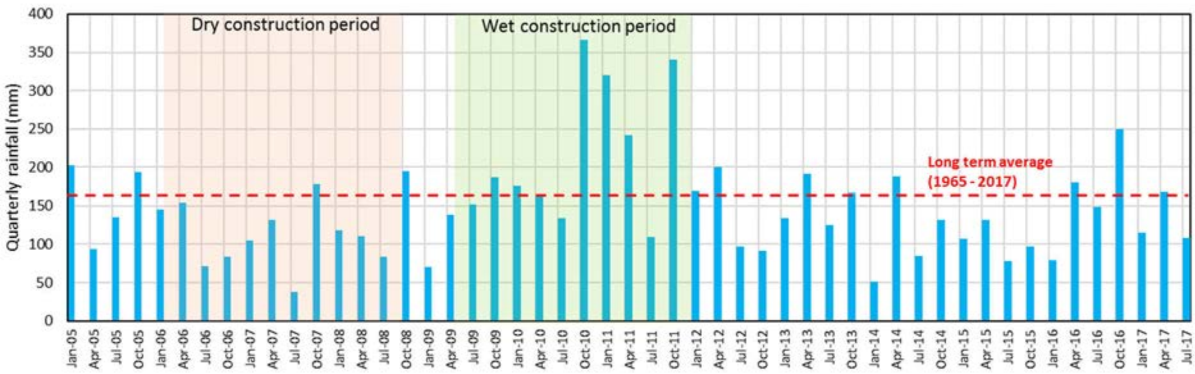
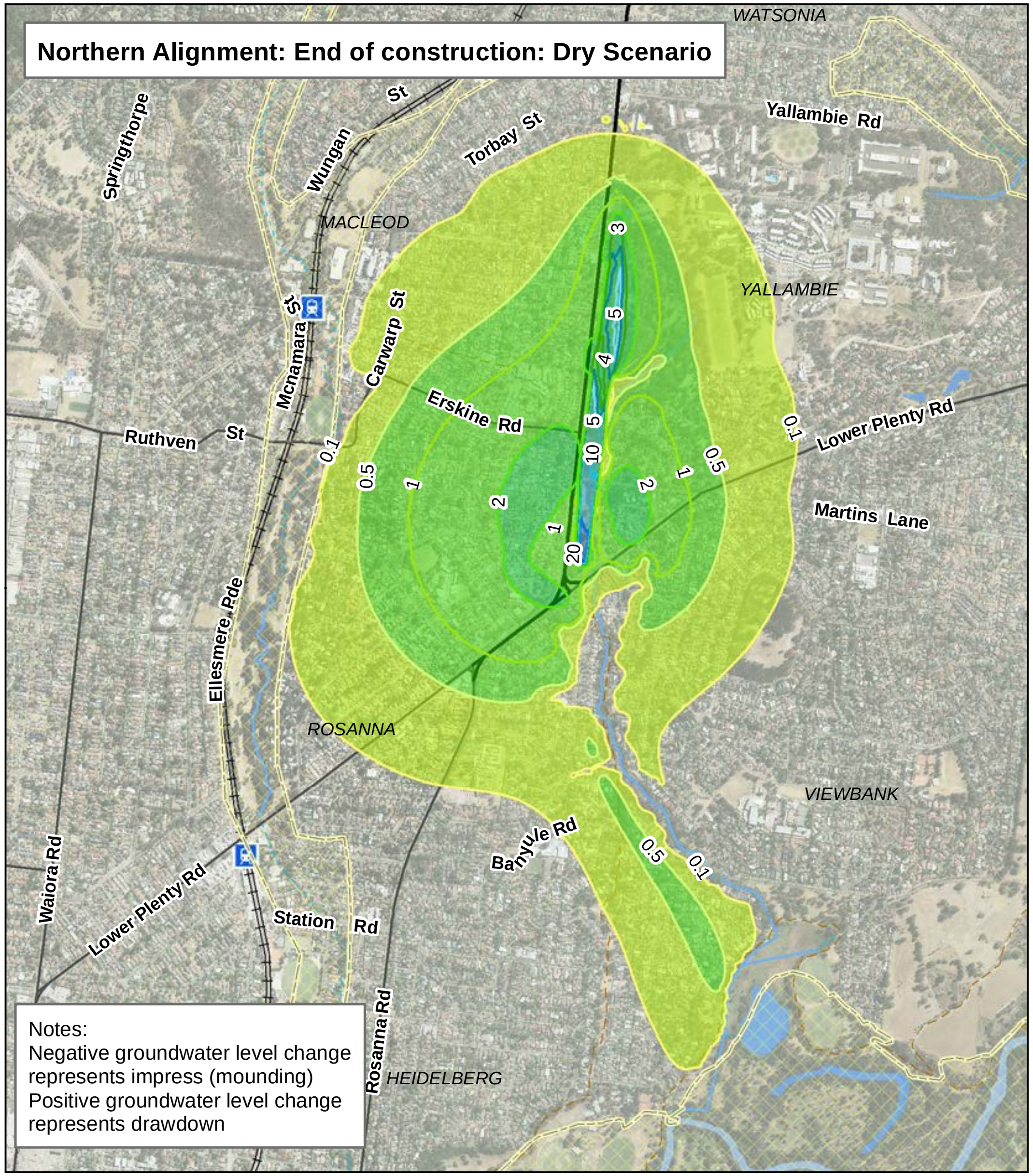


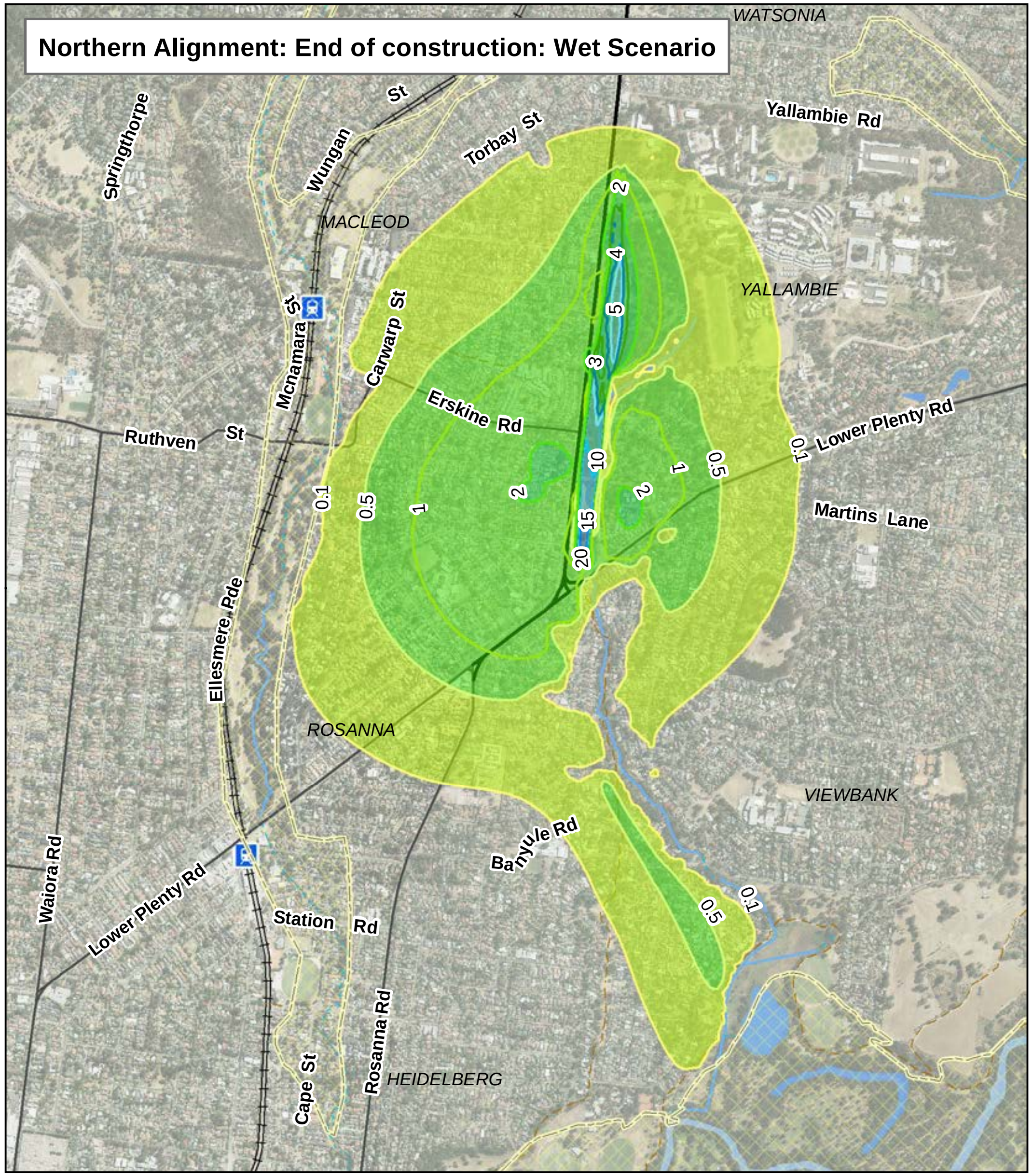
Figure 49 Dry and wet periods for modelling short-term climate variability

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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Predicted groundwater level changes at end of construction for dry and wet climate scenarios - north

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Figure 50

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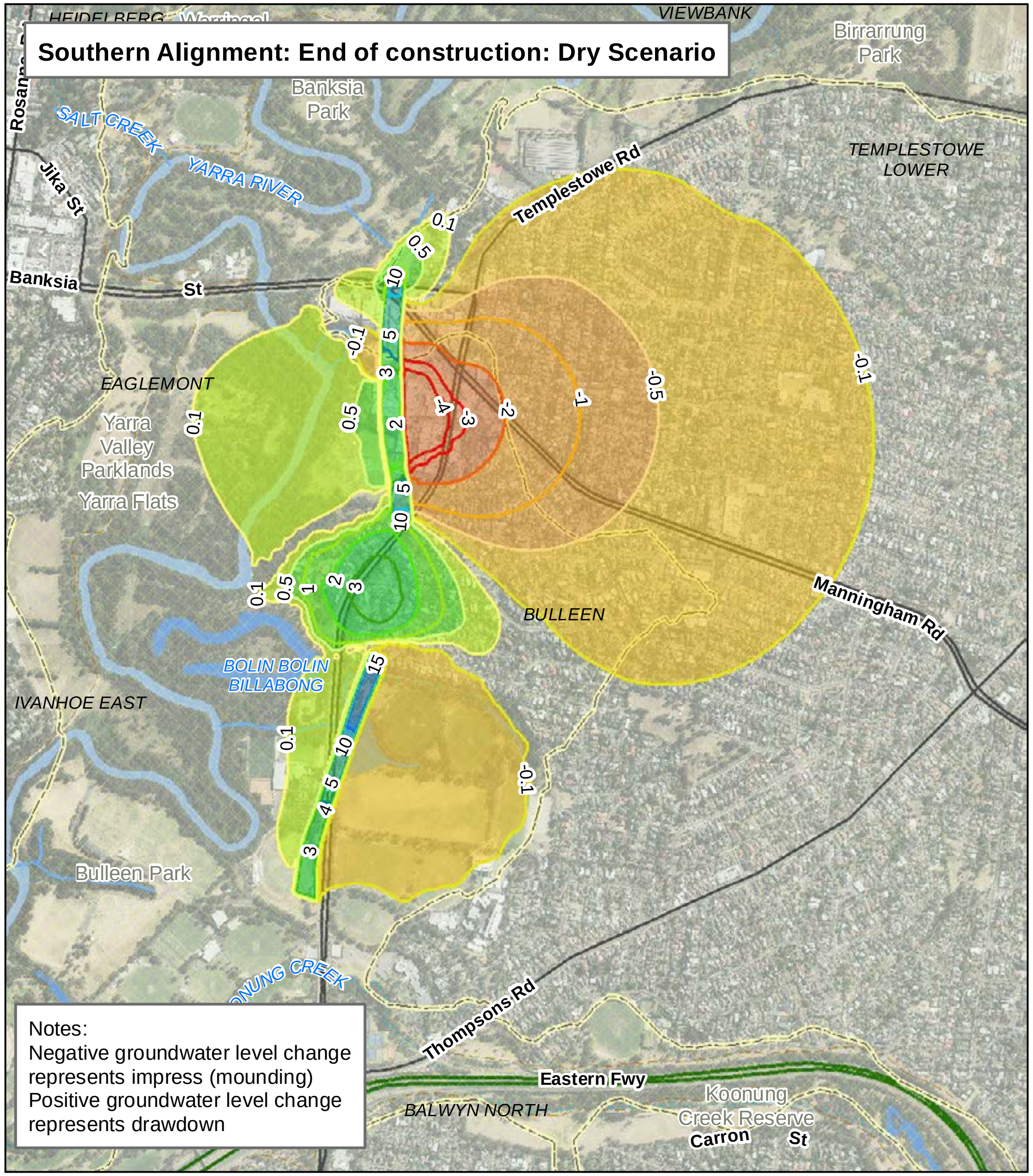
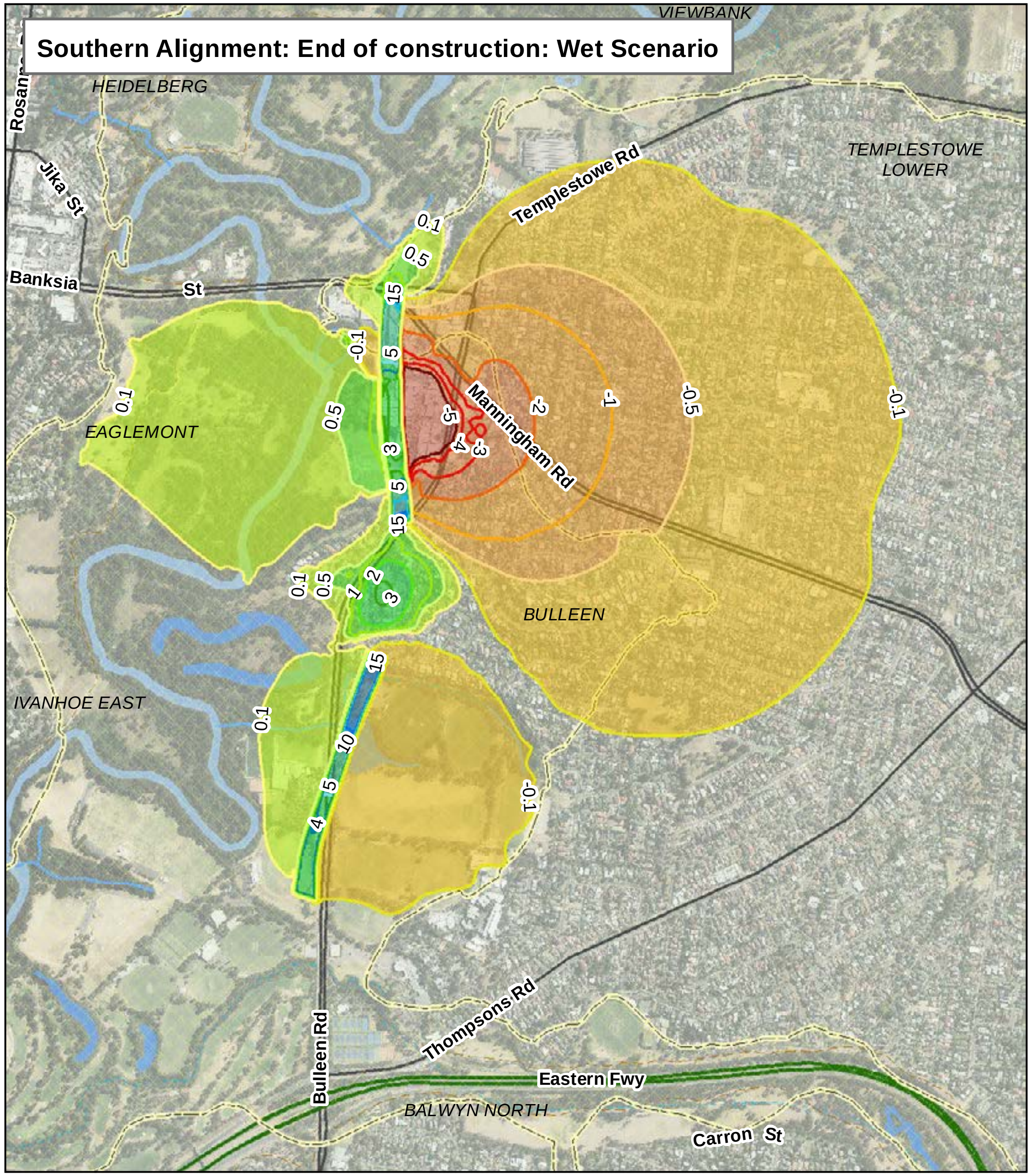
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo





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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Date	28 Feb 2019

Predicted groundwater level changes at end of construction for dry and wet climate scenarios - south

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).

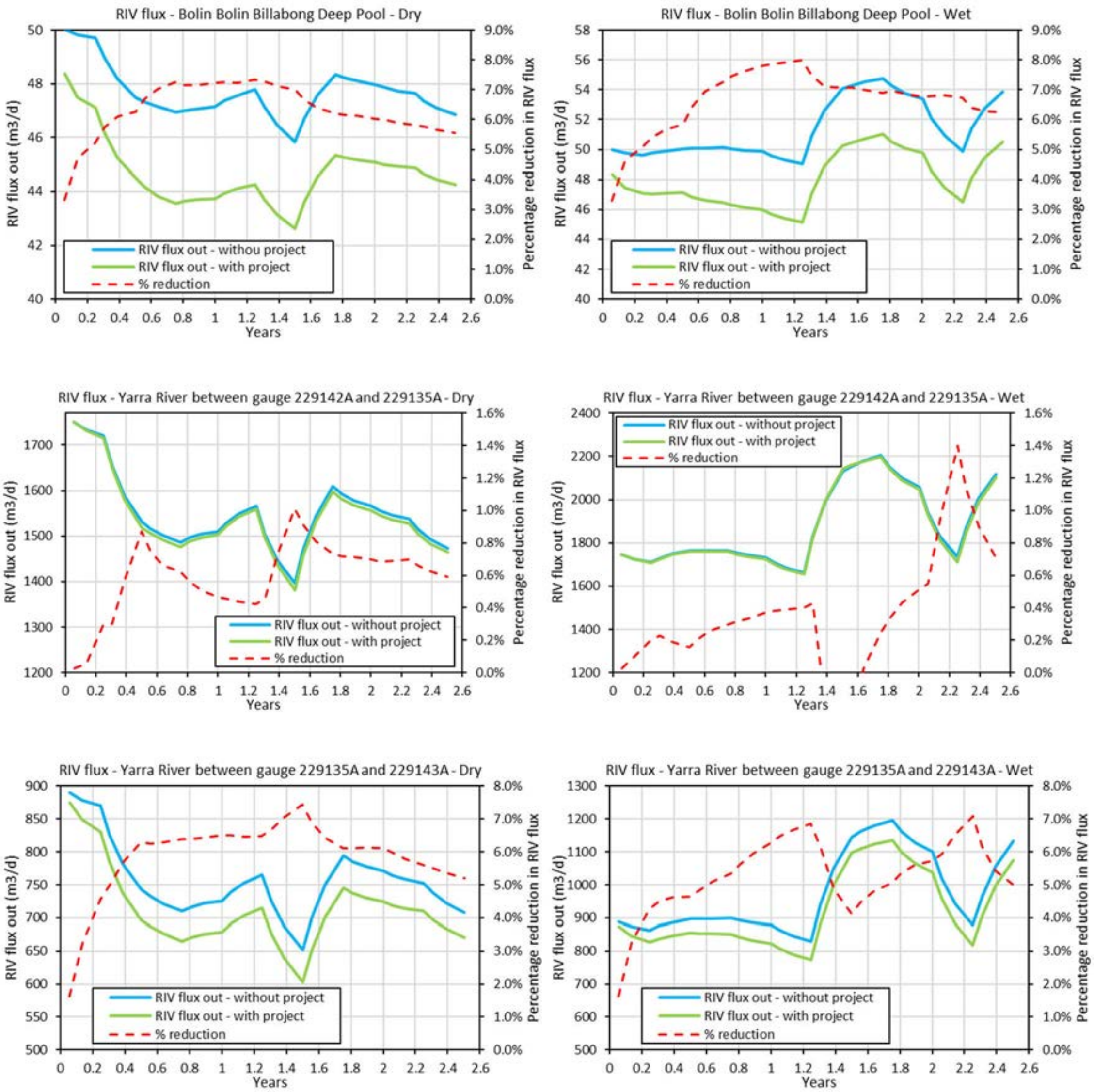


Figure 52 Predicted dry and wet scenarios groundwater fluxes (baseflow)

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

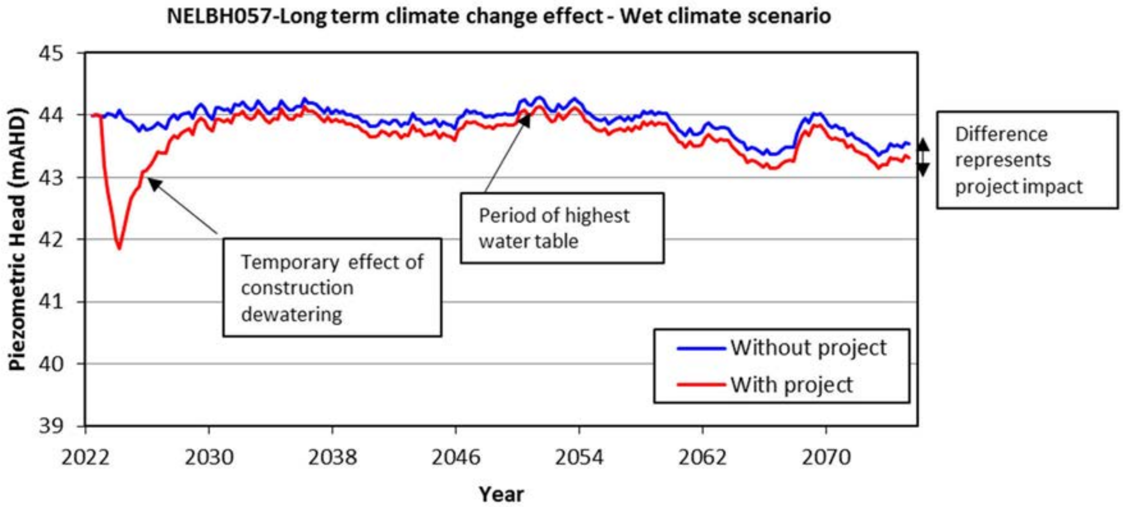
For the wet climate change scenario, the period of the highest water table/baseflow is chosen to show the predicted impact of the project under the wettest possible condition. For the dry climate change scenario, the period of the lowest water table/baseflow is chosen to show the predicted impact of 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.



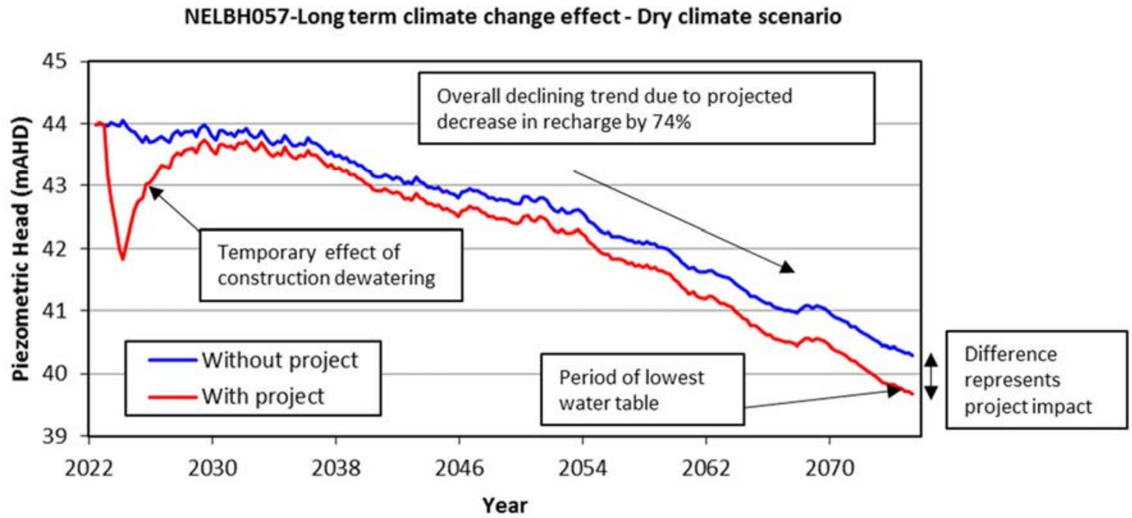
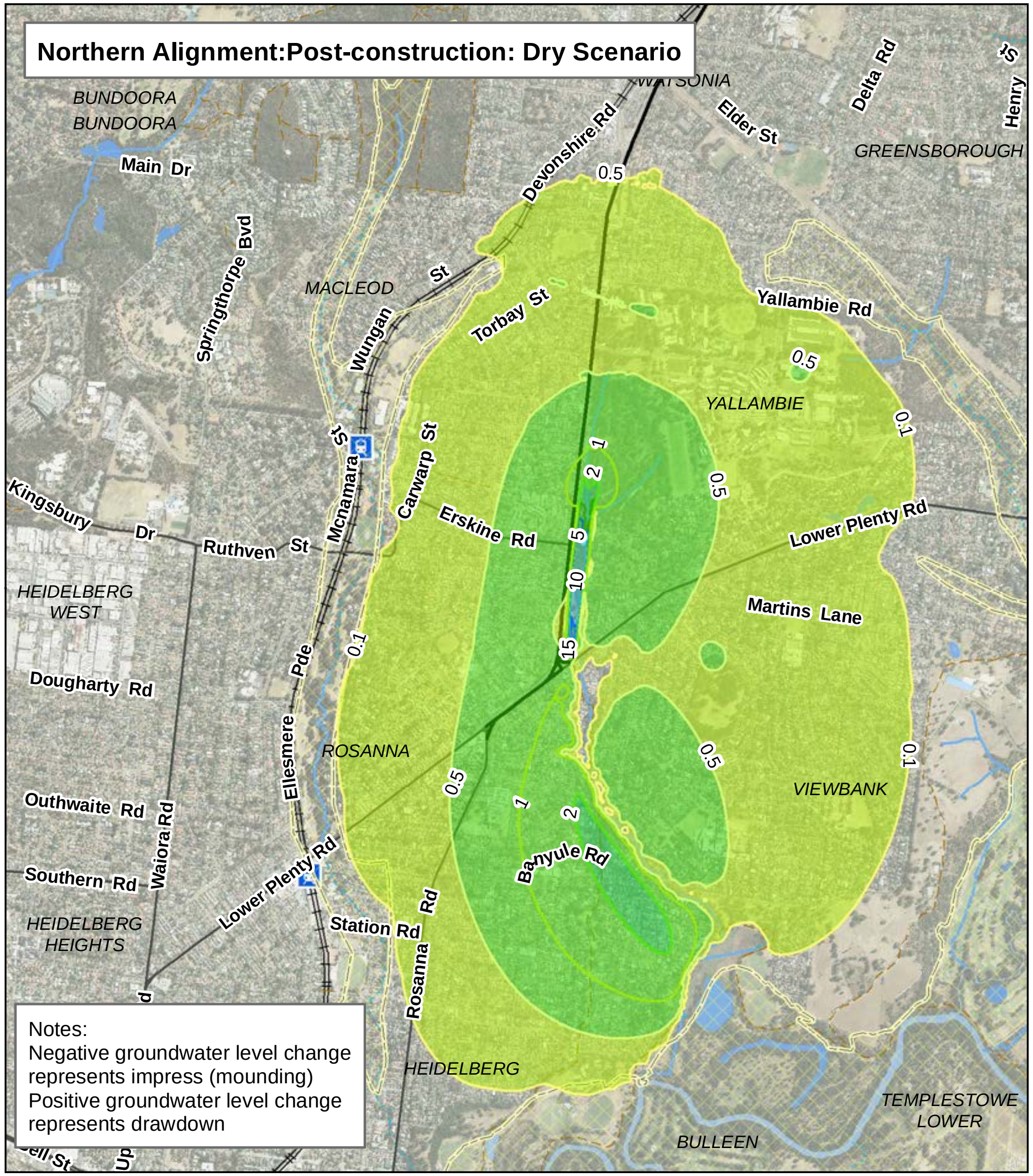
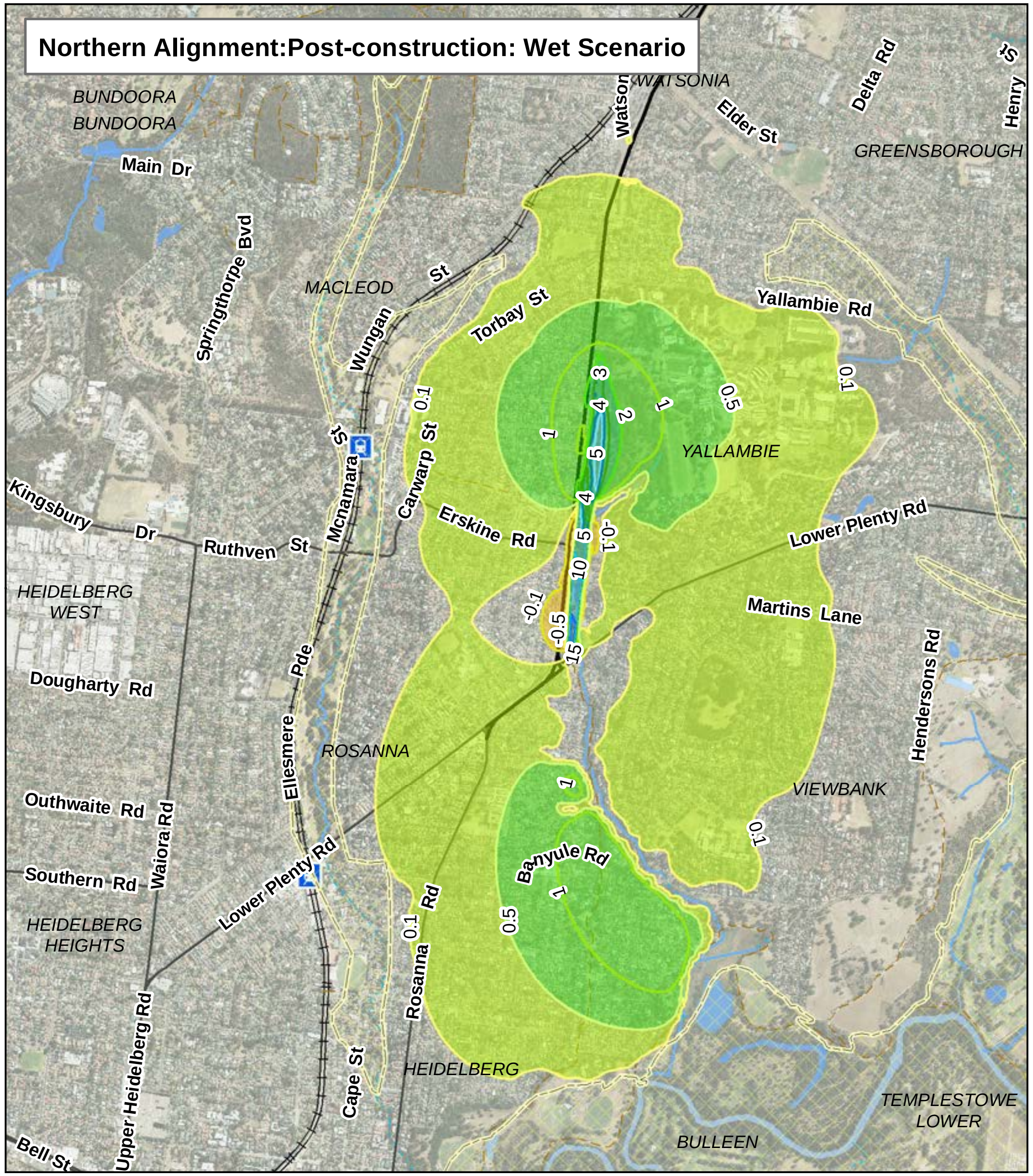


Figure 53 Wet and dry climate change scenario





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

North East Link Project
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Predicted post-construction groundwater level changes for dry and wet climate scenarios - north

