Central Queensland Coal Project

Chapter 10 – Groundwater

Central Queensland Coal

CQC SEIS, Version 3

October 2020

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Terms and Abbreviations

°C	Degrees Celsius
µS/cm	Micro siemens per centimetre
AEP	Annual Exceedance Probability
AGE	Australasian Groundwater and Environmental Consultants Pty Ltd
AHD	Australian Height Datum
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water quality
AWQG	Australian Water Quality Guidelines
BoM	Bureau of Meteorology
BTEXN	Benzene, toluene, ethylbenzene, xylene, naphthalene
CP	Core Permeability Test
CQC	Central Queensland Coal
CSG	Coal Seam Gas
DAWE	Commonwealth Department of Agriculture, Water and the Environment
DES	Department of Environment and Science
DGV	Default Guideline Value
DNRME	Department of Natural Resources, Mines and Energy
EA	Environmental Authority
EC	Electrical Conductivity
EHP	Department of Environment and Heritage Protection
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
ELVIS	Elevation Information System
EMP	Environmental Management Plan
EP Act	*Environmental Protection Act 1994*
EP Regulation	Environmental Protection Regulation 2019
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
EPP	Environmental Protection Policy
EV	Environmental Values
FHA	Fish Habitat Area
FHT	Falling Head Slug Test
GBR	Great Barrier Reef

GBRMP	Great Barrier Reef Marine Park
GDE	Groundwater Dependent Ecosystem
GIS	Geographic Information System
gm/cc	Grams per cubic centimetre
GMWL	Global meteoric water line
GWDB	Groundwater Database
GWDBQ	Groundwater Database Queensland
GWMMP	Groundwater management and monitoring plan
HSU	Hydrostratigraphic units
IESC	Independent Expert Scientific Committee
k	Hydraulic Conductivity
km	Kilometre
km^2	Square kilometres
Kx	Styx Coal Measures geological unit
L/s	Litres per second
LHS	Latin Hypercube Sampling
LiDAR	Light Detection and Ranging
LMWL	Local meteoric water line
m	Metres
m^2	Square Metres
m^3/s	Cubic metres per second
mAHD	Metres Australian Height Datum
mbgl	Metres below ground level
mg/L	Milligram per litre
MHWS	Mean High Water Spring
ML	Mining Lease Application
ML/day	Megalitres per day
mm	Millimetres
mm/month	Millimetres per month
MNES	Matters of National Environmental Significance
MWMP	Mineral Waste Management Plan

NWC	National Water Commission
NWQMS	National Water Quality Management Strategy
OEPT	Open end Permeability Test
OGIA	Office of Groundwater Impact Assessment
ORP	Oxidation / Reduction Potential
OWS	Office of Water Science
PAH	Polynuclear Aromatic Hydrocarbons
pH	Potential for Hydrogen
PT	Packer Testing
Qa	Quaternary Alluvium
QA/QC	Quality Assurance / Quality Control
Qh	Quaternary Holocene geological unit
Qpa	Quaternary Pleistocene Alluvium geological unit
QUA	Quantitative Uncertainty Analysis
QWQG	Queensland Water Quality Guidelines
REMP	Receiving Environment Monitoring Plan
RHART	Rising Head Airlift Recovery Test
RHCRRT	Rising Head Constant Rate Recovery Test
RHT	Rising Head Slug Test
ROM	Run of mine
SEIS	Supplementary Environmental Impact Study
SRMS	Scaled Root Mean Square
SWL	Standing Water Level
TARP	Trigger Action Response Plan
TDS	Total Dissolved Solids
TEM	Transient Electromagnetic
The Project	The Central Queensland Coal Project
ToR	Terms of Reference
TPH	Total Petroleum Hydrocarbons
TRH	Total Recoverable Hydrocarbons
TVM	Temporal Parameter Variability (Time-Variant Materials)

UWIR	Underground Water Impact Report
VWP	Vibrating Wire Piezometer
WMP	Mine Site Water Management Plan
WQO	Water Quality Objectives

10 Groundwater

10.1 Introduction

This chapter addresses the potential impacts on Groundwater from the construction and operation of the Central Queensland Coal (CQC) Project (the Project), and provides baseline and impact assessment information to support the studies in other Chapters of this Supplementary Environmental Impact Study (SEIS).

This Chapter has been rewritten since that presented in the SEIS Version 2 to include recent work undertaken to assess changes to the Project layout and operations that have occurred since then, and to address comments by regulatory agencies on the SEIS v2. See Chapter 3 – Project Changes and Responses to Regulator Comments for the full description of Project changes since SEIS v2, and the responses to submissions received.

The chapter draws on several assessments, which have been prepared to address the requirements of the Terms of Reference (ToR) for the Project (approved by the Department of Environment and Heritage Protection (EHP) on 4 August 2017) and the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) Information Guidelines for proponents preparing coal seam gas and large coal mining development proposals (Information Guidelines, dated May 2018) and associated explanatory notes. Primary assessments include:

- HydroAlgorithmics (2020) ‘Numerical Groundwater Model and Groundwater Assessment Report, for the Central Queensland Coal Project Supplementary Environmental Impact Statement Version 3 – Responses to Submissions’ (Appendix A6b)
- Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) (2020) ‘Central Queensland Coal groundwater model peer review – Stage 4’ (Appendix A6e)
- Eco Logical Australia (ELA 2020a) ‘Technical Report - Investigations on Groundwater – Surface Water Interactions, Central Queensland Coal Project’ (Appendix A6d)
- Eco Logical Australia (ELA 2020b) ‘Groundwater Dependent Ecosystem Management and Monitoring Plan (Appendix A10e) and
- WRM Water and Environment (2020) ‘Flood Study and Site Water Balance Technical Report’ (Appendix A5b).

The findings of these studies are outlined in this chapter with reference to the requirements of the Project ToR and the relevant State (Queensland) and Commonwealth regulatory frameworks, as detailed in Section 10.1.3. Additional sources are referenced as needed throughout the chapter.

10.1.1 Environmental Objectives and Outcomes

The environmental objective and performance outcomes relevant to groundwater are provided in Schedule 8, Part 3, Division 1 of the EP Regulation. Objectives and outcomes for groundwater that are specific to the Project are given in Table 1 of the Project ToR. The overarching objective with reference to the management and protection of groundwater, is to operate the Project in a way that protects the environmental values of groundwater including any associated surface ecological systems.

10.1.1.1 Environmental Protection Regulation Objectives and Performance Outcomes

The environmental objective and performance outcomes relating to groundwater outlined in the EP Regulation are:

Environmental Objective

The activity will be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems.

Performance Outcomes

1. Both of the following apply -
   a. there will be no direct or indirect release of contaminants to groundwater from the operation of the activity
   b. there will be no actual or potential adverse effect on groundwater from the operation of the activity and
2. The activity will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems.

10.1.1.2 Objectives and Performance Outcomes Relevant to the Project

The objectives and outcomes for water and water resources that are specific to the Project are given in Table 1 of Section 8 of the Project TOR and are summarised below.

Water

- The activity will be operated in a way that protects environmental values of waters.
- The activity will be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems.
- The activity will be managed in a way that prevents or minimises adverse effects on wetlands.

Water resources

- Ensure an equitable, sustainable and efficient use of water resources.
- Maintain environmental flows and water quality to support the long-term condition and viability of terrestrial, riverine, wetland, lacustrine, estuarine, coastal and marine ecosystems, in a way that maintains the ecological processes on which aquatic biota depend.
- Identify environmental values and establishment of pre-disturbance (baseline) water quality objectives (WQOs) for surface- and ground- waters suitable for use as assessment criteria in accordance with appropriate national and state guidelines and policies.
- Maintain the stability of beds and banks of watercourses, and the shores of waterbodies, estuaries and the coast.
- Maintain supply to existing users of surface and groundwater resources, including during construction, operation and decommissioning of the project.

10.1.2 Terms of Reference Addressed in this Chapter

Table 10-1 summarises the requirements from the ToR for the Project relevant to this chapter and where in this chapter they are addressed.

Table 10-1: ToR cross reference

Terms of Reference	Section of the EIS
8.3 Water Quality	
The assessment of water quality is considered a critical matter given the proximity of the Great Barrier Reef World Heritage Area, the presence of a wetland of national significance within the project area, and usage of water resources for grazing purposes in the area. Conduct impact assessment in accordance with the EHP's Environmental Impact Statement (EIS) information guideline—Water.	Noted The EIS information guideline – water is included in Section 10.1.3.5 and addressed within this Chapter for groundwater
With reference to the Environmental Protection (Water) Policy 2009 and section 9 the EP Act, identify the environmental values of surface waters within the project area, downstream and upstream that may be affected by the project, including any human uses of the water and any cultural values.	Chapter 9 – Surface Water Groundwater EVs are defined in Section 10.3.6.8
Define and/or establish the relevant water quality objectives applicable to the environmental values and demonstrate how these will be met by the project during construction, operation and decommissioning.	Sections 10.3.6.6 and 10.6.4
Quantify sediment and contaminant load increases in streams and to the reef as a result of mining operations.	Chapter 9 – Surface Water
Detail the chemical, physical and biological characteristics of surface waters and groundwater within the area that may be affected by the project and at suitable reference locations using sufficient data to define background conditions and natural variation in accordance with appropriate national and state guidelines and policies.	Section 10.3.6.6
Describe the quantity, quality, location, duration and timing[1] of all potential and/or proposed releases of contaminants addressing applicable standards from any relevant regional water quality management plans, strategies, or guidelines relating to water quality. Releases may include controlled water discharges to surface water streams, uncontrolled discharges when the design capacity of storages is exceeded, spills of products during loading or transportation, spills of product from the conveyor, contaminated run-off from operational areas of the site (including seepage from waste rock dumps), or run-off from disturbed acid sulfate soils.	Sections 10.4 and 10.5
Assess the likely impacts of any releases from point or diffuse sources on all relevant environmental values of the receiving environment, including environmentally sensitive areas; such as the Great Barrier Reef World Heritage Area and Broad Sound Directory of Important Wetlands in Australia (DIWA) nationally important wetland as well as near-field and mid-field locations. The assessment should consider the quality and hydrology of receiving waters and the assimilative capacity of the receiving environment.	Chapter 9 – Surface Water
Describe how impacts on water quality objectives and environmental values would be avoided or minimised through the implementation of management strategies that comply with the management hierarchy and management intent of the Environmental Protection (Water) Policy 2009. Appropriate management strategies may include the use of erosion and sediment control practices, and the	Chapter 9 – Surface Water

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[1] Duration and timing are important aspects of the risk characteristics that affect the impacts of mine and CSG water releases; e.g. for how long will water be released in total and when will it occur with respect to existing 'natural' flows

Terms of Reference	Section of the EIS
separation of clean storm water run-off from the run-off from disturbed and operational areas of the site.	
Describe how monitoring would be used to demonstrate that objectives were being assessed, audited and met. For example, provide measureable criteria, standards and/or indicators that will be used to assess the condition of the ecological values and health of surface water environments. Propose corrective actions to be used if objectives are not being met.	Chapter 9 – Surface Water
8.4 Water Resources	
The assessment of surface water and groundwater resources is considered a critical matter given the usage of water resources for grazing purposes in the area. Conduct impact assessment in accordance with the EHP's *EIS information guidelines—Water.*	The EIS information guideline – water is included in Section 10.1.3.5 and addressed within this Chapter for groundwater
Describe and present potential users and uses of water in areas potentially affected by the project, including municipal, agricultural[2], industrial, recreational and environmental uses of water.	Section 10.3.6.9
Provide details of any proposed changes to, or use of, surface water or groundwater. Identify any approval or allocation that would be needed under the *Water Act 2000*.	Section 10.5.1.1
Describe all aquifers that would be impacted by the project, including the following information: • nature of the aquifer/s • geology/stratigraphy - such as alluvium, volcanic, metamorphic • aquifer type - such as confined, unconfined • depth to and thickness of the aquifers • groundwater quality and volume • current use of groundwater in the area • survey of existing groundwater supply facilities (e.g. bores, wells, or excavations) • information to be gathered for analysis to include: - location - pumping parameters - drawdown and recharge at normal pumping rates, and - seasonal variations (if records exist) of groundwater levels	Section 10.3.6
• proposal to develop network of groundwater monitoring bores before and after the commencement of the project.	Section 10.6.4
Include maps of suitable scale showing the location of diversions and other water-related infrastructure in relation to mining infrastructure. Detail any significant diversion or interception of overland flow.	Chapter 9 – Surface Water
Assess the potential impacts of any new water infrastructure (including diversions, pits, dams, etc.) and any proposed changes to water supply or take, on ground and surface water hydrology, quality and hydrological processes.	Section 10.5

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[2] https://publications.qld.gov.au/dataset/daff-environmental-impact-assessment-companion-guide/resource/7b1825c4-5e42-4cf8-aa2d-7fa55c2f5e4c

Terms of Reference	Section of the EIS
Describe the options for supplying water to the project and assess any potential consequential impacts in relation to the objectives of any water resource plan and resource operations plan that may apply.	Section 10.5.1.1 and Chapter 9 – Surface Water describes water supply No WRP or ROP applies
Describe how 'make good' provisions would apply to any water users that may be adversely affected by the project.	Section 10.6.4
Describe the proposed supply of potable water for the project, including temporary demands during the construction period. Also describe on-site storage and treatment requirements for waste water from accommodation and/or offices and workshops.	Chapter 9 – Surface Water
Describe the practices and procedures that would be used to avoid or minimise impacts on water resources.	Section 10.6
Quantify the volume of all takes from the groundwater system (including pit dewatering, degassing, etc.) and assess the impacts on groundwater levels, quality and ecosystem interactions for each aquifer and any implications for surface-groundwater interactions.	Section 10.5
8.4.1 The Independent Expert Scientific Committee Response	
The EIS must include a specific section responding to the information requirements contained in the Independent Expect Scientific Committee's (IESC's) Information guidelines for proposals relating to the development of coal seam gas and large coal mines where there is a significant impact on water resources (Commonwealth of Australia 2015).	Section 10.8
8.5 Flooding	Addressed in Chapter 9 – Surface Water
8.6 Regulated Structures	Addressed in Chapter 9 – Surface Water

10.1.3 Relevant Legislation and Guidelines

The regulatory framework for groundwater-related matters in Australia consists of both State and Commonwealth legislative requirements. The following key environmental planning and water-related legislation are relevant to the Project:

Queensland regulatory framework

- *Environmental Protection Act 1994* (EP Act)
- Environmental Protection Regulation 2019 (EP Regulation)
- *Water Act 2000*
- Water Regulation 2016
- Environmental Protection (Water and Wetland Biodiversity) Policy 2019 and
- *Marine Parks Act 2004*.

Commonwealth regulatory framework

- *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and
- Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) and Office of Water Science (OWS).

The following sections provide a summary of the above legislation and how these pertain to the groundwater assessment for the Project.

10.1.3.1 *Environmental Protection Act 1994* and Environmental Protection Regulation 2019

The EP Act 1994 and the Environmental Protection Regulation 2019 (EP Regulation) enable the protection of Queensland's environment to maintain ecological processes during development. The Project Environmental Impact Statement (EIS) is required, under the EP Act, to assess potential environmental impacts related to the development and outline the requirements for how such impacts will be avoided, minimised and/or managed. The EIS also informs approval decisions under the EP Act (and Water Trigger) and other legislation, including the *Water Act 2000* and subsidiary Water Regulation 2016*.*

Under the EP Act, the final ToR for the Project were developed and issued by the EHP specifying the objectives and performance outcomes for water quality and water resources. Section 10.1.1 outlines these objectives and performance outcomes and where they have been addressed in this chapter.

10.1.3.2 *Water Act 2000* and Water Regulation 2016

The *Water Act 2000* and subsidiary Water Regulation 2016 provide a framework for the sustainable management of Queensland's water resources, primarily for the planning, allocation and use of groundwater and surface water, provision of a sustainable and secure water supply and demand management, and the management of groundwater impacts due to the resource sector. Section 808 of the Act specifies that a person must not take, supply or interfere with water unless authorised and all mining activities must be assessed and approved for the take of produced water during operations.

A system of interrelated water plans, licences and permits are provided under the Act to regulate groundwater and surface water use within each catchment. Currently, a water plan has not been established under the Act for the Styx Catchment in which the Project resides. Should a future catchment-specific water plan be developed, relevant licensing requirements for the Project will need to be considered at that time.

The Act establishes the Office of Groundwater Impact Assessment (OGIA), an independent entity that provides advice on matters relating to groundwater impacts from resource development. The OGIA core functions are to:

- undertake evidence-based independent scientific assessment of cumulative groundwater impacts from resource operations
- set management arrangements within the cumulative management areas and
- assign statutory responsibilities to tenure holders for the implementation of management strategies within cumulative management areas.

A cumulative management area has not been established in the Styx Basin, and therefore the OGIA's current role in relation to the Project is an advisory role to Department of Environment and Science (DES) only.

10.1.3.2.1 Environmental Protection (Water and Wetland) Policy 2019

The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP [Water and Wetland Biodiversity]) seeks to achieve the objectives set within the EP Act in relation to Queensland waters by seeking to 'protect Queensland's waters while allowing for development that is ecologically sustainable' (s3 EP Act).

This purpose of this policy is achieved by:

- Identifying Environmental Values (EVs) and management goals for Queensland waters
- Stating water quality guidelines and WQOs to enhance or protect the EVs
- Providing a framework for making consistent, equitable and informed decisions about Queensland waters and
- Monitoring and reporting on the condition of Queensland waters.

The Styx River basin, including all waters of the basin, Broad Sound and adjacent coastal waters (basin 127 and adjacent to basin 127) are scheduled waters under Schedule 1 to the EPP (Water and Wetland Biodiversity). EVs and WQOs are described for these waters in the document 'Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives' (EHP 2014), made pursuant to the previous Environmental Protection (Water) Policy 2009.

Subsequently, draft updated EVs and 'water quality chemistry ranges' have been developed by the Queensland Government as part of consultation materials, which will form the basis for groundwater EVs, WQOs, and mapping for inclusion in the EPP (Water and Wetland Biodiversity), presented in the 'Regional groundwater chemistry zones: Fitzroy-Capricorn-Curtis Coast and Burdekin-Haughton-Don regions: Summary and results report' (McNeil et al. 2018).

Scheduled WQOs for Great Barrier Reef catchment waters are also incorporated under s11(4) of the policy, and addressed further in Chapter 9 – Surface Water.

10.1.3.3 *Marine Parks Act 2004*

The *Marine Parks Act 2004* provides a framework for the conservation of the marine environment, including the monitoring and enforcing of compliance with the Act. The Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 (Schedule 2), under the Act, defines the General Use Zone at the mouth of the Styx River. This zone, at its nearest point, generally aligns with the Broad Sound Fish Habitat Area (FHA) boundary located north of the Project.

10.1.3.4 *Environment Protection and Biodiversity Conservation Act 1999*

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is administered by the Commonwealth Department of Agriculture, Water and the Environment (DAWE) to protect and manage nationally and internationally recognised flora, fauna, ecological communities and heritage items, listed as Matters of National Environmental Significance (MNES). The MNES include water resources, in relation to coal seam gas development and large coal mining development. This MNES is often referred to as the 'the water trigger'.

The EPBC Act defines a process for identifying whether the action has, or is likely to have, a significant impact on MNES, and provides a framework for the environmental assessment and approval of the proposed actions (Commonwealth of Australia 2013). The Project has been referred to the DAWE as 'likely to have a significant impact' on local and regional water resources and the project has been subsequently classified as a Controlled Action, which requires assessment and approval under the EPBC Act. Assessment criteria is specified in the EPBC Act 'Significant Impact Guidelines 1.3: Coal Seam Gas and Large Coal Mining Developments – Impacts on Water Resources' (Commonwealth of Australia 2013).

The Act requires that advice be sought from the Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Large Coal Mining Development prior to deciding whether or not to approve an action if it involves coal seam gas development or large coal mining development, and the action is likely to have a significant impact on water resources.

The IESC is further addressed in the next section.

10.1.3.4.1 The IESC

The IESC is a statutory body formed under the EPBC Act with key legislative functions to provide scientific advice to the Commonwealth Environment Minister and the relevant Queensland Ministers on coal seam gas (CSG) and large coal mining development proposals that are likely to significantly impact water resources. The IESC is supported by the Office of Water Science (OWS) in the consideration of requests for advice on development proposals, with the OWS providing formal assessment of the proponent's response to the IESC advice.

The IESC has developed the 'Information guidelines for proponents preparing coal seam gas and large coal mining development proposals' (the 'Information Guidelines', May 2018) to outline the information considered necessary by the IESC for the review of CSG or large coal mining development proposals, and the following 'Information Guidelines Explanatory Notes' which have been referenced within this Chapter:

- 'Uncertainty Analysis – Guidance for Groundwater Modelling within a Risk Management Framework', which includes the fatal flaw checklist
- 'Assessing groundwater-dependent ecosystems' (Doody et al. 2019) and
- 'Deriving site-specific guideline values for physico-chemical parameters and toxicants' (IESC 2019).

The IESC also released the fact sheet 'Environmental Water Tracers in Environmental Impact Assessments for Coal Seam Gas and Large Coal Mining Developments' (OWS 2020).

10.1.3.5 Applicable Guidelines

Key guidelines relevant to groundwater assessment for the Project are as follows:

- IESC Information Guidelines, Explanatory Notes and fact sheets
- Australian Groundwater Modelling Guidelines and
- National Water Quality Management Strategy and related documentation.

The IESC Information Guidelines and Explanatory Notes are listed in Section 10.1.3.4.1, while the remainder are described further below.

Australian Groundwater Modelling Guidelines

The Australian groundwater modelling guidelines were published by the National Water Commission in June 2012 to provide technical information related to the development of groundwater models in Australia. It aimed to promote a consistent and sound approach to the development of groundwater models. The guidelines incorporated the model confidence classification system, which aim to provide an indication as to the relative confidence with which a model can be used in predictive mode.

National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) presents the overarching national approach to improving and managing water quality in Australia's waterways. The Australian and New Zealand Guidelines for Fresh and Marine Water quality (ANZG 2018) (hereafter the Australian

Water Quality Guidelines, or AWQG) are a key part of the NWQMS and provide authoritative guidance on the management of water quality in Australia and New Zealand. The AWQGs are implemented through the Water Quality Management Framework - a framework providing a logical process to be followed for the long-term management of receiving water/sediment quality.

The AWQGs provide guidance on developing monitoring programs, selecting relevant indicators, and adopting relevant guideline values to assess change in receiving environments, including a framework for developing locally derived guidelines.

In Queensland, the approach to adopting guideline values for receiving waters is:

- EPP (Water and Wetland Biodiversity) scheduled EVs and WQOs, unless sufficient local data is available to derive improved local guideline values from appropriate reference sites
- End of catchment anthropogenic pollutant reduction targets in Great Barrier Reef catchments contained in the Great Barrier Reef River Basins, End-of-Basin Load Water Quality Objectives (DES 2019a), derived from the Reef 2050 Water Quality Improvement Plan 2017–2022 (State of Queensland 2018)
- Queensland water quality guidelines (EHP 2013) (QWQGs) in - the absence of EPP (Water and Wetland Biodiversity) scheduled values and
- AWQG Default guideline values.

The above existing default guideline values are referred to herein as default guideline values (DGVs), after the term used by the AWQGs.

As noted in Section 10.1.3.2.1 the Styx basin is scheduled under the EPP (Water and Wetland Biodiversity). The QWQGs provide regional guideline values for Queensland water types and regions, and approaches that complement the AWQGs for Queensland conditions, including a framework for deriving and applying local guideline values.

Water monitoring protocols are contained in the Queensland Monitoring and Sampling Manual (DES 2018).

This assessment has also been undertaken with reference to the following guideline documents:

- The DES ‘EIS Information Guideline – Water’

10.1.4 Terminology

Groundwater is defined by the Commonwealth *Water Act 2007* as:

a. ‘water occurring naturally below ground level (whether in an aquifer or otherwise) or
b. water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there,

but does not include water held in underground tanks, pipes or other works.’

It is defined somewhat differently under the Queensland *Water Act 2000*, particular to the purposes of that Act to include ‘water that occurs naturally in, or is introduced artificially into, an aquifer’, which is further defined as ‘a geological structure, formation or formations that holds water in sufficient quantity to provide a source of water that can be tapped by a bore’.

The ‘IESC Information Guidelines Explanatory Note: Assessing groundwater-dependent ecosystems’ (Doody et al. 2019, p13) state that the definition of **groundwater** includes ‘water in the soil capillary zone (capillary fringe) but not the water held in the soil above this zone in the unsaturated or vadose zone. Within the saturated zone, pores are filled with water, whereas the capillary fringe and unsaturated zone increasingly have pores containing air as well as water. Water in caves that is sourced from groundwater is also included as groundwater, as are perched aquifers in the unsaturated zone.'

Groundwater Dependent Ecosystems (**GDEs**) are defined by Doody et al. (2019) as 'ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services'.

This Chapter refers to the concept of **bank storage**. In the context of this assessment bank storage is a temporary source of groundwater stored within the banks of creeks or rivers which is derived from infiltration associated with flooding or rainfall. Water held in bank storage may be released to the adjacent creek or river over varying timescales following the recession of surface water levels. Water can also be held in bank storage for prolonged periods, where it may be accessed by Terrestrial GDEs.

In this assessment, the **water table aquifer** refers to an aquifer associated with the water table. In most parts of the Project Site and surrounds, this is the alluvial aquifer. However, in some locations, particularly at Tooloombah Creek, the creek channel intersects the deeper weathered Styx Coal Measures. The term 'water table aquifer' therefore refers to the aquifer associated with the water table, regardless of which geological layer the aquifer is located within.

Enhanced leakage refers to the potential for water stored within the unsaturated zone to be depleted, due to the drawdown of the underlying water table aquifer, which can increase the rate of water infiltration from the unsaturated zone into underlying sediments.

10.2 Methods

A combination of desktop assessment, field investigations and numerical groundwater modelling were completed to understand current groundwater conditions. The numerical groundwater model presented in the Groundwater Model and Assessment Report in Appendix A6b is based upon the data gathered from the desktop assessments and the field surveys and is the primary mode of assessment for potential impacts of the Project to groundwater.

Following the completion of the numerical groundwater modelling, additional technical studies were undertaken to increase the understanding of shallow groundwater – surface water interactions that occur within the predicted Project impact area and characterise any relationships between groundwater and identified riparian vegetation and GDEs.

Reports and data contained in the previous EIS and SEIS v1 and SEIS v2 were drawn upon, and the following specific studies were commissioned to support the updated groundwater numerical model and assessment:

- HydroAlgorithmics (2020) 'Numerical Groundwater Model and Groundwater Assessment Report, for the Central Queensland Coal Project Supplementary Environmental Impact Statement Version 3 – Responses to Submissions' (Appendix A6b)
- Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) (2020) 'Central Queensland Coal groundwater model peer review – Stage 4' (Appendix A6e)

- Eco Logical Australia (ELA 2020a) 'Technical Report - Investigations on Groundwater – Surface Water Interactions, Central Queensland Coal Project' (Appendix A6d)
- Eco Logical Australia (ELA 2020b) 'Groundwater Dependent Ecosystem Management and Monitoring Plan (Appendix A10e)
- WRM Water and Environment (2020) 'Flood Study and Site Water Balance Technical Report' (Appendix A5b)
- 3D Environmental (2020) 'Groundwater Dependent Ecosystem Assessment' (Appendix A10d)
- Groundwater Imaging (2019) 'CQC Ogmore AgTEM Survey for Groundwater Investigation' (Appendix A6f)
- Fluvial Systems (Gippel 2020) 'Central Queensland Coal Project, Environmental Impact Statement, Supplementary Technical Study Report, Fluvial Geomorphology' (Appendix A5d)
- Groundwater monitoring (Section 10.2.2.2) and
- Orange Environmental (2020) Groundwater Quality Data Summary Report (Appendix A6c).

10.2.1 Data Review and Desktop Study

A desktop review and assessment was conducted, involving analysis of available groundwater data, geological and Project specific mapping, existing groundwater users, database and relevant literature searches, aerial imagery and LiDAR data as outlined below. This was used in the first instance to inform the development of improvements to the numerical groundwater model and the groundwater impact assessment, as well as the supplementary studies outlined above.

The desktop study comprised the collation and review of the following key information:

Mapping, Reports and Guidelines

- Geological mapping, including the 1:100,000 Marlborough (DNR&M 2006) and 1:250,000 St. Lawrence (Malone et al. 1965) and St. Lawrence explanatory notes (Malone 1970)
- Existing water users, from the Queensland Government's 'Water Entitlement Viewer'
- Groundwater dependent ecosystems, including data from the Queensland Government's Spatial Catalogue – Qspatial and the Bureau of Meteorology's (BoMs) Groundwater Dependent Ecosystems Atlas
- BoMs National Groundwater Information System
- Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014a) and
- Queensland Water Quality Guidelines (EHP 2013).

Available Data

- Existing and historical groundwater bores within the numerical model extent, from the Queensland Government's (Department of Natural Resources, Mines and Energy [DNRME]) registered Groundwater Database (GWDBQ) – water quality and level data was available from 64 bores from 1965 to August 2019, although at most only two data points per site were available.
- BoMs Australian Groundwater Explorer Database, which identified additional exploration holes from other proponents.

- Two Stygofauna surveys conducted for the Project – one in November 2011 and another in March 2012 - with field water quality of standing water columns and water level available (included in Appendix A10c).
- Coal exploration drillholes and well installation logs, including geology / lithology, standing water level, recorded by CQC during and (for some holes) after installation.
- LiDAR elevation data collected in 2011 by CQC for the Project (3 x 3m grid), and data available from 2009 from the Intergovernmental Committee on Surveying and Mapping's Elevation Information System (ELVIS).
- Waterways, using the Queensland Government's *Watercourse lines – Queensland* (DNRME 2019) (these were confirmed as largely suitable as part of the Fluvial Geomorphology assessment (Appendix A5d).
- Other Geographic Information System (GIS) data, obtained from the Queensland Government's Spatial Catalogue – Qspatial, including FHA, Great Barrier Reef (GBR) Marine Park and GBR Coast Marine Park, World Heritage Area, NRM Region Land Use 2017, for example.

10.2.2 Field Investigations

10.2.2.1 Bore Census

A census of existing third-party groundwater bores within approximately a 10 km radius of the Project was conducted in 2011. This was repeated by CDM Smith in February 2017 covering the bores identified in the 2011 census, results from the GWDBQ and anecdotal information from landholders. The 2017 census plan included 27 bores, of which 20 could be visited and verified, four could not be accessed and three could not be found (expected to be abandoned/destroyed). An additional six bores were identified during the census, which are expected to be unregistered or location details in the GWDBQ inaccurate.

The GWDBQ was analysed again as part of the desktop data review, identifying an additional bore (RN187278).

The results of the bore census are discussed in Section 10.3.6.9, and tabulated in Attachment 4 (Table A4-2) of the Groundwater Model and Assessment Report in Appendix A6b).

10.2.2.2 Groundwater Sampling and Well Installation

The earlier data collected as part of other studies (e.g. stygofauna surveys, bore census, drilling work) was followed up with targeted groundwater monitoring and new well installation was undertaken by CQC from 2017 onwards as follows:

- February 2017 – November 2017: monitoring of a select number of existing landholder bores, starting with site visits and field data for the bore census and monthly sampling at seven of the sites over the period (continuing two of these long-term up to the present, generally in monthly rounds).
- September 2017 – March 2018: installation of the WMP02 – WMP15 series of groundwater monitoring wells, monitoring of which commenced in November 2017 and has continued generally in monthly rounds.
- September – October 2018: installation of the WMP16 – WMP29 series of groundwater monitoring wells, monitoring of which commenced in September 2019 and continues generally in monthly rounds.

- December 2019: installation of WMP31 Vibrating Wire Piezometer (VWP) in the Back Creek Group to the east of the Project.
- April 2020: installation of WMP06D, WMP21B, WMP31B, WMP31C and WMP32.
- 2019 – 2020: installation of water level loggers in WMP04, WMP05, WMP06, WMP29A standpipes.

The sampling events and monitoring sites are summarised in Table 10-2, and the monitoring sites are shown in Figure 10-1. Site details and well diagrams are provided as part of the Groundwater Quality Data Summary Report in Appendix A6c[3].

As can be seen, many of the sites, particularly in the WMP02 - 15 series, have relatively high numbers of samples (~30), above the recommended 24 data points from the ANZG (2018) for derivation of site-specific guideline values. For the WMP16 - 29 series, around 6 - 8 data points are available. These provide supporting data but are not, on their own, sufficient for deriving long term guideline values based on ANZG (2018) guidance, nor the QWQG recommended 18 data points.

Table 10-2: Groundwater monitoring - number of events by site

Sites		Feb 2017 – Nov 2017	Nov 2017 – Aug 2019	Sep 2019 - May 2020	Total
Landholder bores	BH01x	5	18	-	23
	BH05x	1	-	-	1
	BH06x	5	2	-	7
	BH07	1	-	-	1
	BH13	5	2	-	7
	BH16	5	18	-	23
	BH29	5	1	-	6
	BH30	5	1	-	6
	BH32	5	1	-	6
WMP02 - 15 series	WMP02	-	23	6	29
	WMP04	-	24	7	31
			Logger installed Sep 2019 - SWL		~11 months
	WMP04D	-	24	6	30
	WMP05	-	24	6	30
			Logger installed Sep 2019 - SWL		~11 months
	WMP06	-	24	8	32
				Logger installed Jun 2020 - SWL	2 months
	WMP06D	-		1	1
	WMP07	-	22	4	26
	WMP08	-	24	7	31
	WMP08D	-	24	7	31
	WMP09	-	24	9	33
	WMP10	-	24	7	31

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[3] Note that the data presented in the Groundwater Model and Assessment Report (Appendix A6b) was based on monitoring data to January 2020. The data presented herein has been updated to May 2020, and so some inconsistencies may be noted. These have been assessed and do not change the findings of either the model or the assessment beyond minor changes to the values presented.

Sites		Feb 2017 – Nov 2017	Nov 2017 – Aug 2019	Sep 2019 - May 2020	Total
	WMP11	-	17	5	22
	WMP11D	-	17	6	23
	WMP12	-	22	5	27
	WMP13	-	21	7	28
	WMP14	-	19	7	26
	WMP15	-	18	8	26
WMP16 - 29 series	WMP16	-	-	5	5
	WMP16D	-	-	6	6
	WMP17	-	1	4	5
	WMP17D	-	-	4	4
	WMP18	-	-	5	5
	WMP18D	-	-	5	5
	WMP19	-	-	8	8
	WMP19D	-	-	8	8
	WMP20	-	1	5	6
	WMP20D	-	-	5	5
	WMP21	-	-	7	7
	WMP21B	-	-	2	2
	WMP21D	-	-	7	7
	WMP22A	-	1	7	8
	WMP22B	-	1	7	8
	WMP22C	-	1	7	8
	WMP23A	-	1	8	9
	WMP23B	-	1	8	9
	WMP24	-	-	7	7
	WMP25	-	-	4	4
	WMP26	-	-	7	7
	WMP27	-	-	7	7
	WMP28	-	-	6	6
	WMP29A	-	1	6	7
				Logger installed Oct 2019 - SWL	~10 months
	WMP29B	-	1	6	7
	WMP29C	-	1	6	7
	WMP29D	-	-	6	6
	WMP29E	-	1	6	7
WMP32 - 32 series	WMP30A	-	-	7	7
	WMP30B	-	-	7	7
	WMP30C	-	-	7	7
	WMP31	-	-	1	1
				VWP Logging from Dec 2019 - SWL	~8 months

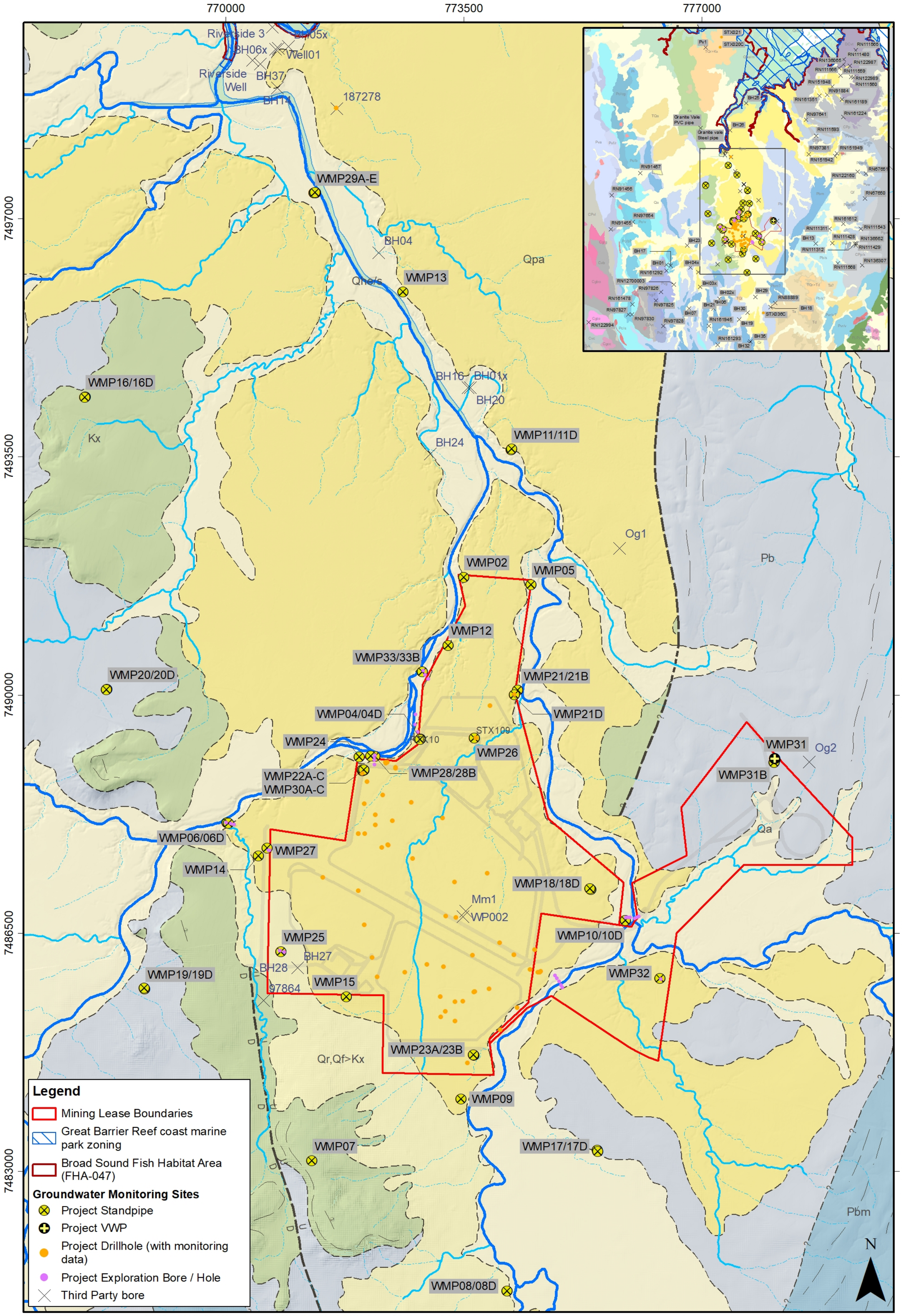
Sites		Feb 2017 – Nov 2017	Nov 2017 – Aug 2019	Sep 2019 - May 2020	Total
	WMP31B	-	-	1	1
	WMP31C	-	-	-	0
	WMP32	-	-	1	1

Water samples were collected in general accordance with the Queensland Government's Monitoring and Sampling Manual (DES 2018, and earlier versions EHP 2009 and DERM 2010). Sample collection generally involved bailing an initial sample for testing (zero purge sample), and then bailing with an aim to purge 3 x well volumes, or until field water quality (regularly taken) stabilised. Following purging, a final sample was taken, representative of the bulk groundwater at the screen depth.

