Appendix B5

Groundwater CEMP Sub-plan

M6 Motorway Stage 1

20 December 2021

Document Number:	M6S1-CGU-NWW-ENPE-PLN-000411
Revision:	05

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Contents

Document control

Approval and authorisation

Title	M6 Stage 1 Groundwater CEMP Sub-plan
Endorsed by Environment Representative	Derek Low
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Dated	20/12/2021
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Dated	20/12/2021
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Signed	Craig Gibson
Dated	20/12/2021

Document status

Revision	Date	Description	Approval
00	24/09/2021	Submission to TfNSW	
01	08/10/2021	Submission to TfNSW, DPIE and Sydney Water	
02	12/11/2021	Issued for Approval	
03	23/11/2021	Issued for Approval	
04	10/12/2021	Updated with DPIE comments and issued for approval	
05	20/12/2021	Appendix A Updated with DPIE comments and issued for approval	

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The document is uncontrolled when printed. One controlled hard copy of the GMP as part of the CEMP and supporting documentation will be maintained by the Quality Manager at the Project office and on the Project website (https://caportal.com.au/rms/m6).

Copy number	Issued to	Version

Glossary/ Abbreviations

Abbreviations	Expanded text
ASS	Acid Sulfate Soil
CEMP	Construction Environmental Management Plan
CGU	CPB Contractors Ghella UGL Engineering Joint Venture
CoA	Conditions of Approval
CSSI	Critical State Infrastructure, as described in Schedule 1, the carrying out of which is approved under the terms of the SSI 8931 approval
CSWMP	Soil and Surface Water CEMP Sub-plan
DPIE / DPIE Water	NSW Department of Planning, Industry and Environment (former NSW Department of Industry – Lands and Water, and former NSW Department of Primary Industries including DPI Agriculture, DPI Biosecurity and Food Safety, DPI Land and Natural Resources, DPI Water and DPI Fisheries)
EC	Electrical Conductivity
EIS	F6 Extension Stage 1 – Environmental Impact Statement
EMM	Environmental Management Measures
EMS	Environmental Management System
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EWMS	Environmental Work Method Statements
ER	Environmental Representative
GDEs	Groundwater Dependent Ecosystems
GIR	Geotechnical Interpretive Report
GWMP	Groundwater Monitoring Program
GWQ	Groundwater Quality
HIR	Hydrogeological Interpretive Report (M6S1-COF-NWW-ENEV-RPT-680440)
HFR	Hydrogeological Factual Report (M6S1-COF-NWW-ENGE-RPT-680520)
m AHD	Elevation in metres with respect to the Australian Height Datum
mbgl	Metres below ground level
mbtoc	Metres below top of casing
m/day	Metres per day

Abbreviations	Expanded text
m/s	Metres per second
NRAR	Natural Resources Access Regulator
PIR	Preferred Infrastructure Report
PIRMP	Pollution Incident Response Management Plan
POEO Act	*Protection of the Environment Operations Act 1997*
PFAS	Per- and polyfluoroalkyl substances
RMS	Roads and Maritime Services
TfNSW	Transport for NSW
SWTC	Scope of Works and Technical Criteria
µS/cm	Micro-Siemens per centimetre
WAL	Water Access Licence
WTP	Water Treatment Plant

1 Introduction

1.1 Context

This Groundwater CEMP Sub-plan (GMP or Plan) and accompanying Groundwater Monitoring Program (GWMP, Appendix A) forms part of the Construction Environmental Management Plan (CEMP) for the M6 Stage 1 Project (the Project).

This GMP has been prepared to address the requirements of the Minister's Conditions of Approval (CoA), the Environmental Management Measures (EMM) the listed in the M6 Stage 1 Environmental Impact Statement (EIS), Scope of Works and Technical Criteria (SWTC) and all applicable legislation. This report has been prepared by Tetra Tech Major Projects Pty Ltd (Coffey) on behalf of CGU.

1.2 Project background and project description

The Project comprises a new twin motorway tunnel (around four kilometres in length) between the M8 Motorway at Arncliffe and President Avenue at Kogarah with a tunnel portal and entry and exit ramps connecting the tunnels to the surface (Figure 1). Works will include a connection to the M8 Motorway, line marking of additional travel lanes between the St Peters interchange to the M6 Stage 1 tunnels, an intersection with President Avenue (including widening and raising of President Avenue), and intersection improvements at the President Avenue/Princes Highway intersection. Mainline tunnel stubs would be constructed to allow for connections to future stages of the M6 Extension.

The Project was declared as a Critical State Significant Infrastructure and the M6 Stage 1 Project was approved by the Minister for Planning and Public Spaces on 18 December 2019.

Key features of the Project include:

- Mainline tunnels approximately 3.0 km in length, sized for three lanes of traffic and line marked for two lanes on opening of the motorway;
- Entry and exit ramp tunnels approximately 1.5 km in length and a tunnel portal connecting the tunnels to a surface intersection with President Avenue;
- Provision of a new intersection at President Avenue including the widening and raising of President Avenue at this location;
- Upgrade of the President Avenue and Princes Highway intersection to improve capacity and network integration;
- Provision of a new shared cycle and pedestrian pathways;
- Mainline tunnel stubs for a future connection to extend the Project to the south;
- Two motorway operation complexes (MOCs) as follows:
    - Arncliffe: including mechanical and electrical fit-out of the ventilation facility built by the M8 Motorway project, and provision of a new water treatment plant and substation.
    - Rockdale (south): including a ventilation building, Disaster Recover Site (DRS), substation and power supply, deluge tanks.
- A tunnel ventilation system, including ventilation facilities located at Marsh Street, Arncliffe and West Botany Street, Rockdale, and in-tunnel ventilation systems (jet fans and ventilation ducts);
- New Utility Services, and modifications and connections to existing Utility Services;

- A permanent power supply connection to the Rockdale Ventilation Facility Site MOC from Ausgrid's Canterbury Sub-Transmission Substation;
- Emergency access and evacuation facilities, including pedestrian and vehicular cross, long passages, fire and safety life systems;
- Ancillary infrastructure for motorway operations including operations management and control systems, permanent power supply, communications, lighting, electronic toll collection system, toll gantries and traffic control and signage (both fixed and variable signage);
- Drainage infrastructure to collect surface water and groundwater inflows for treatment;
- Reinstatement of Bicentennial Park and recreation facilities;
- Reinstatement and rehabilitation of construction leased areas within the Arncliffe Site;
- Minor adjustments to local roads in the Project area;
- Development and implementation of systems integration and operating procedures with WestConnex Motorways to ensure safe operation of the interfaces between the Project and the WestConnex Motorways; and
- Any other works as required to complete the project within the scope of the Environmental Impact Statement (EIS), Preferred Infrastructure Report (PIR), Submissions report (including EMMs) and CoA requirements.

The following six surface compounds will facilitate construction of the Project:

- Arncliffe construction ancillary facility (C1), an existing construction site which was used for the construction of the M8 Motorway;
- Rockdale construction ancillary facility (C2), within an existing TfNSW depot;
- President Avenue construction ancillary facility (C3) at Rockdale, within Rockdale Bicentennial Park and an industrial area west of West Botany Street;
- Construction ancillary facilities (C4 and C5) near Muddy Creek to support construction of the Active Transport Corridor; and
- Princes Highway construction ancillary facility (C6) on the corner of Princes Highway and President Avenue, Kogarah to support the intersection surface works.

1.3 Scope of the Sub-plan

The scope of this Plan is to describe how the CPB Contractors, Ghella, UGL Engineering (CGU) joint venture (CGU) proposes to manage groundwater during construction of the Project.

1.4 Environmental management systems overview

The environmental management system is based on CPB Contractors Environmental Management Systems. An overview of this System is described in Section 1.5 of the CEMP.

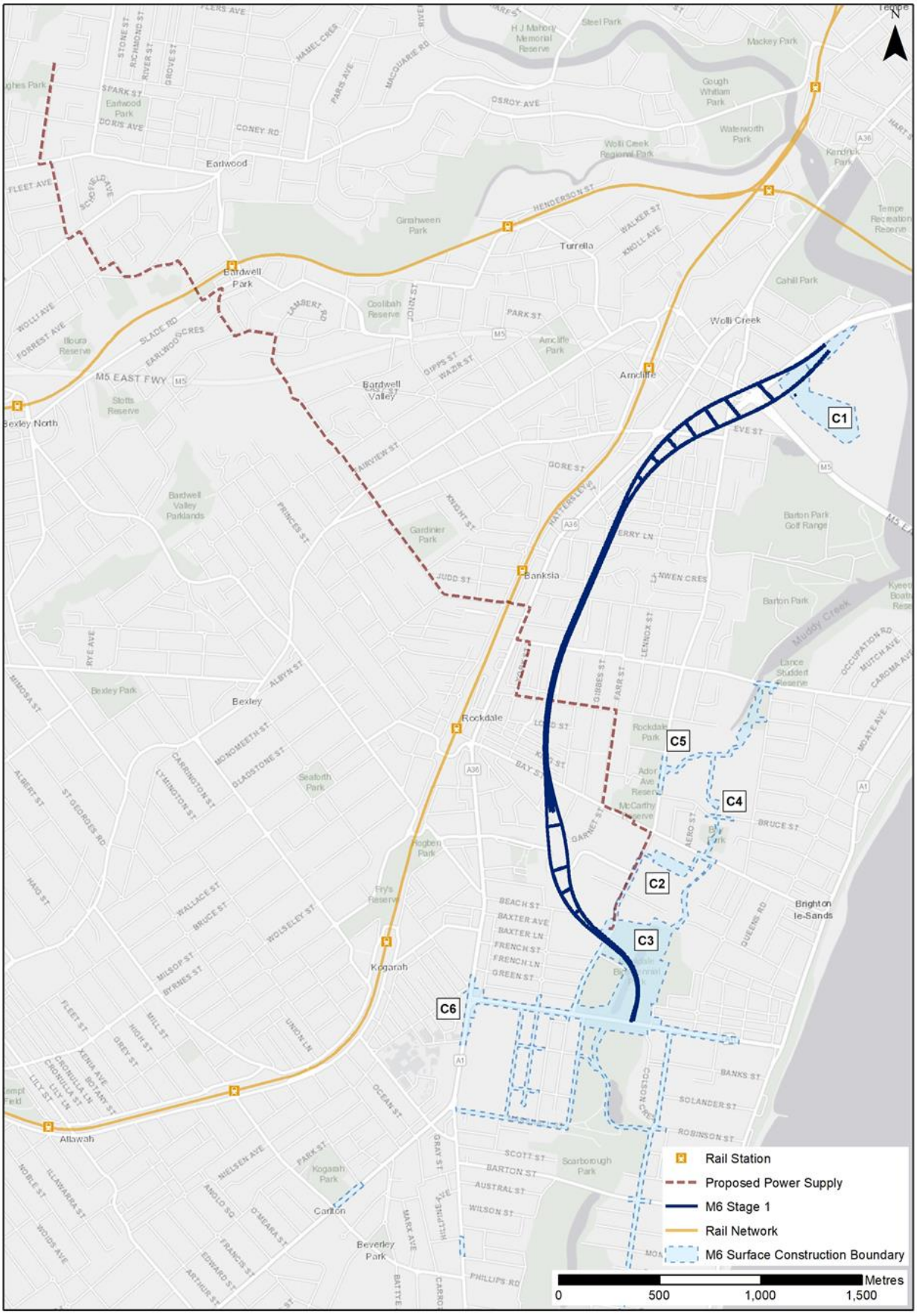

Figure 1: Project overview

1.5 Consultation

The Groundwater CEMP Sub-plan and associated Groundwater Monitoring Program (GWMP) was prepared in consultation with Bayside Council and Sydney Water and the Department of Planning, Industry and Environment – Water Group (DPIE Water), however, consultation was deferred by DPIE Water to the Natural Resources Access Regulator (NRAR).

The key issue in consultation with Bayside Council was the location of discharge points from the construction Water Treatment Plants. A detailed response was provided to Council along with a commitment to seek connection approvals from asset owners if/as required. Sydney Water did not have any specific comment on the plans other than noting their comprehensive nature.
NRAR and DPIE Water were in receipt of the Groundwater CEMP Sub-plan and GWMP for more than five weeks, prior to responding that NRAR were experiencing delays due to a volume of requests (unrelated to the Project).

The Groundwater CEMP Sub-plan and GWMP were finalised and submitted pending NRAR feedback (noting that NRAR is not an agency listed within the Conditions of Approval for consultation). It is noted that NRAR will no longer provide advice on management plans, DPIE Water has been included in the Major Projects website and is the agency responsible for providing advice in regard to groundwater.

The Project commits to receiving and responding to DPIE Water feedback on the Groundwater CEMP Sub-plan and GWMP when/if it is received. If amendment of either document is required following NRAR's feedback, the documents will be updated and submitted to the ER for endorsement within four weeks of receipt of feedback (and sent to DPIE for approval if/where required). Table 1 includes summary details of the consultation for documents M6S1-CGU-NWW-ENPE-PLN-000411 and M6S1-CGU-NWW-ENPE-PLN-000412.

Table 1 Stakeholder consultation and comments register

Stakeholder	Stakeholder Comments	CGU Response	Outstanding Issues
Bayside Council	It is not clear whether there are treatment plants at all three sites being Arncliffe, Rockdale Depot and Bicentennial Park, whether there is going to be groundwater recharge at Bicentennial, and where it is going to be discharged for each site i.e. Sydney Waters sewerage system, Cooks River/Muddy Creek or Councils stormwater system, or a combination of these. Sydney Water do not permit water from dewatering to be discharged into their sewerage system. If it is proposed to discharge the water from dewatering, whether through the WTPs or not, into Council managed or Sydney Water managed stormwater system, what approval will be sought from the responsible party?	Water treatment plants during the construction phase will be at all three tunnelling sites being C1 Arncliffe, C2 Rockdale depot and C3 Bicentennial Park. At the completion of construction, there will be one water treatment plant for operation (separate from the construction phase plants), which will be located at Arncliffe. Water will be reused as far as possible, minimising the amount of discharge required. This reuse will include (where possible), groundwater recharge, further minimising disposal. It is not proposed to discharge into council assets, however if a connection to an asset is required, approval for the connection will be sought from the asset owner prior to the connection.	If a connection to council assets is required, CGU will seek approval from the council.
DPIE Water	NRAR receives post approval requests for coordination with DPIE Water and requests should be directed to them.	Plan was sent to NRAR on 11/10/2021	None
NRAR	Thank you for your enquiry about the progress of your enquiry: Reference number V15/3875-5#87. We apologise for the delay in providing our response to your enquiry, and any inconvenience this delay has caused. We are currently experiencing a high number of Enquiries which is affecting our response times. We are endeavouring to address all enquiries as soon as possible, in the order in which we have received the enquiries. An NRAR officer (Jessica Braden) has been assigned to your enquiry and we will update you as soon as possible regarding its progress.	N/A	NRAR and DPIE Water have been in receipt of the Groundwater CEMP Sub-plan and Groundwater Monitoring Program for more than 6 weeks and have not commenced review (despite several contact attempts). The Groundwater CEMP Sub-plan and Groundwater Monitoring Program are submitted for approval by DPIE while NRAR delays continue, however the Project commits to receiving and responding to NRAR feedback on the Groundwater CEMP Sub-plan and Groundwater Monitoring Program when/if it is received. If amendment of either document is required following NRAR's feedback, the documents will be updated and

Stakeholder	Stakeholder Comments	CGU Response	Outstanding Issues
			submitted to the ER for endorsement within 4 weeks of receipt of feedback (and sent to DPIE for approval if/where required)
Sydney Water	Acknowledged that the plans have been reviewed and are “comprehensive”	None	None

2 Purpose and objectives

2.1 Purpose

The purpose of this Plan is to describe how the CGU proposes to manage groundwater and protect groundwater water quality during construction of the Project.

2.2 Objectives

The key objective of the Plan is to ensure all CoA, EMM and licence/permit requirements relevant to groundwater are described, scheduled and assigned responsibility as outlined in:

- The Environmental Assessment prepared for M6 Stage 1 Project, including the EIS, the Response to Submissions on the EIS, the PIR and Response to Submissions on the PIR;
- CoA granted to the project on 18th December 2019 (SSI 8931);
- Roads and Maritime specifications G36, G38 and G40;
- SWTC requirements including Appendix D.5 Sustainability Requirements;
- The Project's Environment Protection Licence; and
- All relevant legislation and other requirements described in Section 3.1 of this Plan.

2.3 Environmental Performance Outcomes and Targets

The desired environmental performance outcome for groundwater management, as outlined and addressed in the EIS, is that long term impacts on groundwater (including drawdown, inflow rates and volumes) are minimised.

The environmental values of groundwater and dependent ecological systems including estuarine water are to be maintained or improved (where values are achieved) and maintained where values are not achieved. Table 2 outlines environmental performance outcomes and targets.

Table 2 Environmental Performance Outcomes and Targets

No.	Desired performance outcome	Project Outcome	Source	Document Reference
1	Water – Hydrology Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	Potential impacts to surface water hydrology, geomorphology and water resources are considered to be confined to the construction footprint with the application of the proposed management measures.	EIS, Chapter 24, Section 24.7	Soil and Surface Water CEMP Sub-plan
		Treated construction wastewater will be discharged to highly disturbed less sensitive estuarine environments	EIS, Chapter 24, Section 24.7	Section 5 and Section 6
		The tunnels will be designed and constructed to minimise groundwater inflow	EIS, Chapter 24, Section 24.7	Section 6 Construction Management Plan
		The project will aim to maximise reuse of treated water	EIS, Chapter 24, Section 24.7	Water Reuse Strategy
		Baseline and continuous groundwater level monitoring will be conducted prior to and during construction works.	EIS, Chapter 24, Section 24.7	Appendix A Groundwater Monitoring Program
2	Water – Quality The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).	Potential impacts to surface water quality during construction of the project are considered to be management with the application of the proposed management measures	EIS, Chapter 24, Section 24.7	Soil and Surface Water CEMP Sub-plan
		Potential impacts to surface water quality during operation of the project are able to be mitigated by the proposed design and application of the proposed management measures	EIS, Chapter 24, Section 24.7	Soil and Surface Water CEMP Sub-plan

3 Environmental requirements

3.1 Relevant legislation and guidelines

3.1.1 Legislation

All legislation relevant to this GMP is included in Appendix A1 of the CEMP.

State legislation

Groundwater in NSW is regulated by Department of Planning, Industry and Environment Water group (DPIE Water) under the *NSW Water Act 1912* and the *NSW Water Management Act 2000.*

The processes and requirements that DPIE Water apply to assess aquifer interference of a project under the *Water Management Act 2000* is outlined in the Aquifer Interference Policy (AIP) (NSW Office of Water (2012)). Key components of the AIP are:

- Where an activity results in the loss of water from the environment, a water access licence (WAL) is required under the Water Management Act 2000 to account for this water take
- An activity must address minimal impact considerations in relation to the water table, groundwater pressure and groundwater quality
- Where the actual impacts of an activity are greater than predicted, planning measures must be put in place ensuring there is sufficient monitoring

As the Project is considered CSSI, a planning review has determined the following exemptions apply to the Project:

- The *Environmental Planning and Assessment Act 1979* (EP&A Act 1979) Clause 5.23 Part 1 (g) states that water use approval, water management work approval, or activity approval under the *Water Management Act 2000* is not required for SSI
- The *Water Management (General) Regulation 2018* under the *Water Management Act 2000* Division 2 Clause 21 exempts transport authorities (including TfNSW) from requirement for water access licence under the *Water Management Act 2000* if the transport authority, after considering the environmental impact of the activity, is satisfied that the activity is not likely to significantly affect the environment.

The Project footprint is subject to the rules of the Sydney Basin Central and Botany Sands Groundwater Source which is covered by the Greater Metropolitan Region Groundwater Source Water Sharing Plan. The water sharing plan outlines the recommended management approaches of surface and groundwater connectivity, minimisation of interference between neighbouring water supply works, protection of water quality and sensitive environmental areas and limitations to the availability of water.

The majority of the proposed alignment is located within the Sydney Basin Central Groundwater Source, with the exception of the northern end (Arncliffe palaeochannel), the southern end (Muddy Creek palaeochannel), and a section in the middle where the alignment crosses Spring Street, Arncliffe (Spring Street palaeochannel), which is located in the Botany Sands Groundwater Source as shown on Figure 2.

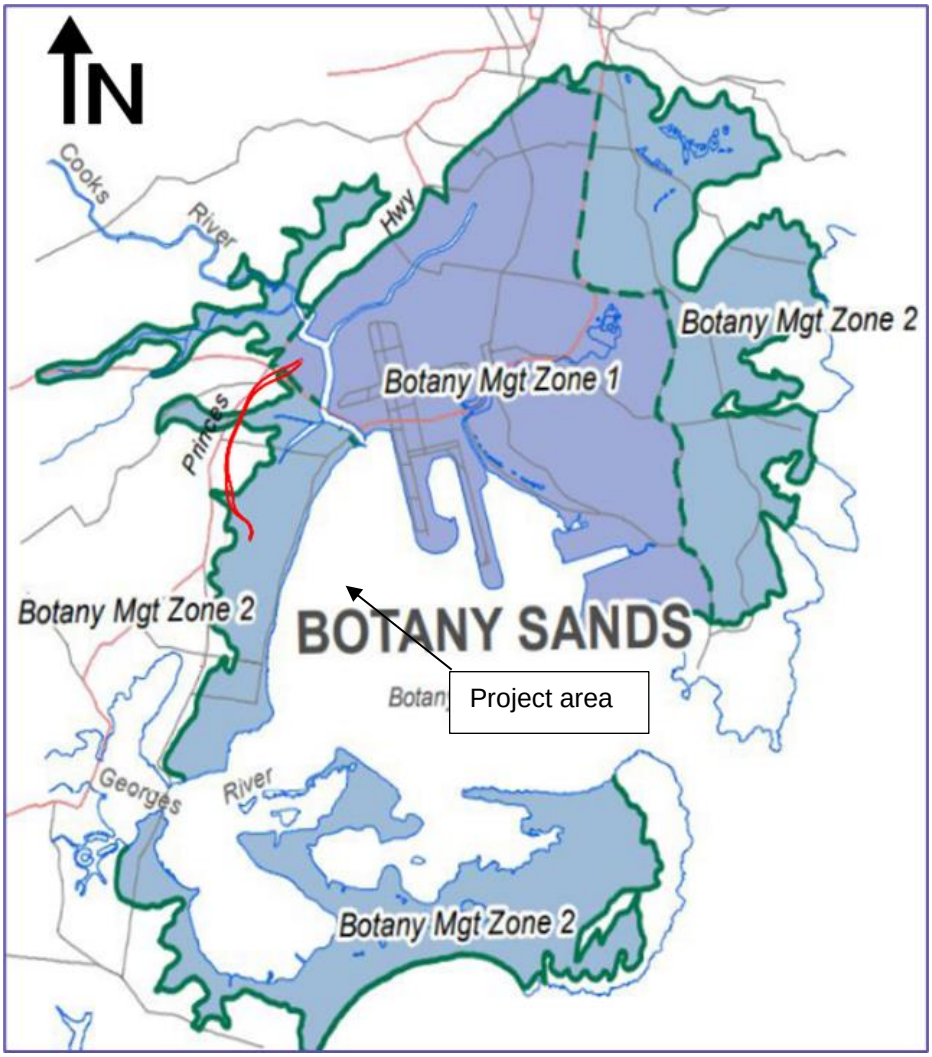

Figure 2: Location of proposed alignment in relation to Botany Sands Groundwater Source (NSW Office of Water (2011))

The Sydney Basin Central Groundwater Source is a porous hard rock aquifer and is considered to be a “less productive” groundwater source as defined in the AIP.

The Botany Sands Groundwater Source consists of aeolian sand deposits (Botany Sands) and is considered to be a “highly productive” groundwater source as defined in the AIP. In 2003, the NSW government placed an embargo on the northern section of the aquifer due to the depletion of available clean water which was followed by a ban on the construction of new domestic bores in 2006, and subsequently by a commercial ban on water extraction in 2007. The Botany Sands Groundwater Source is managed under Zone 1 and Zone 2 (as shown on Figure 2). Zone 1 covers the embargoed area of 2003, and Zone 2 covers the area of where bans were implemented in 2007. The Project corridor lies within the Botany Sands management zones at Arncliffe, Spring Street, and Muddy Creek palaeochannel. A license must be held to held to undertake aquifer interference activities in the Botany Sands management zones. In the permanent case, the proposed tunnels and structures intersecting the Botany Sands are to be undrained (tanked) to prevent direct groundwater inflow from the coastal deposit aquifer.

Key considerations for the Sydney Basin Central Groundwater Source with respect to the level 1 minimal harm considerations for a less productive porous rock aquifer and highly productive coastal aquifer (as defined in the AIP) are:

- Water table impacts:

- Less than or equal to 10 per cent cumulative variation in the water table allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any high priority groundwater dependent ecosystem or high priority culturally significant site listed in the Schedule of the water sharing plan.
- A maximum of two metres cumulative groundwater level decline at any water supply works.

- Water pressure impacts:
  - A cumulative pressure head decline of not more than two metres at any supply work.
- Water quality impacts:
  - Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.

Developments conducted on waterfront land and along major creeks and canals, are regulated by the *Water Management Act 2000* in accordance with the Guidelines for riparian corridors on waterfront land (DPI-Water, 2012). These guidelines state that waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the waterbody.

The Project footprint does not include waterfront land as defined by the guidelines, since the tunnels are greater than 40 metres from major creeks, rivers and the foreshore. Controlled activities on waterfront land are administered by DPIE Water and include removal of vegetation, earthworks and construction of temporary detention basins. A controlled activity approval must be obtained from DPIE Water prior to commencing the controlled activity.

An overview of the relevant legislation and policy and their Project implications is provided in Table 3.

Table 3 Relevant legislation

Legislation or Policy	Relevance
Water Management Act 2000 (NSW)	State Significant Infrastructure projects are exempt from requiring some water supply works approvals and controlled activity approvals. Transport authorities (including TfNSW) are exempt from requirements for a water access licence if the transport authority, after considering the environmental impact of the activity, is satisfied that the activity is not likely to significantly affect the environment. Aquifer interference activity approval provisions have not yet commenced but are administered under the Act. Water Sharing Plans are administered under this Act.
Water Act NSW (1912)	Administration of water access licences and trade of water licences and allocations.
NSW Aquifer Interference Policy (2012)	Manages the impacts of aquifer interference activities in accordance with the Water Management Act and Water Sharing Plans. Aquifer interference activities must address

Legislation or Policy	Relevance
	minimal impact considerations as outlined in the policy. In the event that actual impacts are greater than predicted there should be sufficient monitoring in place.
Water Sharing Plan, Greater Metropolitan Region Groundwater Sources (2011)	Manages the long-term surface and groundwater resources of a defined area. The plan outlines rules for the sharing and sustainability of water between various uses such as town water supply, stock and domestic, industry and irrigation.

3.1.2 Additional Standards, Codes and Technical Publications

This design package has been prepared in accordance with the relevant Codes and Standards referred to in SWTC D.3 and in accordance with the order of precedence set out in SWTC Clause 1.7. Relevant SWTC are presented in Appendix B of this document.

Standards, Codes and Technical Publications not covered in the SWTC which have been used in this design package are listed in Table 4.

Table 4 Additional Standards, Codes and Technical Publications

Reference	Title
ANZG (2018)	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
Heads of Environmental Protection Authority/Agency Australia and New Zealand (HEPA) (2020)	PFAS National Environmental Management Plan (NEMP) Version 2.0
National Environment Protection (Assessment of Site Contamination) Measure	The NEPM 2013 is given effect by individual legislation and guidelines in each state and territory. The purpose of the NEPM is to establish a nationally consistent approach to the assessment of site contamination. With respect to assessing site investigation results, health and ecological criteria suitable for generic land uses have been provided in Schedule B1, Investigation Levels for Soil and Groundwater (NEPM, 2013). The criteria for a commercial/industrial land use have been considered for the Project. The investigation and screening levels presented in the NEPM are not clean-up or response levels, nor are they desirable soil quality criteria. Investigation levels presented in the NEPM may not be protective of intrusive or construction workers on the site. Assessment for intrusive or construction workers would be undertaken in accordance with responsibilities under relevant Occupational Health and Safety legislation and relevant industry guidelines.
ASSMAC (1998)	NSW Acid Sulfate Soils Management Advisory Committee. Acid Sulfate Soil Assessment Guidelines.

3.1.3 Licences and permits

An Environment Protection Licence (EPL) was issued for the Project on 8 November 2021. The EPL sets out discharge criteria for groundwater for the Project. Relevant criteria are presented in the GWMP.

3.2 Minister's Conditions of Approval

CoA relevant to this Plan are listed in Table 5 and a cross-reference is included to indicate where the condition is addressed in this Plan or other Project management document.

Table 5 CoA relevant to Groundwater CEMP Sub-plan

CoA No.	Condition Requirements	Document Reference (relates to this Plan unless otherwise stated)	Compliance with condition
Groundwater			
C4	**CEMP Sub-plans** must be prepared in consultation with the relevant government agency(s) and council(s) as identified for each CEMP Sub-plan in Table 4 of the CoA in the Infrastructure approval for the Project.	Section 1.5	This GMP has been prepared in accordance with this condition. The plan will be provided to DPIE Water and Sydney Water (where it is proposed to discharge groundwater into Sydney Water assets).
C5	The **CEMP Sub-plans** must state how: (a) the environmental performance outcomes identified in the documents listed in Condition A1 as modified by these conditions will be achieved;	Section 2.3	This GMP and the GWMP have been prepared in accordance with this condition. The GMP outlines mitigation measures to be implemented and the GWMP details the monitoring program to assess compliance with mitigation measures.
	(b) the mitigation measures identified in the documents listed in Condition A1 as modified by these conditions will be implemented;	Section 6, Appendix A – GWMP	A description of the mitigation measures to be applied is presented in Table 16
	(c) the relevant terms of this approval will be complied with; and	Table 5, Sections 6, 7 and 8 and the GWMP in Appendix A.	Table 5 outlines where compliance with conditions is demonstrated and Sections 6, 7 and 8 and the GWMP in Appendix A detail the approach to compliance with the relevant approvals.

CoA No.	Condition Requirements	Document Reference (relates to this Plan unless otherwise stated)	Compliance with condition
	(d) issues requiring management during construction (including cumulative impacts), as identified through ongoing environmental risk analysis, will be managed.	Sections 4, 5 and 6, Section 3.2 of the CEMP	Sections 4 and 5 outline the existing environment and predicted construction impacts and Section 6 outlines mitigation measures. Section 3.2 of the CEMP details the ongoing risk analysis process.
C10	The **CEMP Sub-plans** must be endorsed by the **ER** and then submitted to the Planning Secretary for approval no later than one (1) month prior to the commencement of the construction activities to which they apply.	Section 1.5, Section 2 of the CEMP	The Plan will be provided to the Planning Secretary and the ER for approval in accordance with this condition.
C11	Any of the **CEMP Sub-plans** may be submitted to the Planning Secretary along with, or subsequent to, the submission of the **CEMP**.	Section 1.5, Section 2 of the CEMP	The Plan will be provided to the Planning Secretary.
C12	Construction must not commence until the **CEMP** and all relevant **CEMP Sub-plans** for such construction activities to which they apply have been approved by the Planning Secretary. The **CEMP** and **CEMP Sub-plans**, as approved by the Planning Secretary, including any minor amendments approved by the **ER,** must be implemented for the duration of construction. Where construction is staged, construction of a stage must not commence until the relevant **CEMP** and **CEMP Sub-plans** for that stage have been endorsed by the **ER** and approved by the Planning Secretary.	Section 1.5, Section 2 of the CEMP	The Plan will be provided to the Planning Secretary for approval and the ER for endorsement prior to construction commencing. Groundwater construction works will not commence until the CEMP and all relevant CEMP Sub-plans related to Stage 2 are approved by the Planning Secretary.
C13	**The Construction Monitoring Programs** set out in Table 5 (of the CoA in the Infrastructure approval for the Project) must be prepared and implemented to enable comparison of the actual construction performance against the predicted performance. **The Construction Monitoring Programs** must be prepared in consultation with the relevant government agencies and councils as identified for each **Construction Monitoring Program**.	GWMP in Appendix A	The GWMP was prepared in accordance with this condition. The GWMP will be provided to DPIE Water.

CoA No.	Condition Requirements	Document Reference (relates to this Plan unless otherwise stated)	Compliance with condition
C14	**Construction Monitoring Programs** must provide: (a) details of baseline data available;	Section 4.3 and Appendix C, Section 3.1 of the GWMP in Appendix A and the HFR	Baseline data is collated and reported in the HFR. Data has been summarised in Section 4.3. The GWMP details the locations, frequency, parameters and potential actions to mitigate adverse impacts (if required).
	(b) details of baseline data to be obtained and when;	Section 3.1 of the GWMP	Section 3.1 of the GWMP outlines proposed baseline monitoring to be conducted.
	(c) details of all monitoring that will be undertaken;	Section 3.2 of the GWMP	Section 3.2 of the GWMP outlines the proposed construction monitoring program.
	(d) the parameters of the project to be monitored;	Section 3.2 of the GWMP	Section 3.2 of the GWMP outlines the monitoring parameters for the construction monitoring program.
	(e) the frequency of monitoring;	Section 3.2 of the GWMP	Section 3.2 of the GWMP outlines the monitoring frequency for the construction monitoring program.
	(f) the location of monitoring;	Sections 3.2 and 4.4.2 of the GWMP	Sections 3.2 and 4.4.2 of the GWMP outlines the monitoring locations for the construction monitoring program.
	(g) the reporting of monitoring and analysis results against relevant criteria, including details of the timing and frequency for reporting the results to the Planning Secretary and relevant government agencies;	Section 5 of the GWMP	Section 5 of the GWMP outlines the reporting and analysis program including the timing and frequency of reporting to relevant stakeholders.
	(h) details of the methods that will be used to analyse the monitoring data;	Section 5 of the GWMP	Section 5 of the GWMP outlines the analysis methodology.

CoA No.	Condition Requirements	Document Reference (relates to this Plan unless otherwise stated)	Compliance with condition
	(i) procedures to identify and implement additional mitigation measures where results of monitoring indicate adverse impacts or levels above relevant criteria;	Table 6 and Table 16, Section 3 and 6 of the GWMP	Table 16 of this plan outlines mitigation measures and actions for review where monitoring observations differ from predictions. Sections 3 and 6 of the GWMP outline the process for review of monitoring data and mitigation measures.
	(j) any consultation to be undertaken in relation to the monitoring programs; and	Section 1.5, Section 1.3 of the GWMP	Section 1.5 of this plan and Section 1.3 of the GWMP outline consultation conducted for the GMP and GWMP.
	(k) any specific requirements as required by Conditions C15, as relevant.	GWMP in Appendix A	The GWMP details the monitoring program, trigger levels and contingency actions if adverse conditions are reported.
C15	The **Leachate and Landfill Gas Monitoring Program** must include, but not be limited to: (b) a monitoring bore network to monitor leachate movement; (c) reporting trigger and contingency actions in the event that unacceptable levels are reached or reported above safe thresholds	GWMP in Appendix A	The GWMP details the monitoring program, trigger levels and contingency actions if adverse conditions are reported.
C17	The **Groundwater Monitoring Program** must include: (a) results from existing monitoring bores and from any additional monitoring bores required following a review of the monitoring bore network, with the review based on actual results of existing monitoring and groundwater modelling findings in relation to the final tunnel detailed design;	Section 4.3 and Appendix C, Section 3.1 GWMP in Appendix A and the HFR	Baseline data is collated and reported in the HFR. Data has been summarised in Section 4.3. The GWMP details the monitoring program for volume and quality of discharged water from the WTP, level and quality of nominated groundwater monitoring locations across the alignment, tunnel inflow estimation methodology and data reporting methodology.
	(b) daily measurement of the amount of water discharged from the water treatment plants;	Section 3.2.5 of the GWMP	Section 3.2.5 of the GWMP outlines monitoring of water discharged from the WTP

CoA No.	Condition Requirements	Document Reference (relates to this Plan unless otherwise stated)	Compliance with condition
	(c) water quality testing of the water discharged from the treatment plants;	Sections 3.2.5 and 4.4.2 of the GWMP	Sections 3.2.5 and 4.4.2 of the GWMP outlines water quality testing for discharge water from the WTP
	(d) monitoring of groundwater levels in aquifers adjacent to the tunnel alignment;	Section 3.2.2 of the GWMP	Section 3.2.2 of the GWMP outlines proposed groundwater level monitoring
	(e) monitoring of groundwater levels, electrical conductivity and temperature in key locations between saline water bodies and the tunnel (including in saturated sediments besides the wetland in Rockdale Bicentennial Park);	Sections 3.2.2, 3.2.3 and 4.3 of the GWMP	Sections 3.2.2, 3.2.3 and 4.3 of the GWMP outline proposed EC monitoring and methodology in selected locations.
	(f) measures to record or otherwise estimate and report groundwater inflows into the tunnels during their construction;	Section 3.2.4 of the GWMP	Inflow predictions will be updated as construction progresses.
	(g) methods for providing the data collected under (a) and (b) to Sydney Water where discharges are directed to their assets; and	Section 5.5 of the GWMP	Section 5.5 of the GWMP outlines data reporting requirements for relevant stakeholders.
	(h) a method for providing the groundwater monitoring data to DPIE Water every three (3) months during construction of the tunnels and portal. *Note: With regards to monitoring data to be provided to DPIE Water, the format of the dataset must be both in a tabulated and electronic quality-controlled data (csv, excel) ready to use format.*	Section 5.5 of the GWMP	Section 5.5 of the GWMP outlines data reporting requirements for relevant stakeholders
C19	The **Construction Monitoring Programs** must be developed in consultation with the relevant government agencies as identified in **Condition C13** of this approval, and must identify information, including monitoring parameters, requested by a relevant agency to be included in a monitoring program.	GWMP in Appendix A	The GWMP was prepared in accordance with this condition. The GWMP will be provided to DPIE Water for consultation.
C20	The **Construction Monitoring Programs** must be endorsed by the ER and then submitted to the Planning Secretary for approval at least one (1) month prior to the commencement of construction.	GWMP in Appendix A CEMP Section 2	The Plan will be provided to the Planning Secretary and the ER for approval in accordance with this condition.