Figure 54

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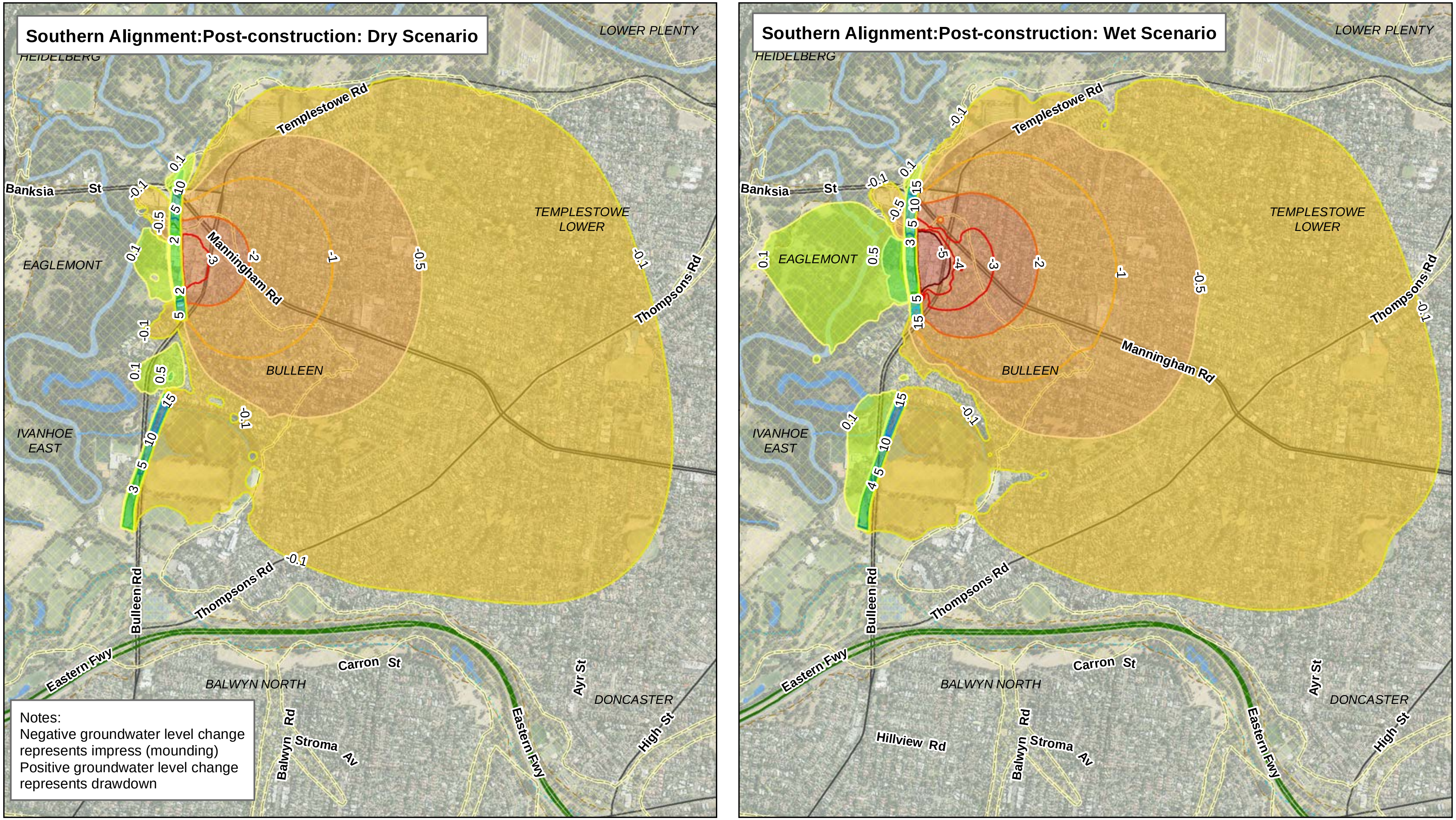
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



Paper Size A4

0 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 post-construction groundwater level for dry and wet climate scenarios - south

Figure 55

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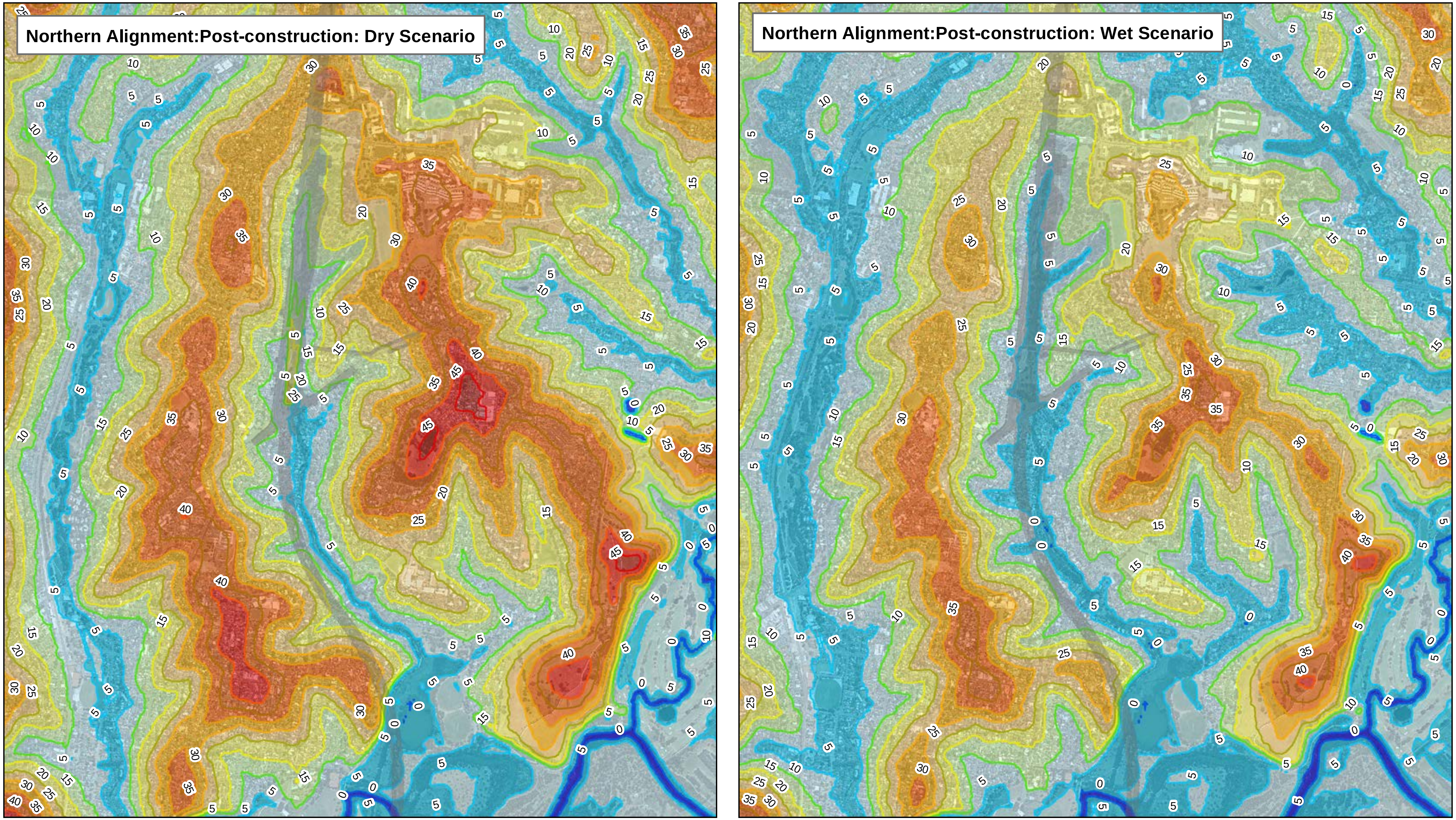
Data source: Aerial, CIP, 2017. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:sacevedo



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

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NORTH EAST LINK PROJECT

Predicted post-construction depth to groundwater for dry and wet climate scenarios - north

Figure 56

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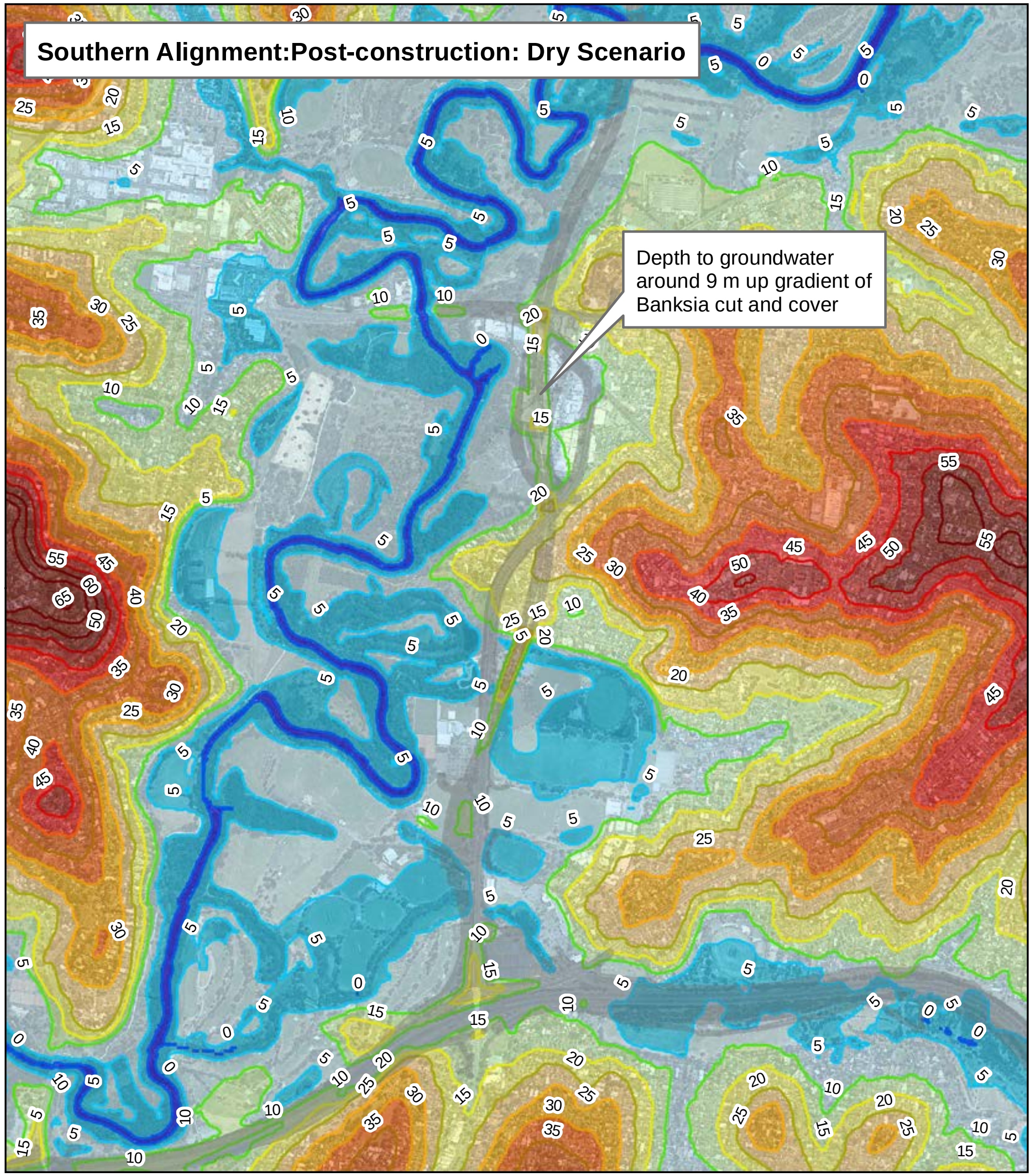

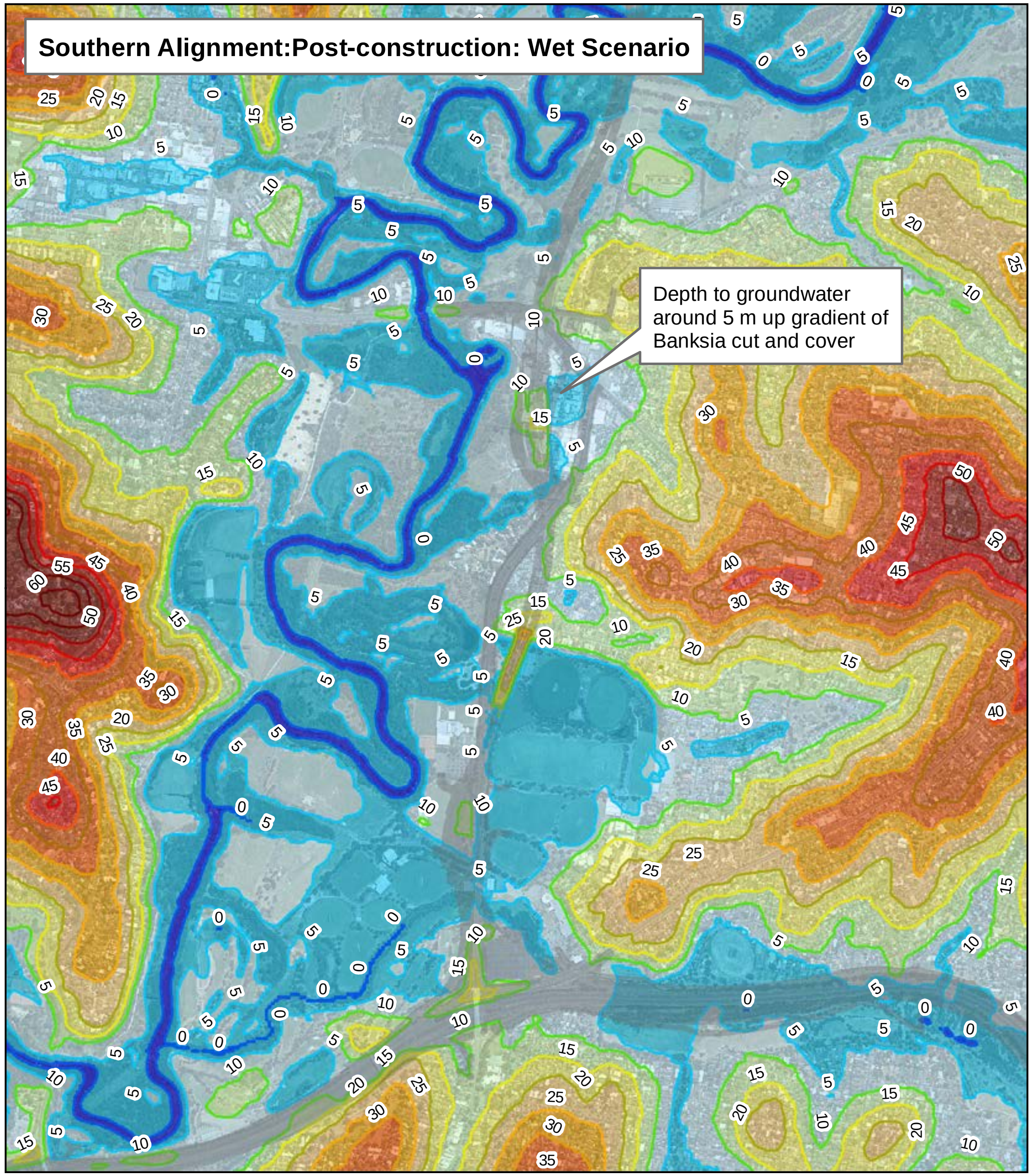

Paper Size A4

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
Public Environment Report

Job Number | 31-35006
Revision | A
Date | 27 Feb 2019

Predicted post-construction depth to groundwater for dry and wet climate scenarios - south

Figure 57

G:\31\35006\GIS\Maps\Deliverables\20180625_NEv3_GWModel_Figures\20190227\3135006_NEv3_A4L_GWModel_Fig057_DTW_ClimateScenarios_South_2075_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

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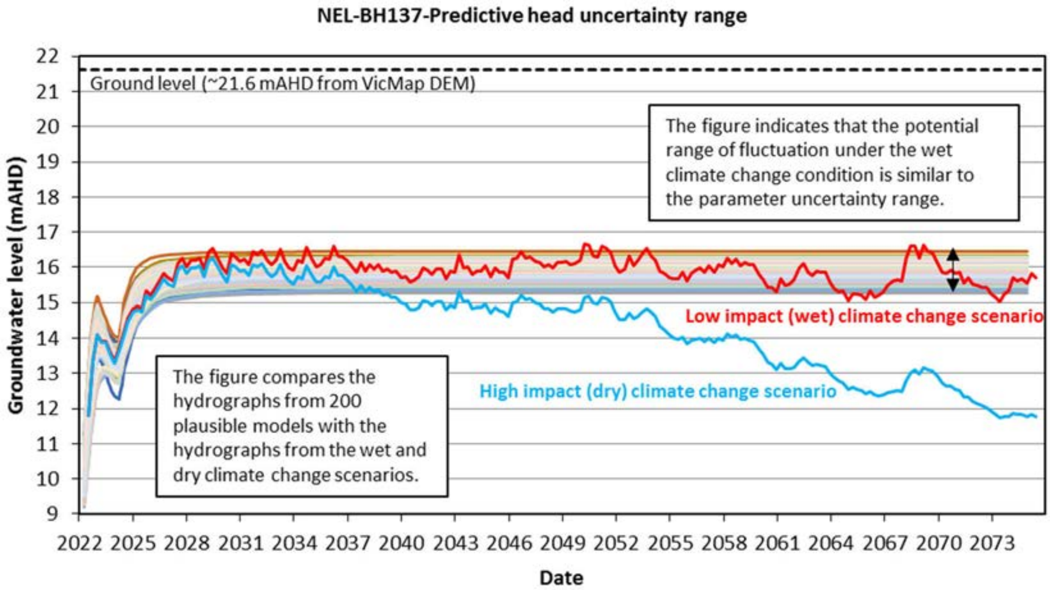

Figure 58 Predicted effects of climate change on mounding

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.

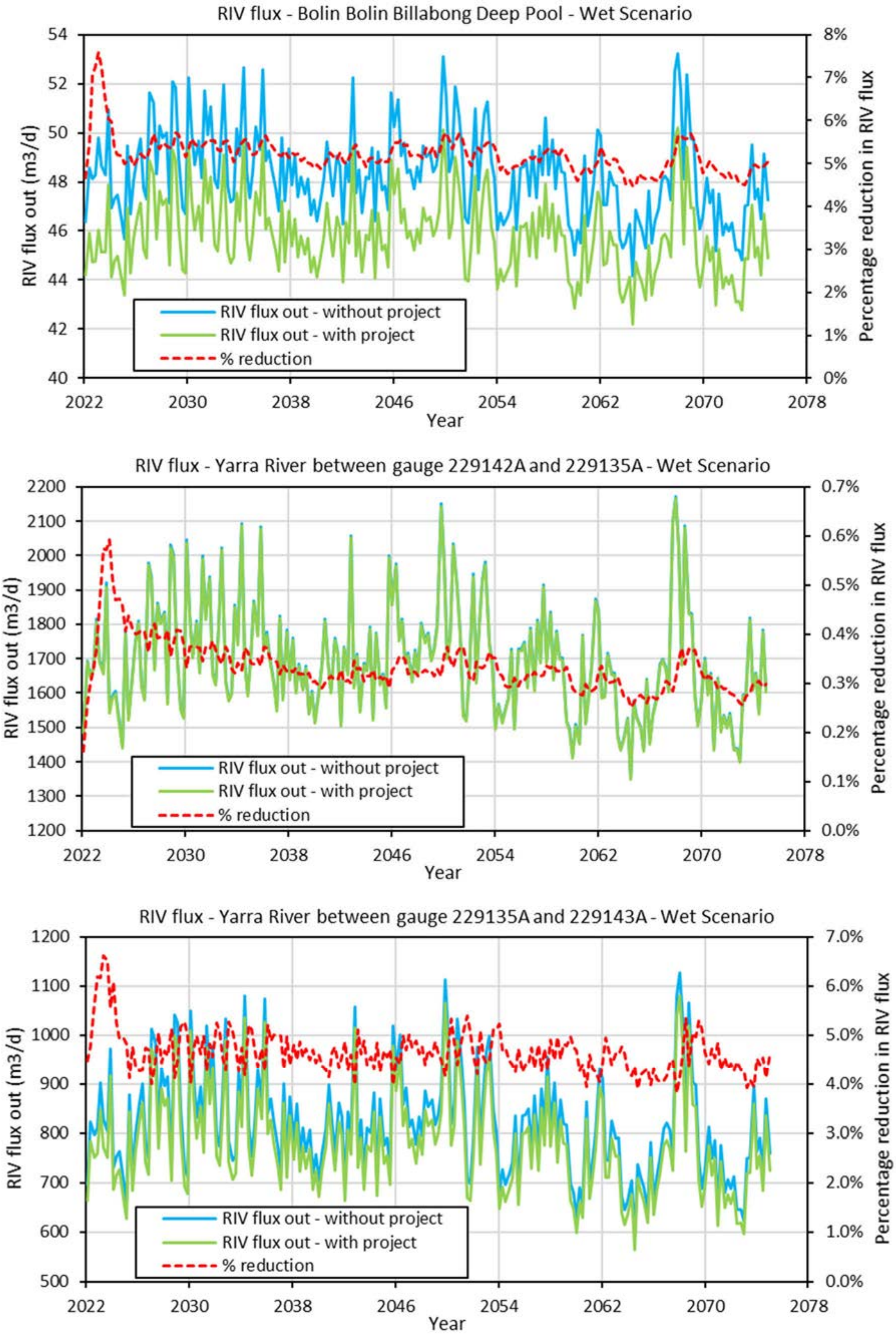

Figure 59 Predicted wet scenario groundwater fluxes (baseflow)

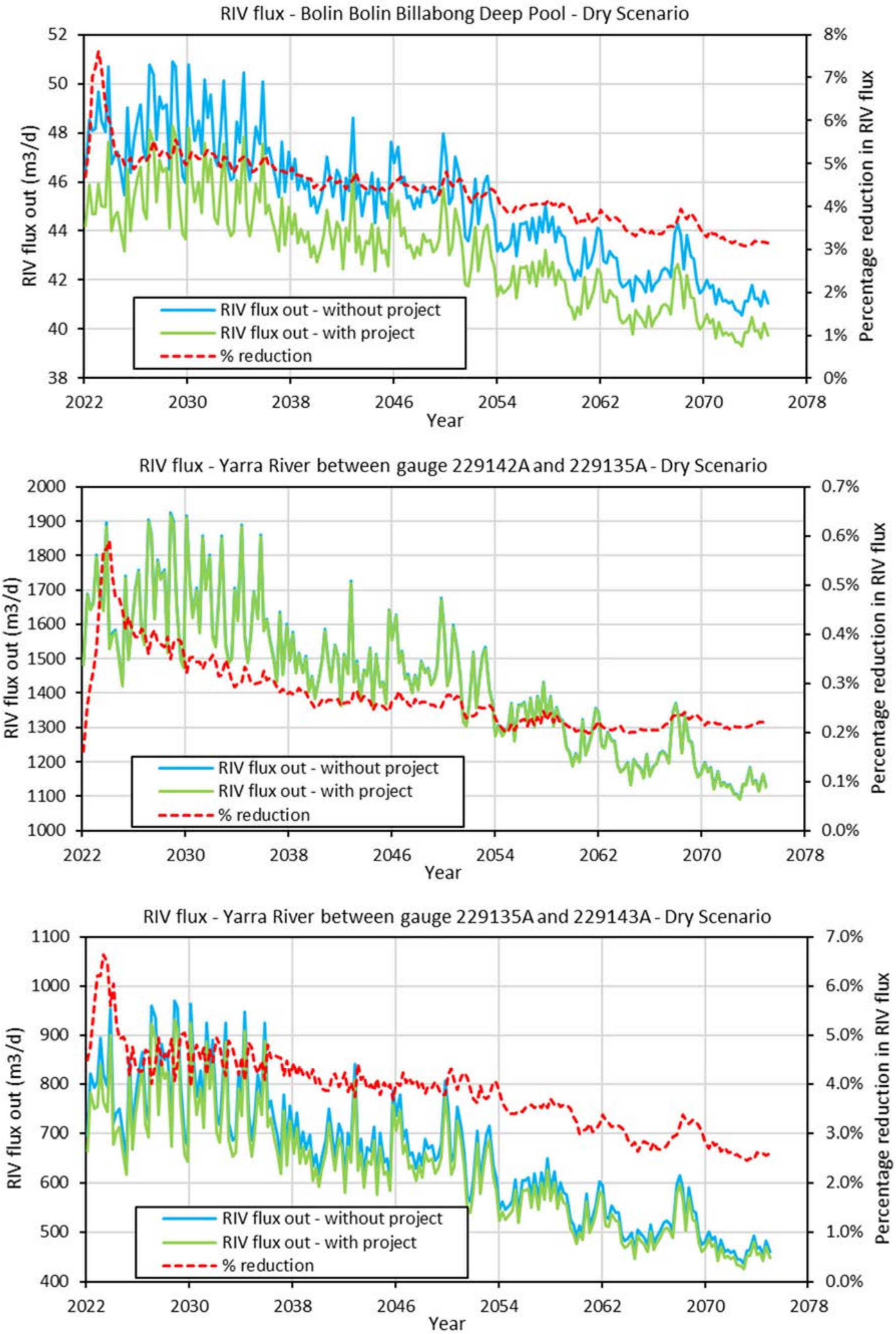

Figure 60 Predicted dry scenario groundwater fluxes (baseflow)

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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GHD

180 Lonsdale Street
Melbourne, Victoria 3000
T: (03) 8687 8000 F: (03) 8687 8111 E: melmail@ghd.com.au

www.ghd.com

Appendix B – Report on Additional Groundwater Modelling

North East Link Project

North East Link
Report on Additional Groundwater Modelling

July 2019

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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.

The 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).

To assist with the preparation of the EES and the Public Environment Report for assessment under the EPBC Act, numerical groundwater modelling was undertaken for the project. The findings of the modelling were presented in Technical Report N of the EES, with detailed description of the modelling provided in Appendix C Numerical Groundwater Model Report of Technical Report N.

This report describes further numerical groundwater modelling undertaken for the project following the preparation of the EES. The purpose of further modelling is to incorporate additional groundwater data collected over a period of approximately 12 months to enable transient calibration to seasonal variations in groundwater levels and to assess whether or not the additional calibration efforts result in changes to the assessment of project-induced groundwater impacts outlined in the EES.

The report focuses on the key updates made to the model based on the additional data. Detailed descriptions of the model including model design, boundary conditions and parameterisation are provided in Appendix C of Technical Report N and are not duplicated herein. References are made throughout the report to relevant sections of the Numerical Groundwater Model Report where further details can be found.

2. Model calibration

2.1 Additional calibration data

The numerical groundwater model developed for the EES was calibrated to single measurements of groundwater level collected from 95 monitoring bores and drawdown measured during constant rate pumping tests completed at three locations. Estimates of baseflow to the Yarra River from other studies were also used as loose calibration targets, placing sensible upper bounds on the modelled baseflow (see Section 3.2.1 of the Numerical Groundwater Model Report).

Over a period of around 12 months following the completion of calibration, additional measurements of groundwater level have been collected from the existing, as well as new monitoring bores on a monthly basis (when/where accessible). Time series of groundwater level measurements are currently available from a total of 116 monitoring bores, providing greater spread of data both spatially and temporally. Additionally, continuous measurements of groundwater levels have been collected from 10 monitoring bores using automated data loggers. These additional data provide the opportunity to calibrate the model transiently to seasonal variations in groundwater levels, which could assist in improving model's representation of recharge and surface water – groundwater interactions.

2.2 Model calibration approach

2.2.1 Automated calibration workflow

In order to take advantage of the knowledge gained from the prior calibration efforts, the following three model runs have been incorporated into the automated calibration workflow to estimate model parameters:

1. Existing steady state model calibrated to groundwater levels collected in April 2018 and estimated average baseflow to the Yarra River, as per the EES model calibration.
2. Existing transient model calibrated to drawdown measured during constant rate pumping tests completed at three locations, as per the EES model calibration.
3. New transient model calibrated to seasonal variations in groundwater levels collected over a period of around 12 months, using time-varying recharge and river stages.

The model simulation period of the new transient model begins on 1 April 2018 and ends on 20 April 2019, using 55 weekly stress periods to simulate seasonal variations in recharge. Time-varying recharge has been calculated as a fraction of rainfall sourced from the Scientific Information for Land Owners (SILO) database, averaged over the duration of each stress period. Additionally, time-varying river stage has been assigned to the River (RIV) boundary condition along the Yarra River and a portion of Koonung Creek where the shallow groundwater levels indicate potential influence of river leakage (Figure 1). The river stage for the Yarra River and Koonung Creek has been calculated using the measured river stage at gauge 229135A and 229229A respectively. The standing water level above each river gauge has been corrected for the difference between the gauge zero elevation and the elevation of model top (bathymetry) at the location of each gauge. The corrected standing water levels, averaged over the duration of each stress period, are added to the top of RIV cells (representing the top of the river bed) to derive time-varying river stage for each RIV cell (Figure 2).

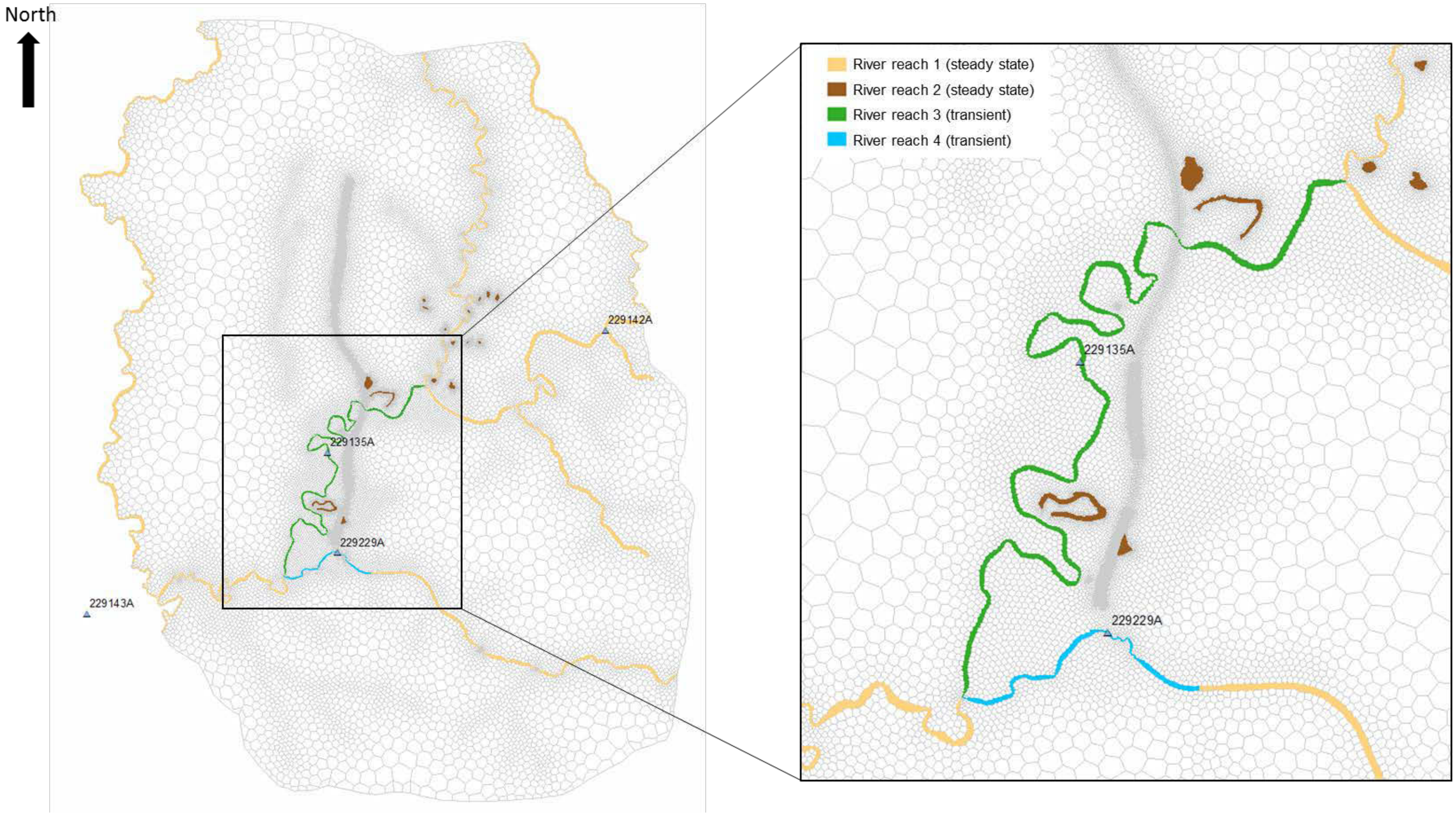


Figure 1 River boundary conditions for transient calibration

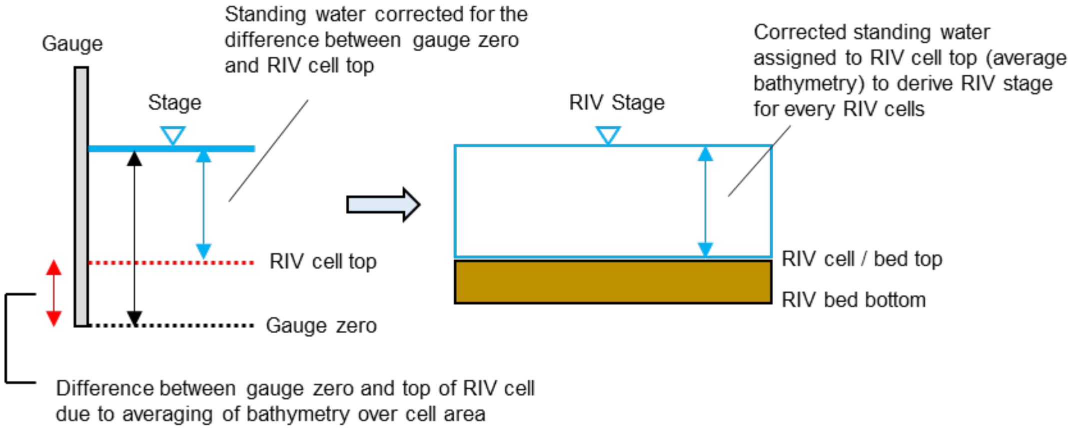


Figure 2 RIV boundary condition – transient stage

The calibration targets for the new transient model include monthly measurements of hydraulic heads from manual water level gauging events and continuous measurements of hydraulic heads obtained using automated data loggers. For the purpose of calibration, the continuous logger data have been reduced to average weekly heads consistent with the length of each stress period.

