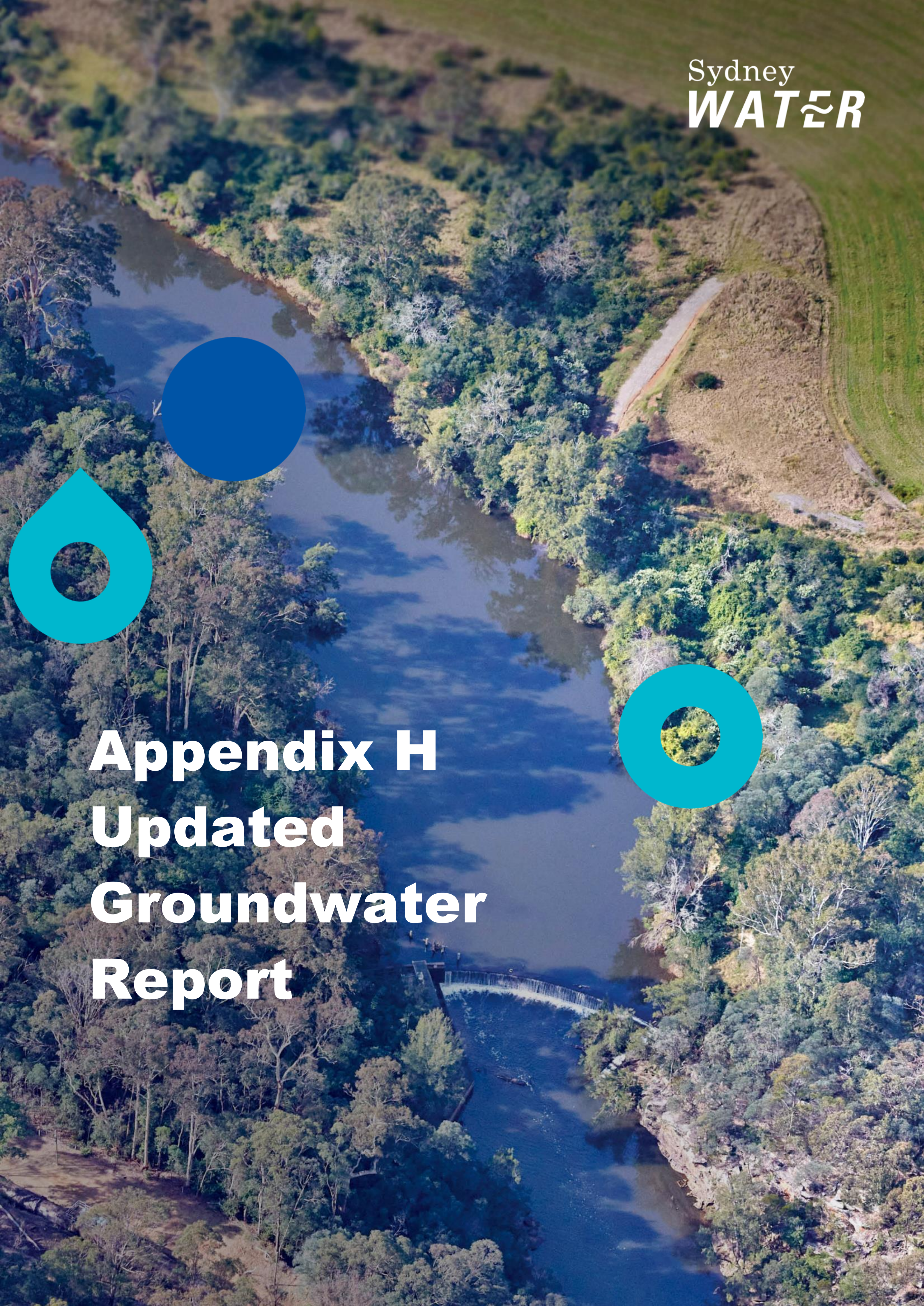

Sydney WATER

Appendix H Updated Groundwater Report

Upper South Creek Advanced Water Recycling Centre

Groundwater Impact Assessment

FINAL

Executive Summary

The objective of the Groundwater Impact Assessment is to identify and address potential impacts to groundwater impacts associated with the construction and operational phases of the Upper South Creek Advanced Water Recycling Centre (AWRC), treated water pipelines, brine pipeline and all ancillary infrastructure (the project). It also aims to provide guidance on ways of mitigating and managing the potential impacts to avoid environmental degradation.

Based on a review of available background information on groundwater conditions across the desktop assessment area, along with an assessment of the existing environmental setting, two principal groundwater systems have been identified and are relevant to this assessment, these are:

- Unconfined to semi-confined groundwater systems associated with Quaternary alluvial deposits, most prevalent in areas surrounding the rivers and streams that intersect the project.
- Unconfined to semi-confined groundwater systems within the bedrock formations (Wianamatta Group formations overlying Hawkesbury Sandstone).

Five key hydrostratigraphic units are identified within the desktop assessment area. Each hydrostratigraphic unit is comprised of geological formations, which have grouped together based on their hydrogeological properties, including the nature and connectivity or the void spacing (porosity and hydraulic conductivity) and transmission / storage properties. The hydrostratigraphic units (in descending stratigraphic order) that have been defined within the desktop assessment area include:

1) Unconsolidated Quaternary alluvial aquifer.
2) Unconsolidated residual / regolith soils associated with weathered Triassic Bringelly Shale.
3) Upper Wianamatta Group (Triassic Bringelly Shale), weathered zone with fractures.
4) Lower Wianamatta Group (Triassic Bringelly Shale, Minchinbury Sandstone and Ashfield Shale), widely spaced fractures.
5) Triassic Hawkesbury Sandstone.

Both alluvial and porous/fractured rock aquifers intersected by the project are categorised as “less productive groundwater sources” as defined by the NSW Aquifer Interference Policy criteria based on the relatively low number of registered supply bores, expected low yields and poor water quality (high salinity).

Several groundwater dependent ecosystems have been identified across the project with a high level of interaction with groundwater. There are currently large volumes of unallocated groundwater in the Water Sharing Plan associated with the desktop assessment area. The desktop assessment area covers the Advanced Water Recycling Centre (AWRC) site and pipeline alignments (treated water pipeline, brine pipeline and environmental flows pipeline) as well as a wider 2 km impact assessment (buffer) area around the project features.

Construction of the proposed AWRC and pipelines has the potential to impact the groundwater systems in a number of ways, including:

- Induced drawdown of groundwater from required construction dewatering activities, reducing the availability of groundwater for Groundwater Dependent Ecosystems and surrounding groundwater users.
- Seepage and/or unintentional return of drilling fluid via groundwater to the surface via preferential pathways (e.g. fault lines, fractures, or loose materials) during Horizontal Directional Drilling construction (frac-outs).
- Mobilisation and migration of contaminated groundwater or acid sulfate soil leachate (resulting from drawdown), altering pH and water quality, and causing potential soil contamination and possible downstream ecological impacts.

- Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increasing the turbidity and reducing the water quality in receiving waters.
- Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts.
- Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.
- Disruption of surface water and groundwater connectivity.

Operation of the proposed AWRC and pipelines has the potential to impact the groundwater systems in several ways:

- Induced drawdowns from any underdrainage systems employed for underground structure floatation management, reducing the availability of groundwater for GDEs and surrounding groundwater users.
- Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery at the AWRC, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.
- Groundwater seepage via preferential pathways (e.g. fault lines, fractures, or loose materials) after HDD construction.
- Leakage of water from pipelines during operation resulting in localised increases to groundwater levels and degradation in groundwater quality. Water transmitted through the treated water and environmental flows pipelines will be predominately fresh and unlikely to cause direct significant impacts to groundwater quality. Water transmitted through the brine pipeline will have much higher total dissolved solids and any leaks/bursts occurring across this pipeline has the potential to cause direct localised degradation of groundwater quality and/or groundwater dependent ecosystems.
- Increased groundwater recharge from stormwater irrigation at the AWRC site, leading to increased water levels of saline aquifer.

To minimise impacts to groundwater systems, a range of mitigation measures would be implemented during the detailed design, construction and operational phases of the project. These include:

- Design and construction of trench/shaft support systems that minimise groundwater drawdowns (e.g. sheet piling), particularly in areas with coarse-grained soils with higher hydraulic conductivity and storage properties.
- Where feasible, “key” the trenchless launch and reception shafts into underlying material with relatively low permeability (e.g. competent bedrock) to reduce the amount of groundwater that may enter through the floor.
- Adopting a staged approach to dewatering through dewatering in discrete, areas aligned closely with the construction schedule.
- Developing and implementing an approach to manage extracted groundwater. Depending on extracted groundwater quality, treatment may be required to meet the applicable water quality criteria, prior to discharge (e.g. to a receiving surface water body).
- Install permanent vertical cut-offs within the trench to prevent the lateral migration of groundwater along the alignment of the pipelines. In the residual / regolith soils associated with weathered Bringelly Shale, which is expected to have relatively low permeability, these trench cut-offs may be located at spacings of several hundred metres. In alluvial soils, or at river crossings, trench cut-off spacing should be significantly smaller e.g. every ten metres. Horizontal trench cut-offs should also be considered where the perched aquifers are encountered, to prevent lateral migration and dewatering of the system. Maintenance of the perched layers may also be achieved through backfilling to prevent vertical migration.

The majority of these groundwater impacts would be constrained to a short period of time during construction and are not expected to impact the long-term viability of the affected ecosystems or groundwater resources.

Dewatering estimates indicate that approximately 64 ML of groundwater will be extracted from the “Sydney Basin Central” groundwater source and 1.89 ML of groundwater will be extracted from the “Sydney Basin Nepean” groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011) during construction of the project.

The degree or severity of any impact during construction is largely based on the duration of dewatering and disruption of groundwater connection to any potential GDEs in the vicinity where a disruption occurs. Other factors include the depth to the groundwater table which influences the extent of dewatering required and the hydraulic characteristics of the intersected ground material.

A groundwater quantity (i.e. levels and dewatering volumes) and quality monitoring program is recommended. Monitoring should incorporate pre-construction monitoring of groundwater conditions to form a baseline dataset to which the construction and operational monitoring data could be compared against. The baseline dataset would assist in developing site-specific action levels and responding to any identified impacts during construction and operation.

Based on the available information and the analyses conducted in this impact assessment, with the successful implementation of the proposed mitigation measures the impacts to groundwater systems across the project are expected to be of low significance overall, with a minor contribution to any foreseen cumulative groundwater impacts from other identified projects in the vicinity.

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Document title		Groundwater Impact Assessment		**File reference:** as above	
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		Name	Harry Gregg	David Harris	Freeternity Rusinga
		Signature			

Issue Document Verification with Document ✓

Glossary and Abbreviations

Term	Abbreviation	Definition
Advanced Water Recycling Centre	AWRC	Proposed centre for treatment of the wastewater prior to reuse applications or discharge, which includes liquids treatment, advanced water treatment, solids treatment, odour treatment, and residuals management
Ancillary infrastructure	-	This is permanent infrastructure to support operation of the AWRC and may include a range of infrastructure such as access roads and provision of utilities such as power.
Australian Height Datum	AHD	A common reference level used in Australia which is approximately equivalent to the height above sea level in metres.
Brine pipeline	-	A pipeline to transport brine (salty/concentrated wastewater). Brine water is a by-product of reverse osmosis in the wastewater treatment process.
Construction Environmental Management Plan	CEMP	A CEMP describes how activities undertaken during the construction phase of development will be managed to avoid or mitigate environmental or nuisance impacts, and how those environmental management requirements will be implemented.
Critical State Significant Infrastructure	CSSI	Critical State significant infrastructure projects are high priority infrastructure projects that are essential to the State for economic, social or environmental reasons.
Desktop assessment area	-	The area defined for footprint-related specialist desktop assessments.
Drawdown		Reduction in hydraulic head in an aquifer due to an applied stress (e.g. pumping from a well)
Electrical Conductivity	EC	The ability of a material to conduct an electric current. In groundwater studies, electrical conductivity is used as an indicator of water quality, as it relates to the concentration of charged particles in water. Electrical conductivity provides an indication of the amount of total dissolved solids and the amount of salts in the water.
Environmental Impact Statement	EIS	An Environmental Impact Statement is a publicly available document that provides information on a project, including its environmental impacts and mitigation measures, and is used to inform development consent decisions
Environmental flows	-	Environmental flows refer to water released from a dam or weir to sustain healthy rivers. Some of the Sydney Water wastewater treatment and water recycling facilities also release treated wastewater into creeks and rivers. This can help improve conditions for native fish, frogs, birds, plants and other animals. It can also reduce the likelihood of algal blooms and enhance recreational uses. Environmental Flows from the AWRC may be used, supplement or replace flows that would have been released from Warragamba Dam.
Environmental Values	EVs	Environmental Values for water are the qualities that make it suitable for supporting aquatic ecosystems and human water uses. These qualities need to be protected from the effects of habitat alteration, waste releases, contaminated run-off and changed flows to ensure healthy aquatic ecosystems and waterways that are safe for community use.

Term	Abbreviation	Definition
Highly treated water	-	What wastewater becomes after it has been treated. We treat wastewater so clean water can be safely returned to the environment or re-used. We filter the water and disinfect it with chlorine or ultraviolet light (UV). This kills any remaining microorganisms. We force the water at high pressure through reverse osmosis membranes to remove even smaller bacteria and particles. This is the finest level of filtration.
Hydraulic Conductivity		The measure of how easily water can pass through a porous material. High values indicate permeable material through which water can pass easily and low values indicate a less permeable material. Hydraulic conductivity is dependent upon the intrinsic permeability of the material, the degree of saturation and the fluid properties (i.e. density and viscosity).
Hydrostratigraphic unit		A general grouping of geologic materials that form a distinct hydrologic unit with respect to the flow and behaviour of groundwater.
Impact assessment area	-	The area within which project impacts may occur. This will be larger than the actual impact area to give some flexibility with regards to exacts construction locations. This may be refined as the infrastructure reference design progresses.
Impact area	-	This refers to the actual area impacted by construction and operation. Sydney Water has indicated an expected impact corridor of 25 metres either side along the pipeline alignments.
Porosity		A measure of the void spaces within a material, presented as a fraction of the volume of void spaces over the total volume (between 0 and 1 or a percentage between 0% and 100%)
Project	-	The construction and operation of the Upper South Creek Advance Water Recycling Centre (AWRC), pipelines and all ancillary infrastructure. Construction of the AWRC is subject to environmental approval and has been identified as critical infrastructure. There are many stages and we are at the very early planning. Detailed construction staging will be established by the detailed design contractor. Noting that the timelines aren't finalised, it's expected that construction will start in mid-2022.
Radius of influence		The maximum distance from an applied stress at which the drawdowns can be detected.
Secretary's Environmental Assessment Requirements	SEARs	These are issued by the Secretary of the NSW Department of Planning and Environment for projects declared by the Minister of Planning as Critical State Significant Infrastructure. These SEARS provide the technical requirements for the impact assessment of each potential key issue, including the desired performance outcome, requirement and current guidelines.
Service area	-	The intention is to treat wastewater from Western Sydney Airport, Western Sydney Aerotropolis Growth Area (WSAGA) and South West Growth Area (SWGA). Additional areas may be transferred over time, pending growth distribution and servicing efficiency analysis.

Term	Abbreviation	Definition
		Sydney Water is currently planning for the major wastewater pipelines and other infrastructure required to transfer wastewater from these servicing areas to the AWRC site for treatment.
Temporary ancillary facilities	-	These are temporary facilities to support construction including: ■ Access roads ■ Construction compounds ■ Laydown areas ■ Parking ■ Site offices and amenities.
Treated water pipeline	-	The pipelines that will convey the treated effluent water to the receiving environment. The pipelines will transport water from the AWRC to the discharge points at the Nepean and Warragamba Rivers. These pipelines will range in size from about 0.6 m to 1.5 m in diameter and will generally consist of steel, glass reinforced plastic and polyethylene pipe materials.
Upper South Creek	USC	The catchment in which the AWRC will be located. South Creek discharges to the Nepean River which flows directly into the Hawkesbury River and then discharges out to the Pacific Ocean
Wastewater	-	The used water from baths, showers and washing machines ('greywater') and toilets ('blackwater') and enters into the sewerage system. About 99% of this is water with the remaining 1% composed of the components added to water during the previous use.
Water Quality Objectives	WQO	Water Quality Objectives are long-term goals for water quality management. They are measures, levels or narrative statements of indicators of water quality that protect EVs. They define what the water quality should be to protect the EVs—after consideration of the socio-economic assessment of protecting the water quality.

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Appendices

1 Introduction

1.1 Background

The Groundwater Impact Assessment has been undertaken to support the Environmental Impact Statement (EIS) for the Upper South Creek Advanced Water Recycling Centre (AWRC) along with its ancillary infrastructure (henceforth referred to as "the project"). The AWRC will be located in Kemps Creek, NSW, with pipelines traversing Western Sydney from the Nepean River in the West to Cabramatta in the East (**Figure 1-1**).

This report provides a review of the existing groundwater conditions and potential project impacts during the construction and operation phases. It also provides recommended mitigation measures to minimise any identified residual impacts.

The project is State Significant Infrastructure (SSI) and the Secretary of the Department of Planning, Industry and Environment has issued project specific environmental assessment requirements (SEARs). This report addresses the project specific SEARs relating to groundwater (see **Section 1.4**).

Potential adverse impacts to receiving surface waters are addressed in the Surface Water Impact Assessment report (Aurecon Arup, 2021).

1.2 Project Overview

Sydney Water is planning to build and operate new wastewater infrastructure to service the South West and Western Sydney Aerotropolis Growth Areas. The proposed development will include a wastewater treatment plant in Western Sydney, known as the Upper South Creek Advanced Water Recycling Centre. Together, this Water Recycling Centre and the associated treated water and brine pipeline, will be known as the 'project'. An overview of the location of the proposed infrastructure is provided in **Figure 1-1**. Further details of each component of the project are provided in chapter 6.

1.2.1 Advanced Water Recycling Centre (AWRC)

A wastewater treatment plant with the capacity to treat up to 50 ML of wastewater per day, with ultimate capacity of up to 100 ML per day

The AWRC would produce:

- High-quality treated water suitable for a range of uses including recycling and environmental flows.
- Renewable energy, including through the capturing of heat for cogeneration.
- Biosolids suitable for beneficial reuse.
- Brine, as a by-product of reverse osmosis treatment.

1.2.2 Treated water pipelines

The treated water pipelines refer to:

- A pipeline about 17 km long from the Advanced Water Recycling Centre to the Nepean River at Wallacia Weir, for the release of treated water.
- Infrastructure from the Advanced Water Recycling Centre to South Creek to release excess treated water and wet weather flows.

- A pipeline about five kilometres long from the main treated water pipeline at Wallacia to a location between the Warragamba Dam and Warragamba Weir, to release high-quality treated water to the Warragamba River as environmental flows.

1.2.3 Brine pipeline

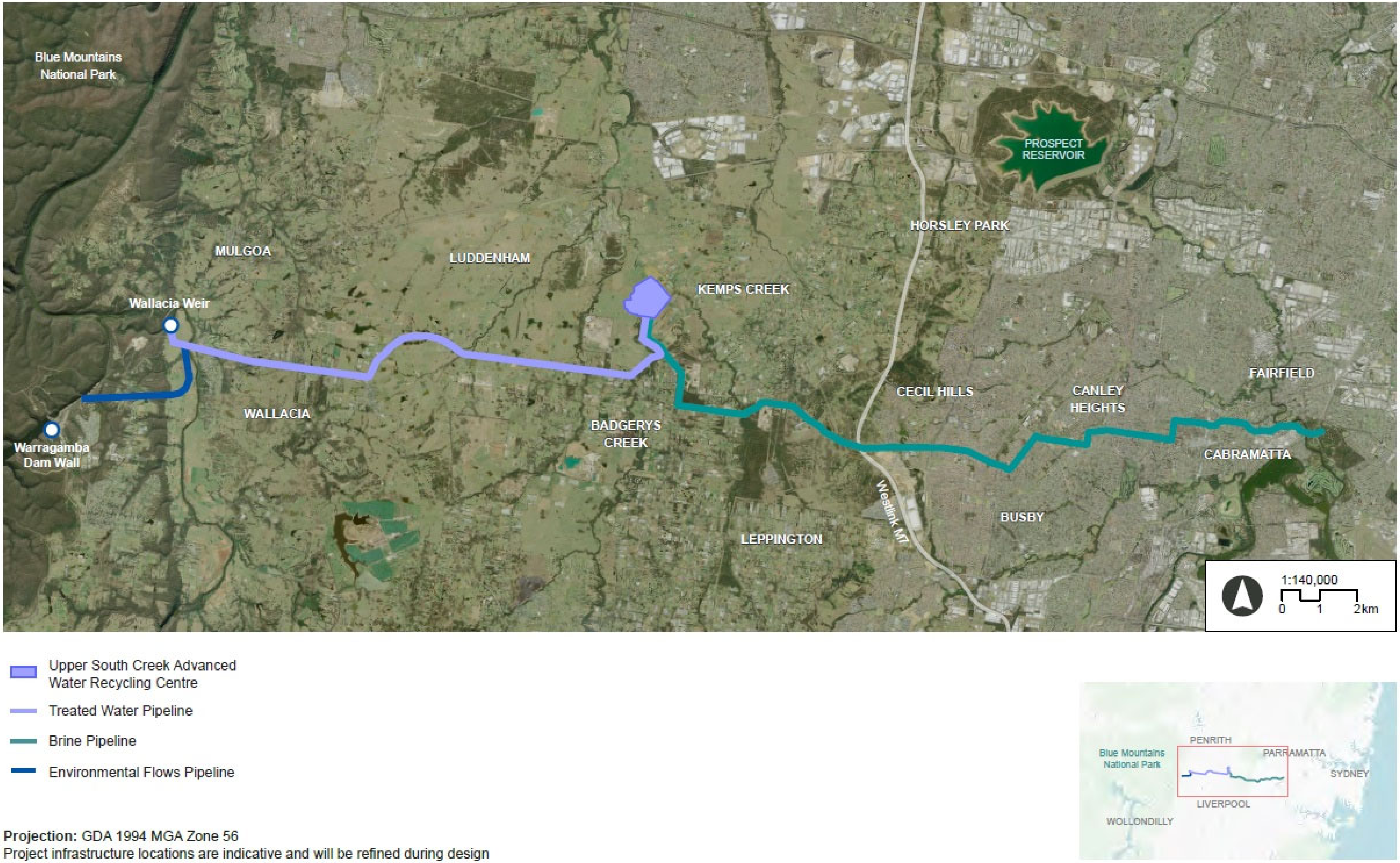
The Brine pipeline refers to:

- A pipeline about 24 km long that transfers brine from the Advanced Water Recycling Centre to Lansdowne, in south-west Sydney, where it connects to Sydney Water's existing Malabar wastewater network.

Sydney Water is planning to deliver the project in stages, with Stage 1 comprising:

- Building and operating the Advanced Water Recycling Centre to treat an average dry weather flow of up to 50 ML per day.
- Building all pipelines to their ultimate capacity, but only operating them to transport and release volumes produced by the Stage 1 Advanced Water Recycling Centre.

The timing and scale of future stages will be phased to respond to drivers including population growth rate and the most efficient way for Sydney Water to optimise its wastewater systems.



Projection: GDA 1994 MGA Zone 56
Project infrastructure locations are indicative and will be refined during design

Figure 1-1 USC AWRC Project Overview

1.3 Study Objectives

The objective of the *Groundwater Impact Assessment* is to assess and address potential groundwater impacts associated with the construction and operational phases of the project. It also aims to provide guidance on ways of mitigating and managing the potential sources of impacts to avoid environmental degradation.

A reference design for the Project has been developed which informs the various impact assessments. Several studies have been undertaken in parallel to cover various aspects relating to the potential water environment impacts. These studies and the extent of each study's considerations are indicated in **Figure 1-2**.

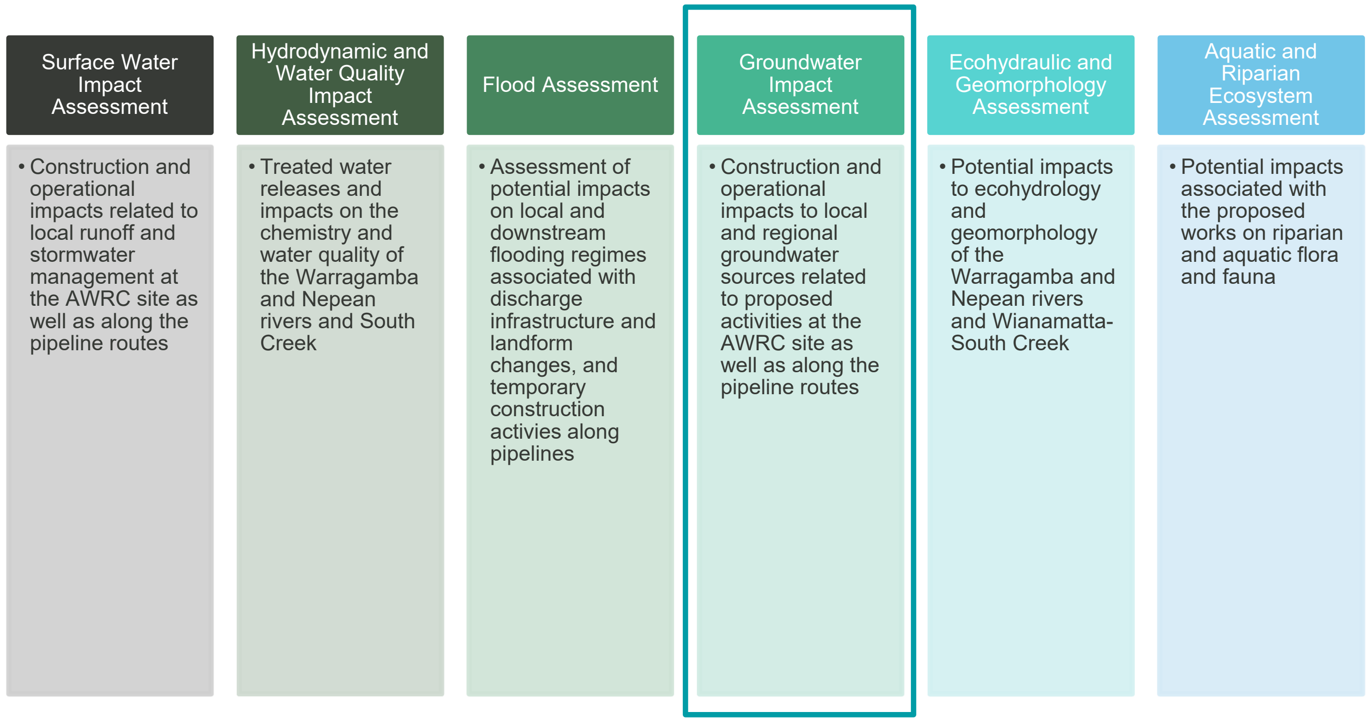


Figure 1-2 Specific water cycle impacts addressed by each study in this EIS

1.4 Secretary environmental assessment requirements (SEARs)

The project is State Significant Infrastructure (SSI) and the Secretary of the Department of Planning, Industry and Environment has issued project specific environmental assessment requirements (SEARs). These SEARs provide the technical requirements for the impact assessment of each potential key issue, including the desired performance outcome, requirement and current guidelines.

The scope of work undertaken to address groundwater related matters for each component of the issued SEARs is summarised in **Table 1-1**.

Table 1-1 Groundwater related project specific SEARS and associated scope of works

Requirement (groundwater specific assessment requirements in addition to the general requirements)	Scope of work undertaken to address	Location addressed in report
1. Water Describe background conditions for any water resource likely to be affected by the development, including:		
a) existing surface and groundwater	Description of the receiving hydrogeological environment (including a hydrogeological conceptual model). Surface water conditions are described in the *Surface Water Impact Assessment* report.	Section 4.3 Section 4.5
c) Water Quality Objectives (as endorsed by the NSW Government) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	Applicable groundwater quality objectives are stated. WQO's related to surface water are provided in the *Surface Water Impact Assessment* report.	Section 2.2
d) indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	Applicable groundwater quality objectives are stated. WQO's related to surface water are provided in the *Surface Water Impact Assessment* report.	Section 2.2
2. Assess the impacts of the development on water quality, including:		
a) the nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of	Available groundwater quality data within the desktop assessment area (defined in Section 3.2) has been collated and compared against applicable legislation, WQ objectives and trigger values. The potential changes to the to the receiving hydrogeological environment during the construction and operational phases of the project (AWRC and pipelines) entering South Creek and the local creeks along the pipeline have been assessed using groundwater numerical modelling (AWRC site) and analytical modelling (pipelines).	Section 9.1 Section 9.2

Requirement (groundwater specific assessment requirements in addition to the general requirements)	Scope of work undertaken to address	Location addressed in report
proposed stormwater and wastewater management during and after construction.	Where impacts to the receiving hydrogeological environment have been identified, mitigation measures have been proposed. The proposed mitigation measures have been assessed for both the operational and construction phases of the project.	
b) Identification of proposed monitoring of water quality	Recommendations for future monitoring to establish a pre-construction baseline, in addition to monitoring during the project construction and operation phases are provided.	Section 11
3. Assess the impact of the development on hydrology, including:		
a) water balance including quantity, quality and source.	Water-take / discharge activities associated with potential dewatering requirements during construction and operation have been included in this assessment. Stormwater discharge and both an operations water balance as well as an environmental water balance for the AWRC site have been developed in the *Surface Water Impact Assessment* report. The primary treated water discharge location will be to the Nepean River and potential associated impacts have been assessed and are documented in the *Hydrodynamic and Water Quality Impact Assessment* report.	Section 9.1 Section 9.2
c) effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.	Potential changes to the receiving hydrogeological environment have been assessed and compared to existing conditions. Impacts to Groundwater Dependent Ecosystems (GDEs) are included in this assessment and also documented in the Aquatic Ecology Impact Assessment.	Section 4.8 Section 7.2 Section 8
g) identification of proposed monitoring of hydrological attributes.	The proposed monitoring during the project construction and operation phases has been included where relevant to groundwater. Other monitoring recommendations will align with the programmes proposed in the other water studies.	Section 10
4. Map		
c) groundwater	Features relevant to the existing hydrogeological environment (including a hydrogeological conceptual model) have been mapped.	Section 4.5 Section 5
d) groundwater dependent ecosystems	GDE's have been mapped in this assessment and the *Aquatic Ecology Impact Assessment* report.	Section 4.8
7. Consult/coordinate with the Department of Planning, Industry and Environment (and Planning Partnership Office) in respect to environmental impacts on the South Creek catchment and the Wianamatta South Creek program. This includes:		

Requirement (groundwater specific assessment requirements in addition to the general requirements)	Scope of work undertaken to address	Location addressed in report
c) assess the potential impacts on the quantity and quality of surface and groundwater resources along South Creek, including the implications of dry and wet weather flows from the project.	Potential groundwater related impacts associated with development along South Creek have been identified and assessed. Mitigation measures to prevent, minimise and / or contain these impacts are included. Potential impacts associated with site-runoff on the quantity and quality of surface water resources along South Creek have been assessed in the *Surface Water Impact Assessment* report. Dry and wet weather treated effluent discharges have been assessed in the *Hydrodynamic and Water Quality Impact Assessment, Aquatic Ecology Impact Assessment and Ecohydraulic and Geomorphology Impact Assessment* reports.	Section 8.1.1 Section 8.1.2 Section 9.1 Section 9.2
d) details about how the project will be designed, operated and maintained to ensure post-development flows do not exceed pre-development flows into and through the Pipelines Corridor and additional surface and groundwater entering the Pipelines Corridor must be prevented.	Potential operational impacts from groundwater entering the Pipelines Corridor has been assessed and mitigation measures developed. An assessment of pre-development and post-development surface flows has been documented in the *Surface Water Impact Assessment and Flood Impact Assessmen*t reports.	Section 9.1 Section 9.2

2 Legislation, policy and guidelines

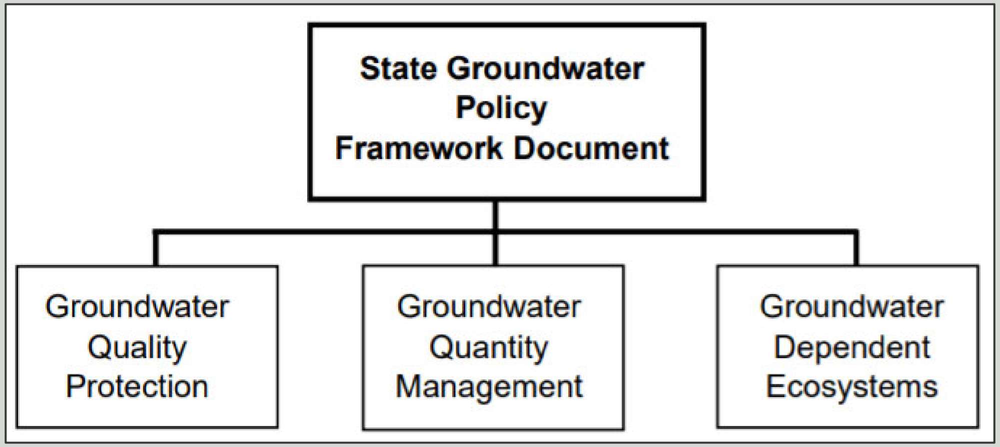
2.1 General legislation, policy and guidelines

This section summarises the current legislative requirements and guidelines relevant to groundwater considerations for the project.

Table 2-1 Legislation and policy context

Legislation/Policy	Brief description and intent	Relevance to project
Water Act 1912, Water Management Act 2000 Water Management Regulation 2018	The objects of the Water Management Act 2000 are to provide for the sustainable and integrated management of the water sources of the state for the benefit of both present and future generations. In NSW, the regulator and policy maker for water resource management is the NSW Department of Planning, Industry and Environment – Water (DPIE Water). The department develops natural resource management policy frameworks, strategies and plans related to water management. DPI Water is accountable for water sharing plans (WSPs), which define the rules for sharing the water resources of each regulated river valley between consumptive users and the environment. WSPs are made under the Water Management Act 2000. In accordance with section 5.23(1) of the EPA act the following approvals which may have otherwise been required to undertake the project would not be required: ■ Water use approval under section 89 of the WM Act ■ Water management work approval (including a water supply works approval) under section 90 of the WM Act ■ Activity approval (other than an aquifer interference approval) under section 91 of the WM Act.	Consideration of the project against the objects, water management principles and the applicability of access licence dealing principles under the Water Management Act, 2000. The project is located within an existing Water Sharing Plan (discussed below) for which the Water Management Act applies. An aquifer interference approval under section 91 of the WM Act is required.
Water Sharing Plan	The project is located within the existing Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. The Water Sharing Plan area covers approximately 32,500 km^2, spanning from the Hawkesbury River catchment in the north, Shoalhaven River catchment in the south/south-west and Lithgow/Goulburn in the west. The plan covers 13 distinct groundwater sources, the project is predominately located within the "Sydney Basin Central" groundwater source, with the exception of the project features that lie west of the Nepean River. West of the Nepean River, the project is located within the "Sydney Basin Nepean" groundwater source area Within the Sydney Basin Central groundwater source, there are currently 187 aquifer access licences, with a total volume of water made available of 3,929.5 ML/year. The long-term average	As more than 3 ML/year of groundwater is anticipated to be extracted for the Sydney Basin Central Groundwater Source, a Water Access Licence, under the Water Management Act 2000, must be sought through the Natural Resource Access Regulator (NRAR). The water access licence would specify the allocated shares in the Water Sharing Plan and the allowable groundwater extraction rates, timing and location(s). The water access licence would specify the allocated shares in the Water

Legislation/Policy	Brief description and intent	Relevance to project
	annual extraction limit for the Sydney Basin Central groundwater source is 45,915 ML/year, which approximates to 20% of the total estimated annual aquifer recharge rate of 229,223 ML/year for the area (Water NSW, 2022). Within the Sydney Basin Nepean groundwater sources, there are currently 388 aquifer access licences, with a total volume of water made available of 31,446.4 ML/year. The long-term average annual extraction limit for the Sydney Basin Central groundwater source is 99,568 ML/year, which approximates to 40% of the total estimated annual aquifer recharge rate of 244,483 ML/year for the area (Water NSW, 2022). Therefore, the project lies within groundwater source areas that currently have large volumes of unassigned water (i.e. those that have not reached the long-term average annual extraction limit set in the Water Sharing Plan).	Sharing Plan and the allowable groundwater extraction rates, timing and location(s). Water Access License and shares in the groundwater source(s), may be purchased through a controlled allocation order (DPIE, 2021) to make new water access licences available. The order made in October 2021 makes aquifer access licences available in specific groundwater sources that have unassigned water (i.e. those that have not reached the long-term average annual extraction limit set in the Water Sharing Plan). Under the Environmental Planning and Assessment Act 1979, the project may be exempt from the need to hold an approval under the Water Management Act 2000 prior to taking from the groundwater source(s), due to the project's status as State Significant Infrastructure (SSI).
The NSW State Groundwater Policy Framework (Department of Land & Water Conservation (DLWC), 1998)	The NSW State Groundwater Policy Framework was established to manage groundwater resources in NSW so that they can sustain environmental, social and economic uses for the people of NSW, so as to: ▪ Slow and halt or reverse any degradation of groundwater resources. ▪ Ensure long term sustainability of the systems ecological support characteristics. ▪ Maintain the full range of beneficial uses of these resources. ▪ Maximise economic benefit to the Region, State and Nation. The framework includes a set of three component policies, providing principles concerning the management of groundwater dependent ecosystems, groundwater quantity and groundwater quality. The policy relationships are shown in **Figure 2-1.** Each of these component policies are discussed in further detail in subsequent rows below.	The policy identifies management tools to achieve groundwater protection, some of which are relevant to the development of the project, including groundwater quality protection, groundwater quantity management and protection of groundwater dependent ecosystems.

Legislation/Policy	Brief description and intent	Relevance to project
	 **Figure 2-1 NSW State Groundwater Policy Framework and component policy relationships.**	
NSW Groundwater Quality Protection Policy (DLWC, 1998)	The NSW Groundwater Quality Protection Policy adopts the principles outlined in the NSW State Groundwater Policy Framework Document in relation to groundwater quality protection, and specifically the following management principles: ■ All groundwater systems should be managed so that the most sensitive identified beneficial use (or environmental value) is maintained. ■ Town water supplies should be afforded special protection against contamination. ■ Groundwater pollution should be prevented so that future remediation is not required. ■ For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the resource. ■ A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation or receiving waters. ■ Groundwater dependent ecosystems will be afforded protection. ■ Groundwater quality protection should be integrated with the management of groundwater quantity.	The policy identifies management tools to achieve groundwater protection, some of which are relevant to the development of the project, including the use of groundwater management plans, groundwater vulnerability mapping and groundwater monitoring. The project may also impact on groundwater dependent ecosystems which are afforded special protection under the NSW Groundwater Protection Policy. The policy is relevant to the project in governing how groundwater quality impacts are assessed in relation to surrounding groundwater dependent ecosystems and groundwater users. Groundwater beneficial use categories are defined in the policy based on ranges of background concentrations of Total Dissolved Solids (TDS) (a measure of salinity) in the groundwater source (detailed in Section 2.2.1). The overriding

Legislation/Policy	Brief description and intent	Relevance to project
	■ The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource. ■ Where possible and practical, environmentally degraded areas should be rehabilitated, and their ecosystem support functions restored.	principle is that groundwater quality should be maintained within its beneficial use category. The potential impacts to groundwater dependent ecosystems have also been assessed in the *Aquatic and Riparian Ecosystem Impact Assessment* report.
NSW Groundwater Quantity Protection Policy (DLWC, 1998)	The NSW Groundwater Quantity Protection Policy adopts the principles outlined in the NSW State Groundwater Policy Framework Document in relation to groundwater quantity protection, and specifically the following management principles: ■ Total use of groundwater in a water source or zone will be managed within the sustainable yield, so that groundwater is available for future generations, and dependent ecological processes remain viable. ■ Significant groundwater dependent ecosystems must be identified and protected. ■ Total licensed entitlements will not exceed 125% of the sustainable yield in currently over-allocated groundwater sources or zones. ■ Groundwater access must be managed in such a way that it does not cause unacceptable local impacts. ■ Artificial recharge of groundwater will be strictly controlled. ■ Landholders overlying an aquifer will have basic right to access groundwater for domestic and stock purposes. ■ Access to groundwater will be managed according to an established priority of use. ■ All rights (excepting basic rights) to access and extract groundwater must be licensed and metered. ■ In systems that are not subject to a licence embargo or a Ministerial order, groundwater access licences will be issued on the basis of demonstrated need, within the sustainable yield. ■ Groundwater access licence holders have resource stewardship obligations and are required to abide by the conditions of their licence. ■ Permanent and temporary transfer of groundwater access will be permitted within sustainable yield constraints, if the transfer does not cause unacceptable impacts on other users, water quality or dependent ecosystems. Inter-aquifer transfers will not be permitted.	This policy details the various mechanisms available for sustainable groundwater resource management, recognising the variety of aquifer types and behaviours and the need for flexible management, whilst safeguarding dependent ecosystems and reducing interference effects between users. The policy is relevant to the project in governing how groundwater level/availability impacts are assessed in relation to surrounding groundwater dependent ecosystems and groundwater users.

Legislation/Policy	Brief description and intent	Relevance to project
	■ Within environmental and interference constraints, the management of groundwater access should provide business flexibility for existing users through carryover and borrowing provisions on annual entitlements. ■ Approvals must be obtained before any groundwater access licence can be activated at a particular location. ■ All activities or works that intersect an aquifer and are not for the primary purpose of extracting groundwater, need an aquifer interference approval.	
NSW Groundwater Dependent Ecosystems Policy (Department of Land & Water Conservation, 2002)	Groundwater Dependent Ecosystems (GDEs) refer to both terrestrial and aquatic ecosystems that require access to groundwater to meet all or some of their water requirements for their ecological processes and ecosystem services. The GDE Policy adopts principles outlined in the NSW State Groundwater Policy Framework Document and provides a framework the management of GDEs in NSW, including: ■ The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected. ■ Groundwater extraction should be managed within sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems area maintained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health, and controls on extraction in the proximity of groundwater dependent ecosystems. ■ Priority should be given to ensuring that sufficient groundwater of suitable quality is available at the time when it is needed, for: ■ Protecting ecosystems which are known to be, or are most likely to be, groundwater dependent. ■ For the GDEs which are under an immediate or high degree of threat from groundwater-related activities. ■ Where scientific knowledge is lacking, the Precautionary Principle should be applied to protect GDEs. The development of adaptive management systems and research to improve understanding of these ecosystems is essential to their management. ■ Planning, approval and management of development and land use activities should aim to minimise adverse impacts on GDEs by.	The policy contains management principles and methods to protect GDEs that may be relevant if these ecosystems are encountered during the development and /or operation of the AWRC. The policy is relevant to the project in governing how groundwater impacts are assessed in relation to surrounding groundwater dependent ecosystems. The potential impacts to groundwater dependent ecosystems has also been assessed in the *Aquatic and Riparian Ecosystem Impact Assessment* report.

Legislation/Policy	Brief description and intent	Relevance to project
	■ Maintaining, where possible, natural patterns of groundwater flow and not disruption groundwater levels that are critical for ecosystems. ■ Not polluting or causing adverse changes in groundwater quality. ■ Rehabilitating degraded groundwater systems where practical.	
NSW Aquifer Interference Policy (2012)	The NSW Aquifer Interference Policy (NSW DPI, 2012) outlines the requirements to minimise impacts to a groundwater system (minimal impact considerations for water table, water pressure and water quality), with consideration for high priority groundwater dependent ecosystems (GDE), high priority culturally significant sites and existing groundwater users (as identified in the Water Sharing Plan. The aquifer interference conditions that apply to the project, in relation to the location of any high priority GDE or high priority culturally significant site, are outlined in **Sections 2.2** and **2.3** below. Groundwater sources have been divided into "highly productive" and "less productive". Highly productive groundwater is defined in this Policy as a groundwater source that is declared in the Regulations and is based on the following criteria: ■ Has total dissolved solids of less than 1,500 mg/L. And, ■ Contains water supply works that can yield water at a rate greater than 5 L/sec.	There may be localised areas/geologies where groundwater conditions could potentially be within the criteria of the "highly productive" groundwater source category (e.g. within the Hawkesbury Sandstone), however the vast majority of the desktop assessment area is within a "less productive groundwater source" as defined by the Aquifer Interference Policy based on the relatively low number of registered supply bores, expected low yields, poor water quality (high salinity) and outcomes of other groundwater investigations within the same groundwater source area (detailed in Section 3.2 and Section 4). For the purposes of this assessment, the "less productive" category has been applied to both alluvial and porous/fractured rock groundwater within the Sydney Basin Central groundwater source area. Therefore the relevant minimal impact considerations are applicable (outlined in **Sections 2.2** and **2.3**). If these cannot be met, then appropriate studies will need to demonstrate that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. Otherwise, remedial provisions must be applied.
National Water Quality Management Strategy	The National Water Quality Management Strategy (NWQMS) provides a nationally consistent approach to water quality management and the information and tools to help water resource managers, planning and management agencies, regulatory agencies and community groups manage and protect their water resources. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development.	Construction and operational phases of the project have the potential to impact water quality within groundwater systems and within the adjacent surface water bodies. As such, construction and operational phases should integrate water quality management strategies (consistent with NWQMS) such that the environmental values of the sensitive receiving

Legislation/Policy	Brief description and intent	Relevance to project
		environments are not adversely impacted. These should be included in the construction and operational EMPs.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)	The Water Quality Guidelines provide authoritative guidance on the management of water quality for natural and semi-natural water resources in Australia and New Zealand. The 2018 revision of the Water Quality Guidelines is presented as an online platform, to improve usability and facilitate updates as new information becomes available. Where site-specific guideline values are not present, the ANZG's give directions to default guideline values (DGVs) for a range of stressors relevant to different community values, such as aquatic ecosystems, human health and primary industries.	The guidelines do not provide guideline values for toxicants in groundwaters, however, the Water Quality Guidelines generally applies to the quality of both surface water and of groundwater, since the community values which they protect relate to above-ground groundwater uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems). For example, where groundwater fauna (e.g. stygofauna) need to be protected, Default Guideline Values (DGVs) for surface water ecosystem protection could be applied in the absence of any site-specific data that indicate the DGVs will be under- or over-protective. As regional physical and chemical stressor default guideline values are not yet provided for the project's ecoregion and local jurisdictions have not yet derived finer scale guideline values, these guidelines direct back to the regional DGVs provided in the ANZECC & ARMCANZ (2000) guidelines (see below).
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)	The ANZECC Water Quality Guidelines provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters and list a range of environmental values assigned to that waterbody. The ANZECC Water Quality Guidelines provide recommended trigger values for various levels of protection which have been considered when describing the existing water quality and key indicators of concern. The level of protection applied in this assessment when assessing ambient water quality is for slightly to moderately disturbed ecosystems.	The ANZECC Water Quality Guidelines provide recommended trigger values for various levels of protection which have been considered when describing the existing water quality and key indicators of concern. The level of protection applied in this assessment when assessing ambient water quality is for slightly disturbed ecosystems in NSW Lowland Rivers.
National Environment Protection (Assessment of Site Contamination) Measure (2013)	The National Environment Protection (Assessment of Site Contamination) Measure (1999) (NEPC, as amended 2013) (NEPM, 2013) exists to establish a nationally consistent approach to the assessment of site contamination to ensure sound environmental management practices by the community, which includes regulators, site assessors, environmental auditors, landowners, developers and industry.	The NEPM is relevant to the assessment of groundwater quality during future monitoring, as the framework and investigation levels can be used to evaluate the potential risks to human health and ecosystems from groundwater contamination.

Legislation/Policy	Brief description and intent	Relevance to project
	The primary purpose of the NEPM is to provide a framework for the efficient and effective national approach to the assessment of site contamination to promote the protection of human health and the environment. The NEPM provides guidance on investigation levels of specific contaminants, including groundwater quality screening criteria for fresh waters, marine waters and drinking water.	The selection and use of the groundwater investigations levels should be considered in the context of the hydrogeological conceptual model, along with relevant human/ecological exposure pathways and risk to groundwater resources.
Protection of the Environment Operations Act (1997)	The Protection of the Environment Operations Act (POEO), 1997 is a piece of legislation administered by the Environment Protection Authority (EPA) and provides a licensing arrangement to reduce pollution and protect the environment. Licences can be granted under the POEO Act for activities that may impact on the environment (e.g. discharge of extracted groundwater to a natural watercourse). The licenses specify the conditions under which those activities must be carried out, which may include monitoring requirements, compliance certification, mandatory environmental audits, pollution studies etc.	The project includes activities under which Environmental Protection Licence(s) (EPL) under the POEO Act would be required during both construction (scheduled development work) and operation (scheduled activity). For example, the discharge of extracted groundwater to a receiving surface water body such as creek, river or stream.

2.2 Groundwater Quality Objectives

2.2.1 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy's minimal impact considerations for groundwater quality have been included in this assessment.

Groundwater sources in the NSW Aquifer Interference Policy have been divided into "highly productive" and "less productive". Highly productive groundwater is defined in this Policy as a groundwater source that is declared in the Regulations and is based on the following criteria:

- Has total dissolved solids of less than 1,500 mg/L. And,
- Contains water supply works that can yield water at a rate greater than 5 L/sec.

There may be localised areas/geologies where groundwater conditions could potentially be within the criteria of the "highly productive" groundwater source category (e.g. within the Hawkesbury Sandstone), however the vast majority of the desktop assessment area is within a "less productive groundwater source" as defined by the Aquifer Interference Policy based on the relatively low number of registered supply bores, expected low yields, poor water quality (high salinity) and outcomes of other groundwater investigations within the same groundwater source area.

For the purposes of this assessment, the "less productive" category has been applied to both alluvial and porous/fractured rock groundwater within the Sydney Basin Central groundwater source area.

The minimal impact considerations for groundwater quality under the Aquifer Interference Policy for "less productive" groundwater sources are presented in **Table 2-2**. If these conditions are not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source (for alluvial groundwater sources) will not be reduced at the nearest point to the activity and/or change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Table 2-2 Minimal water quality impact considerations for Aquifer Interference Activities – NSW Water

Groundwater System	Water Quality
Alluvial Water Sources	Any change in groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m of the activity And No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity.
Porous and Fractured-Rock Water Sources	Any change in groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m of the activity.

The beneficial use category of a groundwater source refers to a general categorisation of groundwater uses based on water quality, dependent upon groundwater salinity and the presence/absence of contamination. The beneficial use categories are defined in the NSW Groundwater Protection Policy (outlined in **Table 2-1**). The salinity thresholds for each beneficial use category and the associated groundwater uses are outlined in **Table 2-3** below. An overriding principle of the NSW Groundwater Protection Policy is that groundwater quality should be maintained within its beneficial use category, which is reflected in the NSW minimal impact considerations for groundwater quality under the Aquifer Interference Policy outlined above. The natural distribution of water quality will vary spatially across a groundwater system, an overview of the expected beneficial use categories across the desktop assessment area is provided in **Section 4.5.6**.

Table 2-3 Beneficial uses of groundwater (based on salinity)

Beneficial uses of groundwater – based on salinity ranges				
Total Dissolved Solids (mg/L)	0 – 1,200	1,201 – 3,000	3,001 – 10,000	> 10,000
Electrical Conductivity (µS/cm)	0 – 1,791	1,792 – 4,478	4,479 – 14,925	> 14,925
Beneficial use category	A	B	C	D
Aquatic ecosystem protection	✓	✓	✓	✓
Irrigation	✓	✓		
Stock drinking water	✓	✓	✓	
Recreation and aesthetics	✓	✓	✓	✓
Raw drinking water	✓			
Industrial water	✓	✓	✓	✓
Cultural and spiritual	✓	✓	✓	✓

2.2.2 Project Waterway Objectives

In addition to the above, to assess the potential impacts of the project in relation to water quality in the receiving hydrogeological environment, waterway objectives have been identified in accordance with the project specific environmental assessment requirements (SEARs). The SEARS relating to waterway objectives are further detailed in **Section 1.4.** These waterway objectives relate to surface water and are detailed in the *Surface Water Impact Assessment* report.

The ANZECC/ARMCANZ (2000) Water Quality Guidelines outline linkages to groundwater, which remain applicable under the ANZG (2018) Water Quality Guidelines as groundwater is an essential water resource for many aquatic, riparian and terrestrial ecosystems. The ANZG 2018 guidelines state:

> *"Generally, the Water Quality Guidelines should apply to the quality of both surface water and of groundwater, since the community values which they protect relate to above-ground uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems). Hence, groundwater should be managed in such a way that when it comes to the surface, whether from natural seepages or from bores, it will not cause the established water quality objectives for these waters to be exceeded, nor compromise their designated community values. In addition to this, underground aquatic ecosystems and any novel fauna also need to be protected. Relatively little is still known of the lifecycles and environmental requirements of groundwater communities.*
>
> *Where potentially high conservation values are identified, the groundwater upon which the communities depend should be afforded the highest level of protection, at least until further knowledge is gained. Basing groundwater quality objectives on data from groundwater reference condition locations is recommended to achieve this protection. It is important to note that different biological, physical and chemical conditions and processes operate in groundwater compared with surface waters, and these can affect the fate and transport of many chemicals. This may have implications for the application of guideline values and overall management of groundwater quality."*

2.2.2.1 Nepean River, Warragamba River and Wianamatta-South Creek

The objectives are specific to this project and were developed in accordance with the *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* (OEH, 2017). The numerical criteria are sourced from existing guidelines and objectives. Predicted impacts from the Project will be assessed against the waterway objectives.

The Risk Based Framework defines waterway objectives as consisting of:

- community's environmental values and uses of the water
- indicator(s) and corresponding numerical criteria to assess whether the waterway will support a particular environmental value or use.

The values and uses adopted for the Nepean and Warragamba Rivers and South Creek are:

- aquatic ecology
- recreation and aesthetics
- primary industries
- drinking water (Nepean River only).

Management goals and numerical criteria for each of these values have been informed by the following guidelines:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000 and ANZG 2018)
- Guidelines for managing risks in recreational water (NHMRC, 2008)
- Australian Drinking Water Guidelines 2011, Version 3.5 Updated August 2018 (NHMRC, NRMMC 2011)
- Regulating nutrients from STPs in Lower Hawkesbury Nepean River catchment (EPA 2019)
- Draft Wianamatta-South Creek Waterway Health Objectives (DPIE, 2020)

The Department of Planning, Industry and Environment (DPIE) has developed draft water quality and flow objectives as part of the precinct planning work for the Aerotropolis. These draft objectives include performance criteria that have been included in our objectives for South Creek.

A list of the waterway objectives and adopted numerical criteria/metrics for the Nepean and Warragamba Rivers and Wianamatta-South Creek are provided in the *Surface Water Impact Assessment* report.

These have been used as to compare against baseline groundwater quality and will be used during construction to monitor discharges to the environment.

2.2.2.2 Georges River catchment

A large section of the brine pipeline will be in the Georges River catchment. The environmental values and numerical criteria applicable for lowland rivers in this catchment have been sourced from the NSW Water Quality and River Flow Objectives (NSW DEC, 2006).

A list of the waterway objectives and adopted numerical criteria/metrics for the Georges River catchment are provided in the *Surface Water Impact Assessment* report.

2.3 Groundwater Level/Availability Criteria

The potential impacts of the project in relation to groundwater levels and availability in the receiving hydrogeological environment are assessed against the Level 1 minimal impact considerations defined in the NSW Aquifer Interference Policy with consideration to the location of any high priority GDE, high priority culturally significant site and existing groundwater users. The Level 1 minimal groundwater level/ availability impact considerations for "less productive" groundwater sources are outlined in **Table 2-4**.

It is noted that minimal impact considerations for water pressure are also presented in the NSW Aquifer Interference Policy, however these are not applicable due to the nature of the groundwater sources within the desktop area. Unconfined to semi-confined conditions are expected in the groundwater systems intersected by the project (described in Section 4), therefore only the water table criteria is considered relevant regarding groundwater level/availability.

Where the predicted impacts are greater than the Level 1 minimal groundwater level/availability impact considerations, a more detailed impact assessment is required. If the assessment demonstrates that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then the impacts will be considered acceptable.

Table 2-4 Minimal water table impact considerations for Aquifer Interference Activities – NSW Water

Groundwater System	Water Table
Alluvial Water Sources **&** **Porous and Fractured-Rock Water Sources**	Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 m from any; a) high priority GDE, or b) high priority culturally significant site listed in the relevant water sharing plan Or A maximum of a 2m decline cumulatively at any water supply work unless make good provisions should apply.

At the time of this investigation, no long-term groundwater hydrographs were available within the desktop assessment area to determine the cumulative variation of the groundwater table. A natural seasonal variation of 1.0 m for the water table in the alluvial and the porous fractured rock water sources has been assumed as a conservative approach to assessing the potential impacts from project activities. Accordingly, the drawdown threshold for predicted impact assessment has been taken as 0.1 m (i.e. 10% of 1.0 m). This assumed seasonal variation should be reviewed against groundwater level monitoring data collected during future stages of the project to verify this assumption or refine the drawdown impact criteria.

A review of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 Schedule 4* indicated that there are no high priority GDEs within the desktop assessment area. To meet the SEARs, potential impacts to other GDEs (identified in Section 4.8) have been assessed using the Aquifer Interference Policy criteria as a conservative approach.

3 Assessment Methodology

3.1 Site Walkover and Inspection

A walkover of the proposed AWRC site was conducted on the 20th of April 2020. The visit focused on visual inspection of the site including the condition and geomorphology of South Creek and Kemps Creek, topography, soil and flood plain.

In addition, a site visit of the proposed environmental flows pipeline alignment was conducted on 22nd September 2020 with the purpose of measuring groundwater levels in existing registered bores in close proximity to the pipeline corridor to close data gaps and determine the current groundwater conditions within the area. No direct groundwater measurements were able to be obtained during this site visit due to pump manifolds on the registered bores preventing access for the water level meter. However, interviews with the landowners were carried out, providing a general understanding of groundwater conditions (albeit anecdotal). The information provided by the landowners is described in **Section 4.7**.

3.2 Desktop Assessment

The desktop assessment has been prepared using a combination of variable scale publicly available datasets, and information / datasets specific to the Project. The information summarised within this desktop assessment specifically focuses on information relevant to characterisation of hydrogeological conditions within and around the desktop assessment area, including:

- Topography, soil and geology – relevant to groundwater recharge and hydraulics.
- Local and regional climatic conditions – relevant to groundwater recharge.
- Local aquifers intercepted by the project – relevant to groundwater storage and availability.
- Existing groundwater users/extraction within and around the desktop assessment area.
- The presence of Groundwater Dependent Ecosystems (GDEs) in the desktop assessment area and vicinity.
- Groundwater levels and local/regional groundwater flow directions.
- Groundwater quality, including potential sources of groundwater contamination.

The desktop assessment area covers the Advanced Water Recycling Centre (AWRC) site and pipeline alignments (treated water pipeline, brine pipeline and environmental flows pipeline) as well as a wider 2 km impact assessment (buffer) area around the project features. The buffer area has been included to examine hydrogeological systems at a sub-regional scale and assess a wide extent of potential groundwater impacts and to allow for uncertainty within the current pipeline alignment and changes that may need to occur during detailed design. The buffer does not necessarily cover the full extents of the associated aquifers but has been selected to encapsulate the full extent to which the potential impacts are expected to propagate.

Previous Investigations

A number of historic investigations have been undertaken in the desktop assessment area. Reports containing information on subsurface and groundwater conditions are summarised in **Table 3-1**.

Table 3-1 Sources of Information – Previous Investigations and Reports

Document Title	Author	Date Published
University of Sydney Preliminary Site Investigation, Badgerys Creek, NSW	JBS & G	2018
Heritage Assessment Historic Period Resources, University of Sydney Western Sydney Lands Badgerys Creek Farm Centre, Elizabeth Drive, Badgerys Creek	CRM	2019
Badgerys Creek Development – Elizabeth Drive Geotechnical Investigation	Pells Sullivan and Meynink	2018
M12 Motorway Environmental Impact Statement – Appendix N: Groundwater quality and hydrology assessment report	RMS	2019
Western Sydney Airport Environmental Impact Statement – Appendix L3: Groundwater assessment	GHD	2015
Environmental Impact Statement – Geology, Soils and Water: Proposal for a Second Sydney Airport at Badgerys Creek or Holsworthy Military Area	PPK	1999

3.3 Modelling Methodologies

3.3.1 Pipeline Analytical Modelling

To assess potential groundwater impacts during pipeline construction, likely groundwater inflow rates and the extents of induced groundwater drawdowns were calculated using analytical equations derived from Darcy's law. Darcy's law describes fluid flow through porous media, which is controlled by hydraulic conductivity (the ability of a material to transmit fluid through pore spaces) and hydraulic gradient (head difference between two points over the length of the flow path).

As groundwater conditions are expected to vary across the extent of the pipelines, the reference design alignment was divided into discrete sections based on "Hydrogeological Landscapes" (described in **Section 4.5**) to provide realistic inputs to the analytical calculations. For each section, reference design features and expected hydrogeological properties were collated to form the basis of the analytical calculations.

In accordance with the hydrogeological conceptual model developed in this assessment (described in **Section 5**), the following analytical equations were applied:

- Radius of influence (i.e. extent of induced groundwater drawdowns) calculated using Sichardt's formula (Sichardt, 1930) for unconfined aquifers:

$$R_o = C \times s\sqrt{K}$$

  Where:

  R_o = Radius of influence (m)

  C = Radial/linear flow conversion factor = 2000 for linear flow into trenches (dimensionless)

  s = Maximum drawdown (m)

  K = Hydraulic conductivity (m/d)

- Total discharge from a single row of partially penetrating well points in an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962). This analytical scenario is applicable to total groundwater inflow into a linear trench:

$$Q = \left[\left(0.73 + 0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2 - h_w^2)\right]$$

Where:

Q = Total discharge from the well points (m^3/d)

H = Height of the water table at the radius of influence (m)

h_w = Height of the water table at well point (m)

K = Hydraulic conductivity (m/d)

x = Length of trench (m)

R_o = Radius of influence = calculated from Sichardt's formula above (m)

The results from these analytical calculations provide an understanding of the potential groundwater impacts and the amount of dewatering that may be required during construction of the pipelines. The results were then assessed against the groundwater level/availability criteria outlined in **Section 2.3** with consideration to the location of surrounding groundwater users and groundwater dependent ecosystems.

Analytical calculations and assumptions are provided in **Appendix B** and results are discussed in **Section 7.2**. Understanding model assumptions is crucial in interpreting the results. Worthy of note is the assumption that the analytical model is in equilibrium / steady state. This assumes that pumping has continued for a period where the zone of influence has intercepted sufficient recharge to equal the amount being pumped. This is unlikely for this project because the excavation of the trenches for the pipe will be undertaken as a moving system aimed at minimising exposure time, progressing at the assumed daily pipe lay rates provided in **Section 7.2** (and summarised in **Table 7-13**).

The progressive excavation will introduce non-steady state or transient conditions where the pumped water will be released mainly from storage. This phenomenon is not considered in the adopted analytical model. The potential effects of aquifer storage characteristics were checked using the principle of superposition to Cooper-Jacob's approximation of the Theis nonequilibrium equation using the Aquiworx wellfield tool, with pumping wells at 1 m spacing for a one-day pumping period. The checks were tested using average values of the parameters provided in **Section 7.2** and **Appendix B**. As expected, the results indicate that the Mansur & Kaufman solution generally overestimates the radius of influence and underestimates the expected volume of water to be pumped. In general, for the same drawdown, low storage capacity aquifers such as fractured rocks produce less amount of water from storage with rapid propagation of drawdown compared to high storage capacity aquifers such as alluvial aquifers. After cessation of dewatering as the excavation progresses, the water table is expected to recover to original levels rapidly. The water table is therefore expected to be depressed for very short periods. These factors should be considered in interpreting the modelling results provided in **Section 7.2**.

3.3.2 AWRC Numerical Modelling

Potential groundwater impacts at the AWRC were assessed using a numerical groundwater model to simulate the existing and future behaviour of the groundwater systems at the site. Specifically, groundwater flow responses and potential impacts in response to construction dewatering during construction of the AWRC were evaluated.

The application of a computer based numerical model provides a powerful tool for the prediction of flow in a complex spatially and temporally varying environment. This approach applies a system of mathematical equations derived from Darcy's Law for flow of water through porous media to simulate flow in the aquifer.

Groundwater numerical modelling can overcome the difficulties inherent in the assessment of hydrogeological systems using classical analytical methods, which assume aquifer homogeneity and are more applicable to the interpretation of localised aquifer response. With a computer numerical model, it is possible to simulate complex conditions by introducing variations in aquifer transmissivity or hydraulic loads. This is accomplished by discretising the modelled area into a number of blocks each representing a volume of aquifer with constant hydraulic parameters. The accuracy of model predictions depends on the knowledge of all parameters having an impact on the groundwater regime, both in the area of interest as well as in more distant areas.

The development of a model also facilitates sensitivity analysis which provide a means of understanding the dominant parameters and mechanisms operating within a hydrogeological system.

Groundwater modelling for the AWRC was undertaken using MODFLOW-USG, with the aid of Groundwater Vistas pre- and post-processing environment. MODFLOW-USG is a groundwater flow simulation computer code developed by the United States Geological Survey (USGS).

The following predictive model scenarios were assessed:

- Scenario 1: Construction Phase modelling

  This scenario relates to construction dewatering for the bioreactors which would penetrate below the water table. Only Stage 1 has been assessed. Since this is located closer to South Creek than the proposed future stages' works, it is considered that this represents the worst-case scenario of impact to the environmental values of the creek.
- Scenario 2: Operational Phase modelling

  These scenarios were used to simulate the predicted impacts of the listed conditions and events:
  - partial blockage of groundwater due to the AWRC bioreactors which have with foundations below the groundwater table;
  - impermeable surfaces across the AWRC site on the local water balance due to the reduction in recharge; and
  - maintenance dewatering regimes at the bioreactors.

Full details of the AWRC numerical modelling approach, including model build, model calibration, sensitivity analysis and the outcomes of predictive modelling and the associated impact assessment is provided in **Appendix A**.

3.4 Impact assessment

The impact assessment for construction and operation of the project incorporated quantitative and qualitative methods to assess the potential impacts pre- and post-mitigation attributable to the activities and the physical changes proposed by the project.

Proposed activities associated with the project development, construction and operation have been reviewed to identify those activities with the potential to lead to a disturbance or a change in the groundwater systems. These activities are indicated in **Section 6.1** for the construction phase and **Section 6.2** for the operational phase of the project.

Pipelines

The pipeline infrastructure will primarily be below ground and therefore potential impacts to groundwater associated with the pipelines are expected, predominately associated with the construction phase where dewatering would be required. Potential groundwater impacts associated with the construction of the trenched pipeline sections have been quantitatively assessed using analytical calculations (further detailed in **Section 8**).

Due to the nature of trenchless pipeline construction techniques, groundwater impacts are inherently mitigated (e.g. through the use of shaft supports, headwall and seal assembly within each shaft etc). Therefore, the conditions and underlying assumptions in the quantitative analytical calculations are not applicable to the trenchless pipeline sections and potential groundwater impacts associated with the construction of trenchless pipeline sections and operation of the pipelines have been qualitatively assessed.

AWRC Site

Significant below ground changes are expected to occur during the construction phase of the AWRC site, these changes will mostly remain in place during the operational phase as well. Given these expected changes a more detailed numerical groundwater modelling has been developed to quantify the potential impacts.

As the AWRC will be constructed in stages, the initial modelling and assessment focused on the Stage 1 footprint, however the models were subsequently expanded to represent the ultimate footprint associated with potential future stages and assess the resultant impacts.

An overview of the methodology adopted for numerical groundwater modelling, which was used to inform AWRC groundwater impact assessments is described in **Section 3.3.2** with further details of the model provided in **Appendix A**.

3.4.1 Impact Significance

The significance of any potential project impact on the local groundwater systems has been determined by considering the sensitivity of the environment related to the assessed criteria (outlined in **Sections 2.2** and **2.3**) as well as the magnitude of the expected change. The resultant matrix of significance is shown in **Table 3-2**.

Table 3-2 Matrix of impact significance

Magnitude of Impact	Sensitivity of Environmental Values		
	High	Moderate	Low
High	Major	High	Moderate
Moderate	High	Moderate	Low
Low	Moderate	Low	Negligible

The *Sensitivity of Environmental Values* evaluation is influence by the following criteria:

- Condition of the environmental value, i.e. how far is it understood to have already been changed from its original natural form or state?
- How unique or rare is the condition or value or it’s dependant ecological receptors?
- How sensitive are the dependant receptors to changes?
- How to the results compare against the identified groundwater level/availability and quality criteria?

The *Magnitude of Impact* evaluation is influence by the following criteria:

- If a qualitative assessment has been conducted, how do the results compare to the pre-development conditions?
- How to the results compare against the identified groundwater level/availability and quality criteria?
- For quantitative assessments the following is considered:
  - Expected duration of impact: Temporary vs. long-lasting/permanent.
  - Expected extent of impact: Local vs. regional/widespread.
  - Estimated degree of change from pre-development conditions.

4 Existing Environment

4.1 Climate

The Department of Environment and Science (DES) provides an enhanced climate database SILO (Scientific Information for Land Owners) that holds Australian climate data from 1889. The interpolated climate data is stored on a regular 0.05° latitude x 0.05° longitude grid, which is approximately 5 km x 5 km. This database was used to obtained long-term geostatistically determined climate records at 150.75ºE, 33.85ºS near geographical centre of the AWRC groundwater model domain (**Appendix A**) for the period 1 January 1900 to 30 April 2020 (119 years). This is considered representative for the entire desktop assessment area for the purposes of this assessment.

Figure 4-1 and **Figure 4-2** display the annual rainfall and pan evaporation at the site, respectively.

Table 5-1 provides annual rainfall and evaporation statistics generated for the site over the 119-year period. **Table 4-2** indicates average monthly maximum and minimum temperature, rainfall, pan evaporation and potential evapotranspiration. The monthly statistics of rainfall and evaporation is shown in **Figure 4-3**.

From **Table 4-2** it is evident that the site receives relatively uniform rainfall with no distinct dry or wet seasonal variation. On average most of the rainfall (456 mm or 61%) is received between November and April. The least rainfall (124 mm or 17%) falls between July and September.

The mean annual evaporation (1,456 mm) exceeds annual rainfall (746 mm) by a factor of 2 (**Table 4-1**) and is greater than rainfall on average for all months of the year (**Table 4-2**). However, the upper quartile for rainfall in May, June and July exceeds the upper quartile value for evaporation in the same winter months (**Figure 4-3**). This indicates that large wet seasons do occur periodically at the site, and when they occur such events produce rainfall that exceeds exceed the evaporation rate and this occurs during the cold winter months.

It is expected that groundwater recharge and water levels will increase during wetter months with lower evaporation rates (e.g. May, June and July). During drier months with higher evaporation rates, (e.g. January to April and August to December), groundwater recharge and water levels are expected to decrease.

Annual rainfall at the site is highly variable with historical rainfall ranging from 314 mm to 1,725 mm with a standard deviation of 235 mm.

Another way to assess these long-term cycles is to examine a plot of cumulative residuals of monthly rainfall from mean monthly rainfall, and monthly rainfall. Such plots provide an indication of the state of the groundwater storage where groundwater storage is most strongly influenced by rainfall recharge and where there is no immediately adjacent groundwater discharge site that might otherwise act as a control on maximum groundwater elevations, which is the case for the desktop assessment area.

Figure 4-4 provides a plot of cumulative residuals of monthly rainfall from mean monthly rainfall for the site, and this indicates drought conditions which is expected to correlate with a decline in groundwater storage since 1990 to present times.

