WestConnex M4-M5 Link Mainline Tunnels

Operational Groundwater Management Plan

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00	15/09/2022	ASBJV	DPE	
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WestConnex

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Glossary of terms

Term/acronym	Definition
AIP	NSW Aquifer Interference Policy (NSW Office of Water 2012)
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARI	Annual Rainfall Index
Asset	M4-M5 Link Mainline Tunnels between the M4 at Haberfield and the M8 at St Peters.
CoA	Conditions of Approval
CSSI	Critical State Significant Infrastructure
DAF	Dissolved Air Flotation
DLWC	Department of Land and Water Conservation
DPE	NSW Department of Planning and Environment (now DPE)
DPI	NSW Department of Primary Industries
DPE	NSW Department of Planning, Industry and Environment (formerly DPE)
DPE Water	NSW Department of Industry Water (formerly DPI Water)
DWE	NSW Department of Water and Energy
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EMS	Environmental Management System
EPA	NSW Environment Protection Authority
EPL	Environment Protection Licence
GDE	Groundwater Dependent Ecosystems
GWL	Groundwater Level
GWQ	Groundwater Quality (EC)
HSS	Hawkesbury Sandstone
I&M	Incident and Maintenance
I&M Contractor	TBC
KPI	Key performance indicator
LPS	Low Point Sump
mAHD	elevation in metres with respect to the Australian Height Datum
mBTOC	metres below top of casing
mBGL	Metres below ground level
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measure
NRAR	Natural Resources Access Regulator (formerly part of DPI Water)
NSW	New South Wales
OEMP	Operational Environmental Management Plan
OGMP	Operational Groundwater Management Sub-Plan
OGWMP	Operational Groundwater Monitoring Program
ORP	Oxidation Redox. Potential
POEO Act	Protection of the Environment Operations Act 1997

Term/acronym	Definition
PPE	Personnel Protective Equipment
QA	Quality Assurance
REMM	Revised Environmental Management Measures
SDS	Safety Data Sheet
SOP	Standard Operating Procedure
SP	Standpipe piezometer
SPIR	Submissions and Preferred Infrastructure Report
SSTV	Site Specific Trigger Value
µS/cm	micro-Siemens per centimetre
VWP	Vibrating Wire Piezometer
WTP	Water Treatment Plant

1 Introduction

1.1 Context

This Operational Groundwater Management Sub-plan (OGMP) forms part of the Operation Environmental Management Plan (OEMP) for the M4-M5 Link Mainline Tunnels (the Asset). This document also includes the Operational Groundwater Monitoring Program (OGWMP).

This OGMP has been prepared to address the requirements of the Minister's Conditions of Approval (CoA), the WestConnex M4-M5 Link Environmental Impact Statement (EIS), the revised environmental management measures (REMM) listed in the Project Submissions and Preferred Infrastructure Report (SPIR), the WestConnex M4-M5 Link Mainline Tunnel Modification reports and all applicable legislation.

1.2 Asset background

The M4-M5 Link EIS (AECOM 2017) initially assessed the impacts of construction and operation of the Project on groundwater, within Chapter 19 and Appendix T (Technical working paper: Groundwater). Groundwater impacts have been further assessed during the design and construction of the Project and are summarised in Section 4.2

Both the EIS and Project groundwater investigations identified the potential for impacts on groundwater during operation typically associated with drawdown and changes to water quality. However, they concluded any potential impacts could be managed by the environmental control measures described in this OGMP.

Please refer to Section 2 of OEMP for Asset description.

1.3 Scope of the Sub-plan

The scope of this OGWMP is specific to the operation of the Asset and outlines how the Incident and Maintenance (I&M) Contractor propose to manage and protect groundwater as described in the EIS.

1.4 Implementation of the Sub-plan

The OEMP Sub-plans must be submitted to the Secretary for approval no later than one (1) month prior to the commencement of the operation. Any of the OEMP Sub-plans may be submitted to the Secretary along with, or subsequent to, the submission of the OEMP.

Operation must not commence until the required Operational Monitoring Programs have been approved by the Secretary, and all the relevant baseline data has been collected in accordance with CoA D15.

Operational documents, as approved by the Secretary, and as amended from time to time, must be implemented for the duration of operation. Where the CSSI is being staged, operation of that stage is not to commence until the relevant OEMP, OEMP sub-plans and monitoring programs have been approved by the Secretary.

1.5 Environmental management system overview

The environmental management system overview is described in Section 5.1 of the OEMP.

2 Purpose and objectives

2.1 Purpose

The purpose of this Plan is to describe how the I&M Contractor proposes to manage and protect groundwater during operation of the Project. This Plan should be read in conjunction with the OEMP.

2.2 Objectives

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

- The EIS prepared for WestConnex M4-M5 Link
- The SPIR prepared for WestConnex M4-M5 Link
- The Modification reports for WestConnex M4-M5 Link Mainline Tunnel
- CoA granted to the Project on 17 April 2018 and as altered by the Modification reports
- The Roads and Maritime Services (Roads and Maritime) specifications G36, G38 and G40
- The Project's Environment Protection Licence (EPL)
- All relevant legislation and other requirements described in Section 3 of this Plan.

2.3 Environmental performance outcomes and targets

The targets presented in Table 2-1 have been established for the management of groundwater during operation of the Asset. Key performance indicators (KPIs) have been established for these targets.

Table 2-1: KPIs for groundwater management during operation

Target / KPI number	Target	KPI	Records	Source
GW1	Groundwater management during the operation phase of the Project performed in accordance with this OGMP	Compliance with OGMP	Operational Monitoring Reports Audit Reports	CoA
GW2	Water Treatment Plant (WTP) discharge within defined water quality discharge criteria	Treated water will be of suitable quality for discharge to the receiving environment	Water quality monitoring results Discharge records	CoA / EPL
GW3	Groundwater changes in level and salinity in line with EIS and Asset Groundwater Model	Groundwater drawdown consistent with model predictions	Groundwater monitoring results	EIS Appendix A (project performance outcome)
GW4	Minimal impacts on groundwater quality during the Project operation	No measurable decline in water quality of receiving waters outside of predictions	Groundwater monitoring results	EIS Appendix A (project performance outcome)

Target / KPI number	Target	KPI	Records	Source
GW5	Groundwater monitoring during the operation phase of the project performed in accordance with the Operation Groundwater Monitoring Program (OGWMP) (refer to Annexure A)	Compliance with OGWMP	Operational Monitoring Reports	CoA

3 Environmental obligations

3.1 Legislation

All legislation relevant to this OGMP is described Section 4.1.3 of the OEMP.

3.2 Guidelines and standards

The main guidelines, specifications and policy documents relevant to this Plan include:

- Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC): National Water Quality Management Strategy, Paper No. 4, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1, The Guidelines (ANZECC 2000)
- Environment Protection Authority (EPA): Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (EPA 2004)
- Department of Planning and Environment (DPE): Guideline for riparian corridors on waterfront land (DPE 2012)
- Department of Land and Water Conservation (DLWC):
  - NSW Groundwater Dependent Ecosystems Policy (DLWC 2002)
  - NSW Groundwater Policy Framework Document (DLWC 1998)
  - NSW Groundwater Quality Protection Policy (DLWC 1998)
  - NSW Groundwater Quantity Management Policy (DLWC 2007)
- Department of Water and Energy (DWE): NSW Water Extraction Monitoring Policy (DWE 2007)
- NSW Office of Water (NoW):
  - NSW Aquifer Interference Policy (NoW 2012)
  - Water Sharing Plan, Greater Metropolitan Regional Groundwater Sources Background Document, Sydney (NoW 2011)

3.3 Conditions of approval

Conditions of Approval (CoA) relevant to groundwater management during operation and maintenance activities are included in Table 3-1. A cross-reference is included to indicate where the condition is addressed in this OGMP or other project management documents.

Table 3-1: Relevant Conditions of Approval

CoA	Relevant requirement	Reference
D3(a)	Where an OEMP is required, the Proponent must include the following OEMP Sub-plans in the OEMP: (a) Groundwater management - DPI Water and Sydney Water	This document
D4	Each of the OEMP Sub-plans must include the information set out in Condition D2 (a), (b) and (c). The OEMP Sub-plans must be developed in consultation with relevant authorities as identified in Condition D3.	Section 3.5

CoA	Relevant requirement		Reference
	D2	An OEMP is not required for the CSSI if the Proponent has an Environmental Management System (EMS) or equivalent as agreed with the Secretary, and can demonstrate, to the written satisfaction of the Secretary, that through the EMS: (a) the performance outcomes, commitments and mitigation measures, detailed in the documents listed in Condition A1, and specified relevant terms of this approval, can be achieved;	Sections 2.3 and 3
		(b) issues identified through ongoing risk analysis can be managed; and	Sections 4 and 5
		(c) procedures are in place for rectifying any non-compliance with this approval identified during compliance auditing, incident management or any other time during operation	Section 6
D5	The OEMP Sub-plans must be submitted to the Secretary as part of the OEMP.		Section 1.4
D8	The following Operational Monitoring Programs must be prepared in consultation with the relevant authorities identified for each Operational Monitoring Program to compare actual operational performance against predicted performance. (b) Groundwater Monitoring Program - DPI Water, relevant council(s), EPA and Sydney Water		Section 2.3 of OGWMP (Annexure A)
D9	Each operational monitoring program must include: (a) details of baseline data;		Section 3 of OGWMP (Annexure A)
	(b) details of all monitoring of the project to be undertaken;		Section 4 of OGWMP (Annexure A)
	(c) the parameters of the project to be monitored;		Section 4 of OGWMP (Annexure A)
	(d) the frequency of monitoring to be undertaken;		Section 4 of OGWMP (Annexure A)
	(e) the location of monitoring;		Section 4 of OGWMP (Annexure A)
	(f) the reporting of monitoring and analysis results against relevant criteria;		Sections 4 and 6 of OGWMP (Annexure A)
	(g) details of the methods that will be employed to analyse the monitoring data;		Section 5 of OGWMP (Annexure A)
	(h) procedures to identify and implement additional mitigation measures where results of monitoring are unsatisfactory; and any consultation to be undertaken in relation to the monitoring programs.		Sections 2.2 and 4.1 of OGWMP (Annexure A)
D11	The Operational Groundwater Monitoring Program must include: (a) daily measurement of the amount of water discharged from all water treatment plants;		Section 4.3 of OGWMP (Annexure A)
	(b) water quality testing results of the water discharged from all water treatment plants;		Section 4.3 of OGWMP (Annexure A)
	(c) monitoring of groundwater pore pressures in the Hawkesbury Sandstone aquifers adjacent to the tunnel alignment, in consultation with DPI Water		Section 4.1 of OGWMP (Annexure A)

CoA	Relevant requirement	Reference
D11	(d) monitoring of groundwater electrical conductivity in key locations between saline water bodies and the tunnel as identified by the project groundwater model including: (i) in the Haberfield / Lilyfield area to the south of Iron Cove, (v) in the St Peters area to the north west of Alexandra Canal, with a minimum of two (2) groundwater monitoring wells provided in each key location in consultation with DPI Water;	Section 4.1 of OGWMP (Annexure A)
	(e) measures to record or otherwise estimate and report groundwater inflows into the tunnels;	Sections 4.2 and 6 of OGWMP (Annexure A)
	(f) a method for providing the data collected in (a) and (b) to Sydney Water every three (3) months to demonstrate the project's compliance with the discharge criteria and, if applicable, the Proponent's trade waste licence;	Section 6 of OGWMP (Annexure A)
	(g) a process for annually forwarding data on the monthly volume of groundwater discharged from each water treatment plant to DPI Water for a minimum period of five (5) years, consistent with Condition D12; and	Section 6 of OGWMP (Annexure A)
D12	Groundwater monitoring must continue for a period of at least five (5) years following the completion of construction of the Rozelle Interchange (and commence once the mainline tunnels are operational). At least one (1) month prior to the end of the five (5) year monitoring period, the Proponent must undertake a review of future monitoring requirements in consultation with DPI Water. The review must determine if additional monitoring is required, and the time period for continued monitoring. The Proponent must notify the Secretary within two (2) weeks of the review as to the outcomes of the review and any requirements for future monitoring.	Sections 4 and 6 of OGWMP (Annexure A)
D13	The Operational Monitoring Programs must be developed in consultation with relevant authorities as identified in Condition D8 of this approval.	Section 2.3 of OGWMP (Annexure A)
D14	The Operational Monitoring Programs must be submitted to the Secretary for approval at least one (1) month prior to the commencement of operation.	Section 1.3 of OGWMP (Annexure A)
D15	Operation must not commence until the Secretary has approved all of the required Operational Monitoring Programs, and all relevant baseline data has been collected.	Section 1.3 of OGWMP (Annexure A)
D16	The Operational Monitoring Programs, as approved by the Secretary, must be implemented for the duration identified in the relevant Operational Monitoring Program or specified by the Secretary, whichever is the greater.	Section 1.3 of OGWMP (Annexure A)
D17	The results of the Operational Monitoring Programs must be submitted to the Secretary, and relevant regulatory authorities, for information in the form of an Operational Monitoring Report at the frequency identified in the relevant Operational Monitoring Program.	Section 6 of OGWMP (Annexure A)
D18	Where a relevant OEMP Sub-plan exists, the relevant Operational Monitoring Program may be incorporated into that OEMP Sub-plan.	OGWMP is contained in Annexure A of this document
E187	The CSSI operational water treatment plant discharge criteria must comply with the ANZECC (2000) 95 per cent species protection level and a 99 per cent protection level for contaminants that bioaccumulate unless other discharge criteria are agreed in consultation with relevant stakeholders including EPA, DPI Water and Sydney Water. Discharge criteria for iron during operation must comply with the ANZECC (2000) recreational water quality criteria.	Section 5.5
E190	The Proponent must take all practicable 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.	Section 5.1 and 5.2

CoA	Relevant requirement	Reference
E191	The Proponent must identify and commit to the implementation of ‘make good’ provisions for groundwater users in the event of a 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.	Sections 3.5 and 4.2.3.3

3.4 Revised environmental management measures

The revised environmental management measures (REMMs) included in the WestConnex M4-M5 Link Submissions and Preferred Infrastructure Report that are relevant to the management of groundwater during the operations and maintenance of the Asset are included in Table 3-2.