Field analysis of pH, dissolved oxygen, electrical conductivity (EC), oxidation/reduction potential (ORP) and temperature were conducted, with water samples for laboratory analysis tested for the following parameters:

- physico-chemical
    - EC, total dissolved solids (TDS)
    - alkalinity and
    - pH
- nutrients and major ions
    - sulfate, chloride, major cations (calcium, magnesium, potassium and sodium), fluoride, total hardness
    - ammonia, nitrite, nitrate, nitrite + nitrate, total kjeldahl nitrogen and total nitrogen and
    - filterable reactive phosphorous, total phosphorous
- metals and metalloids
    - dissolved metals – aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc and
    - total metals – aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc (only in 2020)
- hydrocarbons
    - total petroleum hydrocarbons (TPH) / total recoverable hydrocarbons (TRH)
    - polynuclear aromatic hydrocarbons (PAH) and
    - BTEXN – benzene, toluene, ethylbenzene, xylene, naphthalene.

In terms of general water quality parameters, all rounds included general physico-chemical parameters (pH, EC, TDS, etc.), and most rounds included nutrients and cations, with the only exceptions being the stygofauna sampling rounds (field data only), the surface-groundwater interaction study (looking at physico-chemical, cations and radioisotopes), and several rounds which were measurements from well installations. Radioisotopes were measured during one round (July 2018).



Source: Sites, various, compiled by OE 2020 | Waterways: DNRME 2010 | GBR Coast Marine Park Zoning: DERM 2009
Fish Habitat Areas: DNPSR 2016 | Tenements: DNRME 2019 | Geology: DNRME 2018

Figure 10-1: Groundwater monitoring sites

Dissolved metals were sampled in most rounds (97% of events, excluding stygofauna and well installation rounds), with total metals collected in only 3 (8%) of rounds. Hydrocarbons were sampled in 79% of rounds (from 2017 to the end of 2019), testing for total petroleum / recoverable hydrocarbons (TPH / TRH) and BTEXN, with PAHs and phenolic compounds added in November 2018, and again sampled until the end of 2019, corresponding to 31% of events.

Water samples were collected in general accordance with the Queensland Government's 'Monitoring and Sampling Manual' (DES 2018, and earlier versions EHP 2009 and DERM 2010). An assessment of purge methods indicated that the results were expected to be largely representative of the bulk groundwater at the screen depth. Laboratory documentation and quality assurance/ quality control (QA/QC) samples indicated generally low levels of holding time breaches or similar errors and overall minimal error in laboratory testing and sample handling.

Further details on the sampling and testing procedures, sites sampled and QA/QC assessment are provided in Appendix A6c.

10.2.2.3 Isotope Monitoring of Surface and Groundwaters

During July 2018, an assessment of the relationship between surface water and groundwater in the area was undertaken by sampling and analysis of anionic / cationic concentrations and relationships, and radon isotopes and the stable isotopes in water samples collected from Deep Creek and Tooloombah Creek.

10.2.2.4 Surface Water – Groundwater Interactions Assessment

A program of GDE assessment was undertaken for the previous SEIS v2, including pools assessments coupled with groundwater monitoring (refer Chapter 9 – Surface Water, and Appendix A10a), which assessed pool levels and EC changes to determine whether EC increases may be due to saline groundwater, or evaporation alone. A targeted GDE assessment was undertaken in August to September 2018 including shallow exploration boreholes, soil and leaf moisture and moisture potential testing to determine their reliance on groundwater (refer Appendix A10d, which is summarised into the technical report in Appendix A10a).

In May and June 2020, an alluvial drilling program was undertaken across six creek transects – four in Tooloombah Creek (South, Central 1 and 2 and North) and two in Deep Creek (South and North). Data collected consisted of stratigraphic logs, geological cross-section diagrams and laboratory analysis of sediment samples (particle size distribution, soil moisture and salinity) collected from 24 boreholes, across the six transects. Moreover, field geological descriptions of outcrops were completed along the areas were drilling was not possible (mostly in creeks beds and banks), this information helped to correlate and improve the transects and geological interpretation. This cross sectional information, including lithological interpretation, groundwater levels, soil moisture and texture, was utilised as part of the detailed surface water – groundwater interactions assessment described in Section 10.2.5.

10.2.2.5 Transient Electromagnetic (TEM) ground survey

To support the groundwater conceptualisation and develop the numerical groundwater model structure, the finer scale depth and location of the different alluvial units was interrogated by Transient Electromagnetic (TEM) ground survey. This maps electrical conductivity at various depths, and was undertaken across a number of properties in proximity to the Project, in particular along creek banks. The survey results are provided in Appendix A6f.

Essentially, the method allows electrically conductive and electrically resistive layers to be differentiated, noting that clays and saline aquifers show as electrically conductive, with fresh aquifers and basement rock showing as electrically resistive. The work specifically aimed to provide information to support the delineation of Quaternary (Holocene) Alluvium (Qa) and Quaternary Pleistocene Alluvium (Qpa).

10.2.2.6 Aquifer Testing

A comprehensive program of aquifer testing was completed for the Project as part of the monitoring well installation program, and for other related exploration works. A total of 73 separate hydraulic conductivity test estimates across 31 groundwater monitoring locations were completed.

As part of ongoing investigations at the site, AMEC (2019) undertook open end permeability and packer testing at two exploration drill holes, STX1901 and STX1902, with the data presented in Attachment 7 of Appendix 6b.

Core sampling from two exploration drill holes, STX1812 and STX1903, was undertaken by Groundwater Exploration Services, including laboratory permeability and porosity testing, with the results provided in Appendix A6g.

10.2.3 Water Quality Data Analysis

Water quality data have been collated into a database (along with surface water data), coded with a confidence value to indicate potential issues, and further investigated to ensure only reliable data were included. For the derivation of medians and guideline value statistics, measurements taken close together at the same sites were combined into a single value by averaging, to ensure reasonably independent events were utilised (results less than 2 weeks apart was used as the cut off). Field results for the fully purged sample were utilised rather than the pre- or during purge results.

Statistics were generated from the data using the methods outlined in Appendix A6c. Grouped statistics were generated for the groundwater chemistry zones identified by McNeil et al. (2018) (refer Section 10.3.6.2).

10.2.4 Groundwater Model Development

The conceptual hydrogeological model and the collated baseline information formed the basis for the development of the updated numerical groundwater model. The model was designed to be consistent with, but more comprehensive than, previous models developed for the Project as well as to incorporate targeted research findings undertaken to support the updated groundwater assessment.

Model development followed the process of desktop and literature review, including of the previous EIS and SEIS v1 and v2, geological information and related data to develop the conceptual hydrogeological model, and to parameterise the model Hydrostratigraphic units (HSUs).

10.2.4.1 Conceptual Hydrogeological Model

The CQC geological block model and available geological mapping, along with drillhole data and TEM survey findings, was combined with the previous groundwater model structure from the SEIS v2 and related supporting information (refer Sections 10.2.1 and 10.2.2) to develop the conceptual model. The basement rock was based on interpretation of the available geological mapping and in consultation with CQC's geologists. The model also incorporates the mapped structures and faults within the basement rock at the interface of the Early Cretaceous Styx Coal Measures and the Permian Measures to the east/north-east of the Project.

The conceptual model was developed to be generally consistent with the four chemistry zones identified by McNeil et al. (2018), which is supported by the water quality data. Parameterisation was undertaken for the key HSUs based on field and literature values as detailed in Appendix A6b, with the source information summarised in Table 10-3.

Compared to the previous SEIS v2 conceptual model, significant work has been undertaken to delineate and parameterise the model into further layers to allow for a better overall understanding of the system. This has included:

- Splitting of the Qa into Quaternary Holocene and Qpa Alluvium, from indications that the Qa, relative to the Qpa Alluvium, can be conceptually less compacted and of a different composition. This was based on CQC geologist's interpretation, the results of the TEM survey (Appendix A6f), review of soil and groundwater data and geomorphology (Appendices A3a, A6b and A5d respectively) and the results from aquifer testing (refer Appendix A6b). This allows for sensitivities of the two layers to be explored and a better understanding of groundwater flow in these important aquifer areas.
- The coal seams and interburden were lumped together in the previous SEIS v2 model. In the updated model, these have been split out into five layers, representing three coal seam layers, aggregated to the red, blue and violet seam respectively, and two interburden layers. Both the previous and current models cap these with overburden (at the top) and underburden (at the bottom) layers, and so the three layers used for the Styx Coal Measures in the SEIS v2 have now been split into seven in the current model.
- The model also includes historical coal mining to the north of the Project, and has been incorporated to account for the effects of long-term recovery in the coal seams due to the long period of historic mining in the area.

10.2.4.2 Numerical Model

The numerical groundwater model development was guided by the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), IESC Information Guidelines and Explanatory Notes, previous improvements suggested through external and peer reviews and improvements made by the Queensland OGIA, as well as improvements in uncertainty analysis through a combination of statistical methods and scenario-based analysis.

It was developed using the following software packages (refer to Appendix A6b for further detail):

- MODFLOW-USG Software
- AlgoMesh Software
- USG-Transport Software and
- AlgoCompute Platform and HGSUQ Software.

The development has been undertaken in consultation with regulatory agencies and the AGE peer reviewers.

Model Domain and Structure

The numerical groundwater model was developed to be consistent with the conceptual model and comprises a total of 14 layers (compared with 6 layers in the previous SEIS v2 model) plus the Basement layer. Layers 2 to 4 represent the Qa, estuarine deposits, Tertiary sediments and the regolith. These layers have been developed to improve the overall connectivity analysis. Layers 5 to 11 represent the Early Cretaceous Styx Coal Measures and have been segregated to allow for interpretation of variant permeability throughout the coal measures as well as the interburden. Layers 12 to 14 represent the basement layers comprising the Permian Back Creek Group and the Lizzie Creek and Connors Volcanic Groups. The model also considered faulting and various geological features and structures identified through geological mapping.

A top layer (layer 1) was included with a zero depth (i.e. inactive) for pre-mining, but which was used for modelling of elevated landforms such as waste rock dumps and modelling post mining scenarios such as groundwater mounding beneath these elevated landforms.

The model boundaries comprise no-flow boundaries at the topographical ridges of the Styx River catchment, the pinching out of selected layers (i.e. Styx Coal measures to the west of the model domain), water courses represented as river cells with the application of conductance values for the river beds, application of recharge and evapotranspiration inputs across the model domain, as well as the inclusion of historical mining operations during stress periods as part of the transient calibration.

Transient recharge has been applied based on a constant proportion of rainfall for the averaging period, and where the less consolidated Cainozoic Sediments (i.e. Quaternary Alluvium) are present, higher recharge rates have been applied relative to the mapped Qpa (consistent with the conceptual model). Episodic flood events were not be applied to the predictive model, however, allowing for a conservative impact assessment.

The model structure is shown in Table 10-4, including a comparison of the previous SEIS v2 model layers, and the extent in Figure 10-2. Improvements over the previous model structure include:

- Expanding of the boundary to the north-east to include a greater portion of FHA-047, existing tidal monitoring point and to envelope Wellington Creek (including Stoodleigh Creek) catchments, and to the north-west to envelope the Granite Creek catchment (from 43 x 54 km to 57 x 54 km).
- Expansion of the model layers as summarised into Section 10.2.4.1 above, from 6 layers + Basement to 14 layers + Basement, and refinement of the layer structure, based on additional drilling, geological block model information, review of existing geological mapping and interpretation of TEM survey and groundwater monitoring well data, including well logs, as detailed in Appendix A6b.
- Depth dependence of the coal seams was incorporated into the model, as recommended by past (and current) peer review comments.
- Change from a structured grid with 0.47 million active cells, ranging from 20 – 640m (coarse to very fine), to an unstructured grid of 0.49 million active cells (coarse to fine), which allows more refined groundwater connectivity analysis along watercourses, drainage features and wetlands
- Inclusion of historic mine workings to allow historic depressurisation (and recovery) in coal seams at depth.
- Inclusion of faulting in the new model, to allow for zones of enhanced or reduced hydraulic conductivity to consider in the uncertainty analysis.
- Tidal boundary adjusted from a constant 2 mAHD boundary condition, to a 3.5 mAHD boundary condition, with sensitivity range of 2 – 4.5 mAHD, based on tidal measurements and LiDAR data, and considering the correction factor for seawater density. This tidal boundary extended along

the mapped estuarine reach of the Styx River to the Ogmore Bridge. No-flow boundary conditions were extended along topographic ridges for the whole of the catchment.

Table 10-3: Summary of model parameterisation data sources

Hydrostratigraphic Unit	Field Tests[1]	Literature sources[2]
Quaternary Alluvium	WMP05 (FHT), WMP29A (FHT, RHT)	Ausenco-Norwest (2012), AGE Consultants (2006), JBT (2012), Matrix Plus (2012), URS (2009), CDM Smith (2013), McNeil, et al. (2018), URS (2012)
Quaternary Pleistocene Alluvium / Regolith	WMP02 (RHCRRT), WMP04 (FHT), WMP08 (FHT), WMP09 (FHT), WMP12 (RHCRRT), WMP25 (FHT), WMP26 (FHT), WMP29B (FHT, RHT), STX1901B (OEPT), STX1901C (OEPT), STX1902B (OEPT), STX1902C (OEPT)	SKM (2014), Rau et al. (2018)
Styx Coal Measures (Overburden and Interburden)	WMP04D (FHT), WMP10 (FHT), WMP13 (FHT), WMP17D (FHT, RHT), WMP18D (FHT), WMP21D (FHT), WMP22A (RHT), WMP23A (FHT), WMP24 (FHT), WMP27 (FHT), WMP28(FHT), STX1812 (CP), STX1903 (CP), STX1901A & STX1902A (PT with STX1901B, STX1902B, STX1901C, STX1902C)	Coffey (2014)
Styx Coal Measures (Coal Seams)	WMP22B (FHT, RHT, RHART)	Mackie (2009), Coffey (2014)
Styx Coal Measures (Underburden)	WMP06 (FHT), WMP08D (FHT), WMP22C (FHT, RHT, RHART), bottom intervals of STX1901A & STX1902A (PT)	
Back Creek Group (including Boomer Formation)	WMP16 (FHT, RHT), WMP16D (FHT, RHT), WMP19 (FHT), WMP19D (FHT), WMP20 (FHT, RHT), WMP20D (FHT, RHT)	URS (2012), CDM Smith (2013),

Table notes

1 Test abbreviations (data included in the numerical groundwater model and groundwater assessment report in Appendix A6b unless otherwise specified): FHT – Falling head slug test; RHT – Rising head slug test; RHCRRT – Rising head constant rate recovery test; OEPT – Open end permeability test; CP – Core permeability test work of recovered core (included in Appendix A6g); PT – Packer testing, with shallow observation holes in brackets after packer testing holes; RHART – Rising head airlift recovery test

2 Other data provided in the SEIS v2 and Appendix A6b

Table 10-4: Numerical model layers

Model Layers			Unit / Geology	Lithology	Indicative Thickness (m)[2]	
SEIS v2[1]	SEIS v3 (current)					
N/A	Upper	1	Inactive Layer for Elevated Landforms (e.g. Out-of-pit Waste Rock Emplacements)	Predominantly (Bulk) Kx (Broken Overburden / Interburden)	Up to 75	
1		2	Quaternary / Tertiary / Weathered Regolith (Early Cretaceous / Permian / Volcanics)	Qhe/s, Qhe/m, Qhcm Qa Qpa, Qr, Qf > Kx Ta Kx Pb, Pbm Pc, Pv, Cp	10	20.2
		3		Qa Qpa Ta Kx Pb, Pbm Pc, Pv, Cp	5	
2		4	Weathered Regolith (Early Cretaceous / Permian / Volcanics)	Kx Pb, Pbm, Pvw Pc, Pv, Cp	5.2	
3	Middle	5	Overburden / Interburden (Upper)	Kx (Overburden)	43.6	242.1
4		6	Coal Seams (Aggregated to Red Seam)	Kx (Coal)	2.6	
		7	Interburden	Kx (Interburden)	55.8	
		8	Coal Seams (Aggregated to Blue Seam)	Kx (Coal)	4.3	
		9	Interburden	Kx (Interburden)	21.3	
		10	Coal Seams (Aggregated to Violet Seam)	Kx (Coal)	2.2	
5		11	Underburden	Kx (Underburden)	112.3	
6	Bottom	12	Back Creek Group (including Boomer Formation) and Glenprairie/Wangrabry Beds	Pb, Pbm, Pvw	859 m – 1,005	
		13	Carmila Beds / Lizzie Creek Volcanic Group	Pc, Pv, Cp		
		14	Intrusive Rocks / Connors Volcanic Group	CPvo, CMzg [West Only]		
	Basement (to -1000 mAHD)					

Table notes

1 Layers are approximate in their relation from SEIS v2 to SEIS v3 model structures

2 Median Model Cell Thickness.

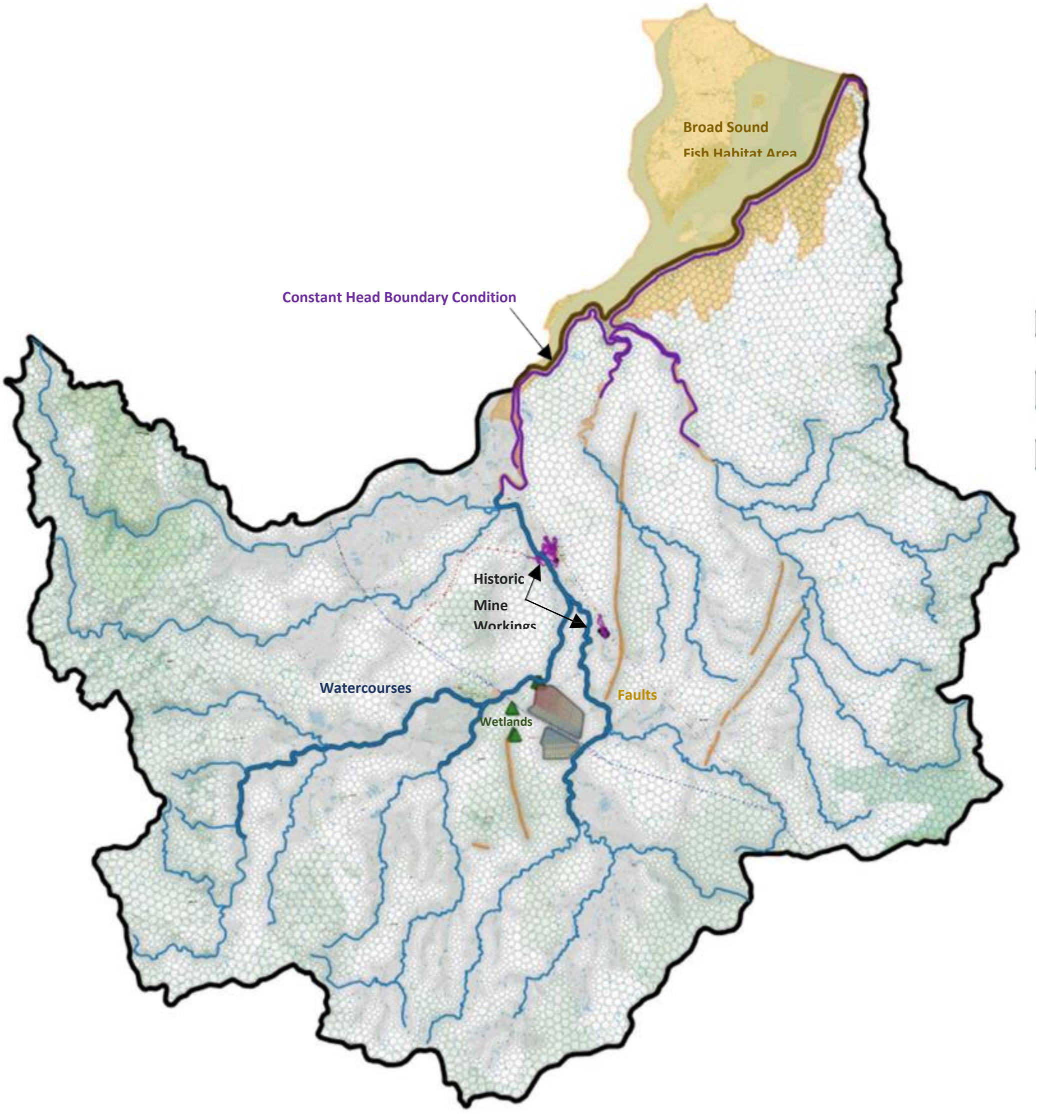


Figure 10-2: Numerical model domain (sourced from HydroAlgorithmics 2020)

- All the key river (and drainage) reaches located within the model domain have been assigned as river cells and partitioned consistent with the conceptual groundwater model. As an improvement to the previous groundwater model, river cells (with Stage Depth > 0 m) are used instead of drain cells. Conductance values have been applied to river cells based on an average bed area for each of the key river (and drainage) reaches. Stage heights were applied as follows:
    - Styx River Mouth - constant head boundary of 3.5 mAHD
    - Styx River, downstream of the Granite / Montrose Creek confluence; Wellington Creek downstream of the Wangraby Creek confluence - 2m stage height
    - Styx River, upstream of the Granite / Montrose Creek confluence; Tooloombah Creek, downstream of the Mamelon Creek confluence to the Styx River; Wellington Creek upstream of the Wangraby Creek confluence to Landsborough Creek confluence - 1m stage height and
    - All other streams and reaches – 0m stage height.

- Additional drainage reaches were applied to Granite, Montrose, Barrack, Brumby, Kyour, Oaky, Magdelan, Gilnorchie, Stoodleigh, Ewan, Landsborough, Wangraby and Stotts Creeks, Clive Gully, Tooloombah Creek South and North branches.
- Application of evapotranspiration extinction depths based on maximum rooting depths of vegetation types, with the depth varying dependent on the lithology (i.e. mapped unconsolidated sediments), the mapped high, moderate and low potential GDE areas, and vegetation cover.
- Extension of calibration period to include available datasets collected in 2011-2012 and 2014, additional data collected since March 2018, and consideration of around 40 years of historic mining and 60 years of recovery.
- Application of the Temporal Parameter Variability (TVM) Package to model time varying properties to backfilled spoil within the open cut pits.

Additional minor model changes are detailed in Appendix A6b.

Parameterisation and Calibration

The numerical model was calibrated mainly focusing on historical groundwater level observations in comparison to the groundwater levels predicted by the model. Both a steady state calibration and transient calibration was undertaken, with the steady state calibration using the average measured groundwater levels and the transient calibration using data recorded in the period between 2010 and 2019. Calibrated parameters and their spatial representation used for the model are reported in Appendix A6b.

Calibration was initially undertaken manually to assess model stability, before being automated using the PEST suite of software (Doherty 2016). Model calibration for the steady-state and transient modes gave scaled root mean square (SRMS) errors of 3.49% and 2.01%, respectively and indicate good overall model calibration across the model domain and indicative vertical head gradients are generally consistent. The mass water balance error achieved a target threshold of <0.5% mass balance closure error for both steady state and transient calibration.

Details of the calibration undertaken including calibration targets is provided in Section 7 of Appendix A6b.

The modelled water balance used during the numerical model estimated an overall net water surplus of 0.003 ML/day, with recharge forming the biggest input (51 ML/day) and evapotranspiration (-67 ML/day) the biggest output.

Based on the calibration results the model is considered to meet the expectation of, and be classed as, a Class 2 model as defined by the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), confirmed by the groundwater peer reviewers (Appendix A6c), making it capable of a number of specific uses, namely:

- providing estimates of dewatering requirements for mines and excavations and the associated impacts
- providing impact predictions of proposed developments in medium value aquifers
- predicting long-term impacts of proposed developments in low value aquifers and
- evaluating to inform management of medium risk impacts.

Predictive Modelling

Model predictions were undertaken in line with the mine plan / schedule, incorporating the initial model conditions, stress period lengths as well as climate and climate change as part of the predictive model runs. The excavation and backfilling of the pit and the construction and management of the external waste landforms (incl. storage dams, and coal rejects) were considered as part of the predictive modelling.

Note that the model was developed based on a July 2020 (Year 1) to July 2038 (Year 18) mine operational period, which is (as is obvious) incorrect, due to the timing of the model development. Reporting within this Chapter is undertaken generally by year number (Year 1, Year 2, …. Year 18), or with reference to the revised timeline presented in Chapter 1 – Introduction and Project Description.

The initial conditions for predictive modelling were based on the groundwater system at the end of the initial transient calibration period (September 2019) with an additional monthly prelude transient prediction period up to commencement of mining to ensure continuity in the transient prediction model runs. The stress period lengths ranged from monthly (for refined calibration, mine prediction and mine closure) to annual (for extended calibration and post-mining), five yearly (for precalibration and 100 years post mining) and 400 years (for long-term post-mining recovery) using Adaptive Time Stepping to optimise model convergence. Climatic conditions were kept constant within the predictive model runs to allow comparison of Project only impacts, allowing for a conservative assessment. Climate change predictions were addressed as part of the uncertainty analysis.

The active open cut mining areas were simulated using drain cells with the invert elevation guided by model layer geometry as well as provided mine progression plans. No advanced dewatering is proposed nor modelled.

Given the temporary nature of the out-of-pit waste rock landforms that are re-handled, to reflect changes during mining the final rehabilitated landform was used, despite the changes in elevation that occur during the life of the Project. This is considered to be of no material consequence to the numerical groundwater model predictions during mining as the groundwater table would generally be in excess of tens of metres deep during the operational life and lower due to the advancing open cut mining areas. Final elevated landforms were applied with an elevation up to 75 m above pre-mining levels, and incorporating higher permeability, higher infiltration rates and higher evapotranspiration rates, due to the broken unconsolidated nature of the material.

Uncertainty Analysis and Sensitivity Testing

A combination of parameter identifiability, sensitivity and qualitative analyses have been used to identify bounds (or constraints), recognising the challenge of non-uniqueness, whereby multiple combinations of parameters may be equally good at fitting historical measurements. Parameter identifiability analysis assesses this issue, to understand whether it is theoretically possible to estimate unique parameter values from data – i.e. whether multiple combinations of different parameter values will fit the calibration data equally well.

Identifiability analysis undertaken for the Project identified hydraulic conductivity, infiltration rates, specific storage and specific yield as important parameters, which is supportive of the targeted design for site-specific investigations including localised aquifer testing, open end and packer testing, TEM survey for the upper model layers (Layers 2-4), and laboratory core permeability and porosity testwork for the model middle layers (Layers 5-11).

These parameters were specifically investigated across all layers as part of the quantitative Uncertainty Analysis.

Quantitative Uncertainty Analysis

Uncertainty analysis is a key component of modern groundwater modelling, to quantify and qualify the uncertainty in model predictions. Quantitative uncertainty analysis (QUA) aims to quantify the uncertainty in the model by generating a range of model prediction scenarios based on viable input ranges of the parameters, in comparison to the single set used in the base model scenario, and producing statistical analysis to understand the likelihood of certain outcomes.

A stochastic modelling approach was used in this study, using the Latin Hypercube Sampling (LHS) method to generate numerous alternative parameterisations (i.e. parameter sets). The model was run for each set (forming a model realisation), and the results aggregated for statistical analysis. LHS is similar to the classical Monte Carlo method but uses a stratified sampling technique, which typically provides faster convergence, but places no reliance on a linearization of the model and is free from the problem of autocorrelated samples that may occur with other approaches.

Uncertainty was assessed on hydraulic conductivity, infiltration rates, specific storage and specific yield properties throughout the model, with pilot points selected throughout Layers 2 – 14 to allow for spatial variation. All parameters were assigned a log-normal statistical distribution with the mean at the calibrated model value and a log standard deviation of 0.5 (with 0.25 used for specific yield). Randomly selected parameter values were selected from the statistical distribution for each parameter and applied to the pilot points, from which parameters for the entire model were applied by kriging.

The model realisations were run using AlgoCompute (HydroAlgorithmics 2020, Merrick 2017) as the platform for executing model runs in parallel and ‘in the cloud’, utilising cloud computing to evaluate up to 100 realisations simultaneously. The model-independent uncertainty quantification software HGSUQ (Miller et al. 2018) was used to generate the LHS parameter realisations and orchestrate the model runs within the AlgoCompute environment. Calibration statistics were generated for each realisation to determine whether it was a realistic parameter set for subsequent analysis.

In total, 1,000 realisations were evaluated, with a cutoff SRMS of 3%. Of these, 393 (39.3%) of the realisations were rejected as having an SRMS that was above the cutoff, and 5 were rejected due to non-convergence (0.5%), leaving 602 (60.2%) accepted realisations.

The Uncertainty Analysis results indicate the improved numerical model predictions are on the lower side of the QUA 50th percentile results (i.e. as likely as not to exceed), but it is noted that the SRMS error diverges (i.e. increases) as the QUA percentile increases (which is not unexpected).

Further detail on the methodology for the QUA is provided in Attachment 11 to Appendix A6b.

10.2.4.3 Model Peer Review

As part of developing the updated conceptual and numerical groundwater models, a staged independent peer review process was undertaken, with AGE undertaking four stages of peer review, as the model progressed through conceptualisation, calibration, prediction and uncertainty analysis - refer to the final Stage 4 peer review in the Numerical Groundwater Model Peer Review in Appendix A6e.

The final Stage 4 peer review concluded that:

> 'The groundwater assessment and supporting groundwater modelling work described in the HA report [Appendix A6e] and various attachments have been carried out in a professional and rigorous manner that meets current industry standards. The modelling work has generally been completed in line with the Guiding Principles included in the Australian Groundwater Modelling Guidelines and in the IESC Uncertainty Analysis Guidance Note and we [AGE] have not identified any fundamental flaws in the work which are likely to significantly effect model predictions.'

AGE noted and agreed with the commitment to review the numerical model at least every three years from the commencement of open cut mining, which has been adopted within this Chapter. They further recommended the following be included in each review (which has also been adopted by CQC):

- 'Re-calibration of the groundwater flow model to observed head differences in nested monitoring facilities and to estimated baseflow at the Tooloombah Creek and Deep Creek [streamflow] gauges and
- Re-running the predictive uncertainty analysis including the river bed conductance parameter, assessing a wider range of parameter values and adopting a higher SRMS cut off.'

10.2.5 Surface water / Groundwater Interaction Studies

Following the completion of the numerical groundwater modelling additional technical studies were undertaken to increase the understanding of shallow groundwater – surface water interactions that occur within the predicted Project impact area and characterise relationships between groundwater and identified riparian vegetation and GDEs (Appendix A6d). These studies follow an assessment undertaken by 3D Environmental (Appendix A10d), which developed conceptual models for four defined GDE assessment areas along Tooloombah Creek and Deep Creek.

Six transects of drilling were undertaken in the vicinity of the 3D Environmental GDE assessment areas to provide further quantitative data, including observed lithology, particle size distribution, soil water, EC and standing groundwater level. One transect was located on the eastern bank of Tooloombah Creek and two across Deep Creek. Drilled sediment samples were collected to the base of the alluvium and at various depths within the Styx Coal Measures. The sampled parameters were used to estimate hydraulic conductivity (K), water retention and likelihood of environmental use, respectively.

The data obtained was used to inform simple analytical modelling to:

- verify the feasibility of flood recharge and bank storage as a groundwater source
- identify whether moisture within the alluvial sediments can support GDEs in the region
- assess the feasibility for groundwater to sustain surface water pools in the region and
- estimate potential discharge volumes and discharge rates from the alluvial aquifer to the Tooloombah Creek and Deep Creek assessment areas, assuming lateral flow from bank storage.

Modelling of one of the pools (at site To2) was coupled with similar modelling of pool level and EC at the Tooloombah Creek gauging station site reported in the Flood Study and Water Balance in Appendix A5b.

10.3 Desription of Environmental Values

10.3.1 Climate

The Project region experiences a sub-tropical climate, with cool winters and hot summers. Mean winter (July) temperatures range between around 8 and 25°C, whilst mean summer (December-January) temperatures range between around 23 and 33°C.

The Study Area experiences a distinct wet season with more rainfall occurring during the summer months (December to March), and drier periods predominating in the winter and early spring months (June to September). The wet season experiences an increased number of storm events leading to relatively short-lived but intense rainfall events and cyclonic rain depressions can develop over the area. The average annual rainfall at Strathmuir (BoM Station 033189) is 759 mm, with the highest average rainfall month (143 mm) being February and the lowest average rainfall month (16 mm) being September (Figure 10-3). Recharge and stream runoff potential is highest during the summer months, when most rainfall occurs, although long lasting rainfall events at other times of the year could also give rise to sustained rates of recharge.

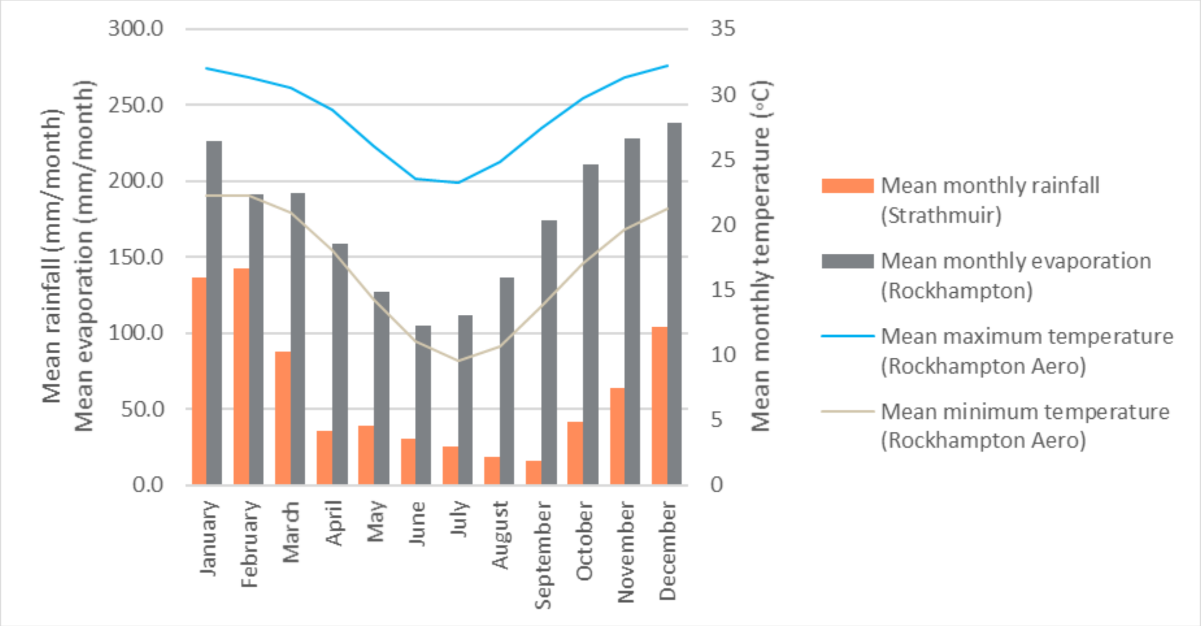


Figure 10-3: Mean climatic conditions

The mean monthly evaporation (calculated from the long-term average daily evaporation at Rockhampton Aero (BoM Station 039083) ranges from a maximum of around 240 mm/month in the summer months to a minimum of around 105 mm/month in the winter months. Total average annual evaporation (around 2,100 mm) is considerably higher than average annual rainfall, and on average evaporation rates exceed rainfall rates in every month of the year (Figure 10-3).

10.3.1.1 Rainfall during water sampling events

Figure 10-4 shows the actual rainfall for the November to May period (which covers wet season events) and full years versus the long-term average annual rainfall from the Mamelon weather station (with some infill rainfall from the St. Lawrence Post Office station - BOM station 033065, May – June 2017).

As can be seen, monitoring has coincided with a range of rainfall periods, from above average (2017) to well below average (2018, 2019).

