Appendix B6

Groundwater Management Sub-plan

M4-M5 Link Mainline Tunnels

April 2021

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Contents

Tables

Appendices

Document control

Approval and authorisation

Title	M4-M5 Link Mainline Tunnels Groundwater Management Sub-plan
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Internal Review

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Glossary/ Abbreviations

Abbreviations	Expanded text
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ASBJV	Acciona Samsung Bouygues Joint Venture
Bi-monthly	Every two months
CEMP	Construction Environmental Management Plan
CoA	Conditions of Approval
CFU	Colony Forming Unit
DPIE	NSW Department of Planning, Industry and Environment
DoI Water	NSW Department of Industry Water (*formally DPI Water*)
DPI	NSW Department of Primary Industries
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPL	Environment Protection Licence
ER	Environmental Representative
ESCP	Erosion and Sediment Control Plan
EWMS	Environmental Work Method Statements
GDEs	Groundwater Dependent Ecosystems
GMP	Groundwater Management Sub-Plan
GWMP	Groundwater Monitoring Program
GWL	Groundwater level
GWQ	Groundwater quality
HSS	Hawkesbury Sandstone

Abbreviations	Expanded text
KPI	Key performance Indicator
LoR	Limit of Reporting
mAHD	elevation in metres with respect to the Australian Height Datum
mBGL	metres below ground level
mTOC	metres below top of casing
m/day	metres per day
NRAR	Natural Resources Access Regulator
POEO Act	*Protection of the Environment Operations Act 1997*
µS/cm	micro-Siemens per centimetre
REMM	Revised Environmental Management Measures
Roads and Maritime	Roads and Maritime Services
SEMP	Site Establishment Management Plan
SMC	Sydney Motorway Corporation
SP	Standpipe piezometer
SPIR	Submissions and Preferred Infrastructure Report
SSTV	Site Specific Trigger Value
SSWMP	Soil and Surface Water Management Sub-plan
SWQMP	Surface Water Quality Monitoring Program
VWP	Vibrating Wire Piezometer
WTP	Water Treatment Plant

1 Introduction

1.1 Context

This Groundwater Management Sub-plan (GMP or Plan) forms part of the Construction Environmental Management Plan (CEMP) for the M4-M5 Link Mainline Tunnels (the Project). This document also included the Groundwater Monitoring Program (GWMP).

This GMP 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 report (September 2018) and all applicable legislation.

1.2 Project background

The M4-M5 Link EIS (AECOM 2017) assessed the impacts of construction and operation of the Project on groundwater, within Chapter 19 and Appendix T (Technical working paper: Groundwater).

The EIS identified the potential for minor impacts on groundwater during construction typically associated with drawdown and contamination. However, it concluded any potential impacts could be managed by the standard mitigation and management measures that are described in this GMP. The potential minor impacts on groundwater during construction are discussed in Section 5.

Please refer to Section 1.3 of CEMP for Project Description.

1.3 Scope of the Sub-plan

The scope of this Plan is to describe how Acciona Samsung Bouygues Joint Venture (ASBJV) (formerly Lendlease Samsung Bouygues Joint Venture) propose to manage and protect groundwater during construction of the Project. Operational management measures do not fall within the scope of this Plan and therefore are not included within the processes contained within this Plan.

1.4 Implementation of the Sub-plan

The CEMP Sub-plans must be endorsed by the Environmental Representative (ER) and then submitted to the Secretary for approval no later than one (1) month prior to the commencement of the construction activities to which they apply.

Any of the CEMP Sub-plans may be submitted to the Secretary along with, or subsequent to, the submission of the CEMP.

Construction must not commence until the CEMP and all CEMP Sub-plans have been approved by the Secretary. The CEMP and CEMP Sub-plans, as approved by the Secretary, including any minor amendments approved by the ER, must be implemented for the duration of construction. Where the CSSI is being staged, construction of that stage is not to commence until the relevant CEMP and CEMP sub-plans have been endorsed by the ER and approved by the Secretary.

1.5 Environmental management systems overview

The environmental management system overview is described in Section 1.5 of the CEMP.

2 Purpose and objectives

2.1 Purpose

The purpose of this Plan is to describe how ASBJV proposes to manage and protect groundwater during construction of the Project. This Plan should be read in conjunction with the CEMP.

2.2 Objectives

The key objective of the GMP is to ensure all CoA, REMM, and licence/permit requirements relevant to groundwater 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 report for WestConnex M4-M5 Link Mainline Tunnel (September 2018)
- CoA granted to the Project on 17 April 2018 and as modified on 25 February 2019
- 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 3.1 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 construction of the Project. The Project has also established key performance indicators (KPIs) for these targets.

Table 2-1 KPIs for groundwater management

Target / KPI number	Target	KPI	Records	Source
GMP1	Groundwater management during the construction phase of the Project performed in accordance with this GMP	Compliance with GMP	Water monitoring reports	CoA
GMP2	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	EPL
GMP3	Groundwater changes in level and salinity in line with EIS	Groundwater level and salinity in line within predictions	Groundwater monitoring results	EIS Appendix A (project performance outcome)
GMP4	Minimal impacts on quality during the Project construction	No measurable decline in water quality of receiving	Groundwater monitoring results	EIS Appendix A (project

Target / KPI number	Target	KPI	Records	Source
		waters outside of predictions		performance outcome)
GMP5	Minimal impacts on groundwater level during the Project construction	Groundwater drawdown consistent with model predictions	Groundwater monitoring results	EIS Appendix A (project performance outcome)
GWM1	Groundwater monitoring during the construction phase of the project performed in accordance with this groundwater monitoring program (GWMP) (refer Appendix B)	Compliance with GWMP	Groundwater monitoring results Water monitoring reports	CoA
GWM2	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 Water Monitoring Reports	EPL
GWM3	Change in groundwater level/pressure at monitored points within groundwater model predictions	Groundwater level within groundwater model predictions	Groundwater monitoring results Water monitoring reports	EIS Appendix A (project performance outcome)

3 Environmental requirements

3.1 Relevant legislation and guidelines

3.1.1 Legislation

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

3.1.2 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)
- Road and Maritime: Dewatering Guideline (Roads and Maritime 2011)

3.2 Minister's Conditions of Approval

The CoA relevant to this Plan are listed in Table 3-1 below. A cross reference is also included to indicate where the condition is addressed in this Plan or other project management documents.

Table 3-1 Conditions of Approval relevant to the GMP

CoA No.	Condition Requirements	Document Reference	How addressed
C4(f)	The following CEMP Sub-plans must be prepared in consultation with the relevant authorities identified for each CEMP Sub-plan and be consistent with the CEMP referred to in the EIS. (f) Groundwater – DPI Water	Section 3.4	This Groundwater Management Sub-plan has been prepared in accordance with this condition and describes how ASBJV propose to manage groundwater during construction of the Project. This Plan was provided to DoI Water / Natural Resources Access Regulator (NRAR) (formerly DPI Water) for consultation.
C5	The CEMP Sub-plans must state how:		
	(a) the environmental performance outcomes identified in the EIS and SPIR as modified by these conditions will be achieved;	Section 2.3 Table 2-1 Table 6-4	This plan was prepared in accordance with the environmental performance outcomes identified in the EIS and SPIR and is evidenced primarily in Section 2.3 and Table 2-1.
	(b) the mitigation measures identified in the EIS and SPIR as modified by these conditions will be implemented;	Section 6	The implementation of groundwater management and mitigation measures identified in the EIS and SPIR are listed in Table 6-1.
	(c) the relevant terms of this approval will be complied with; and	Section 3.2 Table 3-1	Details regarding how ASBJV propose to comply with the relevant terms of approval are listed in this Table and in Appendix A.

CoA No.	Condition Requirements	Document Reference	How addressed
	(d) issues requiring management during construction (including cumulative impacts), as identified through ongoing environmental risk analysis, will be managed.	Section 5.2 and Section 6 Environmental Risk Assessment Workshop (Section 3.2.1 of CEMP) Section 7.1 of the GWMP (Appendix B)	Groundwater management issues requiring management during construction of the Project have been identified through the EIS, SPIR and Environmental Risk Assessment Workshop. These issues including cumulative impacts have been detailed in Section 5 of this plan and Appendix A2 of the CEMP. Environmental risk analysis will be ongoing and regularly reviewed in accordance with Section 3.9 to Section 3.13 of the CEMP to ensure effective management of groundwater. Mitigation and management measures for these issues are listed in Table 6-1, Appendix A and Appendix A2 of the CEMP.
C6	The CEMP Sub-plans must be endorsed by the ER and then submitted to the Secretary for approval no later than one (1) month prior to the commencement of the construction activities to which they apply.	Section 1.4	This Groundwater Management Sub-plan (Revision 03) will be endorsed by the ER. The Groundwater Management Sub-plan will be submitted to DPIE for approval no later than one month prior to the commencement of the construction activities.
C7	Any of the CEMP Sub-plans may be submitted to the Secretary along with, or subsequent to, the submission of the CEMP.	Section 1.4	This Sub-plan has been submitted for approval to DPIE prior to the final submission of the CEMP for DPIE approval.

CoA No.	Condition Requirements	Document Reference	How addressed
C8	Construction must not commence until the CEMP and all CEMP Sub-plans have been approved by the Secretary. The CEMP and CEMP Sub-plans, as approved by the Secretary, including any minor amendments approved by the ER, must be implemented for the duration of construction. Where the CSSI is being staged, construction of that stage is not to commence until the relevant CEMP and CEMP sub-plans have been endorsed by the ER and approved by the Secretary.	Section 1.4	Construction will not commence until the CEMP and all CEMP Sub-plans have been approved by DPIE. The CEMP and CEMP Sub-plans will be implemented for the duration of construction.
C9 (b)	The following Construction Monitoring Programs must be prepared in consultation with the relevant authorities identified for each Construction Monitoring Program to compare actual performance of construction of the CSSI against predicted performance. (b) Groundwater Monitoring Program: DPI Water, Sydney Water and relevant council(s)	Section 2.3 of the GWMP (Appendix B)	The Groundwater Monitoring Program has been prepared in accordance with this condition and describes how ASBJV propose to conduct groundwater monitoring during construction of the Project. This Plan was provided to DoI Water / NRAR (formerly DPI Water), Sydney Water, City of Sydney Council and Inner West Council for consultation.
C10	Each Construction Monitoring Program must provide: (a) details of baseline data available; (b) details of baseline data to be obtained and when;	Section 4.1 of the GWMP (Appendix B)	Details of the groundwater baseline date available, as well as data to be obtained and when, during developing the Groundwater Monitoring Program are presented in Section 4.1 of the Groundwater Monitoring Program. This is supported by Table 4-1 and Figure 4-1.

CoA No.	Condition Requirements	Document Reference	How addressed
	(c) details of all monitoring of the project to be undertaken; (d) the parameters of the project to be monitored; (e) the frequency of monitoring to be undertaken; (f) the location of monitoring;	Section 4.2 of the GWMP (Appendix B)	The details of monitoring to be undertaken by the project, the parameters to be monitored, the frequency of monitoring and the identification of monitoring locations and described in Section 4.2 of the Groundwater Monitoring Program.
	(g) the reporting of monitoring and analysis results against relevant criteria; (h) details of the methods that will be used to analyse the monitoring data;	Section 4.2 and Section 6.5 of the GWMP (Appendix B)	Section 4.2 and Section 6.5 of the Groundwater Monitoring Program details the reporting of monitoring and analysis against relevant criteria as well as the methods that will be used to analyse the monitoring data.
	(i) procedures to identify and implement additional mitigation measures where results of monitoring are unsatisfactory; and	Section 4.2 and Section 6.3 of the GWMP (Appendix B)	Procedures to identify and implement additional mitigation measures where results of monitoring are unsatisfactory are presented in Section 4.2 and Section 6.3 of the Groundwater Monitoring Program.
	(j) any consultation to be undertaken in relation to the monitoring programs.	Section 2.3 of GWMP (Appendix B)	Section 2.3 of the Groundwater Monitoring Program details the consultation undertaken during the development of the Program and also the ongoing consultation identified during construction.

CoA No.	Condition Requirements	Document Reference	How addressed
C12	The Groundwater Monitoring Program must include: (a) daily measurement of the amount of water discharged from the water treatment plants; (b) water quality testing of the water discharged from the water treatment plants;	Section 4.2.5 of the GWMP (Appendix B) Section 6.1	Provisions allowing for the daily measuring of water discharged from the WTPs has been presented in Section 4.2.5 of the Groundwater Monitoring Program. The testing of the water to be discharged from the WTPs is presented is Section 6.1 of this Plan
	(c) monitoring of groundwater pore pressures in the Hawkesbury Sandstone aquifers adjacent to the tunnel alignment, in consultation with DPI Water;	Section 4.2.2 of the GWMP (Appendix B)	Section 4.2.2 details the monitoring of groundwater pore pressures in the Hawkesbury Sandstone aquifers adjacent in the tunnel alignment. This is also set out in Table 4-5. This Groundwater Monitoring Program was provided to DoI Water/NRAR (formerly DPI Water) as required by CoA C9(b)
	(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 to be provided in each key location in consultation with DPI Water;	Section 3.1.3 and Section 4.2.3 of the GWMP Table 4-6 of the GWMP (Appendix B)	Monitoring of groundwater electrical conductivity at these locations applicable to the Project are detailed in Section 3.1.3, Section 4.2.3 and Table 4-6 of the Groundwater Monitoring Program and includes a minimum of two groundwater monitoring wells at each key location. The Groundwater Monitoring Program was provided to DoI Water/NRAR (formerly DoI Water) for consultation in accordance with CoA C9(b).

CoA No.	Condition Requirements	Document Reference	How addressed
	(e) measures to record or otherwise estimate and report groundwater inflows into the tunnels during their construction;	Section 4.2.4 and Section 6.5 of the GWMP (Appendix B)	Measures to record or otherwise estimate and report groundwater inflows into the tunnel during their construction have been detailed in Section 4.2.4 and Section 6.5 of the Groundwater Monitoring Program. This will use a water balance approach, which is presented in Section 4.2.4.
	(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; and (g) a method for providing the groundwater monitoring data to DPI Water every three (3) months during construction.	Section 6.5 of the GWMP (Appendix B)	Section 6.5 of the Groundwater Monitoring Program, including Table 6-5 set out the reporting requirements for the Groundwater Monitoring Program. Included in this is the required quarterly reporting to Sydney Water and DoI Water (formerly DPI Water).
C13	The Construction Monitoring Programs must be developed in consultation with the relevant authorities as identified in Condition C9.	Section 2.3 of the GWMP (Appendix B)	The Groundwater Monitoring Program has been prepared in accordance with this condition and describes how ASBJV propose to manage groundwater during construction of the Project. This Plan was provided to DoI Water / NRAR (formerly DPI Water), Sydney Water, Inner West Council and City of Sydney Council for consultation.