Table 3-2: Relevant revised environmental management measures

No.	Relevant requirement	Reference
OSW16	The operational water treatment facilities will be designed and managed such that effluent will be of suitable quality for discharge to the receiving environment. Discharge criteria will be developed in accordance with the ANZECC (2000) and relevant NSW WQOs, including the following discharge criteria: • 0.3 milligrams per litre for iron • 1.9 milligrams per litre for manganese. The discharge criteria for the treatment facilities will be nominated during detailed design in consultation with relevant stakeholders and included in the OEMP.	Section 5.5
GW2	Appropriate waterproofing measures will be identified and included in the detailed design to permanently, where reasonable and feasible, reduce the inflow into the tunnels to below one litre per second per kilometre for any kilometre length of the tunnel.	Section 5.1 and 5.2
OGW10	The groundwater monitoring program prepared and implemented during construction will be augmented and continued during the operational phase. Groundwater will be monitored during the operations phase for three years or as otherwise required by the project conditions of approval and will include trigger levels for response or remedial action based on monitoring results and relevant performance criteria.	Section 4 of OGWMP (Annexure A)
	At least three monitoring wells and vibrating wire piezometers (VWPs) should be constructed as close as possible to the tunnel centrelines to allow for the comparison of pore pressures and standing water levels. The wells could be constructed about 5-10 metres above the top of the tunnel crown to allow for groundwater drawdown monitoring in the Hawkesbury Sandstone.	Section 4.1.1 of OGWMP (Annexure A)
	The program will include procedures for monitoring and reporting of extracted groundwater volumes to DPI-Water annually for the duration of construction and operation, unless otherwise agreed to or directed by the Secretary. The operational groundwater monitoring program will be developed in consultation with the NSW EPA, DPI-Water and the relevant councils and documented in the OEMP or EMS.	Sections 2.3 and 6 of OGWMP (Annexure A)
OGW11	Where the corrosion assessment that will be carried out prior to construction indicates potential issues, corrosion and other associated impacts of highly aggressive groundwater on the tunnel infrastructure will be monitored during operations. The monitoring program will be documented in the OEMP or EMS. Corroded or otherwise impacted infrastructure will be repaired or replaced as required to maintain operational integrity of the road infrastructure.	Sections 4.2.4.1 and 5.2
OGW12	In accordance with the NSW Aquifer Interference Policy (DPI-Water 2012), measures will be taken to ‘make good’ the impact on an impacted water supply bore by restoring the water supply to pre-development levels. The measures taken will be dependent upon the location of the impacted bore but could include, for example, deepening the bore, providing a new bore or providing an alternative water supply.	Sections 3.5 and 4.2.3.3

3.5 Aquifer Interference Policy

The Aquifer Interference Policy (AIP) was released in 2012 to address the assessment of potential impacts, and water licensing of aquifer interference activities within NSW. The AIP defines the regime for protecting and managing the impacts of aquifer interference activities on NSW's water resources. Approval for aquifer interference activities will not be granted unless the Minister is satisfied that adequate arrangements are in place to ensure that no more than minimal harm will be done to any water source, or its dependent ecosystems as a consequence of the interference.

The 'minimal impact considerations' are employed to assess impacts to water table levels, water pressure levels and water quality in different groundwater systems. If the predicted impacts are less than 'Level 1 minimal impact considerations' as defined in the AIP, then these impacts are considered acceptable. However, if impacts exceed the 'Level 1' thresholds then monitoring must be undertaken and mitigation measures such as 'make good' provisions may be required for impacted sources and receptors. As the Asset will intercept groundwater during operation, it is defined as an aquifer interference activity under the AIP.

The majority of the groundwater around the Asset is considered to be in the 'less productive' groundwater source category as defined in the AIP, based on the low number of registered groundwater users. The minimal impact assessment (AECOM 2017) indicates compliance with all 'Level 1' thresholds with the exceptions of groundwater drawdown at one registered bore in the vicinity of the Asset. As a result, 'make good' provisions in accordance with CoA E191 will be investigated in consultation with the bore owner (refer to Section 4.2.3.3).

3.6 Consultation

This Plan and the Operation Groundwater Monitoring Program (OGWMP) in Annexure A were provided to DPE Water and Natural Resources Access Regulator (NRAR) (formerly DoI Water), Sydney Water, City of Sydney Council, Inner West Council and the Environment Protection Authority (EPA) for review and comment in accordance with CoA D3 and D8(b).

Refer to Section 1.5 of the OEMP for consultation requirements relating to the OEMP, sub-plans and monitoring programs.

All community feedback, complaints and notification (including those relating to groundwater) will be managed in accordance with Section 7.3 of the OEMP.

4 Environmental aspects and impacts

4.1 Operational activities

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

- Dewatering of groundwater inflows into tunnels
- Operation of the Water Treatment Plant (WTP)

Environmental risks including those on groundwater will be identified, monitored and managed in accordance with Section 8 of the OEMP. Refer to the Aspects and Impacts Register included in Annexure D of the OEMP.

4.2 Potential Impacts

4.2.1 Overview

The potential for impacts on groundwater will be dependent on the nature, extent, and magnitude of operation activities and their interaction with the natural environment. Potential impacts in addition to those described in the EIS in relation to groundwater attributable to operation may include:

- Reduced groundwater recharge
- Groundwater level decline (drawdown due to tunnel inflows) including potential impacts on:
  - GDEs
  - Existing groundwater users
  - Surface water baseflow
  - Ground movement (settlement)
- Changes in groundwater quality, as a result of:
  - Intercepting contaminated groundwater
  - Saline intrusion

Groundwater impacts attributable to the operation of the Asset are anticipated and initially predicted in the baseline groundwater model (AECOM 2017). These predictions were refined as part of the detailed design of the Project (compliance with CoA E193/194) using a three-dimensional regional groundwater model (Golders Associates 2020) which also includes the M4 and M8 Motorways to ensure cumulative impacts were captured. The results of the model have been used to evaluate potential groundwater impacts associated with the operation of the Asset. They have also been used to inform the detailed design of the tunnel including durability, water treatment and ground improvement requirements.

4.2.2 Reduced groundwater recharge

The majority of the Asset is below ground and will not directly impact groundwater recharge.

The above ground footprint represents a small increase in built infrastructure including the motorway operations complexes, ventilation infrastructure, substations and WTP. Given the scale of the above ground footprint, a reduction in rainfall recharge is considered negligible (AECOM 2017).

4.2.3 Groundwater level decline

4.2.3.1 Groundwater inflows and drawdown

Operation of drained tunnels beneath the water table is expected to cause ongoing groundwater inflow to the tunnels, inducing groundwater drawdown along the tunnel alignment. Actual groundwater level drawdown would be dependent on a number of factors, including proximity to the tunnel alignment, the specific geological conditions present as well as any water treatment measures implemented during construction (AECOM 2017).

As expected, tunnel inflows were predicted to be greatest immediately after tunnel excavation and would decrease with time while the surrounding water table decline would gradually continue outwards from the tunnel until a steady state equilibrium is reached. At the commencement of operation, the majority of groundwater inflows are predicted to comply with the criteria of 1 litre per second across any given kilometre (1 L/sec/km) as required by CoA E190.

Modelling (Golders Associates 2020) indicated that two sections of tunnel may initially exceed inflow criteria of 1 L/s/km due to increased rock permeability associated with the Luna Park Fault and Hawthorne Canal high permeability zone. Observations during construction however showed the Luna Park Fault was generally dry and following the completion of ground improvement (i.e. grouting) works, Hawthorne Canal will comply with inflow criteria. Isolated locations, such as tunnel cross passage four and five at Haberfield, have seen higher than predicted groundwater inflows locally. These elevated inflows have been monitored during construction and will not impact the overall capacity of the WTP or Asset drainage system. Overall groundwater inflows are expected to be significantly lower than the initially forecast 17 L/sec on opening of the Asset Refer to Section 5.3 for details of reasonable and feasible measures such as ground improvement (i.e. grouting) implemented during construction to minimise groundwater inflows.

Groundwater drawdown and depressurisation of the aquifer along Asset alignment is expected to occur to elevations equivalent to tunnel inverts as expected for fully drained tunnels. Modelling suggests groundwater drawdowns will potentially extend laterally more than 2 km from the tunnel alignment, with greatest drawdowns occurring along permeable geological structures within the Hawkesbury Sandstone and Ashfield Shale. Long-term steady state drawdown predictions are shown in Figure 4-1.

Groundwater levels in bores along the tunnel alignment will be routinely monitored during operation and compared against predictions as detailed in the Operation Groundwater Monitoring Program (OGWMP) in Annexure A.

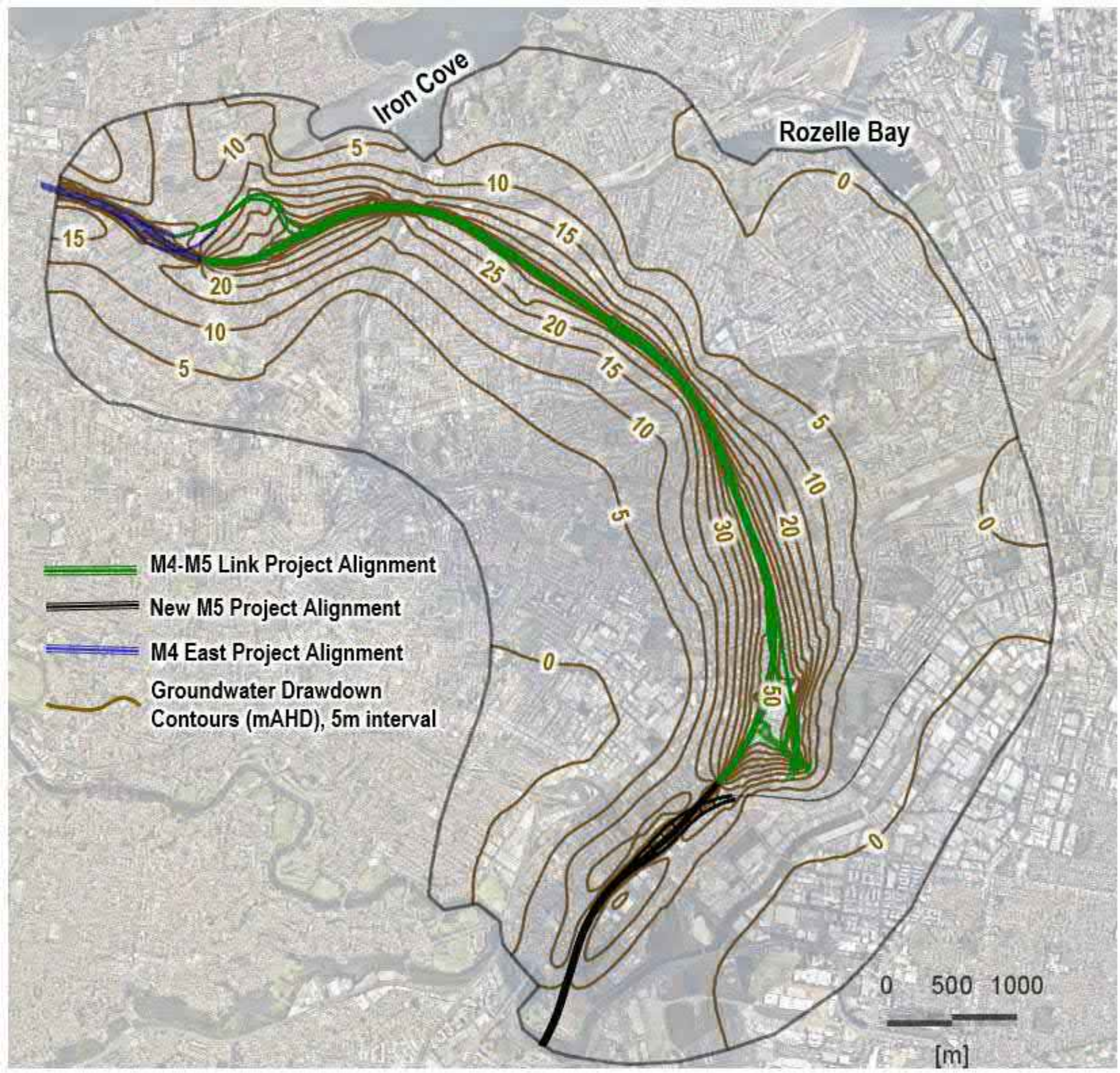


Figure 4-1: Predicted long-term groundwater drawdown (100 years after opening)

4.2.3.2 Potential impacts on groundwater dependent ecosystems (GDE)

Groundwater dependent ecosystems (GDE) are communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater, such as wetlands and vegetation on coastal sand dunes. Priority GDE are ecosystems with a high ecological value which are considered high priority for management action as defined in the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources (2011).

As identified in the EIS (AECOM, 2017) and construction-phase groundwater investigations, there are no priority GDE within 5 km of the Project alignment. No groundwater aquatic, terrestrial or subterranean GDE along or within 10 km of the Asset alignment were identified in the National Atlas of Groundwater Dependent Ecosystems. Consequently, no GDEs are likely to be impacted by groundwater level decline or changes to groundwater quality associated with the operation of the Asset.

4.2.3.3 Potential impacts on groundwater users

One bore registered for domestic use (GW110247) was identified within the Asset's hydrogeological zone of influence. GW110247 is a 210m deep bore constructed in 2009 at the University of Sydney at Camperdown. The land which the bore is located is now owned by Moore Theological College.

GW110247 is predicted to have a drawdown of approximately 5 m to the hydraulic head in Hawkesbury Sandstone during the design life of the tunnel (Golders Associates 2020). As detailed in Section 3.5, this predicted drawdown exceeds 'Level 1' minimal impact thresholds as defined in the NSW AIP (DPI Water 2012) and triggers the need implement 'make good' provisions in accordance with CoA E191 and REMM OGW12.

Consultation with the owner of the registered bore, confirmed GW112047 was decommissioned prior to developing the property in 2016. Therefore, groundwater drawdown associated with the operation of the Asset will have no impact as groundwater is no longer being used for domestic purposes and 'make good' provisions will not be required.

4.2.3.4 Potential impacts on surface water baseflows

Predicted long-term changes to baseflow from the groundwater modelling (Golders Associates 2020) indicate that the overall contribution to flow to surface watercourses from groundwater is relatively small, since the watercourses in the vicinity of the Asset are typically highly modified including concrete lined channels. AECOM (2017) concluded that flows of the creeks and canals is primarily derived from stormwater run-off and tidally driven flow rather than groundwater flow.

4.2.3.5 Groundwater movement (settlement)

Ground movement (settlement) or subsidence can be caused by the compression of the soil structure due to groundwater drawdown.

Within the Project footprint, residual soil profiles developed on the weathered Hawkesbury Sandstone and Ashfield Shale bedrock are typically relatively thin, stiff, and of low compressibility and as such would be less susceptible to ground settlement (AECOM 2017). In areas of alluvium such as Hawthorne Canal, sediments are more compressible and vary in thickness and are therefore more susceptible to potential settlement induced by groundwater drawdown. Groundwater levels will be monitored during operation in these areas of alluvial sediments as detailed in the OGWMP in Annexure A.