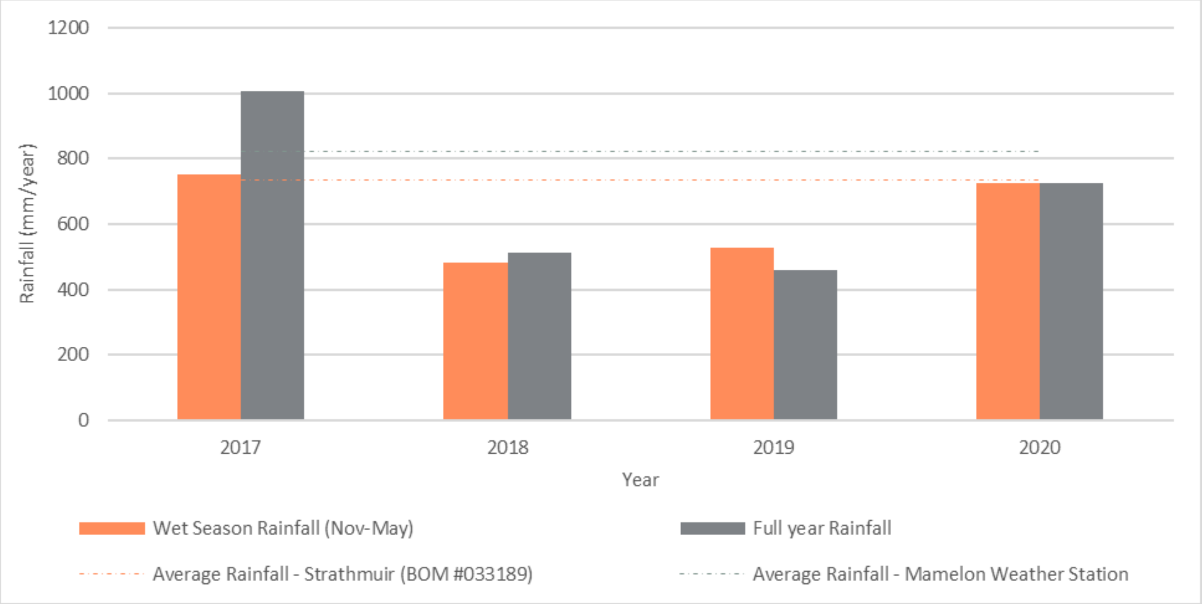


Figure 10-4: Average vs actual annual rainfall – sampling period

10.3.2 Topography

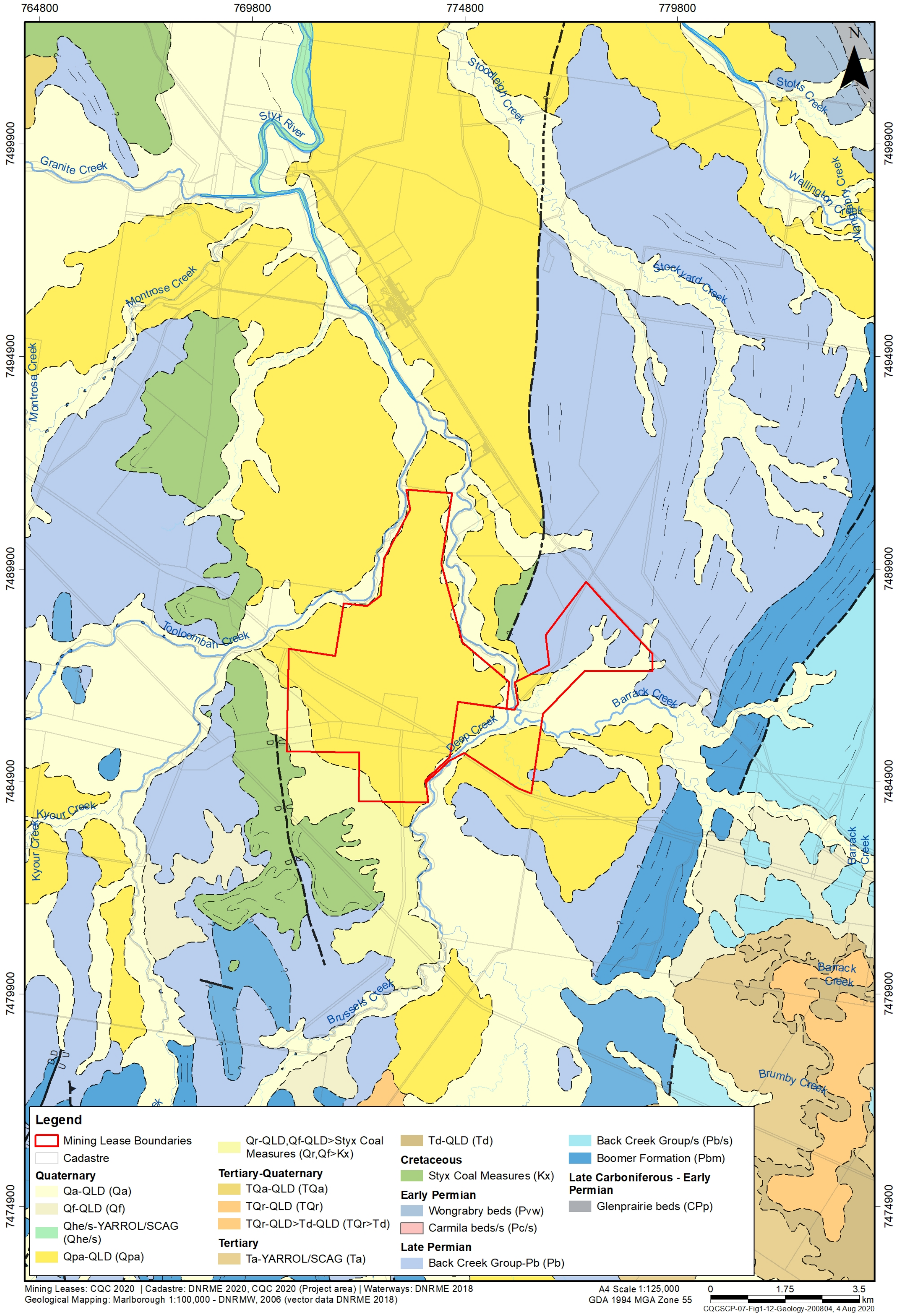
The Project lies within the Styx River catchment of the larger Styx River Basin, which has elevations ranging from 540 mAHD (metres Australian Height Datum) along the western catchment boundary to sea level at the coast. Topography at the Project can be described as floodplains that are generally flat or undulating land draining via several smaller creeks and tributaries to the Styx River and estuary with elevations ranging between around 10 and 155 mAHD.

A detailed description of the topographic setting of the Project is provided in Chapter 5 – Land.

10.3.3 Geology, Geochemistry and Geomorphology

The surficial geology of the Styx River catchment (refer Figure 10-5) is characterised as Holocene sediments in the estuary, with large areas of Qa deposits overlying the early Cretaceous Styx Coal Measures, which comprises quartzose, calcareous, lithic and pebbly sandstones, pebbly conglomerate, siltstone, carbonaceous shale and coal. The Styx Coal Measures overlie a progression of Late Carboniferous to Late Permian deposits. Alluvial lithological units Qpa and Qa dominate the Project area with Holocene Qh sediments also occurring in the estuary.

The alluvium in the Styx River valley was formed within the Quaternary Period (2.58 million years ago to the present) of the Cainozoic Era (66 million years to the present). Two main periods of Qa deposition occurred in coastal streams within alluvial valleys - the first was responsible for formation of the Qpa terraces that bound the rivers of the region, while the second was responsible for formation of the Qa benches and inset floodplains that are found within the macro-channel formed in Qpa sediments (refer to the Supplementary Technical Study Report, Fluvial Geomorphology in Appendix A5d).



Mining Leases: CQC 2020 | Cadastre: DNRME 2020, CQC 2020 (Project area) | Waterways: DNRME 2018
Geological Mapping: Marlborough 1:100,000 - DNRMW, 2006 (vector data DNRME 2018)

Figure 10-5: Surficial geology in proximity to the Project

The current watercourses are characterised by active channels deeply incised into a broad plain of older alluvium. The active channel comprises depositional benches and inset floodplains formed through the Holocene from a mix of material sourced from the catchments in recent times plus reworked older Pleistocene material. The main channels are thus considered partly confined by the older alluvium unit.

The fluvial geomorphology assessment (Appendix A5d) found most of the stream reaches were in a stable, moderate geomorphic condition. One migrating bend on the Styx River was identified as a significant source of sediment to the river. No knickpoints or zones of major geomorphic instability were observed on the mapped watercourses. However, the area contains a significant number of alluvial gullies and small tributaries incised into old alluvium. These are potentially sources of high sediment loads to the river system, and thus the GBR.

An assessment of the geochemical characteristics of waste rock and rejects, along with leachate testing, was conducted for the Project, detailed in Chapter 8 - Waste Rock and Rejects, and in the Geochemical Assessment of Waste Rock and Coal Reject technical report in Appendix A3b.

The assessment found that none of the samples were significantly enriched with metals/metalloids, when compared to the median background concentration (median crustal abundance) in unmineralised soil. Only zinc showed an abundance index (based on the ratio of the concentration to the median crustal abundance) greater than zero, although this was still below the level at which further investigation is warranted.

The assessment also demonstrated that the overwhelming majority of the waste rock and coal reject materials have a low reactive sulfur content, excess acid neutralising capacity, and are classified as non-acid forming. While a small fraction of the waste rock and coal reject materials may have some potential to generate acidity, the bulk materials will have excess acid neutralising capacity and will therefore generate alkaline surface runoff and seepage. Water extract testing on a ground sample and kinetic leach testing where water is leached through a crushed sample over time (and therefore both worst case) found pH to range from 8.6 to 10.0, with a low salinity and typically low levels of trace metals/metalloids other than aluminium, arsenic and selenium which were elevated compared to the ANZG (2018) DGVs in some of the samples. Major ions were dominated by sodium, chloride and sulfate.

Mapping of the lithology and geology along a number of transects of Deep and Tooloombah Creeks close to the Project (refer Appendix A6d - Surface Water/Groundwater Interactions Report) identified the following:

- transmissive units exist within the alluvium, typically as sands and gravels
- while the geological cross sections show the Quaternary sediments extend as a continuous unit across the transect, the transmissive alluvial sediments within this formation (specifically sands and gravels) consist in sporadic, discontinuous pockets, and generally present with a poor hydraulic connection with the underlying Styx Coal Measures
- Deep Creek:
    - the north transect intersects the north-south trending geological fault line that has been mapped on the eastern side of Deep Creek, and shows incisions of approximately 8 - 10 m into the Qa but does not intersect the underlying Styx Coal Measures and

  - the south transect shows incision into the Qa on the south-eastern bank and into the channel, and implies a very thin alluvial layer over the Styx Coal Measures on the north-western bank and
- Tooloombah Creek:
  - investigations conducted within the creek bed to the north-west of the Tooloombah Creek transect showed areas of the creek bed consist of Weathered Styx Coal Measures, with creek incisions at approximately 15 m within the Qpa and
  - Tooloombah Creek contains a higher clay content than Deep Creek, which generally underlies the alluvium sediments and is likely to restrict connection between the alluvial aquifer (where present) and the underlying Styx Coal Measures.

10.3.4 Acid Sulfate Soils

As detailed in Chapter 5 – Land, no acid sulfate soils are anticipated to be intercepted during mining, or to exist within the projected drawdown extent of the Project. This was based on the geology and geomorphology of the Project and its surrounds – namely, acid sulfate soil risk mapping shows low to extremely low probability, and the morphology of alluvial soils in the Project area are associated with freshwater long valley stream sediments and not marine sediment or weathered coal measures that could be associated with pyrite and acid sulfate soils.

10.3.5 Surface Water

10.3.5.1 Catchments and Key Waterways

The Project is located within the North East Coast Drainage Division, within the Styx River basin (Queensland river basin 127), a small basin of around 3,000 km^2 discharging into the Coral Sea. Landuse in the basin is predominantly ‘Production from relatively natural environments’ (91%) – predominantly grazing - followed by ‘Conservation and natural environments’ (8%) and ‘Intensive uses’ (1%) which comprise transport and communication, residential and farm infrastructure, services and mining (DES 2019b). The remainder is predominantly water (saline coastal wetland areas, rivers and dams), with minor areas of dryland and irrigated agriculture (0.5%). The Styx basin has been extensively cleared for grazing.

The Styx subbasin comprises several coastal catchments, grouped into three overarching areas, with the Project located within the Southern Styx Freshwaters under the EPP (Water and Wetland Biodiversity), and is within the Tooloombah and Deep Creek sub-catchment areas. These Creeks bound the Project, with Tooloombah Creek passing along the western boundary of (Mining Lease Application (ML) 80187, and Deep Creek along the east. Both join at the confluence approximately 2.3 km downstream from the Project, and drain into the Styx River and then into the Styx River and Broadsound Estuaries. The Broad Sound Declared Fish Habitat Area (FHA-047) and a General Use Zone of the Great Barrier Reef Marine Park are located within the Styx River approximately 10 km downstream of the Project lease boundary.

The normal tidal limit (mean high water spring, [MHWS]) within the Styx River is located approximately 3.7 km downstream from the Project, with the peak tidal limit (defined by the limit of the highest astronomical tide) extending upstream to the confluence of Deep and Tooloombah Creeks, approximately 2.3 km downstream from the Project.

10.3.5.2 Flood Hydrology

A flood assessment was undertaken for the Project, showing that flood events are largely confined to the Deep and Tooloombah Creek main channels, with minor breakouts from Deep Creek in the 1% Annual Exceedance Probability (AEP) event upstream of the Bruce Highway that contributes flow to the local drainage paths through the proposed mine area.

Further information on flooding is provided in Chapter 9 - Surface Water and Appendix A5b.

10.3.5.3 Surface Water Quality

The salinity (EC) ranges (4,884-37,800 µS/cm; 20th–80th percentiles) of the Styx River are large at surface water sampling point St2 (downstream from the proposed Project) reflecting the effects of tides and discharge of freshwater to sea following rainfall events. Since the installation of the Tooloombah Creek Gauging Station (ToGS01) in September/October 2019, and during the prevailing dry conditions in the second half of 2019, recorded salinity (EC) levels in the pool upstream of ToGS01 were shown to be gradually increasing and over a three-month period had more than doubled from 4,000 µS/cm to approximately 9,000 µS/cm. A comparable pool on Deep Creek, however, did not exhibit these extreme increases and assessment of both pools' volume and salinity changes suggest the Tooloombah pool receives groundwater inflow while the pool on Deep Creek does not (ELA 2020a).

Stable isotopic analysis of surface water in several locations within both Tooloombah and Deep Creeks (De2, De3, De5; To1, To2, To3) and a selection of nearby groundwater bores was undertaken in July 2018. The results indicate that the water at these locations undergoes evaporation (i.e. it is progressively enriched with heavier isotopes). However, radioactive isotope results and relative comparison to chloride and bicarbonate/chloride concentrations indicated that there is a potential for groundwater contributions to Tooloombah Creek, more so than Deep Creek, albeit potentially not in any significant quantities.

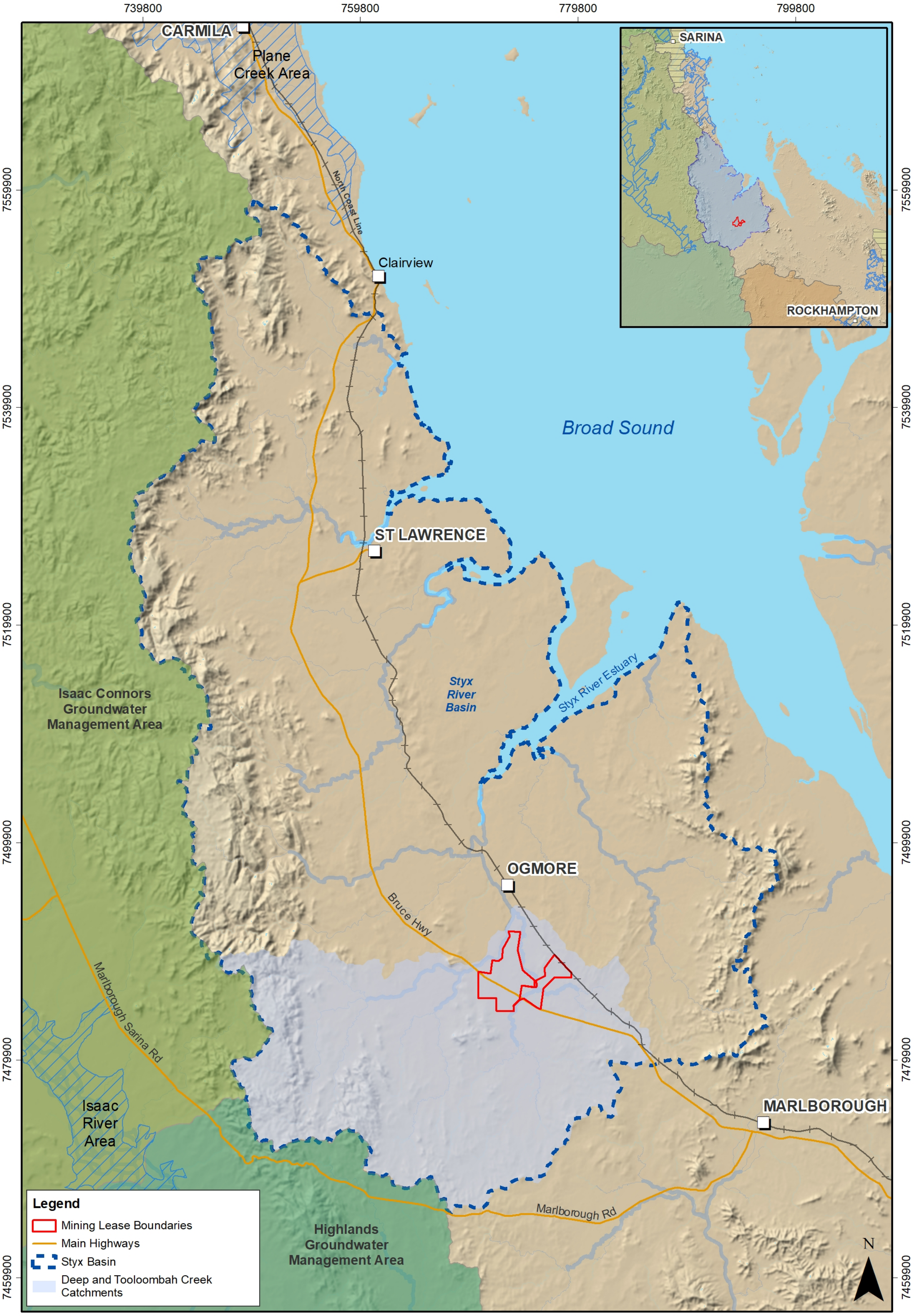
The indications from this data are that there is generally limited groundwater contribution from the water table, but it does appear to occur in some areas and to a limited degree.

10.3.6 Hydrogeology

10.3.6.1 Overview

The Styx River Basin lies outside of any declared underground water areas or groundwater management areas, as shown in Figure 10-6. The National Groundwater Information System lists the purpose for all bores in the basin as 'unknown', although as discussed further in Section 10.3.6.9 most bores identified in the bore census where a use could be identified were for stock watering, with only some used for domestic purposes.

On a catchment scale, the general direction of groundwater flow is toward the Styx River and the coast. However, groundwater flow patterns vary across the catchment in response to local-scale recharge and discharge mechanisms. Figure 10-7 presents the depth to the water table on the top, and the absolute elevation of the water table (in mAHD) across the model domain at the bottom, along with the flow net across this surface. This is based on the modelled water table surface at the end of the transient calibration period (September 2019), described further in the Groundwater Model and Assessment Report in Appendix A6b.



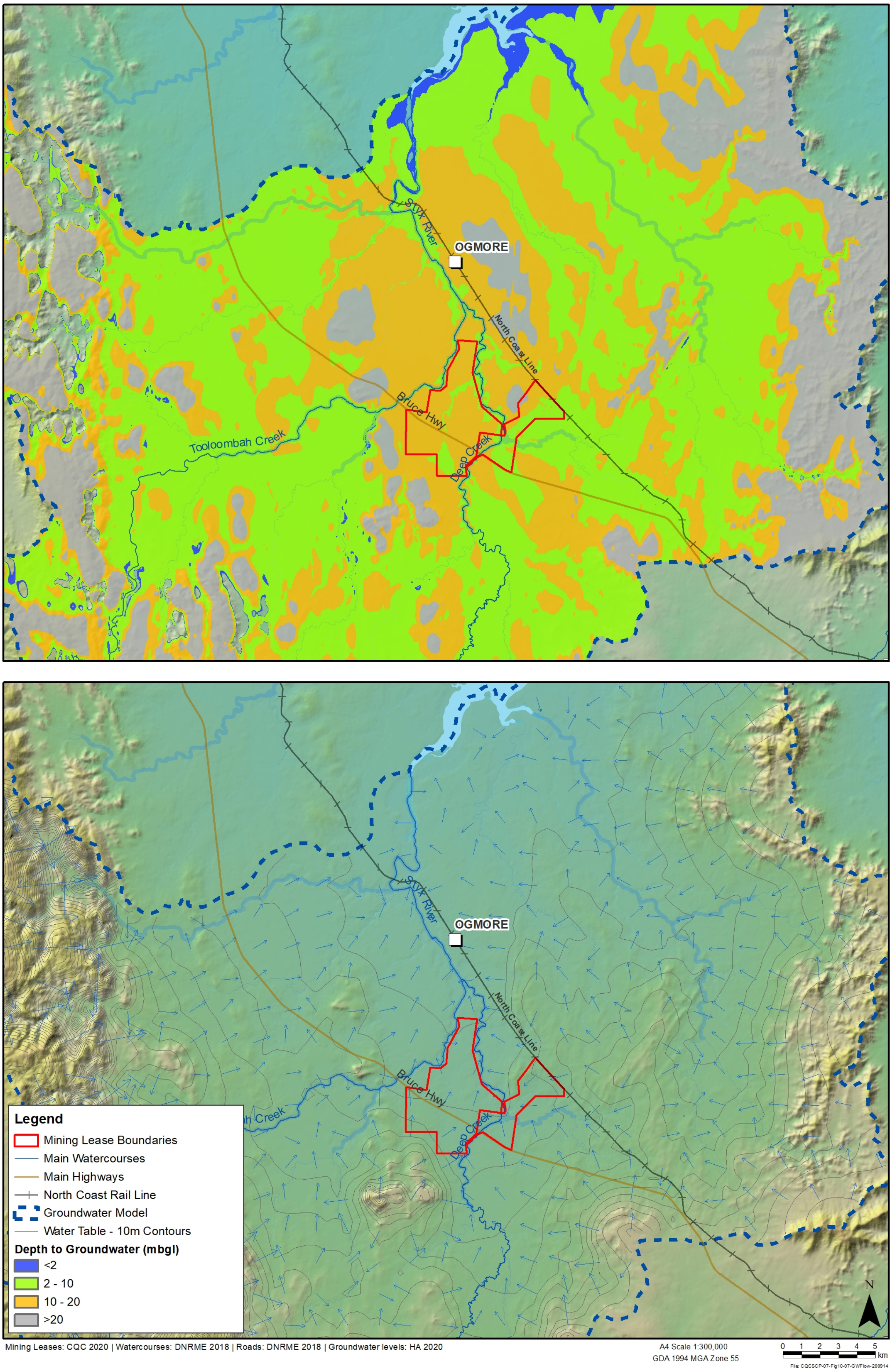
Mining Leases: CQC 2020 | Infrastructure: CQC 2020 | Watercourses: DNRME 2018 | Roads: DNRME 2018 | Sub-Catchments: OE 2020 | Basin Sub-Areas DNRME 2020

A4 Scale 1:500,000
GDA 1994 MGA Zone 55

0 5 10 km

File: CQCSCP-07-Fig10-06-StyxBasin-200914

Figure 10-6: Styx River basin



Mining Leases: CQC 2020 | Watercourses: DNRME 2018 | Roads: DNRME 2018 | Groundwater levels: HA 2020

A4 Scale 1:300,000
GDA 1994 MGA Zone 55

File: CQCSCP-07-Fig10-07-GWFlow-200914

Figure 10-7: Inferred water table elevation and groundwater flow

This shows the water table surface is likely a subdued reflection of topography, and that it generally occurs within 10 – 20 m of the ground surface in the less elevated parts of the Basin, and is very shallow in lower areas close to Styx River and Broad Sound. The inferred contours show groundwater flowlines from the upper catchment (the Tooloombah and Deep Creek sub-catchments) converge on the lower reaches of the creeks, whilst lower in the catchment the flowlines converge on the Styx River.

Relatively steep water table gradients are observed in Figure 10-7 in areas of the catchment where steep topography occurs and / or lower less permeable materials are likely to predominate, e.g. where there is surface exposure of basement rocks. Flatter water table gradients are observed where alluvium is extensive, likely due to higher permeability materials and / or relatively higher rates of evapotranspiration (from shallow water tables and / or phreatophytic vegetation). The pattern of water table contours around the major watercourses suggest that alluvial aquifer permeabilities are higher nearer to the watercourses.

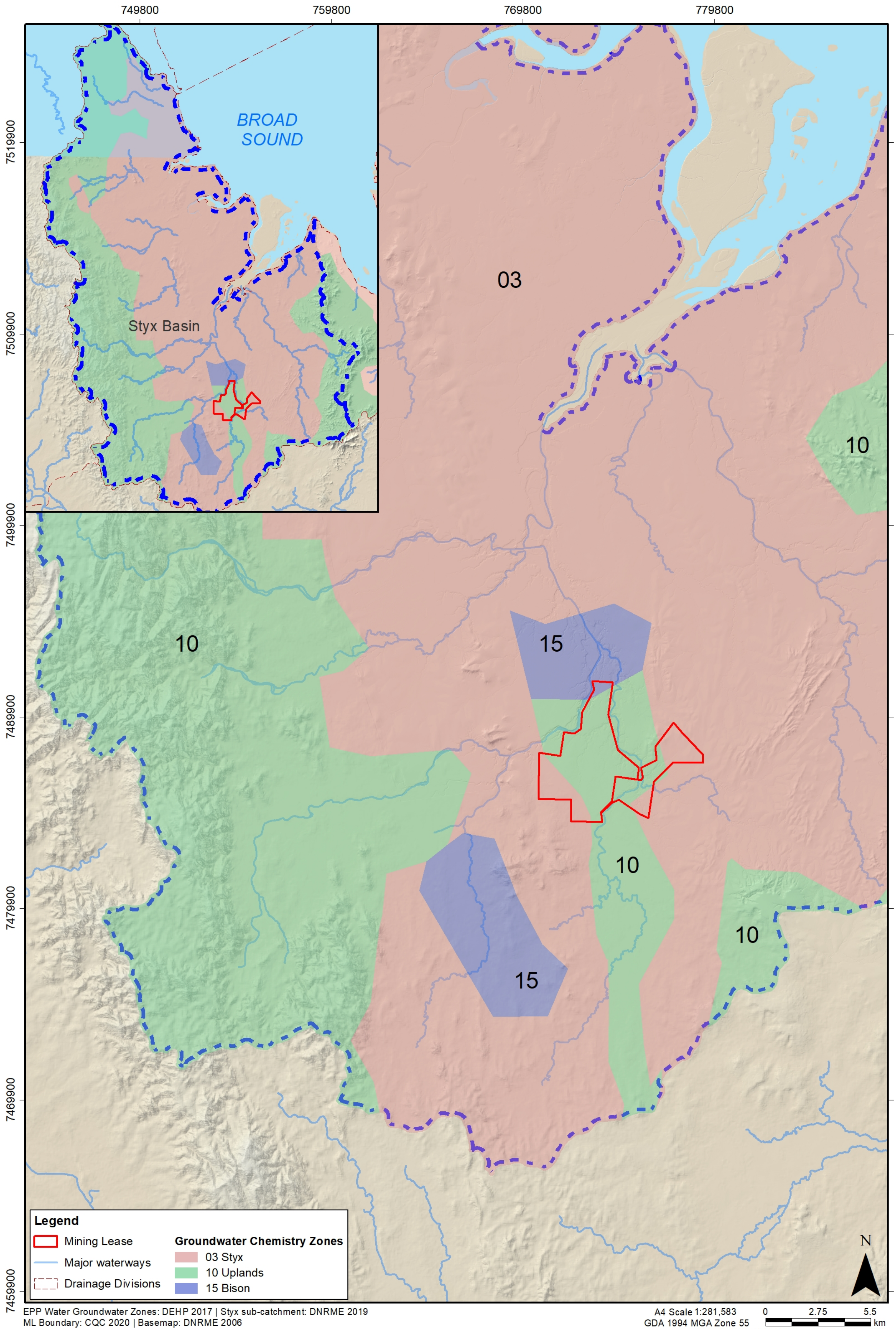
10.3.6.2 Hydrostratigraphy

Hydrostratigraphic Units (HSUs) are zones within a geological system that have similar hydrogeological properties with respect to their influence on groundwater occurrence and flow. While HSUs are often chosen based on geology, the type of rock is less important than the properties of the rock that control conductance and resistance to groundwater flow and groundwater storage. At the broadest level, HSUs are categorised as aquifers and aquitards, where aquifers consist of stratigraphic units (or sequence of units) that store and transmit useful amounts of groundwater, and aquitards consist of stratigraphic units (or sequence of units) that generally restrict groundwater flow and do not transmit useful amounts of water.

With reference to the EPP (Water and Wetland Biodiversity) and EHP (2014), as shown in Figure 10-8, the Project is located within the Styx (03), Uplands (10) and Bison (15) groundwater chemistry zones. However, analysis of the baseline water quality data indicates relatively high variability within these EHP (2014) groundwater areas, and a general disagreement with the EPP (2014) guideline values for the areas.

However, the hydrogeology and groundwater data in the Project area aligns much better to the draft consultation materials prepared by McNeil et al. (2018), which has provided four updated groundwater chemistry zones as shown in the first and second columns of Table 10-5 and in Figure 10-9. Based on the geology of the area and groundwater quality and characteristics, the HSUs adopted for the Project have been developed consistent with these zones, and are shown in the right hand column of Table 10-5 where they relate to the four zones of McNeil et al. (2018).

The water quality data shows much better consistency with these units, and better agreement with the draft guideline values provided by McNeil et al. (2018). Justification for the identified units is detailed in the Numerical Groundwater Model and Groundwater Assessment Report in Appendix A6b, and the Groundwater Quality Data Summary Report in Appendix A6c.



EPP Water Groundwater Zones: DEHP 2017 | Styx sub-catchment: DNRME 2019
ML Boundary: CQC 2020 | Basemap: DNRME 2006

A4 Scale 1:281,583
GDA 1994 MGA Zone 55
CQCSCP-07-Fig10-08-EPPWater-200917, 17 Sep 2020

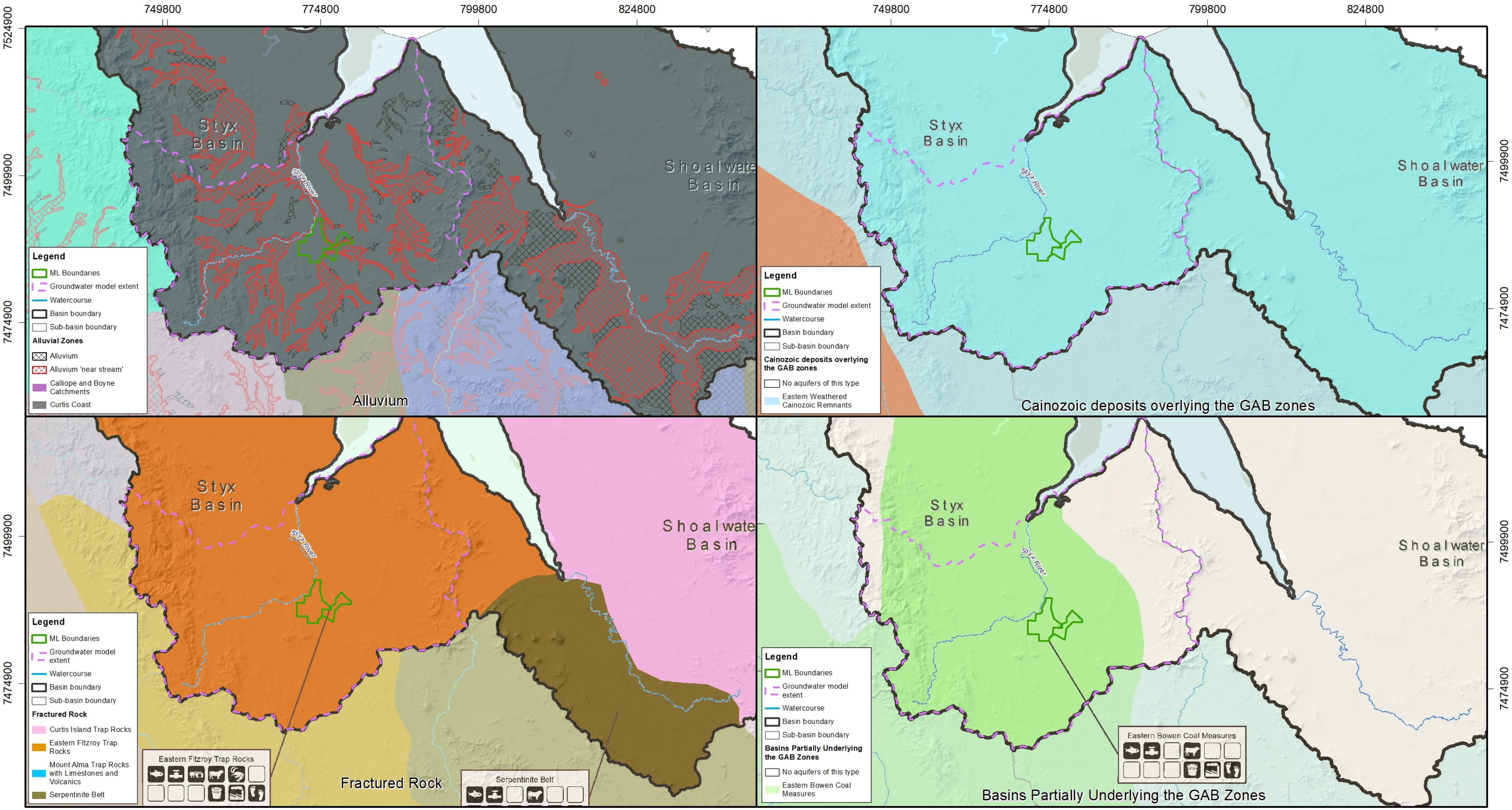
Figure 10-8: EPP (Water and Wetland Biodiversity) 2014 Groundwater Chemistry Zones (EHP 2014)

Table 10-5: Adopted hydrostratigraphic units (HSUs)

McNeil et al. (2018) zones		Adopted HSUs (and ID No.)	Geology
Alluvial zones (AZ6)	Alluvium	Quaternary Alluvium (Qa) (1)	Quaternary Holocene aged Cainozoic floodplain alluvium, comprising clay, silt, sand and gravel; also includes estuarine alluvium
	Alluvium 'near stream'		
Cainozoic deposits overlying the GAB zones (CZ2)	Eastern weathered Cainozoic remnants	Quaternary Pleistocene Alluvium (Qpa) / Quaternary Alluvium (lower) / Regolith (2)	Quaternary Pleistocene aged Cainozoic alluvium on higher terraces, comprising sand, mud and gravel
Basins partially underlying the GAB zones (GZ11)	Eastern Bowen Coal Measures	Styx Coal Measures (Kx) (upper)[1] - Overburden (and Quaternary Alluvium [Lower]) / Weathered Regolith (3)	Lower (Early) Cretaceous coal bearing strata comprising: • overburden - variably weathered interbedded quartzose sandstone (dominant) and siltstone / mudstone, and traces of coal • coal seams and interburden - coal seams, variably weathered interbedded siltstone/mudstone (dominant) and sandstone • underburden - interbedded sandstone (dominant) and siltstone / mudstone
		Styx Coal Measures (Kx) (lower)[1] - Overburden / Coal Seams, Interburden / Coal Seams, Underburden (and Quaternary Alluvium [Lower]) / Weathered Regolith (4)	
Fractured Rock (FZ10)	Eastern Fitzroy Trap rocks	Permian Measures - Back Creek Group (and Styx Coal Measures - Underburden) (5)	Permian aged basement rocks, comprising: • Back Creek Group – quartzose to lithic sandstone, siltstone, mudstone, carbonaceous shale, calcareous sandstone and siltstone, conglomerate, coal, limestone and sandy coquinite • Lizzie Creek Volcanics (Carmilla Beds), Basaltic to andesitic lava and volcaniclastic rocks (including breccia and arenite), rhyolitic to dacitic lava and volcaniclastic rocks (including ignimbrite); local siltstone, shale and polymictic conglomerate
		Permian Measures – Carmila Beds (and/or Back Creek Group) (6)	

Table notes:

[1] the two units have been simplified for use in the following sections of this Chapter as the Styx Coal Measures (upper), and Styx Coal Measures (lower), which is a generalisation for brevity.



Sources: Draft Water EPP Groundwater Zones: McNeil et al 2018 (Qld DES)
ML Boundary: CQC 2020 | Model boundary: HA 2020

Figure 10-9: Draft 2018 groundwater zones (McNeil et al. 2018)

The previous SEIS v2 described four HSUs – Alluvium (aquifer), Styx Coal Measures (aquitard), weathered residual and fractured basement (aquifer), and unweathered possibly fractured basement (aquitard). The system described in this SEIS v3 reflects the extensive work conducted to differentiate the Qa and Qpa units and to better define the differences within the Styx Coal Measures, warranted by the results of the TEM survey (Appendix A6f), geological assessment (Groundwater Model and Assessment Report in Appendix A6b), and the water quality data (Groundwater Quality Data Summary, Appendix A6c summarised in Section 10.3.6.6). As such, the alluvium described in the SEIS v2 has been split into the Qa and Qpa units, the Styx Coal Measures have been split into the upper and lower units. Other units remain the same.

10.3.6.3 Groundwater level

As noted in Section 10.3.6.1, groundwater is present at around 10 – 20 metres below ground level (mbgl) at the site. Data for the standing water level recorded at each site, grouped by the major HSU, is shown in Figure 10-10. As can be seen, most of the Qa is at less than 10 mbgl, while the Qpa Alluvium, the upper Styx Coal Measures and the upper Permian Back Creek Group cluster around 14 mbgl. The lower coal measures are a little deeper, with a large range, and the Carmilla Beds, represented by one bore, was measured at ground level (and at times overflowing).