CoA No.	Condition Requirements	Document Reference (relates to this Plan unless otherwise stated)	Compliance with condition
C21	Construction, which is required to be monitored under the **Construction Monitoring Programs**, must not commence until the Planning Secretary has approved all of the required Construction Monitoring Programs and all relevant baseline data for the specific construction activity has been collected	HFR, GWMP in Appendix A CEMP Section 2	The GWMP outlines the monitoring plan to be undertaken prior to construction. The Plan will be provided to the Planning Secretary for approval in accordance with this condition.
C22	The **Construction Monitoring Programs**, as approved by the Planning Secretary and including any minor amendments approved by the ER, must be implemented for the duration of construction and for any longer period set out in the monitoring program or specified by the Planning Secretary, whichever is the greater.	GWMP in Appendix A CEMP Section 2	The GWMP was prepared in accordance with this condition and outlines the during for monitoring during construction. The GWMP will be implemented for the duration of construction and for any longer period set out in the monitoring program or specified by the Planning Secretary, whichever is the greater.
C23	The results of the **Construction Monitoring Programs** must be made publicly available in the form of a Construction Monitoring Report at the frequency identified in the relevant Construction Monitoring Program. *Note: Where a relevant **CEMP Sub-plan** exists, the relevant **Construction Monitoring Program** may be incorporated into that CEMP Sub-plan.*	Section 3.9.4 of the CEMP, GWMP in Appendix A	The CEMP outlines the process for public consultation. The GWMP details the frequency of monitoring reporting.
E93	A geotechnical model of representative geological and groundwater conditions must be prepared prior to excavation and tunnelling to identify geological structures and groundwater features. The model must include details of proposed excavations and tunnels, construction staging, and identify surface and sub-surface structures, including any specific attributes, which may be impacted by the CSSI. The Proponent must use this model to assess the cumulative predicted settlement, ground movement, stress redistribution and horizontal strain profiles caused by excavation and tunnelling, including groundwater drawdown and associated impacts, on adjacent surface and sub-surface structures.	Table 8 of this Plan	A geotechnical model has been prepared and is detailed in the geotechnical interpretive report (GIR) which informs detailed design. The hydrogeological interpretive report (HIR) presents a project wide hydrogeological model, and summarises the groundwater condition (including groundwater quality, levels, flow direction, and subsurface hydraulic parameters), and provides assessment of groundwater

CoA No.	Condition Requirements	Document Reference (relates to this Plan unless otherwise stated)	Compliance with condition
			related impacts and design considerations.
E97	Where the modelled inputs and parameters in Condition E93 (including groundwater drawdown) have been monitored as exceeding the limits prescribed in this approval or as modelled, the requirements of Conditions E93 to E96 must be undertaken again within three (3) months of the exceedance occurring.	Section 3.2.2 and Section 3.2.3 of GWMP in Appendix A	If the exceedance is determined to be attributable to Project works and outside of approved model predictions for saline intrusion the groundwater model will be reviewed and updated within 3 months of the exceedance occurring.
E168	The CSSI must be designed, constructed and operated so as to maintain the NSW Water Quality Objectives where they are being achieved as at the date of this approval, and contribute towards achievement of the NSW Water Quality Objectives over time where they are not being achieved as at the date of this approval, unless an EPL in force in respect of the CSSI contains different requirements in relation to the NSW Water Quality Objectives, in which case those requirements must be complied with. *Note: Discharge criteria for construction water treatment plant discharges will be included in the EPL for the project.*	Section 3.2.3 of the CEMP and Section 3.2.5 of the GWMP.	The CEMP outlines regulatory requirements and compliance. The GWMP includes reference to the Project EPL. The criteria adopted for assessment of baseline groundwater quality (refer to Appendix C of the GMP) are based on the proposed groundwater disposal to stormwater, and discharge criteria provided in Section L2.5 of Environment Protection Licence (EPL) 21600.
E172	The Proponent must take measures to limit operational groundwater inflows into each tunnel to no greater than one litre per second across any given kilometre (1L/s/km). Compliance with this condition cannot be determined by averaging groundwater inflows across the length of the tunnel(s)	Section 5.2.4	Table 16 GWM1 and GWM2
E173	The Proponent must identify and commit to the implementation of 'make good' provisions for groundwater users in the event of a material decline in water supply levels, quality and quantity from registered existing bores associated with groundwater changes from either construction and/or ongoing operational dewatering caused by the CSSI.	Section 5.2.3	Section 5.2.3 of this Plan outlines 'make good' provisions to be implemented if required.

3.3 Environmental Management Measures

The EIS identified EMM that would be adopted to avoid or reduce environmental impacts. Following consideration of issues raised in stakeholder and community submissions on the EIS, the environmental management measures were updated and set out in the EIS Submissions Report. Conditions listed in Table 6 below match those in the EIS Submissions Report.

Other conditions relevant to groundwater are address in other management plans:

- Conditions B3 and B4 which require the development of a Wetlands Management Plan to protect wetlands and a Construction Flora and Fauna CEMP Sub-plan and will address management of impacts associated with changes in groundwater level during construction.
- Condition SC1 which requires the development of a Construction Soil and Water Management Plan (CSWMP) which will detail the process and measures to manage and monitor soil and water impacts associated with the construction works, including contaminated land.
- Conditions SC5 and SC6 require the development of an Acid Sulfate Management Plan and a Leachate and Landfill Gas Management Plan. These Plans will address potential impact associated with groundwater level changes during construction.

Relevant EMM from the EIS Submissions Report are listed in Table 6 below. This includes reference to required outcomes, the timing of when the commitment applies, relevant documents or sections of the environmental assessment influencing the outcome and implementation.

Table 6 EMM relevant to Groundwater CEMP Sub-plan

Impact	Ref #	Commitment	Timing	Document Reference
Groundwater				
Operational tunnel inflows higher than expected which may exceed the inflow criteria of 1 L/sec/km for any kilometre length of tunnel.	GW1	Where fractured Hawkesbury Sandstone is intersected, a combination of techniques will be investigated to reduce the bulk hydraulic conductivity.	Construction	The Design Package Report for Tunnel Standard Details and Water Resistant Lining (M6S1-WSP-STTU-1505) and drawing number M6S1-WSP-ML-STTU-DRG-404821 set out probing and grouting methodology where inflows exceed triggers.
Groundwater drawdown impacting a water supply well water level by more	GW3	Impacts on water supply bores will be 'made good' as soon as practicable. Where water supply bores cannot be made good, alternate measures are to be implemented to replace supply.	Construction and Operation	Recharge mitigation system outlined in GMP Section 6. Potential 'made good' measures presented in GMP Section 5.2.3.

Impact	Ref #	Commitment	Timing	Document Reference
than two metres				
Potential impacts to groundwater flows due to subsurface components	GW4	Measures to reduce potential impacts to groundwater flows due to subsurface components of the project will be identified and included in the detailed construction methodology and the detailed design as relevant.	Construction	Refer to the Groundwater Modelling Report.
Actual groundwater inflows and drawdown in adjacent areas exceed predictions	GW5	A detailed groundwater model will be developed by the construction contractor. The model will be used to predict groundwater inflow rates and volumes within the tunnels and groundwater levels (including drawdown) in adjacent areas during construction and operation of the project.	Detailed design	Refer to the Groundwater Modelling Report. The assessment of drawdown and inflow rate was informed through the use of two-dimensional numerical models and is presented in the Hydrogeological Interpretive Report (HIR).
Actual groundwater inflows and drawdown in adjacent areas exceed predictions	GW6	Groundwater inflow and groundwater levels in the vicinity of the tunnels will be monitored during construction and compared to model predictions and groundwater performance criteria applied to the project. The detailed groundwater model will be updated based on the results of the monitoring as required and proposed management measures to minimise potential groundwater impacts adjusted accordingly to ensure that groundwater inflow performance targets are met.	Construction	Groundwater management mitigation measures are presented in Section 6 and Section 3.2.5 of the GWMP is attached as Appendix A.
Impacts to groundwater quality, groundwater levels or groundwater flows	GW7	Prior to construction, a groundwater monitoring program will be prepared and implemented to monitor groundwater levels, construction and operational groundwater inflows in the tunnels, and groundwater quality in the three main aquifers impacted by construction works. The program will identify groundwater monitoring	Prior to construction	The GWMP sets out monitoring to be conducted during the construction phase and is attached as Appendix A.

Impact	Ref #	Commitment	Timing	Document Reference
		locations, performance criteria in relation to groundwater inflow and levels, and potential remedial actions that will be considered to address potential impacts. As a minimum the program will include monthly manual groundwater level and quality monitoring and weekly monitoring of inflow volumes and quality.		
Adverse impacts on the local hydrogeological regime due to groundwater discharge	GW8	An operational water treatment plant will be constructed at the Arncliffe Motorway Operations Complex (MOC1) to manage and treat groundwater from the tunnel prior to discharge. Discharge will be undertaken in accordance with the approval conditions and agreed discharge criteria.	Operation	This condition will be addressed in the Operational Environmental Management Plan.
Risks of bore water contamination impacting local bore users	GW10	Potential risks of the project contaminating bore water during construction will be identified. Affected bore users will be notified that the bore water is not suitable for use and the corrective actions being taken by the project. Bore users will be notified again once the bore water is safe for use.	Construction	Potential impacts to registered extractive users and 'made good' measures are summarised in Section 5.2.3. Mitigation measures are outlined in Section 6. Trigger levels and the stakeholder notification process is summarised in the GWMP in Appendix A.
Impacts on site workers and/or local community through disturbance and mobilisation of contaminated material	SC1	A Construction Soil and Water Management Plan (CSWMP) will be prepared for the project. The plan will detail the process and measures to manage and monitor soil and water impacts associated with the construction works, including contaminated land. The CSWMP will: • Describe procedures for managing groundwater impacts including treatment	Prior to construction	Soil and Surface Water CEMP Sub-plan

Impact	Ref #	Commitment	Timing	Document Reference
		requirements • Detail surface water and groundwater monitoring requirements, including discharge criteria.		
Impacts on soil and water quality through incorrect handling of contaminated material	SC4	Construction water treatment plants will be established and operated at the Arncliffe Construction Ancillary Facility (C1), Rockdale Construction Ancillary Facility (C2) and President Avenue Construction Ancillary Facility (C3) to treat water from the tunnel works. Discharge from these plants will be managed to achieve the applicable ANZECC criteria. Where feasible, water from the water treatment plants will be reused for construction activities.	Construction	Section 5.2.2

3.4 Scope of Works and Technical Criteria (SWTC)

A summary of the key requirements relevant to the hydrogeological aspects of the project as set out in the SWTC is provided in Appendix B.

3.5 Primary information sources

The primary documents supporting this summary report are detailed below. Additional sources have been reviewed as necessary to support the understanding of project design and construction processes.

3.5.1 Environmental Impact Statement

The EIS for the Project (formerly known as the F6 Extension Stage 1 project) was publicly released on 26 October 2018. Technical reports and data releases provide relevant hydrogeological information. Key documents referenced in relation to hydrogeological conditions include:

- AECOM (2018). F6 Extension Stage 1 EIS Technical Report K: Groundwater Technical Report. October 2018.
- RPS (2018). F6 Extension Stage 1 – Groundwater Modelling Report Ref. EWP72727.001 (Annexure F of AECOM (2018)). April 2018.

3.5.2 Information documents (INFO DOCs) and other sources

Previous hydrogeological investigation data for this report was obtained from the sources shown in Table 7. For data sources which were provided as INFO DOCs by CGU, a reference to the relevant INFO DOC number/s is provided in the table.

Table 7 Data sources

Reference	INFO DOC	Report
AECOM (2015)	19 to 30	WestConnex Stage 2: M5 Geotechnical Investigation Report of Completed Work (Ref. WCX2-RPT-00-2000-GT-0009A dated 27 March 2015)
Cardno (2019b)	67	F6 Extension Stage One Reference Design Geotechnical Investigation - Final Geotechnical Factual Report (Ref: 80019028-RPT01-GFR-Rev, dated 23 July 2019)
Cardno (2019d)	124	F6 Extension Stage One Active Transport Corridor & Contamination Investigation – Geotechnical Factual Report. (Ref: 8001902801-RPT05-GFR-Rev0, dated 01 November 2019)
Cardno (2020a)	283 to 286	Geotechnical Factual Report – M6 Extension Stage One Pre-Tender Geotechnical Investigation (Ref: Cardno-M6E-S1-RPT05-GFR-Rev2, dated 1 May 2020)
Cardno (2020c)	282	F6 Extension Stage One Reference Design Geotechnical Investigation - Final Geotechnical Factual Report (Ref: 80019028-RPT01-GFR-Rev4, dated 13 May 2020)
Cardno (2020d)	556	M6 Stage 1, Pre-Awarded Geotechnical and Contamination Investigation – Geotechnical Factual Report (Ref: Cardno-M6S1-RPT08-GFR-Rev0, dated 17 December 2020)
GHD (2021)	591	M6 Stage 1 Project Hydrogeological Assessment (Ref: 12542584, dated March, 2021).
Golder (2016)	31 to 33	Geotechnical Data Report – New M5 Motorway - Final FD (Ref: M5N-GOL-TER-100-200-GT-1545-C, dated 8 August 2016)
Golder (2017)	n/a	Hydrogeological Design Report – The New M5 Design and

Reference	INFO DOC	Report
		Construct (Ref. M5N-GOL-DRT-100-200-GT-1525-R, dated 13 April 2017)
Golder (2019b)	n/a	WestConnex Stage 2 New M5 - 24 Month groundwater monitoring review (Ref: M5N-GOL-DAN-100-200-HG-0290-D, dated 17 May 2019)
SMEC (2017a)	35	F6 Northern Geotechnical Investigations – Geotechnical Factual Report (Ref. 30012460-032-Rev0, dated 23 February 2017)
SMEC (2017b)	37	F6 Northern SEA Geotechnical Investigations – Final Geotechnical Factual Report (Ref: 30012460_SEA_GI_Final_GFR_Rev1, dated 13 September 2017)
SMEC (2018a)	40	F6 Extension – EIS and Concept Design Section A Phase 1: Groundwater Monitoring Boreholes – Geotechnical Factual Report (Ref: 30012460-053-Rev01, dated 15 Feb 2018)
SMEC (2018b)	42 to 47	F6 Extension Stage 1 Geotechnical Investigations – Final Geotechnical Factual Report (Ref: 30012161-023-RevC-Final GFR, dated 4 May 2018)
SOLDATA (2020)	n/a	Arncliffe Groundwater Monitoring Report - Period report from 07.12.2016 to 20.05.2020 (dated 20 May 2020)
ID576 GWM Q2 xlsx	575, 576	(Cardno) M6 Groundwater Monitoring Quarter 2 Report (Ref: AWE200230_M6_GWMR_Q2_Rev1, dated 15 January 2021)
ID595 GWMQ3	595	(Cardno) M6 Groundwater Monitoring Quarter 3 Report (Ref: AWE200230_M6_GWMR_Q3_Rev1, dated 17 March 2021)
Telemetry	n/a	Groundwater level telemetry monitoring data (downloaded on 25 June 2021 from https://geomotion-v2.cloud/)

3.5.3 CGU Documentation

CGU have prepared documents to support hydrogeological assessment for the Project design phase and these are listed in Table 8 .

Table 8 Related hydrogeological packages

Report Title	Report Reference	Purpose
Geotechnical Interpretive Report – Project wide	M6S1-COF-NWW-ENGE-RPT-681040	Presents a project wide geotechnical model, and summarises geological conditions along the route
Interim Hydrogeological Factual Report – Project wide	M6S1-COF-NWW-ENGE-RPT-681240	Summarise hydrogeological and groundwater related factual findings from site investigation to inform hydrogeological interpretation and groundwater model development
Hydrogeological and Groundwater Interpretive Report	M6S1-COF-NWW-ENEV-RPT-680620	Presents a project wide hydrogeological model, and summarises the groundwater condition (including groundwater quality, levels, flow direction, and parameters), and provides assessment groundwater related impacts and design considerations

Report Title	Report Reference	Purpose
Groundwater Management Sub Plan	This Appendix	Details how CGU proposes to manage potential adverse impacts to groundwater during construction of the Project.
Recharge system design - Bicentennial Park	M6S1-COF-SWBIP-ENWA-RPT-416300	Presents the recharge system to manage groundwater related settlement for the Bicentennial Park area
Recharge system design – West Botany Street Depot	M6S1-COF-SWWBS-ENWA-RPT-419500	Presents the recharge system to manage groundwater related settlement for the West Botany Street Depot area (including the drawdown related to the temporary construction decline)
Hydrogeological Factual Report - Spring Street Pump Test /Recharge Test	M6S1-COF-SWMOC1-ENEV-RPT-419000	Presents the factual findings for the pump test / recharge test in the Spring Street area to inform hydrogeological interpretation and groundwater model development
Hydrogeological Factual Report - Bicentennial Park Pump Test/Recharge Trial	M6S1-COF-SWMOC3-ENEV-RPT-418000	Presents the factual findings for the pump test / recharge trial in the Bicentennial Park area to inform hydrogeological interpretation and groundwater model development. Results will be used to check the recharge system design at Bicentennial Park
Hydrogeological Factual Report – West Botany Street Depot Pump Test / Recharge Trial	M6S1-COF-SWWBS-ENEV-RPT-419250	Presents the factual findings for the pump test / recharge trial in the West Botany Street Depot area to inform hydrogeological interpretation and groundwater model development. Results will be used to check the recharge system design at West Botany Street Depot area
Hydrogeological Factual Report – Rockdale Plaza Pump Test / Recharge Test	M6S1-COF-SWWBS-ENWA-RPT-419500	Presents the factual findings for the pump test / recharge test near the Rockdale Plaza area to inform hydrogeological interpretation and groundwater model development
Groundwater Modelling Report	M6S1-COF-NWW-ENEV-RPT-680820	Presents the 3D numerical groundwater model developed for the project. To be refined during construction (including operational response to the recharge system) to inform predictions of future impacts. Findings will be used provide projections of groundwater response for comparison with observations and predictions made in the Hydrogeological and Groundwater Interpretive Report, and the recharge system design at Bicentennial Park and West Botany Street.

3.5.4 Publicly available data

The following publicly available data and reports were referred to:

- BoM (2016). Design Rainfall Data System

  http://www.bom.gov.au/water/designRainfalls/revised-ifd/

- BoM (2020a). Groundwater Dependent Ecosystem Atlas

  http://www.bom.gov.au/water/groundwater/gde/map.shtml

- BoM (2020b). Climate Data Online

  http://www.bom.gov.au/climate/data/

- Colquhoun G.P., Hughes K.S., Deyssing L., Ballard J.C., Folkes C.B, Phillips G., Troedson A.L. & Fitzherbert J.A. (2020). New South Wales Seamless Geology dataset, version 2.0 [Digital Dataset]. Geological Survey of New South Wales, Department of Regional NSW, Maitland

- CSIRO and Bureau of Meteorology (2015). Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia

- Department of Environment, Climate Change and Water NSW (2007): NSW Sea Level Rise Policy Statement

- Department of Infrastructure, Planning and Natural Resources (2005). Floodplain Development Manual – the Management of Flood Liable Land

- Hatley (2004). Hydrogeology of the Botany Basin. Australian Geomechanics Journal 39(3):73-90. September 2004

- NSW Department of Land and Water Conservation (2020). Acid Sulfate Soil Risk Map for Botany Bay. Access 4/06/2020

  https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation/acid-sulfate-soils

4 Existing Environment

The following sections summarise what is known about factors influencing groundwater within and adjacent to the Project corridor.

Further detail is provided in the Hydrogeological Interpretive Report (HIR), Hydrogeological Factual Report (HFR) and Geotechnical Interpretive Report (GIR). Other key reference documents are listed in Table 7 and Table 8 .

4.1 Topography and drainage

4.1.1 Topography

The project crosses slightly undulating terrain from the M8 Motorway at Arncliffe to President Avenue at Kogarah. The regional bedrock (Hawkesbury Sandstone) forms rolling hills which have been incised by the Cooks River and its tributary creeks.

The more elevated ground (10 to 30 mAHD) generally comprises Hawkesbury sandstone at or near the surface. Lower lying areas (with elevations up to 10 mAHD) generally comprise surficial coastal deposits. These areas are encountered at the following locations on the Project:

- At the northern end of the project around Kogarah Golf Club
- The area immediately east of Banksia railway station around Spring Street
- Areas to the south east of Rockdale

4.1.2 Drainage catchments

The Project is located within the Cooks River catchment which covers an area of approximately 10,200 hectares in southern and south western Sydney, discharging at Botany Bay to the west of Sydney Airport. The Cooks River catchment in the Project area is extensively modified due to urbanisation and associated drainage via the stormwater network.

Sub-catchments of the Cook River in the project area are summarised below and shown in Figure 3.

Muddy Creek

Comprises a series of concrete and brick lined channels and closed box culvert structures that extend from Willison Road in Carlton to Bestic Street in Kyeemagh. The concrete lined channel discharges into an estuarine channel north of Bestic Street.

Spring Street Drain

The Spring Street Drain sub-catchment of Muddy Creek and is a concrete lined channel which flows easterly for approximately 1.3 km from Short Street in Banksia, connecting to Muddy Creek at Kyeemagh.

Scarborough Ponds

Scarborough Ponds extend between Rockdale Bicentennial Park and Tonbridge Street Reserve and comprise Rockdale Wetland (Rockdale Bicentennial Park Pond and Kings Wetland), Northern Scarborough Ponds and Southern Scarborough Ponds.

Kogarah Golf Club Drain

An unnamed watercourse runs easterly through the Kogarah Golf Club course. This drain is an artificial, tidally affected watercourse.

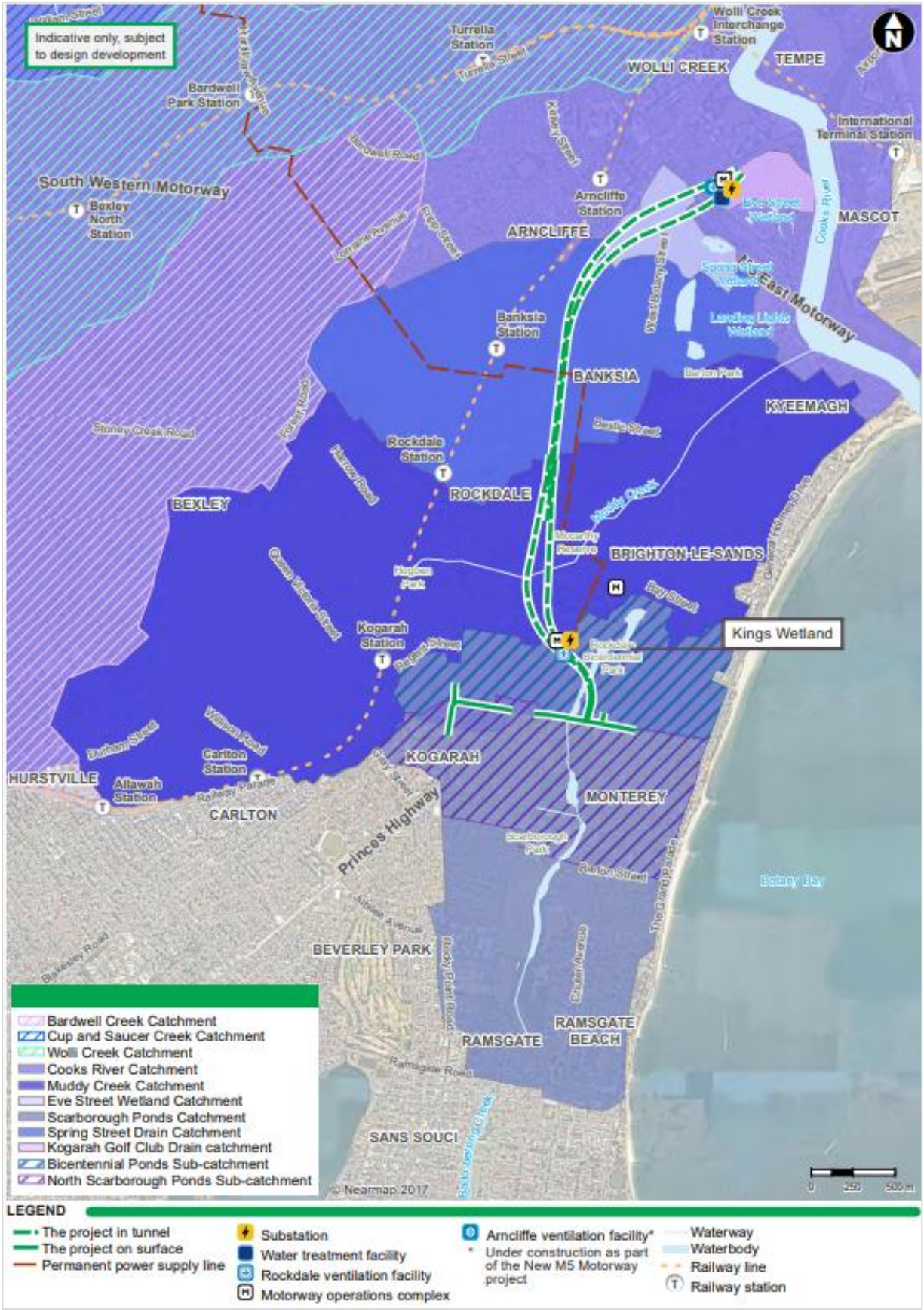

Figure 3: Catchments and water courses within the project footprint. Reproduced from Figure 4-5 of the EIS, Volume 6B, Appendix K Part 1, Groundwater Technical Report

4.2 Geological setting

The Project alignment is to be located within the Permo-Triassic Sydney Basin near the boundary between unconsolidated Quaternary sediments (referred to as coastal deposits in this report) of the Botany Bay sub-basin to the east, and the Triassic aged Hawkesbury Sandstone to the west.

Geological units encountered along the project, from most to least recently deposited, are:

- Fill material;
- Quaternary Coastal deposits (Holocene and Pleistocene) (paleochannels); and
- Triassic aged Hawksbury Sandstone.

An igneous dyke is inferred to intersect the project alignment approximately 388 m south of the Arncliffe precinct. This dyke was also encountered in Bexley, where a dolerite dyke dipping approximately 80° to the north and striking 280° was observed.

Though not encountered in any other boreholes within the project area, given the general east-west trend of dykes in Sydney and the north-south alignment of the M6S1 tunnel, it is possible unknown dykes will intersect the tunnel perpendicularly. These dykes are likely to be highly variable in weathering and strength, ranging from extremely weathered soil strength margins, to slightly weathered to fresh, high to extremely high strength inner cores.

Further detail is presented in the HIR and GIR.

4.3 Hydrogeological setting

4.3.1 Aquifers

The aquifers present across the project alignment can be broadly characterised as either the consolidated bedrock aquifer of the Hawkesbury Sandstone formation (bedrock aquifer), or unconsolidated coastal deposit aquifers of the Botany Basin.

Fill

Fill is not designated as an aquifer in the model and it is assumed the fill is of sufficiently high permeability as to not confine the coastal deposit aquifer as described below.

Coastal deposit aquifer

The term “coastal deposit” has been used in this report is to encompass the Botany Sands Aquifer as described in Hatley (2004), which comprises Holocene and upper Pleistocene marine, alluvial, aeolian and estuarine deposits. These include:

- Alluvial deposits which flank major rivers and creeks including the Cooks River, Georges River and Muddy Creek. The alluvial sediments consist of sand, silt, clay, gravels and some peat with a basal clay occasionally defining the base of the sequence. Some of the alluvium deposited in an estuarine environment contains shells and marine muds. Beneath the Rockdale Wetlands swamp deposits consisting of peat, sandy peat and mud. These are present in low lying areas and have been covered in fill including landfill in places.
- Coastal sands occurring along the western edge of Botany Bay between the beach sand and swamp deposits. The alluvial, aeolian and estuarine deposits of the coastal sands composed of quartz sand, minor shell content, inter-dune silt and fine sand and transgressive dune systems composed of medium to fine grained marine sand and podzols.

The coastal deposit is generally of high permeability and has been used for the extraction of groundwater since the 18th century (Hatley (2004)). The coastal deposit aquifer is generally unconfined. However, the aquifer can be semi-confined where discontinuous bands and lenses of clays, silts, peat, or cemented sands (aquitards) locally create conditions which fully or partially

confine the groundwater. The alluvium infilling the palaeochannels is considered to be highly transmissive due to the coarse sands and gravels present and a low clay content.

Review of the results of drilling and cone penetrometer testing indicates increasing clay content beneath palaeochannels in the vicinity of Bicentennial Park and the West Botany Street Depot construction sites. Transmissivity is expected to be significantly lower in these areas compared with the conditions closer to the coastline.

At the base of the coastal deposit, there is potential for presence of residual clay that separates the coastal deposit aquifer from the underlying bedrock, restricting groundwater leakage to or from the bedrock.

Bedrock aquifer

The Hawkesbury Sandstone is the dominant lithology across the study area and is present beneath the entire length of the mainline tunnel alignment, although it is at depth where the Cooks River palaeochannel (also noted as the Arncliffe palaeochannel) is incised. Lithologically, the Hawkesbury Sandstone is described as a medium to coarse grained quartzose sandstone. The Hawkesbury Sandstone displays bedding but also contains secondary structural features such as joints, fractures and faults. Igneous dykes may also be present. The Hawkesbury Sandstone can be characterised as a dual porosity aquifer whereby groundwater is transmitted by both the primary porosity or interconnected void space between grains of the rock matrix and the secondary porosity which is due to secondary structural features such as joints, fractures, faults, shear zones and bedding planes. The dominant flow occurs through the secondary structural features (rock defects) and flow through the pore space is typically minor to negligible.

The Hawkesbury Sandstone is not one aquifer but several ‘stacked aquifers’ due to the heterogeneous and layered nature of the unit. Interbedded shale lenses can provide local or extensive confining layers creating separate aquifers with different hydraulic properties including hydraulic heads.

4.3.2 Groundwater recharge and discharge

Recharge to the coastal deposit aquifer is primarily via direct rainfall recharge, locally enhanced by rainfall runoff and by rainfall infiltration in green spaces such as parks, gardens and golf courses. Recharge can also occur via limited upward leakage of water from the bedrock aquifer. Groundwater recharge has typically decreased as the extent of the urbanisation has increased due to enhanced runoff from hardstand areas directing stormwater directly into Botany Bay.

Groundwater flow within the deep palaeochannels is generally eastward discharging into Botany Bay.

In addition to groundwater discharge to the coastal environment, the contribution of baseflow to creeks and other groundwater dependent surface water bodies represents a groundwater discharge pathway for the coastal deposit aquifer.

Recharge of the bedrock aquifer is via rainfall infiltration on fractured rock outcrops and through leakage from the overlying soil profile. Discharge of the bedrock aquifer is typically via seepage from outcrops in topographically elevated areas, and evapotranspiration. Discharge of the bedrock aquifer also includes the upward leakage of water to the coastal deposit aquifer, although seepage from the bedrock may also occur in areas where tunnels (notably the M8 tunnels at the north of the project area) or deep basements are constructed.

4.3.3 Groundwater levels

An assessment of baseline groundwater levels across the project alignment is provided in Table 9 based on the information presented in the project-wide HFR and HIR and the information sources referred to in Section 3.5. Seasonal variation in groundwater levels in bores with 6 months or more data is summarised in Table 10. Figure 4 presents interpreted groundwater levels following the construction of the M8 tunnels (post M8) for the coastal deposits and the bedrock aquifer.

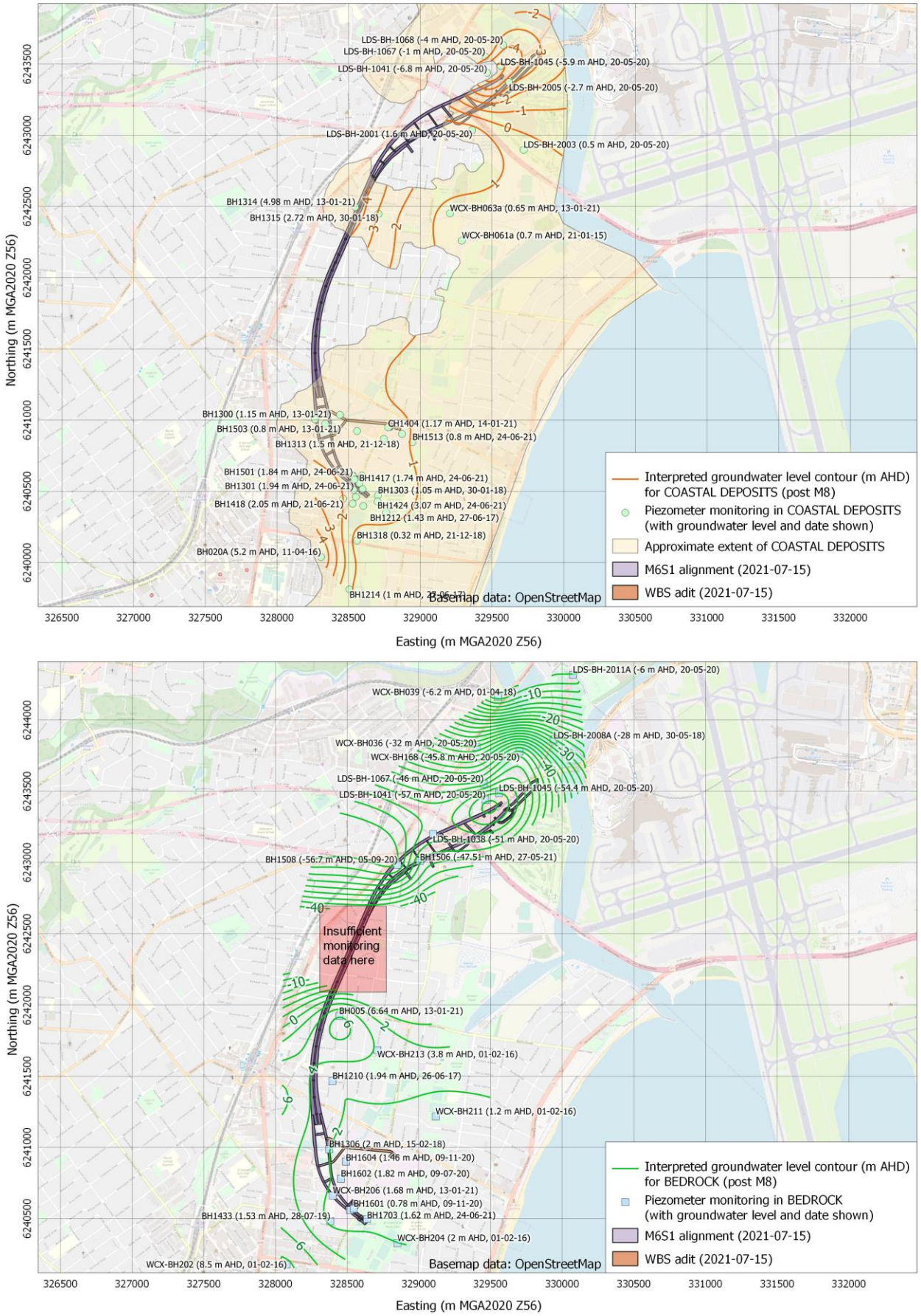

Figure 4: Interpreted (post M8 motorway) groundwater levels (m AHD) along the project alignment in the coastal deposits / alluvium and the bedrock aquifers

Baseline groundwater levels were measured at 49 existing groundwater bores in October 2021 and results are shown in Table 9 .