4.2.4 Groundwater quality

4.2.4.1 Intercepting contaminated groundwater

Contamination assessments and modelling indicates that groundwater from contaminant sources in the vicinity of Asset alignment may migrate to the tunnel during its design life. These contaminant sources include a range of former landfills and other industrial sources. Migration of contaminants such as ammonia would be induced by groundwater inflows towards the tunnel during operation.

The mobilisation of contaminated groundwater towards the tunnel has been considered in the design and construction of the Asset with secondary linings constructed in various locations to ensure the tunnel achieves the specified design life to prevent issues such as corrosion. Additional monitoring bores have also been installed in St Peters to monitor any potential contamination migration during operation and validate model predictions.

Any contaminated groundwater that inflows to the tunnel will be captured by the tunnel drainage system and treated by the water treatment plant (WTP) at St Peters Interchange as detailed in Sections 5.4 and 5.5 and discharged in accordance with an Environmental Protection Licence (EPL).

Contamination generated within the tunnels as result of incidents and spills is unlikely to impact on groundwater quality as flow gradients will be towards the tunnel. This contamination would also be captured within the tunnel drainage system and removed by the WTP.

4.2.4.2 Saltwater intrusion

Over time, groundwater drawdown and reduced hydraulic pressure in the aquifer is predicted to result in saline water flowing towards the tunnels.

In accordance with CoA E192, an assessment of potential saltwater intrusion using particle tracking was undertaken as part of the groundwater model (Golders Associates 2020). Saltwater migration from Iron Cove and Iron Cove Creek is predicted to reach the northern portion of the mainline tunnels and Wattle St ramps generally between 25 and 50 years. Saltwater is predicted to travel faster along Hawthorne Canal and is predicted to reach those tunnel sections within about 10 years. The groundwater model also indicates saline migration from Rozelle Bay is unlikely to occur due to the Asset. No saltwater intrusion was predicted from Alexandra Canal in St Peters.

As detailed in the EIS (AECOM, 2017), the areas where saltwater intrusion is predicted are located close to the shorelines and their groundwater composition is assumed to be consistent with the water in the Iron Cove. Therefore, groundwater quality impacts due to saltwater migration and considered negligible.

Groundwater quality (salinity as Electrical Conductivity (EC)) during operation will be routinely monitored at key locations between saline water bodies and the tunnel as identified by the groundwater model (Golders Associates 2020) including in the Haberfield / Lilyfield area to the south of Iron Cove and adjacent to Hawthorne Canal. Details of operational groundwater monitoring are presented in the OGWMP (Annexure A).

Changes to groundwater quality as a result of saltwater migration was considered in the design of the WTP. Water captured in the tunnel and treated by the WTP will be discharged to Alexandra Canal. Alexandra Canal is an estuary which drains into the Cooks River catchment and is tidally influenced by brackish conditions. Discharges of saline groundwater would be consistent with the existing water quality of Alexandra Canal and would therefore have no environmental impact.

Saltwater intrusion during the operation of the Asset was considered with tunnel design measures implemented to ensure durability during the entire 100 year design life (refer to Section 5.1).

5 Environmental Control measures

5.1 Tunnel design

The Project mainline tunnel was designed and constructed to meet the groundwater inflow criteria of 1 litre per second across any given kilometre (1 L/sec/km) using water-control treatments along the mainline tunnel. Five lining types were installed, depending on the ground conditions and the level of water ingress observed:

- Type A: shotcrete and rockbolts
- Type B: Type A + weepholes (where required), strip drains at >3000mm spacing and shotcrete
- Type C: Type A + weepholes (where required), strip drains at >500mm spacing and shotcrete
- Type D: Type B/C + spray-on membrane between the primary and secondary layers of shotcrete
- Type E: Type B + geotextile and sheet membrane between primary and secondary layers of shotcrete

Where specific areas within the tunnel were still likely to exceed the 1 L/sec/km criterion after the implementation of reasonable and feasible measures, consultation with, and agreement by DPE Water was sought.

The remaining ongoing inflow of groundwater into the tunnels will be managed through the tunnel drainage system, which has been designed to accommodate the capture, removal, treatment and discharge of groundwater.

Groundwater inflows during operation will be estimated and reported to relevant stakeholders. Further detail on groundwater inflow monitoring is detailed in Section 4.2 of the OGWMP (Annexure A).

5.2 Tunnel durability

As detailed in Section 4, groundwater quality assessments and modelling were undertaken to inform the durability design of all tunnel components to achieve the specified design life. These additional durability measures ensure Asset infrastructure will not be impacted or corroded by groundwater during operation and therefore, monitoring in accordance with REMM OGW11 is not required.

Additional action has also been taken in regards to the contaminant migration predicted in St Peters, where additional monitoring bores were installed to validate this prediction. Any potential contamination migration in this region will be detected in these bores before contaminated groundwater reaches the tunnel and its durability lining. This monitoring will also provide an early warning should conditions be observed to vary from those predicted and provide insight into any rectification works to be undertaken if required.

Durability for saline intrusion has been considered during the design phase and validation has occurred during the construction phase. Observed saline groundwater locations have been broadly consistent with assumptions in the design phase around Hawthorne canal and other areas of the Haberfield.

5.3 Ground improvement

In accordance with CoA E190 and REMM GW2, reasonable and feasible measures including ground improvement by grouting was undertaken in the tunnel and above ground where required to limit groundwater inflows and potential settlement risks during construction and operation.

Ground improvement by grouting aims to fill voids and fissures in the rock as much as practical to reduce and control groundwater inflows and achieve compliance with the criteria of 1 L/sec/km. Depending on the level of groundwater inflows predicted or observed during construction of the Asset, grouting was undertaken at one or combination of the following stages:

- Pre-excavation grouting from surface
- Pre-excavation grouting in the tunnel
- Post grouting in the tunnel.

Groundwater inflows and surrounding water levels during operation will monitored as detailed in Section 4 of the OGWMP (Annexure A).

5.4 Tunnel sump and pump

A sump with two separate chambers to capture groundwater, hydrocarbons and stormwater/deluge water within the tunnels is located at the Northern and Southern low points. The storage capacity of each sump is detailed in 1 and has been designed to store the following concurrent water inputs.

- First flush surface water flows outside tunnel portals
- Liquid tanker spill
- Fire-fighting foam in spill containment
- Deluge water generated by twenty minutes operation of the fire protection system
- Groundwater ingress (including from other interfacing WestConnex stages).

The Northern Low Point Sump is located adjacent the cross passage and Substation on the Northbound side under Haberfield and the Southern Low Point Sump adjacent to the cross passage on the Southbound side under Camdenville Park as shown in Figure 5-1.

Water captured in the Northern sump will be pumped over the high point in the tunnel, into the drainage pipes, and will gravity flow into the Southern sump. The Southern Sump will pump water to the Water Treatment Plant (WTP) on the surface at St Peter's Interchange for treatment prior to discharge under the requirements of an EPL.

The sumps capture and transfer all liquids from within the tunnels (groundwater, washdown, deluge water and hydrant water) as well as any stormwater ingress from the daylight portals. The two chambers consist of the Minor Flows Sump and the High Flows Sump.

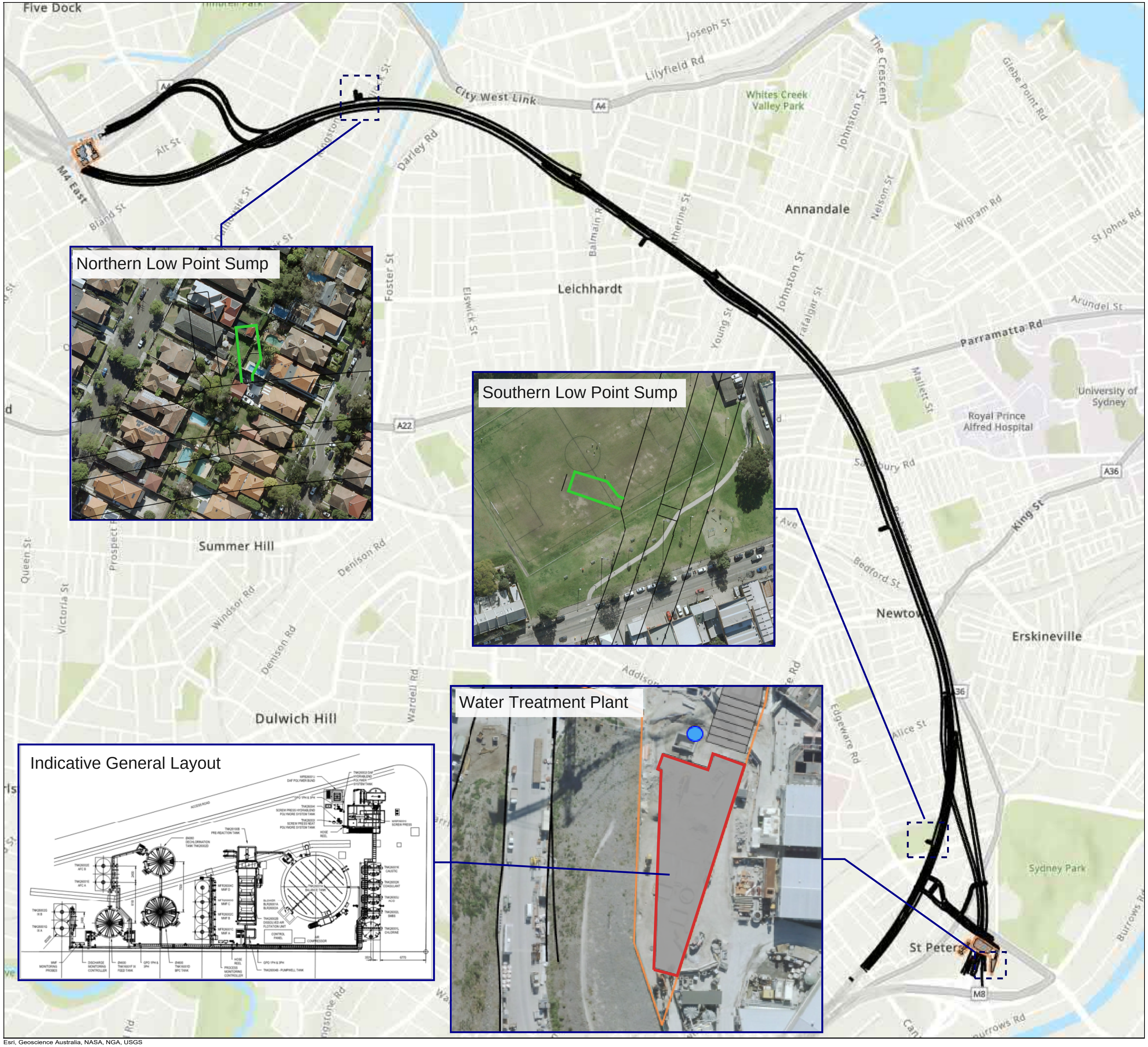
The Minor Flows Sump allows the pumping of minor inflows (predominately groundwater and first flush from the tunnel portal) to the WTP. As the inflow to the Minor Flows Sump increases (either during normal operation, deluge, or a critical event), the water level in the sump will rise and overtop the under/over weirs into the High Flow Storage Sump. The under/over weir system will trap hydrocarbons (including those from a major spill) in the Minor Flow Sump. Foam suppression will also be triggered on detection of hydrocarbons in the Minor Flow Sump to reduce combustion risks.

Table 5-1 Low point sump capacity

Water input	Northern sump (m^3)	Southern sump (m^3)
Minor Flow: Groundwater inflow and hydrocarbon spill storage	66	66
High Flow: Buffer storage for high flow events	440	423

WestConnex M4-M5 Link Mainline Tunnels

Figure 5-1: Tunnel Low Point Sumps, Operational WTP and Discharge Location



Legend

- Tunnel Alignment
- Tunnel Low Point Sump
- Water Treatment Plant
- WTP Discharge Location
- Ancillary Facility Boundary
- Operational Ancillary Infrastructure

Notes

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5.5 Water treatment

During the operation of the Asset, there will be an ongoing inflow of groundwater into the tunnels. The tunnel drainage system has been designed to accommodate the capture, removal, treatment and discharge of groundwater. Groundwater inflows would be directed to one of the two low point sumps at Haberfield and St Peters Interchange. During normal operation, the WTP will treat and discharge a maximum of approximately 24 L/s.

The WTP has been designed to treat water in accordance with CoA E187 and REMM OSW16 to ensure water is of suitable quality for discharge to the receiving environment in compliance with applicable ANZECC (2000) criteria and in accordance with the WTP EPL. It has also been designed with consideration of predicted groundwater inflow quality including the potential effects of saltwater intrusion and migration of contaminants such as ammonia from former landfills in the vicinity of the Asset.

The WTP will consist of the following steps:

- Water from the tunnel is pumped to the surface from the Southern Low Point Sump through a trash screen to remove any large solids, plastics and debris. Incoming raw water will be monitored for conductivity, pH, ORP and turbidity. If a raw water alarm is triggered, the transfer pumps will be inhibited so water can be removed by other means (i.e. tanker truck).
- At the Balance Tank, water is flow balanced and aerated to oxidise heavy metals, remove ammonia and suspend solids for later removal.
- Water from the Balance Tank is pumped to the Dissolved Air Flotation (DAF) Reaction Tank and is dosed with caustic or acid depending on the in-tank pH readings, coagulant and polymer to aid in the removal of solids. Accumulated solids will be pumped to the Sludge Tank for removal by the Screw Press. Water from the sludge removal process will be pumped back to the Balance Tank for treatment.
- Clean water from the DAF flows through the multimedia filtration system for further polishing of metals and metal oxides. Backwashing will be undertaken to remove waste metal oxides that gradually build up during the filtration process. Filtered water will then flow to a Breakpoint Chlorination Tank to remove ammonia and then pass through Activated Carbon and Ion Exchange filters. Under treatment water quality (pH, turbidity, ORP, chlorine and conductivity) will be monitored to inform chemical dosing rates.
- pH, conductivity and turbidity will be monitored in the treated water and if of acceptable quality will discharge into a piped surface water drainage network on Campbell Road that ultimately drains into Alexandra Canal.

The WTP is controlled and monitored via an external control room with full control functionality. At the control room the operator is able to monitor the quality of water at various stages in the treatment process, along with the status of all water treatment plant system alarms and plant.