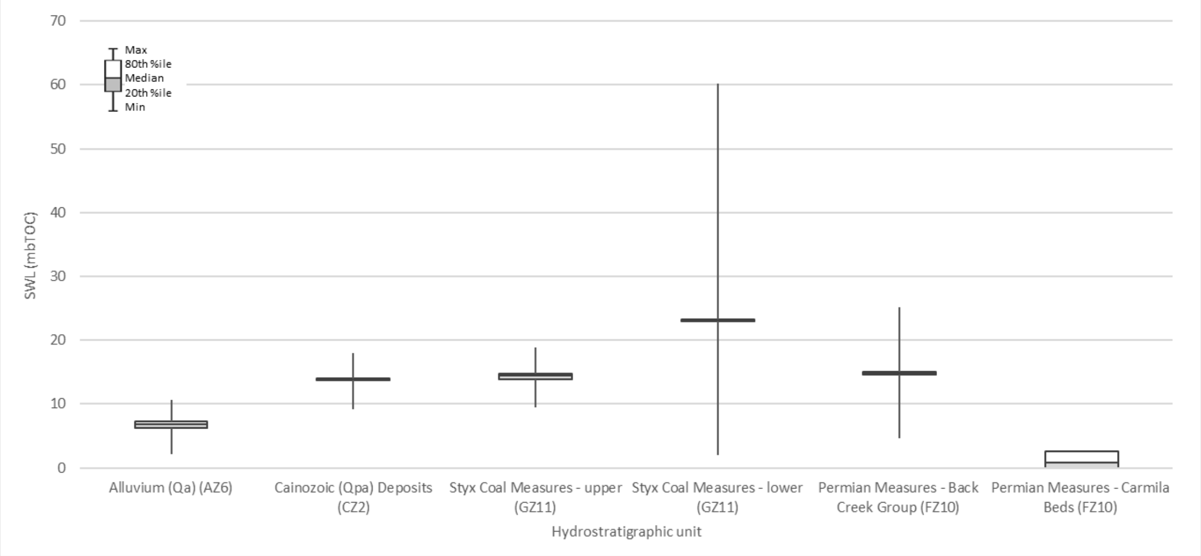


Figure 10-10: Boxplot of SWL for key bores in Project area

Figure 10-11 to Figure 10-15 show the recorded standing water level at each site over time, categorised by the screened HSU. As can be seen, the more permeable and surficial Qa groundwater system saw a fall over time in groundwater levels after late 2017, however, this was not seen in the other units, other than one site (WMP10) in the upper Styx Coal Measures. Some variation is seen in the deeper wells, but this is generally explained by the development of the wells soon after installation, or otherwise levels represent very small variations.

The sustained fall in the Qa may be explained by the low rainfall conditions over the period from mid-2017 to early 2020. A rise is then seen with the larger event at the start of 2020. The levels are also seen to respond to the earlier wet event at the start of 2017. This supports the idea of recharge of the Qa groundwater system mainly during larger events, but not extensively for below average wet seasons (notwithstanding that bank storage would recharge to some extent every wet season, close to the stream), and given the minimal response to the 2018 / 2019 wet season, it appears that these larger flood events are the primary source of recharge for the alluvial systems investigated.

Of interest is the lack of corresponding response to rainfall in the Qpa alluvial system, showing that the two units act, and recharge, in quite different ways – clearly the flood recharge seen in the Qa alluvium is not mirrored in the Qpa alluvium (or other units), with as noted above the exception of WMP10 – it is possible there is some input from the above alluvial units into the well at this site. This is readily explained by the Qa units being confined to stream areas.

The groundwater level (and therefore pressure head) in the nested wells was examined, and the hydraulic gradient inferred from the different pressure heads in overlying and underlying units – where the head is higher in deeper units, an upward gradient is inferred, whereas where the shallower units are higher, a downward gradient is inferred.

The data is shown graphically in Figure 10-16 to Figure 10-27, this time showing the SWL elevation, in mAHD. Some correspondence to the extended dry period (declining groundwater head) and reactions to the early 2020 rainfall events (rising groundwater head) can be seen in most of the sites, although the effect is very subtle compared to that for the Qa alluvial unit (and thus cannot be clearly seen in the earlier figures). This implies recharge from the larger events does affect the deeper / confined units, albeit more slowly and to a much lesser degree.

Comparing heads within each nested bore, the following relationships can be seen:

- The following nested sites show a hydraulic head within the deeper Styx Coal Measures that is higher than within the surface alluvium layer, indicating an upward hydraulic gradient and the potential for groundwater flow from the coal measures to the alluvium, and possibly to the creek (as baseflow) in this area, where connectivity exists:
    - WMP04 (alluvium) and WMP04D (Styx Coal Measures overburden), located near Tooloombah Creek at the north western boundary of the ML
    - WMP08 (alluvium) and WMP08D (Styx Coal Measures underburden), located near Deep Creek immediately upstream of the ML and
    - WMP18 (alluvium) and WMP18D (Styx Coal Measures overburden), located around 1 km west of Deep Creek in the eastern area of the ML.
- The hydraulic gradient within the deeper layers is more variable, with the following results:
    - The WMP11 and WMP11D nested sites (both upper Styx Coal Measures [overburden], with WMP11 at 24m depth, and WMP11D at 36m depth), located above the confluence of Deep Creek and Tooloombah Creek downstream of the ML, indicate a similar upward gradient, but since they do not include surface alluvium, further extrapolations as to the effect on the alluvium and/or baseflow to creeks cannot be made.
    - The monitoring sites WMP22A (Styx Coal Measures overburden), WMP22B (Styx Coal Measures coal seams/interburden) and WMP22C (Permian Back Creek Group) are located near Tooloombah Creek and around 1 km southwest of WMP04/WMP04D. The data suggests that there is an upward gradient between the deeper Permian Measures and the overlying Styx Coal Measures, but within the coal measures, the gradient shows a very slight downward hydraulic gradient.
    - Five nested bores have been installed at WMP29A (estuarine Qa), WMP29B (Qa), WMP29C (Styx Coal Measures overburden), WMP29D (Styx Coal Measures overburden) and WMP29E (Permian Back Creek Group / Styx Coal Measures underburden). This site is located adjacent to the tidal portion of the Styx River, around 4.5 km downstream of the Tooloombah and Deep Creek confluence or 2 km further downstream from the Ogmore bridge. The data indicates a downward hydraulic gradient from the surface (alluvium) down to WMP29C (coal

measures overburden). This reverses to an upward gradient within the coal measures, and between the coal measures and the deeper Permian Measures. This is similar to what was found at the WMP22 nested sites above, and shows that a deeper upward gradient does not necessarily imply a similar gradient at the surface.

- At the location of the paired WMP16 / WMP16D, located 7 km north west of the Project on an elevated area, and WMP19 / WMP19D located 2 km west of the Project also on an elevated area (all Permian Back Creek Group), the shallower bore has a higher head than the deeper bore, indicating a downward gradient within the unit.

  However, the paired WMP20/WMP20D site, also within the Permian Back Creek Group, west of the site around 4 km west-north-west of the Project, but west of (and lower than) the above elevated areas, the gradient is in the other direction – i.e. the deeper bore has a higher hydraulic head than the shallower, indicating an upward gradient in this location.

Overall, the data shows the potential for the deeper coal measures to supply water to the overlying alluvium, where connectivity exists. As noted in Section 10.3.3, Tooloombah Creek contains a higher clay content which generally underlies the alluvium sediments and is likely to restrict connection between the alluvial aquifer (where present) and the underlying Styx Coal Measures. Refer to Section 10.3.7 where this is explored more closely.

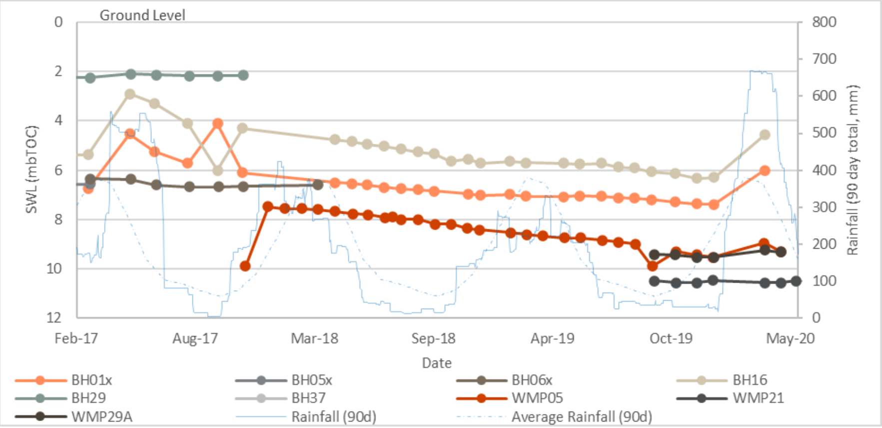


Figure 10-11: Quaternary Alluvium – changes in standing water level over time

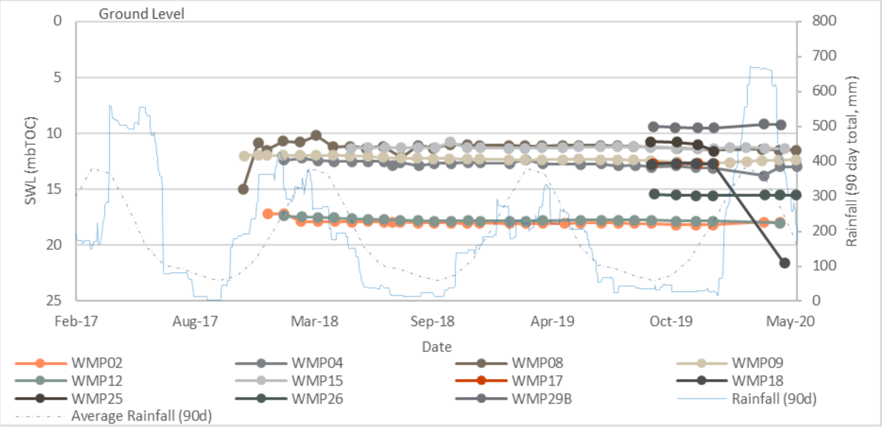


Figure 10-12: Quaternary Pleistocene Alluvium – changes in standing water level over time

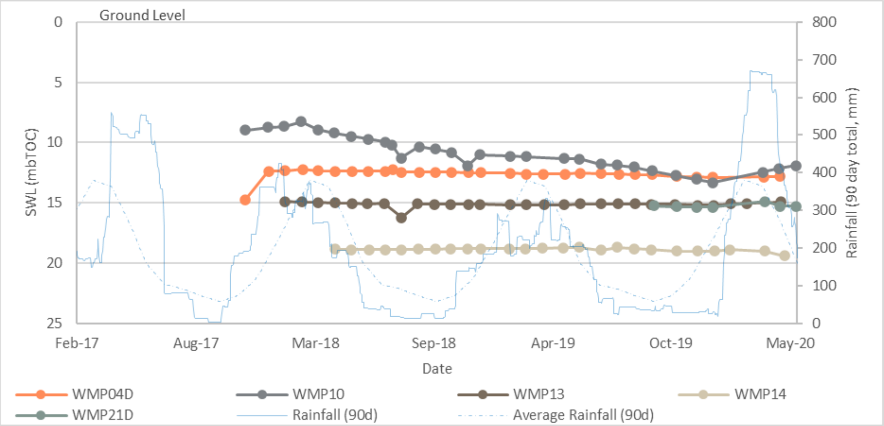


Figure 10-13: Styx Coal Measures (upper) – changes in standing water level over time

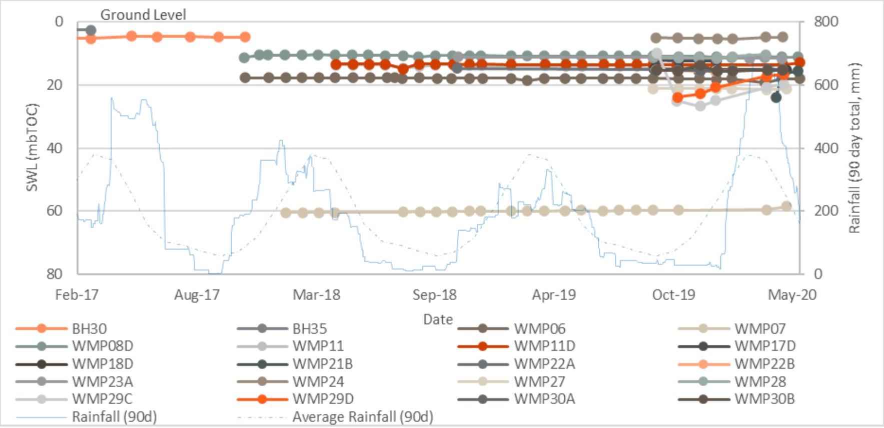


Figure 10-14: Styx Coal Measures (lower) – changes in standing water level over time

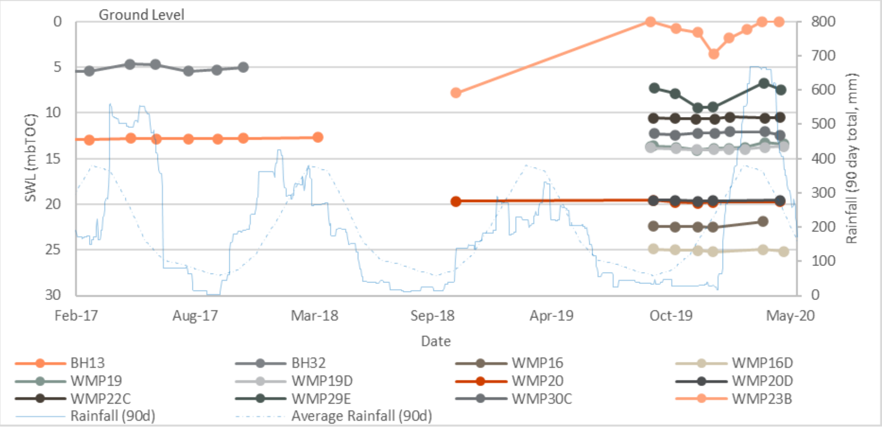


Figure 10-15: Permian Measures – changes in standing water level over time

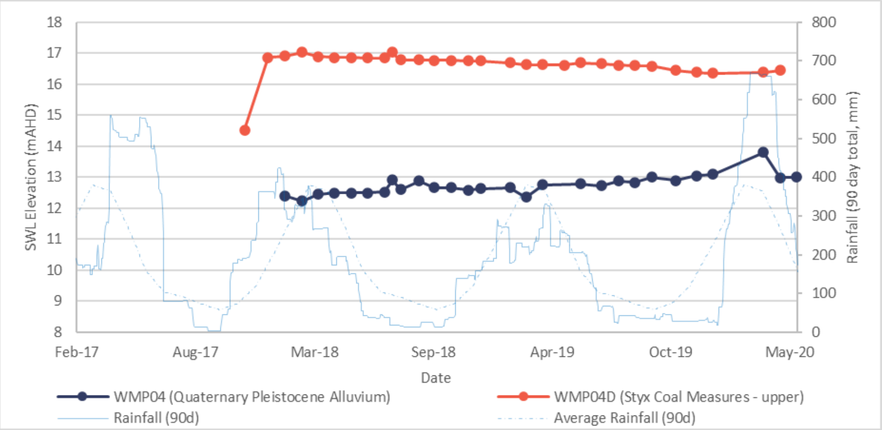


Figure 10-16: Standing water level elevation (mAHD) – WMP04/WMP04D nested bores

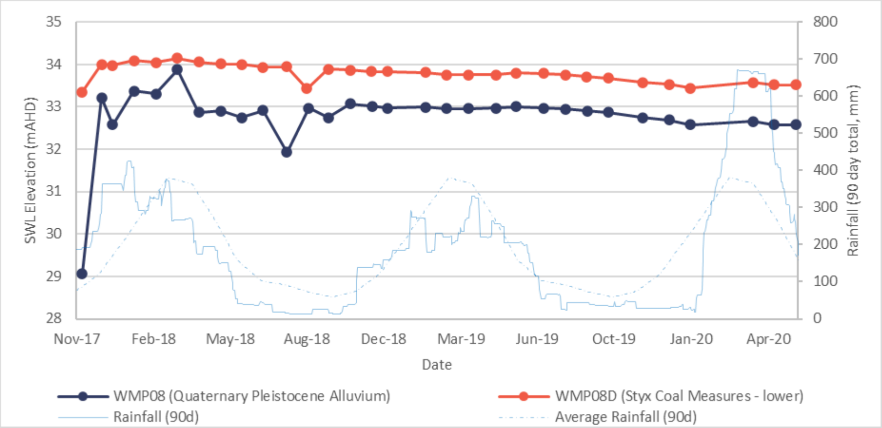


Figure 10-17: Standing water level elevation (mAHD) – WMP08/WMP08D nested bores

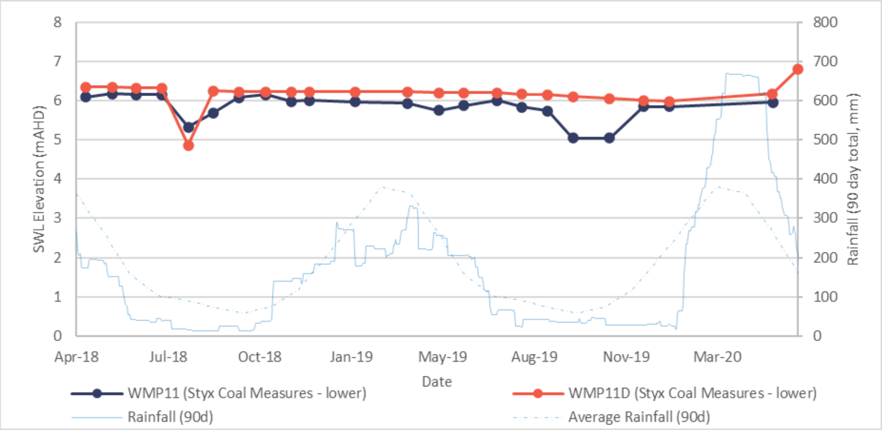


Figure 10-18: Standing water level elevation (mAHD) – WMP11/WMP11D nested bores

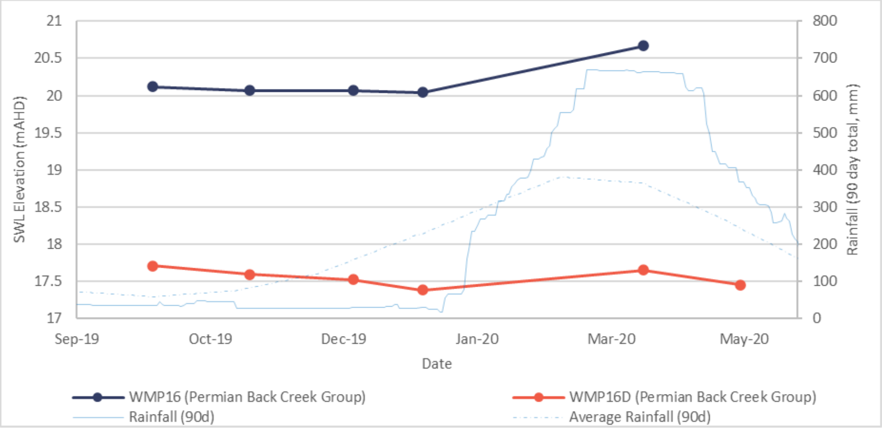


Figure 10-19: Standing water level elevation (mAHD) – WMP16/WMP16D nested bores

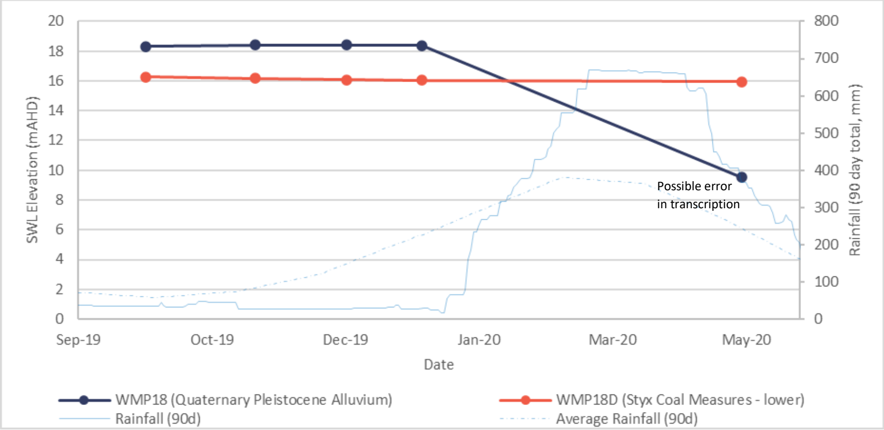


Figure 10-21: Standing water level elevation (mAHD) - WMP18/WMP18D nested bores

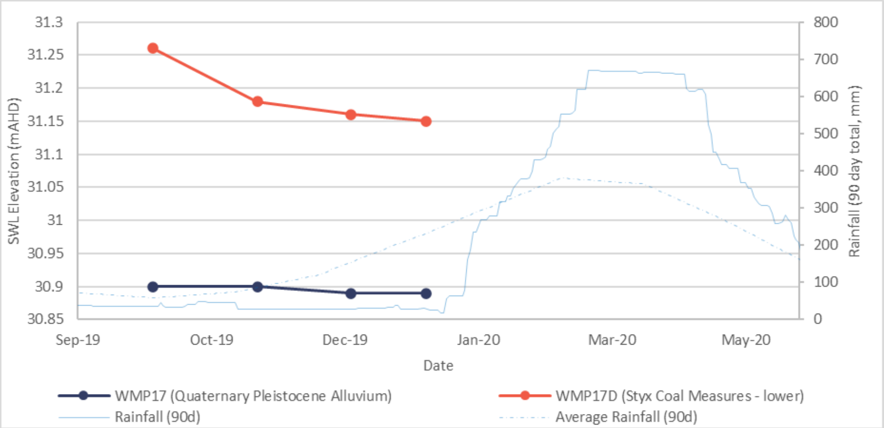


Figure 10-20: Standing water level elevation (mAHD) - WMP17/WMP17D nested bores

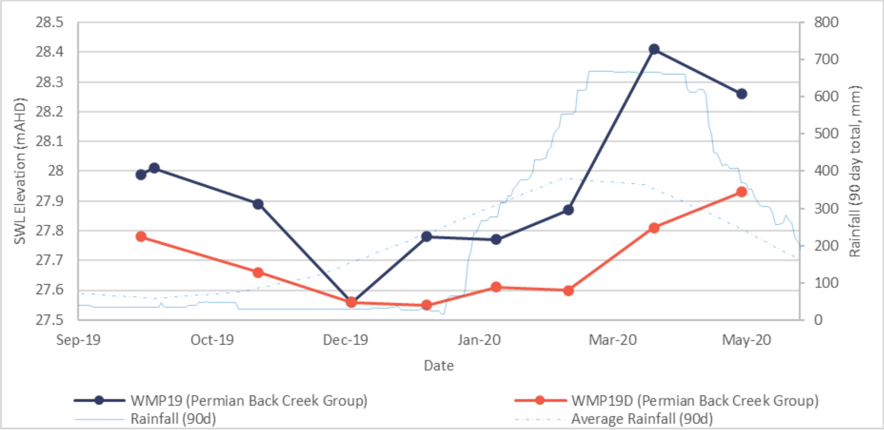


Figure 10-22: Standing water level elevation (mAHD) - WMP19/WMP19D nested bores

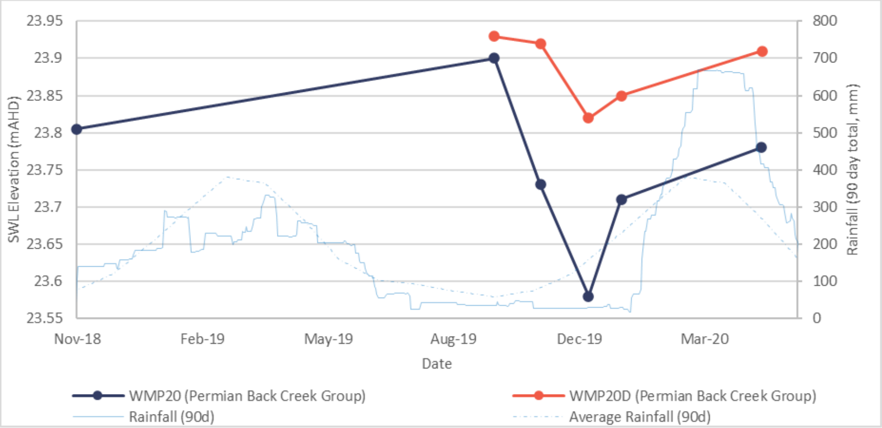


Figure 10-23: Standing water level elevation (mAHD) - WMP20/WMP20D nested bores

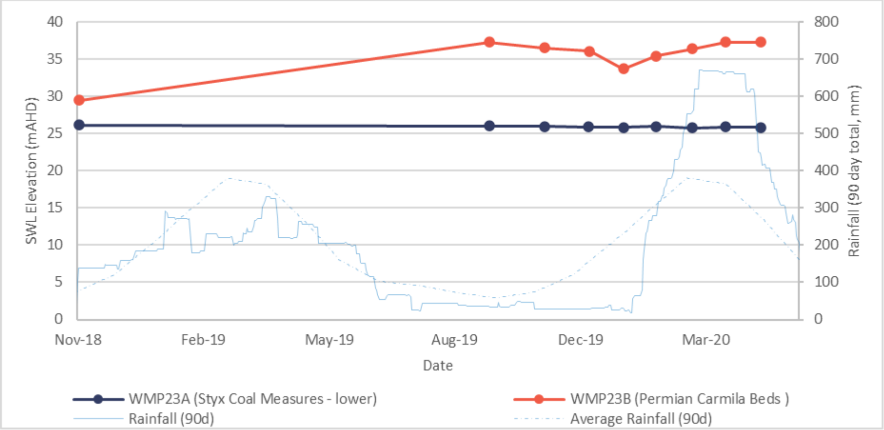


Figure 10-25: Standing water level elevation (mAHD) - WMP23A/WMP23B nested bores

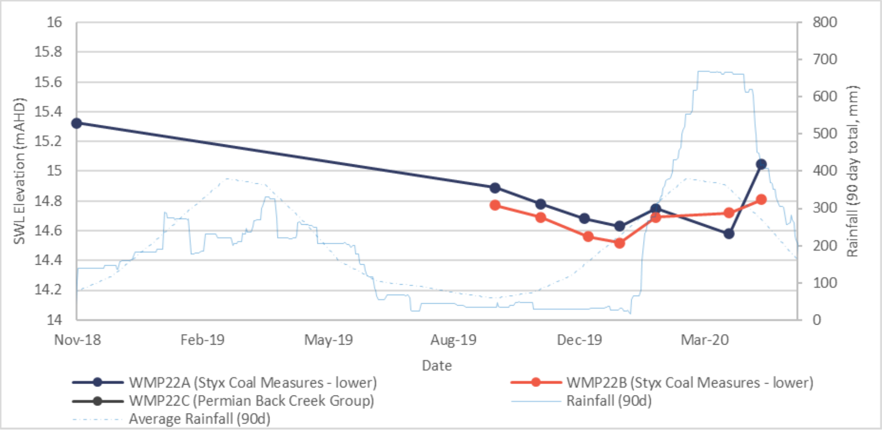


Figure 10-24: Standing water level elevation (mAHD) - WMP22A/WMP22B/WMP22C nested bores

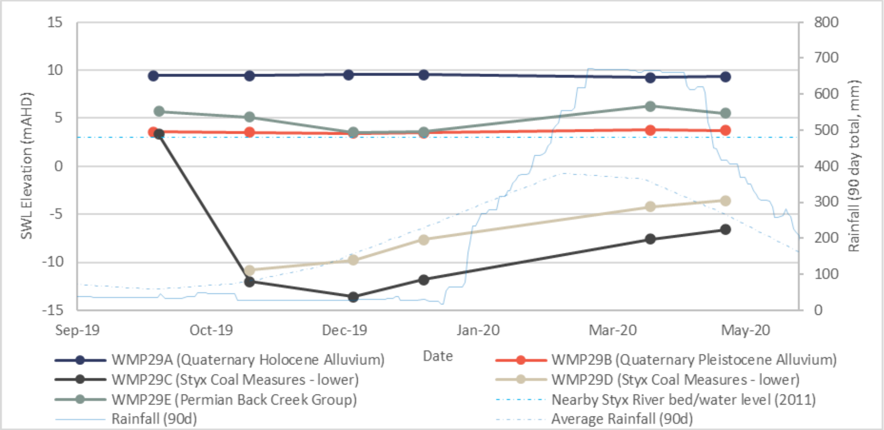


Figure 10-26: Standing water level elevation (mAHD) - WMP29A/WMP29B/WMP29C/WMP29D/WMP29E nested bores

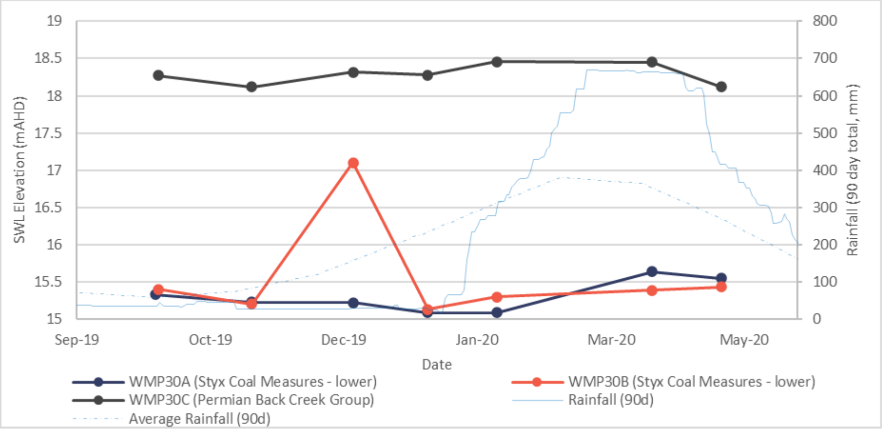


Figure 10-27: Standing water level elevation (mAHD) - WMP30A/WMP30B/WMP30C nested bores

10.3.6.4 Groundwater Recharge and Discharge

Diffuse rainfall recharge occurs across the Styx River catchment at varying rates with higher recharge expected where less consolidated Cainozoic sediments (i.e. Quaternary Alluvium) is present, as opposed to Quaternary Pleistocene Alluvium, and less again for Tertiary and weathered regolith (i.e. outcropping Early Cretaceous, Permian and Volcanic basement rocks). Flood recharge events occur over extensive areas of Quaternary Alluvium during large and sustained streamflow events and are expected to result in the highest rates of recharge, albeit episodic. Recharge of the alluvium close to streams occurs each wet season, recharging the bank store.

The data shown in Section 10.3.6.3 supports this, showing the effect of larger rainfall events but not the smaller seen over the relatively dry 2017 – 2019 years. Recharge is seen in the other units due to the early 2020 rainfall event, but generally to a much smaller extent, indicating lower rainfall – recharge from the surface and/or feeding in from recharged Qa units from flood events.

Groundwater discharge occurs from the catchment via evapotranspirative losses from shallow water tables (direct evaporation) and riparian vegetation (transpiration), and in some locations discharge to surface water bodies (including permanent and semi-permanent pools), although refer to Section 10.3.7 where this is discussed further.

10.3.6.5 Aquifer Test Results

Aquifer testing conducted as part of the Project are summarised in Section 10.2, with the data used to develop the conceptual and numerical groundwater models discussed and detailed in the Groundwater Model and Assessment Report in Appendix A6b.

10.3.6.6 Existing Groundwater quality

Existing groundwater quality has been assessed and is detailed in the Groundwater Quality Data Summary Report in Appendix A6c. This is summarised for each of the HSUs described in Section 10.3.6.2, with the salinity variation between the units shown in Figure 10-28.

In general, the Qa unit had low salinity, and was found to be suitable for most uses, with various limitations for the other units. The Styx Coal Measures were the most saline of all the units and also recorded the highest sulfate level, followed by the Qpa unit. For aquatic ecosystem protection, all sites (other than BH29) exceeded the QWQG 80th percentile guideline value for salinity, with exceedances against the DGVs for metals at some sites in all units, particularly for aluminium, chromium, copper, zinc, and against the low reliability guideline values for cobalt, iron, molybdenum, uranium and vanadium.

1. Quaternary Alluvium (AZ6)

Water in the surficial aquifers appears suitable for most purposes with only minor limitations, with pH generally neutral, typically low salinity, from 289 – 2,580 µS/cm, other than two sites (BH05x and WMP29A at 13,100 and 8,170 µS/cm respectively, the latter in estuarine sediments). Sulfate was also low.

Nutrients are generally highest in both the Cainozoic sediments, with a wider range than other units, particularly for total nitrogen and total phosphorous. Standing water levels are 2 - 10 mbgl, typically 7 mbgl. Dissolved metals are generally low, or comparable to other units, with the exception of arsenic and iron, which were similar to the Styx Coal Measures (lower).

Other than elevated salinity at two sites (BH05x, WMP29A), around half of the sites were above the taste threshold for drinking water for TDS. Some limitations for drinking water for chloride, sulfate and sodium, elevated ammonia, iron and manganese exist, with all of these being aesthetic criteria, other than manganese at BH01x and BH16 which exceed the health criteria. Based on chloride and sodium levels, waters are likely suitable for sensitive to moderately sensitive crop irrigation, other than WMP29A and WMP05, and some limitations in some sites (particularly BH01x, BH06x) for fluoride, nitrogen and phosphorous, iron, manganese are present. Phosphorous was high for all sites, also a limitation for long term irrigation.

All sites were above the QWQG EC guideline for aquatic ecosystems, other than BH29, with nutrients above the relevant DGVs at all sites. For metals, the aquatic ecosystem protection DGV was exceeded for copper at BH16, WMP05 and WMP29A; and zinc at WMP05 and WMP29A. The low reliability guideline value was exceeded for cobalt at BH16; iron at BH01, BH06x; and uranium at WMP05.

2. Quaternary Pleistocene Alluvium / Quaternary Alluvium (lower) / Regolith (CZ2)

This unit is much more saline than the above Qa unit, with only two sites below the stock watering criteria (WMP15, WMP25), and only one below the drinking water taste threshold. Salinity ranges from 4,500 – 48,800, with one site lower at 780 µS/cm. Sulfate is higher than all other units other than the upper Styx Coal Measures. pH is similar to the Qa unit, being neutral, and standing water level is between 9 and 18 mbgl, typically 12 mbgl.

As noted above, nutrients are elevated in both the Cainozoic units, although total nitrogen and ammonia are both low compared to the other units, and nitrate is higher than the Qa unit units. Metals are low or comparable to the other units, other than slightly elevated levels of uranium compared to other units.

Limitations exist for stock water for salinity, chloride, sodium and for elevated nutrients for irrigation, and for salinity, chloride, sulfate, sodium and manganese for drinking water, with one site (WMP08) above the health criteria for manganese.

All sites were above the QWQG EC guideline for aquatic ecosystems, with nutrients above the relevant DGVs at all sites. For metals, the aquatic ecosystem protection DGV was exceeded for aluminium at WMP26; chromium at WMP04 and WMP12; and copper and zinc at most sites. The low reliability guideline value was exceeded for cobalt at WMP08 and WMP09; uranium at most sites; and vanadium at WMP12.

3. Styx Coal Measures - upper (GZ11)

In general, water quality from the coal measures is poor, with the highest salinity, chloride and sulfate recorded in this upper unit. pH is very slightly below neutral, but salinity, with site medians ranging from 18,000 to 47,800 µS/cm, and high chloride, sulfate and sodium precludes its use for stock water, irrigation or drinking water.

Nutrients are lower than the Cainozoic sediments, although nitrate and total phosphorous are slightly higher than the deeper units, and phosphorous is limiting for long term irrigation. Metals are generally low, with the exception of cobalt, manganese and uranium, all of which are the highest of all the units. Iron and manganese exceed the long-term irrigation limits at all sites, and the drinking water limits at two sites (WMP13 and WMP21D), with the manganese health limit for drinking water exceeded at the WMP13 site. Standing water levels are similar to the Qpa Alluvium, at 10 - 18 mbgl, averaging 14 mbgl.

All sites were above the QWQG EC guideline for aquatic ecosystems, with nutrients above the relevant DGVs at all sites. For metals, the aquatic ecosystem protection DGV was exceeded for zinc at WMP04D and WMP13. The low reliability guideline value was exceeded for cobalt at WMP10 and WMP13; iron at WMP13; and uranium at all sites.

4. Styx Coal Measures - lower (GZ11)

Salinity and sulfate levels in the lower Styx Coal Measures unit are a little lower than in the upper coal measures unit, but similar to the Qpa Alluvium unit, with an EC range of 5,500 to 39,800 µS/cm. pH and alkalinity remain similar to the upper coal measures and the Alluvium units, with the exception of three sites – WMP23A, WMP29C and WMP29D, all of which are above pH 10, though expected to be due to well development issues. Salinity is generally too high for stock watering, irrigation and drinking water, with chloride and sodium also limiting. Nitrogen and phosphorous are also potentially limiting for irrigation, although they are low compared to the other units, and sulfate is elevated for drinking water use, and for stock watering at one site, BH30.

Metals are low with the exception of arsenic, cobalt, barium and iron, with each being the highest of all the units. Molybdenum recorded low overall unit statistics but one site returned a high level, above all the other units. As noted above, several wells within this unit recorded high pH, but this is due to poor well development in at least some of them.

For metals, exceedances of the health criteria for drinking water were identified at WMP11 and WMP11D for barium, WMP23A for chromium, WMP23A, WMP29C and WMP29D for molybdenum and manganese at many of the sites. Aluminium and iron exceeded the aesthetic criteria for drinking water.

Standing water levels are between 2 to 60m, but more typically between 10 and 18 mbgl, averaging 15 mbgl.

All sites were above the QWQG EC guideline for aquatic ecosystems, with pH exceeding the DGVs at the three sites with elevated pH. Nutrients were above the relevant DGVs at all sites. For metals, the aquatic ecosystem protection DGV was exceeded for aluminium at WMP29C and WMP29D; chromium at WMP23A; copper at WMP06, WMP11D, WMP23A, WMP29C; manganese at WMP23A; nickel at WMP29C; and zinc at most sites.

The low reliability guideline value was exceeded for cobalt at WMP06, WMP11, WMP11D; iron at most sites; molybdenum at WMP23A, WMP29C, WMP29D; uranium at most sites tested; and vanadium at WMP29C.

5. Permian Measures - Back Creek Group (FZ10)

Salinity and sulfate are reduced compared to the coal measures, and are instead more similar to the Cainozoic sediments, with EC ranging from 1,880 to 12,900 µS/cm. pH is generally consistent with the other units, being generally neutral, with the exception of two sites (WMP22C and WMP29E) which reported high pH, potentially due to poor well development (refer to Section 10.3.6.6).

In general, this unit remains unsuitable for irrigation and drinking water due to high salinity, chloride and sodium, with high phosphorous, and high nitrogen in WMP29E limiting its use for long term irrigation. Wells WMP16D and WMP29E are unsuitable for stock watering due to salinity. Ammonia is elevated for drinking water, exceeding the aesthetic criteria, and chromium exceeds the health criteria in one well - WMP29E. Two sites exceeded the irrigation and drinking water criteria for iron, and three sites exceeded the health criteria for manganese.