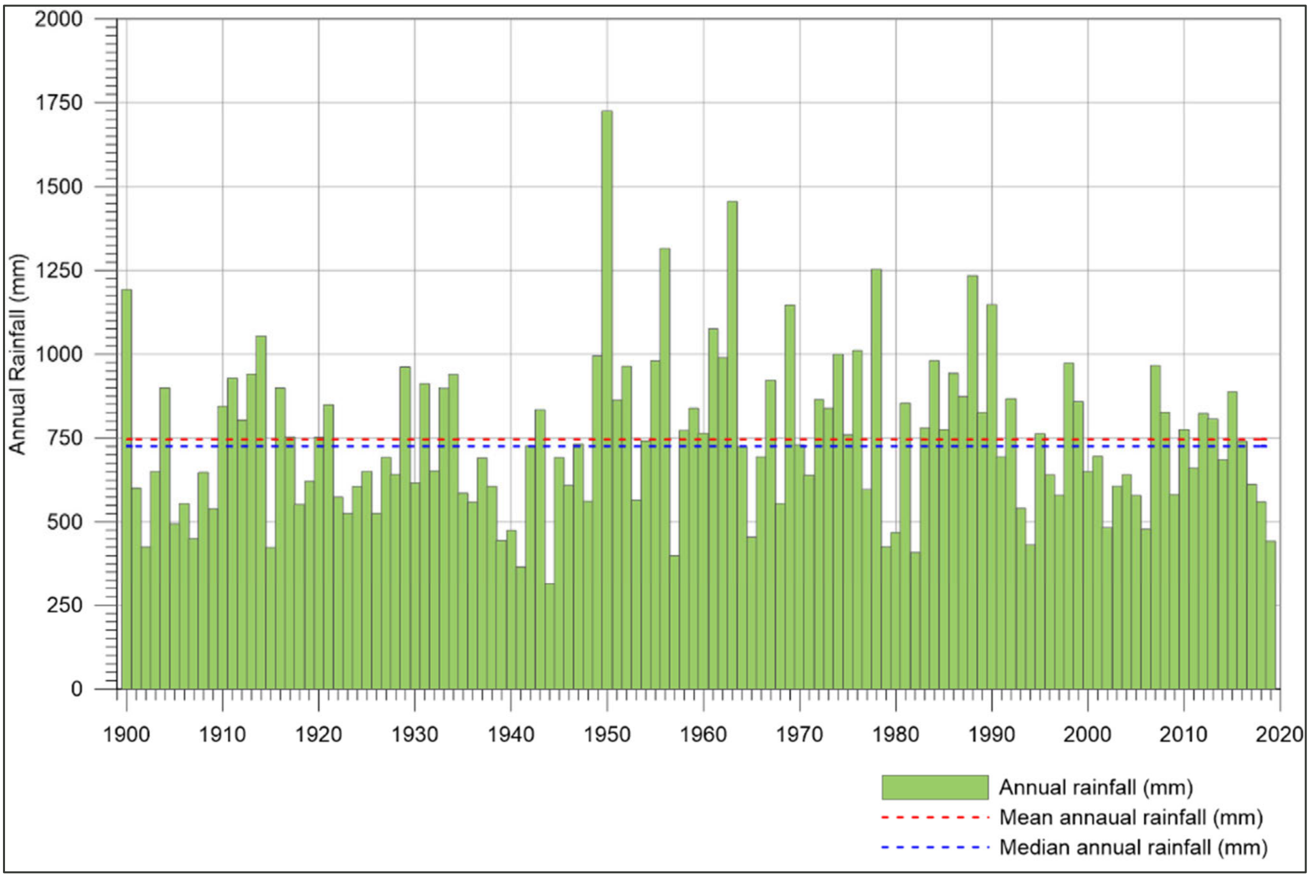


Figure 4-1 **Historical annual rainfall (SILO climate data 1900 to 2019)**

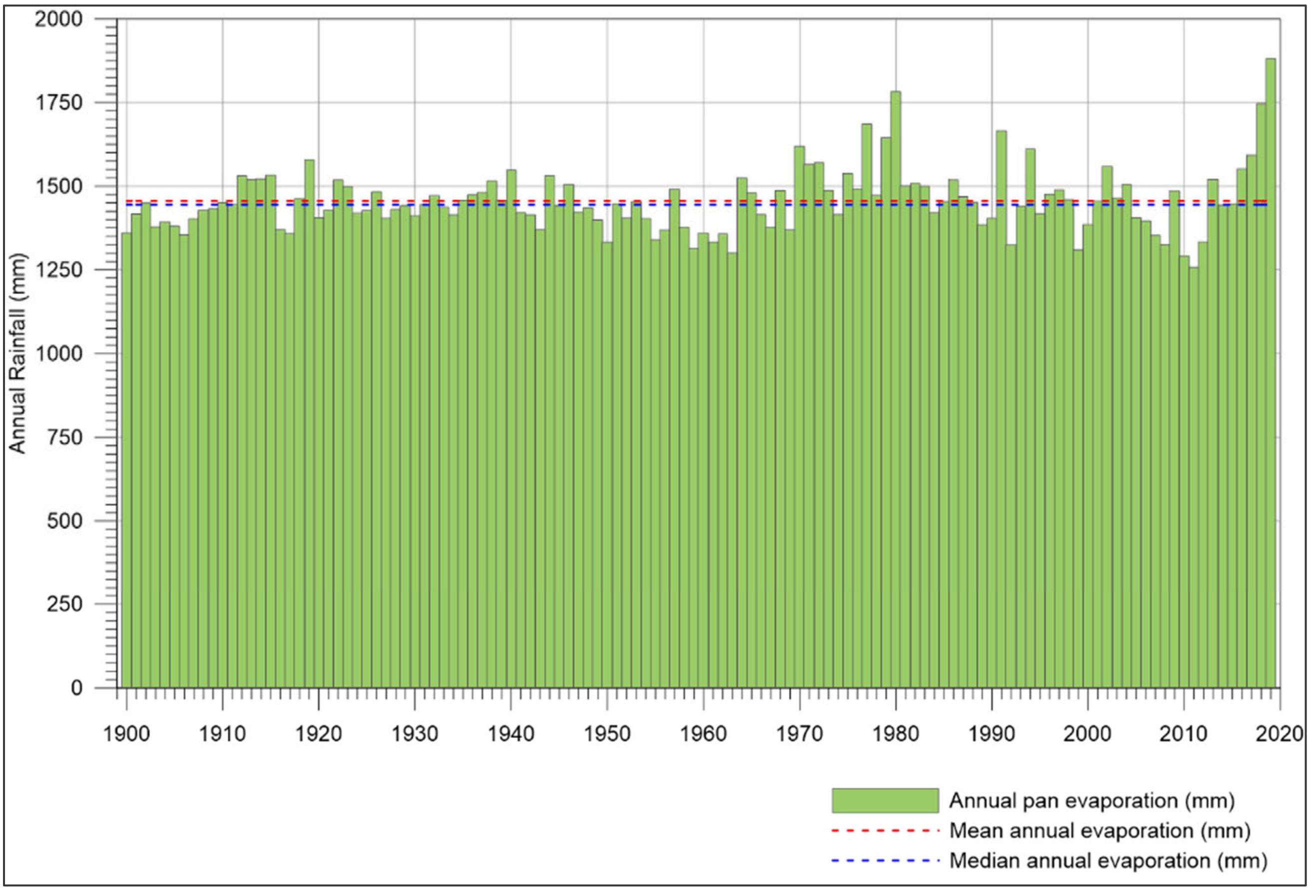


Figure 4-2 **Historical annual evaporation (SILO climate data 1900 to 2019)**

Table 4-1 Annual rainfall and evaporation statistics

Statistic	Annual Rainfall (mm)	Annual Pan Evaporation (mm)	FAO-56 Potential Evapotranspiration (mm)
Mean	746	1,456	1,227
Minimum	314 (year 1944)	1,257 (year 2011)	N/A
Median	725	1,445	N/A
Maximum	1,725 (year 1950)	1,881 (year 2019)	N/A

Table 4-2 Average monthly climate data

Month	Ambient Temperature (°C)		Rainfall (mm)	Pan evaporation (mm)	FAO-56 Potential Evapotranspiration (mm)
	Minimum	Maximum			
Jan	17.4	29.2	84.2	185.7	156.4
Feb	17.4	28.7	86.7	147.1	126.4
Mar	15.8	27.0	82.5	135.1	114.1
Apr	12.2	24.0	63.8	98.1	82.2
May	8.6	20.5	53.8	68.0	59.9
Jun	6.2	17.6	58.8	57.0	45.3
Jul	4.7	17.3	45.1	62.2	51.3
Aug	5.5	19.0	40.1	87.2	70.4
Sep	8.2	22.0	38.4	113.9	94.8
Oct	11.1	24.4	53.7	144.1	125.3
Nov	13.8	26.4	67.3	166.6	140.8
Dec	16.0	28.6	71.3	190.7	159.7

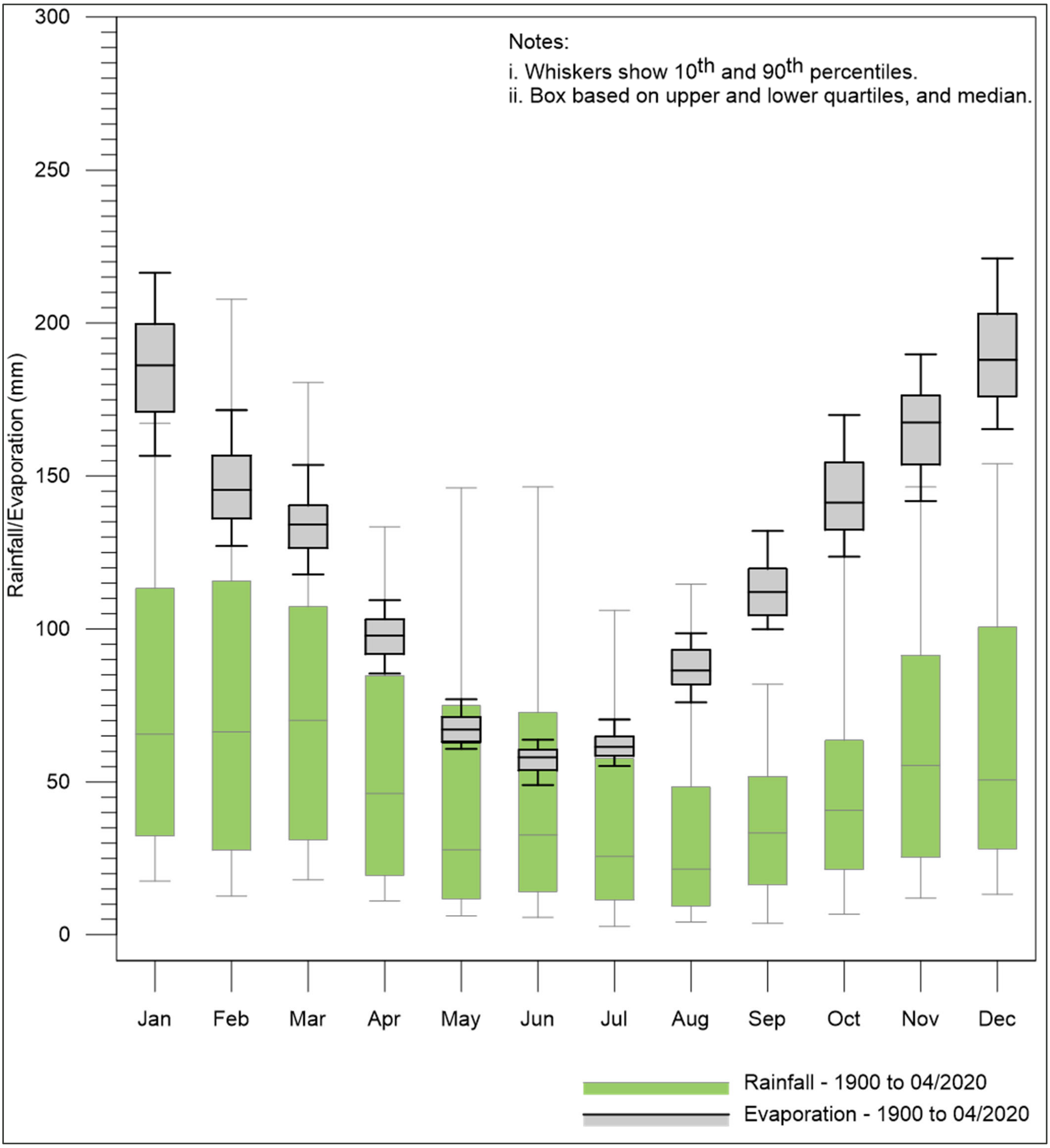


Figure 4-3 **Monthly rainfall and evaporation statistics based on SILO (1900 to 2020)**

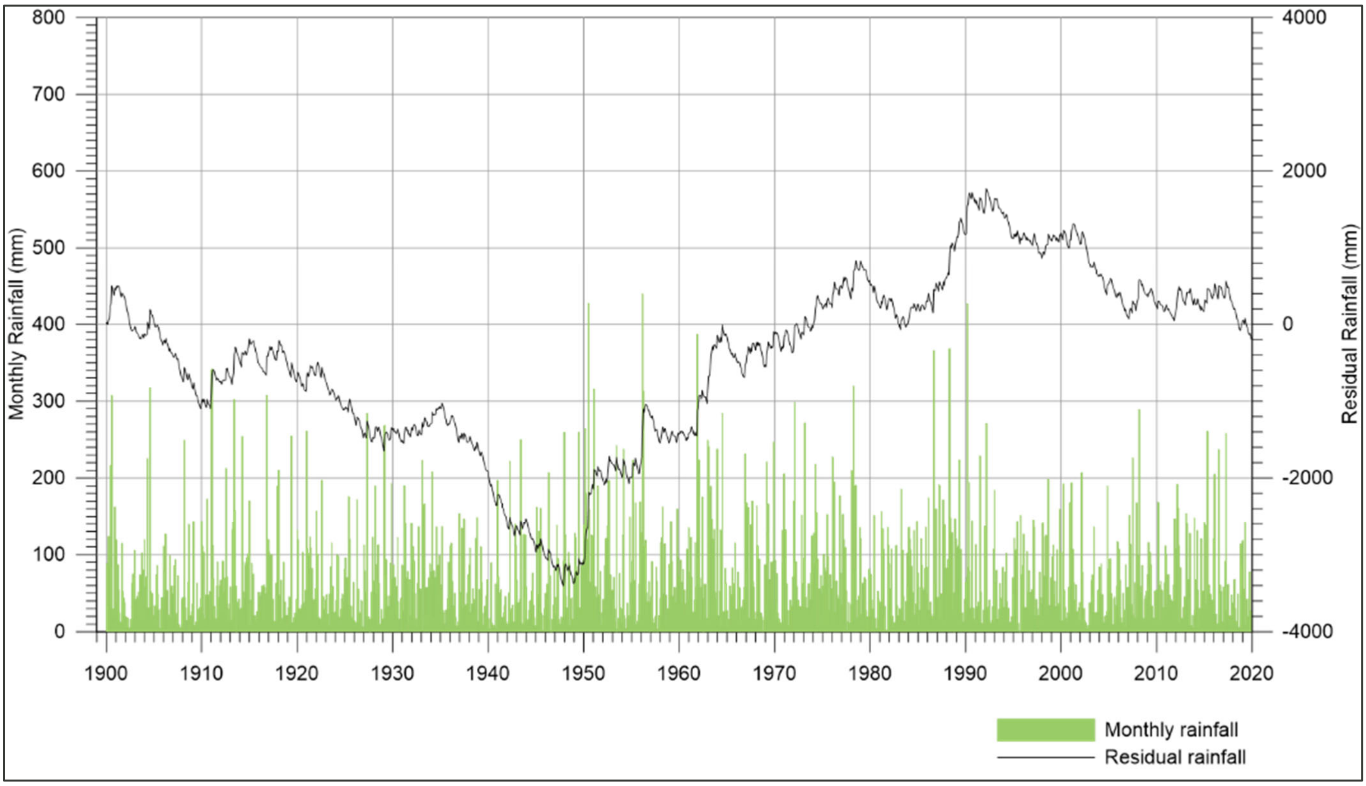


Figure 4-4 **Monthly rainfall plus cumulative residuals from mean monthly rainfall - SILO (1900 to 2020)**

4.1.1 Climate change

Consideration of potential climate change is a crucial factor in assessing the future water resources, as it has the potential to influence the general environmental water balance as well as groundwater availability, soil and water salinity and water quality. The NSW Office of Environment and Heritage (OEH) has published several documents detailing the expected effects of climate change on water resources. Study results documented in a 2015 report, *"Climate change impacts on surface runoff and recharge to groundwater"* (OEH, 2015), have been used to assess expected local climatic changes.

There are two models of climate data in use in Australia which are applicable to this desktop assessment area. The national model, CSIRO, and a local model, the NSW and ACT Regional Climate Model (NARCliM). The CSIRO data is not as granular as NARCliM, which uses downscaled regional climate models (RCM's) derived from IPCC's Global Climate Models (GCM) to project their findings across three time periods.

Utilising NARCliM, the OEH study predicted near future (2020-2039) and far future (2060-2079) changes to rainfall, runoff and recharge to groundwater. **Table 4-3** presents a summary of the statistical analysis for Metropolitan Sydney.

Table 4-3 **Percent changes to multi-model mean annual rainfall, surface runoff and recharge**

	Percentage change in near future (2020-2039)			Percent change in far future (2060-2079)		
State planning region	**Rainfall**	**Runoff**	**Recharge**	**Rainfall**	**Runoff**	**Recharge**
Metropolitan Sydney	0.4	4.0	-5.0	8.1	17.6	12.5

The results of this model for the Hawkesbury catchment are presented in **Table 4-4**. In summary, the study predicted that changes in near future, were likely to be a reduction in the rainfall and recharge to the groundwater and increase in the surface runoff, while in far future, the model predicted an increase in all three parameters (rainfall, surface runoff and recharge to the groundwater).

Table 4-4 Percentage change in rainfall, runoff and groundwater recharge for the Hawkesbury catchment

	Percentage change in near future (2020-2039)			Percent change in far future (2060-2079)		
State planning region	**Rainfall**	**Runoff**	**Recharge**	**Rainfall**	**Runoff**	**Recharge**
Hawkesbury Nepean Catchment	-0.1	0.9	-9.3	6.1	13.4	5.6

4.2 Topography

Light detection and ranging (LiDAR) data with +/- 1 m resolution has been used to define the physiographic context of the project. Results from LiDAR mapping are presented in **Figure 4-6**, **Figure 4-7** and **Figure 4-8** as topographic elevation maps. The following sections discuss the topography for the AWRC and each of the USC AWRC pipelines, including the treated water pipeline, environmental flows pipeline and brine pipeline.

4.2.1 Advanced water recycling centre

The AWRC is located within a regional alluvial plain associated with Badgery's Creek, South Creek and Kemps Creek watercourses. The topography in this area is predominately flat, with a gentle slope towards the north. Elevations across the AWRC generally range between about 35 to 40 mAHD.

4.2.2 Treated water pipeline

The treated water pipeline follows undulating, gently sloping terrain from the low-lying areas around the Nepean River in Wallacia (35 mAHD) in the east to South Creek/Kemps Creek (40-45 mAHD) with some areas of higher elevation (90 mAHD) around The Northern Road, Luddenham.

4.2.3 Environmental flows pipeline

The environmental flows pipeline traverses south from Silverdale Road along a plateau adjacent to the Nepean River valley before turning west towards the Warragamba River downstream of the Warragamba Dam. The pipeline route encounters a steep north-south aligned ridge along the westward route with the surface elevations increasing from about 61 mAHD to about 153 mAHD within a distance of about 300 m equating to a slope of about 31%.

The proposed construction methodology for the environmental flows pipeline along the westward route is via horizontal directional drilling (HDD) cutting through east side of the ridge line at about 66 mAHD and exiting on the west side of the ridge line at an elevation of about 34 mAHD adjacent to the Warragamba River for discharge.

The complete elevation profile for the environmental flows pipeline along its approximate 4.4 km length is illustrated in **Figure 4-5**. The orientation and direction of this cross-section is indicated by the "Environmental Flows Pipeline" illustrated in **Figure 4-6**.

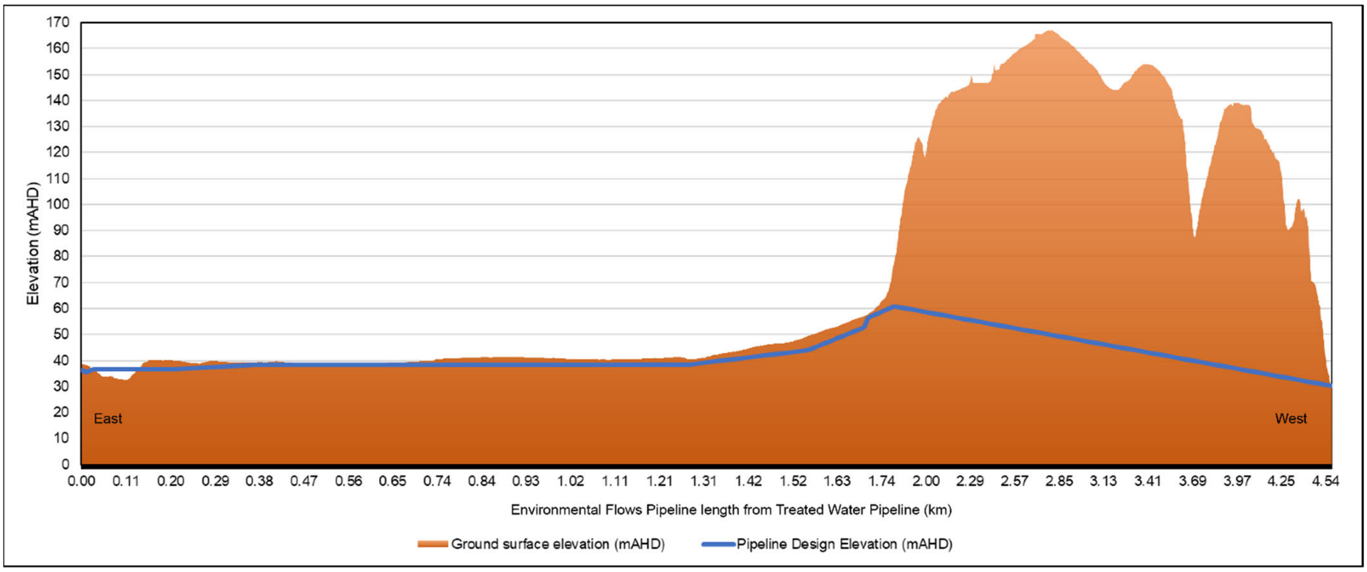


Figure 4-5 Elevation profile along the environmental flows pipeline

4.2.4 Brine pipeline

East of the AWRC, along the brine pipeline, the alignment follows gently undulating, sloping topographies, rising from about 40 mAHD, reaching a high point at Cecil Hills at approximately 80 mAHD before sloping down towards Prospect Creek and the Georges River in Fairfield at approximately 10 mAHD.

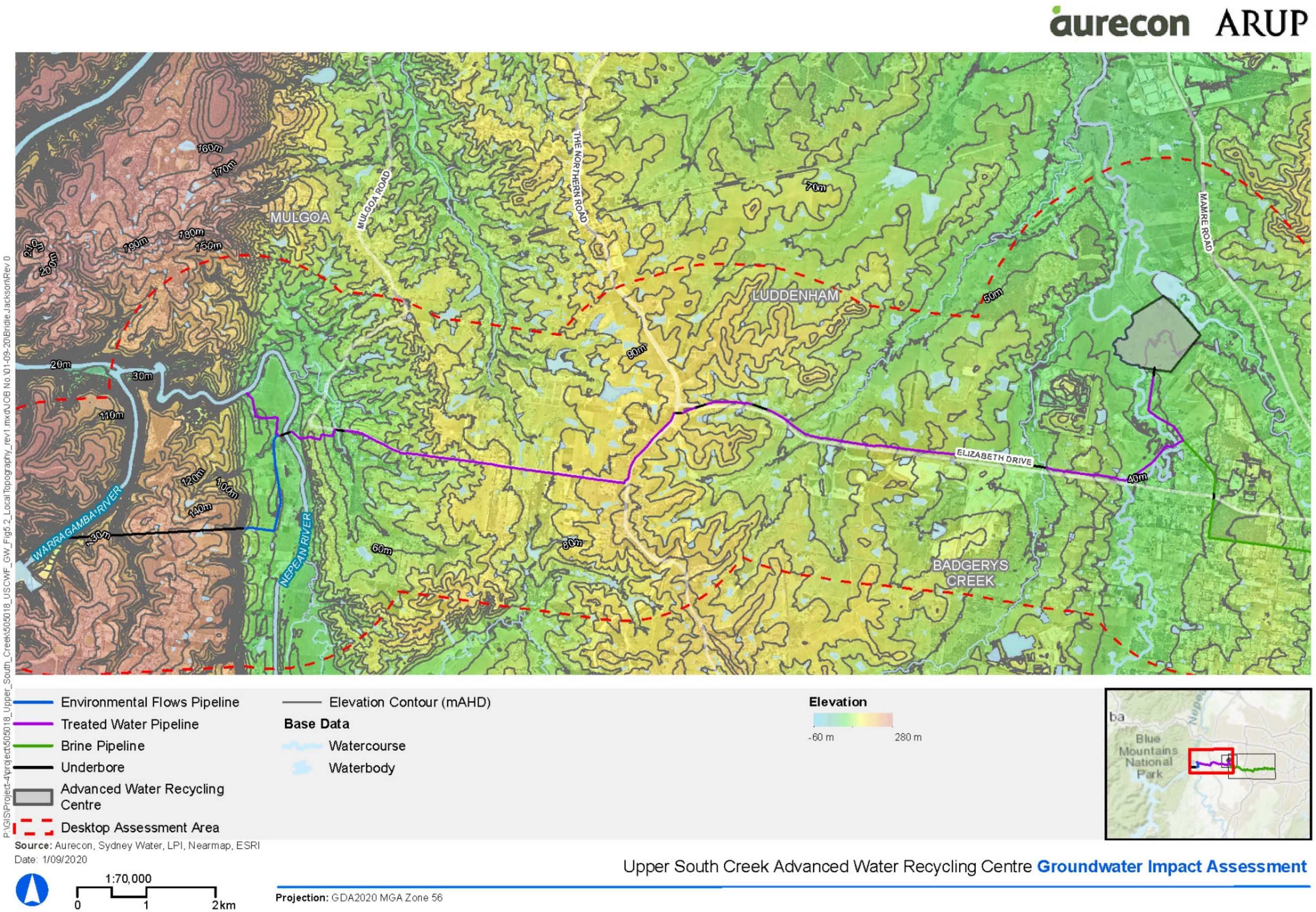


Figure 4-6 Local Topography – Treated Water / Environmental Flow Pipelines

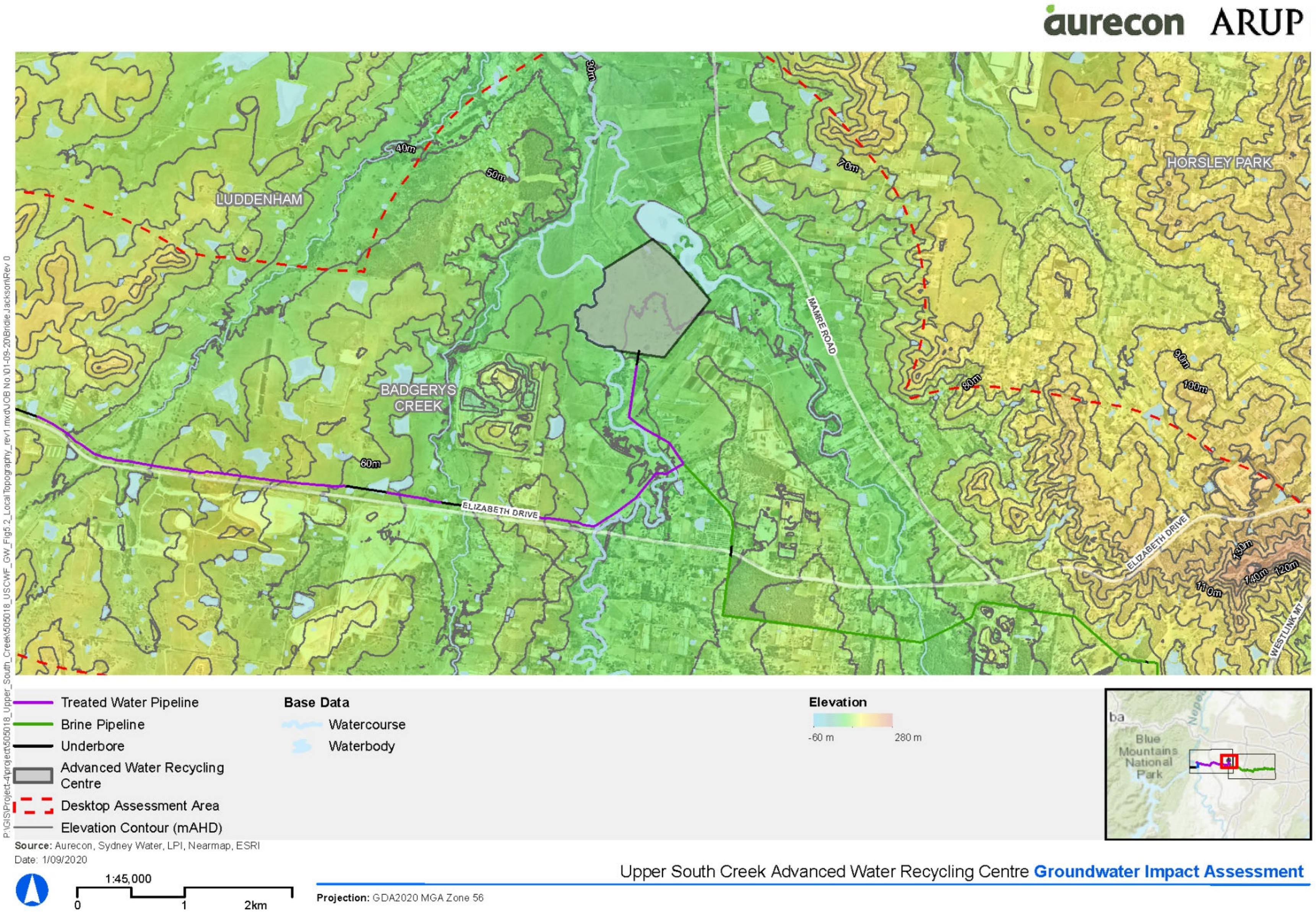


Figure 4-7 Local Topography – The AWRC

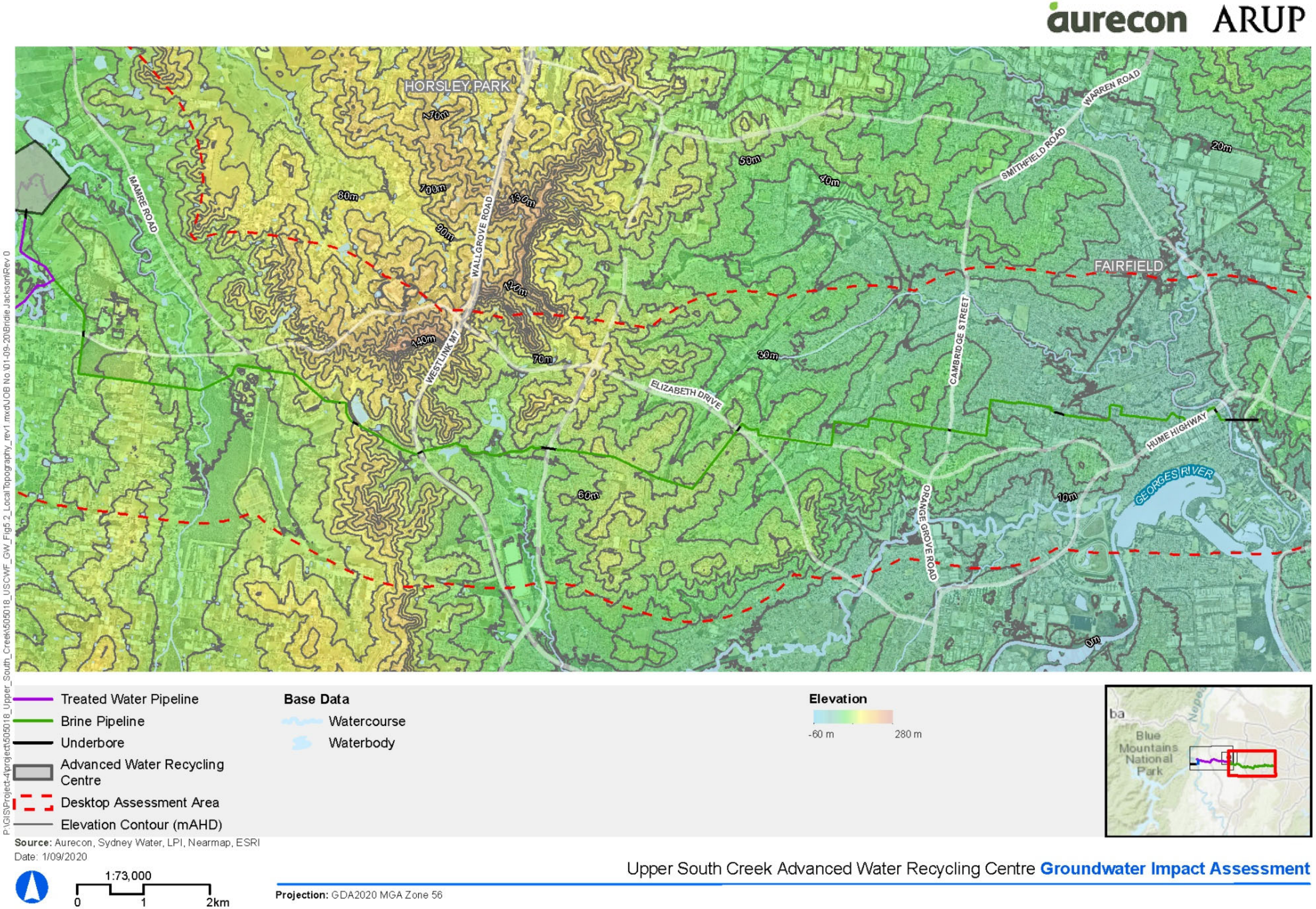


Figure 4-8 Local Topography – Brine Pipeline

4.3 Drainage and Hydrology

The hydrology of the site is described in detail in the *Surface Water Impact Assessment* report (Aurecon Arup, 2021). A brief summary of features pertinent to the groundwater impact assessment is provided below for context to the discussions in this report.

4.3.1 Catchments

Most of the desktop assessment area including the AWRC, treated water pipelines and the western portion of the brine pipeline is located in the Hawkesbury-Nepean catchment. A smaller portion of the desktop assessment area, including the eastern portion of the brine pipeline, is located within the Georges River catchment.

The catchments and sub-catchment boundaries for the AWRC site are illustrated in **Figure 4-9**.

The principal waterways intersected by the pipelines from west to east include:

- Hawkesbury Nepean catchment:
  - Nepean River
  - Jerrys Creek (tributary to Nepean River)
  - Baines Creek (tributary to Nepean River)
  - Warragamba River (tributary to Nepean River)
  - Megarritys Creek (tributary to Warragamba River)
  - South Creek (tributary to Hawkesbury River)
  - Badgerys Creek (tributary to South Creek)
  - Kemps Creek (tributary to South Creek)
  - Cosgrove Creek (tributary to South Creek)
  - Oaky Creek (tributary to Cosgrove Creek)
- Georges River catchment:
  - Prospect Creek (tributary to Georges River)
  - Green Valley Creek (tributary to Prospect Creek)
  - Hinchinbrook Creek (tributary to Cabramatta Creek)

The Hawkesbury-Nepean catchment provides drinking water, agricultural and fisheries produce, recreational opportunities and tourism resources for Metropolitan area of Sydney and is one of the largest coastal basins in NSW with an area of 21,400 km^2 (NSW DPI, 2017). Over its 470 km flowing length, it originates from the headwaters of the Nepean River in Goulburn before joining the Hawkesbury River in the west of Sydney and draining to Broken Bay.

The Georges River catchment has an area of 960 km^2 and the Georges River itself extends approximately 60 km south-west of Sydney. It is one of the most highly urbanised catchments in Australia. It includes parts of 14 local government areas and covers a significant portion of the Greater Metropolitan Region (Georges Riverkeeper, n.d.). The Georges River, having come together from such widespread sources as Wollongong and Wollondilly in the south and Blacktown in the north, initially flows northward until Chipping Norton where it bends and ultimately flows eastwards into Botany Bay.

While almost half the Hawkesbury-Nepean Catchment is protected in national parks and water catchment reserves, the AWRC lies within the Badgerys Creek, South Creek and Kemps Creek sub-catchments which have been extensively modified and disturbed by agriculture, increasing urbanisation and associated land clearing. Specifically, the AWRC is located within a floodplain bordered by Kemps Creek to the northeast and South Creek to the southwest. Surface water flow would be consistent with the topography, outward toward both creeks.

The hydrology of both the Georges River and local Lower Hawkesbury-Nepean catchment have been significantly altered due to increasing impervious surfaces which has in turn altered the geomorphology and ecology of the watercourses.

Additional flows within the Lower Hawkesbury-Nepean catchment are derived from a number of major Sewage Treatment Plants (STPs) which discharge treated effluent (HNCMA, 2007). The Hawkesbury River is the ultimate downstream receiving environment and is located about 29 kilometres from the project at the closest point.

Some local drainage ditches also exist within the AWRC site, most prominently observed in a generally straight line from northeast to southwest. Any remaining discharge should percolate through the soil into groundwater. The creeks and their associated ecosystems are the environmental receptors for potential impacts from the AWRC development.

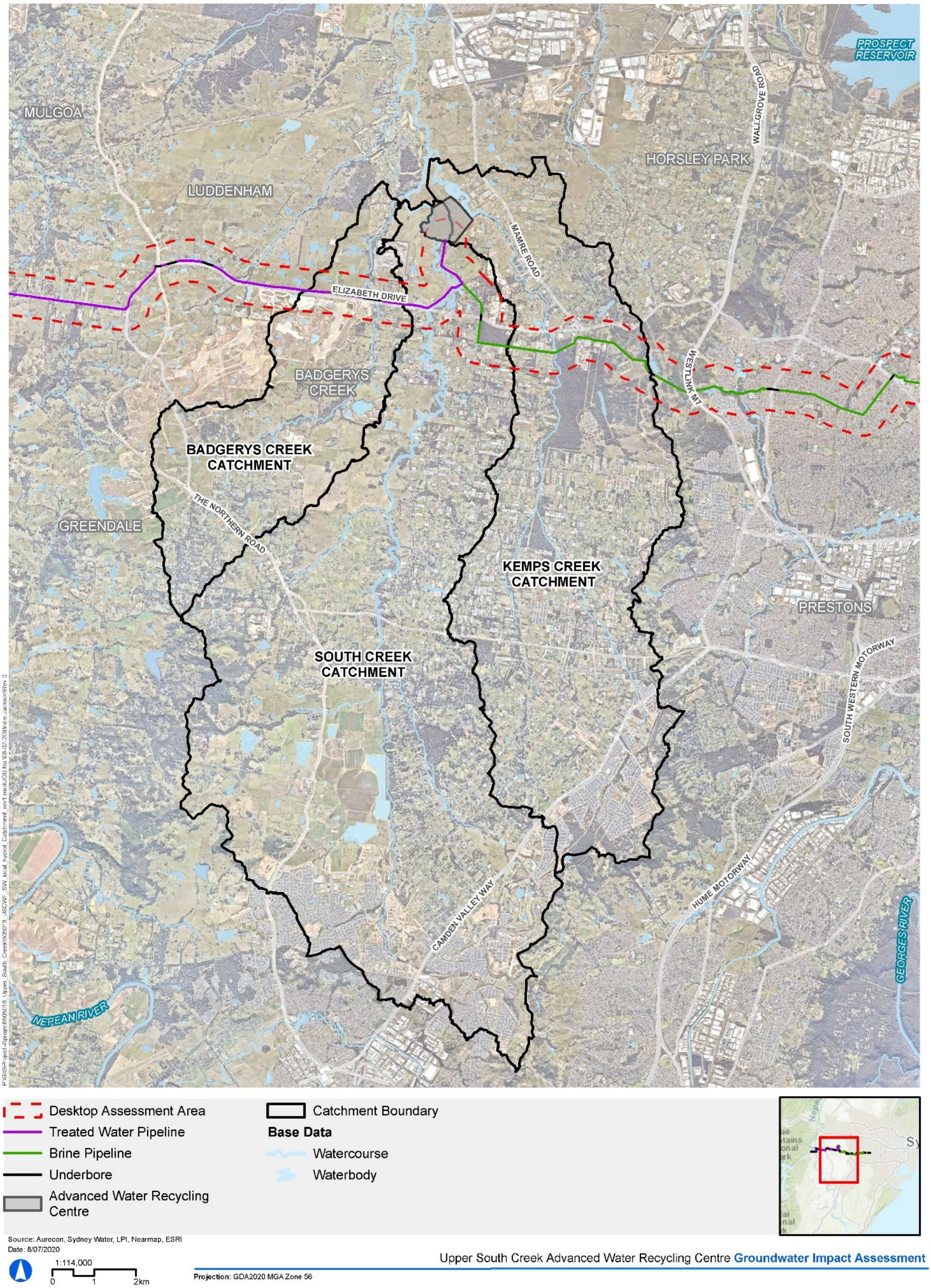


Figure 4-9 Drainage & Hydrology – Key sub-catchments relevant to the AWRC site

South Creek Sub-Catchment

South Creek sub-catchment covers an area of approximately 490 km^2, forming part of the Hawkesbury Nepean catchment and a tributary of the Hawkesbury-Nepean River. It rises around Oran Park, flowing generally north, where it is joined by other tributaries such as Badgerys Creek and Kemps Creek before reaching its confluence with the Hawkesbury River, near Windsor. The creek generally flows from south to north, descending approximately 94 m over its 70 km course.

The confluence of Kemps Creek and Badgerys Creek into South Creek is about three kilometres north of Elizabeth Drive.

Kemps Creek Sub-Catchment

Kemps Creek is a tributary of South Creek and is a fourth order stream which flows into the Hawkesbury-Nepean River. The creek originates about two kilometres east of Catherine Fields and flows for about 17 km through the suburbs of Rossmore, Bringelly, Austral and Kemps Creek before entering South Creek north of Elizabeth Drive.

The Kemps Creek sub-catchment is known to experience flooding and associated drainage problems due to limited hydraulic capacity in the creek channels, filling activities on the floodplain and inadequate hydraulic capacity at culverts and bridges. As a result of drainage problems, considerable earthworks have been conducted to control water including construction of dams to store water, construction of channels or banks to divert flow of water and enlarging the creek channel to reduce flood levels (Liverpool City Council, 2003). Land use within the Kemps Creek sub-catchment largely includes agriculture (grazing, market gardens, poultry), residential, commercial and extractive industry.

Badgerys Creek Sub-catchment

Badgerys Creek has a catchment area of approximately 28 km^2 and has its headwaters in the vicinity of Findley Road, Bringelly, approximately 10 km upstream of the AWRC. It flows generally in a north to north-east direction. The creek then forms the south-eastern boundary of the Western Sydney Airport as far as Elizabeth Drive. It then passes the Elizabeth Drive landfill site, operated by SUEZ Environment. It then continues to flow until its confluence with South Creek at nearly 500 m (at the closest point) downstream of the AWRC.

4.3.2 Interconnection between surface water and groundwater systems

Interactions between surface water and groundwater system occurs through either the river leaking into the underlying groundwater system or vice versa, depending on the relative levels of the water levels in the two systems and the permeability of the riverbed material.

For hydraulically connected systems, rivers may lose water to the underlying aquifer when the water level in the river is higher than the water level in the aquifer. In this case the river is considered as a losing stream. If the groundwater table is higher than the water level in the creek the aquifer discharges water to the river. When this occurs, it is referred to as a gaining stream and the discharge is referred to as baseflow.

A river may comprise multiple gaining and losing reaches. No studies to date have been carried for South Creek which identify gaining and losing reaches for this creek. Information on observed baseflow was obtained from the water balance modelling of South Creek catchment undertaken by Cooperative Research Centre (CRC) for Irrigation Futures (2009). The model used by CRC comprised sub-catchments of South Creek which discretised at selected stream gauges as shown in **Figure 4-10**.

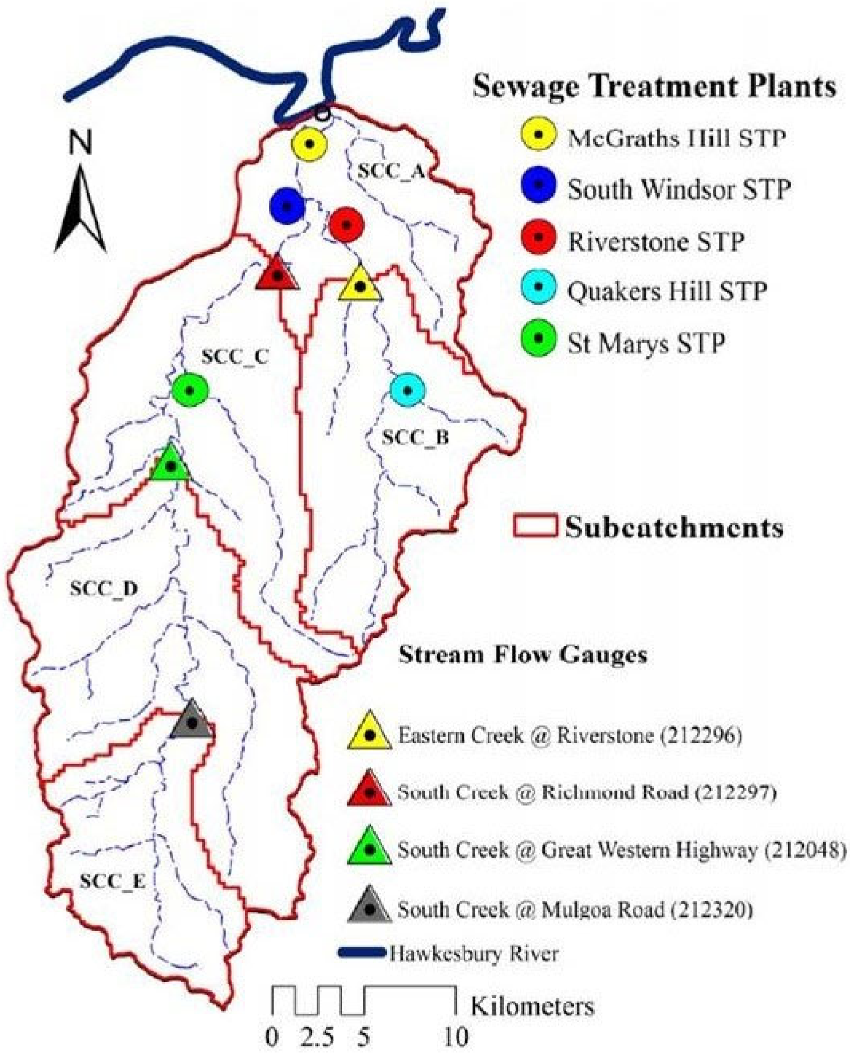


Figure 4-10 The South Creek catchment and its sub-catchments (CRC, 2009)

The simulated annual and monthly runoff volumes determined by CRC for Irrigation Futures (2009) are provided in **Figure 4-11** and **Figure 4-12**, respectively.

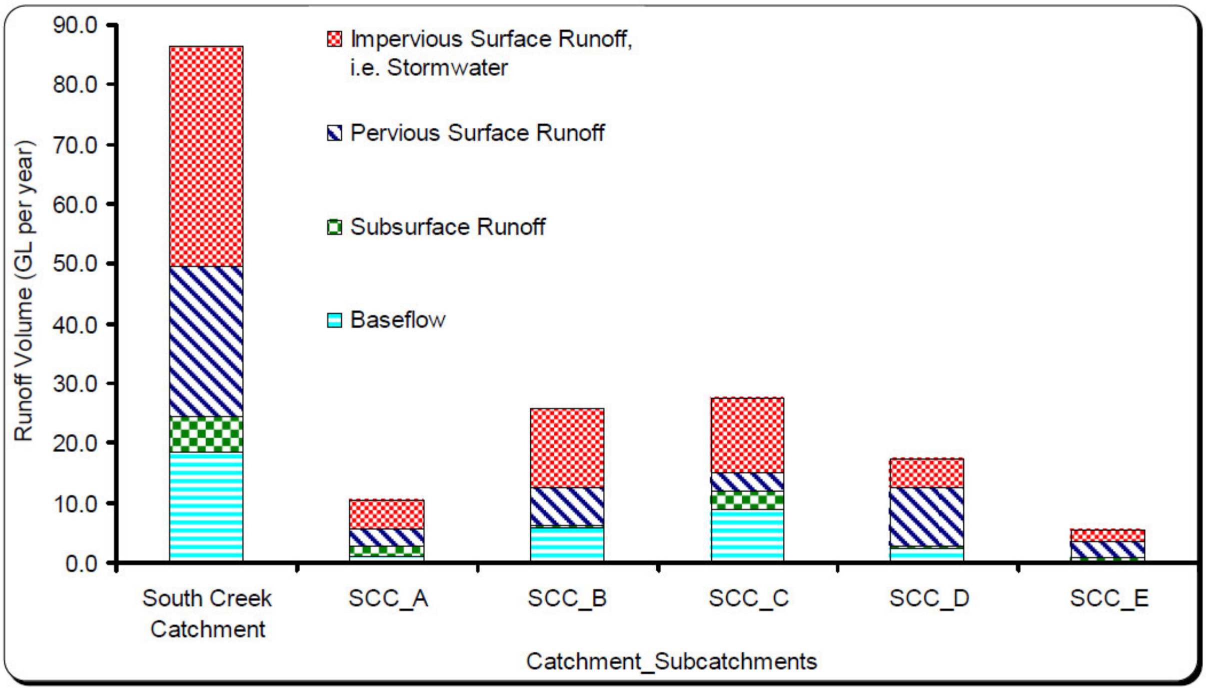


Figure 4-11 Average annual rainfall runoff volumes in the South Creek catchment (GL/year) (CRC, 2009)

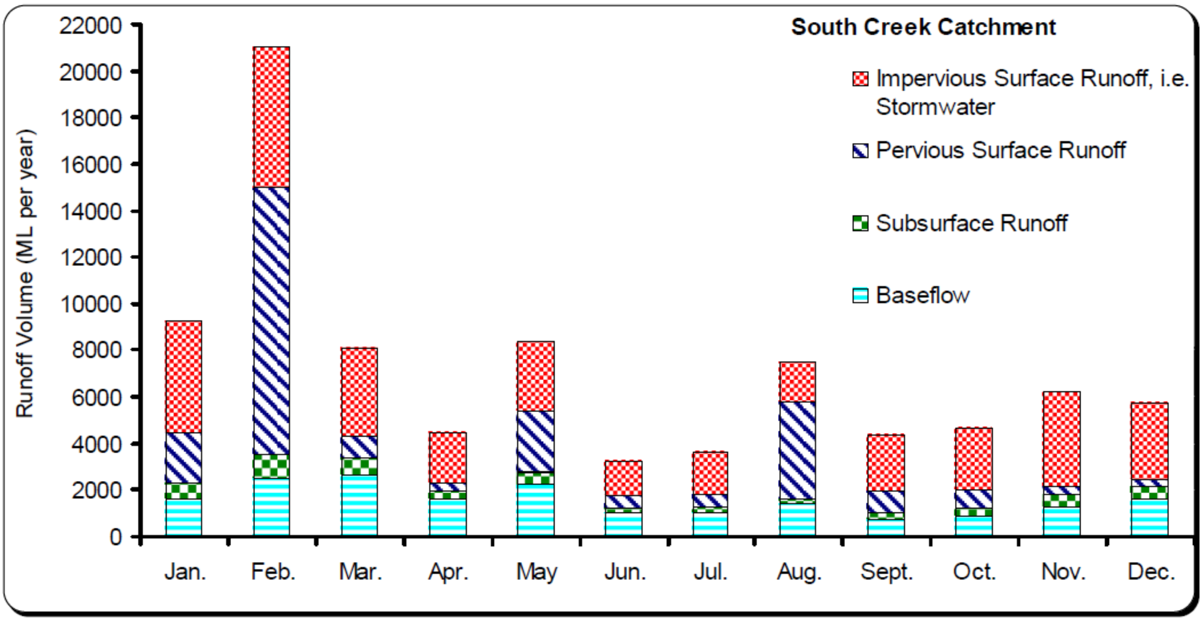


Figure 4-12 Average monthly rainfall runoff volumes in the South Creek catchment (ML/month) (CRC, 2009)

The AWRC is in catchment SCC_D shown in **Figure 4-10** and the simulated annual and monthly runoff volumes for this catchment in are of direct relevance to the AWRC numerical groundwater model (**Appendix A**).

The total annual modelled and calibrated baseflow at Great Western Highway Gauge 212048 is 2.5 GL/year (or 6,926 m^3/d). The total length of major creeks discharging at this streamflow gauge is 63.9 km. Assuming uniform contribution from these creeks, this baseflow equates to 0.108 m^3/d/m. The total length of major creeks within the ARWC groundwater model domain is 37.0 km, and this translates to approximately 4,007 m^3/d (maximum) as baseflow being generated annually within the AWRC model domain. However, in reality rivers could comprise alternating gaining and losing reaches depending on a number of factors including local hydrogeological conditions, the characteristics of the riverbed material and the elevation of the riverbed relative to local groundwater level. It is expected that gaining reaches of the creek would likely be in the lowland sections. Observed groundwater levels at AWRC during the project fieldwork, as well as those from nearby studies were all higher than the observed water levels in the adjacent creeks (South Creek and Kemps Creek). The reaches of the creeks in these areas are therefore gaining river segments.

4.4 Regional Geology

The project is located within the Permo-Triassic Sydney Basin. The Sydney Basin is characterised by sub-horizontal sedimentary deposits, which mainly comprise sandstone with interbedded shale layers deposited unconformably on a basement of the Lachlan fold belt (Haworth, R.J., 2003). Surface outcrops of geological units associated with the desktop assessment area has been determined from a review of the NSW Seamless Geology dataset (Department of Regional NSW, 2020) and are presented in **Figure 4-13**, **Figure 4-14** and **Figure 4-15**.

A depositional and descriptive summary of the geological units (in order of age: most recent to oldest) that occur within the desktop assessment area is presented in **Table 4-5**. Further details of each identified stratigraphic unit are provided in the following sections.

The regional geology is the physical setting of groundwater systems in the desktop assessment area, therefore the information presented in this section has been used to form the basis of the hydrogeological conceptual model (outlined in **Section 5**) and the subsequent impact assessment.

Table 4-5 Relevant geological units within the desktop assessment area

Age	Stratigraphic unit	Deposition environment	Description
Anthropocene	Anthropogenic Fill	Sub-aerial	Highly variable fill materials (includes topsoil, embankments, road pavements, landscaped areas etc.)
Quaternary	Alluvial Sediments/Deposits	Non-marine rivers, creeks and streams	Loose, unconsolidated fine to medium grained sand, silt and clay.
Triassic	Bringelly Shale	Swampy alluvial plain with streams flowing from the west.	Variable sedimentary rock types. Black and grey shales and sandstones with small scale bedding.
	Minchinbury Sandstone	Shoreline marine environment	Fine to medium grained quartz sandstone with calcite and volcanic lenses.
	Ashfield Shale	Low energy marine environment	Black mudstones and grey shales with small scale bedding.
	Hawkesbury Sandstone	Braided alluvial channel fill	Medium to coarse-grained quartz sandstone with minor shale and laminate lenses. Sandstones are either massive or cross-bedded sheet facies with vertical or sub-vertical joint sets. The combination of bedding planes and widely spaced joints gives sandstone outcrops a distinctive blocky appearance.

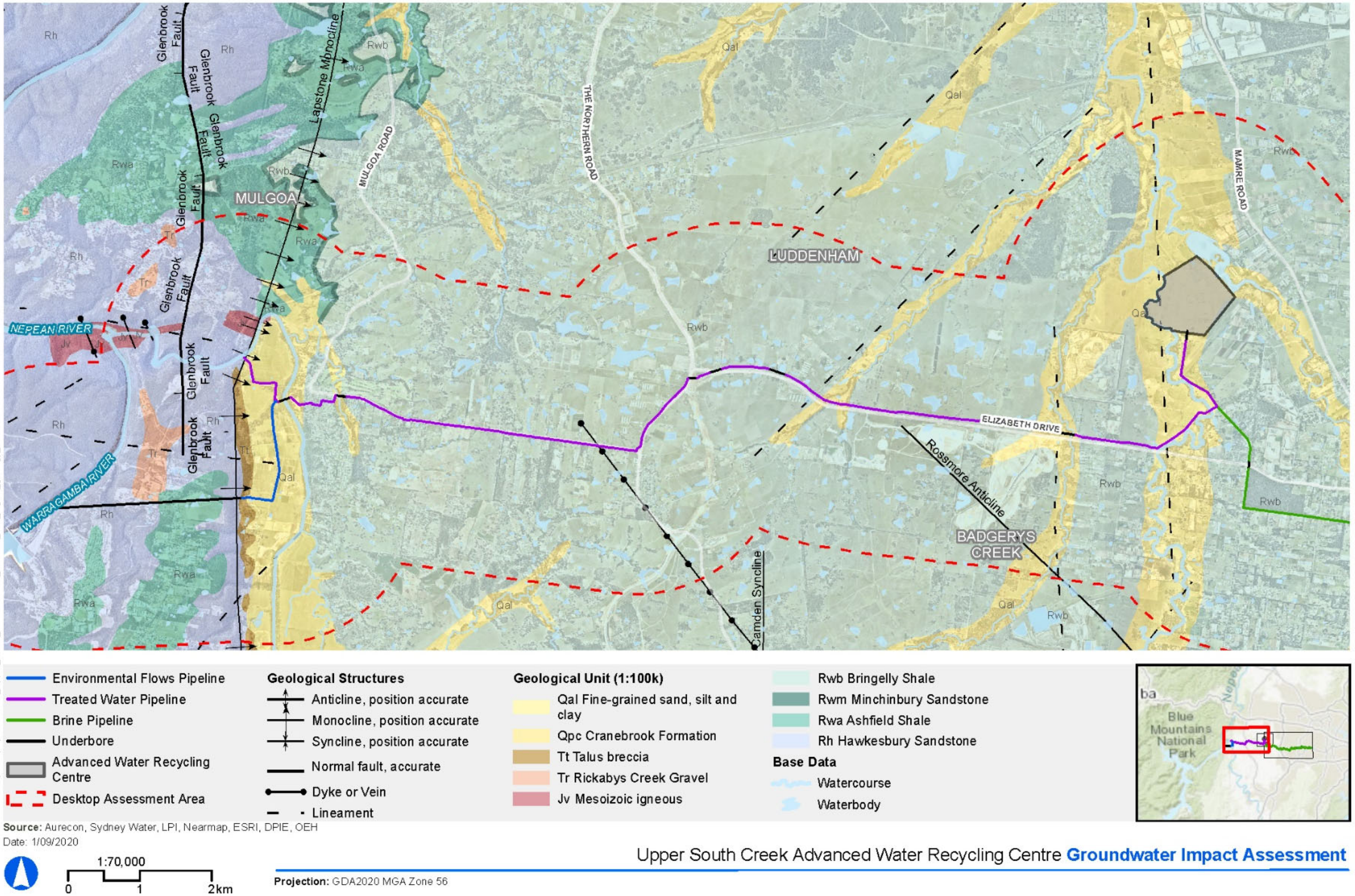


Figure 4-13 Regional Surface Geology – Treated Water / Environmental Flow Pipelines

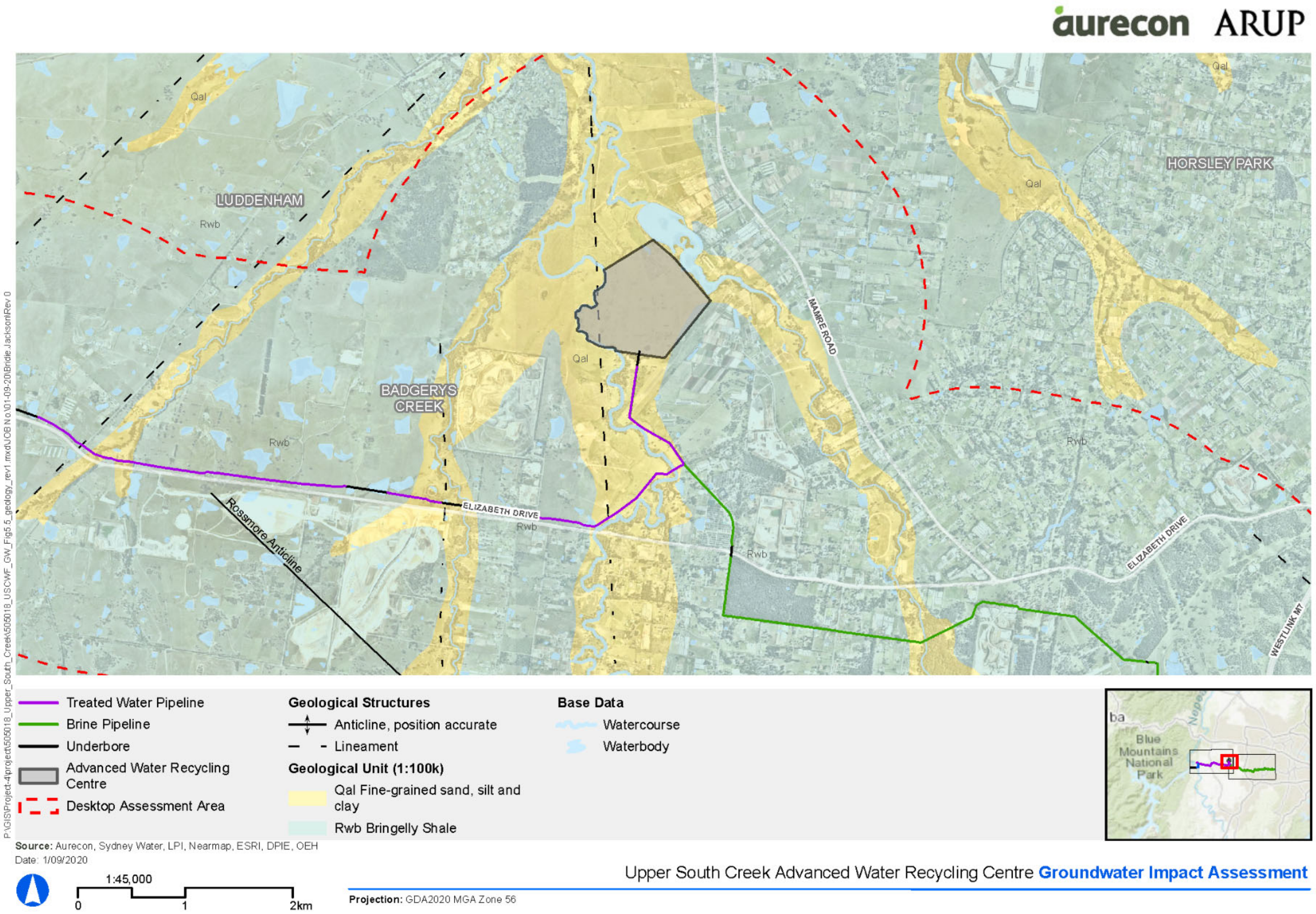


Figure 4-14 **Regional Surface Geology – AWRC site**

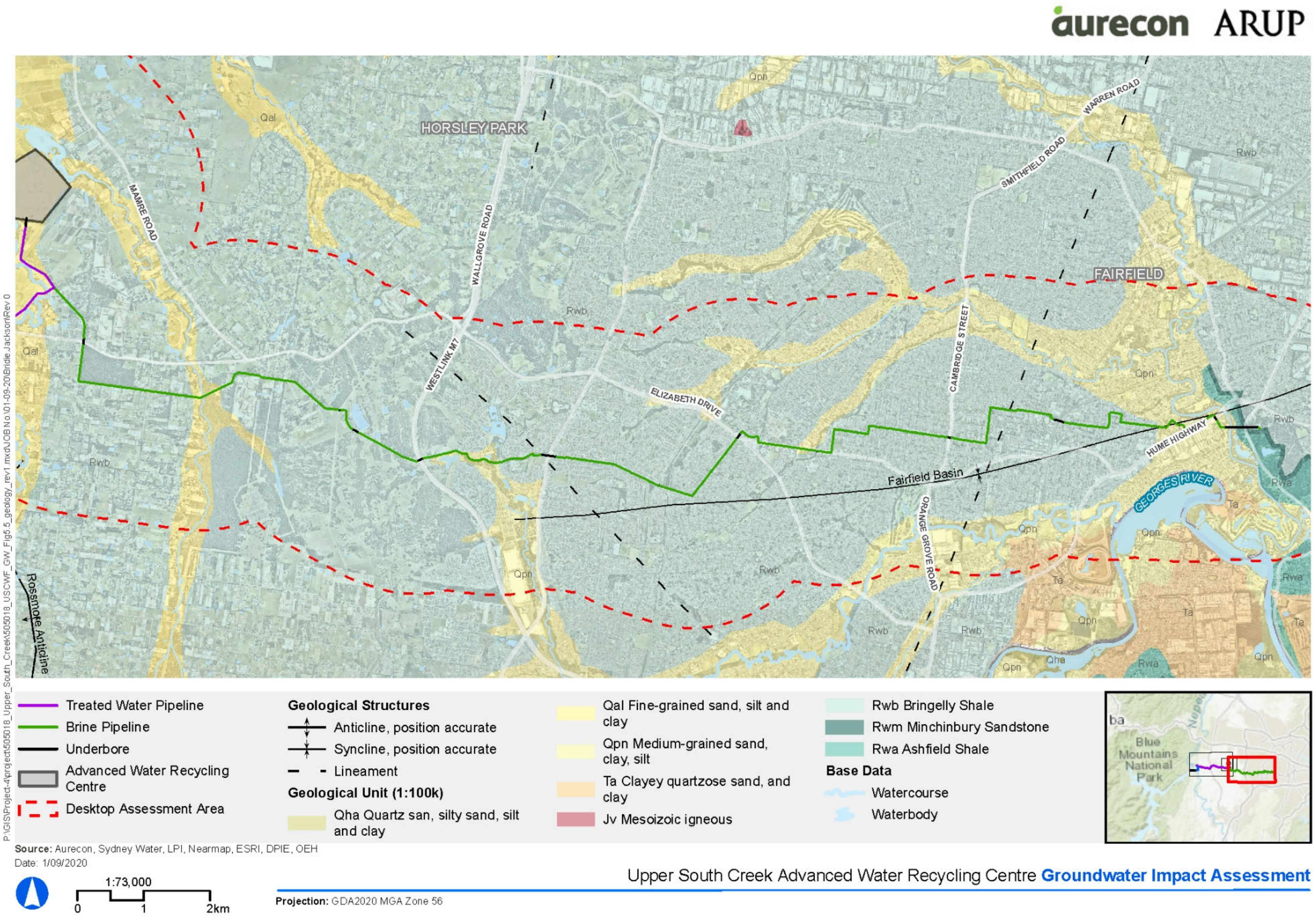


Figure 4-15 Regional Surface Geology – Brine Pipeline

4.4.1 Quaternary deposits

Anthropogenic Fill

Artificial ground (anthropogenic deposits of fill material) is likely to be present as a thin layer across the desktop assessment area, associated with pavement construction, landscaping and building foundations. Deeper fill deposits may be present in areas mapped as “disturbed terrain” in the east around Prestons and Liverpool.

Quaternary Alluvium

Quaternary alluvium is commonly encountered in areas adjacent to and within floodplains of rivers and streams throughout the desktop assessment area, including Nepean River, Badgerys Creek, South Creek, Kemps Creek, Cabramatta Creek, Clear Paddock Creek, Georges River and Prospect Creek.

Areas where alluvium is presented are associated incisions in the underlying bedrock formed by river/stream erosion, later infilled with sediments as a result of changes in potential energy associated with sea level fluctuations.

Alluvial deposits in the desktop assessment area comprise fine-grained sand, silt and clay. The extents of alluvial deposits are based on the available 1:100,000 scale geological mapping. Based on this mapping, the total width of the alluvium deposits around the rivers/streams are as follows:

- Nepean River: 900 metres
- Cosgroves Creek: 300 metres
- Badgerys Creek: 600 metres
- South Creek: 850 metres
- Kemps Creek: 450 metres
- Cabramatta Creek: 1,500 metres

A larger area of alluvial deposition is present at the confluence between Kemps Creek, South Creek and Badgerys Creek, with a width of approximately 1,600 m edge to edge.

4.4.2 Triassic sediments

The Wianamatta Group (Late-Triassic)

The Wianamatta Group was deposited in the Triassic Age during a single regressive period following the subsidence of the Hawkesbury Sandstone alluvial plain. The deposition of sedimentary rock types occurred continuously during the period in connection with a large river delta, with vertical accumulation of sediments and a shoreline progressing from west to east.

Deposition of the Wianamatta Group began with a basal unit of offshore low energy marine muds/clays (Ashfield Shale), which then became a shoreline/beach sand deposit (Minchinbury Sandstone) and finally became marshy alluvial plain deposits across the delta (Bringelly Shale).

The Wianamatta Group is up to 300 m thick and typically expressed as a shale with sporadic thin lithic sandstone beds. The Wianamatta Group represents the last phase of sedimentation directly related to the tectonic development of the Sydney Basin (O’Neill & Danis, 2013). The following sections discuss the geological features of each unit associated with the Wianamatta Group within the desktop assessment area.

Bringelly Shale

Bringelly Shale is the most prevalent surface outcropping geological formation across the desktop assessment area and comprises variable sedimentary rock types, including shale, carbonaceous claystone, claystone, laminate, fine to medium grained lithic sandstone, rare coal and tuff. Bringelly Shale is the upper member of the Wianamatta Group.

The variable rock types arise from the alluvial plain depositional environment, which included swampy organic rich sediments, overbank alluvial clays, channel sands and lake deposits.

The average thickness of the Bringelly Shale formation is approximately 60 m (Lovering, 1954) and is often deeply weathered to depths up to 10 metres. Weathering of the Bringelly Shale typically forms clays and silty clays of medium to high plasticity (and low permeability).

Minchinbury Sandstone

The Minchinbury Sandstone is a relatively thin stratigraphic unit that lies between the Bringelly Shale and Ashfield Shale formations within the Wianamatta Group. The unit comprises fine to medium grained quartz lithic sandstone with calcite and volcanic lenses. The high quantities of quartzite and limited amount of felspar in the Minchinbury Sandstone differentiate it from the sandstones that occur within the Bringelly Shale.

The unit ranges in vertical thickness between 1.5 and 6 m and is less than 3 m thick in most areas (Lovering, 1954).

Ashfield Shale

Ashfield Shale occurs below in the Minchinbury Sandstone, forming the basal unit of the Wianamatta Group. The unit comprises black claystone, siltstone, mudstone and grey shales with interbedded ironstone bands. Small-scale bedding is prevalent, with thin alternating layers of siltstone and sandstone that is sometime carbonaceous with variable silt and clay particles throughout.

Hawkesbury Sandstone (Triassic)

The Hawkesbury Sandstone formation is the predominant bedrock in the Sydney Basin. It occurs below the Ashfield Shale and Minchinbury Sandstone formations (Wianamatta group) across the Sydney area. It is associated with the Narrabeen Group; a prograding sequence of alluvial deposits that characterised the Late Permian to Middle Triassic. The Hawkesbury Sandstone is up to 250 m thick and is typically expressed as coarse quartz-rich sandstone with very minor shale and laminite lenses. Sediments that comprise the Hawkesbury Sandstone may be associated with erosion of Upper Devonian Quartzites belonging to the Lachlan Fold Belt (O’Neill & Danis, 2013).

4.4.3 Intrusions and structural elements

Triassic sediments in the Sydney Basin are highly fractured and faulted due to transpressional tectonic stresses resulting from the Hunter-Bowen Orogeny (HBO) in the Late Triassic. Subsequent transtension volcanic activity in the Jurassic period resulted in the intrusion of syenitic volcanics into the Hawkesbury Sandstone and other Permian and Triassic formations (including dykes, sills and laccoliths) throughout the Sydney region (O’Neill & Danis, 2013; Cook and Ross, 2009). Passive margin development, extension, and uplift following the Jurassic period resulted in opening of fractures because of both tectonic and erosional stress release.

Post Jurassic extension created a topographic depression resulting in the Sydney Basin. The basin persisted into the late Quaternary Period when sea level fluctuation conditions favoured the persistence of sedimentary deposition over erosion (Hatley, 2004).

Major faults and shear zones affecting the Triassic units are principally aligned along a NW-SE direction because of the prevailing tectonic stresses which formed them. They include high angle displacement faults, low angle thrusts and bedding shear zones.

The mapped surface outcrop of the geological units and associated intrusions and structural are shown on **Figure 4-13**, **Figure 4-14** and **Figure 4-15** and include:

- Luddenham Dyke: A basaltic dyke with a NW-SE orientation, intersecting Park Rd, Wallacia.
- Narellan Lineament: Aligning with the overall linearity of South Creek, suggesting that the creek may be structurally controlled. There are also a number of north-east trending tributaries into the Narellan Lineament, (e.g. Cosgrove Creek) with align with regional faulting trends.
- Rossmore Anticline: This feature forms a structural high point of the Wianamatta Group. Geological bedding dips in the vicinity of the Rossmore Anticline are likely and are expected to dip to the west on the western side of this structure.

4.4.4 Acid Sulfate Soils and Rock

Acid Sulfate Soils (ASS) refer to soils containing sulfides. When the sulfides contained in ASS are exposed to oxygen, such as from groundwater drawdown and/or excavation, sulfuric acid can be generated, which may result in a number of detrimental effects on groundwater dependant ecosystems, underground structures and receiving water bodies, including:

- Sulfuric acid causing leaching/mobilisation of metals from otherwise stable soil matrices, increasing the concentration of heavy metals in the groundwater to potentially toxic levels.
- Reduced durability of underground structures, such as steel and concrete, through corrosion.
- Degradation of soil quality in affected areas, preventing vegetation growth.

Acid sulfate rock (ASR) can also occur within some geological units such as marine sedimentary units, coal measures and igneous rock with sulfide and pyrite mineralisation. All ASR contains appreciable iron sulfide that when disturbed and specifically crushed, presents a risk of environmental and durability impacts for road structures when in contact with water and atmospheric oxygen. ASR presents a risk for fresh rock when excavated and not weathered rock that has been exposed to weathering process and leaching of pyrite over time.

A review of the Office of Environment and Heritage NSW Acid Sulfate Soils Risk Maps (OEH, 2015) check with contaminated land, indicates that the majority of the desktop assessment area is not located within an area of potential acid sulfate soils (potential ASS). The exception is some potential ASS risk areas are present around Georges River and Prospect Creek in the eastern portion of the desktop assessment area (refer to **Figure 4-16**), including:

- A high potential for occurrence of ASS along the brine pipeline for bottom sediments and surrounding embankments where Hume Hwy intersects Prospect Creek.
- A high potential for occurrence of ASS for bottom sediments in the George Rivers near Moorebank, and a low probability for occurrence of ASS along the sides of the Georges River.
- Areas surrounding the Georges River in Chipping Norton and Milperra, where a mixture of ASS probability zones are present, including disturbed terrain, high probability ASS, high probability bottom sediments, and low probability for ASS.

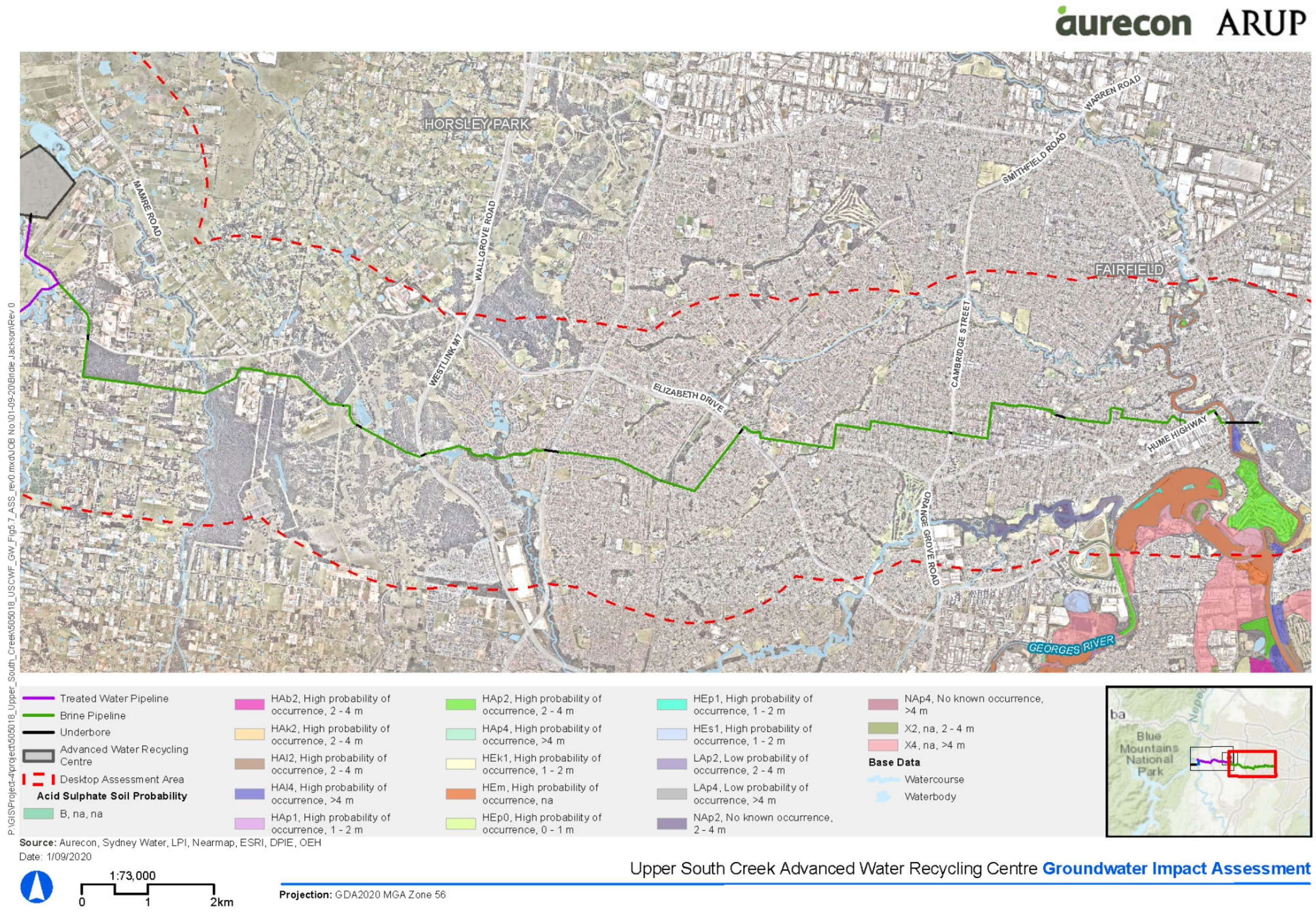


Figure 4-16 **Distribution of Acid Sulfate Soils Risk – Brine Pipeline**

4.5 Catchment hydrogeology

4.5.1 Hydrostratigraphy

Based on the regional geology and information gathered from available data sources, two main groundwater systems are identified across the desktop assessment area, including:

- Unconfined to semi-confined groundwater systems associated with Quaternary alluvial deposits, most prevalent in areas surrounding the rivers and streams that intersect the project.
- Unconfined to semi-confined groundwater systems within the bedrock formations (Wianamatta Group formations overlying Hawkesbury Sandstone).