The discharge location was selected as the nearest saline environment. The discharge location is identified in Figure 5-1. The use of existing infrastructure also minimises the potential impacts due to excavation and laying new pipes.

Additional information regarding the operational water treatment plant, including treatment criteria and monitoring is found in Section 4.3 of the OGWMP (Annexure A).

5.6 Management measures

Steps that will be implemented to plan, manage, monitor and/or review environmental impacts are identified in Table 5-1.

Table 5-2: Environmental management controls

Groundwater management controls	Responsibility
Encountering and handling contaminants	
General provisions	
Prepare and implement an SOP for managing and handling contaminated materials that accords with the Guideline for The Management of Contamination (Roads and Maritime, 2013), RMS Quality Assurance Specification G36: Environmental Protection, and National Environment Protection Measure (NEPM) guidelines on contaminated land management. The SOP will provide detail on: • areas of known contamination; • the management of unexpected contamination finds; • actions to be taken for any land contamination caused by the I&M Contractor.	I&M Contractor
Encountering unexpected contamination finds	
Prepare and implement an SOP for dealing with unexpected contaminated materials (or include in a combined contaminated materials SOP, referenced above). This will include a stop-work procedure and the need to notify the Project Company Representative within 24-hours of encountering any suspected or potential contamination.	I&M Contractor
Groundwater quality monitoring and auditing	
After a major spill or accident, implement the Emergency Response Plan (or associated documents – refer Section 8.2 of the OEMP).	I&M Contractor / Project Company
Ensure that all monitoring is undertaken in accordance with the Groundwater Monitoring Program.	I&M Contractor
Record any exceedances of the water quality parameters as a non-conformance and report this directly to the Project Company Representative. Implement the response action process nominated in the Groundwater Monitoring Program.	I&M Contractor

5.7 Operational monitoring

An OGWMP has been developed to describe how I&M Contractor propose to monitor potential impacts to groundwater during operation of the Asset (refer to Annexure A).

5.8 Licences and permits

Operation of the WTP will be regulated by an EPL issued by the EPA. The EPL typically prescribes water quality parameters to be measured and associated discharge criteria from licensed discharge points. They also detail the monitoring and analytical requirements by reference to authority publications (e.g. Methods for Sampling and Analysis of Water Pollutants in NSW (EPA 2004)).

As detailed in Section 4.1.4 of the OEMP, other relevant licences or permits will be obtained in the lead up to and during operation as required

6 Monitoring, Notification and Reporting

Monitoring, notification and reporting for operational activities of the Asset will be undertaken in accordance with Section 8 and Section 9 of the OEMP. Specific requirements relevant to this OGMP are identified below.

6.1 Groundwater monitoring

In accordance with CoA D12, groundwater monitoring will commence at operation and be undertaken for a period of at least 5 years following the completion of construction of the Rozelle Interchange project (Stage 2). This will enable the I&M Contractor to assess the performance of the Asset against the objectives and KPIs detailed in Section 2 and identify potential impacts and management responses.

Operational monitoring requirements are detailed in the OGWMP (Annexure A) and include:

- Groundwater monitoring locations
- Parameters/analytes to be monitored
- Type of monitoring
- Frequency of monitoring
- Monitoring methodology

6.2 Notification

Project Company will immediately notify and consult with DPE Water and/or NRAR (formerly DPI Water) on any groundwater bores (for monitoring or otherwise) removed or damaged as a result of operational activities.

6.3 Reporting

Reporting and data provision requirements relevant to this OGMP are outlined in Table 6-1.

Table 6-1: Reporting requirements

Schedule (during operation)	Requirements	Recipient (relevant authority)
Reporting		
Operational Groundwater Monitoring Reports (every six months for a minimum of 5 years)	Raw groundwater data to be collected and tabulated. Trigger exceedances to be highlighted. Report to confirm implementation and compliance of required operational water control measures including the operational WTP. Extracted groundwater volumes to be reported in accordance with CoA D11(g).	DPE, DPE Water (formerly DPI Water), Relevant Council(s), EPA, Sydney Water, TfNSW
EPL Monitoring Reports and Annual Returns	EPL monitoring data reports will be prepared in accordance with the requirements of the EPL. An EPL Annual Return will be prepared in respect of each EPL reporting period (typically 12 months).	EPA
Groundwater Monitoring Review (1 month prior to end of 5-year monitoring period)	Report of justification for continuation or cessation of the Groundwater Monitoring Program. To demonstrate compliance with CoA D12.	DPE, TfNSW

Schedule (during operation)	Requirements	Recipient (relevant authority)
WTP Performance (monthly)	Compliance report for WTP performance and discharge criteria.	Project Company, TfNSW
Data provision		
Quarterly (every 3 months)	WTP discharge water quality and volume data (raw data collated and tabulated in Excel) To demonstrate compliance with the CoA D11(f) and the EPL	Sydney Water, TfNSW

7 Auditing and review

7.1 Continuous improvement

Continuous improvement of this OGMP 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 continuous improvement process will be designed 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 plan of corrective and preventative action to address any non-conformances and deficiencies
- Verify the effectiveness of the corrective and preventative actions
- Document any changes in procedures resulting from process improvement
- Make comparisons with objectives and targets.

7.2 OGMP update and amendment

The processes described in Sections 9 and 10 of the OEMP may result in the need to update this OGMP and its associated monitoring program. Plan updates will occur on an as needed basis.

As outlined in Table 6.1 and as required by CoA D12, at least one (1) month prior to the end of the five (5) year monitoring period, a review of future monitoring requirements in consultation with DPI Water will be undertaken. The review must determine if additional monitoring is required, and the time period for continued monitoring. The Secretary must be notified within two (2) weeks of the review as to the outcomes of the review and any requirements for future monitoring.

Document updates to the plan in response to regular reviews (refer to Section 10.1 of the OEMP) may be approved internally if they are considered minor. Where necessary, the OGMP will be provided to relevant stakeholders for review and comment if required and provided to the Secretary for approval.

A copy of updated plans will be made public ally available on the WestConnex project website (https://www.westconnex.com.au/) and provided to the relevant stakeholders on request.

7.3 Auditing

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

Audit requirements are detailed in Section 9.3 of the OEMP.

Annexure A Operation Groundwater Monitoring Program

WestConnex M4-M5 Link Mainline Tunnels

Annexure A - Operational Groundwater Monitoring Program

Project:	M4-M5 Link Mainline Tunnels – Design and Construct
Contract Number:	TBC
Revision Date:	November 2022

Document Approval

Rev	Date	Prepared by	Reviewed by	Remarks
00	15/09/2022	ASBJV	DPE	
01	02/11/2022	ASBJV	DPE	Update to address DPE feedback

WestConnex

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Tables

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1 Introduction

1.1 Context

This Operational Groundwater Monitoring Program (OGWMP or Program) has been prepared for the operation and maintenance of the M4-M5 Link Mainline Tunnels (the Asset).

The OGWMP addresses the requirements of the Minister's Conditions of Approval (CoA), the WestConnex M4-M5 Link Environmental Impact Statement (EIS), the revised environmental management measures (REMM) listed in the WestConnex M4-M5 Link Submissions and Preferred Infrastructure Report (SPIR), the WestConnex M4-M5 Link Mainline Tunnel Modification reports and all applicable guidance and legislation.

1.2 Scope

The scope of this OGWMP is to describe how the Incident and Maintenance (I&M) Contractor propose to monitor groundwater during operation of the Asset.

1.3 Implementation

Operational Monitoring Programs must be submitted to the Secretary for approval at least one (1) month prior to commencement of operation.

Operation will not commence until the Secretary has approved all of the required Operational Monitoring Programs relevant to that activity and all the relevant baseline data has been collected.

The Operational Monitoring Programs, as approved by the Secretary, must be implemented for at least five (5) years following the completion of construction of the Rozelle Interchange project (Stage 2) and for any longer period set out in the monitoring program or specified by the Secretary, whichever is the greater.

2 Purpose and objectives

2.1 Purpose

The purpose of the OGWMP is to describe how the I&M Contractor propose to monitor the extent and nature of potential impacts to the groundwater level and quality during operation of the Asset.

The OGWMP will be implemented to monitor the effectiveness of mitigation measures implemented as part of the Asset. 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 OGWMP supplements the Operational Groundwater Management Sub-plan (OGMP), which, itself, is an annexure of the Operational Environmental Management Plan (OEMP).

This OGWMP is based on baseline studies developed for the project EIS (AECOM 2017) and the potential impacts predicted by the Groundwater Model developed by Golders Associates during the design and construction phase of the Asset.

2.2 Objectives

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

- The EIS prepared for WestConnex M4-M5 Link
- The SPIR prepared for WestConnex M4-M5 Link
- The Modification reports for WestConnex M4-M5 Link Mainline Tunnel
- CoA granted to the project on 17 April 2018 and as altered by the Modification reports
- The Asset's Environment Protection Licence (EPL)
- All relevant legislation and other requirements

2.3 Consultation

This program was provided to Department of Planning and Environment (DPE) Water/Natural Resources Access Regulator (NRAR) (formerly Department of Primary Industries (DPI) Water), Sydney Water, City of Sydney Council, Inner West Council and the Environment Protection Authority (EPA) for review and comment in accordance with CoA D8(b) and REMM OGW10.

Refer to Section 1.5 of the OEMP for consultation requirements relating to the OEMP, sub-plans and monitoring programs.

An overarching Consultation Report has been prepared separately to this program to provide detail relating to the consultation received and where feedback has been coverer or addressed in this document.

3 Baseline groundwater monitoring

Groundwater level and groundwater quality monitoring from the baseline groundwater monitoring network commenced in June 2016. This baseline dataset was augmented by data collected since October 2015 for adjacent M4 and M8 Projects.

The baseline monitoring network was installed between May 2016 and May 2017 and consisted of 19 monitoring bores intersecting groundwater within the alluvium, Ashfield Shale, and Hawkesbury Sandstone as listed in Table 3-2 and shown in Figure 3-1. Monitoring bores were designed and constructed to target the expected tunnel zone and allowed assessment of potential impacts to groundwater. At one location where alluvium was present, nested monitoring bores were constructed,

The majority of monitoring bores (13) target the Hawkesbury Sandstone. Five bores target the Ashfield Shale, and one bore intersects the alluvial sediments associated with the Hawthorne Canal.

In addition to the collection of groundwater quality and groundwater level data, baseline studies to inform the project EIS (AECOM 2017) included the collection of hydraulic data for the local aquifer systems (including packer tests). This data is not discussed further in this document as it has no relevance to the operational monitoring program.

Baseline groundwater monitoring data has provided inputs to the groundwater modelling documented in the Groundwater Modelling Report prepared to satisfy CoA E192 and E193 and 24-Month Construction Monitoring Groundwater Review required by CoA E194. The baseline monitoring bore network is shown in Table 3-2 and Figure 3-1, and is detailed in Appendix T (Technical working paper: Groundwater) of the EIS (AECOM 2017).

3.1 Groundwater level

Baseline groundwater level data included monthly manual dips and continuous data from dedicated pressure logging transducers (dataloggers). Dataloggers were installed in key groundwater monitoring bores and programmed to record baseline data on an hourly basis. The data was corrected for barometric pressure effects, converted to a groundwater level measurement and compared to local rainfall.

The purpose of the baseline groundwater level monitoring was to establish pre-construction groundwater level and flow conditions across the project area to inform groundwater modelling and the EIS (AECOM 2017).

Manual baseline groundwater level monitoring results are included in Annexure A.

3.2 Groundwater quality

Baseline monthly groundwater quality monitoring commenced in June 2016 or later as each monitoring location became operational (refer to Table 3-2). The objectives of the baseline groundwater quality monitoring program included:

- Characterise the existing hydrogeochemistry in the three main aquifers units (alluvium, Ashfield Shale, and Hawkesbury Sandstone)
- Establish the environmental value and beneficial use of groundwater under existing (pre-construction) conditions
- Develop a groundwater quality baseline dataset to inform the EIS
- Characterise the potential aggressiveness of the native groundwater to the building material used to construct the project infrastructure
- Obtain a preliminary understanding of the groundwater treatment requirements required prior to discharge during the construction and operation phases

A summary of the groundwater quality samples collected from June 2016 for each aquifer formation is shown in Table 3-3.

Table 3-1: Baseline groundwater quality sampling program

	Alluvium	Ashfield Shale	Hawkesbury Sandstone	Total
Number of samples	12	30	66	108

A summary of the baseline water quality data is included in Annexure A. Interpretation of the baseline groundwater monitoring data is included in the EIS (AECOM 2017) and is summarised in Table 3-3.