CoA No.	Condition Requirements	Document Reference	How addressed
C14	The Construction Monitoring Programs must be endorsed by the ER and then submitted to the Secretary for approval at least one (1) month prior to commencement of construction.	Section 1.3 of the GWMP (Appendix B)	The Groundwater Monitoring Program (Revision 02) will be endorsed by the ER. The Groundwater Monitoring Program will be submitted to DPIE, as part of the Groundwater Management Sub-plan, for approval no later than one month prior to the commencement of the construction activities.
C15	Construction must not commence until the Secretary has approved all of the required Construction Monitoring Programs relevant to that activity and all the necessary baseline data for the required monitoring programs has been collected, to which the CEMP relates.	Section 1.3 of the GWMP (Appendix B)	Construction will not commence until the CEMP and all CEMP Sub-plans, including relevant construction monitoring programs, have been approved by DPIE, as detailed in Section 1.3 of this Program.
C16	The Construction Monitoring Programs, as approved by the Secretary, including any minor amendments approved by the ER, must be implemented for the duration of construction and for any longer period set out in the monitoring program or specified by the Secretary, whichever is the greater.	Section 1.3 of the GWMP (Appendix B)	The Groundwater Monitoring Program will be implemented for the duration of construction as detailed in Section 1.3 of this Program.
C17	The results of the Construction Monitoring Programs must be submitted to the Secretary, and relevant regulatory authorities, for information in the form of a Construction Monitoring Report at the frequency identified in the relevant Construction Monitoring Program.	Section 6.5 of the GWMP (Appendix B)	Section 6.5 of the Groundwater Monitoring Program details the reporting requirements and the frequency required for this reporting.

Please refer to Appendix A for all other CoA relevant to the development of this Plan.

3.3 Revised Environmental Management Measures

Refer to Appendix A for all REMMs relevant to the development of this Plan.

3.4 Consultation

This plan and the groundwater monitoring program (GWMP) were provided to DoI Water (formally DPI Water) in accordance with CoA C4(f) and DoI Water (formally DPI Water), Sydney Water, Inner West Council and City of Sydney Council in accordance with CoA C9(a). Refer to Section 2 of the CEMP for consultation requirements relating to the CEMP and all sub-plans.

Ongoing consultation with relevant councils and other stakeholders, including any unique local receivers, may be undertaken for particular issues pertaining to the Project's impact on groundwater. Community feedback and complaints relating to groundwater will be dealt with in accordance with the Community Communication Strategy and Complaints Management System.

4 Existing Environment

4.1 Overview

The following sections summarise the factors influencing groundwater within the Project area. The Project transects a highly urbanised environment that consists of established industrial, commercial, recreational, and residential areas. The alignment extends from the M4 East at Haberfield, following a route through Leichardt, Annandale, Stanmore, Camperdown, Enmore, and Newtown, emerging at the St Peters interchange.

The key reference document is Chapter 19, Groundwater of the EIS (AECOM 2017).

4.2 Topography and drainage

The topography of the Project footprint is relatively flat and low lying, ranging from sea level (adjacent to Sydney Harbour at Iron Cove and the Alexandra Canal) up to approximately 30 m Australian Height Datum (AHD) at Leichardt.

The majority of the Project alignment is located in a heavily urbanised area and is drained by the stormwater network. The primary surface water features in the area are creeks, infilled creeks, and concrete lined canals that discharge into Sydney Harbour and Botany Bay.

The creeks along the Project alignment include the Alexandra Canal, Hawthorne Canal, Johnstons Creek, and Dobroyd Canal (Iron Cove Creek). Dobroyd Canal is the lower tidal section of Iron Cove Creek, a concrete lined channel that drains Haberfield, discharging into Iron Cove on the Parramatta River. Hawthorne Canal is a concrete lined channel draining Haberfield and Leichhardt that discharges into Iron Cove. Johnstons Creek is a lined channel that drains Annandale and Glebe, discharging into Rozelle Bay. Alexandra Canal drains into the Cooks River to the south.

The majority of the creeks and canals in the Project area are concrete lined, thereby have no hydraulic connection with the local groundwater resource.

4.3 Geological setting

Regionally, the Project footprint is located within the Permo-Triassic Sydney Basin, which is characterised by sub-horizontal sedimentary sequences, mainly sandstone and shale. The Project footprint is underlain by two main geological units, the Ashfield Shale and Hawkesbury Sandstone. These are sometimes separated by the transitional Mittagong Formation. To the east of the Project footprint, the unconsolidated Quaternary-aged Botany Sands overlap the Sydney Basin and the bedrock.

The main stratigraphic units encountered within the Project area, from youngest to oldest, are:

- Anthropogenic fill
- Quaternary alluvium (recent beneath creeks, palaeochannels) (minor occurrence)
- Triassic Ashfield Shale (Wianamatta Group)
- Triassic Mittagong Formation
- Triassic Hawkesbury Sandstone Formation

Further detail on the stratigraphic units, including weathering profiles and implications for hydraulic conductivity, is provided in Appendix T of the EIS (Technical working paper: Groundwater, AECOM 2017).

4.4 Hydrogeological setting

4.4.1 Regional

The Sydney Basin comprises sub-horizontal layered clastic sedimentary successions with localised igneous volcanic rocks and dykes, and geological faults. Dykes such as those identified beneath the Hawthorne Canal palaeochannel typically impede groundwater flows. Geological faults, typically found within the Hawkesbury Sandstone, are typically associated with increased groundwater flow.

Groundwater resources are recharged via the infiltration of surface runoff derived from rainfall. Regional groundwater systems discharge via leakage, throughflow, and to local springs, watercourses, and the ocean. The regional groundwater table typically reflects a subdued version of topography.

Groundwater in the Sydney Basin is described at a large scale in the Water Sharing Plan for the Greater Metropolitan Region (NoW 2011). Within the porous rock aquifer the level of connection between groundwater and surface water is stated as low to moderate. The travel time between shallow groundwater and unregulated rivers is estimated to be years to decades.

Groundwater is present within the following hydrogeological units along the Project alignment, described below:

- Quaternary alluvium
- Botany Sands aquifer
- Ashfield Shale
- Mittagong Formation
- Hawkesbury Sandstone

4.4.2 Alluvium

Minor occurrences of quaternary alluvium are present along the Project alignment beneath man-made fill and as relatively young, unconfined palaeochannels. The alluvial groundwater table is typically shallow, within 1 m of the ground level. Although the alluvium surrounding creeks is generally of high permeability providing potential discharge areas and delayed recharge to surface watercourses, the creeks along the Project alignment are mostly concrete lined, thereby have no hydraulic connection with the local groundwater resource.

The palaeochannels that occur beneath some of the major watercourses or valleys within the Project alignment are saturated, highly transmissive, and extend to depths of up to 25 m. Groundwater within the palaeochannels is typically saline, due to recharge via the saline Ashfield Shale and leakage from tidal tributaries.

4.4.3 Botany Sands aquifer

The Botany Sands are a shallow unconfined aquifer. The groundwater level is variable but is typically within 5 m of the ground surface when not influenced by localised pumping. Regionally, groundwater flow is to the east, discharging into Botany Bay and Alexandra Canal. The aquifer naturally contains low salinity groundwater and is moderately acidic, but in many areas has been contaminated by industrial activities, most notably in the southern portion of the aquifer near the Botany Industrial Park. Groundwater use has been embargoed by DoI Water since 2007 due to contamination (NoW 2011).

While the Botany Sands are not intersected by the Project, groundwater from the Botany Sands may be hydraulically linked with the drained Project tunnels. The residual alluvial clay that separates the sands from the underlying bedrock (the Ashfield Shale) acts like a hydraulic seal, which would reduce Project induced groundwater drawdown in the Botany Sands. Groundwater flow to the Ashfield Shale is also expected to be low due to the shale’s low hydraulic conductivity.

4.4.4 Ashfield Shale

Groundwater flow within the Ashfield Shale is low due to the limited pore space and poor connectivity of the bedding planes resulting in typically low bulk hydraulic conductivity. Regionally, the Ashfield Shale reduces groundwater infiltration to the underlying Mittagong and Hawkesbury Sandstone Formations.

Groundwater quality within the shale is highly variable but is typically brackish or saline, due to its brackish - shallow marine depositional environment. The shale groundwater system is characterised by low yields, limited storage, and poor groundwater quality. Due to elevated salinity, low pH, and the presence of sulphides, the groundwater can be corrosive to tunnel and infrastructure building materials.

4.4.5 Mittagong Formation

The Mittagong Formation is a relatively thin transition unit, where present, between the Ashfield Shale and Hawkesbury Sandstone. Although the Mittagong Formation is siltier than the Hawkesbury Sandstone, the hydraulic properties of the two formations are similar and they are hydraulically connected. Groundwater quality in the formation is generally poor within the Project area, due to leakage from the Ashfield Shale and the high clay content of the Mittagong Formation.

4.4.6 Hawkesbury Sandstone

The Hawkesbury Sandstone is a heterogeneous layered unit characterised as a *dual porosity aquifer* dominated by secondary fracture flow. Interbedded shale lenses can provide local or extensive confining layers, creating separate aquifers with different hydraulic properties. Typically the bulk hydraulic conductivity of the Hawkesbury Sandstone is low although high groundwater yields can be encountered when saturated fractures are intersected. Increased groundwater flow to tunnels is typically associated with the intersection of such major joints or fractures.

Regionally, groundwater flow is eastward, discharging into the Tasman Sea. Recharge is via rainfall infiltration on fractured outcrops and through the soil profile and alluvium. Discharge within the Project area is via creeks and evapotranspiration.

Groundwater quality within the Hawkesbury Sandstone is generally acidic but of low salinity in the Project area. The salinity of the upper part of the aquifer, however, can be elevated due to leakage from the Ashfield Shale. Elevated concentrations of dissolved iron and manganese naturally occur within the Hawkesbury Sandstone, which can cause staining when discharged and oxidised. In tunnels, groundwater ingress becomes oxidised, causing dissolved iron and manganese to precipitate and form sludge in drainage lines.

4.4.7 Groundwater recharge and discharge

The Project is located in a highly urbanised part of Sydney where rainfall recharge to groundwater has been reduced by hardstand and roof captured runoff being directed to stormwater. The majority of groundwater recharge occurs in parks, gardens, bushland, and creeks.

Groundwater discharge is typically to Sydney Harbour and Botany Bay.

4.4.8 Groundwater levels and flow

Baseline monitoring

Baseline groundwater level and groundwater quality monitoring data has been collected from the Project groundwater monitoring network since June 2016. This baseline dataset is augmented by baseline data for the Stage 2 WestConnex 3B project, and baseline and construction data collected since October 2015 for adjacent M4 East and New M5 Projects.

The Project baseline monitoring network was installed between May 2016 and May 2017 and consists of 19 monitoring bores intersecting groundwater within the alluvium, Ashfield Shale, and Hawkesbury Sandstone. 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.

Alluvium

As discussed in Section 4.4.2, minor occurrences of quaternary alluvium are present along the Project alignment beneath man-made fill and as relatively young, unconfined palaeochannels. Baseline groundwater level in the alluvium associated with the Hawthorne Canal, recorded from June 2016, fluctuates between 0.6 mAHD and 1.2 mAHD in response to seasonal rainfall.

Ashfield Shale

Groundwater level within the Ashfield Shale is monitored within the Camperdown and St Peters areas of the Project at five monitoring bores.

The highest groundwater level measured in the Ashfield Shale was measured at Camperdown, at an elevation of 22.1 mAHD, where the topography along the alignment is at a corresponding high point. At the southern part of the proposed alignment, next to the St Peters interchange, groundwater flows towards the western part of the Alexandria landfill due to ongoing leachate pumping. This radial flow pattern and reversed hydraulic gradients prevent leachate contamination from dispersing into the Ashfield Shale.

Hawkesbury Sandstone

Groundwater level within the Hawkesbury Sandstone is monitored at 13 monitoring bores within the Project area. Artesian groundwater has been intersected at two monitoring bores within the Hawkesbury Sandstone in the low-lying areas beneath Hawthorne Parade. At this location the groundwater is under pressure and would flow from the bore if a cap was not in place.

At Haberfield, measured groundwater level within the Hawkesbury Sandstone is variable and ranges from 0.5 mAHD to 8.0 mAHD. The groundwater level tends to reflect the position of the monitoring bore in the landscape, with the hydraulic head increasing with distance from Iron Cove.

4.4.9 Hydraulic conductivity

Hydraulic conductivity testing (packer tests and laboratory core testing) was conducted during the field investigation program to inform the EIS (AECOM 2017) and to provide parameters to support the groundwater modelling. Packer test results are summarised in Table 4-1. The majority (86%) of packer tests were conducted within the Hawkesbury Sandstone, through which the majority of the tunnels are located. The majority of results are of low permeability, suggesting that inflows along the majority of the tunnels will be low. No site specific data was collected during the groundwater investigations (AECOM 2017) for the hydraulic conductivity of the alluvium. Typical hydraulic conductivity values for similar lithologies across the Sydney Basin would be expected to range from 0.001 metres per day (m/day) for clayey alluvium up to 1 m/day for sandy alluvium (AECOM 2017).

4.4.10 Groundwater dependant ecosystems

A review of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* (NoW 2011) and the *National Atlas of Groundwater Dependent Ecosystems* (BoM 2012) indicated there are no high priority groundwater dependent ecosystems (GDEs) within the study area or area of predicted drawdown impact (refer Section 4.7).

The nearest high priority wetlands are the Botany Wetlands and Lachlan Swamps within the Botany Sands, located at Centennial Park, around 5 km east of the easternmost point of the project alignment, and beyond the range of potential groundwater impact (AECOM 2017).

Table 4-1 Monitored hydraulic conductivity for each hydrogeological unit (from the M4-M5 Link EIS)

	Hydraulic conductivity (m/day[1])	
	Ashfield Shale	Hawkesbury Sandstone
Mean	0.02	0.10
Minimum	0.01	0.01
Maximum	0.12	1.17
Number of tests[2]	24	181

[1]metres per day [2]Tests conducted at bores across the entire WestConnex M4-M5 Link project area

Hydraulic conductivity (K) converted from results of the packer tests expressed as Lugeon (L) units (1 L is equivalent to a K of 8.8 x 10^{-3} m/day)

4.5 Groundwater quality

4.5.1 Baseline groundwater quality

The baseline water quality data is discussed in Section 4 of Appendix B and summarised in Table 4-2. Interpretation of the baseline groundwater monitoring data is also included in the EIS (AECOM 2017)

Table 4-2 Summary of baseline groundwater quality within the Project area

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.

Parameter	alluvium	Ashfield Shale	Hawkesbury Sandstone
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.	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. Ammonia values exceeded guideline[1] concentration values.	Nitrite and nitrate concentrations indicate that background nutrient levels are low. Reactive phosphorous levels are also low. Ammonia values exceeded guideline[1] concentration value.	Nitrite and nitrate concentrations indicate that background nutrient levels are low. Reactive phosphorous levels are very low. Ammonia values marginally exceeded guideline[1] concentration 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.