All three model runs have been integrated into a single automated calibration workflow, as shown schematically in Figure 3. This ensures consistent use of parameters for all three model runs e.g. the same hydraulic conductivity arrays for all three model runs, ensuring that the calibrated hydraulic conductivities satisfy all three calibration datasets. The steady state model provides initial heads for the two transient models.

The automated calibration procedure has been undertaken using PEST_HP in a parallelized computing environment (Doherty, 2017) with several PEST utilities to facilitate pre- and post-processing efforts (see Section 3.2.2 of the Numerical Groundwater Model Report).

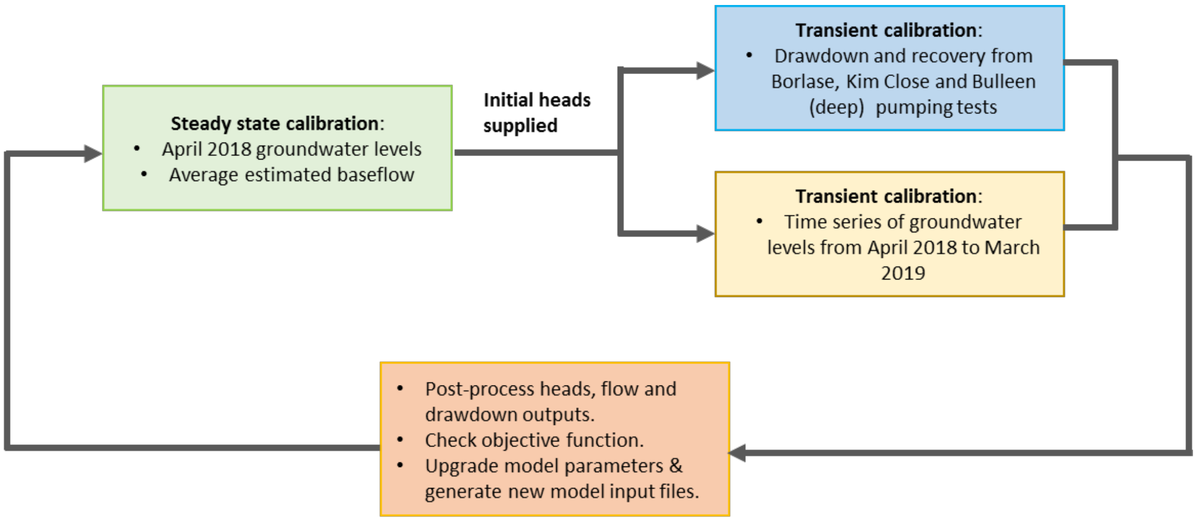


Figure 3 Calibration workflow

The calibration involved several iterations, with each iteration providing the opportunity to re-assess the parameter bounds and parameterisation (such as the number and location of pilot points) to better guide the calibration process. In particular, simulating the effect of river leakage observed in bore NEL-BH062-S, located within the Alluvium approximately 70 m from the Yarra River, required targeted calibration efforts by taking into consideration local variations in the abundance of sand and findings from the analysis of a pumping test undertaken concurrently with the model calibration. Adjustments to the river stage were also required on several RIV cells adjacent to bores NEL-BH062-S and NEL-BH061-S, where errors in the modelled bathymetry resulted in river stages that were inconsistent with the observed groundwater levels e.g. minimum river stage well above minimum groundwater level.

As outlined in Section 5 of the Numerical Groundwater Model Report, different realisations of the model with different combinations of parameters can result in a model that is equally well calibrated to the observed data albeit with slight difference in the quality of calibration both spatially and temporally. The final model parameters values presented in Section 2.3.1 have been chosen not only on the basis of the statistical measure of calibration quality but also on the reasonableness of model parameters and model response to transient stresses.

2.2.2 Calibration parameters

The model design, boundary conditions and parameterisation are based on those of the EES model with the exception of the following updates:

- Additional 10 adjustable pilot points assigned along the project alignment for estimating the horizontal hydraulic conductivity of the Bedrock, reflecting the greater spatial spread of data available. Additionally, two regional pilot points have been converted from tied to adjustable so that the hydraulic conductivity to the west of the project alignment is allowed to vary from that to the east if deemed necessary during calibration. A total of 27 adjustable and 21 tied pilot points are used to estimate the horizontal hydraulic conductivity of the Bedrock.
- Converting the Alluvium from a zone of homogeneous hydraulic conductivity to a zone of spatially varying hydraulic conductivity using a total of 10 adjustable pilot points. This change reflects the additional data available from the Alluvium and observed spatial variations in groundwater levels that could not be calibrated as effectively assuming homogeneity. As the adjustable pilot points are positioned in the southern portion of the project alignment where the bores in the Alluvium are located, a large number of tied pilot points are used regionally to prevent spurious interpolation of hydraulic conductivity values some distance from the project alignment (see Figure 5).
- Delineating four separate RIV bed hydraulic conductivity parameters based on the RIV reaches shown in Figure 1. Preferred difference in parameter value between these four parameters was set to zero so that these parameter values could remain as close as possible unless deemed necessary during calibration.

Recharge has been calibrated using a multiplier that converts rainfall into recharge. Separate recharge multipliers are used for the Alluvium and Bedrock to account for the difference in their material properties, as per the EES model. For each aquifer, the same recharge multiplier is used for both the steady state model and transient model to ensure consistency in estimating recharge rates. This means long term average rainfall is multiplied by the recharge multiplier to derive long term average recharge for the steady state model and the same recharge multiplier is used for the transient model to convert average weekly rainfall into average weekly recharge for each stress period.

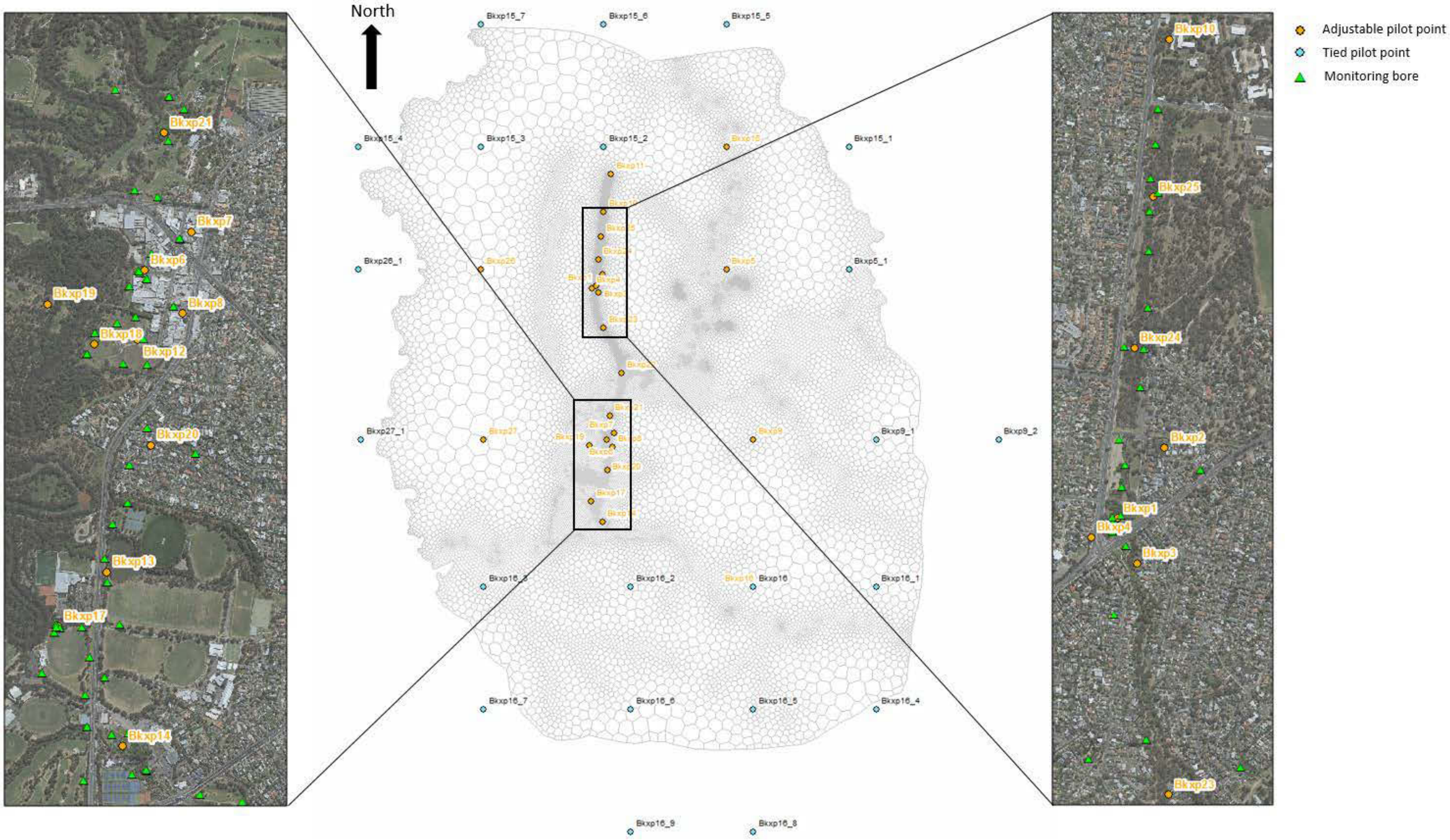


Figure 4 Horizontal hydraulic conductivity pilot points - Bedrock

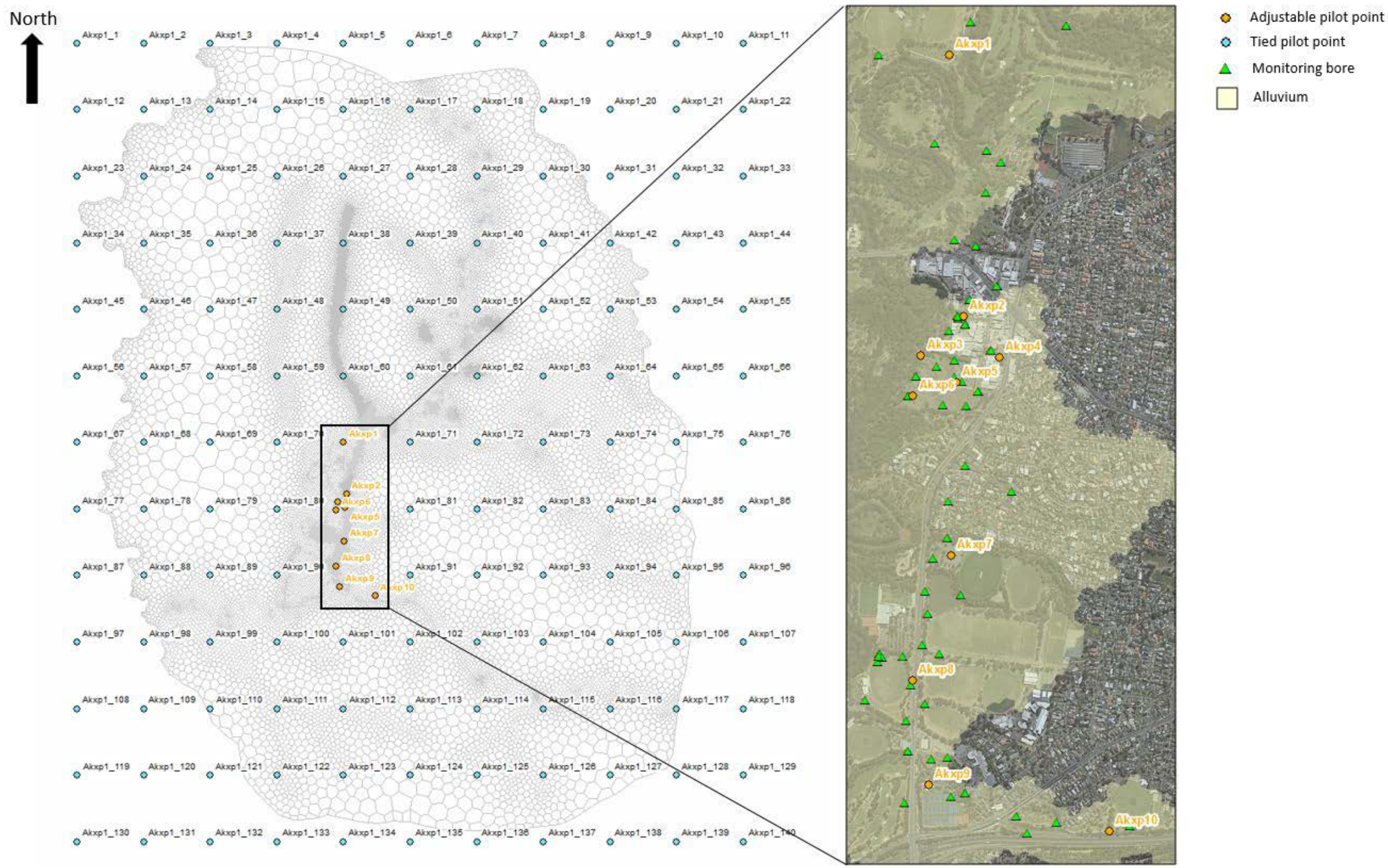


Figure 5 Horizontal hydraulic conductivity pilot points - Alluvium

2.3 Calibration performance

2.3.1 Calibrated model parameters

Table 1 summarises the parameter bounds used for the calibration and the calibrated parameter values. The calibrated parameter values have been chosen on the basis of the following:

- High calibrated hydraulic conductivity at Akxp6 (40 m/d) reflects the abundance of sand at this location, supported by river leakage effects observed in nested bores NEL-BH062-S and NEL-BH62-D and high transmissivity estimated from the recent pumping test completed at this location. For example, borehole logs at NEL-BH062-S/D indicate two sand intervals from 7 to 10 metres below ground level (bgl) and 15 to 17 metres bgl, with a metre thick gravel bed at 9 metres bgl. The analysis of transmissivity from the constant rate pumping test indicates transmissivity of around 240 m^2/d, equating to a hydraulic conductivity of around 48 m/d assuming a total sand/gravel (effective aquifer) thickness of 5 metres. The calibration confirmed that the fluctuations in groundwater levels observed at bore NEL-BH62-S is sensitive to the horizontal hydraulic conductivity as well as river bed hydraulic conductivity. For the purpose of calibration, a maximum value of 40 m/d was chosen as the bulk average for the full thickness of the Alluvium (model layer 1).
- In other parts of the Alluvium, different calibrated hydraulic conductivities at the pilot points generally reflect the lithological variations identified in the borehole logs, including:
  - Lower calibrated hydraulic conductivity at Akxp3 (1 m/d) compared to AKxp6 (40 m/d), consistent with a thinner sand bed (8.5 to 10 metres bgl) and absence of gravel bed observed in the borehole log from NEL-BH061-S/D.
  - Low calibrated hydraulic conductivity at Akxp4, consistent with the presence of high plasticity clay to around 10.6 metres bgl, underlain by a less than a metre thick sand bed, as observed in the borehole log from NEL-BH137.
  - High hydraulic conductivity at Akxp7, consistent with the presence of clayey sand from 5.5 to 13.8 metres bgl with traces of gravel from 7.4 to 8.8 metres bgl and 10.9 to 13.8 metres bgl, as observed in the borehole log from NEL-BH254.
  - Low hydraulic conductivity at Akxp8, Akxp9 and Akxp10, consistent with predominantly sandy clay lithology with a thickness typically less than 10 m and hydraulic conductivity of <1 m/d derived from slug testing of nearby bores (NEL-BH125 and NEL-BH040-S).
- For the regional Alluvium pilot point, Akxp1, hydraulic conductivity was constrained at 15 m/d during calibration which is considered a realistic upper limit for the bulk hydraulic conductivity of the Alluvium.
- The calibrated Bedrock horizontal hydraulic conductivities at pilot points close to the locations of pumping tests are similar to their initial estimates, as the calibration at these locations is constrained by drawdown observed during pumping tests.
- The river bed hydraulic conductivity along the portion of the Yarra River with transient stage (River reach 3) has a calibrated value of 0.5 m/d. This is higher than the previously calibrated value due to the river leakage effects observed in the monitoring bores near the river, indicating greater hydraulic connection with the Alluvium than previously modelled. The maximum river bed hydraulic conductivity permitted during calibration was reduced from 1 m/d to 0.5 m/d, as any value greater than 0.5 m/d is considered unrealistic given the calibrated average vertical hydraulic conductivity of around 0.3 m/d for the underlying Alluvium.

- The river bed hydraulic conductivity along the portion of Koonung Creek with the transient stage (River reach 4) has a calibrated value towards the lower end of the range, broadly consistent with the generally low calibrated hydraulic conductivity of the Alluvium in this area (0.1 to 0.23 m/d). For water bodies (River reach 2), the river bed hydraulic conductivity was adjusted to account for the likely presence of swamp deposits and to prevent unrealistically high fluxes that are considered inconsistent with the water balance of these features e.g. very high baseflow to the deep pool of the Bolin Bolin Billabong compared to evaporation from pool surface.
- Calibrated steady state recharge rate is around 51.5 mm/yr over the Alluvium and 20 mm/yr over the Bedrock. Recharge has been reduced over the Alluvium and increased over the Bedrock compared to the EES model based on the calibration to seasonal trends.

2.3.2 Calibrated hydrographs

The transient monitoring data generally indicates subtle seasonal variations of <1 metre along the project alignment, with an overall declining trend between April 2018 and October 2018 over a period of low rainfall. The exception to this general trend is seen in a number of bores located near the Yarra River, where the seasonal variations in groundwater levels more closely reflect the seasonal variations in the river stage. The transient calibration focused on simulating these subtle seasonal trends in groundwater levels, capturing the effect of rainfall-derived recharge and river leakage.

Figure 8 shows a number of modelled and observed hydrographs some distance from the Yarra River where the effect of subtle seasonal variations in rainfall-derived recharge can be seen. For example, at bore NEL-BH123, located up gradient of the Bolin Bolin Billabong, the modelled hydrograph simulates around 0.6 metre drop in the groundwater level observed between April 2018 and October 2018 over a period of low rainfall. At bore NEL-BH59, short-term fluctuations captured by the data logger are generally well replicated by the model although the modelled response to rainfall events is more subdued.

Figure 9 shows the modelled and observed hydrographs from several bores located near the Yarra River where the effect of river leakage is discernible. At bore NEL-BH62-S, the peak groundwater level recorded in August 2018 is around 1.6 m higher than the lowest groundwater level and corresponds with the timing of the peak river level recorded at gauge 229135A, indicating strong hydraulic connection with the river (most likely via the sand/gravel layer encountered at around 7 metres bgl). This is supported by the sensitivity of model calibration to the Alluvium hydraulic conductivity, river bed hydraulic conductivity and river stage. As shown in the Figure, the model simulates the timing of river leakage effects well, although the simulated response is somewhat subdued. This could partly be due to the confined storage effect within the sand/gravel layer, which cannot be adequately simulated with a single model layer, and partly due to the accuracy of the river stage adjacent to the bore which is based on the upstream gauge 229135A. At other bores such as NEL-BH29 and NEL-BH76-S, the modelled heads are overestimated but the trends are broadly consistent with those observed, indicating that the surface water – groundwater interactions are appropriately simulated.

Appendix A includes several bore location plans with hydrographs inserted at key locations. All hydrographs used in the model calibration are included in Appendix B.

Table 1 Calibration parameters

PEST ID	Parameter	Min	Max	Initial	Calibrated
kzfact_bedr	Bedrock Kx/Kz (-)	0.01	1	0.176	0.342
kzfact_alluv	Alluvium Kx/Kz (-)	0.01	1	0.01	0.021
ss_bedr	Bedrock SS (-)	1.00E-06	1.00E-04	1.02E-05	6.35E-06
sy_bedr	Bedrock Sy (-)	0.01	0.2	0.01	0.01
sy_alluv	Alluvium Sy (-)	0.05	0.4	0.05	0.05
bedrch	Bedrock Rfac (-)	0.014091	0.14091	0.015	0.028
avmrch	Alluvium Rfac (-)	0.014091	0.14091	0.141	0.073
evt_mult	EVT multiplier (-)	0.9	2.36	2.36	2.36
exdp	Extinction depth (m)	2	8	5	6.732
riverk1	River bed K (m/d)	0.001	0.5	0.008	0.05
riverk2	River bed K (m/d)	0.001	0.5	0.008	0.011
riverk3	River bed K (m/d)	0.001	0.5	0.008	0.5
riverk4	River bed K (m/d)	0.001	0.5	0.008	0.005
bkxp1	Bedrock Kx (m/d)	0.005	0.5	0.129	0.144
bkxp2	Bedrock Kx (m/d)	0.005	0.5	0.01	0.005
bkxp3	Bedrock Kx (m/d)	0.005	0.5	0.005	0.005
bkxp4	Bedrock Kx (m/d)	0.005	0.5	0.043	0.005
bkxp5	Bedrock Kx (m/d)	0.005	0.5	0.005	0.005
bkxp6	Bedrock Kx (m/d)	0.005	0.5	0.099	0.138
bkxp7	Bedrock Kx (m/d)	0.005	0.5	0.008	0.005
bkxp8	Bedrock Kx (m/d)	0.005	0.5	0.417	0.5
bkxp9	Bedrock Kx (m/d)	0.005	0.5	0.5	0.5
bkxp10	Bedrock Kx (m/d)	0.005	0.5	0.005	0.007
bkxp11	Bedrock Kx (m/d)	0.005	0.5	0.005	0.005
bkxp12	Bedrock Kx (m/d)	0.005	0.5	0.015	0.005
bkxp13	Bedrock Kx (m/d)	0.005	0.5	0.007	0.008
bkxp14	Bedrock Kx (m/d)	0.005	0.5	0.241	0.5
bkxp15	Bedrock Kx (m/d)	0.005	0.5	0.014	0.039
bkxp16	Bedrock Kx (m/d)	0.005	0.5	0.005	0.038
bkxp17	Bedrock Kx (m/d)	0.005	0.5	0.036	0.052
bkxp18	Bedrock Kx (m/d)	0.005	0.5	0.007	0.005

PEST ID	Parameter	Min	Max	Initial	Calibrated
bkxp19	Bedrock Kx (m/d)	0.005	0.5	0.011	0.006
bkxp20	Bedrock Kx (m/d)	0.005	0.5	0.013	0.005
bkxp21	Bedrock Kx (m/d)	0.005	0.5	0.01	0.022
bkxp22	Bedrock Kx (m/d)	0.005	0.5	0.01	0.007
bkxp23	Bedrock Kx (m/d)	0.005	0.5	0.007	0.023
bkxp24	Bedrock Kx (m/d)	0.005	0.5	0.012	0.265
bkxp25	Bedrock Kx (m/d)	0.005	0.5	0.007	0.007
bkxp26	Bedrock Kx (m/d)	0.005	0.5	0.005	0.006
bkxp27	Bedrock Kx (m/d)	0.005	0.5	0.5	0.343
akxp1	Alluvium Kx (m/d)	0.1	15	13.918	15
akxp2	Alluvium Kx (m/d)	0.1	15	13.918	4.879
akxp3	Alluvium Kx (m/d)	1	15	13.918	1
akxp4	Alluvium Kx (m/d)	0.1	15	13.918	0.315
akxp5	Alluvium Kx (m/d)	0.1	15	13.918	0.1
akxp6	Alluvium Kx (m/d)	5	40	13.918	40
akxp7	Alluvium Kx (m/d)	0.1	15	13.918	15
akxp8	Alluvium Kx (m/d)	0.1	15	13.918	0.226
akxp9	Alluvium Kx (m/d)	0.1	15	13.918	0.137
akxp10	Alluvium Kx (m/d)	0.1	15	13.918	0.1

Note: Kx – horizontal hydraulic conductivity, Kx/Kz – vertical hydraulic conductivity factor, Ss – specific storage, Sy – specific yield, Rfact – recharge factor and EVT – evapotranspiration.

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. The calibrated specific storage is within the range of plausible values proposed by Rau et al (2018).