Table 9 Baseline groundwater levels measured at existing bores in October 2021

Bore ID	Easting MGA2020	Northing MGA2020	Ground level (mAHD)	TOC (mAHD)	Screened stratigraphic unit	Screen from (mbgl)	Screen to (mbgl)	Date	Groundwater level (mAHD)	Groundwater depth (mbgl)
BH002	328930	6243014	21.18	21.03	Bedrock	58	70	25-Oct-21	-21.70	42.88
BH005	328445	6241920	25.68	25.61	Bedrock	56.3	68.7	26-Oct-21	6.50	19.18
BH014A	328528	6240413	4.71	4.63	Alluvium	7	10	25-Oct-21	1.52	3.19
BH1102	328559	6242552	8.76	8.69	Bedrock	71	74	18-Oct-21	4.95	3.81
BH1143	328597	6240515	4.58	4.52	Alluvium	15.4	18.4	19-Oct-21	1.47	3.11
BH1212	328762	6240351	4.50	4.42	Alluvium	13	16	19-Oct-21	1.26	3.24
BH1300	328265	6241005	2.53	2.36	Alluvium	13	16	25-Oct-21	1.01	1.52
BH1301	328535	6240509	3.21	3.11	Alluvium	9.65	12.65	25-Oct-21	1.60	1.61
BH1303	328704	6240471	5.02	4.92	Alluvium	10	19	19-Oct-21	1.32	3.70
BH1313	328746	6240868	2.92	2.86	Alluvium	23.1	29.1	19-Oct-21	1.26	1.66
BH1314	328546	6242495	7.95	7.80	Alluvium	19	25	26-Oct-21	5.05	2.90
BH1315	328709	6242448	3.88	3.78	Alluvium	25.6	31.6	18-Oct-21	3.29	0.59
BH1318	328558	6240154	2.38	2.32	Alluvium	5.8	8.8	19-Oct-21	1.03	1.35
BH1415	328665	6240495	5.25	5.15	Fill/Alluvium	2.4	14.4	25-Oct-21	2.23	3.02
BH1417	328574	6240556	3.12	3.02	Alluvium	2.65	5.65	26-Oct-21	1.63	1.49
BH1418	328462	6240448	3.16	3.06	Alluvium	4	7	26-Oct-21	1.56	1.60

Bore ID	Easting MGA2020	Northing MGA2020	Ground level (mAHD)	TOC (mAHD)	Screened stratigraphic unit	Screen from (mbgl)	Screen to (mbgl)	Date	Groundwater level (mAHD)	Groundwater depth (mbgl)
BH1421	328872	6240903	3.15	3.05	Alluvium	1.8	13.8	25-Oct-21	1.43	1.72
BH1424	328701	6240429	2.87	2.77	Alluvium	2	14	25-Oct-21	1.73	1.14
BH1425	328739	6240382	3.59	3.49	Fill/Alluvium	2	14	25-Oct-21	1.45	2.14
BH1428	328519	6240559	3.22	3.17	Bedrock	17	35	26-Oct-21	1.39	1.83
BH1429	328549	6240460	4.04	3.94	Alluvium	5.8	8.8	25-Oct-21	1.40	2.64
BH1432	328602	6240396	4.54	4.44	Alluvium	5	8	25-Oct-21	1.51	3.03
BH1501	328529	6240609	3.18	3.08	Alluvium	3.1	6.1	26-Oct-21	1.60	1.58
BH1503	328337	6240975	3.45	3.35	Alluvium	14.2	17.2	25-Oct-21	0.80	2.65
BH1511	328559	6240923	3.24	3.14	Alluvium	10.8	13.8	26-Oct-21	0.80	2.44
BH1513	328945	6240845	2.99	2.89	Alluvium	21	25	25-Oct-21	0.99	2.00
BH1514	328540	6240583	3.15	3.05	Alluvium	2.6	5.6	26-Oct-21	1.60	1.55
BH1701	328600	6240532	4.56	4.45	Bedrock	27	30	19-Oct-21	0.77	3.78
BH1702	328619	6240513	5.06	4.94	Alluvium	20.8	22.8	19-Oct-21	1.24	3.82
BH1703	328639	6240495	5.08	4.94	Bedrock	24.8	27.8	19-Oct-21	0.93	4.15
CH1403	328593	6240610	3.23	3.13	Alluvium	5	8	26-Oct-21	1.27	1.96
CH1404	328775	6240948	3.10	3.05	Alluvium	1.8	13.8	25-Oct-21	1.19	1.91
CH1411	327956	6240257	12.53	12.48	Fill	1.6	3.6	26-Oct-21	10.10	2.43
LDS-BH-1038	329099	6243199	15.15	15.08	Bedrock	65	74	26-Oct-21	-50.18	65.33

Bore ID	Easting MGA2020	Northing MGA2020	Ground level (mAHD)	TOC (mAHD)	Screened stratigraphic unit	Screen from (mbgl)	Screen to (mbgl)	Date	Groundwater level (mAHD)	Groundwater depth (mbgl)
LDS-BH-2001	329362	6243036	2.21	2.13	Alluvium	1.5	5	18-Oct-21	1.54	0.67
LDS-BH-2003	329720	6242897	2.41	2.36	Alluvium	6	9	18-Oct-21	0.53	1.88
LDS-BH-2008A	329940	6243863	1.79	1.68	Bedrock	44	50	18-Oct-21	-39.03	40.82
WCX-BH029	329350	6242710	4.28	4.20	Bedrock	33	36	19-Oct-21	-1.34	5.62
WCX-BH036	329403	6243810	1.58	1.53	Bedrock	60	63	18-Oct-21	-31.48	33.06
WCX-BH039	329554	6244159	3.32	3.22	Bedrock	49	52	18-Oct-21	-12.11	15.43
WCX-BH063a	329207	6242451	3.41	3.31	Alluvium	5	8	25-Oct-21	0.69	2.72
WCX-BH070	329042	6242922	17.54	17.46	Bedrock	35	38	18-Oct-21	4.76	12.78
WCX-BH074	329228	6243672	2.58	2.49	Bedrock	39	42	18-Oct-21	-16.38	18.96
WCX-BH094	327868	6243176	31.17	31.05	Bedrock	54	57	18-Oct-21	25.34	5.83
WCX-BH168	329703	6243777	1.36	1.27	Bedrock	48	51	18-Oct-21	-44.97	46.33
WCX-BH202	328078	6240176	12.91	12.83	Bedrock	35.5	38.5	19-Oct-21	8.39	4.52
WCX-BH206	328399	6240660	2.39	2.25	Bedrock	19	22	26-Oct-21	1.41	0.98
WCX-BH213	328710	6241681	10.84	10.74	Bedrock	29	32	18-Oct-21	4.70	6.14
WCX-BH214	329228	6241856	4.44	4.36	Bedrock	31.5	34.5	18-Oct-21	0.73	3.71

Table 10 Variation in groundwater levels for bores with more than 6 months of monitoring data

Borehole reference	Easting (m)	Northing (m)	Elevation (mAHD)	Logged Screened lithology	Monitoring period	Approximate duration of monitoring (month)	Typical groundwater level during monitoring period (m AHD)	Measured variation during monitored period (m)
Coastal Deposits								
WCX-BH061a	329289	6242259	0.9	Sand/Sandy Silt	Dec 14 to Jun 15	6	0.6	0.2
WCX-BH063a	329206	6242450	3.3	Silty Sand	May 20 to Jan 21	6	0.8	0.4
BH014A	328527	6240412	4.7	Sand/Sandy Clay	May 20 to Jan 21	8	1.6	0.5
BH1301	328534	6240508	3.2	Sand	Feb 19 to Mar 20	13	1.7	1.1
BH1417	328574	6240554	3.1	Silty Sand	Mar 19 to Mar 20	12	1.7	0.7
BH1418	328462	6240446	3.2	Sand	Feb 19 to Mar 20	13	1.6	1.0
BH1421	328872	6240901	3.1	Sand/Clay	Nov 18 to Mar 20	16	1.3	0.9
BH1424	328700	6240427	3.6	Sand	Jan 19 to Mar 20	13	1.7	1.2
BH1429	328549	6240459	4.0	Sand	Mar 19 to Mar 20	12	1.5	0.9
BH1432	328602	6240395	4.5	Sand	Mar 19 to Mar 20	12	1.6	0.6
CH1403	328592	6240609	3.2	Sand/Sandy Clay	Feb 19 to Mar 20	13	1.5	0.9
CH1404	328775	6240947	3.1	Sand	Nov 18 to Mar 20	16	1.0	0.8
Bedrock								
WCX-BH029	329350	6242709	4.3	Sandstone	Dec 14 to Apr 18	40	1.0	3.3
WCX-BH039	329553	6244158	3.3	Sandstone	Feb 15 to Jan 17	23	-1.1	1.0

Borehole reference	Easting (m)	Northing (m)	Elevation (mAHD)	Logged Screened lithology	Monitoring period	Approximate duration of monitoring (month)	Typical groundwater level during monitoring period (m AHD)	Measured variation during monitored period (m)
WCX-BH070	329042	6242920	17.5	Sandstone	Nov 14 to Feb 17	27	6.7	2.2
WCX-BH093	327657	6243183	36.4	Sandstone	Dec 14 to May 18	41	-1.6	4.5
WCX-BH094	327867	6243174	31.2	Sandstone	Apr 15 to May 18	37	27.5	4.0
WCX-BH202	328078	6240175	12.9	Sandstone	Feb 15 to Feb 16	12	8.3	0.6
WCX-BH204	328850	6240325	4.2	Sandstone	Mar 15 to Jan 16	10	2.2	0.6
WCX-BH206	328399	6240659	2.4	Sandstone	May 20 to Jan 21	8	1.8	0.5
WCX-BH211	329117	6241214	2.1	Sandstone	Feb 15 to Jan 16	11	1.2	1.0
WCX-BH213	328710	6241680	10.8	Sandstone	Feb 15 to Jan 16	11	4.0	1.2
WCX-BH214	329228	6241854	4.4	Sandstone	Feb 15 to Jan 16	11	-0.5	2.6
BH002	328930	6243013	21.2	Sandstone	May 20 to Jan 21	8	-20.5	0.4
BH005	328444	6241919	25.7	Sandstone	Jun 20 to Jan 21	7	6.7	0.4
BH1403	328489	6241045	2.5	Sandstone	Jan 19 to Jul 19	6	2.1	1.5
BH1428	328518	6240557	3.2	Sandstone	Mar 19 to Mar 20	12	1.5	1.0

The following sections discuss groundwater levels along the Project alignment from the northern end at Arncliffe to President Avenue. The positions along the alignment are referred to by chainage along the southbound main tunnel (the M110 alignment).

North of M110 CH700 – Arncliffe Palaeochannel

Groundwater in the coastal deposits and bedrock aquifers is inferred to flow towards the M8 motorway and the existing M5 East tunnels. Recent monitoring of groundwater level within the coastal deposits indicates that the shallower deposits experienced a slower and reduced fall in groundwater level due to the M8 motorway construction compared with deeper deposits. It is also noted that the groundwater level in the coastal deposits is significantly higher than the groundwater level within the bedrock aquifer. This may be caused by the following:

- Presence of aquitards within and at the base of the coastal deposits, separating the coastal deposits from the bedrock (bands and lenses of clays, silts, peat, or cemented sands in the coastal deposits, and residual soil above the bedrock).
- Shallower deposits being better connected to the ocean (via Cooks River) compared to the deeper deposits and bedrock, and therefore drawdown in the shallower deposits is suppressed.
- Groundwater head gradients towards the M8 and M5 East tunnels.

Vibrating Wire Piezometer (VWP) results illustrate that groundwater levels in the soil and rock profile have reduced due to the M8 motorway construction, but saturation of the soil profile remains, and groundwater levels at deep locations in the rock have fallen well below the base of the soil at two locations west of the M8 motorway (at the MOC1 Project location). Coffey interprets this to indicate restricted hydraulic connection between the soil and the rock. Coffey considers that where the groundwater level within bedrock aquifer is currently below the base of the soil, further change in groundwater level within the sandstone due to the construction of the M6S1 tunnels will have a limited effect on groundwater levels within the soil profile.

M110 CH700 to CH1450

The ground surface elevation increases to 32 mAHD in this area. The bedrock aquifer contains the watertable in this section. The groundwater flow direction is inferred to be towards the M8 and M5 East tunnels.

M110 CH1450 to CH1850 (Spring Street Drain palaeochannel)

The Spring Street Drain palaeochannel exists in a topographic low and is infilled with coastal deposit material. Groundwater in both the coastal deposit and bedrock aquifers flows to the east and discharges to Muddy Creek and Cooks River. Within this palaeochannel, the groundwater level within the bedrock is likely to be influenced by the existing M8 and M5 East tunnels. South of Spring Street the pre M8 groundwater level in the rock is interpreted to rise to approximately 6 to 7 mAHD while the groundwater level in the coastal deposits is interpreted to be approximately 4 mAHD. This suggests an upward gradient from the bedrock to the coastal deposit.

Interpreted post M8 groundwater levels in the bedrock are not provided for this area due to insufficient data availability.

M110 CH1850 to CH2750

Groundwater level in the rock is inferred to be up to approximately 7 mAHD in the northern end of this section, and approximately 4 mAHD at the southern end of this section.

Groundwater flow is expected to flow east and south east towards the lower topography areas, ultimately flowing into Botany Bay.

South of M110 CH2750 (Muddy Creek palaeochannel)

Groundwater flow is inferred to be generally eastward towards the Botany Bay in both the alluvial and bedrock aquifer.

Approximately west of southbound ramp (M1A0) CH650, the groundwater level within the bedrock is noted to be slightly higher than the groundwater level in the coastal deposits, indicating an upward gradient from the bedrock to the coastal deposit.

Groundwater level variability

Groundwater levels vary in response to climatic conditions. Typical seasonal fluctuations are within 2 m of the average pre-development groundwater levels. Allowance of short term increase in groundwater level associated with severe storm events during construction is considered in the Project design and in the construction methodology.

4.3.4 Groundwater quality

An assessment of baseline water quality was conducted and is attached in Appendix C based on the HIR and key identified contaminants are summarised below. A detailed assessment is provided in Appendix C and the available baseline water quality data was collated and presented in the HFR.

- In the coastal deposit aquifer the total dissolved solids (TDS) is generally in the range 200 mg/L to 1,200 mg/L though higher salinity will be present adjacent to estuarine and marine waters. In the bedrock aquifer along the Project alignment TDS is generally in the range of 300 mg/L to 2,500 mg/L. Higher TDS (up to 12,000 mg/L) concentrations are likely to be encountered in the northern end of the of the tanked structure, west of Rockdale Wetland.
- In the area west of Barton Park and Barton Park golf range groundwater in the coastal deposit aquifer is likely to be categorised as ‘severely aggressive’ towards steel structures and ‘moderately aggressive’ towards concrete structures. The EIS characterised groundwater across the alignment as mildly aggressive.
- Former landfills are present to the east and west of Bicentennial Park Wetlands. Elevated TDS, ammonia, total nitrogen, bicarbonate and sulfate in the coastal deposit aquifer in the area suggest groundwater may be impacted by landfill leachate. Minor impact is reported in the bedrock aquifer in the area.
- Low level hydrocarbon contamination is reported in Spring Street palaeochannel. Hydrocarbons were also reported in the vicinity of Bicentennial Park with landfill waste and an industrial estate in the area nominated as likely sources.
- PFAS was detected in excess of ecosystem protection criteria in wells in the vicinity of MOC1 Arncliffe, Spring Street and MOC3 Bicentennial Park.

4.3.5 Groundwater receptors

Potential impacts resulting from Project activities prior to the implementation of mitigation measures were identified and assessed as part of this preliminary groundwater impact assessment presented in the HIR.

The Project will interact with the groundwater environment during the construction phase. The construction methods and permanent design adopted for the underground structures directly influences the way in which the project will impact groundwater systems and sensitive receptors.

Key sensitive receptors identified in the vicinity of the Project include:

- Registered extractive groundwater users
- Groundwater dependent ecosystems (GDEs)

Registered extractive groundwater users

Details of registered groundwater bores near the Project is provided in the HFR. Section 5.2.3 of this Plan summarises the assessment of registered groundwater users that are potentially

impacted by Project construction activities. Further detail of the assessment is presented in the HIR.

Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are receptors that rely wholly or partially on groundwater to provide all or some of their water needs. GDEs relevant to this project can broadly be categorised as:

- **Terrestrial GDEs:** Ecosystems reliant on the subsurface presence of groundwater (i.e. vegetation that is accessing the watertable and/or capillary fringe).
- **Aquatic GDEs:** Ecosystems reliant on the surface expression of groundwater (i.e. wetlands and baseflow fed watercourses).

Subterranean GDEs have not been mapped in the vicinity of the proposed alignment, are not expected, and as such are not considered further.

The following primary resource was used to identify potential GDE landscapes within and in the vicinity of the tunnels: *BoM (2019) Australian Government Bureau of Meteorology Groundwater Dependent Ecosystems Atlas (http://www.bom.gov.au/weave/gde.html).*

This was supplemented with assessments made in the following reports:

- Aurecon 2020, M6S1 Hydrogeological Interpretive Report. Appendix S of the Environmental Impact Statement

A search of groundwater dependent ecosystems within a 2 km buffer of the project alignment identified a number of aquatic and terrestrial ecosystems listed as having a moderate or high potential to be groundwater dependent.

The location of mapped potential aquatic and terrestrial GDEs are presented in Figure 5.

Aquatic groundwater dependent ecosystems

The following sections describe the existing condition of aquatic GDEs within 2 km of the Project alignment that have been assessed as having high likelihood of groundwater dependence. Additional high value GDEs identified at distances greater than 2 km have also been included and discussed below.

A summary of aquatic GDEs and an assessment of likelihood of groundwater dependence and ecosystem value is presented in Table 11 and their locations shown on Figure 5.

Cooks River

Cooks River is a tidally-influenced estuary that discharges to Botany Bay. The river is a regional groundwater discharge feature and receives baseflow contribution under natural conditions.

Modelling completed for the M8 motorway predicted that the coastal deposit aquifer which provides baseflow discharge to Cooks River is likely to be hydraulically connected to the underlying bedrock aquifer. Groundwater levels within the bedrock aquifer have been drawn down below the base of the overlying coastal deposit aquifer over a wide area as a result of construction of the M8 motorway (discussed in Section 7 of the HIR). Groundwater drawdown around the M8 tunnels is likely to have reversed hydraulic gradients between Cooks River and the coastal deposits aquifer and the section of Cooks River may no longer receive groundwater discharge where it passes the Project alignment.

Coastal Wetlands

The coastal wetlands system is comprised of a chain of wetlands following the Muddy Creek and Scarborough Ponds sub-catchments, both of which have been highly developed for urban land use with the creek itself concrete and brick-lined. The wetlands form part of a recreation corridor and are highly altered from their original form, which was part of a more extensive complex of wetlands along the western shore of Botany Bay (Aurecon, 2020).

The wetland system provides highly altered freshwater grading to marine (estuarine) aquatic ecosystems which receive groundwater discharge from the Botany Sands unit of the coastal deposit aquifer. The wetlands have been drained and reworked to create largely artificial lakes, however they still form part of important habitat for a variety of native animals and migratory birds.

The wetland system in the project area is comprised of the following individual wetlands which are identified in Figure 5:

- Rockdale and Bicentennial Park wetlands: Between Cooks River and Georges River.
- Marsh St wetland: south west of Kogarah Golf Course.
- Eve Street wetland
- Spring Street Drain and Landing Lights wetland
- Kinds Wetland
- Scarborough Ponds

Further description of each wetland and pond is provided in Table 11 together with an assessment of their likelihood of groundwater dependence. Predicted impacts to wetlands are summarised in Section 5.

Botany Wetlands and Lachlan Swamps

Botany Wetlands, located 4.6 km east of the Project and the Lachlan Swamps, located in Centennial Park approximately 8 km north east of the Project are identified as high priority GDEs which source groundwater from the coastal deposit aquifer.

Impacts these wetlands were assessed as part of the M8 Motorway EIS. They are considered to be at a sufficient distance from the project that there is no feasible impact pathway from the Project. Botany Wetlands and Lachlan Swamps are not considered further.

Salt Pan Creek

Located 8 km west of the project alignment, Salt Pan Creek is listed as high priority GDE. The creek is located at sufficient distance from the project that there is no feasible impact pathway from the project. The surface water study supporting the EIS did not assess Salt Pan Creek and it is not considered further by this assessment.

Table 11 Summary of aquatic GDEs within 2 km of project alignment

GDE	Relevant aquifer	Likelihood of groundwater dependence	Preliminary Ecosystem Value	Comments
Marsh St Wetland	Coastal deposit	Low	Moderate	Site of M8 construction activities. Breeding ponds for Green and Golden Bell Frogs constructed near golf course (RTA ponds) to mitigate impacts of the M8 Motorway. Not groundwater dependent.
Eve Street wetland	Coastal deposit	High	High	Marine and coastal wetland covering approximately 2 ha, subject to saline tidal flows twice daily. Receives stormwater runoff from the surrounding catchment. Marsh listed on directory of important wetlands of Australia.
Spring Street Drain	Coastal deposit	Moderate	Low	Concrete lined drain flowing to the east from Rockdale to Muddy Creek (AECOM, 2018)
Landing Lights wetland	Coastal deposit	High	High	Tidal saline salt marsh, flushed with saline water from Cooks River and fresh water runoff from storm events (AECOM, 2018). Provides important habitat for migratory birds. The northern pond is referred to as the Spring Street Wetland. It is reported to have potential for recharge of saline water to coastal deposits and underlying basement aquifers.
Rockdale/Bicentennial Park Wetlands	Coastal deposit	High	Low	Highly modified wetland ecosystem acts as a stormwater retention system. Approximately 1.2 to 2.0 m deep, relies on groundwater to maintain shallow levels of 1 to 1.5 mAHD. Water quality is degraded from local groundwater contamination sources (nearby landfills).
Kings wetland	Coastal deposit	High	Moderate	200 m^2 wetlands surrounded by parkland. Water level monitoring indicates Kings Wetland and Rockdale Wetland naturally fluctuate up to 0.5 m in line with groundwater, and are groundwater dependent (AECOM, 2018).

GDE	Relevant aquifer	Likelihood of groundwater dependence	Preliminary Ecosystem Value	Comments
Scarborough Ponds	Coastal deposit	High	High	Receives surface water flow from Kings Wetland to the north. Northern pond is stratified between fresh (surface) and saline water (base) and receives fresh water inflow from Rockdale Bicentennial Park Pond. Important habitat for fish in Botany Bay. Becomes tidal further south.
Muddy Creek (downstream)	Coastal deposit	High	Low	Estuarine setting, likely to receive groundwater but expected to be brackish. Highly altered ecosystem (EES Appendix K - Groundwater technical report)
Muddy Creek (upstream)	Coastal deposit	Low*	Low	Upstream of Bestic Street, Muddy Creek is concrete lined and is unlikely to either receive substantial groundwater baseflow and is highly modified.
Cooks River	Coastal deposit	High	Moderate	Key fish habitat, however poor water quality and highly altered riparian zone. Some recreational use. Low sensitivity.

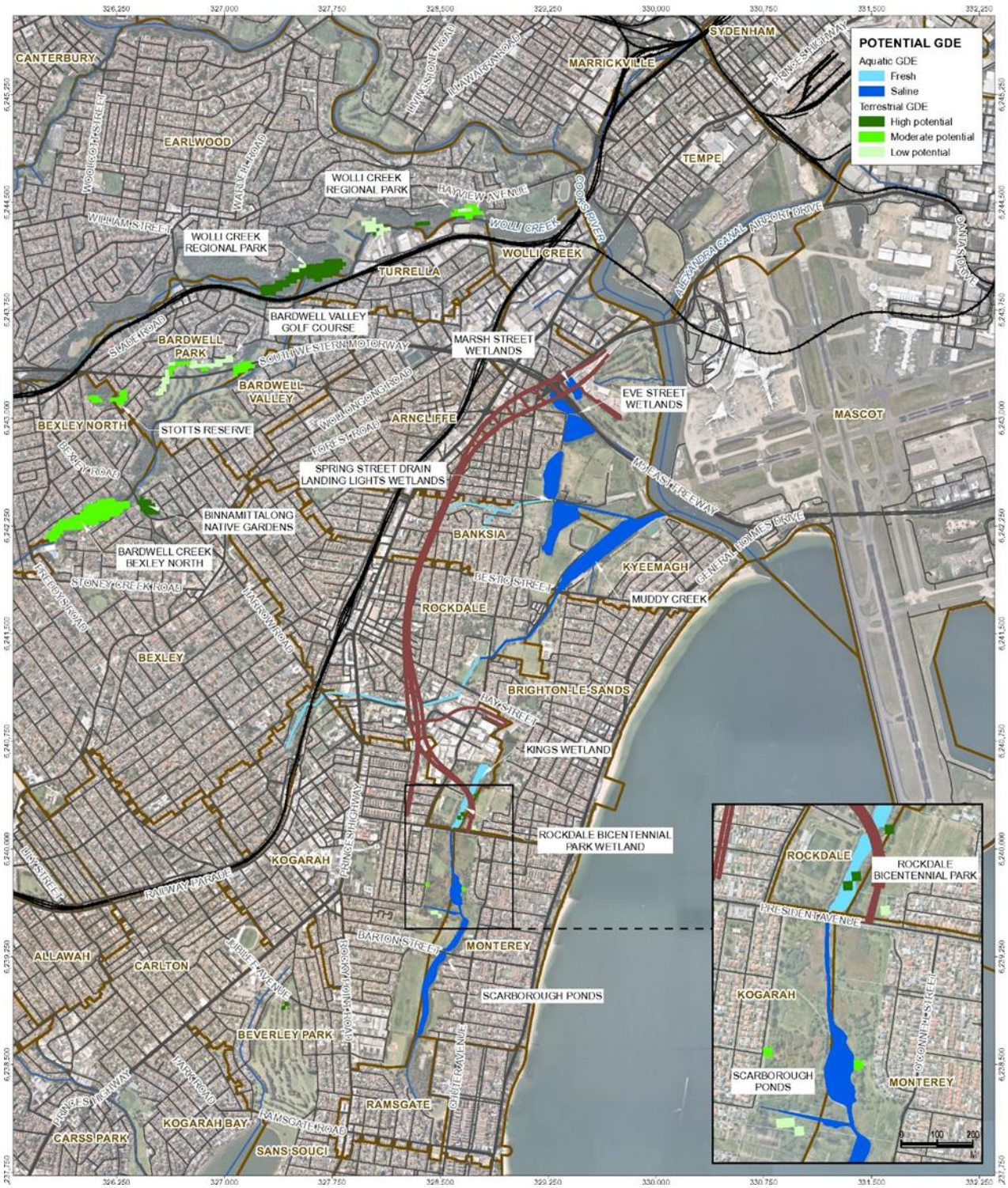

Figure 5: Location of potential aquatic & terrestrial GDEs

Terrestrial groundwater dependent ecosystems

Terrestrial GDEs are ecosystems with vegetation that relies on the availability of shallow groundwater, which is within reach of the root zone. Mature, large trees are likely to have the deepest root systems and are the most likely vegetation type in a given ecosystem to access groundwater.

The summary presented in Table 12 describes the terrestrial GDEs identified within 2 km of the Project alignment. Their locations are shown in Figure 5.

All of the identified terrestrial GDEs are listed with moderate to high likelihood of groundwater dependence.

Table 12 Summary of terrestrial GDEs within 2 km of project alignment

GDE	Terrestrial ecosystem type	Relevant aquifer	Likelihood of groundwater dependence [1]
Wolli Creek Regional Park	Riparian vegetation of Floodplain Swamp Forest	Coastal Deposits	Low to High potential
Bardwell Creek (Bexley North)	Hinterland Sandstone Gully Forest	Basement	Moderate potential
Bardwell Valley Golf Course	Hinterland Sandstone Gully Forest and Coastal Sandstone Ridgetop Woodland	Coastal Deposits	Low to moderate potential
Stotts Reserve	Coastal Sandstone Ridgetop Woodland	Coastal Deposits	Moderate potential
Binnamittalong Native Gardens	Hinterland Sandstone Gully Forest	Basement	High potential
Civic Avenue Reserve / Scarborough Ponds	Eastern Suburbs Banksia Scrub	Coastal Deposits	Low to moderate potential
Rockdale Wetland / Bicentennial Park	Estuarine Fringe Forest	Coastal Deposits	High potential

1. Likelihood based on GDE Atlas (GDE Atlas)

5 Environmental aspects and impacts

5.1 Construction activities

Key aspects of the Projects that could result in adverse impacts to groundwater include:

- Tunnelling activity associated with the construction of the mainline tunnels.
- Dewatering associated with excavation of decline and temporary and permanent shaft structures at Bicentennial Park and Rockdale Depot.
- Operation of the construction WTP at C1, C2 and C3.
- Site activities, including chemical storage and incident management.

5.2 Impact prediction and assessment

Predicted impacts of construction on sensitive receptors was discussed in the HIR. The findings are summarised in the following sections.

5.2.1 Overview

The potential for impacts on groundwater will be dependent on the nature, extent and magnitude of construction activities and their interaction with the natural environment. Key risks posed by the project to the groundwater environment during construction are summarised in Table 13 .

Table 13 Key potential groundwater risks

Issue	Risk
Change in groundwater level	Reduced availability for groundwater dependent ecosystems (aquatic and terrestrial)
	Reduced availability for existing extractive groundwater users
	Acidification of groundwater due to oxidation of acid sulfate soil and rock
	Impact on third party structures (property, utilities and the environment) due to consolidation settlement
	Mounding and barrier effects
Change in groundwater quality	Mobilisation of existing groundwater contamination into previously unaffected areas resulting in unacceptable risk to sensitive receptors/third parties
	Mobilisation or generation of groundwater having quality that is adverse to underground structures
	Degradation of groundwater quality by drawing saline water from estuaries, wetlands and the coast into the aquifer
	Contamination of groundwater due to surface spills and leaks
Disposal of groundwater	Management of groundwater seepage into construction excavations or permanent structures resulting in unacceptable impacts at the point of discharge

Some impacts on groundwater attributable to the Project are anticipated. Relevant aspects and the potential for related impacts have been considered in a risk assessment in the Aspects and Impacts Register included in Appendix A2 of the CEMP. Environmental control measures

Specific measures and requirements to meet the objectives of this GMP and to address impacts on groundwater are outlined in Table 16 which summarises a suite of mitigation measures that will be implemented to avoid or minimise those impacts.

Cumulative impacts to groundwater are not anticipated to occur from staging of the Project or during construction of the Project. Where unexpected cumulative impacts are identified during works, they will be managed through compliance with relevant CoAs, coordination with external stakeholders including utility providers, and implementation of EMMs related to key environmental impacts. The mechanism for identifying any potential unexpected cumulative impacts will be through monitoring, inspections, reporting and auditing.

5.2.2 Groundwater treatment and discharge

Construction water treatment plants will be established and operated at the Arncliffe Construction Ancillary Facility (C1), Rockdale Construction Ancillary Facility (C2) and President Avenue Construction Ancillary Facility (C3) to treat water from the tunnel works.

Groundwater will be treated by the WTPs prior to being used on site, or discharged to surface or groundwater environments. Where feasible, water from the water treatment plants will be reused for construction activities. Discharge from WTPs will be accordance with the parameters of the Project EPL (EPL 21600).

Treatment and discharge processes for surface water are detailed in the Soil and Surface Water CEMP Sub-plan (Appendix B4 of the CEMP).

5.2.3 Registered extractive groundwater users

Extractive groundwater users require consideration of both potential level and quality impacts associated with the construction phase of the Project.

The Project is required to comply with *Table 1 – Minimal Impact Considerations for Aquifer Interference Activities* of the NSW Aquifer Interference Policy which specifies that the project must not result in a cumulative water level decline of more than 2 m at any water supply work (groundwater bore).

Groundwater modelling has been applied to predict drawdown impacts at each registered extractive use bore.

Nine active bores with a registered extractive or unknown use are predicted to experience greater than 2 m drawdown and will likely require rectification works during construction phase. The bore construction details are summarised in Table 14.

All bores are located in the vicinity of Spring Street and the locations are included in Figure 6.

In the Bicentennial Park and West Botany Street depot areas, the recharge systems for the construction period will limit drawdown to less than 2 m, therefore registered bores in these areas will not be impacted.

In addition to the above assessment, further consideration has been given to other bores where drawdown of less than 2 m might result in a loss of more than 10% of the available water column. While bores falling into this category do not require rectification works under the NSW Aquifer Interference Policy, CoA E173 requires identification and commitment for ‘make good’ provisions in the event of a material decline in water supply levels, quality and quantity.

Affected bore users will be notified that the bore water is not suitable for use and the corrective actions being taken by the project. Bore users will be notified again once the bore water is safe for use.

Rectification works may take different forms for different users and will require negotiation on a case by case basis.

Some potential options (based on previous experience with other projects) include:

- Installation of rainwater tanks (feasible option)
- Compensation for long term potable water supply costs

Table 14 Predicted drawdown in registered bores in excess of 2 m

Bore ID	Use	Easting (MGA2020)	Northing (MGA2020)	Screened aquifer	Bore depth (m)
GW023191	Water supply	329042	6242526	Coastal deposits	3.6
GW023194	Water supply	329157	6242812	Coastal deposits	4.8
GW024062	Water supply	328681	6242386	Coastal deposits	3.6
GW106450	Water supply	329137	6242026	Coastal deposits	2
GW108295	Water supply	328907	6242467	Coastal deposits	8
GW108439	Water supply	328893	6242479	Coastal deposits	8
GW108870	Water supply	329102	6242292	Coastal deposits	5
GW110735	Water supply	328936	6242530	Coastal deposits	8
GW111790	Water supply	328909	6242515	Coastal deposits	6

Figure 6: Location of registered bores where drawdown greater than 2m is predicted

5.2.4 Groundwater modelling and design

A detailed groundwater model will be developed by CGU. The model will be used to predict groundwater inflow rates and volumes within the tunnels and groundwater levels (including drawdown) in adjacent areas during construction and operation of the project.

In accordance with CoA E172, CGU will implement measures to limit operational groundwater inflows into each tunnel to no greater than one litre per second across any given kilometre (1 L/s/km) and notes that compliance with this condition cannot be determined by averaging groundwater inflows across the length of the tunnel(s). Measures to reduce potential impacts to groundwater flows due to subsurface components of the project will be identified and included in the detailed construction methodology and the detailed design as relevant.

5.2.5 Settlement

Ground movement is an expected outcome of tunnelling projects. The ground movement anticipated is predominantly settlement (also termed subsidence). Upward ground movement (also termed heave) may also occur. The causes of ground movement due to tunnelling can be classified as:

- Consolidation of the soil profile - due to water inflow into the tunnel resulting in groundwater drawdown in the overlying soil profile. This results in an increase in stress in the soil matrix as water is lost from the soil pores (settlement only)
- Tunnel induced movement - due to the change in stresses in the surrounding rock mass and ground loss caused by the tunnel excavation (settlement or upward heave).

5.2.6 Groundwater quality

Groundwater quality may be impacted by Project activities by in the following ways:

- Groundwater drawdown leading to saline water intrusion
- Groundwater drawdown leading to groundwater acidification
- Groundwater drawdown mobilising existing groundwater contamination

Preliminary assessment of these potential impacts is presented below.

Saline groundwater intrusion

Groundwater in the coastal deposit aquifer is fresh with TDS concentrations typically below 500 mg/L. Under existing conditions groundwater discharges to the wetlands to the east of the project alignment or continues to the coast. Many of these wetlands are tidally influenced and contain saline or brackish water.

Modelling work completed during reference design identified that saline water may be drawn into the aquifer and towards underground structures from the following areas:

- Cooks River/Alexandra Canal
- Wolli Creek
- Spring Street Drain
- Muddy Creek

Reference design modelling included particle tracking to show the predicted movement of saline water as it is drawn into the aquifer and towards the drained structures (refer to Figure 7).