4.5.2 Aquifers

Alluvial Groundwater Systems

Quaternary alluvium in the desktop assessment area is most prevalent in areas surrounding the rivers and streams that intersect the project, including Nepean River, Badgerys Creek, South Creek, Kemps Creek, Cabramatta Creek, Clear Paddock Creek, Georges River and Prospect Creek.

These areas are associated with infilled incisions in the underlying bedrock formed by river/stream erosion. Alluvial deposits comprise fine-grained sand, silt and clay and are expected to be relatively thin (i.e. between 2.5 to 7.0 m in vertical thickness) based on previous investigations in the region (M12 Motorway EIS, Appendix N).

Based on the geological mapping presented in **Section 4.4**, the width of the alluvium deposits around the rivers/streams are approximately 900 m for the Nepean River, 300 m for Cosgroves Creek, 600 m for Badgerys Creek, 850 m for South Creek, 450 m for Kemps Creek and 1,500 m for Cabramatta Creek. A larger area of alluvial deposition is present at the intersection between Kemps Creek, South Creek and Badgerys Creek, with a width of approximately 1,600 m. Larger vertical thicknesses of the alluvial deposits are expected to occur in these areas.

These deposits form predominately unconfined aquifers that are likely connected to the associated rivers/streams and responsive to rainfall. The presence of clays in the alluvial deposits may form localised aquitards leading to semi-confined groundwater conditions in some areas.

Bedrock Groundwater Systems

The bedrock groundwater systems expected to be intercepted by the project in the desktop assessment area are characterised as unconfined to semi-confined dual porosity (granular and fractured) bedrock systems. Several distinct hydrostratigraphic units are expected to be present, including Bringelly Shale, Minchinbury Sandstone and Ashfield Shale of the Wianamatta Group, overlying Hawkesbury Sandstone (in stratigraphic order).

The hydrostratigraphic units present within the bedrock groundwater systems are summarised as:

- Residual / regolith soils associated with weathered Bringelly Shale. Comprising floodplain alluvial soils, weathered shale and saprolite.
- Upper aquifer within the Wianamatta Group, weathered/fractured Bringelly Shale, with typical vertical thicknesses ranging between 3 to 10 m. Fractures formed by weathering of the Bringelly Shale are typically filled with clays and silty clays of medium to high plasticity and low permeability where this is encountered.

- Lower aquifer within the Wianamatta Group, occurring at the base of weathering, comprising fine-grained mudstone/shale. Some degree of widely spaced fracturing may be present allowing some groundwater flow, however in unfractured areas the shale will be effectively impermeable.
- Hawkesbury Sandstone aquifer, strongly influenced by secondary porosity, with groundwater flow occurring mostly through fractures along joints and/or shear zones. Rock defect characteristics within this hydrostratigraphic unit are influenced by depth and in-situ stress conditions, in addition to regional structural features.

4.5.3 Hydrogeological Properties

The hydrogeological properties presented in the subsequent sections have been used to characterise the groundwater systems and the mechanics of groundwater movement in the desktop assessment area. This forms a key component of the hydrogeological conceptual model (outlined in **Section 5**).

Porosity

Porosity is defined as the total void space of geological materials. Consolidated bedrock materials often have distinct primary and secondary porosities (also known as 'dual porosity). The primary porosity is the original porosity of the rock when it was formed, and secondary porosity is the void space caused by subsequent fracturing.

Porosity in geologic materials provide space for groundwater storage. However, in geologic materials there are regions where void spaces exist but do not have the ability to transmit groundwater. Not all pores are connected, therefore, when discussing groundwater flow an important property is "effective porosity" which is the total interconnected void space. Effective porosity is a measure of aquifers ability to store and release groundwater, therefore, dictates an aquifer's response to stresses such as rainfall events and construction dewatering.

Available data relating to storage properties in the desktop assessment area is scarce, therefore the following literature values have been derived to estimate the porosity of the identified geological materials (Morris and Johnson, 1967).

- Unconsolidated sedimentary materials associated with the Quaternary alluvial and residual/regolith soils:
  - Fine-grained sands = 26% to 53%
  - Silts = 34% to 61%
  - Clays = 34% to 57%
- Sedimentary rocks associated with the bedrock groundwater systems:
  - Shale = 1% to 10%
  - Claystone = 41% to 45%
  - Siltstone = 21% to 41%
  - Sandstone = 14% to 49%

Hydraulic Conductivity

In general, the hydraulic conductivity of shallow unconsolidated materials associated with alluvial deposits and residual soils is comparatively higher than the hydraulic conductivity of deeper consolidated rocks present in the Wianamatta Group and Hawkesbury Sandstone.

Hydraulic tests carried out in the quaternary alluvial materials during previous investigations in the region indicate that hydraulic conductivities range between 0.017 to 0.14 m/day (WSA EIS – Appendix L3; M12 EIS – Appendix N). Hydraulic tests carried out in the quaternary alluvial materials at the AWRC site indicate that hydraulic conductivities range between 0.01 to 1.29 m/day (Aurecon Arup, 2020). Lower hydraulic conductivities occur in areas with an increased presence of clay deposits and weathered shale, and higher hydraulic conductivities occur in areas with an increased presence of sands and gravels.

Hydraulic tests carried out in the residual soils and weathered Wianamatta Group shales at the AWRC indicate that hydraulic conductivities range between 0.05 to 0.48 m/day (Aurecon Arup, 2020). Hydraulic conductivities within the Upper Wianamatta Group are expected to be highly variable, ranging between 10^{-5} and 0.01 m/day (Bradd et al., 2012). The higher end is associated with open fractures occurring in the upper weathered zone.

The Lower Wianamatta Group is expected to have lower hydraulic conductivities due to less frequent occurrence of fractures, ranging between 0.001 and 10^{-8} m/day (Bradd et al., 2012). The lower end reflects the intrinsic impermeability of unfractured shale. Vertical hydraulic conductivities within the Wianamatta Group shales are expected to be two to three orders of magnitude lower than horizontal hydraulic conductivities, due to the horizontal bedding planes that are present throughout the geological units.

The hydraulic conductivity of the Hawkesbury Sandstone is related to the rock defect characteristics, which are influenced by the depth and in-situ stress conditions as well as the presence of regional structural features. Conductivities in the Hawkesbury Sandstone are expected to range between 0.01 to 0.5 m/day (Tammetta & Hewitt, 2004), reflecting the difference between deep and near surface conditions.

Storage Properties

Storage properties represent the ability of an aquifer to store and release groundwater. These properties dictate the aquifer's response to stresses such as rainfall events and construction dewatering.

Two main properties that dictate the amount of storage within an aquifer and the amount of groundwater able to be released from storage from an aquifer are:

- Specific Yield (S_y): Relates to unconfined aquifers. Defined as the volume of water released from storage per unit of water table drawdown. Generally equivalent to the effective porosity of an aquifer.
- Storativity (S): Relates to confined aquifers. Defines as the volume of water released from storage per unit decrease in hydraulic head.

Available data relating to storage properties in the desktop assessment area is scarce, therefore literature values have been derived to estimate the storage properties of the identified geological materials (Morris and Johnson, 1967; Hazel, 2009).

- Unconsolidated sedimentary materials associated with the unconfined Quaternary alluvial aquifer and residual/regolith soils:
  - Specific Yield (Sy) = 0.06 (clays) to 0.33 (fine-grained sand).
- Sedimentary rocks associated with the bedrock groundwater systems.
  - Storativity (S) = 0.00005 (shales) to 0.001 (sandstone).

4.5.4 Hydrostratigraphic Units

Based on the information presented in previous sections, five main hydrostratigraphic units are identified in the desktop assessment area. These units are general groupings of geological formations based on their hydrogeological properties, including the nature and connectivity or the void spacing (porosity and hydraulic conductivity) and transmission / storage properties. The hydrostratigraphic units (in stratigraphic order) are defined as:

1) Unconsolidated Quaternary alluvial aquifer.
2) Unconsolidated residual / regolith soils associated with weathered Triassic Bringelly Shale.
3) Upper Wianamatta Group (Triassic Bringelly Shale), weathered zone with fractures.

4) Lower Wianamatta Group (Triassic Bringelly Shale, Minchinbury Sandstone and Ashfield Shale), widely spaced fractures.
5) Triassic Hawkesbury Sandstone.

A summary of the hydrostratigraphic units and their estimated hydrogeological properties is provided in **Table 4-6** below.

Table 4-6 Overview of identified hydrostratigraphic units within the desktop assessment area.

Hydrostratigraphic Unit	Approximate thickness (m)	Porosity (%)	Hydraulic Conductivity (m/day)	Storage Properties (unitless)
Quaternary alluvial aquifer	2.5 – 9.0	26% – 57%	0.017 – 1.287	Specific Yield (S_y) = 0.06 (clays) to 0.33 (fine-grained sand)
Residual / regolith soils associated with weathered Bringelly Shale	1 - 5	26% - 45%	0.05 – 0.484	Specific Yield (S_y) = 0.06 (clays) to 0.33 (fine-grained sand)
Upper Wianamatta Group (Bringelly Shale), weathered zone with fractures	10	1% - 45%	0.01 – 1 x 10^{-5}	Storativity (S) = 0.00005 (shales) to 0.001 (sandstone)
Lower Wianamatta Group (Bringelly Shale, Minchinbury Sandstone and Ashfield Shale), widely spaced fractures.	120	1% – 10%	0.001 – 1 x 10^{-8}	Storativity (S) = 0.00005 (shales)
Hawkesbury Sandstone	250	14% - 49%	0.01 – 0.5	Storativity (S) = 0.00005 (shales) to 0.001 (sandstone)

4.5.5 Secondary Hydrogeological Structures

Aquifer characteristics of hydraulic conductivity and storativity reflect both primary and secondary features. Primary features reflect the composition of the skeletal material comprising the aquifer; while the secondary features reflect elements that develop after the initial formation of the strata (e.g. faults and dykes).

Faults and dykes can have variable flow properties and features may act as either flow barriers, conduits or just zones of high storage. Where significant clays are present in fault zones or dykes, they are more likely to act as barriers to flow.

Secondary features relevant to the aquifers in the impact assessment area comprise the following:

- Fracturing due to faulting or erosional unloading that creates defects in the aquifer material (such as jointing or parting of bedding).
  - Extensive faulting can often create an extensive network of broken material that exhibits elevated values of hydraulic conductivity.
  - Enhanced weathering can occur along these defects such that clays develop, which reduce the overall hydraulic conductivity of the material (Pells et al., 2019).
- Deformation associated with igneous intrusions, such as the Luddenham Dyke. These features can often impede the lateral flow of groundwater across the intrusion but may have enhanced hydraulic conductivity within the interior of the intrusion.

4.5.6 Hydrogeological Landscape Mapping

The Hydrogeological Landscape (HGL) units spatially define and characterise discrete areas of similar character, including salt accumulation, salt stores, saline manifestations and pathways for salt mobilisation. The terms 'hydrogeological' and 'landscapes' reflect the importance of lithology, bedrock structure, regolith (including soils), landforms, climate (including rainfall, seasonality, evaporation) and vegetation on recharge, groundwater flow or movement, storage and discharge of a particular hydrological system. The combination of these factors provides a structure for understanding how salinity manifests in the landscape, the differences in salinity development, and the impacts (land salinity/ salt load/ water electrical conductivity) in the landscape (DPIE, 2011a) (DPIE, 2011b).

A review of hydrogeological landscape (HGLs) mapping presented in **Figure 4-17**, **Figure 4-18** and **Figure 4-19**, indicates the project intersects nine main HGLs. **Table 4-7** summarises the nine HGLs and their definitive characteristics as described in the associated landscape information reports. The most prominent HGL within the desktop assessment area is the Upper South Creek (and Upper South Creek Variant A) HGL, which is intersected by the Treated Water pipeline east of Luddenham, the AWRC and brine pipeline in the vicinity of Kemps Creek and between Cecil Hills and Prospect Creek in Lansdowne.

Table 4-7 Summary descriptions of HGLs relevant to the desktop assessment area

Hydrogeological Landscape	Relevance to project feature(s)	Description
Hawkesbury	Intersected by E-Flows pipeline, in elevated areas between Warragamba River and Nepean River.	The Hawkesbury HGL is characterised by plateau, scarps, benches and hills on sandstones from the Triassic Hawkesbury Sandstone and Narrabeen Group as well as minor outbreaks of Tertiary Basalt and Jurassic Volcanics. Unconsolidated colluvial sediments and talus derived from Triassic sedimentary rocks have been deposited on the slopes and valley floors across this HGL. Groundwater flow to be intercepted by the project facilities for this HGL relates to the upper systems which are expected to be predominantly unconfined along structural features (bedding, joints, faults etc.) in the fractured bedrock and through connected pore spaces in the sandstones. Depth to water table is typically deep (>8 mBGL). Land salinity is low, groundwater is generally fresh (EC less than 0.8 dS/m or 800 µS/cm) which equates to the beneficial use category "A" (refer to **Table 2-3**).
Mid-Nepean River	Intersected by E-Flows and Treated Water pipelines in low-lying areas west of the Nepean River.	The Mid-Nepean River HGL is characterised by floodplains and gentle rises on the active floodplain of the Nepean River, comprising unconsolidated alluvial sediments of fine-grained sands, silts and clays of the Quaternary period derived from the surrounding Wianamatta Group rocks and Hawkesbury Sandstone. Groundwater flow is unconfined through unconsolidated alluvial sediments. Localised perching of water tables may occur above clay lenses during wetter periods. Depth to water table is typically shallow to intermediate (0-8 mBGL) with seasonal variation. Land salinity is low, groundwater is generally fresh (EC between 0.8-1.6 dS/m or 800-1600 µS/cm) which equates to the beneficial use category "A" (refer to **Table 2-3**).
Mulgoa	Intersected by Treated Water pipeline in Wallacia, east of the Nepean River and again in the vicinity of Elizabeth Dr in Luddenham.	The Mulgoa HGL is characterised by hillslopes and benches on Triassic shale and sandstones (Bringelly Shale and Ashfield Shale) overlain by unconsolidated colluvial and alluvial gravels, sands and silts deposited on lower slopes and along streams. Groundwater flow is unconfined to semi-confined through unconsolidated alluvial/colluvial sediments and along structural features (bedding, joints, faults etc) in the fractured bedrock. Localised perching of water tables occurs above clay lenses during wetter periods. In the fractured rock, groundwater predominantly moves laterally through the shale layers (although vertical movement through fracturing does occur) and vertically through interbedded sandstone and sandstone fracturing. Depth to water table is intermediate (2-8 mBGL) with seasonal variation. Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8

Hydrogeological Landscape	Relevance to project feature(s)	Description
		dS/m or 1,600-4,800 µS/cm) which equates to the beneficial use category "B" (refer to **Table 2-3**).
Greendale	Intersected by Treated Water pipeline between Park Rd in Wallacia and Elizabeth Dr in Luddenham.	The Greendale HGL is characterised by low rises, gently sloping plains and ponded drainage lines on Triassic Wianamatta Group rocks (predominately Bringelly Shale) overlain by unconsolidated sediments of sands, silts and clays of the Quaternary period. Groundwater flow is unconfined to semi-confined through unconsolidated alluvial/colluvial sediments and along structural features (bedding, joints, faults etc) in the fractured bedrock. Localised perching of water tables occurs above clay lenses during wetter periods. In the fractured rock, groundwater predominantly moves laterally through the shale layers (although vertical movement through fracturing does occur) and vertically through interbedded sandstone and sandstone fracturing. Depth to water table is intermediate (2-8 mBGL) with seasonal variation. Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8 dS/m or 1,600-4,800 µS/cm) which equates to the beneficial use category "B" (refer to **Table 2-3**).
Upper South Creek	Intersected by Treated Water pipeline east of Luddenham, the AWRC site and brine pipeline in the vicinity of Kemps Creek	The Upper South Creek HGL is characterised by low, undulating hills with colluvial/ alluvial foot slopes and plains (often ponding) and drainage lines on Triassic Wianamatta Group rocks (predominately Bringelly Shale). Groundwater flow is unconfined along structural features (bedding, joints, faults etc) in the fractured bedrock, predominantly moving laterally through the shale layers (although vertical movement through fracturing does occur) and vertically through interbedded sandstone and sandstone fracturing. Lateral flow occurs through alluvial sediments on slopes and plains. Localised perching of water tables may occur above clay lenses during wetter periods. Depth to water table is intermediate (2-6 mBGL). Land salinity is high, groundwater is generally saline (EC greater than 4.8 dS/m or 4,800 µS/cm) which equates to the beneficial use category "C" (refer to **Table 2-3**).
Mount Vernon	Intersected by the Brine pipeline in Cecil Park	The Mount Vernon HGL is characterised by steep low hills on Triassic Wianamatta Group rocks (predominately Bringelly Shale). Alluvial sands and gravel are present along current streams. Groundwater flow is unconfined along structural features (bedding, joints, faults etc) in the fractured bedrock, predominantly moving laterally through the shale layers (although vertical movement through fracturing does occur) and vertically through interbedded sandstone and sandstone fracturing. Lateral flow occurs through alluvial sediments on slopes and plains. Localised perching of water tables may occur above clay lenses during wetter periods. Depth to water table is intermediate (2-6 mBGL). Land salinity is moderate, groundwater is generally brackish (EC between 0.8-1.6 dS/m or 800-1600 µS/cm) which equates to the beneficial use category "A" (refer to **Table 2-3**).
Denham Court	Intersected by the Brine pipeline in Cecil Hills	The Denham Court HGL is characterised by steep low hills on Triassic Wianamatta Group rocks (predominately Bringelly Shale). Quaternary alluvial soils (fine-grained sands, gravels, silts and clays) are present along drainage lines. Groundwater flow is unconfined along structural features (bedding, joints, faults etc) in the fractured bedrock, predominantly moving laterally through the shale layers (although vertical movement through fracturing does occur) and vertically

Hydrogeological Landscape	Relevance to project feature(s)	Description
		through interbedded sandstone and sandstone fracturing. Lateral flow occurs through alluvial sediments on slopes and plains. Depth to water table is intermediate (2-6 mBGL). Land salinity is moderate, groundwater is generally fresh (EC less than 0.8 dS/m or 800 µS/cm) which equates to the beneficial use category “A” (refer to **Table 2-3**).
Upper South Creek variant A	Intersected by the Brine pipeline between Cecil Hills and Prospect Creek in Lansdowne	The Upper South Creek Variant A HGL is characterised by low, undulating hills with colluvial/ alluvial foot slopes and plains (often ponding) and drainage lines on Triassic Wianamatta Group rocks (predominately Bringelly Shale). Groundwater flow is unconfined along structural features (bedding, joints, faults etc) in the fractured bedrock, predominantly moving laterally through the shale layers (although vertical movement through fracturing does occur) and vertically through interbedded sandstone and sandstone fracturing. Lateral flow occurs through alluvial sediments on slopes and plains. Depth to water table is intermediate (2-6 mBGL). Land salinity is high, groundwater is generally brackish to saline (EC between 1.6-4.8 dS/m or 1,600-4,800 µS/cm) which equates to the beneficial use category “B” (refer to **Table 2-3**).
Moorebank	Intersected by the Brine pipeline east of Prospect Creek	The Moorebank HGL is characterised by alluvial deposits associated with the Georges River, including broad, flat alluvial plains intersected by present day drainage channels (e.g. Prospect Creek). Unconsolidated materials comprise Neogene alluvial sediments (sands and clays) overlying small areas of Triassic Hawkesbury Sandstone and Wianamatta Group shales (predominately Ashfield Shale). Groundwater flow is unconfined through unconsolidated alluvial sediments. Localised perching of water tables may occur above clay lenses during wetter periods. Unconfined to semi-confined flow also occurs along structural features (bedding, joints, faults etc) in the fractured bedrock. Depth to water table is shallow to intermediate (0-8 mBGL) with seasonal variation. Land salinity is moderate, groundwater is generally fresh (EC between 0.8-1.6 dS/m or 800-1,600 µS/cm) which equates to the beneficial use category “A” (refer to **Table 2-3**).

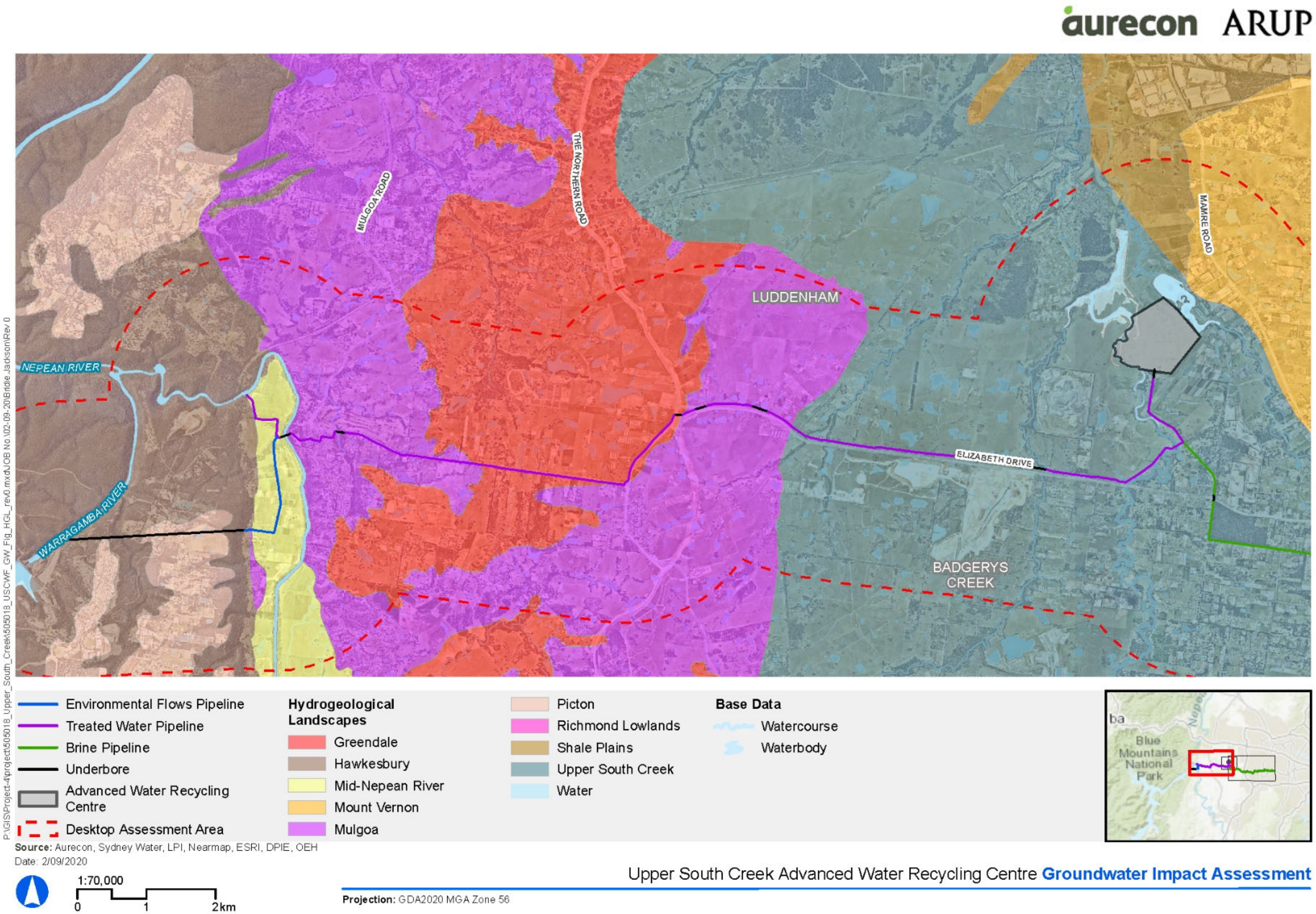


Figure 4-17 Hydrogeological Landscapes – Treated Water / Environmental Flow Pipelines

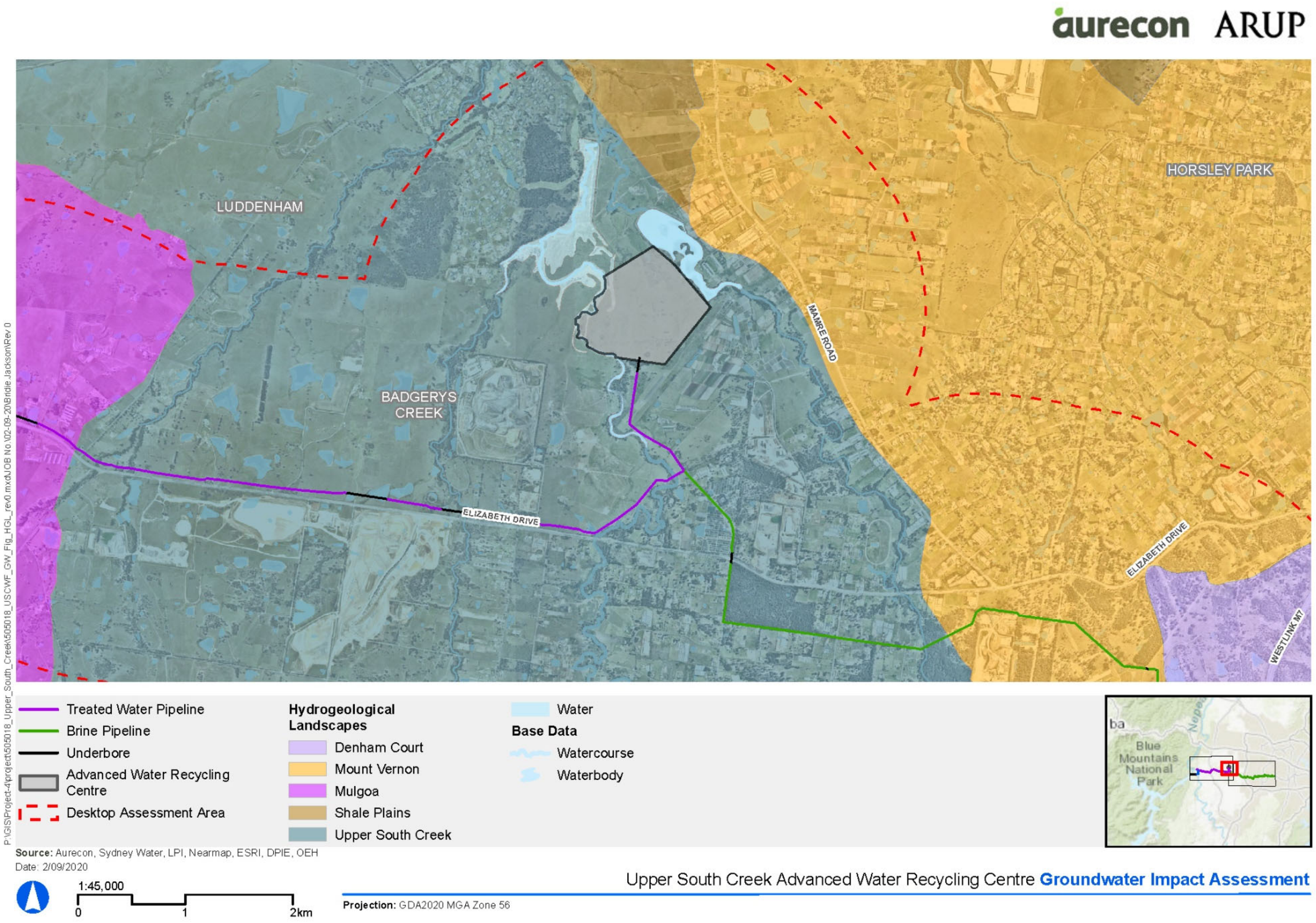


Figure 4-18 Hydrogeological Landscapes – The AWRC

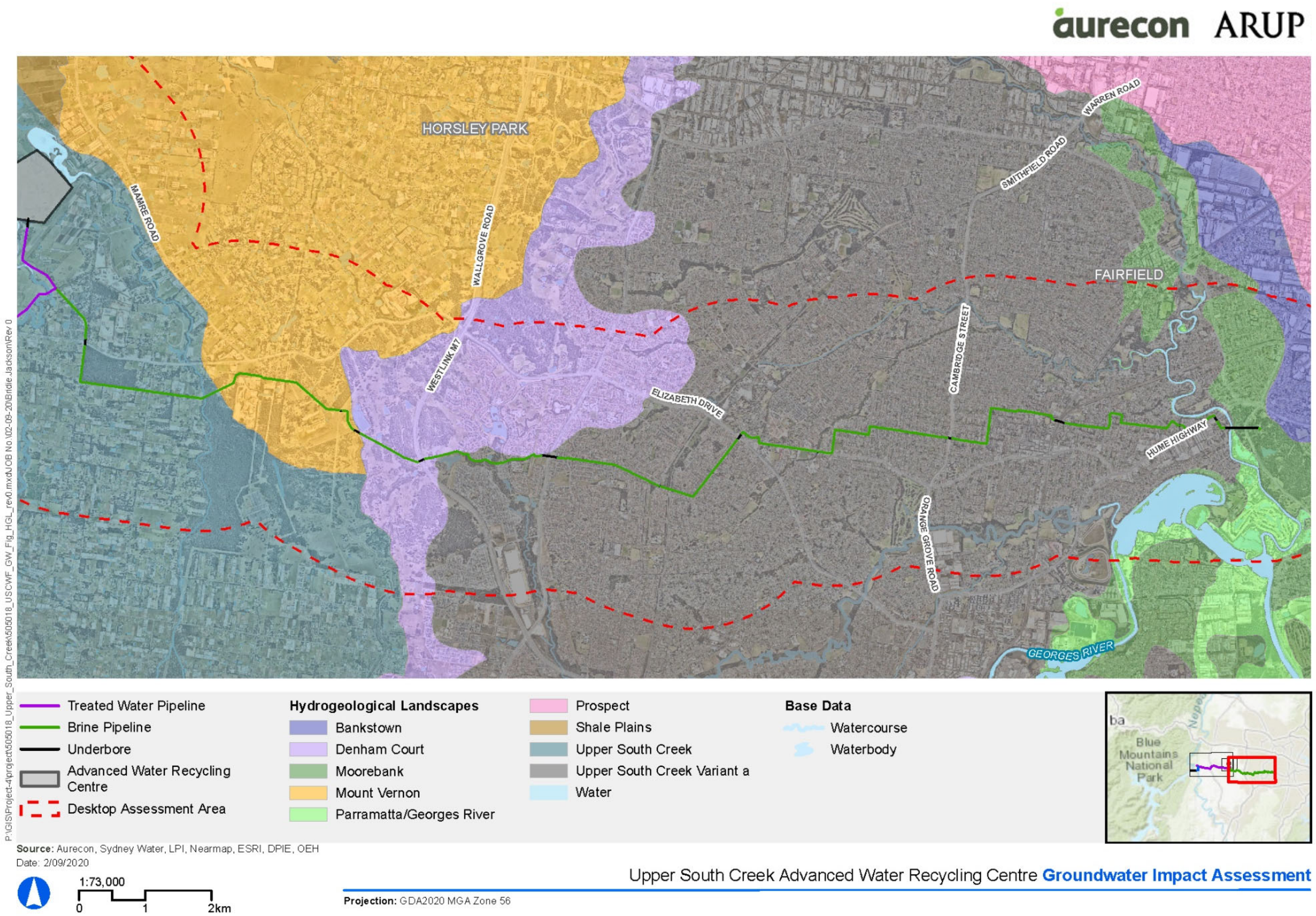


Figure 4-19 **Hydrogeological Landscapes – Brine Pipeline**

4.6 Groundwater chemistry

Groundwater chemistry can be defined both in terms of major ions and by minor and trace elements. Minor and trace elements, along with man-made chemicals can be present at elevated concentrations in areas that have been modified by human activity, and where elevated can form toxicants / stressors to aquatic ecosystems.

The major and trace element chemistry of groundwater is controlled by a number of environmental factors that include climate, geology, biochemistry, hydrological conditions, composition of precipitation, and anthropogenic influences. Other principles and processes controlling hydrochemistry of natural waters include thermodynamics, equilibrium, chemical kinetics, solubility, and interface reactions.

As groundwater moves through a system it typically undergoes a geochemical evolution that is defined by increasing salinity as the concentrations of major ions increase through dissolution of rocks. Major ion concentrations typically to shift from bicarbonate (HCO_3) type, to sulfate (SO_4^{2-}) type / mixed type, to chloride (Cl-) type with increasing age (Chebotarev, 1955). These changes occur as the water moves from shallow zones of active flushing through intermediate zones and deeper zones where the flow rates are slower and water is of greater age and reflect changes expected in large sedimentary basins. It should be noted however that this typical geochemical evolution can be influenced by local driving factors including geochemical composition of rocks, and proximity to the coastline.

The ionic composition of groundwater is used to classify it into ionic types based on the dominant dissolved cation and anion. Previous groundwater investigations in the region indicate the dominant groundwater type is sodium chloride, as indicated in **Figure 4-20** (RMS, 2019). These investigations reported Total Dissolved Solids (TDS) results in groundwater between 2,650 to 19,500 mg/L. These results correspond with the brackish to saline groundwater expected across the majority of the desktop assessment area.

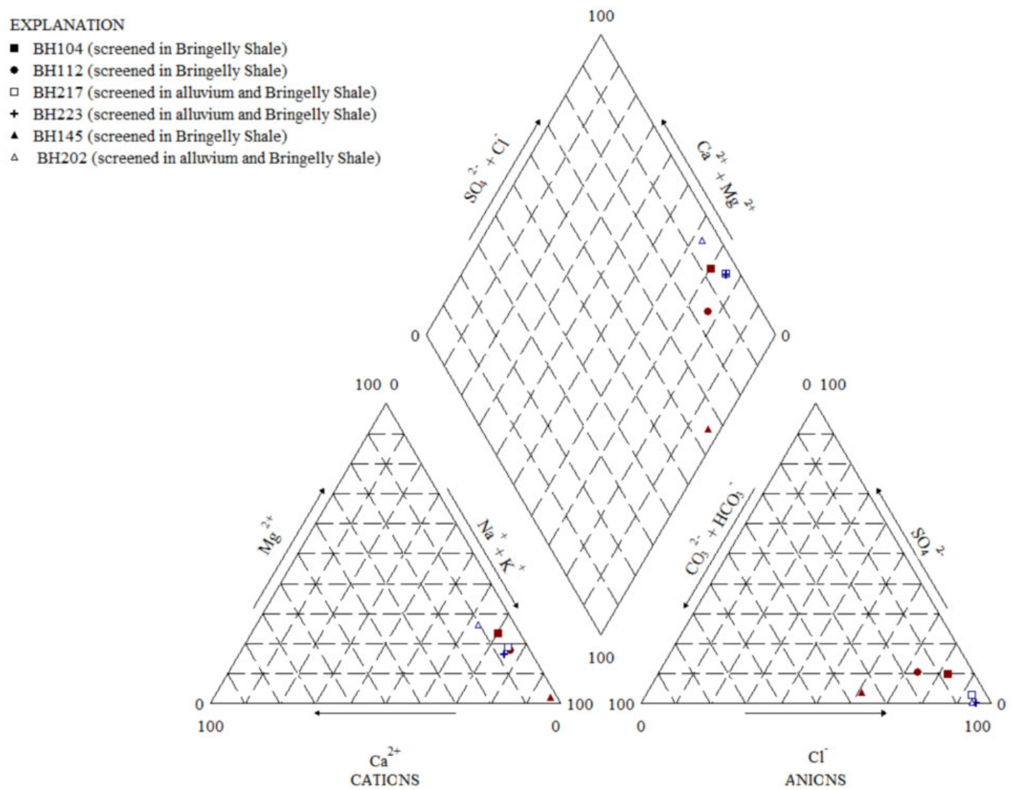


Figure 4-20 Piper Plot for M12 Motorway Groundwater Monitoring Bores (RMS, 2019)

Electrical conductivity ranges for Mulgoa, Greendale, Upper South Creek and Upper South Creek Variant A HGLs (described in Section 4.5.6), have maximum values that exceed the project waterway objectives criteria of 125 – 2200 μS/m.

The groundwater across the majority of the desktop assessment area is of relatively poor quality and has low potential for beneficial use for agricultural and potable purposes. Salinity, metals and nutrients in the groundwater may require management during construction and operation, particularly in relation to the potential impacts to surface water bodies and GDEs present in the impact assessment area.

4.6.1 Groundwater Contamination

The potential presence of contamination is described in detail in the *Soils and Contamination Impact Assessment* report (Aurecon Arup, 2021). A brief summary of features pertinent to the groundwater impact assessment is provided below for context to the discussions in this report.

Groundwater toxicants may be present in the desktop assessment area, associated with anthropogenic influences such as widespread agricultural land use, areas of disturbed terrain, landfilling etc. Exceedances of the adopted project waterway objectives have been reported for heavy metals (copper, arsenic, nickel and zinc), speciated nitrogen (nitrogen and ammonia), sodium and TDS have been identified in previous investigations in the region (RMS, 2019).

Contaminated sites notified to the NSW EPA

Under Section 60 of the *Contaminated Land Management Act 1997* (CLM Act), a person whose activities have contaminated land, or a landowner whose land has been contaminated, is required to notify the EPA if certain conditions are met. For example, if contaminant levels are above current or approved land use criteria and people have been (or will foreseeably be) exposed to the contamination, the EPA is to be notified.

A review of contaminated sites within the desktop assessment area has been undertaken to assess the potential presence of groundwater contamination at the locations. The risk of project activities inducing contaminant mobilisation / migration and the associated impacts have been assessed in **Section 7.3.2**.

If this occurs, it is likely that extracted groundwater would contain contaminants and would therefore require management / treatment prior to discharge / disposal.

The EPA maintains a register of sites of which it has been notified under Section 60 of the CLM Act. The register identifies sites of which the EPA is aware in its regulatory role and is not a list of all contaminated sites in NSW.

A search of the NSW EPA public register (notified sites and the contaminated land record) of contaminated sites was undertaken on the 25 March 2020. The results identified a number of records for addresses within 500 m of the pipeline alignments and within 2 km of the AWRC site have been summarised in **Table 4-8**.

Table 4-8 EPA notified contaminated sites within the desktop assessment area.

Contaminated Land Record	Site Location	Site Description	Approximate distance from project feature
Caltex Service Station	3019-3035 The Northern Rd, Luddenham	Service Station	115 m from treated water pipeline
BP-Branded Service Station Bonnyrigg	451 North Liverpool Rd, Bonnyrigg	Service Station	10 m from brine pipeline

Contaminated Land Record	Site Location	Site Description	Approximate distance from project feature
Metro (Formerly United & AP SAVER) Service Station Bonnyrigg	709 Cabramatta Rd W, Bonnyrigg	Service Station	10 m from brine pipeline
Caltex Service Station Cabramatta	168 John St, Cabramatta	Service Station	10 m from brine pipeline
Mobil Service Station	44 Hume Hwy, Lansvale	Service Station	7 m from brine pipeline
Coles Express Lansvale	99 Hume Hwy, Lansvale, Canley Vale	Service Station	40 m from brine pipeline
Caltex (former Mobil) Lansvale Service Station	141 Hume Hwy, Lansvale	Service Station	200 m from brine pipeline
BP Lansvale	115-119 Hume Hwy, Cabramatta West	Service Station	50 m from brine pipeline
Former Mobil Service Station	96 Canley Vale Rd, Canley Vale	Service Station	190 m from brine pipeline
Former Caltex Canley Heights	368 Canley Vale Rd, Canley Heights	Service Station	160 m from brine pipeline
Caltex Service Station	1163 Mamre Road, Kemps Creek	Service Station	1.1 km east of the AWRC site
United Petroleum petrol station	1465-1467 Elizabeth Drive, Kemps Creek	Service Station	1.2 km south-east of the AWRC site
BP Petrol Station	Lot 5 / 1443 Elizabeth Drive, Kemps Creek	Service Station	1.3 km southeast of the AWRC site

Most of the notified sites are listed as not requiring regulation under the CLM Act. However, the Caltex on 141 Hume Hwy was formerly regulated for contamination under the CLM Act.

The risks of the EPA notified sites impacting the alignment areas are generally considered to be low due to management class and/or distance from the pipeline options. Metro Service Station Bonnyrigg is considered to be moderate risk due to known contamination and distance from pipeline options.

In addition, an active landfill (SUEZ Kemps Creek Resource Recovery Park) is located approximately 800 m south-west of the AWRC site. Groundwater monitoring data from this site has not been made publicly available through the Environment Protection License, however, the site is not notified to the EPA as a contaminated site. Contaminants of concern associated with landfill sites include ground gases (methane, carbon dioxide, hydrogen sulfide etc) and leachate (acidic water, nitrogen, phosphorous and heavy metals).

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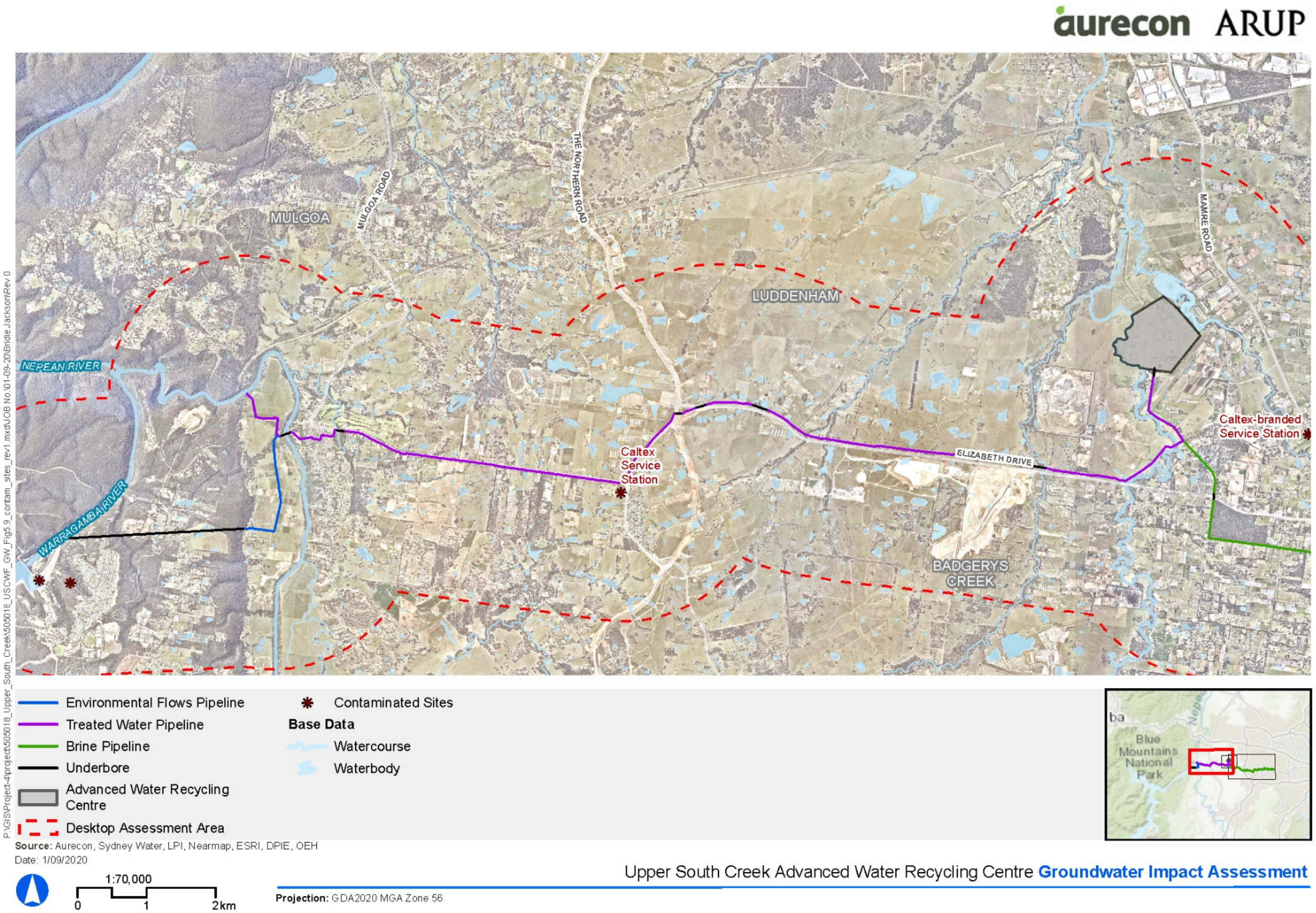


Figure 4-21 **Contaminated sites notified to the EPA – Treated Water / Environmental Flow Pipelines**

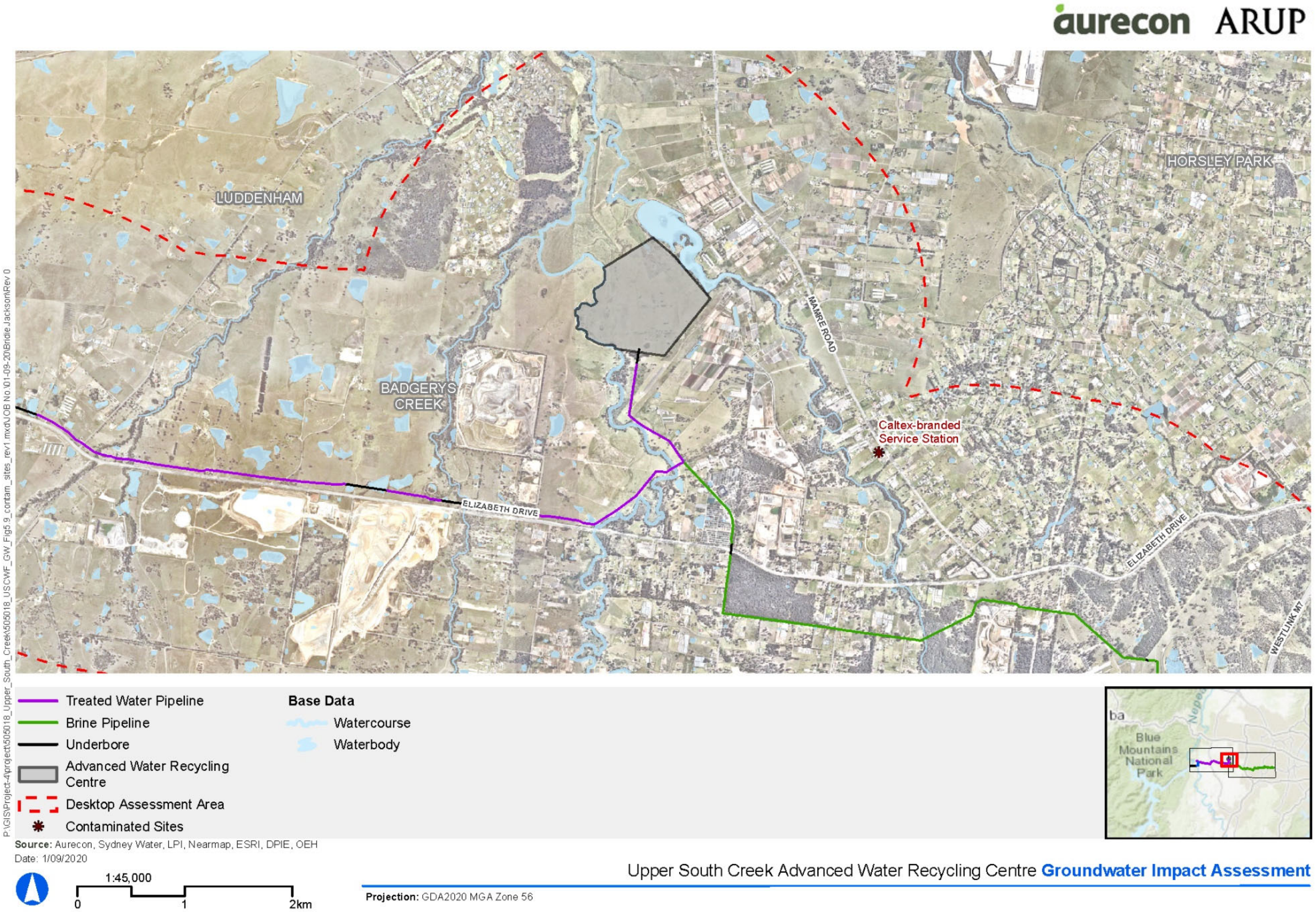


Figure 4-22 Contaminated sites notified to the EPA – AWRC site

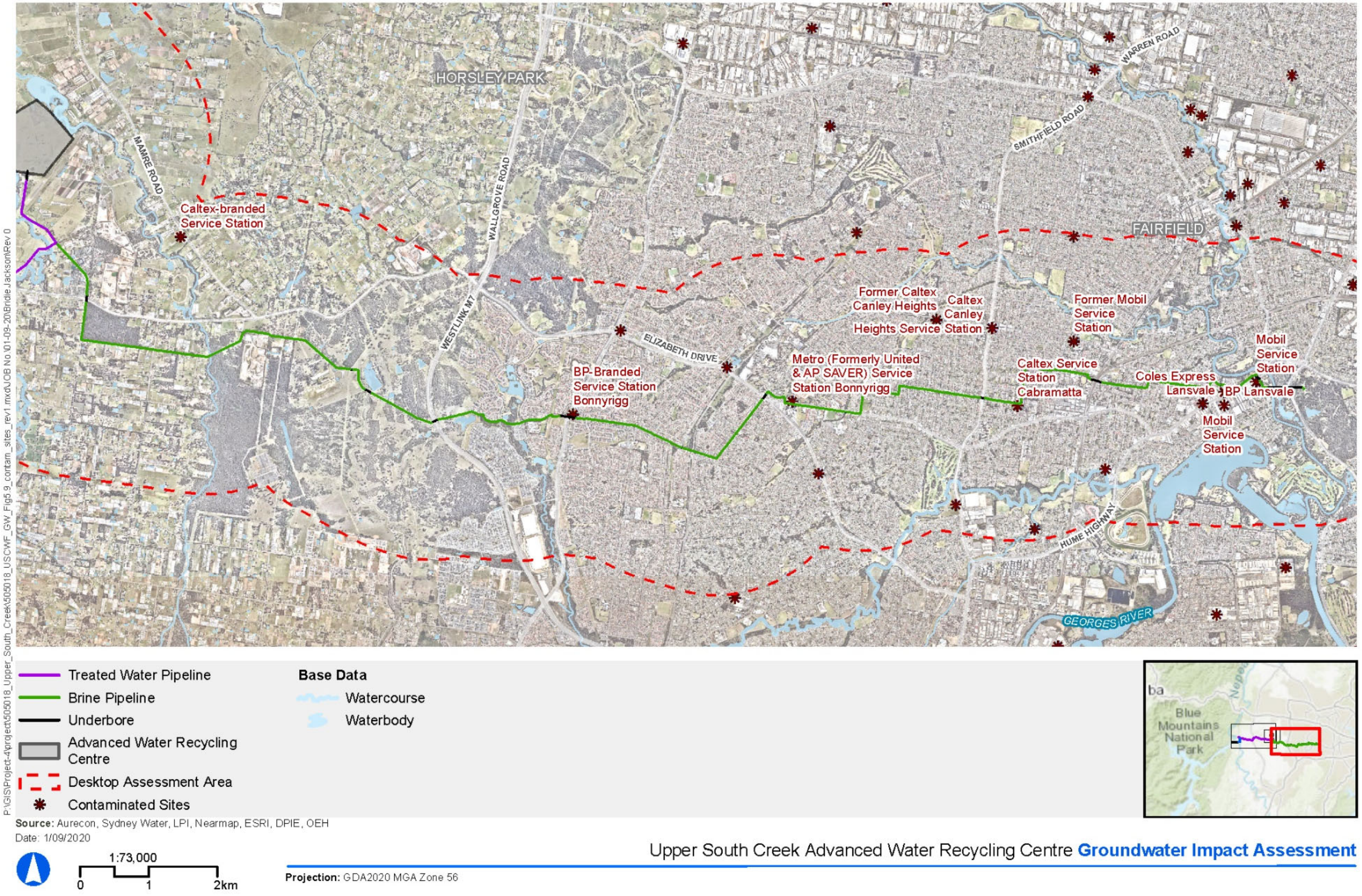


Figure 4-23 **Contaminated sites notified to the EPA – Brine Pipeline**

4.6.2 Groundwater salinity

Salinity occurrence in the region is associated with historical evaporation of inland seas, prevailing winds carrying ocean salt and the weathering of rocks. Salt infiltrates into the saturated zone where it gets left behind by natural evaporation processes and therefore concentrates. Salinity is therefore associated with drainage systems or low lying/flat grounds with shallow water tables where there is high potential for the ground to become waterlogged.

Groundwater quality is expected to vary across the desktop assessment area. Groundwater is expected to be brackish to saline across a significant portion of desktop assessment area (e.g. Upper South Creek Hydrogeological Landscape), with some small areas of fresh water (e.g. in the Hawkesbury and Mid-Nepean Hydrogeological Landscapes). An overview of the varying groundwater quality reported in each Hydrogeological Landscape intersected by the project can be found in **Section 4.5.6**

Historic investigations on groundwater in the Wianamatta Group (Bringelly Shale, Minchinbury Sandstone and Ashfield Shale) have reported total dissolved solids (an indicator of salinity) between 5,000 and 26,000 mg/l (PPK, 1999; McNally, 2004). The high salinities reported in the Wianamatta Group are suggested to be a result of the marine depositional environment in which they were formed, in addition to windblown aerosols accumulating in the subsoils (McNally, 2004).

Groundwater salinity in the Hawkesbury Sandstone is variable, ranging from fresh to brackish in the upper aquifers and freshening with depth. The increased salinity in the upper Hawkesbury Sandstone is attributed to leakage of saline groundwater from the overlying Ashfield Shale (Hawkes et al., 2009; McLean & Ross, 2009). Salinity in Hawkesbury Sandstone is generally fresh where it is not overlain by the Ashfield Shale. At the same time, upward flow and migration of brackish/saline groundwater from the underlying Narrabeen Group may be contributing to brackish conditions of the deeper Hawkesbury Sandstone (Webb et al., 2009). The high salinity of groundwater within the Bringelly and Ashfield Shales can be attributed to connate water within the formations reflecting their marine origin.

It is expected that groundwater quality in the local flow systems is comparatively fresher than that of the Bringelly and Ashfield Shales and underlying intermediate and regional flow systems (outlined in **Section 4.7**). Within the alluvial groundwater systems, it is possible that localised lenses of fresh groundwater overly saline groundwater. Salt is more likely to accumulate in areas with slow groundwater flow and low hydraulic gradients.

Electrical conductivity ranges for Mulgoa, Greendale, Upper South Creek and Upper South Creek Variant A have maximum values that exceed the project waterway objectives criteria of 125-2200 µS/m.

There is potential for saline conditions to be present in shallow soils across the desktop assessment area. Surface water quality data from June 2018 in Kemps Creek and South Creek alongside the AWRC site reported electrical conductivities of 1,889 and 2,640 µs/cm respectively, indicating brackish conditions in surface water (Aurecon Arup, 2021).

A review of the Map of Salinity Potential in Western Sydney (Department of Infrastructure, Planning and Natural Resources, 2002) is presented in **Figure 4-24**, **Figure 4-25** and **Figure 4-26**, indicating a variable salinity risk across the project. Areas to the west around Warragamba and Wallacia have a very low to moderate salinity risk, while all other areas are within moderate to high salinity risk areas, with some areas of known salinity. Areas with high salinity potential include the low-lying areas around Cosgrove Creek and along Kemps Creek.

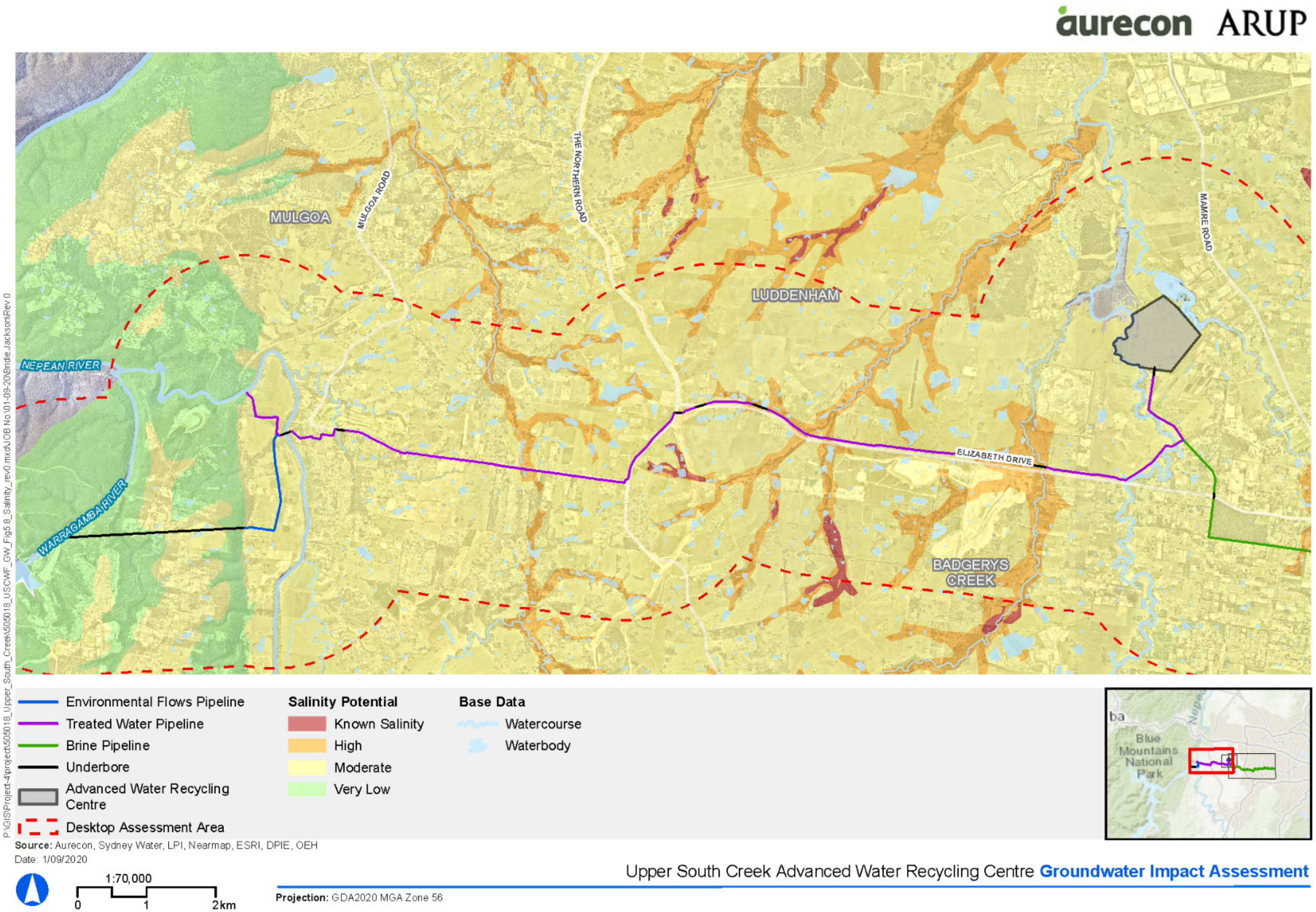


Figure 4-24 Distribution of Salinity Risk– Treated Water / Environmental Flow Pipelines

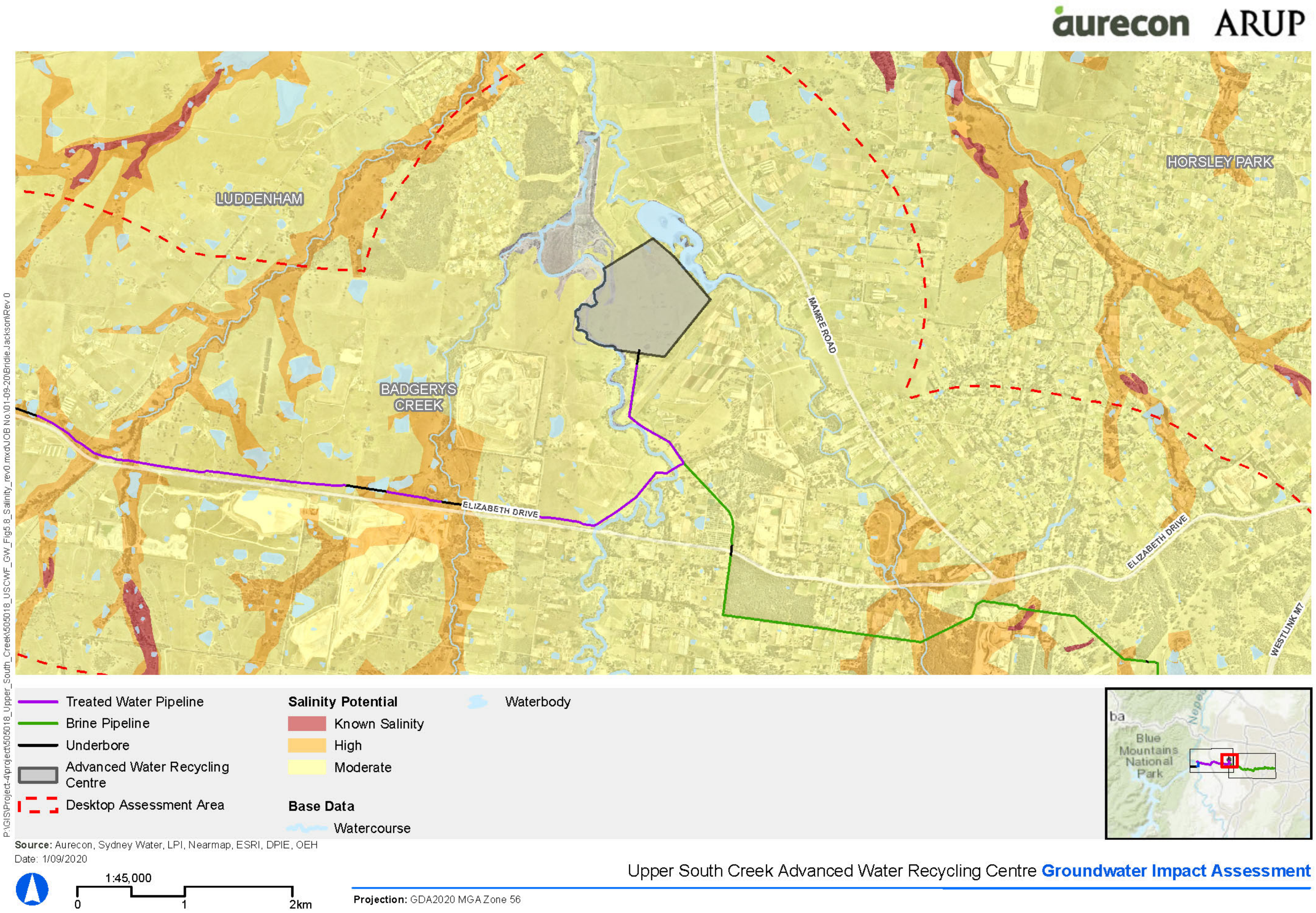


Figure 4-25 Distribution of Salinity Risk – The AWRC

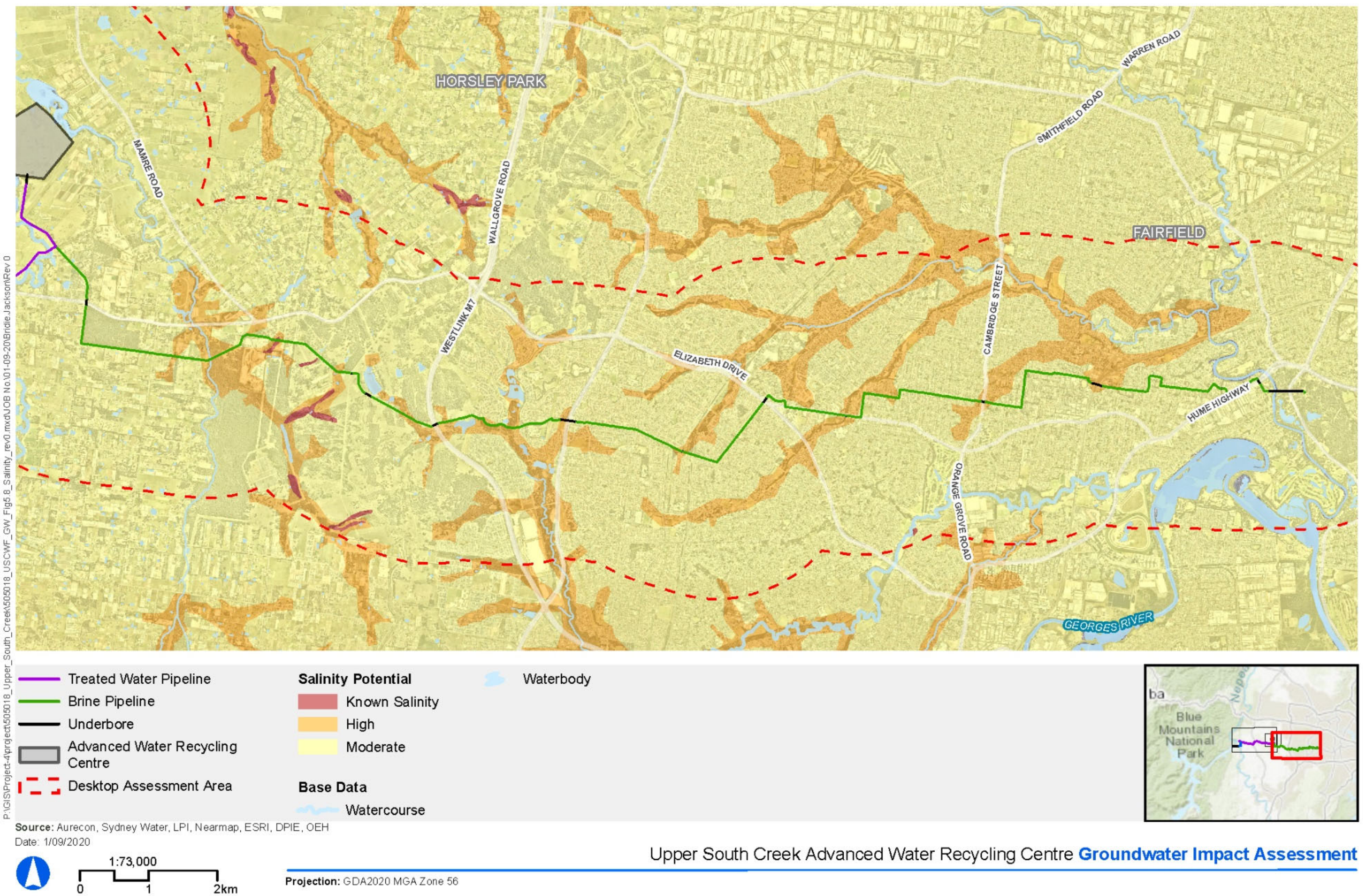


Figure 4-26 Distribution of Salinity Risk – Brine Pipeline

4.7 Groundwater Levels and Flow

Topography is most important driving force for groundwater flow in groundwater systems. Flow occurs because hydraulic head decreases from a high-elevation recharge area (high hydraulic head) to a low elevation discharge area (low hydraulic head). The topographic setting across the project is outlined in **Section 4.2**.

In sedimentary basins different orders of flow systems can exist, including local, intermediate, regional flow systems. The type of groundwater flow system depends on topographic variations, aquifer permeability, heterogeneity and anisotropy and recharge.

In the desktop assessment area, local scale flows are expected in the alluvial groundwater systems. The shallower alluvial groundwater systems are generally present in areas adjacent to mapped waterways, including Nepean River, Badgerys Creek, South Creek, Kemps Creek, Cabramatta Creek, Clear Paddock Creek, Georges River and Prospect Creek, which intersect the project (see **Section 4.4**).

The direction of local groundwater flow is likely to be controlled by the proximity to local surface water bodies and areas of higher permeability soils. Shallow groundwater through unconsolidated and surface material flows (i.e. alluvial groundwater systems) tend to be much faster relative to consolidated rocks in the Wianamatta Group (Stammers, 2012; Bradd et al., 2012).

Intermediate and regional flow directions are expected in the underlying bedrock aquifers (Wianamatta Group formations and Hawkesbury Sandstone). Intermediate and regional groundwater flow direction is expected to be generally consistent with the topography.

Waters recharging a flow system may be discharged at local topographic depressions for local flow systems or at regional / intermediate discharge areas at the base of catchments / sub-catchments respectively. Where local relief is minimal, regional systems may prevail. Conversely where topography is pronounced, local systems may dominate groundwater flow.

Groundwater elevation data taken across the central portion of the desktop assessment area in August 2018 as part of the M12 EIS are illustrated in **Figure 4-27**, indicating the following intermediate/regional groundwater flow directions:

- From west to east, groundwater elevations range from 90 mAHD in Luddenham to 35 mAHD in the vicinity of the AWRC site, indicating intermediate/regional groundwater flow is in an easterly direction between these areas.
- Continuing from west to east, groundwater elevations range from 35 mAHD in the vicinity of the AWRC to 112 mAHD in Cecil Park, indicating intermediate/regional groundwater flow is in a westerly direction between these areas.
- Therefore, groundwater levels and flow appear to converge towards the low-lying areas in the vicinity of Badgerys Creek, South Creek, Kemps Creek and the AWRC site, which is consistent with local topographical observations (outlined in **Section 4.2**). Hydraulic gradients in this central area are relatively low, in comparison to surrounding gradients from the east and west.

Beyond the extents of the M12 EIS groundwater elevation data, the following intermediate/regional groundwater flow directions are expected, in sympathy with local topographic observations:

- Generally, east to west between Luddenham and the Nepean River;
- Generally, west to east between Cecil Park and Cabramatta, tending south-east towards Georges River.

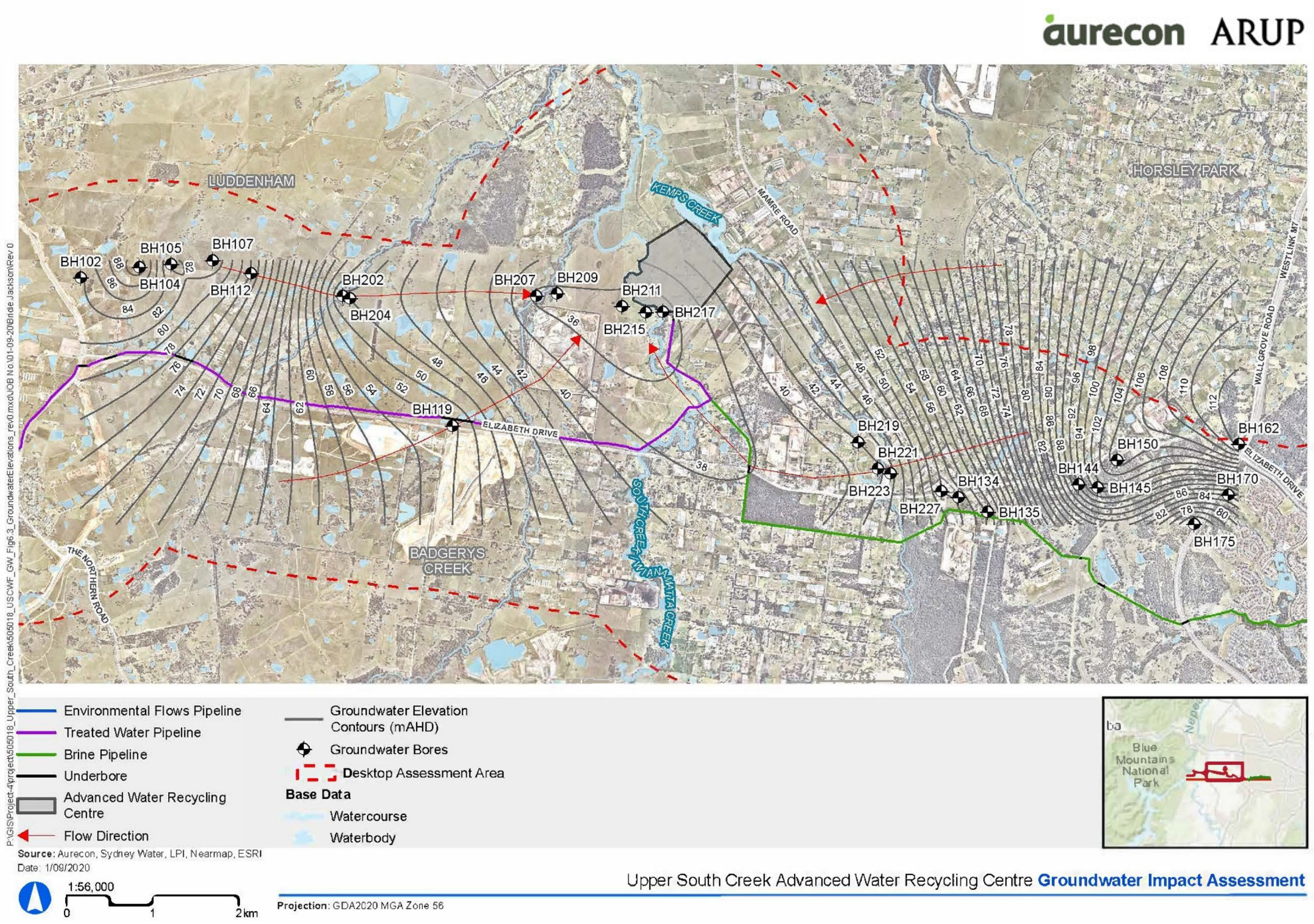


Figure 4-27 M12 EIS August 2018: Groundwater Elevations – Intermediate/Regional Groundwater Flow

As outlined in **Section 4.2**, part of the environmental flows pipeline involves a proposed horizontal directional drilling (HDD) section through a steep ridge between the Nepean River valley and the Warragamba River. Attempts were made to measure groundwater levels in registered water supply bores along this ridge in close proximity to the proposed HDD alignment. Direct measurements were unable to be collected (discussed in **Section 3.1)** however anecdotal information about the registered bores from interviews with landowners was gathered and is summarised below.