Table 3-2: Baseline groundwater monitoring network

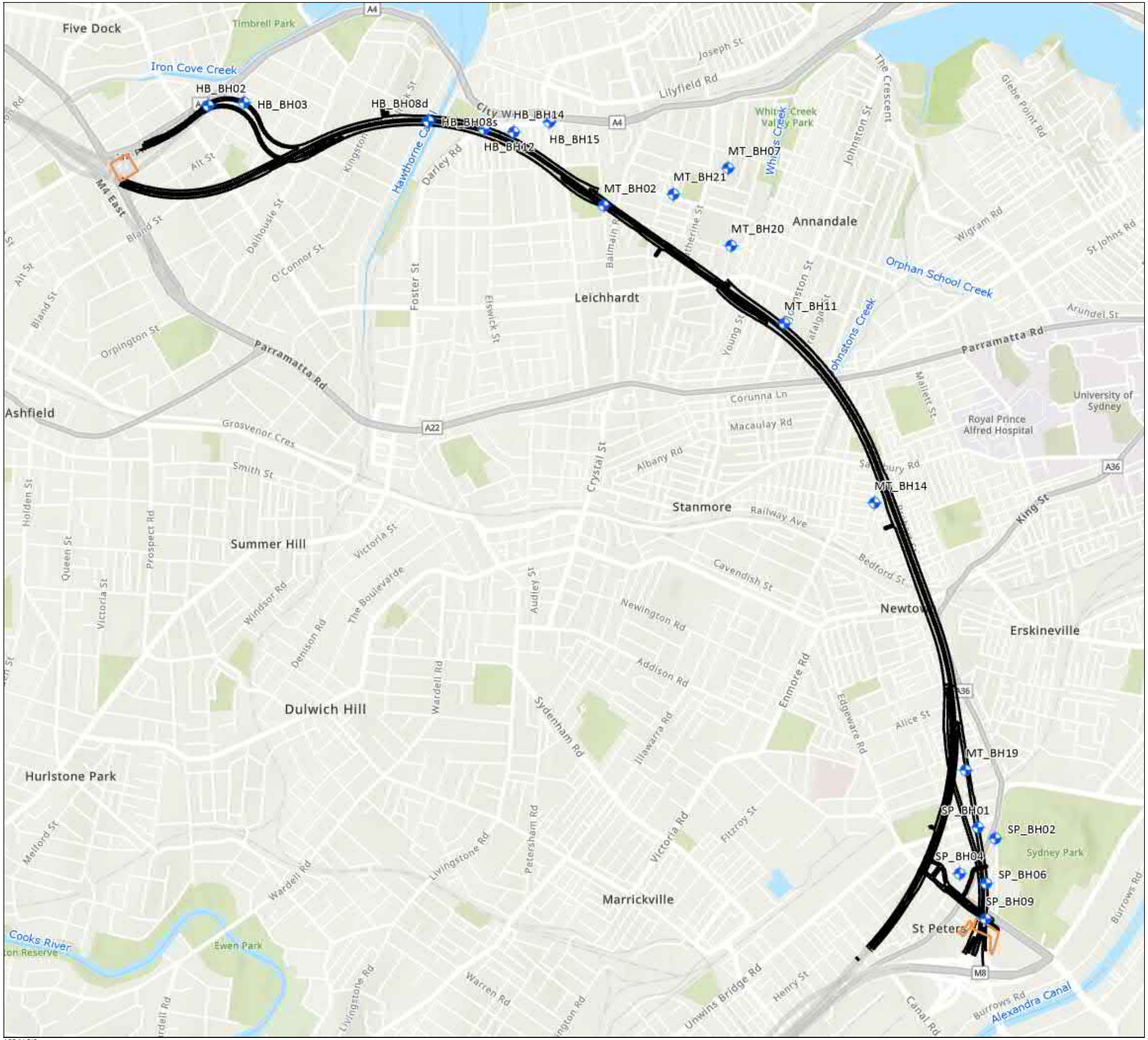
Bore ID	Location	Easting	Northing	Screened interval (mBGL)	Lithology screened	Start of baseline groundwater level monitoring	Start of baseline Groundwater quality monitoring
HB_BH02	Haberfield	327574.77	6250197.42	14 - 17	HSS	June 2016	July 2016
HB_BH03	Haberfield	327764.93	6250217.19	14 - 17	HSS	August 2016	August 2016
HB_BH08d	Haberfield	328751.96	6250138.18	22 - 25	HSS	June 2016	June 2016
HB_BH08s	Haberfield	328750.60	6250135.51	10 - 13	Alluvium	June 2016	June 2016
HB_BH12	Haberfield	329047.41	6250099.10	27 - 30	HSS	July 2016	July 2016
HB_BH14	Haberfield	329206.55	6250086.27	37 - 40	HSS	July 2016	July 2016
HB_BH15	Haberfield	329396.41	6250142.83	19 - 22	HSS	June 2016	June 2016
SP_BH01	St Peters	331750.58	6246432.73	36 - 39	Ashfield Shale	September 2016	October 2016
SP_BH02	St Peters	331844.84	6246375.94	4 - 10	Residual Clay (Shale)	June 2016	July 2016
SP_BH04	St Peters	331657.95	6246185.60	32 - 35	Ashfield Shale	August 2016	August 2016
SP_BH06	St Peters	331800.08	6246136.08	20 - 23	Ashfield Shale	June 2016	June 2016
SP_BH09	St Peters	331800.90	6245948.32	23 - 26	Ashfield Shale	June 2016	June 2016
MT_BH02	Main Line Tunnel	329696.1	6249704.0	42 - 45	HSS	February 2017	March 2017
MT_BH07	Main Line Tunnel	330355.81	6249914.91	43 - 46	HSS	February 2017	February 2017
MT_BH11	Main Line Tunnel	330670.67	6249095.13	48 - 51	HSS	March 2017	NA
MT_BH14	Main Line Tunnel	331168.37	6248149.99	27 - 30	HSS	January 2017	January 2017
MT_BH19	Main Line Tunnel	331680.25	6246735.87	55 - 58	HSS	NA	January 2017

Bore ID	Location	Easting	Northing	Screened interval (mBGL)	Lithology screened	Start of baseline groundwater level monitoring	Start of baseline Groundwater quality monitoring
MT_BH20	Main Line Tunnel	330379.4	6249503	41 - 44	HSS	March 2017	NA
MT_BH21	Main Line Tunnel	330066.72	6249771	47 - 50	HSS	February 2017	February 2017

Notes: HSS = Hawkesbury Sandstone; NA = no baseline data available

WestConnex M4-M5 Link Mainline Tunnels

Figure 3-1: Location of baseline groundwater monitoring bores



Legend:

- Groundwater monitoring bore
- Tunnel alignment
- Ancillary Facility Boundary

0 0.5 1 km

This map is shown for reference purposes only. Acciona provides this information "as is" with the understanding that it is not guaranteed to be accurate, correct or complete and conclusions drawn from such information are the responsibility of the user. While every effort is made to ensure the information displayed is as accurate and current as possible, Acciona will not be held responsible for any loss, damage or inconvenience caused as a result of reliance on such information or data.

ASBJV GIS

Table 3-3: Summary of baseline groundwater quality

Parameter	Alluvium	Ashfield Shale	Hawkesbury Sandstone
Electrical Conductivity (EC)	Variable marginal to slightly saline Range: 1,561 to 9,068 µS/cm	Fresh to moderately saline Range: 242 to 11,986 µS/cm	Fresh to moderately saline Range: 558 to 16,300 µS/cm
pH	Weakly acidic to weakly basic Range: 5.96 to 8.06	Acidic to strongly basic Range: 5.51 to 12.13	Slightly acidic to strongly basic Range: 5.77 to 12.69
Major ions	Dominated by sodium, magnesium, chloride and bicarbonate. The dominance of sodium and chloride is attributed to tidal influences.	Highly variable, likely due to the intermittent development of secondary mineralisation such as calcite (calcium carbonate) and siderite (iron carbonate) and the variable flushing of salts of marine origin.	Dominated by sodium and chloride, which may be in part due to the influence of saline water intrusion.
Metals	Maximum levels exceeded guideline[1] concentration values for all but cadmium and nickel. In most cases the exceedance is marginal, indicating that background levels are already elevated.	Maximum levels exceeded relevant guideline[1] concentration values for chromium, copper, iron, manganese, nickel and zinc. Iron and manganese are commonly elevated within the Ashfield Shale.	Maximum levels exceeded guideline[1] concentration values for chromium, copper, iron, lead, manganese, nickel and zinc. Consistently elevated iron and manganese.
Nutrients	Nitrite and nitrate concentrations indicate that background nutrient levels are low. Reactive phosphorous levels are also low and ammonia values exceeded guideline[1] value.	Nitrite and nitrate concentrations indicate that background nutrient levels are low. Reactive phosphorous levels are also low and ammonia values exceeded guideline[1] value.	Nitrite and nitrate concentrations indicate that background nutrient levels are low. Reactive phosphorous levels are very low and ammonia values marginally exceeded guideline[1] value.
Sulfate reducing bacteria[2]	Sulfate reducing bacteria was not assessed for alluvium.	No pattern was assessed for sulfate reducing bacteria because many samples were above the measurement limit (500,000 CFU/ml). Seawater is a known prime habitat for sulfate reducing bacteria, and it is possible that the dissolution of marine salts from the Ashfield Shale into the Hawkesbury Sandstone makes the groundwater prone to sulfate reducing bacteria growth.	
Soil salinity	Salt concentrations within the alluvium are variable and impacted by tidal influences.	Ashfield Shale typically has a high salt content due to the presence of connate marine salts.	Salt concentrations within the Hawkesbury Sandstone are variable.
Groundwater aggressivity	Groundwater aggressivity was not assessed for alluvium.	Groundwater within the Ashfield Shale is: 1. Non-aggressive towards concrete piles for average concentrations of chloride, pH, and sulfate 2. Non-aggressive towards steel piles for average concentrations of chloride and pH Moderately aggressive towards steel pipes for groundwater with low conductivity.	Groundwater within Hawkesbury sandstone is: 1. Mildly aggressive towards concrete piles for average concentrations of chloride, pH, and sulfate 2. Mildly aggressive towards steel piles for average concentrations of chloride and pH Severely aggressive towards steel piles for groundwater with low conductivity.

Notes: µS/cm = micro-Siemens per centimetre

[1]Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000a)

[2]measured as a colony forming unit (CFU) per 100 ml

4 Operational groundwater monitoring

In accordance with CoA D12, groundwater monitoring will commence at operation, being once the mainline tunnels (Stage 1) are operational and continue for a minimum period of five years following the completion of construction of the Rozelle Interchange project (Stage 2). It will be undertaken in accordance with Australian Standards, ANZECC/ARMCANZ (2000) and the OEMP.

As discussed in Section 4 of the OGMP, potential impacts on groundwater during operation are identified as:

- Groundwater level decline due to tunnel inflows (groundwater drawdown)
- Intrusion of saline water in tidal zones (increase in groundwater salinity in the area to the south of Iron Cove)

Groundwater level and groundwater quality monitoring will be carried out during operation at monitoring bores located in the vicinity of the tunnel alignment. Groundwater inflows intercepted in the tunnel during operation and their subsequent discharge via the water treatment plant (WTP) at St Peters Interchange, will also be monitored.

4.1 Groundwater monitoring

4.1.1 Overview

Groundwater level and groundwater quality (as electrical conductivity (EC)) monitoring will be carried out during operation at the monitoring network listed in Table 4-1 and shown in Figure 4-1.

Monitoring bores target the three main aquifer units (alluvium, Ashfield Shale, and Hawkesbury Sandstone) around the tunnel alignment with a minimum of two groundwater monitoring bores located in the following key locations:

- Haberfield / Lilyfield area to the south of Iron Cove
- St Peters area to the north west of Alexandra Canal

Three vibrating wire piezometers (VWPs) were installed in accordance with REMM OGW10 (with the exception of depth, following consultation with DPE Water) as close as possible to the tunnel centrelines of the Project mainline tunnels to allow for the comparison of pore pressure (recorded by the VWPs) and groundwater water level (recorded by standpipe groundwater monitoring bores).

The VWPs were constructed below the depth of the tunnel invert to allow for groundwater drawdown monitoring in the Hawkesbury Sandstone. The VWPs are located as close to an existing standpipe piezometer and target equivalent depths to allow comparison (refer to Table 4-1 and Figure 4-1).

Table 4-1: Operational groundwater monitoring network

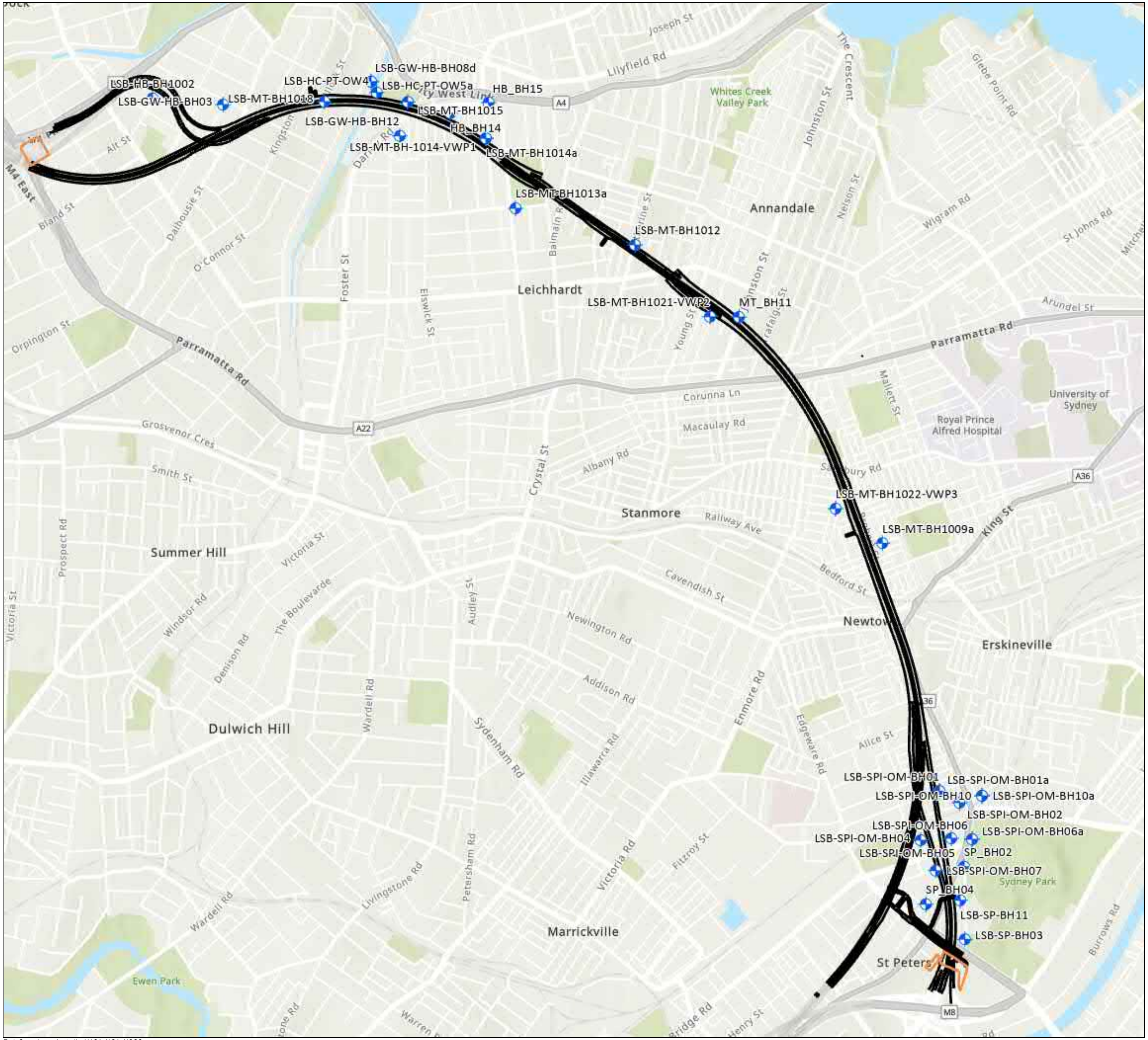
Bore ID	Location	Easting	Northing	Surface Elevation (mAHD)	Screened interval (mBGL)	Lithology screened	Type	Parameters
LSB-GW-HB-BH03	Haberfield	328069.55	6250108.81	20.78	54.4 – 60.4	HSS	SP	GWL
LSB-HB-BH1002	Haberfield	327716.76	6250133.19	4.97	22.15 – 28.15	HSS	SP	GWL
LSB-GW-HB-BH08d	Haberfield	328807.04	6250235.62	1.78	22.45 – 25.45	HSS	SP	GWL/GWQ (EC)
LSB-HC-PT-OW5a	Haberfield	328808.19	6250236.19	1.79	10.5 – 13.5	Alluvium	SP	GWL/GWQ (EC), Atmospheric Pressure
LSB-MT-BH1018	Haberfield	328575.12	6250131.40	8.92	46.5 – 51	HSS	SP	GWL/GWQ (EC)
LSB-GW-HB-BH12	Haberfield	328955.61	6249968.52	4.95	37.4 – 43.4	HSS	SP	GWL/GWQ (EC)
LSB-MT-BH1015	Haberfield	328993.20	6250137.84	2.39	33.5 – 39.5	HSS	SP	GWL/GWQ (EC)
LSB-HC-PT-OW4	Haberfield	328836.57	6250183.01	1.83	33 – 39	HSS	SP	GWL
HB_BH14	Haberfield	329206.55	6250086.27	4.27	37 – 40	HSS	SP	GWL
HB_BH15	Haberfield	329396.41	6250142.83	17.87	19 – 22	HSS	SP	GWL/GWQ (EC)
LSB-MT-BH1014a	Haberfield	329386.68	6249963.88	17.48	41.78– 47.78	HSS	SP	GWL/GWQ (EC)
LSB-MT-BH1014-VWP1	Mainline Tunnel	329387.53	6249962.30	17.49	48.5	HSS	VWP	Pore pressure/GWL
MT_BH11	Mainline Tunnel	330670.67	6249095.13	28.67	48 – 51	HSS	SP	GWL
LSB-MT-BH1021-VWP2	Mainline Tunnel	330526.59	6249094.96	27.08	49.5	HSS	VWP	Pore pressure/GWL