This tender phase hydrogeological assessment considered both the reference design model results as well as tender phase drawdown assessment in the coastal deposit aquifer. Groundwater drawdown of 0.5 m or more has been assumed as a trigger for potentially reversing hydraulic gradients at saline surface water features leading to saline groundwater intrusion. The following assessment is provided.

Cooks River, Wolli Creek and Alexandra Canal

Groundwater in the vicinity of these saline surface water features is expected to have already been drawn down by construction of the M8 tunnel. Project construction activities are not expected to increase the risk profile, however more detailed modelling is underway to further assess potential adverse impacts to existing groundwater conditions.

Spring Street Drain, Muddy Creek

Reference design modelling shows that groundwater is likely to be drawn down below the base of both Spring Street Drain and Muddy Creek causing surface water to recharge groundwater. While this was identified as a saline groundwater intrusion risk by the reference design modelling, information available during the assessment suggests that surface water is likely to be fresh where they pass the project alignment, and where groundwater drawdown is greatest.

For Muddy Creek, the tender stage drawdown assessment places the 0.5 m drawdown contour approximately where the creek becomes tidally influenced (described as somewhere around West Botany Street or further east). There is a moderate potential for some saline groundwater intrusion to occur depending on the extent of the tidal zone along Muddy Creek. Further input from the

surface water study is required and will be considered in conjunction with ongoing modelling to confirm risk.

Monitoring of groundwater levels and groundwater quality will be carried out to check for changes in groundwater level and salinity during and following the construction of the road tunnels.

Spring Street Drain Wetland and Landing Lights Wetland

These two wetlands are understood to be tidally influenced and may be a source of saline recharge to the aquifer if groundwater is drawn below their base. Salinity of the Spring Street Drain wetland is less certain based on the limited available data.

Groundwater drawdown at the Spring Street Drain wetland is predicted to range from 1.0 m to 3.0 m and, if this wetland is confirmed as saline, may represent a risk of saline groundwater intrusion. Further work is required to confirm surface water salinity. There are approximately seven groundwater supply bores between the wetland and the Project alignment that may experience increased groundwater salinity over time.

Groundwater drawdown at the Landing Lights Wetland is predicted to range from 0.5 m to 1.0 m and may result in saline groundwater intrusion to the aquifer. There are approximately seven groundwater supply bores (including one irrigation bore) between the wetland and the project alignment that may experience increased groundwater salinity over time.

In total, eight private water supply bores may be at risk of reduced water quality over time. Further input from the surface water study is required and will be considered in conjunction with ongoing modelling to confirm risk. Depending on the level of impact, rectification works may be required to provide an alternative water supply for the affected groundwater users.

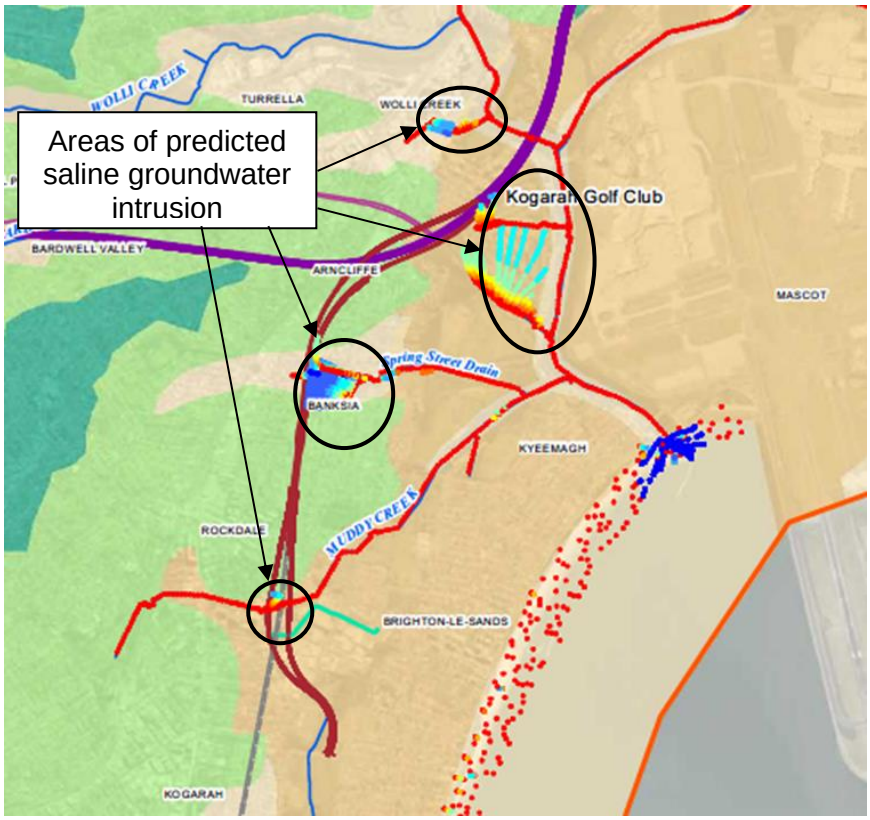

Figure 7: Modelling of saline groundwater intrusion - forward particle tracking (RPS Group, 2018)

Groundwater acidification

There is a high probability that the Project will interact with potentially acid generating soils at the Arncliffe area, Spring Street palaeochannel, and Muddy Creek palaeochannel.

In the Arncliffe area, groundwater drawdown within the coastal deposit aquifer has occurred due to the M8 motorway construction, and it is not anticipated that significant additional drawdown will occur within the coastal deposits associated with the Project construction.

Risk associated with drawdown related acidification of acid sulfate materials will be addressed by operation of temporary recharge system at West Botany Street Depot and Bicentennial Park sites during construction until the structure is tanked.

Site investigation to assess the nature of the sediments in these areas is ongoing and will inform characterisation of the acid sulfate soil and rock risk so that appropriate mitigations can be developed.

The effectiveness of any measures implemented will be validated via implementation of a comprehensive groundwater and GDE monitoring network and program, detailed in the GWMP in Appendix A.

Mobilisation of existing contamination

Potential for influence on the movement of existing groundwater contamination is considered for the following cases:

- Groundwater contamination associated with past land use in the Arncliffe area
- Groundwater contamination south of the Arncliffe palaeochannel in proximity to the main road tunnels
- Groundwater contamination in fill and alluvium in the Bicentennial Park

Arncliffe Area

Groundwater quality in the Arncliffe area is affected by previous land use including former operation of a landfill. The works associated with the Project are not anticipated to have a significant influence on the groundwater regime in the Arncliffe area. In this area groundwater levels have been drawn down within the rock profile and a gradient towards the M8 has been established. As a result, the Project is not anticipated to result in additional migration of existing contamination in this area either in the direction or rate of migration.

Main road tunnels south of Arncliffe

The main road tunnels of the Project alignment will be deep within the sandstone rock profile. They are separated by at least 30 m from overlying soils within the Spring Street palaeochannel and will be at greater depth below surface soils elsewhere. Groundwater levels are predicted to be drawdown into the rock profile as a result of seepage to the road tunnels. This will result in approximately vertical infiltration to the saturated groundwater within the rock and lateral migration at depth to the road tunnels. This general flow behaviour will be modified by the presence of geological features including permeable pathways associated with faults and dykes.

Under this groundwater flow regime, the influence of the road tunnels will be to promote vertical migration of shallow contamination where this is present and then lateral flow towards the road tunnels. It is expected that this lateral flow will be at depth within the rock profile and will pose low risk to surface activities including use of domestic groundwater wells screened in the alluvial sediments.

Bicentennial Park

Groundwater influence in Bicentennial Park will be managed through the use of groundwater recharge during the construction stage to reduce the effects of construction seepage to excavations for shafts and access. The recharge system will be operated with the objective of

maintenance of groundwater levels within the fill and alluvial sediments close to predevelopment levels. This will preserve existing flow paths.

Once the shallow structures are completed and furnished with permanent linings the seepage to these tunnels and shafts will be minimal and will be unlikely to affect groundwater flow. In additional the action of the wetlands within Bicentennial Park will term to maintain stable groundwater levels. These will remain a discharge area for local groundwater flow.

5.2.7 Groundwater dependent ecosystems

The NSW Aquifer Interference Policy states that drawdown of greater than 10% of natural variation will require management for high priority GDEs. The EIS set a 0.1 m allowable drawdown based on a 1 m natural variation range.

A summary of the advice on groundwater levels and likely fluctuation ranges is provided in Section 4.3.3. Further detail is provided in Section 7 of the HIR.

The mean measured variation (seasonal variability) in the coastal deposit aquifer mean measured variation in the coastal deposit aquifer is 0.8 m, with a standard deviation of 0.3 m. This is consistent with the 0.1 m trigger adopted for the EIS.

Aquatic GDE impact assessment

There are no high priority GDEs within the area of predicted drawdown from our tender phase assessment.

The same 0.1 m drawdown threshold has been applied when assessing potential impacts to other non-high priority GDEs in the vicinity of the project (Table 15).

Note that the impact rating has been based on multiple factors including ecosystem value, likelihood of the ecosystem requiring a fresh groundwater input, alternative water inputs (such as stormwater), ecosystem value, and professional judgement.

Table 15 GDE impact assessment

Wetland	Groundwater dependence	Ecosystem value	Potential impact	Comment
Cooks River	Low	Moderate	Low	Important fish habitat unlikely to be reliant on fresh groundwater inputs for level or quality.
Marsh Street Wetlands	Low	High	Low	Artificial wetland (RTA ponds) redeveloped during M8 construction.
Eve Street Wetlands	High (tidal)	High	Low	Receives stormwater runoff and tidal inundation. Directory of important wetlands. Reliance on groundwater input is unknown. Drawdown below base is already likely to have occurred.
Spring Street Drain	Low	Low	Low	Concrete lined drain.
Spring Street Wetland	High	Moderate	Moderate	Limited information available. Likely to be ecosystem for migratory birds.
Landing Lights Wetland	High (tidal)	High	Moderate	Important habitat for migratory birds. Wetland ecosystem may rely on fresh groundwater input during dry periods.
Muddy Creek	Low	Low	Low	Concrete lined and highly altered ecosystem. Creek will receive treated

Wetland	Groundwater dependence	Ecosystem value	Potential impact	Comment
(upper)				water discharge from the project
Muddy Creek (lower)	Moderate (tidal)	Moderate	Low	Predominantly estuarine setting and brackish groundwater input.
Kings Wetland	High	High	High	Wetland water level is reliant on groundwater. 0.5 m natural fluctuation range linked to groundwater. High potential for impact. A recharge system will be employed at Bicentennial Park during construction and therefore Kings Wetland is unlikely to be drawn down.
Bicentennial Park Wetland	High	Moderate	Moderate	Highly modified ecosystem receiving stormwater input. Approximately 1.5 to 2 m deep. Relies on groundwater to maintain minimum levels during dry periods. Flow from wetland provides freshwater input to Bicentennial Park. Bicentennial Park wetland will receive treated groundwater ingress from the tunnels during construction and are unlikely to be drawn down. A recharge system will be employed at Bicentennial Park during construction which will further suppress drawdown effects.
Scarborough Ponds	Moderate	High	Low	Northern pond is stratified with freshwater input from Bicentennial park. Unknown reliance on freshwater input from groundwater. Important fish habitat.

Drawdown may cause either (or both) level and quality impacts to freshwater ecosystems. Level impacts, such as reduced water levels or complete drying of wetlands, are more likely to occur at wetlands where external inputs from creeks and the coast are not available. Quality impacts may occur where the ecosystem relies on the freshwater input from groundwater to balance an otherwise saline or brackish tidal system.

The highest potential for impact is noted at the following wetlands:

- Spring Street Wetland (quality and level impact)
- Landing Lights Wetland (quality impact)
- Kings Wetland (level impact)
- Bicentennial Park Wetland (level impact)

Construction stage impacts to Kings Wetland and Bicentennial Park Wetland will be addressed using recharge system discussed in Section 6. Water levels at these wetlands are highly dependent on groundwater levels and any drawdown is likely to be reflected in the surface water levels. A Wetland Monitoring Program will be developed and to detail monitoring of potential impacts due to construction at selected wetlands.

Terrestrial GDE impact assessment

Adverse impacts to terrestrial GDEs are not expected. Predicted groundwater level drawdown in the Wolli Creek and Bardwell Creek catchments is minor (less than 0.5 m) and is unlikely to result in impacts to large native vegetation that may periodically rely on groundwater.

6 Environmental control measures

Specific measures and requirements to meet the objectives of this GMP and to address impacts on groundwater are outlined in Table 16.

Table 16 Groundwater environmental control measures

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWM1	The tunnels will be designed to minimise groundwater ingress during construction and comply with the relevant operational inflow requirement of 1L/s/km (GW1, Table 6).	Design	Design Manager	EMM GW1, SWTC 6.1 e), 6.2 c) (i) A, 6.2 c) (i) B, 6.2 c) (i) C, 6.2 c) (ii) A, 6.2 c) (ii) B, 6.2 c) (ii) C & D, 6.2 e)	Tunnelling design, GWMP Section 5.2.4
GWM2	Further investigations will be conducted to identify areas where groundwater ingress to the tunnels may be higher than 1 L/s/km due to fracture zones anticipated in the Arncliffe area, to inform tunnel design and construction methodology including treatment requirements.	Pre-construction, Construction	Design Manager Construction Manager	EMM GW1, GW6, SWTC 6.1 e), 6.2 c) (i) A, 6.2 c) (i) B, 6.2 c) (i) C, 6.2 c) (ii) A, 6.2 c) (ii) B, 6.2 c) (ii) C & D, 6.2 e)	Tunnelling design
GWM3	Groundwater recharge will be employed at the Bicentennial Park and West Botany Street sites to mitigate drawdown propagation, manage groundwater related settlement, and impacts to registered extractive bores.	Design	Design Manager	SWTC 6.1 e), GW3	Recharge design
GWM4	A groundwater monitoring program (GWMP, Appendix A) will be prepared and implemented during the construction phase to monitor potential adverse impacts from construction activities to sensitive receptors. Monitoring will enable comparison between observations, expected impacts and model predictions. Where observed impacts from project construction differ from expected impacts and/or model predictions, the	Construction	Construction Manager Environmental Manager	CoA C14, GW6, GW7, GW10	GWMP, periodic groundwater level and quality monitoring during construction

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
	monitoring program and existing mitigation measures will be reviewed. If required, consideration for the implementation of additional mitigation measures will be made. The groundwater model will be periodically revised to include data collected during the construction phase				
GWM5	Site Specific Trigger Values (SSTV) have been developed for EC for selected monitoring locations using baseline data as part of the HIR assessment. SSTV development methodology for EC is presented in the GWMP. The methodology for development of SSTV for volatile organic compounds (VOCs) will be updated in future revisions of the GWMP following review of data from baseline and ongoing monitoring. The EC SSTVs provide an identifiable indication of a potential change in salinity. A management response would be initiated if any of the following occurs: • EC data continuously exceeds the SSTV over a period of three months and depicts a rising trend • EC data exceeds the SSTV at any time by more than 150% If one or both of the above EC triggers are observed a review will be initiated to determine the significance of the exceedance(s) and possible causes. The review will assess the historical and surrounding monitoring bore data, and modelling predictions. If the exceedance is determined to be attributable to Project works and outside of approved model predictions for saline intrusion the groundwater model will be reviewed and updated. The updated model will be used to assess potential impacts and inform potential mitigation measures.	Construction	Environmental Manager	CoA C14, GW6, GW7, GW10	GWMP

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWM6	Water Treatment Plants will be designed to treat all tunnel drainage and groundwater inflows to comply with the relevant discharge criteria (GWMP, Appendix A) prior to discharge.	Design	Design Manager Construction Manager Environmental Manager	CoA E168, SWTC 6.1 e), 14.3	Water Treatment Plant Design, periodic monitoring during construction
GWM7	Design site layout and manage potential construction related spills and incidents to prevent contamination to groundwater during construction.	Construction	Construction Manager Environmental Manager	SWTC 6.1 e), 6.2 a)	Site layout design, site staff training, periodic reporting on construction activities and incidents
GWM8	Groundwater drawdown will be monitored and comparison between observed and predicted drawdown will be carried out. The assessment will determine whether the observed decrease (if any) is attributable to the Project and, if so, whether it aligns with approved predictions. A traffic light system will be adopted for assessing groundwater drawdown as detailed in the GWMP. Where drawdown attributable to the Project in excess of the requirements of the AIP is observed, 'make good' provisions will be implemented. 'Make good' measures will require negotiation on a case-by-case basis but may include installation of rainwater tanks (feasible option) and compensation for long term potable water supply costs. Affected bore users will be notified that the bore water is not suitable for use	Construction	Environmental Manager	CoA E173, EMM GW3, GW10	GWMP

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWM9	During tunnel excavation, probe holes will be installed at major geological features. The groundwater inflow through the probe holes will be monitored and where the inflow is high, pre-excavation grouting will be undertaken. Grouting will minimise the groundwater inflow into the tunnels. Where required, post-excavation grouting may be undertaken to control groundwater inflow into the tunnels. Temporary water recharge will also be undertaken, as required, on the southern end of the Project within Bicentennial Park and West Botany Street Depot to suppress water inflows effects during construction. Temporary water recharge will be in place until the permanent tunnel undrained structure is built and the temporary access adit off West Botany Street Depot is backfilled.	Construction	Environmental Manager	CoA E172, EMM GW4	GWMP, periodic monitoring during construction, design reports and through the Permit to Tunnel (construction) process

7 Compliance management

7.1 Roles and responsibilities

The CGU Project Team's organisational structure and overall roles and responsibilities are outlined in Section 3.4 of the CEMP. Specific responsibilities for the implementation of environmental controls are detailed in Section 6 of this Plan.

7.2 Training

All employees, contractors and utility staff working on site will undergo site induction training relating to groundwater issues. The induction training will address elements related to groundwater management including:

- Groundwater monitoring (Appendix A).
- Permit system in place for the discharge of treated groundwater; and
- Spills and incident management.

Targeted training in the form of toolbox talks or specific training will also be provided to personnel with a key role in soil and water management.

Further details regarding staff induction and training are outlined in Section 3.10 of the CEMP.

7.3 Groundwater monitoring

The GWMP is presented in Appendix A. Additional requirements and responsibilities in relation to inspections are documented in Section 3.9.1 and Section 3.9.2 of the CEMP.

A baseline of groundwater level and quality data has been compiled and is presented in Section 4.3.3 and Appendix C, respectively. Further groundwater data will be obtained prior to construction commencing.

The GWMP complies with CoA C14 and C17.

7.4 Licences and permits

A summary of legislative requirements is presented in Section 3.1.1 and relevant licences and permits are discussed in Section 3.1.3.

7.5 Auditing

Audits (both internal and external) will be undertaken to assess the effectiveness of environmental controls, compliance with this Plan, CoA, EMM's and other relevant approvals, licenses and guidelines. Audit requirements are detailed in Section 3.9.3 of the CEMP.

7.6 Reporting

Reporting requirements relevant to groundwater management are summarised in Table 17. Further detail on reporting requirements is provided in the GWMP.

Table 17 Groundwater reporting schedule

Reporting timing / frequency	Reporting requirement	Report recipient
Reporting		
Groundwater Review Report	A review report will be prepared to document results of the first three months of monitoring new bores. This report will recommend monitoring frequency and analytical suites for future monitoring. Timing of this review report may be the start of construction monitoring rather than the end of baseline monitoring. Selected bores will be monitored monthly and the remaining bores monitored quarterly.	DPIE Water, Planning Secretary, ER, Sydney Water
Groundwater Monitoring Report (six monthly)	Construction groundwater level and quality monitoring reports	DPIE Water, Planning Secretary, ER, Sydney Water
Data		
Groundwater monitoring data (quarterly)	Groundwater level and quality data in tabulated and electronic quality-controlled ready to use format. Compliant with CoA C17(h).	DPIE Water

8 Review and improvement

8.1 Continual improvement

Section 3.2.2 of the CEMP describes the process for the continual improvement of project documents.

Continual improvement of this Plan will be achieved by the ongoing evaluation of environmental management performance against environmental policies, objectives and targets for the purpose of identifying opportunities for improvement.

The continual improvement process is designed to:

- Identify areas of opportunity for improvement of environmental management and performance;
- Determine the cause or causes of non-conformances and deficiencies and develop and implement a plan of corrective and preventative action (refer Section 3.10 of the CEMP);
- Verify the effectiveness of the corrective and preventative actions;
- Document any changes in procedures resulting from process improvement; and
- Make comparisons with objectives and targets.

8.2 GMP update and amendment

Section 3.13 of the CEMP describes the process for revising and updating the CEMP and its Sub-plans.

Only the Environment Manager, or delegate, has the authority to change any of the environmental management documentation.

A copy of the updated plan and changes will be distributed to all relevant stakeholders in accordance with the approved document control procedure – refer to Section 3.13 of the CEMP.

9 References

AECOM. 2018. F6 Extension Stage 1 EIS Technical Report K: Groundwater Technical Report. October 2018.

ANZG. 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality, August 2018 http://waterquality.gov.au/anz-guidelines.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021a. Hydrogeological Factual Report – Project wide. M6 Motorway Stage 1. Report reference M6S1-COF-NWW-ENGE-RPT-680520.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021b. Hydrogeological and Groundwater Interpretive Report – Project wide. M6 Motorway Stage 1. Report reference M6S1-COF-NWW-ENEV-RPT-680440.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021c. Recharge system design – Bicentennial Park. M6 Motorway Stage 1. Report reference M6S1-COF-SWBIP-ENWA-RPT-416300.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021d. Recharge system design – West Botany Street Depot. M6 Motorway Stage 1. Report reference M6S1-COF-SWWBS-ENWA-RPT-419500.

Appendix A – Groundwater Monitoring Program

Groundwater Monitoring Program (GWMP)

M6 Motorway Stage 1

20 December 2021

Document number:	M6S1-CGU-NWW-ENPE-PLN-000412
Revision	05

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Contents

Document control

Approval and authorisation

Title	M6 Motorway Stage 1 Groundwater Monitoring Program
Endorsed by Environment Representative	Derek Low
Signed	
Dated	20/12/2021
Approved on behalf of Transport for NSW by	David Lehrbach
Signed	
Dated	
Approved on behalf of CGU by	Craig Gibson
Signed	Craig Gibson
Dated	20/12/2021

Document status

Revision	Date	Description	Approval
00	24/09/2021	Submission to TfNSW	
01	08/10/2021	Submission to TfNSW, DPIE and Sydney Water	
02	12/11/2021	Issued for Approval	
03	23/11/2021	Issued for Approval	
04	10/12/2021	Updated with DPIE comments and issued for approval	
05	20/12/2021	Updated with DPIE comments and issued for approval	

Distribution of controlled copies

This Groundwater Monitoring Program (GWMP) as part of the CEMP is available to all personnel and sub-contractors via the Project document control management system. An electronic copy can be found on the Project website.

The document is uncontrolled when printed. One controlled hard copy of the GWMP as part of the CEMP and supporting documentation will be maintained by the Quality Manager at the Project office and on the Project website (https://caportal.com.au/rms/m6).

Copy number	Issued to	Version

Glossary/ Abbreviations

Abbreviations	Expanded text
ASS	Acid Sulfate Soil
CEMP	Construction Environmental Management Plan
CGUJV	CPB Contractors Ghella UGL Engineering Joint Venture
CoA	Conditions of Approval
CSSI	The Critical State Infrastructure, as described in Schedule 1, the carrying out of which is approved under the terms of the SSI 8931 approval
DPIE	NSW Department of Planning, Industry and Environment (former NSW Department of Industry – Lands and Water, and former NSW Department of Primary Industries including DPI Agriculture, DPI Biosecurity and Food Safety, DPI Land and Natural Resources, DPI Water and DPI Fisheries)
EC	Electrical Conductivity
EIS	F6 Extension Stage 1 – Environmental Impact Statement
EMM	Environmental Management Measures
EMS	Environmental Management System
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EWMS	Environmental Work Method Statements
GDEs	Groundwater Dependent Ecosystems
GWMP	Groundwater Monitoring Program
GWQ	Groundwater Quality
HIR	Hydrogeological Interpretive Report
m AHD	Elevation in metres with respect to the Australian Height Datum
mbgl	Metres below ground level
mbtoc	Metres below top of casing
m/day	Metres per day
m/s	Metres per second
NRAR	Natural Resources Access Regulator
PIRMP	Pollution Incident Response Management Plan
POEO Act	*Protection of the Environment Operations Act 1997*

Abbreviations	Expanded text
RMS	Roads and Maritime Services
SSTV	Site-Specific Trigger Value
TfNSW	Transport for NSW
µS/cm	Micro-Siemens per centimetre
WTP	Water Treatment Plant

1 Introduction

1.1 Context

This Groundwater Monitoring Program (GWMP or Program) has been prepared for the implementation during construction of the M6 Stage 1 (the Project), and forms part of the Construction Environmental Management Plan (CEMP). This Program is Appendix A of the Groundwater CEMP Sub-Plan (GMP) and has been prepared to address the requirements of the Minister's Conditions of Approval (CoA), the Environmental Management Measures (EMM) listed in the M6 Stage 1 Environmental Impact Statement (EIS) and other applicable legislation. Further detail is provided in the Groundwater CEMP Sub-plan.

1.2 Scope of the groundwater monitoring program

The scope of this GWMP is to describe how CPB Contractors, Ghella, UGL Engineering (CGU) joint venture propose to monitor the extent and nature of potential impacts to groundwater levels and quality during construction of the Project which will allow for implementation of appropriate management measures to address impacts during construction.

Operational monitoring and operation measures do not fall within the scope of the construction phase and therefore are not included in the processes contained within this GWMP.

1.3 Consultation

The Groundwater CEMP Sub-plan and associated Groundwater Monitoring Program (GWMP) was prepared in consultation with Bayside Council and Sydney Water, the Department of Planning, Industry and Environment – Water Group (DPIE Water), however, consultation was deferred by DPIE Water to the Natural Resources Access Regulator (NRAR).

The key issue in consultation with Bayside Council was the location of discharge points from the construction Water Treatment Plants. A detailed response was provided to Council along with a commitment to seek connection approvals from asset owners if/as required. Sydney Water did not have any specific comment on the plans other than noting their comprehensive nature.
NRAR and DPIE Water were in receipt of the Groundwater CEMP Sub-plan and GWMP for more than five weeks, prior to responding that NRAR were experiencing delays due to a volume of requests (unrelated to the Project).

The Groundwater CEMP Sub-plan and GWMP were finalised and submitted pending NRAR feedback (noting that NRAR is not an agency listed within the Conditions of Approval for consultation). It is noted that NRAR will no longer provide advice on management plans, DPIE Water has been included in the Major Projects website and is the agency responsible for providing advice with regard to groundwater.

The Project commits to receiving and responding to DPIE feedback on the Groundwater CEMP Sub-plan and GWMP when/if it is received. If amendment of either document is required following DPIE's feedback, the documents will be updated and submitted to the ER for endorsement within four weeks of receipt of feedback (and sent to DPIE for approval if/where required). Table 1 includes summary details of the consultation for documents M6S1-CGU-NWW-ENPE-PLN-000411 and M6S1-CGU-NWW-ENPE-PLN-000412.

Table 1 Stakeholder consultation and comments register

Stakeholder	Stakeholder Comments	CGU Response	Outstanding Issues
Bayside Council	It is not clear whether there are treatment plants at all three sites being Arncliffe, Rockdale Depot and Bicentennial Park, whether there is going to be groundwater recharge at Bicentennial, and where it is going to be discharged for each site i.e. Sydney Waters sewerage system, Cooks River/Muddy Creek or Councils stormwater system, or a combination of these. Sydney Water do not permit water from dewatering to be discharged into their sewerage system. If it is proposed to discharge the water from dewatering, whether through the WTPs or not, into Council managed or Sydney Water managed stormwater system, what approval will be sought from the responsible party?	Water treatment plants during the construction phase will be at all three tunnelling sites being C1 Arncliffe, C2 Rockdale depot and C3 Bicentennial Park. At the completion of construction, there will be one water treatment plant for operation (separate from the construction phase plants), which will be located at Arncliffe. Water will be reused as far as possible, minimising the amount of discharge required. This reuse will include (where possible), groundwater recharge, further minimising disposal. It is not proposed to discharge into council assets, however if a connection to an asset is required, approval for the connection will be sought from the asset owner prior to the connection.	If a connection to council assets is required, CGU will seek approval from the council.
DPIE Water	NRAR receives post approval requests for coordination with DPIE Water and requests should be directed to them.	Plan was sent to NRAR on 11/10/2021	None
NRAR	Thank you for your enquiry about the progress of your enquiry: Reference number V15/3875-5#87. We apologise for the delay in providing our response to your enquiry, and any inconvenience this delay has caused. We are currently experiencing a high number of Enquiries which is affecting our response times. We are endeavouring to address all enquiries as soon as possible, in the order in which we have received the enquiries. An NRAR officer (Jessica Braden) has been assigned to your enquiry and we will update you as soon as possible regarding its progress.	N/A	NRAR and DPIE Water have been in receipt of the Groundwater CEMP Sub-plan and Groundwater Monitoring Program for more than six weeks and have not commenced review (despite several contact attempts). The Groundwater CEMP Sub-plan and Groundwater Monitoring Program are submitted for approval by DPIE while NRAR delays continue, however the Project commits to receiving and responding to NRAR feedback on the Groundwater CEMP Sub-plan and Groundwater Monitoring Program when/if it is received. If amendment of either document is required

Stakeholder	Stakeholder Comments	CGU Response	Outstanding Issues
			following NRAR's feedback, the documents will be updated and submitted to the ER for endorsement within four weeks of receipt of feedback (and sent to DPIE for approval if/where required)
Sydney Water	Acknowledged that the plans have been reviewed and are "comprehensive"	None	None

2 Purpose and objectives

2.1 Purpose

The purpose of the GWMP is to describe how CGU propose to monitor the extent and nature of potential impacts to the groundwater level and quality during construction of the Project.

The GWMP will be implemented to monitor the effectiveness of mitigation measures applied during the construction phase of the Project. Monitoring of groundwater will be undertaken to identify potential impacts and ensure a comprehensive management regime can be implemented to address those impacts and manage local groundwater quality.

This Program provides details of the groundwater monitoring network, frequency of monitoring, and test parameters. This GWMP supplements the Groundwater Management Sub-Plan (GMP), which itself is an appendix of the CEMP.

This GWMP is based on baseline studies developed for the M6 Stage 1 EIS (AECOM 2018) and baseline monitoring reports (Cardno 2021).

2.2 Objectives

This GWMP details specific steps that are required to monitor groundwater in accordance with the CoA and management and mitigation measures outlined in the GMP. Specifically, the purpose of this GWMP is to:

- Ensure the identified impacts in the GMP are not resulting in unexpected impacts;
- Ensure mitigation and management measures are achieving the stated objectives; and
- Identify if adaptive management responses are required to further manage groundwater impacts.

Key objectives of the GWMP are to ensure that all CoA are met, compliance with relevant legislation, and address agency submissions and the EMM outlined in the Response to Submissions on the Environmental Impact Assessment (EIS).

This is achieved through the following:

- Establishing monitoring parameters that enable comparison of the actual construction performance against the predicted performance of mitigation measures;
- Identifying thresholds for monitoring parameters that if exceeded will trigger the need for management responses; and
- Scheduling and assignment of responsibilities of monitoring requirements.

2.3 Requirements

This GWMP includes the following:

- Groundwater monitoring to be undertaken, including the location and frequency of monitoring and parameters to be monitored;
- Detail of water treatment plant monitoring to be undertaken;
- Detail regarding analysis and reporting of monitoring data.

3 Groundwater monitoring

The following sections outline the existing and proposed groundwater monitoring locations and details of the baseline and construction monitoring program. Groundwater monitoring locations along the alignment are illustrated in Figure 1 to Figure 5.

3.1 Baseline monitoring

Baseline groundwater level data is included in Section 4.3.3 of the GMP and baseline groundwater quality data including discussion of key contamination sources and their impact on groundwater quality is provided in Appendix C of the GMP.

3.1.1 Existing monitoring network

Baseline groundwater level and quality monitoring data has been collected from the Project groundwater monitoring network since 2015. This baseline dataset is augmented by baseline data and construction data for the adjacent M8 project.

The Project baseline monitoring network was installed between 2015 and 2020 and consists of 179 monitoring bores and vibrating wire piezometers (VWPs), identified during the tender phase. Monitoring bores were designed to target the following three hydrogeological units:

- Fill
- Coastal deposits - alluvium
- Hawkesbury Sandstone

For the design phase Interim Hydrogeological Factual Report (HFR) (Coffey 2021a), 61 monitoring bores and 31 VWPs at 18 locations were identified, with recent available groundwater level and / or quality data from key reports listed in the GMP. Data from these monitoring locations have been included in the Hydrogeological Interpretive Report (HIR) (Coffey 2021b).

The Interim HFR includes hydrogeological information acquired during the tender and project planning phases. The Draft HFR will be issued externally on 29 November 2021 and will include additional information obtained by Coffey during the site investigation phase of the project.

A baseline of available groundwater level and quality data has been compiled for the Interim HFR. The existing monitoring bores and VWPs with recent data are listed in Table 2 and Table 3 respectively. These existing locations with recent data were considered to provide sufficient spatial coverage for assessment of baseline conditions.

26 existing monitoring bores were selected previously by others for ongoing monthly monitoring which commenced in mid-2020. Monthly groundwater monitoring was conducted by Cardno (NSW/ACT) Pty Ltd (Cardno) until July 2021. Since August 2021, Coffey have commenced monitoring of the 26 bores detailed in Table 4.

Monthly monitoring at each of the 26 bores includes manual groundwater level measurements, downloading water level data loggers, measuring field water quality parameters (electrical conductivity (EC), pH, redox, dissolved oxygen and temperature) and collection of groundwater samples for laboratory testing of the following analytes:

- General indicators (EC, resistivity and total dissolved solids (TDS))
- Major cations (calcium, magnesium, sodium, potassium)
- Major anions (chloride, sulfate) and speciated alkalinity (bicarbonate, carbonate, hydroxide)

- Dissolved metals (arsenic, cadmium, chromium, copper, lead, iron, manganese mercury, nickel, zinc) (field filtered)
- Total metals (iron, manganese) (unfiltered)
- Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorous, reactive phosphorous)
- Per- and poly- fluoroalkyl sulfonate (PFAS) for bore WCX-BH063a.

The status of existing monitoring bores with recent data but not included in the monthly monitoring of the previously selected 26 bores in Table 4, has been checked. Nine bores were identified as lost or damaged as follows and have been excluded from Table 2.

- BH020A - buried
- BH022A - not found
- BH1316 - blocked at 13 m
- LDS-BH-2007A - damaged and blocked
- LDS-BH-2011A - buried
- LDS-BH-2011B - buried
- WCX-BH061a - not found
- WCX-BH204 - buried
- WCX-BH211 - not found

Available baseline groundwater quality data has been combined into one electronic Esdat database. A list of analytes tested at existing monitoring bores has been collated to identify which additional analytes should be tested at each location including PFAS (refer to Appendix C Tables C-6 and C-7).

Further baseline groundwater data will be obtained prior to construction commencing in early 2022, as outlined in the following section for the proposed monitoring network.