Parameter	alluvium	Ashfield Shale	Hawkesbury Sandstone
Groundwater aggressivity	Groundwater aggressivity was not assessed for alluvium.	Groundwater within the Ashfield Shale is: • Non-aggressive towards concrete piles for average concentrations of chloride, pH, and sulfate • 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: • Mildly aggressive towards concrete piles for average concentrations of chloride, pH, and sulfate • Mildly aggressive towards steel piles for average concentrations of chloride and pH • Severely aggressive towards steel piles for groundwater with low conductivity.

µS/cm = micro-Siemens per centimetre

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

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

4.5.2 Potential sources of groundwater contamination

An assessment of contaminated land risk is provided in the EIS, Appendix R (Technical working paper: Contamination) (AECOM 2017). Areas within the Project footprint that may contain contaminated soil and/or groundwater due to past or present land use practices have been investigated. During routine monthly baseline groundwater monitoring to inform the EIS (refer Section 4.5.1), a suite of contaminants were assessed for laboratory analyses including cations and anions, heavy metals, and nutrients.

The Hawthorne Canal and Leichhardt North area has undergone historic, widespread land reclamation with fill from unknown sources, indicating that subsurface soil contamination could be present in some areas. Other potential soil contamination sources include the storage and use of chemicals, pesticides, fuels and oils, and hazardous building materials at the former Public Works Depot and the former Ordnance Depot within Blackmore Park. Potential acid sulfate soils have been mapped across the majority of this area.

Contamination investigations undertaken for the M4 East and New M5 projects have been reviewed to provide an understanding of potential groundwater contamination in the vicinity of the Wattle Street interchange at Haberfield and the St Peters interchange at St Peters, respectively. The EIS (AECOM 2017) assessed the risk of potential groundwater contamination in the vicinity of the Wattle Street interchange at Haberfield as low. Potential contaminating land uses were identified as being located topographically downgradient of the Project and therefore would be very unlikely to impact groundwater within the Project footprint. The St Peters interchange is to be constructed on the rehabilitated Alexandria Landfill. The New M5 tunnels and access portals through the former landfill are to be undrained (tanked), preventing the ingress of contaminated groundwater into the tunnel drainage system. The deeper tunnels constructed in the Hawkesbury Sandstone or Ashfield Shale are to be drained, but are unlikely to intersect contaminated groundwater.

4.6 Groundwater users

A review of bores registered with DoI Water (AECOM 2017) indicates that of the registered bores within 2 km of the Project alignment (153 bores), the majority are registered as monitoring bores. Only one bore is currently registered for domestic use, a 210 m deep bore (GW110247) at the University of Sydney at Camperdown extracts groundwater from the Hawkesbury Sandstone. The EIS (AECOM 2017) references a standing water level (undated) at 31 metres below ground level (mBGL).

Two other bores were registered for domestic water supply purposes (GW106192 and GW111164, located 1750 m and 935 m from the Project alignment respectively), however these bores are in the Botany Sands and are no longer permitted to be used for domestic purposes due to restrictions imposed by DoI Water (NoW 2011).

Even though groundwater quality is generally good within the Hawkesbury Sandstone, groundwater use across most of the Project area is low, as bore yields are typically low and the area has access to reticulated water.

4.7 Groundwater Dependent Ecosystems

A review of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources (NoW 2011) and the National Atlas of Groundwater Dependent Ecosystems (BoM 2012) indicates there are no high priority GDEs within the Project area. The nearest high priority wetlands are the Botany Wetlands and Lachlan Swamps within the Botany Sands, located at Centennial Park, around 5 km east of the easternmost point of the Project alignment, and beyond the range of potential groundwater impact (AECOM 2017).

5 Environmental aspects and impacts

5.1 Construction activities

Key aspects of the construction phase of the Project that could result in adverse impacts to groundwater include:

- Tunnelling
- Dewatering of groundwater inflows into tunnels
- Operation of Water Treatment Plants (WTP)

Refer also to the Aspects and Impacts Register included in Appendix A2 of the CEMP.

5.2 Impacts

5.2.1 Overview

The potential for impacts on groundwater will be dependent on the nature, extent, and magnitude of construction activities and their interaction with the natural environment. Potential impacts to groundwater attributable to construction, discussed in detail below, 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:
    - Spills and incidents
    - Intercepting contaminated groundwater
    - Groundwater treatment - Surface water impacts as a result of discharges the groundwater collection & discharge system
    - Saline intrusion
- Impacts to utilities
- Cumulative impacts

Some impacts on groundwater attributable to the Project are anticipated and predicted in the groundwater model (AECOM 2017). Relevant aspects and the potential for related impacts have been considered in a risk assessment in Appendix A2 of the CEMP. Section 6 provides a suite of mitigation measures that will be implemented to avoid or minimise those impacts.

5.2.2 Reduced groundwater recharge

The majority of the Project 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).

5.2.3 Groundwater level decline

Groundwater drawdown

Construction 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 and the specific geological conditions present (AECOM 2017).

In accordance with REMM GW9 probing (drilling) ahead of the excavated face will occur at various locations within the tunnel in order to gain an understanding of the groundwater inflow within the geology yet to be excavated. Information obtained through these investigations will inform the design of the subsequent tunnelling advances. In addition, a geotechnical pump test will be carried out at Hawthorne Canal. Groundwater inflow rates are predicted to be high around Hawthorne Canal. The pump test will help to develop an understanding on whether the alluvium aquifer and Hawkesbury sandstone aquifer are connected in this area. This is turn will help to predict potential groundwater inflow rates in the area. In addition, the pump test will aid in the complying with CoA's E101, E190 and E192.

In zones where the inflow rates are anticipated to exceed one litre per second per kilometre for any kilometre length of tunnel, water bearing fractures/rock defects would be grouted as required to reduce ongoing groundwater inflow to no more than one litre per second per kilometre for any kilometre.

Potential groundwater drawdown due to the Project construction (to proposed opening in 2023) has been predicted in the groundwater model (AECOM 2017), in summary:

- The predicted drawdown of the water table is expected to be up to 34 m with the maximum drawdown centred at Haberfield. Predicted drawdowns along the alignment are 26 m at Annandale, 18 m at Newtown, and 22 m St Peters.
- Water table drawdown is predicted to extend up to 500 m either side of the Project alignment, with the widest areas being mid-way along the tunnel around Newtown and at the Wattle Street and St Peters interchanges. The lateral extent of drawdown is narrower where the alignment passes under watercourses due to the transmission of water through the higher hydraulic conductivity of the alluvium preventing the drawdown from propagating far.
- Predicted drawdown centres are discontinuous along the alignment and are a reflection of tunnel depth and timing of excavation, as well as geological boundaries.
- There is minimal predicted drawdown within the minor occurrences of alluvium. Along relevant sections of the Project alignment, the tunnels have been designed so there will be no direct inflow from the alluvium into the tunnels. This would be achieved by designing the tunnels to dive beneath the alluvium, such as at Hawthorne Canal, and potential additional measures where the portals and cut-and-cover sections intersect alluvium, such as at Haberfield.
- Within the Ashfield Shale the predicted drawdown (to a maximum of 25 m at Leichardt) is presented from the top of the shale extending into the underlying Hawkesbury Sandstone. The drawdown has a maximum lateral extent of about 700 m either side of the Project alignment at Newtown.
- In the Hawkesbury Sandstone predicted drawdowns (to a maximum of 34 m at Haberfield) follow the tunnel alignment, with a maximum extent of approximately 800 m drawdown either side of the alignment around Newtown/Erskineville.

Potential impacts on GDEs

There are no priority GDEs identified in the Water Sharing Plan (NoW 2011) within 5 km of the Project alignment. Consequently, no priority GDEs are likely to be impacted by groundwater level decline associated with either the construction or the long-term operation of the Project.

Potential impacts on existing groundwater users

Groundwater modelling (AECOM 2017) has been used to predict drawdown at the location of registered bores within 2 km of the Project alignment. Only one bore (GW110247) is currently registered for domestic use. GW110247 is predicted to have a drawdown of approximately 2.4 m to the hydraulic head in Hawkesbury Sandstone by the end of the long-term simulation in 2100. Given the standing water level is recorded as 31 mBGL and the bore is 210 m deep, the drawdown is likely to have a negligible impact on the bore capacity. The impact on water quality in GW110247 due to saltwater intrusion is also anticipated to be negligible, since the bore is at least 2 km from the nearest saline water body at Rozelle Bay and predicted saline water travel times are in excess of 1,000 years (AECOM 2017). No existing groundwater users are likely to be impacted by groundwater level decline associated with the construction of the Project.

The Project Interface Manager will contact the owner of GW110247 to facilitate ongoing monitoring of to assess drawdown during the construction phase. Should the owner of this bore permit access then ongoing monitoring of drawdown will occur at GW110247 and this bore will be added to the Groundwater Monitoring Program.

Potential impacts on surface water baseflow

Predicted long-term changes to baseflow from the groundwater modelling (AECOM 2017) indicate that the overall contribution to flow to surface watercourses from groundwater is relatively small, since the watercourses are mostly concrete lined channels. It is expected that the majority of stream flow would be derived from rainfall runoff and tidal inflow. There is also no impact predicted on the baseflow of other major creeks (including Cooks River, Wolli Creek, and Bardwell Creek) due to the Project.

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). Settlement within the alluvium would be dependent on the amount of groundwater drawdown and would be expected negligible due to design measures for the tunnels including constructing tanked tunnels through the alluvium to minimise groundwater drawdown. Below Hawthorne Canal and Johnstons Creek, the tunnels have been designed to dive beneath the alluvium to reduce groundwater ingress, which would reduce potential settlement.

During tunnel construction, the bulk hydraulic conductivity of the Hawkesbury Sandstone would be decreased by grouting off the tunnel faces, decreasing groundwater inflow and thereby reducing potential settlement.

Small scale dewatering of the alluvium and Hawkesbury Sandstone may be required during construction. This could result in an increase in effective stress, leading to ground settlement. Movement in clay soils between hydrogeological units would cause both consolidation settlement and creep settlement, which may result in settlement continuing over a long period of time.

5.2.4 Groundwater quality

Spills and incidents

There is potential to contaminate groundwater through incidents associated with the storage of hazardous materials or refuelling operations at the surface, particularly if a leak or incident occurs over the alluvium, a palaeochannel, or fractured sandstone. Stockpiling of construction materials may also introduce contaminants that could potentially leach into and contaminate local groundwater (AECOM 2017).

The risks to groundwater as a result of such incidents would be managed through construction management procedures in accordance with the CEMP. Runoff from high rainfall events during construction would be managed in accordance with the measures outlined in the SSWMP. Following high rainfall events, groundwater quality impacts would be minor, as the majority of runoff would discharge to receiving waters.

Intercepting contaminated groundwater

There are potentially pockets of soil contamination present across the Hawthorne Canal and Leichhardt North areas that could contaminate groundwater within the underlying palaeochannels. The tunnels are to be constructed at depth to extend beneath the palaeochannel associated with the Hawthorne Canal so groundwater from the alluvium will not directly flow into the tunnels (refer Section 5.2.3).

The risk of contaminated groundwater entering the Project tunnels at St Peters from leachate derived from the Alexandria landfill is low since leachate will continue to be pumped, collected, and treated in a newly constructed WTP as part of the New M5 project, drawing groundwater away from the tunnels. Leachate generation is to be reduced due to the cut-off wall constructed by the New M5 contractor along the eastern perimeter of the landfill to reduce groundwater inflow and capping the former landfill to reduce rainfall infiltration.

Groundwater from the Botany Sands aquifer is likely to enter the tunnel through hydraulic connection with the Ashfield Shale and Hawkesbury Sandstone at Alexandria. This groundwater has the potential to be contaminated, however, groundwater modelling (AECOM 2017) indicates flow from the Botany Sands would be a minor component of tunnel inflow. Inflow water will also be treated prior to discharge.

Groundwater treatment and surface water impacts

The existing groundwater quality within the study area is described in Section 4.5.1. In order to prevent adverse impacts on downstream surface water quality, Water Treatment Plants (WTPs) will be installed at three locations along the tunnel alignment. WTPs will be designed so that the quality of the discharge will be in compliance with the ANZECC derived discharge criteria (refer Section 7.4), the Project EPL, and if applicable, ASBJV's trade waste licence.

The GWMP provides further detail on the design and discharge criteria for the WTPs (refer Section 4.2.5 and Section 5.4 in Appendix B).

Saltwater intrusion

Over time, saline intrusion is predicted to result in saline water reaching the tunnels. The proportion of saline water flowing into the tunnels, however, would be low (especially during the relatively short construction phase). A capture zone analysis has been undertaken as part of the groundwater modelling (AECOM 2017) to investigate saltwater intrusion within the tunnel catchment areas. From this analysis it is not possible to quantify volumes or concentrations of saline water entering the tunnels and therefore the following discussion is based on a qualitative analysis.

Alexandra Canal

The minimum travel times for saline water from Alexandra Canal to enter the tunnels are predicted by the groundwater model (AECOM 2017) to be two days, although this initial inflow would have a negligible impact on groundwater quality. Initially (minimum travel time), the saline water would be a small fraction of total groundwater entering the tunnel, although this is expected to increase over time as water is drawn from further afield. Groundwater modelling predicts the travel time for saline water to enter the tunnel during operation to be in the order of 30 years. As the saline water entering the tunnels would remain a minor component of the total inflow changes to groundwater quality are expected to be minimal.

Tidal zones

The groundwater model (AECOM 2017) predicts that saline groundwater from the alluvium associated with the Cooks River would enter the Project tunnels near the St Peters interchange. Groundwater level is predicted to decline below sea level therefore saline waters from tidal zones would flow towards the tunnels and would ultimately enter the tunnels via a hydraulic connection with the alluvium. The saline water would initially be a small fraction of total groundwater entering the tunnels and increase over time.

Average times for saline water to enter the tunnels are predicted to be more than 100 years and maximum times are in the order of thousands of years. As a result, groundwater in the tunnel catchment zones would gradually become saline over thousands of years. Since the operational lifetime for major infrastructure is in the order of 100 years, the slow salinity increase should have minimal impacts on the tunnels and infrastructure in the Project's operational lifetime, and negligible impacts during construction.

Groundwater quality (salinity as Electrical Conductivity (EC)) during construction will be routinely monitored at key locations between saline water bodies and the tunnel as identified by the Project groundwater model (AECOM 2017) including in the Haberfield / Lilyfield area to the south of Iron Cove, and in the St Peters area to the north west of Alexandra Canal.

Details of the construction groundwater quality monitoring program are presented in the GWMP (refer Section 4 in Appendix B).

5.2.5 Utilities

The Project would involve works that would include the protection of existing utilities, construction of new utilities, and relocation of existing utilities. The majority of the utility works for the Project have been undertaken by previous projects and the impacts from minor works associated with the Project are likely to be negligible.

5.2.6 Cumulative impacts

A cumulative impact assessment was undertaken for the EIS (AECOM 2017). The assessment:

- Used the groundwater model to predict the cumulative impacts on groundwater due to the Project in combination with other WestConnex tunnel projects (M4 East and New M5)
- Qualitatively assessed the cumulative impacts of the Project, other WestConnex projects, and other proposed infrastructure projects (Sydney Metro City and Southwest).