The low reliability guideline value was exceeded for cobalt at BH13; iron at BH13, WMP19D; molybdenum at WMP29E; uranium at BH13 and BH32; and vanadium at WMP29E.

6. Permian Measures - Carmila Beds (FZ10)

Only one site was located in this unit - WMP23B. This site had the shallowest standing water level, as it was recorded at ground level (and at times overflowing). Salinity and chloride were similar to the Qpa units, with sulfate low. pH and alkalinity are the highest of all units, though this is again likely due to poor well development. Ammonia and total nitrogen were elevated, similar to the Qa unit, but total phosphorous was low. Of the metals, results show the highest aluminium (possibly due to poor well development), high copper and molybdenum.

Water in this bore appears unsuitable for stock watering, irrigation or drinking water, due to elevated salinity, chloride and sodium as well as pH. Ammonia is above the aesthetic threshold for drinking water, and total nitrogen for irrigation, with molybdenum above the criteria for irrigation and stock watering. Chromium and molybdenum are above the drinking water health criteria.

Compared to the aquatic ecosystem protection guideline values, the QWQG EC guideline was exceeded, with pH and nutrients above the relevant DGVs. For metals, the aquatic ecosystem protection DGV was exceeded for aluminium, chromium, copper and zinc.

The low reliability guideline value was exceeded for molybdenum.

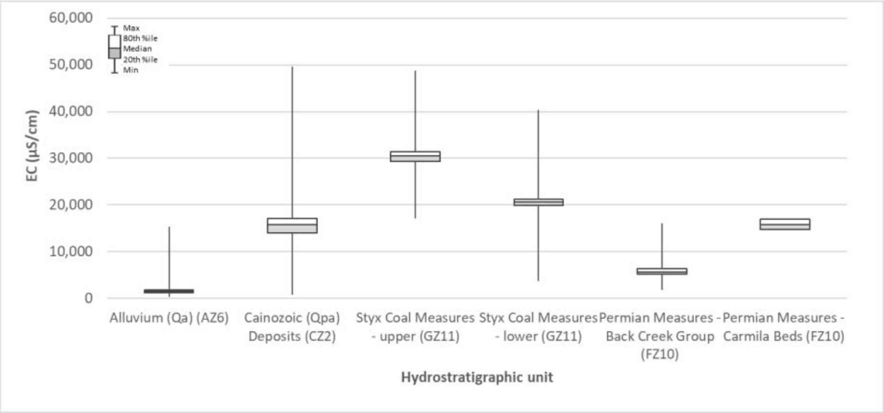


Figure 10-28: Summary of EC by HSU

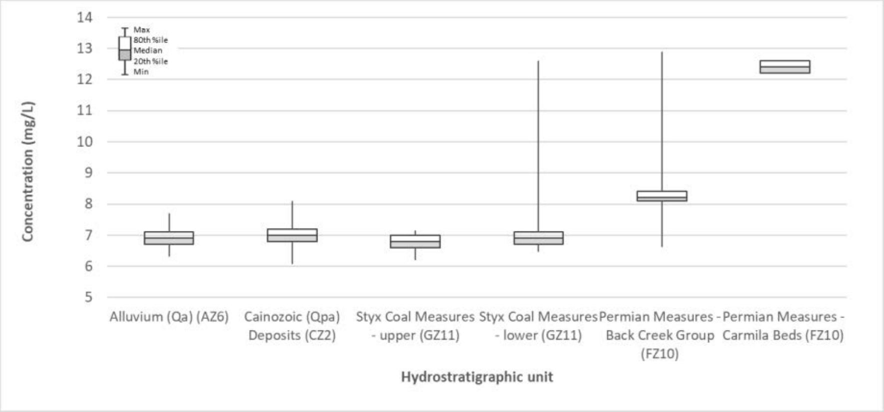


Figure 10-29: Summary of pH by HSU

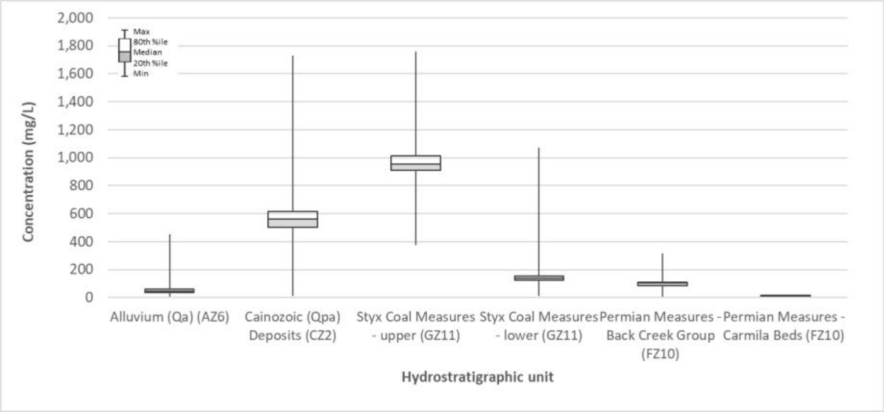


Figure 10-30: Summary of sulfate by HSU

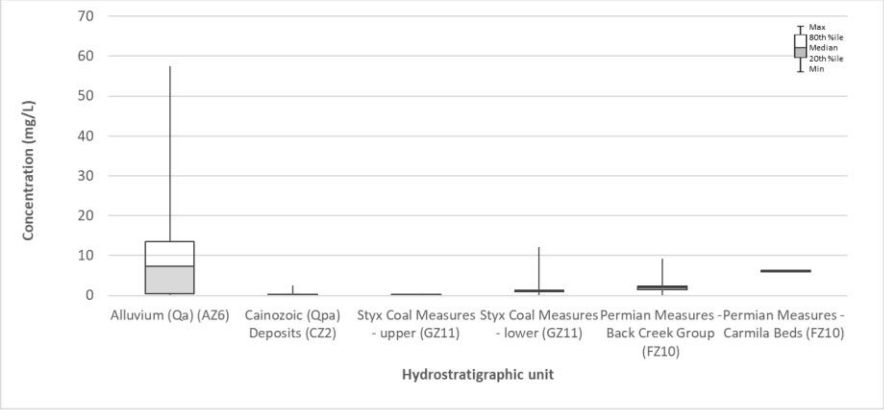


Figure 10-31: Summary of ammonia by HSU

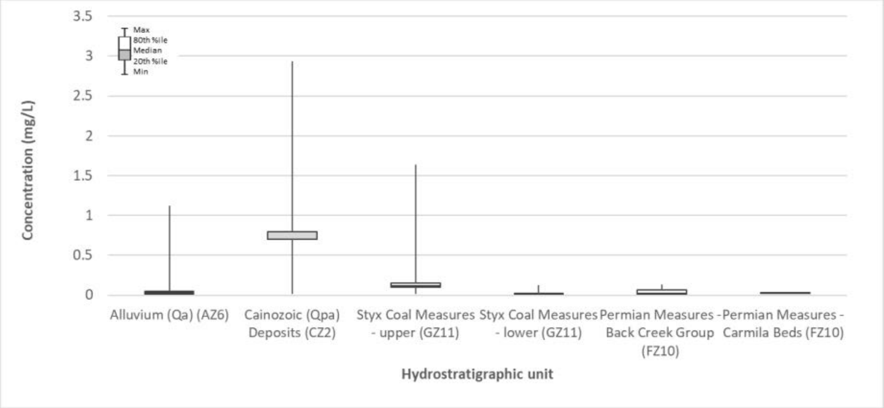


Figure 10-32: Summary of nitrate by HSU

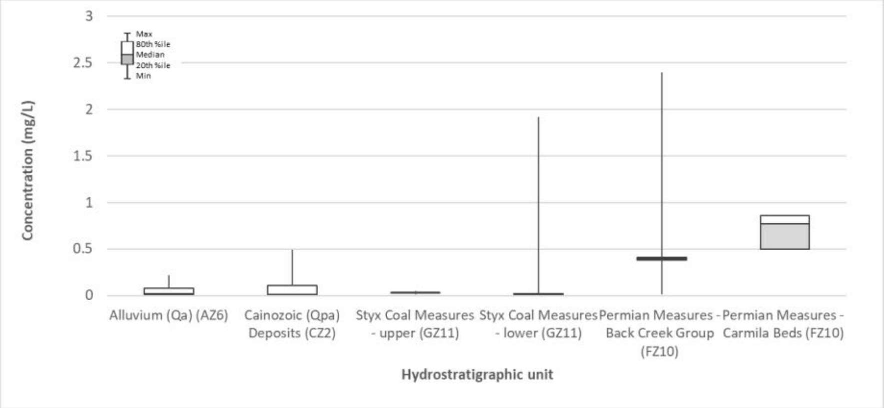


Figure 10-33: Summary of dissolved aluminium by HSU

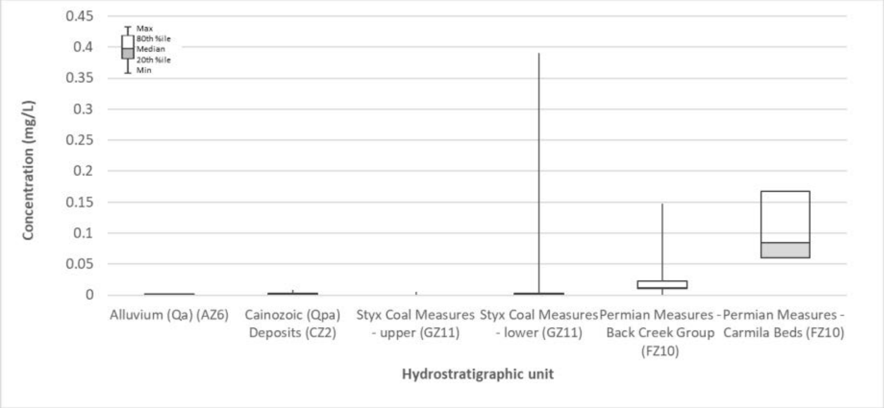


Figure 10-34: Summary of dissolved chromium by HSU

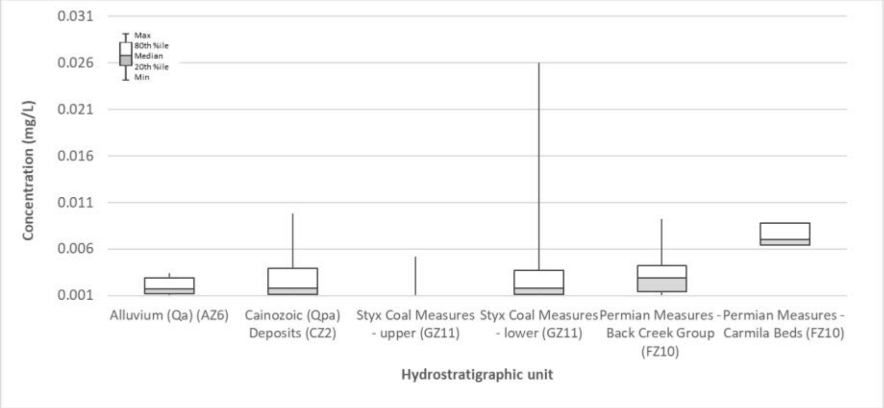


Figure 10-35: Summary of dissolved copper by HSU

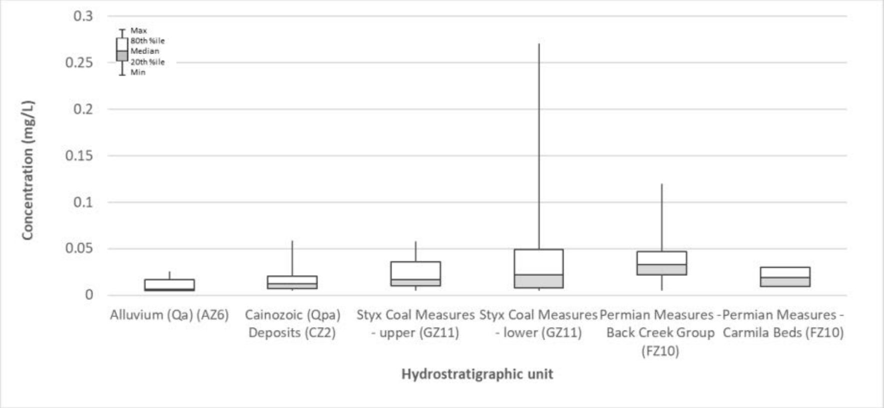


Figure 10-36: Summary of dissolved zinc by HSU

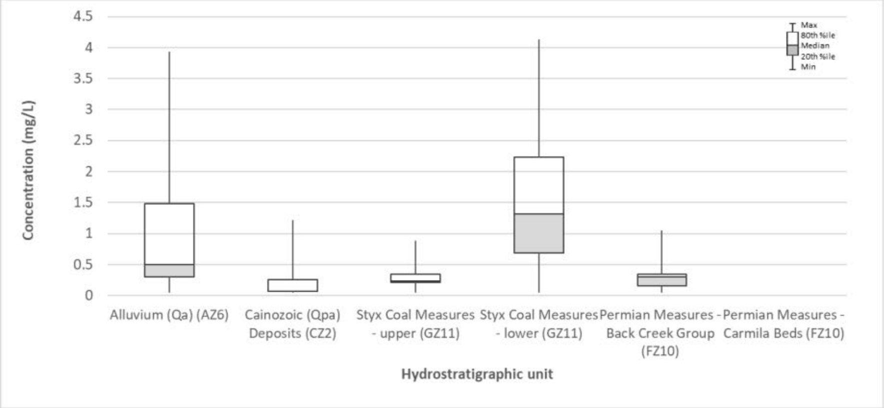


Figure 10-38: Summary of dissolved iron by HSU

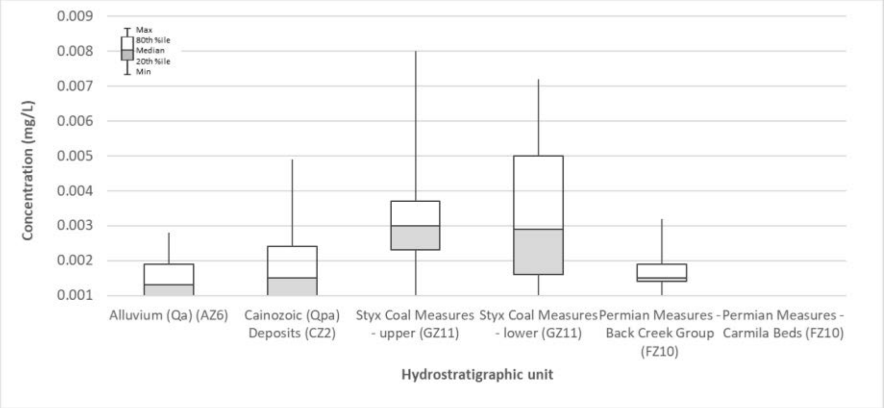


Figure 10-37: Summary of dissolved cobalt by HSU

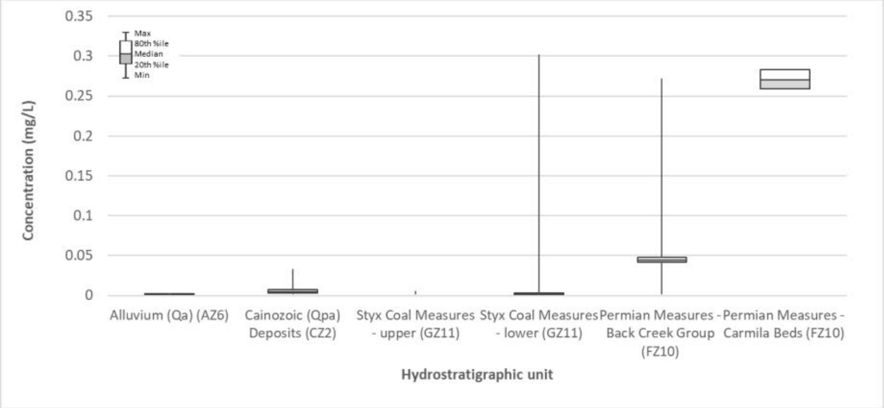


Figure 10-39: Summary of dissolved molybdenum by HSU

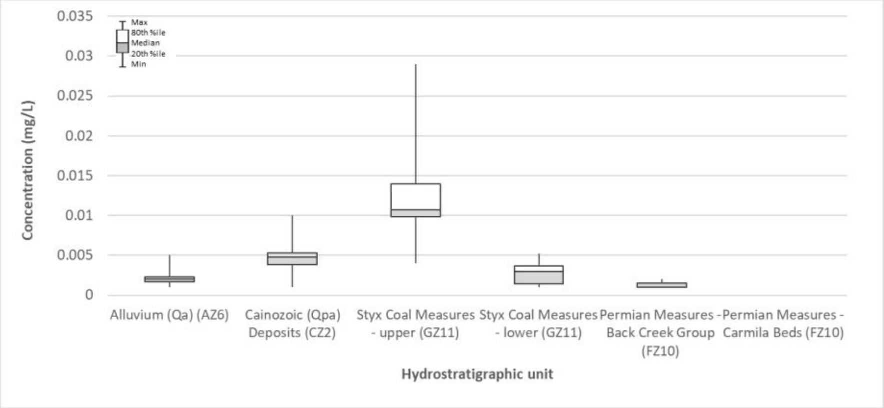


Figure 10-40: Summary of dissolved uranium by HSU

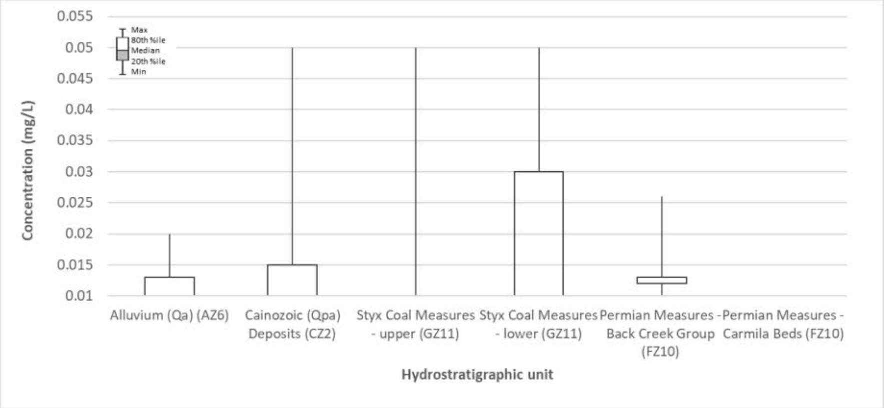


Figure 10-41: Summary of dissolved vanadium by HSU

10.3.6.7 Freshwater-Seawater Interface

Despite the salinity evident in some of the groundwater samples collected at the Project Site and surrounding areas, it has been determined that the salinity in the groundwaters intersected by the Project is derived from regional geochemistry, and not an oceanic saltwater interface (based on the below justification, plus information from Section 10.3.7.3). If any interface between oceanic saltwater and freshwater does exist within the groundwater in the vicinity of the Project, it will be hundreds of meters below sea level at the location of the pits, or beyond the extent of any drawdown influence from the Project, and would therefore not result in any movement of any interface between seawater and groundwater. The following gives an explanation regarding this reasoning.

Theoretical interface

At a macro level, the location of the steady-state interface between oceanic saltwater and inland (fresher) groundwaters can be conceptually based on the generalisation that discharge of inland fresh water is maintained toward the ocean (Verruijt 1968). The Ghyben-Herzberg Principle can be used to infer where the interface between the fresh and oceanic saltwater lies according to the following formula:

$\mathbf{h_f = \alpha h_s}$

where

h_f = height of free groundwater above sea level

h_s = depth of seawater interface below sea level, and

$\alpha = (\rho_s - \rho_f)/\rho_f$

and

ρ_f = freshwater density (1.000 grams per cubic centimetre [gm/cc]), and

ρ_s = saltwater density (1.025 gm/cc).

The equation returns a ratio which states that essentially for every meter of fresh water in an unconfined aquifer that lies above sea level, there will be forty meters of fresh water in the aquifer below sea level. The Ghyben-Herzberg Principle reflects the fact that freshwater is 1/40 less dense than sea water. This is shown in Figure 10-42.

The Ghyben-Herzberg Principle has been used to derive the theoretical interface between seawater and fresh water at the location of the open cut mines, the confluence of Tooloomba and Deep Creeks (north of the Project and downstream of the Project), and also just beyond the Ogmore Road Bridge (further north of the Project, several kilometres downstream of the Project) (refer also to the Groundwater Model and Assessment Report in Appendix A6b).

As can be seen from Table 10-6, based on the Ghyben-Herzberg Principle, if seawater did extend as far inland as the location of the mine, the interface between freshwater and seawater would be likely to be -480 to -680m Australian Height Datum (AHD).

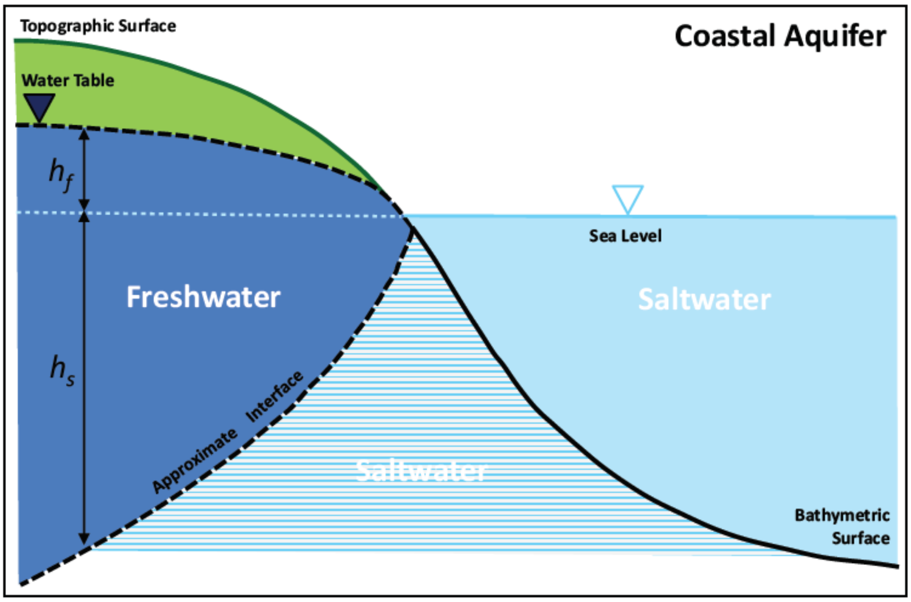


Figure 10-42: Ghyben-Herzberg relationship

Table 10-6: Theoretical location of seawater interface with fresh groundwater based upon the Ghyben-Herzberg Principle (ρ_f = 1.000 gm/cc)

Location	Height of surface of free groundwater (hf) (AHD)*	Theoretical depth of the seawater interface (hs) (AHD)
Ogmore Road Bridge	1-2 m	-40 to -80 m
Tooloombah Creek and Deep Creek confluence	7 m	-280 m
Open Cut	12-17 m	-480 to -680 m

*Based on average-static conditions above the long term mean sea level. The long term mean sea level (equivalent to mAHD) records [published by the Queensland Government in the Queensland Tide Tables Standard Port Tide Time 2019 (Maritime Safety Queensland, 2019)] at locations along the Queensland eastern coastline to the north and south of the Broad Sound are respectively:

- 3.420 m - Hay Point (near Mackay) [January 1985 to December 2016]; and
- 2.472 m - Rosslyn Bay (near Rockhampton) [January 1993 to December 2016].

Therefore, a value of 3 mAHD was used to conservatively calculate the “delta”.

However, the application of the Ghyben-Herzberg Principle above presents an interface based on freshwater with a density of 1.000 gm/cc. As mentioned above, the groundwaters contained within some of the Cainozoic sediments at the Project site tend to be brackish to saline. Therefore, to account for the increase in density of groundwater that may result from higher salinity levels, an increased differential was applied where the density of the groundwater was assumed to lie between that of seawater and freshwater (i.e. where ρ_f ~1.012 gm/cc)[4].

Under this scenario the groundwater-seawater interface at the three locations given in Table 10-6 would be as given in Table 10-7 below (which also includes the theoretical depths from Table 10-6 for comparison).

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[4] This is considered an appropriate number as it represents water with a density midway between seawater and freshwater. The value of half the salinity of seawater is based on salinity data from various depths sampled at the WMP29 series of bores (located ~7km downstream of the Project, between the Project and the Styx estuary) which shows that salinity measured as EC in this location is up to half of that of seawater.

Table 10-7: Theoretical location of seawater interface with brackish groundwater based upon the Ghyben-Herzberg Principle (ρ_f = 1.012 gm/cc)

Location	Height of surface of free groundwater (hf) (AHD)*	Theoretical depth of the seawater interface (hs) (AHD)	
		ρf = 1.000 gm/cc (freshwater)	ρf = 1.012 gm/cc (halfway between fresh and sea water)
Ogmore Road Bridge	1-2 m	-40 to -80 m	-78 to -156 m
Tooloombah Creek and Deep Creek confluence	7 m	-280 m	-545 m
Open Cut	12-17 m	-480 to -680 m	-934 to -1323 m

As can be seen from Table 10-6 and Table 10-7, the ratio of 1 meter of fresh water above to 40 meters of freshwater below sea level changes to 1 meter of brackish water above to 78 meters of freshwater below sea level. As such, based on the Ghyben-Herzberg Principle, a seawater interface with groundwater in the vicinity of the mine would be at least -480 m AHD. The bottom of the proposed open cut at the deepest point is approximately -152 m AHD. As such, if a groundwater-seawater interface did exist here, it would be more than 300 m below the base of the proposed open cut, and therefore below the lowest extent of groundwater drawdown. Hence there would be highly unlikely to be any interaction between drawdown effects as a result of the project and the interface between oceanic saltwater and inland groundwaters, should one occur at this location.

Evidence from data

WMP29 is a nested bore comprising WMP29A to WMP29E (from shallowest to deepest) near the Ogmore Road Bridge that tap the topmost Cainozoic sediments as well as those below to a depth of 228.5m below ground level (-216 mAHD), including the Styx Coal Measures and (at WMP29E) the Permian Measures. It is located around 7 km downstream of the Project and closer to the coast than the Project, and therefore more likely to be closer to any freshwater-seawater interface. Table 10-8 shows that salinity, measured as TDS and EC, in this location is almost half that of seawater. Based on the values given in Table 10-6 and Table 10-7, if a seawater interface did exist in this location it would be located between -40 and -156 m AHD (52 to 168 m below ground level). However, as can be seen from Table 10-8, even at 228.5 meters below ground level (i.e. WMP29E), the salinity values are half that of seawater. Hence there is no evidence of a groundwater seawater interface at any depth likely to be affected by drawdown as a result of the Project.

It is noted that two groundwater monitoring locations have reported TDS concentrations in excess of seawater and EC levels approaching that of seawater. One of these, WMP26 (located within the Project footprint at the boundary between Dam 1 and Waste Rock Stockpile 2 – see Figure 10-1) is screened at 7m AHD, which is 4 meters above sea level (see footnote to Table 10-6 to explain the derived sea levels in the Project area).

Table 10-8: Salinity levels at differing depths for bore series WMP29

WMP29 bore series	Screen Depth (mbgl)	Total Dissolved Solids (mg/L)	Electrical Conductivity (µS/cm 80th%ile)
WMP29A	12.5	5,760	8,849
WMP29B	20.0	14,400 – 15,700	22,700
WMP29C	58.0	11,600 – 12,000	20,560

WMP29 bore series	Screen Depth (mbgl)	Total Dissolved Solids (mg/L)	Electrical Conductivity (µS/cm 80th%ile)
WMP29D	121.0	11,800 – 13,100	19,900
WMP29E	228.5	5,410 – 6,140	19,370
Typical Seawater Salinity	n/a	~35,000	~50,000

Given the information above, the salinity must be explained by other factors than a freshwater-seawater interface. The other bore, WMP13, is 1.5 km upstream of the WMP29 series of bores (5.5km downstream from the Project – see Figure 10-1) and is screened at and immediately below 0m AHD. Based on the evidence presented above regarding the WMP29 series of bores it seems unlikely that at groundwater seawater interface exists at sea level at this location, given that WMP13 is 1.5 km upstream of WMP29, and the shallowest WMP29 bore (WMP29A) records only brackish salinity levels.

10.3.6.8 Environmental Values

Specific EVs and WQOs were developed for the Styx River, Shoalwater Creek and Water Park Creek Basins in 2014 under the Environmental Protection (Water) Policy 2009 (EPP Water) in the document 'Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives' (EHP 2014) as shown in Table 10-10. Draft EVs are also provided in Table 10-10 for the draft updated EVs from McNeil et al. (2018) for the relevant groundwater chemistry zones.

10.3.6.9 Bore Census

The bores identified in the bore census described in section 10.2.2.1 are summarised in the Groundwater Quality Data Summary in Appendix A6c. In the previous SEIS v2, the bore census undertook a review of bores within the GWDBQ in a 50 km radius of the Project, of which 118 were within the Styx River Basin. In this SEIS v3, with the refinement of the groundwater numerical model, the census was updated to combine data from the previous two census rounds, and added additional bores from the GWDBQ within the numerical model domain, with:

- A total of 171 bores identified
- 23 bores abandoned and/or destroyed (13%) and
- 19 bores identified as not in use (11%).

Table 10-9 presents statistics sourced from both the GWDBQ and the bore census' concerning the purpose of these bores.

Table 10-9: Bore census – bore purposes

Registered purpose	Count (%)
Water supply (mostly stock)	95 (55%)
Mineral exploration (incl. coal)	7 (4%)
Mine Monitoring	56 (33%)[1]
Water resources investigation	1 (1%)
Not specified	12 (7%)
Total	**171 (100%)**

Table notes

[1] These are the Project monitoring bores

Table 10-10: Environmental Values for Project catchments

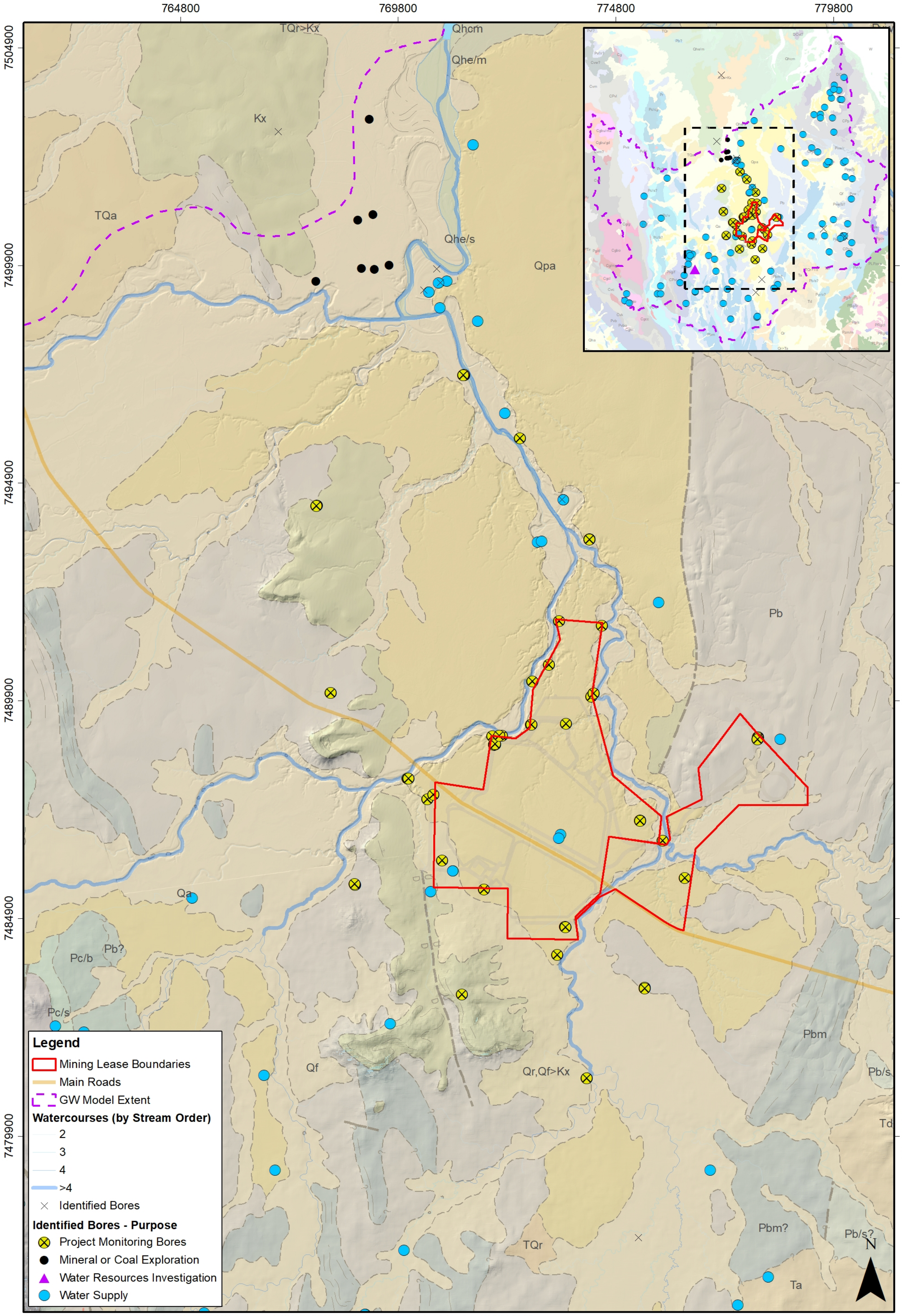
Symbol	Environmental Value	2014 EPP (Water and Wetland Biodiversity) (EHP 2014)	2018 Draft Consultation Materials (McNeil et al. 2018)			
		Styx Groundwaters	Curtis Coast	Cainozoic deposits overlying the GAB zones: Eastern weathered Cainozoic remnants	Fractured Rock: Eastern Fitzroy Trap rocks	Basins partially underlying the GAB zones: Eastern Bowen Coal Measures
🐟	Aquatic ecosystems (SMD)	✓	✓	✓	✓	✓
🚰	Irrigation	✓			✓	✓
🏠	Farm supply	✓			✓	
🐄	Stock water	✓			✓	✓
🦐	Aquaculture				✓	
🐚	Human consumer					
🏊	Primary recreation					
⛵	Secondary recreation					
👁	Visual recreation					
🥛	Drinking water				✓	✓
🏭	Industrial use				✓	✓
👣	Cultural and spiritual values	✓	✓	✓	✓	✓

Most bores are located within or at the fringes of the mapped Cainozoic deposits (Figure 10-43), which suggests the alluvium and, possibly, geological structure that controls the occurrence and alignment of water courses have been targeted for local groundwater supplies by third-party users.

The field work conducted in 2011 and 2017 included 27 bores, identified from the GWDBQ or previous studies. Of these locations, 20 could be visited and verified, four could not be accessed and three could not be found (expected to be abandoned/destroyed). An additional six bores were identified during the census, which are expected to be unregistered or location details in the GWDBQ inaccurate. The census found that of the bores that could be visited, only 10 are currently in use or possibly in use.

Depth to standing water levels were able to be measured at 17 bores and the collection of water samples was possible from eight, with the results incorporated into the water quality database. The following general observations are made:

- several bores identified from the GWDBQ were either found in different locations or could not be found
- bores that were not in use are generally in poor condition
- pumping equipment present within some bores prevented access for measurement of water levels and collection of water samples
- bores that were operational are used for stock watering, domestic or industrial / farm use and
- bores are constructed to between 6 and 31 m deep, and measured standing water levels are inferred to be representative of the water table elevation.



Source: Sites, various, compiled by OE 2020 | Waterways: DNRME 2010 | GBR Coast Marine Park Zoning: DERM 2009
Fish Habitat Areas: DNPSR 2016 | Tenements: DNRME 2019 | Geology: DNRME 2018

A4 Scale 1:125,000 0 1.25 2.5 km
GDA 1994 MGA Zone 55
File: CQCSCP-07-Fig10-43-Bore-Census-200914, 14 Sep 2020

Figure 10-43: Identified bores in proximity to the Project

10.3.7 Groundwater – Surface Water Interactions

10.3.7.1 Overview

Due to the ephemeral nature of the surface water systems in the Project area, the interplay between rainfall and storm events, storage and return of groundwater from the alluvial banks and groundwater is complex. A number of studies have been undertaken for past versions of the EIS/SEIS, and more recently for the SEIS v3, including environmental tracer and stable isotope analysis (Section 10.2.2.3), nested bore installation, soil and leaf moisture and moisture potential testing (Section 10.2.2.4), pool water and salt balances and targeted transect sampling and modelling (Section 10.2.2.4). Assessments conducted as part of the Surface Water/Groundwater Interactions Report in Appendix A6d looked more closely at bank storage and groundwater inflow potential for Tooloombah and Deep Creek adjacent to the site.

For Deep, Tooloombah and Barrack Creeks, a lateral wet season / flood recharge process occurs, whereby water rising in the creeks recharges bank storage, which will affect surrounding alluvial aquifers and cause a rise in the water table close the creeks. Once the storm event has passed, water levels in the creeks subside, and return flow from bank storage to the creek occurs, resulting in a period of post-storm baseflow. The duration of this bank flow return varies, but will continue until the bank storage is emptied back into the creek, or it drains into the underlying, seasonally lowered, water table.