Table 4-9 Registered groundwater bore information in the vicinity of the environmental flows pipeline

Well ID	Easting	Northing	Distance from proposed alignment	Bore Type	Surface Elevation (mAHD)	Approximate groundwater elevation (mAHD)	Total Bore Depth (mbgl)	Approximate yield (L/s)
GW072366	280175	6248743	35 m north	Water supply	151.1	-23 *	178.4	<1 *
GW101239	279882	6247603	1 km south	Water supply	164.5	34.5 *	180	>4 *

* Denotes anecdotal information gathered from landowners. All other data is sourced from the Bureau of Meteorology (BoM) National Groundwater Information System (NGIS) (see **Section 4.9** for more details regarding NGIS data).

When considered alongside the topography and elevation profile of the environmental flows pipeline, this information indicates there is no significant aquifer present at the depth and location of the proposed HDD alignment and groundwater is unlikely to be encountered.

4.8 Groundwater Dependent Ecosystems (GDEs)

Groundwater Dependent Ecosystems (GDEs) are ecological communities that rely upon groundwater, either entirely or in part, for their health or survival. The level of dependence or interaction with the groundwater can be variable, ranging from partial dependence (e.g. seasonal or episodic) to total dependence (continuous).

The potential impacts to GDEs are described in detail in the *Aquatic and Riparian Ecosystem Impact Assessment* report. A brief summary of GDEs pertinent to the groundwater impact assessment is provided below for context to the discussions in this report.

A review of the Bureau of Meteorology's GDE Atlas (BOM, 2020) indicates that a number of GDE's are present within the desktop assessment area. GDEs can be characterised as Terrestrial, Aquatic or Subterranean. Aquatic ecosystems rely on the surface expression of groundwater, including surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs. Terrestrial ecosystems rely on the subsurface presence of groundwater, this includes all vegetation ecosystems. Subterranean ecosystems include cave and aquifer ecosystems (BOM, 2020).

A review of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 Schedule 4* indicated that there are no high priority GDEs within the desktop assessment area. To meet the SEARs, potential impacts to all identified GDEs have been assessed.

There is no data for subterranean GDEs in the proposal area. The approximate location of each aquatic and terrestrial GDE is illustrated on **Figure 4-29**, **Figure 4-28** and **Figure 4-30** and are summarised in **Table 4-10**.

Table 4-10 Groundwater Dependant Ecosystems (GDEs) within the desktop assessment area.

GDE Name	GDE Type	Location	Level of Groundwater Interaction
South Creek	Aquatic - River	South Creek	High
Nepean River	Aquatic – River + Wetland	Nepean River	Low, moderate and high
Warragamba River	Aquatic – River + Wetland	Warragamba River	Low, moderate and high
Cumberland River Flat Forest	Terrestrial - Vegetation	Appears throughout entire desktop assessment area, most prevalent along banks of surface water bodies.	Moderate to high
Castlereagh Ironbark Forest	Terrestrial - Vegetation	Kemps Creek (suburb) along Elizabeth Drive	Low to moderate
Castlereagh Scribbly Gum Woodland	Terrestrial - Vegetation	Kemps Creek (suburb) along Elizabeth Drive	Low to moderate
Castlereagh Shale-Gravel Transition	Terrestrial - Vegetation	Throughout Kemps Creek (suburb)	High
Castlereagh Swamp Woodland	Terrestrial - Vegetation	Throughout Kemps Creek (suburb)	High
Coastal Sandstone Ridgetop Woodland	Terrestrial - Vegetation	Along banks of Warragamba River.	Moderate
Cumberland Shale Hills Woodlands	Terrestrial - Vegetation	Appears throughout areas between Wallacia and Kemps Creek	Low, moderate and high
Cumberland Shale Plains Woodlands	Terrestrial - Vegetation	Appears throughout entire desktop assessment area.	Low, moderate and high
Cumberland Shale Sandstone Transition	Terrestrial - Vegetation	Wallacia, along the banks of Nepean River and Baines Creek	Moderate to high
Hinterland Sandstone Gully Forest	Terrestrial - Vegetation	Wallacia, along the banks of Nepean River and Warragamba River	High
Southern Highlands Basalt Forest	Terrestrial - Vegetation	Wallacia, along the banks of Nepean River and Warragamba River	High
Sydney Hinterland Transition Woodland	Terrestrial - Vegetation	Wallacia, in vegetated areas west of the Nepean River and along the banks of Warragamba River.	High

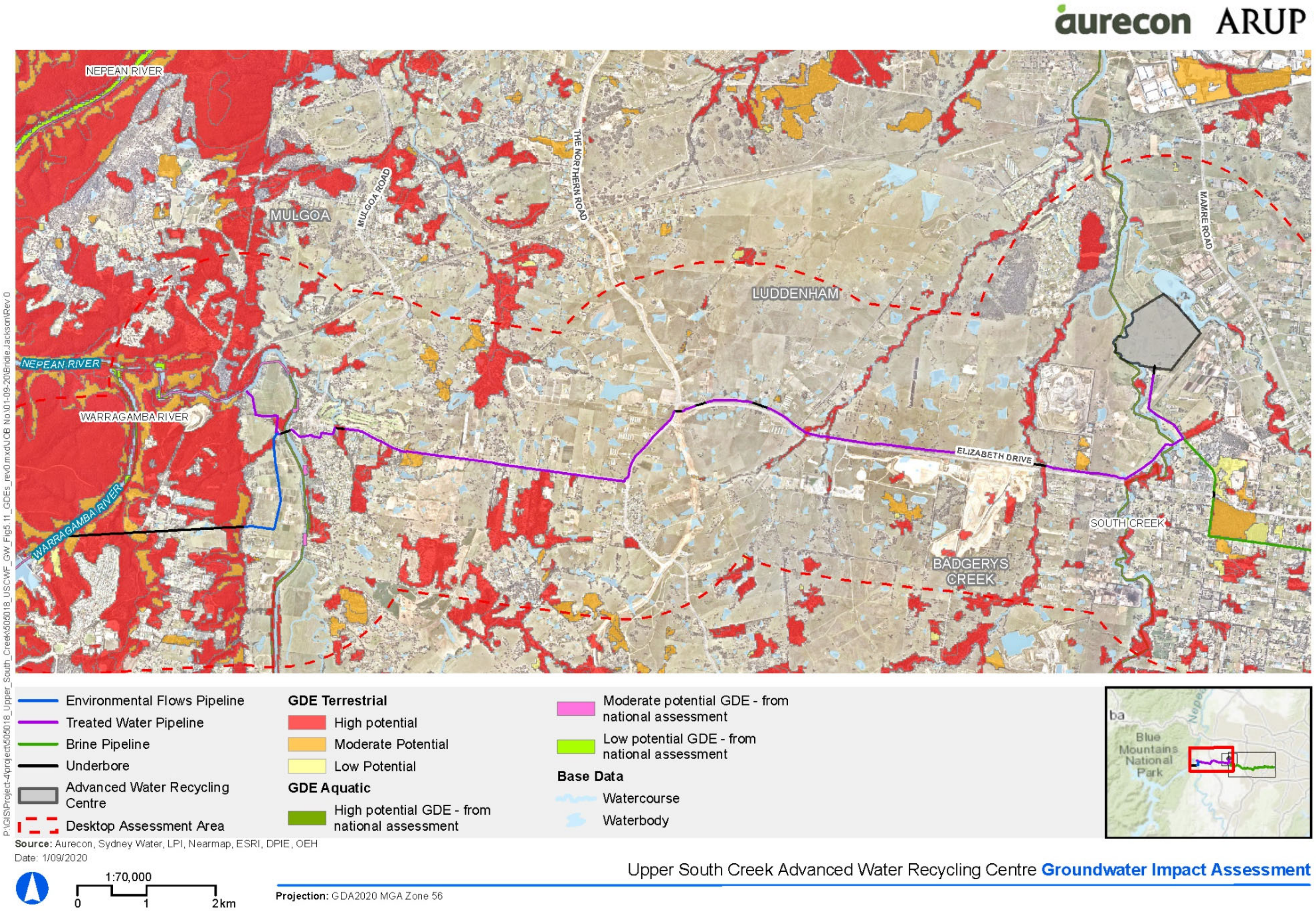


Figure 4-28 Groundwater Dependent Ecosystems (GDEs) – Treated Water / Environmental Flow Pipelines

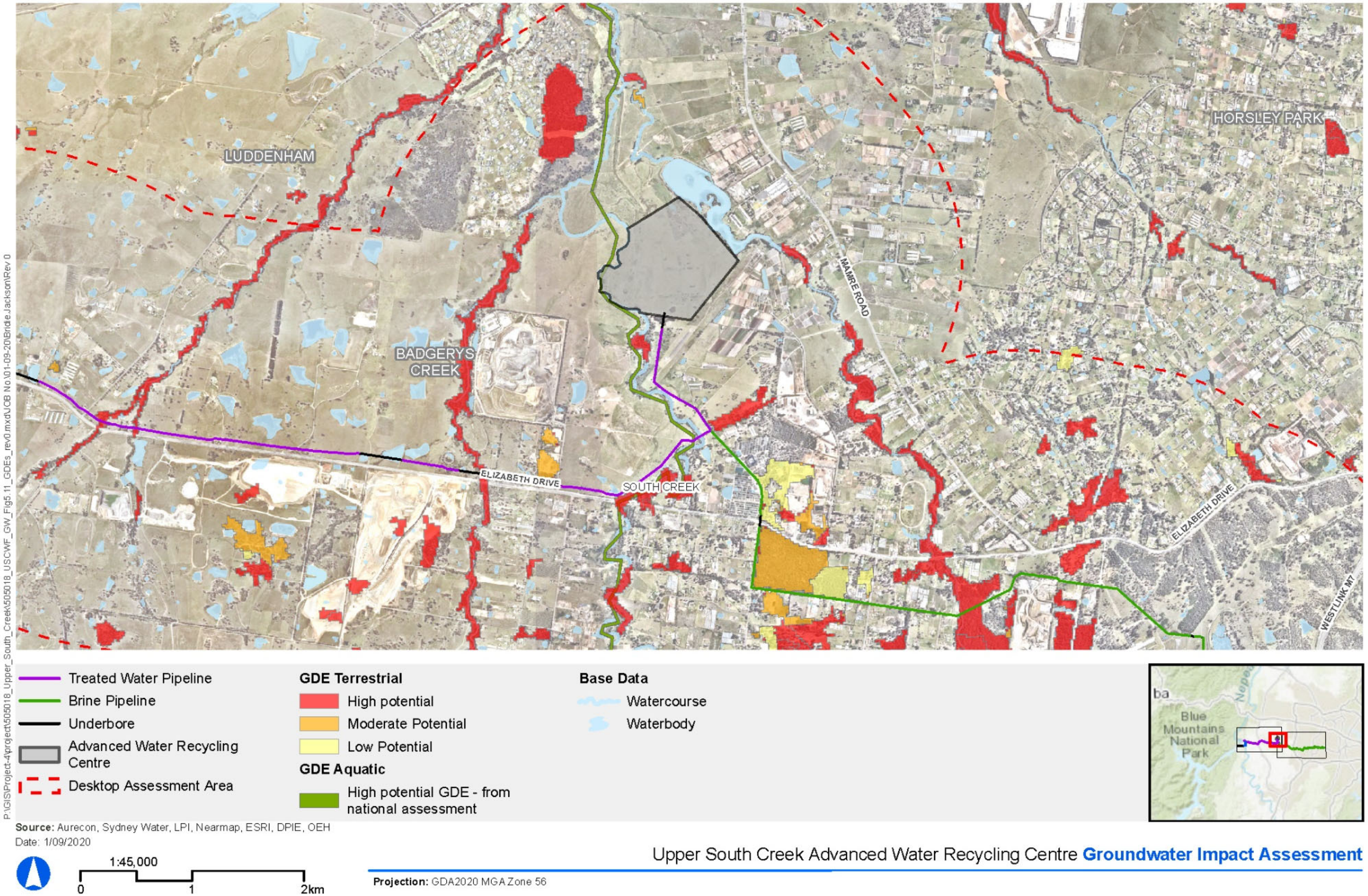


Figure 4-29 Groundwater Dependent Ecosystems (GDEs) – The AWRC

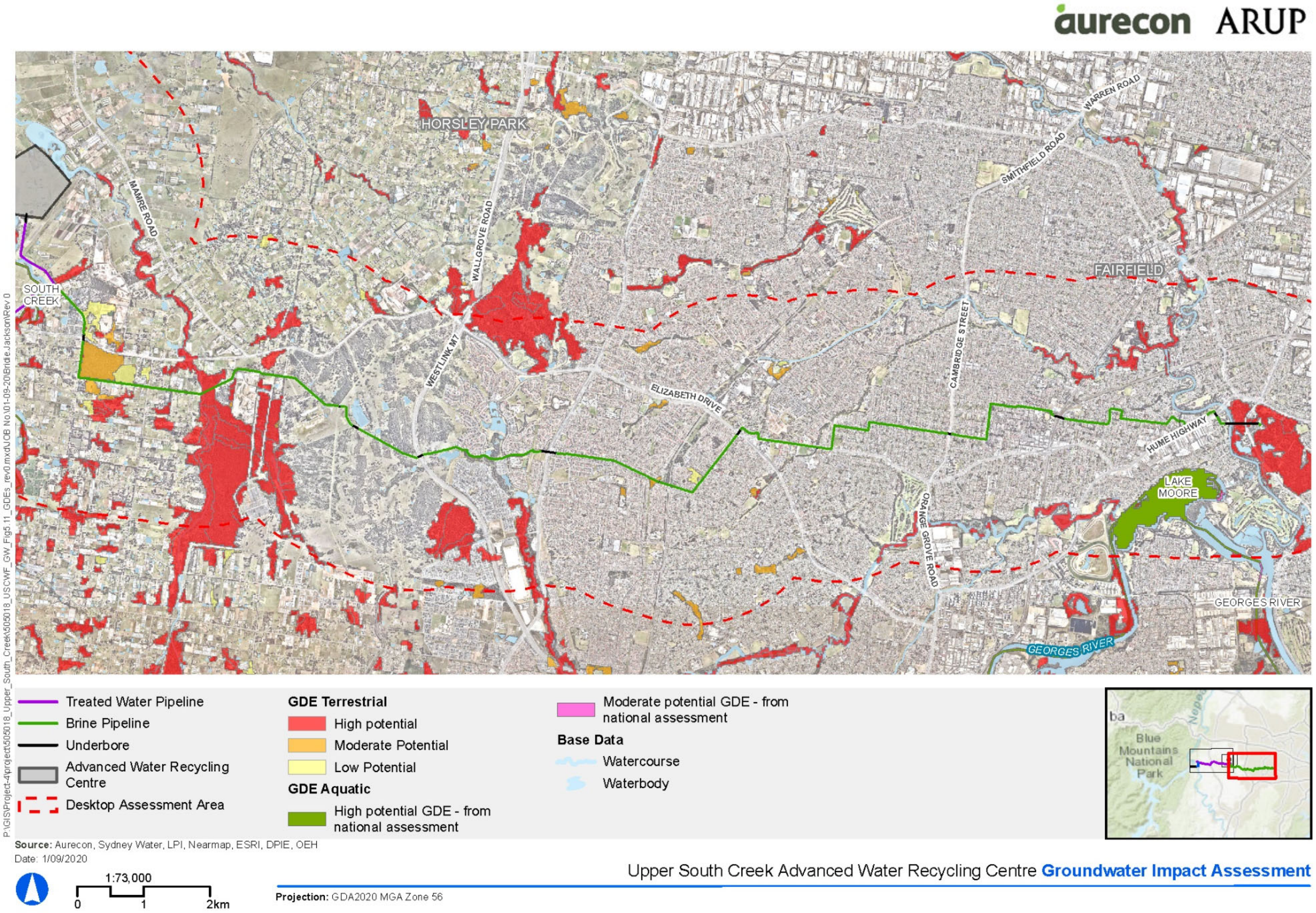


Figure 4-30 Groundwater Dependent Ecosystems (GDEs) – Brine Pipeline

4.9 Regional groundwater users and Water Sharing Plans

The project is predominately located within the “Sydney Basin Central” groundwater source. In areas west of the Nepean River, the project is located within the “Sydney Basin Nepean” groundwater source. Both groundwater sources are covered under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*.

Within the Sydney Basin Central groundwater source, there are currently 187 aquifer access licences, with a total volume of water made available of 3,929.5 ML/year. The long-term average annual extraction limit for the Sydney Basin Central groundwater source is 45,915 ML/year, which approximates to 20% of the total estimated annual aquifer recharge rate of 229,223 ML/year for the area (Water NSW, 2022).

Within the Sydney Basin Nepean groundwater sources, there are currently 388 aquifer access licences, with a total volume of water made available of 31,446.4 ML/year. The long-term average annual extraction limit for the Sydney Basin Central groundwater source is 99,568 ML/year, which approximates to 40% of the total estimated annual aquifer recharge rate of 244,483 ML/year for the area (Water NSW, 2022).

Therefore, the project lies within groundwater source areas that currently have large volumes of unassigned water (i.e. those that have not reached the long-term average annual extraction limit set in the Water Sharing Plan).

Both alluvial and porous/fractured rock aquifers intersected by the project are within a “less productive groundwater source” category as defined by the NSW Aquifer Interference Policy criteria based on the relatively low number of registered supply bores, expected low yields and poor water quality (high salinity).

Review of access data available through the Bureau of Meteorology (BoM) National Groundwater Information System (NGIS) indicated a number of registered groundwater bores that lie within the desktop assessment area. No groundwater level information from the NGIS is available for these bores. The locations of the registered groundwater bores are illustrated in **Figure 4-31**, **Figure 4-32** and **Figure 4-33**.

A summary of the registered groundwater bores within the desktop assessment area is provided in **Table 4-11**.

Table 4-11 Summary of registered bores within the desktop assessment area.

Groundwater Bore Type	Impact assessment areas		
	The AWRC site (2 km buffer)	Brine pipeline (2 km buffer)	Treated water pipeline and environmental flows (2 km buffer)
Commercial and industrial	1	1	1
Stock and domestic	0	0	1
Monitoring	19	67	5
Irrigation	0	4	0
Exploration	1	0	0
Unknown	0	0	0
Water Supply	0	1	2
Total	**21**	**73**	**9**

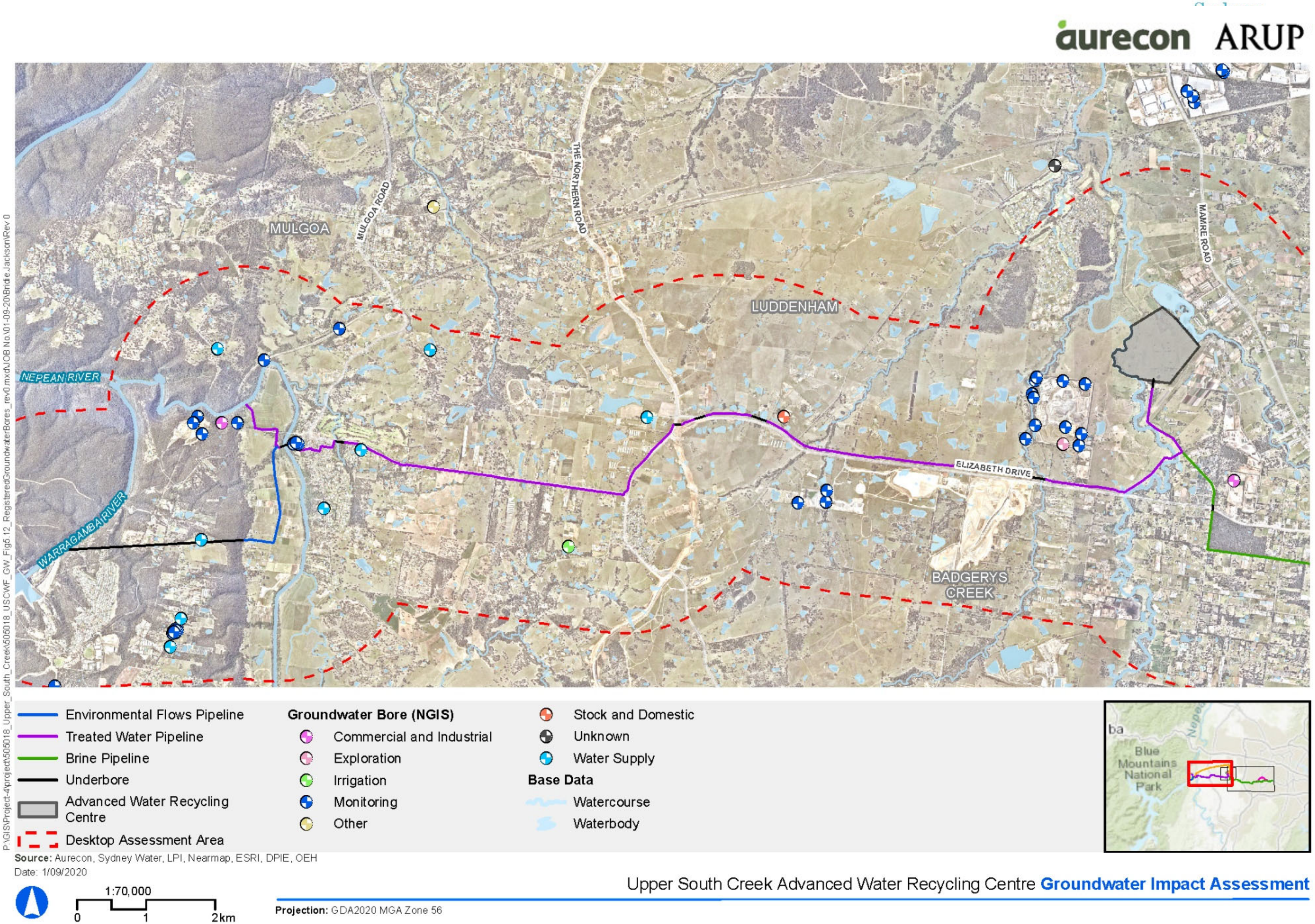


Figure 4-31 **Registered Groundwater Bores – Treated Water / Environmental Flow Pipelines**

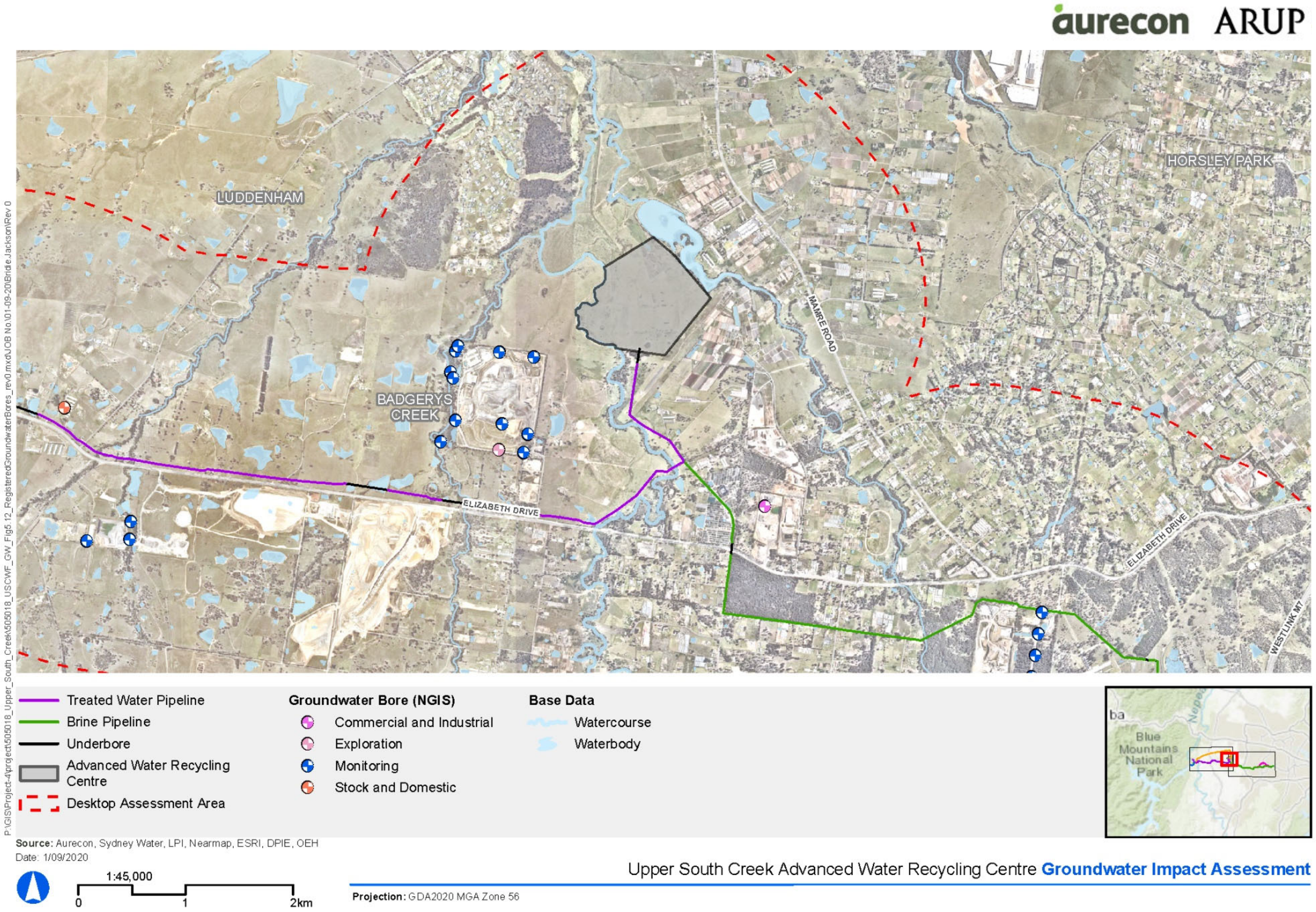


Figure 4-32 **Registered Groundwater Bores – The AWRC**

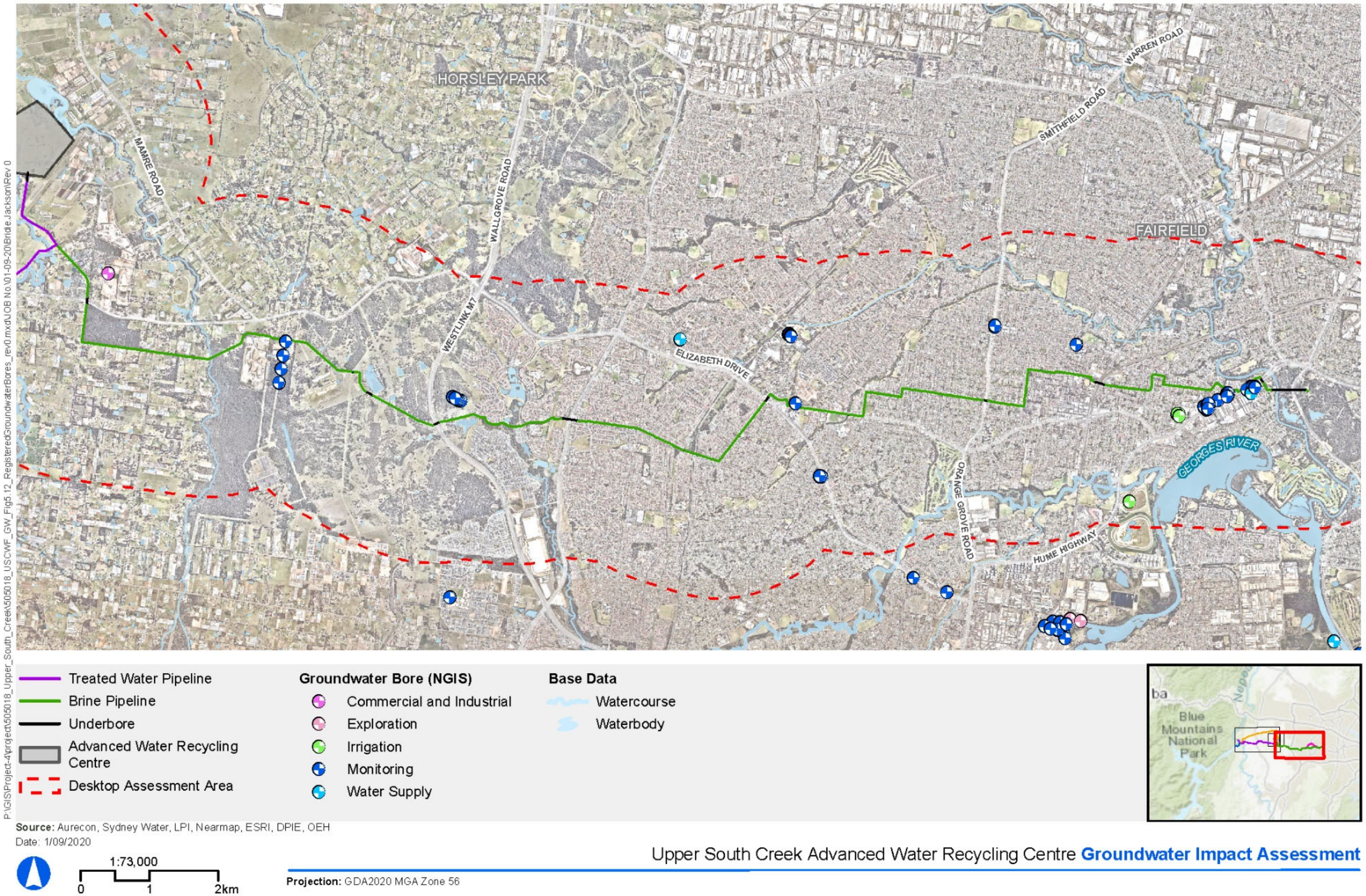


Figure 4-33 Registered Groundwater Bores – Brine Pipeline

5 Hydrogeological Conceptual Model

The following sections describe the hydrogeological conceptual model (HCM) for the desktop assessment area. The HCM is a simplified representation of the natural system, identifying the most important geological units and hydrogeological processes (the hydrogeologic framework) and hydrological processes (the hydrologic system), which control fluid (groundwater in this case) flow and contaminant transport of consequence (if present) at a specific site, based upon available data and understanding of the system mechanics.

HCMs are generally accompanied by pictorial, diagrammatic and/or tabular interpretations and representations of site hydrogeologic conditions as well as corresponding flow/transport dynamics.

In this section, conceptual cross-sections illustrating key hydrological / hydrogeological processes encountered in the environments across the desktop assessment area are presented. In principle the HCM answers the following key questions which are addressed by the methodology in **Section 4**:

- Groundwater flow direction (and contaminants if present), where is it coming from and where is it going? This is assessed based on monitored groundwater levels or conceptually based on geomorphology/topography (**Section 4.7**).
- The type of porous media containing groundwater. This is characterized in terms of porosity and permeability of the geologic material which can be either primary or secondary (**Section 4.5.3**).
- How much of groundwater (and contaminant) is there, and how fast is it flowing? This is quantified based on aquifer hydraulic parameters such as hydraulic conductivity, and storage coefficients of the aquifer units (**Section 4.5.3**).
- Description of climate (Hydrometeorology) and hydrologic budget and stresses (**Section 4.1**). Type and nature of recharge sources? Nature and type of groundwater-surface water interactions?
- Description of regional and site-specific hydrostratigraphic units (**Section 4.5**) based on the nature and connectivity of the openings (void space) in the geologic material, which determine transmission and storage properties. The void space is characterized by porosity and permeability.
- Groundwater flow system boundary locations including hydraulic features such as groundwater divides and physical features such as bodies of surface water and relatively impermeable rock?
- How did the groundwater system behave in the past, and how will it change in the future based on both natural and anthropogenic influences? This is covered in the Groundwater Modelling Report in **Appendix A**.

Figure 5-1 and **Figure 5-2** show conceptual cross-sections for the trenched and trenchless pipelines, respectively. **Figure 5-3** show the conceptual cross-section for the AWRC site.

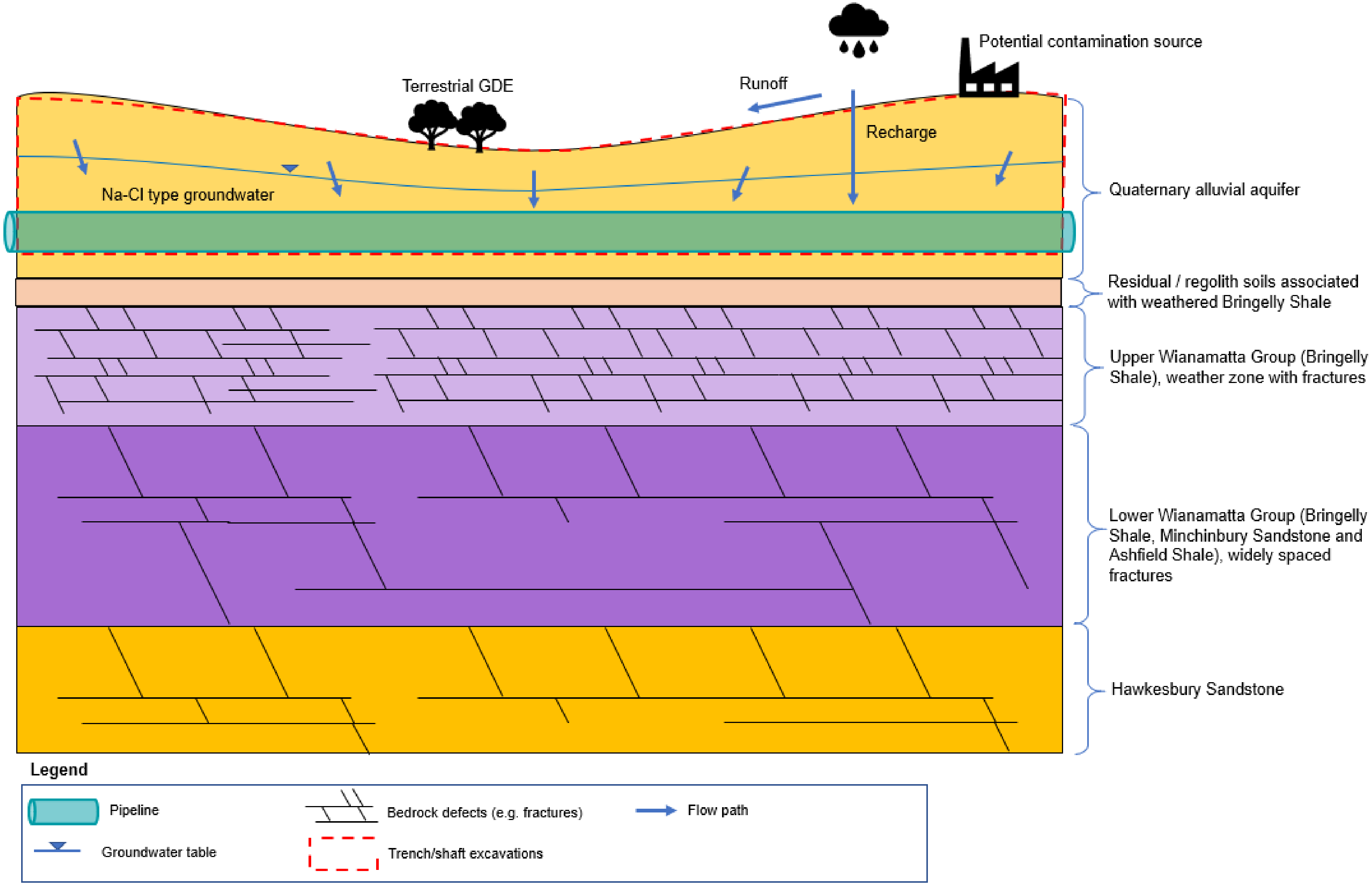


Figure 5-1 Trenched Pipeline – Hydrogeological Conceptual Model Overview

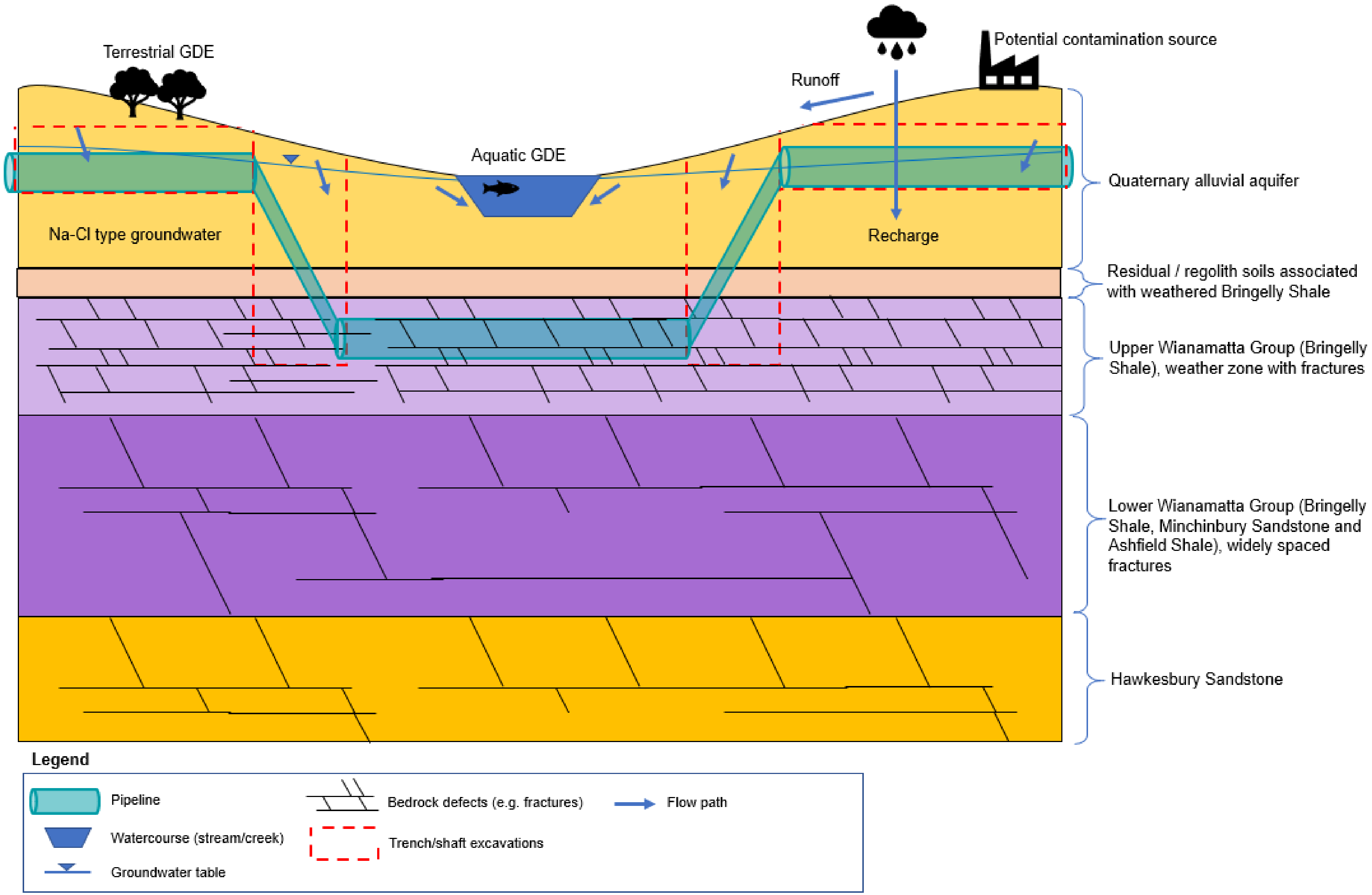
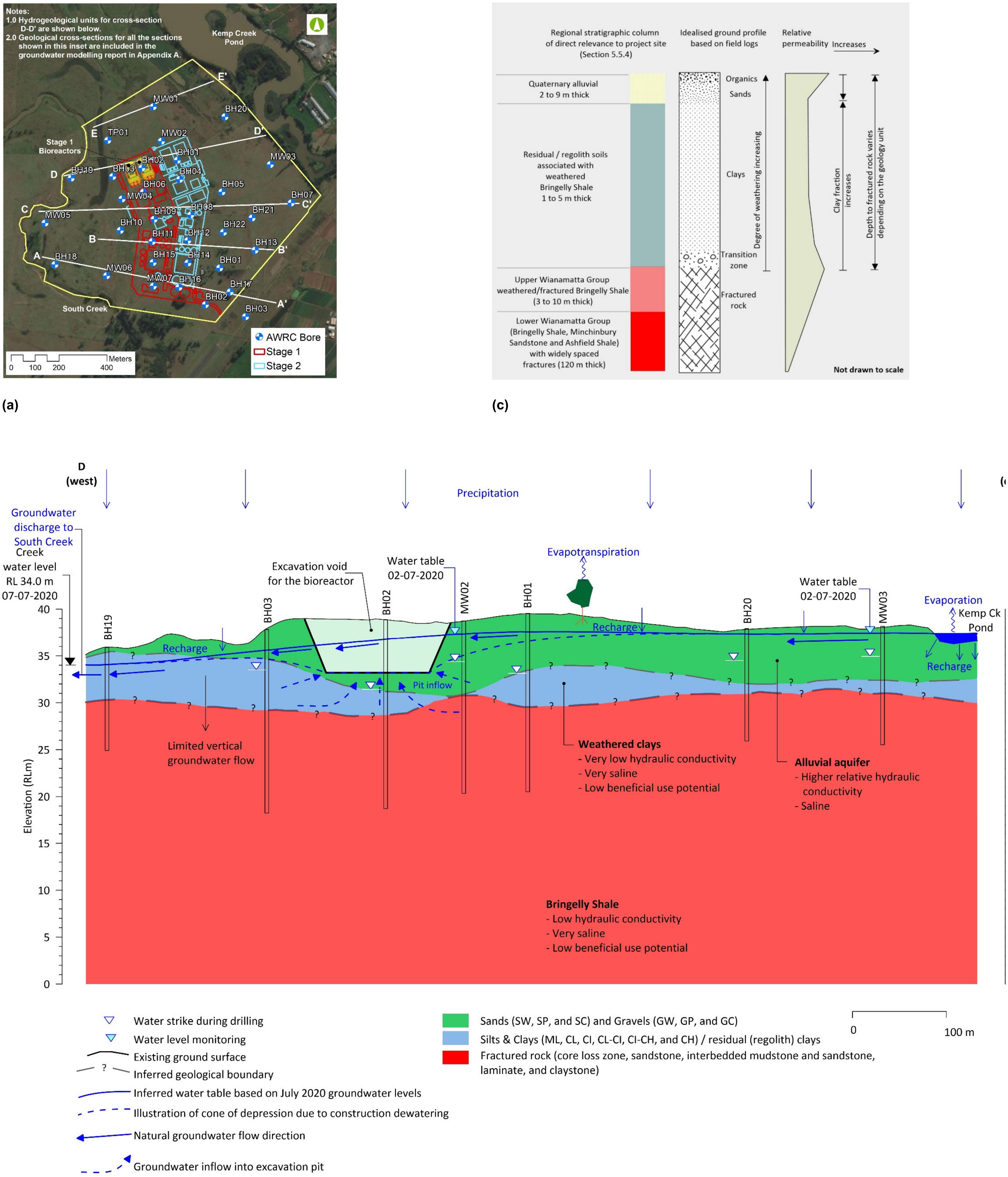


Figure 5-2 Trenchless Pipeline – Hydrogeological Conceptual Model Overview



(b)

Figure 5-3 (a) AWRC site cross-section location map (b) AWRC site conceptual Hydrogeological profile of D-D' showing simplified lithology and groundwater flow direction (c) Idealised subsurface profile of the AWRC site

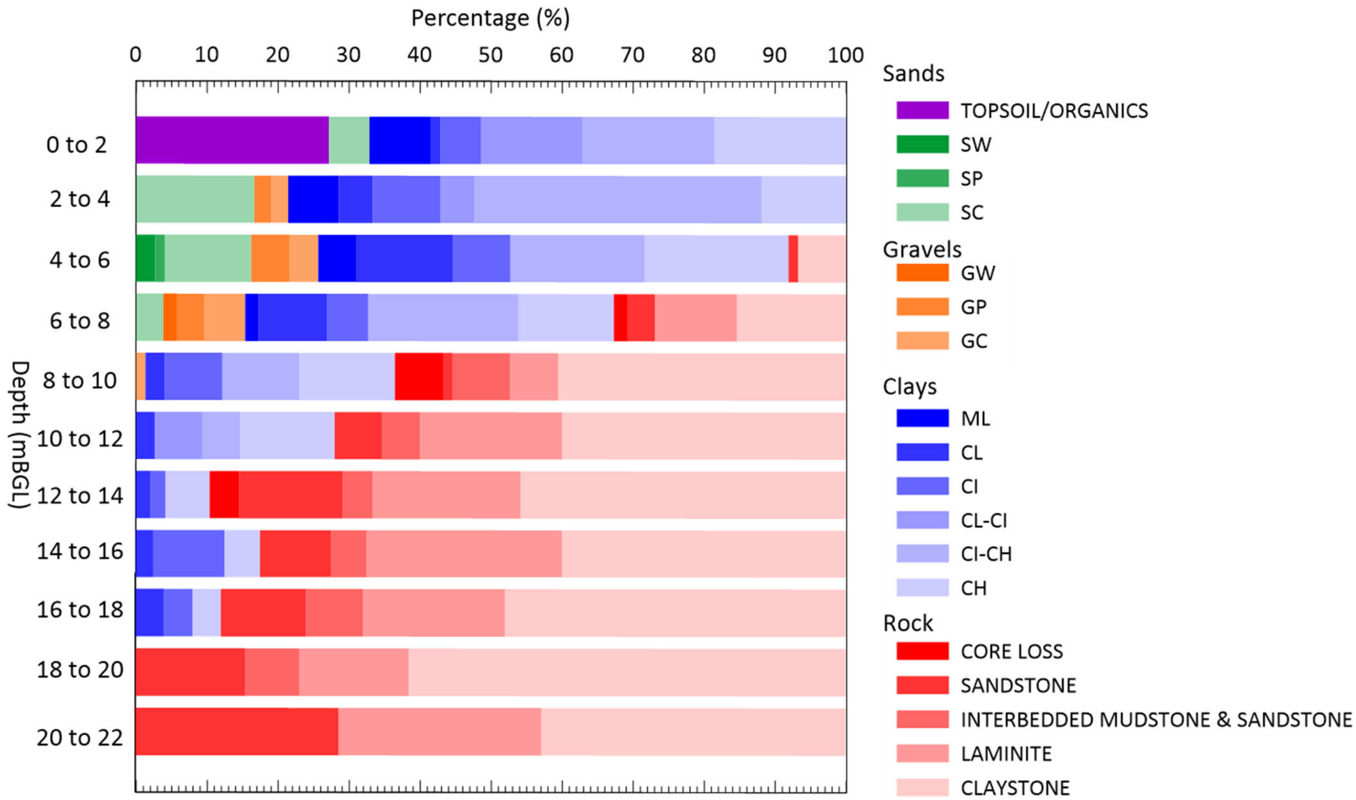


Figure 5-4 Graphical illustration of the stratigraphy encountered at the proposed AWRC site

6 Project Features

6.1 Construction Phase

6.1.1 AWRC Site

The key construction phase activities for the proposed AWRC site include the following:

- Establishment site runoff control
- Establishment of bench. The detailed approach to this has not been finalised but a typical methodology would involve:
  - Grubbing
  - Removal and stockpiling of 200-300 mm of topsoil for re-use later (following chemical and geotechnical testing for suitability). An area of approximately 115,000 m^2 will need to be stripped equating to a topsoil volume around 34,500 m^3
  - Geotechnical investigation identified the underlying 200 mm of material below the topsoil is unsuitable for construction and is to be removed and disposed offsite
  - Stormwater management (e.g. installation of appropriate erosion and sediment controls)
  - A water tank will be required for dust suppression
  - Cut and fill to bench levels with import of quality engineered fill as required and removal of any excess / poor quality material if it cannot be re-used on site elsewhere for landscaping purposes
  - Filling performed in layers of up to about 300 mm, which is compacted before the next layer is added. The fill depth on this site will generally increase from southeast to northwest up to a depth of about 2.5 m
- Excavation for construction of below surface infrastructure, including targeted dewatering of surficial local aquifer systems to required depths.
- Installation of subfloor drainage, foundations and underground infrastructure.

6.1.2 Pipelines

Key construction phase activities associated with the installation of the pipelines will include the following:

- Excavation (trench, shafts and/or pits) for construction of below surface infrastructure, including targeted dewatering of surficial local aquifer systems to required depths.
- Installation of foundations and underground infrastructure.
- Installation of aboveground civil, mechanical and electrical plant and equipment.

Different construction methods are proposed along the pipeline routes. In general, the pipelines will be constructed using standard trenching methods Trenchless methodologies will be will be used at most watercourse or infrastructure intersections with the pipeline occur.

Trenchless sections completed using HDD generally involve the activities listed above, in addition to the following:

- Mobilising the drill equipment and installing measures to manage groundwater if required.
- Inject a bentonite-based drilling fluid to lubricate the drill head and flush the drilled hole. Remove drill cuttings to be contained, collected and recycled/disposed.
- As the HDD bore and drill head advances, a casing pipe and the pipeline is inserted while grouting the annulus.

Trenchless sections completed using microtunneling / pipe-jacking generally involve the activities listed above, in addition to the following:

- Establish launch and reception shafts, install jacking frame and headwalls.
- Mobilising the drill equipment and installing within the launch pit, including measures to manage groundwater if required.
- Remove drilling fluids and cuttings via vacuum extraction.
- Once the jacking pipe reaches the reception shaft, the pipeline is inserted, and annulus is grouted.

6.2 Operational Phase

6.2.1 AWRC Site

The primary activities that could lead to groundwater impacts associated with the operational phase of the project all relate to site stormwater management practices as well as potential underdrainage systems for underground structure flotation management.

The key operational phase activities for the proposed AWRC site include the following:

- On and off-site irrigation
- Pumped underdrainage systems
- Storage and use of chemicals and contaminants

6.2.2 Pipelines

During standard operating conditions limited activities will be conducted directly relating to the operation of the pipelines. However, maintenance activities or breakdowns leading to potential impacts to local groundwater systems are:

- Pipe leaks/bursts

7 Analysis Results

A combination of qualitative and quantitative analyses were conducted to assess the potential and degree of impacts associated with the following key activities or physical changes:

- AWRC site
  - Construction phase
    - Construction dewatering and groundwater management
  - Operational phase
    - Underdrainage systems employed for underground structure flotation management
- Pipelines
  - Construction phase
    - Construction dewatering and groundwater management
  - Operational phase
    - Groundwater seepage after trenchless pipeline construction
    - Pipe leaks/bursts
- Other key considerations
  - Acid sulfate soils
  - Mobilisation and migration of contaminants

7.1 AWRC Site

7.1.1 Construction phase

Potential impact assessed in this section: Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.

Temporary groundwater impacts could potentially arise from dewatering which will be required to provide a stable platform for the construction of underground structures (e.g. the bioreactors). The potential impacts from construction dewatering have been assessed using predictive numerical modelling scenarios, which are detailed in **Appendix A** and summarised below. The focus of the predictive modelling is on bioreactors as they have deep foundations which will penetrate below the existing groundwater table.

A comparison of pre-development groundwater levels and maximum predicted construction dewatering groundwater levels (i.e. just before cessation of bioreactor dewatering) is shown in **Figure 7-2** below.

During construction of the AWRC, high initial inflow would occur and would stabilise at about 115 m^3/day (i.e. 75 m^3/d and 40 m^3/d, respectively for the eastern and western bioreactors). The construction period comprises 492 days. Total pumped volume over 492 days construction period has been estimated to be about 57ML, with approximately 50ML pumped within the first 365 days of the construction.

The extent of influence due to construction dewatering can be interpreted to be similar to the extent of the cone of depression and is described in terms of the radial distance from the area where dewatering is being implemented to the point where there is zero drawdown. The modelling results indicate that the extent of influence due to AWRC Stage 1 construction dewatering will be about 325 m from the central part of the bioreactor site as shown **Figure 7-2**. The extent of influence due to construction dewatering associated with future stages of the AWRC has not been modelled as part of this study. Since the designs for Stage 1 and the current future stages are expected to be similar, it is expected that it will also be around 325 m. Based on these modelling results, the impact of construction dewatering is expected to be of local extent, which will be contained within the extent of the footprint of the proposed AWRC site. Beyond this extent, the groundwater flow pattern is unimpacted. **Figure 7-2** compares simulated groundwater level contours representative of current conditions and groundwater level contours due to simulated construction dewatering.

The creeks were discretised into segments referred to as the river reaches. Discretising the river into reaches provide the modelling software a way of summarising water mass balances at specific areas. For this study, creek segments were discretised at approximately 400 m to 500 m lengths. Reach 10 and Reach 11 are directly adjacent to AWRC site. An inspection of the simulated water balances for the modelled river reaches shows that a small section of South Creek (approximately 650 m length) will be impacted, with a slight reduction in baseflow to the creek in this area during construction reducing from an average of about 79 m^3/d to 74 m^3/d over Reach 10 and Reach 11. This represents a baseflow reduction of approximately 6% during construction (full details are provided in **Appendix A**).

The degree of impact is dependent on the distance between the dewatering and the creek (reducing with distance). In terms of foundation design, the degree of impact increases with depth below current ground surface.

This groundwater impact could affect the aquatic ecosystems (South Creek) with a high level of interaction with groundwater near the proposed AWRC site shown in **Figure 4-29**, in particular areas in Reach 10 and Reach 11 (**Figure 7-2**). Climate change influences during future stages are not expected to exacerbate the impact, as the reduction in baseflow will be negligible in comparison to the predicted increase in surface water runoff. The predicted groundwater drawdowns are within the range of acceptability defined by the NSW Aquifer Interference Policy (outlined in **Section 2.3**) are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.

The potential impacts of the solar panels during is a reduction in the permeable surface and groundwater recharge, this has not been directly modelled in the construction phase, but has been captured in the long-term modelling (see **Section 7.1.2**).

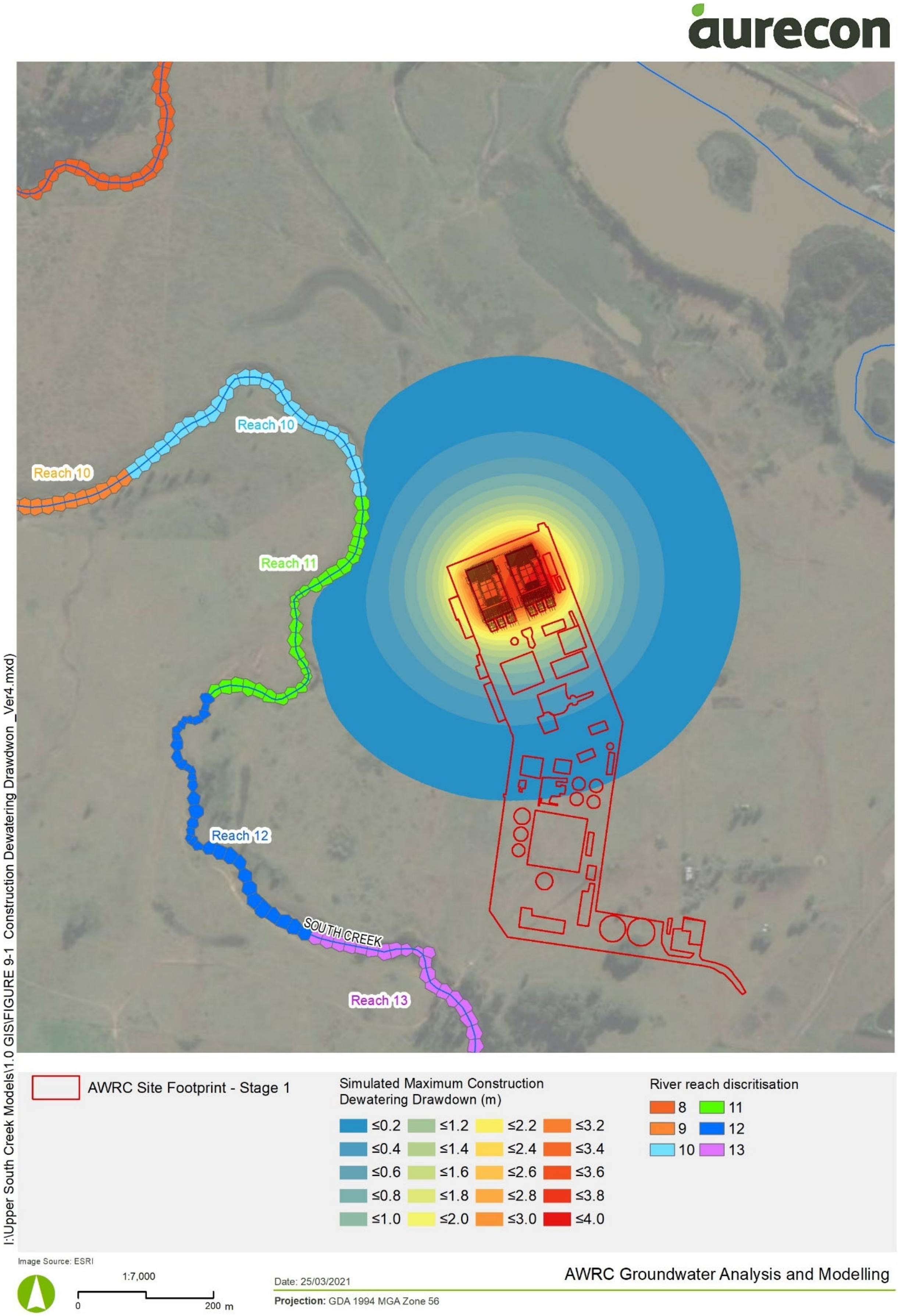


Figure 7-1 Simulated construction dewatering drawdown (Cone of depression extent)

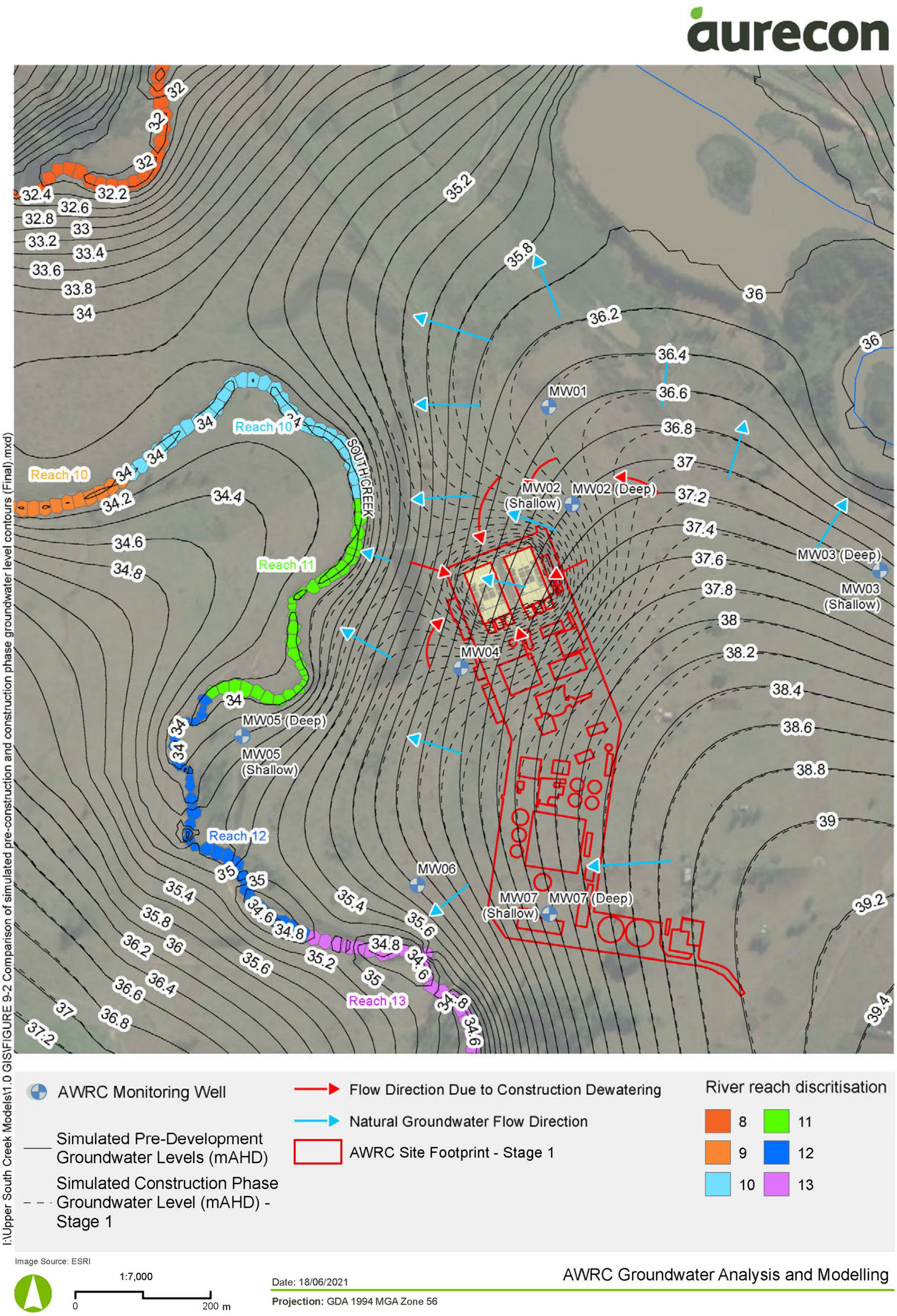


Figure 7-2 Comparison of simulated pre-construction and construction phase groundwater level contours

7.1.2 Operational phase

Underdrainage systems

Potential impact assessed in this section: Induced drawdowns from any underdrainage systems employed for underground structure floatation management, temporarily intercepting groundwater for GDEs and surrounding groundwater users.

Ongoing operational activities at the AWRC site have the potential to impact on groundwater levels in a range of ways.

The underdrainage systems employed for underground structure flotation management have the potential to impact on groundwater levels. Diffuser replacement (nominally every 5 years) would require emptying of bioreactors, causing a reduction in dead load. Groundwater may need to be dewatered to reduce buoyancy and negate potential floatation forces on the structure. This would be achieved through pumping of the subsoil drainage system, which may induce drawdown and locally lower the groundwater table. The inflow volumes from the underdrainage systems are expected to be relatively low and discontinuous (e.g. may only be required for the duration of specific maintenance activities).

The dewatering which will be required for maintenance purposes was also assessed via predictive numerical modelling (detailed provided in **Appendix A**). The modelling results indicate that during operation of underdrainage systems at the bioreactors, water levels in the aquifer will reach equilibrium in about 5 days, with inflows stabilising (i.e. maintaining a relatively constant inflow rate) at about 40 L/min (0.66 L/s). Note that initial inflows associated with draining the pore spaces will be relatively high (averaging 1,900 L/min (31 L/s)). The simulated average inflow rate is 50 L/min (3 m^3/hr). Estimates of the total volume expected to be pumped for each maintenance regime should be assessed based on this average flow. For example, for a 5-day maintenance period the total volume is estimated to be around 0.4 ML. The modelling assumed that the head (water level) in the aquifer will be lowered to 35.6 mAHD just below the base of the bioreactor tank floor slab.

The extent of the drawdown is expected to be localised and the Level 1 minimal groundwater level/availability impact considerations are not expected to be exceeded. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered to be acceptable

An approach to manage the extracted groundwater would need to be developed and implemented through an appropriate dewatering management plan. Depending on extracted groundwater quality, treatment may be required to meet the applicable water quality criteria, prior to discharge (e.g. to a receiving surface water body). Further discussion on the management options for extracted groundwater is provided in **Section 8.2**.

The long-term potential impacts associated with the AWRC features would be due to localised reduction in groundwater recharge / infiltration due to impervious surfaces created at the site, which will lead to a local depression and long-term reduction in groundwater levels at the AWRC site occurring during operation. Predictive numerical modelling (detailed provided in **Appendix A**) indicate a corresponding minor reduction (approximately 1%) of baseflow in the creek reaches adjacent to the site. However, the strategy for stormwater management at the AWRC site is intended to re-create the pre-development environmental water balance by offsetting the lost recharge (due to the impermeable surfaces) through increasing post-construction recharge via detention basins and local irrigation. If this is achieved, it follows that the effects of the long-term impact on the local water balance would be minimal. More details regarding the AWRC stormwater strategy are provided in the USC Surface Water Impact Assessment Report (Aurecon Arup, 2021).

A comparison of pre-development groundwater levels and post-construction long term groundwater levels (i.e. during operational phase) is shown in **Figure 7-3** below. The predicted groundwater change in groundwater levels are within the range of acceptability defined by the NSW Aquifer Interference Policy (outlined in **Section 2.3**) in relation to the aquatic ecosystems (South Creek). Therefore, this is not expected to prevent the long-term viability of surrounding water-related assets and is considered acceptable. Climate change influences during future stages are not expected to exacerbate the impact, as the reduction in baseflow will be negligible in comparison to the predicted increase in surface water runoff.

The proposed monitoring, triggers and actions to address potential impacts during operation identical to those outlined in the previous section, with an overview provided in **Section 10**.

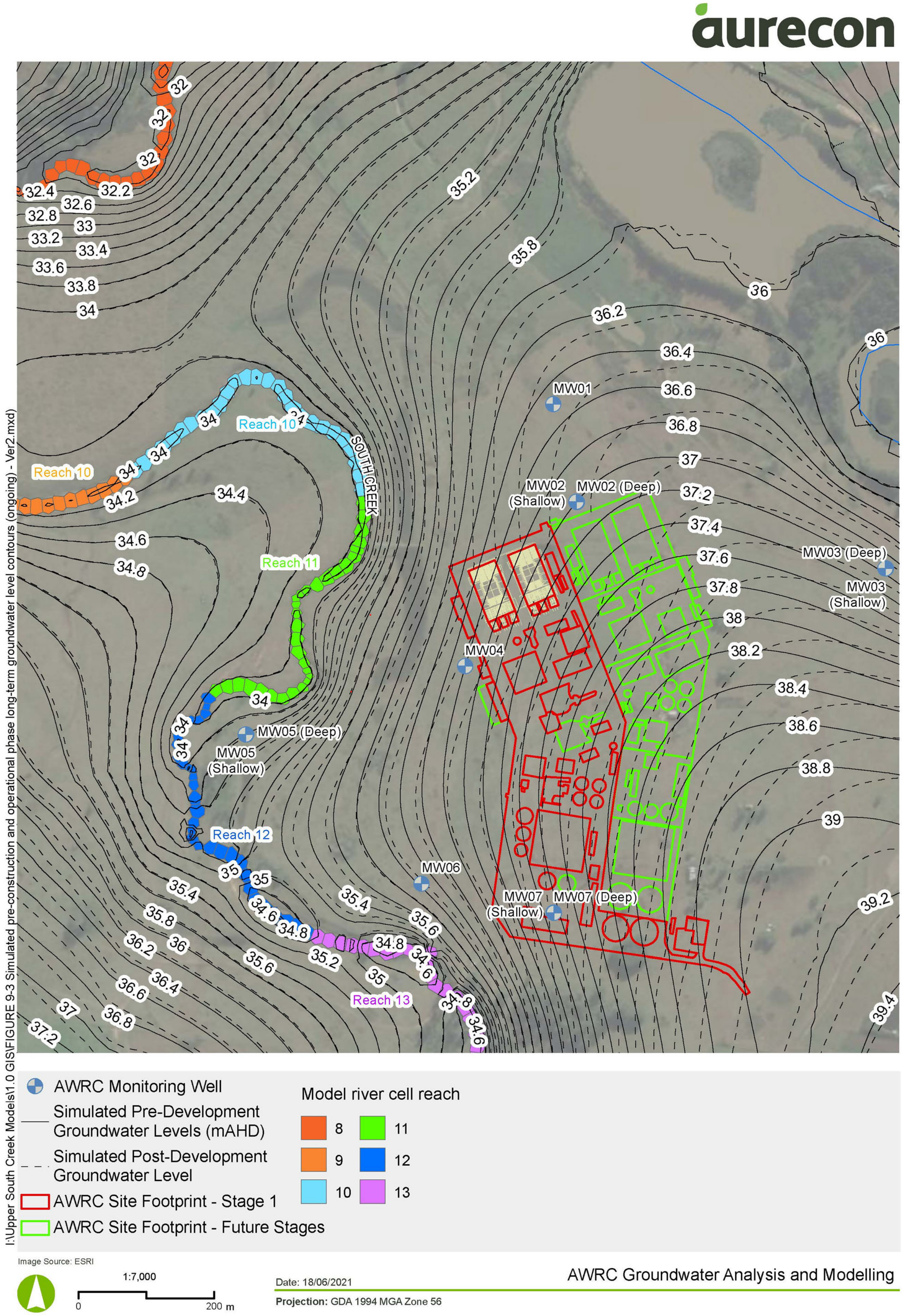


Figure 7-3 Simulated pre-construction and operational phase long-term groundwater level contours (ongoing)

Stormwater Irrigation

Potential impact addressed in this section: Increased groundwater recharge from stormwater irrigation at the AWRC site, leading to increased water levels of saline aquifer.

The Low Flow and Stormwater Study (as documented in the Surface Water Impact Assessment report (Aurecon Arup, 2021)) proposes harvesting stormwater from the ARWC site for irrigation application of the adjacent regional park as a means of contributing to the regional Waterway Health (flow) targets. The irrigation rate proposed will strike a balance between retaining stormwater in the catchment, providing for a quality regional park, and preventing salinification of groundwater by avoiding excessive infiltration of water into soils.

Proposed landscape planting across the adjacent regional park will comprise a mix of turf and native species giving a high-quality landscape character. The proposed irrigation rate (4.5 ML/Ha/yr) makes up the local rainfall deficit or shortfall between rainfall (approximately 700 mm/yr) and potential evapotranspiration (approximately 1200 mm/yr). Through controlled irrigation which avoids watering saturated soils and areas of no vegetation cover, the risk of increased groundwater recharge beneath the park and irrigated zones will be low.

Soil salinity mapping of the desktop assessment area (outlined in **Section 4.6.2**) and supplementary soil salinity testing as part of the *Soils and Contamination Impact Assessment* report, indicate that soil across the AWRC site exhibit non saline properties near surface. In several instances the sampling indicates a vertical salinity profile of saline to moderately saline soils within the 1 to 3 m below ground depths and this salinity profile is expected to increase at depth within nearing the water table.

The proposed controlled irrigation rate on low saline soils is therefore considered to have a combined low risk of salinity impacts on soils and underlying groundwater table.

7.2 Pipelines

7.2.1 Construction phase

Trenched Pipeline construction dewatering and groundwater management

Potential impact assessed in this section: Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.

During trenched pipeline construction, groundwater is likely to be encountered during excavations where the pipeline invert depth intersects the groundwater table. Where this occurs, construction dewatering would be required to provide a stable platform for the construction of the pipelines.

To assess the significance of these impacts, likely groundwater inflow rates and the extents of induced groundwater drawdowns were calculated using analytical equations derived from Darcy's law (further detail provided in **Section 3.3.1**).

As groundwater conditions are expected to vary across the extent of the pipelines, the reference design alignment was divided into discrete sections based on "Hydrogeological Landscapes" (described in **Section 4.5**) to provide realistic inputs to the analytical calculations. For each section, reference design features and expected hydrogeological properties were collated to form the basis of the analytical calculations.

Analytical results for each section where then assessed in relation to surrounding GDEs and groundwater users and compared against the minimal groundwater level/availability impact criteria outlined in **Section 2.3**. The following sections detail the findings of each pipeline section, with summary/overview of all analytical results provided in **Table 7-13**.

7.2.1.1 Environmental Flows Pipeline

Environmental Flows Section 1: Mid-Nepean Hydrogeological Landscape

A summary of the reference design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-1**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-4**.

Table 7-1 Reference Design Features & Groundwater Conditions – E-Flows Section 1: Mid-Nepean HGL

Design Feature	Description		
Pipeline	Environmental Flows		
Trenched Length	1850 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	26 days (three crews operating simultaneously)		
Trenchless Length	0 m		
Approximate Pipeline Invert Depth (mBGL)	**Min**	**Mean**	**Max**
	2.0	3.2	5.7
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Nepean River (approx. 200 m distance)		
Hydrogeological Landscape	Mid-Nepean River		
Groundwater Source Area	"Sydney Basin Nepean" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is low, groundwater is generally fresh (EC between 0.8-1.6 dS/m).		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	0	4	8
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.1	0.15	0.2

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 17.1 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 238.8 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day, this equates to total groundwater inflows of 1,335.4 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest) with a high level of interaction with groundwater.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to adversely impact the long-term health of the affected ecosystems and are considered acceptable.

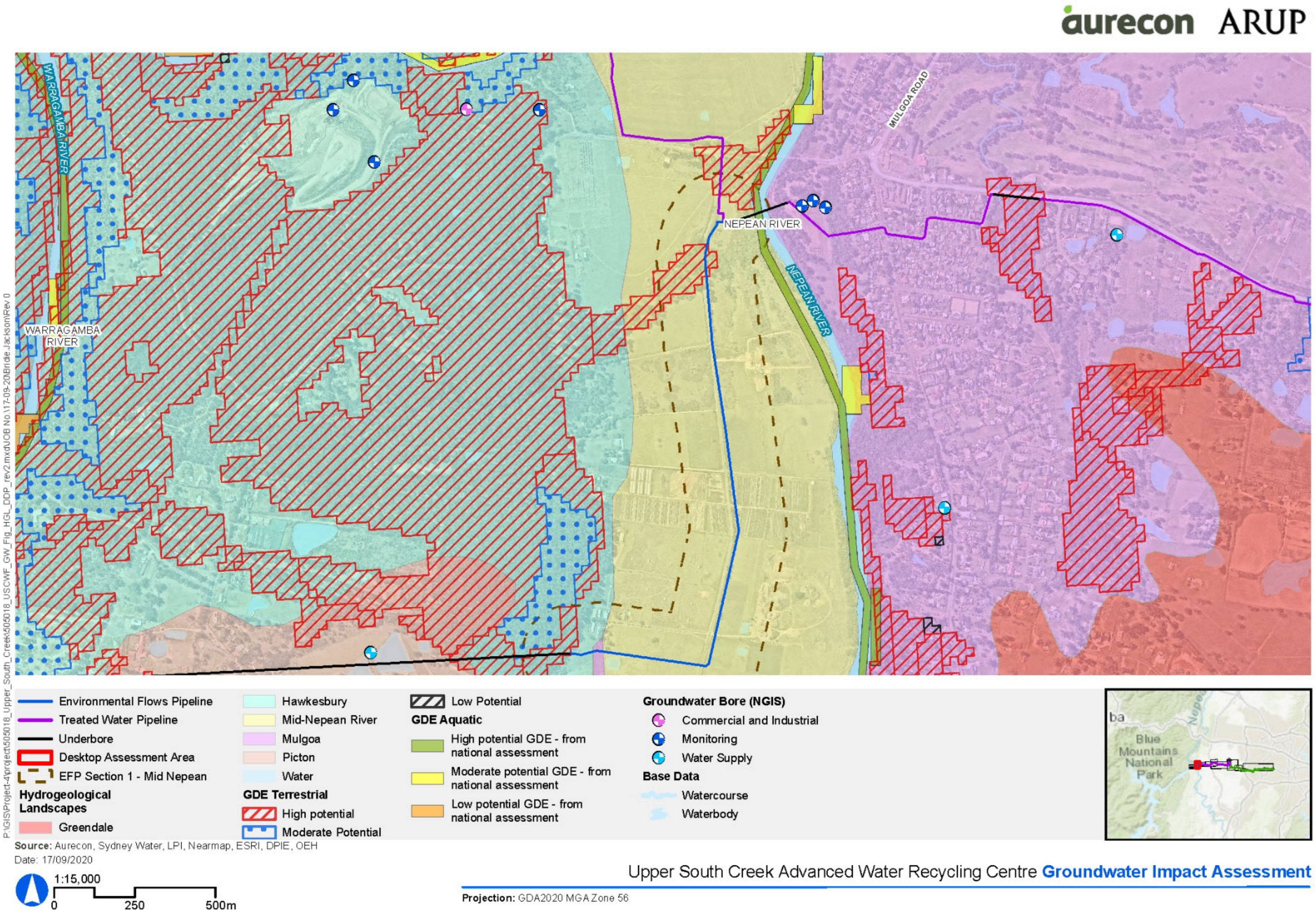


Figure 7-4 Environmental Flows Section 1: Mid-Nepean HGL

Environmental Flows 2: Hawkesbury Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-2**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-5.**

Table 7-2 Design Features & Groundwater Conditions – E-flows Section 2: Hawkesbury HGL

Design Feature	Description		
Pipeline	Environmental Flows		
Trenched Length	0 m		
Trenchless Length	2600 m		
Approximate Pipeline Invert Depth (mBGL)	**Min**	**Mean**	**Max**
	1.4	55	110
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary(s)	Nepean River (approx. 800 m distance), Warragamba River (approx. 50 m distance)		
Hydrogeological Landscape	Hawkesbury (note: Picton HGL is considered less relevant due to the depth profile of the HDD alignment)		
Groundwater Source Area	"Sydney Basin Nepean" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is low, groundwater is generally fresh (EC less than 0.8 dS/m).		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Hawkesbury Sandstone	Mid-Triassic	Medium to very coarse-grained quartz sandstone, minor laminated mudstone and siltstone leases
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	8	N/A	N/A
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.01	0.2	0.5
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.05	1.5	0.3

Numerous ecosystems, both aquatic (Warragamba River) and terrestrial (Coastal Sandstone Ridgetop Woodland, Sydney Hinterland Transition Woodland, Cumberland Shale Sandstone Transition Forest, Hinterland Sandstone Gully Forest and Sydney Hinterland Transition Woodland), with a moderate to high level of interaction with groundwater are present.