Bore ID	Location	Easting	Northing	Surface Elevation (mAHD)	Screened interval (mBGL)	Lithology screened	Type	Parameters
LSB-MT-BH1012	Mainline Tunnel	330144.20	6249445.60	21.96	40.7 – 46.7	HSS	SP	GWL
LSB-MT-BH1022-VWP3	Mainline Tunnel	331171.89	6248149.11	27.28	54	HSS	VWP	Pore pressure/GWL
LSB-MT-BH1009a	Mainline Tunnel	331407.74	6247978.94	40.17	18 – 24	Ashfield Shale	SP	GWL
SP_BH02	St Peters	331844.84	6246375.94	19.49	4 – 10	Residual Clay (Shale)	SP	GWL
SP_BH04	St Peters	331657.95	6246185.60	12.31	32 – 35	Ashfield Shale	SP	GWL
LSB-SP-BH11	St Peters	331829.58	6246208.19	13.63	24.06 – 30.06	Ashfield Shale	SP	GWL/GWQ (EC)
LSB-SP-BH03	St Peters	331854.25	6246012.89	12.52	14.95 – 20.32	Ashfield Shale	SP	GWL/GWQ (EC)
LSB-SPI-OM-BH01	St Peters	331716.12	6246749.00	17.00	69.96 – 73.96	HSS	SP	GWL
LSB-SPI-OM-BH01a	St Peters	331716.12	6246749.00	17.00	60 – 64	HSS	SP	GWL
LSB-SPI-OM-BH02	St Peters	331816.81	6246692.38	17.50	55.5 – 59.5	HSS	SP	GWL
LSB-SPI-OM-BH04	St Peters	331626.41	6246504.05	10.50	55.3 – 59.3	HSS	SP	GWL
LSB-SPI-OM-BH05	St Peters	331778.83	6246514.89	15.00	57.4 – 61.4	HSS	SP	GWL
LSB-SPI-OM-BH06	St Peters	331882.17	6246512.72	17.50	56.5 – 60.5	HSS	SP	GWL
LSB-SPI-OM-BH06a	St Peters	331882.17	6246512.72	17.50	32.2 – 36.2	Ashfield Shale	SP	GWL
LSB-SPI-OM-BH07	St Peters	331703.61	6246354.01	18.50	54.5 – 58.5	HSS	SP	GWL
LSB-SPI-OM-BH10	St Peters	331927.91	6246730.24	18.50	59.2 – 63.2	HSS	SP	GWL
LSB-SPI-OM-BH10a	St Peters	331927.91	6246730.24	18.50	41 – 45	Ashfield Shale	SP	GWL

HSS = Hawkesbury Sandstone; GWL = Groundwater level; GWQ (EC) = Groundwater quality (electrical conductivity); SP = Standpipe piezometer; VWP = Vibrating Wire Piezometer

WestConnex M4-M5 Link Mainline Tunnels

Figure 4-1: Location of operational groundwater monitoring bores



Esri, Geoscience Australia, NASA, NGA, USGS

Legend:

- Groundwater monitoring bore
- Tunnel alignment
- Ancillary Facility Boundary

0 0.5 1 km

This map is shown for reference purposes only. Acciona provides this information "as is" with the understanding that it is not guaranteed to be accurate, correct or complete and conclusions drawn from such information are the responsibility of the user. While every effort is made to ensure the information displayed is as accurate and current as possible, Acciona will not be held responsible for any loss, damage or inconvenience caused as a result of reliance on such information or data.

4.1.2 Groundwater level

Dataloggers which measure groundwater level (as pressure) will be installed in each monitoring bore (refer to Table 4-1) to provide continuous data collection. Dataloggers will be programmed to record on six-hourly intervals. The VWPs will also be equipped with dataloggers set to record pore pressures on six-hourly intervals.

To supplement the above continuous monitoring, manual measurements of water levels at each bore will be collected quarterly, pending access. Measurements will be recorded in metres below top of casing (mBTOC) and converted to metres Australian Height Datum (mAHD). Details on the methods for measuring static water levels in bores are summarised in Section 5.2.

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.

4.1.2.1 Performance Criteria

Groundwater levels will be compared to the results of the groundwater model (Golders Associates 2020) to determine if drawdown exceeds the predictions. The Project groundwater model was developed in accordance with CoA E192 and was updated with 24 months of available construction monitoring data in accordance with CoA E194.

If drawdown is identified outside of model predictions contained in Annexure B and attributable to the Asset, a management response will be triggered as presented in Figure 4-3.

4.1.3 Groundwater quality

Dedicated groundwater level dataloggers which also measure electrical conductivity (EC) will be installed at key monitoring bores between the tunnel alignment and saline water bodies (refer to Table 4-1). These dataloggers will be programmed to record on hourly intervals. Figure 4-2 presents the predicted saltwater particle pathways for mainline carriageway tunnels at 100 years after excavation. Dataloggers will be downloaded quarterly. EC results will be assessed to detect changes in water quality that may indicate the intrusion of saline water towards the tunnel in accordance with CoA D11 (d).

4.1.3.1 Performance criteria

Baseline monitoring showed that some groundwater quality parameters exceed the default ANZECC (2000) water quality trigger values for slightly to moderately disturbed ecosystems. This is not unexpected given the highly disturbed and urbanised Asset area.

Site-specific trigger values (SSTV) (Table 4-2) for EC have been developed for each water quality monitoring bore using the baseline data used to inform the EIS (AECOM 2017).

The SSTV's were derived by calculating the 80th percentile values of the baseline or construction EC data. A percentile is the value below which a given percentage of observations fall. The 80th percentile is therefore the value below which 80% of observations are found. Using these percentiles removes anomalous data that is outside of the normal range (defined here as 0 – 80 % of values).

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

- The EC data continuously exceeds the SSTV over the period of three months and depicts a rising trend
- The EC data exceeds the SSTV at any time by more than 100%

In the event that 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 which do forecast potential saline migration from Iron Cove to surrounding groundwater.

If the exceedance is determined to be attributable to the Asset and outside of approved model predictions for saline intrusion (Golder Associates 2020) a management response will be triggered as presented in Figure 4-4.

Table 4-2: Water quality EC (electrical conductivity) trigger values

Monitoring bore	Lithology	Baseline / Construction data			SSTV[2] (µS/cm)
		Sample count	EC min (µS/cm)	EC max (µS/cm)	
LSB-HC-PT-OW5a	Alluvium	6,507	16,600	20,838	19,700
LSB-GW-HB-BH08d	HSS	65	558	16,300	4,700
LSB-GW-HB-BH12					
HB_BH15					
LSB-MT-BH1018					
LSB-MT-BH1015					
LSB-MT-BH1014a					
LSB-SP-BH11	Ashfield Shale	30	242	11,986	4,000
LSB-SP-BH03					

[2]SSTV = site specific trigger value (80th percentile of baseline data, rounded to nearest 100)

Figure 4-2 Predicted Saltwater Particle Pathways for Mainline Carriageway Tunnels at 100 Years after Excavation

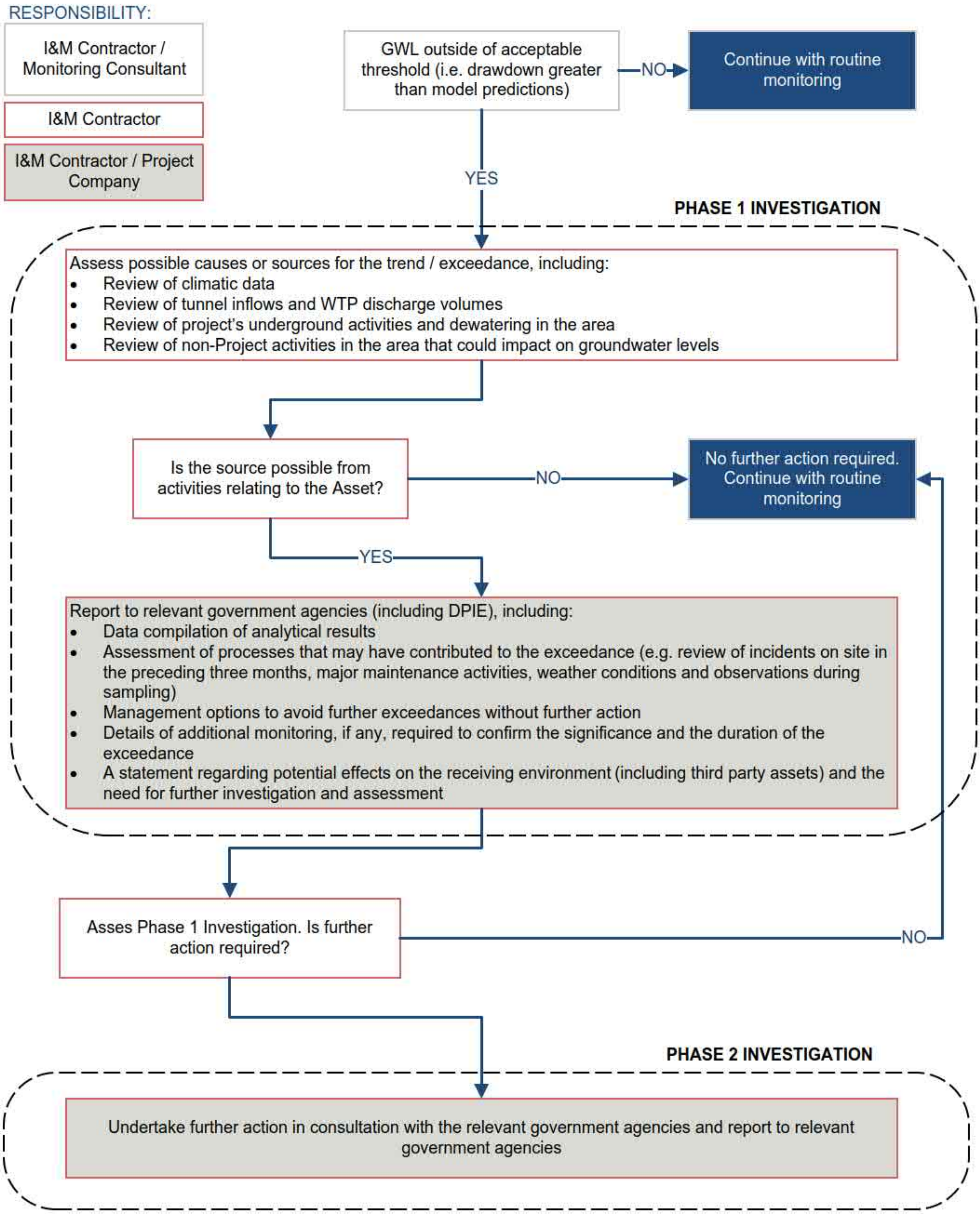


Figure 4-3: Management Response process flow for exceedance of groundwater level threshold

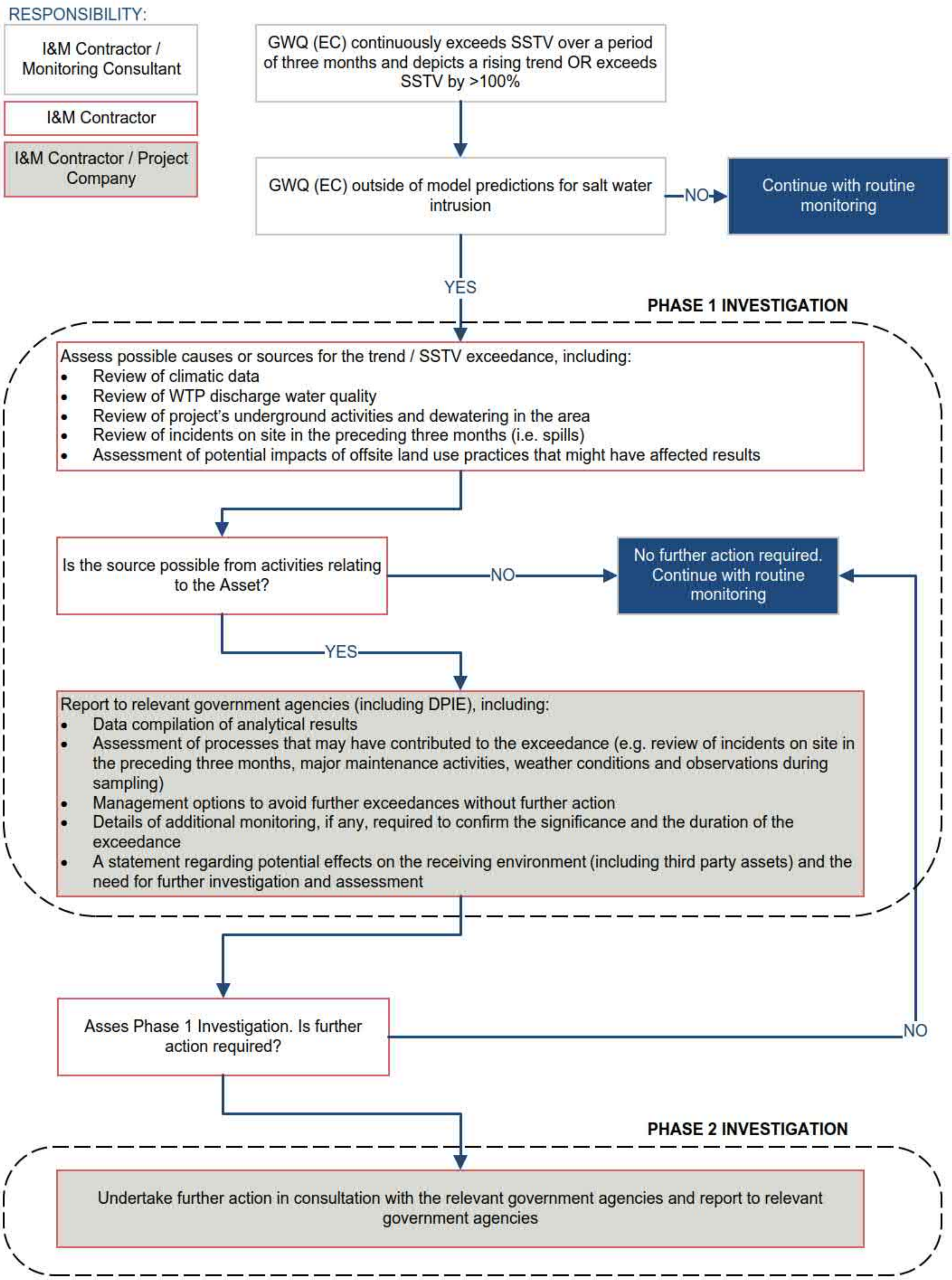


Figure 4-4: Management Response process flow for exceedance of groundwater quality SSTV

4.2 WTP discharge monitoring

Metering will be installed at various locations throughout the WTP to enable the daily measurement of the amount of incoming water and outgoing discharges from the WTP at St Peters Interchange.