WestConnex projects

During construction, cumulative impacts on groundwater would be greatest at either end of the Project alignment where the Project tunnels would overlap with the tunnels for the M4 East at the Wattle Street interchange and with the New M5 tunnels at the St Peters interchange. Once all three of these WestConnex tunnel projects are operational, groundwater drawdown due to the cumulative impact of the three tunnel projects is not predicted to be greater than in any one section of the overall project footprint (AECOM 2017).

The tunnels and associated lining for each project would be designed and constructed to comply with the groundwater inflow criterion of one litre per second per kilometre for any kilometre length of tunnel. Consequently, the groundwater inflows along the tunnels would vary within a known range. A comprehensive GWMP would be required for each project to confirm that the actual inflows do not exceed the criterion and drawdown does not exceed predictions. The GWMP for the Project is provided as Appendix B of this Plan.

Long term cumulative groundwater tunnel inflows due to the WestConnex tunnel projects may cause groundwater salinity to increase due to surface water from tidal reaches being drawn into or towards the tunnels. Initially, as discussed in Section 5.2.4, the saline water would be a small fraction of total tunnel ingress but this is expected to increase over time as water is drawn from further afield, although it is expected to always be a minor component of total inflow volume and negligible during construction.

Other relevant projects

The Sydney Metro City and Southwest rail tunnels are to be constructed as undrained (tanked) tunnels that would cross the Project alignment near St Peters. As the twin Sydney Metro tunnels are to be constructed as tanked tunnels, there will be negligible impacts on groundwater drawdown. The station boxes are to be constructed and operated as drained shafts and will extract groundwater over time. The closest drained structure is proposed at Marrickville Station which is some distance to the west of the Project alignment, and as such is considered unlikely to have significant cumulative impacts on groundwater drawdown. There is potential for the concrete lined tunnels of the Sydney Metro project to create a partial hydraulic barrier to groundwater flow, however the risk is considered low since the tunnels are constructed below the water table.

5.2.7 Construction monitoring

A GWMP has been developed to describe how ASBJV propose to monitor potential impacts to groundwater during construction of the project (refer Section 4.2 of Appendix B).

6 Environmental control measures

6.1 Water treatment

Water treatment forms a key environmental control measure. Water treatment plants (WTP) will be designed so that the water will be of suitable quality for discharge to the receiving environment in compliance with the discharge criteria described below.

Groundwater captured during construction will be treated at one of the three WTP (Table 6-1), tested and either reused or discharged in accordance with the project EPL and ASBJV's trade waste licence requirements (as applicable).

Table 6-1 Water treatment plant details

WTP	Receiving water course
Northcote Street civil and tunnel site, Haberfield	Iron Cove Creek
Pyrmont Bridge Road, Annandale	Johnstons Creek
Campbell Road, St Peters	Alexandra Canal

Discharge volume

Discharge volumes will be continuously monitored at the WTP's via calibrated flow meters.

Discharge water quality

In accordance with CoA E186 and the Project EPL (#21149), water will be treated by the WTPs in order to produce water quality consistent with the criteria listed in Table 6-2 and Table 6-3.

All WTPs will undergo commissioning and post commissioning testing in accordance with Section 6.1.1 and Section 6.1.2.

In addition, water quality will be monitored via in-line calibrated pH and turbidity sensors with appropriate alerts set to inform management of any drift in WTP performance.

Table 6-2 WTP construction discharge criteria

Parameter	Discharge criteria	Reference
pH	6.5 – 8.5	EPL
Oil and grease	None visible	EPL
Turbidity	An NTU value calibrated[1] to achieve <50 mg/L equivalent Total Suspended Solids	EPL

1. NTU converted to TSS relationship via interpretation by linear regression analysis.

2. All instrumentation to be calibrated in accordance with manufacturer specifications.

Table 6-3 Water Treatment Plant monthly design performance criteria

Parameter	unit	WTP performance criteria		
		Northcote Street civil and tunnel site Iron Cove Creek (SW8[3])	Pyrmont Bridge Road Johnstons Creek (SW4[3])	St Peters Interchange Alexandra Canal (SW15[3])
pH[1]	pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Arsenic[2]	mg/L	0.05	0.05	0.05
Cadmium	mg/L	0.014	0.014	0.014
Chromium (III+VI) [Cr(III)/Cr(VI)]	mg/L	0.0486/0.02	0.0486/0.02	0.0486/0.02
Copper	mg/L	0.003	0.003	0.008
Iron[2]	mg/L	0.3	0.3	0.3
Lead	mg/L	0.0066	0.0066	0.0066
Manganese	mg/L	2.5	2.5	2.5
Mercury	mg/L	0.0007	0.0007	0.0007
Nickel	mg/L	0.2	0.2	0.2
Zinc	mg/L	0.023	0.04	0.023
Ammonia as N	mg/L	-	-	1.2

Source: ANZECC (2000a) – Trigger values for 90% species protection level except where:

[1]guideline value for south-east Australian estuaries

[2]guideline for recreational water quality

[3]Please refer to Figure 3-2 of the Surface Water Quality Monitoring Program for these locations

Procedures relating to the management of the WTP will also be prepared and implemented via Standard Operating Procedure (SOPS) or an Environmental Work Method Statement (EWMS).

WTP will be of a modular design so that they can be modified if required to ensure discharge can be conducted in accordance with the EPL criteria.

6.1.1 WTP Commissioning

During commissioning of each of the WTPs, a minimum of two rounds of commissioning sampling will be undertaken to confirm their efficacy. All of the parameters listed in Table 6-2 and Table 6-3 will be tested during this commissioning phase. The main objectives of the commissioning testing will be to determine:

1. If the WTPs perform to meet the proposed discharge criteria in Table 6-2 and the design performance in Table 6-3 and what (if any) design or operational modifications may be required to the WTP in order for it to meet the required specifications
2. The relationship between TSS and turbidity to allow turbidity to be measured as a proxy for TSS — this will require more samples than for the other parameters and may continue into the post-commissioning phase.

The WTP will not be deemed "commissioned" until two subsequent rounds of testing confirm compliance with the criteria.

6.1.2 Post-commissioning

In addition to the commissioning sampling, the WTP discharge will be sampled for water quality analysis for the parameters listed in Table 6-2 during discharge. Sampling will be undertaken in accordance with the EPL requirements. The results will be reviewed by trained personnel to ensure that the discharged water meets discharge criteria.

Monthly sampling of the design performance criteria listed in Table 6-3 will be undertaken to ensure that each of the WTP continues to meet design specifications. Where in-line sensors or monitoring identify WTP performance drift outside of the required criteria the WTP will be shut down and measures implemented to return the WTP performance back into the required range. In these instances, water will be discharged to trade waste (where permitted), recycled or disposed offsite at an appropriate licenced liquid waste facility.

Water quality results and an overview of corrective actions will be reported in the six-monthly Water monitoring report.

6.2 Other environmental control measures

Specific measures and requirements to meet the objectives of this GMP (refer Section 2.2) and to address impacts on groundwater are outlined in Table 6-4. Based on the mitigation and management measures it is considered that potential groundwater impacts that may arise as a result of the construction of the Project can be effectively managed.

Table 6-4 Groundwater management and mitigation measures

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWMM1	The tunnels will be designed so there will be no direct groundwater inflow from the alluvium (and palaeochannels) into the tunnels.	Design Construction	Design Manager	EIS Section 19.5	Tunnel design
GWMM2	Further assessment of the risk posed by the presence of sulfate reducing bacteria and groundwater aggressivity will be undertaken prior to construction. A corrosion assessment will be undertaken to assess the impact on building materials that may be used in the tunnel infrastructure such as concrete, steel, aluminium, stainless steel, galvanised steel, and polyester resin anchors. The outcomes of the corrosion assessment will be considered when selecting building materials likely to encounter groundwater.	Pre-construction	Design Manager	EIS Section 19.5	Corrosion assessment / durability report
GWMM3	Potential impacts associated with subsurface components of the Project intercepting and altering groundwater flows and levels will be considered during detailed design. Measures to reduce potential impacts will be identified and included in the detailed construction methodology and the detailed design as relevant.	Design	Design Manager	EIS Section 19.5	Tunnel design
GWMM4	A detailed groundwater model will be developed by ASBJV. The model will be used to predict groundwater inflow rates and volumes within the tunnels and groundwater levels (including drawdown) in adjacent areas during construction and operation of the Project.	Pre-construction	Design Manager	CoA E193 REMM GW7	Groundwater modelling report
GWMM5	Groundwater inflow within and groundwater levels in the vicinity of the tunnels will be monitored during construction and compared to model predictions and groundwater performance criteria applied to the Project. The groundwater model will be updated based on the results of the monitoring as required and proposed management measures to minimise potential groundwater impacts adjusted accordingly to ensure that groundwater inflow performance criteria are met.	During construction	Environment & Sustainability Manager Design Manager	REMM GW8	Groundwater model updates

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWMM6	Further investigations will be carried out to identify areas where groundwater inflows to the tunnels are likely to be elevated, to guide the development of the detailed design and construction methodology. The investigations will be carried out prior to the commencement of excavations with the potential to result in groundwater inflow at each identified location. This could involve the advance probing during excavation.	Pre-construction Construction	Design Manager Construction Manager	REMM GW9	Tunnel design
GWMM7	In order to prevent adverse impacts on downstream surface water quality, water treatment plants will be designed so that the effluent will be of suitable quality for discharge to the receiving environment in compliance with the discharge criteria (Section 7.3), the Project EPL, and if applicable, ASBJV's trade waste licence.	Pre-construction and during construction	Construction Manager	CoA E186 REMM SW10	Water monitoring reports

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWMM8	Site-specific trigger values (SSTV) for electrical conductivity (EC) were initially 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 EC data (refer Section 4.2 of Appendix B). These SSTV were reviewed following 12 months of construction monitoring data (refer to Section 7.1 of Appendix B). 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. If the exceedance is determined to be attributable to Project works and outside of modelling predictions for saline intrusion, additional management measures (including review of the groundwater model) may be implemented in consultation with the relevant authorities.	During construction	Environment & Sustainability Manager	CoA C5 CoA C10	Groundwater monitoring reports

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWMM9	A groundwater level decline outside of the seasonal fluctuation will be assessed and compared against predicted drawdown as simulated in the groundwater model (refer Section 4.2.2 of Appendix B). The assessment will determine whether the observed decline is attributable to the Project and, if so, whether it aligns with approved predictions. If drawdown is identified outside of model predictions, management actions will be initiated including (but not limited to) a review of baseline groundwater level data in the relevant and surrounding monitoring bores as well as an assessment of groundwater inflow rates into the tunnel.	During construction	Environment & Sustainability Manager Design Manager	CoA E193 REMM GW7 REMM GW8	Groundwater monitoring reports
GWMM10	Identification of a groundwater decline (beyond seasonal fluctuations in nearby monitoring bores) will be monitored to determine whether the decline is attributable to dewatering from the Project. The assessment will include a review of groundwater levels in the surrounding monitoring bore network. Where an impact is confirmed, in accordance with the Aquifer Interference Policy (NoW 2012), measures will be taken to 'make good' the impact on an impacted water supply bore. The measures taken could include, for example, deepening the bore, providing a new bore or providing an alternative water supply. 'Make good' will only apply to registered bore users identified in Section 4.6 and Section 5.2.3.	During construction	Environment & Sustainability Manager	CoA E191 REMM GW5	Groundwater monitoring reports
GWMM11	In zones where the inflow rates are anticipated to exceed one litre per second per kilometre for any kilometre length of tunnel, water bearing fractures/rock defects will be grouted as required to reduce ongoing groundwater inflow. This grouting will help to mitigate long-term drawdown impacts.	During construction	Construction Manager	CoA E190	Construction reports

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWMM12	Any known contaminated soils or groundwater on the site likely to cause risk to health, safety or the environment will be identified, signposted and segregated from site activities by the erection of physical barriers to prevent unauthorised entry, exposure and/or cross contamination.	Pre-construction and during construction	Environment & Sustainability Manager	LLE 713 – Contaminated Sites CS1 (internal document)	Site inspection report
GWMM13	Any site activities that involve soil or groundwater disturbance where the contamination levels of the soil and groundwater are either unknown, or where evidence of possible contamination is presented, will cease until competent persons are able to make a determination of the contamination status or risk.	During construction	Environment & Sustainability Manager	LLE 713 – Contaminated Sites CS2 (internal document)	Site inspection report
GWMM14	Excavation or remediation of contaminated soils or groundwater will be planned and conducted in accordance with regulatory requirements including provision for any decontamination and wash/disposal facilities. Any areas where remediation has been completed will be clearly demarcated, secured and signposted to prevent cross-contamination from ongoing remediation works and be validated by a competent person to confirm completeness of the remediation works.	Pre-construction and during construction	Environment & Sustainability Manager	LLE 713 – Contaminated Sites CS3 (internal document)	Site inspection report
GWMM15	Leachate generation will be limited by minimising infiltration or ingress of water into identified contamination areas.	During construction	Environment & Sustainability Manager	LLE 713 – Contaminated Sites CS5 (internal document)	Site inspection report

ID	Measure/Requirement	When to implement	Responsibility	Reference	Evidence
GWMM16	Groundwater quality (salinity as Electrical Conductivity (EC)) during construction will be routinely monitored at key locations between saline water bodies and the tunnel as identified by the groundwater model (AECOM 2017) including in the Haberfield / Lilyfield area to the south of Iron Cove, and in the St Peters area to the north west of Alexandra Canal.	During construction	Environment & Sustainability Manager	CoA C12 (d)	Groundwater monitoring results
GWMM17	Groundwater intercepted during construction will be managed by either capturing the water that enters the tunnels, caverns and portals, or by other suitable measures. All captured inflow will be treated prior to discharge (refer Section 4.2.5 and Section 5.4 in Appendix B).	During construction	Construction Manager	EIS Section 19.5	Site inspection report
GWMM18	The groundwater model will be used to predict influences on the Project as well as the cumulative impacts from the other WestConnex projects and local infrastructure projects.	Pre-construction and during construction	Design Manager	CoA C5(d)	Groundwater modelling report

7 Compliance management

7.1 Roles and responsibilities

The ASBJV Project Team's organisational structure and overall roles and responsibilities are outlined in Section 3.1.1 of the CEMP. Specific responsibilities for the implementation of environmental controls are detailed in Table 6-4 of this Plan.

7.2 Training

All employees, contractors and utility staff working on site will undergo site induction training relating to relevant aspects of this Plan, particularly construction risks which have the potential to impact on groundwater resources (refer Section 5.2).

Targeted training in the form of toolbox talks or specific training will also be provided to personnel with a key role in groundwater management. Groundwater specific training will include:

- Groundwater monitoring methodology and protocols (refer Section 5 of Appendix B)
- Project obligations including requirements to assess and classify contamination on site

Further details regarding staff induction and training are outlined in Section 3.5 of the CEMP.