A single registered water supply bore (private property off Silverdale Rd, Wallacia) is present in the vicinity of this pipeline section. Information on this water supply bore gathered from the landowner (discussed in **Section 4.7**) indicates that there is no significant aquifer present at the depth and location of the proposed HDD alignment and therefore groundwater impacts associated with construction dewatering are not expected in this section. Groundwater impacts associated with HDD pipelines have been qualitatively assessed in **Sections 8** and **8.2**.

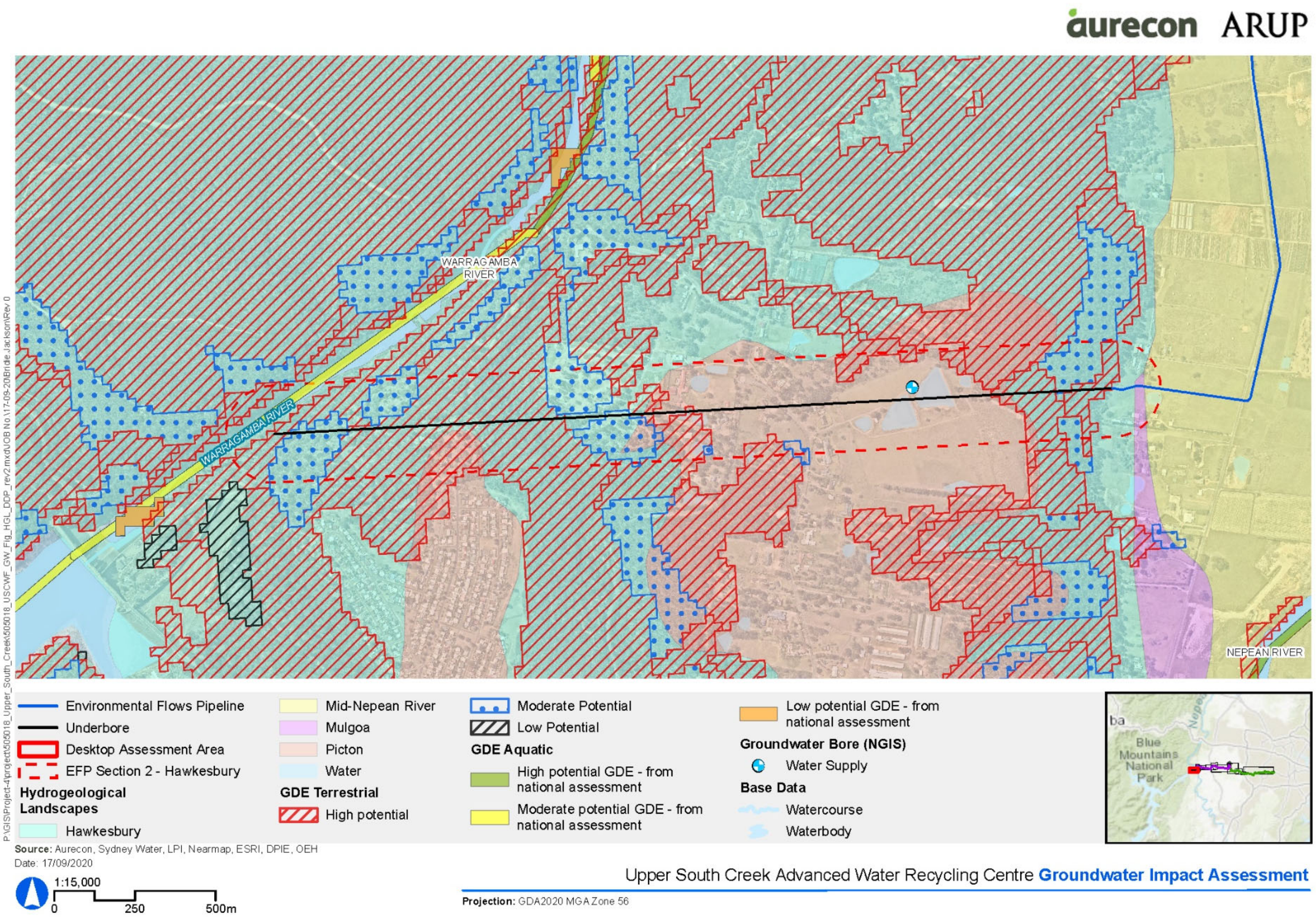


Figure 7-5 Environmental Flows Section 2: Hawkesbury HGL

7.2.1.2 Treated Water Pipeline

Treated Water Section 1: Mid-Nepean Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-3**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-6**.

Table 7-3 Design Features & Groundwater Conditions – Treated Water Section 1: Mid-Nepean HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	1,000 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	14 days (three crews operating simultaneously)		
Trenchless Length	180 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	0.4	3.0	7.0
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Nepean River (approx. 120 m distance)		
Hydrogeological Landscape	Mid-Nepean River		
Groundwater Source Area	"Sydney Basin Nepean" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is low, groundwater is generally fresh (EC between 0.8-1.6 dS/m).		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	0	4	8
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.1	0.15	0.2

* Includes trenched pipeline sections only

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 13.2 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 183.5 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 552.3 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland) with a moderate to high level of interaction with groundwater.

Impacts to the registered commercial/industrial water supply bore present approximately 230 m from this pipeline section are not expected.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered to be acceptable.

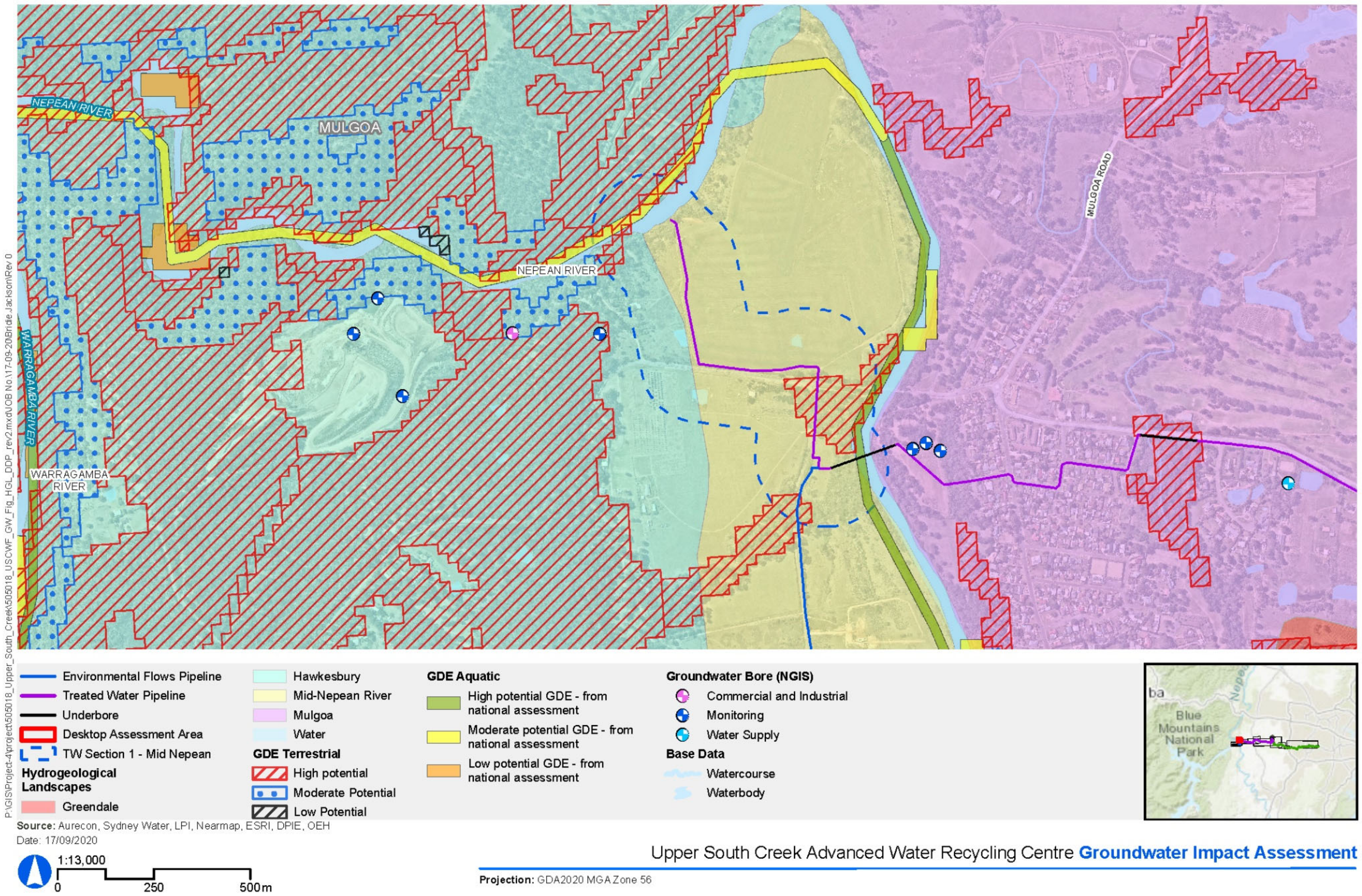


Figure 7-6 **Treated Water Section 1: Mid-Nepean HGL**

Treated Water Section 2: Mulgoa Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-4**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-7**.

Table 7-4 Design Features & Groundwater Conditions – Treated Water Section 2: Mulgoa HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	2,800 m		
Approximate Trenched Pipe Lay Rate	18 m/day (Mixed greenfield and urban conditions, passing through Wallacia)		
Approximate Trenched Construction Duration	52 days (three crews operating simultaneously)		
Trenchless Length	150 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	2.3	3.3	6.5
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Nepean River (approx. 120 m distance)		
Hydrogeological Landscape	Mulgoa		
Groundwater Source Area	"Sydney Basin Central" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8 dS/m)		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	2	5	8
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.1	0.15	0.2

* Includes trenched pipeline section only

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 6.9 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 96.9 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 18 m/day per crew, this equates to total groundwater inflows of 1082.6 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland) with a high level of interaction with groundwater.

Impacts to the registered water supply bore present approximately 70 m from this pipeline section (in a private property off Park Rd, Wallacia) are unlikely.

The predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected water-dependent assets and are considered to be acceptable.

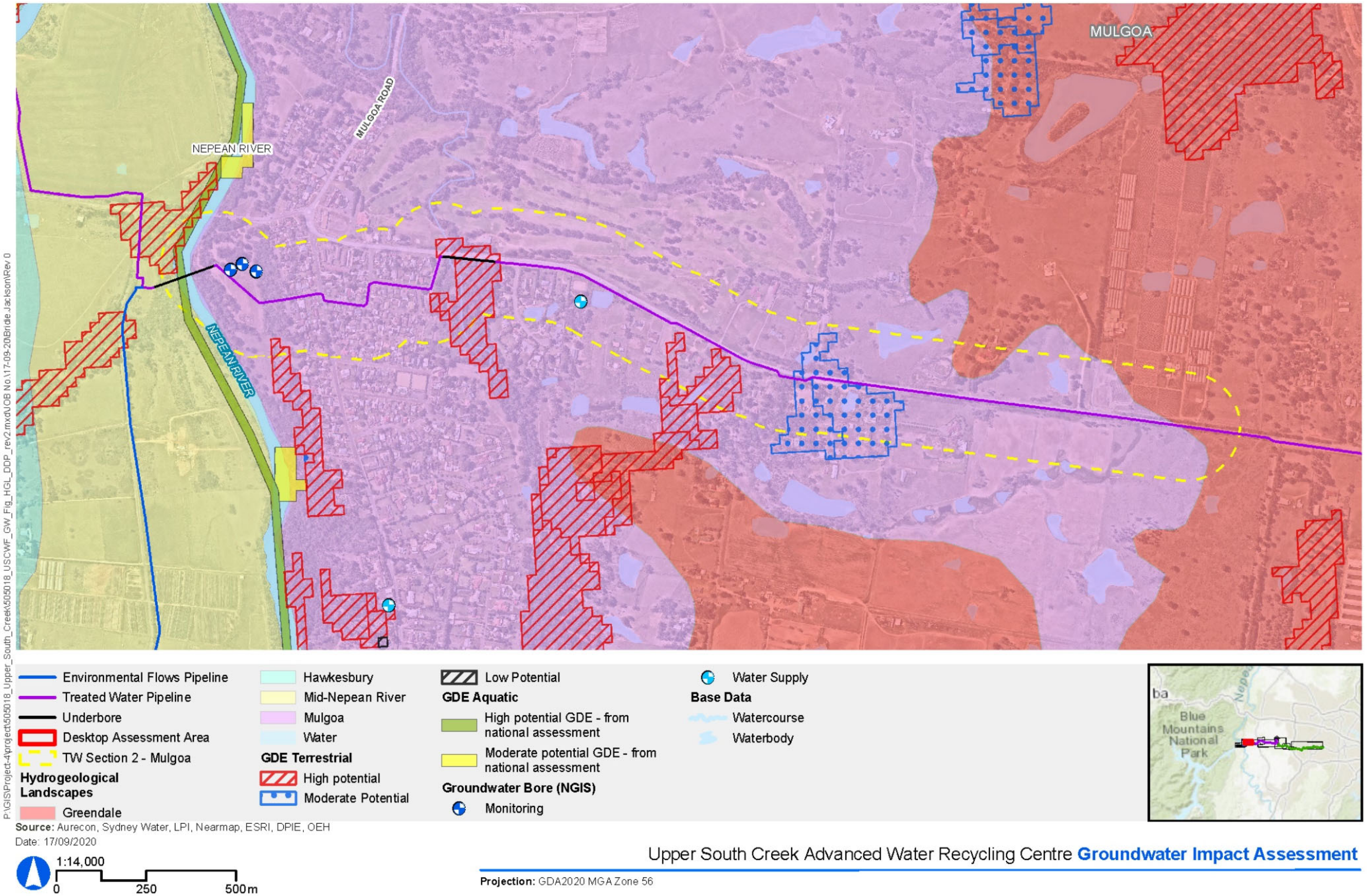


Figure 7-7 **Treated Water Section 2: Mulgoa HGL**

Treated Water Section 3: Greendale Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-5**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-8**.

Table 7-5 Design Features & Groundwater Conditions – Treated Water Section 3: Greendale HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	3,400 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	48 days (three crews operating simultaneously)		
Trenchless Length	120 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	2.0	3.1	5.7
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Surrounding farm dams (approx. 300 m distance)		
Hydrogeological Landscape	Greendale		
Groundwater Source Area	"Sydney Basin Central" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8 dS/m)		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Residual / regolith soils associated with weathered Bringelly Shale	Middle Triassic	Residual/regolith soils associated with weathered shale, carbonaceous claystone, claystone, laminate, fine to medium-grained lithic sandstone, rare coal and tuff
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	2	4	6
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.05	0.3	0.484
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 4.0 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 27.4 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 581.8 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland Shale Plains Woodland) with a high level of interaction with groundwater.

Impacts to the registered water supply and irrigation bores present approximately 400 m from this pipeline section are not expected.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered to be acceptable.

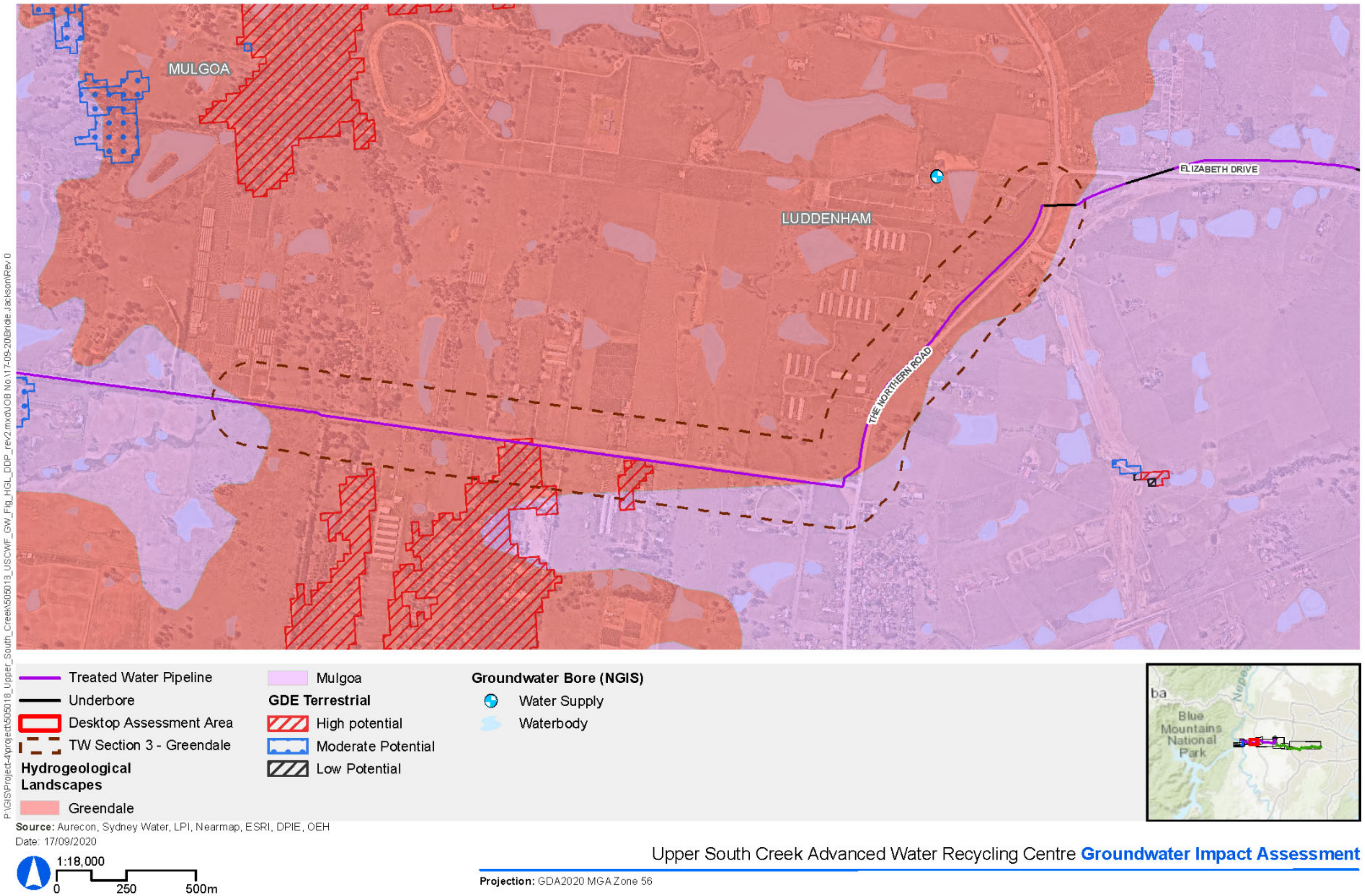


Figure 7-8 **Treated Water Section 3: Greendale HGL**

Treated Water Section 4: Mulgoa Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-6**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-9**.

Table 7-6 Design Features & Groundwater Conditions – Treated Water Section 4: Mulgoa HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	1,260 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	18 days (three crews operating simultaneously)		
Trenchless Length	445 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	2.0	2.9	5.9
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Surrounding farm dams (approx. 50 m distance)		
Hydrogeological Landscape	Mulgoa		
Groundwater Source Area	“Sydney Basin Central” groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8 dS/m)		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	2	5	8
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.1	0.15	0.2

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 5.8 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 80.5 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 311.6 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Impacts to the registered stock/domestic water supply bore present approximately 170 m from this pipeline section are not expected.

Water-dependent assets are not present in the immediate vicinity of the proposed alignment, therefore the predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are considered acceptable.

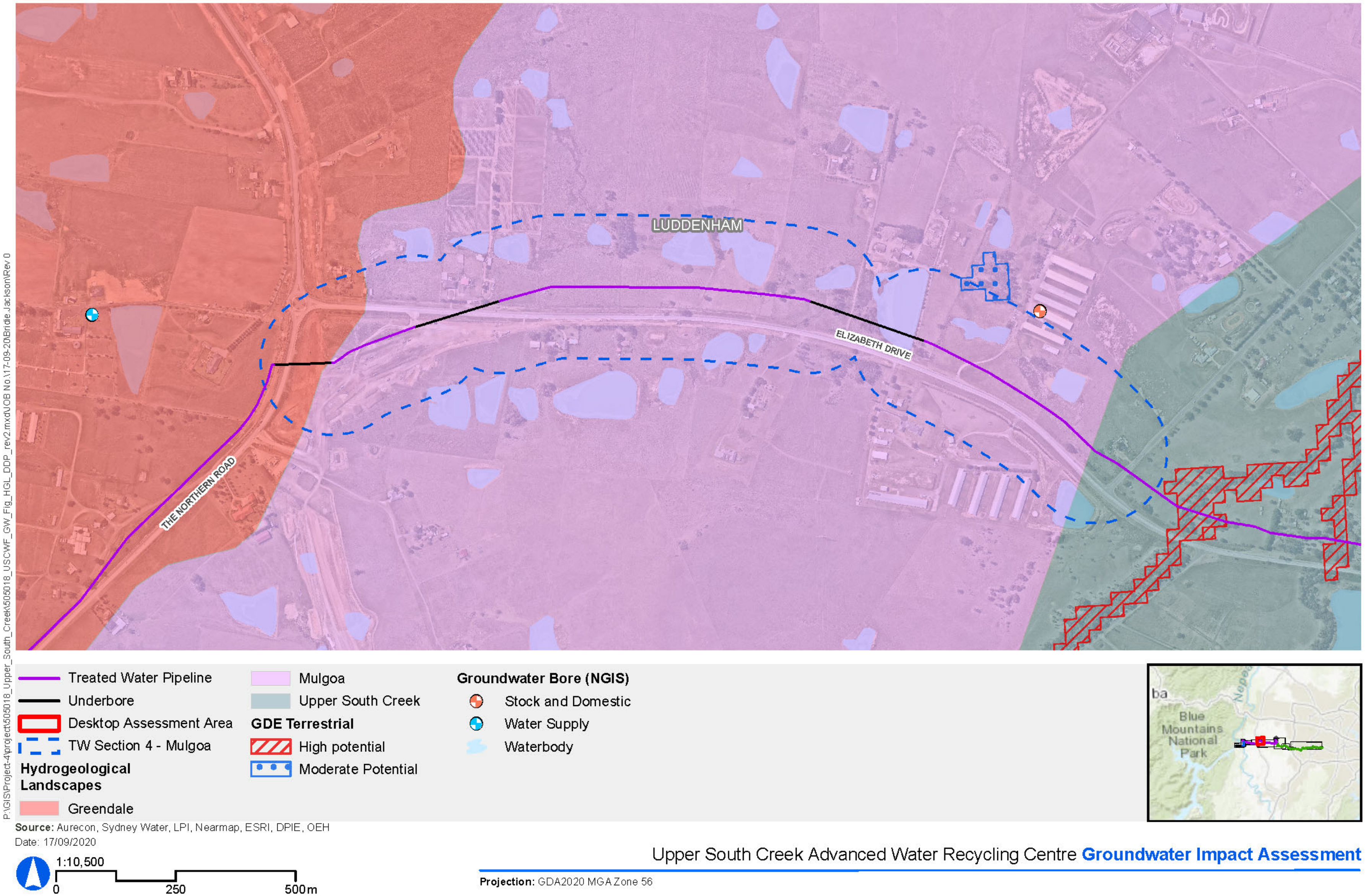


Figure 7-9 Treated Water Section 4: Mulgoa HGL

Treated Water Section 5: Upper South Creek Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-7**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-10**.

Table 7-7 Design Features & Groundwater Conditions – Treated Water Section 5: Upper South Creek HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	6,250 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	87 days (three crews operating simultaneously)		
Trenchless Length	945 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	2.0	2.9	6.8
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Badgery's Creek (approx. 20 m distance)		
Hydrogeological Landscape	Mulgoa		
Groundwater Source Area	"Sydney Basin Central" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is high, groundwater is generally saline (EC greater than 4.8 dS/m)		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	2	4	6
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 4.7 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 65.4 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 1,224.1 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest) with a moderate to high level of interaction with groundwater.

No registered water supply bores are present in the vicinity of this pipeline section.

The predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

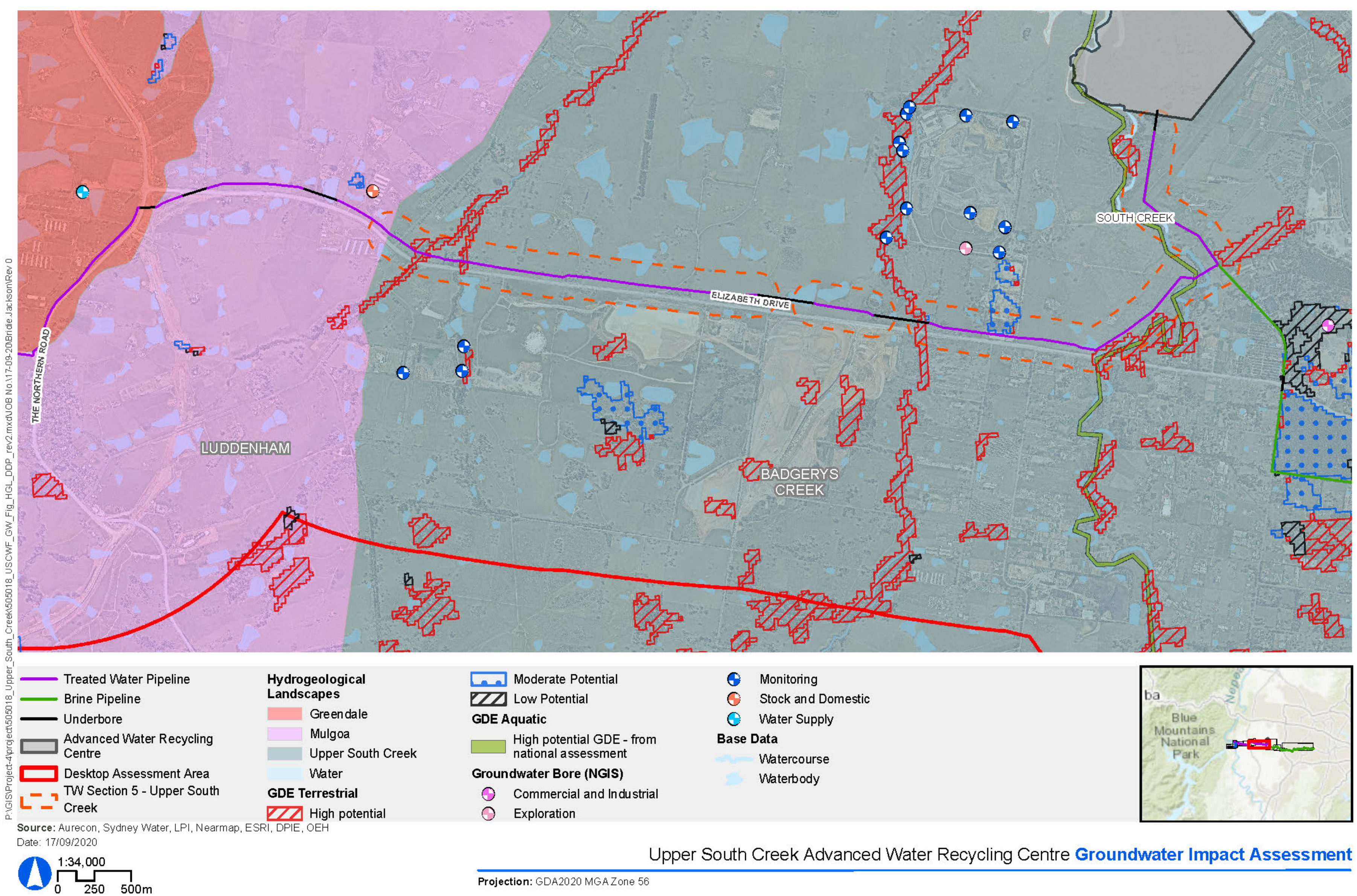


Figure 7-10 Treated Water Section 5: Upper South Creek HGL

7.2.1.3 Brine Pipeline

Brine Section 1: Upper South Creek Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-8**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-11**.

Table 7-8 Design Features & Groundwater Conditions – Brine Section 1: Upper South Creek HGL

Design Feature	Description		
Pipeline	Brine		
Trenched Length	4,800 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	67 days (three crews operating simultaneously)		
Trenchless Length	120 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	1.3	2.6	5.4
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	South Creek (approx. 150 m distance), Kemps Creek (approx. 20 m distance)		
Hydrogeological Landscape	Upper South Creek		
Groundwater Source Area	“Sydney Basin Central” groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is high, groundwater is generally saline (EC greater than 4.8 dS/m)		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	2	4	6
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 10.1 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 141.5 m^3/day.

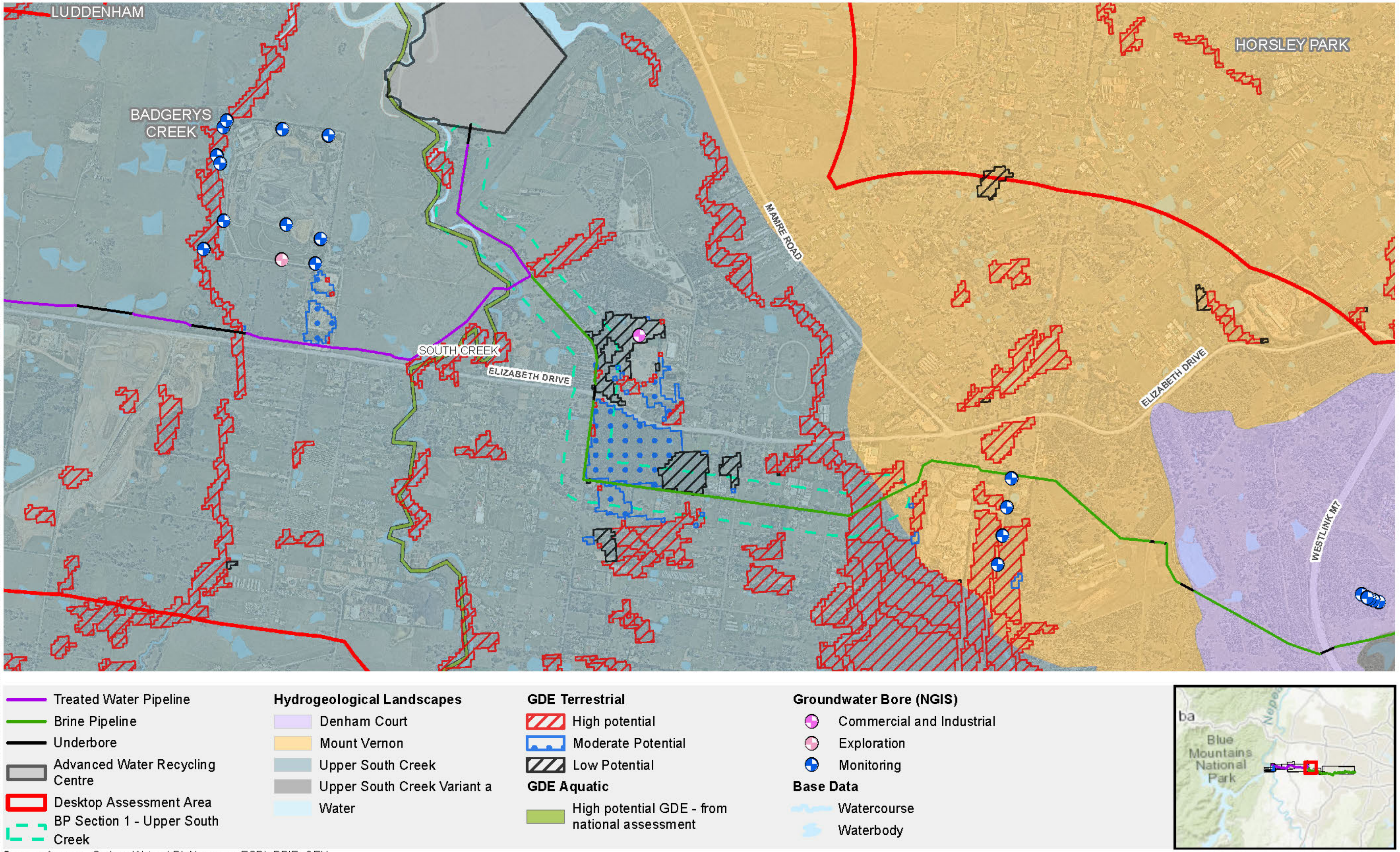
Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 2,038.1 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest, Castlereagh Shale-Gravel Transition Forest and Castlereagh Scribbly Gum Woodland) with a low to high level of interaction with groundwater.

Impacts to the registered commercial/industrial water supply bore present approximately 320 m from this pipeline section are not expected.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.



Source: Aurecon, Sydney Water, LPI, Nearmap, ESRI, DPIE, OEH
Date: 17/09/2020

1:36,000
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Upper South Creek Advanced Water Recycling Centre **Groundwater Impact Assessment**

Projection: GDA2020 MGA Zone 56

Figure 7-11 Brine Section 1: Upper South Creek HGL

Brine Section 2: Mount Vernon Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-9**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-12**.

Table 7-9 Design Features & Groundwater Conditions – Brine Section 2: Mount Vernon HGL

Design Feature		Description	
Pipeline		Brine	
Trenched Length		2,500 m	
Approximate Trenched Pipe Lay Rate		24 m/day (greenfield conditions)	
Approximate Trenched Construction Duration		35 days (three crews operating simultaneously)	
Trenchless Length		185 m	
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	1.3	2.0	3.8
Groundwater Conditions		**Description**	
Most Relevant Constant Head Boundary		Kemps Creek (approx. 250 m distance)	
Hydrogeological Landscape		Mount Vernon	
Groundwater Source Area		"Sydney Basin Central" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).	
Water Quality		Land salinity is moderate, groundwater is generally brackish (EC between 0.8-1.6 dS/m)	
Intersected Geology	**Formation**	**Period**	**Lithology**
	Residual / regolith soils associated with weathered Bringelly Shale	Mid-Triassic	Residual/regolith soils associated with weathered shale, carbonaceous claystone, claystone, laminate, fine to medium-grained lithic sandstone, rare coal and tuff
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	2	4	6
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.05	0.3	0.484
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 6.6 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 44.5 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 687.8 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodlands) with a moderate to high level of interaction with groundwater.

No registered water supply bores are present in the vicinity of this pipeline section.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

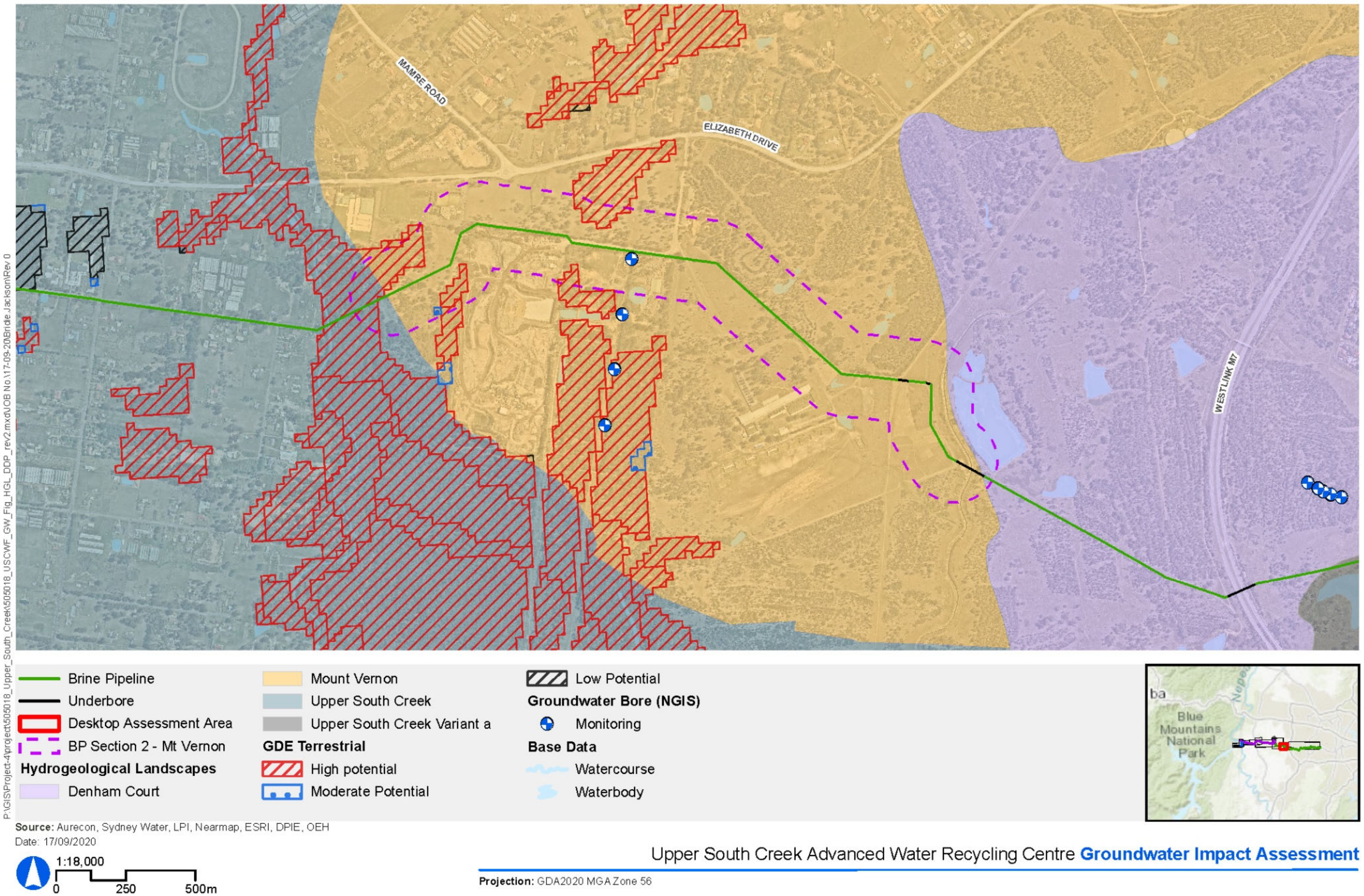


Figure 7-12 Brine Section 2: Mount Vernon HGL

Brine Section 3: Denham Court Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-10**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-13**.

Table 7-10 Design Features & Groundwater Conditions – Brine Section 3: Denham Court HGL

<table>
<tr><th>Design Feature</th><th colspan="3">Description</th></tr>
<tr><td>Pipeline</td><td colspan="3">Brine</td></tr>
<tr><td>Trenched Length</td><td colspan="3">1,220 m</td></tr>
<tr><td>Approximate Trenched Pipe Lay Rate</td><td colspan="3">24 m/day (greenfield conditions)</td></tr>
<tr><td>Approximate Trenched Construction Duration</td><td colspan="3">17 days (three crews operating simultaneously)</td></tr>
<tr><td>Trenchless Length</td><td colspan="3">115 m</td></tr>
<tr><td rowspan="2">Approximate Pipeline Invert Depth (mBGL)*</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>1.4</td><td>2.0</td><td>3.9</td></tr>
<tr><th>Groundwater Conditions</th><th colspan="3">Description</th></tr>
<tr><td>Most Relevant Constant Head Boundary</td><td colspan="3">Liverpool Offtake Reservoir (approx. 60 m distance)</td></tr>
<tr><td>Hydrogeological Landscape</td><td colspan="3">Denham Court</td></tr>
<tr><td>Groundwater Source Area</td><td colspan="3">“Sydney Basin Central” groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).</td></tr>
<tr><td>Water Quality</td><td colspan="3">Land salinity is moderate, groundwater is generally fresh (EC less than 0.8 dS/m)</td></tr>
<tr><td rowspan="2">Intersected Geology</td><td>Formation</td><td>Period</td><td>Lithology</td></tr>
<tr><td>Residual / regolith soils associated with weathered Bringelly Shale</td><td>Mid-Triassic</td><td>Residual/regolith soils associated with weathered shale, carbonaceous claystone, claystone, laminate, fine to medium-grained lithic sandstone, rare coal and tuff</td></tr>
<tr><td rowspan="2">Groundwater Depths (mbgl)</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>2</td><td>4</td><td>6</td></tr>
<tr><td rowspan="2">Hydraulic Conductivities (m/day)</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>0.05</td><td>0.3</td><td>0.484</td></tr>
<tr><td rowspan="2">Storage Properties (Specific Yield)</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>0.05</td><td>0.1</td><td>0.15</td></tr>
</table>

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 6.4 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 43.0 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 323.9 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

No registered water supply bores or groundwater dependant ecosystems are present in the vicinity of this pipeline section.

Water-dependent assets are not present in the immediate vicinity of the proposed alignment, therefore the predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**). In addition, the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are considered acceptable.

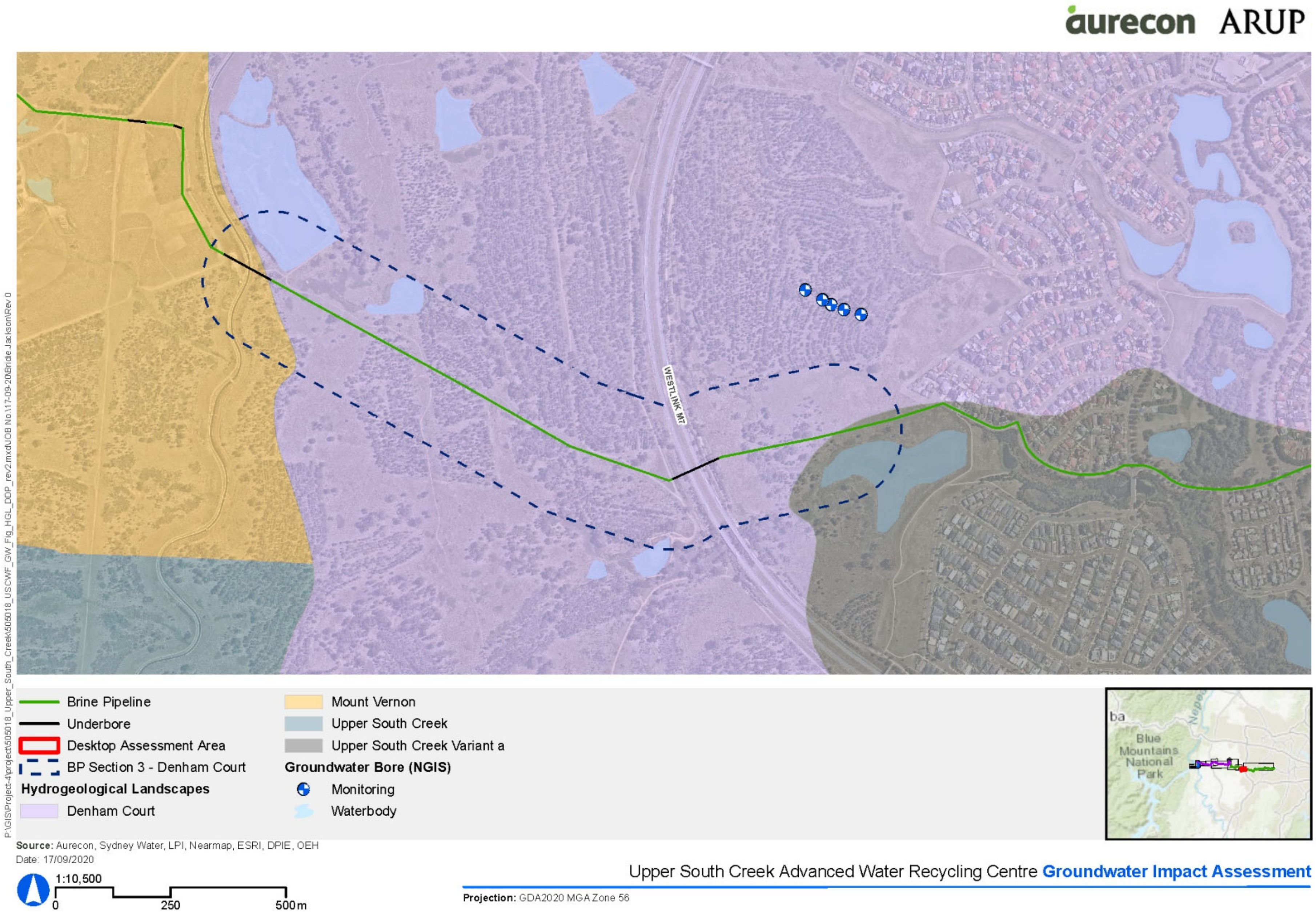


Figure 7-13 **Brine Section 3: Denham Court HGL**

Brine Section 4: Upper South Creek (Variant A) Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-11**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-14**.

Table 7-11 Design Features & Groundwater Conditions – Brine Section 4: Denham Court HGL

Design Feature	Description		
Pipeline	Brine		
Trenched Length	11,800 m		
Approximate Trenched Pipe Lay Rate	12 m/day (Urban conditions)		
Approximate Trenched Construction Duration	328 days (three crews operating simultaneously)		
Trenchless Length	820 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	1.3	2.4	8.6
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Green Valley Creek, Hinchinbrook Creek, Prospect Creek (approx. 50 m distance)		
Hydrogeological Landscape	Upper South Creek (Variant A)		
Groundwater Source Area	"Sydney Basin Central" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is high, groundwater is generally brackish to saline (EC between 1.6-4.8 dS/m)		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Quaternary	Fine-grained sand, clay and silt
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	2	4	6
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.1	0.15	0.2

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 0.8 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 10.7 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 12 m/day per crew, this equates to total groundwater inflows of 757.7 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest) with a low to high level of interaction with groundwater.

Impacts to the registered water supply bores present approximately 120 m from this pipeline section are not expected.

The predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

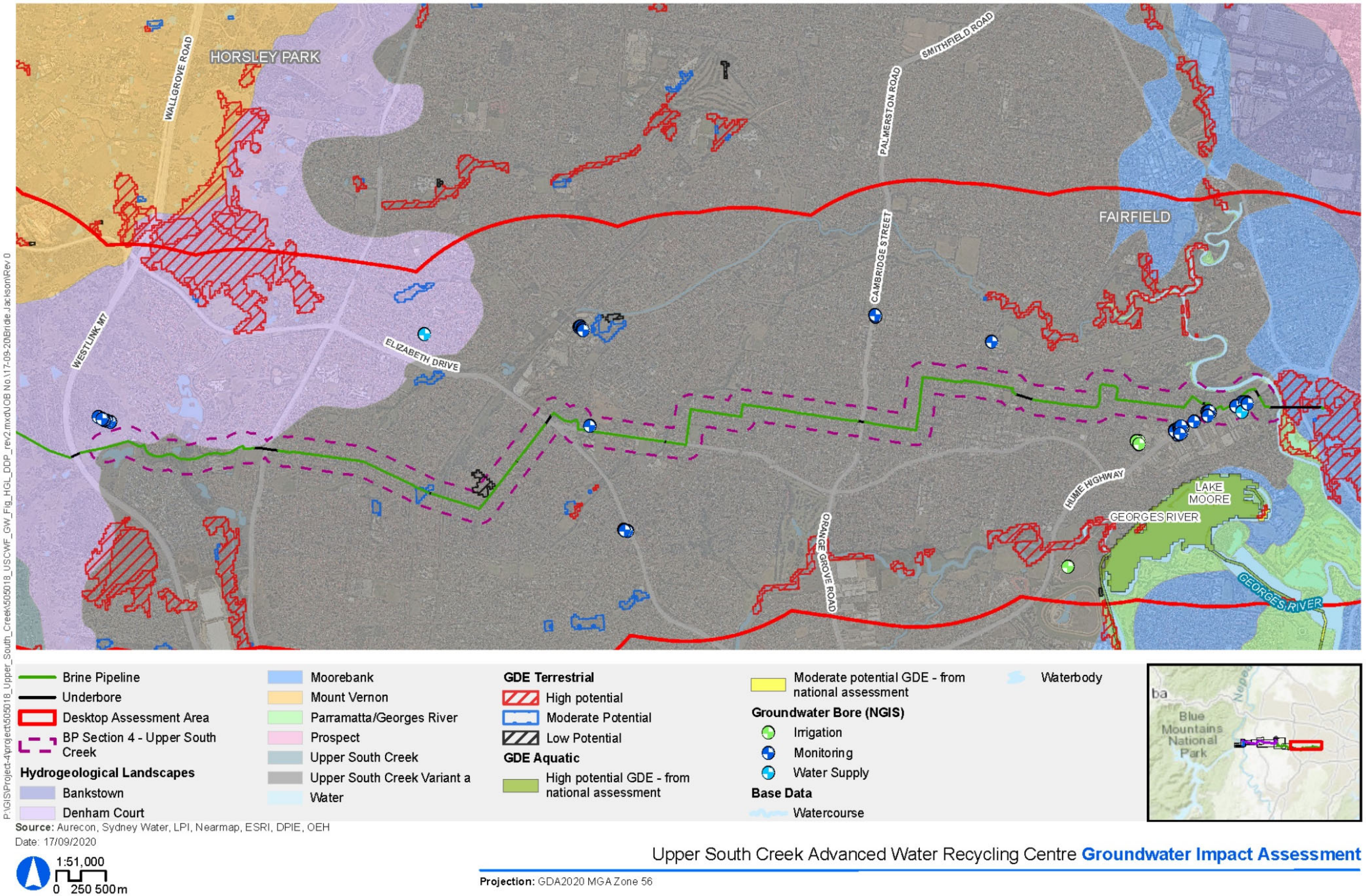


Figure 7-14 **Brine Section 4: Upper South Creek (Variant A) HGL**

Brine Section 5: Moorebank Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-12**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-15**.

Table 7-12 Design Features & Groundwater Conditions – Brine Section 5: Moorebank HGL

Design Feature	Description		
Pipeline	Brine		
Trenched Length	30 m		
Approximate Trenched Pipe Lay Rate	12 m/day (Urban conditions)		
Approximate Trenched Construction Duration	3 days		
Trenchless Length	530 m		
Approximate Pipeline Invert Depth (mBGL)*	**Min**	**Mean**	**Max**
	2.0	3.7	5.3
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Prospect Creek (approx. 20 m distance)		
Hydrogeological Landscape	Moorebank		
Groundwater Source Area	"Sydney Basin Central" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011).		
Water Quality	Land salinity is moderate, groundwater is generally fresh (EC between 0.8-1.6 dS/m)		
Intersected Geology	**Formation**	**Period**	**Lithology**
	Unconsolidated	Neogene	Medium-grained sand, clay and silt
Groundwater Depths (mbgl)	**Min**	**Mean**	**Max**
	0	4	8
Hydraulic Conductivities (m/day)	**Min**	**Mean**	**Max**
	0.017	0.5	1.287
Storage Properties (Specific Yield)	**Min**	**Mean**	**Max**
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 7.8 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 109.3 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 12 m/day, this equates to total groundwater inflows of 23.5 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest) with a high level of interaction with groundwater.

No registered water supply bores are present in the vicinity of this pipeline section.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

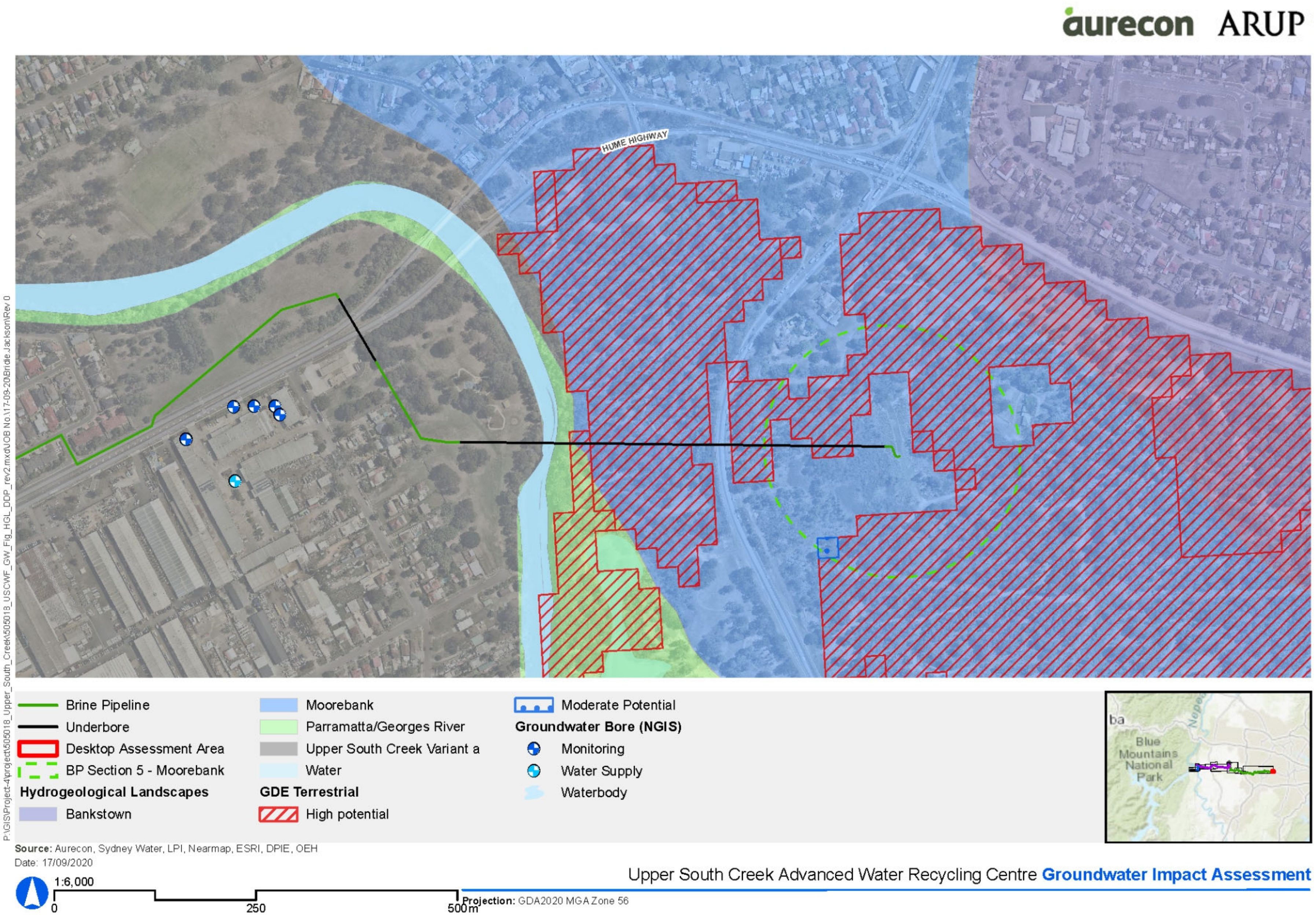


Figure 7-15 **Brine Section 5: Moorebank HGL**

Trenchless Pipeline Sections

Pipe Jacking and Microtunneling

Potential impact assessed in this section = Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.

During microtunneling and pipe jacking activities, construction dewatering will be required at the launch and reception shafts if they extend below the groundwater table. The method used to support the shaft excavations and ground conditions would be the most important factors determining the amount of dewatering that would be required.

Groundwater impacts associated with the pipe-jacking and microtunneling shafts are expected to be minimised through appropriate construction techniques such as the use of a headwall and seal assembly within each shaft and watertight wall supports for the shafts.,

Dewatering along the alignment of the pipe-jacked sections may be required, depending on the pressure limitations of the chosen pipe jacking equipment. Frictional forces that build up around the pipeline is dependent upon many factors (e.g. ground conditions, overburden depth, pipe curvature and friction angle), including depth of the groundwater table. If these frictional forces cannot be overcome by the chosen equipment, dewatering along the pipe-jacking alignment may be the most practical ground treatment solution.

Potential groundwater impacts associated with pipe jacking and microtunneling have been qualitatively assessed as moderate (temporary, but potentially widespread unless mitigation measures are implemented).

Horizontal Directional Drilling

Potential impact assessed in this section = Groundwater seepage and/or unintentional return of drilling fluid to the surface or waterways via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs).

When performing Horizontal Directional Drilling (HDD) in aquifers, there is a possibility of groundwater seepage occurring through the borehole, particularly in areas with elevated water pressures (e.g. semi-confined aquifers). Groundwater seepage will occur when hydraulic heads in the aquifer exceed the static pressures of the drilling fluid. In addition, if excavations associated with the entry and exit points for the HDD intersect the saturated material, seepage into the open excavations will occur and dewatering will be required (as with trenched pipeline construction).

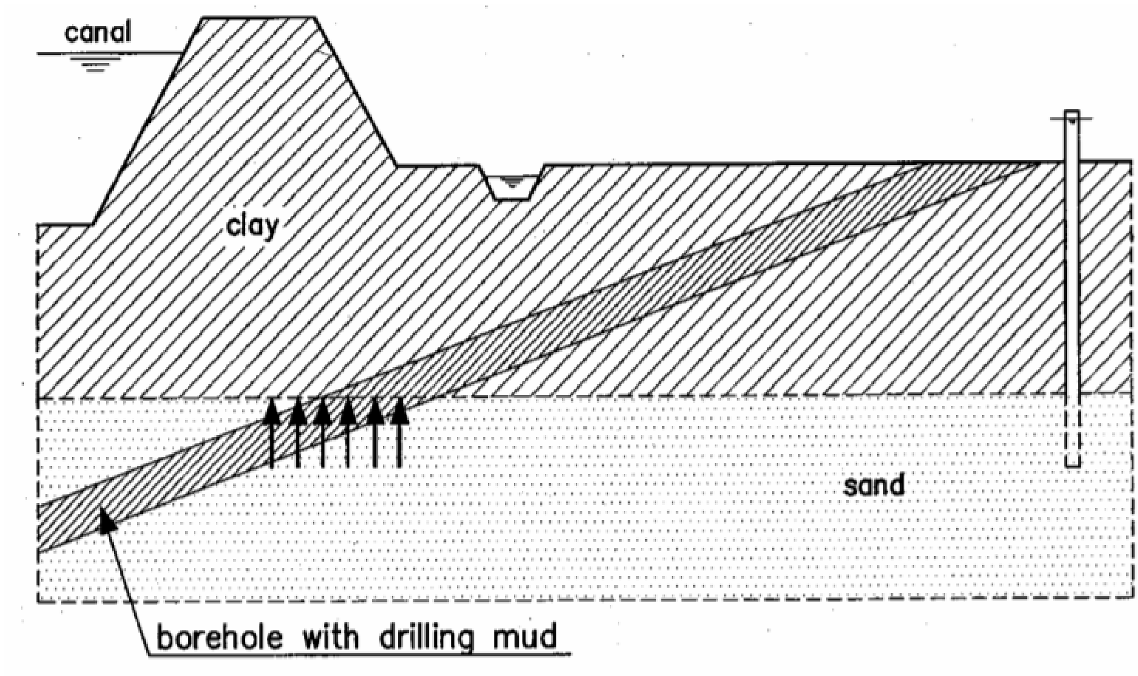


Figure 7-16 **Upward groundwater seepage during HDD construction in semi-confined groundwater conditions (Hergarden et al., 2001)**

Another potential impact from underbore / HDD construction is the unintentional return of drilling fluid to the surface. This occurs when the pressures in the drilling fluid exceed the overburden pressure or if preferential pathways (e.g. fault lines, fractures or loose materials) are present. Frac-outs can cause deleterious environmental effects, such as sedimentation within watercourses, groundwater and surface water quality impacts and harm to ecological communities (particularly in aquatic environments).

Groundwater quality can also impact the level of seepage that occurs during HDD construction. Groundwater across the majority of the desktop assessment area is expected to be brackish to saline (as discussed in **Section 4.6**), which can create conditions where the solids used in drilling fluids (e.g. bentonite) flocculate and sink, decreasing the density of the fluid. If the density of the drilling fluid becomes lower than that of the surrounding groundwater, seepage will occur.

Groundwater seepage during construction should be minimised to reduce environmental impacts, but also to reduce the risk of borehole collapse and subsidence of the ground surface (mitigation measures to reduce groundwater seepage outlined in **Section 8.2**).

7.2.2 Operational Phase

Groundwater seepage after construction of trenchless pipelines

Potential impact assessed in this section: Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.

Once trenchless pipelines are installed, drilling fluids will solidify. Therefore, groundwater seepage through the pipeline annulus is expected to be negligible. However, there will be a relatively short period after construction where the drilling fluid will still be in a liquid condition. If damage to the pipeline and leakage occurs during this period, upward groundwater seepage can be induced.

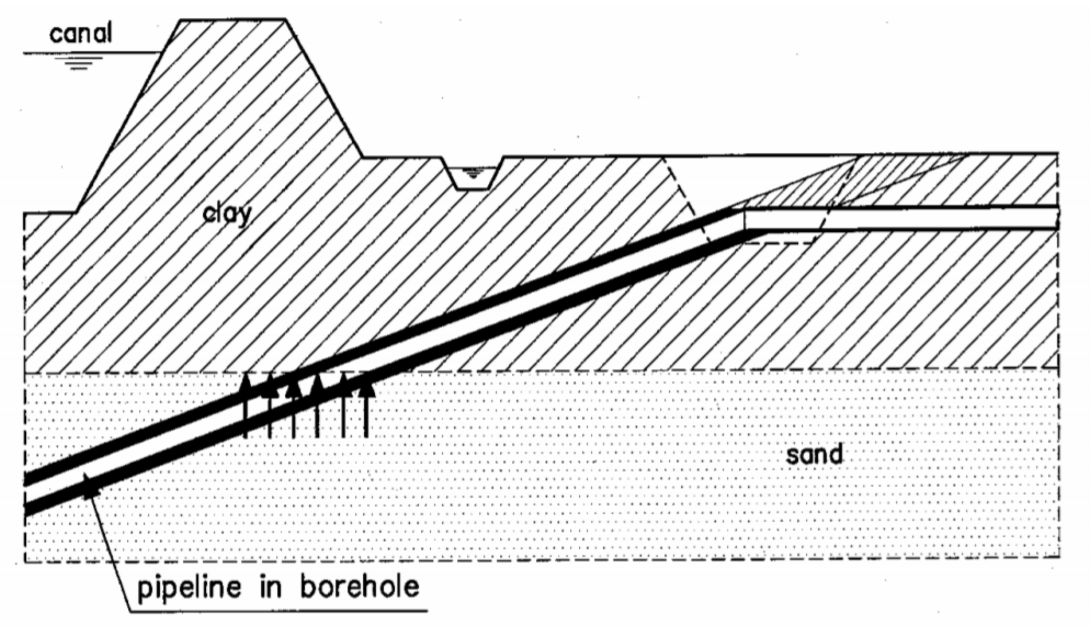


Figure 7-17 Upward groundwater seepage during HDD operation in semi-confined groundwater conditions (Hergarden et al., 2001)

Pipeline leaks/bursts

Potential impact assessed in this section: Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.

Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination. Water transmitted through the treated water and environmental flows pipelines will be predominately fresh and unlikely to cause significant impacts to groundwater quality. Water transmitted through the brine pipeline will have much higher total dissolved solids and leaks/bursts occurring across this pipeline is likely to cause localised degradation in groundwater quality.

7.3 Other Key Considerations

7.3.1 Acid Sulfate Soils

Potential impact assessed in this section: Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts

As discussed in **Section 4.4.4**, potential ASS risk areas are present around Georges River and Prospect Creek in the eastern portion of the desktop assessment area.

If saturated materials in these areas were exposed to oxygen (e.g. drawdown of the groundwater table from construction dewatering), sulfuric acid and iron can be released from the ASS. This potentially results in a number of knock-on effects including:

- Leaching/mobilisation of metals from otherwise stable soil matrices, increasing the concentration of heavy metals in the groundwater to potentially toxic levels.
- Reduced durability of underground structures, such as steel and concrete, through corrosion; and
- Degradation of soil quality in affected areas, preventing vegetation growth.

7.3.2 Mobilisation and Migration of Contaminants

Potential impact assessed in this section: Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts

As discussed in **Section 4.6.1**, groundwater toxicants may be present in the desktop assessment area, associated with anthropogenic influences such as widespread agricultural land use, areas of disturbed terrain, landfilling etc.

Alterations to the groundwater systems, through construction dewatering and the construction of underground structures, could induce hydraulic gradients with the potential to induce contaminant migration. Migration of contaminant would be in sympathy with the direction of induced groundwater flows.

If this occurs, it is likely that extracted groundwater would contain contaminants and would therefore require management / treatment prior to discharge / disposal. Areas of environmental concern and their corresponding risk rating for the potential presence of contamination are discussed in further detail in the *Soils and Contamination Impact Assessment* report

7.3.3 Interception of aquifers during excavation

Potential impact assessed in this section: Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.

As discussed in **Section 4.6**, the local groundwater systems are generally highly saline and also relatively shallow. By increasing the vertical hydraulic connection between the local groundwater systems and the underlying regional systems through excavations, or by increasing the lateral hydraulic connection through the pipeline backfill material, preferential migration pathways may be formed affecting water qualities, hydraulic gradients and flow regimes in the groundwater systems.

This is considered likely to occur in the following areas:

- At the interface between alluvial deposits and the underlying Bringelly Shale. From a horizontal perspective, this is expected at the interface between these geologies as mapped in **Section 4.4**. From a vertical perspective, this is expected where the excavation is deep enough to intersect the different geological units (e.g. where the trenchless shafts extent into bedrock or where bedrock is encountered above the pipeline invert level).
- Due to the longer duration of construction dewatering at the AWRC site, dewatering is expected to induce an upward flow field which will potentially cause deeper low quality water to be mobilised into the upper alluvial system as illustrated in the hydrogeological conceptual model in **Figure 6-3**.
- In addition, the potential presence of localised perched aquifers occurring above clay rich lenses in the alluvial deposits have been noted in the HGLs listed below as outlined in **Section 4.5.6**. Where these are intersected, a connection between the perched aquifer and the underlying aquifer may be formed.
  - Mid-Nepean River HGL
  - Mulgoa HGL
  - Greendale HGL
  - Upper South Creek HGL
  - Mount Vernon HGL
  - Upper South Creek Variant A HGL
  - Moorebank HGL

The severity of this impact is dependant upon the backfill material used upon completion of the excavation. Using a relatively impermeable material or vertical/horizontal cut-offs would minimise this impact.

7.4 Analysis Results Summary

7.4.1 All Trenched Pipeline Sections: Summary

Table 7-13 Trenched pipelines - construction dewatering analytical calculation summary

Pipeline Section	Groundwater Source Area	Approx Trenched Pipe Lay Rate (m/day)	Approximate Duration of Trenched Construction (Full Section) (days)	Simulated Groundwater Drawdown (m)	Calculated Maximum Radius of Influence (m)	Estimated Groundwater Inflow Rates (m^3/day)			Estimated Total Groundwater Inflow (m^3)*		
						Min	Expected	Max	Min	Expected	Max
Environmental Flows Section 1: Mid-Nepean HGL	Sydney Basin Nepean	24	26	3.2	44	0.4	17.1	238.8	28.1	1,335.4	18,626.4
Environmental Flows Section 2: Hawkesbury HGL	Sydney Basin Nepean	N/A	0	Horizontal Directional Drilling (HDD) only. No trenched component.							
Treated Water Section 1: Mid-Nepean HGL	Sydney Basin Nepean	24	14	3	54	0.3	13.2	183.5	11.8	552.3	7,708.7
Treated Water Section 2: Mulgoa HGL	Sydney Basin Central	18	52	1.3	35	0.2	6.9	96.9	23.4	1,082.6	15,121.1
Treated Water Section 3: Greendale HGL	Sydney Basin Central	24	48	1.1	18	0.5	4.0	27.4	76.3	581.8	3,941.3
Treated Water Section 4: Mulgoa HGL	Sydney Basin Central	24	18	0.9	30	0.1	5.8	80.5	6.5	311.6	4,346.5
Treated Water Section 5: Upper South Creek HGL	Sydney Basin Central	24	87	0.9	37	0.1	4.7	65.4	26.1	1,224.1	17,061.6
Brine Section 1: Upper South Creek HGL	Sydney Basin Central	24	67	1.4	26	0.2	10.1	141.5	44.2	2,038.1	28,431.5
Brine Section 2: Mount Vernon HGL	Sydney Basin Central	24	35	1.8	17	0.9	6.6	44.5	90.3	687.8	4,668.3
Brine Section 3: Denham Court HGL	Sydney Basin Central	24	17	1.9	19	0.8	6.4	43.0	42.3	323.9	2,194.0
Brine Section 4: Upper South Creek (A) HGL	Sydney Basin Central	12	328	0.3	51	0.02	0.8	10.7	19.7	757.7	10,519.0
Brine Section 5: Moorebank HGL	Sydney Basin Central	12	3	4.7	41	0.2	7.8	109.3	0.5	23.5	327.9
Totals		**N/A**	**695**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	369.2	8,918.6	112,946.1

* The duration of active dewatering is assumed to be linked to the daily pipe lay rates. In this case, the completed segment would be backfilled following each day at which time dewatering for most of the section of the pipe is ceased (except at the open front end where sump dewatering may need to be continued to prevent flooding of the pipe). These estimates therefore represent minimum expected flow (See **Section 3.3.1** for an explanation of model limitations, assumptions and consequences). If unexpected conditions are encountered or there are delays with pipe preparations etc, extended dewatering may be required resulting in more pumped volume than presented in this table.

7.4.2 AWRC Summary

Table 7-14 AWRC Summary of construction dewatering numerical modelling results

Project Phase	Duration	Simulated Drawdown / depression (m)	Calculated Maximum Radius of Influence (m)	Estimated Average Groundwater Inflow Rates[C] (L/Min)			Estimated Total Groundwater Inflow (ML)			Impact on baseflow[D]
				Min	Expected	Max	Min	Expected	Max	
Construction Phase (Stage 1 only)	365	4	325	30	80	200	23	50	97	-6%
Operation[A]	Long-term	0.9[B]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-1%

[A] NB as mentioned in **Section 9.1.2**, it is intended to re-create the pre-development environmental water balance by offsetting the lost recharge through increasing operational recharge through detention basins and local irrigation. This will reduce the depression across the AWRC site.
[B] This occurs at the centre of the ARWC footprint reducing to zero before intersecting South Creek.
[C] These estimate are based on relatively stable flow rates after 30 days of pumping
[D] Affected river reaches – Reach 10 and Reach 11.

8 Impact Assessment

8.1 Potential Impacts

Potential impacts that may occur during the construction and operational phases are assessed in accordance with the methodology outlined in **Section 3**, leading to informed mitigation measures to prevent, minimise and / or contain these impacts.

The potential impacts associated with the construction phase activities of the project, also described in section 7 include:

- Induced drawdowns from required dewatering activities, potentially reducing the availability of groundwater for GDEs and surrounding groundwater users.
- Groundwater seepage and/or unintentional return of drilling fluid to the surface or waterways via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs).
- Discharge of contaminated hydrostatic test water.
- Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts.
- Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increasing the turbidity and reducing the water quality in receiving waters.
- Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts.
- Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.
- Disruption of surface water and groundwater connectivity.

The potential impacts associated with the operation phase activities of the project, also described in section 7 include:

- Induced drawdowns from any underdrainage systems employed for underground structure floatation management, temporarily intercepting potential groundwater for GDEs and surrounding groundwater users.
- Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery at the AWRC, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.
- Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.
- Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.
- Increased groundwater recharge from stormwater irrigation at the AWRC site, leading to increased water levels of saline aquifer.

The significance of each groundwater related impact during construction and operation of the project has been derived based on findings presented in **Section 7** in relation to the matrix of impact significance outlined in **Section 3.4.1**. This section was developed and applied to inform the project's reference design and ensure appropriate mitigation measures have been considered in relation to the sensitivity of environmental values and magnitude of impacts.

The following sections respond to the SEARs (**Section 1.4**) while providing an overview of potential construction and operational phase impacts for the AWRC site and pipeline alignments. The potential impacts have been assessed with consideration to the relevant components of the design, which were developed iteratively during the assessment to reduce potential impacts to groundwater across the project.

A summary of quantitative analysis results from dewatering activities (see **Section 7.1.1** and **Section 7.2.1**) in relation to the adopted impact assessment criteria is provided in **Table 8-1**.

The potential impacts associated with the construction phase activities of the project are identified and assessed in **Table 8-2,** any additional impacts potentially arising during the operational phase are indicated in **Table 8-3**.