The WTP has been designed in accordance with CoA E187 and REMM OSW16 to ensure water is of suitable quality for discharge to the receiving environment in compliance with the applicable discharge criteria. Further information on the WTP treatment process is detailed in Section 5.4 of the OGMP.

Water within the WTP will be continuously monitored for physical parameters including pH, oxidation reduction potential (ORP), turbidity, EC and chlorine to inform the treatment process. Once treated, water will also be continuously monitored for pH, turbidity and EC before being discharged.

Treated water from the WTP will also be monitored at the discharge point on a monthly basis for compliance against the following performance criteria or as permitted under the Asset EPL:

- ANZECC (2000) 95 per cent species protection level
- ANZECC (2000) 99 per cent protection level for contaminants that bioaccumulate
- ANZECC (2000) recreational water quality criteria for iron

Further details on WTP discharge quality sampling are provided in Section 5.4.

4.3 Tunnel inflows

During operation, groundwater will flow into the tunnel and will be captured by the drainage system and pumped to the WTP for treatment prior to discharge as detailed in Section 5 of the OGMP. The tunnel was also designed and constructed using water-resisting treatments and ground improvement to ensure compliance with the performance criteria of 1 litre per second across any given kilometre (1 L/s/km) in accordance with CoA E190. As a first pass, tunnel inflows will be estimated by monitoring incoming water to the WTP. Using this data, a simple water balance approach will be applied to estimate groundwater inflows to the tunnel during operation:

Groundwater inflow = incoming WTP water – Asset water inputs

As detailed in Section 4.2, WTP discharge volumes will be monitored using a water meter on the stormwater discharge line.

Asset water inputs that will need to be considered and potentially estimated during operation include:

- Surface water ingress from the portals at St Peters Interchange and Wattle St
- Surface water ingress from the Ventilation Building Cut and Cover at St Peters Interchange
- Occurrence and duration of any deluge events and/or fire hydrant use in the tunnel including testing events
- Operation and maintenance activities including washdown
- Any large spills or incidents that occurred in the tunnel including rupture of the fire main

Where required, in-tunnel measurements of inflows to be undertaken during planned 3-monthly shutdown periods to further validate estimates made using the water balance approach. During these shutdowns, water inflows could be measured at tunnel drainage pits using a portable flow meter to enable a flow rate (L/s) to be calculated for any section of tunnel. Pending the outcomes of this inflow monitoring, a management response will be actioned as outlined in Figure 4-5.

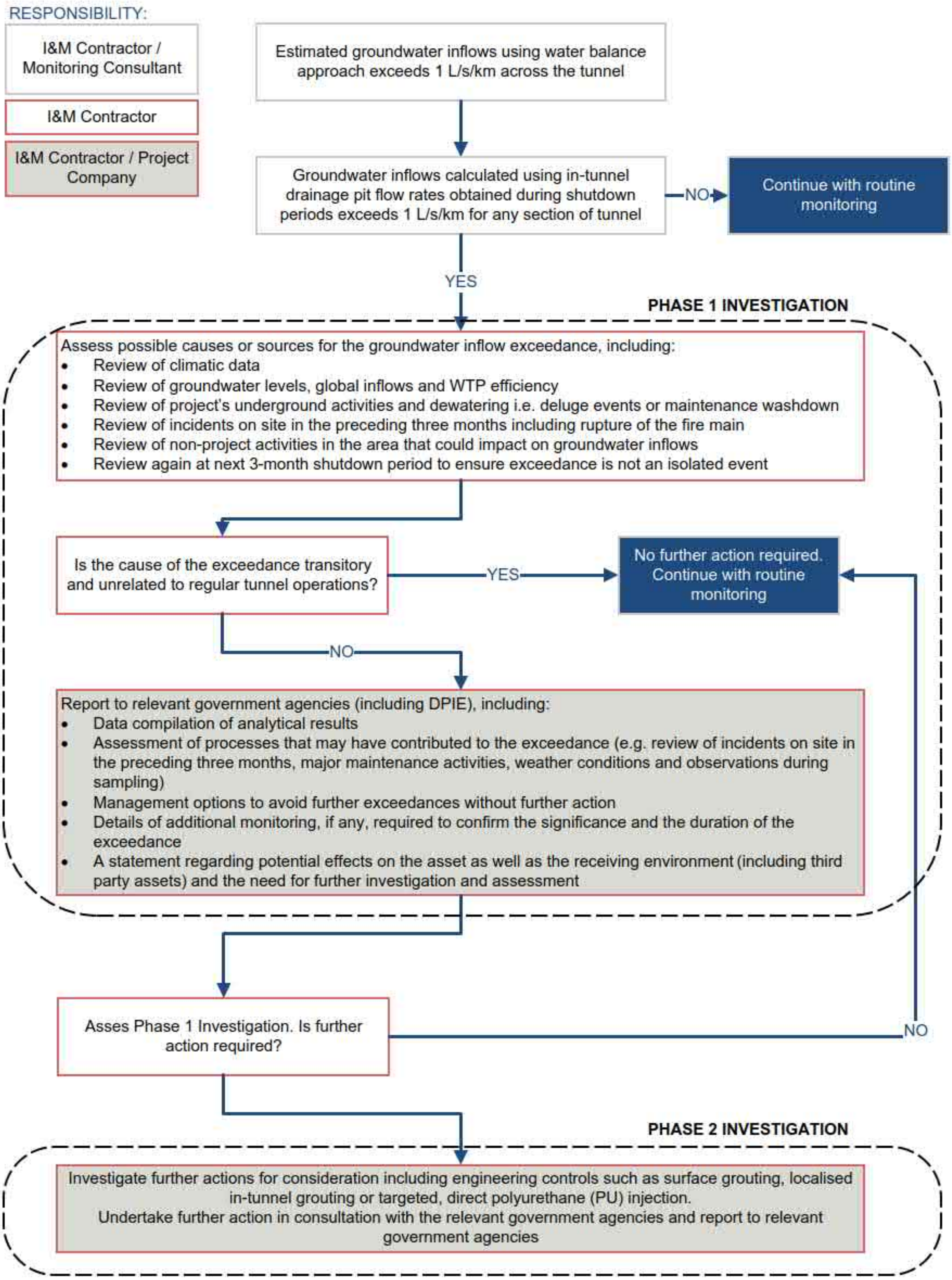


Figure 4-5: Management Response process flow for exceedance of tunnel inflows

5 Monitoring Methodology

5.1 Overview

The methodology for monitoring groundwater for the project includes:

- Assessment of groundwater level (manual measurement and datalogger download)
- Assessment of groundwater quality as EC (datalogger download)
- Assessment of WTP discharge water quality (grab samples and analysis)
- Assessment of groundwater inflows
- Implementation of quality control plan including appropriate chain-of-custody for laboratory analysis and provision of appropriate documentation.

Groundwater monitoring is to be undertaken by suitably qualified personnel at all times.

5.2 Manual groundwater level measurements

Groundwater monitoring will be overseen by personnel with appropriate qualifications and experience. Trained field personnel will complete monitoring rounds using appropriate personal protective equipment (PPE) and monitoring equipment.

The static groundwater level will be measured and recorded at each standpipe groundwater monitoring bore using an electronic groundwater level dip meter (dipper) to verify the continuous data recorded by dataloggers. Levels will be measured prior to dataloggers being downloaded. The level (to the nearest millimetre) will be referenced to a known (and consistent) surveyed point at the top of the bore casing (mTOC). This measurement will be corrected to mAHD using survey data. Recorded groundwater level will be tabulated in mBTOC and mAHD.

The base of the bore will be measured and recorded periodically by lowering the dipper to the base of the bore until it touches the bottom.

5.3 Continuous groundwater level and quality (EC) measurements

Groundwater level (as pressure) and EC will be measured continuously by calibrated dataloggers at key monitoring locations and VWPs (pore pressure only). Continuous data (recorded every 6 hours) will be periodically validated by manual measurements.

Data loggers will be downloaded in accordance with the manufacturer’s guidelines. It will be ensured that the datalogger is located in the groundwater column at a depth below expected natural fluctuations (or near the base of the monitoring bore and within the range of the logging device) and that the hanger cable is not tangled or damaged.

Groundwater level/pressure measurement will be converted to standing mAHD using calibration coefficients, installation data, and survey data. Spreadsheets will be maintained detailing the conversion and converted groundwater level measurement.

Dataloggers will be downloaded quarterly and will be checked and maintained as necessary before being re-calibrated and then returned to the monitoring bore at a known depth below the top of casing.

5.4 WTP discharge samples

5.4.1 Sample collection

Grab samples will be collected manually from the WTP and sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis.

5.4.2 Field measurements

Field physico-chemical parameters including pH, and turbidity will be measured at the Operational WTP at St Peters Interchange using fully calibrated water quality probes.

The water quality meter probes will be calibrated against known standards, as supplied by the manufacturer, at the start and completion of each day of water quality sampling. Calibration records will be maintained in accordance with the appropriate standard.

5.4.3 Decontamination

Equipment will need to be cleaned periodically to prevent a build-up of dirt and cross contamination.

The following method will be followed:

- Rinse the equipment in tap water
- Clean with De-Con 90 (a phosphate free detergent), or equivalent
- Rinse again with tap water
- Rinse three times with de-ionised water, and finally
- Allow to dry.

De-ionised and tap water will be available for washing equipment in the field, if required.

5.4.4 Quality assurance and documentation

Quality assurance and control protocols during sampling and recording of physico-chemical (field) parameters will be undertaken in accordance with ANZECC/ARMCANZ (2000b) to ensure the integrity of the dataset.

As part of sampling, quality assurance and control samples during sampling will be undertaken to ensure the integrity of the dataset, including:

- Samples were collected in clearly labelled bottles with appropriate preservation solutions;
- Samples were delivered to the laboratories within the specified holding times;
- Unstable parameters were analysed in the field (physico-chemical parameters); and
- Duplicate and triplicate samples (Quality Assurance (QA) samples) were collected at a rate of one in ten samples.

All containers are to be clearly labelled with the location, date/time, method, name and duplicate details, with the same documented on dedicated field sheets. Samples are to be placed immediately in chilled containers and transported to a NATA-accredited laboratory under documented chain-of-custody protocols.

Field results will be checked for accuracy before leaving the site and errors or discrepancies will be cross-checked, and further investigation initiated if required.

5.5 Recording and documentation of results

All monitoring and sampling will be documented and transferred to a central electronic database under the responsibility of the I&M Contractor.

Results for each monitoring location will be recorded on appropriate field sheets (hard copy or digital) using unique sampling identification nomenclature and will record the following information:

- Site ID
- Time and date of sampling
- Prevailing weather conditions
- Condition of bore headworks (i.e. absent end-caps, presence of surface water inside the gattic cover) (where applicable)
- Name of sampler
- Other relevant information and commentary

6 Reporting

Reporting and data provision requirements relevant to this OGWMP are outlined in Section 6.3 of the OGMP.

7 Review and improvement

Continual improvement is achieved through constant measurement and evaluation, audit and review of the effectiveness of the plan, and adjustment and improvement of the OEMP, project environmental outcomes and I&M Contractor's Environmental Management System (EMS).

This program will be updated as required:

- To take into account changes to the environment or generally accepted environmental management practices, new risks to the environment, any hazardous substances, contamination or changes in law;
- Where requested or required by DPE or any other Authority; or
- In response to internal or external audits or quarterly management reviews.

During operation the updated program would be reviewed and approved in accordance with the process in Section 10.1 of the OEMP.