Table 2: Existing monitoring bores with recent data

Bore ID	Easting MGA2020	Northing MGA2020	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)
BH014A	328528	6240413	Alluvium	7	10
BH1143	328597	6240515	Alluvium	15.4	18.4
BH1212	328762	6240351	Alluvium	13	16
BH1214	328506	6239812	Alluvium	10.5	13.5
BH1300	328265	6241005	Alluvium	13	16
BH1301	328535	6240509	Alluvium	9.65	12.65
BH1303	328704	6240471	Alluvium	10	19
BH1313	328746	6240868	Alluvium	23.1	29.1
BH1314	328546	6242495	Alluvium	19	25
BH1315	328709	6242448	Alluvium	25.6	31.6
BH1318	328558	6240154	Alluvium	5.8	8.8
BH1417	328574	6240556	Alluvium	2.65	5.65
BH1418	328462	6240448	Alluvium	4	7
BH1421	328872	6240903	Alluvium	1.8	13.8
BH1424	328701	6240429	Alluvium	2	14
BH1429	328549	6240460	Alluvium	5.8	8.8
BH1432	328602	6240396	Alluvium	5	8

Bore ID	Easting MGA2020	Northing MGA2020	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)
BH1501	328529	6240609	Alluvium	3.1	6.1
BH1503	328337	6240975	Alluvium	14.2	17.2
BH1511	328559	6240923	Alluvium	10.8	13.8
BH1513	328945	6240845	Alluvium	21	25
BH1514	328540	6240583	Alluvium	2.6	5.6
BH1702	328619	6240513	Alluvium	20.8	22.8
CH1403	328593	6240610	Alluvium	5	8
CH1404	328775	6240948	Alluvium	1.8	13.8
LDS-BH-2001	329362	6243036	Alluvium	1.5	5
LDS-BH-2003	329720	6242897	Alluvium	6	9
WCX-BH063a	329207	6242451	Alluvium	5	8
CH1411	327956	6240257	Fill	1.6	3.6
BH1415	328665	6240495	Fill/Alluvium	2.4	14.4
BH1425	328739	6240382	Fill/Alluvium	2	14
BH002	328930	6243014	Bedrock	58	70
BH005	328445	6241920	Bedrock	56.3	68.7
BH1102	328559	6242552	Bedrock	71	74
BH1428	328519	6240559	Bedrock	17	35
BH1701	328600	6240532	Bedrock	27	30
BH1703	328639	6240495	Bedrock	24.8	27.8
LDS-BH-1038	329099	6243199	Bedrock	65	74
LDS-BH-2005A	329610	6243366	Bedrock	25.18	28.2
LDS-BH-2008A	329940	6243863	Bedrock	44	50
WCX-BH025	328637	6243272	Bedrock	54.7	57.7
WCX-BH029	329350	6242710	Bedrock	33	36
WCX-BH036	329403	6243810	Bedrock	60	63
WCX-BH039	329554	6244159	Bedrock	49	52
WCX-BH070	329042	6242922	Bedrock	35	38
WCX-BH074	329228	6243672	Bedrock	39	42
WCX-BH093	327657	6243185	Bedrock	47.5	50.5
WCX-BH094	327868	6243176	Bedrock	54	57
WCX-BH168	329703	6243777	Bedrock	48	51
WCX-BH202	328078	6240176	Bedrock	35.5	38.5
WCX-BH206	328399	6240660	Bedrock	19	22
WCX-BH213	328710	6241681	Bedrock	29	32
WCX-BH214	329228	6241856	Bedrock	31.5	34.5

Table 3. Existing VWPs with recent data

VWP ID	Easting MGA2020	Northing MGA2020	Stratigraphic unit	VWP sensor elevation (mAHD)
BH1210	328397	6241465	Bedrock	-30.9
BH1213	328238	6240243	Bedrock	-40.3
BH1306	328374	6240985	Bedrock	-57.2
BH1307	328355	6241124	Bedrock	-66.9
BH1310	328578	6242166	Bedrock	-74.9
BH1402	328106	6240831	Bedrock	-57.2
BH1403	328489	6241047	Bedrock	-57.1
BH1433	328382	6240480	Bedrock	-18.7
BH1506	329007	6243010	Bedrock	-69.1
BH1508	328851	6242983	Bedrock	-59.2
BH1601	328545	6240568	Bedrock	-36.9
BH1602	328456	6240778	Bedrock	-27.7
BH1602	328456	6240778	Bedrock	-57.2
BH1604	328491	6240899	Bedrock	-27.3
BH1604	328491	6240899	Bedrock	-55.3
LDS-BH-1041	329465	6243438	Alluvium	-12.3
LDS-BH-1041	329465	6243438	Alluvium	-21.0
LDS-BH-1041	329465	6243438	Alluvium	-25.7
LDS-BH-1041	329465	6243438	Bedrock	-60.3
LDS-BH-1045	329560	6243486	Alluvium	-7.4
LDS-BH-1045	329560	6243486	Alluvium	-28.4
LDS-BH-1045	329560	6243486	Alluvium	-38.0
LDS-BH-1045	329560	6243486	Bedrock	-57.0
LDS-BH-1067	329452	6243551	Alluvium	-2.3
LDS-BH-1067	329452	6243551	Alluvium	-19.7
LDS-BH-1067	329452	6243551	Bedrock	-54.3
LDS-BH-1068	329578	6243633	Alluvium	-3.5
LDS-BH-1068	329578	6243633	Alluvium	-23.5
LDS-BH-1068	329578	6243633	Bedrock	-43.5
LDS-BH-2005	329618	6243372	Alluvium	-11.4
LDS-BH-2005	329618	6243372	Bedrock	-26.9

Table 4. Existing bores previously selected by others for monthly groundwater level and quality monitoring

Bore ID	Easting MGA2020	Northing MGA2020	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)
BH002	328930	6243014	Bedrock	58	70
BH005	328445	6241920	Bedrock	56.3	68.7
BH014A	328528	6240413	Alluvium	7	10
BH1300	328265	6241005	Alluvium	13	16
BH1301	328535	6240509	Alluvium	9.65	12.65
BH1314	328546	6242495	Alluvium	19	25
BH1415	328665	6240495	Fill/Alluvium	2.4	14.4
BH1417	328574	6240556	Alluvium	2.65	5.65
BH1418	328462	6240448	Alluvium	4	7
BH1421	328872	6240903	Alluvium	1.8	13.8
BH1424	328701	6240429	Alluvium	2	14
BH1425	328739	6240382	Fill/Alluvium	2	14
BH1428	328519	6240559	Bedrock	17	35
BH1429	328549	6240460	Alluvium	5.8	8.8
BH1432	328602	6240396	Alluvium	5	8
BH1501	328529	6240609	Alluvium	3.1	6.1
BH1503	328337	6240975	Alluvium	14.2	17.2
BH1511	328559	6240923	Alluvium	10.8	13.8
BH1513	328945	6240845	Alluvium	21	25
BH1514	328540	6240583	Alluvium	2.6	5.6
CH1403	328593	6240610	Alluvium	5	8
CH1404	328775	6240948	Alluvium	1.8	13.8
CH1411	327956	6240257	Fill	1.6	3.6
LDS-BH-1038	329099	6243199	Bedrock	65	74
WCX-BH063a	329207	6242451	Alluvium	5	8
WCX-BH206	328399	6240660	Bedrock	19	22

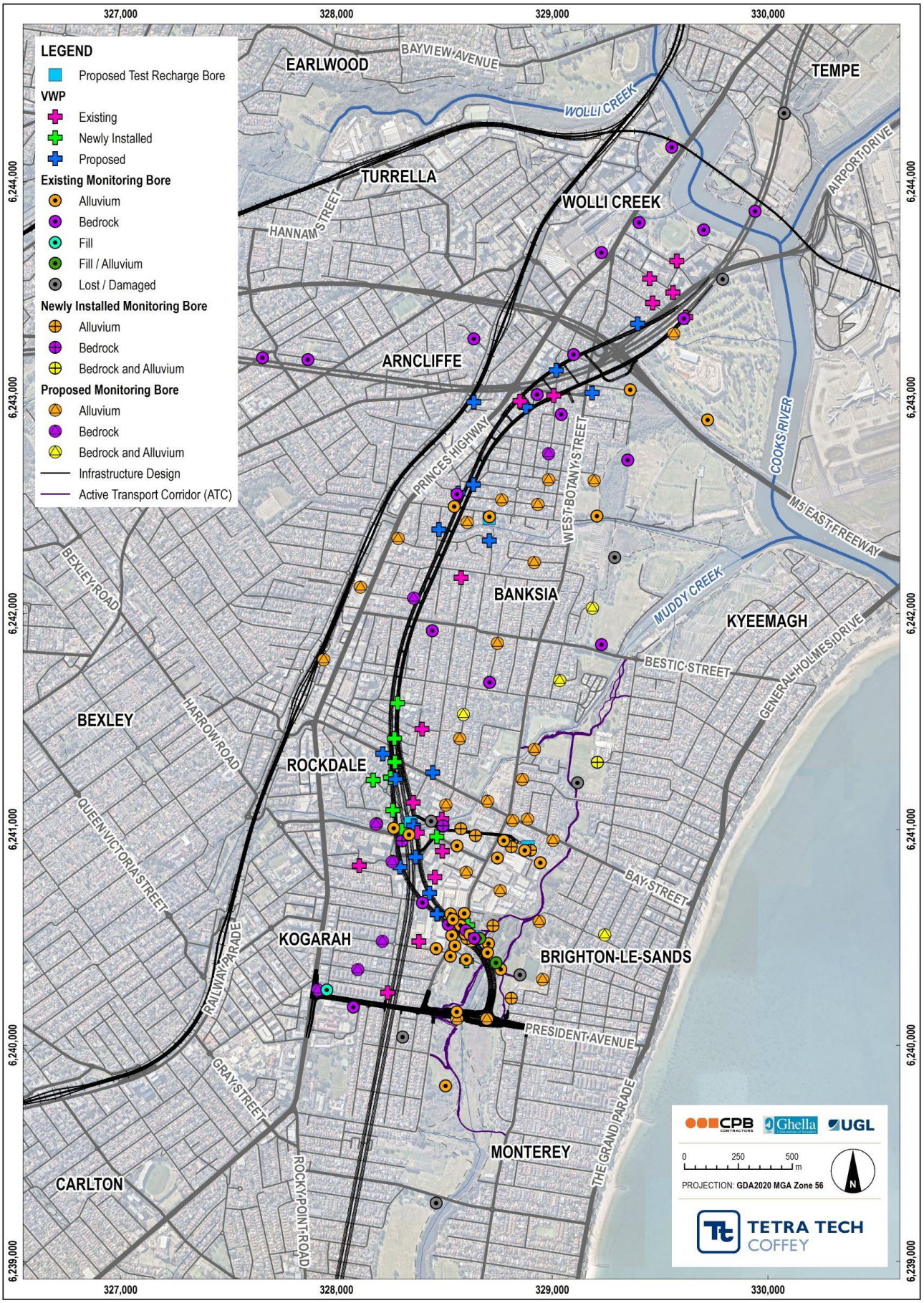

Figure 1. Groundwater monitoring locations - whole Project alignment

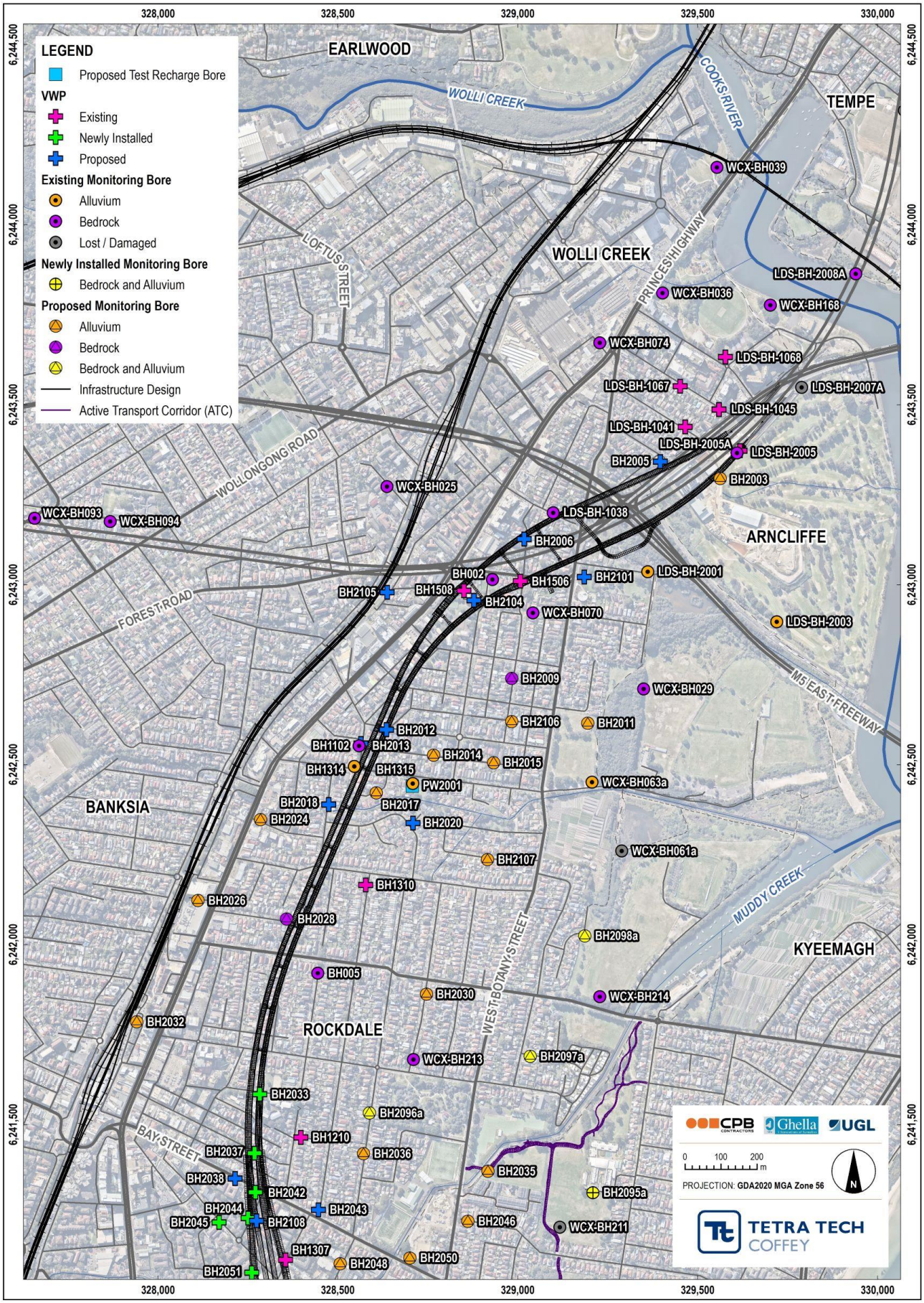

Figure 2. Groundwater monitoring locations - northern and central area

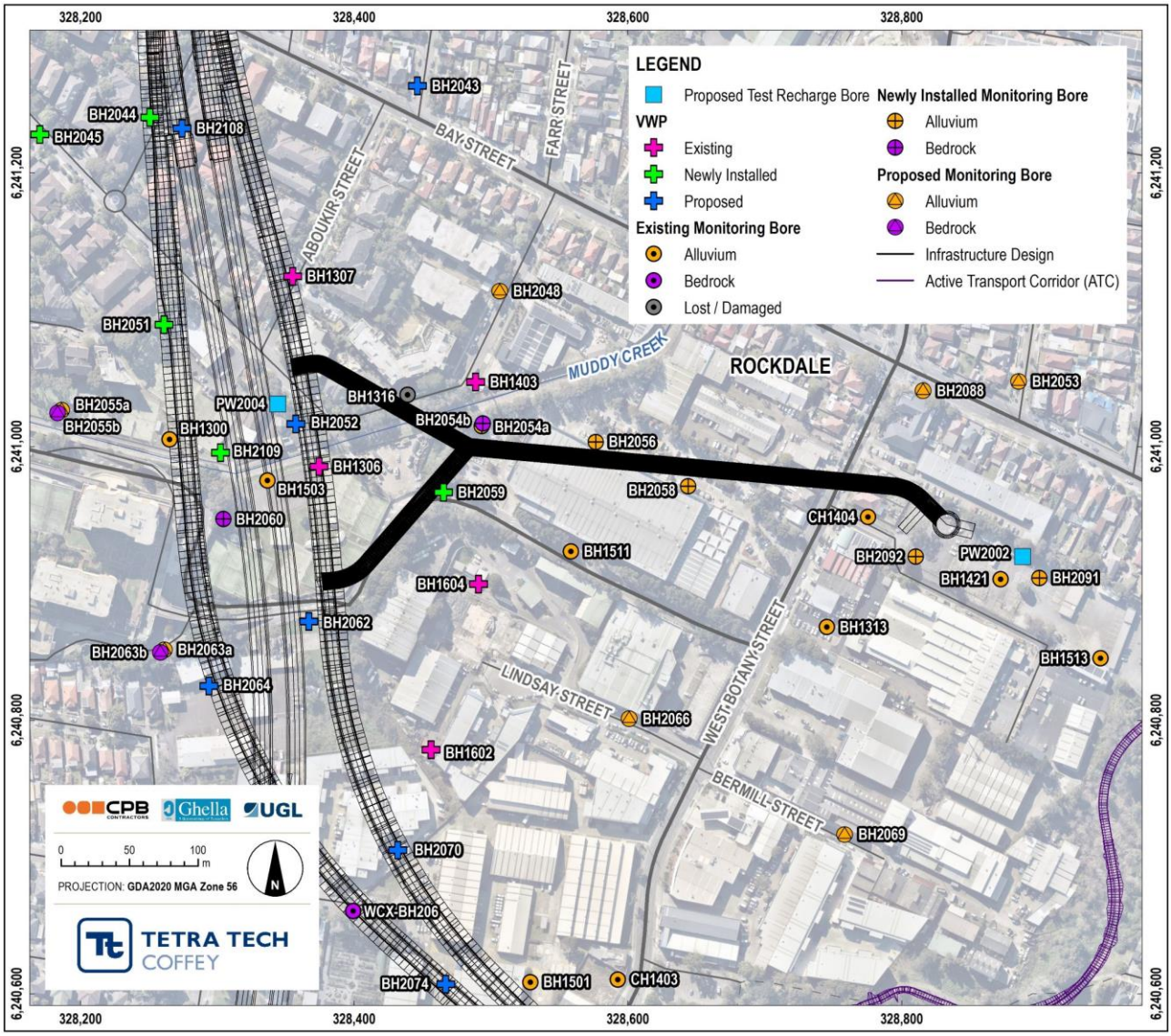

Figure 3. Groundwater monitoring locations - WBS Depot

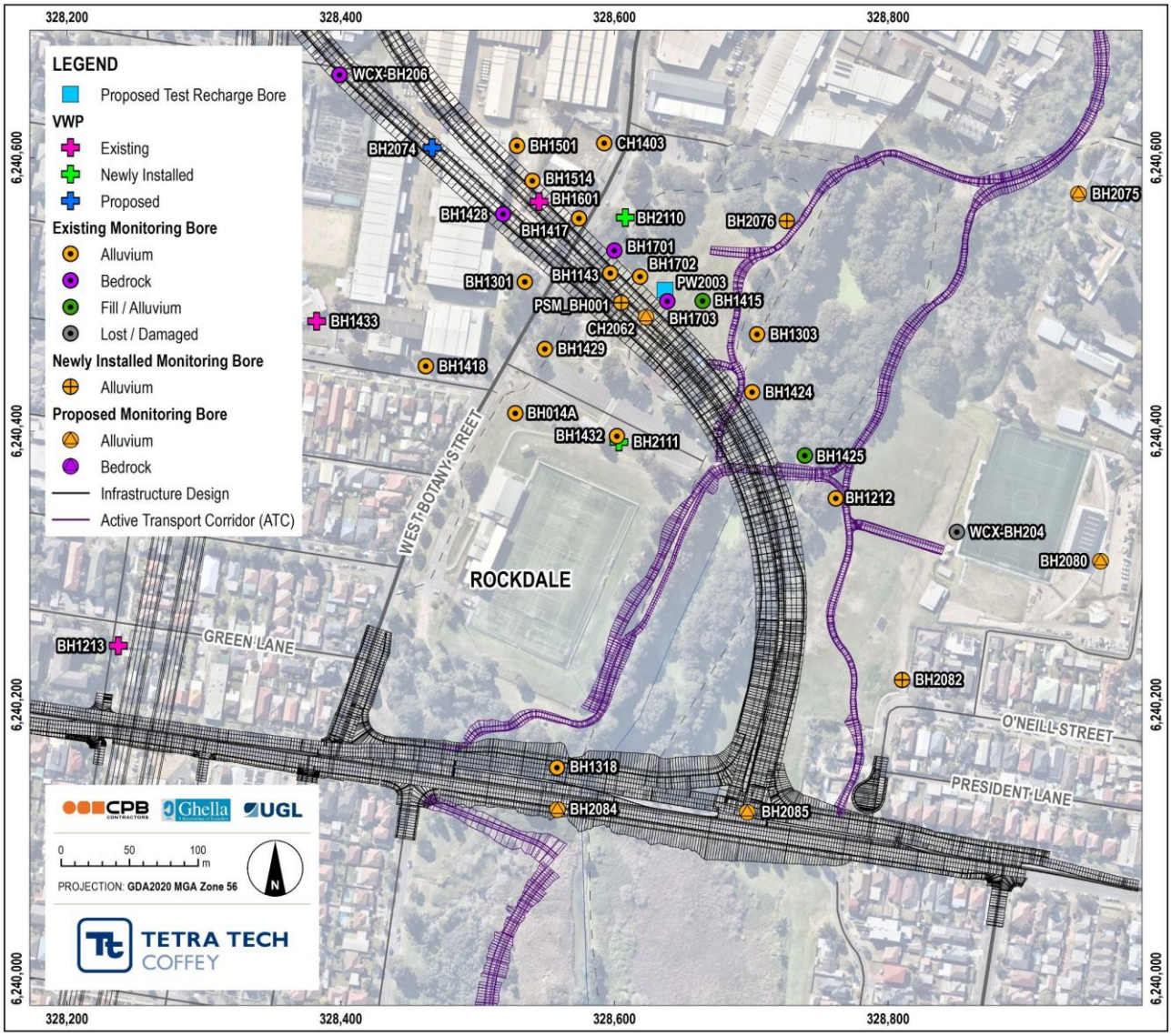

Figure 4. Groundwater monitoring locations - Bicentennial Park

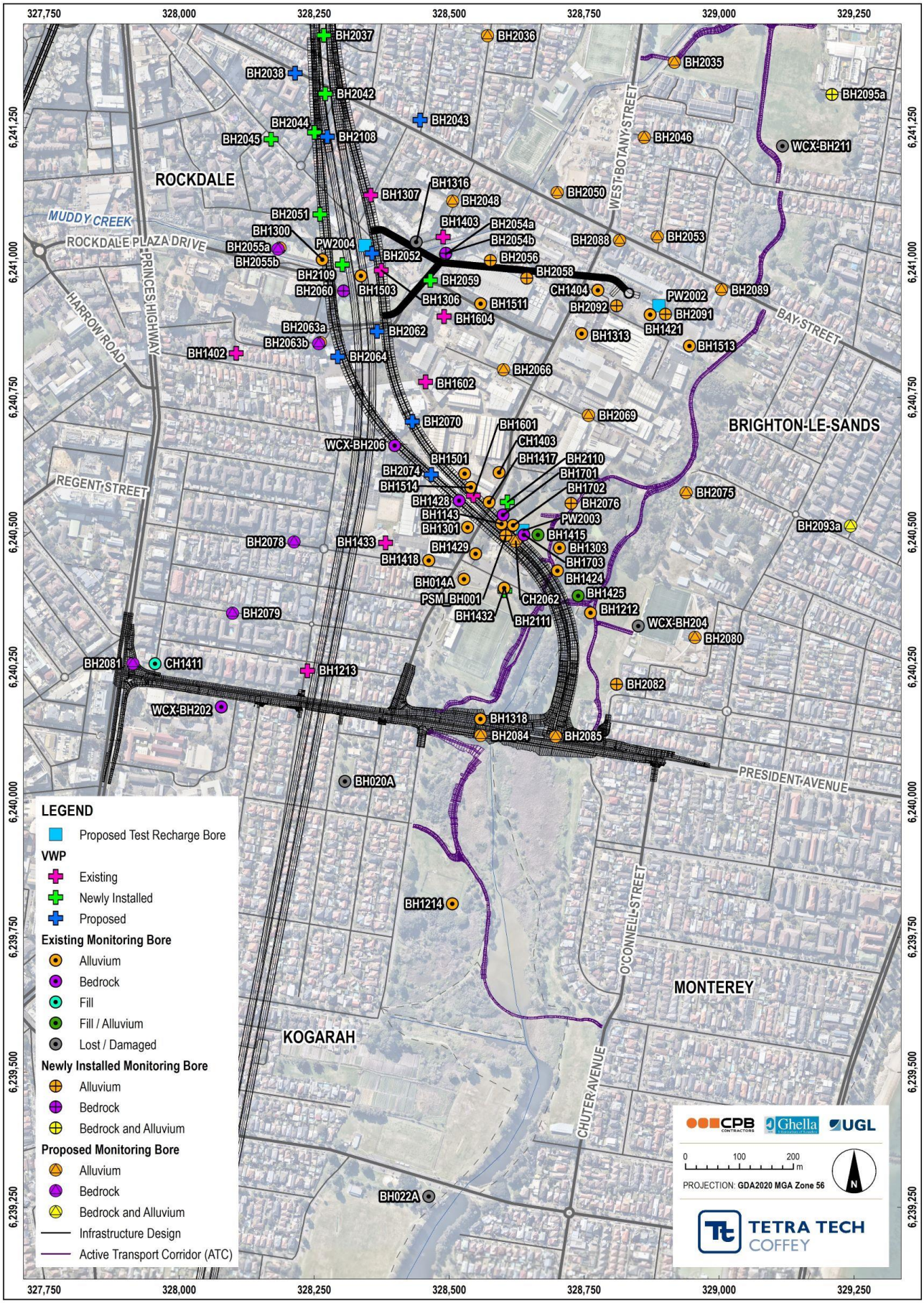

Figure 5. Groundwater monitoring locations - central and southern area

3.1.2 Proposed monitoring network

Coffey have commenced fieldwork for the geotechnical site investigation program which includes installation of 50 new monitoring bores, as detailed in Table 5 and 27 new VWPs, as detailed in Table 6.

Bore and VWP locations are illustrated in Figure 1 to Figure 5. Monitoring bores have been located to provide thorough spatial coverage across the alignment in both sediment and rock to allow comprehensive groundwater level and quality monitoring.

Four test bores are proposed in key locations, as detailed in Table 7. Groundwater recharge in Bicentennial Park and the West Botany Street Depot area is an important groundwater management measure to limit groundwater drawdown during construction in these areas (Coffey 2021c, 2021d). The recharge test bores will be used to inform the proposed recharge system design in Bicentennial Park and the West Botany Street Depot area.

Ongoing groundwater level monitoring will be conducted on a continuous basis using telemetry at all new monitoring bores, recharge bores and VWPs. A baseline of groundwater level elevation will be established through the monitoring network to allow comparison against the observed response during construction.

Groundwater quality monitoring will be conducted at each of the new monitoring bores including the recharge bores, initially for a comprehensive analytical suite at all new bores which will be reviewed, after which selected bores will continue with monthly monitoring and monitoring frequency of the remaining bores and the analytical suite will be reviewed. This frequency will continue until commencement of construction, at which time construction phase monitoring will take over.

The following comprehensive laboratory analytical suite is proposed for the first round of groundwater sampling at each new monitoring bore:

- General indicators (EC, TDS and resistivity)
- Major cations (calcium, magnesium, sodium, potassium)
- Major anions (chloride, sulfate) and speciated alkalinity (bicarbonate, carbonate, hydroxide)
- Dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc) (field filtered) and total metals (iron, manganese) (unfiltered sample)
- Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorous, reactive phosphorous)
- Total recoverable hydrocarbons (TRH)
- Benzene, toluene, ethylbenzene, xylene (BTEX)
- Polycyclic aromatic hydrocarbons (PAHs)
- Volatile organic compounds (VOCs)
- PFAS
- Total organic carbon (TOC)

The following limited laboratory analytical suite is proposed for bores where hydrocarbon and PFAS are assessed not to be an issue after the first round of sampling:

- General indicators (EC, TDS and resistivity)
- Major cations (calcium, magnesium, sodium, potassium)
- Major anions (chloride, sulfate) and speciated alkalinity (bicarbonate, carbonate, hydroxide)
- Dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc) (field filtered) and total metals (iron, manganese) (unfiltered sample)

- Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorous, reactive phosphorous)

The amount of baseline data collection for the new groundwater monitoring network will depend on the timing of the drilling and installation program, with at least one round of baseline data to be collected prior to construction.

Proposed sampling and analysis from new and existing monitoring bores to address identified data gaps is summarised in Tables C-6 and C-7 of Appendix C. The full dataset will provide pre-construction baseline groundwater conditions along the alignment, and will be used to inform the construction-phase groundwater monitoring program and where management or treatment of groundwater may be required.

Table 5. Proposed new monitoring bore network

Bore ID	Easting MGA2020	Northing MGA2020	Target stratigraphic unit	Target depth (m)	Status
BH2054a	328493	6241015	Alluvium	35	Newly installed
BH2054b	328494	6241017	Bedrock	50	Newly installed
BH2056	328577	6241003	Alluvium	50	Newly installed
BH2058	328644	6240971	Alluvium	50	Newly installed
BH2060	328305	6240947	Bedrock	70	Newly installed
BH2076	328726	6240554	Alluvium	15	Newly installed
BH2082	328810	6240218	Alluvium	15	Newly installed
BH2091	328901	6240904	Alluvium	31	Newly installed
BH2092	328810	6240919	Alluvium	34	Newly installed
BH2095a	329209	6241311	Bedrock and Alluvium	40	Newly installed
PSM_BH001	328605	6240494	Alluvium	40	Newly installed
BH2003	329563	6243295	Alluvium	30	Newly installed
BH2009	328983	6242739	Bedrock	40	Proposed
BH2011	329195	6242615	Alluvium	10	Proposed
BH2014	328766	6242526	Alluvium	12	Proposed
BH2015	328933	6242505	Alluvium	12	Proposed
BH2017	328607	6242422	Alluvium	90	Proposed
BH2024	328285	6242347	Alluvium	45	Proposed
BH2026	328111	6242122	Alluvium	45	Proposed
BH2028	328357	6242071	Bedrock	115	Proposed
BH2030	328746	6241862	Alluvium	8	Proposed
BH2032	327942	6241785	Alluvium	45	Proposed
BH2035	328917	6241371	Alluvium	10	Proposed
BH2036	328571	6241419	Alluvium	6	Proposed
BH2046	328861	6241231	Alluvium	15	Proposed
BH2048	328506	6241113	Alluvium	40	Proposed
BH2050	328700	6241129	Alluvium	8	Proposed
BH2053	328885	6241047	Alluvium	15	Proposed
BH2055a	328186	6241026	Alluvium	20	Proposed
BH2055b	328183	6241024	Bedrock	40	Proposed
BH2063a	328261	6240851	Alluvium	9	Proposed
BH2063b	328258	6240849	Bedrock	60	Proposed
BH2066	328601	6240801	Alluvium	27	Proposed
BH2069	328758	6240716	Alluvium	27	Proposed
BH2075	328939	6240573	Alluvium	15	Proposed

Bore ID	Easting MGA2020	Northing MGA2020	Target stratigraphic unit	Target depth (m)	Status
BH2078	328213	6240482	Bedrock	30	Proposed
BH2079	328099	6240350	Bedrock	30	Proposed
BH2080	328955	6240305	Alluvium	15	Proposed
BH2081	327914	6240256	Bedrock	10	Proposed
BH2084	328558	6240123	Alluvium	15	Proposed
BH2085	328697	6240122	Alluvium	15	Proposed
BH2088	328816	6241041	Alluvium	16	Proposed
BH2089	329004	6240949	Alluvium	27	Proposed
BH2093a	329243	6240511	Bedrock and Alluvium	20	Proposed
BH2096a	328588	6241532	Bedrock and Alluvium	20	Proposed
BH2097a	329034	6241689	Bedrock and Alluvium	20	Proposed
BH2098a	329186	6242024	Bedrock and Alluvium	20	Proposed
BH2106	328983	6242619	Alluvium	15	Proposed
BH2107	328916	6242236	Alluvium	8	Proposed
CH2062	328623	6240483	Alluvium	30	Proposed

Table 6. Proposed new VWP network

VWP ID	Easting MGA2020	Northing MGA2020	Target stratigraphic unit	Status
BH2033	328283	6241584	Bedrock	Newly installed
BH2037	328268	6241420	Bedrock	Newly installed
BH2042	328271	6241312	Bedrock	Newly installed
BH2044	328251	6241240	Bedrock	Newly installed
BH2045	328171	6241228	Bedrock and Alluvium	Newly installed
BH2051	328261	6241089	Bedrock and Alluvium	Newly installed
BH2059	328465	6240966	Bedrock and Alluvium	Newly installed
BH2109	328302	6240995	Alluvium	Newly installed
BH2110	328608	6240556	Alluvium	Newly installed
BH2111	328603	6240392	Alluvium	Newly installed
BH2005	329396	6243341	Bedrock and Alluvium	Proposed
BH2006	329018	6243126	Bedrock	Proposed
BH2012	328635	6242597	Bedrock	Proposed
BH2013	328564	6242558	Bedrock and Alluvium	Proposed
BH2018	328475	6242389	Bedrock and Alluvium	Proposed
BH2020	328709	6242338	Bedrock and Alluvium	Proposed
BH2038	328215	6241350	Bedrock	Proposed
BH2043	328446	6241263	Bedrock and Alluvium	Proposed
BH2052	328357	6241016	Bedrock and Alluvium	Proposed
BH2062	328367	6240872	Bedrock and Alluvium	Proposed
BH2064	328294	6240825	Bedrock	Proposed
BH2070	328432	6240705	Bedrock and Alluvium	Proposed
BH2074	328467	6240607	Bedrock and Alluvium	Proposed
BH2101	329185	6243021	Bedrock	Proposed
BH2104	328878	6242956	Bedrock	Proposed
BH2105	328637	6242978	Bedrock	Proposed
BH2108	328274	6241232	Bedrock	Proposed

Table 7. Proposed test recharge bore locations

Test recharge bore ID	Location	Easting MGA2020	Northing MGA2020	Target stratigraphic unit	Target depth (m)
PW2003	Bicentennial Park	328637	6240503	Alluvium	20
PW2002	West Botany Street Depot	328888	6240919	Alluvium	38
PW2004	Rockdale Sydney Water Depot	328344	6241031	Alluvium	20
PW2001	Spring Street	328707	6242440	Alluvium	30

3.1.3 Registered bores

Based on the groundwater impact assessment in the HIR (Coffey 2021b), there are nine registered groundwater bores in the Spring Street palaeochannel area which will be impacted by construction drawdown. These bores are detailed in Table 8 and locations are illustrated in Figure 6. L.

Figure 6. Location of registered bores with predicted construction drawdown greater than 2 m

A bore survey of these bores will be conducted to assess status, baseline groundwater level, bore depth and pump depth if applicable.

Registered bores in the Bicentennial Park and West Botany Street area will not be impacted during construction as the proposed recharge system will limit drawdown to less than 2 m in these areas.

Table 8. Registered bores with predicted construction drawdown greater than 2 m

Bore ID	Use	Easting (MGA2020)	Northing (MGA2020)	Stratigraphic unit	Bore depth (m)
GW023191	Water supply	329042	6242526	Alluvium	3.6
GW023194	Water supply	329157	6242812	Alluvium	4.8
GW024062	Water supply	328681	6242386	Alluvium	3.6
GW106450	Water supply	329137	6242026	Alluvium	2
GW108295	Water supply	328907	6242467	Alluvium	8
GW108439	Water supply	328893	6242479	Alluvium	8
GW108870	Water supply	329102	6242292	Alluvium	5
GW110735	Water supply	328936	6242530	Alluvium	8
GW111790	Water supply	328909	6242515	Alluvium	6

3.1.4 Groundwater dependent ecosystems

A Wetland Monitoring Program was prepared in accordance with CoA C18, including monitoring potential impacts due to construction to Patmore Swamp, Kings Wetland and upstream and downstream of creek diversion works in Rockdale Bicentennial Park.

A Surface Water Monitoring Program was developed in accordance with CoA C13.

As part of the groundwater monitoring program, four groundwater monitoring bores located near key GDEs are monitored for groundwater levels and quality. Bore details are shown in Table 9.

Table 9. GDE groundwater monitoring bores

GDE	Bore ID	Easting MGA2020	Northing MGA2020	Ground level (m AHD)	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)
Kings Wetland / Bicentennial Park Wetland	BH1424	328701	6240429	2.87	Alluvium	2	14
Muddy Creek (downstream)	BH2098a	329186	6242024	TBC	Alluvium	TBC	TBC
Landing Lights Wetland	WCX-BH063a	329207	6242451	3.41	Alluvium	5	8
Eve Street Wetland	LDS-BH-2001	329362	6243036	2.21	Alluvium	1.5	5

TBC - to be confirmed following installation

3.2 Construction monitoring

3.2.1 Overview

Potential impacts of Project construction on groundwater were assessed in Section 5.2 or the GMP. Impacts requiring groundwater monitoring during construction are identified as:

- Groundwater level decrease in the vicinity of the Project tunnels (groundwater drawdown)
- Intrusion of saline water
- Mobilisation of existing groundwater contamination

Ongoing investigation is proposed to assess baseline conditions prior to construction commencing that may impact groundwater (refer to Appendix C and Tables C-6 and C-7). Baseline groundwater data from new and existing bores will be added to the database as it is generated. Groundwater monitoring requirements during construction, such as location, frequency and analytes, will be reviewed and updated based on results of the baseline investigation currently being conducted.