7.3 Monitoring and inspection

Section 4 of the GWMP (Appendix B) provides detailed inspection criteria including:

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

ASBJV's Environmental Management System internal documents relevant to this GMP are:

- LLE701A - Environmental Work Method Statement (internal document)
- LLE702: Figure 1 - Potential Critical Incident Notification (internal document)
- LLE702A - Environmental Incident Report (internal document)
- LLE702B - Environmental Incident Investigation (internal document)
- LLE703A - Environmental Inspection Checklist (internal document)
- LLE703B - Environmental Observation Report (internal document)
- LLE703C - Environmental Improvement Notice (internal document)
- LLE705A - Sediment Basin Discharge Permit (internal document)
- LLE705B - Dewatering Permit (internal document)

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

7.4 Licences and permits

The Project construction activities 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)).

Other relevant licences or permits will be obtained in the lead up to and during construction as required.

7.5 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 3.9.3 of the CEMP.

7.6 Reporting

Reporting requirements relevant to this GMP are outlined in Table 7-2 with data provision requirements outlined in Table 6-1 of the GWMP (refer Section 6.5 of Appendix B).

Additional reporting requirements for the Project are outlined in Section 3.9.4 and Section 3.9.5 of the CEMP.

Table 7-1 Reporting requirements

Schedule (during construction)	Requirements	Recipient (relevant authority)
Reporting		
Water Monitoring Reports (every six months)	Data summary reports presenting tabulated groundwater monitoring data collected during the reporting period. Groundwater level hydrographs (including rainfall) and water quality results will be presented and SSTV exceedances will be highlighted. Applicable management responses will be documented. Compliance against discharge criteria will also be presented. Report will present validation of groundwater modelling and determine the need for any necessary adjustments to the GWMP (Appendix B).	DPIE, DoI Water, Sydney Water
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
Data provision		

Schedule (during construction)	Requirements	Recipient (relevant authority)
Quarterly (every 3 months)	WTP discharge water quality and flow data (raw data collated and tabulated in Excel) To demonstrate compliance with the CoA (C12(f)), project discharge criteria (defined in Section 6 this Plan and Section 4.2.5 of the GWMP), EPL, and if applicable ASBJV's trade waste licence.	Sydney Water
Quarterly (every 3 months)	Groundwater level and groundwater quality monitoring data (raw data collated and tabulated in Excel) To demonstrate compliance with the CoA (C12(g)).	DoI Water

8 Review and improvement

8.1 Continuous improvement

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

The 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.

8.2 Groundwater model update

The results of the groundwater modelling will be documented in a Groundwater Modelling Report. The Groundwater Modelling Report will be finalised in accordance with the Australian Groundwater Modelling Guidelines (National Water Commission, 2012) and prepared in consultation with DPI Water.

The groundwater model will be updated once 24 months of construction groundwater monitoring data are available and the results of the updated modelling provided to the Secretary and DPI Water in an updated Groundwater Modelling Report.

8.3 GMP update and amendment

The processes described in Section 3.9 to Section 3.13 of the CEMP may result in the need to update or revise this Plan. The groundwater model update (Section 8.2) may result in the need to update or revise this Plan. Plan updates will occur on an as needed basis.

Only the Environment and Sustainability Manager, or delegate, has the authority to change any of the environmental management documentation. All amendments to environmental management documentation require endorsement from the Environmental Representative.

A copy of the updated plan and changes will be distributed to all relevant stakeholders in accordance with the approved document control procedure – refer to Section 3.11.2 of the CEMP.

8.4 WTP performance

Performance criteria for water to be discharged from the WTP during the construction stage were developed in accordance with CoA E186. The discharge criteria for turbidity, and oil and grease reflect standard EPL requirements for discharges from sedimentation basins. The pH criteria are the default trigger values for chemical and physical stressors for estuaries in South east Australia (refer Table 3.3.2 of ANZECC 2000). Estuarine triggers values are used as the salinity in the receiving environment is typical of the salinity found in estuaries.

The performance criteria for monthly WTP discharge samples are the default trigger values for estuaries in South east Australia (pH); for the protection of 90% of marine species (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc); and for the protection of recreational water quality (iron) as listed in Tables 3.4.1, 3.3.2 and 5.2.3 of ANZECC 2000 respectively or as otherwise permitted under the Project EPL.

9 References

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC), 2000.Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Bureau of Meteorology (BoM) 2012. National Atlas of Groundwater Dependent Ecosystems

Department of Land and Water Conservation (DLWC), 2002. NSW Groundwater Dependent Ecosystems Policy.

DLWC, 1998. NSW Groundwater Policy Framework Document.

DLWC, 1998. NSW Groundwater Quality Protection Policy.

DLWC, 1997. NSW Groundwater Quantity Management Policy.

Department of Planning and Environment (DPE), 2012. Guideline for riparian corridors on waterfront land.

Department of Water and Energy (DWE), 2007. NSW Water Extraction Monitoring Policy.

Environment Protection Authority (EPA), 2004. Approved Methods for the Sampling and Analysis of Water Pollutants in NSW.

NSW Office of Water (NoW), 2011. Water Sharing Plan, Greater Metropolitan Regional Groundwater Sources Background Document, Sydney.

NoW, 2012. NSW Aquifer Interference Policy.

Roads and Maritime Services (Roads and Maritime), 2011. Road and Maritime Dewatering Guideline.

Appendix A Other Conditions of Approval and Revised Environmental Management Measures relevant to this Plan

Other relevant Conditions of Approval relevant to the development of this Plan.

CoA No.	Condition Requirements	Document Reference
E154	The Proponent must not destroy, modify or otherwise physically affect any heritage items, including human remains, outside of the CSSI boundary, or undertake works in or on Alexandra Canal.	Section 6.1, Table 6-1
E186	The CSSI construction water treatment plant discharge criteria must comply with the ANZECC (2000) 90 per cent species protection level unless an EPL is in force in respect to the CSSI. Discharge criteria for iron during construction must comply with the ANZECC (2000) recreational water quality criteria.	Table 6-3
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 6, Table 6-4
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.	Section 4.6, Section 5.2.3, and Section 6, Table 6-4
E192	The Proponent must undertake further modelling of groundwater drawdown, tunnel inflows and saline water migration (using particle tracking) prior to finalising the design of the tunnels and undertaking any works that would impact on groundwater flows or levels. The modelling must be undertaken in consultation with DPI Water and include the results and hydrogeological analyses of at least 12 continuous months of current baseline groundwater monitoring data from bores identified in the EIS and SPIR. The modelling must also include data from any other existing monitoring bores identified in consultation with DPI Water, as required to supplement baseline data.	Section 4.1.1 of the GWMP (Appendix B)

CoA No.	Condition Requirements	Document Reference
E193	The results of the groundwater modelling must be documented in a Groundwater Modelling Report. The Groundwater Modelling Report must be finalised in accordance with the Australian Groundwater Modelling Guidelines (National Water Commission, 2012) and prepared in consultation with DPI Water.	Section 8.2
E194	The groundwater model must be updated once 24 months of construction groundwater monitoring data are available and the results of the updated modelling provided to the Secretary and DPI Water in an updated Groundwater Modelling Report.	Section 8.2

Revised Environmental Mitigation Measures relevant to the development of this Plan.

Outcome	Ref #	Commitment	Timing	GMP Reference
Excess water from the Project will be of suitable quality for discharge to the receiving environment.	REMM SW10	Temporary construction water treatment plants will be designed and managed so that treated water will be of suitable quality for discharge to the receiving environment. An ANZECC (2000) species protection level of 90 per cent is considered appropriate for adoption as discharge criteria for toxicants where practical and feasible. The discharge criteria for the treatment facilities will be included in the CSWMP.	Pre-construction	Table 6-4

Outcome	Ref #	Commitment	Timing	GMP Reference
Groundwater yields in affected bores will be restored to pre-development levels.	REMM GW5	In accordance with the 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.	During/post-construction	Section 5.2.3, Section 6, and Table 6-4
Measures to reduce potential impacts to groundwater will be identified and included in the construction methodology and the detailed design.	REMM GW6	Potential impacts associated with subsurface components of the project intercepting and altering groundwater flows and levels will be considered during detailed design. Measures to reduce potential impacts will be identified and included in the detailed construction methodology and the detailed design as relevant.	Pre-construction	Section 5.2.3
Groundwater model developed to predict groundwater inflow rates and volumes within the tunnels and groundwater level (including drawdown) in areas adjacent to construction.	REMM GW7	A detailed groundwater model will be developed by the construction contractor during detailed design. The model will be used to predict groundwater inflow rates and volumes within the tunnels and groundwater levels (including drawdown) in adjacent areas during construction and operation of the project.	Pre-construction	Section 6, Table 6-4

Outcome	Ref #	Commitment	Timing	GMP Reference
Groundwater model calibrated to provide accurate predictions of groundwater impact due to the Project.	REMM GW8	Groundwater inflow within, and groundwater levels in the vicinity of, the tunnels will be monitored during construction and compared to model predictions and groundwater performance criteria applied to the project. The groundwater model will be updated based on the results of the monitoring as required and proposed management measures to minimise potential groundwater impacts adjusted accordingly to ensure that groundwater inflow performance criteria are met.	Pre-construction and during construction	Section 6, Table 6-4 Section 4.2.2 and Section 4.2.4 of the GWMP (Appendix B)
Mitigation of potential impacts from groundwater inflows to excavations.	REMM GW9	Further investigations will be carried out to identify areas where groundwater inflows to the tunnels are likely to be elevated, to guide the development of the detailed design and construction methodology. The investigations will be carried out prior to the commencement of excavations with the potential to result in groundwater inflow at each identified location.	Pre-construction	Section 5.2.3

Outcome	Ref #	Commitment	Timing	GMP Reference
	REMMs OGW09	A groundwater monitoring program will be prepared and implemented to monitor groundwater inflows in the tunnels and groundwater levels as well as groundwater quality in the three main aquifers and inflows during construction. The program will identify groundwater monitoring locations, performance criteria in relation to groundwater inflow and levels and potential remedial actions that will be considered to address any non-compliances with performance criteria. As a minimum, the program will include manual groundwater level and quality monitoring monthly and inflow volumes and quality weekly. The monitoring program will be developed in consultation with the NSW EPA, DPI-Fisheries, DPI Water, City of Sydney Council and Inner West Council.	Construction	Appendix B
Continuation of groundwater monitoring program during operational phase of the project.	REMMs 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 4.3 of the GWMP (Appendix B)

Outcome	Ref #	Commitment	Timing	GMP Reference
Monitoring and comparison of pore pressures and standing water levels along the tunnel alignment.		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.	Operation (VWP to be installed during construction phase)	Section 4.2.2 of the GWMP (Appendix B)
Reporting of extracted groundwater volumes to DoI Water.		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 relevant councils and documented in the OEMP or EMS.	Annually during construction	Section 6.5 of the GWMP (Appendix B)

Appendix B Groundwater Monitoring Program

Appendix B

Groundwater Monitoring Program

M4-M5 Link Mainline Tunnels

April 2021

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Contents

Figures

Tables

Appendices

Document control

Approval and authorisation

Title	M4-M5 Link Mainline Tunnels Groundwater Monitoring Program
Document No/Ref	M4M5-LSBJ-PRW-EN-MP01-PLN-0014-10
Document Path	

Document status

Revision	Date	Description
01	17 September 2018	For DPE Review
02	23 October 2018	For DPE Review
03	6 November 2018	For DPE Review
04	7 November 2018	For DPE Approval
05	4 February 2019	Updated monitoring locations
06	27 February 2019	Minor updates – for ER approval
07	4 September 2019	Updated monitoring locations following completion of Project Geotechnical Investigation
08	25 September	Updated following WestConnex Transurban review – for ER approval
09	21 July 2020	Minor update – for ER approval
10	28 April 2021	Update following SSTV review - for ER approval

1 Introduction

1.1 Context

This Groundwater Monitoring Program (GWMP or Program) has been prepared for the construction stage of the M4-M5 Link Mainline Tunnels (the project).

The GWMP 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) and all applicable guidance and legislation.

1.2 Scope of the groundwater monitoring program

The scope of this GWMP is to describe how ASBJV propose to monitor potential minor impacts to groundwater during construction of the project. Operational monitoring and operation measures do not fall within the scope of the construction phase and therefore are not included within the processes contained within the GWMP.

1.3 Implementation of the groundwater monitoring program

The Construction Monitoring Programs must be endorsed by the Environmental Representative (ER) and then submitted to the Secretary for approval at least one (1) month prior to commencement of construction.

Construction will not commence until the Secretary has approved all of the required Construction Monitoring Programs relevant to that activity and all the necessary baseline data for the required monitoring programs has been collected, to which the CEMP relates.

The Construction Monitoring Programs, as approved by the Secretary, including any minor amendments approved by the ER, must be implemented for the duration of construction and for any longer period set out in the monitoring program or specified by the Secretary, whichever is the greater.

2 Purpose and objectives

2.1 Purpose

The purpose of the GWMP is to describe how ASBJV propose to monitor actual performance of the project and compare against predicted performance. ASBJV will monitor the extent and nature of potential impacts to the groundwater level and quality during construction of the project.

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

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

This GWMP is based on baseline studies developed for the project EIS (AECOM 2017).

2.2 Objectives

The key objective of the GWMP 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 report for WestConnex M4-M5 Link Mainline Tunnel (September 2018)
- Conditions of Approval granted to the project on 17 April 2018 and as modified on 25 February 2019
- Roads and Maritime specifications G36, G38 and G40
- The project's Environment Protection Licence (EPL)
- All relevant legislation and other requirements

2.3 Consultation

This program was provided to DoI Water, Sydney Water, City of Sydney Council, Inner West Council in accordance with CoA C9(b). In addition the document was also offered to the EPA and NSW Fisheries for review and comment in accordance with REMM OGW9. Refer to Section 2 of the CEMP for consultation requirements relating to the CEMP and all sub-plans.

Ongoing consultation with relevant councils and other stakeholders, including any unique local receivers, may be undertaken for particular issues pertaining to the Project's impact on groundwater. Community feedback and complaints relating to groundwater will be dealt with in accordance with the Community Communication Strategy and Complaints Management System. This GWMP was provided to DoI Water/Natural Resources Access Regulator, DoI Fisheries, Sydney Water, City of Sydney Council, and Inner West Council for review and comment.

3 Environmental aspects and impacts

3.1.1 Reduced groundwater recharge

The majority of the project 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 water treatment plants. Given the scale of the above ground footprint a reduction in rainfall recharge is considered negligible (AECOM 2017).

3.1.2 Groundwater level decline

Groundwater drawdown

Construction 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 and the specific geological conditions present (AECOM 2017).

In zones where the inflow rates are anticipated to exceed one litre per second per kilometre for any kilometre length of tunnel, water bearing fractures/rock defects would be grouted during construction to reduce ongoing groundwater inflow. This grouting helps to mitigate long-term drawdown impacts.