Table 8-1 Impact assessment for induced drawdowns from required dewatering activities

Project Feature	Span of Active Dewatering	Calculated Maximum Radius of Influence (m)	Water supply bores within radius of influence	GDEs		Maximum Calculated Drawdowns (m)			Assessment against minimal groundwater level/availability criteria (Section 2.3)
				GDEs present within radius of influence	Potential for groundwater interaction	At project feature	At GDE	At Water Supply bore*	
AWRC	356 days	325	None	Aquatic ecosystems (South Creek)	High	3.9	0.2	N/A	GDE with high potential for groundwater interaction located within radius of influence, therefore drawdown criteria (0.1m) is exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Environmental Flows Section 1: Mid-Nepean HGL	24 m/day pipeline lay rate	44	None	Aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest).	High	3.2	3.2	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Environmental Flows Section 2: Hawkesbury HGL	N/A	Horizontal Directional Drilling (HDD) only. Impacts assessed qualitatively (see **Table 8-2** below)							
Treated Water Section 1: Mid-Nepean HGL	24 m/day pipeline lay rate	54	None	Aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland).	Moderate to high	3.0	3.0	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 2: Mulgoa HGL	18 m/day pipeline lay rate	35	None	Aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland)	High	1.3	1.3	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 3: Greendale HGL	24 m/day pipeline lay rate	18	None	Terrestrial ecosystems (Cumberland Shale Plains Woodland)	High	1.1	1.1	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 4: Mulgoa HGL	24 m/day pipeline lay rate	30	None	None	N/A	0.9	N/A	N/A	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Treated Water Section 5: Upper South Creek HGL	24 m/day pipeline lay rate	37	None	Aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest)	Moderate to high	0.9	0.9	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 1: Upper South Creek HGL	24 m/day pipeline lay rate	26	None	Aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest, Castlereagh Shale-Gravel Transition Forest and Castlereagh Scribbly Gum Woodland)	Low, moderate and high	1.4	1.4	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 2: Mount Vernon HGL	24 m/day pipeline lay rate	17	None	Terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodlands	Moderate to high	1.8	0.2*	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 3: Denham Court HGL	24 m/day pipeline lay rate	19	None	None	N/A	1.9	N/A	N/A	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Brine Section 4: Upper South Creek (A) HGL	12 m/day pipeline lay rate	51	None	Terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest)	Low, moderate and high	0.3	0.3	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 5: Moorebank HGL	12 m/day pipeline lay rate	41	None	Terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest)	High	4.7	0.5*	N/A	Drawdown criteria (0.1m) for high potential GDE exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.

* Based on linear interpolation between point of maximum drawdown and edge of radius of influence (point of zero drawdown)

The overall impact significance associated with the sections in close proximity to any GDE's with high potential for groundwater interaction remains *Moderate*, even though the predicted impacts are considered acceptable, due to the high sensitivity of the environmental value.

Table 8-2 Impact assessment outcomes and significance (Construction phase)

Potential Impact	Project location/Activity	Impact significance
■ Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.	**AWRC site:** Excavation, dewatering and installation of underground infrastructures	**Low** Sensitivity of environmental values: Moderate (GDEs are present at the AWRC site) Magnitude of impact: Low (temporary and local) Baseflow reduction within adjacent reaches of South Creek. If the groundwater elevations drop below the water elevation in South Creek for a sustained period, then there will be a complete reversal of groundwater direction extending to the creek resulting in flow reversal at the riverbed. Under these conditions the affected section of the creek would be recharging the groundwater instead groundwater discharging as baseflow. It is considered that the aquatic ecosystems in these reaches may be impacted under such conditions. The induced drawdowns are expected to exceed the Level 1 minimal impact considerations defined in the NSW Aquifer Interference policy (outlined in **Section 2.3**). However, the induced drawdowns will be constrained to a short period of time during construction. Therefore, based on the reference design details and the available information, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.
	Pipelines Excavation, dewatering and installation of underground infrastructures	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and local) The induced drawdowns at the majority of pipeline sections are expected to exceed the Level 1 minimal impact considerations defined in the NSW Aquifer Interference policy (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, based on the reference design details and the available information, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

Potential Impact	Project location/Activity	Impact significance
■ Groundwater seepage and/or unintentional return of drilling fluid to the surface or waterways via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs). ■ Discharge of contaminated hydrostatic test water	**Pipelines:** HDD and micro tunnelling	**Moderate** Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (localised) Any significant volumes of these chemicals entering the local water environment could lead to local ecological degradation or destruction, albeit temporary. Loss of groundwater storage from drilling fluids moving into aquifer material would be localised.
■ Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts	**AWRC site and pipelines:** Excavation, dewatering and installation of underground infrastructures. ASS risk areas are present around Georges River and Prospect Creek in the eastern portion of the desktop assessment area	**Moderate** Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (temporary) Groundwater toxicants may be present in the desktop assessment area, associated with anthropogenic influences such as widespread agricultural land use, areas of disturbed terrain, landfilling etc. Elevated concentrations of heavy metals and nutrients within groundwater, above project waterway objectives, have been identified in previous investigations (RMS 2019). The potential presence of saline or contaminated soils/groundwater and/or acid sulfate soils has been discussed in **Section 4.6.2**, **4.4.4** and **7.3.1**. Alterations to the groundwater systems, through construction dewatering and the construction of underground structures, will create a cone of depression that will direct groundwater in the affected area to flow towards the point of dewatering. If the cone of depression intercepts a contaminant source, it is likely that extracted groundwater would contain contaminants and would therefore require management / treatment prior to discharge / disposal. Areas of environmental concern and their corresponding risk rating for the potential presence of contamination are discussed in further detail in the Soils and Contamination Impact Assessment report. The analysis results presented in Section 7 indicate that registered bores relating to beneficial groundwater uses (e.g. irrigation, stock drinking water and raw drinking water) in the vicinity of the project will not be impacted. Any potential migration of saline or contaminated groundwater induced during construction will be towards the point of dewatering, therefore changes to the

Potential Impact	Project location/Activity	Impact significance
		existing groundwater quality and beneficial use category of the groundwater source will not extend beyond 40 m of the activity and the criteria outlined in Table 2-2 will be met.
■ Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increase the turbidity and reduce the water quality in receiving waters	**AWRC site and pipelines:** Discharges from dewatering activities	**Moderate** Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (temporary) Extracted groundwater quality is expected to vary across the project. Groundwater in some areas is expected to be fresh (e.g. in the Hawkesbury and Mid-Nepean Hydrogeological Landscapes), but groundwater across the majority of the project is expected to be brackish to saline (e.g. Upper South Creek Hydrogeological Landscape). Therefore, discharging the extracted groundwater without treatment is likely to have a deleterious impact to the receiving water body and exceed the NSW AIP criteria for water quality. An overview of the varying groundwater quality reported in each Hydrogeological Landscape across the desktop assessment area can be found in **Section 4.5.6**
■ Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts	**AWRC site, pipelines and access roads:** Compaction and concreting	**Low** Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area). Magnitude of impact: Low (temporary and local)
■ Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.	**AWRC site and pipelines:** Excavation, dewatering and installation of underground infrastructures	**High** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: High (permanent) The local groundwater systems are generally highly saline and also relatively shallow. By increasing the vertical hydraulic connection between the local groundwater systems and the underlying regional systems through excavations, or by increasing the lateral hydraulic connection through the pipeline backfill material, preferential migration pathways may be formed affecting water qualities, hydraulic gradients and flow regimes in the groundwater systems.
■ Disruption of surface water and groundwater connectivity	**AWRC site and pipelines:**	**Low**

Potential Impact	Project location/Activity	Impact significance
	Horizontal directional drilling under a watercourse	Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area.) Magnitude of impact: Low (temporary and local) Any disruption in connectivity would be very localized.

Table 8-3 Impact assessment outcomes and significance (Operational phase)

Potential Impact	Project location/Activity	Impact significance
■ Induced drawdowns from any underdrainage systems employed for underground structure floatation management, temporarily intercepting groundwater for GDEs and surrounding groundwater users.	**AWRC site and pipelines:** Excavation, dewatering and installation of underground infrastructures	**Moderate** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (permanent but localised) The groundwater inflow volumes are expected to be relatively low and discontinuous (e.g. may only be required for the duration of specific maintenance activities). However, when combined with localised reduction in groundwater recharge / infiltration due to impervious surfaces created at the AWRC, long-term reduction in groundwater levels may occur during operation.
■ Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.	**AWRC site:** Operation of vehicles and machinery. Moving and storing chemical and untreated or partially treated wastewater throughout the plant	**Low** Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (localised) Any spills or accidental discharges will be temporary in nature but could lead to localised groundwater contamination (e.g. hydrocarbons, metals, suspended sediments, nutrients and biological constituents such as faecal coliforms).
■ Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.	**Pipelines:** HDD and micro tunnelling	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and local)

Potential Impact	Project location/Activity	Impact significance
		Any significant volumes of these chemicals entering the local water environment may lead to local ecological degradation or destruction, albeit temporary. The likelihood of this occurring decreases once drilling fluid solidifies.
▪ Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.	**Pipelines**	**Moderate** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area)) Magnitude of impact: Moderate (local) Any spills or accidental discharges will be temporary in nature but could lead to localised groundwater contamination. Water transmitted through the brine pipeline will have much higher total dissolved solids and leaks/bursts occurring across this pipeline is more likely to cause localised degradation in groundwater quality.
▪ Increased groundwater recharge from stormwater **harvesting and** irrigation at the AWRC site, leading to increased water levels of saline aquifer.	**AWRC site:** Harvesting of stormwater and irrigation application of adjacent regional park	**Moderate** Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (local) Underlying groundwater at the AWRC site is expected to be saline. Increasing the water levels in this area could lead to increased salinity in the localised area and degradation of the local fauna and flora as well as the surface water resources.

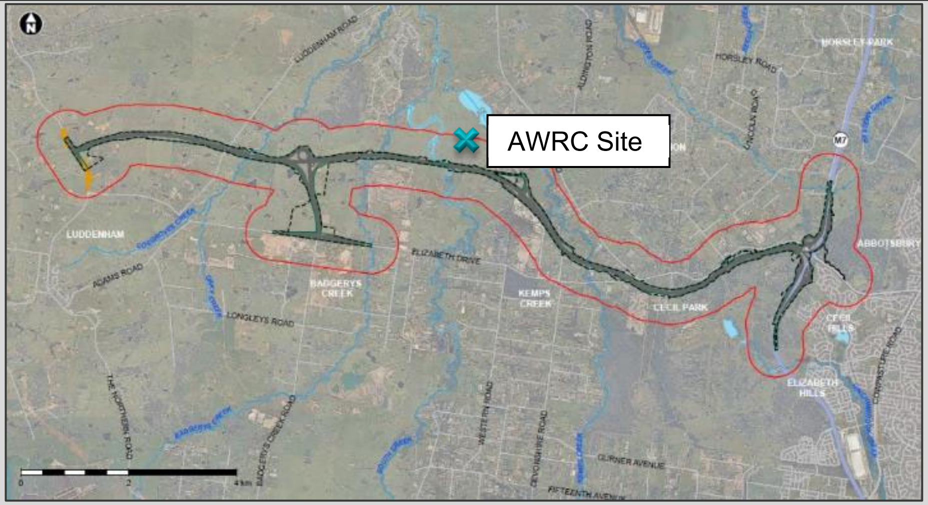
8.2 Cumulative Impacts

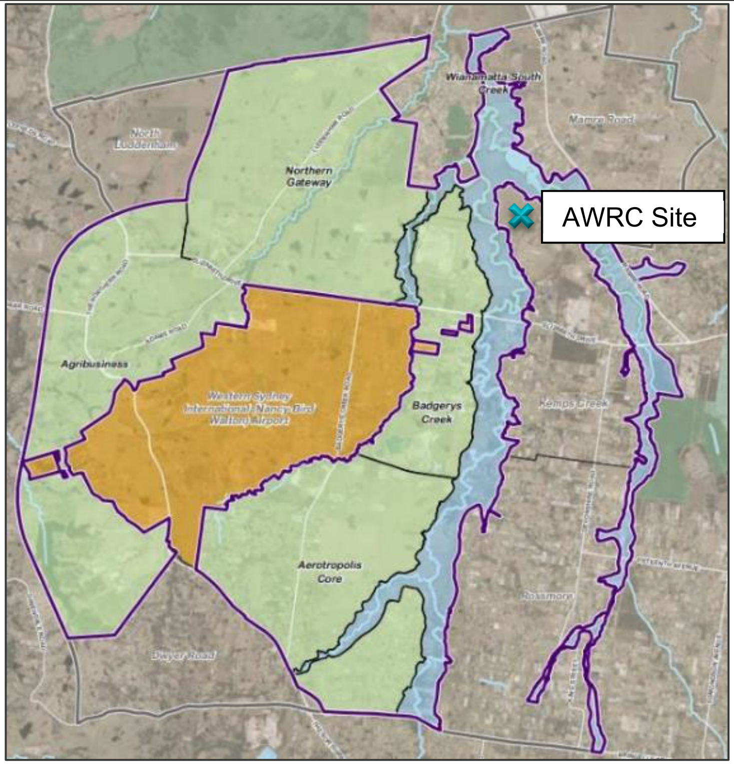
The Western Sydney Aerotropolis has been earmarked for major growth and urbanisation in the near future. This growth is the primary driver for the development of the AWRC project. However, rapid change in topography, surface coverage and general land use will result in major impacts to the natural environment, including groundwater.

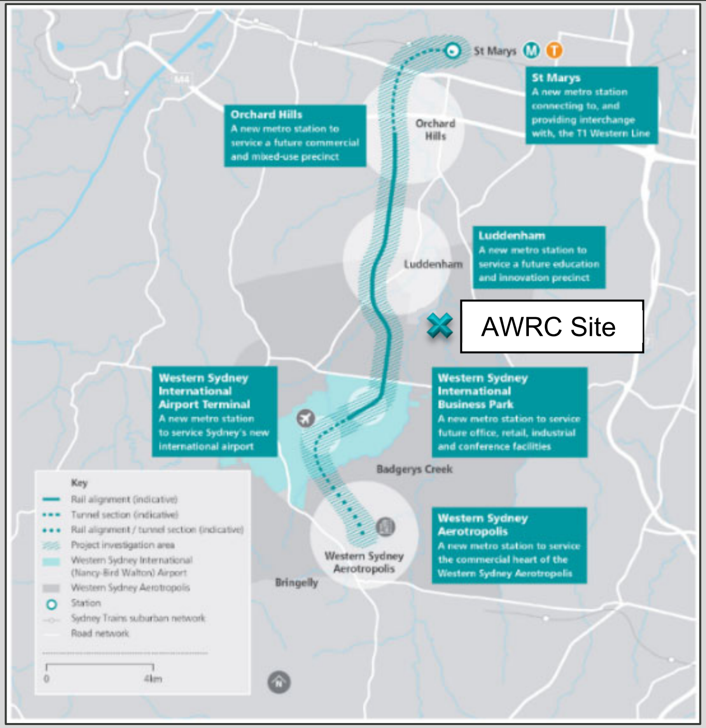
When considered in isolation, any identified project impacts may be considered minor. These minor impacts may, however, be compounded, when the cumulative impacts of multiple projects on the same receivers are considered. As such, the potential groundwater impacts identified and discussed in **Section 8**, need to be considered alongside recently completed, ongoing and proposed projects. The major projects currently being proposed within close proximity to the project are indicated in **Table 8-4**.

Table 8-4 Proposed major projects in close proximity to the project

Project	Project description, relation to current proposed AWRC project and expected residual impacts
Western Sydney Airport	The proposed Western Sydney Airport site will be located approximately 3.2 km south-west of the AWRC site, south of Elizabeth Drive. The site is primarily drained by Badgerys Creek and Cosgroves Creek. Construction at the Western Sydney Airport site has already commenced. The Western Sydney Airport EIS groundwater assessment (GHD, 2016) concluded that: ■ Impacts to registered groundwater bores are expected to be negligible during construction and operation of the airport. ■ Impacts to artificial wetlands within the airport site are expected to be negligible as they are located in low permeability clays with limited groundwater interactions. ■ Sensitive riparian vegetation will be retained along the corridors of Duncans, Oaky and Badgery's Creeks. This vegetation is expected to intersect alluvial deposits which has limited hydraulic connection to the shale aquifers potentially impacted by the airport. ■ There may be enhanced drawdown in localised areas where cuttings or building basements are present. Due to the hydraulic characteristics of the intersected geology, this impact is expected to be very localised. ■ Construction and development of the airport would reduce rainfall recharge and hence reduce groundwater discharge to surrounding creek systems. Historical water quality data and existing hydrogeological conditions that groundwater discharge forms a very low component of creek flow. ■ There is a risk presented by the migration of impact within the saline aquifer beneath shallow sensitive vegetation located along creek riparian areas with discharge to creeks and artificial wetlands in farm dams. The groundwater assessment suggests that the inherent hydrogeological conditions result in low risk of overall adverse groundwater impacts from construction and operation of the airport. There would be minor residual risks present which could be effectively managed using standard onsite procedural controls, engineered solutions and monitoring techniques.
M12 Motorway	The proposed M12 Motorway will run between the M7 Motorway at Cecil Hills and The Northern Road at Luddenham for a distance of about 16 kilometres and would be opened to traffic prior to opening of the Western Sydney Airport. The AWRC site itself is located within the extents of the M12 groundwater study area. The pipelines will follow a similar alignment to the M12 along portions of their routes.

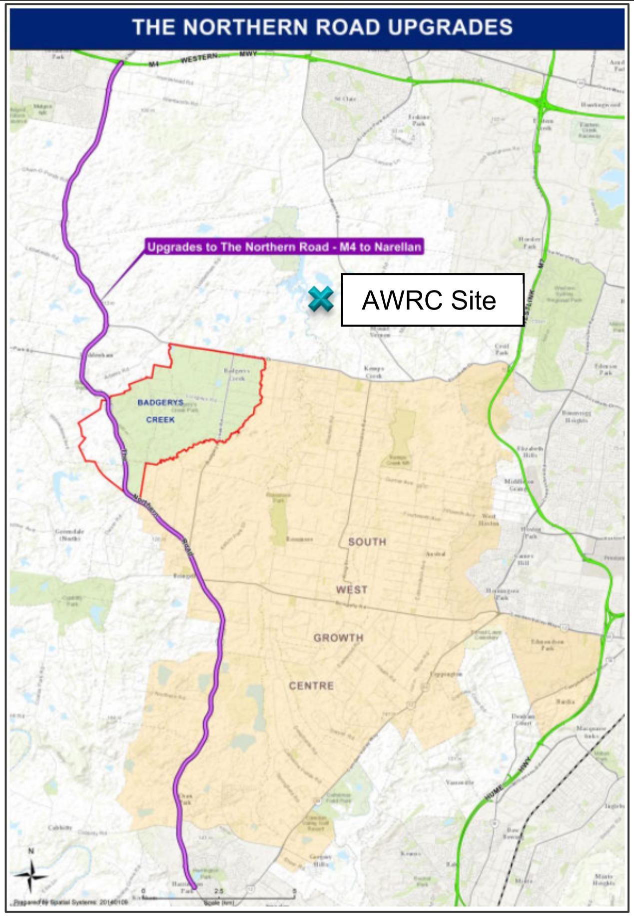
Project	Project description, relation to current proposed AWRC project and expected residual impacts
	 Based on the groundwater assessment and the proposed design, the project is expected to generate negligible impacts on groundwater, with the exception of groundwater cultural values. As such, the project was determined to present a negligible contribution to potential cumulative impacts associated with other major projects in the surrounding area. Direct interaction with groundwater systems is expected to be limited to: ▪ A single cut in the west of the alignment (the “Western Cut”), which may intersect the water table by up to 1.6 metres over a distance of 250 metres. ▪ Bridge footings, where piles are drilled below the water table.
Aerotropolis initial precincts	The Western Sydney Planning Partner (WSPP) has identified several precincts as priority precincts which will targeted for early land release. These precincts all directly border the Western Sydney Airport site, they include: the Aerotropolis Core, Badgerys Creek, Northern Gateway, Agribusiness and adjoining areas of Wianamatta-South Creek as indicated below. These precincts are primarily located within the South Creek catchment as the pipelines will transect several of them.

Project	Project description, relation to current proposed AWRC project and expected residual impacts
	 An integrated water management plan targeting these precincts is currently being developed. The purpose of the plan is to identify measures and control mechanisms to ensure sustainable water management practices are established and consequently mitigate the cumulative hydrological and geomorphological impacts that the rapid urbanization may lead to.
Sydney Metro – Western Sydney Airport	The proposed new railway will link St Marys to the new airport and the Western Sydney Aerotropolis, alignment indicated below (Sydney Metro, 2020).

<table>
<tr><th>Project</th><th>Project description, relation to current proposed AWRC project and expected residual impacts</th></tr>
<tr><td></td><td>


The project footprint is primarily located within the South Creek catchment (or its tributaries). The scoping document reiterates the degraded water quality within the area and references a water management system associated with the Western Sydney International Stage 1 which is expected to effectively mitigate potential flooding and water quality impacts. The EIS is currently being developed and expected impacts identified will need to be considered to determine the potential for compounding of impacts.</td></tr>
<tr><td>The Northern Road Upgrade – Glenmore Road to Bringelly</td><td>The project will upgrade around 35 kilometres of The Northern Road between The Old Northern Road at Narellan and Jamison Road at South Penrith. The project will see The Northern Road upgraded to a minimum four-lane divided road, and up to an eight-lane divided road with dedicated bus lanes.

The treated effluent pipeline will run alongside the Northern Road for a stretch of approximately 1.4 km. Construction works within this area may overlap. Groundwater impacts associated with the road construction are expected to be negligible. Post-construction, the road upgrades will likely result in increased local impervious areas, subsequently leading to decreased groundwater recharge. However, pipeline operational groundwater impacts are expected to be minimal for pipeline operation, therefore cumulative impacts should be negligible.</td></tr>
</table>

Project	Project description, relation to current proposed AWRC project and expected residual impacts
	
Warragamba Dam Raising	Warragamba Dam Raising is a project to provide temporary storage capacity for large inflow events into Lake Burragorang to facilitate downstream flood mitigation and includes infrastructure to enable environmental flows. The EIS for this project is still being developed and thus potential impacts have not been assessed and published as yet. Cumulative impacts are expected to be minimal as the dam is located upstream of the e-flows discharge location, and the raising is aimed at storing major flood events rather than retaining more water on a regular basis.

These proposed major projects along with the general expected future urban development in the area have the potential to alter the groundwater conditions. These alterations could exacerbate any impacts arising from the construction and operation of the AWRC and the pipelines.

Generally major projects are designed and delivered in accordance with current environmental legislation and incorporate sufficient control measures to mitigate associated impacts and primarily targeting a Neutral or Beneficial Effect (NorBE) outcome. Given the widespread expected urbanization of the local environment, which would include numerous small-scale developments as well, the cumulative impacts from these smaller developments could become a more likely source of compounded impacts.

Most groundwater impacts associated with the AWRC project are expected to be minor and short-term (during construction). The AWRC project is not expected to generate significant groundwater impacts during operation. If the proposed mitigation measures are incorporated, the project would have a minor contribution to any foreseen cumulative groundwater impacts from other identified projects in the vicinity.

9 Mitigation Measures

A summary of the identified potential impacts along with their proposed mitigation measures and resultant impact significance are provided for the construction phase activities and are listed in **Table 9-1**. Any additional impacts associated only with the operational phase are indicated with their proposed mitigation measured in **Table 9-2**.

Table 9-1 Potential project specific mitigation measures (Construction phase)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
▪ Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.	**AWRC site:** Excavation, dewatering and installation of underground infrastructures	Where feasible, select trench/shaft support systems like sheet piling that minimise groundwater drawdown, particularly in areas with coarse grained soils with higher hydraulic conductivity and storage properties. Possible construction dewatering techniques are: ▪ **Open pumping techniques** (e.g. sumps and drains). A suitable and cost-effective approach in stable ground conditions (i.e. low permeability soils, small required drawdowns and no immediately adjacent source of recharge) after excavation. ▪ **Pre-drainage/eductor techniques** (e.g. installation of dewatering well point(s)). Lowering of the water table prior to excavation may be required in more unstable ground conditions (i.e. high permeability soils and large required drawdowns). Develop a risk-based approach to assess drawdowns and impacts to South Creek during construction at the AWRC. This approach should include: ▪ Monitoring the difference in elevation between South Creek and groundwater levels to verify the predicted drawdowns and assess the magnitude of impacts to South Creek ▪ Identify trigger values to assess if groundwater elevations between the bioreactor and South Creek drop below the water elevation in South Creek for a sustained period. For example, if a drawdown greater than 1.5 m is observed in MW04, this would indicate a flow reversal at the riverbed is occurring (based on surveyed elevation of water levels in South Creek and the simulated pre-development groundwater levels indicated in **Figure 7-2)**. The 1.5 m drawdown trigger at MW04 is based on the surveyed water level of 34 mAHD (observed on 7th July 2020) and the modelled groundwater level of 35.4 mAHD midway between the eastern bioreactor and South Creek.	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
		However, since the predicted reduction in baseflow is assessed as having low impact significance, no mitigation measures (e.g. reinjection of abstracted groundwater or cessation of dewatering) are expected to be required. The potential impacts to GDEs within South Creek are described in more detail in the *Aquatic and Riparian Ecosystem Impact Assessment* report.	
	Pipelines: Excavation, dewatering and installation of underground infrastructures HDD and micro tunnelling	Where feasible, select trench/shaft support systems like sheet piling that minimise groundwater drawdown, particularly in areas with coarse grained soils with higher hydraulic conductivity and storage properties. Possible construction dewatering techniques are: ▪ **Open pumping techniques** (e.g. sumps and drains). A suitable and cost-effective approach in stable ground conditions (i.e. low permeability soils, small required drawdowns and no immediately adjacent source of recharge) after excavation. ▪ **Pre-drainage/eductor techniques** (e.g. installation of dewatering well point(s)). Lowering of the water table prior to excavation may be required in more unstable ground conditions (i.e. high permeability soils and large required drawdowns). Where feasible, select trenchless construction techniques (like the use of a headwall and seal assembly in each shaft) that minimise groundwater drawdown. Where feasible, ‘key’ the launch and reception shafts into underlying material with relatively low permeability (e.g. competent bedrock) to reduce the amount of groundwater entering through the floor.	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)
▪ Groundwater seepage and/or unintentional return of drilling fluid to the surface via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs).	**Pipelines:** HDD and micro tunnelling	Develop a process for assessing and mitigating the risk of ‘frac-outs’, including: ▪ risk assessment by experienced personnel to determine the likelihood of “frac-outs” and if design changes or additional management actions are required ▪ assess geotechnical conditions at each underbore / HDD site to determine the maximum allowable drilling fluid pressures. ▪ based on the outcomes of the risk assessment, develop mitigation measures to reduce the risk of frac-outs and subsequent environmental impacts. These should include consideration of: – design to intersect more competent rock and avoid any preferential pathways such as fault lines, fractures, unconsolidated material etc).	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and local)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
		– casing at the entry / exit points where there are unconsolidated materials, reduced ground cover and reduced bearing pressure. – Drill pressure relief wells to provide a pathway for controlled release of drilling fluid pressures. – Continuous monitoring of drilling fluid properties during construction with alarms to alert the operator if nearing maximum allowable drilling fluid pressures. – Ceasing drilling if any unexpected variations in drilling fluid properties occur and investigating the cause. Develop an incident response plan in the event of a frac-out occurring.	
■ Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts	**AWRC site and pipelines:** Excavation, dewatering and installation of underground infrastructures	Mitigation measures to reduce the amount of dewatering and minimise groundwater drawdowns will also be effective in mitigating the mobilisation and migration of contaminated groundwater and acid sulfate soils. These include: ■ Where feasible, select trench/shaft support systems like sheet piling that minimise groundwater drawdown, particularly in areas with coarse grained soils with higher hydraulic conductivity and storage properties. ■ Where feasible, select trenchless construction techniques (like the use of a headwall and seal assembly in each shaft) that minimise groundwater drawdown. Where feasible, 'key' the launch and reception shafts into underlying material with relatively low permeability (e.g. competent bedrock) to reduce the amount of groundwater entering through the floor. ■ Adopt a staged approach to dewatering by dewatering in discrete, smaller areas that align more closely to the construction schedule. In addition to the above, the following mitigation measure can be implemented to control the migration of contaminants in groundwater: ■ Construct adjacent recharge trenches to maintain saturation in high risk areas. If the extent of the drawdown is likely to include an area with existing contamination, consider constructing recharge trenches to limit the cone of depression and create a hydraulic barrier that could prevent the migration of contaminants. If acid sulfate soils are encountered and disturbed during excavation, the soil should be treated with an alkaline material (e.g. agricultural lime) to neutralise the material prior to reinstatement. Alternatively, the material should be disposed of in accordance with the NSW Waste Classification Guidelines.	**Low** Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
		It is recommended that the implementation of these mitigation measures be considered alongside the areas of environmental concern outlined in the Soils and Contamination Impact Assessment Report.	
■ Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increase the turbidity of the receiving waters ■ Discharge of contaminated hydrostatic test water	**AWRC site and pipelines:** Discharges from dewatering activities	Develop and implement an approach to manage extracted groundwater and/or wastewater via one or a combination of these methods: ■ **Discharge to a receiving surface water body** such as creek, river, stream etc. An Environment Protection Licence (EPL) would be required under the Protection of the Environment Operations Act (1997). Water quality monitoring prior to discharge would be required to ensure WQO's are not exceeded and to demonstrate the discharge will not have significant deleterious impacts to the receiving water body. The EPL would stipulate the volume of water that could be discharged and the water quality discharge criteria (outlined in **Section 2.2**). Depending on extracted groundwater quality, temporary storage and treatment may be required to meet the applicable water quality criteria, prior to discharge. An overview of the varying groundwater quality reported in each Hydrogeological Landscape across the desktop assessment area can be found in **Section 4.5.6** ■ **Discharge to stormwater collection system.** This would require a similar level of assessment to discharging to receiving surface water body as described above. ■ **Discharge to sewer via a Trade Waste Agreement (TWA)** with the wastewater system operator. Discharge to sewer is to be conducted in accordance with the TWA, which may require temporary storage and treatment of the water prior to discharge. ■ **Land based application or reinjection / irrigation.** Feasibility of this option is dependent upon soil properties (infiltration rates, salinity etc.) at the reinjection / irrigation area. Generally precluded as a discharge option in areas with low permeability soils and salinity issues. However, for incidental or small volumes of extracted groundwater, this option could be considered provided the groundwater quality is suitable and other approval mechanisms are in place. Stability of nearby trenches / excavations and surrounding underground structures must be considered. ■ **Offsite disposal**. Extracted groundwater will be trucked offsite and treated and/or disposed of at a licensed wastewater treatment plant.	**Low** Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and local) If the identified mitigation measures are implemented, groundwater quality impacts are not expected to exceed the criteria outlined in **Section 2.2**.
■ Release of alkaline concrete wash water, which may cause	**AWRC site, pipelines and access roads:**	Capture all polluted runoff and dispose of appropriately via one or a combination of these methods: ■ **Discharge to a receiving surface water body** such as creek, river, stream etc. An Environment Protection Licence (EPL) would be required under the Protection of the	**Low** Sensitivity of environmental values:

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
localised soil, surface water or groundwater contamination and possible downstream ecological impacts	Compaction and concreting	Environment Operations Act (1997). Water quality monitoring prior to discharge would be required to ensure WQO's are not exceeded and to demonstrate the discharge will not have significant deleterious impacts to the receiving water body. The EPL would stipulate the volume of water that could be discharged and the water quality discharge criteria (outlined in **Section 2.2**). Depending on extracted groundwater quality, temporary storage and treatment may be required to meet the applicable water quality criteria, prior to discharge. An overview of the varying groundwater quality reported in each Hydrogeological Landscape across the desktop assessment area can be found in **Section 4.5.6** ▪ **Discharge to stormwater collection system.** This would require a similar level of assessment to discharging to receiving surface water body as described above. ▪ **Discharge to sewer via a Trade Waste Agreement (TWA)** with the wastewater system operator. Discharge to sewer is to be conducted in accordance with the TWA, which may require temporary storage and treatment of the water prior to discharge. ▪ **Land based application or reinjection / irrigation.** Feasibility of this option is dependent upon soil properties (infiltration rates, salinity etc.) at the reinjection / irrigation area. Generally precluded as a discharge option in areas with low permeability soils and salinity issues. However, for incidental or small volumes of extracted groundwater, this option could be considered provided the groundwater quality is suitable and other approval mechanisms are in place. Stability of nearby trenches / excavations and surrounding underground structures must be considered. ▪ **Offsite disposal**. Wastewater will be trucked offsite and treated and/or disposed of at a licensed wastewater treatment plant.	Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area). Magnitude of impact: Low (unlikely to occur) If the identified mitigation measures are implemented, groundwater quality impacts are not expected to exceed the criteria outlined in **Section 2.2**.
▪ Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities,	**Pipelines** Excavation, dewatering and installation of underground infrastructures	▪ Install permanent vertical cut-offs within the trench to prevent the lateral migration of groundwater along the alignment of the pipelines. In the residual / regolith soils associated with weathered Bringelly Shale which is expected to have relatively low permeability, these trench cut-offs may be located at spacings of several hundred metres. In alluvial soils, or at river crossings, trench cut-off spacing should be significantly smaller e.g. every ten metres. ▪ Horizontal trench cut-offs should also be considered where the perched aquifers are encountered, to prevent lateral migration and dewatering of the system. Maintenance of the perched layers may also be achieved through backfilling to prevent vertical migration.	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
hydraulic gradients, and flow regimes in the groundwater systems.			
■ Disruption of surface water and groundwater connectivity	**Pipelines:** Horizonal directional drilling under a watercourse	■ Identify potential surface water - groundwater linkages around watercourses to be crossed by trenchless construction methods prior to drilling and subsequent avoidance of disrupting the connectivity as far as reasonable (e.g. where feasible, installing permanent vertical cut-offs between the shafts and the surface water bodies to prevent the lateral migration of groundwater into surface water bodies, and vice-versa).	**Low** Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)

Table 9-2 Potential project specific mitigation measures (Operational phase)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
■ Induced drawdowns from any underdrainage systems employed for underground structure floatation management, reducing the availability of groundwater for GDEs and surrounding groundwater users.	**AWRC site and pipelines:** Excavation, dewatering and installation of underground infrastructures	■ Adopt a staged approach to dewatering by dewatering in discrete, smaller areas that align more closely to the maintenance schedule. ■ Consider the inclusion of vertical and horizontal drainage layers and "chimneys" with coarse filter material in order to achieve desired drawdowns against the underground structures more quickly and reduce the amount of dewatering required.	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (localised).
■ Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery, chemical spills and	**AWRC site:** Operation of vehicles and machinery. Moving and storing chemical and untreated or partially treated	■ Adopt controls for storage and handling of chemicals, as outlined in the relevant Material Safety Data Sheets for each chemical. ■ Implement a spill response plan and incident response procedure. ■ All chemical storage and delivery areas to be designed to have sufficient storage volumes to contain a worst-case spill, including the full volume being delivered and the full volume stored simultaneously	**Low** Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
overflow/leakages of untreated or partially treated wastewater to the groundwater systems.	wastewater throughout the plant	■ Any spills that occur outside the containment area shall be contained within a first flush structure across roads and hardstand. Once full, flow bypass to surrounding waterways via the stormwater management system.	Magnitude of impact: Low (unlikely to occur)
■ Groundwater seepage and/or unintentional return of drilling fluid to the surface via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.	**Pipelines:** HDD and micro tunnelling	■ Confined aquifers under significant pressure are not expected to be encountered by the project, therefore the likelihood of this occurring is considered low and decreases as drilling fluids solidify. However, drilling fluid properties should be selected by experienced HDD construction personnel to account for drying times and reduce the risk of upward seepage of groundwater through the borehole annulus. ■ Allow adequate time for annulus grout to solidify before beginning pipeline operation, in accordance with the grout manufacturers specifications and recommendations.	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (unlikely to occur)
■ Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.	**Pipelines**	■ Adhere to existing Sydney Water operational management systems. ■ Implement maintenance plans as well as routine inspections to ascertain the condition of the pipes and auxiliary infrastructure ■ Actively observe pipe pressures to enable immediate identification of an incident ■ Implement an incident response plan which will include procedures directed at containing discharges and subsequent clean up requirements. ■ Implement automatic pressure releases in case of damage to the pipeline to minimise the risk of groundwater seepage and restrict impacts to a small area and time interval.	**Low** Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (unlikely to occur)
■ Increased groundwater recharge from stormwater harvesting and irrigation at the AWRC site, leading to increased water levels of saline aquifer.	**AWRC site:** Harvesting of stormwater and irrigation application of adjacent regional park	■ The stormwater management strategy for AWRC (detailed in the *Surface Water Impact Assessment Report*) is intended to re-create pre-development environmental water balance by offsetting the lost recharge due to AWRC impermeable surfaces through increasing post-construction recharge through leaky wetlands and detention basins, as well as local irrigation.	**Low** Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur) If this these mitigation measures are achieved, it predicted that the effects of

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
			the proposed stormwater management would maintain pre-development water balance, with localised and low impacts at the AWRC.

9.1 Management of Change / Unexpected Conditions

This impact assessment is based on the project's reference design. As the project progresses, changes to the design may be necessary which could change the magnitude of the identified groundwater impacts. The impact assessment has been carried out to provide some flexibility for these changes, for example a wider impact assessment area has been included so lateral alignment changes within this area have been accounted for. Where possible, a conservative approach has been adopted to assess 'worst-case' scenarios.

Design changes with the most potential to affect the magnitude of identified groundwater impacts would include:

- Excavation depths and extents (e.g. increasing the depth of the bioreactors).
- Pipeline construction methodology (e.g. trenchless vs trenched).
- Construction scheduling and pipeline lay rate.

Such changes to the design and construction should be assessed as part of tender evaluations to determine the change in magnitude of the potential groundwater impacts.

In addition, it is possible that unexpected hydrogeological conditions may be encountered due to previously unknown heterogeneities in the subsurface. For example, it is possible that during the implementation of a dewatering management strategy, that greater than anticipated groundwater volumes will require management due to an intercepted lens of very high permeability soils. To account for this possibility, uncertainty and sensitivity analyses have been included in this impact assessment (outlined in **Section 7**) which addressed a reasonable range of hydrogeological conditions that may be encountered.

Therefore, the impact assessment outlined in this report is considered sufficient to inform the project's Environmental Impact Assessment. It is recommended that the feasibility of the proposed mitigation measures be assessed in response to any additional information on groundwater conditions that is collected during detailed design or pre-construction monitoring (outlined in **Section 10**). During construction and operation, it is recommended that the mitigation measures be implemented through adaptive management strategies to mitigation groundwater impacts in response to the specific methodologies, schedules and potential unexpected conditions.

10 Monitoring Requirements

The findings of this EIS are based on the information available at the time of publication. The information has been considered sufficient to inform the level of detail required for this groundwater impact assessment. However, it is recommended that further works are conducted to collect additional information on groundwater conditions to inform detailed design and construction activities, which should be incorporated into the evolving Hydrogeological Conceptual Model.

The application of a groundwater monitoring program is important in ensuring construction and operational phase mitigation measures are effective, and groundwater impacts across the project do not exceed acceptable limits.

A groundwater quantity (i.e. levels and dewatering volumes) and quality monitoring program is recommended. Monitoring should incorporate pre-construction monitoring of groundwater conditions to form a baseline dataset to which the construction and operational monitoring data could be compared against. The baseline dataset would assist in developing site-specific action levels and responding to any identified impacts during construction and operation.

The groundwater monitoring program will include monitoring of groundwater levels (e.g. installation of pressure transducers / data loggers and manual water level dipping) and water quality sampling for the following general water quality indicators:

- Field measured physiochemical parameters (electrical conductivity, pH, turbidity, temperature, dissolved oxygen and redox potential).
- Total dissolved solids (TDS).
- Total suspended solids (TSS).
- Nutrients (including ammonia, nitrate, nitrite, total nitrogen and total phosphorous).
- Major ions (chloride, sulfate, sodium, potassium, magnesium, calcium, carbonate and bicarbonate).
- Other contaminants/toxicants of concern where applicable (e.g. heavy metals, hydrocarbons, biological constituents etc. See soils and contamination specialist report for further details).

The frequency, locations and water quality indicators for groundwater monitoring would be confirmed during detailed design.

Reporting of groundwater level and quality monitoring against site-specific guideline values should be conducted after each monitoring event throughout the establishment of the baseline dataset, during construction and during operation.

11 Key Findings & Conclusions

Construction of the proposed AWRC and pipelines has the potential to impact the groundwater systems in a number of ways, including:

- Induced drawdown of groundwater from required construction dewatering activities, reducing the availability of groundwater for Groundwater Dependent Ecosystems and surrounding groundwater users.
- Seepage and/or unintentional return of drilling fluid via groundwater to the surface via preferential pathways (e.g. fault lines, fractures or loose materials) during Horizontal Directional Drilling construction (frac-outs).
- Mobilisation and migration of contaminated groundwater or acid sulfate soil leachate (resulting from drawdown), altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts.
- Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increasing the turbidity and reducing the water quality in receiving waters.
- Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts.
- Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.
- Disruption of surface water and groundwater connectivity.

Operation of the proposed AWRC and pipelines has the potential to impact the groundwater systems in several ways:

- Induced drawdowns from any underdrainage systems employed for underground structure floatation management, reducing the availability of groundwater for GDEs and surrounding groundwater users.
- Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery at the AWRC, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.
- Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.
- Leakage of water from pipelines during operation resulting in localised increases to groundwater levels and degradation in groundwater quality. Water transmitted through the treated water and environmental flows pipelines will be predominately fresh and unlikely to cause direct significant impacts to groundwater quality. Water transmitted through the brine pipeline will have much higher total dissolved solids and any leaks/bursts occurring across this pipeline has the potential to cause direct localised degradation of groundwater quality and/or groundwater dependent ecosystems.
- Increased groundwater recharge from stormwater irrigation at the AWRC site, leading to increased water levels of saline aquifer.

To minimise impacts to groundwater systems, a range of mitigation measures would be implemented during the detailed design, construction and operational phases of the project. These include:

- Design and construction of trench/shaft support systems that minimise groundwater drawdowns (e.g. sheet piling), particularly in areas with coarse-grained soils with higher hydraulic conductivity and storage properties.
- Where feasible, “key” the trenchless launch and reception shafts into underlying material with relatively low permeability (e.g. competent bedrock) to reduce the amount of groundwater that may enter through the floor.
- Adopting a staged approach to dewatering through dewatering in discrete, areas aligned closely with the construction schedule.

- Developing and implementing an approach to manage extracted groundwater. Depending on extracted groundwater quality, treatment may be required to meet the applicable water quality criteria, prior to discharge (e.g. to a receiving surface water body).
- Install permanent vertical cut-offs within the trench to prevent the lateral migration of groundwater along the alignment of the pipelines. In the residual / regolith soils associated with weathered Bringelly Shale which is expected to have relatively low permeability, these trench cut-offs may be located at spacings of several hundred metres. In alluvial soils, or at river crossings, trench cut-off spacing should be significantly smaller e.g. every ten metres. Horizontal trench cut-offs should also be considered where the perched aquifers are encountered, to prevent lateral migration and dewatering of the system. Maintenance of the perched layers may also be achieved through backfilling to prevent vertical migration.

The majority of these groundwater impacts will be constrained to a short period of time during construction and are not expected to impact the long-term viability of the affected ecosystems or groundwater resources.

Dewatering estimates indicate that approximately 64 ML of groundwater will be extracted from the "Sydney Basin Central" groundwater source and 1.89 ML of groundwater will be extracted from the "Sydney Basin Nepean" groundwater source (Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011) during construction of the project.

The degree or severity of any impact during construction is largely based on the duration of dewatering and disruption of groundwater connection to any potential GDEs in the vicinity where a disruption occurs. Other factors include the depth to the groundwater table which influences the extent of dewatering required and the hydraulic characteristics of the intersected ground material.

A groundwater quantity (i.e. levels and dewatering volumes) and quality monitoring program is recommended. Monitoring should incorporate pre-construction monitoring of groundwater conditions to form a baseline dataset to which the construction and operational monitoring data could be compared against. The baseline dataset would assist in developing site-specific action levels and responding to any identified impacts during construction and operation.

Based on the available information and the analyses conducted in this impact assessment, with the successful implementation of the proposed mitigation measures the impacts to groundwater systems across the project are expected to be of low significance overall, with a minor contribution to any foreseen cumulative groundwater impacts from other identified projects in the vicinity.

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Appendix A – AWRC Numerical Modelling Report

March 2021

Upper South Creek Advanced Water Recycling Centre

AWRC Numerical Modelling Report

FINAL REV 2

aurecon ARUP

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Appendices

Cover photo: Image of borehole drill site located on the proposed AWRC site

1 Introduction

This report is provided as technical appendix for the Upper South Creek Advanced Water Recycling Centre (AWRC) Environmental Impact Statement (EIS) Groundwater Specialist Study Report. It provides the technical details of the process followed to develop the numerical model for the AWRC. Details of the conceptual hydrogeological model (CHM) including hydrostratigraphy and hydrogeological properties of the study area groundwater system are provided in the main text of the AWRC EIS Groundwater Specialist Study Report.

Maps showing locations of various infrastructure and general site layout arrangement of the AWRC are provided in the main text of the AWRC EIS Groundwater Specialist Study Report.

2 AWRC Site Groundwater Modelling Overview

2.1 Modelling objectives

The objective of the groundwater flow modelling has been to support evaluation of the risk posed on groundwater levels and quantities by the construction and operation of the AWRC. The purpose of this report is to document the process followed to model / simulate potential historical and future groundwater flow systems. An assessment of the resulting impacts informed from this modelling is provided in the main Groundwater Impact Assessment Report.

2.2 Scope of modelling

To fulfil the objectives the following tasks were completed:

- Description of the receiving hydrological and hydrogeological environment (including surface flow regimes and hydrogeological conceptual model)
- Reviewed publicly available documents, such as nearby hydrogeological studies for the Western Sydney Airport and M12 Motorway Environment Impact Statement documents with regards to evaluating groundwater conditions, including previous flow modelling
- Reviewed the Aurecon geotechnical reports including the ground model with regards to the vertical extent of geological units and potential water flow characteristics with the rocks based on interpretations of geotechnical investigations results of direct relevance to hydrogeology such as bore logs, rock recovery and rock quality designation (RQD), joint spacing and width and descriptions of any joint infilling, etc
- Short-term aquifer tests within shallow alluvial soils and deep fractured claystone
- Development of hydrogeological conceptual site model (CSM) in light of the field investigations carried for the AWRC and nearby projects (i.e. Western Sydney Airport and M12 Motorway)
- Constructed a groundwater numerical flow model for the AWRC
- Undertook calibration of the flow model
- Undertook sensitivity analysis of key input parameters to explore groundwater model response to these changes
- Using the adopted calibrated model of initial flow conditions, undertook predictive flow simulations that shows the extent of drawdown due to construction dewatering of AWRC
  - Predictive flow modelling results were used to evaluate potential conditions that could adversely impact on groundwater levels and / or water quality occur (including mobilisation of pre-existing contaminant plumes, such as associated with landfills near the AWRC)
  - Evaluation of the potential for adverse impacts to groundwater levels or water quality:
    - GDEs near the AWRC
    - Nearby groundwater users
  - Determination of volume of water expected to be generated during construction dewatering
- Prepared this report to document the modelling process, which was undertaken in general accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012)

2.3 Model exclusions, assumptions and limitations

The accuracy of the groundwater model presented in this report is limited to the accuracy and the distribution of the data used to represent hydrological properties of the groundwater flow system. The following exclusions, assumptions and limitations are associated with the groundwater modelling completed for this investigation:

- Simplifications to the geological structure have been made to translate a complex physical environment into a workable numerical framework represented by the HCM described in **Section 6** of the main AWRC Groundwater Technical Report developed based on available geological and hydrogeological data. The numerical model has therefore been developed as a conservative impact assessment tool.
- The fractured bedrock groundwater flow system has been represented by an Equivalent Porous Medium (EPM) method. One of the inadequacies of an EPM method is that although it replicates the behaviour of a regional flow system well, it is less suitable to reproduce small scale variations in conditions.
- The aquifer hydraulic parameters were based on tests at the AWRC site and some outside of the project site. The geologic conditions and hence the aquifer hydraulic parameters may vary from place to place and the adopted parameters may not be representative of the conditions further away from test locations. It should be noted that the available field test data such the hydraulic conductivities display a very wide range of possible applicable values. This wide range represent high uncertainty associated with the parameters.
- The groundwater flow model assumes that the hydraulic properties are uniform for each hydrostratigraphic layer or zone. In the field, the hydraulic properties will vary significantly across a given hydrogeological unit. As a result, the simplified model will predict a more uniform zones of groundwater drawdown.
- The model was developed with the express intent of providing sufficient information for purposes of this project. In developing the model, we have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request or enquiry were complete, accurate and up to date. Where publicly available data has been used, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware of any reason why any of the assumptions are incorrect.

2.4 Model Classification

The model was developed in accordance with the guiding principles in the National Water Commission (NWC) modelling guidelines (2012). Under NWC modelling guidelines (2012), groundwater models can be classified as either Class 1, Class 2 or Class 3 in order of increasing confidence based on the following factors:

- Available data
- Calibration procedures
- Consistency between calibration and predictive analysis
- Level of stress simulated in the model

The category of the groundwater numerical model for AWRC documented in this report generally adheres to conditions that would define it as a Class 1 model with numerous attributes for Class 2 models. Aurecon considers that there is sufficient groundwater data near the AWRC site and the model can be used to provide reasonably reliable predictions of the likely conditions associated with the construction long-term post-construction phases. Full attributes of model classifications are provided in the National Water Commission (NWC) modelling guidelines (2012). Key attributes are summarised below to provide context for Aurecon's assessment of the AWRC model class.

Class 1 models typically have inadequate calibration data and little or no field-based data for characterising aquifer parameters. Such models are used to provide high levels understanding of the likely conditions of the system. With Class 2 models, there is calibration data to provide reasonable calibration statistics although this may suggest significant errors in parts of the model domain. These would have some long-term data for transient calibration, although this may not extend to present day. Aquifer characteristics for Class 2 models are field tested. Class 3 comprises detailed data for calibration and aquifer parameters which are based on field tests.

3 Model Build

3.1 Modelling Strategy

The application of a computer based numerical model provides a powerful tool for the prediction of flow in a complex spatially and temporally varying environment. This approach applies a system of mathematical equations based on Darcy's Law for flow of water through porous media to simulate flow in the aquifer.

Groundwater numerical modelling can overcome the difficulties inherent in the assessment of hydrogeological systems using classical analytical methods, which assume aquifer homogeneity and more applicable to the interpretation of localised aquifer response. With a computer numerical model, it is possible to simulate complex conditions by introducing variations in aquifer transmissivity or hydraulic loads. This is accomplished by discretising the modelled area into a number of blocks each representing a volume of aquifer with constant hydraulic parameters. The accuracy of model predictions depends on the knowledge of all parameters having an impact on the groundwater regime, both in the area of interest as well as in more distant areas.

The development of a model also facilitates sensitivity analysis which provide a means of understanding the dominant parameters and mechanisms operating within a hydrogeological system.

Groundwater modelling for the AWRC was undertaken using MODFLOW-USG, with the aid of Groundwater Vistas pre- and post-processing environment. MODFLOW-USG is a relatively new version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the United States Geological Survey (USGS). 'USG' is an acronym for Un-Structured Grid, which relates to a variety of flexible unstructured model meshes, including those based on cell shapes such as prismatic triangles, rectangles, hexagons / voronoi, and other cell shapes supported by MODFLOW-USG (Panday et al., 2013). The use of flexible meshes available in MODFLOW-USG offers the following advantages compared to structured rectangular finite-difference grids available in standard MODFLOW:

- Flexible mesh they allow finer grid resolution to be focused solely in areas of a model that require it as opposed to refinement over the entire grid in standard MODFLOW, reducing the cell count significantly and improving model runtimes in the process.
- Spatial areas not required in the model may be omitted rather than deactivating cells or retaining "dummy" layers (e.g. for layer pinch-outs).
- Flexible meshes allow cell boundaries to follow important geographical or geological features, such as watercourses or outcrop traces, more accurately modelling the physical system.

Voronoi mesh type was used to represent model grid for the AWRC groundwater model in Groundwater Vistas. Spatial input data for both software was generated using ESRI Geographical Information Systems (GIS) software ArcGIS Spatial Analyst and 3D Analyst tools in conjunction with Microsoft Excel tools. Both manual approach and the parameter estimation program PEST (Doherty, 2014) were employed to adjust model parameters until the fit between model outputs and field observations was optimised in the weighted least square sense.

Table 3-1 provides a summary of the design software and versions used for the development of the AWRC groundwater model.

Table 3-1: AWRC Groundwater Model Design Software

Project feature	Description	Application
ArcGIS Spatial Analyst and 3D-Analyst in conjunction with Microsoft excel	v10.7	Development, analysis and computation of AlgoMesh and Groundwater Vistas spatial data, including representation of tunnel geometric data and construction schedules
AlgoMesh	v1.2.0.37827	Generation of MODFLOW-USG Voronoi mesh
MODFLOW	MODFLOW-USG Transport (formerly called beta)	Groundwater flow simulation
Groundwater Vistas	v7.24 (build 260), premium version	MODFLOW graphic user interface
PEST	v15.0	Model parameter estimation
Mod-PATH3DU	v2.0	Contaminant transport modelling, assessment of the capture zone for ARWC during construction

3.2 Model Domain and Mesh Design

Figure 3-1 shows the adopted model domain for the AWRC groundwater model domain covering an area of 52.6 km^2. The edge of the domain was selected to be remote to the anticipated hydraulic effects of the AWRC structures and to cover part of the AWRC pipelines crossing major tributaries, as well as incorporating nearby groundwater monitoring wells for M12 Motorway project and Western Sydney Airport project to use for model calibration.

AlgoMesh was used to discretise the horizontal extent of the model domain into Voronoi-based mesh elements required as input for MODFLOW-USG (refer **Figure 3-1**). Various mesh cell sizes were applied with small cell sizes along watercourses and AWRC site while allowing larger cells in areas further away from features of interest resulting in a total of 51,067 elements in each layer. Mesh cell resolution was assigned as follows:

- Maximum mesh cell resolution along watercourses and in alluvium areas – ±20 m
- Maximum grid cell resolution across AWRC site – ± 8 m

Definition of mesh cell resolution for linear features was incorporated in GIS polylines by setting the spacing of polyline vertices at the desired resolution that represents the width of the feature, for example the width river channel.

3.3 Model Layering

Vertically, the model domain was discretised into ten (5) layers with all the covering the full model extent. In areas where a particular hydrogeological unit pinches out (for example, due to erosion), the layer thickness was significantly reduced to 0.5 m, with same hydraulic properties as the layer below. This approach was applied to ensure that each layer represents a discrete hydrogeological unit provided in **Table 6-2** in the main text of the AWRC Groundwater Technical Report.

The following were considered for model layering:

- Accurate representation of key aquifer units
- Accurate representation of steep vertical gradients in the vicinity of AWRC bioreactors to simulate effects of construction dewatering

- Accurate representation of the construction details (screen depths) of the monitoring bores to allow more reasonable comparison of simulation results to observed values at corresponding depths during calibration.

The vertical boundaries between different geologies across the study area were developed based the lithology data provided on the bore logs developed by Aurecon geotechnical Team, in conjunction with the aquifer testing results in **Appendix A**. The AWRC bore logs are provided in **Appendix B**.

Figure 3-2 shows the proportions of the various soil/ground groups encountered in the boreholes at the proposed AWRC site, grouped into sands (SW, SP, and SC), gravels (GW, GP, and GC), silts & clays (ML, CL, CI, CL-CI, CI-CH, and CH), and rock (core loss zone, sandstone, interbedded mudstone and sandstone, laminate, and claystone).

The zone above 8 m to 10 m depth range is comprised of mostly a complex mixture of silts & clays with a small proportion of sands and gravel. This mixture of sediments constitutes more than 65% of the soil/ground encountered. At 8 m to 10 m depth range and below the quantity of the sediments reduces significantly with various rocks starting to dominate. Based on this information, the key units were identified; the alluvium (i.e. mixture of silts & clays, sands and gravel sediments) and fractured claystone overlying low permeability Bringelly Shale. A uniform thickness of 8 m relative to the ground surface was assumed for alluvium. The thickness for fractured claystone underlying the alluvial soil was assumed at 3 m. These thicknesses were applied throughout the model domain in the regions covered by the alluvium surface geology polygon (**Figure 3-1**).

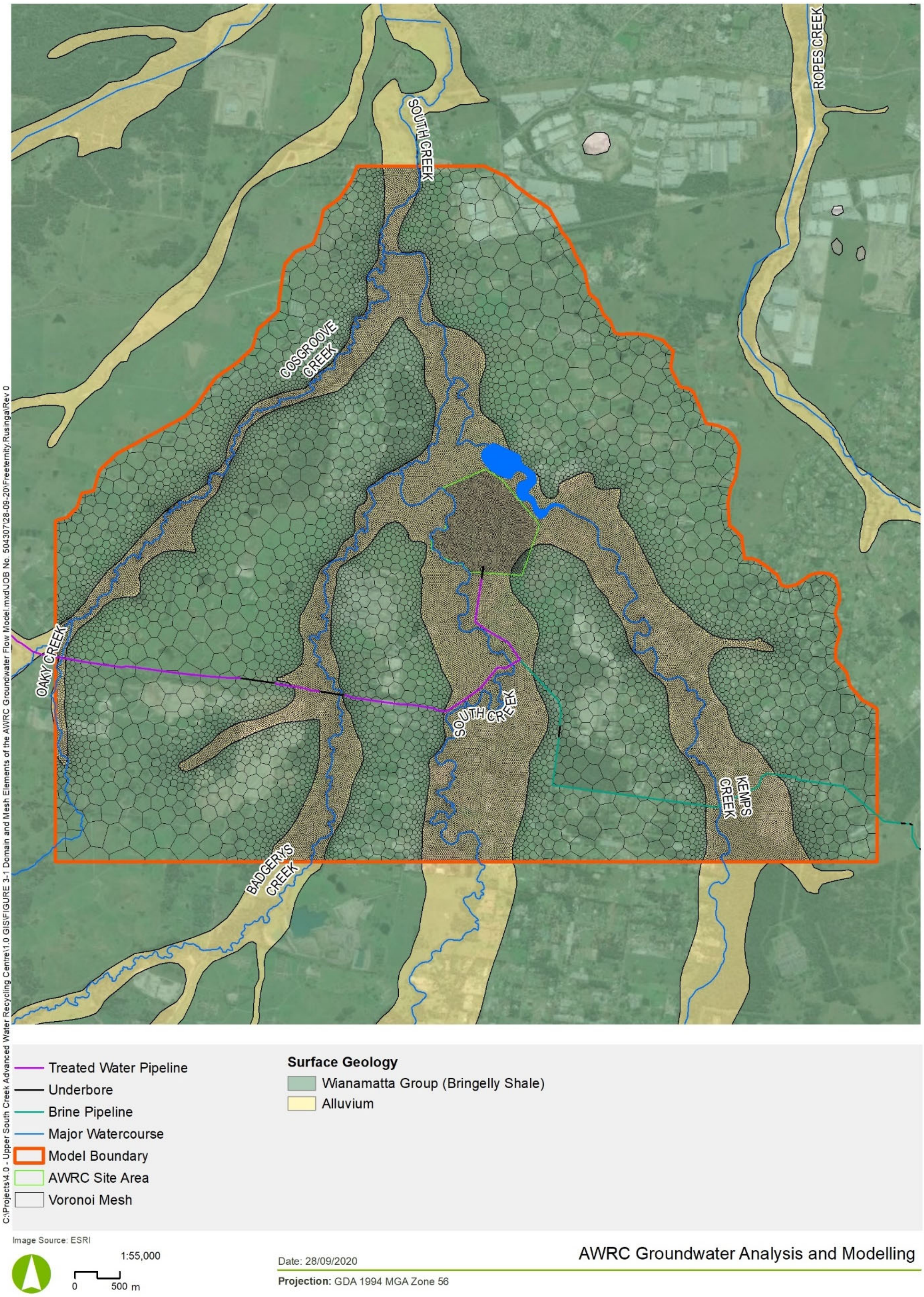

Figure 3-1: Domain and Mesh Elements of the AWRC Groundwater Flow Model

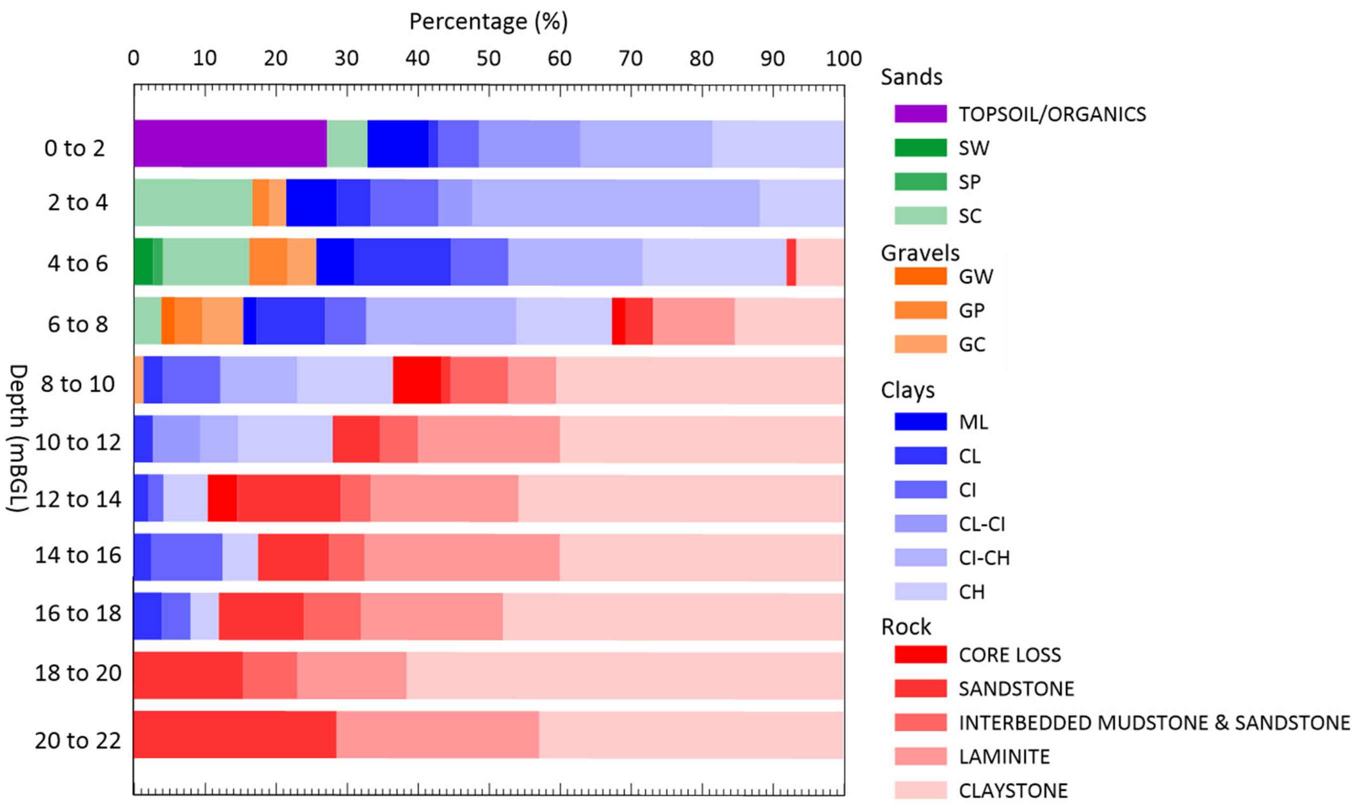

Figure 3-2: Proportion of Soil/ground at the Proposed AWRC site (Based on 29 Bore Logs)

3.4 Boundary Types and Locations

Model boundary conditions are shown in **Figure 3-3** and discussed below.

3.4.1 River Boundaries

Major watercourses (i.e. Kemps Creek, South Creek, Badgerys Creek and Cosgrove Creek) across the model domain were established in the model as 'River' cells using MODFLOW RIV Package to simulate the interaction between groundwater and surface water as follows:

- River stage: Set to river cell ground surface elevation + 0.3 m (based on surveyed river water levels in South Creek and Kemps Creek near AWRC site
- Riverbed elevation: Set at river cell ground surface elevation
- Hydraulic conductance of the riverbed: Set at 100 m^2/d for the main South Creek stem and 0.5 m2/d for the tributaries Kemps Creek, Badgerys Creek and Cosgrove Creek. These values were tested via calibration targeting average annual baseflow rates ranging from 2,000 m^3/d to 4,000 m^3/d. **Section 5.3** of the main text of the AWRC Groundwater Technical Report provides further details of the South Creek baseflow.

3.4.2 General Head Boundary

Regional flow into and out of the model area through Bringelly Shale was simulated using the General Head Boundary (GHB) condition. GHB boundaries allow water to enter the model where the GHB head is higher than modelled head in adjacent model cell and leave the model when the modelled head is lower than GHB head. Boundary cells with general head conditions were assigned in the northern model domain edge, as well as the eastern and western boundaries, and the southern boundary. Head values applied for GHB head were determined using the relationships of observed water level to topography derived from M12 Motorway groundwater monitoring records shown in **Table 3-2** and plotted in **Figure 3-4**. These were applied to Bringelly Shale in model layers 3 to 5. GHB conditions were setup allowing Groundwater Vistas to compute variable conductance values using modelled hydraulic conductivity values of the Hawkesbury Sandstone multiplied by the cell area.

3.4.3 No-flow Boundaries

The north-east and north-west edges of the model domain were specified as no-flow boundaries coinciding with the catchment divides for Thompsons Creek and Kemps Creek, respectively.

3.4.4 Seepage Face Boundaries for Large Deep Excavation Pits

There are three large deep pits within the model domain at the locations shown in **Figure 3-3**. The pit near the AWRC is a landfill site. An inspection of Google Earth images shows ponding water in these pits. The source of the water has not been confirmed at the time of issue of this report. A review of groundwater levels in groundwater monitoring wells near the pits shows that the surrounding groundwater levels area higher than the base of the deep portions of the pits. It has therefore been assumed that groundwater may be discharging into these pits. The pits were established in the model as 'Drain' cells using MODFLOW DRN Package to simulate potential groundwater seepage into these voids.

3.4.5 Recharge

The Water Sharing Plan for the Greater Metropolitan Region Groundwater Resources generally assumes an annual recharge rate of 6% of annual rainfall for assessing available yields within these groundwater aquifer systems. PPK (1999) applied a uniform recharge rate of 1% of annual rainfall in the Western Sydney Airport groundwater model across alluvium and Bringelly Shale aquifers included in the model. Applicable recharge for the AWRC groundwater model was determined via calibration (**Section 4**) by testing the model's response to rates ranging from 1% to 12% of the annual rainfall recharge.

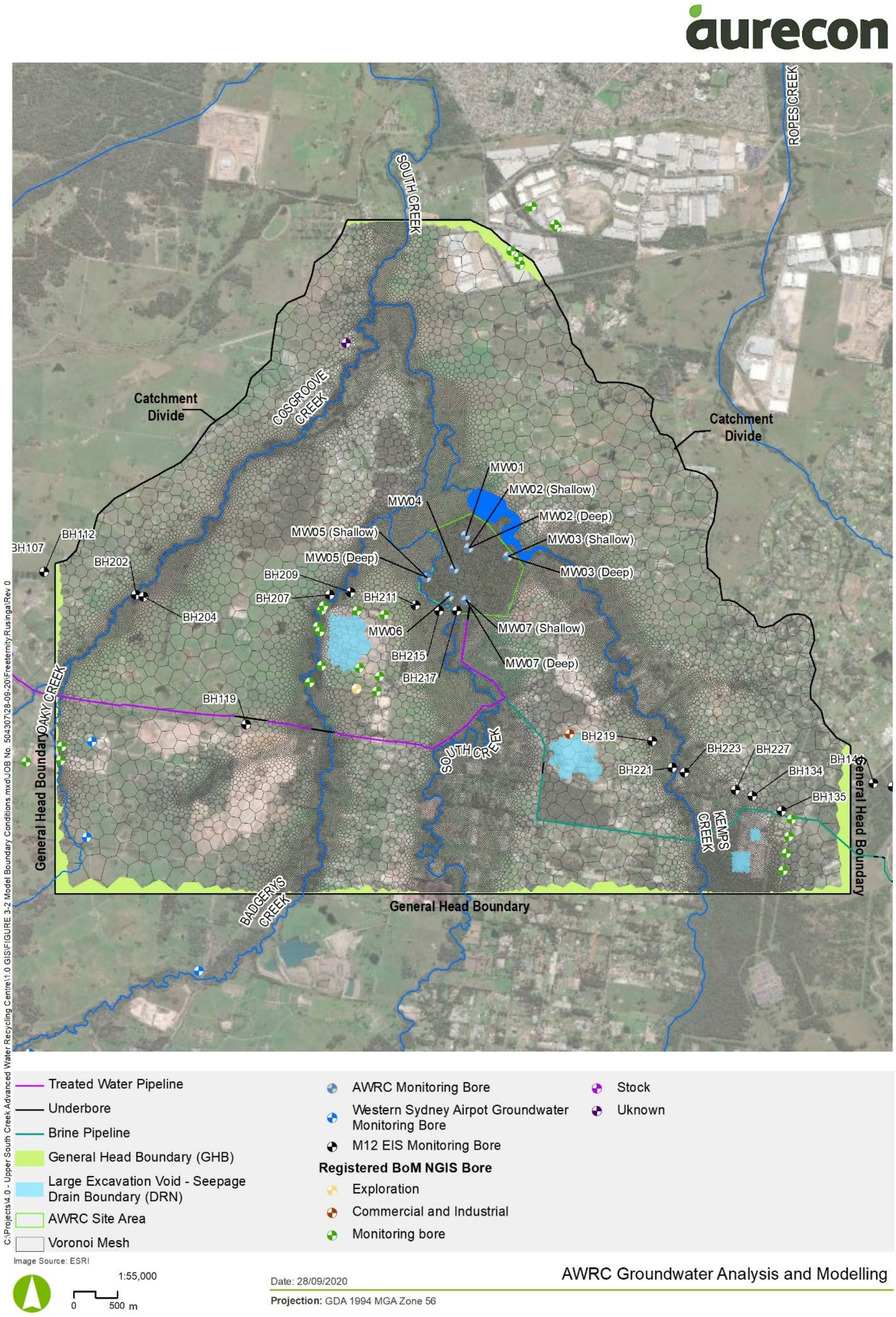

Figure 3-3: Model Boundary Types

Table 3-2: Historical groundwater levels within in Bringelly Shale (Coffey, 2015)

Well ID	Easting	Northing	Well depth (mBGL)	Ground surface level (mAHD)	Groundwater level (mAHD)	Depth to water (mBGL)	Date of GWL observation
D1	286840	6245879	15.20	104.20	96.30	7.90	18/07/1990
D2	287065	6246834	9.85	97.60	93.90	3.70	18/07/1990
D3	287295	6247189	10.00	105.70	102.35	3.35	18/07/1990
D5	288139	6247480	20.15	102.50	98.60	3.90	18/07/1990
D6	287790	6246539	25.10	112.90	105.50	7.40	18/07/1990
D7	288158	6245894	10.35	79.40	75.45	3.95	18/07/1990
D8	289089	6246504	10.05	92.10	84.20	7.90	14/09/1990
D9	289486	6247149	10.25	87.50	83.30	4.20	18/07/1990
D10	289772	6247874	10.00	88.00	83.30	4.70	18/07/1990
D12	291163	6249365	10.50	59.00	55.80	3.20	18/07/1990
D19	288395	6248129	15.00	88.90	83.40	5.50	-
D22	287250	6246322	20.00	103.20	94.10	9.10	-
D23	287118	6247517	20.70	105.60	96.00	9.60	-
D29	288388	6247031	10.05	95.10	87.50	7.60	-
A	288241	6244156	27.30	92.91	81.25	11.66	-
B	289670	6249305	38.50	71.18	61.79	9.39	-
C	285636.8	6247115	26.00	66.52	58.35	8.17	-
E Deep	287865.8	6244956	11.30	78.21	75.36	2.85	-
F Deep	288834.3	6245972	30.30	69.87	65.97	3.90	-
G Deep	290792.5	6246831	24.30	59.64	54.64	5.01	-
H Deep	289190.7	6244469	12.30	84.06	81.08	2.98	-
H Shallow	289188.9	6244469	4.50	84.03	81.62	2.41	-
J Deep	290053.5	6242999	42.30	70.86	65.22	5.64	-
K	289589.8	6248320	32.30	72.01	68.51	3.50	-

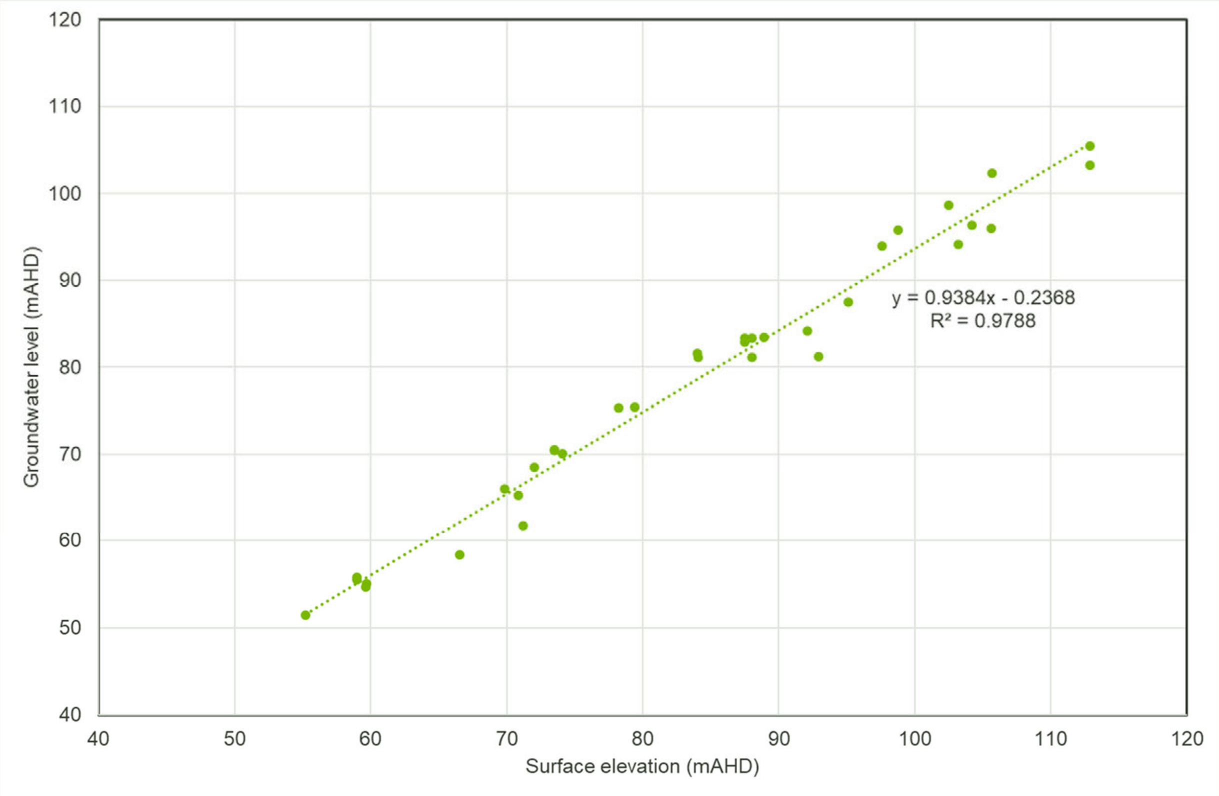

Figure 3-4: Potential relationship Between Topography and Water Level in Bringelly Shale

Recharge rates for the AWRC groundwater model were determined via calibration as outlined in **Section 4**, using MODFLOW Recharge Package.