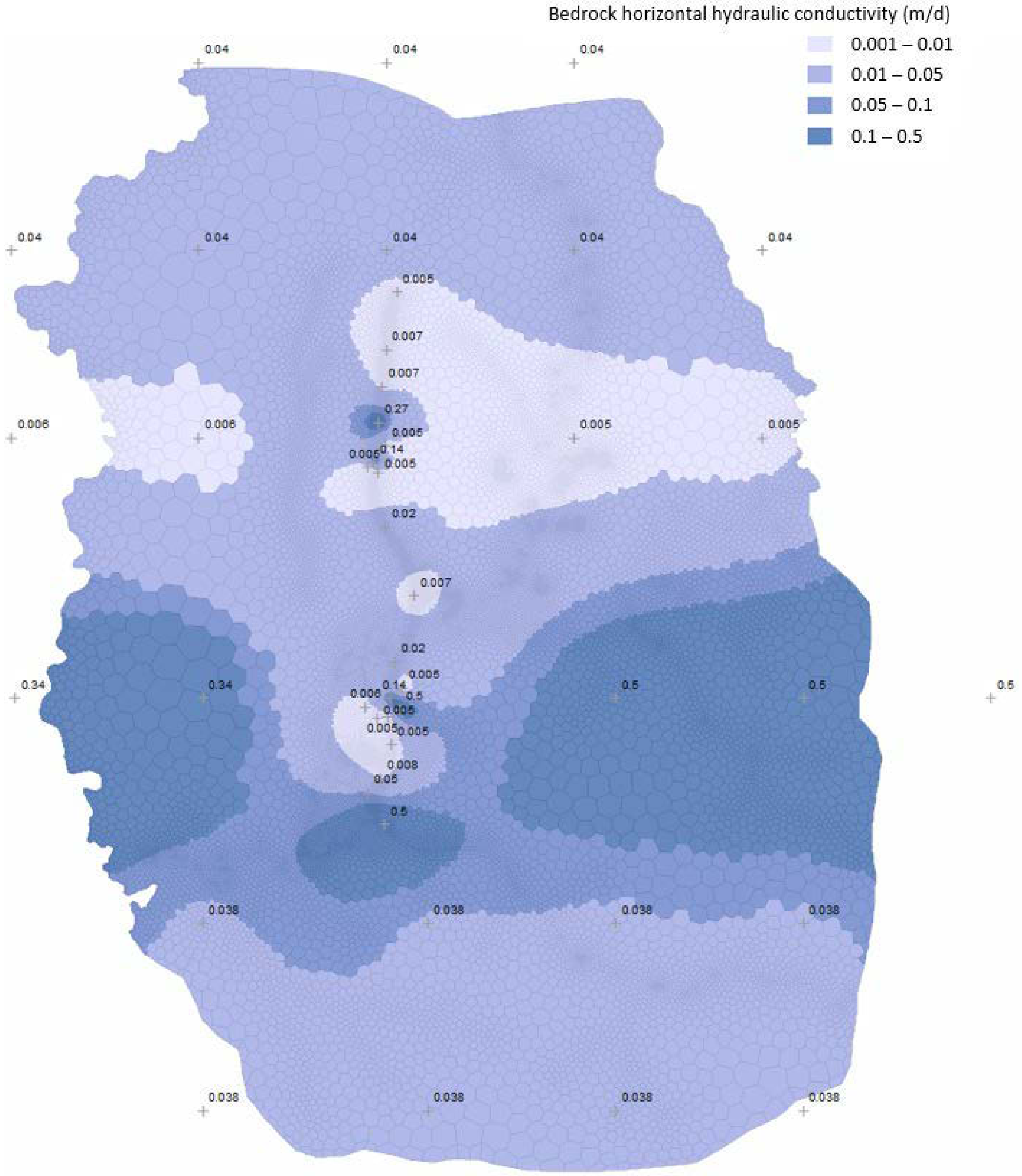


Figure 6 Calibrated hydraulic conductivity - Bedrock

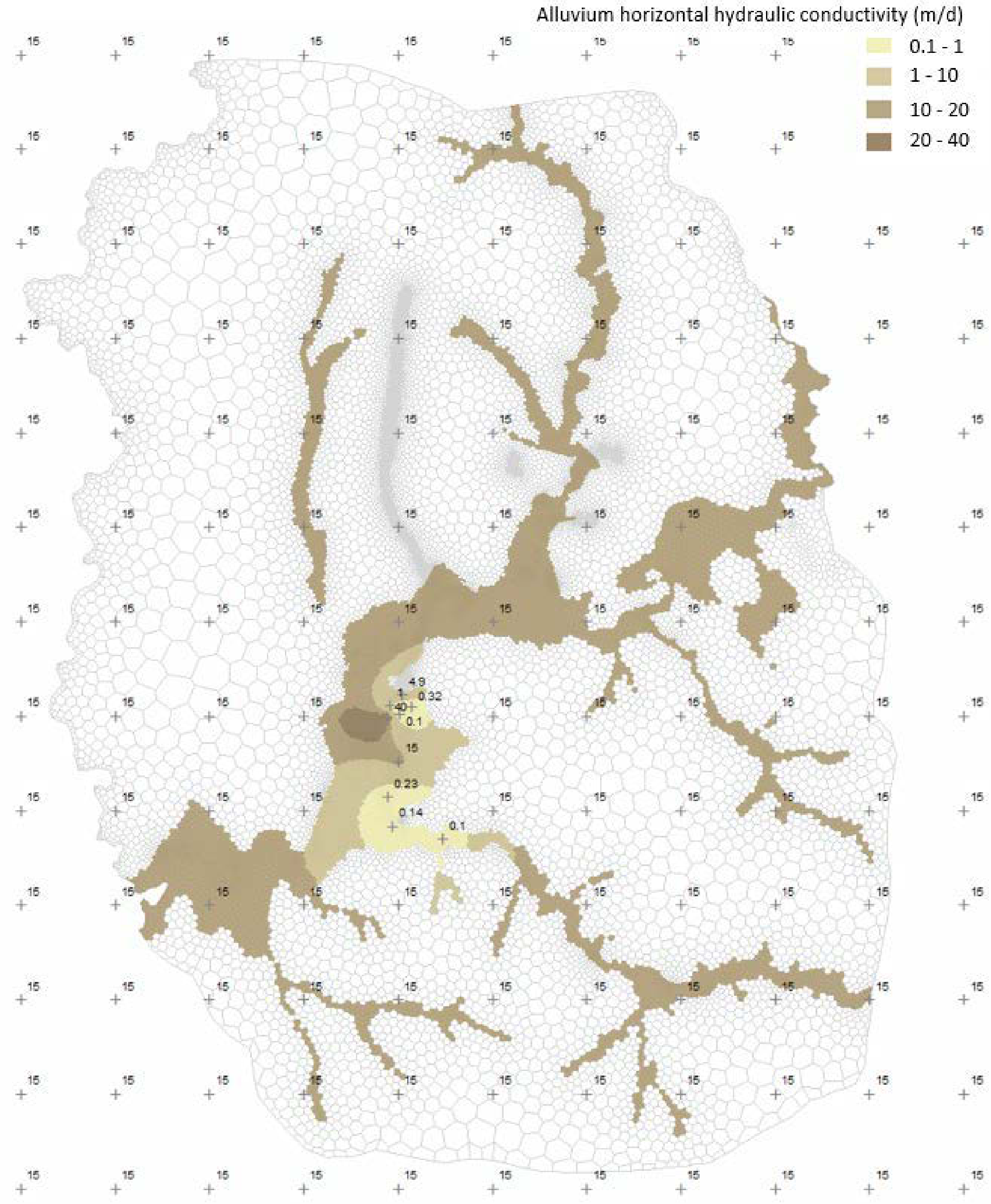


Figure 7 Calibrated hydraulic conductivity - Alluvium

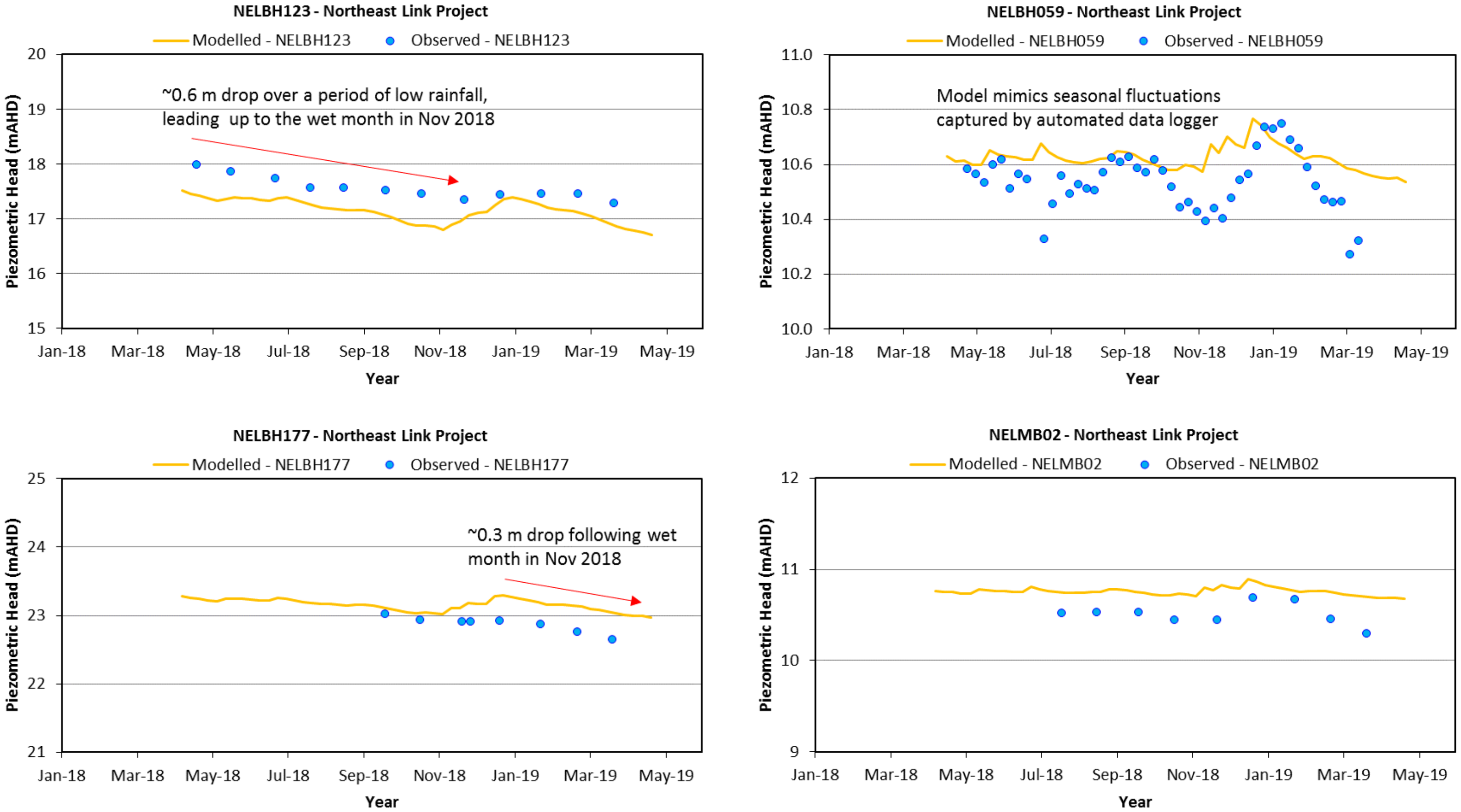


Figure 8 Calibration hydrographs – rainfall-derived recharge

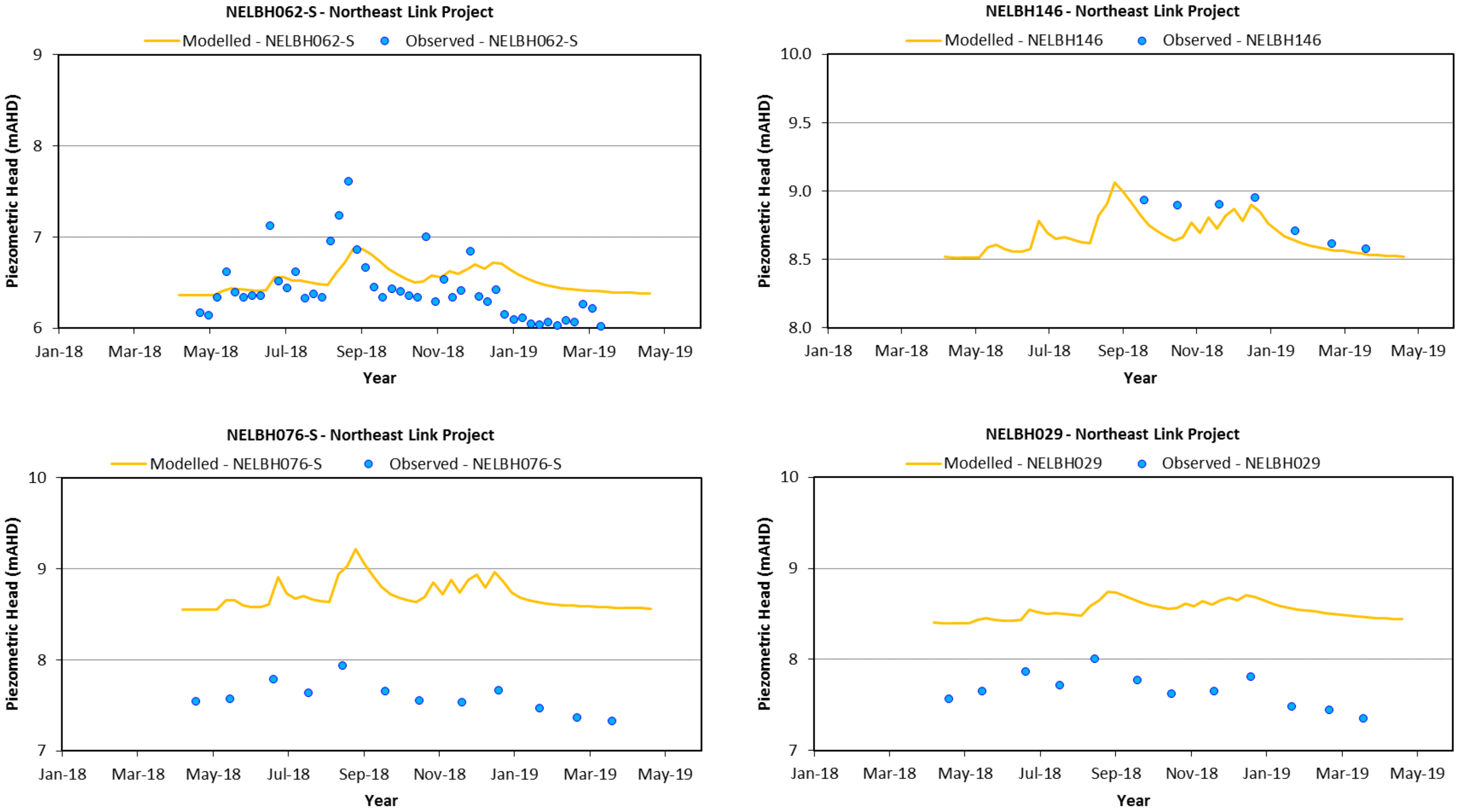


Figure 9 Calibration hydrographs – surface water – groundwater interaction

2.3.3 Calibrated baseflow

The simulated average baseflow to the Yarra River between flow gauges 229142A and 229135A is 6.65 mega litres (ML) per day. This is much higher than the 1.77 ML/d simulated previously with the EES model and is more consistent with the 3.3 ML/d to 6.85 ML/d range computed by the ecoMarkets Port Phillip model (GHD, 2010). While the simulated baseflow is still less than the 23 ML/d estimate derived by SKM (2011), due to the size of the catchment, it should be noted that:

- The simulated average baseflow between flow gauges 229142A and 229135A (6.65 ML/d) is greater than the simulated average leakage (4.6 ML/d), indicating a low gaining condition consistent with the baseflow characteristics defined by SKM (2011).
- The simulated average baseflow between flow gauges 229135A and 229143A (3.7 ML/d) is approximately equal to the simulated average leakage (3.4 ML/d), indicating a neutral condition consistent with the baseflow characteristics defined by SKM (2011).

2.3.4 Water balance

The mass balance error is less than 0.01 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 the steady state and transient models, the model required convergence in heads to within 0.001 metres.

Table 2 provides a breakdown of the water balance for the steady state model and transient model (from April 2018 to April 2019). The steady state (SS) and average transient flow rates are in ML/d and the cumulative transient flow volumes are in ML.

Table 2 Model water balance

Component	Inflow			Outflow		
	SS	Average	Culm	SS	Average	Culm
Recharge	8.53	6.21	2391.12			
Evapotranspiration				12.43	12.11	4660.09
River	19.32	21.33	8151.1	15.43	16.57	6318.49
Storage		8.05	2976.64		6.92	2540.31
Total	27.85		13518.86	27.85		13518.89

SS – Steady state flow rates in ML/d
Average – average flow rates of transient model (April 2018 – April 2019) in ML/d
Culm – cumulative flow volumes of transient model (April 2018 – April 2019) in ML

2.3.5 Calibration statistics

Table 3 provides a summary of the calibration statistics for each observation dataset used in the calibration. The table compares the pre- and post-calibration statistics, where an overall improvement in the quality of calibration can be seen from the reduction in the Scaled Root Mean Squared (SRMS) errors. The SRMS error is less than 3 per cent for all head observation groups, which is well below the 5 per cent error generally considered good calibration for regional scale groundwater models.

Table 3 Calibration statistics

Model	Calibration indicator	Pre-calibration	Post-calibration
Steady state	Head SRMS (%)	3.22	2.47
	Head RMS (m)	2.33	1.79
	River flow (m3/d)	1,768	6,653
Transient (seasonal)	Manual head SRMS (%)	3.34	2.59
	Manual head RMS (m)	2.57	2
	Logger head SRMS (%)	4.45	1.97
	Logger head RMS (m)	1.93	0.91
Transient (pumping test)	Drawdown SRMS (%)	5.9	6.0
	Drawdown RMS (m)	0.5	0.51

Manual head refers to measurements of head taken manually on a monthly basis from 116 bores.
Logger head refers to measurements of heads taken using automated data logger installed in 10 bores.

3. Model prediction

3.1 Approach

The model set up for the predictive modelling is identical to that applied to the EES model, which is described in detail in Section 4 of the Numerical Groundwater Model Report. This section summarises the updated results of predictive modelling utilising the revised model parameters described in Section 2.3.1.

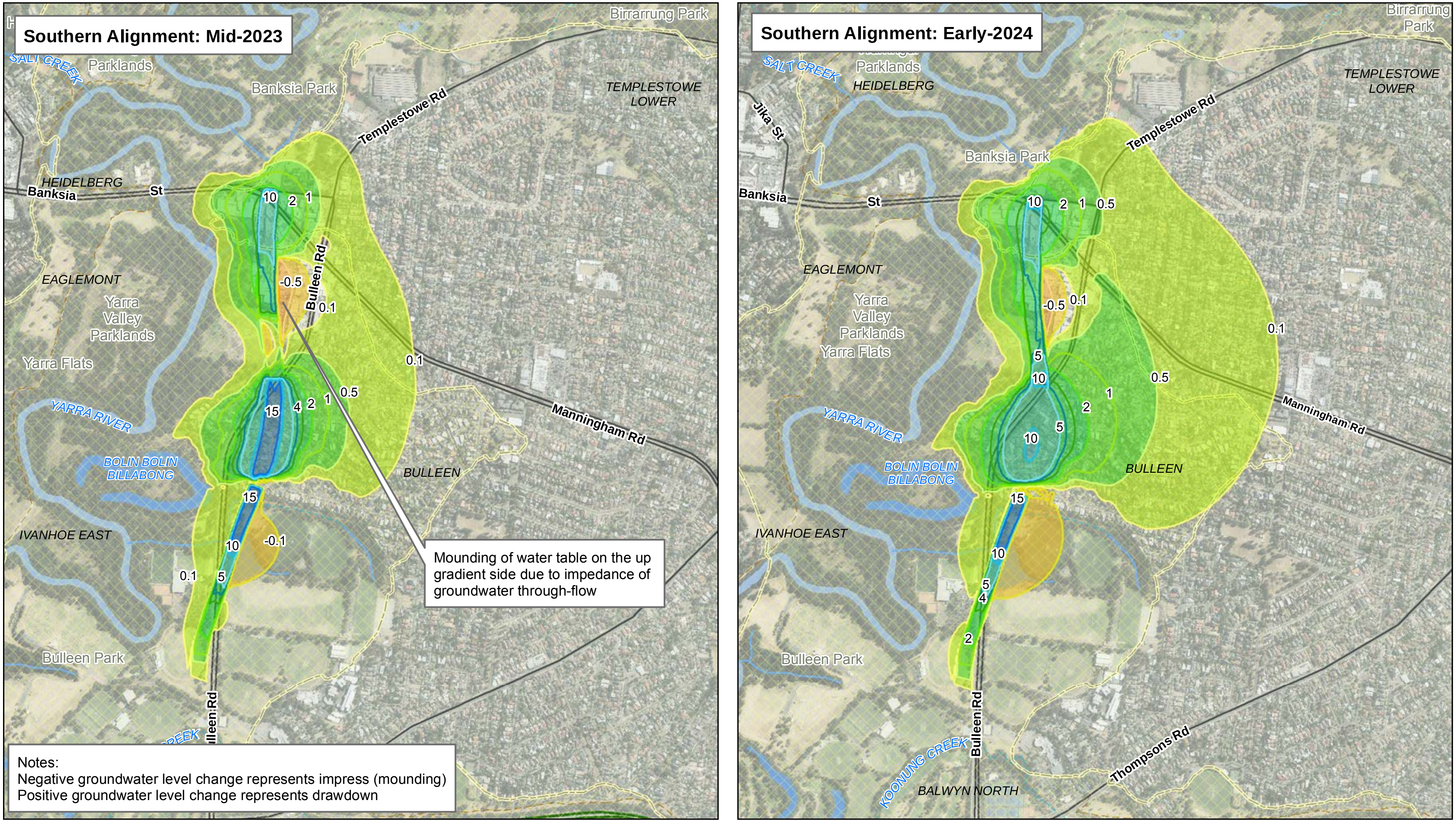
3.2 Results

3.2.1 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) extracted at four time slices to present the progression of the project, as per the EES (see Figure 10 to Figure 13). The contours of changes in piezometric heads are broadly consistent with those of the EES (refer to Figure 26 to Figure 29 of the Numerical Groundwater Model Report), except for the following key differences:

- The mounding of piezometric heads on the up gradient side of the Banksia cut and cover has been significantly reduced. This is partly due to the improved representation of the existing (pre-construction) piezometric heads in this area, which were previously underestimated by several metres at bore NEL-BH137, and partly due to the spatial variability in hydraulic conductivity introduced in the Alluvium that better accounts for the local lithological variation. During construction, mounding is only predicted to occur in a localised area immediately adjacent to the cut and cover, with drawdown extending from the northern end of the cut and cover and the mined tunnels to the south. Following the placement of base slabs and recovery of piezometric heads, the mounding is predicted to develop over the long term albeit at a much smaller extent compared to the EES model, with the maximum mounding of around 2.5 metres.
- The recovery of piezometric heads above the mined tunnels is slower, with around 1 metre drawdown predicted over the long term. This is due to the reduction in recharge assigned to the Alluvium and locally lower hydraulic conductivity in this area compared to the EES model, resulting in insufficient through-flow to completely offset the long term leakage rate assumed for the tunnels (similar to drawdown predicted above the TBM tunnels in the north). The extent of drawdown is localised, however, with the 0.1 metre drawdown contour located adjacent to the Bolin Bolin Billabong.
- The area of influence/extent of the drawdown cone in the northern portion of the alignment is slightly greater during construction; however, long term drawdown adjacent to the free draining section is less partly due to the higher calibrated recharge applied to the Bedrock. For example, drawdown of greater than 0.5 metres is limited to within 180 metres of the trench compared to 580 metres predicted with the EES model. The extent of mounding adjacent to the fully tanked section to the south is slightly larger although this is predicted to be generally less than 0.5 metres.

Figure 14 presents the post-construction depth to groundwater contours derived by subtracting the contours of modelled water table from the Vicmap 1 metre digital elevation model. The area of shallow water table on the up gradient side of the Banksia cut and cover has been reduced, with the predicted depth to groundwater generally ranging from 5 to 7 metres bgl within 200 metres of the alignment. A very localised area of shallow groundwater remains to the south east where the existing depth to water is already less than 4 metres bgl.



Paper Size A4

0 62.5125 250 375 500

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

North East Link Project

NORTH EAST LINK PROJECT

Job Number	31-35006
Revision	C
Date	20 Jun 2019

Predicted groundwater level changes (revised) –south (2023 – 2024)

Figure 10

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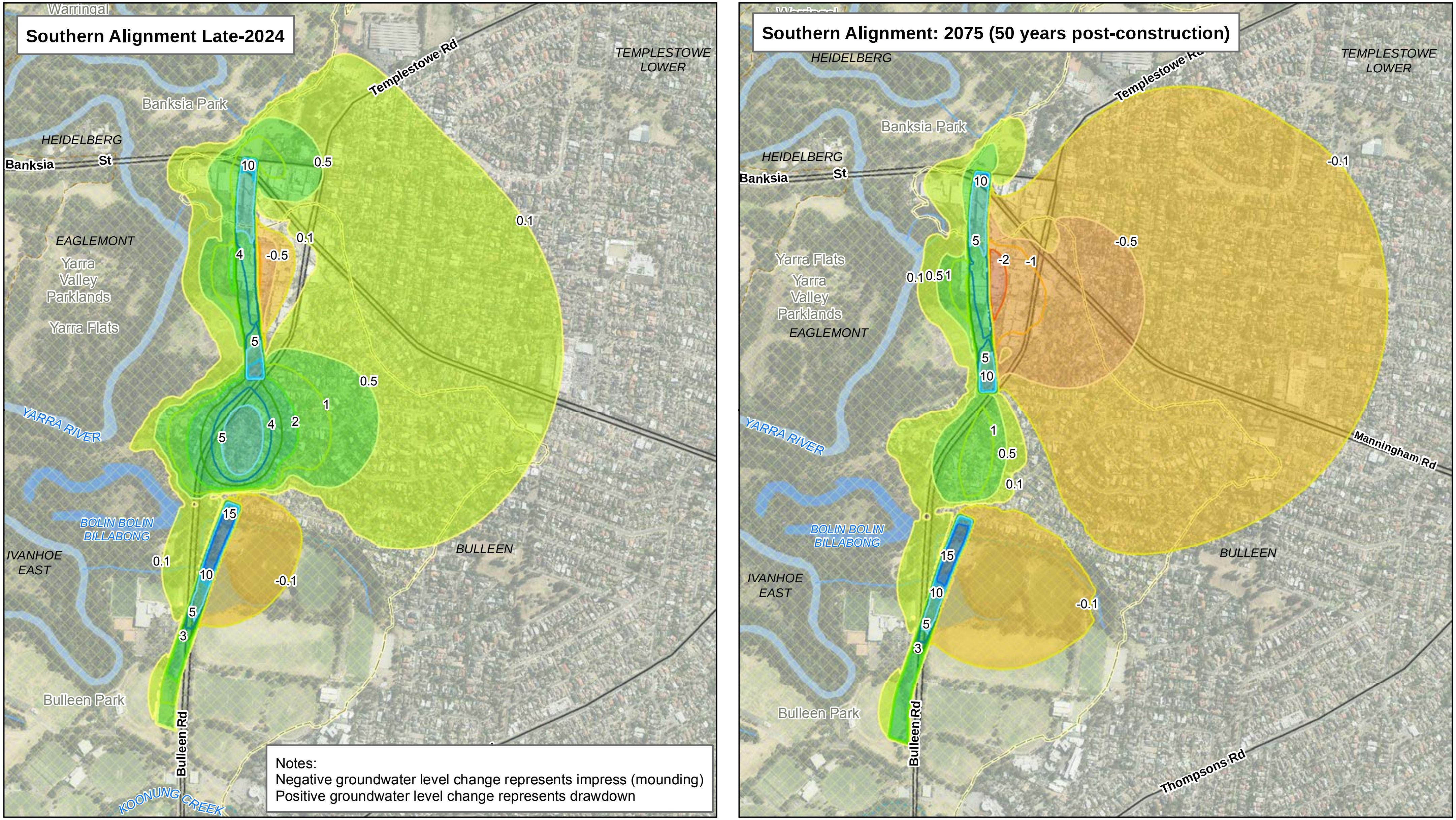
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

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



Paper Size A4

0 62.5 125 250 375 500

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

North East Link Project

Job Number	31-35006
Revision	D
Date	20 Jun 2019

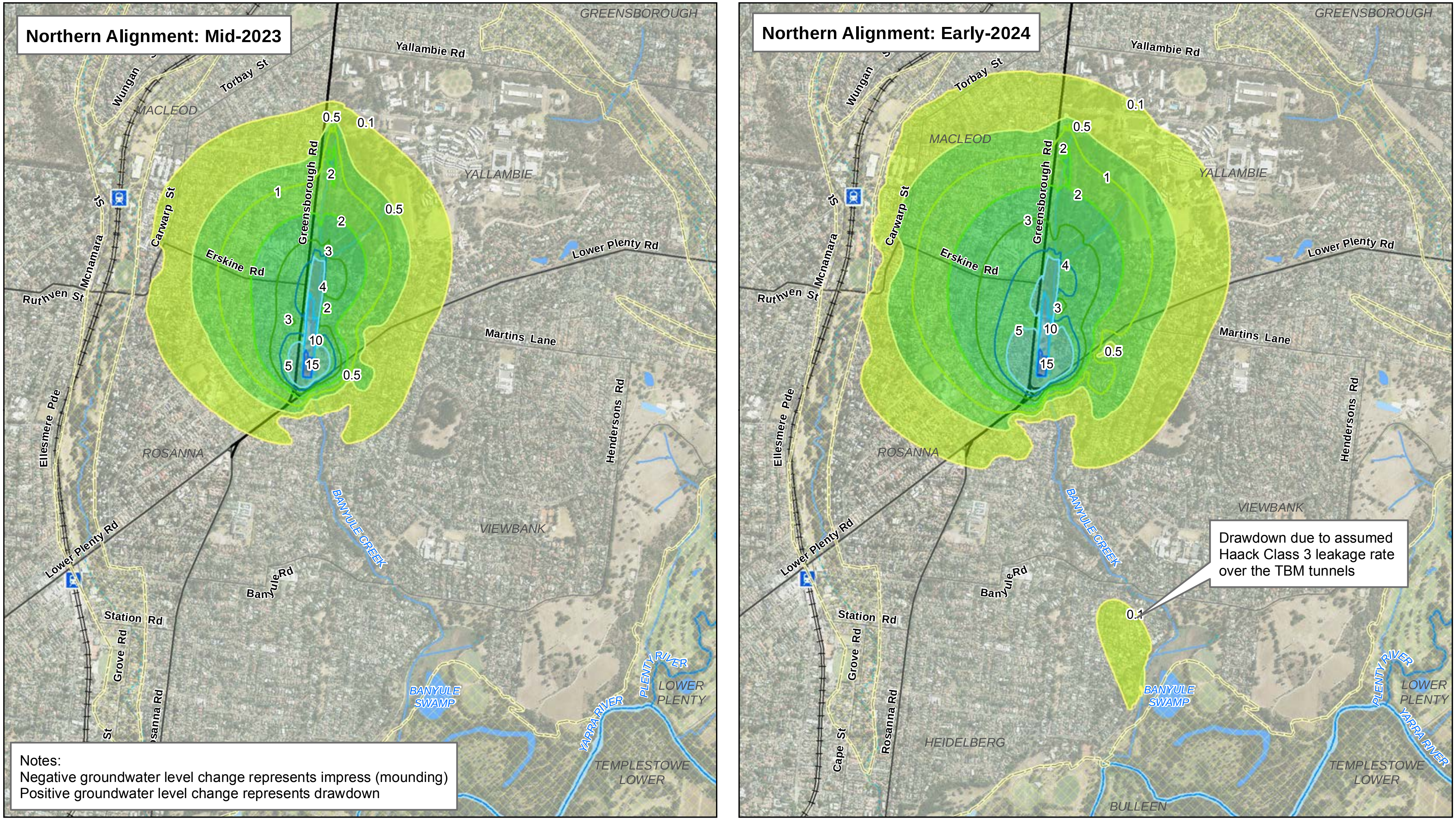
Predicted groundwater level changes (revised) – south (2024, 2075)

Figure 11

G:\31\35006\GIS\Maps\Working\Operational\Groundwater and Hydrology\Post_EES_DDN\3135006_11_BaseCase_South_2024_2075_Post_EES_RevE.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: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti



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

North East Link Project

Job Number 31-35006
Revision C
Date 20 Jun 2019

NORTH EAST LINK PROJECT

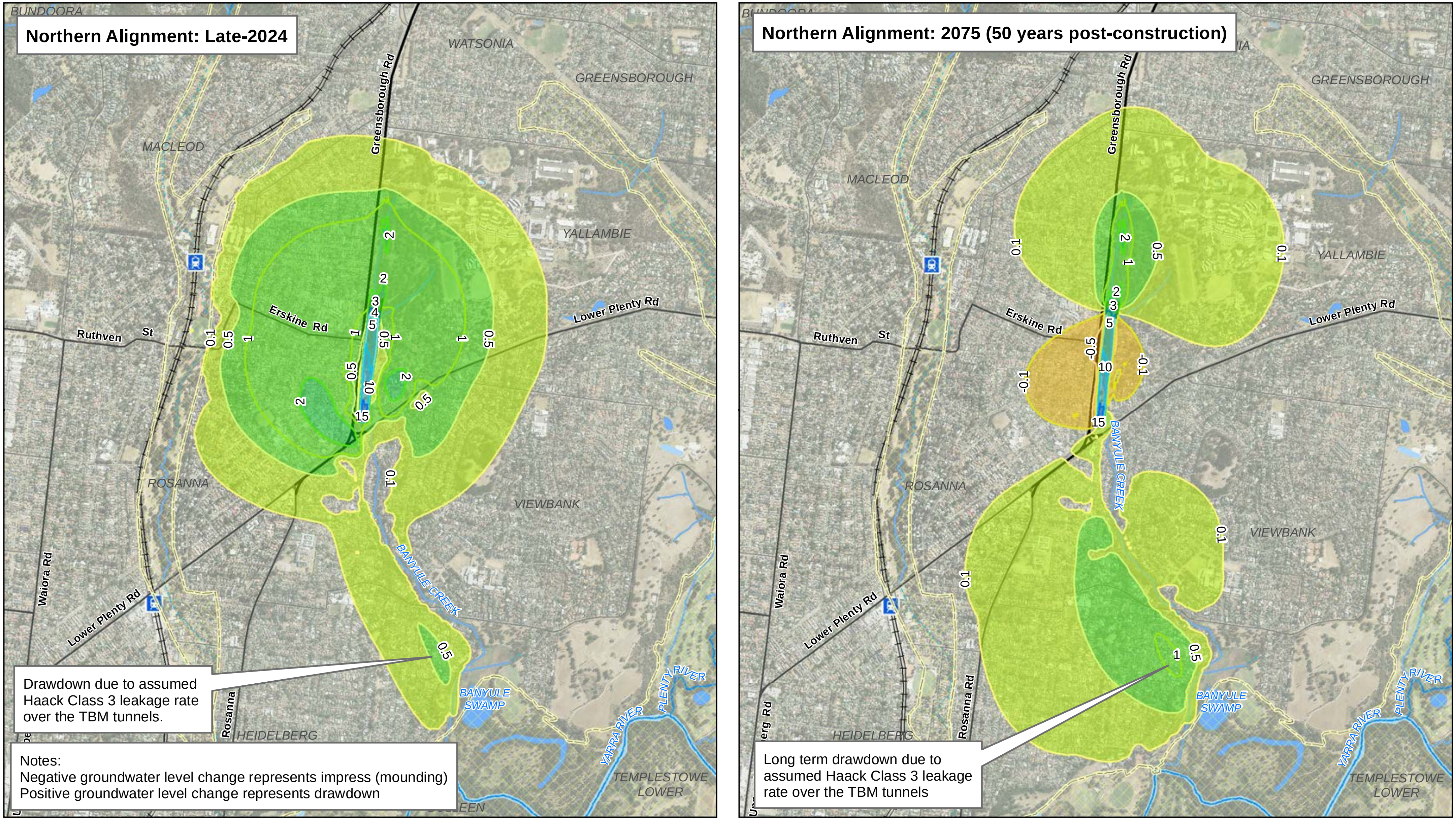
Predicted groundwater level changes (revised) – north (2023 – 2024)

Figure 12

G:\31\35006\GIS\Maps\Working\Operational\Groundwater and Hydrology\Post_EES_DDN\3135006_12_BaseCase_North_2023_2024_Post_EES_RevC.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: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti



Paper Size A4

0 200 400 600 800

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

North East Link Project

Job Number	31-35006
Revision	C
Date	20 Jun 2019

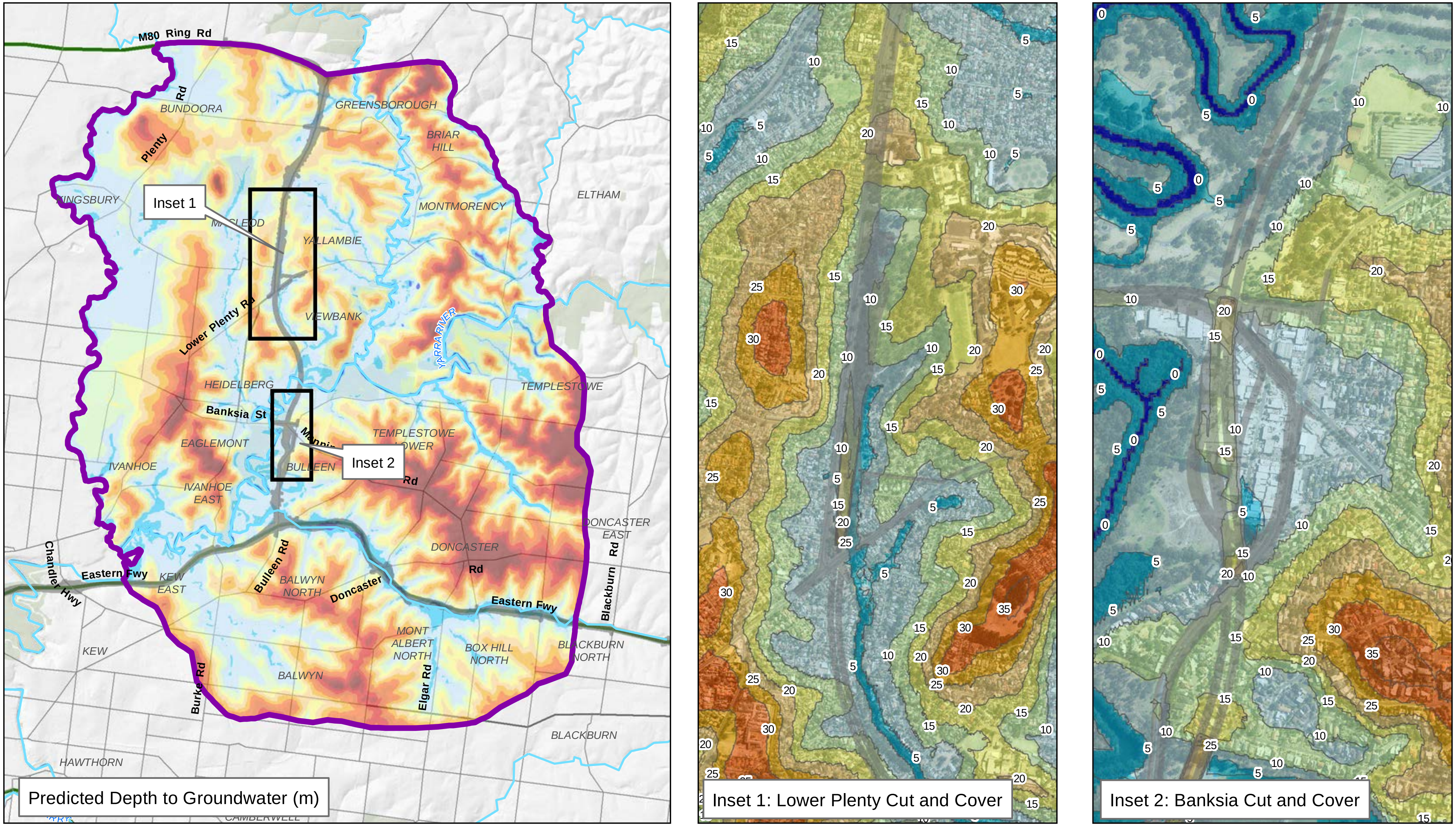
Predicted groundwater level changes (revised) - north (2024, 2075)

Figure 13

G:\31\35006\GIS\Maps\Working\Operational\Groundwater and Hydrology\Post_EES_DDN\3135006_13_BaseCase_North_2024_2075_Post_EES_RevC.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: Aerial, CIP, 2018. BaseMaps, VicMaps, 2018; GW Model Layers, GHD, 2018. Created by:trighetti



Paper Size A4

0 375750 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

Job Number 31-35006
Revision C
Date 20 Jun 2019

Predicted Depth to Groundwater
Post-Construction (revised)

Figure 14

G:\31\35006\GIS\Maps\Working\Operational\Groundwater and Hydrology\Post_EES_DDN\3135006_Predicted_Depth_Groundwater_PostConstruction_A4L_RevC.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, 2018; GW Model Layers, GHD, 2018. Created by:trighetti

3.2.2 Predicted groundwater inflow rates

Figure 15 compares the predicted groundwater inflow rates from the EES model with those from the updated (recalibrated) model. With the exception of temporary spikes in the modelled inflow rates caused by the instantaneous activation of drain cells, the predicted groundwater inflow rates are generally similar. The main difference is seen in the northern portion of the alignment, due to higher recharge applied over the Bedrock (increased from 10 mm/year to 20 mm/year). This results in almost twice as much temporary inflow during construction of the Lower Plenty cut and cover and twice as much long term inflow over the free draining trench. Once the structures are tanked, the long term inflow rates into the fully tanked sections are effectively identical, approximately equal to Haack Class 3 water tightness.