Potential groundwater drawdown due to the project for the long term (to 2100) has been calculated and predicted in the groundwater model (AECOM 2017), in summary:

- The predicted drawdown in the alluvium at the creeks along the alignment varies depending on local geology, horizontal distance from the tunnel, depth to the tunnel, and tunnel design. Along relevant sections of the project alignment, the tunnels have been designed so there will be no direct inflow from the alluvium into the tunnels. This would be achieved by designing the tunnels to dive beneath the alluvium, such as at Hawthorne Canal, and if required constructing cut-off walls where the portals and cut-and-cover sections intersect alluvium, such as at Haberfield. Drawdown within the minor occurrences of alluvium along the project alignment is unlikely.
- Long-term drawdown (year 2100) within the Ashfield Shale and Hawkesbury Sandstone is predicted to extend to the tunnel invert and continue to spread laterally over time. Groundwater movement is restricted in the Hawkesbury Sandstone because it is interbedded with shale lenses that discourage groundwater movement. In the vicinity of the St Peters interchange within the Ashfield Shale, groundwater is predicted to be drawn down to the tunnel invert, with the drawdown extending laterally approximately 0.5 km either side of the tunnel alignment. The lateral extent of drawdown within the Ashfield Shale is less than within the Hawkesbury Sandstone due to the sandstone being more permeable than the shale.

Groundwater level will be routinely monitored during construction (see Section 4.2.2).

Potential impacts on GDEs

There are no priority GDEs identified in the *Water Sharing Plan* (NoW 2011) within 5 km of the project alignment. Consequently, no priority GDEs are likely to be impacted by groundwater level decline associated with either the construction or the long-term operation of the project.

Potential impacts on existing groundwater users

Groundwater modelling (AECOM 2017) has been used to predict drawdown at the location of registered bores within 2 km of the project alignment. Only one bore (GW110247) and is currently registered for domestic use. GW110247 is predicted to have a drawdown of approximately 2.4 m to the hydraulic head in Hawkesbury Sandstone by the end of the long-term simulation in 2100. Given the standing water level is recorded as 31 metres below ground level (mBGL) and the bore is 210 m deep, the drawdown is likely to have a negligible impact on the bore capacity. The impact on water quality in GW110247 due to saltwater intrusion is also anticipated to be negligible, since the bore is at least 2 km from the nearest saline water body at Rozelle Bay and predicted saline water travel times are in excess of 1,000 years (AECOM 2017). No existing groundwater users are likely to be impacted by groundwater level decline associated with the construction of the project.

Potential impacts on surface water baseflow

Predicted long-term changes to baseflow from the groundwater modelling (AECOM 2017) indicate that the overall contribution to flow to surface watercourses from groundwater is relatively small, since the watercourses are mostly concrete lined channels. It is expected that the majority of stream flow would be derived from rainfall runoff and tidal inflow. There is also no impact predicted on the baseflow of other major creeks near the New M5 project footprint (including Cooks River, Wolli Creek and Bardwell Creek) due to the project. Sydney Water is proposing to naturalise parts of creek channels within the project footprint, including sections of Johnstons Creek at Annandale and Dobroyd Canal (Iron Cove Creek) in Haberfield. Removal of sections of the concrete-lined base would allow more groundwater and surface water interaction, leading to a higher contribution of baseflow to surface water flow in the creeks, and additional surface water recharge via bed leakage when the water table is below the creek bed (AECOM 2017).

3.1.3 Groundwater quality

Intercepting contaminated groundwater

The risk of contaminated groundwater entering the project tunnels from leachate derived from the former Alexandria Landfill site is low with a cut-off wall to be constructed along the eastern perimeter of the landfill reducing tunnel inflow. In addition the landfill will be capped and a leachate pumping system (operated as part of the New M5 project) will direct groundwater flow towards the leachate pumps and away from the project tunnels.

Groundwater from the Botany Sands aquifer is likely to enter the tunnel through hydraulic connection with the Ashfield Shale and Hawkesbury Sandstone at Alexandria. This groundwater has the potential to be contaminated, however, groundwater modelling (AECOM 2017) indicates flow from the Botany Sands would be a minor component of tunnel inflow. Inflow water will also be treated prior to discharge.

Groundwater treatment

The existing groundwater quality within the study area (see Section 4.1.3) is brackish with elevated metals and nutrients recorded during baseline groundwater sampling. In order to prevent adverse impacts on downstream water quality, water treatment facilities for tunnel water discharge will be designed so that the water will be of suitable quality for discharge to the receiving environment in compliance with the discharge criteria (Section 4.2.5), the project EPL, the Protection of the Environment Operations Act 1997 (POEO Act) and if applicable, ASBJV's trade waste licence.

Saltwater intrusion

Over time, saline intrusion is predicted to result in saline water reaching the tunnels. The proportion of saline water flowing into the tunnels, however, would be low (especially during the relatively short construction phase). A capture zone analysis has been undertaken as part of the groundwater modelling (AECOM 2017) to investigate salt water intrusion within the tunnel catchment areas. From this analysis it is not possible to quantify volumes or concentrations of saline water entering the tunnels and therefore the following discussion is based on a qualitative analysis.

Alexandra Canal

The minimum travel times for saline water from Alexandra Canal to enter the tunnels are predicted by the groundwater model (AECOM 2017) to be two days, although this initial inflow would have a negligible impact on groundwater quality. Initially (minimum travel time), the saline water would be a small fraction of total groundwater entering the tunnel, although this is expected to increase over time as water is drawn from further afield. Groundwater modelling predicts the travel time for saline water to enter the tunnel during operation to be in the order of 30 years. As the saline water entering the tunnels would remain a minor component of the total inflow changes to groundwater quality are expected to be minimal.

Tidal zones

The groundwater model (AECOM 2017) predicts that saline groundwater from the alluvium associated with the Cooks River would enter the project tunnels near the St Peters interchange. Groundwater level is predicted to decline below sea level therefore saline waters from tidal zones would flow towards the tunnels and would ultimately enter the tunnels via a hydraulic connection with the alluvium. The saline water would initially be a small fraction of total groundwater entering the tunnels and increase over time.

Average times for saline water to enter the tunnels are predicted to be more than 100 years and maximum times are in the order of thousands of years. As a result, groundwater in the tunnel catchment zones would gradually become saline over thousands of years. Since the operational lifetime for major infrastructure is in the order of 100 years, the slow salinity increase should have minimal impacts on the tunnels and infrastructure in the project's operational lifetime, and negligible impacts during construction.

Groundwater quality (salinity as Electrical Conductivity (EC)) during construction will be routinely monitored at key locations between saline water bodies and the tunnel as identified by the project groundwater model (AECOM 2017) including in the Haberfield / Lilyfield area to the south of Iron Cove, and in the St Peters area to the north west of Alexandra Canal in accordance with CoA C12 (d).

Details of the construction groundwater monitoring program are presented in Section 4.2 and Table 4-4.

4 Groundwater monitoring

4.1 Baseline monitoring

4.1.1 Monitoring network

Baseline groundwater level and groundwater quality monitoring data has been collected from the project groundwater monitoring network since June 2016. This baseline dataset is augmented by baseline data and construction data collected since October 2015 for adjacent M4 East and New M5 Projects.

The project baseline monitoring network was installed between May 2016 and May 2017 and consists of 19 monitoring bores intersecting groundwater within the alluvium, Ashfield Shale, and Hawkesbury Sandstone. 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 ongoing monitoring program

Baseline groundwater level and quality data will provide inputs to the groundwater modelling that will be documented in the project Groundwater Modelling Report, in accordance with CoA E192 /193 (*in preparation*). The baseline monitoring bore network is shown in Table 4-1 and Figure 4.1, and is detailed in Appendix T (Technical working paper: Groundwater) of the EIS (AECOM 2017).

Table 4-1 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

Bore ID	Location	Easting	Northing	Screened interval (mBGL)	Lithology screened	Start of baseline groundwater level monitoring	Start of baseline Groundwater quality monitoring
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
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

HSS = Hawkesbury Sandstone; NA = no baseline data unavailable

Where existing monitoring locations that are proposed for construction monitoring in Figure 4.1 and destroyed by construction activities, these will be replaced if monitoring visibility in that area is deemed to be lacking.

Source: EMM (2018); DFSI (2017)

KEY

Groundwater monitoring well

Existing features

Light rail

Rail line

Arterial road

Watercourse / drainage line

Project features

Tunnel connection

Tunnel portal

Proposed M4 - M5 Link Mainline Tunnel alignment

Location of baseline groundwater monitoring bores

Westconnex M4-M5 Link Tunnels
Groundwater monitoring program
Figure 4-1

4.1.2 Groundwater level

Baseline groundwater level data has 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 has since been 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). The EIS presents interpretation of the baseline groundwater level conditions, summarised in Section 3 of this GWMP.

Identified potential project impacts will be routinely monitored during construction and include:

- Groundwater level decline (see Section 3.1.2 and 4.2.2)
- Saline intrusion (see Section 3.1.3 and 4.2.3)

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

4.1.3 Groundwater quality

Baseline monthly groundwater quality monitoring commenced in June 2016 or later as each monitoring location became operational (Table 4-1). The objectives for 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 4-2.

Table 4-2 Baseline groundwater quality sampling program

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

The baseline groundwater quality sampling program included the following analytes:

- Physico-chemical field parameters (temperature, dissolved oxygen, electrical conductivity (EC), pH, and redox potential)
- Major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, carbonate and bicarbonate)
- Dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc)
- Nutrients (nitrite as N, nitrate as N, reactive phosphorus and ammonia)
- Benzene, toluene, ethylbenzene, xylene, and naphthalene (BTEXN)

- Total recoverable hydrocarbons (TRHs)
- Polycyclic aromatic hydrocarbons (PAHs)
- Organochlorine pesticides (OCPs)
- Organophosphate pesticides (OPPs)
- Semi-volatile organic hydrocarbons (SVOCs)
- Volatile organic compounds (VOCs)
- Sulfate reducing bacteria.

A summary of the baseline water quality data is included in Appendix B. Interpretation of the baseline groundwater monitoring data is included in the EIS (AECOM 2017) and is summarised in Table 4-3.

Table 4-3 Summary of baseline groundwater quality within the project area

Parameter	alluvium	Ashfield Shale	Hawkesbury Sandstone
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.	

Parameter	alluvium	Ashfield Shale	Hawkesbury Sandstone
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: 3 Mildly aggressive towards concrete piles for average concentrations of chloride, pH, and sulfate 4 Mildly aggressive towards steel piles for average concentrations of chloride and pH Severely aggressive towards steel piles for groundwater with low conductivity.

EC = electrical conductivity; 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**

4.2 Construction monitoring

4.2.1 Overview

As discussed in Section 3 potential impacts on groundwater during construction are identified as:

- Groundwater level decline in the vicinity of the project tunnels (groundwater drawdown)
- Intrusion of saline water in tidal zones (increase in groundwater salinity in the area to the south of Iron Cove, and in the St Peters area)

Groundwater level and groundwater quality (salinity) monitoring will be carried out during construction at the monitoring network listed in Table 4-4 and shown in Figure 4-2. Groundwater inflows intercepted during tunnelling, and subsequent discharge via the project water treatment plants (WTP), will also be monitored. Construction phase groundwater level and quality data will provide inputs to the groundwater model.

The construction groundwater monitoring program will monitor:

- Groundwater level
- Groundwater quality (EC) at key bores
- Groundwater inflow to the tunnels

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

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

It may be necessary to construct additional monitoring bores or monitor alternative existing bores if some of the bores detailed in the construction monitoring network are inaccessible or damaged during tunnel construction or as a possible management action as part of an investigation into discrepancies in monitoring data, if required. Where alternative existing bores are available, they should be similar to the bore they are replacing in location, well depth and screened lithology where possible.

Three vibrating wire piezometers (VWPs) were installed in accordance with REMM OGW10 (with the exception of depth, following consultation with DoI 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 will be used to validate drawdown predictions from the groundwater model.

The VWPs were constructed below the depth of the tunnel invert to allow for groundwater drawdown monitoring in the Hawkesbury Sandstone. The VWPs will each be located close to an existing standpipe piezometer and target equivalent depths to allow comparison (see Table 4-4 and Figure 4-2).

Following consultation with DoI Water, eight wells from the proposed initial monitoring program targeting the Hawkesbury Sandstone have been duplicated. Please refer to Table 4-5 for these duplications.

Table 4-4 Construction phase groundwater monitoring bores

Bore ID	Location	Easting	Northing	Screened interval (m)	Lithology screened	Type	Parameters
LSB-GW-HB-BH03	Haberfield	328069.55	6250108.81	53.4 – 60.4	HSS	SP	GWL
LSB-HB-BH1002	Haberfield	327716.76	6250133.19	22.15 – 28.15	HSS	SP	GWL
LSB-GW-HB-BH08d	Haberfield	328807.04	6250235.62	22 – 25	HSS	SP	GWL/GWQ (EC)[1]
LSB-HC-PT-OW5a	Haberfield	328808.19	6250236.19	10.5 – 13.5	alluvium	SP	GWL/GWQ (EC)[1]
LSB-MT-BH1018	Haberfield	328575.12	6250131.40	46.5 – 51	HSS	SP	GWL/GWQ (EC)[1]
LSB-GW-HB-BH12	Haberfield	328955.61	6249968.52	37.4 – 43.4	HSS	SP	GWL/GWQ (EC)[1]
LSB-MT-BH1015	Haberfield	328993.20	6250137.84	33.7 – 39.5	HSS	SP	GWL/GWQ (EC)[1]
HB_BH14	Haberfield	329206.55	6250086.27	37 – 40	HSS	SP	GWL
LSB-MT-BH1016	Haberfield	328815.25	6250135.70	31 – 38	HSS	SP	GWL
HB_BH15	Haberfield	329396.41	6250142.83	19 – 22	HSS	SP	GWL/GWQ (EC)[1]
LSB-MT-BH1014a	Haberfield	329386.68	6249963.88	41.78 – 47.78	HSS	SP	GWL/GWQ (EC)[1]

Bore ID	Location	Easting	Northing	Screened interval (m)	Lithology screened	Type	Parameters
LSB-SP-BH06	St Peters	331746.97	6246549.52	44.3 – 49.6	Ashfield Shale	SP	GWL
SP_BH02	St Peters	331844.84	6246375.94	4 – 10	Residual Clay (Shale)	SP	GWL
SP_BH04	St Peters	331657.95	6246185.60	32 – 35	Ashfield Shale	SP	GWL
LSB-SP-BH11	St Peters	331829.58	6246208.19	24 – 30	Ashfield Shale	SP	GWL/GWQ (EC)[1]
LSB-SP-BH03	St Peters	331854.25	6246012.89	14.95 – 20.32	Ashfield Shale	SP	GWL/GWQ (EC)[1]
LSB-MT-BH1013a	Main Line Tunnel	329541.97	6249618.64	49.5 – 55.5	HSS	SP	GWL
LSB-MT-BH1014-VWP1	Main Line Tunnel	329387.53	6249962.30	48.5	HSS	VWP	Pore pressure/GWL
MT_BH11	Main Line Tunnel	330670.67	6249095.13	48 – 51	HSS	SP	GWL
LSB-MT-BH1010b	Main Line Tunnel	330997.68	6248742.94	12.6 – 15.6	HSS	SP	GWL
LSB-MT-BH1021-VWP2	Main Line Tunnel	330526.59	6249094.96	49.5	HSS	VWP	Pore pressure/GWL
LSB-MT-BH1012	Main Line Tunnel	330144.20	6249445.60	46 – 53	HSS	SP	GWL
MT_BH14	Main Line Tunnel	331168.37	6248149.99	27 – 30	HSS	SP	GWL