Monitoring of groundwater inflow to the tunnels will be carried out by the construction team on a monthly basis and the inflow results will be incorporated into regular review of groundwater level response.

The data will be assessed (as per Section 5.3) and reported in the six monthly groundwater monitoring report as identified in Table 13. A monitoring report will be prepared to document results of the first three months of monitoring new bores. This report will recommend monitoring frequency and analytical suites for future monitoring. Timing of this monitoring report may be the start of construction monitoring rather than the end of baseline monitoring.

It may be necessary to construct additional monitoring bores if some of the existing bores are inaccessible or damaged during tunnel construction or as a possible management action as part of an investigation into discrepancies in monitoring data.

Where a bore becomes inoperable, damaged or within the works footprint the Tunnel Design Manager will identify a suitable replacement in consultation with a suitably qualified hydrogeologist. Groundwater inflows intercepted during tunnelling, and subsequent discharge via the construction WTP, will also be monitored. Construction phase groundwater level and quality data will be incorporated into the groundwater model.

In summary, the construction groundwater monitoring program will monitor:

- Groundwater levels at all new monitoring bores using telemetry
- Groundwater quality at selected bores shown in Table 11
- Continuous EC and temperature at key locations shown in Table 12
- Estimated groundwater inflow to the tunnels

3.2.2 Groundwater level

The groundwater level monitoring program will monitor levels in aquifers adjacent to the tunnel alignment.

Data loggers will be installed (or maintained from the baseline monitoring phase) in each construction monitoring bore (Table 4 and Table 5) to provide continuous data collection. Data loggers including existing telemetry are programmed to record at daily intervals.

To supplement the above continuous monitoring, manual measurements will be collected quarterly, at each bore in the construction monitoring network. It is noted that EMM reference GW7 recommends monthly manual groundwater level measurements. As there will be telemetry installed at construction monitoring bores, it is considered that quarterly manual measurements will be sufficient to verify logger data. Groundwater level data will be downloaded and reviewed at monthly intervals.

Measurements will be recorded in metres below top of casing (mbtoc) and converted to metres below ground level (mbgl) and metres Australian Height Datum (m AHD).

Recorded data will be compensated for barometric pressure and converted to a groundwater level measurement. Manual monitoring data will be used to verify continuous data.

Groundwater level data will be compared to local rainfall records to assess trends.

Performance criteria

Seasonal fluctuation considered within the HIR (Coffey 2021b) will facilitate the assessment and comparison between groundwater level decrease and the predicted drawdown from the Project. The assessment will determine whether the observed decrease is attributable to the Project and, if so, whether it aligns with approved predictions. Data analysis is described in Section 5.3 and groundwater monitoring reports will be produced every six months to assess this which will include data summary reports presenting tabulated groundwater monitoring data collected during the reporting period in accordance with Table 13.

If drawdown is identified outside of model predictions, management actions outlined in the GMP will be initiated including (but not limited to) a review of baseline groundwater level and quality data in the relevant and surrounding monitoring bores as well as an assessment of groundwater inflow rates into the tunnel. Following review of groundwater data, review of construction methodologies may be recommended.

For the management and implementation of remedial actions a “traffic light” approach has been adopted for setting trigger groundwater levels and limits. These levels are presented Table 10 with an explanation of the system provided below. Bore locations are presented in Figure 2 to Figure 4.

Early observation of groundwater level response to construction is important in understanding and predicting the longer-term response and these trigger levels may be refined as construction progresses and the groundwater response to excavation is better understood.

Groundwater level triggers for selected bores adjacent to GDEs, in recharge mitigation areas (Bicentennial Park and West Botany Street Depot), the Spring Street palaeochannel and Arncliffe have been developed.

Note that increases in groundwater levels are anticipated at some locations as a result of operation of a recharge system design to reduce temporary drawdown associated with construction excavation and tunnelling activities.

The traffic light system will be adopted based on current groundwater elevation and anticipated groundwater elevation at the completion of the excavation and tunnelling, with the following proposed actions when the specific trigger level is activated.

Green:

The groundwater levels observed during monitoring are within the target / green trigger level range and require no additional action.

Amber:

When the amber values are triggered, the following investigations will be undertaken:

- Investigation to the possible reason for the drawdown or drawdown trend
- Possible increase in monitoring frequency
- Checks on instrumentation, injection recharge bores and any other equipment associated with the groundwater mitigation system
- Consideration to modifications of groundwater level mitigation system in the case where drawdown is not found to be a seasonal variation

Red:

When the red trigger is activated the following investigations / assessments will be undertaken:

- Investigation to the possible reason for the drawdown or drawdown trend
- Increase in monitoring frequency
- Changes to groundwater level mitigation system that could comprise, but not limited to, increase in re-injection, replacement of injection bores or increase in the number of injection bores
- Implement a program of groundwater sampling where there is the potential for the altered groundwater levels to result in mobilisation of existing groundwater contamination

Table 10. Groundwater trigger levels and limits

Area	Monitoring bore or VWP ID	Ground level (m AHD)	Monitoring bore screen or VWP sensor elevation (m AHD)	Pre-development groundwater level range (m AHD)	Anticipated groundwater elevation at completion of excavation and tunnelling (m AHD)	Amber Trigger Level (m AHD)	Red Trigger Level (m AHD)	Status
Bicentennial Park	BH1501	3.2	-2.9 to 0.1	1.3 to 2.1	0.5	0	-0.5	Existing standpipe piezometer
	BH1514	3.2	-2.3 to -0.6	1.5 to 1.9	0.9	0.4	-0.1	Existing standpipe piezometer
	BH1702	5.1	-17.7 to -15.7	1.2	3.1'	0.8	0.3	Existing standpipe piezometer
	BH1415	5.3	-9.1 to -2.9	1.8 to 2.4	3.3'	1.3	0.8	Existing standpipe piezometer
	BH1301	3.2	-9.4 to -6.4	1.4 to 2.0	2.1'	0.9	0.4	Existing standpipe piezometer
	BH1429	4	-3.8 to 1.7	1.2 to 2.0	2.3'	0.7	0.2	Existing standpipe piezometer
	BH1432	4.5	-3.5 to -0.5	1.2 to 1.9	1.9	0.7	0.2	Existing standpipe piezometer
	BH1424**	2.9	-11.1 to 0.9	1.5 to 2.0	1.7	1	0.8	Existing standpipe piezometer
West Botany Street Depot	BH1421	3.1	-10.5 to 1.4	1.0 to 1.7	0.6	0.1	-0.4	Existing standpipe piezometer
	BH1511	3.2	-10.5 to -7.4	0.8 to 1.3	1	0.5	0	Existing standpipe piezometer
	BH1316	2.2	-28.7 to -25.8	1.2 to 1.7	0.8	0.3	-0.2	Existing standpipe piezometer
	BH1513	3	-22 to -18	0.8 to 1.3	0.9	0.4	-0.1	Existing standpipe piezometer
Muddy Creek (downstream)	BH2098a**	TBC	TBC	TBC	TBC	TBC	TBC	Proposed new standpipe piezometer (not yet installed)
Landing Lights Wetland	WCX-BH063a**	3.4	-4.6 to -1.6	0.6 to 1.1	0	-0.5	-1	Existing standpipe piezometer
Spring Street Palaeochannel	BH1315	3.9	-27.7 to -21.7	2.6 to 3.2	0	-0.5	-1	Existing standpipe piezometer

Area	Monitoring bore or VWP ID	Ground level (m AHD)	Monitoring bore screen or VWP sensor elevation (m AHD)	Pre-development groundwater level range (m AHD)	Anticipated groundwater elevation at completion of excavation and tunnelling (m AHD)	Amber Trigger Level (m AHD)	Red Trigger Level (m AHD)	Status
Arncliffe - M8 Monitoring	LDS-BH-2001**	2.2	-2.8 to 0.7	1 to 1.7	1	0.5	0	Existing standpipe piezometer
	BH2003	1.5	-29.5 to -23.5	-20.3	-25.3*	-25.8	-26.3	New standpipe piezometer
	LDS-BH-1041A	1.9	-12.3	-8 to -1	-12*	NA^	NA^	Existing VWP
	LDS-BH-1041B	1.9	-21.0	-12 to -2	-18.6*	-19.1	-19.6	Existing VWP
	LDS-BH-1041D	1.9	-60.3	-58 to -1	-75	NA^	NA^	Existing VWP
	LDS-BH-1038	15.15	-58.85 to -49.85	-50 to -49	-80	NA^	NA^	Existing standpipe piezometer

Note: No baseline trend for BH2003 groundwater level is available. Trigger levels will be updated once baseline data is available
* allowance for continuing influence of the M8 project
^ expected to go dry therefore no trigger set
' rise in groundwater level anticipated due to operation of recharge system
** GDE monitoring bore
TBC - to be confirmed following installation

3.2.3 Groundwater quality

Groundwater level and quality monitoring will be carried out at a combination of existing and proposed baseline monitoring bores. Bore locations are illustrated in Figure 1 to Figure 5. An indication of the proposed construction groundwater monitoring program is provided in Table 11. The construction monitoring program is to be updated following further baseline data collection.

Groundwater quality monitoring will include measuring field water quality parameters (EC, pH, redox, dissolved oxygen and temperature) and collection of groundwater samples for testing at a NATA accredited laboratory. The following laboratory analytical suite is proposed for monthly and quarterly sampling events:

- General indicators (EC, TDS and resistivity)
- Major cations (calcium, magnesium, sodium, potassium)
- Major anions (chloride, sulfate) and speciated alkalinity (bicarbonate, carbonate, hydroxide)
- Dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc) (field filtered) and total metals (iron, manganese) (unfiltered sample)
- Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorous, reactive phosphorous)
- Total organic carbon (TOC)

Additional analytes listed below may also be tested on a quarterly basis for selected bores if hydrocarbon and PFAS contamination is identified in the additional baseline investigations:

- Total recoverable hydrocarbons (TRH)
- Benzene, toluene, ethylbenzene, xylene (BTEX)
- Polycyclic aromatic hydrocarbons (PAHs)
- Volatile organic compounds (VOCs)
- PFAS

Quarterly groundwater sampling events for the majority of the construction monitoring bore network is considered sufficient as the timing for changes in water quality is expected to be greater than three months.

The groundwater monitoring network and program will be refined during construction based on the observed groundwater responses to construction activities and ongoing development and recalibration of the groundwater model.

The proposed construction groundwater monitoring program is suitable for identification of potential groundwater quality issues as bores have been targeted along the alignment where model predicted drawdown has been identified, for bores screened in the coastal deposits as well as rock. This will allow comparison with groundwater model results (refer to Section 5.2.4 of the GMP).

Table 11. Proposed construction groundwater quality monitoring program

Area	Bore ID	Easting MGA2020	Northing MGA2020	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)	Proposed sampling frequency
Arncliffe	LDS-BH-2005A	329610	6243366	Bedrock	25.18	28.2	Quarterly
	BH2003	329563	6243295	Alluvium	25	31	Monthly
	LDS-BH-1038	329099	6243199	Bedrock	65	74	Monthly
	LDS-BH-2001	329362	6243036	Alluvium	1.5	5	Quarterly
	BH002	328930	6243014	Bedrock	58	70	Quarterly
	LDS-BH-2003	329720	6242897	Alluvium	6	9	Quarterly
Spring Street palaeochannel	BH1102	328559	6242552	Bedrock	71	74	Quarterly
	BH1314	328546	6242495	Alluvium	19	25	Quarterly
	WCX-BH063a	329207	6242451	Alluvium	5	8	Monthly
	BH1315	328709	6242448	Alluvium	25.6	31.6	Monthly
	BH005	328445	6241920	Bedrock	56.3	68.7	Quarterly
Rockdale	BH2054a	328493	6241015	Alluvium	14.5	17.5	Monthly
	BH2054b	328494	6241017	Bedrock	32.5	38.5	Monthly
	BH1300	328265	6241005	Alluvium	13	16	Quarterly
	BH1503	328337	6240975	Alluvium	14.2	17.2	Quarterly
West Botany Street	CH1404	328775	6240948	Alluvium	1.8	13.8	Monthly
	BH1511	328559	6240923	Alluvium	10.8	13.8	Quarterly
	BH1421	328872	6240903	Alluvium	1.8	13.8	Monthly
	BH1513	328945	6240845	Alluvium	21	25	Quarterly
Bicentennial Park area	CH1403	328593	6240610	Alluvium	5	8	Quarterly
	BH1702	328619	6240513	Alluvium	20.8	22.8	Quarterly
	BH1301	328535	6240509	Alluvium	9.65	12.65	Quarterly
	BH1415	328665	6240495	Fill/Alluvium	2.4	14.4	Quarterly
	BH1703	328639	6240495	Bedrock	24.8	27.8	Monthly
	BH1429	328549	6240460	Alluvium	5.8	8.8	Quarterly
	BH1424	328701	6240429	Alluvium	2	14	Monthly
	BH1425	328739	6240382	Fill/Alluvium	2	14	Quarterly

Groundwater salinity

Data loggers that can record EC, temperature and groundwater level will be installed at three key monitoring bores between the tunnel alignment and saline water bodies (Table 12, Figure 2 to Figure 4). The data loggers will be programmed to record data daily.

Data loggers will be downloaded monthly for the first three months, followed by quarterly. Quarterly groundwater sampling events for the majority of the construction monitoring network is considered sufficient as the timing for changes in water quality is expected to be greater than three months.

EC results will be assessed to detect changes in water quality that may indicate the intrusion of saline water towards the tunnel. Data analysis is described in Section 5.3 and groundwater monitoring reports will be produced every six months in accordance with Table 13. A review of the monitoring program after the first 12 months of construction will be completed to determine the efficiency of the monitoring program and any required changes.

Table 12. Preliminary EC SSTV and bore details for continuous EC and temperature monitoring

Area	Bore ID	Easting MGA2020	Northing MGA2020	Screened stratigraphic unit	Installed screen depth (m)	Baseline field EC range (µS/cm) May 2020 to Nov 2021	Preliminary EC SSTV (µS/cm)
Spring Street / Landing Lights Wetland	WCX-BH063a	329207	6242451	Alluvium	5 to 8	218 to 291	450
West Botany Street Depot	CH1404	328775	6240948	Alluvium	1.8 to 13.8	318 to 1507	2200
Bicentennial Park	BH1424	328701	6240429	Alluvium	2 to 14	5356 to 15034	22500

Performance criteria

Baseline monitoring shows that some groundwater quality parameters exceed the default Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). The guidelines have been published as an interactive website (http://waterquality.gov.au/anz-guidelines). The criteria adopted (refer to Appendix C of the GMP) are based on the proposed groundwater disposal to stormwater, and discharge criteria provided in Section L2.5 of Environment Protection Licence (EPL) 21600. The screening criteria are based on;

- ANZECC/ARMCANZ 2000 relevant physical and chemical stressors
- ANZG (2018) 90% species protection criteria for marine water, with criteria for toxicants known to bioaccumulate assessed based on the 95% species protection criteria. Water quality for Zone F has also been assessed against the relevant freshwater criteria due to the potential for discharge to the predominantly freshwater ecosystem of the Bicentennial Park Wetlands
- Perfluorooctane sulfonate (PFOS) criteria of 0.13 ug/L, and perfluorooctanoic acid (PFOA) criteria of 220 ug/L.

The Australian Standard AS2159 – 2009 Piling design and installation have also been considered to assess potential groundwater aggressivity risks posed by groundwater to underground concrete and steel structures.

Field EC values at key monitoring locations are summarised in Table 12. Baseline data indicates sampling depth influences EC values as well as proximity to saline water on the eastern boundary of the West Botany Street Depot. EC values in the Bicentennial Park area are influenced by the landfill. BH1424 is screened below fill in saturated sediments near the wetland in Rockdale Bicentennial Park.

Site specific trigger values (SSTVs) will be developed where the potential for an adverse change in risk to receptors due to project activities is identified. The potential for saline intrusion has been identified as a risk, therefore preliminary SSTVs for groundwater EC have been developed (Table 12) using baseline data at three key locations in the Spring Street palaeochannel, West Botany Street Depot and Bicentennial Park in order to monitor and identify if an adverse change in risk profile associated with saline intrusion occurs.

The preliminary EC SSTVs will be refined over time as existing variability including seasonal trends and vertical stratification are further assessed.

The SSTVs will provide an identifiable indication of a potential change in salinity. A management response would be initiated if any of the following occurs:

- EC data continuously exceeds the SSTV over a period of three months and depicts a rising trend
- EC data exceeds the SSTV at any time by more than 150%

If one or both of the above EC triggers are observed a review will be initiated to determine the significance of the exceedance(s) and possible causes. The review will assess the historical and surrounding monitoring bore data, and modelling predictions.

If the exceedance is determined to be attributable to Project works and outside of approved model predictions for saline intrusion the groundwater model will be reviewed and updated within 3 months of the exceedance occurring. The updated model will be used to assess potential impacts and inform mitigation measures such as additional recharge or grouting if required.

Volatile organic compounds (VOCs) can also present a potential vapour intrusion risk in an urban environment. No existing potential vapour intrusion risks have been identified based on baseline data previously collected and therefore no SSTVs for VOCs have been developed. A gap in the existing baseline data was identified for a number of analytes including VOCs, and additional groundwater sampling has been conducted in November and December 2021 to include analysis for VOCs at 30 existing groundwater monitoring bores. If VOCs are detected and assessed as a potential risk from the new data collected, SSTVs will be developed and a risk monitoring framework for vapour intrusion adopted as per the flowchart in Figure 7 to identify where existing conditions have been changed by project activities, and an adverse change in risk may have occurred.

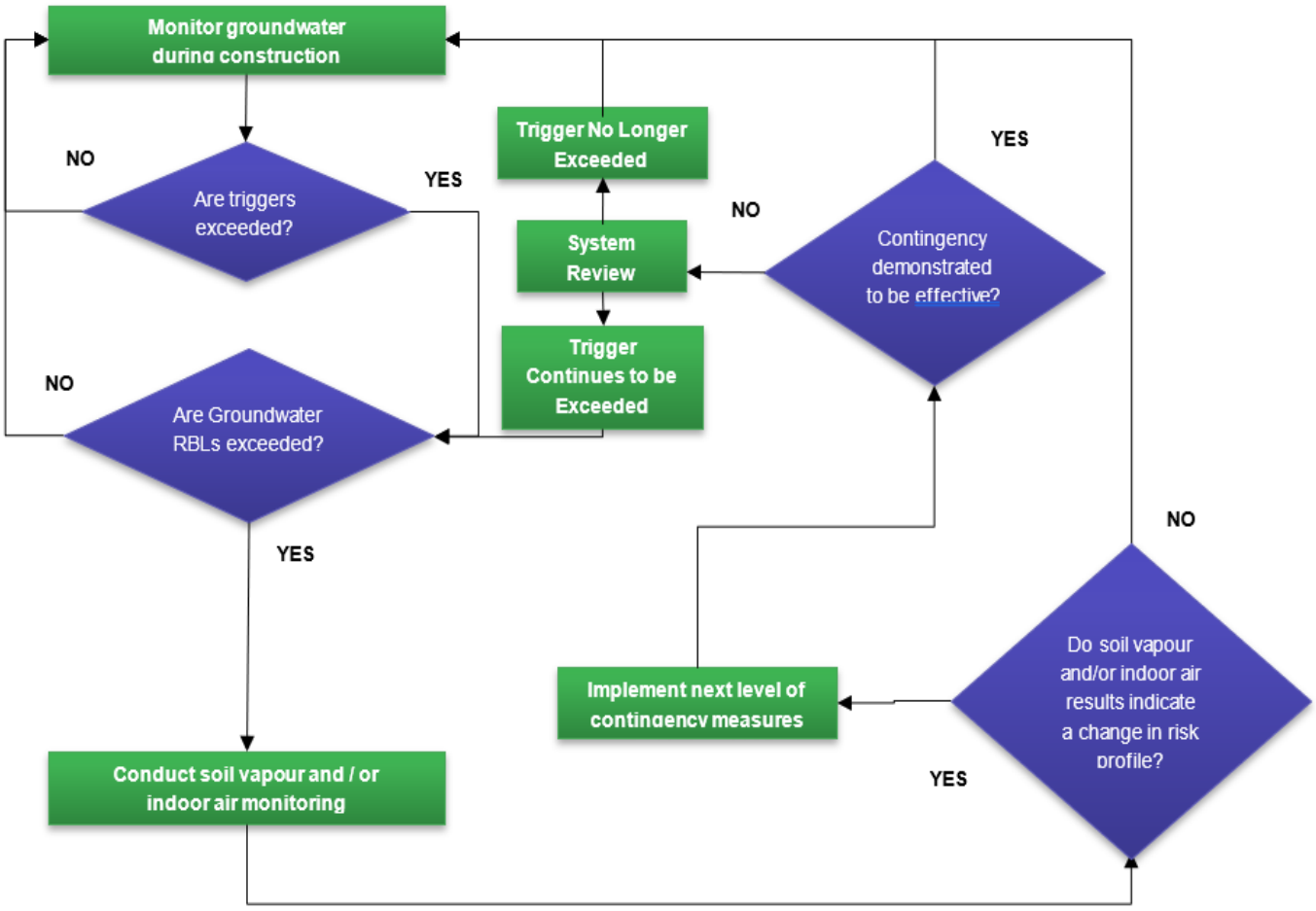

Figure 7. Basement vapour risk decision pathway

3.2.4 Tunnel inflow

During construction, groundwater will be intersected and managed by either capturing the water that enters the tunnels, caverns, and portals or by restricting inflow through targeted grouting where required in cut-and-cover sections.

Groundwater inflow into the tunnels will be monitored during construction, reviewed monthly and compared to model predictions. The groundwater model will be updated as required based on the results of monitoring, and proposed management measures to minimise potential groundwater impacts adjusted accordingly.

Based on modelling conducted for the HIR, predicted inflows without treatment are expected to be approximately 1.5 L/s/km in the Arncliffe area north of Chainage 1250. This flow would be associated with a corresponding reduction in seepage inflow into the adjacent lengths of the existing M8 tunnel. Considering initial higher inflows during construction, the criteria for checking groundwater inflow into the tunnels in this northern area will be 2 L/s/km. For the remaining alignment criteria of 1 L/s/km will be adopted to check model predictions.

If inflow rates are higher than predicted, review of the requirement for management measures including grouting will be undertaken.

A simple water balance approach will be used to estimate groundwater inflows to the tunnel during construction:

Groundwater inflow = WTP discharge – Project water inputs

This simplistic approach does not consider the water that will be extracted in the spoil. This water is accounted for in groundwater modelling for the Project and is predicted to not contribute to ongoing drawdown and associated impacts.

In areas where tunnels and subsurface structures are to be constructed within the alluvium and palaeochannels, additional mitigation measures including targeted grouting and engineered structures such as diaphragm walls will be implemented to restrict groundwater ingress.

High groundwater inflow during excavation is possible in faulted or fractured rock zones and in the alluvium. Mitigation measures to reduce bulk hydraulic conductivity will include grouting which will be undertaken as required through the construction program to reduce tunnel inflow.

3.2.5 Water treatment plant monitoring

Groundwater captured during construction of the Project will be treated at three WTPs at construction ancillary facilities C1 Arncliffe, C2 Rockdale Depot and C3 Bicentennial Park. The water from the treatment plants will be tested and either reused or discharged in accordance with the Project EPL.

At the time of preparation of this document, it is proposed to discharge treated water to the Cooks River from C1 Arncliffe WTP, and to stormwater infrastructure that discharges into Muddy Creek from C2 Rockdale Depot WTP. The discharge location for the WTP at C3 Bicentennial Park is subject to further investigation and design. Confirmation of the receiving environment for any discharge will be made during the design phase, will be assessed through the development of a discharge impact assessment and will be considered in future revisions of this Plan.

In accordance with EPL 21600 (Condition U1), construction water discharge impact assessments are being prepared for each proposed WTP. The primary objective of the discharge impact assessments is to assess the potential impacts of discharges to receiving waterways to inform EPA licencing and compliance requirements. In accordance with the EPL, these discharge impact assessments will be submitted to the EPA for consideration prior to discharge from the proposed M6 WTPs. The EPA will then review the risks and impacts from the assessment and issue discharge and compliance conditions.

The water treatment plants will be designed to treat water to EPL, CoA E168 and SC4 criteria and compliance with these criteria will be described in the discharge impact assessments. It is

envisaged the treatment train of each WTP will include multiple processes to achieve these criteria including:

- bulk settling of solids
- raw water balancing and oxidation
- chemical dosing (pH correction, flocculant/coagulant, heavy metal oxidant)
- clarification (lamella clarifiers)
- media filtrations
- breakpoint chlorination (and de-chlorination)
- activated carbon filtration
- specialist ion exchange treatment

A “bolt-on” approach has been developed to ensure that the WTPs can be tailored and contain appropriate treatment-trains, enabling a confidence that all discharge will meet the specified criteria of the EPL, CoA E168 and SC4 as will be demonstrated to the EPA through the discharge impact assessment.

Monitoring of the WTP processes by trained operators and the monitoring of physical analytes will be used to assure the processes are working, providing confidence in discharge quality. Grab samples for laboratory analysis will be used for verification purposes and ongoing quality assurance. WTP data will be assessed and included in the water monitoring reports produced every six months in accordance with Table 13.

WTP discharge volume

Discharge volumes will be continuously monitored at the WTPs via calibrated flow meters, which will enable the daily measurement of the amount of water discharged from the WTPs.

Discharge water quality

Water treatment plant commissioning

A minimum of two discharge monitoring rounds will be conducted during commissioning of the WTPs. The discharge analysis suite will be confirmed following agreement with EPA. If required, revision of the analytical suite will be undertaken following initial monitoring during commissioning.

Commissioning of the WTP will be dependent on two consecutive discharge water monitoring rounds complying with the discharge criteria. The commissioning process will be undertaken until consecutive samples comply with the adopted criteria.

Water treatment plant post-commissioning

Following commissioning and during construction, discharge water quality will be sampled at monthly intervals. Sampling frequency will be subject to EPL requirements and will occur at frequencies no greater than monthly. Results will be reviewed by suitability trained personnel (refer to Section 5.2).

Sydney Water will be consulted if it is proposed to discharge treated groundwater into Sydney Water assets. Trigger levels will be derived to track performance of the WTP and inform implementation of any management measures if measured parameters are recorded outside of the adopted operating range. Periodic manual readings of the sensors will be made to confirm operation. Where possible, comparison of sensor results will be made with laboratory analytical results to confirm consistency.

Consistent with wider groundwater quality monitoring results, water treatment plant discharge water quality results will be reviewed monthly and reported as part of the six-monthly groundwater monitoring report.

Performance criteria

A discharge impact assessment will be prepared and submitted for review to the EPA. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved).

All discharge from construction WTPs will be carried out in accordance with the Project EPL.

ANZG 2018 default guideline values are based on the stormwater environment discharge points as follows:

- C1 Arncliffe WTP discharge - Cooks River marine environment
- C2 Rockdale Depot WTP discharge - Muddy Creek marine environment (Muddy Creek is a concrete lined drain in upstream area outside tidal zone)
- C3 Bicentennial Park WTP discharge - freshwater environment if discharge can be approved for the Bicentennial Park Ponds (preferred option). Marine environment if discharge needs to be piped further south of weir to Scarborough Ponds.

In the event that discharge from the WTP is detected as out of specification on physical and field measurable parameters (such as pH and turbidity), the WTP will automatically recirculate, preventing discharge. This automated process redirects treated water to the balance tank for retreatment, prior to discharge. For the extended list of laboratory measured parameters, which can only be checked for compliance following discharge, it will be recorded as a non-conformance and/or non-compliance and an investigation will be commenced immediately and in accordance with EPL 21600 and Section 3.10 of the CEMP. A water discharge impact assessment is currently being prepared for each water treatment plant, in accordance with the Pollution Study and Reduction Program included in EPL 21600 and will be submitted to the EPA for approval (including for discharge criteria and monitoring requirements) prior to the operation of new WTPs for the M6 Project.

4 Monitoring methodology

4.1 Overview

The adopted groundwater monitoring methodology for the Project is summarised below and detailed in the following sections.

- Groundwater level will be monitored via manual gauging and data loggers (including VWPs). Selected data loggers will be telemetered and report data to an online portal. Remaining data loggers will be manually downloaded.
- Groundwater salinity will be monitored via EC data loggers and periodically manually downloaded.
- Groundwater quality will be monitored at selected monitoring bores. The methodology will be dependent on a bore condition assessment conducted prior to construction.
- Water treatment plant discharge quality will be monitored via grab samples and continuous monitoring of key parameters to be confirmed with Sydney Water, and discharge volume will be monitored via a flow meter.
- A quality control plan detailing quality assurance and control processes will be implemented.
- All groundwater monitoring will be conducted by suitably qualified and experienced personnel.

4.2 Manual groundwater level measurements

Manual measurement of the static groundwater level will be conducted using an electronic groundwater level meter (dipper) from a known (surveyed) point at the top of the bore casing. Measurements will be recorded to the nearest millimetre, in metres below the top of the casing (mbTOC). Data will be converted to m AHD using survey monitoring data. Data will be provided in m below ground level and m AHD. Monitoring frequency is summarised in Section 3.2.2.

4.3 Continuous groundwater level and EC measurements

Continuous measurement of groundwater level (as pressure) and EC will be undertaken by calibrated data loggers at selected monitoring bores and VWPs (pore pressure). Dataloggers will be installed at predetermined depths in each bore. Where accessible, data will be periodically validated by manual groundwater level measurement. Data loggers will be recalibrated if discrepancies outside of the acceptable range are observed.

Data loggers will be manually downloaded monthly for the first three months and quarterly from then during construction (refer to Section 3.2.2). Data will be downloaded remotely and reviewed monthly during construction.

4.4 Groundwater quality

4.4.1 Groundwater bore monitoring

Representative groundwater samples will be collected from selected bores prior to and during the construction phase. The method of sampling will be use of hydrasleeves. Groundwater samples will be collected in appropriate laboratory supplied bottles and sent to a NATA accredited laboratory for analysis under the Chain of Custody process outlined in Section 4.4.5.

4.4.2 Water treatment plant discharge samples

Grab samples will be collected at a point close to the discharge outlet to ensure samples are representative of treated discharge. Samples will be sent to a NATA accredited laboratory for analysis under the Chain of Custody process outlined in Section 4.4.5.

4.4.3 Field measurements

Water quality parameters will be measured during groundwater quality sampling using a calibrated field water quality meter. Water quality meter accuracy will be reviewed against known calibration standards daily and if needed, re-calibrated in accordance with the manufacturer's instructions. Records of review against calibration standards and any recalibration will be maintained.

Parameters to be monitored include:

- Redox potential: ± 10 mV
- Dissolved oxygen (DO): ± 10%
- Temperature: ± 0.2 °C
- pH: ± 0.1 pH unit
- Electrical conductivity (EC): ± 3%

4.4.4 Decontamination

Decontamination of re-useable sampling equipment will be conducted between sampling locations. Other equipment may be cleaned periodically as required. Equipment will be rinsed with tap water, cleaned with Decon-90 (or equivalent), and undergo further rinsing with tap water then deionised water. Equipment will be allowed to dry before being used.

4.4.5 Quality assurance and control

Quality assurance and control measures during sampling and field data collection will be undertaken to ensure data integrity. Measures include:

- Use of NATA accredited laboratories for sample analysis.
- Use of CoC procedures between sample collection in the field and subsequent reception of the sample by the laboratory. CoC documentation includes the sample type and code, analysis required, collection date, sampler and sample receiver(s).
- Appropriate sample handling and storage including using laboratory supplied containers, keeping samples chilled (or frozen if required) during storage and transport, ensuring samples are received in good condition within specified holding times by the laboratory.

A consistent program of quality control sampling will be adopted for fieldworks for the Project, including:

- Collection of duplicate and triplicate samples at an average frequency of one sample per twenty primary samples (an overall ratio of 1:10).
- Collection of rinsate blanks to measure the effectiveness of decontamination procedures.
- Collection of trip blanks to assess the adequacy of sample storage and transport procedures in preventing cross contamination.

4.4.6 Recording and documentation of results

All monitoring and sampling data will be recorded in the field and transferred to an electronic data base. Data will be reviewed prior to importing into the database. Further detail is provided in Section 5.3.

Field results during monitoring will be recorded on hard copy or digital field forms. Field forms will detail:

- Bore location and condition
- Summary of climatic setting including weather and tide stage
- Type of equipment used and equipment serial numbers
- Method of sampling (hydrasleeve deployment and retrieval dates)
- Details of the sampler
- Field parameters, groundwater level, odour, colour and any other observations made during sampling
- Time and date of sampling

5 Compliance management

5.1 Roles and responsibilities and training

The CGU Project Team's organisational structure and overall roles and responsibilities are outlined in Section 3.4 of the CEMP. Specific responsibilities for the implementation of environmental controls are detailed in Section 6 of the Groundwater CEMP Sub-plan.

All employees, contractors and utility staff working on site will undergo site induction training relating to groundwater management issues, detailed in the Groundwater CEMP Sub-plan.

Further details regarding staff induction and training are outlined in Section 3.6 of the CEMP.

5.2 Groundwater monitoring

Groundwater monitoring requirements are detailed in Section 3.2 and include the location, parameters to be monitored, analysis suite and frequency of monitoring. Groundwater monitoring methodology is summarised in Section 4.

Additional requirements and responsibilities in relation to inspections are documented in Section 3.9.1 and Section 3.9.2 of the CEMP.

5.3 Data analysis

Groundwater level records from data loggers will be manually compensated for barometric pressure and converted to the Project datum (m AHD). Manual groundwater level measurements will be corrected for salinity and used to validate the accuracy of continuous groundwater level records.

Groundwater level monitoring results will be compared to groundwater model predicted drawdown and if potential adverse impacts may arise as a result of this comparison, the implementation of additional mitigation measures will be considered. Local rainfall trends will be considered to assess the impacts of seasonal variability in groundwater levels during construction. Groundwater level observations will be used to inform future revision of the groundwater model.

Groundwater quality results from monitoring bores will be compared to baseline data following each monitoring event. Trends will be reviewed to assess potential mobilisation of existing contamination due to construction. EC results from data loggers will be compared to SSTVs following data collection and if required, inform the implementation of any mitigation measures. Additional SSTVs for VOCs may be developed if additional baseline sampling identifies potential vapour intrusion risk.

Water treatment plant sample results will be compared with discharge criteria monthly and reported in the six-monthly groundwater report as detailed in Groundwater CEMP Sub-plan.

Results and analysis of the groundwater response to recharge and pumping tests will be presented in future revisions of the recharge design reports (Coffey 2021c and 2021d) and the HIR (Coffey 2021b).

5.4 Auditing

Audits (both internal and external) will be undertaken to assess the effectiveness of environmental controls, compliance with this sub plan, CoA and other relevant approvals, licences and guidelines.

Audit requirements are detailed in Section 3.9.3 of the CEMP.

5.5 Reporting

Detailed periodic review and reporting of groundwater level and quality will be conducted during construction, with particular focus during early excavation below the groundwater level. Groundwater level and quality results will be compared to baseline results and adopted performance criteria. Monitoring reports will be submitted to DPIE Water, Sydney Water (where required) and TfNSW within 60 days of the reporting period unless otherwise agreed with DPIE Water.

Project data provision and reporting requirements are summarised in Table 13.

Table 13: Groundwater management reporting schedule

Reporting timing / frequency	Reporting requirement	Report recipient
Reporting		
Groundwater Review Report	A review report will be prepared to document results of the first three months of monitoring new bores. This report will recommend monitoring frequency and analytical suites for future monitoring. Timing of this review report may be the start of construction monitoring rather than the end of baseline monitoring. Selected bores will continue with monthly monitoring and monitoring frequency of the remaining bores and the analytical suite will be reviewed.	DPIE Water, Planning Secretary, ER, Sydney Water
Groundwater Monitoring Report (six-monthly)	Construction groundwater level and quality monitoring reports will include data collected during the reporting period. The report will include comparison of observed levels to model predictions and groundwater quality to SSTV and baseline data. A summary of construction status and inflow during the reporting period will be presented. A summary of WTP discharge compliance will be presented. The operation of groundwater management measures during the reporting period will be summarised and the requirement for any additional management measures will be documented. Compliant with CoA C14(g). If connection to a Sydney Water asset is required, then the reporting of the data collected under C14(a) and (b) would be provided as required by Sydney Water.	DPIE Water, Planning Secretary, ER, Sydney Water. The report will be made publicly available.