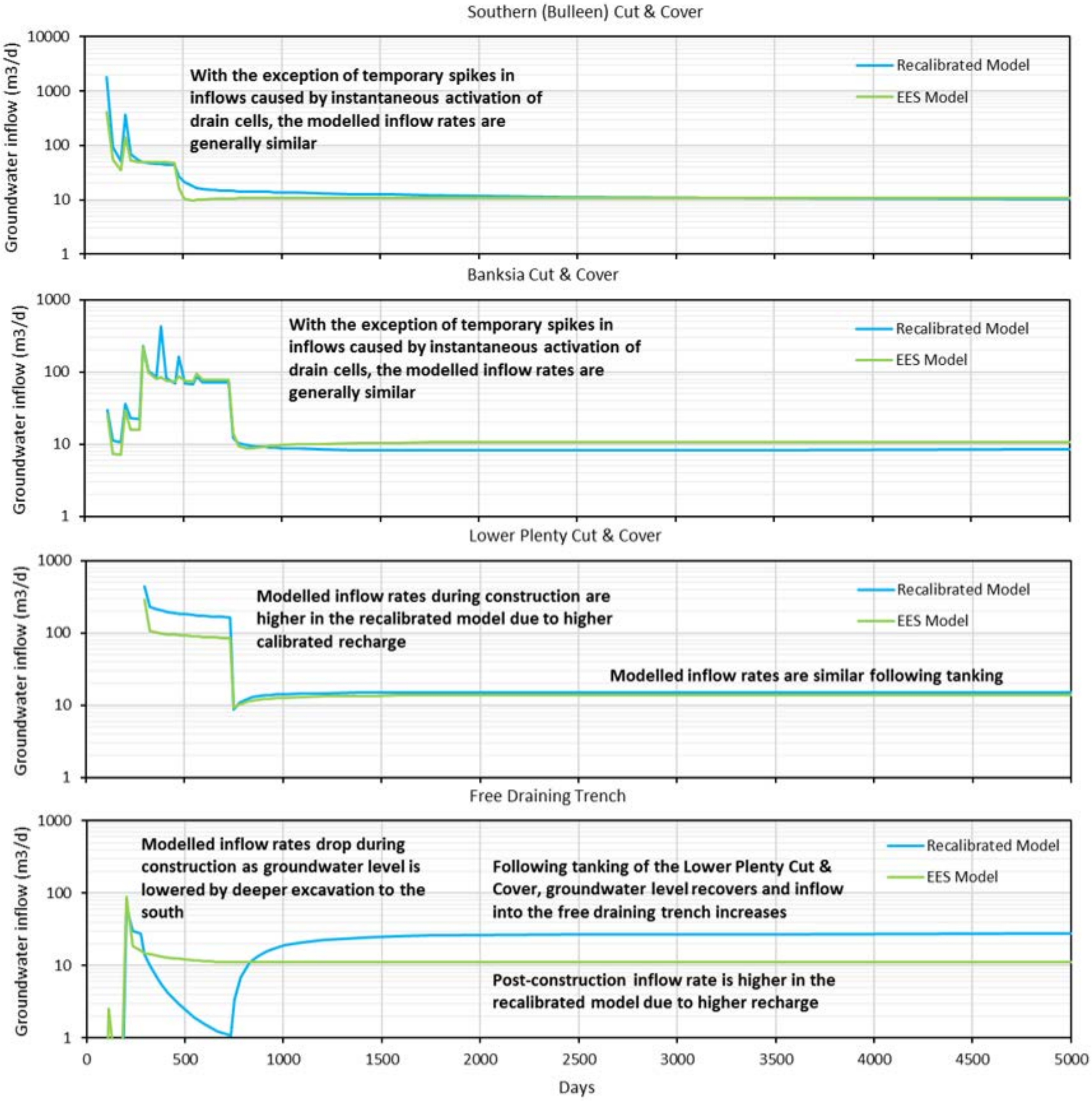


Figure 15 Predicted groundwater inflow rates

3.2.3 Predicted impacts on river fluxes

Figure 16 presents the hydrographs of predicted baseflow changes to the Yarra River. The updated model predicts less than 1 per cent reduction in baseflow due to the project, which is less than up to 5.5 percent reduction predicted with the EES model. The maximum reduction in baseflow is less than 40 m^3/d, which is very small compared to the total flow in the river (more than 360,000 m^3/d for 90 per cent of the time at gauge 229135A).

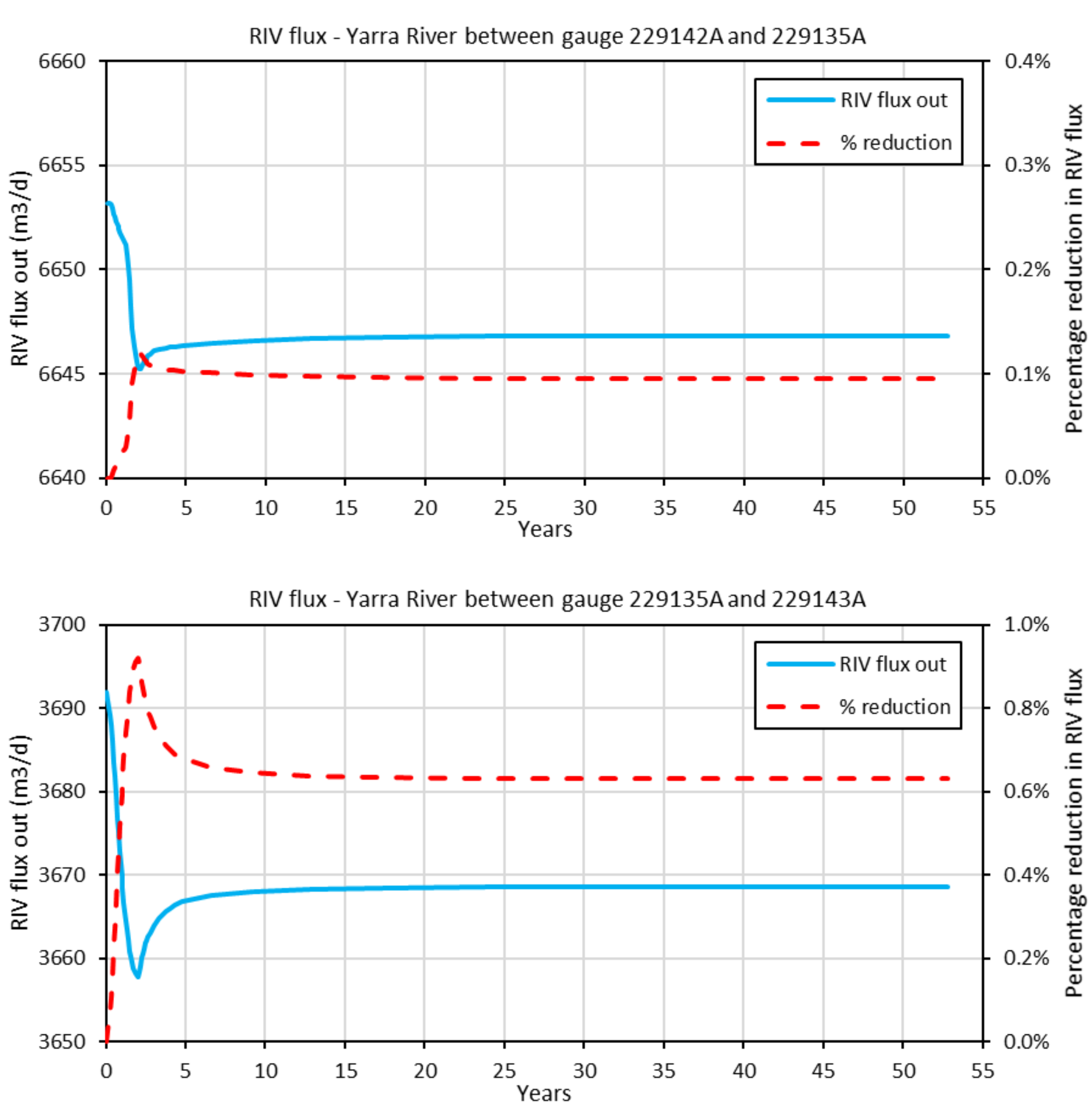


Figure 16 Predicted changes to Yarra River groundwater flux (revised)

Figure 17 presents the predicted changes to groundwater fluxes to the deep pool of Bolin Bolin Billabong. A temporary reduction of up to around 6.3 per cent is simulated during construction, followed by a long term reduction of around 5.2 per cent post-construction. These per cent changes are marginally larger than those of the EES model, partly due to greater drawdown simulated over the mined tunnels to the northeast, although they are still very small (less than 7 per cent). The extent of 0.1 to 0.5 metre drawdown contour is localised at the deep pool and indicates a reduction in groundwater levels at the deep pool to be towards the lower end of this range over the long term.

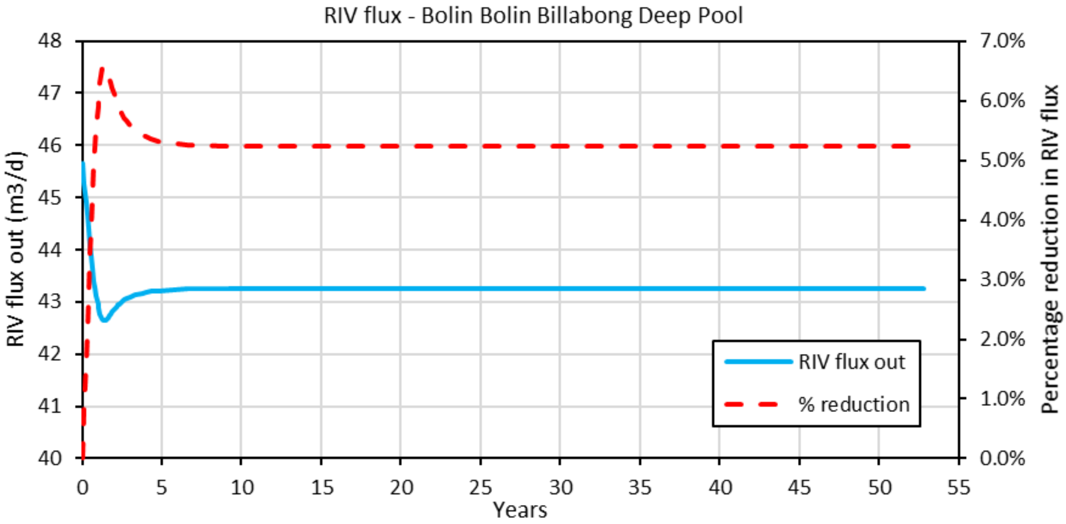


Figure 17 Predicted changes to Bolin Bolin Billabong groundwater fluxes (revised)

4. Conclusion

The numerical groundwater model developed for the EES has been updated using the groundwater level data collected over a period of around 12 months from 116 monitoring bores. The model recalibration focused on matching the modelled groundwater levels to those measured, as well as simulating the temporal trends induced by rainfall-derived recharge, river leakage and pumping. Spatial variability in hydraulic conductivity has been introduced to the Alluvium to better account for the spatial differences in the observed data, using the spatial differences in lithology as the basis for updated parameterisation.

The predictive modelling utilising the recalibrated model parameters produced outputs that are broadly consistent with those presented in the EES. Where notable differences occur, the predictions based on the recalibrated model generally show less (more localised) impacts over the long term e.g. less mounding on the up gradient side of the Banksia cut and cover in the south and less drawdown adjacent to the free draining trench in the north. An exception to this is seen in the predicted baseflow reduction to the deep pool of Bolin Bolin Billabong, which is marginally higher than that predicted by the EES model. However, the predicted reduction in baseflow remains very small (less than 7 per cent) and the extent of 0.1 to 0.5 metre drawdown contour is more localised at the deep pool. The predictions based on the recalibrated groundwater model indicate that the long term reduction in groundwater level at the deep pool is likely to be towards the lower end of the 0.1 to 0.5 metre range.

An important finding of this assessment is that the project related groundwater impacts predicted by the recalibrated groundwater model generally remain within the range of impacts predicted by the EES that formed the basis of the project risk assessment and Environmental Performance Requirements.

5. References

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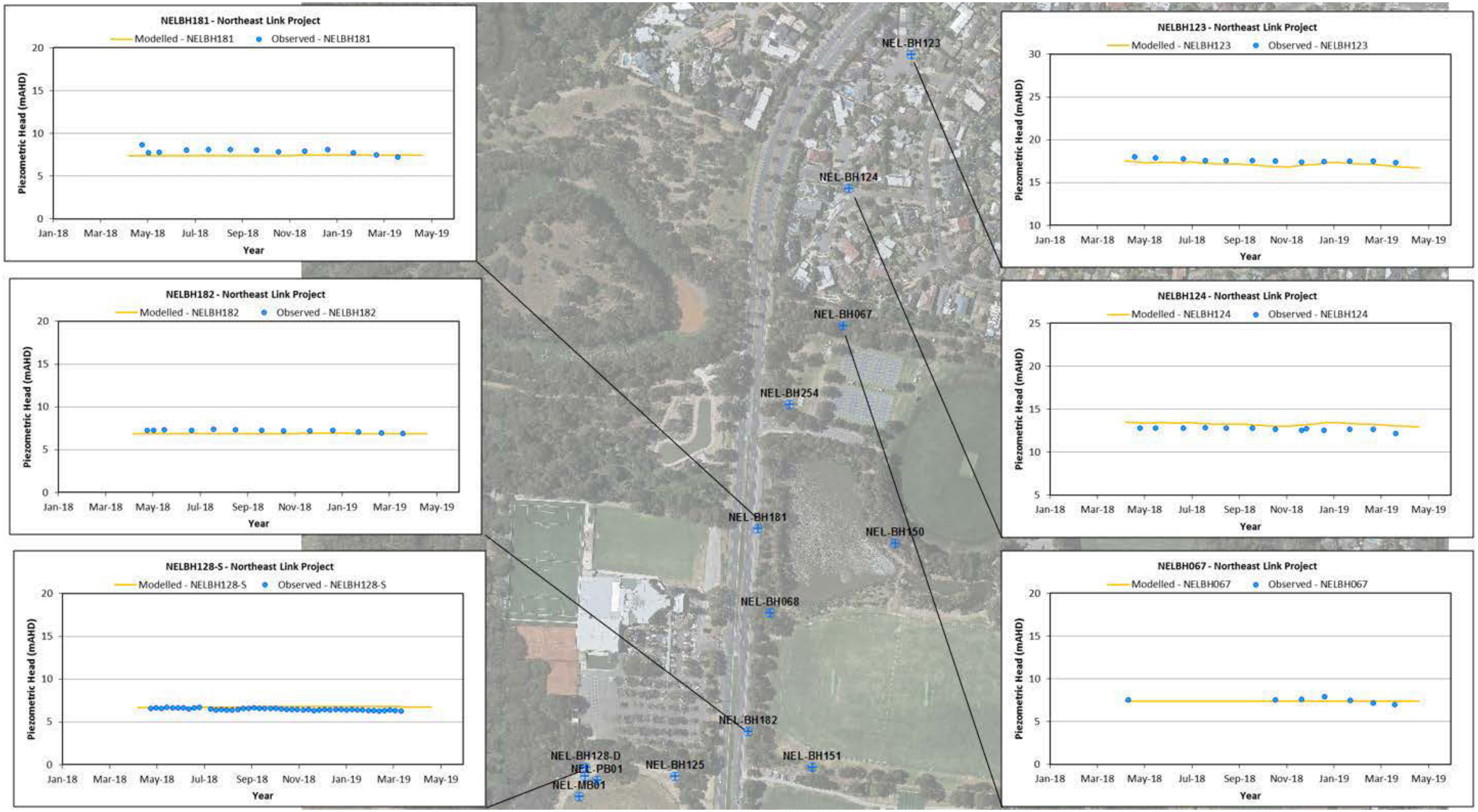
Appendices

Appendix A – Hydrographs and bore location plans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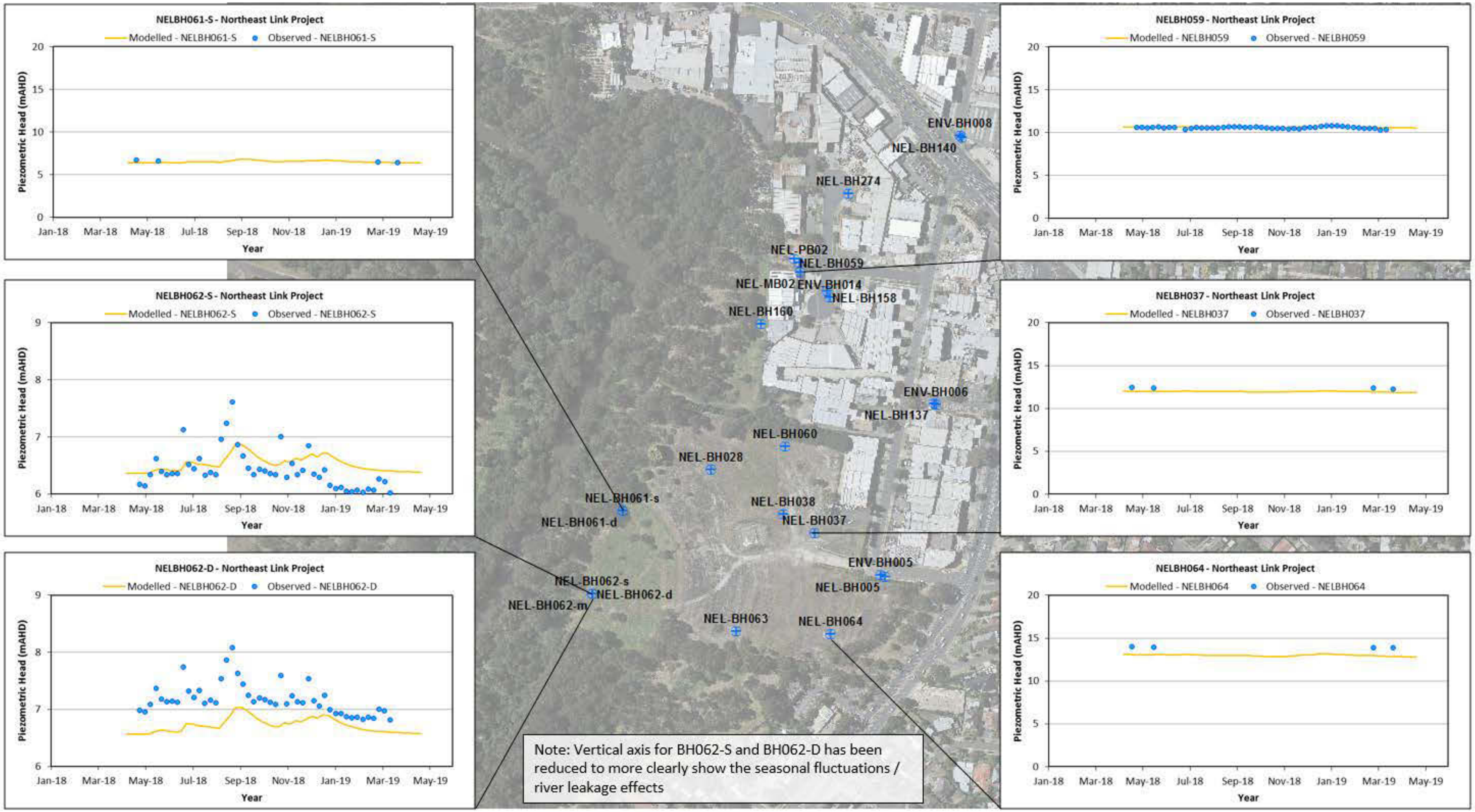
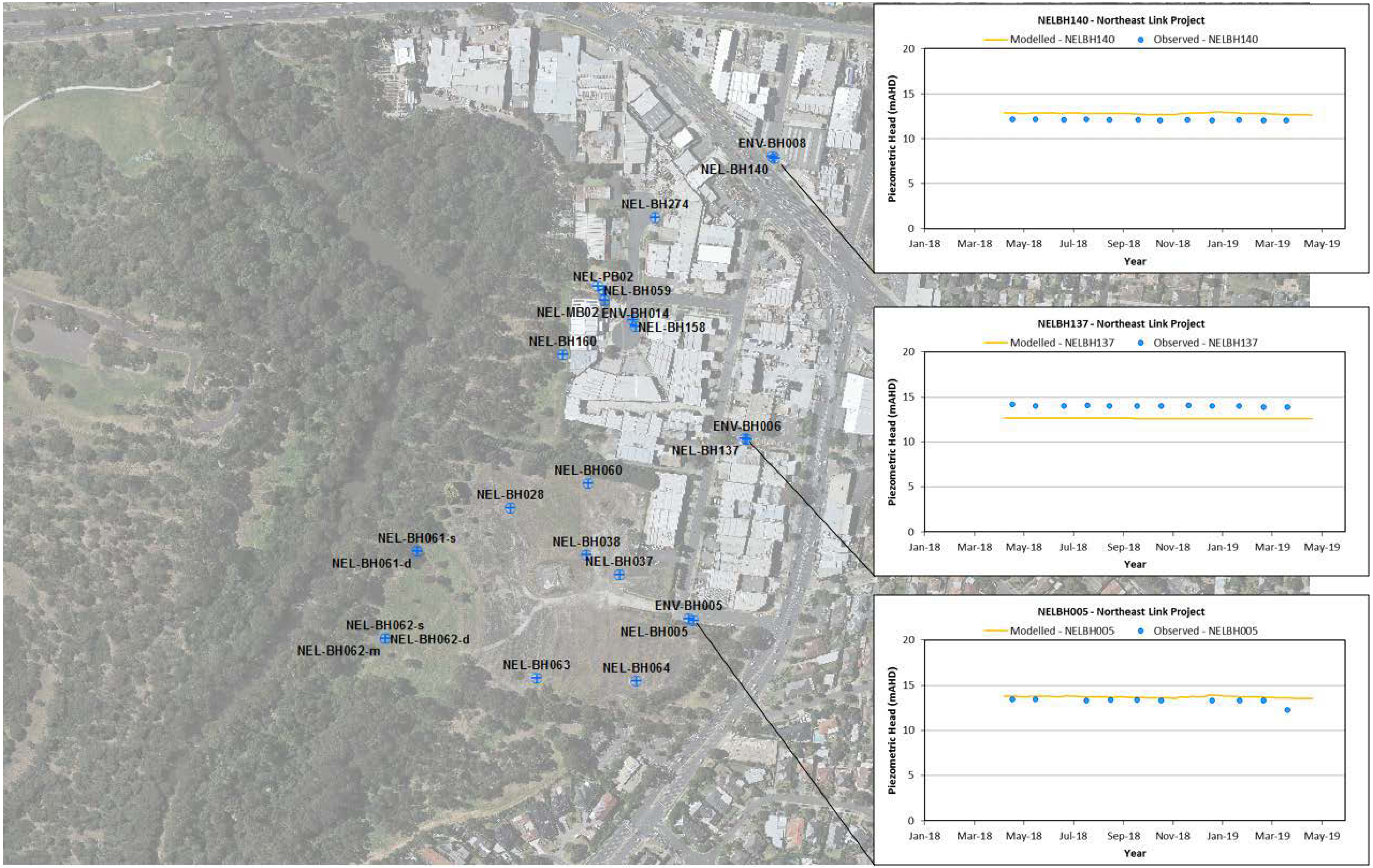
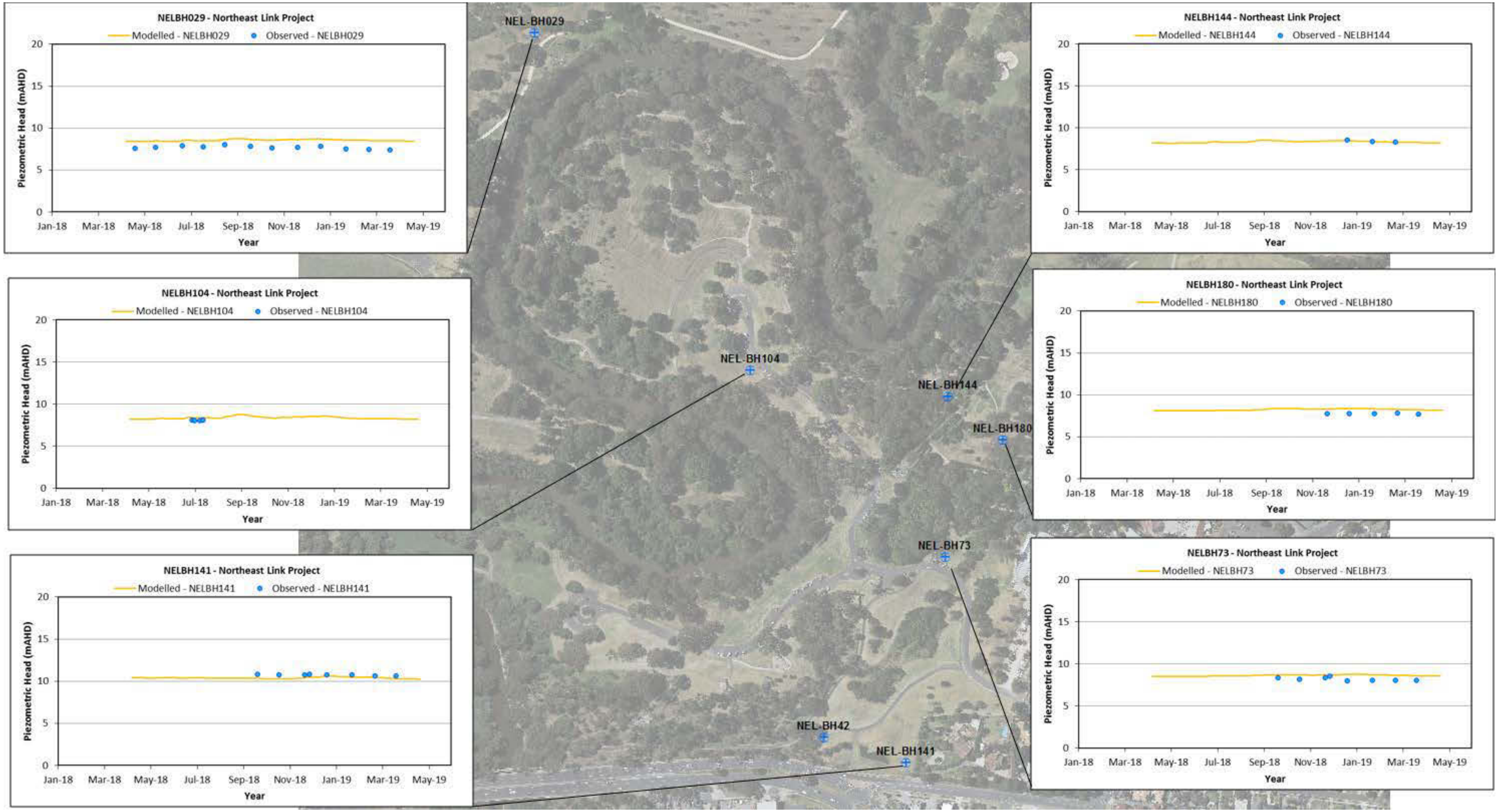
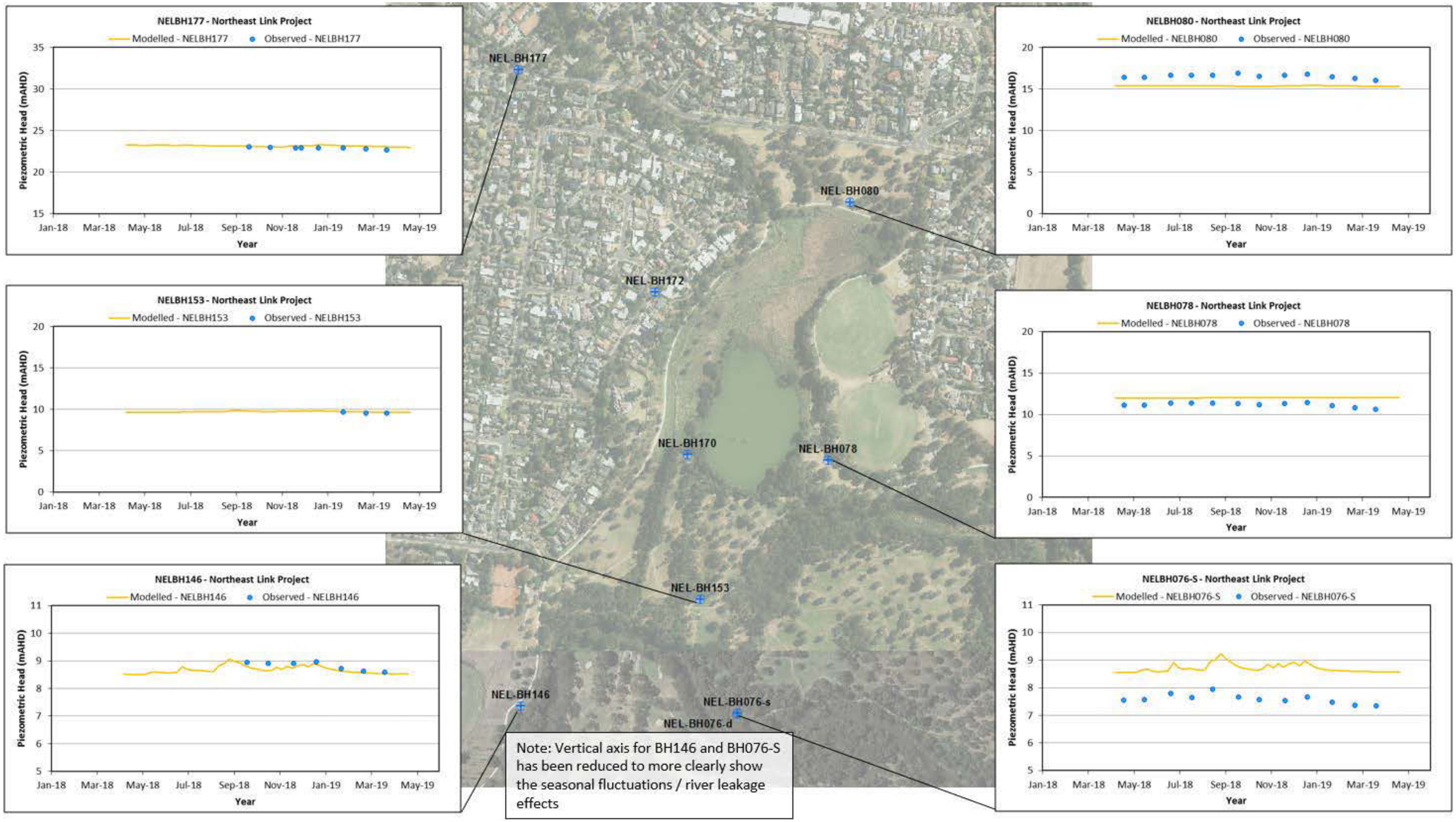
Modelled - NELBH181
Observed - NELBH181
Piezometric Head (mAHD)
Year
NELBH182 - Northeast Link Project
Modelled - NELBH182
Observed - NELBH182
NELBH128-S - Northeast Link Project
Modelled - NELBH128-S
Observed - NELBH128-S
NELBH123 - Northeast Link Project
Modelled - NELBH123
Observed - NELBH123
NELBH124 - Northeast Link Project
Modelled - NELBH124
Observed - NELBH124
NELBH067 - Northeast Link Project
Modelled - NELBH067
Observed - NELBH067
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
NEL-BH123
NEL-BH124
NEL-BH067
NEL-BH254
NEL-BH181
NEL-BH150
NEL-BH068
NEL-BH182
NEL-BH128-D
NEL-PB01
NEL-MB01
NEL-BH125
NEL-BH151