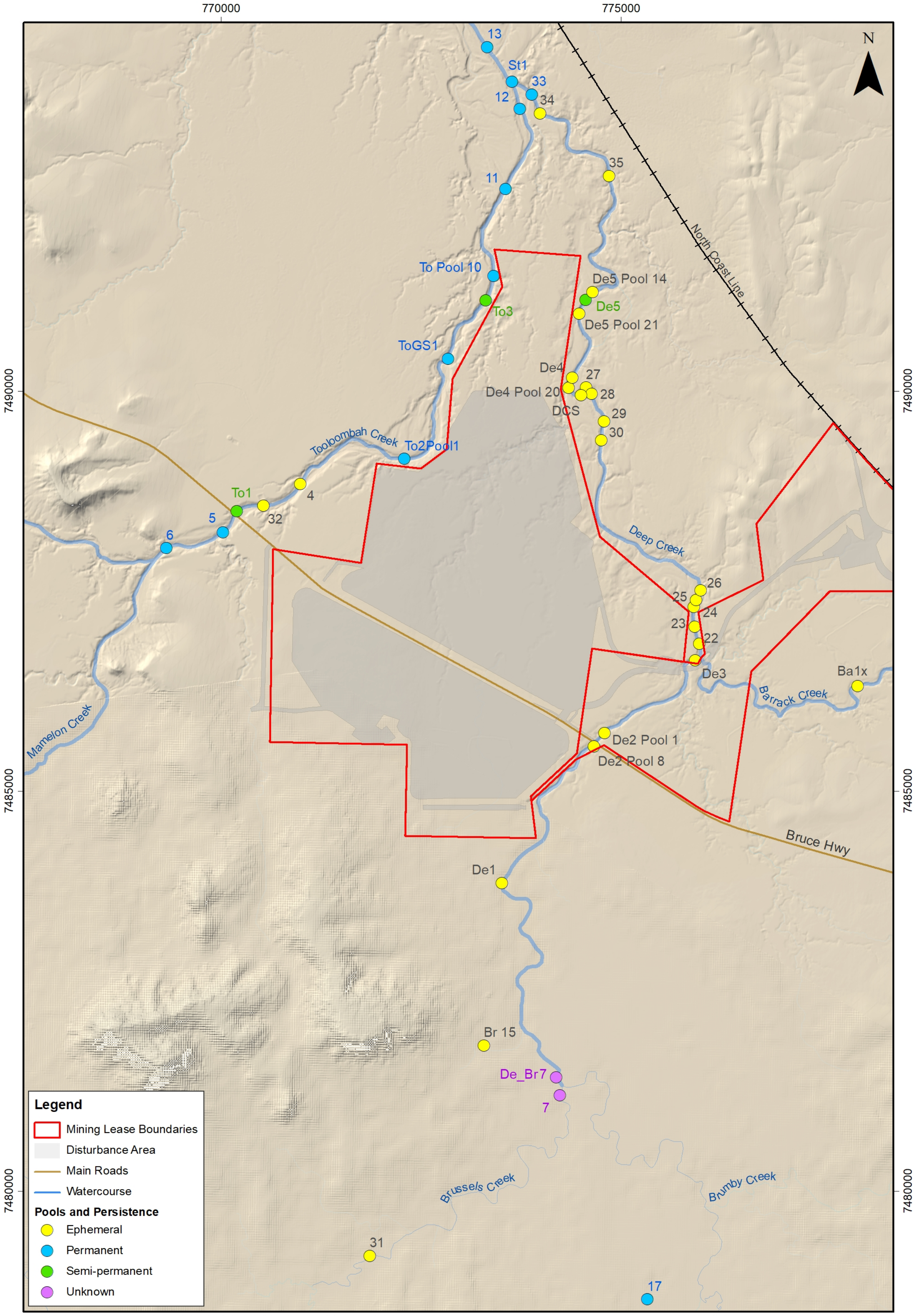
Most reaches of both creeks are identified as having a groundwater table below the base of the creek in the dry season (refer to the Surface Water/Groundwater Interactions Report in Appendix A6d), and are therefore without direct water table aquifer groundwater inflows but instead receive bank storage return.

Two of the Tooloombah Creek pools (To2 and ToGS1) and one of the Deep Creek pools (De2) were modelled to determine whether changes in water level and/or EC could be explained by evaporation alone, or whether an external water source was required to explain observations. Two of the Tooloombah Creek pools appear to have an external saline water source sustaining them through the dry season, with the following estimated inflows:

- Tooloombah Creek stream gauge pool - an inflow of 4.5 kL/day with an EC of 15,000 µS/cm, sustained over at least 3 months until rains occurred and salinity dropped
- Tooloombah Creek To2 pool – an inflow of 2.0 kL/day with an EC of 4,000 µS/cm, sustained for about 4 months before EC dropped, though not in response to rainfall (i.e. the saline groundwater source was removed).

The Deep Creek pool data did not require an external water source to explain the observed results. Examination of EC data from other sites (To1 and To3 in Tooloombah Creek, De1 in Deep Creek), also found no external water source was required to explain the results, indicating evapoconcentration was sufficient. Some of the sites (including De1) showed a small increase in salinity during and shortly after rains occurred (over about two months), likely as a result of seasonally elevated water tables spilling into the creek during and shortly after the wet season.

An assessment of the pools within Deep and Tooloombah Creek was undertaken, identifying their persistence using satellite imagery, field observations and two more recent field investigations to determine presence / absence of pools at different times of year (refer to Section 10.2.5 for more detail). The identified pools and their inferred persistence is summarised in the Surface Water Quality Technical Report in Appendix A5a, and shown in Figure 10-44.



Mining Leases: CQC 2020 | Infrastructure: CQC 2020 | Watercourses: DNRME 2018 | Roads: DNRME 2018 |
Pools: Multiple Sources and dates - compiled by OE 2020

A4 Scale 1:68,000
GDA 1994 MGA Zone 55

0 0.5 1
km

File: CQCSCP-07-Fig09-16-Pools-200907

Figure 10-44: Location of identified pools and their persistence

Overall, creeks along Tooloombah Creek appear to be permanent or semi-permanent, while those in Deep Creek are generally ephemeral, although it is expected that some permanent pools exist in the downstream reach of Deep Creek nearer to the confluence with Tooloombah Creek. The data shows an apparent trend of increasing permanence with distance downstream.

10.3.7.2 Pool – Groundwater Interactions

CQC undertook an alluvial and regolith drilling exercise as well as field geological descriptions of outcrops along six cross sections on Tooloombah and Deep creeks (four and two respectively), associated with pools identified as part of the investigations for the Surface Water/Groundwater Interactions Report in Appendix A6d (although only 3 sections were able to be assessed as part of that report). The data from the drilling exercise as well as water quality and pool monitoring data can clarify the findings and conceptualisation for surface – groundwater interactions. This is undertaken below by examining the cross-sections and measured EC in the pools, moving from upstream to downstream within the creeks. Cross sections are shown in Figure 10-46 to Figure 10-48, and the pools / sections from upstream to downstream show the following:

To1 – a semi-permanent pool located upstream of the Project at the Bruce Highway, 700m long

EC increases can be explained by evapoconcentration alone, without a saline groundwater input - the nearest alluvial monitoring bores indicate salinities in the alluvium of around 7,000 – 17,000 µS/cm and so significant inputs at these EC levels to the pool should be detectable. The modelled water table in September 2019 (end of calibration period, Section 10.3.6.1) is below the base of the creek and within the coal measures, matching the measured level in the nearest monitoring bore (WMP06, Styx Coal Measures). The creek base is mostly covered by at least 50cm of the Quaternary Alluvium HSU and in rare occasions by Styx Coal Measures. Evidence indicates wet season recharge and dry season bank storage return, but no or limited permanent connection to groundwater.

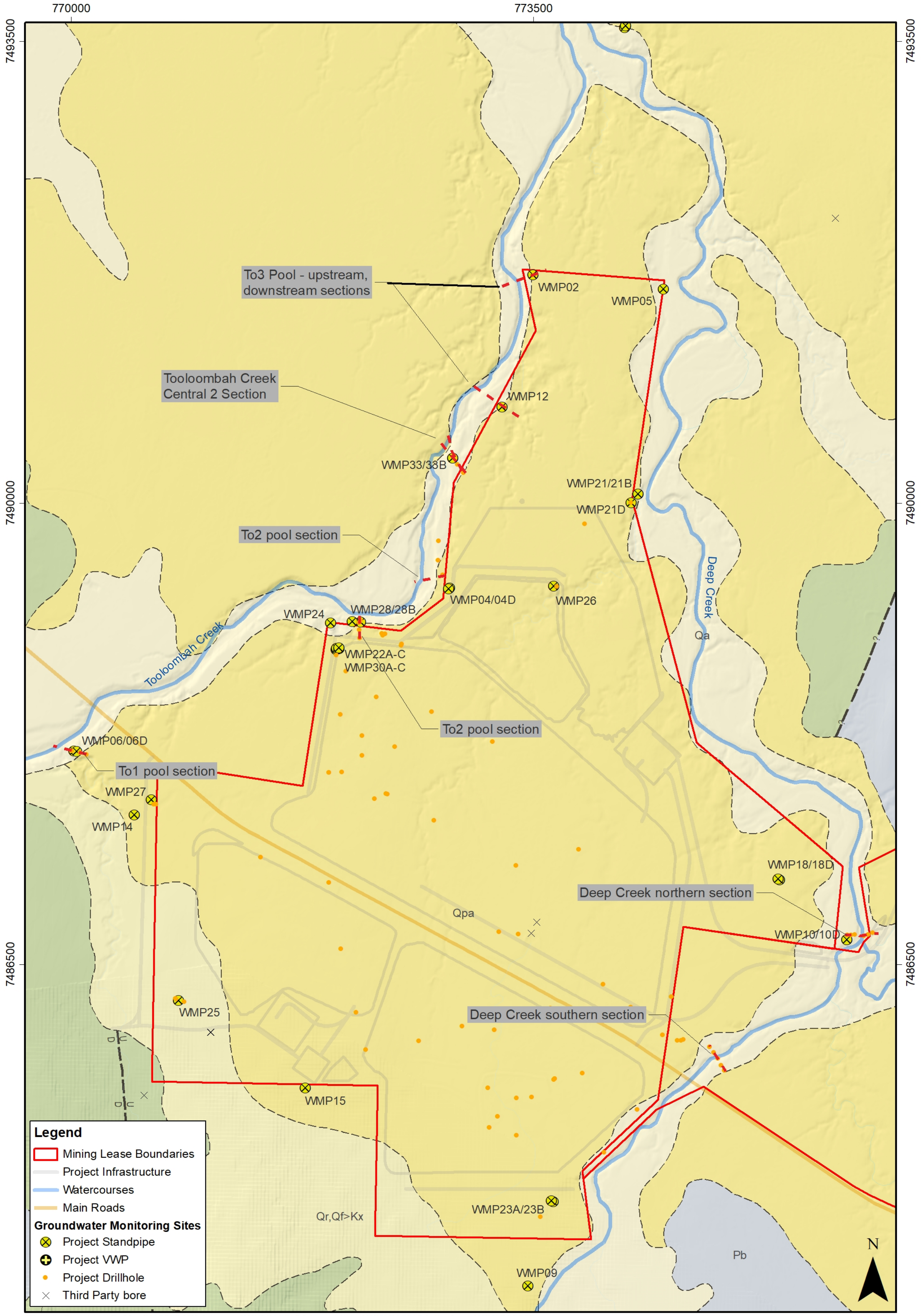
EC increases were generally in the order of 1.2 – 1.4 µS/cm per day, and the pattern over time is shown in Figure 10-49, with the cross section shown in Figure 10-46.

To2 – a permanent or semi-permanent pool located adjacent to the proposed Open Cut 2, 400 – 600 m long

Modelling (Appendix A6d) indicates a bank storage return flow of 2.5 m^3/day and aquifer transmissivity of 6 m^2/day, flowing towards the creek for approximately 150 days (5 months). Further modelling shows that an external inflow of 2.0 kL/day with an EC of 4,000 µS/cm is sufficient to explain the observed results, since the observed EC cannot be explained by evapoconcentration alone. Compared to the increase in EC seen in Figure 10-49 for the To1 pool, EC increases are in the order of 7.6 to 8.5 µS/cm per day, compared to the 1.2 – 1.4 µS/cm per day seen at the To1 pool that does not appear to receive inflows.

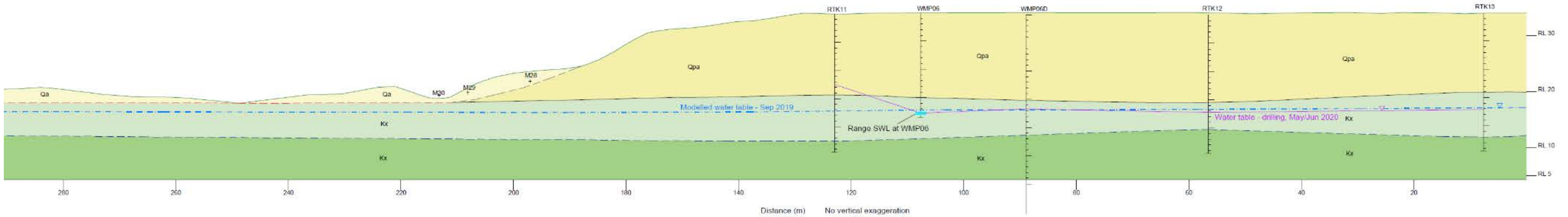
The data shows that these inflows last for about 6 months, before dropping (as seen by the larger drop in water level and EC in November 2019), but this occurs prior to rainfall occurring. Figure 10-50 shows how water level reduces over time and EC increases in the pool (for 6 months), then both reduce comparatively rapidly as the initial saline water source stops.

A temporary borehole excavated in August 2018 located half way between holes RTK01 and RTK02 (refer Figure 10-46) found no water within the alluvium and down to 12 mAHD, while the water table when the cross section holes were drilled was at around 14 mAHD in this location. These two levels show the seasonal changes in water table in this section of the creek of around 2m.

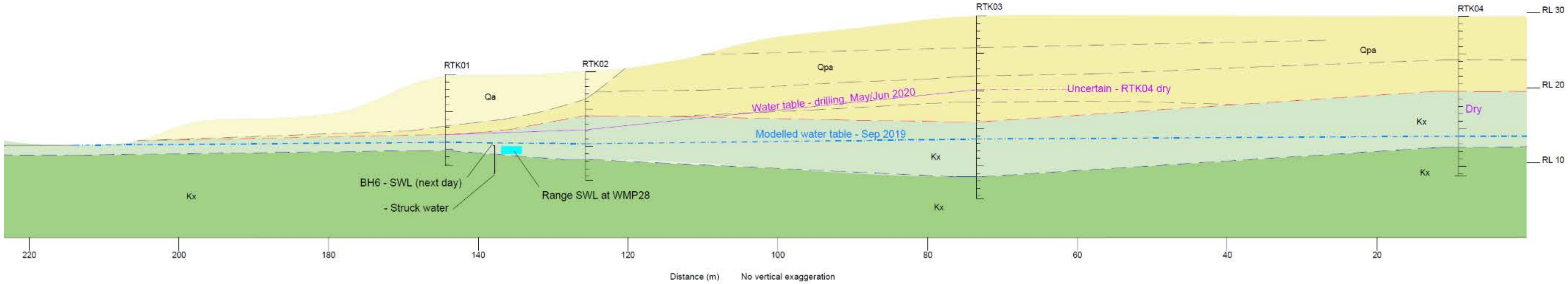


Sites, various, compiled by OE 2020 | Waterways: DNRME 2018 | Tenements: DNRME 2019 | Geology: DNRME 2018
Sections: CQC 2020

Figure 10-45: Location of creek cross sections

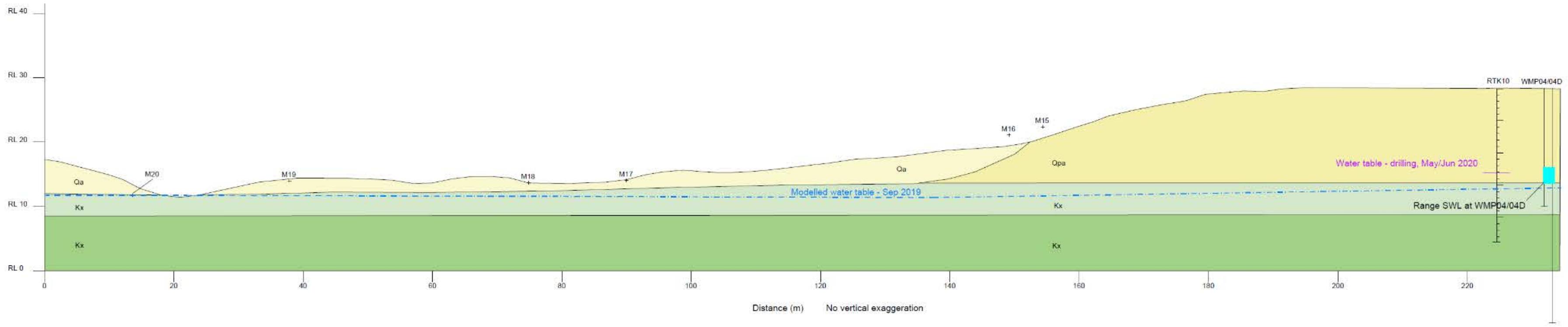


To1 cross section

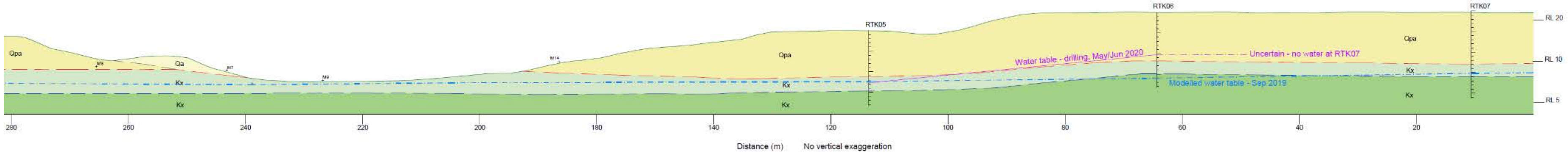


To2 cross section

Figure 10-46: Lithology and water table information, Tooloombah Creek To1 and To2 cross sections



Central 2 cross section



Stream gauge cross section

Figure 10-47: Lithology and water table information, Tooloombah Creek Central 2 and stream gauge cross sections

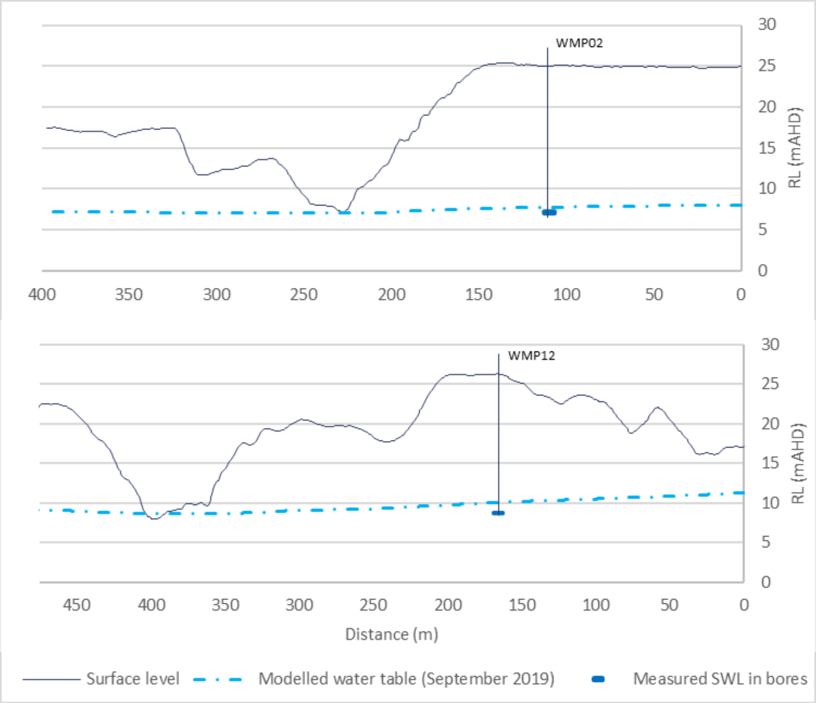


Figure 10-48: Elevation and water table information, Tooloombah Creek To3 cross section

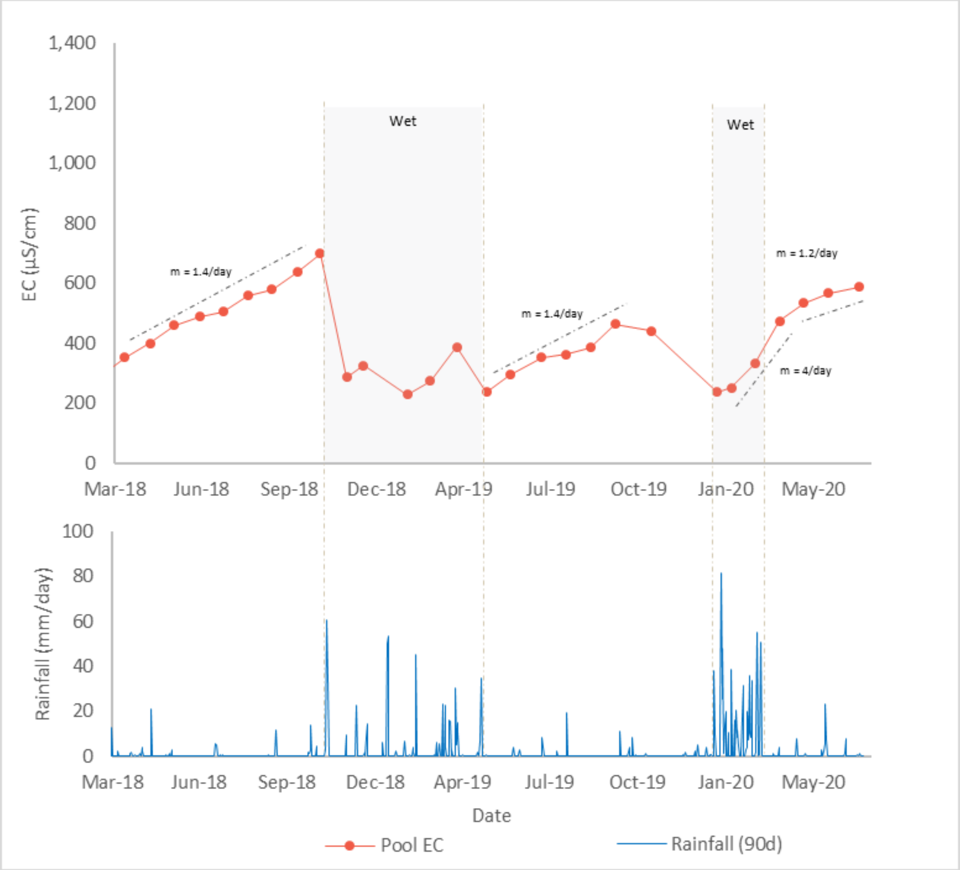


Figure 10-49: Changes in EC in Tooloombah Creek pool To1

Given the creek bed is at 12.1 mAHD, this shows a possible water table inflow into this pool following seasonally raised water table conditions after the wet, which combined with bank storage explains the maintenance of the pool. However, after five to six months, this connection was broken, and the pool rapidly dried, with the salinity reducing rapidly, perhaps due to minor amounts of fresher inflows (possibly from bank storage – the alluvial salinity in this area is still quite high) combined with the much smaller size of the pool. Estimates from satellite imagery and field investigations indicate the pool length diminishes from 850 m long to approximately 150 m long.

The data supports wet season inflows from the water table, with bank flow recharge in the wet season and bank storage return for about 5 – 6 months in the dry season, possibly contributed to by a continued inflow from a seasonally elevated water table (or potentially saline water deposited higher up in the lithology and remaining as perched water). After this time, the more saline inflows rapidly diminished, as did the pool size, but small quantities of fresher water reduced the salinity, but were unable to maintain pool levels in the dry season. Given the large change in size of this pool in dry periods, it might be considered a semi-permanent rather than permanent pool.

Tooloombah Central 2 – a semi-permanent pool located adjacent to the proposed Open Cut 2, 130 m long

There is limited information on the pool itself at this point, which was mapped from satellite imagery in 2011, but could not be identified in later imagery, and areas of dry sand bar are noted in 2018 imagery where there was previously water (indicating some drying), although the presence of water cannot be ruled out due to overhanging vegetation. However, the cross section appears generally similar to the To2 cross section, with a modelled water table elevation equivalent to the base of the creek, which appears to intersect the coal measures over a small section, and a measured water level elevation consistent with slightly higher levels further from the creek, likely dropping as they approach the creek and the interface with the Quaternary Alluvium HSU.

The water level range recorded at WMP04 (Quaternary Alluvium) and WMP04D (Quaternary Pleistocene Alluvium and Styx Coal Measures / Regolith) shows the seasonal range, recorded from approximately level to that measured at the RTK10 drill site (after the wet season) to that predicted by the modelled water table elevation (from September 2019, before the wet season).

The above information indicates this section may act similarly to the To2 cross section site, but is unlikely to be as permanent as that identified for the Tooloombah stream gauge site (see below).

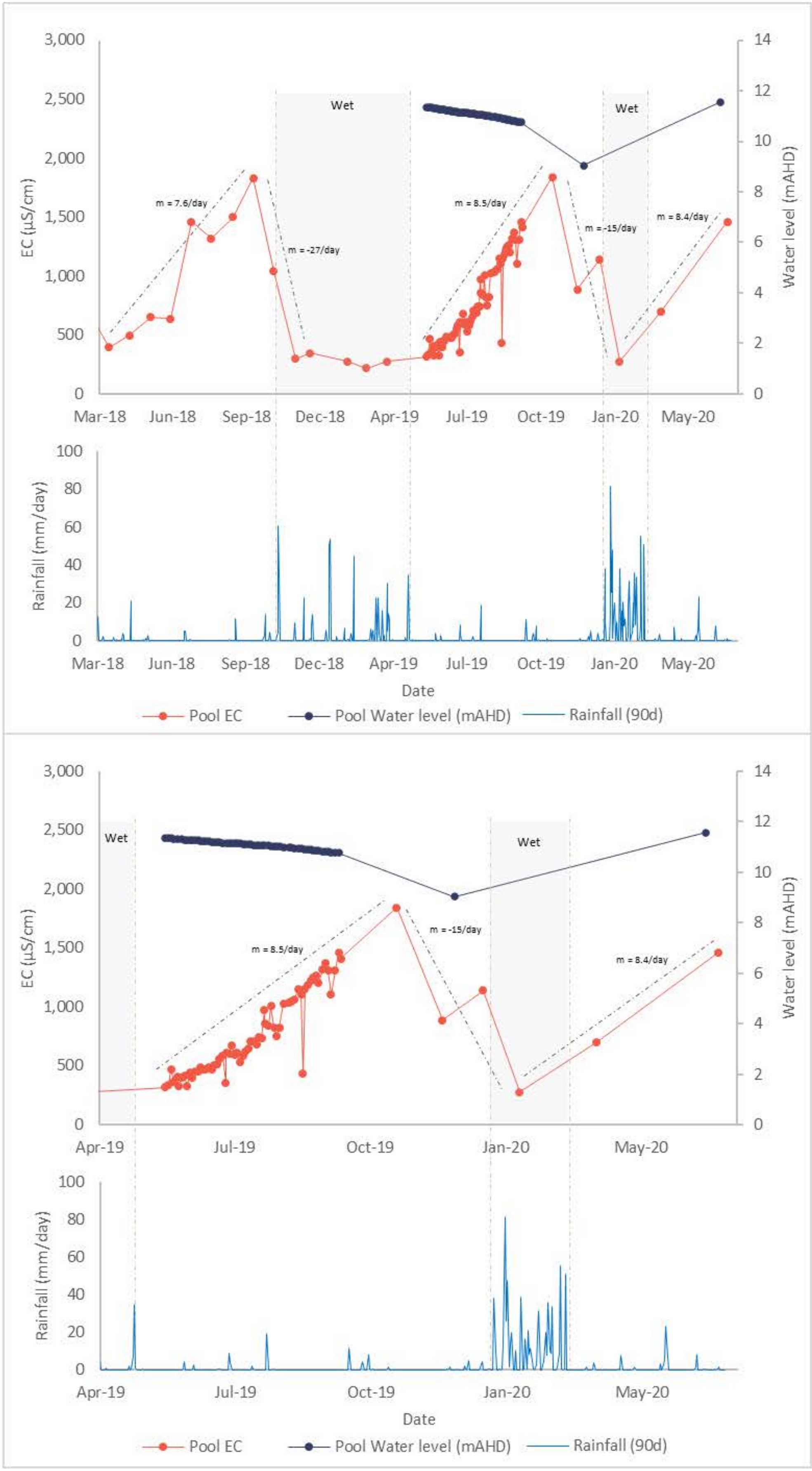


Figure 10-50: Changes in water level and EC in Tooloombah Creek pool To2

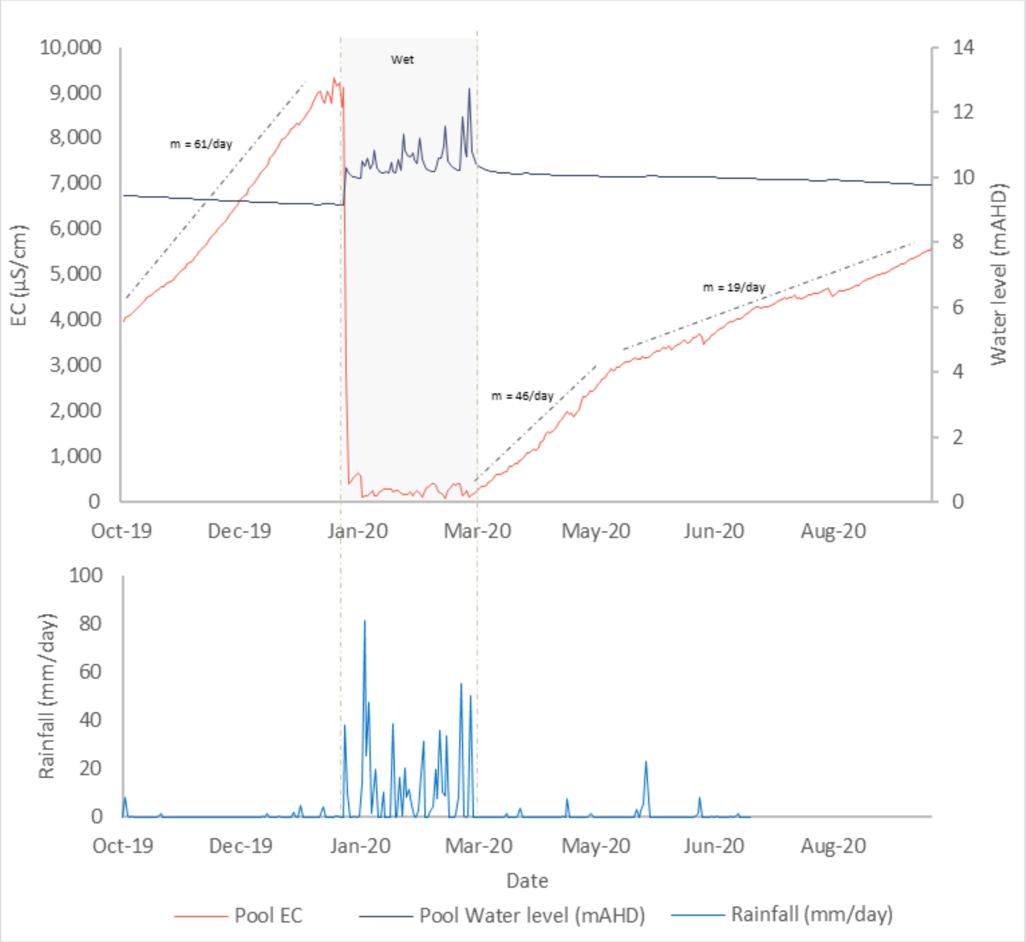


Figure 10-51: Water level and EC changes in the Tooloombah Creek stream gauge pool

Tooloombah Creek stream gauge pool (ToGS1) – a permanent pool located north-west of Dam 1, adjacent to the lease, around 140 m long

Water and salt balance modelling was conducted for this pool as detailed in the Flood Study and Water Balance in Appendix A5b, finding that increases in EC could not be explained by evapoconcentration alone, with an inflow of 4.5 kL/day and EC of 15,000 µS/cm required to sustain observed water level and EC.

The observed increases in EC lasted for three months from when the gauge was commissioned until rains occurred and salinity dropped (refer Figure 10-51). Following the wet season, EC had again risen, over a period of about 195 days (about 6 months) so far – however, the rate of rise has shown two distinct periods – the first for about 2 months up to May 2020, similar to the rise in 2019 (46 µS/cm per day compared to 61 µS/cm per day in 2019), and the second flatter, at around 19 µS/cm per day, so far for 4.5 months.

It is possible that the initial saltier inflows to this system were replaced by fresher recharge water after about two months, potentially when saltier water tables fell as conditions dried further. Changes in evapoconcentration do not appear to explain the change (dropping from 46 to 19 µS/cm per day increase in EC).

The cross section in Figure 10-46 shows that the Styx Coal Measures intersect the creek at this point, although the modelled water table at September 2019 does not intersect the creek. Only a small section of Qa alluvium is mapped along the section.

The data suggests a similar pattern to the To2 site, but with a more pronounced groundwater inflow lasting for longer (the To2 site EC stopped increasing by November 2019, while for this gauge site, it was only the rainfall in January 2020 that appeared to reduce EC). A connection exists to the underlying Styx Coal Measures, however it appears that the water table may not always intersect with the creek bed, although it is suitable to explain the inflows expected into this pool.

Tooloombah Creek To3 pool – a semi-permanent pool located adjacent to the northern lease extent, up to 700 m long

No cross-sectional information is available for this pool, although cross sections are provided in Figure 10-48 showing surface level from the available LiDAR data, and the modelled water table level to September 2019, for two locations – one through the WMP12 groundwater bore located at the upstream end of the pool, and the other through the WMP02 groundwater bore at the downstream end. This shows that the water table may intercept some portions along this section, though not all, and since the pool has been observed dry (January 2020), it must drop below the level of the base of the pool in at least very dry periods.

The location of the observed water levels is similar to that modelled.

EC levels recorded in the pool and shown in Figure 10-52 show a very low increase in EC similar to the To1 site, indicating evapoconcentration rather than saline groundwater inflows, although an increase in EC was noted over the latest wet period, from an increase of 1 µS/cm per day from May to September 2019, to 10.5 µS/cm per day from September 2019 to April 2020 (although there is missing data within the wet period), and so similar to the To2 pool site.

The data shows the large differences between the different pools, even when close together, and for this pool, it appears to show evapoconcentration occurring, along with some saline inflows at times, although with no clear source.

Deep Creek Pools

None of the Deep Creek pools showed EC increases that were indicative of anything other than evapoconcentration, and all pools, other than the De5 site have dried out during the monitoring program, although all pools are generally small.

The cross sections prepared for Deep Creek (Figure 10-53 and Figure 10-54) show the modelled water table to be below the creek for both sections, with the measured water table level confirming this finding.

Pools are generally ephemeral, and limited groundwater inflow to the creeks in the dry season is anticipated. Wet season recharge and some shorter bank storage return flows are predicted by the Surface Water/Groundwater Interactions Report in Appendix A6d.

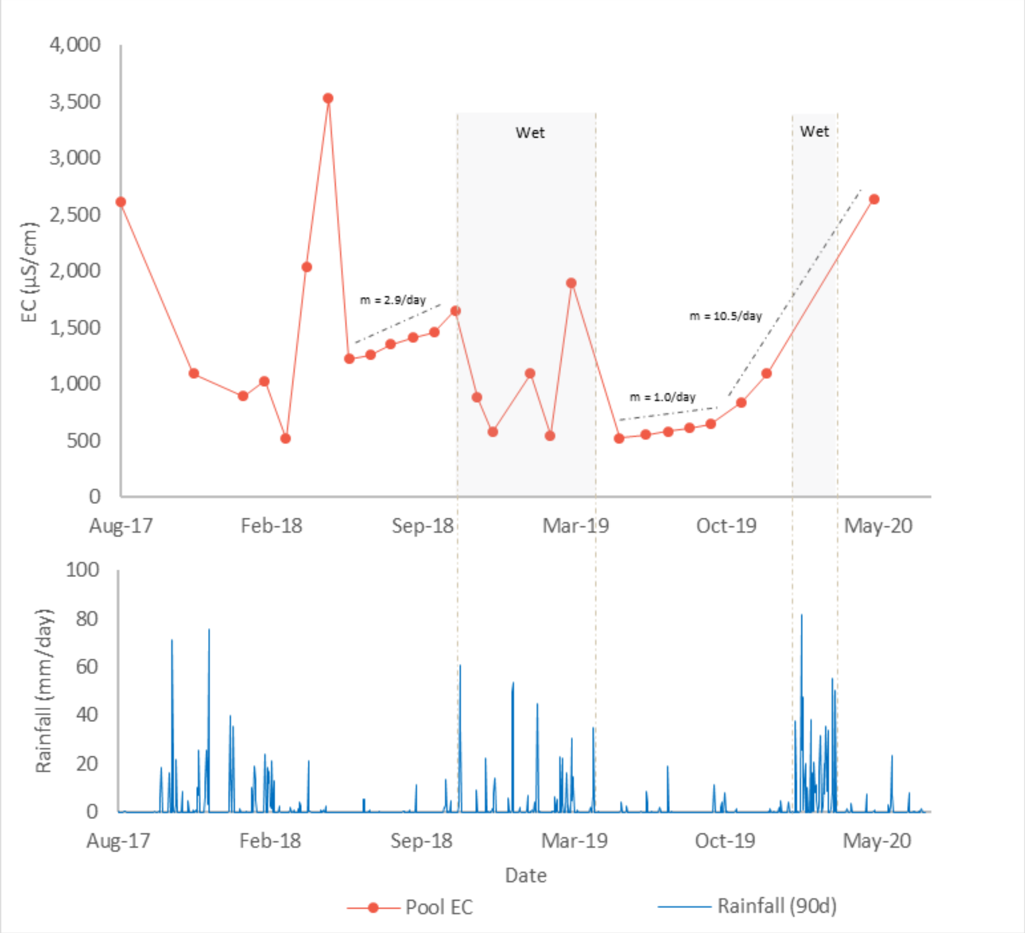


Figure 10-52: EC changes in the Tooloombah Creek To3 pool

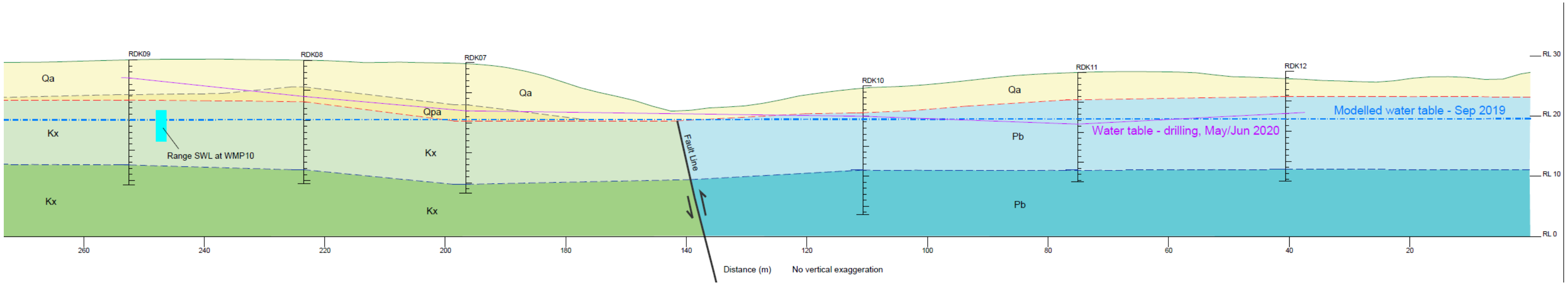


Figure 10-53: Deep Creek northern cross section

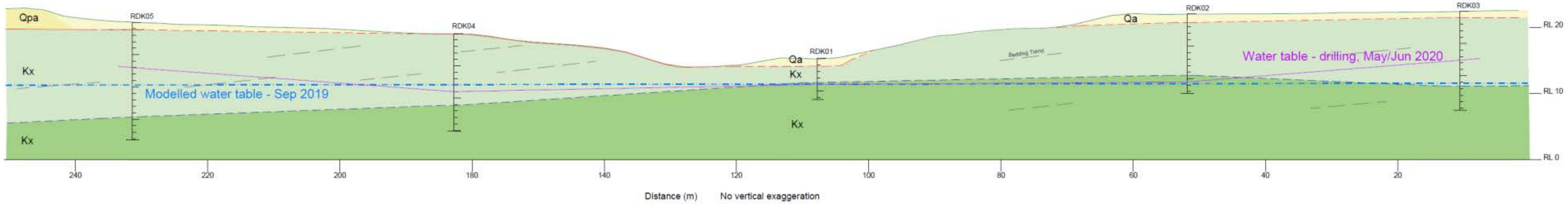


Figure 10-54: Deep Creek southern cross section

Summary

Overall, the assessment conducted in the Surface Water/Groundwater Interactions Report in Appendix A6d concluded that the creeks are primarily bank flow fed, rather than from elevated water table aquifers in the dry season, but that the saline influence during dry periods could be saturation of these sediments from rising regional water tables in the wet season, which is released in the dry when regional water tables lower. The data supports this assessment, but the stream gauge pool may potentially receive direct groundwater inflows during the dry season, at least for part of the time. The work identified a higher bank storage and return flux in Tooloombah Creek compared to Deep Creek.