3.4.6 Evapotranspiration

Evapotranspiration losses occur from the shallow soil zone. This process may be more predominant following wet season recharge of aquifers (i.e. evaporation rates will increase with higher water tables). Groundwater discharge through evapotranspiration was simulated using the MODLFOW Evapotranspiration (EVT) package. An extinction depth of 1 m was specified, below which EVT ceases to occur. A uniform evapotranspiration rate of 10% of annual rainfall adopted for the AWRC similar to the rate applied in the Western Sydney Airport groundwater model by PPK (1999).

3.4.7 Groundwater Abstraction

Review of the National Groundwater Information System (NGIS) groundwater database held by the Bureau of Meteorology (BoM) has identified one commercial and industrial water supply within 3 km of the AWTC site (**Figure 3-3**). Information regarding the abstraction rates for this bore had not been obtained at the time of issue of this report. This bore has therefore not been simulated in the model.

3.5 Model Time Frames

3.5.1 Steady-state Flow Modelling

Steady-state mode modelling was applied for calibration and the post-construction modelling to simulate likely long-term conditions associated with the proposed AWRC works with both Stage 1 and future stages in place.

3.5.2 Transient Flow Modelling

Transient mode modelling was applied to simulate potential impact of construction dewatering required for safe construction the AWRC Stage 1 bioreactors based on the current 100% construction schedule for the reference design shown in **Figure 3-5**, as follows:

- Bioreactor East: from 29/03/2023 to 19/03/2024 (356 days). These correspond to model stress periods 6 and 18, respectively
- Bioreactor West: from 29/05/2023 to 2/08/2024 (431 days). These correspond to model stress periods 7 and 21, respectively

Bioreactor - East	**295 days**	**Wed 29/03/23**	**Mon 22/04/24**
Detail excavation, prepare base and place subfloor drainage	40 days	Wed 29/03/23	Tue 23/05/23
FRP base	50 days	Thu 20/04/23	Fri 23/06/23
FRP Walls and misc structures	**150 days**	**Wed 10/05/23**	**Wed 15/11/23**
FRP inner walls	105 days	Mon 5/06/23	Mon 16/10/23
FRP outer walls	85 days	Wed 10/05/23	Fri 25/08/23
FRP Misc Pit Walls, walkways, etc	80 days	Mon 7/08/23	Wed 15/11/23
Water test tanks	40 days	Tue 3/10/23	Tue 21/11/23
Mech/Elec Fitoff	**100 days**	**Tue 19/09/23**	**Mon 5/02/24**
Fit mixers/membranes	60 days	Fri 27/10/23	Tue 23/01/24
Fit valves, weir plates and misc mechanical items	100 days	Tue 19/09/23	Mon 5/02/24
Fitoff Electrics & Controls	100 days	Tue 19/09/23	Mon 5/02/24
Finish external pipe connections	20 days	Wed 15/11/23	Mon 11/12/23
Backfill tank and finish area	40 days	Mon 29/01/24	Tue 19/03/24
Commissioning	60 days	Mon 5/02/24	Mon 22/04/24
Bioreactor - West	**340 days**	**Tue 23/05/23**	**Thu 8/08/24**
Detail excavation, prepare base and place subfloor drainage	40 days	Tue 23/05/23	Wed 12/07/23
FRP base	50 days	Wed 12/07/23	Wed 13/09/23
FRP Walls and misc structures	**145 days**	**Wed 13/09/23**	**Mon 25/03/24**
FRP inner walls	105 days	Mon 16/10/23	Wed 6/03/24
FRP outer walls	85 days	Wed 13/09/23	Wed 10/01/24
FRP Misc Pit Walls, walkways, etc	80 days	Mon 4/12/23	Mon 25/03/24
Water test tanks	40 days	Thu 22/02/24	Tue 16/04/24
Mech/Elec Fitoff	**100 days**	**Wed 17/01/24**	**Fri 24/05/24**
Fit mixers/membranes	60 days	Thu 22/02/24	Sat 11/05/24
Fit valves, weir plates and misc mechanical items	100 days	Wed 17/01/24	Fri 24/05/24
Fitoff Electrics & Controls	100 days	Wed 17/01/24	Fri 24/05/24
Finish external pipe connections	20 days	Wed 10/04/24	Mon 6/05/24
Backfill tank and finish area	40 days	Thu 13/06/24	Fri 2/08/24
Commissioning	60 days	Fri 24/05/24	Thu 8/08/24

Period over which dewatering will be required

Period over which dewatering will be required

Figure 3-5: Current Proposed 100% Reference Design Construction Schedule for AWRC Bioreactors

4 Model Calibration

4.1 Steady State Model Calibration

There are no long-term groundwater level monitoring records in the area covered by the AWRC groundwater model domain to determine the nature of groundwater flow dynamics. With no recent major works in this area which could be interfering with the groundwater system, it has been assumed that available ground water level data at AWRC and nearby projects are representative of steady-state groundwater conditions and this was used as the basis for steady-state calibration of the AWRC model.

Model calibration involves determination of the magnitude and spatial distribution of the key model hydraulic parameters that allow the model to reproduce the observed/estimated groundwater levels within the model area. A combination of automated adjustments using PEST version 15 (www.PestHomePage.org) and manual adjustments to zone values of hydraulic conductivity, recharge and hydraulic conductance parameters were undertaken such that the model-predicted groundwater levels generally matched the observed groundwater levels and estimated baseflow. The observed groundwater levels comprised 24 targets at the AWRC and M12 Motorway EIS monitoring bores shown in **Figure 3-3**.

The following performance metrics were used to judge the quality of the model conditioning and calibration simulations:

- The Scaled Root Mean Squared (RMS) Error for the model-predicted versus observed hydraulic heads for 24 monitoring bore locations, targeting 10% maximum suggested by the Australian Modelling Guidelines (Barnett et al 2012)
- The systematic/unsystematic nature and magnitude of over-prediction or under-prediction of hydraulic heads at 24 calibration targets (observation points)
- Discharge flow rates to the modelled rivers consistent with observed baseflow rates at Great Western Highway Gauge 212048
- Groundwater level contour gradients consistent with the observed groundwater levels.
- Strategies to reduce model non-uniqueness included:
  - Use of site-specific geology information as described in the bore logs to constrain the three-dimensional limits of the major hydrostratigraphic zones within the model domain
  - Setting calibration targets for hydraulic conductivity based on measured values from field-based aquifer testing. The details of the field investigations are provided in **Appendix A**
  - Adjusting aquifer parameters within field-measured ranges
  - Adjusting hydraulic conductance parameters for riverbeds within plausible bounds to achieve a reasonable calibration match to observed baseflow rate at Great Western Highway Gauge 212048.

The process followed is described below.

Hydraulic conductivities parameters were allowed to vary between the lower and upper bounds of field-tested range of hydraulic conductivity values presented in **Table 4-1** during PEST optimization runs (see the Geotechnical Factual Report (Aurecon Arup, 2021) for details on aquifer testing carried out at the AWRC). Recharge was applied as proportion of 745.6 mm annual rainfall by varying it between 1% and 12% in the alluvium aquifer and between 1% and 3% in the Bringelly Shale during PEST optimization runs.

Following optimization with PEST, the hydraulic conductance parameters of the riverbed were adjusted manually targeting average baseflow rates ranging from 2,000 m^3/d to 4,000 m^3/d (refer **Section 5.3** of the main text of the AWRC Groundwater Technical Report). Once acceptable baseflow was attained, minor adjustments were applied to the PEST optimised hydraulic conductivities and recharge parameters. Final hydraulic conductance values of 100 m^2/d for the main South Creek stem and 0.5 m^2/d for the tributaries Kemps Creek, Badgerys Creek and Cosgrove Creek were adopted for the model. These parameters produced net baseflow of 2,251 m^3/d generated within the model domain. The final calibrated hydraulic conductivities are included **Table 4-1**. Final recharge rates were obtained at 10% and 1% of annual rainfall for the alluvium and Bringelly Shale aquifer, respectively. Over the whole model domain, these recharge rates are equivalent to 3,568 m^3/d or 3.3% of annual rainfall (24.7 mm/yr). These calculations are based on 14.4 km^2 and 38.2 km^2 areas of alluvium and Bringelly Shale aquifers, respectively included in the model domain. EVT was not varied during calibration with a uniform rate of 10% of annual rainfall adopted for the AWRC similar to the rate applied in the Western Sydney Airport groundwater model as mentioned in **Section 3.4.6**.

Table 4-2 compares measured groundwater levels with simulated groundwater levels generated by the calibrated model. The best-match simulated water levels were within 1 m of the measured groundwater levels for 12 records. This represents 50% of the total records used, with 75% of these within 0.5 m of measured groundwater levels, predominantly at AWRC.

The scaled root mean square (SRMS) for calibrated model is 6.1%, and this is well below 10% maximum target suggested by the Australian Modelling Guidelines (Barnett et al 2012). **Table 4-3** summarises the statistics of the attained calibration with scatter plot of simulated versus observed groundwater levels presented in **Figure 4-1**. It was considered that the level of calibration achieved, particularly at AWRC, is reasonably good for the model to be used for prediction modelling of the proposed works for AWRC.

Table 4-1: Parameter Calibration Limits Used During for Hydraulic Conductivity

Layer	Geology		Parameter calibration limits used calibration					Calibrated parameters	
	Zone	Description	Initial K_H	Min K_H	Max K_H	Initial K_V	Allowed H_V/K_H ratio	Final K_H	Final K_V
1	1	Alluvium	0.3	0.01	1.3	0.3	1 to 0.1	0.5	0.5
	3	Bringelly Shale	0.03	0.01	0.09	0.09	0.1 to 0.01	0.06	0.008
2	2	Fractured Claystone of the Bringelly Shale	0.1	0.05	0.8	0.1	1 to 0.1	0.3	0.3
	3	Bringelly Shale	0.03	0.01	0.09	0.09	0.1 to 0.01	0.06	0.008
3	3	Bringelly Shale	0.03	0.01	0.09	0.09	0.1 to 0.01	0.06	0.008
4 to 5	4	Bringelly Shale	0.03	0.003	0.001	0.009	0.1 to 0.01	0.03	0.003

Table 4-2: Measured versus simulated groundwater levels in monitoring wells

Bore ID	Easting	Northing	Model layer	Aquifer	Observed groundwater level	Computed groundwater level	Residual
BH119	291372.41	6249710.50	3	Bringelly Shale Aquifer	52.57	51.37	1.20
BH134	297251.60	6248876.40	3	Bringelly Shale Aquifer	54.40	56.30	-1.90
BH135	297594.01	6248705.90	3	Bringelly Shale Aquifer	58.17	60.67	-2.50
BH202	290089.91	6251218.30	2	Fractured claystone of the Bringelly Shale Aquifer	47.27	49.11	-1.84
BH204	290177.30	6251195.20	2	Fractured claystone of the Bringelly Shale Aquifer	48.02	49.29	-1.27
BH207	292341.60	6251217.10	2	Fractured claystone of the Bringelly Shale Aquifer	35.59	37.63	-2.04
BH209	292587.01	6251246.00	2	Fractured claystone of the Bringelly Shale Aquifer	35.75	36.93	-1.18
BH211	293340.01	6251097.00	2	Fractured claystone of the Bringelly Shale Aquifer	35.47	36.22	-0.75
BH215	293615.01	6251030.00	2	Fractured claystone of the Bringelly Shale Aquifer	34.30	35.43	-1.13
BH217	293817.01	6251033.00	2	Fractured claystone of the Bringelly Shale Aquifer	35.10	35.43	-0.33
BH219	296088.30	6249516.10	2	Fractured claystone of the Bringelly Shale Aquifer	41.88	44.55	-2.67
BH221	296319.71	6249207.70	3	Bringelly Shale Aquifer	41.44	45.28	-3.84
BH227	297056.01	6248945.00	4	Bringelly Shale Aquifer	53.95	53.11	0.84
MW01	293922.34	6251905.16	3	Bringelly Shale Aquifer	34.97	36.48	-1.51
MW02D	293957.24	6251760.59	3	Bringelly Shale Aquifer	36.16	37.00	-0.83
MW03D	294412.95	6251662.78	2	Fractured claystone of the Bringelly Shale Aquifer	37.33	37.16	0.17
MW05D	293469.20	6251417.88	2	Fractured claystone of the Bringelly Shale Aquifer	34.58	34.41	0.17
MW07D	293922.78	6251154.83	3	Bringelly Shale Aquifer	36.32	37.53	-1.20
MW02S	293956.33	6251761.00	2	Fractured claystone of the Bringelly Shale Aquifer	37.01	37.01	0.00
MW03S	294412.37	6251662.41	1	Alluvium Aquifer	37.34	37.17	0.17

Bore ID	Easting	Northing	Model layer	Aquifer	Observed groundwater level	Computed groundwater level	Residual
MW04	293791.89	6251518.90	1	Alluvium Aquifer	36.45	36.60	-0.15
MW05S	293468.17	6251417.73	1	Alluvium Aquifer	34.38	34.41	-0.03
MW06	293727.85	6251197.57	1	Alluvium Aquifer	36.10	36.04	0.06
MW07S	293922.97	6251154.16	1	Alluvium Aquifer	37.16	37.54	-0.38

Table 4-3: Summary of steady state model calibration statistics

Statistic Description	Attained Value
Residual Mean	-0.87
Absolute Residual Mean	1.09
Residual Std. Deviation	1.17
Sum of Squares	51.13
RMS Error	1.46
Min. Residual	-3.84
Max. Residual	1.20
Number of Observations	24.00
Range in Observations	23.87
Scaled Residual Std. Deviation	4.9%
Scaled Absolute Residual Mean	4.6%
Scaled RMS Error	6.1%
Scaled Residual Mean	-0.04

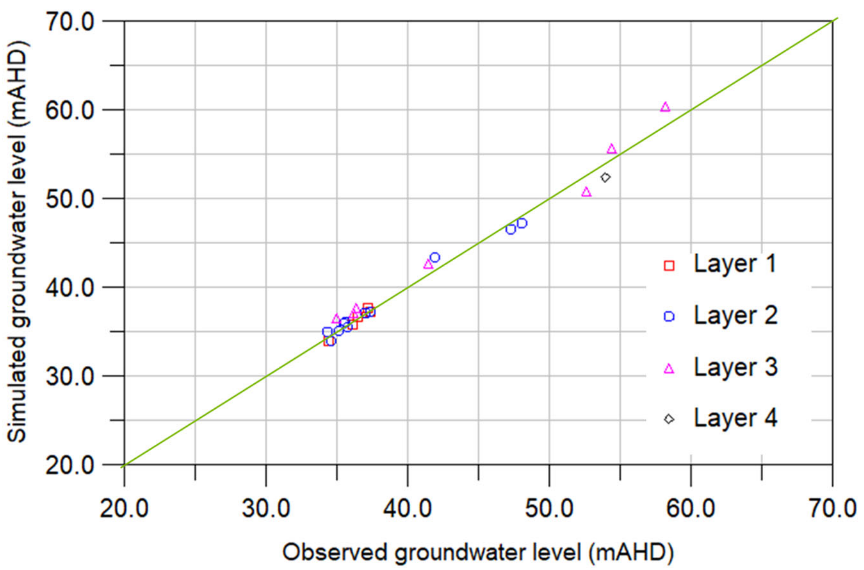

Figure 4-1: Scatter plot of simulated groundwater levels versus observed groundwater levels

4.2 Steady-state Water Balance

Table 4-4 presents the water balance for steady-state simulation, which indicates that inflow of the model water balance is dominated by aerial rainfall recharge. Outflow is dominated by loss of groundwater via baseflow. The simulated net baseflow is approximately 2.25 ML/d (or 2,250 m^3/d) which is within the estimated baseflow described in **Section 4**.

Table 4-4: Steady-state Water Balance

Water Balance Parameter	Inflow		Outflow	
	(ML/d)	(%)	(ML/d)	(%)
SW-Aquifer Interaction Rivers/Channels (RIV)	1.29	24.5%	3.55	67.2%
Regional GW Flow (GHB)	0.97	18.4%	0.73	13.9%
Recharge (RCH)	3.01	57.1%	0.00	0.0%
ET (from GW) (EVT)	0.00	0%	0.94	17.7%
Groundwater loss via large excavation voids (landfill pits and quarries)	0.00	0%	0.06	1.2%
Total	5.28	100%	5.28	100%
% Error	0.00		0.00	

5 Model Sensitivity Analysis

Sensitivity analysis improves the understanding of the importance of the input data on simulated results and how the limitations related to these parameters may affect modelling results. **Table 5-1** summarises the calibration statistics for the steady-state sensitivity simulations. These results indicate that these variations in the modelled parameters generally result SRMS within 10% (max.) stipulated in MDBC, 2001 and Barnett et al., (2012). The model is most sensitive to the horizontal hydraulic conductivity This means that the model performance will be most impacted by uncertainty associated with this parameter.

NOTE: The aquifer hydraulic parameters used in the AWRC model are based on rising and falling head tests. These types of aquifer tests evaluate only a small volume of the aquifer at each tested well location. Poor rock recovery, low rock quality designation (RQD) and core losses observed by Aurecon as part of the logging of rock cores are indicators of potential open joints and fractured zones at AWRC and potential source of groundwater problems in terms of dewatering, that require further investigations. It is recommended to carry pumping tests as part of the development of the dewatering plan for the AWRC construction works.

Table 5-1: Steady-State Calibration Statistics for Sensitivity Runs

Statistic	Calibrated Model	K_h -1 order	K_h +1 order	K_v -1 order	Recharge +50%
Residual Mean	-0.87	-1.86	-0.53	-0.91	-1.43
Absolute Residual Mean	1.09	1.86	1.81	1.11	1.44
Residual Std. Deviation	1.17	0.86	2.32	1.17	1.19
Sum of Squares	51.13	101.25	135.83	52.59	83.40
RMS Error	1.46	2.05	2.38	1.48	1.86
Min. Residual	-3.84	-3.80	-6.57	-3.87	-4.63
Max. Residual	1.20	-0.48	2.74	1.19	0.04
Number of Observations	24.00	24	24	24	24
Range in Observations	23.87	23.87	23.87	23.87	23.87
Scaled Residual Std. Deviation	4.9%	3.6%	9.7%	4.9%	5.0%
Scaled Absolute Residual Mean	4.6%	7.8%	7.6%	4.7%	6.0%
Scaled RMS Error	6.1%	**8.6%**	**10.0%**	**6.2%**	**7.8%**
Scaled Residual Mean	-0.04	-0.08	-0.02	-0.04	-0.060

Notes: K_h – Horizontal hydraulic conductivity; K_v – Vertical hydraulic conductivity

6 Predictive Modelling

The following predictive model scenarios were assessed.

6.1 Scenario 1: Construction Phase Modelling

This scenario relates to construction dewatering and it only applies to the Bioreactors which would penetrate below the water table. This scenario assesses potential impacts which could arise due to construction dewatering which will be required for the construction of the bioreactors. **Figure 6-1** shows a typical cross-section of the bioreactors based on the current version of the reference design. The base of the lower sand layer of the underdrainage system is proposed to be about 1.0 m below the slab of the bioreactor tank. This corresponds to a level of 34.7 mAHD. Observed groundwater levels across the footprint of the bioreactors varies from 36.4 mAHD at MW04 to 37 mAHD at MW2S. Construction dewatering will therefore be required to provide a safe working platform. The required drawdown for dewatering depends on hydrogeologic conditions.

The presence of a confined aquifer at shallow depth beneath the excavation would result in a risk of base heave if the piezometric head is not lowered adequately. A conservative approach is to lower the groundwater level below the formation level to at least 1 m clearance. A clearance of 1.5 m has been adopted for this modelling, meaning that the groundwater table would need to be lowered to RL 33.2 mAHD.

Dewatering modelling was undertaken using transient modelling with the aid of MODFLOW DRN package activated at the timeframes represented in the currently proposed construction program for Stage 1 reference design described in **Section 3.5.2** as follows:

- Bioreactor - East: 01 April 2023 DRN **on** – 01 May 2024 DRN **off**
- Bioreactor- West: 01 June 2023 DRN **on** – 01 September 2024 DRN **off**

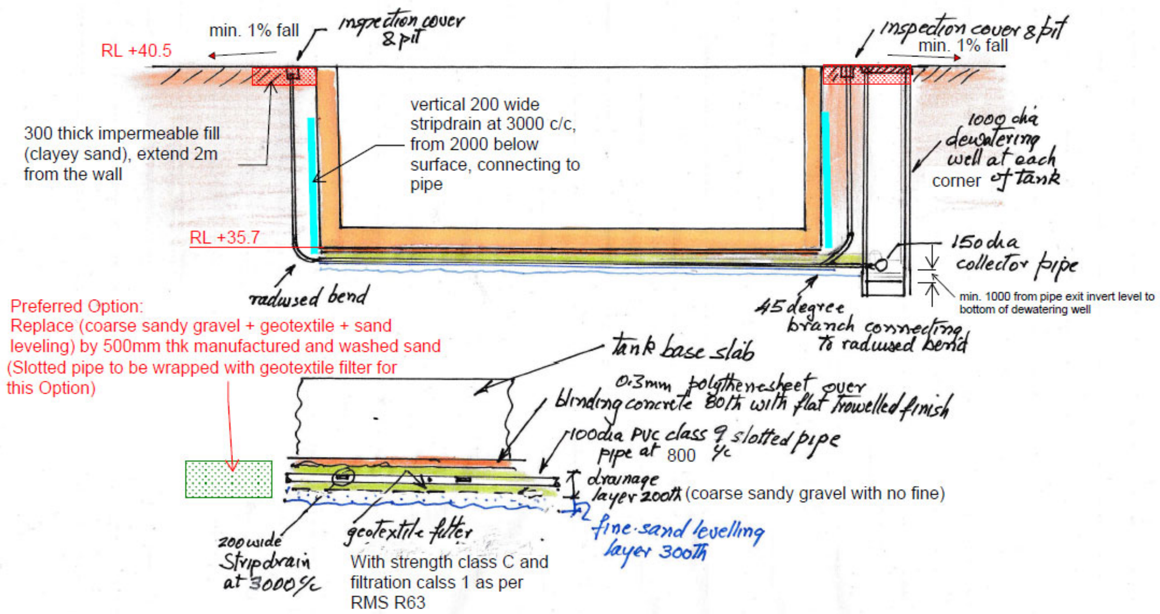

Figure 6-1: Schematic illustration of flushable tank underdrainage of the bioreactor

It should be noted that construction schedule for future stages had not been issued at the time of issue of this report. Due to nearly similar size and design, it is expected that these will be a similar impact to Stage

1 bioreactors. However, it is recommended that impacts of any future bioreactors be assessed via modelling once the construction schedule becomes available.

Modelling of Stage 1 construction dewatering above has assumed the construction will stick to the proposed schedule. In reality, construction program may be affected by other factors beyond the control of the contractor such as bad weather or other issues which could delay the works, resulting in an extended schedule. It is also possible that there may be efficiencies in the construction process.

Storage parameters are required in a transient model and the following were assumed:

- Alluvium: Specific yield (Sy) – 0.18 Specific storage – 0.0001
- Bringelly Shale: Sy – 0.1 Specific storage – 0.0001

A sensitivity / uncertainty analysis was also undertaken in order to assess the significance that variations in hydraulic conductivity (permeability), specific yield and recharge have on the simulated ground water inflow during construction based on the range of parameters in **Table 5-1**. For specific yield, a high value of 0.3 was tested. To maintain the equivalent hydraulic conductivity to recharge ratio, a scenario with doubled hydraulic conductivity and recharge flux was also tested.

6.2 Scenario 2: Operational Phase Modelling

The following could impact on the AWRC groundwater system post-construction:

- AWRC structures below the groundwater table which would partially block the natural groundwater flow pathway
- Impermeable surfaces across the AWRC site would result in the reduction of recharge
- Maintenance regimes which requires dewatering of the bioreactors sub-surface drainage (**Figure 6-1**)
- On site irrigation and potential exfiltration due to proposed biofiltration systems
- Storage and use of chemicals and contaminants

The effects of the first three were assessed through modelling.

The USC Surface Water Impact Assessment Report outlines the recommended strategy for stormwater management which entails the re-creation of pre-development environmental water balance by offsetting the lost recharge due to AWRC impermeable surfaces through increasing post-construction recharge through leaky wetlands and detention basins, as well as local irrigation. If this is achieved, it predicted that the effects of the proposed stormwater management would maintain pre-development water balance, with localised impacts where the works will be provided. This strategy for stormwater management is based on water balance modelling results and is assessed as appropriate for reference design. More detailed infiltration analysis is recommended during the detailed design phase when the final location of the facilities are determined.

In assessing the impacts of the AWRC structures below the groundwater table, which in this case are the bioreactor tanks, the portion of the tanks above the elevation of the tank slab was set to a no-flow internal boundary condition. This was applied to both Stage 1 and the potential future bioreactors. The reduction in recharge was simulated by setting the entire footprint of the AWRC as a zero-recharge zone. The model was run in steady state mode.

The dewatering which will be required for maintenance purposes was also modelled. This was completed using a combination of simple analytical and numerical modelling. Analytical modelling was completed using spreadsheet models based on equations developed by Marinelli and Niccoli (2000). The Marinelli and Niccoli (2000) analytical model is illustrated in **Figure 6-2**. The numerical model has been completed using a simple model developed using MODFLOW. The Marinelli and Niccoli (2000) model computes long-term groundwater inflow into pits and this was used as the basis for constraining the input data for the numerical model, in particular the conductance terms for the Drain (DRN) package in MODFLOW. The MODFLOW model was setup in transient mode to assess the dynamics of the groundwater system in response to dewatering as the basis for the design of the underdrainage system for AWRC bioreactors. The transient model was setup at hourly simulation time intervals, with the drain turned on at the 13-hr time interval.

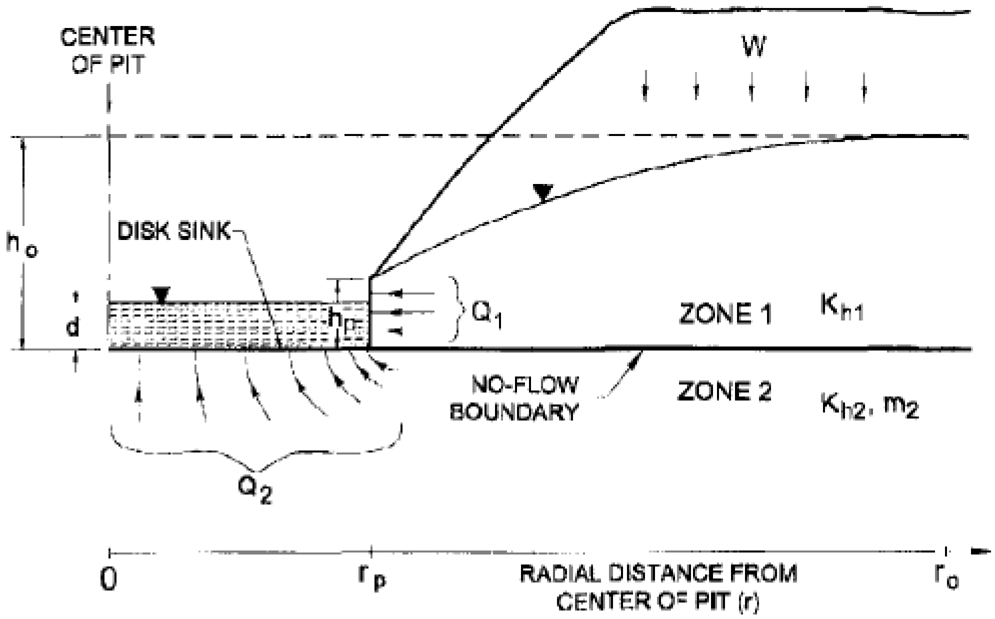

Figure 6-2: Pit inflow Analytical Model (Marinelli and Niccoli, 2000)

The model utilised worst-case conditions with the groundwater table assumed at ground surface at the start of dewatering operations for maintenance purpose. The model was set up prior to the developed of the regional model and it utilised hydraulic parameters derived from the nearby hydrogeology study by PPK (1999) for the Western Sydney Airport. The parameters are within the calibration range of the regional described above and considered appropriate for this assessment.

A summary of the mean hydraulic conductivity values applied are provided below:

- Alluvial aquifer – 0.14m/d.
- Shale aquifer - 0.043m/d with vertical hydraulic conductivity expected to be two to three orders of magnitudes lower than horizontal conductivity.

Storage parameters are provided in **Table 6-1**.

Groundwater recharge has been assumed at a rate of 6% in accordance with Water Sharing Plan for the Greater Metropolitan Region Groundwater Resources. A recharge rate of 41.8 millimetres/year (mm/yr) adopted for the Western Sydney Airport has been assumed for this assessment (GHD, 2016).

The numerical modelling assumed that the head (water level) in the aquifer will be lowered to 35.6 mAHD just below the base of the bioreactor tank floor slab (**Figure 6-1**).

The input data and assumptions applied in the Marinelli and Niccoli (2000) spreadsheet model are provided in **Appendix B**.

Table 6-1: Steady-State Calibration Statistics for Sensitivity Runs

Statistic	Specific Yield (Sy) (dimensionless)			Storativity (dimensionless)		
	Min	Max	Adopted	Min	Max	Adopted
Residual clay	0.01	0.018	0.06	0.00001	0.001	0.001
Bringelly shale	0.001	0.1	0.01	0.00001	0.001	0.001

7 Analysis of Modelling Results

7.1 Scenario 1: Construction Phase Modelling Results

Figure 7-1 compares pre-development and construction dewatering groundwater levels. The construction dewatering groundwater levels shown in **Figure 7-1** relates to the maximum simulated conditions just before cessation of dewatering of Bioreactor- East on 1 May 2024 as outlined in **Section 3.5.2** and **6.1**. This point in time relates to the maximum period over which both the eastern and western bioreactors are subjected to dewatering. **Figure 7-2** shows the simulated maximum drawdown at this time of the assumed construction schedule.

Figure 7-1 includes IDs of the modelled river reaches for South Creek. An inspection of the simulated water balances for the modelled river reaches shows that a small section of South Creek (approximately 650 m length) will be impacted, with a slight reduction in baseflow to the creek in this area during construction reducing from an average of about 79 m^3/d to 74 m^3/d over Reach 10 and Reach 11. This represents a baseflow reduction of approximately 6% during construction. The degree of impact is dependent on the distance between the dewatering and the creek (reducing with distance). In terms of foundation design, the degree of impact increases with depth below current ground surface. This groundwater impact could affect the aquatic ecosystems (South Creek) with a high level of interaction with groundwater near the proposed AWRC site, in particular areas in Reach 10 and Reach 11. Full details of impact assessment are provided in the main Groundwater Impact Assessment Report.

The extent of influence due to construction dewatering is about 325 m from the central part of the bioreactor site as shown in **Figure 7-1** and **Figure 7-2**. The extent of influence is a term used to describe the cone of depression and it represents the radial distance from the area where dewatering is applied to the point where there is zero drawdown. Based on these modelling results, the impact of construction dewatering is expected to be of local extent, which will be contained within the extent of the footprint of the proposed AWRC site. Beyond this extent, the groundwater flow pattern is unimpacted.

To establish a dewatered or pressure-relieved condition, it is necessary to pump the water released by the aquifer from storage within it as the head is lowered to the desired level, before equilibrium is reached. In confined aquifers, the released water comes from elasticity of water and soil skeleton. For unconfined aquifers the released water comes from draining pore spaces. For confined aquifers the volume of water released from storage is usually small and can be neglected. But for unconfined aquifers, the storage release can be significant.

The aquifer at AWRC is an unconfined system and this condition will occur for dewatering of the AWRC aquifer. Simulated inflow rates for the eastern and the western bioreactors would stabilise at 52 L/min and 28 L/min, respectively on average in about 30 days after the storage within pore space is drained. Initial inflow rates to achieve these equilibrium flow rates averages at about 7,900 L/Min and 4,800 L/Min, respectively for the eastern and the western bioreactors, in the first 30 days of pumping. This relates to the initial volume of water which will be released from draining pore spaces. **Figure 7-3** provides simulated cumulative volume of water which will be pumped in the assumed dewatering period for Stage 1 works. Based on these results, the total volume of pumped water in 365 days of the proposed Stage 1 construction schedule will be about 50 ML (31 ML + 19 ML).

Based on the construction schedule described in **Section 6.1**, dewatering for preparations of the works for the Eastern Bioreactor was assumed to commence two months earlier than the Western Bioreactor. This explains why the cumulative volume generated for the Eastern Bioreactor is more than that of the Western Bioreactor in **Figure 7-3**. It should be noted that DRNs cells for simulating construction dewatering were applied to an area approximately equal to the plan area of the bioreactor tanks. In reality, the sides of the excavation would be battered back at least 1 in 1.5, meaning that the overall dimension to be dewatered would be much bigger. Typically, the well array would be designed to dewater bigger area. It implies that actual flow rate may be higher than the estimate above. The estimated inflow rates above provide an initial understanding of dewatering requirements of the likely volumes to be dealt with as the basis for developing a Dewatering Plan for the AWRC works. However, the dewatering plan should be supported by further field tests such as pumping tests as outlined in **Section 5**.

The simulated sensitivity of calculated inflows to model input parameters is provided **Table 7-1**. The results presented in **Table 7-1** show the highest degree of sensitivity to changes in horizontal conductivity of the unconsolidated sediments, with inflow doubling for horizontal hydraulic conductivity an order of magnitude higher than the calibrated values. The choice of one order of magnitude to test the sensitivity of inflow to the hydraulic conductivity values for this geology unit has been based on the falling-head tests completed at the AWRC site, which generally spanned two orders of magnitude.

It is considered unlikely that hydraulic conductivity of unconsolidated sediments would vary by more than one order of magnitude of the calibrated value. However, it should be these parameters were assessed using falling head tests only. Generally hydraulic conductivity analyses from this kind of test is known to underestimate in-situ hydraulic conductivities for soils. Full-scale pumping tests which allow more accurate determination of the hydraulic conductivities over a larger aquifer volume are recommended at detailed design phase or as part of the development of the Dewatering Plan.

The sensitivity of calculated inflows to other parameters in **Table 7-1** show little variation from the baseline calibrated scenario described above. The simulated drawdown also shown little variation. This similarity indicates that in this environment, quasi-steady state conditions are reached very rapidly at the AWRC site.

NOTE: The potential impacts of the solar panels during is a reduction in the permeable surface and groundwater recharge, this has not been directly modelled in the construction phase, but has been captured in the long-term modelling (see **Section 7.2**).

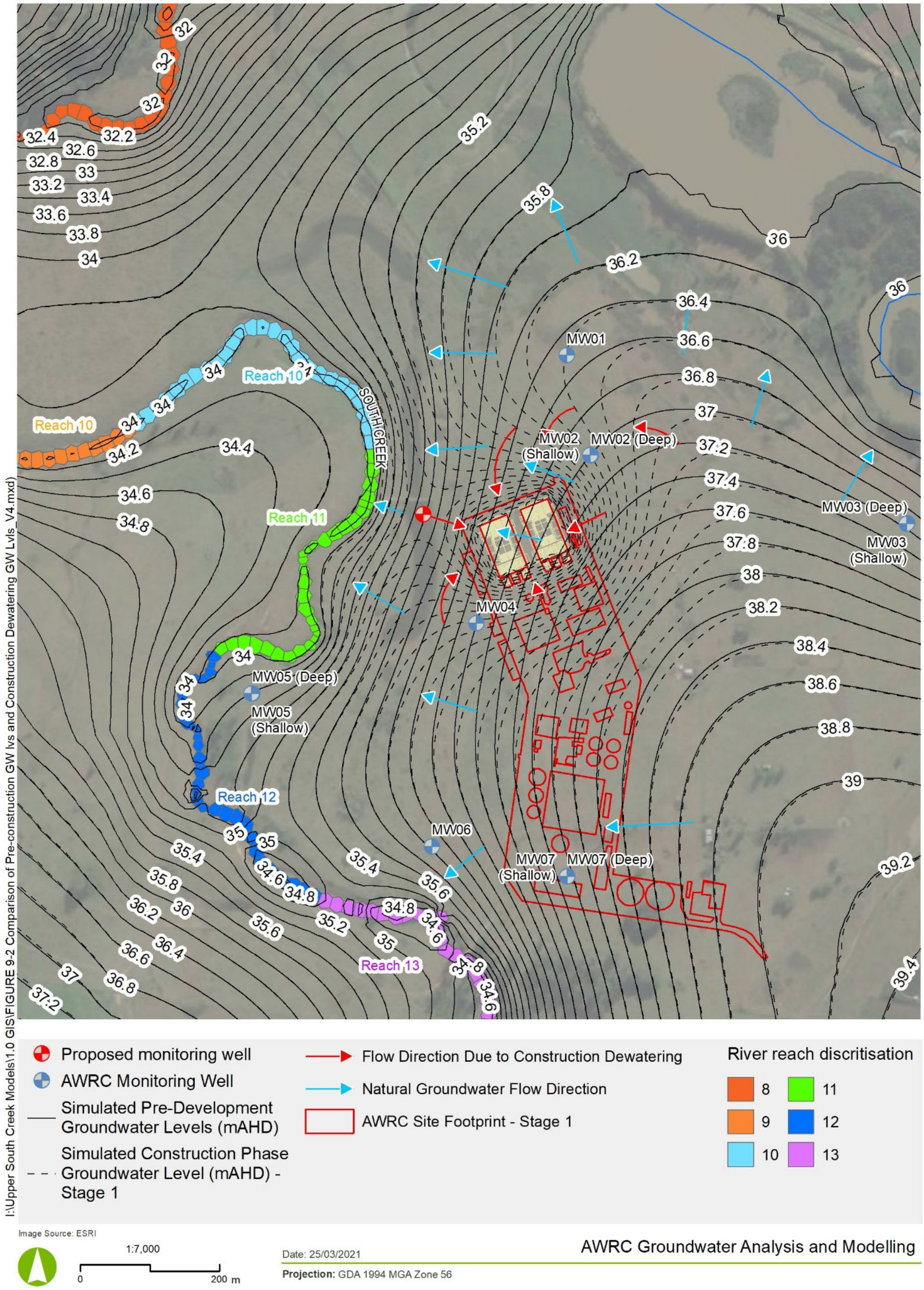

Figure 7-1: Comparison of Simulated Pre-construction and Construction Phase Groundwater Level Contours

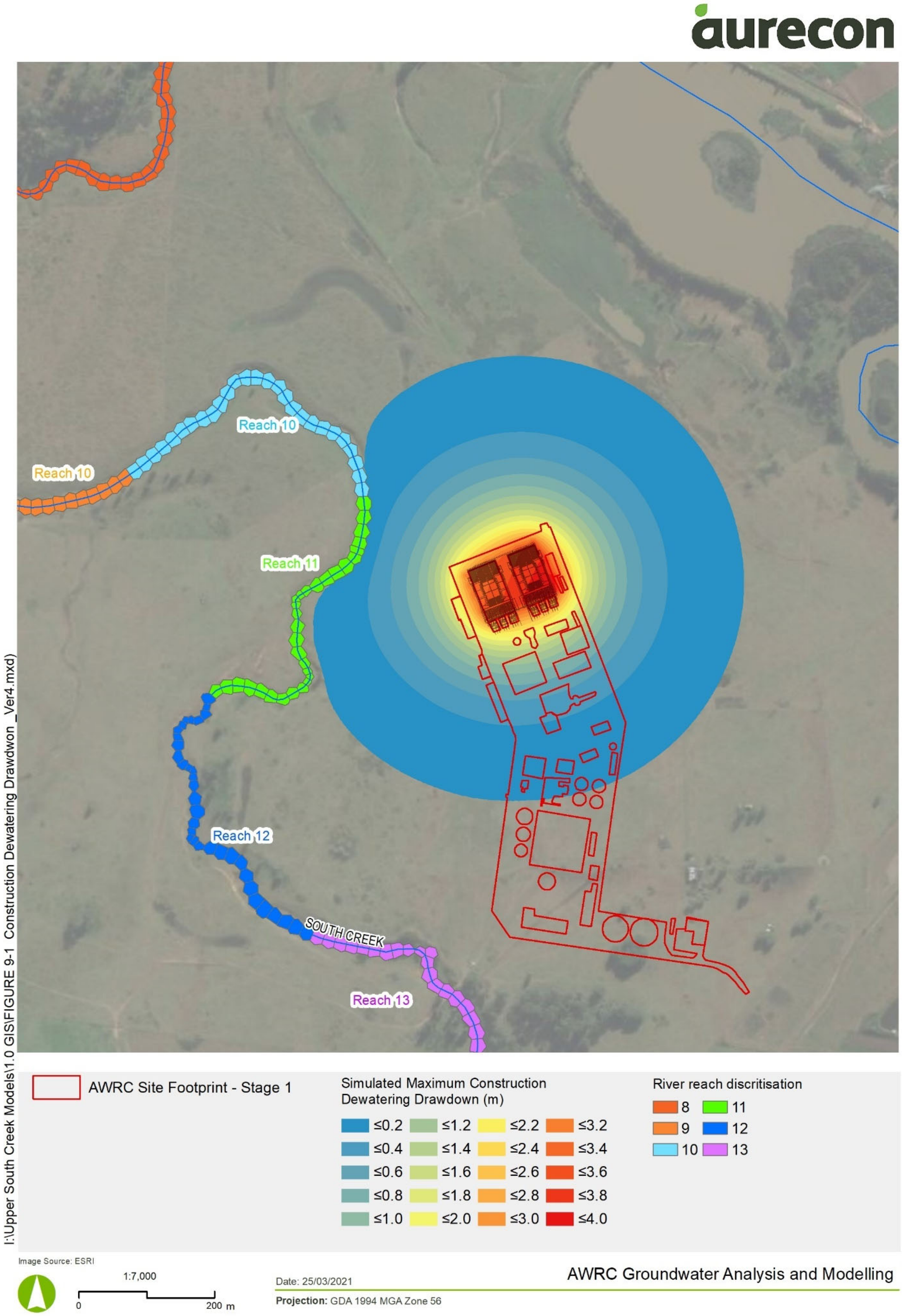

Figure 7-2: Construction Dewatering Drawdown (Cone of Depression)

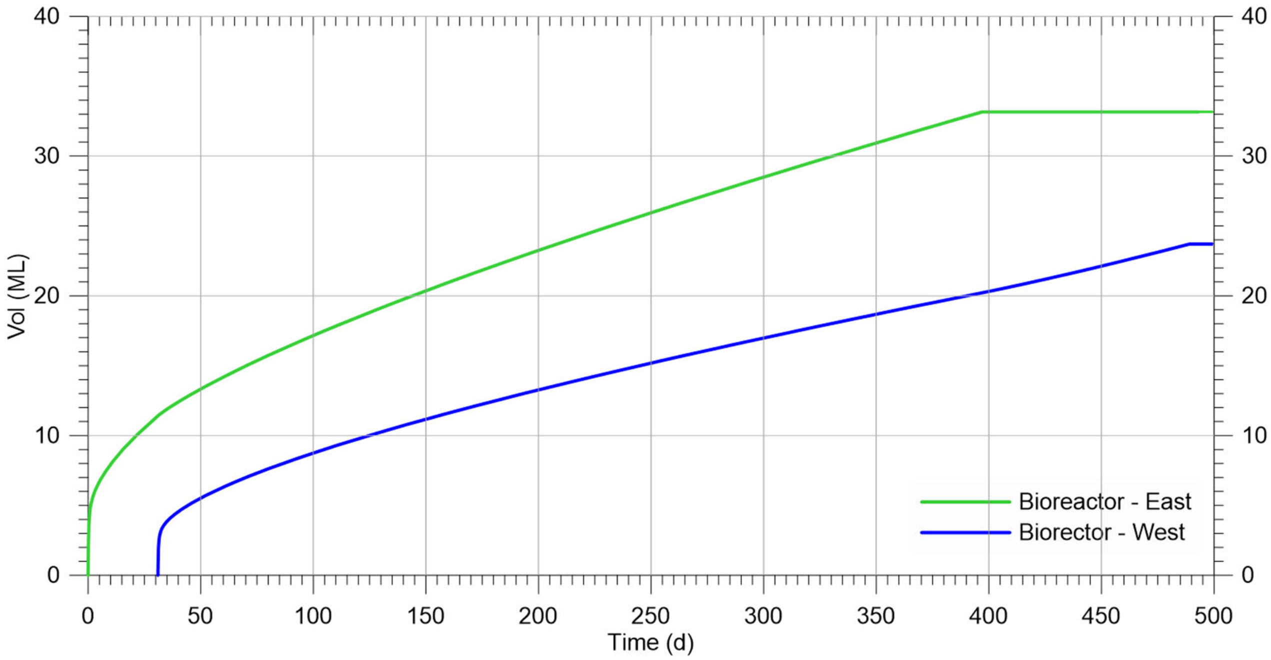

Figure 7-3: Simulated Cumulative Volume of Water During Construction Dewatering (Stage 1 only)

Table 7-1: Sensitivity analysis results for simulated groundwater inflow during construction

Parameter	Simulated Groundwater Inflow Over 365 Days (ML)		
	Eastern Bioreactor	Western Bioreactor	Total
High K_h	61	36	97
Low K_h	13	10	23
High K_v	25	16	41
High recharge	31	20	51
High S_y	30	19	49

7.2 Scenario 2: Operational Phase Modelling Results

Figure 7-4 compares pre-development and post-construction long-term groundwater levels generated based on steady state modelling. These results show that the reduction in recharge across the AWRC will result in local depression of the groundwater table of 0.9 m at the centre of the ARWC footprint reducing to zero before intersecting South Creek. Inspection of the simulated water balance indicates a corresponding minor reduction (around 1%) of baseflow in the creek reaches close the site.

The modelling results for dewatering maintenance regimes are presented in **Figure 7-5** and **Figure 7-6**. The modelling assumes that once the water in the dewatering tank has been lowered below the invert of the drainage blanket, the groundwater will be pumped at rates higher than the inflow rate. Under such circumstances, the hydraulic pressure head is expected to reduce to zero as depicted by the red plot in **Figure 7-5**. However, the groundwater table in in the vicinity of the tank would remain elevated at about 3 m above the drainage system. A drainage layer around the tank wall side should be considered to allow the groundwater table in contact with the wall to drop to the desired level. It is recommended to install the inspection piezometer/ well within the drainage layer.

Groundwater inflow will be very high initially due to draining of pore water reducing to 40 L/min (2.6 m^3/hr) for prolonged maintenance regimes of over 5 days as presented **Figure 7-6**. The simulated average inflow rate is 50 L/min (3 m^3/hr). Estimates of the total volume expected to be pumped for each maintenance regime should be assessed based on this average flow.

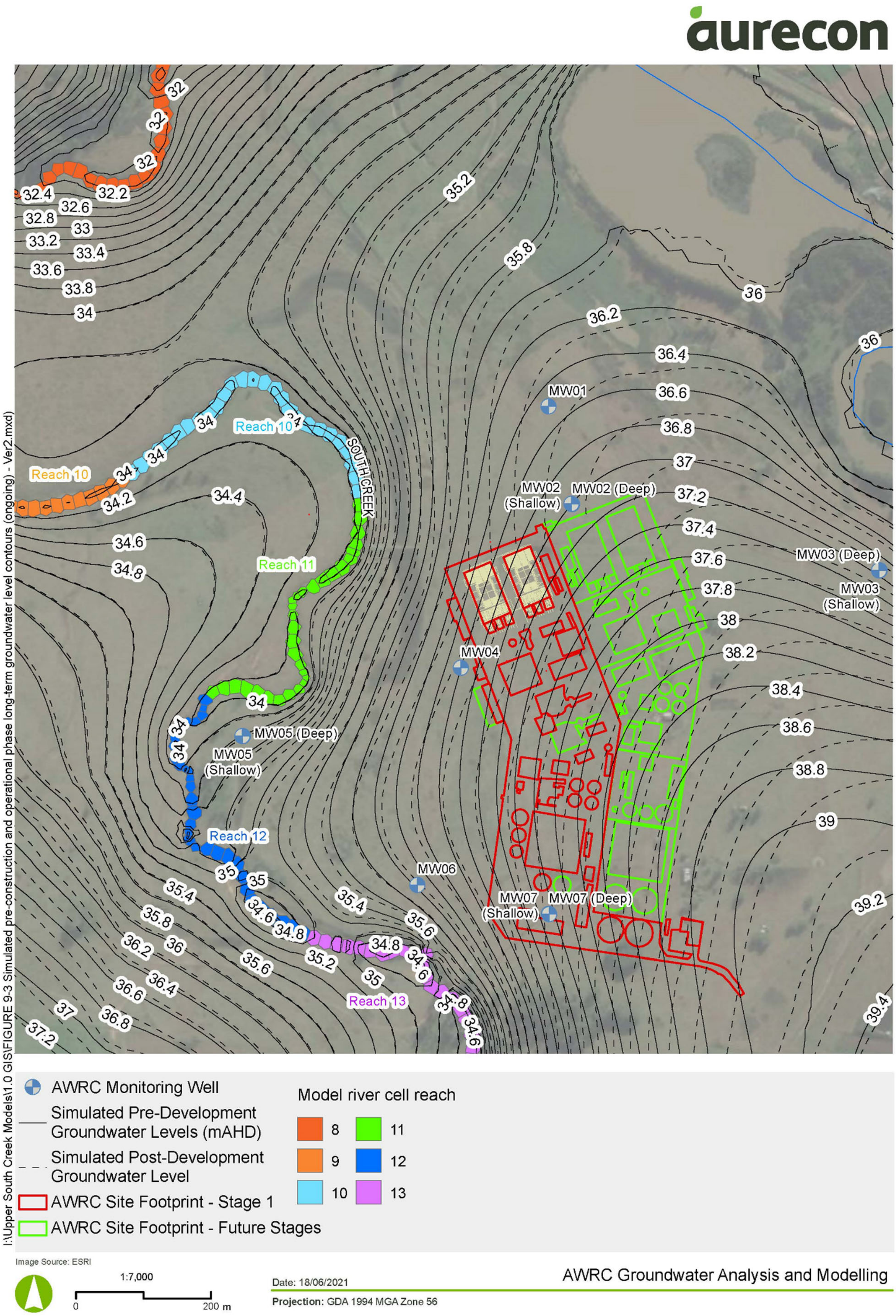

Figure 7-4: Simulated Pre-construction and Post-Construction Long-term Groundwater Level Contours

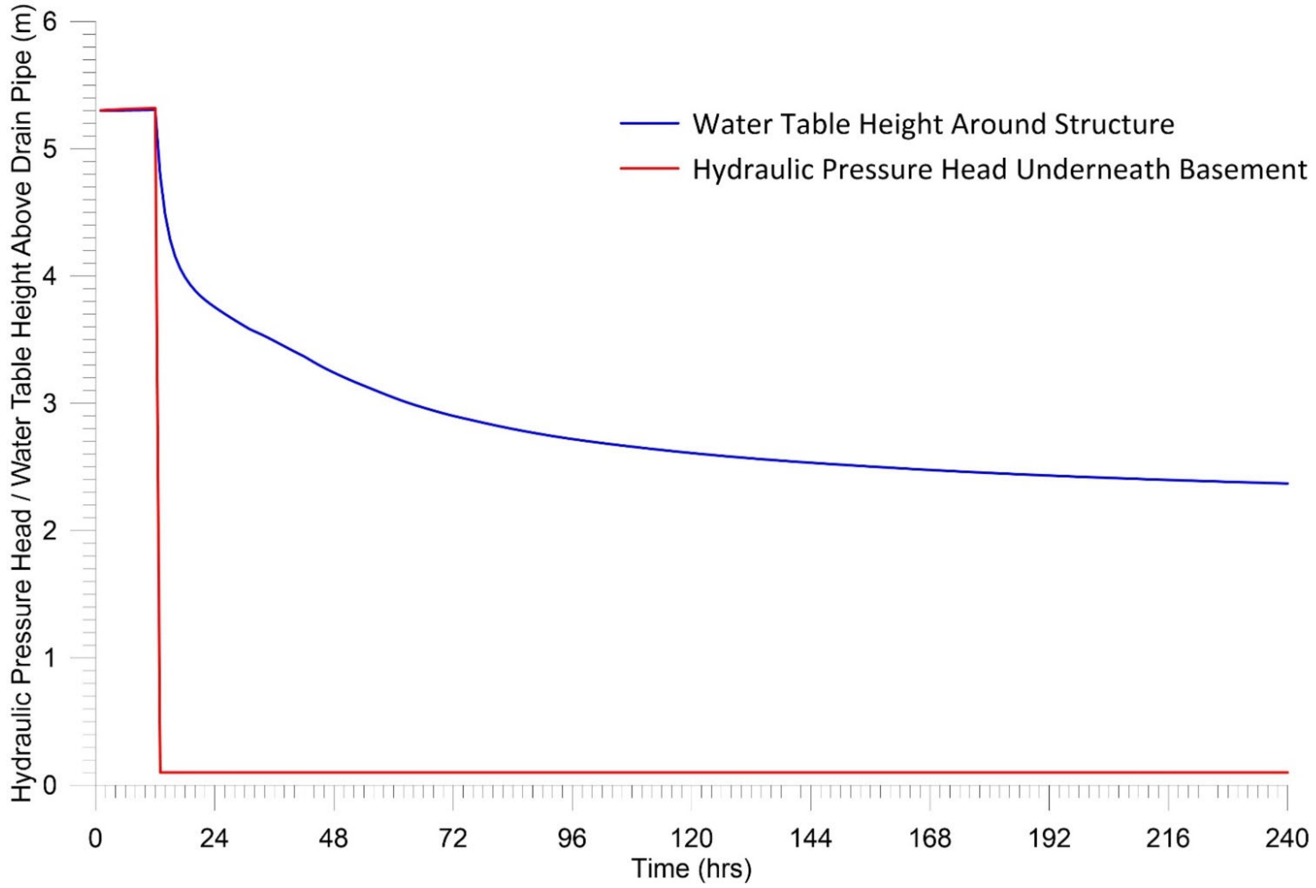

Figure 7-5: Simulated Hydraulic Pressure Head During Maintenance Dewatering

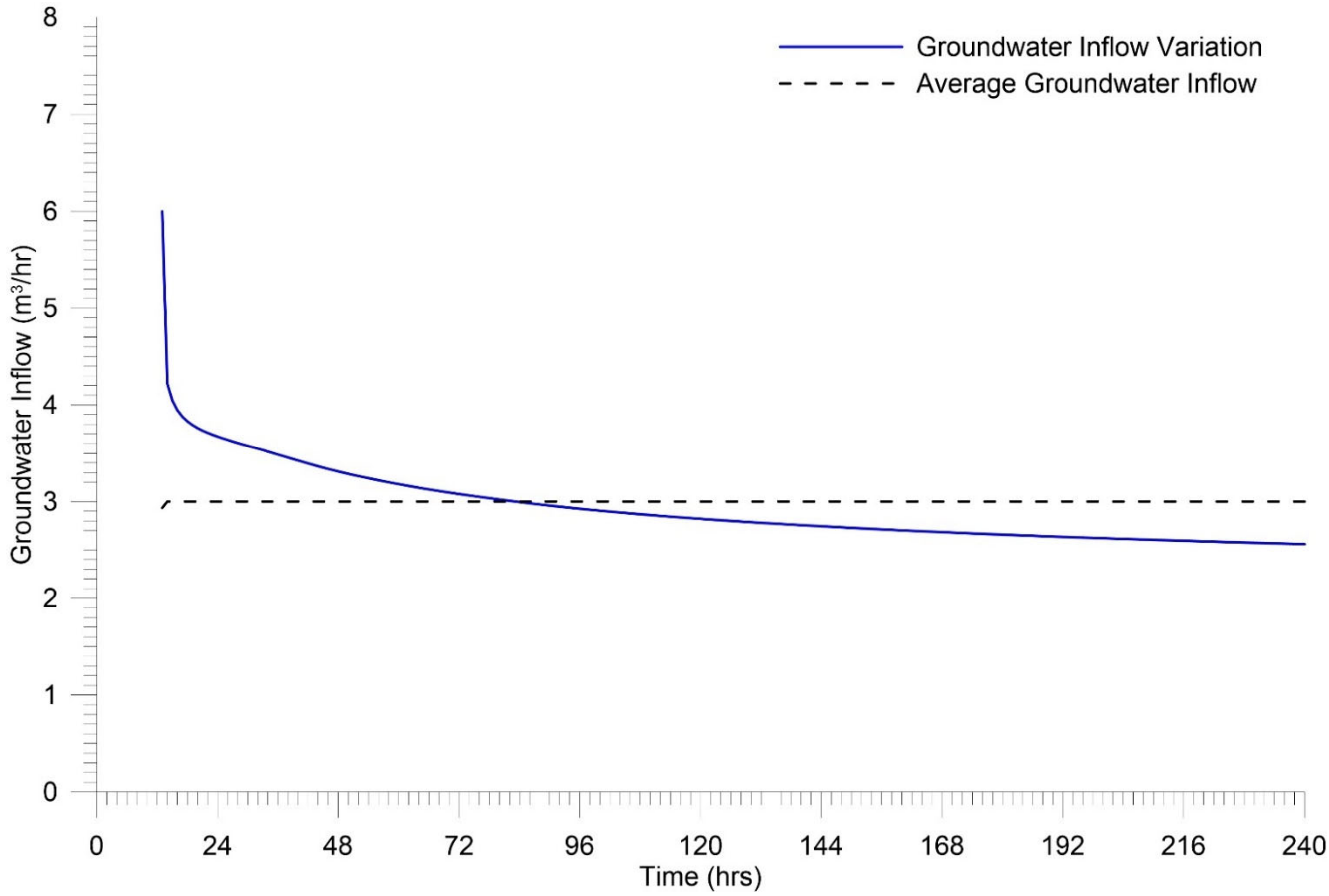

Figure 7-6: Simulated Groundwater Inflow During Maintenance Dewatering

8 Conclusions

A numerical model of regional extent has been developed for the AWRC to support evaluation of the risk posed on groundwater levels and quantities by the construction and operation of the AWRC. The model extent was selected to be remote to the anticipated hydraulic effects of the AWRC structures and to cover part of the AWRC pipelines crossing major tributaries, as well as incorporating nearby groundwater monitoring wells for M12 Motorway project and Western Sydney Airport project to improve model calibration.

The category of the groundwater numerical model for the AWRC site as documented in this report generally adheres to conditions that would define it as a Class 1 model with numerous attributes for Class 2 models. Aurecon considers that there is sufficient groundwater data near the AWRC site and the model can be used to provide reasonably reliable predictions of the likely conditions associated with the construction long-term post-construction phases.

The key findings, conclusions and recommendations of this assessment can be summarised as follows in line with the objectives of the modelling:

Scenario 1: Construction Phase

- The extent of influence due to construction dewatering is about 325 m from the central part of the bioreactor site as shown in **Figure 7-1** and **Figure 7-2**. Based on these modelling results, the impact of construction dewatering is expected to be of local extent, which will be contained within the extent of the footprint of the proposed AWRC site. Beyond this extent, the groundwater flow pattern is unimpacted.
- The impact of construction dewatering to South Creek baseflow has been assessed as being minor. A small section of about 650 m of the South Creek in Reach 10 and Reach 11 will be slightly affected.
- Simulated inflow rates for the eastern and the western bioreactors would stabilise at about 52 L/min and 28 L/min, respectively on average in about 30 days after the storage within pore space is drained. Initial inflow rates to achieve these equilibrium flow rates averages at about 7,900 L/Min and 4,800 L/Min, respectively for the eastern and the western bioreactors, in the first 30 days of pumping. This relates to the initial volume of water which will be released from draining pore spaces. **Figure 7-3** provides simulated cumulative volume of water which will be pumped in the assumed dewatering period for Stage 1 works. Based on these results, the total volume of pumped water in 365 days of the proposed Stage 1 construction schedule will be about 50 ML (31 ML + 19 ML). The simulated sensitivity of calculated inflows to model input parameters indicates that the maximum total volume of pumped water in 365 days could reach 100 ML depending on the hydraulic characteristics the dewatered sediments. The sensitivity of the extent of influence to the tested model parameter is marginal and is expected to be around 325 m stated above.
- It should be noted that DRNs cells for simulating construction dewatering were applied to an area approximately equal to the plan area of the bioreactor tanks. In reality, the sides of the excavation would be battered back at least 1 in 1.5, meaning that the overall dimension to be dewatered would be much bigger. Typically, the well array would be designed to dewater bigger area. It implies that actual flow rate may be higher than the estimate above, especially if the extent of the excavation work changes significantly or moved closer to the creek than compared to the layout assessed in this report. If significant changes are made to the designs assessed in this report, the modelling should be updated according. The estimated inflow rates above provide an initial understanding of dewatering requirements of the likely volumes to be dealt with as the basis for developing a Dewatering Plan for the AWRC works. However, the dewatering plan should be supported by further field tests such as pumping tests as outlined in **Section 5**.

Scenario 2: Operational Phase Modelling Results

- The modelling results show that the reduction in recharge across the AWRC when the proposed infrastructure has been built will result in local depression of the groundwater table. Inspection of the simulated water balance indicates a corresponding minor reduction (around 1%) of baseflow in the creek reaches close the site.
- For maintenance regimes, the modelling results for the required dewatering indicate that groundwater inflow will be very high initially (averaging 1,900 L/min) due to draining of pore water reducing to 40 L/min (2.6 m3/hr) for prolonged maintenance regimes of over 5 days. The simulated average inflow rate is 50 L/min (3 m^3/hr). Estimates of the total volume expected to be pumped for each maintenance regime should be assessed based on this average flow.

9 References

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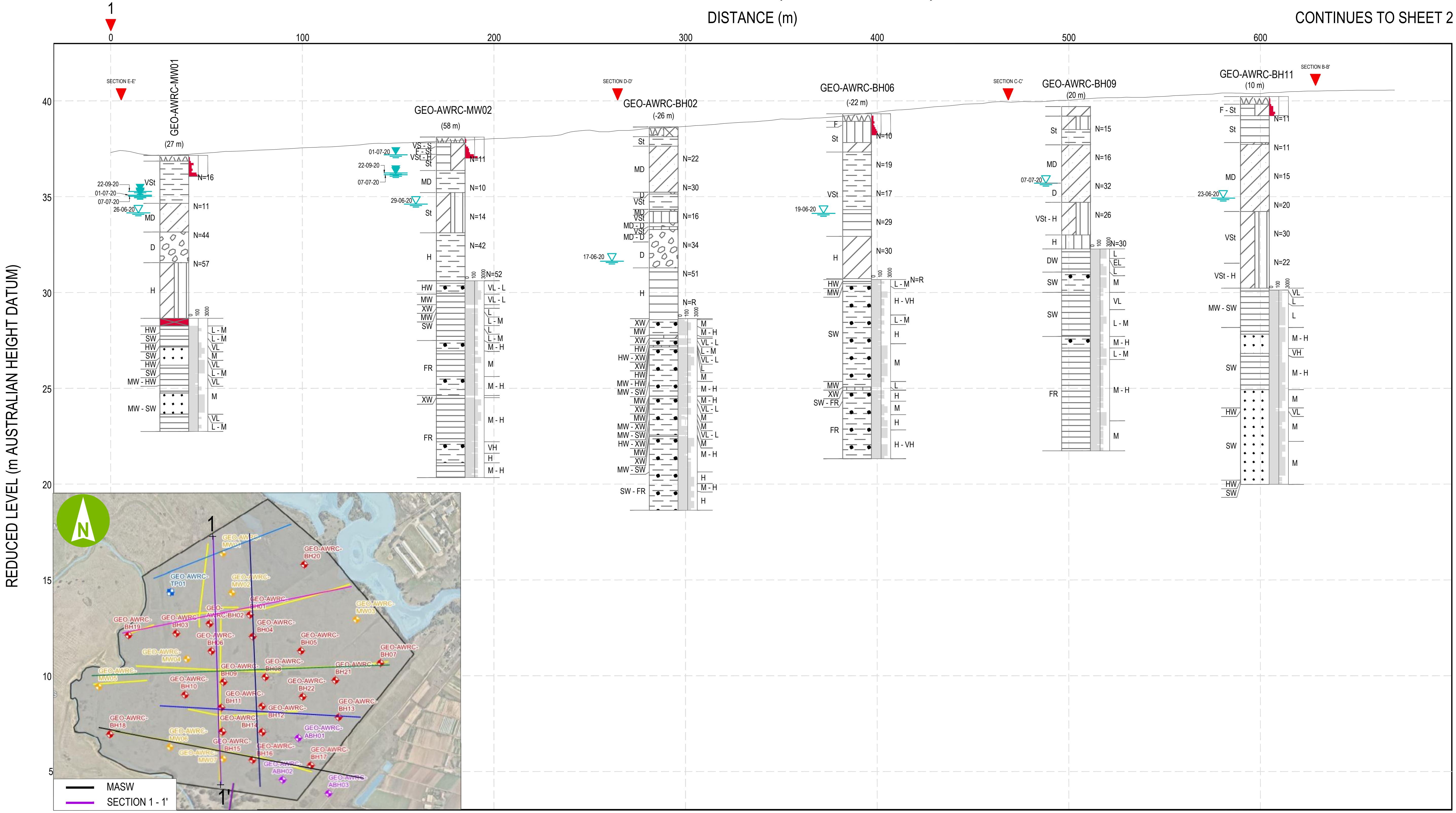
Appendix A – Geological Cross-sections

AWRC - SECTION 1 - 1' (SHEET 1 OF 2)



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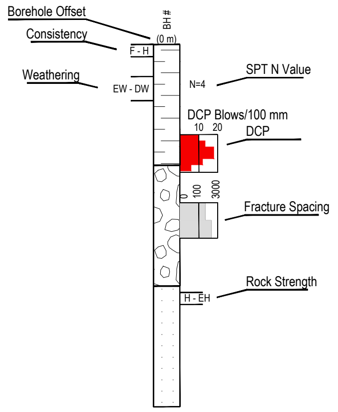


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING

EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m

V 1:200
0 2 4 6 8 10m

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

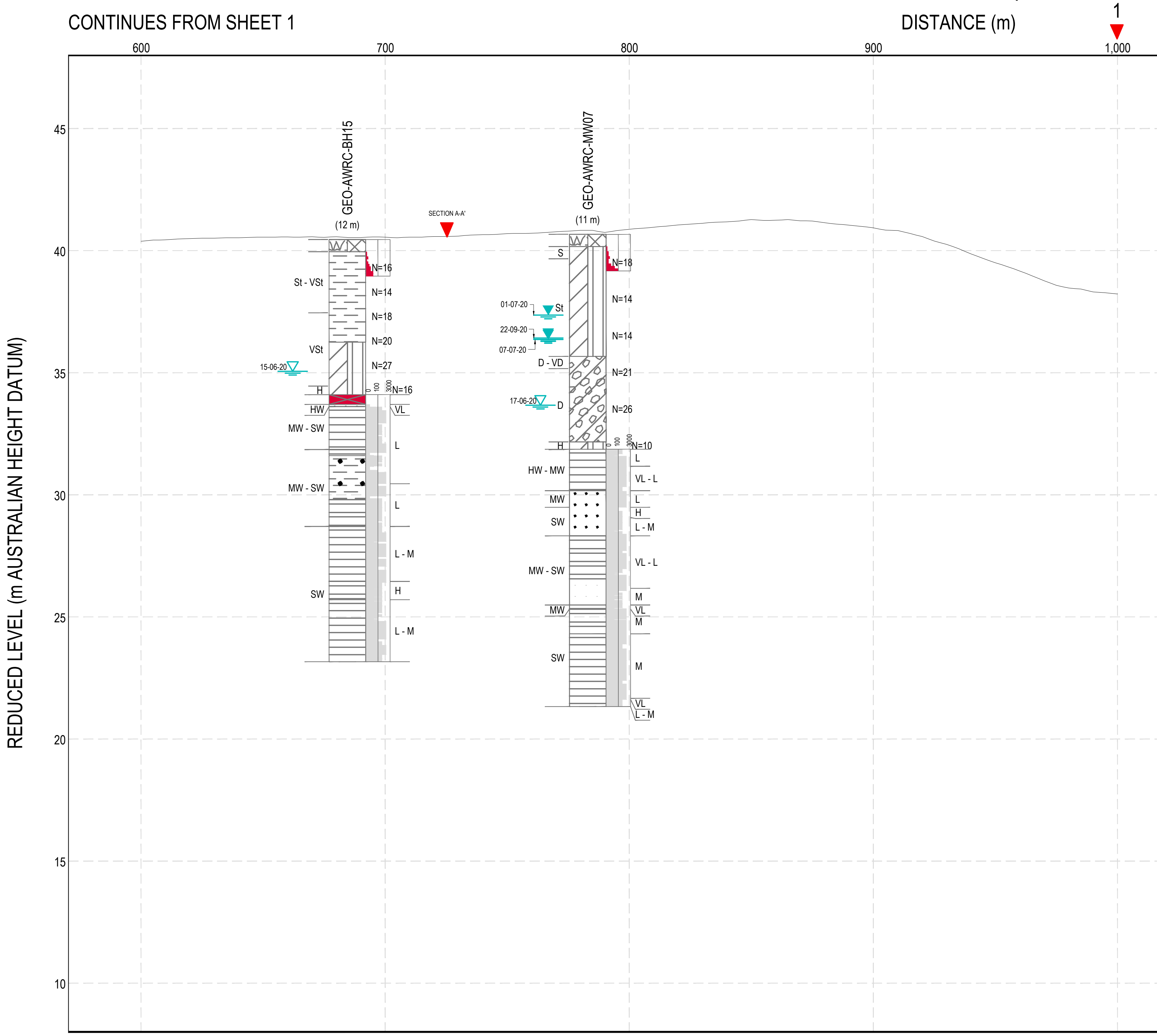
UPPER SOUTH CREEK AWRC

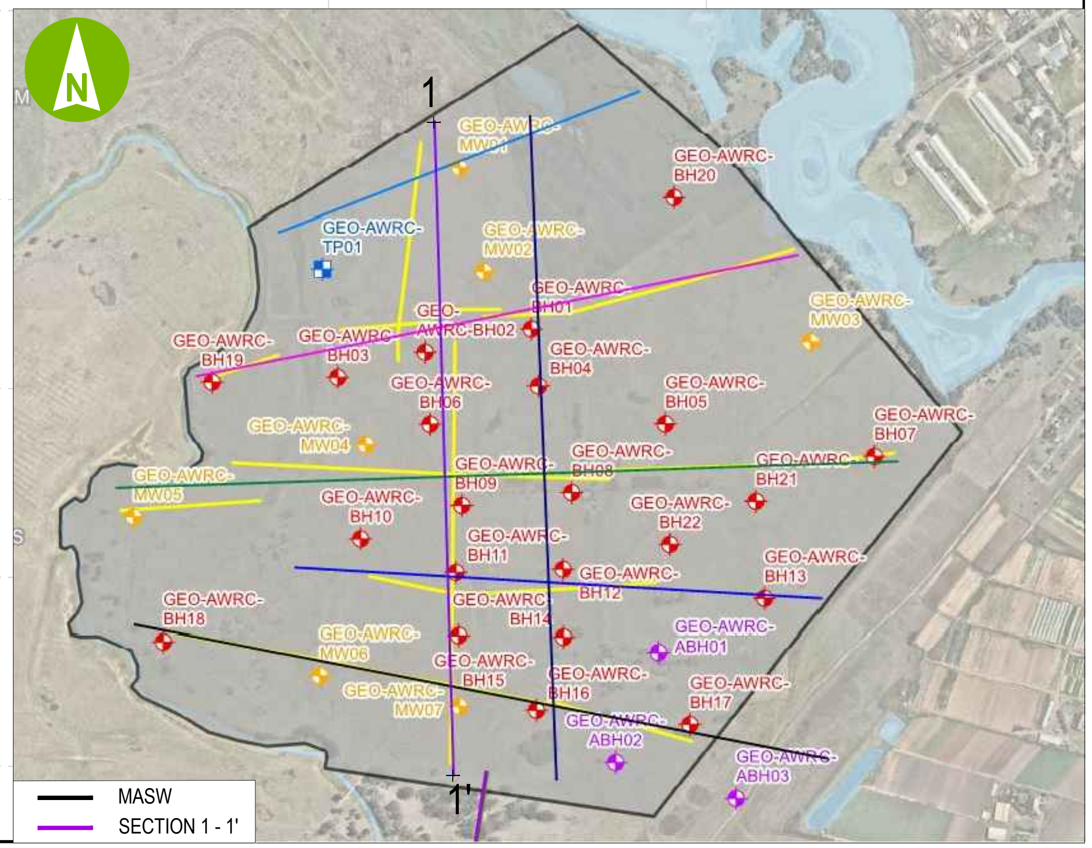
GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION 1 - 1' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1





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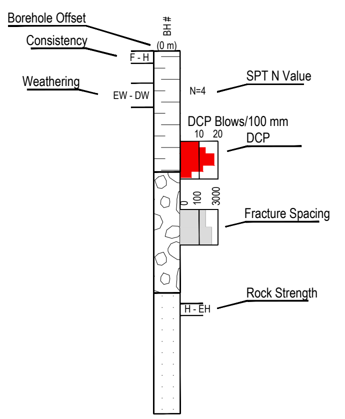


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY GRAVEL
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m

V 1:200
0 2 4 6 8 10m

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

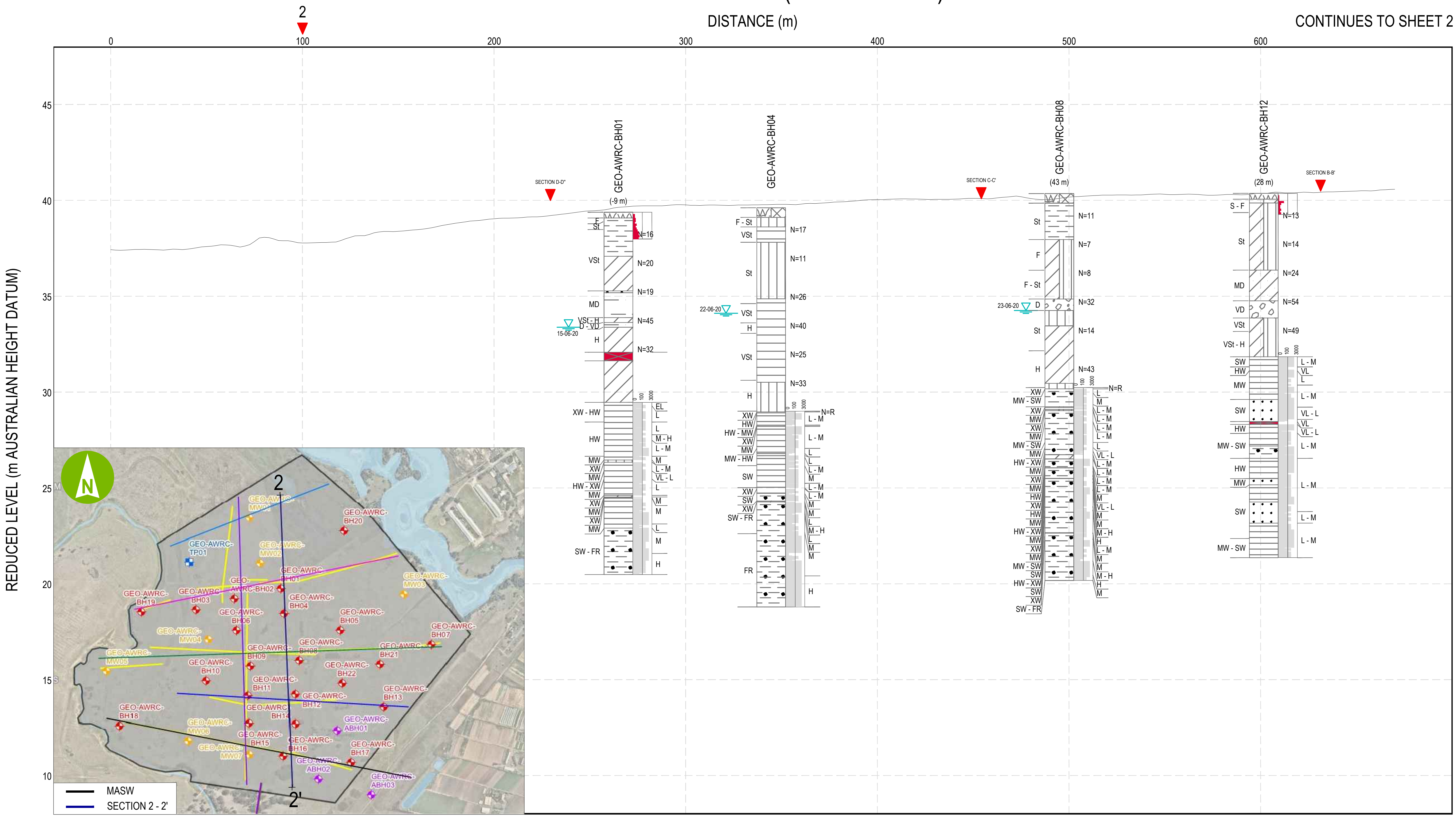
Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION 2 - 2' (SHEET 1 OF 2)