Bore ID	Location	Easting	Northing	Screened interval (m)	Lithology screened	Type	Parameters
LSB-MT-BH1022-VWP3	Main Line Tunnel	331171.89	6248149.11	53	HSS	VWP	Pore pressure/GWL
LSB-MT-BH1008	Main Line Tunnel	331425.84	6247713.48	48.19 – 54.19	Ashfield Shale	SP	GWL
LSB-GW-MT-BH19	Main Line Tunnel	331547.66	6246854.15	46.5 – 54.19	HSS	SP	GWL
LSB-MT-BH1003	Main Line Tunnel	331589.32	6246470.97	57.09 – 63.09	HSS	SP	GWL

HSS = Hawkesbury Sandstone; GWL = Groundwater level; GWQ = Groundwater quality; SP = Standpipe piezometer; VWP = Vibrating Wire Piezometer

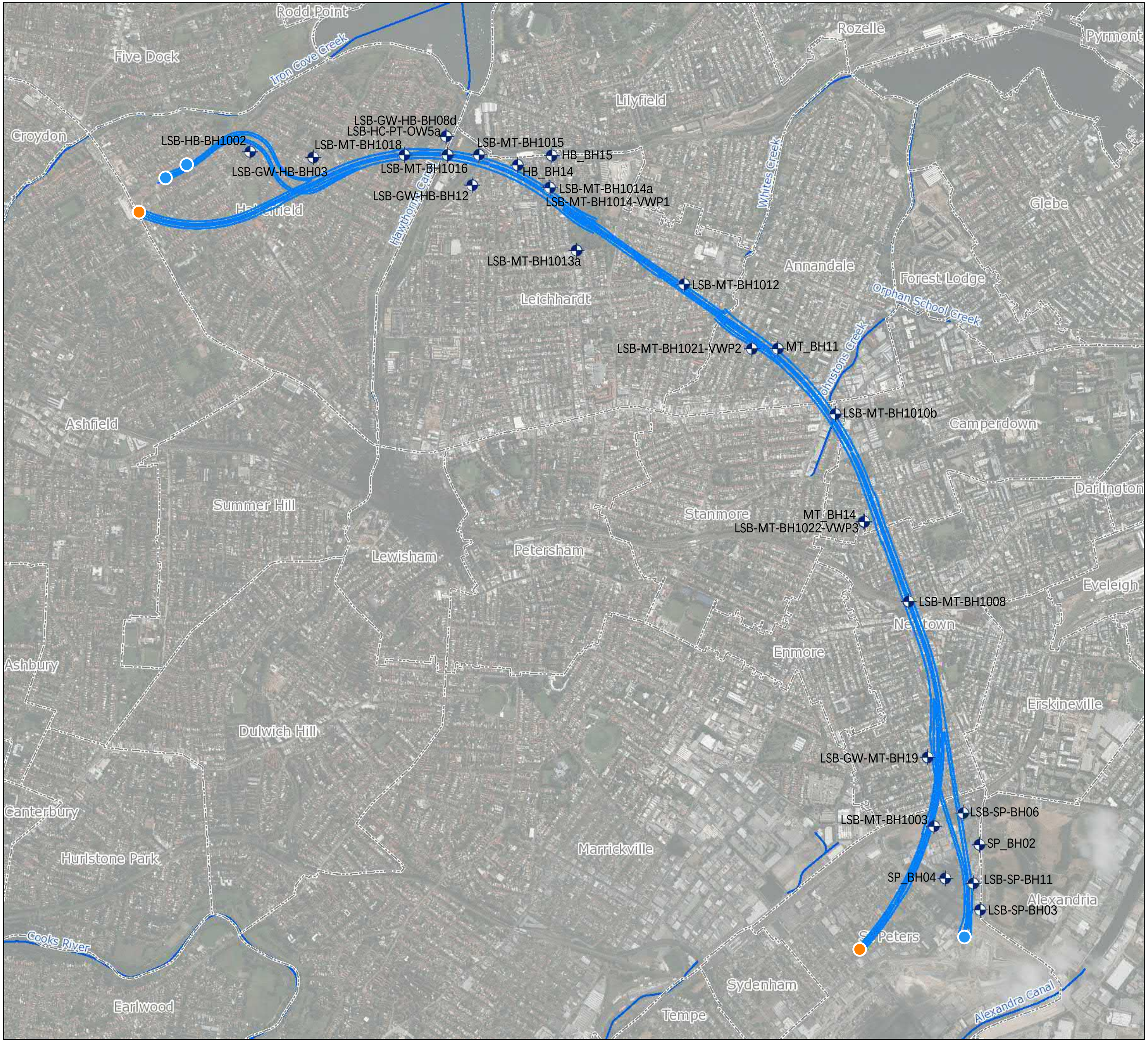
[1]Combined level/electrical conductivity dataloggers to be installed in key monitoring bores

Table 4-5 Deep monitoring wells duplicated following consultation with DoI Water

Exiting well	Duplication well as requested
HB_BH08	LSB-MT-BH1018
HB_BH12	LSB-MT-BH1015
HB_BH14	LSB-MT-BH1016
HB_BH15	LSB-MT-BH1014a
MT_BH02	LSB-MT-BH1012
MT_BH11	LSB-MT-BH1010b
MT_BH14	LSB-MT-BH1008
MT_BH19	LSB-MT-BH1003

WestConnex M4-M5 Link Tunnels
Groundwater monitoring program

Figure 4.2 Location of construction groundwater monitoring bores



0 0.64 1.3 Kilometers
(A3) 1: 25,000

Legend

Groundwater monitoring well

Existing features

Watercourse / drainage line

Project features

Tunnel connection

Tunnel portal

Proposed M4-M5 Link Mainline Tunnel alignment

4.2.2 Groundwater level

Dataloggers will be installed (or maintained from the baseline monitoring phase) in each construction monitoring bore (Table 4-4) to provide continuous data collection. Dataloggers will be programmed to record on six hourly intervals (00:00, 06:00, 12:00, and 18:00). The VWPs will also be equipped with dataloggers set to record pore pressures on six hourly intervals (00:00, 06:00, 12:00, and 18:00).

To supplement the above continuous monitoring, manual measurements will be collected every two months (bi-monthly), pending access, at each bore in the construction monitoring network (Table 4-6). Measurements will be recorded in metres below top of casing (mbTOC), and converted to metres below ground level (mBGL) and metres Australian Height Datum (mAHD).

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.

Table 4-6 Groundwater level monitoring

Monitoring target (aquifer/number of bores)	Datum	Frequency
Alluvium (1 bore)	mBGL; mBTOC; mAHD	6-hourly (via datalogger) Bi-monthly (manual dips)
Ashfield Shale (5 bores)	mBGL; mBTOC; mAHD	6-hourly (via datalogger) Bi-monthly (manual dips)
Hawkesbury Sandstone (21 bores)	mBGL; mBTOC; mAHD	6-hourly (via datalogger) Bi-monthly (manual dips)

mBGL = metres below ground level; mBTOC = metres below top of casing; mAHD = metres above Australian Height Datum

Performance criteria

A groundwater level decline outside of the seasonal fluctuation will be assessed and compared against predicted drawdown as simulated in the groundwater model. The assessment will determine whether the observed decline is attributable to the project and, if so, whether it aligns with approved predictions.

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

4.2.3 Groundwater quality

Dedicated dataloggers with specification allowing the measurement of electrical conductivity (EC) and groundwater level will be installed at the key monitoring bores between the tunnel alignment and saline water bodies (Table 4-4). The dataloggers will be programmed to record all analytes on a six hourly basis (00:00, 06:00, 12:00, and 18:00).

Dataloggers will be downloaded bi-monthly (every two months). Electrical conductivity (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 C12 (d).

Table 4-7 details the parameters to be downloaded and assessed at a bi-monthly frequency at each groundwater quality monitoring bore.

Table 4-7 Groundwater quality monitoring (key monitoring locations[1])

Water quality monitoring bores*	Parameters	Frequency
LSB-SP-BH11 LSB-SP-BH03 LSB-GW-HB-BH08d LSB-HC-PT-OW5a LSB-MT-BH1018 LSB-GW-HB-BH12 LSB-MT-BH1015 HB_BH15 LSB-MT-BH1014a	Electrical Conductivity (EC)	Continuous (dataloggers) Six hourly logging frequency (00:00, 06:00, 12:00, 18:00) Downloaded bi-monthly

[1]Monitoring locations between the tunnel alignment and saline water bodies

A 12 month review of the construction monitoring data was completed to assess the monitoring data and determine the efficiency of the monitoring program and any required changes (reported in the appropriate six-monthly water monitoring report, see Section 6.5).

Performance criteria

Baseline monitoring shows 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 project area.

Site-specific trigger values (SSTV) (Table 4-8) for EC were initially 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 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).

Following 12 months of construction monitoring, SSTV were reviewed and updated to ensure they remained appropriate. This review is presented in Appendix C.

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.

If the exceedance is determined to be attributable to project works and outside of approved model predictions for saline intrusion the groundwater model will be reviewed and updated. The updated model will be used to assess potential impacts and inform potential mitigation measures such as grouting.

Table 4-8 Water quality (electrical conductivity) trigger values

Monitoring bore[1]	Lithology	Baseline 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					

EC = electrical conductivity; µS/cm = micro-siemens per centimetre

[1]Key monitoring locations

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

4.2.4 Tunnel inflow

During construction, groundwater will be intersected and managed by either capturing the water that enters the tunnels, caverns, and portals or by restricting inflow through grouting, temporary dewatering, or the installation of cut-off walls (which limit the movement of groundwater) in cut-and-cover sections.

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

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

Groundwater inflow = WTP discharge – project water inputs

This simplistic approach doesn't consider the water that will be extracted in the spoil. This water is accounted for in groundwater modelling for the Project and is predicted to not contribute to ongoing drawdown and associated impacts. In addition, some forward probing to measure groundwater inflow may be undertaken within specific areas of the tunnel.

High groundwater inflow during excavation conduct is possible in faulted or fractured zones such as beneath the Hawthorne Canal palaeochannel and in the alluvium (AECOM 2017). Grouting will be undertaken as required through the construction program reducing tunnel inflow. Long-term water management solutions will also be constructed such as the installation of water proofing membranes if required.

4.2.5 Tunnel discharge

Metering will be installed at various locations throughout the WTP including to enable the daily measurement of the amount of water discharged from the WTPs;

Further details regarding tunnel discharge are provided in Section 6 of the Groundwater Management Plan.

4.3 Operational monitoring

At regular intervals groundwater pits will be installed to allow measurements of groundwater inflow during operation using probes. The operational groundwater monitoring program will be prepared and implemented in accordance with CoA D8 - D18.

5 Monitoring methodology

5.1 Overview

The methodology for monitoring groundwater for the project includes:

- Assessment of groundwater level (measurement and datalogger download)
- Assessment of groundwater salinity as EC (datalogger download)
- Assessment of WTP discharge water quality (grab samples and analysis)
- 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 (Section 5.3). 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 both metres below top of bore casing (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 automatically 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.

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

The dataloggers will be downloaded bi-monthly. Dataloggers 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 locations and sent to a NATA accredited laboratory for analysis. Further information about WTP monitoring is detailed in Section 6 of the GMP.

5.4.2 Field measurements

Field physico-chemical parameters including temperature, EC, pH, DO, TDS, ORP, and turbidity will be measured at each WTP location using a fully calibrated inline water quality meters. Other observations including odour and colour will also be recorded.

The water quality meter(s) 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.

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. These are to include:

- Rinsate blanks (one per sampling event only)
- Blind duplicates (at a rate not less than 20% of total samples)
- Split duplicates (at a rate not less than 20% of total samples)

Samples are to be 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.

5.4.5 Recording and documentation of results

All monitoring and sampling will be documented and transferred to a central electronic database under the responsibility of the Environment and Sustainability Manager.

Results for each monitoring location will be recorded on appropriate field sheets (hard copy or digital) using unique sampling identification nomenclature consisting of the sample date, location, and sampler details.

The field sheet will detail:

- Prevailing weather conditions
- Prevailing tidal movement (where applicable)
- Name of sampler
- Time and date of sampling.

6 Compliance management

6.1 Roles, responsibility, and training

The ASBJV Project Team's organisational structure and overall roles and responsibilities are outlined in Section 3.1.1 of the CEMP. Specific responsibilities for the implementation of environmental controls are detailed in the GMP.

All employees, contractors and utility staff working on site will undergo site induction and targeted training relating to groundwater management issues detailed in the GMP.

Further details regarding staff induction and training are outlined in Section 3.5 of the CEMP.

6.2 Monitoring and inspection

Section 4.2 and Section 5 of this GWMP provide detailed inspection criteria including:

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

ASBJV's Environmental Management System internal documents relevant to this GWMP are:

- LLE701A - Environmental Work Method Statement (internal document)
- LLE702: Figure 1 - Potential Critical Incident Notification (internal document)
- LLE702A - Environmental Incident Report (internal document)
- LLE702B - Environmental Incident Investigation (internal document)
- LLE703A - Environmental Inspection Checklist (internal document)
- LLE703B - Environmental Observation Report (internal document)
- LLE703C - Environmental Improvement Notice (internal document)
- LLE705A - Sediment Basin Discharge Permit (internal document)
- LLE705B - Dewatering Permit (internal document)

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

6.3 Data analysis

Results from the construction monitoring program will be compared with the SSTVs and groundwater modelling predictions following each bi-monthly sampling event.

Monitoring results for EC will be compared against SSTVs (see Table 4-8) bi-monthly, and reported in the water monitoring reports (Section 6.5). If results trigger a response (see Section 4.2.3), management actions will be implemented as required should an initial review determine a potential impact outside of approved predictions.

The monitoring results for groundwater level and EC will be used to inform the groundwater model updates increasing the confidence level in model predictions with respect to groundwater inflow, drawdown, and saline intrusion. Where required (see Section 4.2) the groundwater model will be calibrated to monitoring results and predictions updated.

6.4 Auditing

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

Audit requirements are detailed in Section 3.9.3 of the CEMP.

6.5 Reporting

During construction, groundwater level and EC will be collected, tabulated and assessed against baseline conditions and performance criteria.

Data provision and reporting requirements associated with the Program for the construction phase of the project are presented in Table 6-1 and Table 6-2 respectively.