Deep Creek is responsive to rainfall and is highly turbid. During the dry season, the riverbed is mostly dry except for a series of disconnected pools (mostly temporary). A fault line exists along the channel of Deep Creek adjacent to the Project, with these reaches likely to lose more water to lateral flow moving east away from the creek than areas to the north and south, rather than being stored for subsequent return to the creek – i.e. soil moisture and surface water pools within these sections are unlikely to be sustained during the dry season.

Tooloombah Creek is also responsive to rainfall, however it is much less turbid than Deep Creek, possibly due to the different substrate material and the deeper channel limiting cattle access. Low-lying areas of the Tooloombah Creek catchment are subject to flooding and large pools of water occur along the creek during dry periods. Tooloombah Creek likely receives higher amounts of groundwater inflow compared with Deep Creek, and groundwater inputs are likely to maintain water in some of the pools.

Observational data supports the above findings.

10.3.7.3 Stable and Radioactive Isotope Sampling

Sampling of stable isotopes (H^{-2} and O^{-18}) and radioactive radon isotopes (Rn^{-222}) was undertaken as part of the SEIS v2 works, targeting Deep and Tooloombah Creeks, potential GDEs (Wetland 1, Wetland 2, Alluvial Vine Thicket), and select groundwater bores, with the results detailed in the Preliminary Isotope Study Results in Appendix A10h.

The stable isotope analysis was conducted at the WMP02, WMP04/WMP04D, WMP05, WMP06 and WMP10 bores plus Deep and Tooloombah Creek sites, and compared to the global meteoric water line (GMWL) and local meteoric water line (LMWL) developed from data collected by CSIRO (Crosbie et al. 2012). This is shown in Figure 10-55, which shows that surface and groundwaters cluster differently, and have therefore undergone different processes. With the exception of WMP06, the groundwater sampling results plot on or at the GMWL and LMWL indicating that the groundwater sampled is derived mainly from rainfall recharge (whether directly from rainfall or from flood recharge) and has undergone little to no evaporation. Surface water samples deviate from the GMWL and LMWL, indicating evaporation processes have occurred.

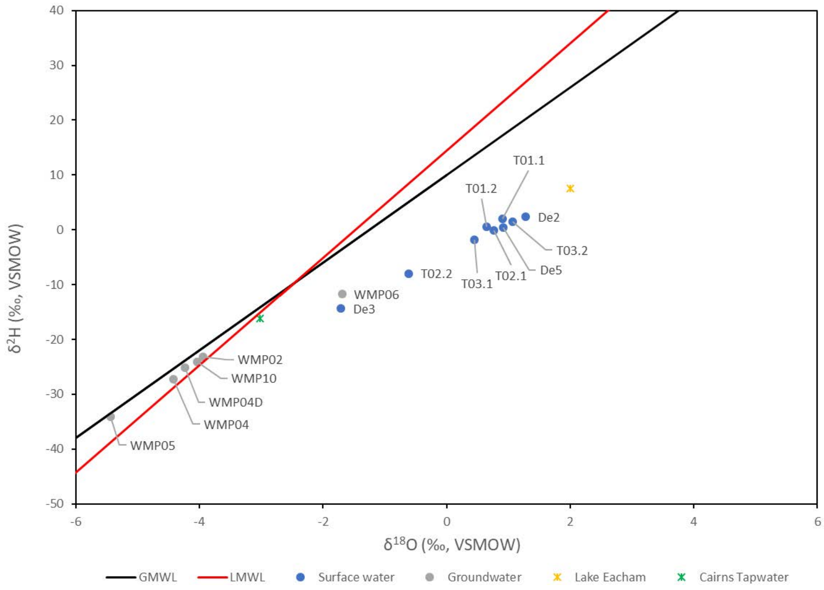


Figure 10-55: Environmental (stable) isotopes

Radioactive isotope analysis was conducted on Tooloombah and Deep Creek samples, and the results compared to chloride and biocarbonate/chloride concentrations. This showed that there was a greater potential for groundwater contributions to Tooloombah than Deep Creek, and more so in the To2 and To3 sites than the upstream To1 site, although not in any significant quantities – a result confirmed by the above assessments of pools and near creek transects (refer to Appendix A6d, and the data provided on pools in the Surface Water Quality Technical Report in Appendix A5a).

10.3.8 Conceptual Hydrogeological Model

10.3.8.1 Broad Conceptualisation

The Groundwater Model and Assessment Report in Appendix A6b utilised the information collated as part of the desktop study assessments as well as information and previous hydrogeological conceptualisations developed as part of the previous SEIS v2 to refine and update the regional hydrogeological conceptual model for the Project. This is shown schematically in Figure 10-56, and is detailed further in Appendix A6b.

The above conceptualisation combined with further discretisation of the alluvium and other HSUs, modelling work, and in particular the further monitoring and stream cross section investigations have allowed a more refined conceptualisation of surface and groundwater interactions in proximity to the Project. This local conceptualisation is shown in Figure 10-57.

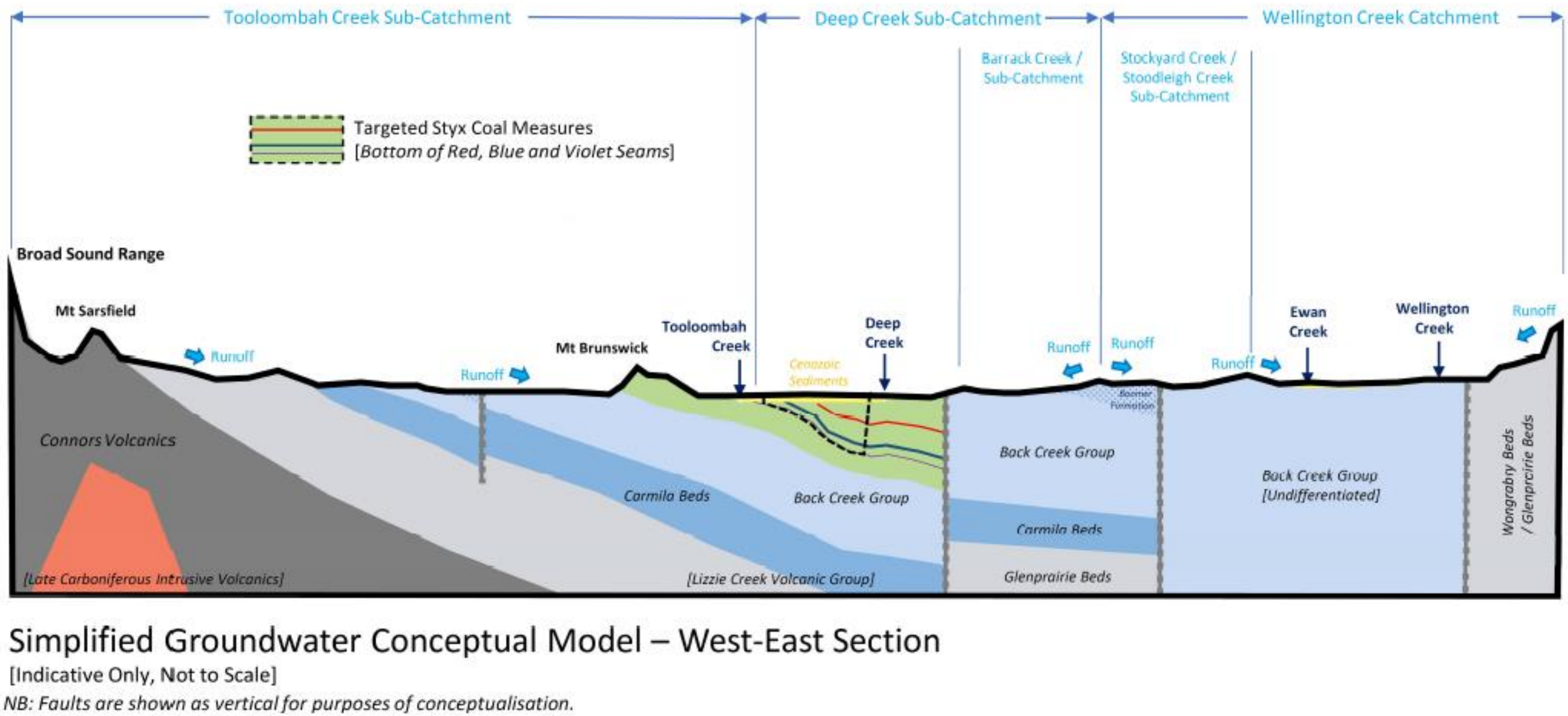


Figure 10-56: Regional conceptual groundwater model (sourced from HydroAlgorithmics 2020)

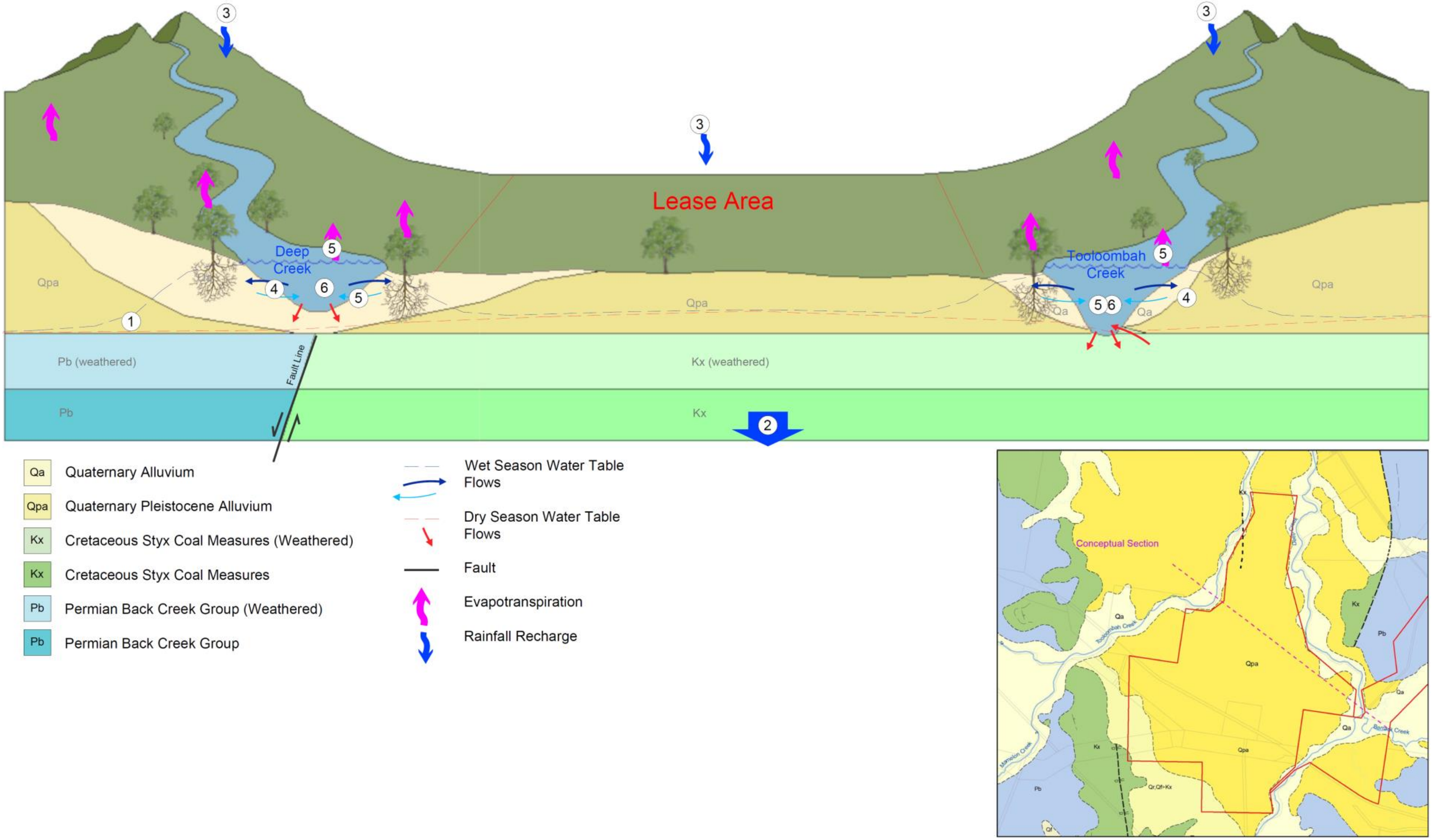


Figure 10-57: Local conceptual groundwater – surface water conceptual model

10.3.8.2 Groundwater Systems

The six HSUs relevant to the Project area can be described as part of four conceptual groundwater systems, with both the two Styx Coal Measures units, and the two Permian Measures units considered together as follows:

- Quaternary Alluvial (Holocene) (Qa)
- Quaternary Pleistocene Alluvial (Qpa)
- Sedimentary Rock - Styx Coal Measures
  - Upper - Overburden / Weathered Regolith and
  - Lower - Overburden / Coal Seams, Interburden / Coal Seams, Underburden / Weathered Regolith and
- Sedimentary and Fractured (Basement) Rock - Permian Measures
  - The upper Back Creek Group and
  - The lower Carmila Beds.

These are described further below:

Quaternary Alluvial (Holocene) Groundwater System

The Holocene aged Qa comprises clay, silt, sand and gravel floodplain alluvium and is generally confined to the watercourses and local drainages. The aquifer includes alluvial (narrow-channel) sediments within the deep cut infills of Tooloombah Creek and Deep Creek as well as estuarine sediments toward the Styx River mouth downstream of the Project. This unit is less consolidated and therefore more permeable than the older Pleistocene Alluvium described below, and the aquifer is considered to be unconfined.

Quaternary Pleistocene Alluvial Groundwater System

The Qpa comprises sand, mud and gravel alluvium on higher terraces, overlying the Styx Coal Measures. Precise subdivision of this unit from the underlying weathered coal measures is not always clear at depth, and this is reflected in some similarities between this unit and the upper coal measures in the water quality data (refer to Section 10.3.6.3).

As noted above, being more consolidated it is also less permeable than the younger Holocene Alluvium described above, though the aquifer is likewise considered to be unconfined.

Sedimentary Rock Groundwater Systems - Styx Coal Measures

The sedimentary rock system includes the shallow rock Early Cretaceous Styx Coal Measures, incorporating higher permeability coal seams/plies, and with reducing permeability with depth. The coal measures unconformably overly the Permian aged Back Creek Group described below.

Aquifers in this unit are generally confined aquifers, although are expected to be less confined where the coal seams subcrop near the surface / regolith. The upper weathered units are comprised of clays and low permeability textures and when compared to the overlying alluvium, act as an impermeable layer to flow between the two units.

Sedimentary and Fractured (Basement) Rock Groundwater Systems - Permian Measures

This includes shallow and deep rock groundwater bearing structures and the Permian Measures of the Back Creek Group to Carmila Beds and Lizzie Creek Volcanic Group to Connors Volcanic Group. The Permian age units are considered to be generally confined aquifers, but again are expected to be less confined where they subcrop near the surface / regolith. This has been separated into two discrete units – the upper Back Creek Group, and the Carmilla Beds groundwater system.

10.3.8.3 Conceptual Processes

The essential processes numbered in the conceptual diagram in Figure 10-57 are described below:

1. The water table is typically hosted in unconsolidated alluvial deposits (HSU 1 and 2) and also within fractured and weathered (residual) zones of outcropping and sub-cropping basement rocks (HSU 3 - 6), and is generally a subdued reflection of topography, with depth to water table typically less than 15 metres below the surface. The water table varies by up to around 3 m seasonally in unconsolidated alluvial deposits.
2. Regional groundwater flow is generally to the north, towards Styx River and the coast. Locally, within the Tooloombah and Deep Creek tributary catchments of Styx River, groundwater flow within the water table aquifers is generally toward the creeks and more dominantly toward the confluence of the creeks.
3. Diffuse rainfall recharge occurs across the Styx River Basin, with higher rates of recharge expected over those parts of the catchments covered by cleared alluvial sediments.
4. Episodic local groundwater recharge (to bank storage and the underlying / adjacent aquifer) occurs from stream losses during large and sustained streamflow events (generally associated with the wet season, and particularly larger wet season and/or flooding events), as evidenced by the SWL in the Qa Alluvium shown in Figure 10-11 and the trend in groundwater chemistry in the Qa Alluvium towards a rainfall/streamflow signature.
5. Groundwater discharge via evapotranspiration occurs from:
    - capillary fringe, typically occurring along the riparian zone of watercourses but also in terrestrial environments where the water table is sufficiently close to the surface (vegetation with rooting zones that access only the vadose zone deplete the soil water reservoir)
    - watercourse pools where the streambed intersects the water table, limited to periods close to the wet season and some pools within Tooloombah Creek and possibly downstream in Deep Creek, with connectivity increasing downstream
    - bank storage return, following streamflow events and
    - in lower lying areas below the confluence of Tooloombah and Deep Creeks.
6. Watercourse pools are supported primarily by bank flow storage return in the dry season. After the wet season in Tooloombah Creek, recharged bank stores return to the creek, providing baseflow, which is generally saline in proximity to the Project. This lasts for five to six months, at which time most of the pools are disconnected from this inflow source, and proceed to dry up more rapidly. A low rate of fresher inflow is seen in some pools once the more saline inflows cease, but this is minor and not sufficient to sustain the pools. This connection is not seen in the upper catchment, and increases with distance downstream.

Deep Creek also recharges the banks in the wet season, but much less water returns, with most lost to the more permeable lithology around the creek to the east, particularly where associated with the local fault line. Deep Creek pools are generally not supported through the dry season, but the local conditions indicate potential for groundwater support (and increased permanence) downstream near to the confluence.

7. The normal tidal limit (MHWS) is located in the Styx River approximately 3.7 km downstream from the Project (1.4 km downstream from the confluence), with the peak tidal limit (HAT) at the confluence. Groundwater discharge occurs to the Styx River and the Broad Sound estuary, although at times during high tides this discharge may be interrupted by leakage for these surface water features.
8. The hydraulic gradient is generally upwards from the confined Styx Coal Measures to the unconfined alluvial units. However, the two units join unconformably and the Styx Coal Measures generally provide for an impediment to flow. This means that the coal measures can supply water upwards into the alluvium, but only where there is good connectivity. Evidence suggests the saltier coal measures aquifers may rise seasonally, providing some water into the alluvium (the bank store) which seeps into pools in Tooloombah Creek during the dry season, once this regional water table has declined.

The conceptual surface water – groundwater processes within the pools described above can be described in terms of gaining and losing systems, and mixes of the two, as follows:

- Predominantly gaining, permanently connected stream reaches - reaches which are permanently connected to groundwater, by being below the steady state water table, predominantly gaining water – this is represented by the Tooloombah Creek stream gauge pool.
- Losing/Gaining, semi-permanently and non-permanently connected stream reach - gaining if intersecting the groundwater table, and losing if not – this is represented by the Tooloombah Creek To2 pool, and potentially the To3 pool.
- Losing, disconnected stream reaches - permanently above the groundwater table and predominantly losing water – this is represented by the Tooloombah Creek To1 pool, and the Deep Creek pools.

These systems are shown in Figure 10-58 for storm event or wet season conditions (top row), post event conditions (middle row), and dry season conditions (bottom row), for the above three dot points (shown left to right respectively).

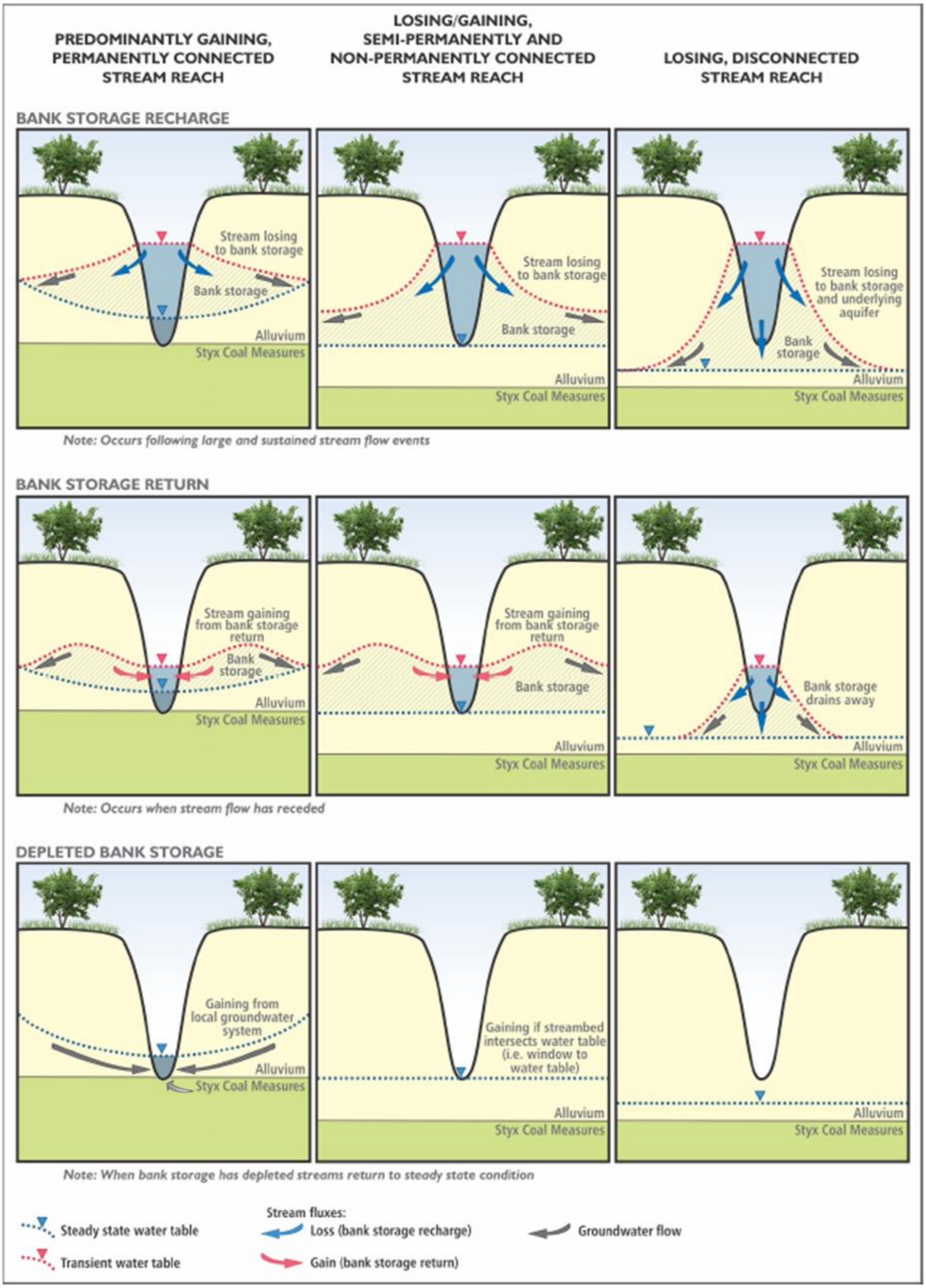


Figure 10-58: Mechanisms of surface water – groundwater interactions

10.4 Potential Impacts of the Project

The National Water Commission (NWC) mining risk framework (Howe 2011) defines the following four direct groundwater effects arising from mining:

- altered groundwater quantity
- altered groundwater quality
- altered surface water – groundwater interaction and
- physical disruption of aquifers.

Direct effects encompass the changes to physical and/or quality aspects of groundwater as a consequence of mining activities, or the changes to the physical characteristics of aquifers affected by mining activities. Examples include changes in water levels, changes in groundwater chemistry or changes in hydraulic properties of aquifers (Moran et al. 2010).

Indirect effects of mine-water affecting activities are those that arise in response to direct effects (Moran et al. 2010) and typically relate to the potential for impact on sensitive receptors. EVs that have been identified for the Project area (Section 10.3.6.8) provide a basis for assessing receptors that may be sensitive to direct effects.

Each of the above potential direct impact effects and impacting activities are summarised in Table 10-11. Table 10-12 presents a summary of direct effects against relevant EVs.

Table 10-11: Potential groundwater impacts of the Project[1]

Direct Effect	Water Affecting Activity / Hazard	Potential Project Impacts	Project Phases
Quantity	• Mine dewatering • Groundwater supply development • Open pit post-closure • Stockpiling and waste storages • Water storages • Backfilling • Containment and pipeline failure	• Dewatering will cause depressurisation in the local aquifers leading to local depletion of groundwater storage, which may result in inter-HSU water transfer. The extent of the affect is determined through the numerical groundwater modelling.	• Operational • Closure and post-closure until stabilisation occurs
		• Dewatering and depressurisation can result in the reduction of supply to local water supply bores.	
		• Evaporative losses from open voids could also increase loss from aquifers, however this will be minimal as the void will be backfilled as mining progresses. Nevertheless, the total take of groundwater and evaporation from pit sump storages has been included in the numerical groundwater model and the site water balance model.	• Operational
		• Due to the elevated waste rock stockpiles and backfilling of voids with stripped waste rock, the hydraulic properties within the disturbed area will change, and recharge may be enhanced. This has been modelled and assessed within the numerical groundwater modelling.	• Operational • Closure and post-closure • Rehabilitated landforms
		• Other changes to aquifer properties such as changes to interconnections between HSUs and laterally within HSUs that could affect aquifers external to directly mined areas and stockpile areas are not anticipated to occur, but nevertheless would become apparent within the numerical groundwater modelling.	• N/A
Quality	• Mine dewatering, HSU depressurisation • Stockpiling and waste storages • Water storages	• Direct impacts to groundwater quality could occur due to seepage and infiltration from mine affected water dams, waste storages and from leaks and spills. These changes could occur throughout the construction, operation and post-closure phases of the Project. AMD of waste storages could affect the quality of this leachate.	• Operational • Closure and post-closure • Rehabilitated landforms

Direct Effect	Water Affecting Activity / Hazard	Potential Project Impacts	Project Phases
	- Equipment & containment failure - Open pits during mining and post-closure - Interconnection of aquifers by poor well completion	- Mobilisation of poorer quality groundwater resources affecting better quality aquifers could occur, due to depressurisation effects (changed hydraulic gradients laterally and vertically), mounding effects of waste storages and linkages between poor and good quality aquifers.	- Operational - Closure and post-closure until stabilisation occurs
		- Mobilisation of the seawater-freshwater interface could reduce the quality of groundwater resources, however it has been shown that this interface is too far removed from the site, and no impact in this regard would occur.	- N/A
		- Evaporative concentration of salts within mine voids and dams could provide a source (through infiltration / seepage) of saltier water into aquifers, although this is limited by the backfilling of pits occurring behind mining operations.	- Operational - Closure and post-closure until dams are rehabilitated
		- Exposure of acid sulfate soils is not considered a project risk, given that none are identified within the potential Project impact area.	- N/A
Groundwater – surface water interaction	- Mine dewatering - Groundwater supply development - Water storages - Mine waste management	- Dewatering will cause depressurisation in the local aquifers leading to local depletion of groundwater storage, with the extent of drawdown determined by the numerical groundwater modelling. This could cause: - the depletion and lowering of aquifers that supply GDEs, by isolating them from aquifers permanently, or at critical life stages or - a reduction in baseflow by either directly reducing groundwater inflows to waterways (although this has been shown to be minimal if any), or by reducing the amount of wet season recharge in bank storage, thereby affecting the bank flow return duration, and so the duration that water may be available to aquatic ecosystems or aquatic GDEs.	- Operational - Closure and post-closure until stabilisation occurs
		- Impacts to groundwater quality identified above (including evapoconcentration in dams, seepage from waste stockpiles, spills and leaks) can affect the quality of aquifers supplying surface waters as baseflow or that of GDEs accessing these aquifers (e.g. through elevated salinity). Induced from of groundwater with	- Operational - Closure and post-closure

Direct Effect	Water Affecting Activity / Hazard	Potential Project Impacts	Project Phases
		different quality can likewise change groundwaters that influence surface water composition	• Rehabilitated landforms
		• Mobilisation of the seawater-freshwater interface could reduce the quality of groundwater resources accessed by GDEs and influencing surface water quality, however it has been shown that this interface is too far removed from the site, and no impact in this regard would occur.	• N/A
Aquifer disruption	• Excavation / mining • Backfilling • Stockpiling & waste storages	• Removal of part or whole of aquifer while mining, however this will be backfilled limiting the extent of impact.	• Operational • Closure and post-closure until stabilisation occurs
		• Altered hydraulic properties of backfill materials will change recharge and groundwater flow properties within the mine pit areas.	• Operational • Closure and post-closure • Rehabilitated landforms
		• Mounding effects from waste rock stockpiles and final elevated landforms may affect local aquifers	• Operational • Closure and post-closure • Rehabilitated landforms

Table notes

[1] Adapted from Howe (2011) and Ford et al. (2016)

Table 10-12: Linkage between direct effects and EVs

Direct effect	EVs that can be impacted	Potential effect
Quantity	Aquatic ecosystems	Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream (potentially extending as far as estuary)
	Irrigation	Potential reduction in pumping rates due to deeper pumping water levels as a result of drawdown Potential failure of bores if drawdowns exceed aquifer thickness or screen sections
	Farm supply	
	Stock supply	
	Cultural / spiritual	Largely associated with 'aquatic ecosystems EV'
Quality	Aquatic ecosystems	Limited in association with evaporative salinisation as mine voids will be open for short periods (around three years) prior to backfilling Limited in association with AMD due to coal measures being typically NAF Potential impact to estuarine ecosystems if ASS is allowed to become exposed due to altered groundwater flow conditions and drawdown
	Irrigation	
	Farm supply	
	Stock supply	
	Cultural / spiritual	
Groundwater – surface water interaction	Aquatic ecosystems	Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream Possible significant effect to estuarine and marine (aquatic) ecosystems if surface water discharges from Styx River catchment due to substantial baseflow reduction (combined with reduced stormwater discharge) is sustained in the mid- to long-term
	Irrigation	None
	Farm supply	None
	Stock supply	None
	Cultural / spiritual	Largely associated with 'aquatic ecosystems EV'
Aquifer disruption	Aquatic ecosystems	Limited to the mine pits
	Irrigation	Limited as there are no bores within the mine pit area
	Farm supply	
	Stock supply	
	Cultural / spiritual	Limited

10.5 Impact Assessment

10.5.1 Groundwater quantity

An extensive calibration was undertaken to pre-mining conditions, as detailed in Section 10.2.4. Predictive modelling followed, which incorporated the proposed mining schedule, backfilling operations, elevated landforms from the waste rock stockpiles, and required dewatering activities. The initial conditions were based on the end of the transient calibration period, with a constant climate to enable examination of Project impacts alone.

The key predictions from the model are summarised in the below sections.

10.5.1.1 Groundwater Inflows / Take

Groundwater inflows into the open cut area are predicted to be between 0.01 ML/day to 1.12 ML/day, with the rates for each Project year provided in Table 10-13 and shown for quarterly intervals in Figure 10-59. The modelling predicts an average groundwater take of 0.5 ML/day during the operational life of the mine, peaking at around 1.2 ML/day in the first 6 years of the mine, and declining thereafter (with some variation).

The Project open cut pits are approximately 150 m from Tooloombah Creek and Deep Creek. Based on the modelling results and the proposed mine water supply system, no direct take of the water from higher permeability surficial Qa units are proposed for the Project.

Table 10-13: Predicted groundwater flow into pits

Year	Daily Average Inflows for Annual Period [ML/day]		
	Open Cut 1	Open Cut 2	Total
1	-	0.21	0.21
2	-	0.64	0.64
3	-	0.93	0.93
4	-	1.12	1.12
5	-	1.09	1.09
6	-	1.09	1.09
7	-	0.86	0.86
8	-	0.77	0.77
9	0.14	0.6	0.73
10	0.14	0.37	0.51
11	0.06	0.09	0.15
12	0.02	0.05	0.07
13	0.01	0.04	0.06
14	0.01	0.01	0.02
15	0.01	<0.01	0.01
16	0.01	<0.01	0.01
17	0.02	<0.01	0.02
18	<0.01	<0.01	<0.01

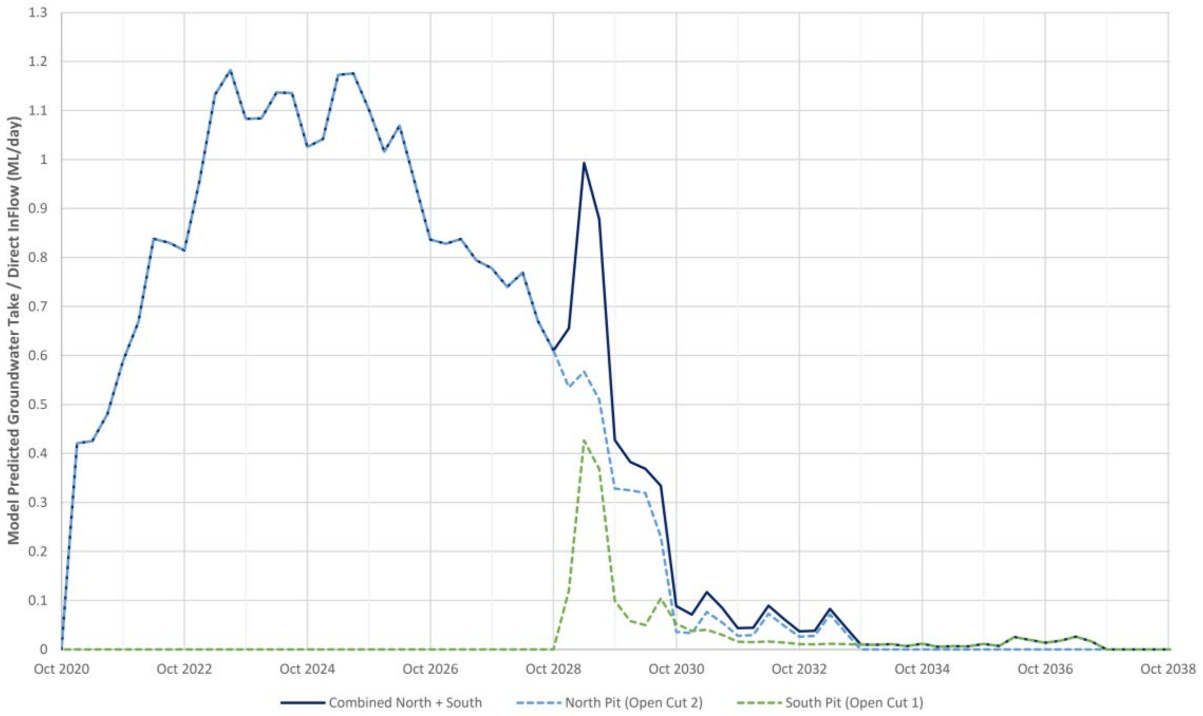


Figure 10-59: Predicted groundwater flow into pits

10.5.1.2 Groundwater Drawdown / Depressurisation

The key component of this groundwater assessment is associated with the drawdown within the open cut pits and how it affects surrounding aquifers. To assess this, the numerical model was run for the mine life of 18 years and for another 500 years post mining, with the following key periods analysed:

- Year 3, which aligns to the timing of impacts to be addressed in the initial Underground Water Impact Report (UWIR)
- Year 10, approximately in the middle of mining, and when both open cut pits are in operation
- At the end of mining
- 5 years after the end of mining and
- For long term recovery (end of modelling period, 500 years after mining).

The analysis also included a worst-case drawdown extent, which combines the furthest extents achieved throughout all of the years modelled (not limited to the years above), and so does not represent any single year). In terms of drawdown extent and impacts, the 0.5, 2 and 5 metre contours are plotted for comparison. The 2 and 5 m contours are the bore trigger thresholds defined in the *Water Act 2000* (2 m for unconsolidated aquifers, and 5 m for consolidated aquifers[5]). The 0.5m contour shows the minimum drawdown able to be defined (that is, drawdown of less than 0.5 m was not shown). For reference, layers 2, 3 and 4 (alluvium and regolith) are considered unconsolidated aquifers.

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[5] Water Act 2000, Section 376

Drawdown is considered below for the water table; along the centreline under the key creek systems affected by the Project – Tooloombah, Deep and Barrack Creeks; and within the Styx Coal Measures. Drawdown is largely confined to the Styx Coal Measures and has limited effect on the basement rocks. An assessment of the recovery of the system is undertaken for each of the above units.