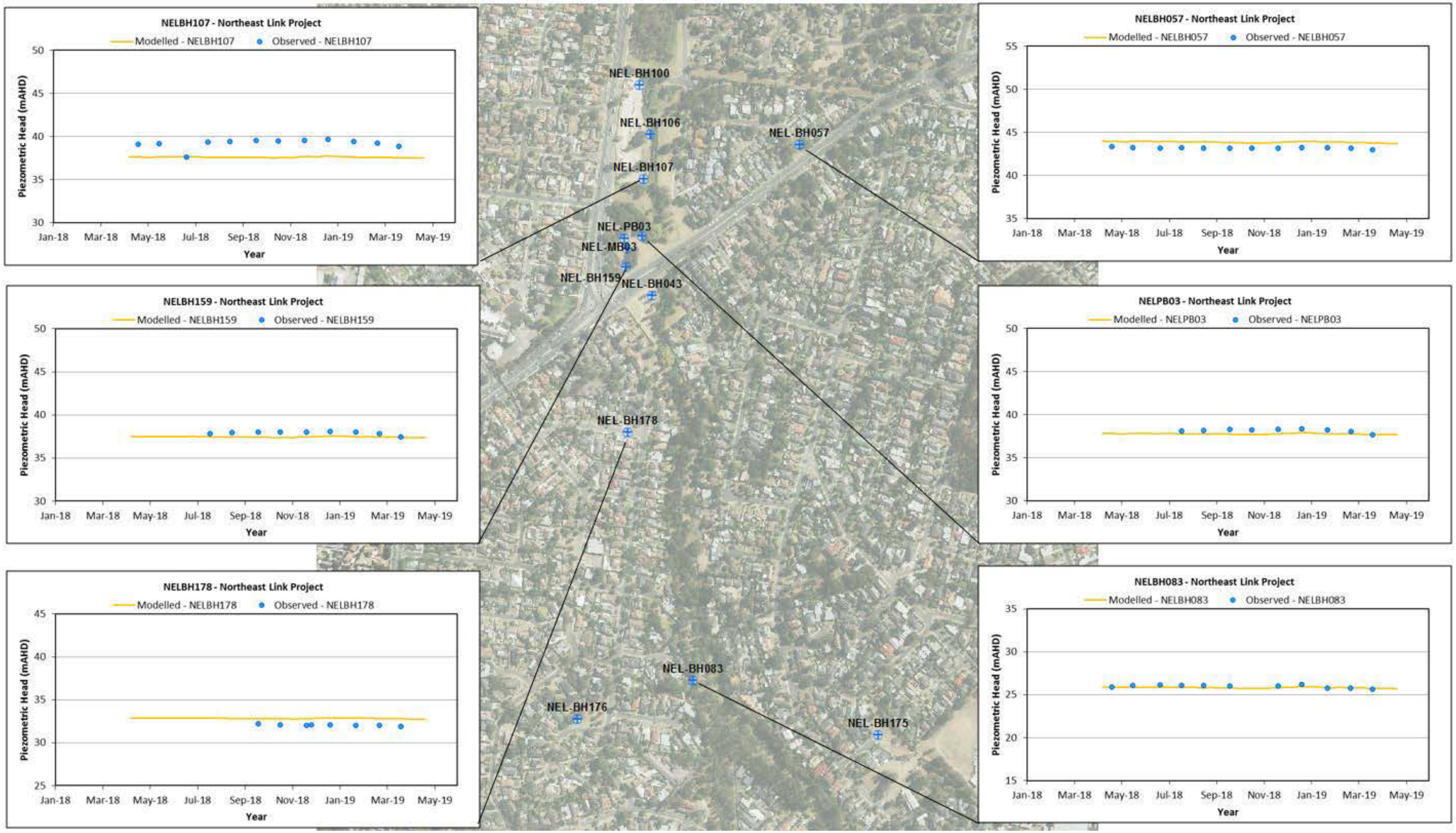

NELBH061-S - Northeast Link Project
Modelled - NELBH061-S
Observed - NELBH061-S
Piezometric Head (mAHD)
Year
NELBH062-S - Northeast Link Project
Modelled - NELBH062-S
Observed - NELBH062-S
NELBH062-D - Northeast Link Project
Modelled - NELBH062-D
Observed - NELBH062-D
NELBH059 - Northeast Link Project
Modelled - NELBH059
Observed - NELBH059
NELBH037 - Northeast Link Project
Modelled - NELBH037
Observed - NELBH037
NELBH064 - Northeast Link Project
Modelled - NELBH064
Observed - NELBH064
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
ENV-BH008
NEL-BH140
NEL-BH274
NEL-PB02
NEL-BH059
NEL-MB02
ENV-BH014
NEL-BH158
NEL-BH160
ENV-BH006
NEL-BH137
NEL-BH060
NEL-BH028
NEL-BH061-s
NEL-BH061-d
NEL-BH038
NEL-BH037
ENV-BH005
NEL-BH005
NEL-BH062-s
NEL-BH062-d
NEL-BH062-m
NEL-BH063
NEL-BH064
Note: Vertical axis for BH062-S and BH062-D has been reduced to more clearly show the seasonal fluctuations / river leakage effects

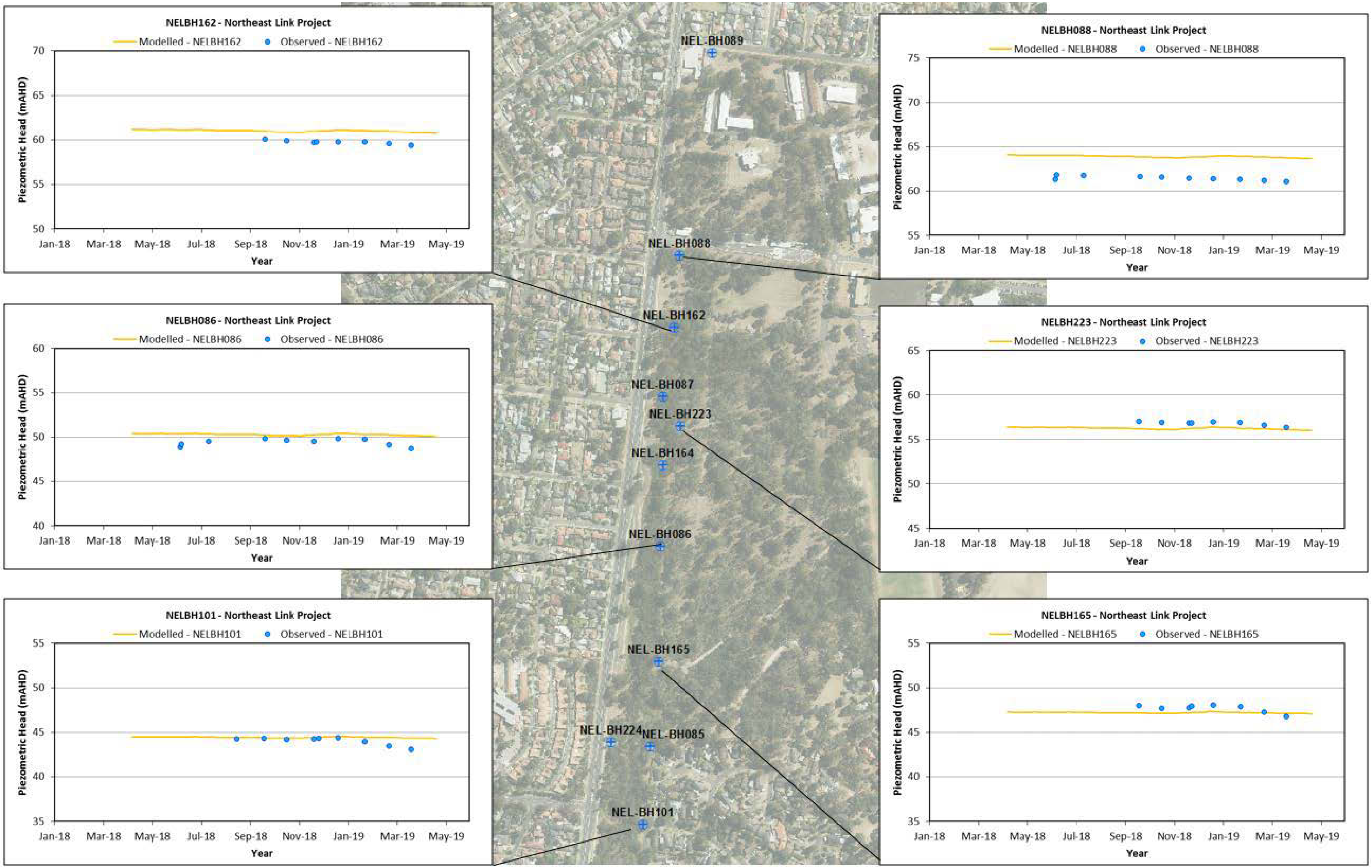


ENV-BH008
NEL-BH140
NEL-BH274
NEL-PB02
NEL-BH059
NEL-MB02
ENV-BH014
NEL-BH158
NEL-BH160
ENV-BH006
NEL-BH137
NEL-BH060
NEL-BH028
NEL-BH061-s
NEL-BH061-d
NEL-BH038
NEL-BH037
ENV-BH005
NEL-BH005
NEL-BH062-s
NEL-BH062-d
NEL-BH062-m
NEL-BH063
NEL-BH064
NELBH140 - Northeast Link Project
Modelled - NELBH140
Observed - NELBH140
NELBH137 - Northeast Link Project
Modelled - NELBH137
Observed - NELBH137
NELBH005 - Northeast Link Project
Modelled - NELBH005
Observed - NELBH005
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Year

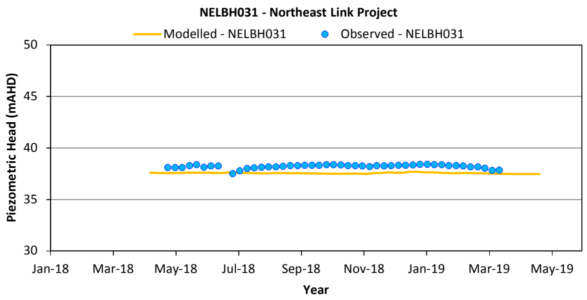
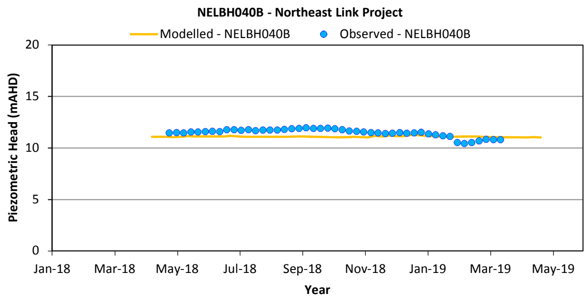
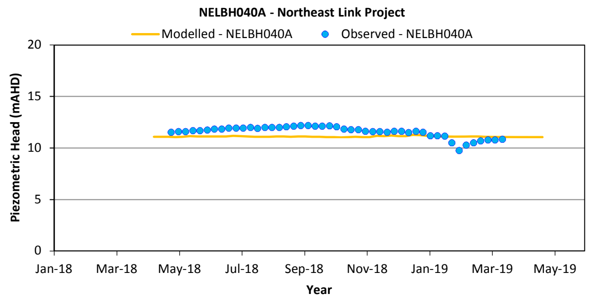

NELBH029 - Northeast Link Project
Modelled - NELBH029
Observed - NELBH029
Piezometric Head (mAHD)
Year
NELBH104 - Northeast Link Project
Modelled - NELBH104
Observed - NELBH104
NELBH141 - Northeast Link Project
Modelled - NELBH141
Observed - NELBH141
NELBH144 - Northeast Link Project
Modelled - NELBH144
Observed - NELBH144
NELBH180 - Northeast Link Project
Modelled - NELBH180
Observed - NELBH180
NELBH73 - Northeast Link Project
Modelled - NELBH73
Observed - NELBH73
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
NEL-BH029
NEL-BH104
NEL-BH144
NEL-BH180
NEL-BH73
NEL-BH42
NEL-BH141


NELBH177 - Northeast Link Project
Modelled - NELBH177
Observed - NELBH177
Piezometric Head (mAHD)
Year
NELBH153 - Northeast Link Project
Modelled - NELBH153
Observed - NELBH153
NELBH146 - Northeast Link Project
Modelled - NELBH146
Observed - NELBH146
NELBH080 - Northeast Link Project
Modelled - NELBH080
Observed - NELBH080
NELBH078 - Northeast Link Project
Modelled - NELBH078
Observed - NELBH078
NELBH076-S - Northeast Link Project
Modelled - NELBH076-S
Observed - NELBH076-S
NEL-BH177
NEL-BH080
NEL-BH172
NEL-BH170
NEL-BH078
NEL-BH153
NEL-BH146
NEL-BH076-s
NEL-BH076-d
Note: Vertical axis for BH146 and BH076-S has been reduced to more clearly show the seasonal fluctuations / river leakage effects


NELBH107 - Northeast Link Project
Modelled - NELBH107
Observed - NELBH107
NELBH159 - Northeast Link Project
Modelled - NELBH159
Observed - NELBH159
NELBH178 - Northeast Link Project
Modelled - NELBH178
Observed - NELBH178
NELBH057 - Northeast Link Project
Modelled - NELBH057
Observed - NELBH057
NELPB03 - Northeast Link Project
Modelled - NELPB03
Observed - NELPB03
NELBH083 - Northeast Link Project
Modelled - NELBH083
Observed - NELBH083
Piezometric Head (mAHD)
Year
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
NEL-BH100
NEL-BH106
NEL-BH107
NEL-BH057
NEL-PB03
NEL-MB03
NEL-BH159
NEL-BH043
NEL-BH178
NEL-BH083
NEL-BH176
NEL-BH175


NELBH162 - Northeast Link Project
Modelled - NELBH162
Observed - NELBH162
Piezometric Head (mAHD)
Year
NELBH088 - Northeast Link Project
Modelled - NELBH088
Observed - NELBH088
NELBH086 - Northeast Link Project
Modelled - NELBH086
Observed - NELBH086
NELBH223 - Northeast Link Project
Modelled - NELBH223
Observed - NELBH223
NELBH101 - Northeast Link Project
Modelled - NELBH101
Observed - NELBH101
NELBH165 - Northeast Link Project
Modelled - NELBH165
Observed - NELBH165
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
NEL-BH089
NEL-BH088
NEL-BH162
NEL-BH087
NEL-BH223
NEL-BH164
NEL-BH086
NEL-BH165
NEL-BH224
NEL-BH085
NEL-BH101

Appendix B – All hydrographs


NELBH031 - Northeast Link Project
Modelled - NELBH031
Observed - NELBH031
Piezometric Head (mAHD)
50
45
40
35
30
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

NELBH040B - Northeast Link Project
Modelled - NELBH040B
Observed - NELBH040B
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

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Modelled - NELBH040A
Observed - NELBH040A
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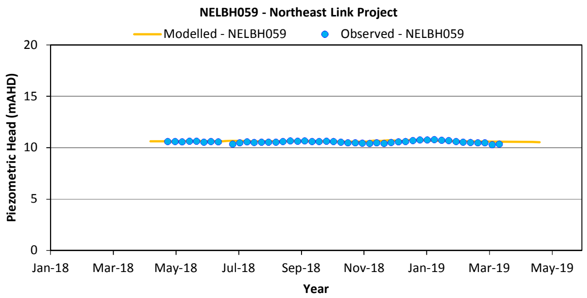
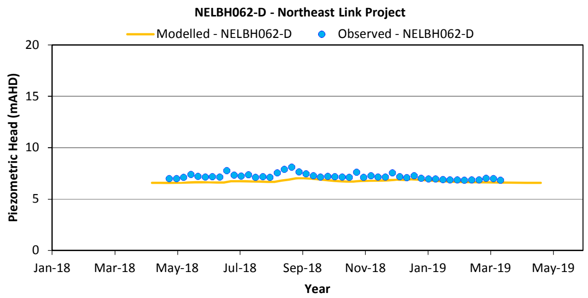
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

NELBH059 - Northeast Link Project
Modelled - NELBH059
Observed - NELBH059
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

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Modelled - NELBH062-D
Observed - NELBH062-D
Piezometric Head (mAHD)
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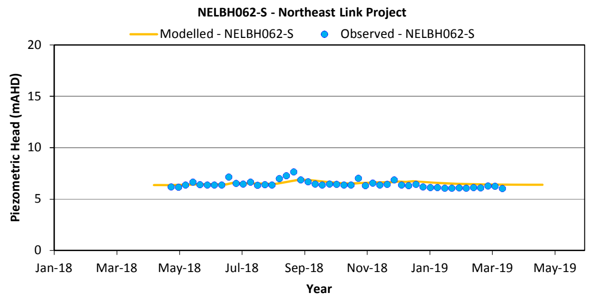
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

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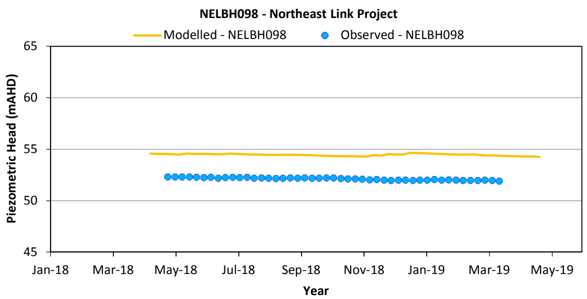
Modelled - NELBH062-S
Observed - NELBH062-S
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

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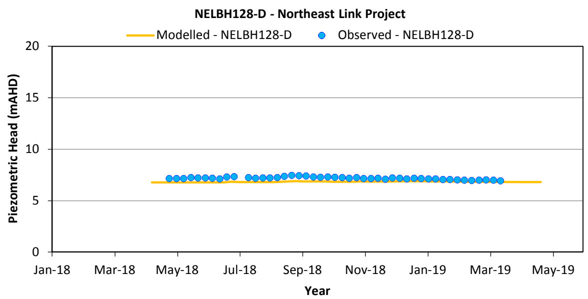
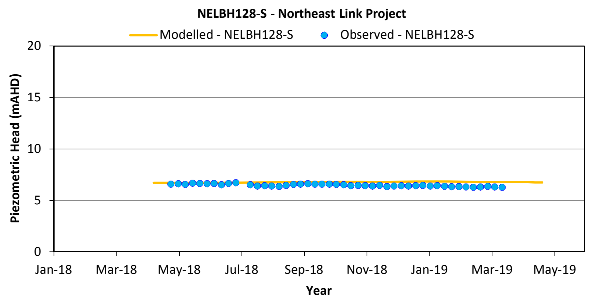
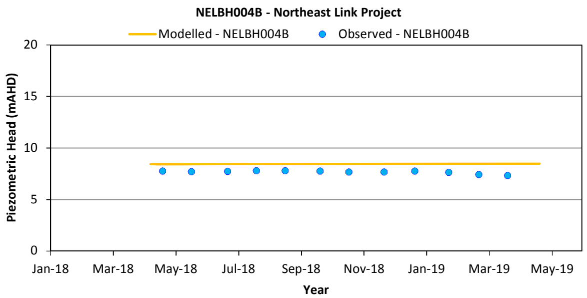
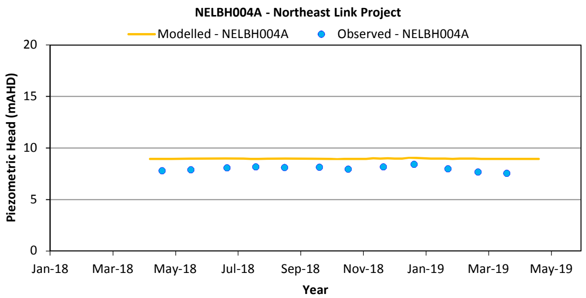
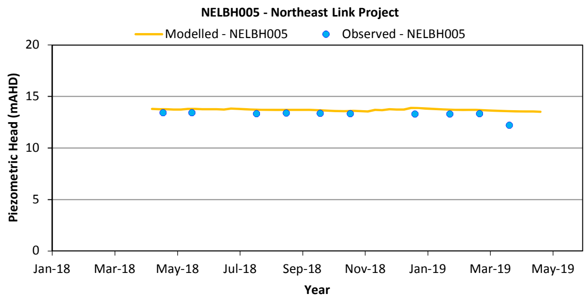
Modelled - NELBH098
Observed - NELBH098
Piezometric Head (mAHD)
65
60
55
50
45
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

NELBH128-D - Northeast Link Project
Modelled - NELBH128-D
Observed - NELBH128-D
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

NELBH128-S - Northeast Link Project
Modelled - NELBH128-S
Observed - NELBH128-S
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH004B - Northeast Link Project
Modelled - NELBH004B
Observed - NELBH004B
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Year


NELBH004A - Northeast Link Project
Modelled - NELBH004A
Observed - NELBH004A
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Year


NELBH005 - Northeast Link Project
Modelled - NELBH005
Observed - NELBH005
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
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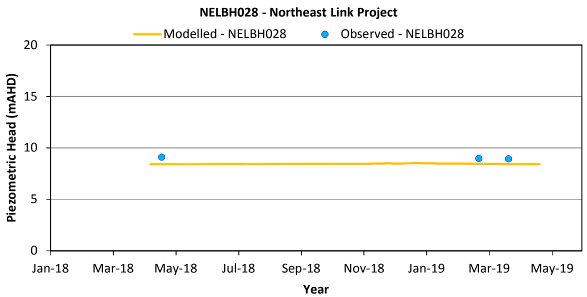
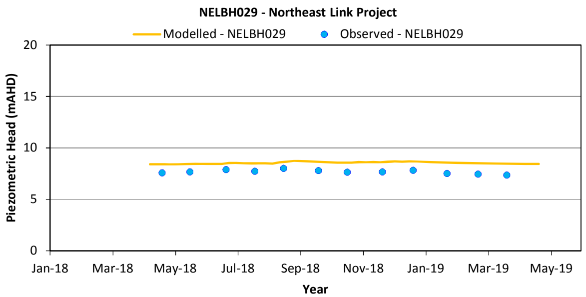
Nov-18
Jan-19
Mar-19
May-19
Year


NELBH028 - Northeast Link Project
Modelled - NELBH028
Observed - NELBH028
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Year


NELBH029 - Northeast Link Project
Modelled - NELBH029
Observed - NELBH029
Piezometric Head (mAHD)
0
5
10
15
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Jan-18
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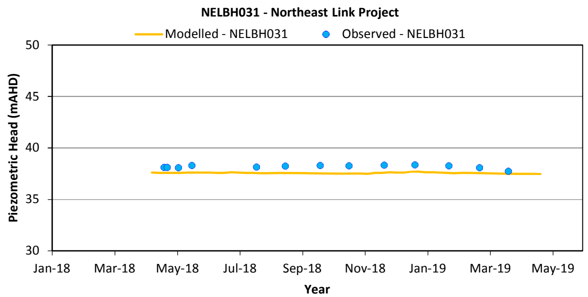
Mar-19
May-19
Year


NELBH031 - Northeast Link Project
Modelled - NELBH031
Observed - NELBH031
Piezometric Head (mAHD)
30
35
40
45
50
Jan-18
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Nov-18
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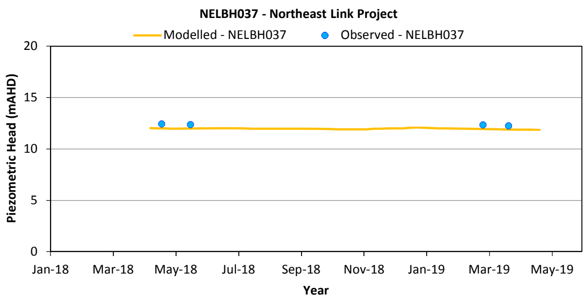
Mar-19
May-19
Year


NELBH037 - Northeast Link Project
Modelled - NELBH037
Observed - NELBH037
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
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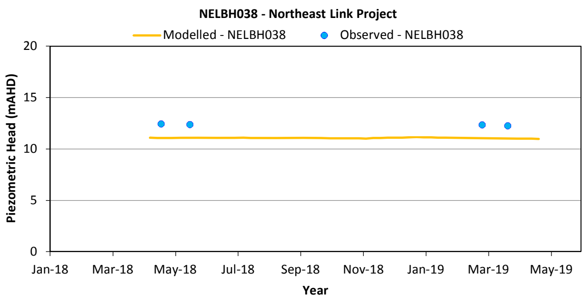
Mar-19
May-19
Year


NELBH038 - Northeast Link Project
Modelled - NELBH038
Observed - NELBH038
Piezometric Head (mAHD)
0
5
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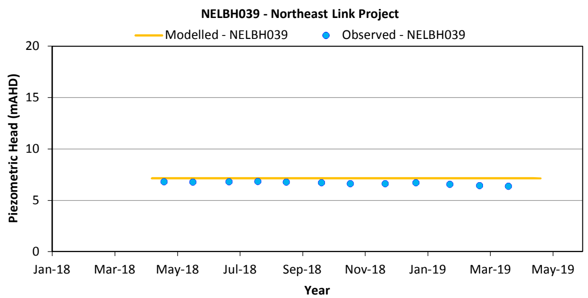
Mar-19
May-19
Year


NELBH039 - Northeast Link Project
Modelled - NELBH039
Observed - NELBH039
Piezometric Head (mAHD)
0
5
10
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Jan-18
Mar-18
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Jul-18
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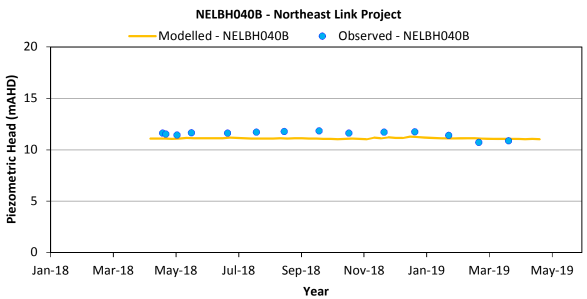
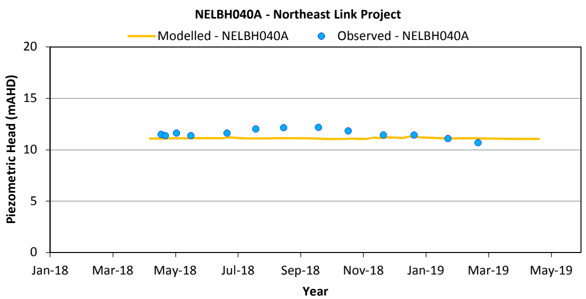
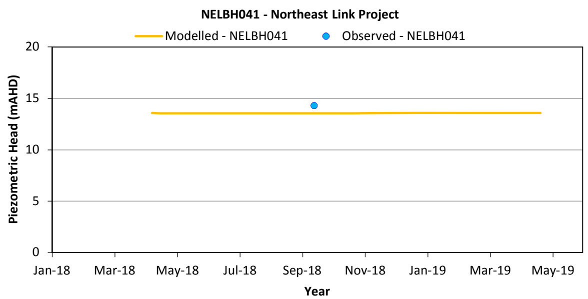
Mar-19
May-19
Year


NELBH040B - Northeast Link Project
Modelled - NELBH040B
Observed - NELBH040B
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Year


NELBH040A - Northeast Link Project
Modelled - NELBH040A
Observed - NELBH040A
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19
Year


NELBH041 - Northeast Link Project
Modelled - NELBH041
Observed - NELBH041
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18
Mar-18
May-18
Jul-18
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Nov-18
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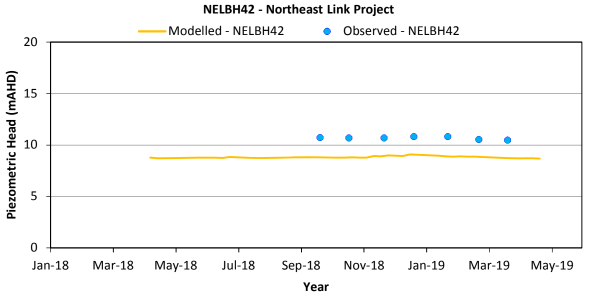
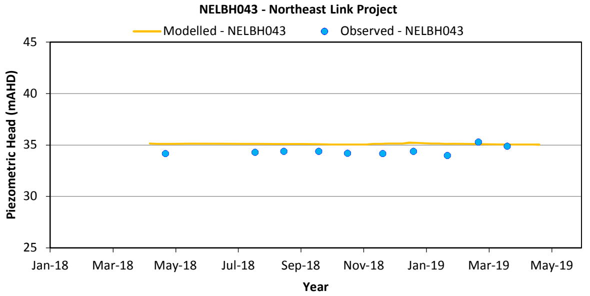
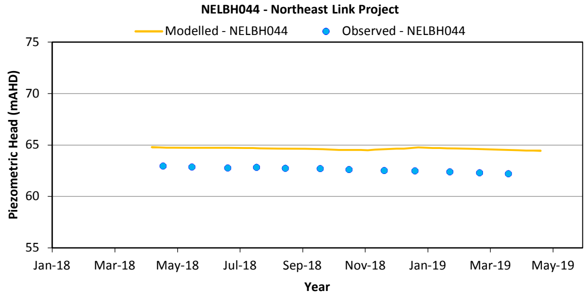
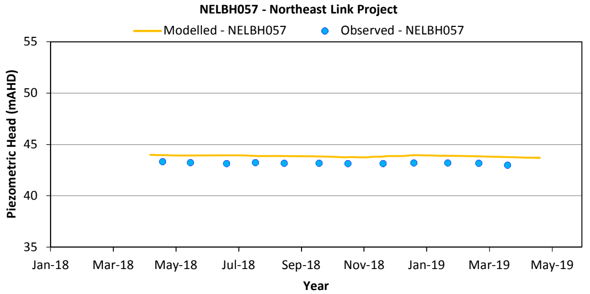
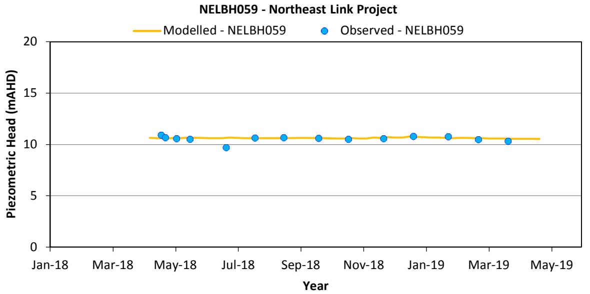
Mar-19
May-19
Year

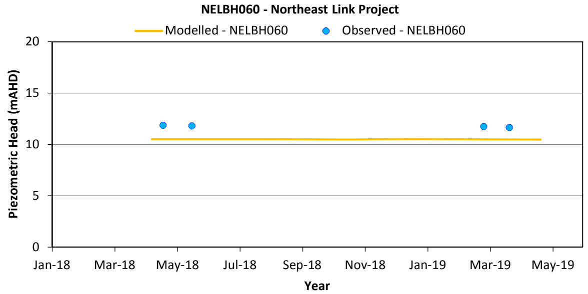

NELBH42 - Northeast Link Project
Modelled - NELBH42
Observed - NELBH42
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

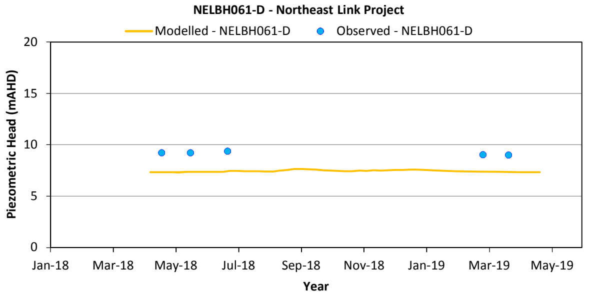

NELBH043 - Northeast Link Project
Modelled - NELBH043
Observed - NELBH043
Piezometric Head (mAHD)
25
30
35
40
45
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

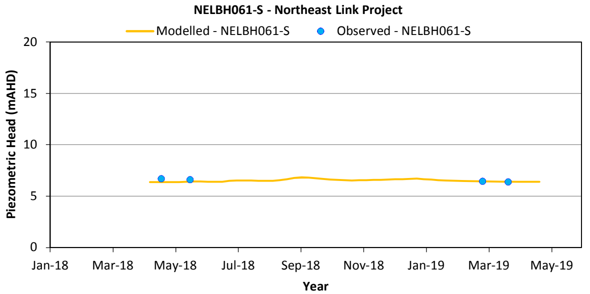

NELBH044 - Northeast Link Project
Modelled - NELBH044
Observed - NELBH044
Piezometric Head (mAHD)
55
60
65
70
75
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

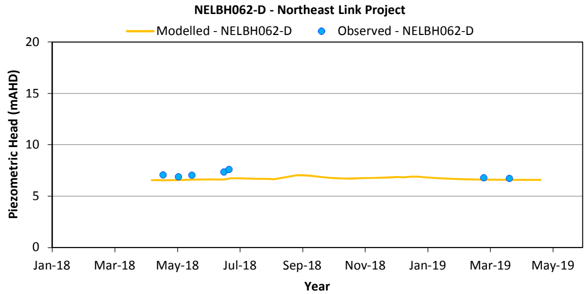

NELBH057 - Northeast Link Project
Modelled - NELBH057
Observed - NELBH057
Piezometric Head (mAHD)
35
40
45
50
55
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

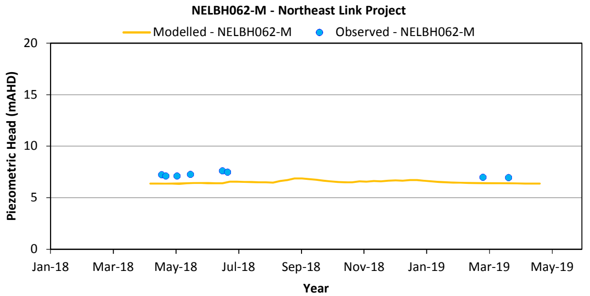

NELBH059 - Northeast Link Project
Modelled - NELBH059
Observed - NELBH059
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

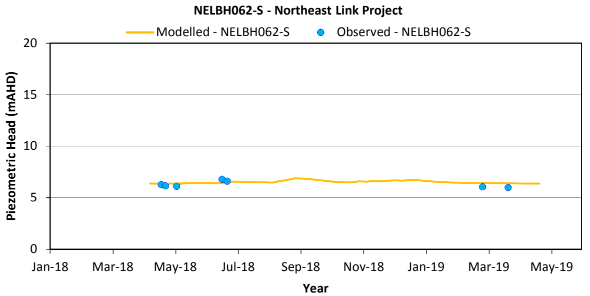

NELBH060 - Northeast Link Project
Modelled - NELBH060
Observed - NELBH060
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