Table 6-1 Data provision requirements

Schedule (during construction)	Requirements		Recipient (relevant authority)
Data provision			
Quarterly (every 3 months)	WTP discharge water quality and flow data (raw data collated and tabulated in Excel)	To demonstrate compliance with the CoA (C12(f)), project discharge criteria (defined in Section 4.2.5), EPL, and if applicable ASBJV's trade waste licence.	Sydney Water
Quarterly (every 3 months)	Groundwater level and groundwater quality monitoring data (raw data collated and tabulated in Excel)	To demonstrate compliance with the CoA (C12(g)).	DoI Water

Table 6-2 Reporting requirements

Schedule (during construction)	Requirements	Recipient (relevant authority)
Reporting		
Water Monitoring Reports (every six months)	Data summary reports presenting tabulated groundwater monitoring data collected during the reporting period. Groundwater level hydrographs (including rainfall), tunnel groundwater inflows and water quality results will be presented and SSTV exceedances will be highlighted. Applicable management responses will be documented. Compliance against discharge criteria will also be presented. Report will also present validation of groundwater modelling and determine the need for adjustments to the GWMP (monitoring location, parameters, and frequencies), if necessary.	DPE, DoI Water, Sydney Water

7 Review and improvement

7.1 Continuous improvement

Monitoring data will be reviewed throughout the construction period to provide validation of the groundwater model and potential requirements to increase, or decrease, the number of sampling locations and/or the analytical suites. SSTV were reviewed for appropriateness following 12 months of construction monitoring. Findings of this first review and the recommended SSTV changes are presented in Appendix C. Alterations to monitoring locations, analytical suites, or frequencies will continue to be reviewed and be reported in the construction compliance monitoring reports (Section 6.5).

Continuous improvement of this Program 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 GWMP update and amendment

The processes described in Section 3.9 to Section 3.13 of the CEMP may result in the need to update or revise this Program. This will occur as needed.

Only the Environment and Sustainability Manager, or delegate, has the authority to change any of the environmental management documentation. All amendments to environmental management documentation require endorsement from the Environmental Representative.

A copy of the updated Program and changes will be distributed to all relevant stakeholders in accordance with the approved document control procedure – refer to Section 3.11.2 of the CEMP.

8 References

AECOM, 2017. WestConnex M4-M5 EIS Technical Working Paper: Groundwater, August 2017.

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Bureau of Meteorology (BoM), 2012. National Groundwater Dependent Ecosystems (GDE) Atlas

DPE, 2012. Guideline for riparian corridors on waterfront land.

Department of Land and Water Conservation (DLWC), 2002. NSW Groundwater Dependent Ecosystems Policy.

DLWC, 1998. NSW Groundwater Policy Framework Document.

DLWC, 1998. NSW Groundwater Quality Protection Policy.

DLWC, 1997. NSW Groundwater Quantity Management Policy.

Department of Water and Energy (DWE), 2007. NSW Water Extraction Monitoring Policy.

Environment Protection Authority (EPA), 2004. Approved Methods for the Sampling and Analysis of Water Pollutants in NSW.

NoW Office of Water (NoW), 2011. Water Sharing Plan, Greater Metropolitan Regional Groundwater Sources Background Document, Sydney.

NoW, 2012. NSW Aquifer Interference Policy.

Roads and Maritime Services (Roads and Maritime), 2011. Road and Maritime Dewatering Guideline.

Appendix A Baseline groundwater level monitoring data

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

Appendix B Baseline groundwater quality monitoring data

	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

Appendix C - Site specific trigger value review

Memorandum

Project	M4-M5 Link Tunnels Project
Subject	Groundwater SSTV Review
Date of issue	28 April 2021
Prepared by	[redacted]

1 Introduction

The WestConnex M4-M5 Link is being constructed in two stages:

- Stage 1 (the project and subject of this document): Mainline tunnels; and
- Stage 2: Rozelle interchange including Iron Cove Link.

WestConnex Transurban has engaged the Acciona Samsung Bouygues Joint Venture (ASBJV) to design and construct Stage 1 (herein referred to as the Project). The Project consists of two parallel tunnels, each approximately 7.5 km long, which link the M4 East tunnel at Haberfield with the M8 tunnel at St Peters.

In accordance with Section 7.1 of the Groundwater Monitoring Program, this memo reviews the site-specific trigger values (SSTV) adopted for the Project, following 12 months of construction groundwater monitoring data.

2 Management Plans and requirements

The Minister for Planning approved the M4-M5 Link under Section 5.19 of the Environmental Planning and Assessment Act 1979 (EP&A Act 1979) on 17 April 2018. The State significant Infrastructure approval (SSI 7485) incorporated the Minister’s Conditions of Approval (CoA).

A series of environmental management plans have been prepared to meet the CoA, including the Groundwater Management Sub-Plan (GMP) and Groundwater Monitoring Program (GWMP).

Section 4.2.3 ‘Groundwater Quality’ of the GWMP identified nine groundwater monitoring bores where electrical conductivity (EC) would be monitored to assess changes in water quality that may indicate the intrusion of saline water towards the tunnel in accordance with CoA C12(d). Of those nine, one monitoring bore (LSB-HC-PT-OW5a) is screened in alluvium at Hawthorne Canal.

This section of the GWMP provides the following performance criteria for bores screened in alluvium, Hawkesbury Sandstone (HSS) and Ashfield Shale lithologies:

Table 4-8 Water quality (electrical conductivity) trigger values

Monitoring bore[1]	Lithology	Baseline data			SSTV[2] (µS/cm)
		Sample count	EC min (µS/cm)	EC max (µS/cm)	
LSB-HC-PT-OW5a	alluvium	12	1,561	9,068	5,600
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					

EC = electrical conductivity; µS/cm = micro-siemens per centimetre

[1]Key monitoring locations

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

These SSTV were developed using the baseline data used to inform the EIS (AECOM, 2017) and were derived by calculating the 80th percentile values of baseline EC data.

Section 4.2.3 'Groundwater Quality' of the GWMP states:

> *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%*

3 Review Objectives

Section 7.1 'Continuous Improvement' of the GWMP states that:

> *SSTV will be reviewed for appropriateness following 12 months of construction monitoring. Alterations to monitoring locations, analytical suites, or frequencies will be reported in the construction compliance monitoring reports*

Monitoring commenced at LSB-HC-PT-OW05a in March 2020 prior to tunnel excavation and associated groundwater changes in that area. To date, EC levels in this bore have continuously exceeded the SSTV and therefore requires review to ensure appropriateness.

This memo has been prepared to address GWMP Section 7.1. It considers whether:

- Construction groundwater monitoring data recorded prior to tunnel excavation is consistent with baseline data collected to derive the SSTV for alluvium
- SSTV are appropriate for determining if a management response is required

4 Groundwater Monitoring Data Review

In accordance with the GWMP, EC monitoring is undertaken at one bore (LSB-HC-PT-OW5a) screened in alluvium at Hawthorne Canal.

As detailed above, EC levels have continuously exceeded the baseline data derived SSTV of 5,600 µS/cm since monitoring commenced as shown in Figure 4-1. This SSTV was calculated from monitoring data collected from a different bore installed as part of the EIS (HB_BH08s).

HB_BH08s is located approximately 110 meters south-west of LSB-HC-PT-OW5a as shown in Figure 4-2. Monitoring ceased at HB_BH08s in March 2019 following its decommissioning by the local council. LSB-HC-PT-OW5a was installed by ASBJV to replace HB_BH08s in accordance with the GWMP.

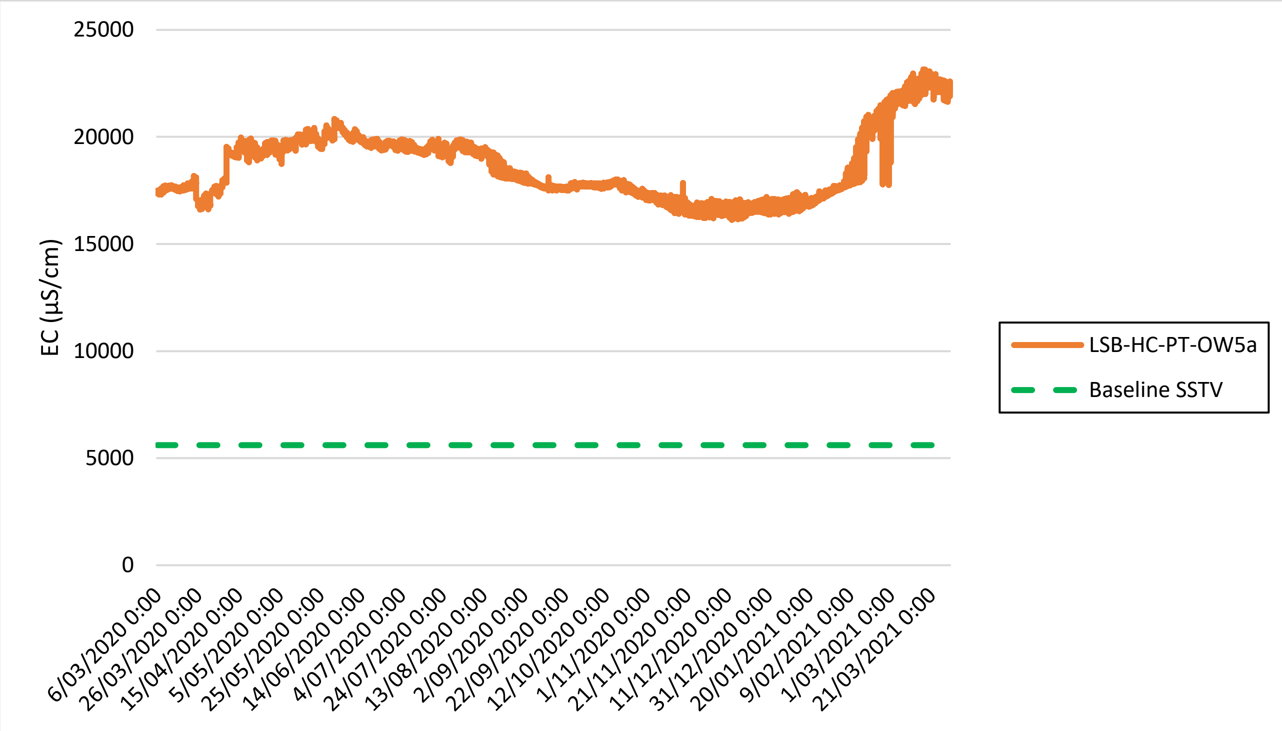

Figure 4-1 EC monitoring results from LSB-HC-PT-OW5a

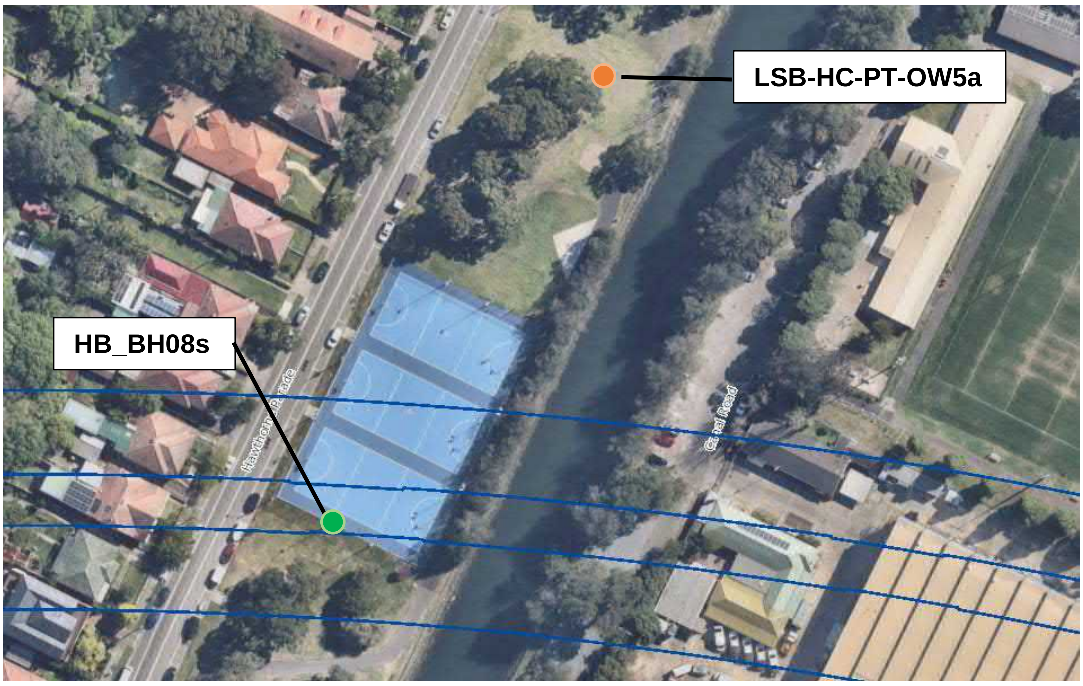

Figure 4-2 Locations of LSB-HC-PT-OW5a and HB_BH08s (Note: Project tunnel alignment shown as blue line)

4.1 Electrical Conductivity Results

Baseline EC data from HB_BH08s and pre-tunnelling data from LSB-HC-PT-OW5a are summarised below in Table 4-1.

EC results from HB_BH08s were substantially lower than LSB-HC-PT-OW5a, with the minimum EC level recorded in LSB-HC-PT-OW5a considerably higher than the maximum EC level recorded in HB_BH08s. This difference suggests that baseline (i.e. pre-impact) EC conditions of HB_BH08s are not similar or representative of LSB-HC-PT-OW5a. Given this difference, using a SSTV derived from HB_BH08s to assess potential impacts on groundwater quality as a result of tunnelling in LSB-HC-PT-OW5a is considered not appropriate.

Table 4-1 EC Monitoring Results Summary Table

Monitoring Bore	Sample Count	EC min (µS/cm)	EC max (µS/cm)	EC 80th Percentile	Baseline SSTV[1]	Proposed SSTV[1]
HB_BH08s	12	1,561	9,068	5,602	5,600	
LSB-HC-PT-OW5a	6,507	16,600	20,838	19,720		19,700

A revised SSTV for EC in alluvium has been developed from pre-tunnelling monitoring data at LSB-HC-PT-OW5a. Consistent with the initial baseline SSTV, it has been derived by calculating the 80th percentile EC value.

[1] SSTV calculated from 80th percentile rounded to the nearest 100

On the basis of the 80th percentile EC value measured in LSB-HC-PT-OW5a (refer to Table 4-1), it is recommended that the SSTV for alluvium is updated to 19,700 µS/cm.

5 Summary

Construction phase monitoring at LSB-HC-PT-OW5a showed EC levels considerably different from EIS alluvial bore HB_BH08s. Given this difference, the SSTV derived from the EIS data is considered not appropriate for assessing potential impacts on groundwater quality and saltwater intrusion as a result of tunnelling.

A review of the SSTV has been undertaken in accordance with Section 7.1 of the Project GWMP. It is recommended that the SSTV for the alluvial monitoring bore LSB-HC-PT-OW5a be increased to 19,700 µS/cm to better allow for changes in groundwater EC to identified and a management response to be implemented where required.