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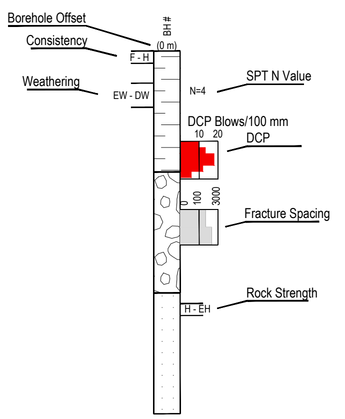

MATERIAL GRAPHIC

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- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- SAND - POORLY GRADED
- SAND - WELL GRADED
- GRAVEL - POORLY GRADED
- GRAVEL - WELL GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000 (0, 20, 40, 60, 80, 100m)

V 1:200 (0, 2, 4, 6, 8, 10m)

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

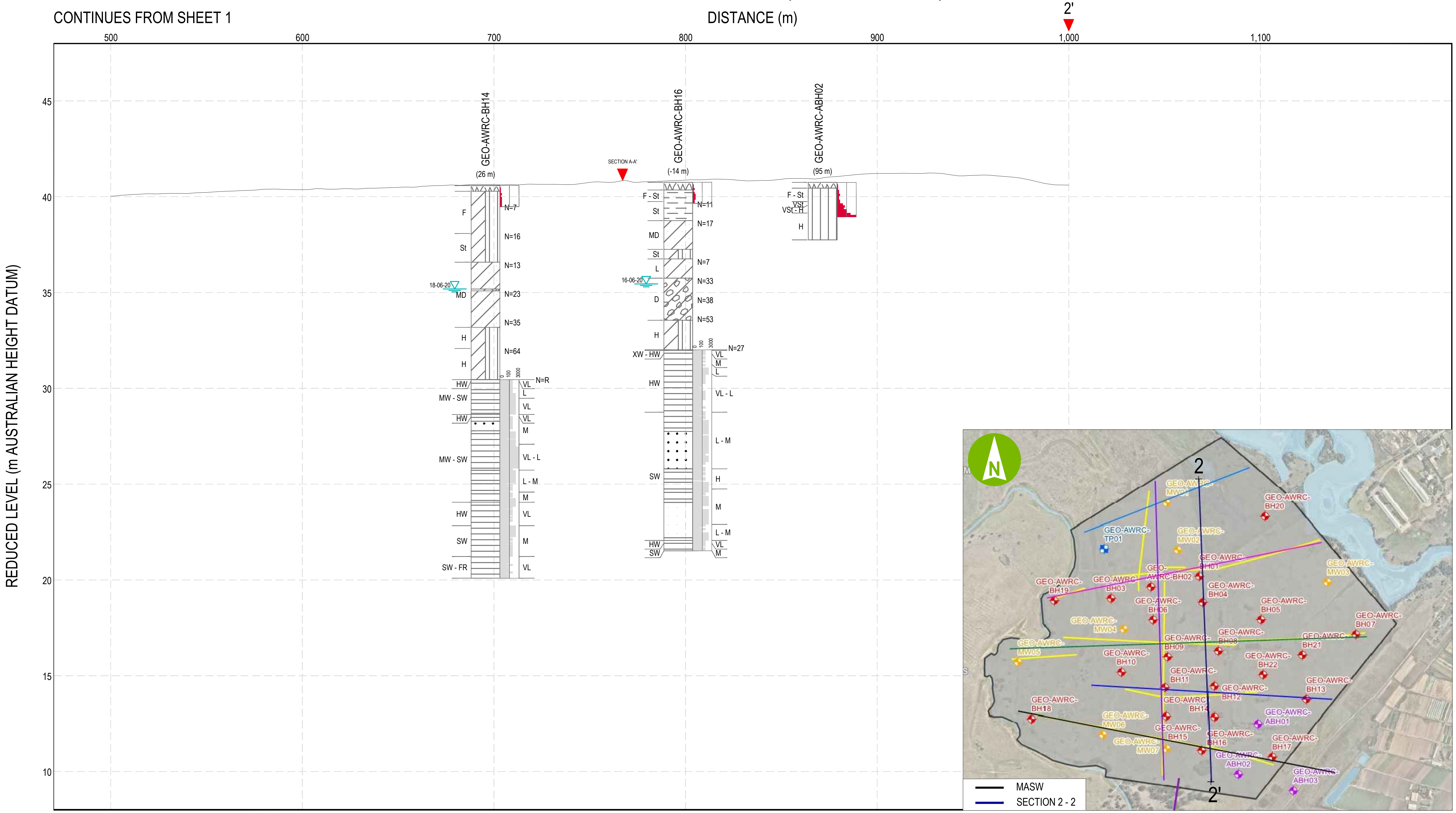
UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION 2 - 2' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1



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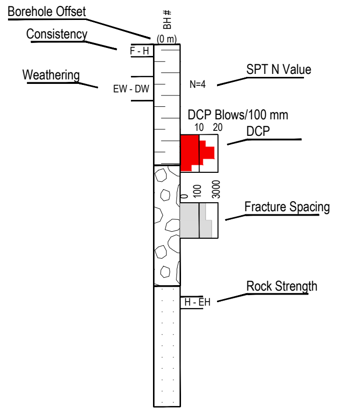

MATERIAL GRAPHIC

- TOPSOIL
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- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- CLAYEY GRAVEL
- GRAVEL - POORLY GRADED
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000 — 0, 20, 40, 60, 80, 100m

V 1:200 — 0, 2, 4, 6, 8, 10m

Coord.System: MGA94 Zone 56 Height Datum: AHD

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

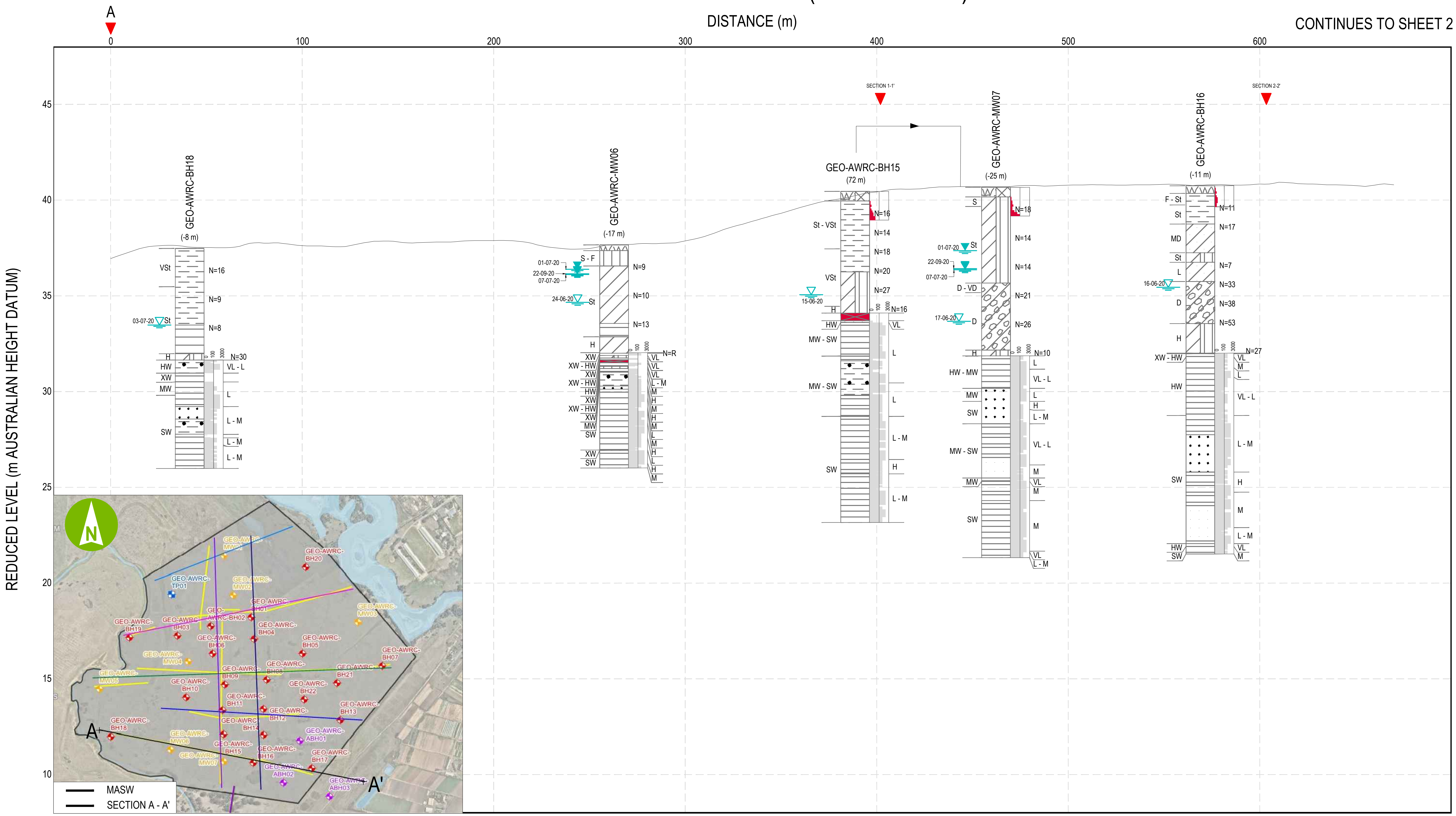
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION A - A' (SHEET 1 OF 2)



POST LEGEND

Borehole Offset
Consistency
Weathering
SPT N Value
DCP Blows/100 mm
DCP
Fracture Spacing
Rock Strength

MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- SILTY SAND
- CLAYEY GRAVEL
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000

0 20 40 60 80 100m

V 1:200

0 2 4 6 8 10m

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

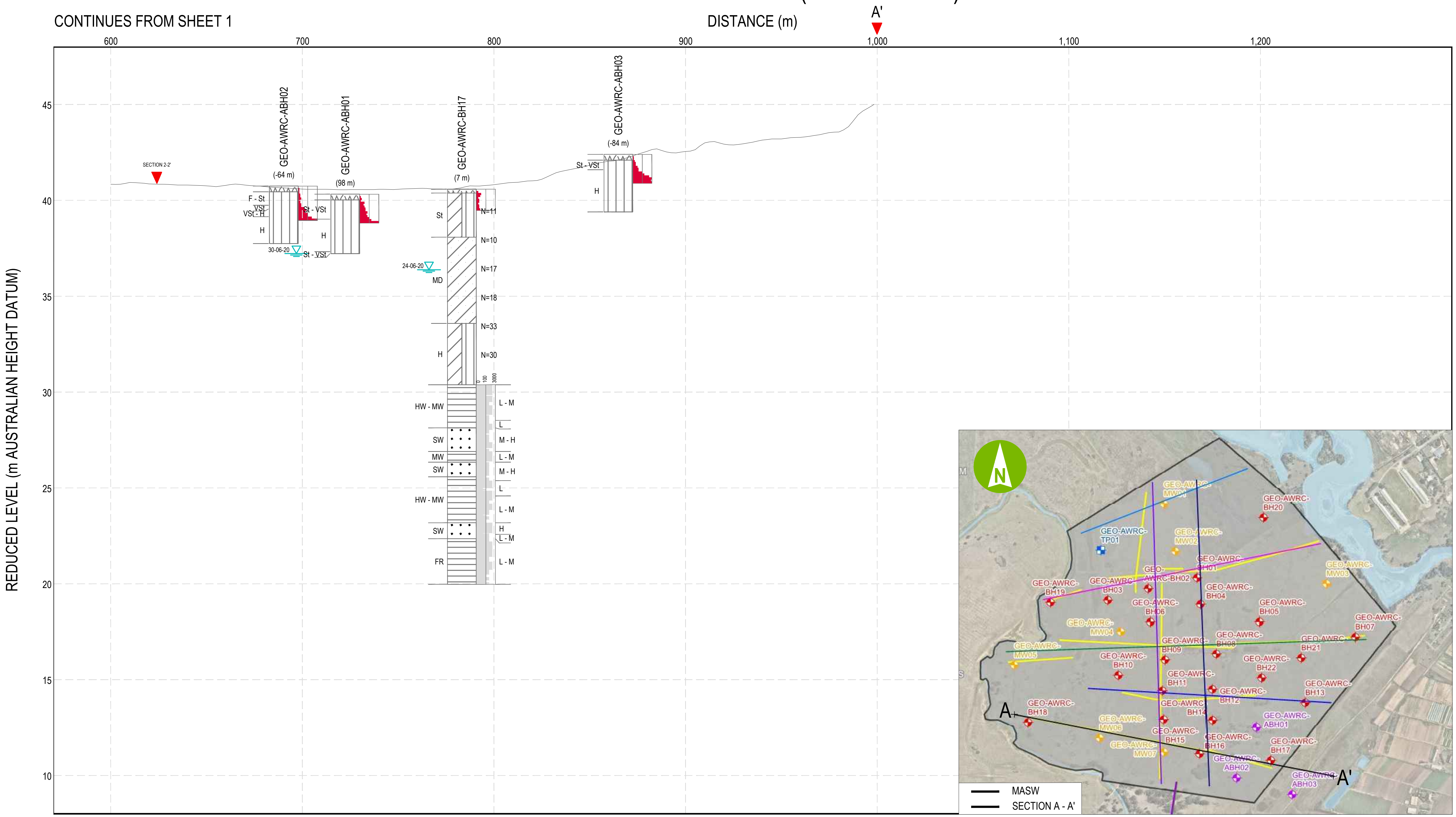
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION A - A' (SHEET 2 OF 2)



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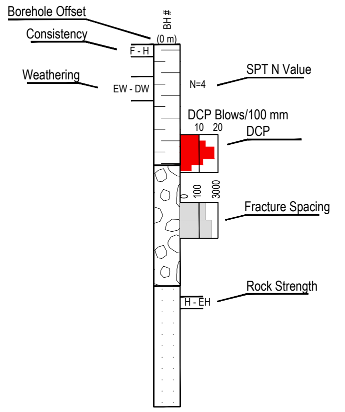

MATERIAL GRAPHIC

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- CLAY - HIGH PLASTICITY
- CLAYEY SAND
- SANDSTONE
- CLAYSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

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V 1:200
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Coord.System: MGA94 Zone 56 Height Datum: AHD

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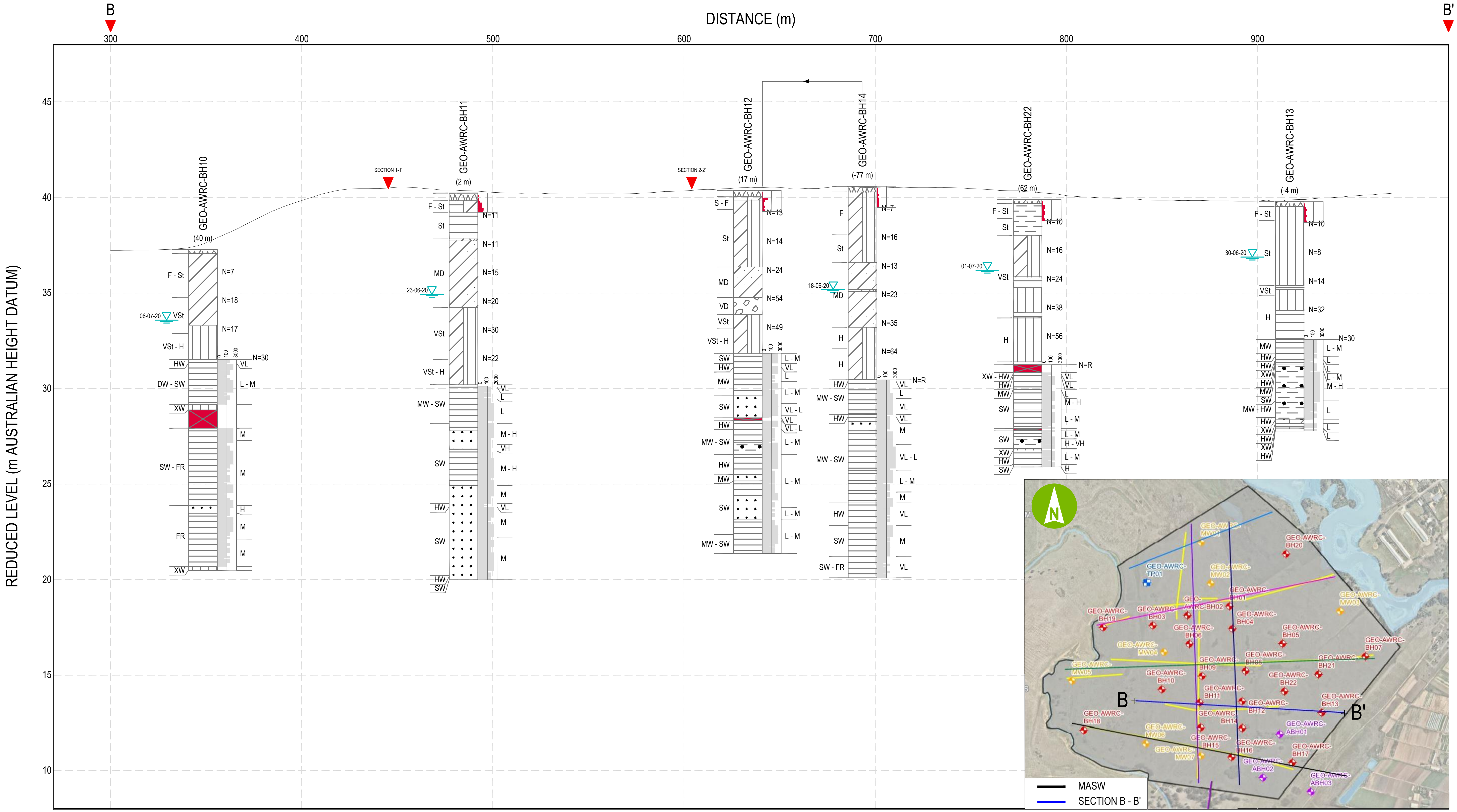
FINAL

Date: 30/10/2020 Version:0 Job No: 20036007
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION B - B'



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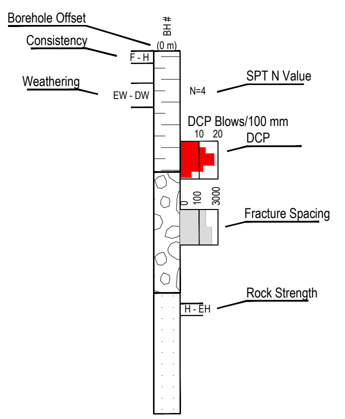

MATERIAL GRAPHIC

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- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

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V 1:200

0 2 4 6 8 10m

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

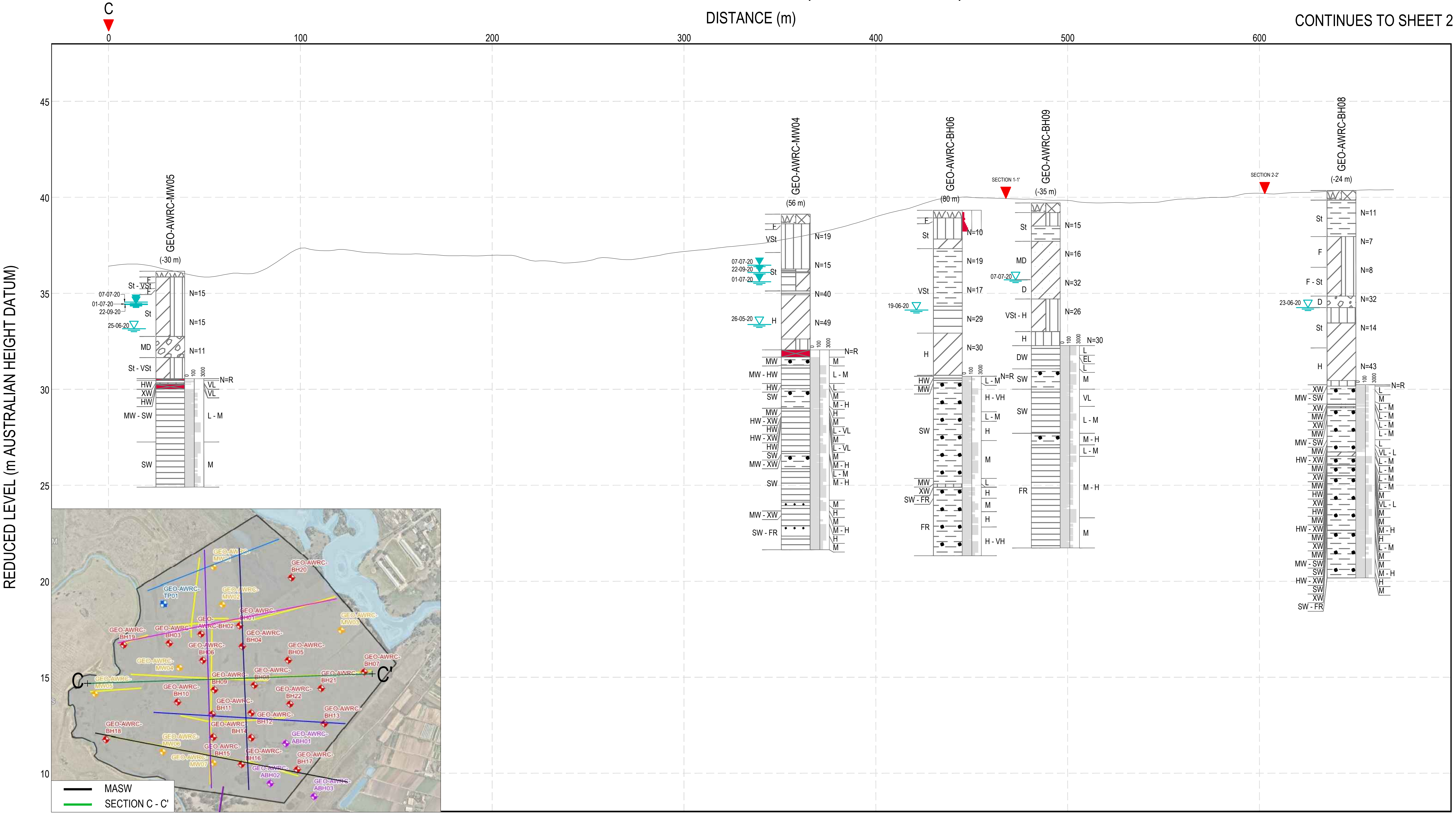
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION C - C' (SHEET 1 OF 2)



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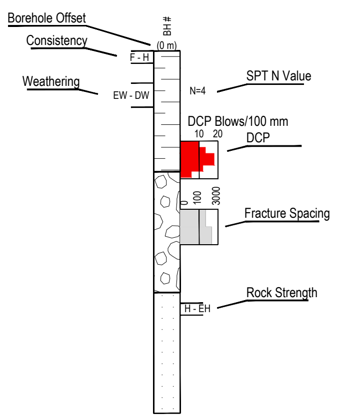

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- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- CLAYEY GRAVEL
- GRAVEL - WELL GRADED
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

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V 1:200 (0, 2, 4, 6, 8, 10m)

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

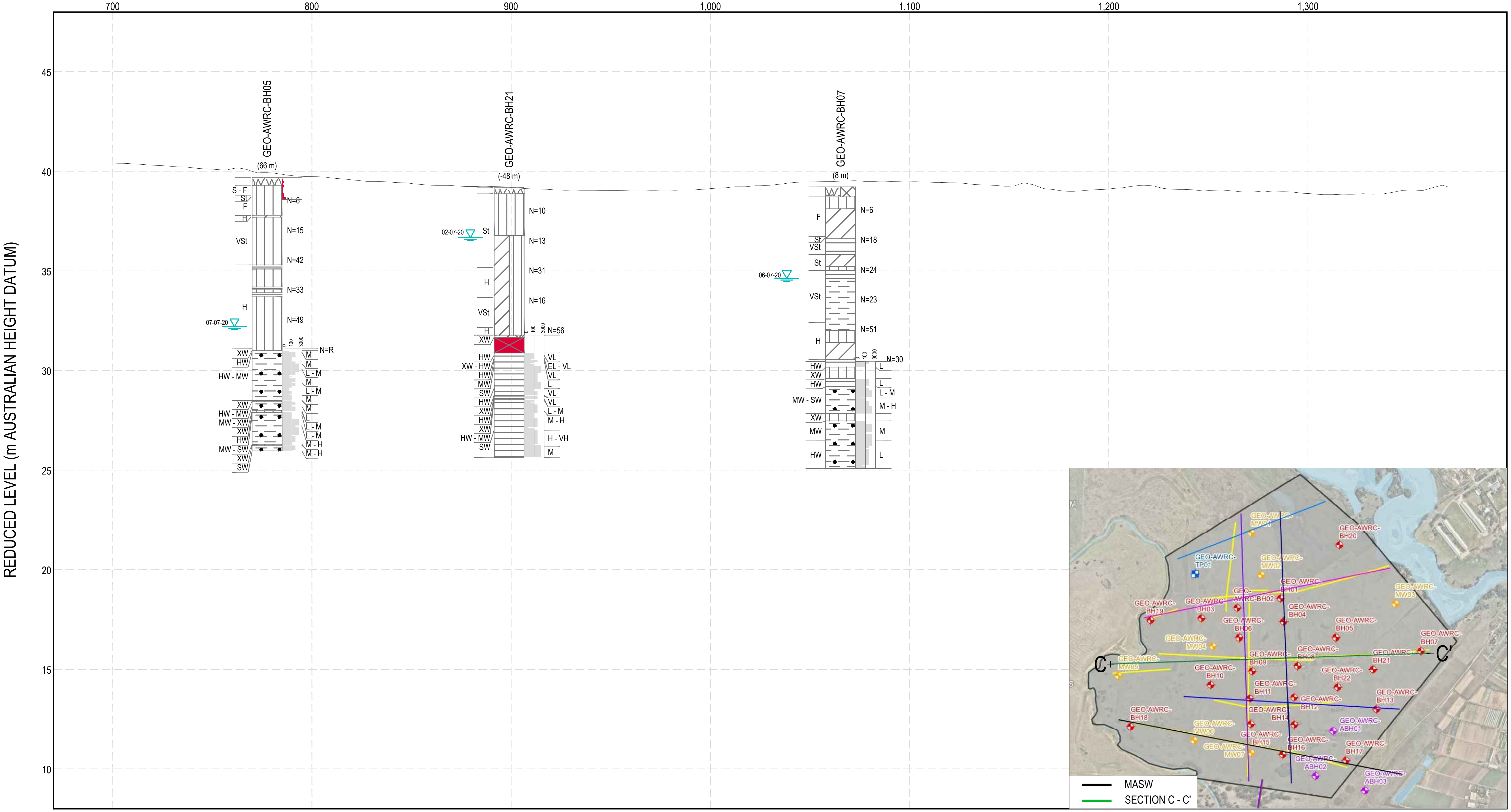
UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION C - C' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1



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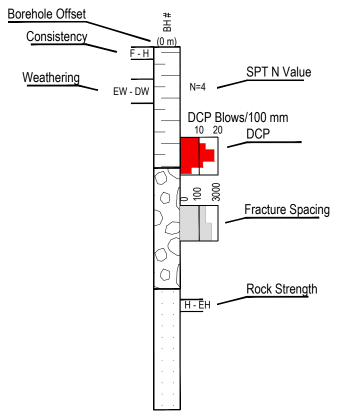

MATERIAL GRAPHIC

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- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- CLAYEY GRAVEL
- CORE LOSS
- CLAYSTONE
- LAMINITE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000 (0, 20, 40, 60, 80, 100m)

V 1:200 (0, 2, 4, 6, 8, 10m)

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

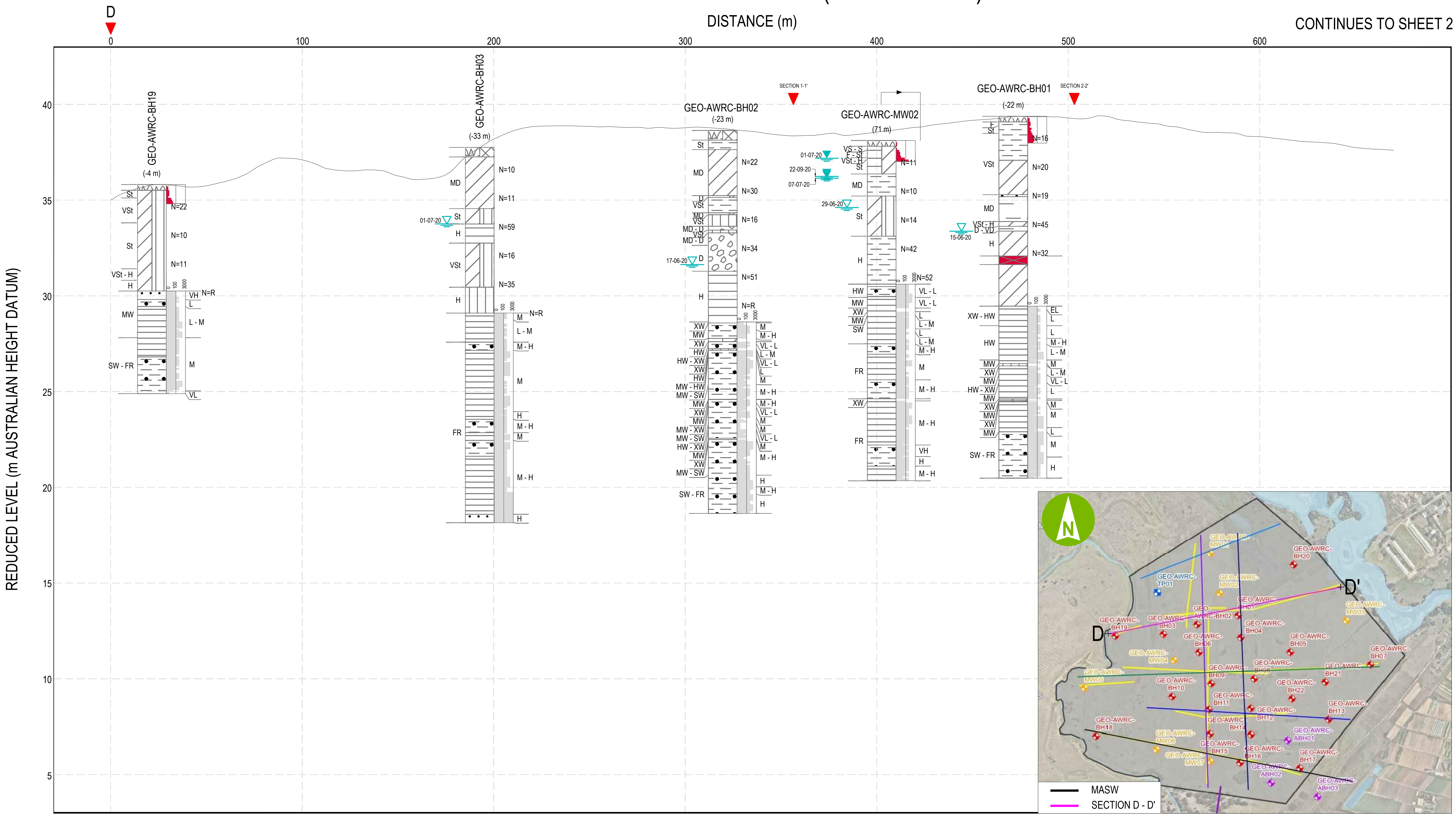
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION D - D' (SHEET 1 OF 2)



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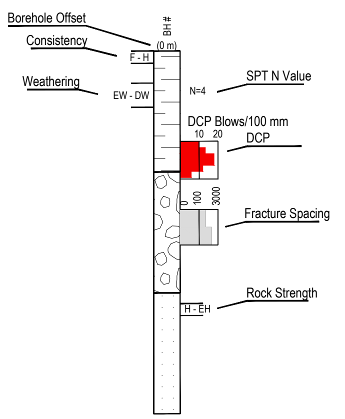

MATERIAL GRAPHIC

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- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- SAND - POORLY GRADED
- SAND - WELL GRADED
- GRAVEL - POORLY GRADED
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m
V 1:200
0 2 4 6 8 10m
Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

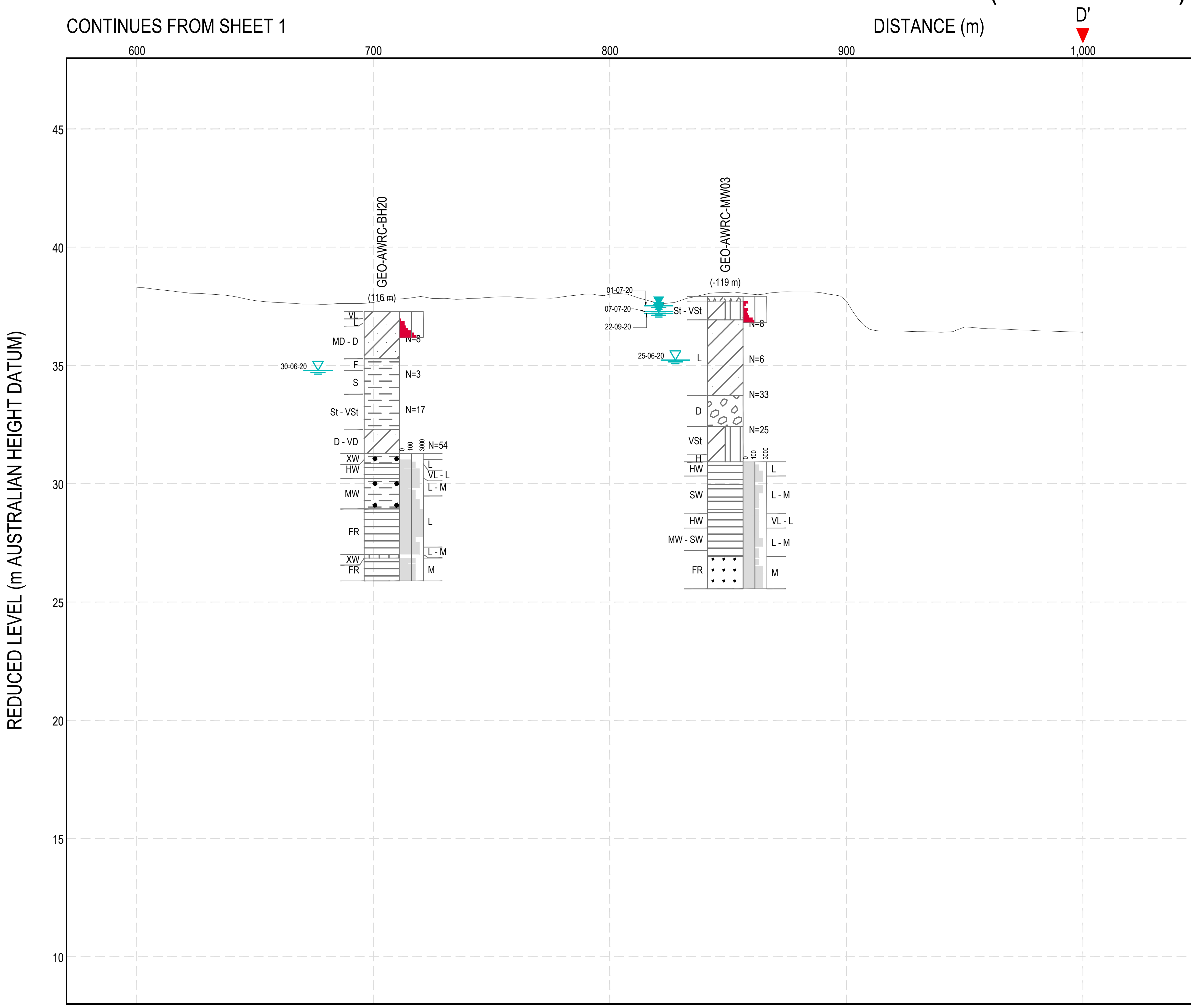
Date: 30/10/2020 Version:0 Job No: 20036007

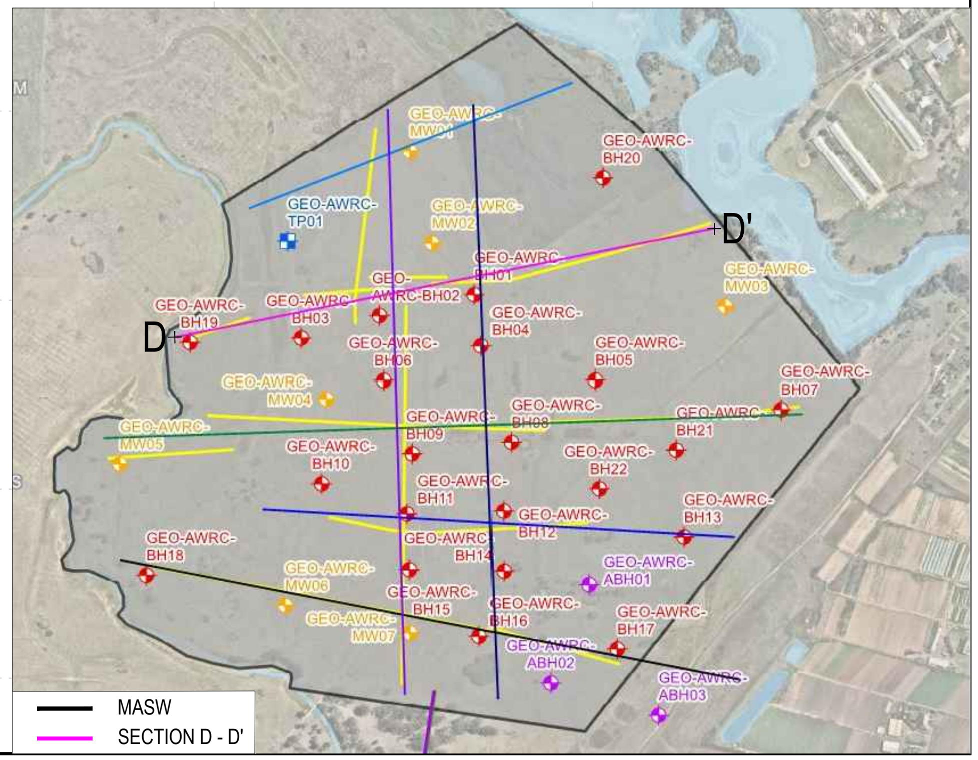
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION D - D' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1





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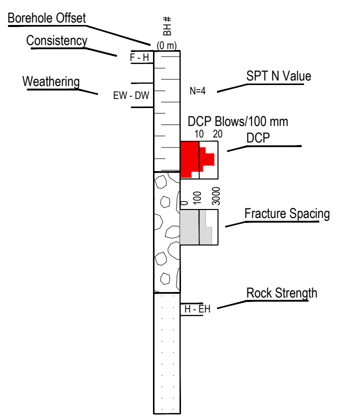


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000 (0, 20, 40, 60, 80, 100m)

V 1:200 (0, 2, 4, 6, 8, 10m)

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

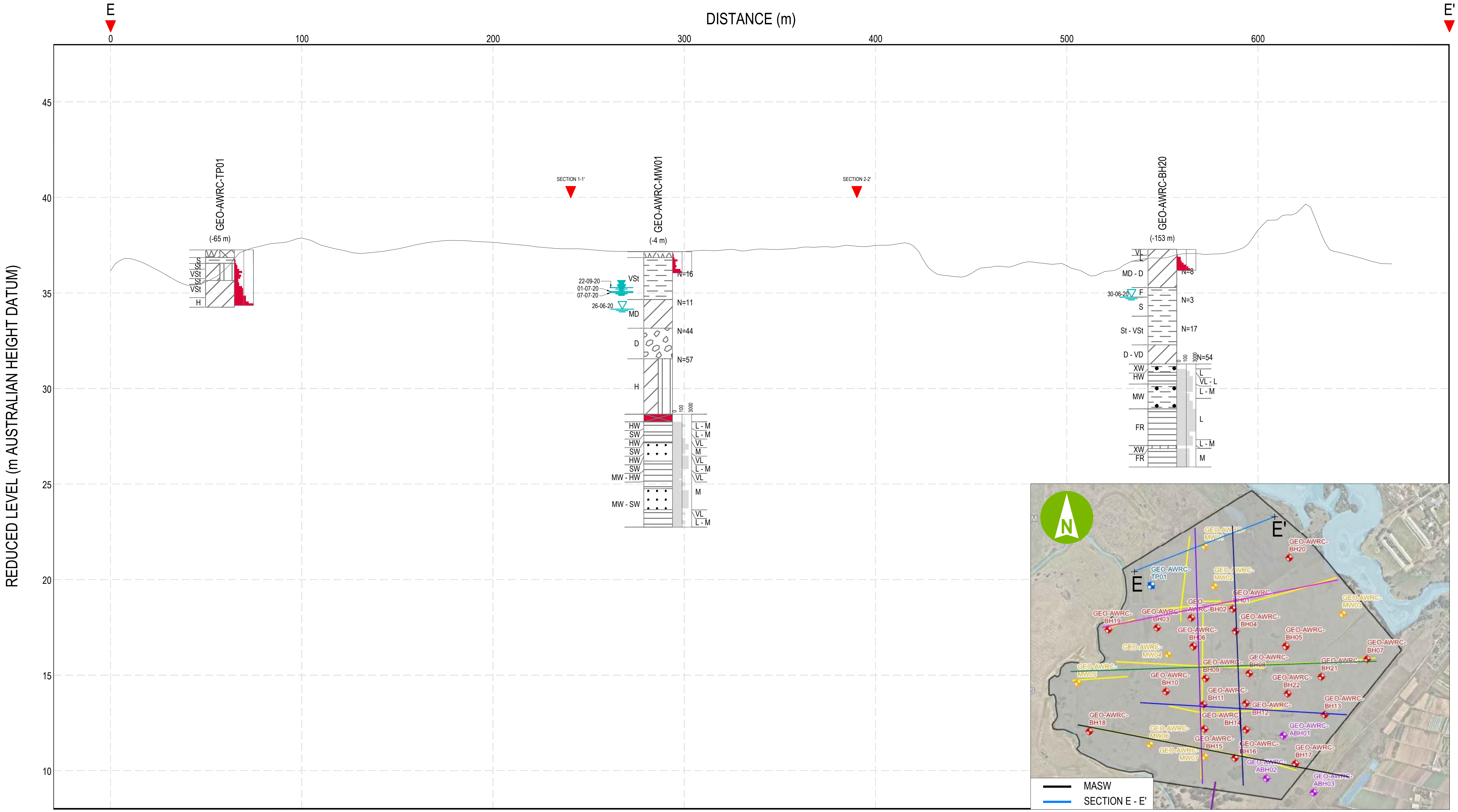
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION E - E'



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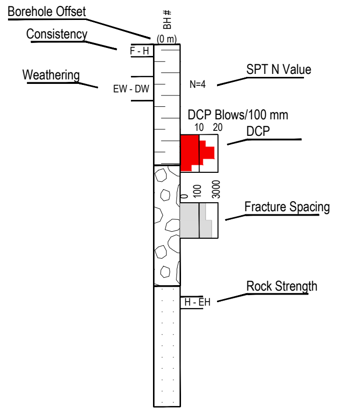


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- EXISTING SURFACE LEVEL
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING

H 1:2000

V 1:200

Coord.System: MGA94 Zone 56 Height Datum: AHD

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

Appendix B – Marinelli and Niccoli (2000) Spreadsheet model

Spreadsheet for calculating radius of influence (ROI) r_o using Niccoli et al. (1998) method.

$$h_0 = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_0^2 \ln\left(\frac{r_0}{r_p}\right) - \frac{(r_0^2 - r_p^2)}{2}\right]} \quad \ldots\ldots\ldots (1)$$

Equation (1) applied in cell J12

Legend
Input
Calculated
Goal Seek Cell J12 Set to Value - h_0 By Changing - r_0 cell J20
Calcuated Iteratively By Goal Seek Function. Choose Initial Value That is Close to r_o.

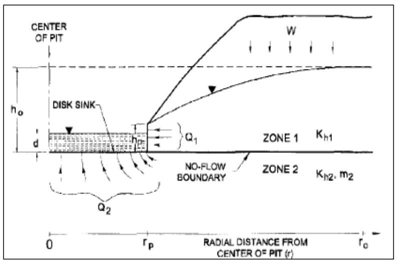
Scenario:

Height of water table at radius of influence (r_0) - Eq (1) Solved by Goal Se	h_0	5.30	m
Saturated thickness above the base of Zone 1 at r_p (saturated thickness at pit wall)	h_p	0.0	m
	K_{h1}	0.14	m/d
Horizontal hydraulic conductivity of material within Zone 1		1.62E-06	m/s
Distributed recharge flux	W	41.8	mm/yr
		1.15E-04	m/d
Effective pit radius	r_p	30.28	m
Radius of of influence (maximum extent of the cone of depression)	r_0	167	m
		183	m
	Rounded to		

General calcs

Maximum Area (A) of Disturbance 64m (L) x 45m (W)		Equivalent/Effective Pit Radius r_p $r_p = \sqrt{A/\pi}$
(ha)	(m^2)	(m)
0.288	2880	30.28

Maximum groundwater level		0	mbgl
Drawdown during dewatering		5.3	mbgl
Height of water table at r_0 above Zone 1 base	h_o	5.3	m
Saturated thickness at pit wall during dewatering operation	h_p	0	m
Saturated thickness at pit wall post closure	h_p	-	m



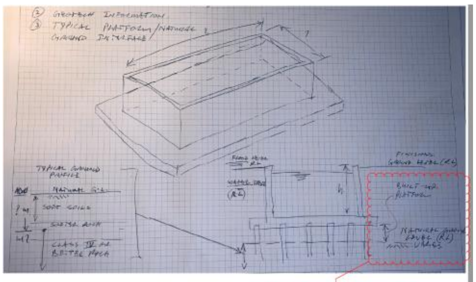
The following assumptions apply to this equation for Zone 1 / Layer 1:
- Steady-state, unconfined, horizontal radial flow.
- Uniformly distributed recharge at the water table.
- Pit walls are approximated as a right circular cylinder.
- The static (premining) water table is approximately horizontal.
- Groundwater flow is horizontal.
- Groundwater flow toward the pit is axially symmetric.

40.5 35.7 #FIELD! 35.2 5.3

Sources of Data:

Type	Model Data		Source
Pit design details	Foundationelevation information		Bioreactor design details as @ 09/07/2020 (Rev 100% Design
	Maximum area of disturbance at any time		Bioreactor design details as @ 09/07/2020 (Rev 100% Design
	Effective radius of pit	r_p	Disturbance area approximated to a circular geometrey
Groundwater Information	Maximum historical groundwater elevation site		Assumed worst case scenario with water level at ground
	Saturated thickness above the base of Zone 1 at r_p (saturated thickness at pit wall)	h_p	Assumption for the conditions during operation
	Height of water table at r_0 above Zone 1 base	h_o	Estimated from maximum groundwater elevation
	Horizontal hydraulic conductivity of material within Zone 1 (layer 1)	K_{h1}	Draft. Environment Impact Statement. Second Sydney Airport Proposal.
	Recharge	W	GHD (2015). Department of Infrastructure and Regional Development. Western Sydney Airport EIS Groundwater Impact Assessment

Prepared by: F Rusinga
Date: 12/07/2020



Natural ground level is close to the finished ground level. Temporary excavation is required.

Spreadsheet for calculating flow to a using Niccoli et al. (1998) method which applies separate solutions for the sides and the base.
This is a follow from ROI spreadsheet which determines the ROI for this procedure

Scenario:

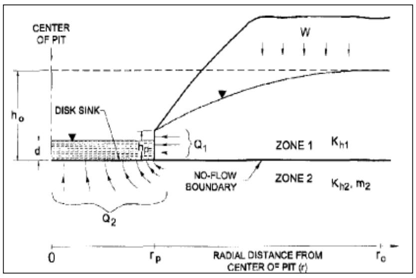
$$Q_1 = W\pi\left(r_0^2 - r_p^2\right) \ldots\ldots\ldots (2)$$

$$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)(h_0 - d) \ldots\ldots\ldots (3)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}} \ldots\ldots\ldots (4)$$

Input	
Calculated	

Head			
Height of water table at radius of influence	h_0	5.3	m
Depth of ponded area	d	0.0	m
Layer 2	From ROI worksheet		
Horizontal hydraulic conductivity	K_{h2}	0.14	m/d
		1.62E-06	m/s
Vertical hydraulic conductivity (2 to 3 time lower than Kh - PPK (1999))	K_{v2}	0.14	m/d
		1.62E-06	m/s
Anisotropy parameter - Eq (4)	m_2	1.0	
Distributed recharge flux	W	1.15E-04	m/d
		1.33E-09	m/s
Radius of quarry	r_p	30.28	m
Radius of of influence	r_0	167	m
Can be taken from ROI worksheet or other source			
Inflow			
Inflow through seepage face - Eq (2)	Q_1	1.13E-04	m^3/s
		0.11	L/s
		0.41	m^3/h
		9.75	m^3/d
Inflow through pit base - Eq (3)	Q_2	1.04E-03	m^3/s
		1.04	L/s
		3.74	m^3/h
		89.87	m^3/d
Total inflow	Q_T	1.15E-03	m^3/s
		1.15	L/s
		4.2	m^3/h
		99.6	m^3/d



The following assumptions apply to this equation:
- There is no groundwater flow between zones 1 and 2.

Zone 1
- Steady-state, unconfined, horizontal radial flow.
- Uniformly distributed recharge at the water table.
- Pit walls are approximated as a right circular cylinder.
- The static (premining) water table is approximately horizontal.
- Groundwater flow is horizontal.
- Groundwater flow toward the pit is axially symmetric.

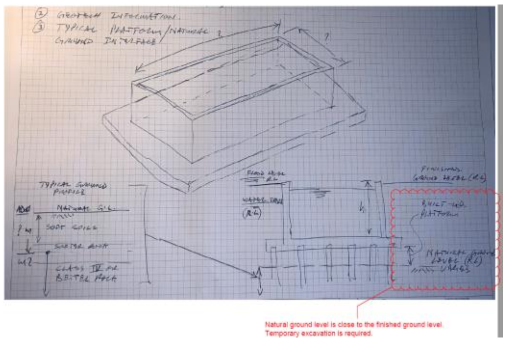
Zone 2
-Steady state flow to one side of a circular disk sink of constant and uniform
drawdown.
- hydraulic head is initially uniform throughout Zone 2.
- Initial head is equal to the eleveation of the initial water table in Zone 1.
- Flow to the disk is 3-dimensional and axially symmetric.

General calcs

Maximum Area (A) of Disturbance 64m (L) x 45m (W)		Equivalent/Effective Pit Radius r_p $r_p = \sqrt{A/\pi}$
(ha)	(m^2)	(m)
0.288	2880	30.28

From ROI worksheet

Maximum groundwater level		0	mbgl
Drawdown during dewatering		5.3	mbgl
Height of water table at r_0 above Zone 1 base	h_o	5.3	m
Saturated thick. at pit wall during dewatering operatio	h_p	0	m
Saturated thickness at pit wall post closure	h_p	-	m



Sources of Data:

Type	Model Data		Source
Pit design details	Foundation elevation information		Bioreactor design details as @ 09/07/2020 (Rev 100%
	Maximum area of disturbance at any time		Bioreactor design details as @ 09/07/2020 (Rev 100%
	Effective radius of pit	r_p	Disturbance area approximated to a circular geometry
Groundwater Information	Maximum historical groundwater elevation site		Assumed worst case scenario with water level at ground
	Saturated thickness above the base of Zone 1 at r_p (saturated thickness at pit wall)	h_p	Assumption for the conditions during operation
	Height of water table at r_0 above Zone 1 base	h_o	Estimated from maximum groundwater elevation
	Horizontal hydraulic conductivity of material within Zone 2 (layer 2)	K_{h1}	PPK (1999).
	Vertical hydraulic conductivity of material within Zone 2 (layer 2)	K_{v2}	PPK (1999).
	Recharge	W	GHD (2015)

Appendix B – Pipeline Groundwater Analytical Calculations

Trenched Pipeline Groundwater Impacts - Analytical Calculation Summary

Pipeline Section	Groundwater Source Area	Approximate Trenched Pipe Lay Rate (m/day)	Approximate Trenched Pipe Length (m)	Approximate Trenched Construction Duration* (days)	Simulated Groundwater Drawdown (m)	Calculated Maximum Radius of Influence (m)	Estimated Groundwater Inflow Rates (m^3/day)			Estimated Total Groundwater Inflow (m^3)			Assessment against minimal groundwater level/availability criteria (Section 2.3)
							Min	Expected	Max	Min	Expected	Max	
Environmental Flows Section 1: Mid-Nepean HGL	Sydney Basin Nepean	24	1850	26	3.2	44.0	0.4	17.1	238.8	28.1	1335.4	18626.4	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Environmental Flows Section 2: Hawkesbury HGL	Sydney Basin Nepean		0	0	Horizontal Directional Drilling (HDD) only. No trenched component.								
Treated Water Section 1: Mid-Nepean HGL	Sydney Basin Nepean	24	1000	14	3	54.0	0.3	13.2	183.5	11.8	552.3	7708.7	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 2: Mulgoa HGL	Sydney Basin Central	18	2790	52	1.3	34.7	0.2	6.9	96.9	23.4	1082.6	15121.1	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 3: Greendale HGL	Sydney Basin Central	24	3400	48	1.1	17.5	0.5	4.0	27.4	76.3	581.8	3941.3	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 4: Mulgoa HGL	Sydney Basin Central	24	1250	18	0.9	30.1	0.1	5.8	80.5	6.5	311.6	4346.5	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Treated Water Section 5: Upper South Creek HGL	Sydney Basin Central	24	6250	87	0.9	37.1	0.1	4.7	65.4	26.1	1224.1	17061.6	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 1: Upper South Creek HGL	Sydney Basin Central	24	4800	67	1.4	26.2	0.2	10.1	141.5	44.2	2038.1	28431.5	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 2: Mount Vernon HGL	Sydney Basin Central	24	2500	35	1.8	17.0	0.9	6.6	44.5	90.3	687.8	4668.3	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 3: Denham Court HGL	Sydney Basin Central	24	1200	17	1.9	18.5	0.8	6.4	43.0	42.3	323.9	2194.0	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Brine Section 4: Upper South Creek (A) HGL	Sydney Basin Central	12	11800	328	0.3	51.0	0.02	0.8	10.7	19.7	757.7	10519.0	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 5: Moorebank HGL	Sydney Basin Central	12	30	3	4.7	40.9	0.2	7.8	109.3	0.5	23.5	327.9	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Totals					N/A	N/A	N/A	N/A	N/A	369.2	8918.6	112946.1	

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	5.7	m	5.7	5.7	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	27.42	m	5.06	44.00	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

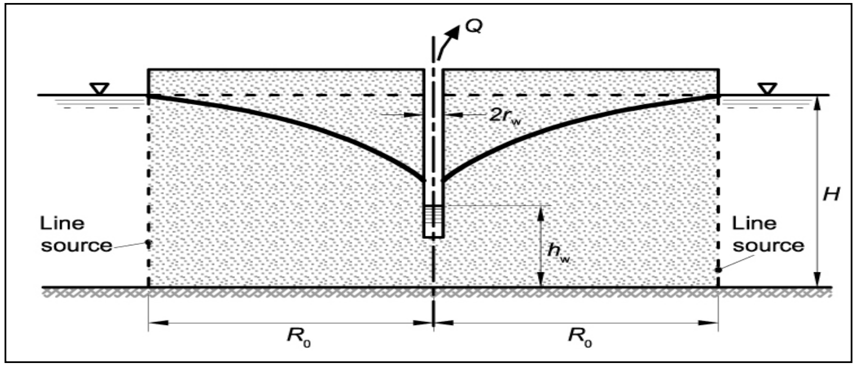
Environmental Flows Section 1: Mid-Nepean Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	9	m	9	9	m
Height of water table at well	h_w	5.8	m	5.8	5.8	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	*x*	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	27.42	m	5.06	44	m
Is R_0/H greater than or equal to 3 ?		Yes		No	Yes	
Total discharge from wellpoints	**Q**	17.12	m^3/d	0.36	238.80	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mid-Nepean HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Essential input	
Optional input	
Calculated	

		expected		min	max	
Drawdown in well	s	7	m	7.0	7.0	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	33.68	m	6.21	54.03	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

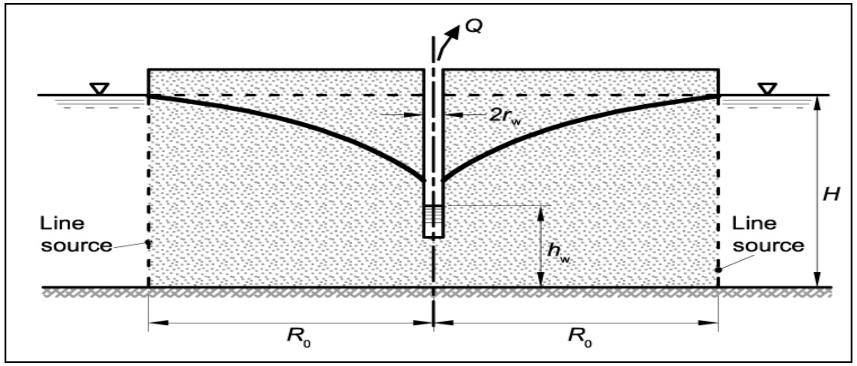
Treated Water 1: Mid-Nepean Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	9	m	9	9	m
Height of water table at well	h_w	6	m	6	6	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	*x*	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	33.68	m	6.21	54.04	m
Is R_0/H greater than or equal to 3 ?		Yes		No	Yes	
Total discharge from wellpoints	**Q**	13.15	m^3/d	0.28	183.54	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mid-Nepean HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	4.5	m	4.5	4.5	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	21.65	m	3.99	34.74	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

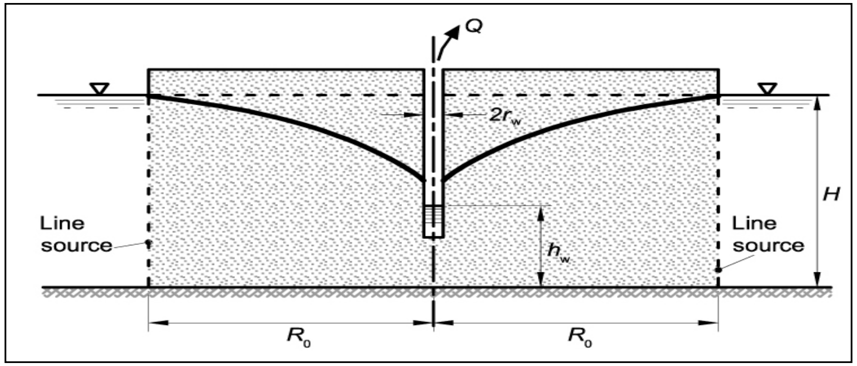
Treated Water 2: Mulgoa Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	9	m	9	9	m
Height of water table at well	h_w	7.7	m	7.7	7.7	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	x	18	m	18	18	m
Distance to line source, equal to radius of influence	R_0	21.65	m	3.99	34.74	m
Is R_0/H greater than or equal to 3 ?		No		No	Yes	
Total discharge from wellpoints	**Q**	6.94	m^3/d	0.15	96.93	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mulgoa HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 18 m/day (mixed urban and greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Treated Water Section 3: Greendale Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	3.7	m	3.7	3.7	m
Hydraulic conductivity	K	3.47E-06	m/s	1.97E-07	5.60E-06	m/s
		0.30	m/d	0.05	0.484	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	13.79	m	3.28	17.51	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Residual/regolith soils associated with weathered Bringelly Shale
Factor	C	Flow into linear trench

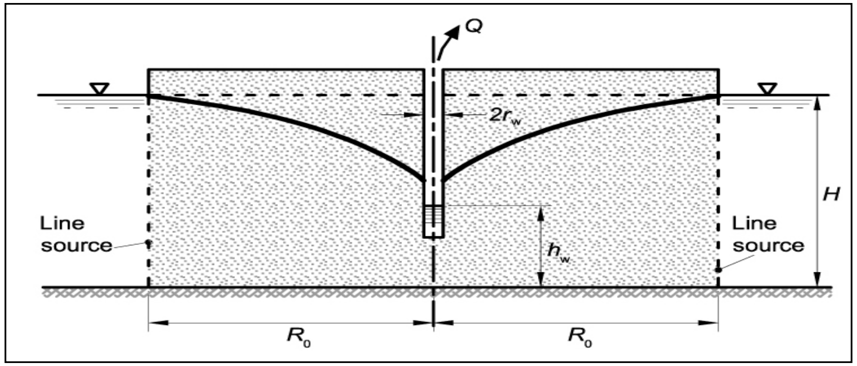
Treated Water 3: Greendale Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^{\,2})\right]$$

Essential input
Optional input
Calculated

Head		expected		min	max	
Height of water table at radius of influence	H	5	m	5	5	m
Height of water table at well	h_w	3.9	m	3.9	3.9	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.3	m/d	0.05	0.484	m/d
Radius						
Length of trench	*x*	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	13.79	m	3.28	17.51	m
Is R_0/H greater than or equal to 3 ?		No		No	Yes	
Total discharge from wellpoints	**Q**	4.04	m^3/d	0.53	27.37	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of residual/regolith soils in the Greendale HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Residual/regolith soils associated with weathered Bringelly Shale
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Treated Water Section 4: Mulgoa Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	3.9	m	3.9	3.9	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	18.76	m	3.46	30.10	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

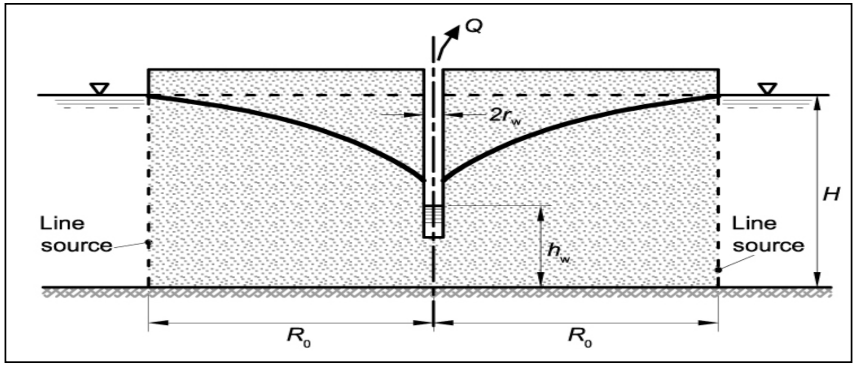
Treated Water 4: Mulgoa Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q = \left[\left(0.73 + 0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2 - h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	7	m	7	7	m
Height of water table at well	h_w	6.1	m	6.1	6.1	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	x	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	18.76	m	3.46	30.1	m
Is R_0/H greater than or equal to 3 ?		No		No	Yes	
Total discharge from wellpoints	**Q**	5.77	m^3/d	0.12	80.49	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mulgoa HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Treated Water Section 5: Upper South Creek Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	4.8	m	4.8	4.8	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	23.09	m	4.26	37.05	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

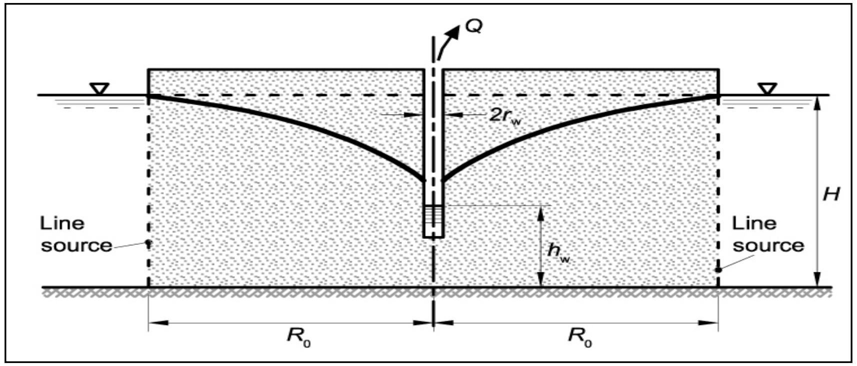
Treated Water 5: Upper South Creek Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q = \left[\left(0.73 + 0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2 - h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	7	m	7	7	m
Height of water table at well	h_w	6.1	m	6.1	6.1	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	x	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	23.09	m	4.26	37.05	m
Is R_0/H greater than or equal to 3 ?		Yes		No	Yes	
Total discharge from wellpoints	**Q**	4.69	m^3/d	0.10	65.37	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the USC HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	3.4	m	3.4	3.4	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	16.36	m	3.02	26.24	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

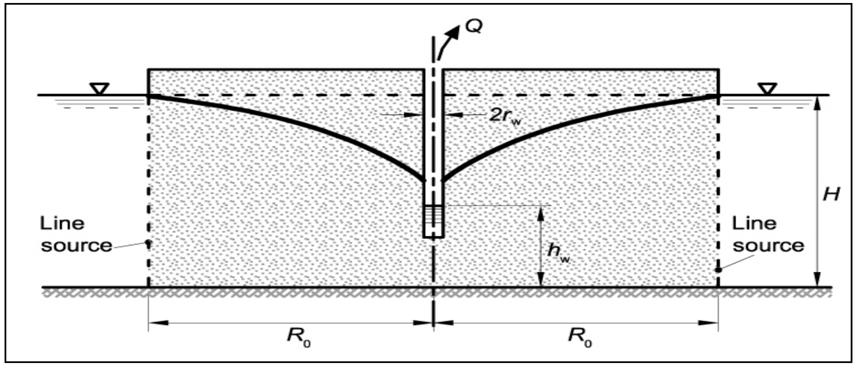
Brine Section 1: Upper South Creek Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q = \left[\left(0.73 + 0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2 - h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	7	m	7	7	m
Height of water table at well	h_w	5.6	m	5.6	5.6	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	x	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	16.36	m	3.02	26.24	m
Is R_0/H greater than or equal to 3 ?		No		No	Yes	
Total discharge from wellpoints	**Q**	10.14	m^3/d	0.22	141.45	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in USC HGL
Height of water table at well	h_w	hw = H + mean GW depth - max pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Brine Section 2: Mount Vernon Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	3.6	m	3.6	3.6	m
Hydraulic conductivity	K	3.47E-06	m/s	1.97E-07	5.60E-06	m/s
		0.30	m/d	0.05	0.484	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	13.42	m	3.19	17.04	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Residual/regolith soils associated with weathered Bringelly Shale
Factor	C	Flow into linear trench

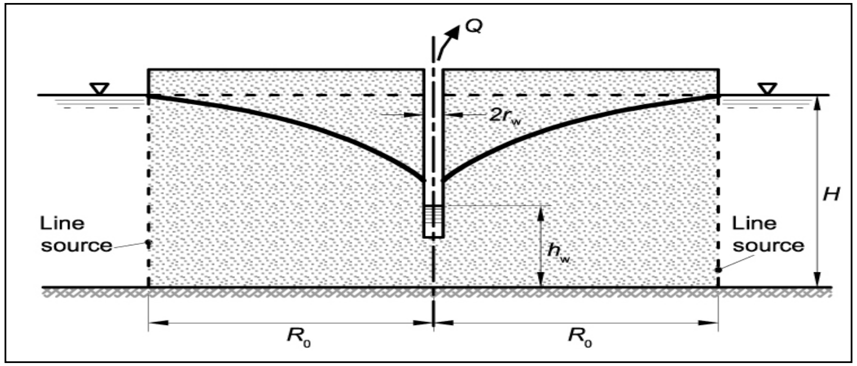
Brine Section 2: Mount Vernon Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q = \left[\left(0.73 + 0.27 \frac{(H - h_w)}{H} \right) \frac{Kx}{R_0} (H^2 - h_w^2) \right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	5	m	5	5	m
Height of water table at well	h_w	3.2	m	3.2	3.2	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.3	m/d	0.05	0.484	m/d
Radius						
Length of trench	*x*	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	13.42	m	3.19	17.04	m
Is R_0/H greater than or equal to 3 ?		No		No	Yes	
Total discharge from wellpoints	**Q**	6.55	m^3/d	0.86	44.46	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of residual/regolith soils in the Mount Vernon HGL
Height of water table at well	h_w	hw = H + min GW depth - max pipeline invert depth
Hydraulic conductivity of aquifer	K	Residual/regolith soils associated with weathered Bringelly Shale
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Brine Section 3: Denham Court Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	3.9	m	3.9	3.9	m
Hydraulic conductivity	K	3.47E-06	m/s	1.97E-07	5.60E-06	m/s
		0.30	m/d	0.05	0.484	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	14.53	m	3.46	18.46	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Residual/regolith soils associated with weathered Bringelly Shale
Factor	C	Flow into linear trench

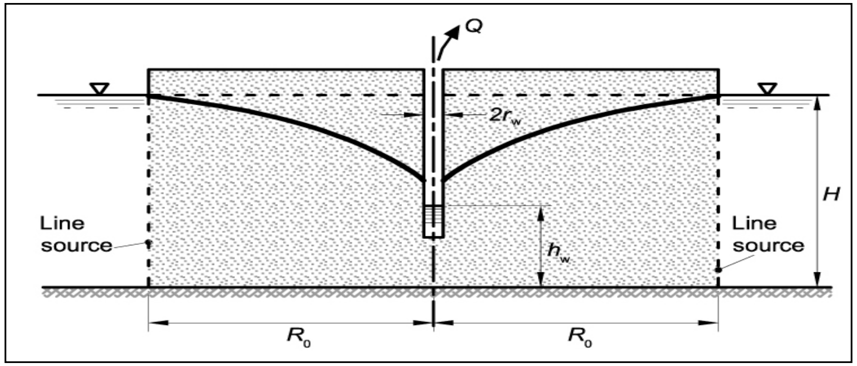
Brine Section 3: Denham Court Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^{\,2})\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	5	m	5	5	m
Height of water table at well	h_w	3.1	m	3.1	3.1	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.3	m/d	0.05	0.484	m/d
Radius						
Length of trench	*x*	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	14.53	m	3.46	18.46	m
Is R_0/H greater than or equal to 3 ?		No		No	Yes	
Total discharge from wellpoints	**Q**	6.35	m^3/d	0.83	43.02	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of residual/regolith soils in the Denham Court HGL
Height of water table at well	h_w	hw = H + min GW depth - max pipeline invert depth
Hydraulic conductivity of aquifer	K	Residual/regolith soils associated with weathered Bringelly Shale
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	6.6	m	6.6	6.6	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	31.75	m	5.86	50.95	m

The following assumptions apply to this equation

- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

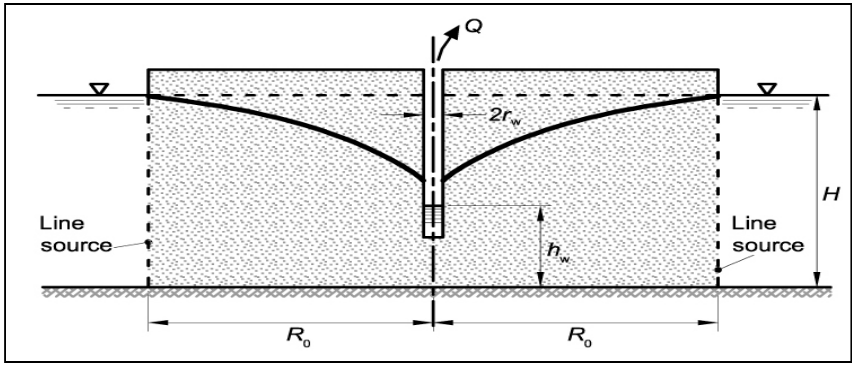
Brine Section 4: Upper South Creek (Variant A) Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	7	m	7	7	m
Height of water table at well	h_w	6.6	m	6.6	6.6	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	*x*	12	m	12	12	m
Distance to line source, equal to radius of influence	R_0	31.75	m	5.86	50.95	m
Is R_0/H greater than or equal to 3 ?		Yes		No	Yes	
Total discharge from wellpoints	**Q**	0.77	m^3/d	0.02	10.69	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the USC-A HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 12 m/day (urban conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Brine Section 5: Moorebank Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

$$R_0 = Cs\sqrt{K}$$

Legend
Essential input
Optional input
Calculated

		expected		min	max	
Drawdown in well	s	5.3	m	5.3	5.3	m
Hydraulic conductivity	K	5.79E-06	m/s	1.97E-07	1.49E-05	m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C	2000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	25.50	m	4.70	40.91	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (medium-grained sand, silt and clay)
Factor	C	Flow into linear trench

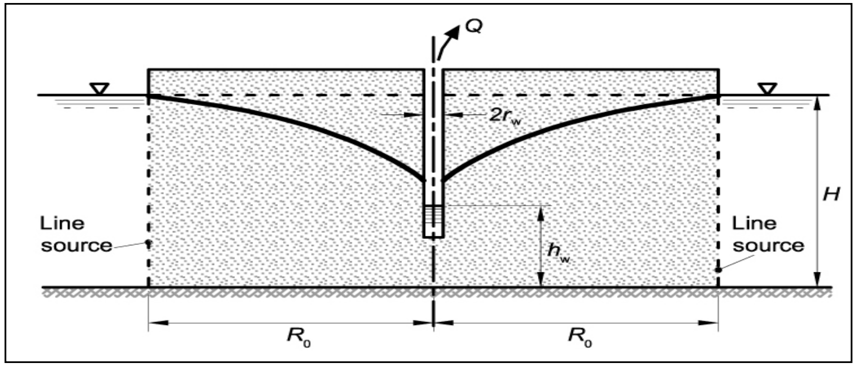
Brine Section 5: Moorebank Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	7	m	7	7	m
Height of water table at well	h_w	3.3	m	3.3	3.3	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	*x*	12	m	12	12	m
Distance to line source, equal to radius of influence	R_0	25.5	m	4.7	40.91	m
Is R_0/H greater than or equal to 3 ?		Yes		No	Yes	
Total discharge from wellpoints	**Q**	7.83	m^3/d	0.17	109.29	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Moorebank HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (medium-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 12 m/day (urban conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)