Reporting timing / frequency	Reporting requirement	Report recipient
Data		
Groundwater monitoring data (quarterly)	Groundwater level and quality data in tabulated and electronic quality-controlled ready to use format. Compliant with CoA C17(h).	DPIE Water

6 Review and improvement

6.1 Continual improvement

Monitoring data will be reviewed throughout construction for continual improvement. Section 3.2.2 of the CEMP describes the process for the continual improvement of project documents.

Continual improvement of this Program will be achieved by the ongoing evaluation of environmental management performance against environmental policies, objectives and targets and Project performance outcomes of the EIS for the purpose of identifying opportunities for improvement.

The continual improvement process is intended to:

- Identify areas of opportunity for improvement of environmental management and performance;
- Determine the cause or causes of non-conformances and deficiencies;
- Develop and implement a Program of corrective and preventative action to address any non-conformances and deficiencies (refer to Section 3.10 of the CEMP);
- Verify the effectiveness of the corrective and preventative actions;
- Document any changes in procedures resulting from process improvement; and
- Make comparisons with objectives and targets.

7 References

AECOM. 2018. F6 Extension Stage 1 EIS Technical Report K: Groundwater Technical Report. October 2018.

ANZECC. 2000. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. National Water Quality Management Strategy - Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

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Cardno (NSW/ACT) Pty Ltd. 2021. M6 Groundwater Monitoring Quarter 3 Report M6 Groundwater Monitoring Services. Report reference AWE200230_M6_GWMR_Q3_Rev1, dated 17 March 2021.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021a. Hydrogeological Factual Report – Project wide. M6 Motorway Stage 1. Report reference M6S1-COF-NWW-ENGE-RPT-680520.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021b. Hydrogeological and Groundwater Interpretive Report – Project wide. M6 Motorway Stage 1. Report reference M6S1-COF-NWW-ENEV-RPT-680440.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021c. Recharge system design – Bicentennial Park. M6 Motorway Stage 1. Report reference M6S1-COF-SWBIP-ENWA-RPT-416300.

Tetra Tech Major Projects Pty Ltd (Coffey) 2021d. Recharge system design – West Botany Street Depot. M6 Motorway Stage 1. Report reference M6S1-COF-SWWBS-ENWA-RPT-419500.

Appendix B – Scope of Works and Technical Criteria (SWTC)

A summary of the key requirements relevant to the hydrogeological aspects of the project as set out in the SWTC is provided in Table B1.

Table B1: Key hydrogeological SWTC conditions

Condition	Condition description	SWTC Appendix B.3 (Tunnels) reference	Relevant report
Control methodology	The groundwater control methodology must be prescribed on long sections. Changes during construction will be treated as a major design change.	6.1 b)	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
Durable remedial measures	Durable remedial measures must be developed to ensure groundwater performance criteria are met	6.1 d)	Relevant design report
No adverse impact	Contractor's Activities must not cause changes to the groundwater regime that adversely impact the natural environmental or existing infrastructure	6.1 e)	Predicted impacts summarised in Section 5.2 of this Plan and Section 13 of the HIR.
Must not cause contamination	Contractor's Activities must not cause groundwater contamination and must minimise movement of existing contamination.	6.2 a)	Predicted impacts summarised in Section 5.2 of this Plan and Section 13 of the HIR.
Permanent dewatering	Not permitted except as indicated below and provided impacts at not greater than 'Acceptable Impacts'	6.2 b)	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
Undrained tunnels	Not exceed 0.2 L/d per square metre of tunnel surface area over any 100 m length of tunnel	6.2 c) (i) A	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
	Not exceed 0.4 L/d per square metre of tunnel	6.2 c) (i) B	Recharge system design reports for Bicentennial Park (M6S1-COF-

Condition	Condition description	SWTC Appendix B.3 (Tunnels) reference	Relevant report
	surface area over and 10 m length of tunnel		SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
	Groundwater seepage through the pavement and floors must be nil	6.2 c) (i) C	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
Drained tunnels	Not exceed 1 L/s/km	6.2 c) (ii) A	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
	Not exceed 0.3 L/s in any given 120 m of tunnel	6.2 c) (ii) B	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
	Not exceed 0.01 L/m^2/d for equipment and plan rooms including Tunnel Equipment Spaces	6.2 c) (ii) C & D	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
Application of inflow limits	Above limits apply to any tunnel (including Carriageway Tunnel and Ventilation Tunnels), Ventilation Shafts.	6.2 d)	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and

Condition	Condition description	SWTC Appendix B.3 (Tunnels) reference	Relevant report
			West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
No drips or seeps on wall	Groundwater must be controlled to prevent drips or flows down walls of permanent structures.	6.2 e)	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
Groundwater Control Systems to be used	Groundwater Control Systems are to be used to achieve nominated limits, behind primary Structural Lining at locations where water bearing features are present.	6.3	Recharge system design reports for Bicentennial Park (M6S1-COF-SWBIP-ENWA-RPT-416300) and West Botany Street Depot (M6S1-COF-SWWBS-ENWA-RPT-419500)
Tunnel Drainage	Minimum tunnel drainage system accommodating the credible combination of stormwater, incident spillage, groundwater, maintenance, firefighting and other liquid ingress events must be provided.	14.2	Relevant design report
Water Treatment Plant (WTP)	WTP must be designed to treat all tunnel drainage and groundwater inflows encountered during tunnel operation and maintenance. The initial water production forecast to be used in the WTP design is: a) groundwater, 16.21 L/s; b) washwater, 5L/s continuous; and c) tunnel portal first flush run-off, 10 L/s for 5 minutes	14.3	Relevant design report

Appendix C – Baseline groundwater quality summary (preliminary)

Baseline groundwater quality summary (preliminary)

Data sources

Groundwater quality data originally presented in reference design documents has been compiled into an electronic ESdat database. A significant amount of additional investigation is proposed to assess baseline conditions prior to construction commencing (refer to Appendix A and Tables C-6 and C-7). Baseline groundwater data from new and existing wells will be added to the database as it is generated.

The database currently includes laboratory-reported groundwater quality data since 2018 that has been available in an electronic form. Historical laboratory data collected during 2016 and 2017 which was not available electronically has been extracted from PDF format tables using PDF editing software so that it could be compiled and imported into the ESdat database. Similarly, field-measured water quality parameters (pH, electrical conductivity, redox potential, dissolved oxygen, TDS, major ions, and resistivity) not provided electronically has either been extracted using PDF editing software or manually digitised.

While all reasonable efforts have been made to ensure manual data transcription errors, and errors introduced during manipulation and importing to a database were identified and corrected, the potential exists for the historical laboratory data reported prior to 2018 and field water quality parameters to include errors and/or results to be omitted or assigned to incorrect analytes.

Adopted criteria

The following sections provide an assessment of groundwater quality across seven zones of the project alignment (Zone A to Zone G) as shown on Figure C-1. The criteria adopted are based on the proposed groundwater disposal to stormwater, and discharge criteria provided in Section L2.5 of Environment Protection Licence 21600. The screening criteria are based on;

- ANZECC/ARMCANZ 2000 relevant physical and chemical stressors;
- ANZG (2018) 90% species protection criteria for marine water, with criteria for toxicants known to bioaccumulate assessed based on the 95% species protection criteria. Water quality for Zone F has also been assessed against the relevant fresh water criteria due to the potential for discharge to the predominantly freshwater ecosystem of the Bicentennial Park Wetlands
- Perfluorooctane sulfonate (PFOS) criteria of 0.13ug/L, and Perfluorooctanoic acid (PFOA) criteria of 220ug/L.

The Australian Standard AS2159 – 2009 Piling design and installation have also been considered to assess potential groundwater aggressivity risks posed by groundwater to underground concrete and steel structures.

Discussion of key contamination sources and their impact on groundwater quality is provided in the following sections, and is based on data and discussion provided in Section 10 of the *Hydrogeological and Groundwater Interpretive Report – Project Wide* (ref: M6S1-CGU-NWW-EV-RPT-680620).

Zone A – Arncliffe Area

Coastal deposit aquifer

Based on the available data, the groundwater in the coastal deposit aquifer is conceptualised to migrate vertically to the underlying, and largely dewatered bedrock aquifer in Zone A.

Field water quality parameters, dissolved metals, and ammonia data has been summarised for the Zone A area based on a 2016 environmental site assessment for the Kogarah Golf Course at Marsh Street, Arncliffe (Golder, 2016). The data indicate a mean calculated TDS of approximately 1,500 mg/L, acidic groundwater conditions with pH ranging from 4.2 to 6.7 and variable, but generally reducing redox potential (from -75.5 to 142.6 mV). The *Acid Sulfate Soil & Salinity Assessment Report* (ref: M6S1-CGU-NWW-EV-RPT-680400) indicates that potential acid sulfate soils were detected in the majority of the sampling locations in the Arncliffe area, generally in the Quaternary sediments.

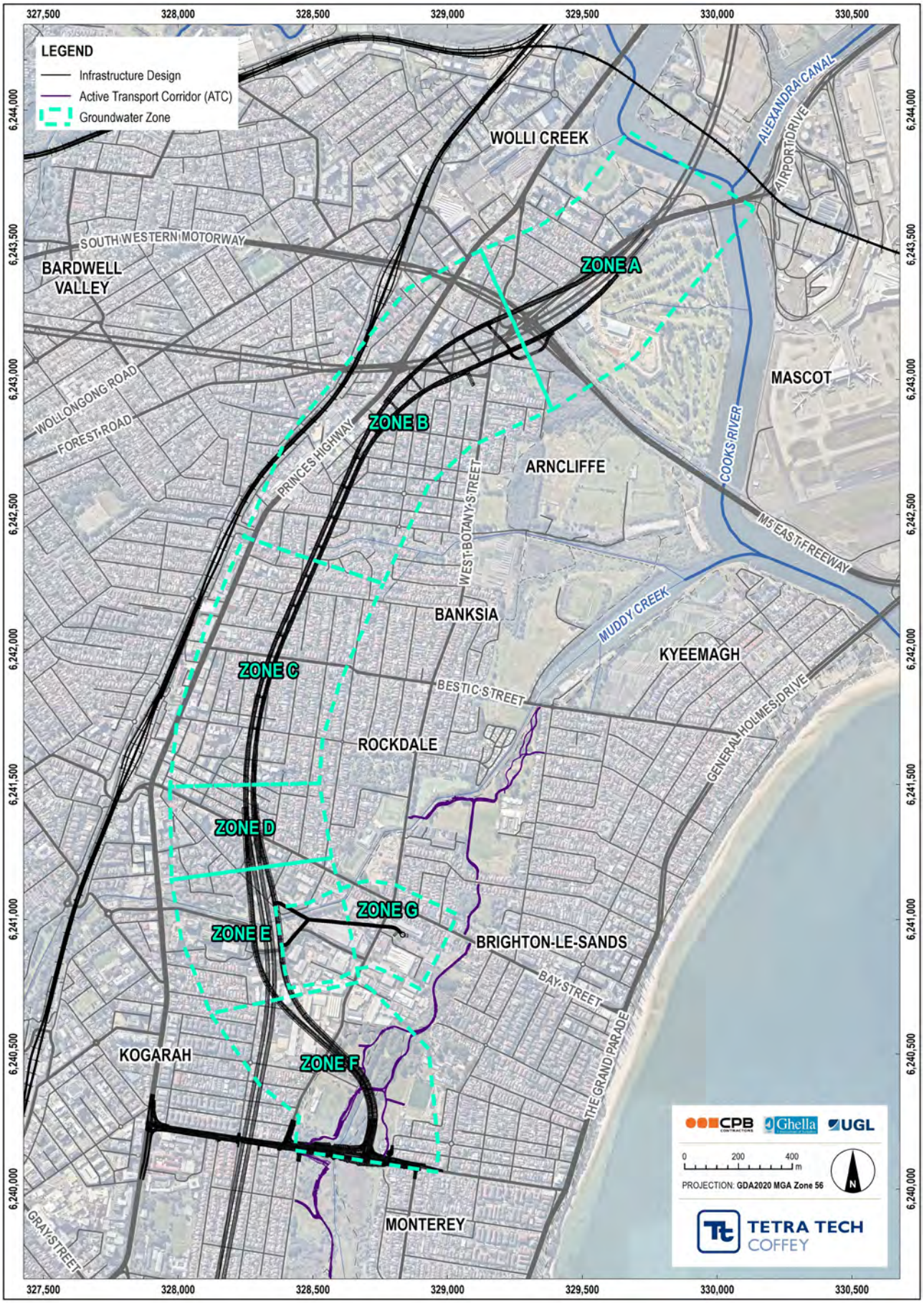

Figure C-1: Zones used for groundwater quality summary

Ammonia was present at concentrations ranging from 0.12 mg/L to 10 mg/L (mean of 3.6 mg/L) together with dissolved methane and visible de-gassing of groundwater samples reported at some locations. Ammonia and dissolved methane are attributed to a former landfill at Barton Park, south of the M5 East Freeway where putrescible waste and sewage was historically disposed. The landfill does not include leachate or landfill gas management systems. The average ammonia concentrations in groundwater in this area exceeds the marine water based discharge criteria of 1.2mg/L indicating treatment may be required prior to release to stormwater or surface water.

One alluvial monitoring well in Zone A (LDS-BH-2001) was sampled during January 2021 for PFAS analysis. The total PFAS concentration reported was 0.414 µg/L, of which PFOS accounted for 0.032 µg/L. The PFOS concentration reported at LDS-BH-2001 does not exceed the discharge criteria of 0.13ug/L, however data from additional locations is required to confirm concentrations and whether groundwater from this area is suitable for disposal to stormwater or surface water.

Leachate impacted groundwater may currently be drawn from the coastal deposit aquifer into the underlying bedrock aquifer and to the north west towards the dewatered M8 tunnels. Further assessment will be undertaken during detailed design to confirm if a component of impacted groundwater may be drawn towards the M6S1 tunnel over time.

Bedrock aquifer

Groundwater quality data was not available for monitoring wells screening the bedrock aquifer in Zone A. In the absence of data it should be assumed that contaminants reported in the alluvial aquifer (such as ammonia and PFAS) may also be present in the underlying bedrock aquifer as groundwater is being drawn down towards the M8 tunnels.

Groundwater quality monitoring during M8 construction

Groundwater quality monitoring during the construction of the M8 was reported by Golder (2019a, 2020).

An increase above background levels was reported for ammonia, dissolved metals (iron, manganese, aluminium, copper and zinc), PAH compounds, total dissolved solids and electrical conductivity in the Arncliffe area in alluvial soils and in sandstone. Total recoverable hydrocarbons (TRH) fraction C29-C36 was detected for the first time during 2020 at LDS-BH-1038, although other fractions have been reported in the past. Similarly, the organochlorine insecticide, aldrin, was detected at low concentration during the latest round.

The measured change in ammonia concentration at monitoring bore LDS-BH-2001, which is screened in alluvium, is shown in Figure C-2. A rise in concentration from 1.1 mg/L to 3.3 mg/L is apparent from 2016 to 2019 over the course of the M8 construction, although when sampled in January 2021 the ammonia concentration had decreased to 0.9mg/L, indicating that concentrations may have now decreased. A similar increase in ammonia concentrations from <1mg/L to over 6mg/L was also recorded during the construction period in monitoring bore LDH-BH-2005A, which is screened in sandstone (Figure C-3). The increase in ammonia concentrations are interpreted to indicate that water had migrated from the shallow alluvial aquifer into the underlying sandstone as a result of dewatering during tunnel construction.

Changes in iron and manganese concentration in sandstone as a result of construction are generally less clear, for example in LDS-BH2005A where dissolved iron concentration over time were variable. Increasing concentrations of total and dissolved iron and manganese at WCX-BH168 have become apparent in recent rounds (Figure C-4).

No trends in measured total dissolved solids were noted in the only alluvial groundwater monitoring location (LDS-BH-2001). Changes in salinity in the sandstone aquifer were unclear. Electrical conductivity increased from a baseline range of 2,390 µS/cm to 3,300 µS/cm, to 12,000 µS/cm. Trends at other locations screened in the sandstone were unclear as testing was limited.

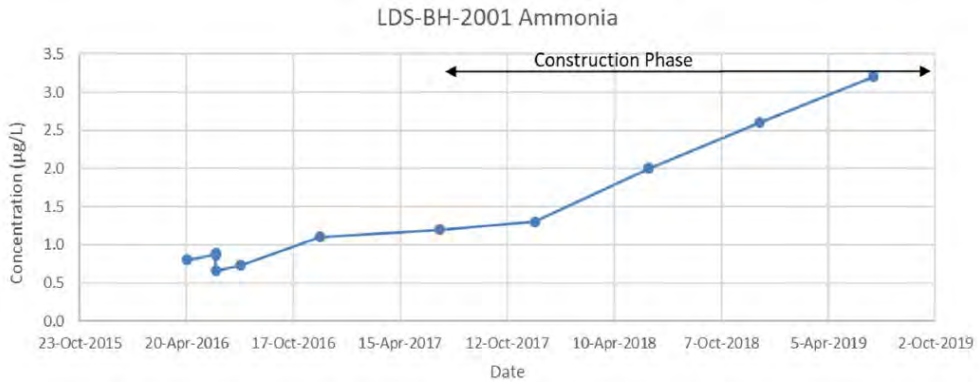

Figure C-2: Measured concentration of ammonia in alluvium (source: Golder 2019, corrected to mg/L)

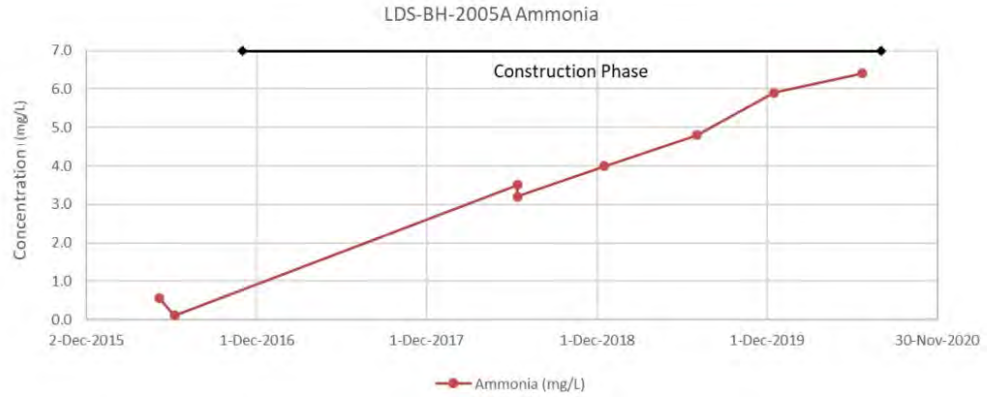

Figure C-3: Measured concentration of ammonia in sandstone (source: Golder 2020, corrected to mg/L)

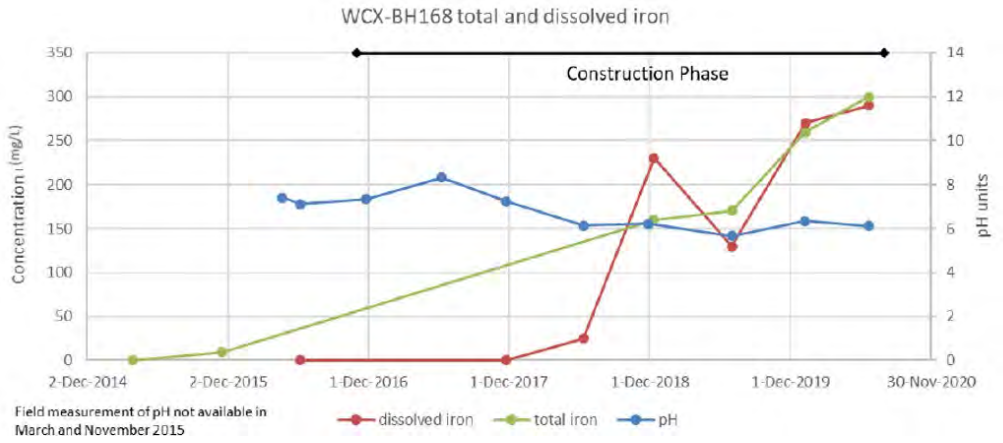

Figure C-4: Measured concentration of iron and pH in sandstone (source: Golder 2020, corrected to mg/L)

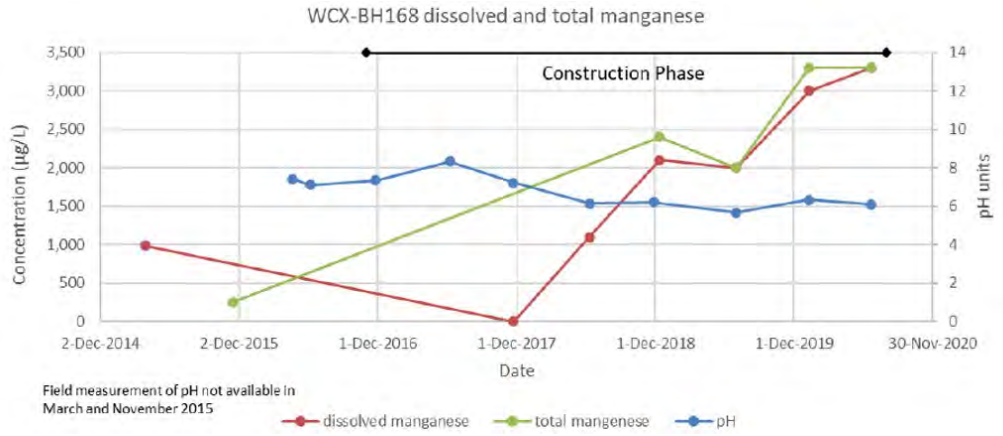

Figure C-5: Measured concentration of manganese in sandstone (source: Golder 2020)

Zone B

Groundwater quality in Zone B has been assessed based on eight monitoring wells installed in the bedrock aquifer (BH002, BH063, BH070, BH1100, BH1102, LDS-BH-1038, WCX-BH063 and WCX-BH070) and three wells installed in the Spring Street palaeochannel, which forms part of the coastal deposit aquifer (BH1314, BH1315, and WCX-BH063A).

Coastal deposit aquifer

Groundwater in the coastal deposit aquifer is generally fresh with a mean calculated TDS of 116 mg/L and a maximum of 140 mg/L. Groundwater tends to be acidic with the field-measured pH ranging from 4.4 to 6.3. Groundwater redox potentials were generally positive, consistent with the unconfined conditions in the coastal deposit aquifer.

Nitrate contamination is present in groundwater with both maximum (5.2 mg/L) and mean (3.1 mg/L) concentrations exceeding the total nitrogen lower estuary discharge criteria of 0.3 mg/L. In proximity to the alignment, the maximum ammonia concentration reported was 0.3 mg/L. Substantially higher ammonia concentrations were however reported at WCX-BH063a (maximum of 36.7 mg/L), which is screened in the Spring Street palaeochannel, and approximately 600 m east of the alignment.

Mean dissolved concentrations of arsenic (0.0025mg/L), copper (0.006 mg/L), manganese (0.3mg/L), iron (2.6mg/L) and zinc (0.029mg/L) exceed the respective marine water discharge criteria of 0.0023mg/L, 0.003mg/L, 0.08mg/L, 0.3mg/L and 0.012mg/L, and are generally considered to be representative of background conditions. The maximum reported concentrations of total lead (0.28 mg/L), and total mercury (0.0014 mg/L) also exceed the marine water discharge criteria. Filtered concentrations of these metals were either much lower, or below the level of reporting, therefore this impact is likely to be associated with fine particulate matter that can be filtered out prior to releasing groundwater to surface water.

Groundwater quality in the coastal deposit aquifer is likely to be categorised as ‘severely aggressive’ towards steel structures due to resistivity values well below the recommended 1000 Ωcm. It is also likely to be ‘moderately aggressive’ towards concrete structures based on pH values below 5.5 at some locations.

A single groundwater sample collected during 2017 from BH1314, which screens the Spring Street palaeochannel approximately above the proposed tunnel alignment, was reported to have low level hydrocarbon contamination; TRH C6-C9 (0.018 mg/L) and total xylene (0.006 mg/L). PFAS compounds were also reported at BH1314 with a total PFAS concentration of 0.106 µg/L. PFOS (0.057 µg/L) was the most abundant PFAS, which is less than half the discharge criteria of 0.13ug/L. The source of TRH and PFAS groundwater contamination in the area is currently unknown but is likely to be attributed to the commercial and light industrial land uses that exist to the west of the tunnel alignment. Furthermore, the limited groundwater quality monitoring data in the area may not represent the maximum contaminant concentrations that could exist locally.

Additional groundwater quality investigation is planned in the Spring Street palaeochannel to improve the understanding of contamination concentrations that might drain to the tunnels (Tables C-6 and C-7).

Bedrock aquifer

Groundwater in the bedrock aquifer has a slightly higher calculated mean TDS of 222 mg/L when compared to the overlying coastal deposit aquifer, with a generally neutral pH (average value of 7.3).

Similar to the overlying coastal deposit aquifer, nitrate and ammonia are both present in the bedrock aquifer, with the maximum concentrations of nitrate (0.94 mg/L) and total nitrogen (2.5 mg/L) exceeding the nitrate and total nitrogen estuary-based discharge criteria of 0.066mg/L and 0.3mg/L respectively. The mean concentration of 0.7mg/L for total nitrogen and 0.29mg/L for nitrate are much lower, but still exceed the criteria, indicating that groundwater may require treatment prior to release to stormwater or surface water.

The mean concentrations of dissolved metals in the bedrock aquifer were generally below their respective marine waters based discharge criteria, with the exception of copper (0.007mg/L), iron (2.58mg/L) and manganese (0.09mg/L) which exceed the respective marine water discharge criteria of 0.003mg/L, 0.3 mg/L and 0.08mg/L, and are generally considered to be representative of background conditions. Dissolved mercury was reported at BH002 up to 0.5 ug/L, which marginally exceeds the discharge criteria of 0.4ug/L.

Groundwater has higher resistivity (based on one value of 1,940 Ωcm at WCX-BH063) and may have a lower classification of ‘moderately aggressive’ towards steel structures, although field electrical conductivity readings indicate that groundwater in the area is relatively fresh. Despite groundwater in the bedrock aquifer having a neutral mean pH in Zone B, low pH groundwater does exist and requires consideration when designing underground concrete structures.

Hydrocarbon contamination was reported in a single sample collected from BH1100 during October 2016. Concentrations of TPH C6-C9 (240 µg/L), toluene (0.18 µg/L) and xylene (1 µg/L) are present, with TPH C6-C9 and toluene concentrations both exceeding the discharge criteria based on marine waters. Phenol is present at the same location with concentrations (170 µg/L), which is less than the marine water-based discharge criteria (520ug/L). The source or extent of these compounds has not been identified, and therefore it is not clear whether the reported concentrations represent the maximum concentrations in groundwater that may be drawn into the alignment. The hydrocarbon contamination detected at BH1100 during 2016 may be attributed to the towing, accident repair and mechanic workshops centred on 90 Princes Highway, Arncliffe. Contamination at BH1100 may have subsequently been mobilised towards the M8 tunnel. The current conceptual model assumes that groundwater ingress to the M6 Stage 1 tunnels will be limited in the vicinity of BH1100 as groundwater levels will continue to be drawn down around the deeper M8 tunnels. As only a single sample from BH1100 has been analysed for organic contaminants, additional groundwater quality investigation is proposed to improve the understanding of contaminant concentrations as a component of groundwater ingress may report to the M6 tunnels (refer Tables C-6 and C-7).

PFAS has been analysed for in bedrock monitoring wells BH002, BH063, BH1100, BH1102, LDS-BH1038, WCX-BH063, WCX-BH063a, and WCX-BH070. Reported concentrations of PFOS varied between rounds from below the laboratory limit of reporting (LOR) to a maximum of 0.03 µg/L, which are all below the discharge criteria of 0.13ug/L.

Table C-1: Groundwater quality summary – Zone B

Parameter		Units	Trigger values		Zone B - Coastal deposits				Zone B - Bedrock			
			AS2159–2009 Piling design	ANZG 2018/ ANZECC 2000 [1]	Samples/ locations	Minimum	Maximum	Mean	Samples/ locations	Minimum	Maximum	Mean
Physical / Alkalinity / Ions	Total dissolved solids [(2)]	mg/L	35000		0	116	1152	248	5/5	323	574	398
	EC (field)	µS/cm			16/3	178	1170	381	19/4	497	833	613
	pH (field)		5.5/6 – 8.3	7.0-8.5	14/3	4.4	6.34	5.5	18/4	4.9	8.31	7.3
	ORP				12/2	-48	195	103	17/3	-24.3	-299	-157
	Chloride		6000		41/3	36	91	55	42/7	45	175	98.4
	Sulfate (as SO_4)	mg/L	1000		41/2	7.5	82	20.2	42/7	<5	200	20.2
	Alkalinity (bicarbonate)	mg/L			41/3	<20	740	93.1	42/7	<20	640	172
Nutrients	Total nitrogen	mg/L		0.3 [(3)]	30/2	<0.2	16	3.4	36/4	<0.01	2.5	0.7
	Total phosphorus	mg/L		0.03 [(3)]	10/2	<0.05	0.08	0.03	11/5	<0.05	0.10	0.06
	Ammonia	mg/L		1.2	35/3	<0.01	36.7	3.1	36/5	<0.01	0.42	0.11
	Nitrate	mg/L		0.066 [(3)]	39/3	<0.01	4.2	3.1	36/5	<0.02	0.94	0.29
Metals (dissolved)	Arsenic	mg/L		0.0023 [(4)]	34/3	<0.001	0.004	0.0025	31/3	<0.001	0.002	0.002
	Cadmium	mg/L		0.0055	34/3	<0.0001	<0.0002	<0.0001	31/3	<0.0002	<0.0002	<0.0002
	Chromium (III+VI)	mg/L		0.02	34/2	<0.001	<0.001	<0.001	31/3	<0.001	<0.001	<0.001
	Copper	mg/L		0.003	34/3	<0.001	0.017	0.006	31/3	<0.001	0.021	0.007
	Iron	mg/L		0.3 [(5)]	10/3	<0.05	7.1	2.6	3/3	0.12	5	2.58
	Lead	mg/L		0.0066	34/3	<0.001	0.002	0.002	31/3	<0.001	0.002	0.001
	Nickel	mg/L		0.2	34/3	<0.001	0.054	0.023	31/3	<0.001	0.016	0.004
	Mercury	µg/L		0.4	34/3	<0.05	<0.1	<0.1	31/3	<0.1	0.5	0.3
	Manganese	mg/L		0.08	8/3	0.007	0.3	0.11	4/3	<0.005	0.13	0.09
	Zinc	mg/L		0.012	34/3	<0.005	0.110	0.029	31/3	<0.005	0.025	0.01

1. *Based on 90% species protection Marine Water guideline, with 95% species protection guideline adopted for toxicants with potential to bioaccumulate*
2. *Calculated based on 0.65 of field measured EC*
3. *Based on estuaries NOx value for South-east Australia, ANZEEC 2000. Nitrate value based on NOx-N trigger value of 0.015mg/L x 4.43*
4. *Arsenic III dissolved (ANZG 2018)*
5. *Interim indicative level (ANZG 2018)*

Zone C and D

The central Zone C area has three monitoring wells with groundwater quality results; BH005, WCX-BH213 and WCX-BH214, all screened in the bedrock aquifer. There are no monitoring wells in Zone D and groundwater quality is likely to be consistent with that reported for Zone C. The coastal deposit aquifer is generally absent through Zone C and D. The groundwater quality discussion has therefore been merged for these two zones.

Groundwater in the bedrock aquifer is relatively fresh with calculated TDS ranging from 340 mg/L to 2,496 mg/L, and a mean concentration of 655 mg/L. Groundwater pH is generally alkaline (mean pH of 8.2), however the wide range of results (up to pH 11.5) may be indicative of instrument calibration errors or monitoring well construction influences rather than actual changes in groundwater pH, however this requires confirmation.

Total nitrogen concentrations are higher in the bedrock aquifer in Zone C and D (mean of 2.0 mg/L) compared to other zones. The absence of the overlying coastal deposit aquifer is likely to result in direct exposure of the bedrock aquifer to surface sources of nitrogen contamination such as landfills, sewers (and other subsurface infrastructure) animal waste, decomposition of organic matter, and fertiliser use. Nitrogen is present mainly in the form of ammonia with a mean concentration of 1.2 mg/L, which is equivalent to the discharge criteria. Concentrations of total nitrogen exceed the marine waters based discharge criteria and will likely require treatment prior to release of groundwater to stormwater or wetlands.

Table C-2: Groundwater quality summary – Zone C and D

Parameter		Units	Trigger values		Zone C - Bedrock			
			AS2159-2009 Piling design	ANZG 2018/ ANZECC 2000 [1]	Samples/ locations	Minimum	Maximum	Mean
Physical / Alkalinity / Ions	Total dissolved solids [2]	mg/L	35000		5/5	323	574	398
	EC (field)	µS/cm			19/4	497	833	613
	pH (field)		5.5/6 – 8.3	7.0-8.5	18/4	4.9	8.31	7.3
	ORP				17/3	-24.3	-299	-157
	Chloride		6000		2/1	15	18	16.5
	Sulfate (as SO_4)	mg/L	1000		20/3	62	516	129
	Alkalinity (bicarbonate)	mg/L			20/3	<5	450	45
Nutrients	Total nitrogen	mg/L		0.3 [3]	18/3	0.05	5.6	2.0
	Total phosphorus	mg/L		0.03 [3]	6/3	<0.01	0.07	0.03
	Ammonia	mg/L		1.2	17/2	0.01	3.2	1.2
	Nitrate	mg/L		0.066 [3]	18/3	<0.1	0.27	-
Metals (dissolved)	Arsenic	mg/L		0.0023 [4]	16/1	<0.001	0.002	0.00054
	Cadmium	mg/L		0.0055	16/1	<0.0002	<0.0002	0.0001
	Chromium (III+VI)	mg/L		0.02	16/1	<0.001	0.002	0.00071
	Copper	mg/L		0.003	16/1	<0.001	0.007	0.003
	Iron	mg/L		0.3 [5]	3/1	<0.05	0.29	0.24
	Lead	mg/L		0.0066	16/1	<0.001	<0.001	0.0005
	Nickel	mg/L		0.2	16/1	<0.001	0.009	0.002
	Mercury	µg/L		0.4	16/1	<0.1	0.6	0.3
	Manganese	mg/L		0.08	3/1	0.031	0.04	0.029
	Zinc	mg/L		0.012	16/1	<0.005	0.012	0.008

1. *Based on 90% species protection Marine Water guideline, with 95% species protection guideline adopted for toxicants with potential to bioaccumulate*
2. *Calculated based on 0.65 of field measured EC*
3. *Based on estuaries NOx value for South-east Australia, ANZEEC 2000. NOx-N trigger value of 0.015mg/L x 4.43*
4. *Arsenic III dissolved (ANZG 2018)*
5. *Interim indicative level (ANZG 2018)*

Only samples from BH005 (located close to the tunnel alignment) were analysed for dissolved metals. No mean dissolved concentrations of metals exceeded the marine water based discharge criteria, however maximum concentrations of total copper (0.007 mg/L) and mercury (0.0006 mg/L) exceeded their respective criteria and may require filtering/treatment prior to discharge.

Detectable concentrations of PFAS were reported at the two locations where they were analysed; BH005 (0.0002 µg/L of PFOS and 0.009 µg/L of 6:2 FTS) and WCX-BH213 (0.0012 µg/L of PFOS).

Zone E

Zone E is centred on the proposed construction cavern where both the bedrock aquifer and the overlying coastal deposit aquifer are present. Groundwater quality results from five monitoring wells located close to the alignment in Zone E have been included in this assessment:

- BH1300 (coastal deposits)
- BH1403 (coastal deposits)
- BH1316 (coastal deposits)
- BH1503 (coastal deposits)
- WCX-BH206 (bedrock)

Coastal deposit aquifer

Groundwater salinity in the coastal deposit aquifer ranges from fresh (457 mg/L) to slightly brackish (938 mg/L) with a mean calculated TDS of 740 mg/L. Field measured pH is generally neutral (mean of 6.8). Low pH (~5.1) values were measured during single monitoring events at some locations and are attributed to equipment calibration errors rather than a change groundwater conditions. Field-measured redox potential indicates groundwater in the coastal deposits aquifer are generally reducing in Zone E.