Annexure A Baseline groundwater monitoring results

Monitoring Well	Lithology Screened	screen interval (m)	RL toc mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD
				Jun-16		Jul-16		Aug-16		Sep-16		Oct-16		Nov-16		Dec-16	
HB_BH02	Hawkesbury Sandstone	14-17	2.80	2.19	0.61			2.28	0.52								
HB_BH03	Hawkesbury Sandstone	14-17	6.15					2.01	4.14	2.06	4.09	2.25	3.90	2.504	3.65		
HB_BH08d	Hawkesbury Sandstone	22-25	1.49	flowing	1.49+	flow	1.49+	flowing	1.49+					flowing	1.49+		
HB_BH08s	Alluvium	10-13	1.43	0.31	1.12	0.37	1.06	0.39	1.04	0.45	0.98	0.52	0.92	0.626	0.80	0.60	0.83
HB_BH12	Hawkesbury Sandstone	27-30	2.13			0.02	2.11	0.02	2.11			0.05	2.08			0.05	2.08
HB_BH14	Hawkesbury Sandstone	37-40	4.20			1.69	2.51	1.66	2.54							1.73	2.47
HB_BH15	Hawkesbury Sandstone	19-22	17.80	9.6	8.20	9.66	8.14	9.76	8.04	9.327	8.47	9.60	8.20	9.695	8.11	9.68	8.12
SP_BH01	Ashfield Shale	36 - 39	17.71							8.27	9.44			9.028	8.68	9.05	8.66
SP_BH02	Residual Clay (Shale)	4-10	19.42	2.39	17.03	2.75	16.67	2.50	16.92	2.552	16.87	9.00	10.43	3.082	16.34		
SP_BH04	Ashfield Shale	32 - 35	12.23					8.55	3.68	7.86	4.37	8.10	4.13	8.023	4.21	8.03	4.20
SP_BH06	Ashfield Shale	20-23	13.28	2.4	10.88									6.055	7.23	6.59	6.69
SP_BH09	Ashfield Shale	23-26	12.84	3.82	9.02	16.37	-3.53										
MT_BH02	Hawkesbury Sandstone	42-45	34.10														
MT_BH07	Hawkesbury Sandstone	43-46	24.41														
MT_BH11	Hawkesbury Sandstone	48-51	28.67														
MT_BH14	Hawkesbury Sandstone	27-30	27.31														
MT_BH20	Hawkesbury Sandstone	41-44	12.27														
MT_BH21	Hawkesbury Sandstone	47-50	25.05														

Note: Blank cells indicate data not available

Monitoring Well	Lithology Screened	screen interval (m)	RL toc mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD	SWL mbtoc	SWL mAHD
				Jan-17		Feb-17		Mar-17		Apr-17		May-17	
HB_BH02	Hawkesbury Sandstone	14-17	2.80										
HB_BH03	Hawkesbury Sandstone	14-17	6.15			2.73	3.42	0.578	5.57	2.20	3.95	2.475	3.68
HB_BH08d	Hawkesbury Sandstone	22-25	1.49							flowing	1.49+		
HB_BH08s	Alluvium	10-13	1.43	0.64	0.79	0.60	0.83	0.503	0.93	0.28	1.15	0.505	0.93
HB_BH12	Hawkesbury Sandstone	27-30	2.13			0.08	2.05	0.02	2.11	0.02	2.11	0.2	1.93
HB_BH14	Hawkesbury Sandstone	37-40	4.20			1.73	2.47	1.538	2.66			1.518	2.68
HB_BH15	Hawkesbury Sandstone	19-22	17.80	9.66	8.14	9.62	8.18	9.674	8.13	9.64	8.16	9.677	8.12
SP_BH01	Ashfield Shale	36 - 39	17.71	9.06	8.65	9.066	8.64	9.069	8.64	9.10	8.61	9.091	8.62
SP_BH02	Residual Clay (Shale)	4-10	19.42			3.454	15.97					3.239	16.18
SP_BH04	Ashfield Shale	32 - 35	12.23	7.95	4.28	7.975	4.26	7.961	4.27	7.51	4.72	8.786	3.44
SP_BH06	Ashfield Shale	20-23	13.28										
SP_BH09	Ashfield Shale	23-26	12.84										
MT_BH02	Hawkesbury Sandstone	42-45	34.10			25.79	8.31	25.431	8.669	25.50	8.60	25.258	8.84
MT_BH07	Hawkesbury Sandstone	43-46	24.41			19.01	5.40	18.837	5.573	18.78	5.63	17.918	6.49
MT_BH11	Hawkesbury Sandstone	48-51	28.67					19.706	8.96				
MT_BH14	Hawkesbury Sandstone	27-30	27.31	16.71	10.60	3.591	23.72	16.726	10.584	16.61	10.70		
MT_BH20	Hawkesbury Sandstone	41-44	12.27					1.956	10.31				
MT_BH21	Hawkesbury Sandstone	47-50	25.05			10.51	14.54	10.26	14.79				

Note: Blank cells indicate data not available

	Date	Temperature (°C)	Dissolved Oxygen (ppm)	Conductivity (µS/cm)	pH	Redox Potential (mV)
HB_BH08S	8/06/2016	20.2	0.2	9068	6.76	-105.4
HB_BH08S	27/07/2016	17.5	1.74	1561	8.06	-105.9
HB_BH08S	30/08/2016	14	1.53	2667	7.12	-78.3
HB_BH08S	27/09/2016	19.6	0.12	3609	6.97	-125
HB_BH08S	26/10/2016	21.4	1.7	5699	6.21	-105.3
HB_BH08S	30/11/2016	21.1	1.47	2637	7.57	-57.9
HB_BH08S	14/12/2016	21.7	3.61	3680	7.31	-89
HB_BH08S	17/01/2017	22.6	2.96	5380	7.02	-71
HB_BH08S	15/02/2017	23	1.66	3467	5.96	-100.4
HB_BH08S	15/03/2017	22.03	3.23	5658	7.37	53.4
HB_BH08S	28/04/2017	19.48	4.05	5065.3	7.51	131
HB_BH08S	25/05/2017	19.9	3.8	1857	6.94	181
SP_BH01	26/10/2016	23.5	1.91	2088	7.23	-103.3
SP_BH01	30/11/2016	22.2	0.8	901	9.79	-216.1
SP_BH01	13/12/2016	22.4	7.26	1824	7.18	-185
SP_BH01	17/01/2017	22.9	2.07	1544	7.19	-166
SP_BH01	15/02/2017	21.6	2.61	2801	6.86	-255.8
SP_BH01	15/03/2017	22.9	0.31	2165.4	7.36	-203
SP_BH01	27/04/2017	19.8	4.95	2681.6	8.43	-169.2
SP_BH01	26/05/2017	18.7	2.28	1062	8.98	-6.5
SP_BH02	27/07/2016	20	0.88	2988	5.95	-29.7
SP_BH02	31/08/2016	21.4	2.51	2349	5.85	19.9
SP_BH02	27/09/2016	19.1	1.52	3548	5.85	-60.1
SP_BH02	26/10/2016	24.4	1.49	2385	6.2	-86.9
SP_BH02	30/11/2016	23	0.2	1015	10.88	-109.3
SP_BH02	15/02/2017	25.1	0	11986	5.51	-103.7
SP_BH02	15/03/2017	23.92	1.89	2429.3	6.16	-1.3
SP_BH02	26/05/2017	20.44	2.09	2913.8	6.43	36.3
SP_BH04	10/08/2016	21.8	0.56	3665	6.99	-86
SP_BH04	29/09/2016	17.8	8.7	5150	7.11	-182.6
SP_BH04	26/10/2016	23.2	0.54	3301	7.46	-121.3
SP_BH04	30/11/2016	21.3	1.29	3141	8.27	-213.6
SP_BH04	13/12/2016	24.1	2.11	3050	7.11	42
SP_BH04	17/01/2017	21.9	2.7	3270	7.14	-88
SP_BH04	15/02/2017	22.1	0.08	5934	6.68	-196
SP_BH04	15/03/2017	22.38	1.48	5114.7	7.05	-28
SP_BH04	27/04/2017	19.93	4.11	5448.3	8.13	-123.7
SP_BH04	26/04/2017	19.46	0.28	3551.4	8.34	-9.6
SP_BH06	8/06/2016	20.9	0.75	9881	12.13	-1619
SP_BH06	30/11/2016	20.6	0.13	1030	12.03	-200.5
SP_BH09	8/06/2016	25.6	0	242	8.19	-288
SP_BH09	27/07/2016	17	3.51	1748	7.69	-62.3
HB_BH02	8/06/2016	20.1	0.5	5574	6.34	-43.4
HB_BH02	27/07/2016	18	1.9	2604	7.08	-164.6
HB_BH02	30/08/2016	19.7	2.43	1793	7.3	-95.1
HB_BH02	15/02/2017	22.9	0.38	1107	6.04	-180.7
HB_BH03	10/08/2016	21.1	1.17	1176	5.94	35.8

	Date	Temperature (°C)	Dissolved Oxygen (ppm)	Conductivity (µS/cm)	pH	Redox Potential (mV)
HB_BH03	29/09/2016	19.4	1.5	558	6.53	-33.2
HB_BH03	26/10/2016	21.1	1.64	792	6.7	-101.4
HB_BH03	30/11/2016	22	1.12	934	8	-72.3
HB_BH03	15/03/2017	23.03	3.02	872.4	7.05	-102.9
HB_BH03	28/04/2017	19.2	5.57	955.4	8.52	-125.5
HB_BH03	25/05/2017	17.38	2.68	1199	6.56	23.1
HB_BH08D	8/06/2016	19.9	1.16	2775	8.75	-228.4
HB_BH08D	30/08/2016	19.3	1.49	2430	7.28	-206.1
HB_BH08D	27/09/2016	19.6	0.16	3154	6.47	-161.8
HB_BH08D	26/10/2016	20.9	2.55	3029	6.53	-106.1
HB_BH08D	30/11/2016	21.4	1.7	2951	7.28	-97.6
HB_BH08D	14/12/2016	22.1	1.92	2660	7.18	-74
HB_BH08D	17/01/2017	26.1	2.85	2030	7.07	-68
HB_BH08D	15/02/2017	22.1	1.28	2964	5.91	-161.3
HB_BH08D	15/03/2017	22.22	3.19	2581.7	7.93	-32
HB_BH08D	24/04/2017	19.93	2.41	2800.2	7.57	-70.9
HB_BH08D	25/05/2017	19.59	1.48	2492.3	6.81	-30.2
HB_BH12	14/07/2016	17.6	1.73	1037	11.19	178.6
HB_BH12	30/08/2016	18.8	1.36	7670	12.25	-235.7
HB_BH12	28/09/2016	18.6	0.22	11946	12.33	-216.5
HB_BH12	26/10/2016	20.6	1.08	5223	11.68	-116.8
HB_BH12	14/12/2016	23.5	1.98	6210	12.03	-15
HB_BH12	15/02/2017	22.3	1.94	4520	10.7	-205.4
HB_BH12	15/03/2017	21.77	0.43	6111.5	12.52	-137.9
HB_BH12	28/04/2017	20.39	2.43	7878.9	11.83	-163
HB_BH12	25/05/2017	18.48	1.86	5422	12.24	16.5
HB_BH14	14/07/2016	19.8	1.31	2169	6.91	141.6
HB_BH14	27/07/2016	19.5	3.75	1196	8.82	-155.3
HB_BH14	30/08/2016	18.9	1.83	1264	7.26	-124.7
HB_BH14	14/12/2016	24.6	2.87	2106	8.72	-138
HB_BH14	15/02/2017	21.9	0.39	2166	7.39	-162.5
HB_BH14	15/03/2017	22.09	1.42	1211.2	8.39	-95.2
HB_BH14	26/05/2017	20.51	2.59	568.8	8.26	43.1
HB_BH15	8/06/2016	19.8	1.68	675	8.25	-14.7
HB_BH15	27/07/2016	19.9	2.37	1010	6.79	-103.7
HB_BH15	30/08/2016	18.5	20.9	958	6.29	-73.4
HB_BH15	28/09/2016	20.2	0.65	1556	7.02	-93
HB_BH15	26/10/2016	22.6	1.61	1517	5.77	-76.7
HB_BH15	30/11/2016	21.7	1.92	967	7.21	-131.8
HB_BH15	14/12/2016	22.7	2.96	16300	7.45	-130
HB_BH15	17/01/2017	24.3	2.97	1385	6.31	-45
HB_BH15	15/02/2017	21.3	2.03	1340	7.08	-136
HB_BH15	15/03/2017	22.11	3.55	1108.3	6.79	15.8
HB_BH15	28/04/2017	19.84	4.46	1337.8	11.01	-229.1
HB_BH15	25/05/2017	20.07	1.29	1216	8.64	-82
MT_BH02	15/03/2017	22.02	4.72	8899.9	12.69	-33.5
MT_BH02	28/04/2017	19.57	5.06	8700.5	11.33	-101

	Date	Temperature (°C)	Dissolved Oxygen (ppm)	Conductivity (µS/cm)	pH	Redox Potential (mV)
MT_BH02	26/05/2017	19.37	4.16	8185.3	12.33	58.1
MT_BH07	17/02/2017	20.4	1.13	2880	10.8	-295.1
MT_BH07	14/03/2017	21.95	1.93	2362	12.13	42.3
MT_BH07	27/04/2017	17	6.12	2139.7	11.73	-40.7
MT_BH07	26/05/2017	20.15	3.48	1737.6	11.22	51.3
MT_BH14	17/01/2017	22.8	2.47	2170	8.18	-51
MT_BH14	17/02/2017	20.8	0.13	2296	7.66	-267.2
MT_BH14	15/03/2017	22.22	1.93	2036.5	8.05	-51
MT_BH14	28/04/2017	17.1	5.27	1961	8.24	-133.2
MT_BH19	16/01/2017	24.2	5.94		12.2	-60
MT_BH19	17/02/2017	22.4	3.12	6690	11.85	-276.7
MT_BH19	26/05/2017	19.54	3.44	3768.3	12.04	27.4
MT_BH21	17/02/2017	20.6	1.76	2797	11.18	-246.3
MT_BH21	14/03/2017	22.31	3.69	1984.6	8.22	194.9

Annexure B Groundwater level model predictions

Bore ID	Predicted Drawdown Level[1] (mAHD)
LSB-GW-HB-BH03	27.5
LSB-HB-BH1002	21.7
LSB-GW-HB-BH08d	14.9
LSB-HC-PT-OW5a	11.2
LSB-MT-BH1018	40.6
LSB-GW-HB-BH12	24.2
LSB-MT-BH1015	30.2
LSB-HC-PT-OW4	19.9
HB_BH14	22.6
HB_BH15	16.4
LSB-MT-BH1014a	32.2
LSB-MT-BH1013a	27.4
LSB-MT-BH1014-VWP1	32.1
MT_BH11	31.0
LSB-MT-BH1021-VWP2	26.5
LSB-MT-BH1012	34.7
LSB-MT-BH1022-VWP3	33.0
LSB-MT-BH1009a	24.3
SP_BH02	4.6
SP_BH04	41.0
LSB-SP-BH11	11.9
LSB-SP-BH03	6.4
LSB-SPI-OM-BH01	42.9
LSB-SPI-OM-BH01a	43.2
LSB-SPI-OM-BH02	31.8
LSB-SPI-OM-BH04	52.1
LSB-SPI-OM-BH05	42.4
LSB-SPI-OM-BH06	21.6
LSB-SPI-OM-BH06a	12.7
LSB-SPI-OM-BH07	45.9
LSB-SPI-OM-BH10	22.6
LSB-SPI-OM-BH10a	21.0

[1] Steady-state predictions from Project groundwater model (Golders Associates, 2022)