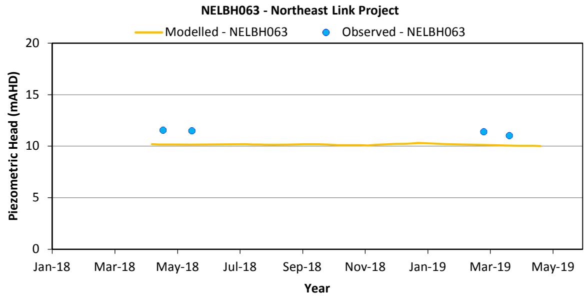

NELBH061-D - Northeast Link Project
Modelled - NELBH061-D
Observed - NELBH061-D
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

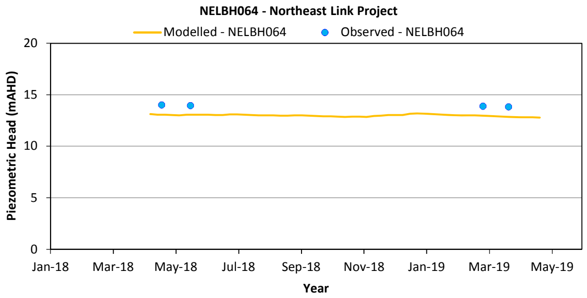

NELBH061-S - Northeast Link Project
Modelled - NELBH061-S
Observed - NELBH061-S
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

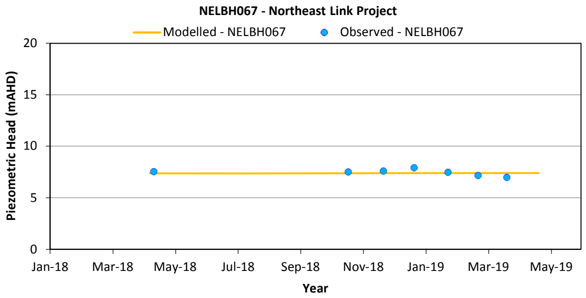

NELBH062-D - Northeast Link Project
Modelled - NELBH062-D
Observed - NELBH062-D
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH062-M - Northeast Link Project
Modelled - NELBH062-M
Observed - NELBH062-M
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH062-S - Northeast Link Project
Modelled - NELBH062-S
Observed - NELBH062-S
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH063 - Northeast Link Project
Modelled - NELBH063
Observed - NELBH063
Piezometric Head (mAHD)
0
5
10
15
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH064 - Northeast Link Project
Modelled - NELBH064
Observed - NELBH064
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH067 - Northeast Link Project
Modelled - NELBH067
Observed - NELBH067
Piezometric Head (mAHD)
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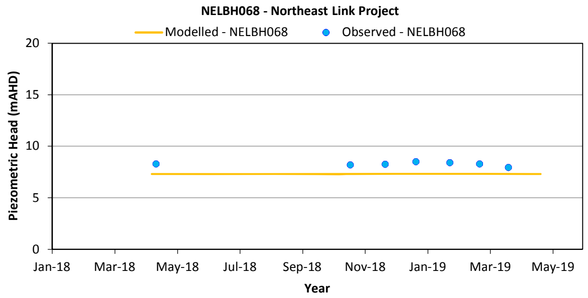
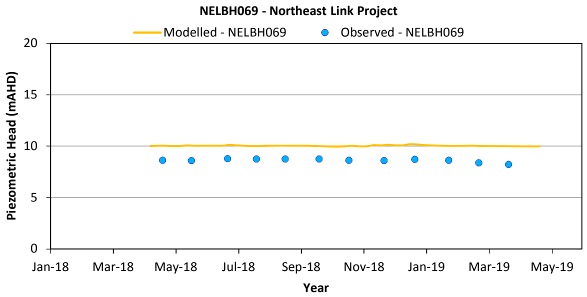
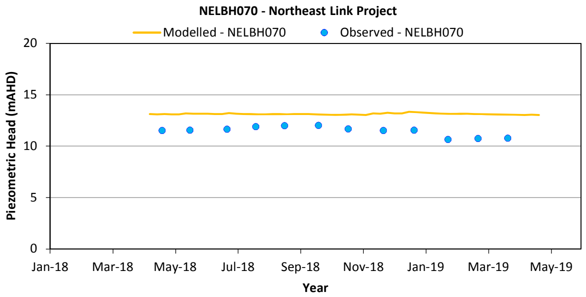
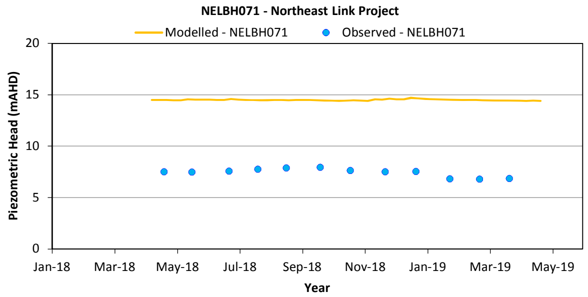
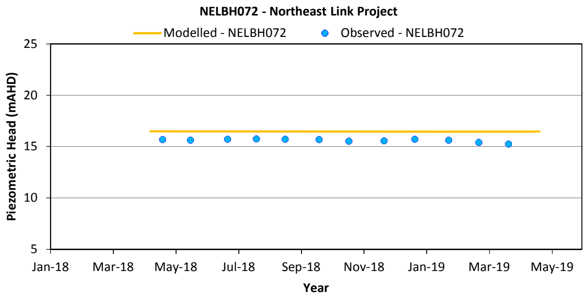
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

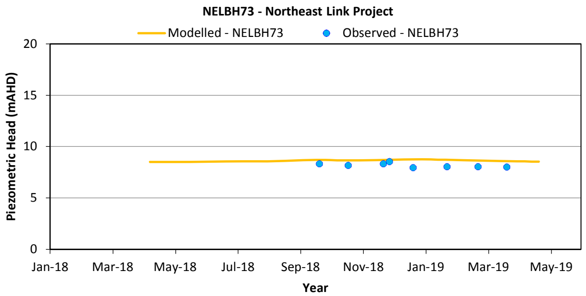

NELBH068 - Northeast Link Project
Modelled - NELBH068
Observed - NELBH068
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

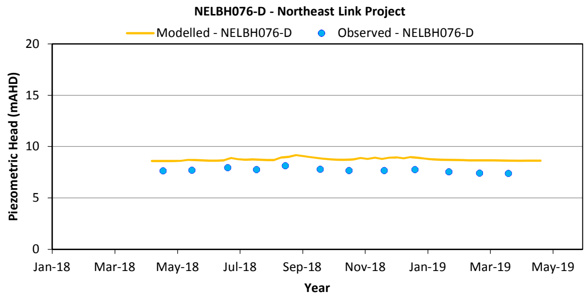

NELBH069 - Northeast Link Project
Modelled - NELBH069
Observed - NELBH069
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

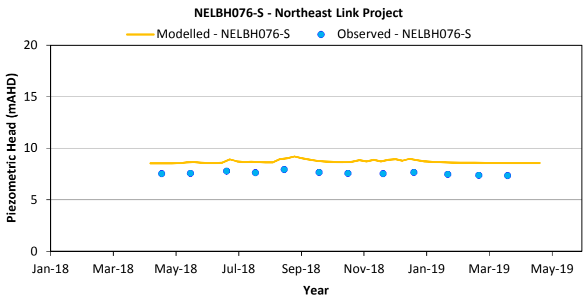

NELBH070 - Northeast Link Project
Modelled - NELBH070
Observed - NELBH070
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

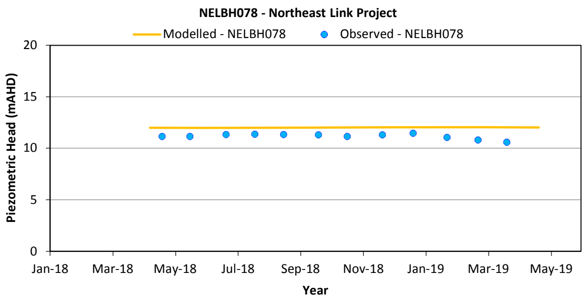

NELBH071 - Northeast Link Project
Modelled - NELBH071
Observed - NELBH071
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

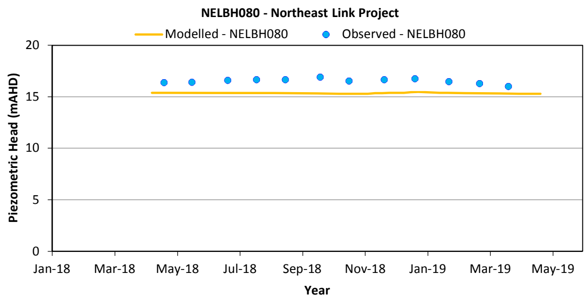

NELBH072 - Northeast Link Project
Modelled - NELBH072
Observed - NELBH072
Piezometric Head (mAHD)
5 10 15 20 25
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

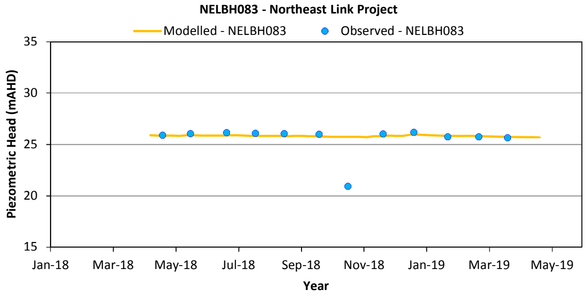

NELBH73 - Northeast Link Project
Modelled - NELBH73
Observed - NELBH73
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

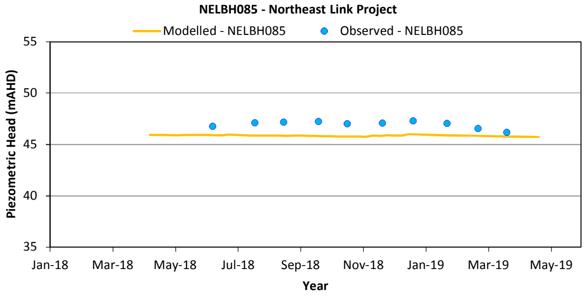

NELBH076-D - Northeast Link Project
Modelled - NELBH076-D
Observed - NELBH076-D
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

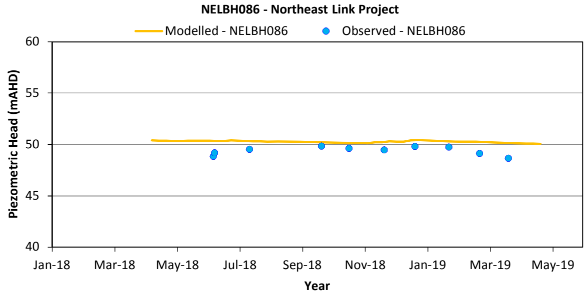

NELBH076-S - Northeast Link Project
Modelled - NELBH076-S
Observed - NELBH076-S
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

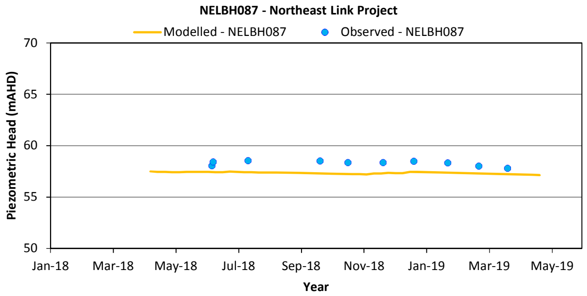

NELBH078 - Northeast Link Project
Modelled - NELBH078
Observed - NELBH078
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

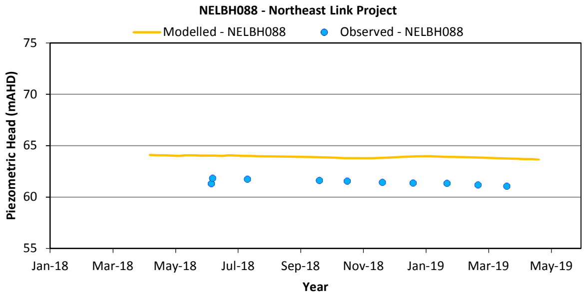

NELBH080 - Northeast Link Project
Modelled - NELBH080
Observed - NELBH080
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

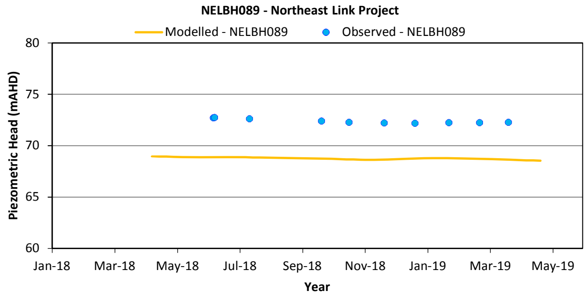

NELBH083 - Northeast Link Project
Modelled - NELBH083
Observed - NELBH083
Piezometric Head (mAHD)
35
30
25
20
15
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

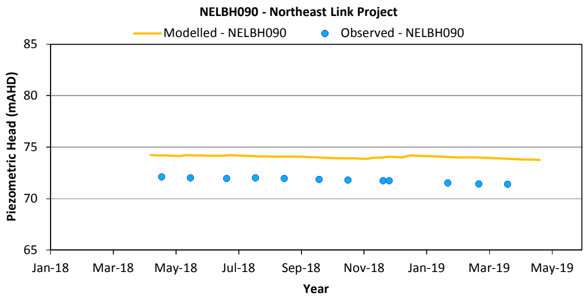

NELBH085 - Northeast Link Project
Modelled - NELBH085
Observed - NELBH085
Piezometric Head (mAHD)
55
50
45
40
35
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

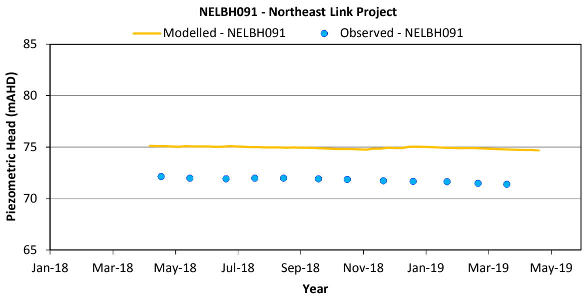

NELBH086 - Northeast Link Project
Modelled - NELBH086
Observed - NELBH086
Piezometric Head (mAHD)
60
55
50
45
40
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

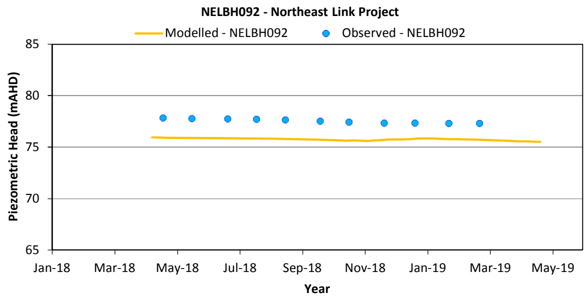

NELBH087 - Northeast Link Project
Modelled - NELBH087
Observed - NELBH087
Piezometric Head (mAHD)
70
65
60
55
50
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

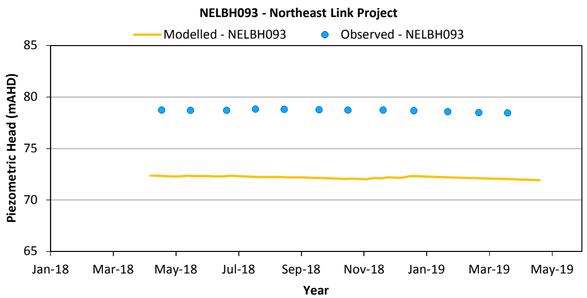

NELBH088 - Northeast Link Project
Modelled - NELBH088
Observed - NELBH088
Piezometric Head (mAHD)
75
70
65
60
55
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

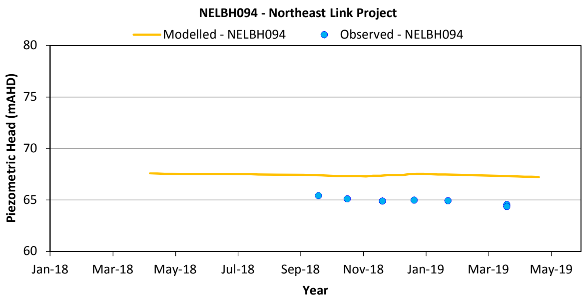

NELBH089 - Northeast Link Project
Modelled - NELBH089
Observed - NELBH089
Piezometric Head (mAHD)
80
75
70
65
60
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

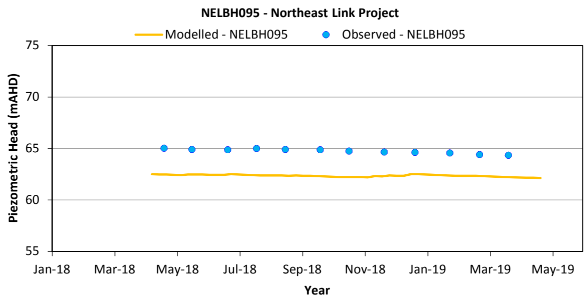

NELBH090 - Northeast Link Project
Modelled - NELBH090
Observed - NELBH090
Piezometric Head (mAHD)
85
80
75
70
65
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

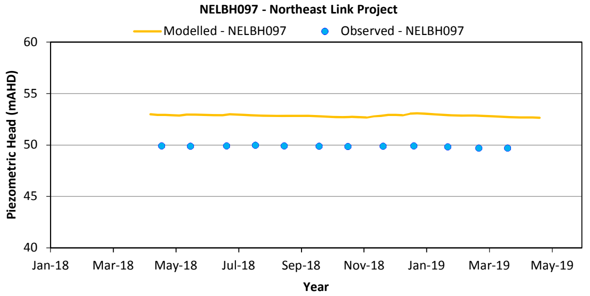

NELBH091 - Northeast Link Project
Modelled - NELBH091
Observed - NELBH091
Piezometric Head (mAHD)
85
80
75
70
65
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

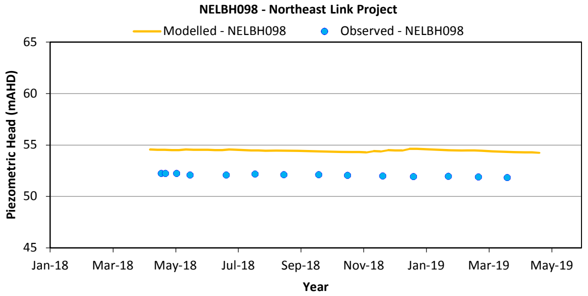

NELBH092 - Northeast Link Project
Modelled - NELBH092
Observed - NELBH092
Piezometric Head (mAHD)
85
80
75
70
65
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

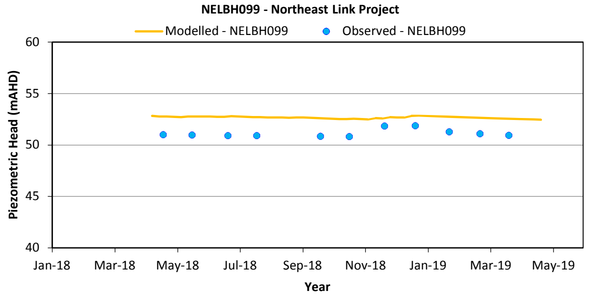

NELBH093 - Northeast Link Project
Modelled - NELBH093
Observed - NELBH093
Piezometric Head (mAHD)
85
80
75
70
65
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

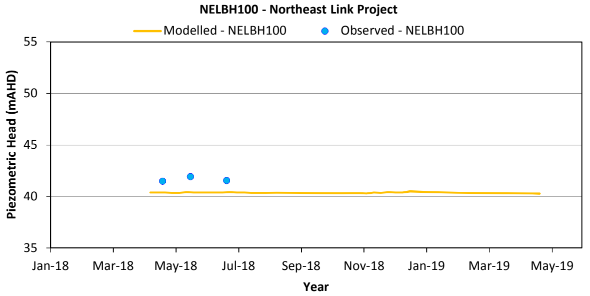

NELBH094 - Northeast Link Project
Modelled - NELBH094
Observed - NELBH094
Piezometric Head (mAHD)
80
75
70
65
60
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

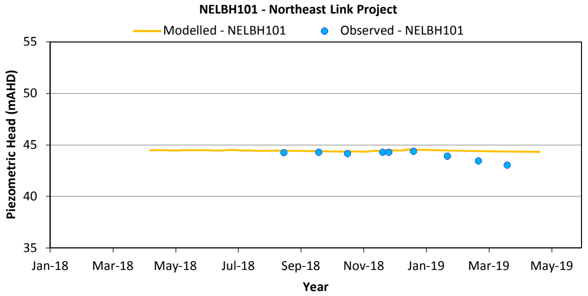

NELBH095 - Northeast Link Project
Modelled - NELBH095
Observed - NELBH095
Piezometric Head (mAHD)
75
70
65
60
55
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

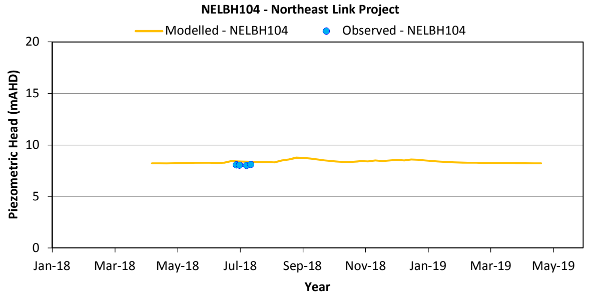

NELBH097 - Northeast Link Project
Modelled - NELBH097
Observed - NELBH097
Piezometric Head (mAHD)
60
55
50
45
40
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

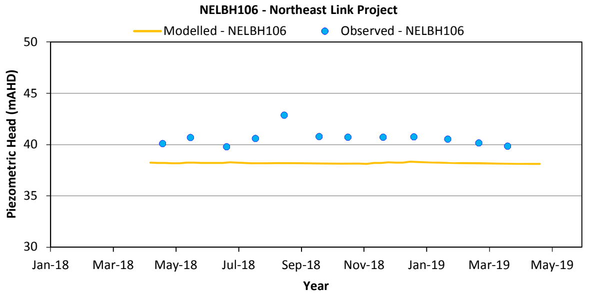

NELBH098 - Northeast Link Project
Modelled - NELBH098
Observed - NELBH098
Piezometric Head (mAHD)
65
60
55
50
45
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

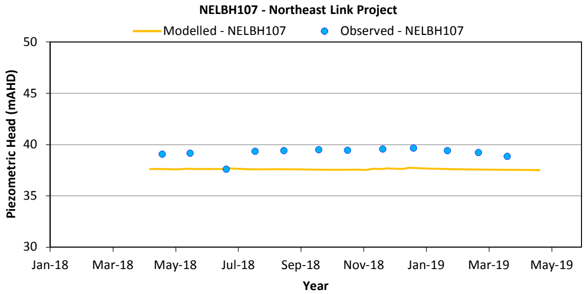

NELBH099 - Northeast Link Project
Modelled - NELBH099
Observed - NELBH099
Piezometric Head (mAHD)
60
55
50
45
40
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

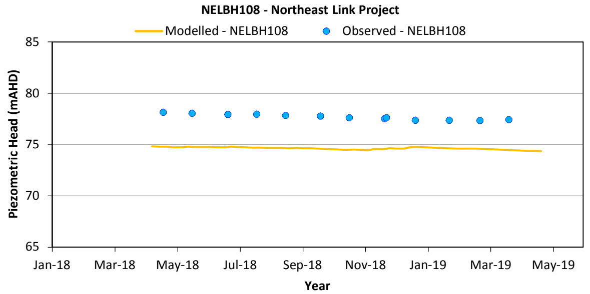

NELBH100 - Northeast Link Project
Modelled - NELBH100
Observed - NELBH100
Piezometric Head (mAHD)
55
50
45
40
35
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

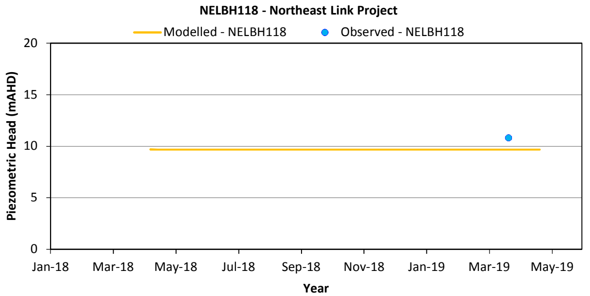

NELBH101 - Northeast Link Project
Modelled - NELBH101
Observed - NELBH101
Piezometric Head (mAHD)
55
50
45
40
35
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

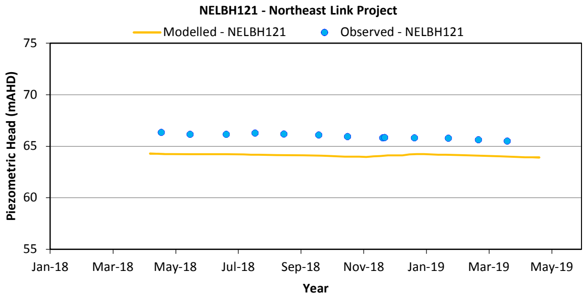

NELBH104 - Northeast Link Project
Modelled - NELBH104
Observed - NELBH104
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

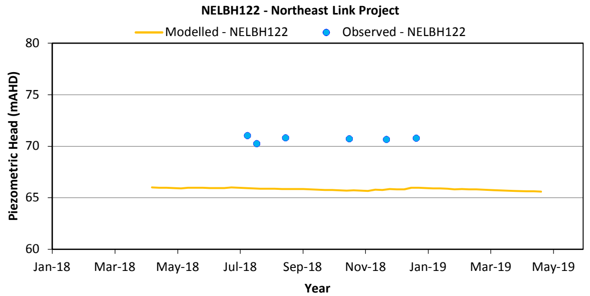

NELBH106 - Northeast Link Project
Modelled - NELBH106
Observed - NELBH106
Piezometric Head (mAHD)
50
45
40
35
30
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

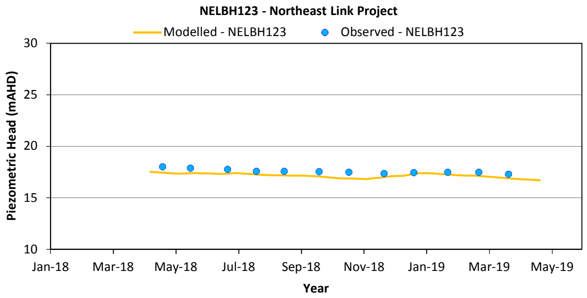

NELBH107 - Northeast Link Project
Modelled - NELBH107
Observed - NELBH107
Piezometric Head (mAHD)
50
45
40
35
30
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

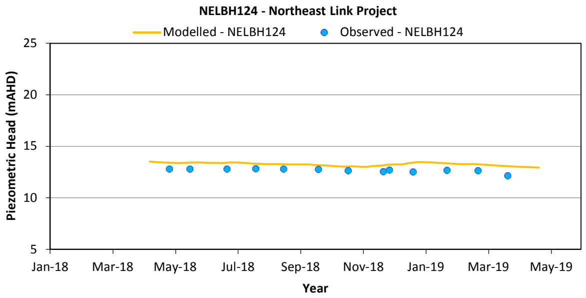

NELBH108 - Northeast Link Project
Modelled - NELBH108
Observed - NELBH108
Piezometric Head (mAHD)
85
80
75
70
65
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

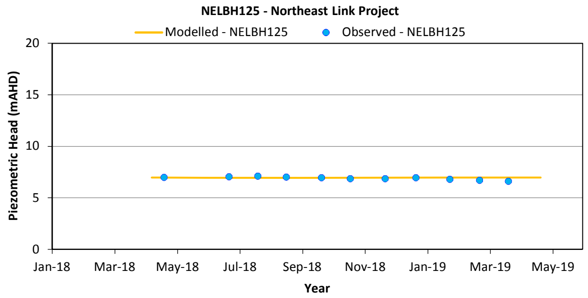

NELBH118 - Northeast Link Project
Modelled - NELBH118
Observed - NELBH118
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

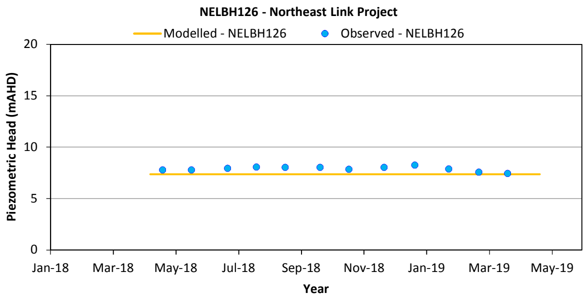

NELBH121 - Northeast Link Project
Modelled - NELBH121
Observed - NELBH121
Piezometric Head (mAHD)
75
70
65
60
55
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

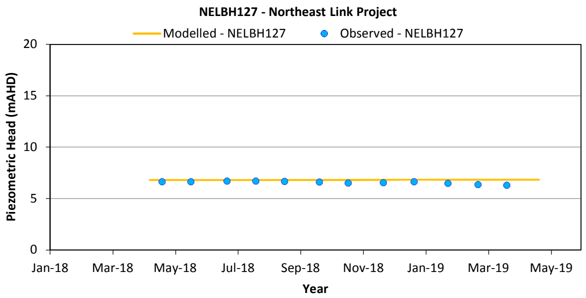

NELBH122 - Northeast Link Project
Modelled - NELBH122
Observed - NELBH122
Piezometric Head (mAHD)
80
75
70
65
60
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

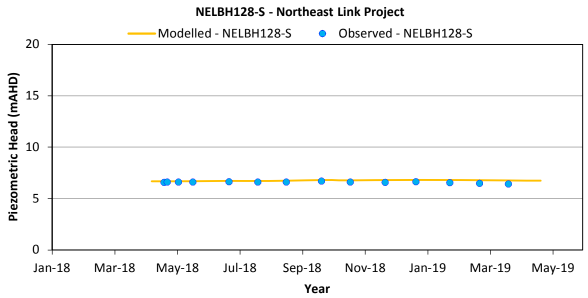

NELBH123 - Northeast Link Project
Modelled - NELBH123
Observed - NELBH123
Piezometric Head (mAHD)
30
25
20
15
10
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

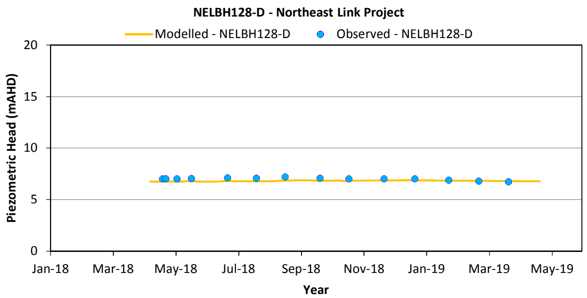

NELBH124 - Northeast Link Project
Modelled - NELBH124
Observed - NELBH124
Piezometric Head (mAHD)
25
20
15
10
5
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

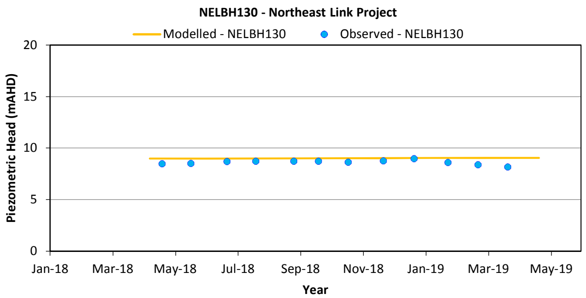

NELBH125 - Northeast Link Project
Modelled - NELBH125
Observed - NELBH125
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

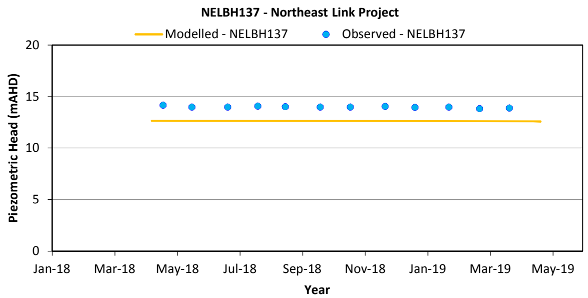

NELBH126 - Northeast Link Project
Modelled - NELBH126
Observed - NELBH126
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

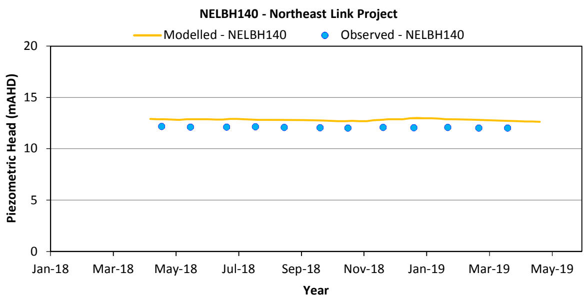

NELBH127 - Northeast Link Project
Modelled - NELBH127
Observed - NELBH127
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

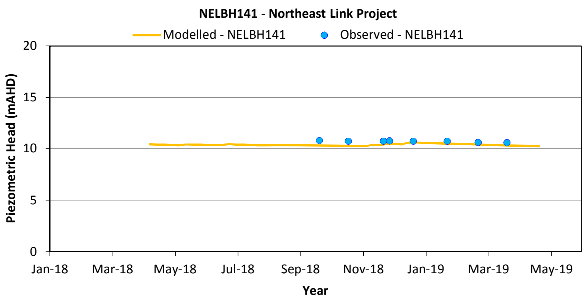

NELBH128-S - Northeast Link Project
Modelled - NELBH128-S
Observed - NELBH128-S
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