Elevated concentrations of ammonia are present in the coastal deposit aquifer E with a mean concentration of 1.1 mg/L which is just below the marine water discharge criteria of 1.2mgL. All reported total nitrogen concentrations exceed marine waters discharge criteria of 0.3mg/L therefore groundwater will likely require treatment prior to discharge to stormwater or surface water.

The mean dissolved concentration of copper marginally exceeds the discharge criteria, however based on data from surrounding areas the concentrations are considered likely to represent background conditions. Mean dissolved iron (4.3mg/L) and manganese (0.19mg/L) concentrations also exceed the marine water discharge criteria of 0.3mg/L and 0.08mg/L respectively. These concentrations are consistent with the reducing conditions reported, and concentrations elsewhere along the project alignment, and may be able to be removed through aeration and precipitation prior to discharge.

A single sample collected from BH1316 during November 2017 was analysed for a range of organic contaminants. Detectable concentrations of light fraction hydrocarbons TPH C6-C9 (0.016 mg/L) were reported, which included xylenes (0.005 mg/L) and chloroform (0.008 mg/L). Monocyclic aromatic hydrocarbons 1,2,4-trimethylbenzene (0.003 mg/L) and 1,3,5-trimethylbenzene (0.002 mg/L) were also reported above the LOR. Additional monitoring is proposed to verify the current concentrations and assess their presence at other monitoring wells in Zone E prior to construction commencing (refer to Tables C-6 and C-7).

PFAS has been analysed for at BH1316 and BH1503 during the January 2021 monitoring event. All compounds were reported below their respective LORs, with the exception of a detectable concentration of 10:2 fluorotelomer sulfonic acid (10:2 FTS) (0.000001 mg/L at BH1316).

Bedrock aquifer

Groundwater in the bedrock aquifer is likely to be more saline than the overlying coastal deposit aquifer, with a single calculated TDS value of approximately 975 mg/L. The field measured pH was neutral (mean 6.97).

Although the mean concentration of ammonia in the bedrock aquifer (0.99 mg/L) does not exceed the discharge criteria, the mean total nitrogen concentration of 1.2mg/L does, indicating that treatment for nutrients may be required prior to discharge, noting that all data are from one location.

Mean concentrations of dissolved copper (0.004 mg/L) and zinc (0.041 mg/L) exceed marine water discharge criteria but are considered to be representative of background conditions.

Table C-3: Groundwater quality summary – Zone E

Parameter		Units	Trigger values		Zone E - Coastal deposits				Zone E - Bedrock			
			AS2159–2009 Piling design	ANZG 2018/ ANZECC 2000 [1]	Samples/ locations	Minimum	Maximum	Mean	Samples/ locations	Minimum	Maximum	Mean
Physical / Alkalinity / Ions	Total dissolved solids [2]	mg/L	35000		0	475	938	740	0	1/1	975	975
	EC (field)	µS/cm			14/2	730	1,444	1,138	1/1	-	1,500	1,500
	pH (field)		5.5/6 – 8.3	7.0-8.5	20/5	5.16	7.36	6.8	1/1	-	6.97	6.97
	ORP				17/4	-268	24	-172	0	-	-	-
	Chloride		6000		31/4	140	1100	359	9/1	310	720	422.8
	Sulfate (as SO_4)	mg/L	1000		31/3	2	174	26	9/1	20	49	35
	Alkalinity (bicarbonate)	mg/L			29/3	85	350	211	9/1	150	420	226
Nutrients	Total nitrogen	mg/L		0.3 [3]	21/3	0.6	3.3	1.7	9/1	0.03	2.5	1.2
	Total phosphorus	mg/L		0.03 [3]	8/2	0.02	0.4	0.2	5/1	0.04	0.06	0.04
	Ammonia	mg/L		1.2	26/2	0.053	1.8	1.1	9/1	0.03	2.2	0.99
	Nitrate	mg/L		0.066 [3]	28/3	<0.005	0.65	0.155	9/1	<0.02	0.03	0.02
Metals (dissolved)	Arsenic	mg/L		0.0023 [4]	26/3	<0.001	0.002	0.0017	8/1	<0.001	<0.001	<0.001
	Cadmium	mg/L		0.0055	26/3	<0.0001	<0.0002	<0.0002	8/1	<0.0002	<0.0002	<0.0002
	Chromium (III+VI)	mg/L		0.02	26/3	0.002	<0.001	<0.001	8/1	<0.001	<0.001	<0.001
	Copper	mg/L		0.003	26/3	<0.001	0.015	0.004	8/1	<0.001	0.005	0.004
	Iron	mg/L		0.3 [5]	9/2	<0.01	8.9	4.3	1/1	-	6.7	-
	Lead	mg/L		0.0066	26/3	<0.001	0.024	0.0019	8/1	<0.001	<0.001	<0.001
	Nickel	mg/L		0.2	26/3	<0.001	0.16	0.022	8/1	0.012	0.036	0.024
	Mercury	µg/L		0.4	26/3	<0.05	0.9	0.4	8/1	<0.1	0.0002	0.00015
	Manganese	mg/L		0.08	8/3	0.072	0.37	0.19	1/1		0.31	-
	Zinc	mg/L		0.012	26/3	0.003	0.039	0.01	8/1	<0.005	0.043	0.024

1. *Based on 90% species protection Marine Water guideline, with 95% species protection guideline adopted for toxicants with potential to bioaccumulate*
2. *Calculated based on 0.65 of field measured EC*
3. *Based on estuaries NOx value for South-east Australia, ANZEEC 2000. Nitrate value based on NOx-N trigger value of 0.015mg/L x 4.43*
4. *Arsenic III dissolved (ANZG 2018)*
5. *Interim indicative level (ANZG 2018)*

Zone F

Zone F centres on the area north of Presidents Avenue and includes the ramps connecting President Avenue with the M6 tunnels. As tunnelling becomes shallower, construction moves to cut and cover, and open trench methods that are partially drained during construction. The higher-conductivity coastal deposit aquifer will be encountered which will require a range of construction methods to prevent excessive groundwater ingress and to minimise potential for groundwater acidification.

Post-construction, the cut and cover tunnel section will be permanently tanked which will largely prevent groundwater ingress in Zone F.

Groundwater from Zone F may potentially be discharged to the predominantly freshwater ecosystem of the Bicentennial Park Wetlands therefore water quality for Zone F has been assessed against the relevant marine and fresh water criteria.

Coastal deposit aquifer

Groundwater quality in the coastal deposit aquifer in Zone F (north of President Avenue) has been characterised based on results from approximately 25 monitoring wells in the area.

Laboratory-reported TDS was not consistently reported for all samples including some locations with the highest field-measured EC values. Representative TDS has been calculated based on field measured EC, which indicates a mean TDS of 1,950 mg/L, and a maximum of 9,100 mg/L at BH1303. Field measured pH was most commonly neutral but ranged from more acidic (pH of 5.73) to slightly basic (pH of 8.1). Redox potential was variable, ranging from oxidising to reducing.

Groundwater is likely to become more saline south of President Avenue where the tidally influenced Scarborough Ponds wetlands may provide a source of saline recharge. Project construction activities are unlikely to cause groundwater drawdown that extends south of President Avenue, and the risk of groundwater salinisation is considered low.

Groundwater at BH1303 (located west of Bicentennial Park Wetland) and nearby monitoring locations BH1424, BH1415, BH1425 suggest a zone of high TDS groundwater, combined with the elevated concentrations of ammonia (250 mg/L), total nitrogen (340 mg/L), bicarbonate (1,700 mg/L) and sulfate (1,100 mg/L). Groundwater geochemistry suggests that groundwater in this area may be impacted by landfill leachate sourced from former landfills present to the east and west of the Bicentennial Park Wetlands (EES – Appendix K, Groundwater Technical Report). Figure C-6 and Figure C-7 show the spatial distribution of mean electrical conductivity and mean total nitrogen in the area. Mean concentrations of nitrate, ammonia and phosphorus would require treatment prior to release to the environment.

Figure C-6: Mean electrical conductivity values – coastal deposit aquifer (Zone F)

Figure C-7: Mean total nitrogen concentration (mg/L) – coastal deposit aquifer (Zone F)

Mean dissolved concentrations of arsenic (0.005mg/L), copper (0.0034 mg/L) and zinc (0.018 mg/L) slightly exceed the adopted freshwater and/or marine water criteria, and are considered to be representative of background conditions. The maximum reported concentration of nickel exceeded the fresh water-based discharge criteria and treatment for these metals may also be required if discharge occurs to a freshwater ecosystem. Mean dissolved manganese concentrations exceeded the marine water based discharge criteria, and iron concentrations exceeded the criteria for fresh and marine water discharge, noting that this is an interim indicative level (ANZG 2018). The elevated concentrations of manganese and iron in the area are attributed to the reducing conditions associated with landfill leachate impact. Both metals are sensitive to redox conditions, and so when extracted groundwater is aerated it is expected that the concentrations of both metals will decrease significantly due to precipitation.

PFAS was analysed for in seven wells screening the coastal deposit aquifer from 2019 to 2021. The seven wells approximately border the northern and southern sides of the proposed cut and cover trench and characterise the water quality expected to drain to the excavation during construction. Where PFAS was detected above the LOR (0.00001 µg/L), PFOS was the most commonly reported PFAS. PFOS was reported above the LOR at four of the seven locations, with concentrations ranging up to a maximum of 0.42 µg/L at BH1415. Up to 9 other PFAS compounds were also detected at BH1415 in 2021 at lower concentrations. Data from additional locations in the area is required to identify whether the average PFOS concentrations along the drained trench will exceed the discharge criteria of 0.13µg/L.

Hydrocarbon contamination has also been reported at some monitoring locations in Zone F. These are discussed below with reference to suspected source areas.

Rockdale Wetland (Bicentennial Park)

Concentrations of benzene, toluene, ethylbenzene or xylenes (collectively referred to as BTEX), naphthalene and heavier fraction hydrocarbons have been detected in several wells around the Rockdale wetland (the northern pond within Bicentennial Park), as well as landfill leachate (nitrate, ammonia, sulfate and bicarbonate), as discussed above.

In 2019 samples from BH1415 reported concentrations of benzene (33 µg/L), toluene (49 µg/L), ethylbenzene (290 µg/L) and total xylenes (120 µg/L). While the concentrations exceed several health-based drinking water criteria, at the concentrations reported, they are unlikely to pose a vapour risk during construction. The ethylbenzene concentration of 290ug/L however exceeds both the fresh water and marine water discharge criteria of 110ug/L, and the TPH C6-C9 concentration in BH1415 of up to 850ug/L also exceeds the marine water discharge criteria of 150ug/L.

Despite being generally down gradient of the 7-Eleven service station (discussed below), the hydrocarbon contamination at Rockdale Park is more likely to be due to a combination of hydrocarbon-impacted landfill

waste at the site, and/or possible groundwater contamination from the industrial estate up-hydraulic gradient to the west.

Groundwater entering drained excavation during construction may require treatment for hydrocarbons and PFAS in addition to landfill contaminants as described above. The highest concentrations of contaminants have been reported in the vicinity of BH1415, therefore further delineation prior to construction is proposed (refer Tables C-6 and C-7) to determine whether targeted groundwater management in this area is required.

7-Eleven service station

Located at the corner of Princes Highway and President Avenue, this former service station has been issued with Declaration of Significantly Contaminated Land by EPA. Contamination associated with leaking underground petroleum storage tanks has led to hydrocarbon and benzene contamination to groundwater. In monitoring well CH1411 which is installed nearby (Figure C-8) concentrations of TRH C6-C9 up to 1.1 mg/L, ethylbenzene (140 µg/L), and xylenes (470 µg/L) have been reported, which exceed the discharge criteria should groundwater be released to surface water without treatment or dilution.

Groundwater in this area is inferred to flow towards the northeast beneath residential properties and towards the project alignment (Figure C-8). As CH1411 is to the east, and not ideally located down gradient where the highest contaminant concentrations would be expected, the concentrations reported may under-represent the contamination in groundwater. Monitoring well MW19 located on the northern boundary of the site is the sole well that continues to be monitored periodically. F2 semi-volatile hydrocarbon fractions C10-C16 concentrations reported when last sampled in February 2021 (and earlier) exceeded the vapour intrusion criteria for residential land. Based on the shallow depth to groundwater and vapour intrusion criteria exceedances (Cardno 2021), ongoing monitoring and further assessment for vapour intrusion is recommended to assess where remediation or management measures are required.

While potential exists for a plume of groundwater contamination to extend from the service station towards the north east, the groundwater monitoring data reviewed to date does clearly delineate the extent of groundwater contamination from the 7-Eleven service station. Assessment reports indicate that the decommissioned tanks remain in situ and are to be removed during construction of the M6 Stage 1 project. Based on the distance of the contamination source from the Stage 1 tunnel alignment (approximately 500 m) there is considered to be a low risk that residual groundwater contamination will be further mobilised by temporary groundwater level drawdown during construction.

Bedrock aquifer

Groundwater salinity in the bedrock aquifer around the proposed cut and cover structure is variable, likely to range from slightly brackish (1,040 mg/L) up to 12,000 mg/L at BH1428. Higher TDS groundwater is likely to be encountered where the northern end of the tanked structure ends and where the drained tunnels commence (BH1428).

Elevated concentrations of chloride (mean of 8,950 mg/L) and sulfate (1,350 mg/L) may be aggressive towards concrete structures in this area.

Nitrogen concentrations in the bedrock aquifer are lower than in the overlying coastal deposit aquifer, but ammonia (mean of 1.2 mg/L) and nitrate (up to 0.19mg/L) are present at concentrations that exceed the adopted criteria for marine and fresh water discharge criteria. Mean dissolved concentrations of nickel (0.12 mg/L) and zinc (0.094 mg/L) exceed both fresh and marine water based discharge criteria, and groundwater drawn into the excavation in this area will likely require treatment prior to release.

PFAS concentrations recently reported for bedrock monitoring wells BH1428, BH1701 and BH1703, were above the LOR at all three locations. PFOS was the dominant PFAS, with reported concentrations ranging from 0.0002 µg/L (BH1428) to 0.0011 µg/L (BH1701), which are all below the discharge criteria of 0.13ug/L for PFOS. Low concentrations reported at BH1428 approximately align with the point where the tanked cut and cover meets the permanently drained tunnels.

Figure C-8: Maximum TRH C6-C9 concentrations in groundwater (mg/L). Location of service station (red) and inferred groundwater flow direction (green)

Table C-4: Groundwater quality summary – Zone F

	Parameter	Units	Trigger values			Zone F - Coastal deposits				Zone F - Bedrock			
			AS2159–2009 Piling design	Marine ANZG 2018/ ANZECC 2000 [1]	FW ANZG 2018/ ANZECC 2000 [2]	Samples/ locations	Minimum	Maximum	Mean	Samples/ locations	Minimum	Maximum	Mean
Physical / Alkalinity / Ions	Total dissolved solids [3]	mg/L	35,000			29/17	230	11,000	1,206	3/1	12,000	25,000	16,300
	EC (field)	µS/cm				47/19	308.3	14,000	2995	6/2	1,610	19,389	10,699
	pH (field)		5.5/6 – 8.3	7.0-8.5		48/21	5.73	8.1	7	4/2	6.69	12.1	8.0
	ORP					45/18	-254	227.5	-111	3/1	-141.2	-13.5	-78
	Chloride		6,000			94/18	12	8,600	566	9/4	99	17,000	8,950
	Sulfate (as SO_4)	mg/L	1,000			94/18	<5	1,400	198	9/4	1	2,700	1,350
	Alkalinity (bicarbonate)	mg/L				92/18	28	2,900	664	9/4	<1	590	191.6
Nutrients	Total nitrogen	mg/L		0.3 [4]		88/15	<0.2	340	45	10/4	0.01	5.0	1.51
	Total phosphorus	mg/L		0.03 [4]		53/14	<0.05	1.1	0.20	8/4	<0.01	0.11	0.05
	Ammonia	mg/L		1.2	1.43	97/15	0.05	250	39	10/4	0.51	3.9	1.2
	Nitrate	mg/L		0.066 [4]		99/15	<0.002	2.3	0.25	10/4	0.01	0.19	0.08
Metals (dissolved)	Arsenic	mg/L		0.0023 [5]	0.042	96/14	<0.001	0.055	0.005	7/1	<0.001	0.007	0.004
	Cadmium	mg/L		0.0055	0.0002	97/14	<0.0001	0.0001	0.0001	7/1	<0.0002	<0.0002	0.0001
	Chromium (III+VI)	mg/L		0.02	0.006	97/14	<0.001	0.007	0.002	7/1	<0.001	0.002	0.001
	Copper	mg/L		0.003	0.0018	97/14	<0.001	0.024	0.003	7/1	<0.001	0.008	0.003
	Iron	mg/L		0.3 [6]	0.3 [6]	6/2	3.2	83	30.2	-	-	-	-
	Lead	mg/L		0.0066	0.0056	97/14	<0.001	0.002	0.002	7/1	<0.001	<0.001	0.0005
	Nickel	mg/L		0.2	0.013	97/14	<0.001	0.081	0.01	7/1	0.009	0.24	0.12
	Mercury	µg/L		0.4	0.6	97/14	<0.05	0.3	0.1	7/1	<0.1	<0.1	<0.1
	Manganese	mg/L		0.08	2.5	12/15	0.008	1.7	0.47	1/1	0.86	0.86	0.86
	Zinc	mg/L		0.012	0.015	14/18	<0.005	0.3	0.022	7/1	0.017	0.25	0.094

1. *Based on 90% species protection Marine Water guideline, with 95% species protection guideline adopted for toxicants with potential to bioaccumulate*
2. *Based on 90% species protection Fresh Water guideline, with 95% species protection guideline adopted for toxicants with potential to bioaccumulate*
3. *Calculated based on 0.65 of field measured EC*
4. *Based on estuaries NOx value for South-east Australia, ANZEEC 2000. Nitrate value based on NOx-N trigger value of 0.015mg/L x 4.43*
5. *Arsenic III dissolved (ANZG 2018)*
6. *Interim indicative level (ANZG 2018)*

Zone G

Construction of the southern access ramps will include a temporary access shaft within the existing West Botany Street Depot and a temporary adit to provide construction access to the main tunnels. The location of the temporary access shaft and adit is shown in Figure C-9.

Six groundwater monitoring wells are installed in Zone G five screened in the coastal deposits, and one in the bedrock:

- CH1404 (coastal deposits)
- BH1421 (coastal deposits)
- BH1313 (coastal deposits)
- BH1511 (coastal deposits)
- BH1513 (coastal deposits)
- WCX-BH208 (bedrock)

The following summary of groundwater quality is based on samples collected from these six wells.

Coastal deposit aquifer

Groundwater quality in the coastal deposit aquifer is generally consistent with that reported in other zones along the alignment. Groundwater is fresh with TDS ranging from 230 mg/L to approximately 1,100 mg/L, neutral pH (mean value of 7.1), and reducing conditions.

At locations where higher TDS was reported in Zone G, elevated sulfate (up to 750 mg/L), bicarbonate (up to 610 mg/L) and ammonia (up to 6.4 mg/L) were reported, suggesting that groundwater has locally been impacted by landfill leachate. Dissolved methane of up to 16 mg/L is also reported at BH1421 consistent with a nearby landfill source.

Surrounding wells show lower concentrations of sulfate and ammonia, but still elevated compared to elsewhere, suggesting lesser impact from landfill leachate. Figure C-9 shows the distribution of ammonia concentrations across both aquifers in the vicinity of the proposed access shaft. Similar conditions were reported approximately 350 m to the south at Bicentennial Park linked to a former landfill at that location. It is unclear if groundwater contamination in Zone G is localised and associated with a nearby landfill source, or has migrated from Bicentennial Park.

Dissolved concentrations of copper and zinc were commonly reported above the marine water based discharge criteria, and may be attributed to natural concentrations in groundwater. Dissolved mercury was detected up to a maximum of 0.0008 mg/L at three locations (BH1421, BH1513, CH1404) and may require treatment prior to discharge. The maximum concentrations of dissolved boron (1.6 mg/L at BH1421) minorly exceeds the marine water discharge criteria of 1.5mg/L. Boron has only been analysed for twice, therefore data from additional locations is required to assess whether the reported exceedance represent broader conditions.

Groundwater in the coastal deposit aquifer also has concentrations of heavy-fraction petroleum hydrocarbons C10-C14 (up to 0.8 mg/L) and C15-C28 (up to 2.9 mg/L) in BH1421. Groundwater has not yet been analysed for PFAS contamination in this area.

Bedrock aquifer

Groundwater in the bedrock aquifer has been assessed based on one sample from WCX-BH208. Groundwater is brackish with a calculated TDS of 2,126 mg/L and neutral pH of 7.68.

Groundwater in the underlying bedrock aquifer appears to be minorly impacted by landfill leachate with concentrations of ammonia (1.23 mg/L) total nitrogen (1.7 mg/L) which exceeds the marine water-based discharge criteria (Table C-5).

Figure C-9: Ammonia concentrations in Zone G (mg/L). Approximate location of access shaft shown in orange

Table C-5: Groundwater quality summary – Zone G

Parameter		Units	Trigger values		Zone G - Coastal deposits				Zone G- Bedrock			
			AS2159–2009 Piling design	ANZG 2018/ ANZECC 2000 [1]	Samples/ locations	Minimum	Maximum	Mean	Samples/ locations	Minimum	Maximum	Mean
Physical / Alkalinity / Ions	Total dissolved solids [(2)]	mg/L	35,000		4/2	230	1,100	595	1/1	-	2,126	2,126
	EC (field)	µS/cm			4/2	270	1,500	815	1/1	-	3,270	3,270
	pH (field)		5.5/6 – 8.3	7.0-8.5	6/2	6.8	7.7	7.2	1/1	-	7.68	7.68
	ORP	mV			5/2	-17.6	-191.6	-147	0	-	-	-
	Chloride	mg/L	6,000		20/5	20	10,000	2,217	1/1	-	830	830
	Sulfate (as SO_4)	mg/L	1,000		20/5	2.4	750	202	1/1	-	1	1
	Alkalinity (bicarbonate)	mg/L			14/4	130	610	358	1/1	-	404	404
Nutrients	Total nitrogen	mg/L		0.3 [(3)]	20/5	0.9	23	7	1/1	-	1.7	1.7
	Total phosphorus	mg/L		0.03 [(3)]	16/5	<0.05	1.2	0.46	1/1	-	0.08	0.08
	Ammonia	mg/L		1.2	20/5	<0.01	6.2	4.1	1/1	-	1.23	1.23
	Nitrate	mg/L		0.066 [(3)]	19/4	<0.02	5.5	0.9	1/1	-	1.7	1.7
Metals (dissolved)	Arsenic	mg/L		0.0023 [(4)]	19/4	<0.001	0.002	0.002	1/1	-	<0.001	<0.001
	Cadmium	mg/L		0.0055	19/4	<0.002	<0.002	<0.002	1/1	-	<0.0001	<0.0001
	Chromium (III+VI)	mg/L		0.02	19/4	<0.001	0.002	0.002	1/1	-	<0.001	<0.001
	Copper	mg/L		0.003	19/4	<0.001	0.058	0.01	1/1	-	<0.001	<0.001
	Iron	mg/L		0.3 [(5)]	15/4	0.53	62	14.4	0	-	-	-
	Lead	mg/L		0.0066	19/4	<0.001	0.004	0.002	1/1	-	<0.001	<0.001
	Nickel	mg/L		0.2	19/4	<0.001	0.056	0.012	0	-	-	-
	Mercury	µg/L		0.4	19/4	<0.001	0.8	0.5	0	-	-	-
	Manganese	mg/L		0.08	0	-	-	-	0	-	-	-
	Zinc	mg/L		0.012	26/3	0.003	0.039	0.01	0	-	-	-

1. *Based on 90% species protection Marine Water guideline, with 95% species protection guideline adopted for toxicants with potential to bioaccumulate*
2. *Calculated based on 0.65 of field measured EC*
3. *Based on estuaries NOx value for South-east Australia, ANZECC 2000. Nitrate value based on NOx-N trigger value of 0.015mg/L x 4.43*
4. *Arsenic III dissolved (ANZG 2018)*
5. *Interim indicative level (ANZG 2018)*

Baseline - additional proposed sampling and analysis

Sampling and analysis from new and existing monitoring wells proposed to address identified data gaps and uncertainties is summarised in Tables C-6 and C-7.

The full dataset will provide pre-construction baseline groundwater conditions along the alignment, and will be used to inform the construction-phase groundwater monitoring program and where management or treatment of groundwater may be required.

Table C-6: Monthly groundwater quality testing schedule

Bore ID	Easting MGA2020	Northing MGA2020	Status	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)	Monthly/ Additional (pre GWMP)	Field EC	Field pH	Lab resistivity	Lab EC	Lab TDS	Lab pH	Cations/ Anions [1]	Dissolved metals [2]	Total Fe, Mn unfiltered	Nutrients [3]	TRH	BTEX	PAH	VOC	PFAS	TOC
Pre-award bores																							
BH002	328930	6243014	Existing	Bedrock	58	70	Monthly	X	X	X	X	X		X	X	X	X						
BH005	328445	6241920	Existing	Bedrock	56.3	68.7	Monthly	X	X	X	X	X		X	X	X	X						
BH014A	328528	6240413	Existing	Alluvium	7	10	Monthly	X	X	X	X	X		X	X	X	X						
BH1300	328265	6241005	Existing	Alluvium	13	16	Monthly	X	X	X	X	X		X	X	X	X						
BH1301	328535	6240509	Existing	Alluvium	9.65	12.65	Monthly	X	X	X	X	X		X	X	X	X						
BH1314	328546	6242495	Existing	Alluvium	19	25	Monthly	X	X	X	X	X		X	X	X	X						
BH1415	328665	6240495	Existing	Fill/Alluvium	2.4	14.4	Monthly	X	X	X	X	X		X	X	X	X						
BH1417	328574	6240556	Existing	Alluvium	2.65	5.65	Monthly	X	X	X	X	X		X	X	X	X						
BH1418	328462	6240448	Existing	Alluvium	4	7	Monthly	X	X	X	X	X		X	X	X	X						
BH1421	328872	6240903	Existing	Alluvium	1.8	13.8	Monthly	X	X	X	X	X		X	X	X	X						
BH1424	328701	6240429	Existing	Alluvium	2	14	Monthly	X	X	X	X	X		X	X	X	X						
BH1425	328739	6240382	Existing	Fill/Alluvium	2	14	Monthly	X	X	X	X	X		X	X	X	X						
BH1428	328519	6240559	Existing	Bedrock	17	35	Monthly	X	X	X	X	X		X	X	X	X						
BH1429	328549	6240460	Existing	Alluvium	5.8	8.8	Monthly	X	X	X	X	X		X	X	X	X						
BH1432	328602	6240396	Existing	Alluvium	5	8	Monthly	X	X	X	X	X		X	X	X	X						
BH1501	328529	6240609	Existing	Alluvium	3.1	6.1	Monthly	X	X	X	X	X		X	X	X	X						
BH1503	328337	6240975	Existing	Alluvium	14.2	17.2	Monthly	X	X	X	X	X		X	X	X	X						
BH1511	328559	6240923	Existing	Alluvium	10.8	13.8	Monthly	X	X	X	X	X		X	X	X	X						
BH1513	328945	6240845	Existing	Alluvium	21	25	Monthly	X	X	X	X	X		X	X	X	X						
BH1514	328540	6240583	Existing	Alluvium	2.6	5.6	Monthly	X	X	X	X	X		X	X	X	X						
CH1403	328593	6240610	Existing	Alluvium	5	8	Monthly	X	X	X	X	X		X	X	X	X						
CH1404	328775	6240948	Existing	Alluvium	1.8	13.8	Monthly	X	X	X	X	X		X	X	X	X						
CH1411	327956	6240257	Existing	Fill	1.6	3.6	Monthly	X	X	X	X	X		X	X	X	X						
LDS-BH-1038	329099	6243199	Existing	Bedrock	65	74	Monthly	X	X	X	X	X		X	X	X	X						
WCX-BH063a	329207	6242451	Existing	Alluvium	5	8	Monthly	X	X	X	X	X		X	X	X	X					X	
WCX-BH206	328399	6240660	Existing	Bedrock	19	22	Monthly	X	X	X	X	X		X	X	X	X						

Notes:
1. Major cations (calcium, magnesium, sodium, potassium) and major anions (chloride, sulfate) and speciated alkalinity (bicarbonate, carbonate, hydroxide)
2. Dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc) (field filtered) and total metals (iron, manganese) (unfiltered sample)
3. Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorous, reactive phosphorous)

Table C-7: Additional groundwater quality testing schedule to address data gaps

Bore ID	Easting MGA2020	Northing MGA2020	Status	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)	Monthly/ Additional (pre GWMP)	Field EC	Field pH	Lab resistivity	Lab EC	Lab TDS	Lab pH	Cations/ Anions [1]	Dissolved metals [2]	Total Fe, Mn unfiltered	Nutrients [3]	TRH	BTEX	PAH	VOC	PFAS	TOC
Pre-award bores																							
BH002	328930	6243014	Existing	Bedrock	58	70	Monthly											X	X		X		X
BH005	328445	6241920	Existing	Bedrock	56.3	68.7	Monthly											X	X		X		X
BH014A	328528	6240413	Existing	Alluvium	7	10	Monthly											X	X		X	X	X
BH1300	328265	6241005	Existing	Alluvium	13	16	Monthly															X	X
BH1301	328535	6240509	Existing	Alluvium	9.65	12.65	Monthly															X	X
BH1314	328546	6242495	Existing	Alluvium	19	25	Monthly															X	X
BH1415	328665	6240495	Existing	Fill/Alluvium	2.4	14.4	Monthly																X
BH1417	328574	6240556	Existing	Alluvium	2.65	5.65	Monthly															X	X
BH1418	328462	6240448	Existing	Alluvium	4	7	Monthly															X	X
BH1421	328872	6240903	Existing	Alluvium	1.8	13.8	Monthly																X
BH1424	328701	6240429	Existing	Alluvium	2	14	Monthly																X
BH1425	328739	6240382	Existing	Fill/Alluvium	2	14	Monthly																X
BH1428	328519	6240559	Existing	Bedrock	17	35	Monthly																X
BH1429	328549	6240460	Existing	Alluvium	5.8	8.8	Monthly																X
BH1432	328602	6240396	Existing	Alluvium	5	8	Monthly																X
BH1501	328529	6240609	Existing	Alluvium	3.1	6.1	Monthly						X					X	X	X	X	X	X
BH1503	328337	6240975	Existing	Alluvium	14.2	17.2	Monthly						X										X
BH1511	328559	6240923	Existing	Alluvium	10.8	13.8	Monthly						X					X	X	X	X	X	X
BH1513	328945	6240845	Existing	Alluvium	21	25	Monthly						X					X	X	X	X	X	X
BH1514	328540	6240583	Existing	Alluvium	2.6	5.6	Monthly						X					X	X	X	X	X	X
CH1403	328593	6240610	Existing	Alluvium	5	8	Monthly															X	X
CH1404	328775	6240948	Existing	Alluvium	1.8	13.8	Monthly															X	X
CH1411	327956	6240257	Existing	Fill	1.6	3.6	Monthly															X	X
LDS-BH-1038	329099	6243199	Existing	Bedrock	65	74	Monthly											X	X	X	X		X
WCX-BH063a	329207	6242451	Existing	Alluvium	5	8	Monthly											X	X	X	X	X	X
WCX-BH206	328399	6240660	Existing	Bedrock	19	22	Monthly						X					X	X	X	X	X	X
BH1102	328559	6242552	Existing	Bedrock	71	74	Additional	X		X					X	X							X
BH1143	328597	6240515	Existing	Alluvium	15.4	18.4	Additional	X	X	X		X	X		X	X	X					X	X
BH1212	328762	6240351	Existing	Alluvium	13	16	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH1214	328506	6239812	Existing	Alluvium	10.497	13.497	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH1303	328704	6240471	Existing	Alluvium	10	19	Additional	X	X	X			X										X
BH1313	328746	6240868	Existing	Alluvium	23.1	29.1	Additional		X	X		X	X		X							X	X
BH1315	328709	6242448	Existing	Alluvium	25.6	31.6	Additional			X													
BH1318	328558	6240154	Existing	Alluvium	5.8	8.8	Additional		X	X		X	X		X							X	X
BH1701	328600	6240532	Existing	Bedrock	27	30	Additional	X	X	X		X									X		X
BH1702	328619	6240513	Existing	Alluvium	20.8	22.8	Additional			X													

Bore ID	Easting MGA2020	Northing MGA2020	Status	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)	Monthly/ Additional (pre GWMP)	Field EC	Field pH	Lab resistivity	Lab EC	Lab TDS	Lab pH	Cations/ Anions [1]	Dissolved metals [2]	Total Fe, Mn unfiltered	Nutrients [3]	TRH	BTEX	PAH	VOC	PFAS	TOC
BH1703	328639	6240495	Existing	Bedrock	24.8	27.8	Additional	X	X	X		X									X		X
LDS-BH-2001	329362	6243036	Existing	Alluvium	1.5	5	Additional	X	X	X					X	X	X	X	X	X	X		X
LDS-BH-2003	329720	6242897	Existing	Alluvium	6	9	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
LDS-BH-2005A	329610	6243366	Existing	Bedrock	25.18	28.2	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
LDS-BH-2008A	329940	6243863	Existing	Bedrock	44	50	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH025	328637	6243272	Existing	Bedrock	54.7	57.7	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH029	329350	6242710	Existing	Bedrock	33	36	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH036	329403	6243810	Existing	Bedrock	60	63	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH039	329554	6244159	Existing	Bedrock	49	52	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH070	329042	6242922	Existing	Bedrock	35	38	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH074	329228	6243672	Existing	Bedrock	39	42	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH093	327657	6243185	Existing	Bedrock	47.5	50.5	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH094	327868	6243176	Existing	Bedrock	54	57	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH168	329703	6243777	Existing	Bedrock	48	51	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH202	328078	6240176	Existing	Bedrock	35.5	38.5	Additional	X	X	X		X	X		X	X		X	X	X	X	X	X
WCX-BH213	328710	6241681	Existing	Bedrock	29	32	Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
WCX-BH214	329228	6241856	Existing	Bedrock	31.5	34.5	Additional	X	X	X		X	X		X	X	X	X	X	X	X	X	X
Post-award bores																							
BH2054a	328493	6241015	Completed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2054b	328494	6241017	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2056	328577	6241003	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2058	328644	6240971	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2060	328305	6240947	Completed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2076	328726	6240554	Completed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2082	328810	6240218	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2091	328901	6240904	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2092	328810	6240919	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2095a	329209	6241311	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
PSM_BH001	328605	6240494	Completed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2003	329563	6243295	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2009	328983	6242739	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2011	329195	6242615	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2014	328766	6242526	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2015	328933	6242505	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2017	328607	6242422	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2024	328285	6242347	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2026	328111	6242122	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2028	328357	6242071	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X

Bore ID	Easting MGA2020	Northing MGA2020	Status	Stratigraphic unit	Screen from (m bgl)	Screen to (m bgl)	Monthly/ Additional (pre GWMP)	Field EC	Field pH	Lab resistivity	Lab EC	Lab TDS	Lab pH	Cations/ Anions [1]	Dissolved metals [2]	Total Fe, Mn unfiltered	Nutrients [3]	TRH	BTEX	PAH	VOC	PFAS	TOC
BH2030	328746	6241862	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2032	327942	6241785	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2035	328917	6241371	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2036	328571	6241419	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2046	328861	6241231	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2048	328506	6241113	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2050	328700	6241129	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2053	328885	6241047	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2055a	328186	6241026	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2055b	328183	6241024	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2063a	328261	6240851	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2063b	328258	6240849	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2066	328601	6240801	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2069	328758	6240716	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2075	328939	6240573	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2078	328213	6240482	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2079	328099	6240350	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2080	328955	6240305	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2081	327914	6240256	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2084	328558	6240123	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2085	328697	6240122	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2088	328816	6241041	Proposed	Bedrock			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2089	329004	6240949	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2093a	329243	6240511	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2096a	328588	6241532	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2097a	329034	6241689	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2098a	329186	6242024	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2106	328983	6242619	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
BH2107	328916	6242236	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
CH2062	328623	6240483	Proposed	Alluvium			Additional	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X

Notes:

1. Major cations (calcium, magnesium, sodium, potassium) and major anions (chloride, sulfate) and speciated alkalinity (bicarbonate, carbonate, hydroxide)

2. Dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc) (field filtered) and total metals (iron, manganese) (unfiltered sample)

3. Nutrients (ammonia, nitrate, nitrite, total kjeldahl nitrogen, total nitrogen, total phosphorous, reactive phosphorous)