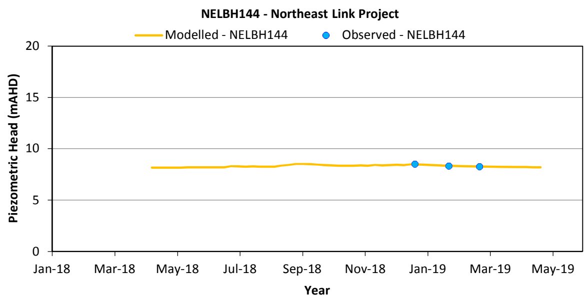

NELBH128-D - Northeast Link Project
Modelled - NELBH128-D
Observed - NELBH128-D
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

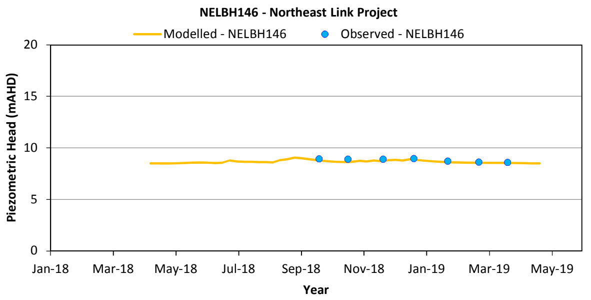

NELBH130 - Northeast Link Project
Modelled - NELBH130
Observed - NELBH130
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

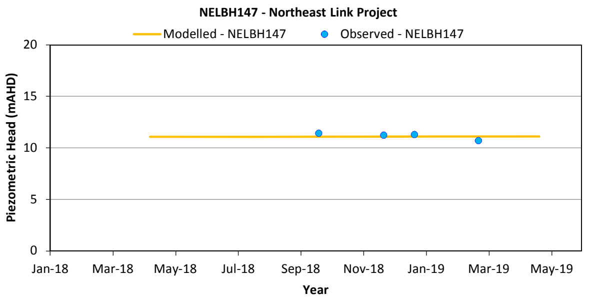

NELBH137 - Northeast Link Project
Modelled - NELBH137
Observed - NELBH137
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

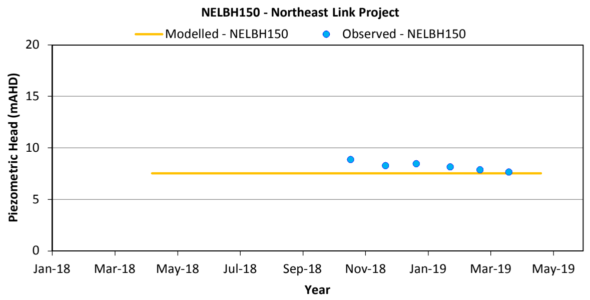

NELBH140 - Northeast Link Project
Modelled - NELBH140
Observed - NELBH140
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

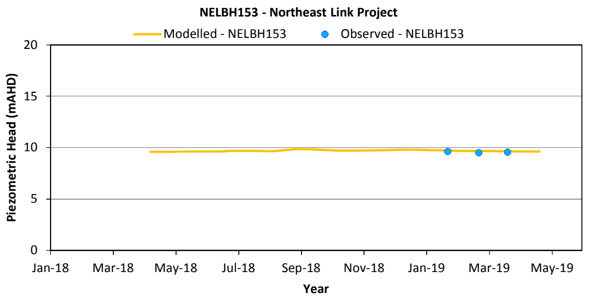

NELBH141 - Northeast Link Project
Modelled - NELBH141
Observed - NELBH141
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

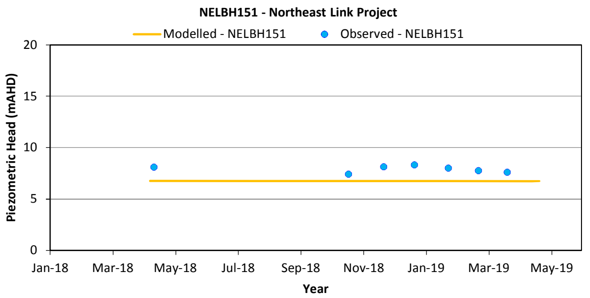

NELBH144 - Northeast Link Project
Modelled - NELBH144
Observed - NELBH144
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

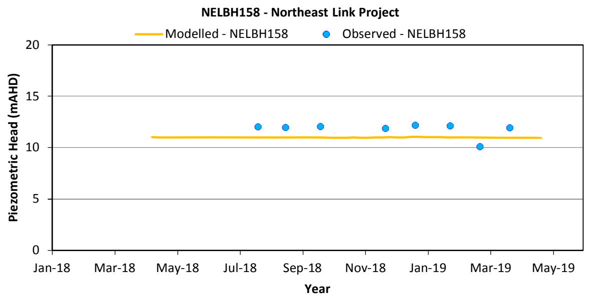

NELBH146 - Northeast Link Project
Modelled - NELBH146
Observed - NELBH146
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

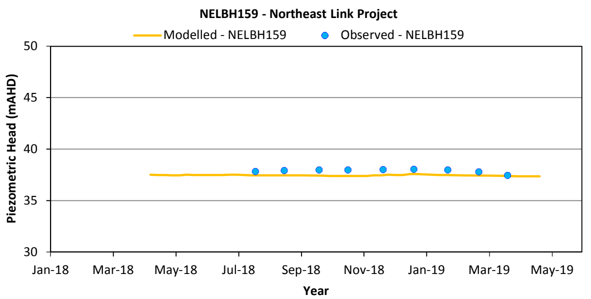

NELBH147 - Northeast Link Project
Modelled - NELBH147
Observed - NELBH147
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

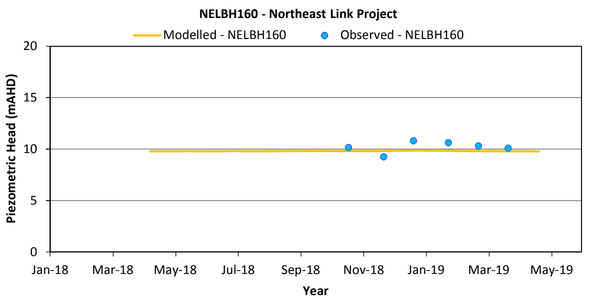

NELBH150 - Northeast Link Project
Modelled - NELBH150
Observed - NELBH150
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

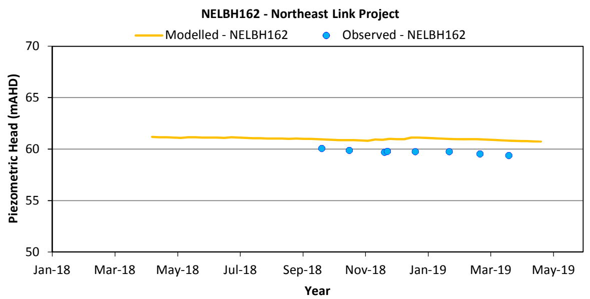

NELBH153 - Northeast Link Project
Modelled - NELBH153
Observed - NELBH153
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

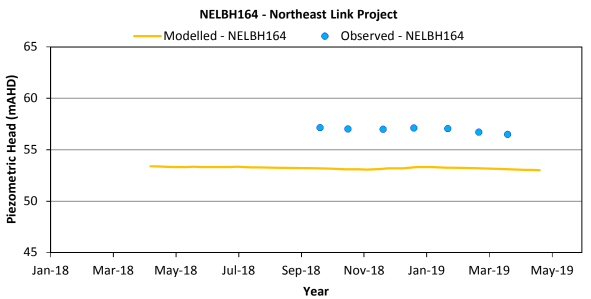

NELBH151 - Northeast Link Project
Modelled - NELBH151
Observed - NELBH151
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

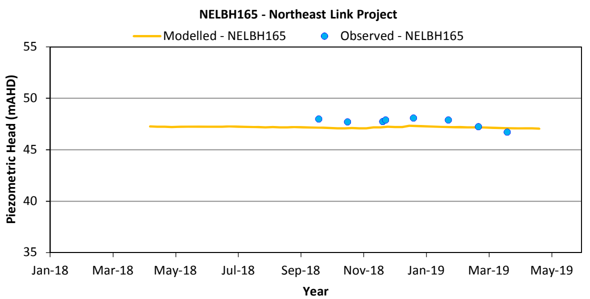

NELBH158 - Northeast Link Project
Modelled - NELBH158
Observed - NELBH158
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

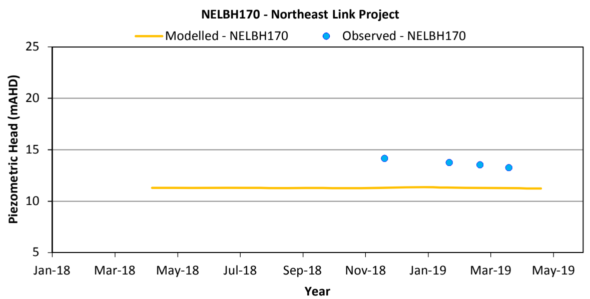

NELBH159 - Northeast Link Project
Modelled - NELBH159
Observed - NELBH159
Piezometric Head (mAHD)
30 35 40 45 50
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

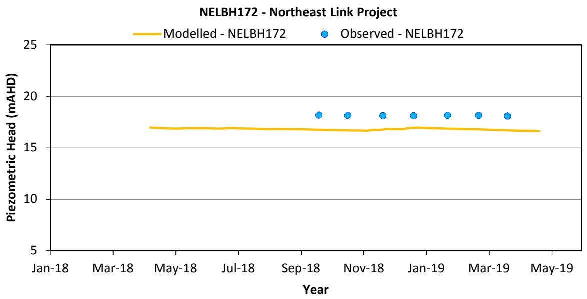

NELBH160 - Northeast Link Project
Modelled - NELBH160
Observed - NELBH160
Piezometric Head (mAHD)
0 5 10 15 20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

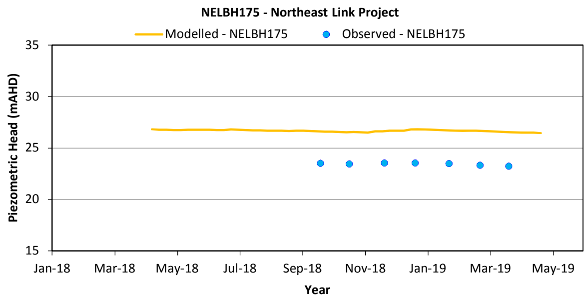

NELBH162 - Northeast Link Project
Modelled - NELBH162
Observed - NELBH162
Piezometric Head (mAHD)
50 55 60 65 70
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

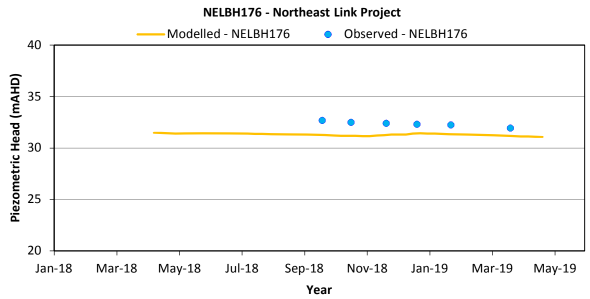

NELBH164 - Northeast Link Project
Modelled - NELBH164
Observed - NELBH164
Piezometric Head (mAHD)
45 50 55 60 65
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

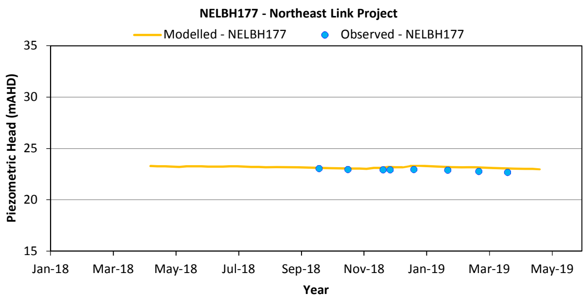

NELBH165 - Northeast Link Project
Modelled - NELBH165
Observed - NELBH165
Piezometric Head (mAHD)
35 40 45 50 55
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

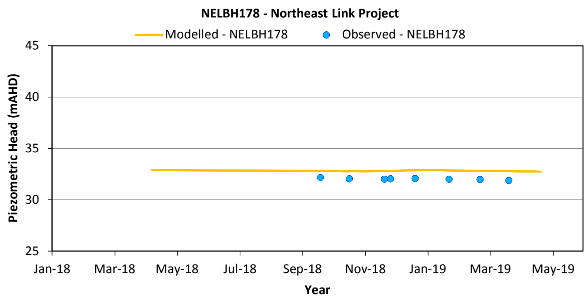

NELBH170 - Northeast Link Project
Modelled - NELBH170
Observed - NELBH170
Piezometric Head (mAHD)
5 10 15 20 25
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

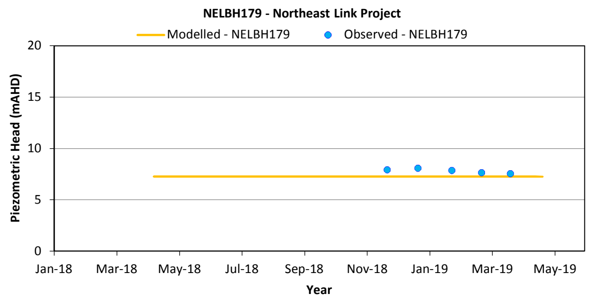

NELBH172 - Northeast Link Project
Modelled - NELBH172
Observed - NELBH172
Piezometric Head (mAHD)
25
20
15
10
5
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

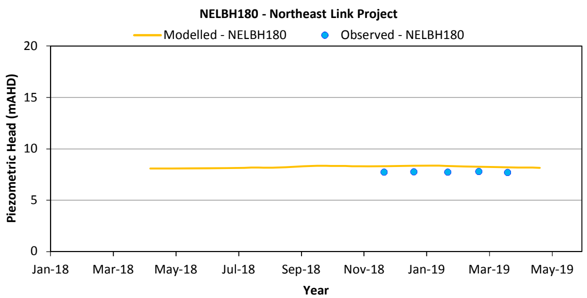

NELBH175 - Northeast Link Project
Modelled - NELBH175
Observed - NELBH175
Piezometric Head (mAHD)
35
30
25
20
15
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

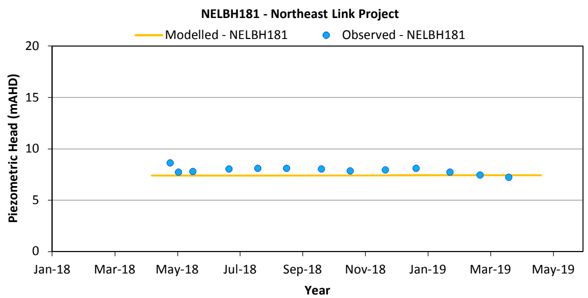

NELBH176 - Northeast Link Project
Modelled - NELBH176
Observed - NELBH176
Piezometric Head (mAHD)
40
35
30
25
20
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

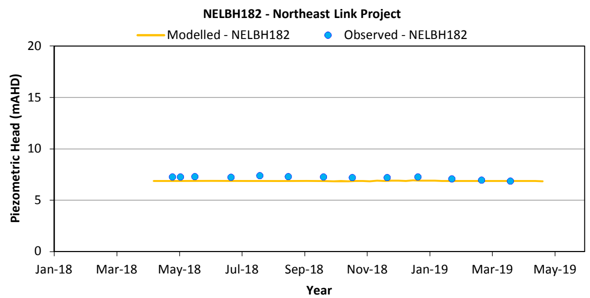

NELBH177 - Northeast Link Project
Modelled - NELBH177
Observed - NELBH177
Piezometric Head (mAHD)
35
30
25
20
15
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

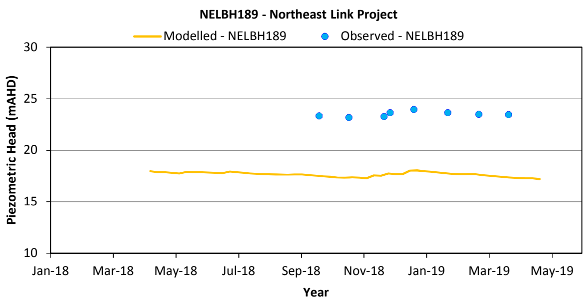

NELBH178 - Northeast Link Project
Modelled - NELBH178
Observed - NELBH178
Piezometric Head (mAHD)
45
40
35
30
25
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

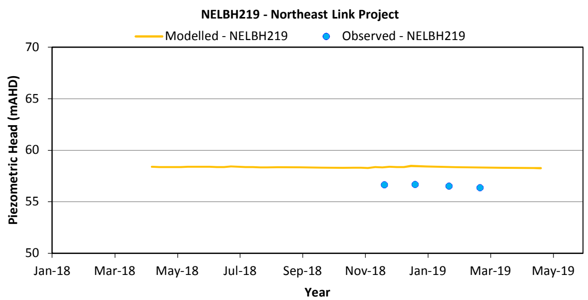

NELBH179 - Northeast Link Project
Modelled - NELBH179
Observed - NELBH179
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

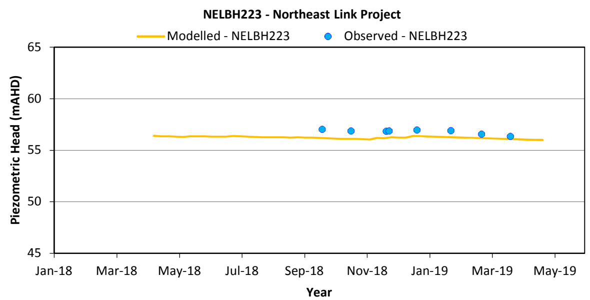

NELBH180 - Northeast Link Project
Modelled - NELBH180
Observed - NELBH180
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

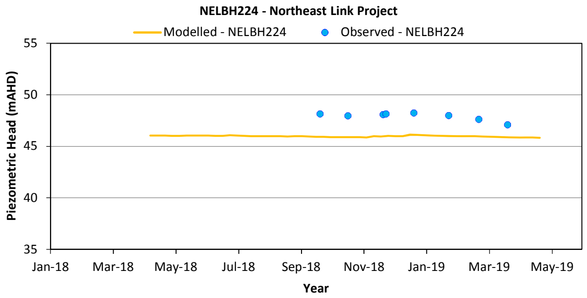

NELBH181 - Northeast Link Project
Modelled - NELBH181
Observed - NELBH181
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

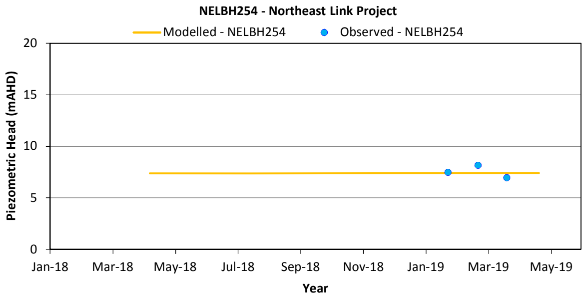

NELBH182 - Northeast Link Project
Modelled - NELBH182
Observed - NELBH182
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

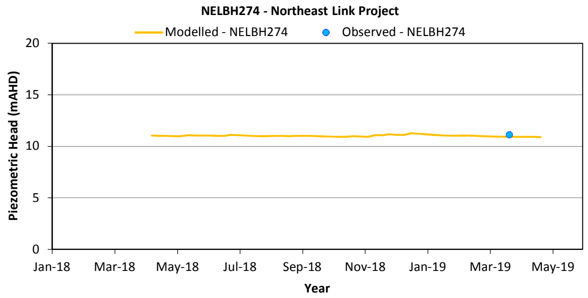

NELBH189 - Northeast Link Project
Modelled - NELBH189
Observed - NELBH189
Piezometric Head (mAHD)
30
25
20
15
10
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH219 - Northeast Link Project
Modelled - NELBH219
Observed - NELBH219
Piezometric Head (mAHD)
70
65
60
55
50
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH223 - Northeast Link Project
Modelled - NELBH223
Observed - NELBH223
Piezometric Head (mAHD)
65
60
55
50
45
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH224 - Northeast Link Project
Modelled - NELBH224
Observed - NELBH224
Piezometric Head (mAHD)
55 50 45 40 35
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH254 - Northeast Link Project
Modelled - NELBH254
Observed - NELBH254
Piezometric Head (mAHD)
20 15 10 5 0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELBH274 - Northeast Link Project
Modelled - NELBH274
Observed - NELBH274
Piezometric Head (mAHD)
20 15 10 5 0
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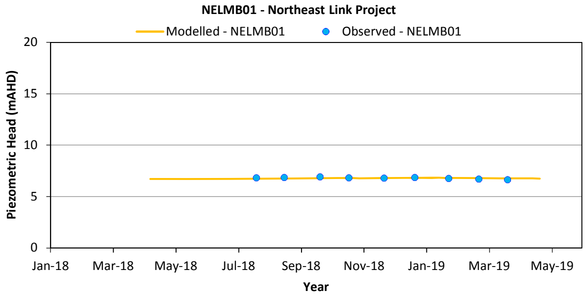
Year


NELMB01 - Northeast Link Project
Modelled - NELMB01
Observed - NELMB01
Piezometric Head (mAHD)
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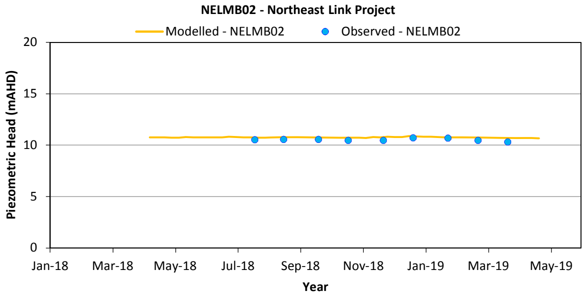
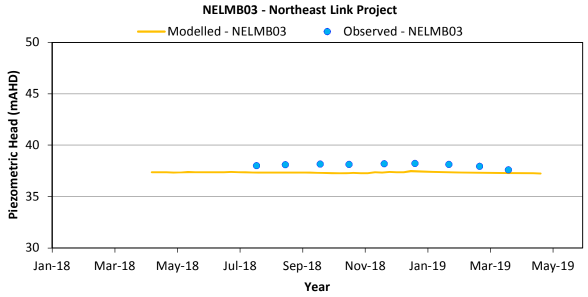
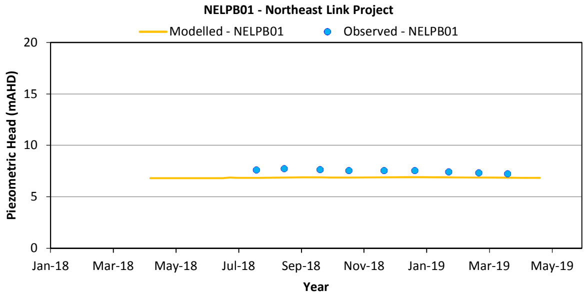
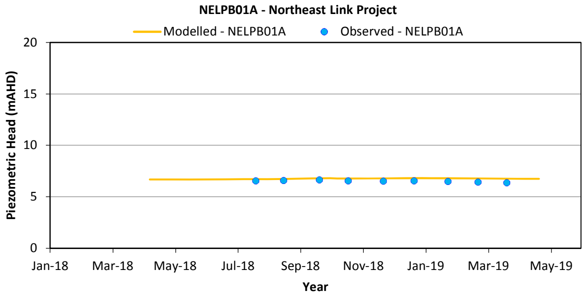
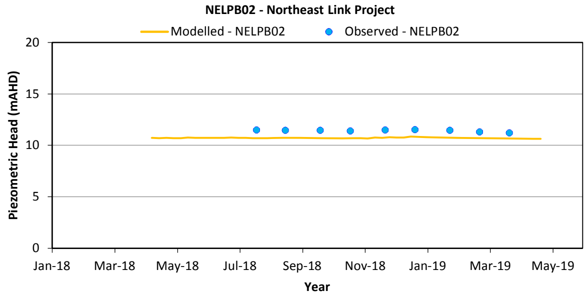
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELMB02 - Northeast Link Project
Modelled - NELMB02
Observed - NELMB02
Piezometric Head (mAHD)
20 15 10 5 0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELMB03 - Northeast Link Project
Modelled - NELMB03
Observed - NELMB03
Piezometric Head (mAHD)
50 45 40 35 30
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELPB01 - Northeast Link Project
Modelled - NELPB01
Observed - NELPB01
Piezometric Head (mAHD)
20 15 10 5 0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELPB01A - Northeast Link Project
Modelled - NELPB01A
Observed - NELPB01A
Piezometric Head (mAHD)
20 15 10 5 0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELPB02 - Northeast Link Project
Modelled - NELPB02
Observed - NELPB02
Piezometric Head (mAHD)
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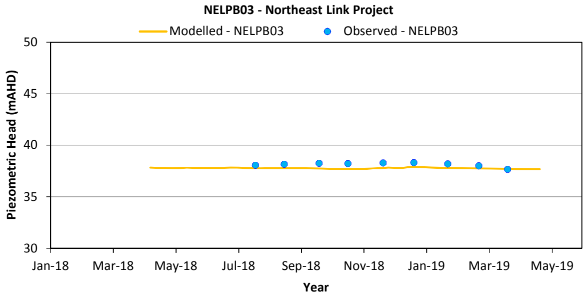
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


NELPB03 - Northeast Link Project
Modelled - NELPB03
Observed - NELPB03
Piezometric Head (mAHD)
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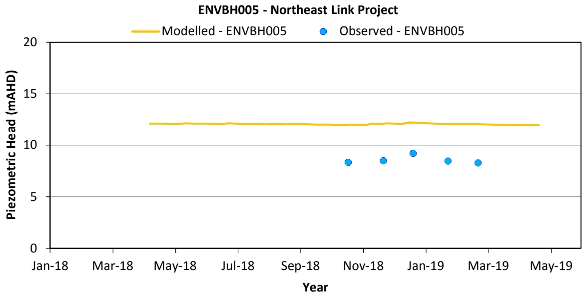
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


ENVBH005 - Northeast Link Project
Modelled - ENVBH005
Observed - ENVBH005
Piezometric Head (mAHD)
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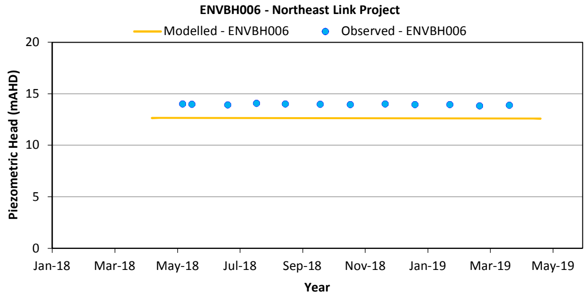
Year


ENVBH006 - Northeast Link Project
Modelled - ENVBH006
Observed - ENVBH006
Piezometric Head (mAHD)
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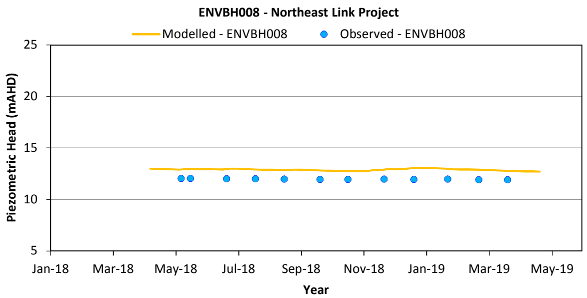
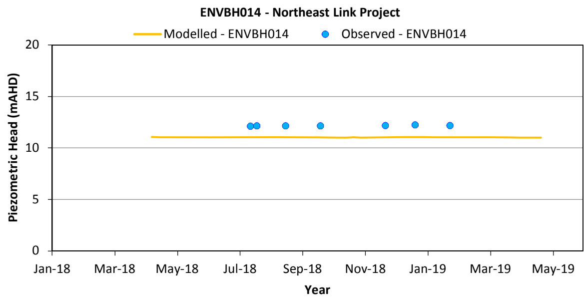
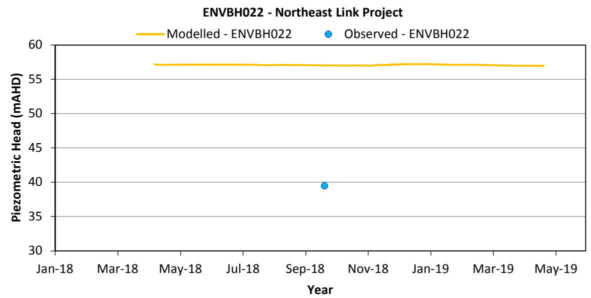
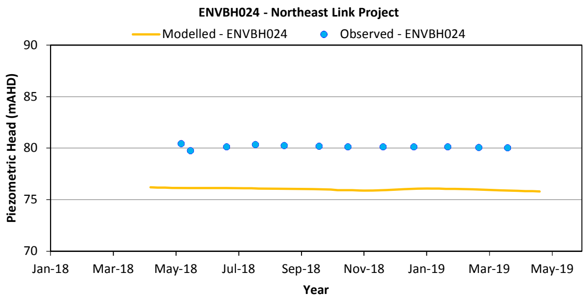
Year


ENVBH008 - Northeast Link Project
Modelled - ENVBH008
Observed - ENVBH008
Piezometric Head (mAHD)
25
20
15
10
5
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


ENVBH014 - Northeast Link Project
Modelled - ENVBH014
Observed - ENVBH014
Piezometric Head (mAHD)
20
15
10
5
0
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


ENVBH022 - Northeast Link Project
Modelled - ENVBH022
Observed - ENVBH022
Piezometric Head (mAHD)
60
55
50
45
40
35
30
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


ENVBH024 - Northeast Link Project
Modelled - ENVBH024
Observed - ENVBH024
Piezometric Head (mAHD)
90
85
80
75
70
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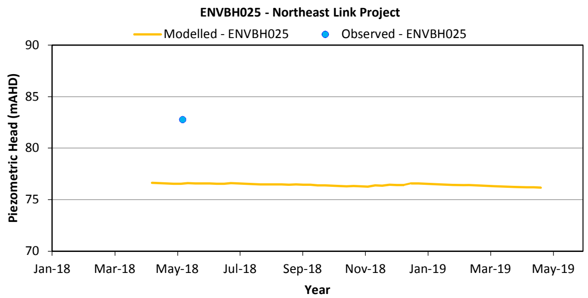
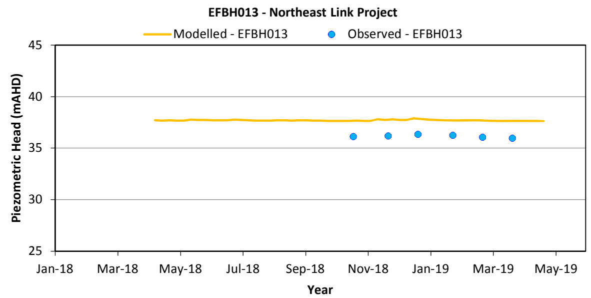
Year


ENVBH025 - Northeast Link Project
Modelled - ENVBH025
Observed - ENVBH025
Piezometric Head (mAHD)
90
85
80
75
70
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year


EFBH013 - Northeast Link Project
Modelled - EFBH013
Observed - EFBH013
Piezometric Head (mAHD)
45
40
35
30
25
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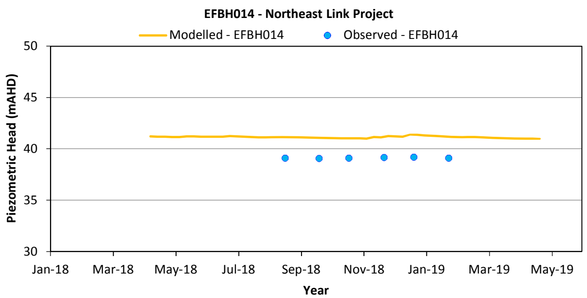
Year


EFBH014 - Northeast Link Project
Modelled - EFBH014
Observed - EFBH014
Piezometric Head (mAHD)
50
45
40
35
30
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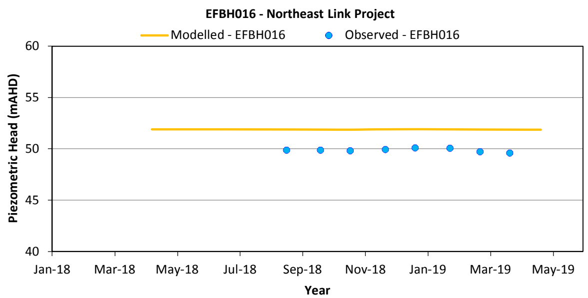
Year


EFBH016 - Northeast Link Project
Modelled - EFBH016
Observed - EFBH016
Piezometric Head (mAHD)
60
55
50
45
40
Jan-18 Mar-18 May-18 Jul-18 Sep-18 Nov-18 Jan-19 Mar-19 May-19
Year

GHD

180 Lonsdale Street
Melbourne, Victoria 3000
T: (03) 8687 8000 F: (03) 8687 8111 E: melmail@ghd.com.au

www.ghd.com

GHD

180 Lonsdale Street
Melbourne Victoria 3000
T: (03) 8687 8000 F:(03) 8687 8111 E: melmail@ghd.com

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft Final	T Anderson	K Aldous		M Roser		April 19
Final	T Anderson	K Aldous		M Roser		September 19

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