Further data and assessment is provided within the Groundwater Model and Assessment Report in Appendix A6b.

10.5.1.2.1 Water Table

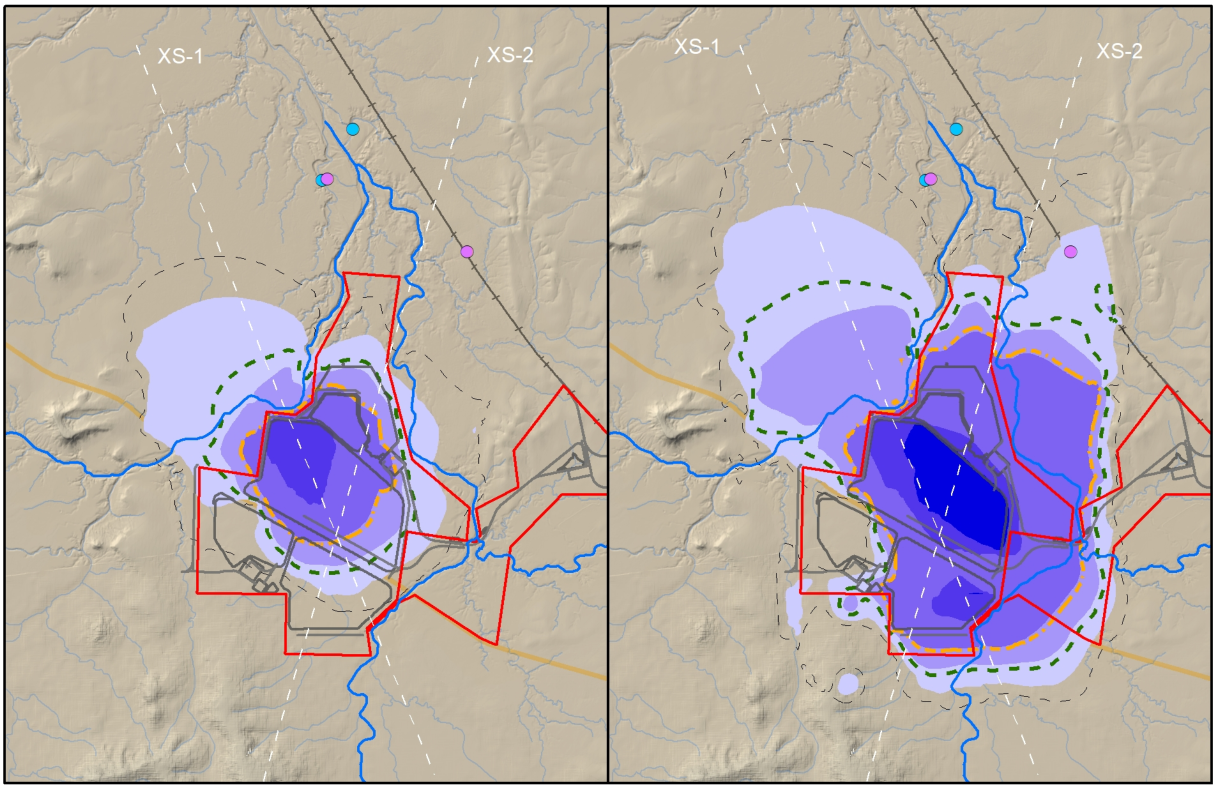
Figure 10-60 shows the predicted drawdown extent in the water table. The cross sections shown on this plan are provided in Figure 10-61 (along cross section XS-1) and Figure 10-62 (cross section XS-2) for the analysis periods described above (Years 3, 10, end of mining, 5 years post mining, long term recovery).

The data shows the drawdown curve extends around 3 km to the north-north-west of Open Cut 2 and 3 km to the south-south-east of Open Cut 1 at its maximum extent. Initially drawdown is centred around the open cut pits, with extensions to the north-west. As mining progresses towards the east and approaches the interface of the Styx Coal Measures and the Back Creek Group, the hydraulic differential between the two units acts as a boundary resulting in the drawdown then extending to the north (on the west side of the fault).

Long term recovery (refer Figure 10-68) shows levels recover across the lease area, with a slight mounding effect seen across both cross sections. This is due to the elevated final landforms providing for enhanced infiltration and the added head pressure of elevated land, and provides in the long term for a rise in groundwater in the location of the pits in the order of up to 3 m – the mounding across the site is shown in Figure 10-63. Since this mounding is due to the effect of infiltration into the landforms themselves, this would not be expected to result in saline water from deeper aquifers finding surface expression where they previously did not (fresher infiltration waters would have the effect of ‘pushing down’ saltier waters from deeper layers).

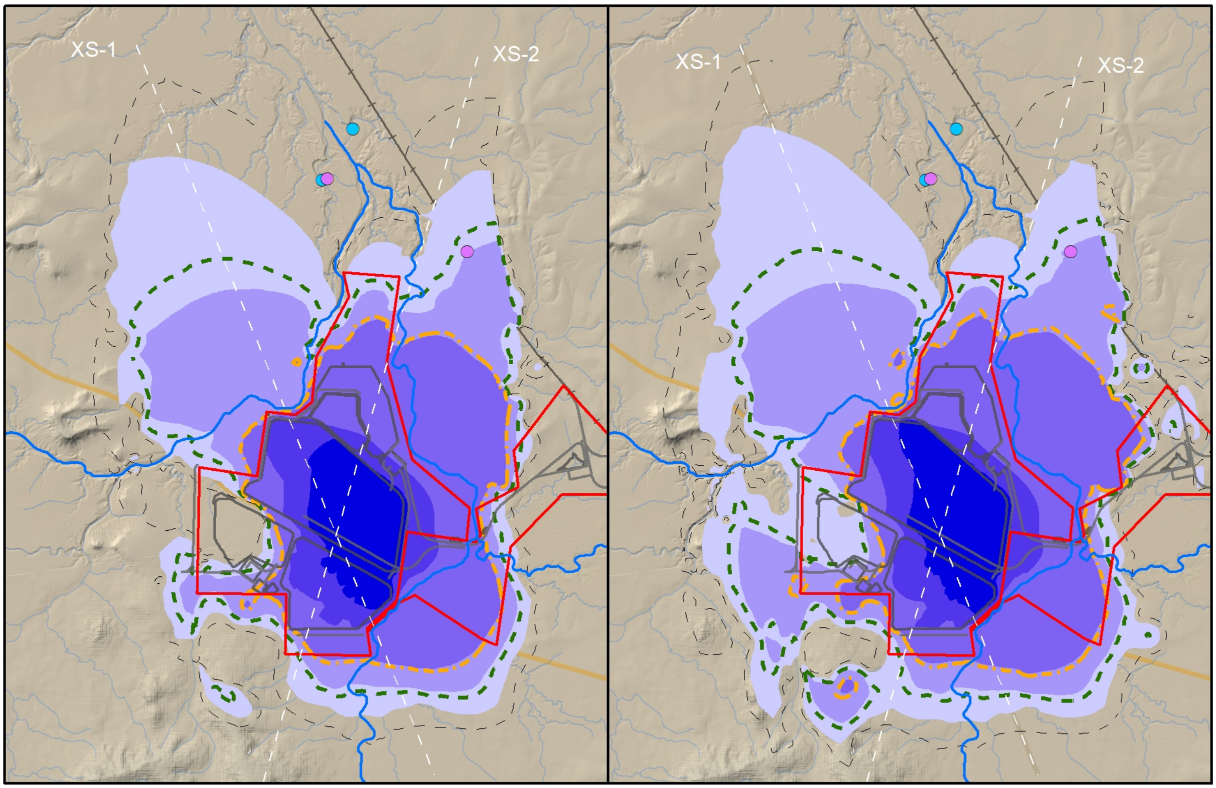
Recovery of groundwater levels occurs after around 150 years, with further slow elevation of groundwater due to mounding effects until stabilisation over approximately the next 100 years (refer Figure 10-68).

A comparison of groundwater head between pre-mining and after full recovery is shown in Figure 10-64 for the Cainozoic deposits/regolith (Layers 2 and 3), further demonstrating that in the long-term levels will substantially recover and re-establish gradients generally equivalent to the pre-mining heads and gradients.



After 3 years of mining

After 10 years of mining



At end of mining

Maximum drawdown (all years)

Mining Leases: CQC 2020 | Infrastructure: CQC 2020 | Watercourses: DNRME 2018 | Roads: DNRME 2018
Groundwater Drawdown: HA 2020

A4 Scale 1:145,000
GDA 1994 MGA Zone 55

CQCSCP-07-Fig10-49-DrawdownWT-200916, 17 Sep 2020

Figure 10-60: Water table drawdown contours

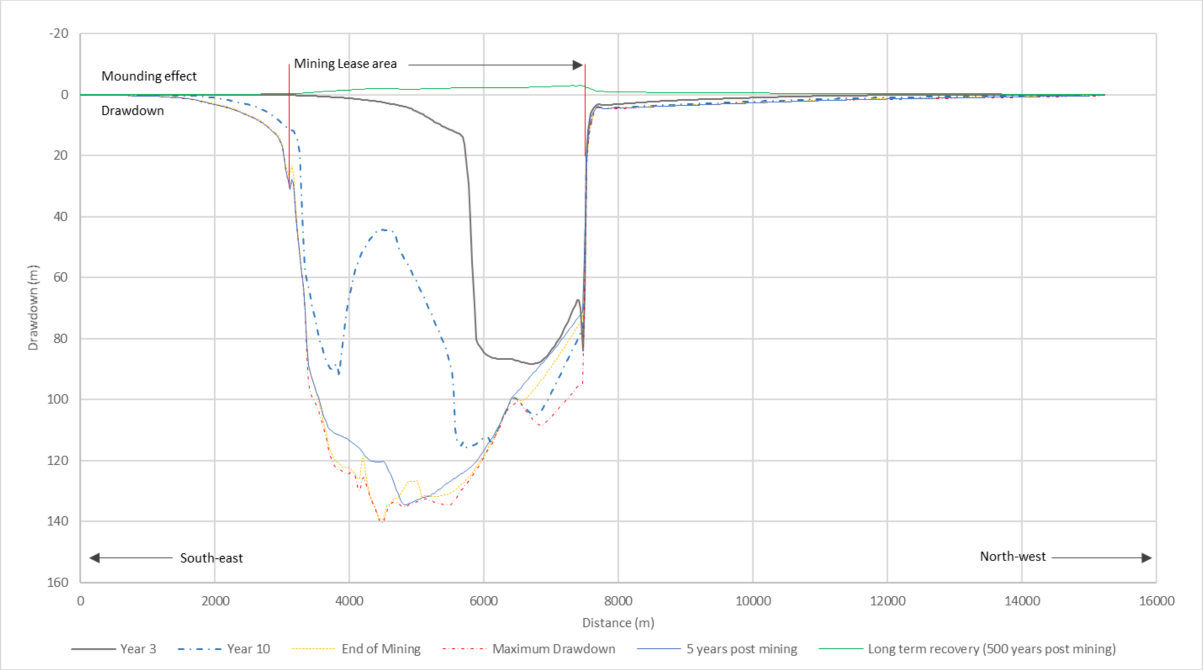


Figure 10-61: Water table drawdown – cross section XS-1

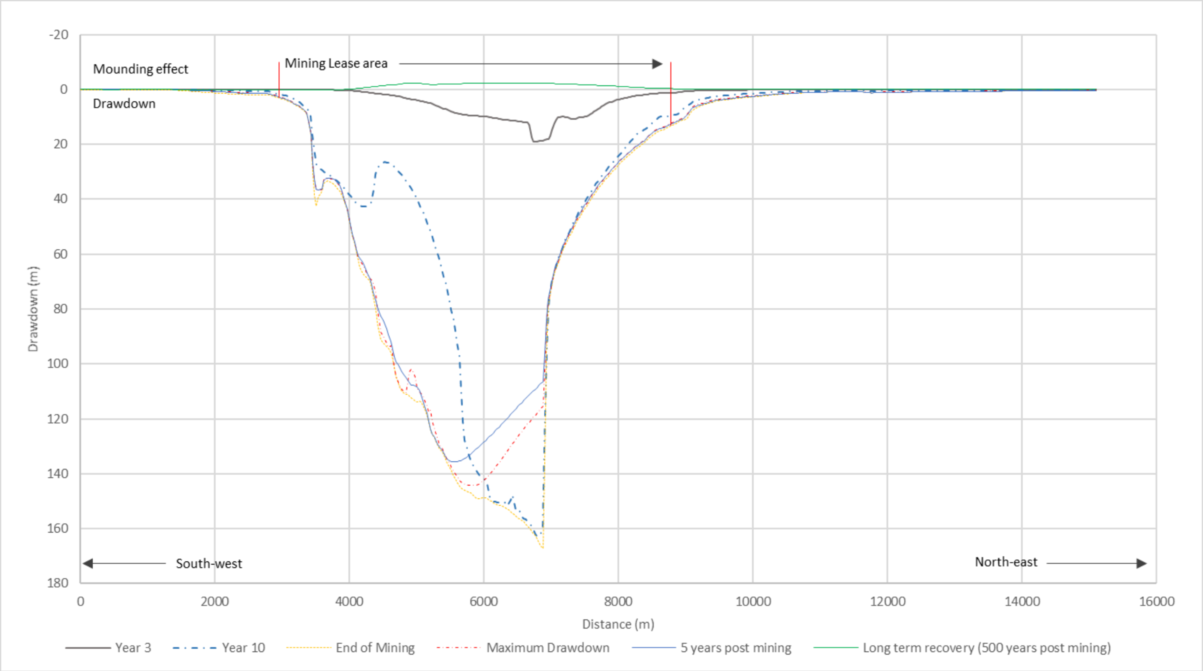
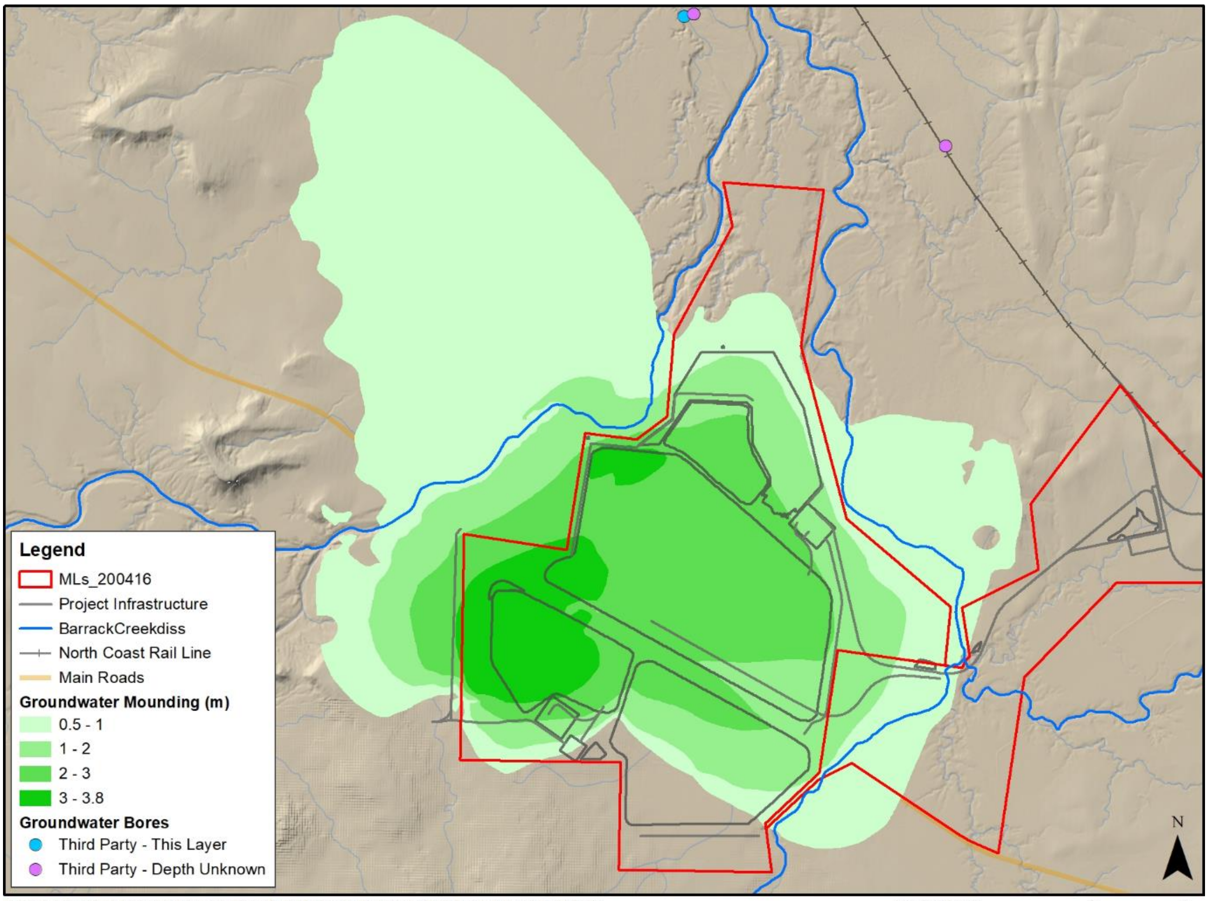


Figure 10-62: Water table drawdown – cross section XS-2

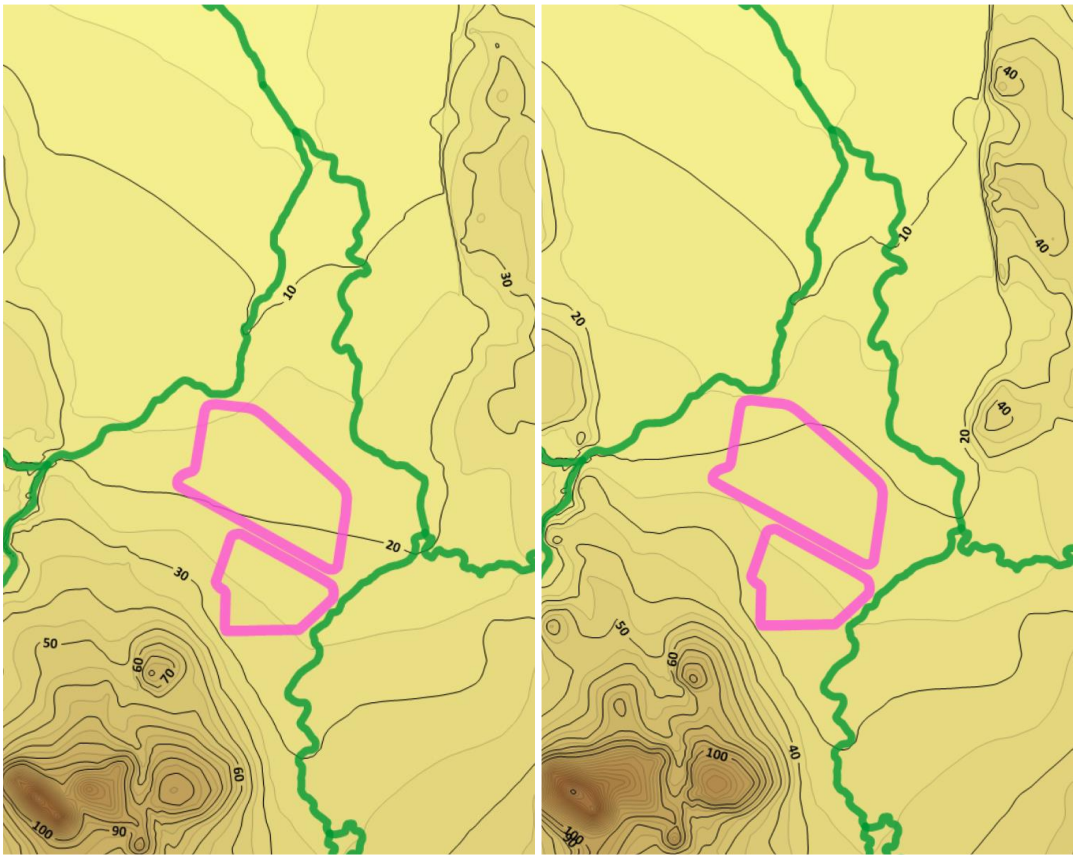


Mining Leases: CQC 2020 | Watercourses: DNRME 2018 | Roads: DNRME 2018 | Groundwater levels: HA 2020

A4 Scale 1:80,000
GDA 1994 MGA Zone 55

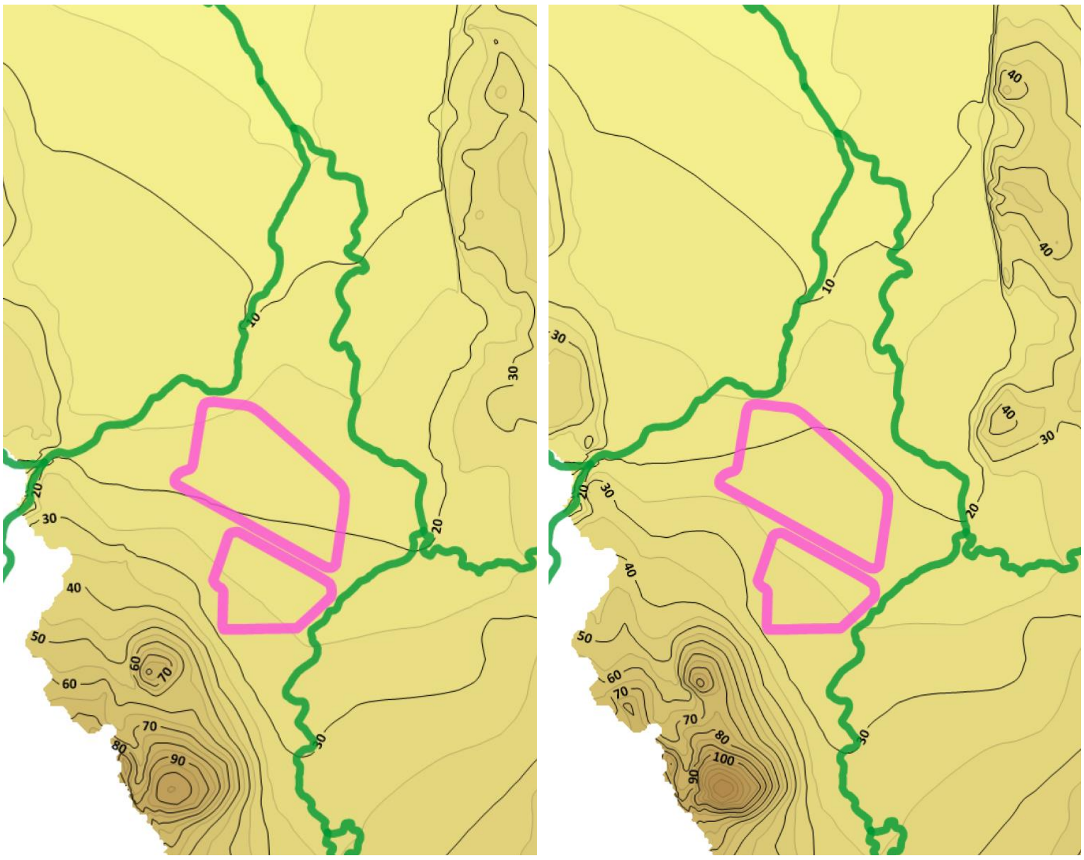
0 1 km

Figure 10-63: Mounding of groundwater at full recovery



Layer 2 - Pre-mining (end of calibration)

Layer 2 - End of recovery period



Layer 3 - Pre-mining (end of calibration)

Layer 3 - End of recovery period

Figure 10-64: Model predicted head plots - Cainozoic deposits / regolith (Layers 2 and 3)

10.5.1.2.2 Drawdown Beneath Creeks

Figure 10-65 to Figure 10-67 show the predicted water table drawdown along the stream centrelines of Tooloombah, Deep and Barrack Creeks. These show that the maximum drawdown within the surficial alluvial layers beneath the creeks are expected to reach:

- Tooloombah Creek - a maximum of about 4.7 m, exceeding 4.0 m for approximately 700 m
- Deep Creek - a maximum of about 60 m, exceeding 50 m for approximately 230 m
- Barrack Creek - a maximum of about 12.6 m, exceeding 10 m for approximately 170 m.

The data shows an early impact at Tooloombah Creek as mining is initiated in the north-west corner of Open Cut 2 (to about 3 m maximum drawdown), then deepening to maximum extent (4.7 m) as mining progresses and dewatering continues. Long term recovery is seen with a slight mounding effect as described in Section 10.5.1.2.1. Drawdown effects of more than 0.5 m can be seen along a 6.5 km reach of the creek (4.7 km in Year 3, 5.9 km in Year 10).

The effects at Deep Creek are felt a little after Tooloombah Creek, as mining moves south-east in Open Cut 2, and opens up in Open Cut 1. Again, long term recovery is seen with a slight mounding effect under the creek. Drawdown effects of more than 0.5 m can be seen along a 13.7 km reach of the creek (4.0 km in Year 3, 12.3 km in Year 10).

Barrack Creek shows the same pattern as Deep Creek, with drawdown effects extending up to 1.9 km (above 0.5 m drawdown), or 1.7 km in Year 10 (all of the creek is below 0.5 m drawdown in Year 3).

The Styx River, being below the last section of Tooloombah Creek shown above (i.e. to the right of the lines shown in Figure 10-65), does not experience any drawdown or mounding effects.

The effects of water table drawdown and consequential predicted worst-case effects on baseflow in the creeks is summarised in Figure 10-68, including the long-term recovery of these systems after mining[6]. This shows recovery to pre-mining levels over around 150 years, with the mounding effect described earlier gradually increasing groundwater levels over a further 100 years. The model predicted effect of this mounding is a long term increase in baseflow (or reduction in leakage) in Tooloombah Creek in the order of 0.4 L/s per km, and in the order of 0.07 L/s per km for Deep Creek.

Note that the effects of drawdown beneath these creek systems depends on whether connectivity exists between the aquifer and the waterway – i.e. whether a saturated zone (connection) or unsaturated zone (disconnection) exists between the aquifer and the creek. This is explored further in Chapter 9 – Surface Water.

Uncertainty Analysis, including parameter sensitivity analysis (Section 8.11 and Attachment 11 of the Groundwater Model and Assessment Report in Appendix A6b), suggest that drawdown could elongate further along the strike of the coal outcrop, however this is localised and not expected to encroach to any appreciable extent to the downstream reach of Tooloombah Creek (at the Deep Creek confluence) nor the Styx River.

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[6] note this assumes full connectivity and 1m stage height at all times in the creek which may overestimate this value

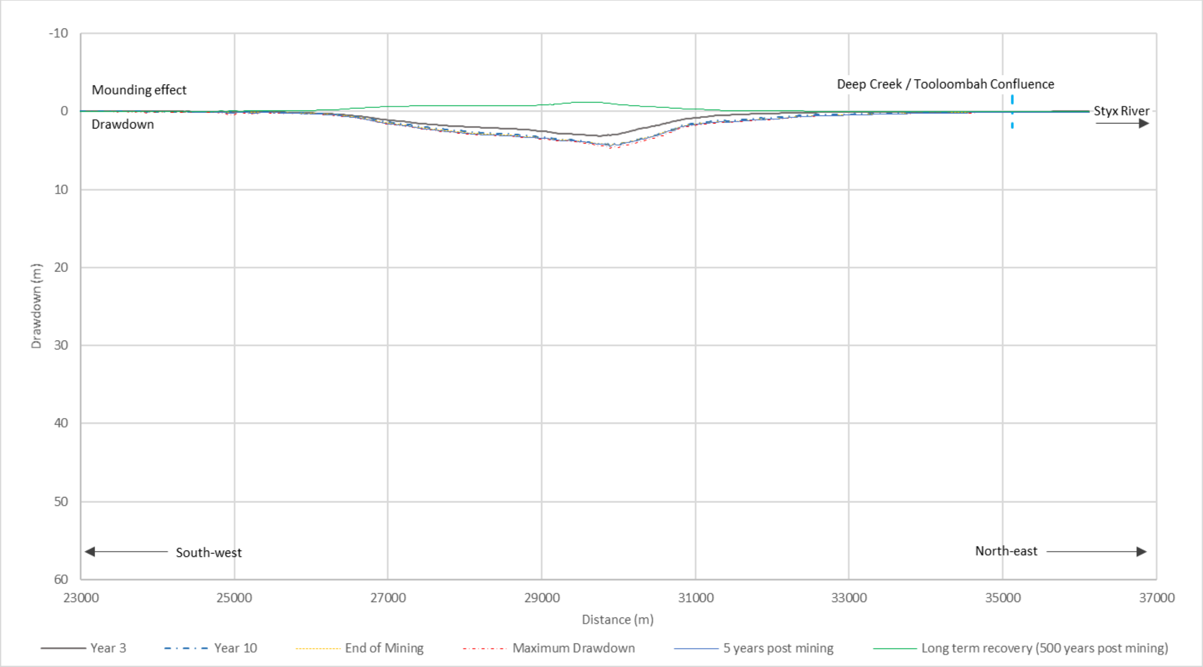


Figure 10-65: Water table drawdown – along Tooloombah Creek

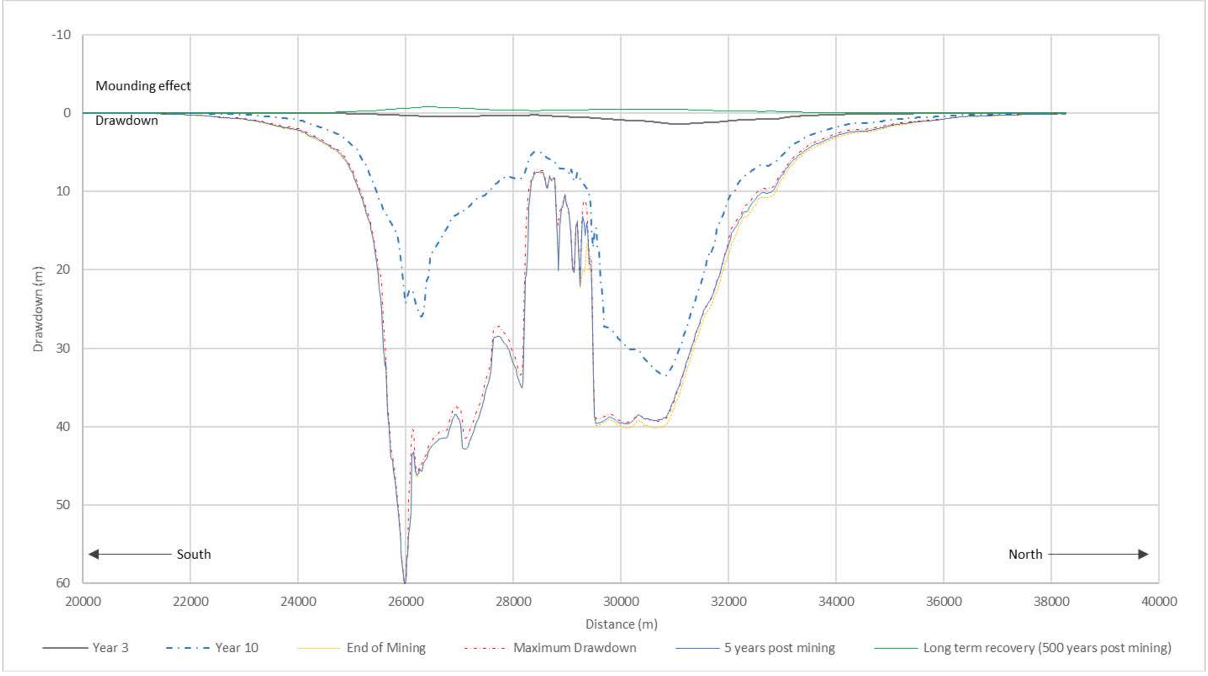


Figure 10-66: Water table drawdown – along Deep Creek

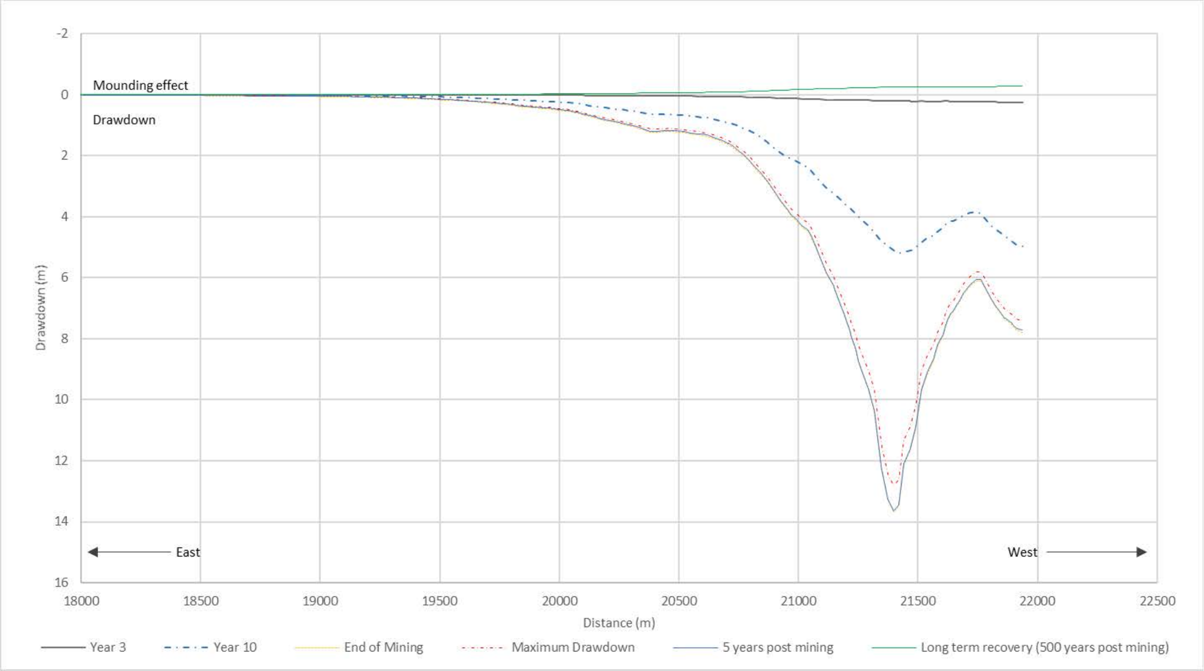
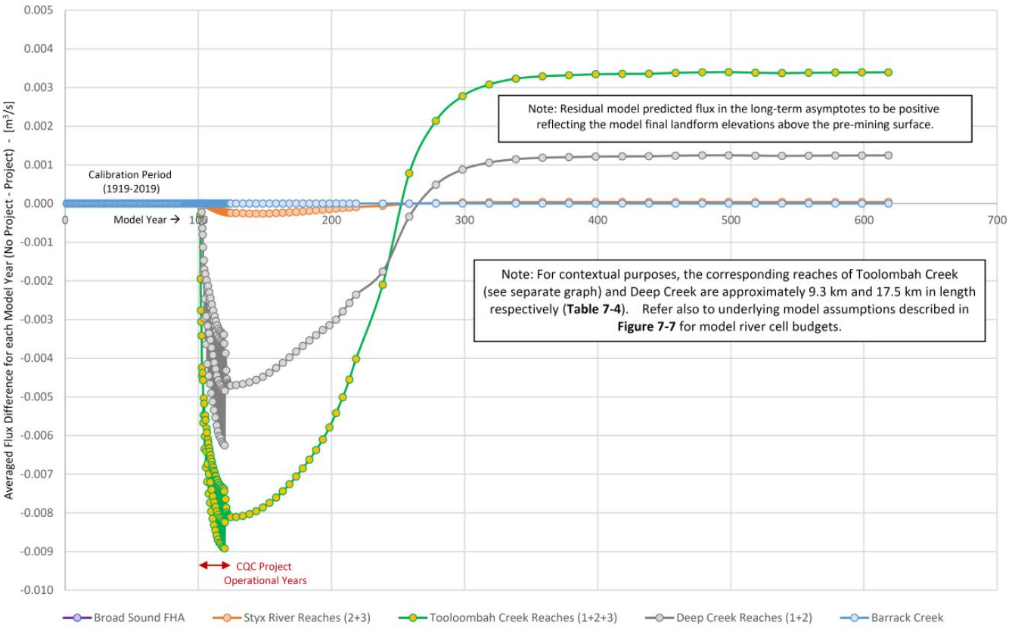


Figure 10-67: Water table drawdown – along Barrack Creek (to junction with Deep Creek)



Note: Residual model predicted flux in the long-term asymptotes to be positive reflecting the model final landform elevations above the pre-mining surface.

Note: For contextual purposes, the corresponding reaches of Toolombah Creek (see separate graph) and Deep Creek are approximately 9.3 km and 17.5 km in length respectively (**Table 7-4**). Refer also to underlying model assumptions described in **Figure 7-7** for model river cell budgets.

Figure 10-68: Model predicted flux (changes to baseflow / enhanced leakage) during and post-mining

10.5.1.2.3 Styx Coal Measures

The modelled drawdown in the Styx Coal Measures, as shown by the predicted drawdown plots in Figure 10-69 for Layer 8, show that the maximum groundwater level drawdown during the first three years are largely contained in the north-western area of Open Cut 2. As mining progresses, the extent of drawdown also extends, moving further to the north and south, extending to a maximum of about 5 km to the north and 2 km to the south.

Drawdown propagation in the overburden (Layer 5) and underburden (Layer 11) of the Styx Coal Measures beyond the open cut extent toward the north-east and west respectively is predicted to be less, which correspondingly reduces indirect groundwater take in the surficial geology (refer to Attachment 14 in the Groundwater Model and Assessment Report in Appendix A6b).

Figure 10-70 shows the post-mining recovery results in the Styx Coal Measures (Layers 5 and 8), showing groundwater heads in the long-term will substantially recover and re-establish gradients generally equivalent to the pre-mining heads and gradients (Attachment 13 to the Groundwater Model and Assessment Report in Appendix A6b).

In addition to the post-mine closure equilibrium groundwater levels, comparisons of head gradients in the Cainozoic deposits/regolith (Layer 2) and Layer 8 (Styx Coal Measures) are presented in Attachment 13 to the Groundwater Model and Assessment Report in Appendix A6b, in Figures 8-6a-f. These show that the regional groundwater flow directions toward the coast are maintained, and that the changes to the head gradients by the Project are localised and temporal.

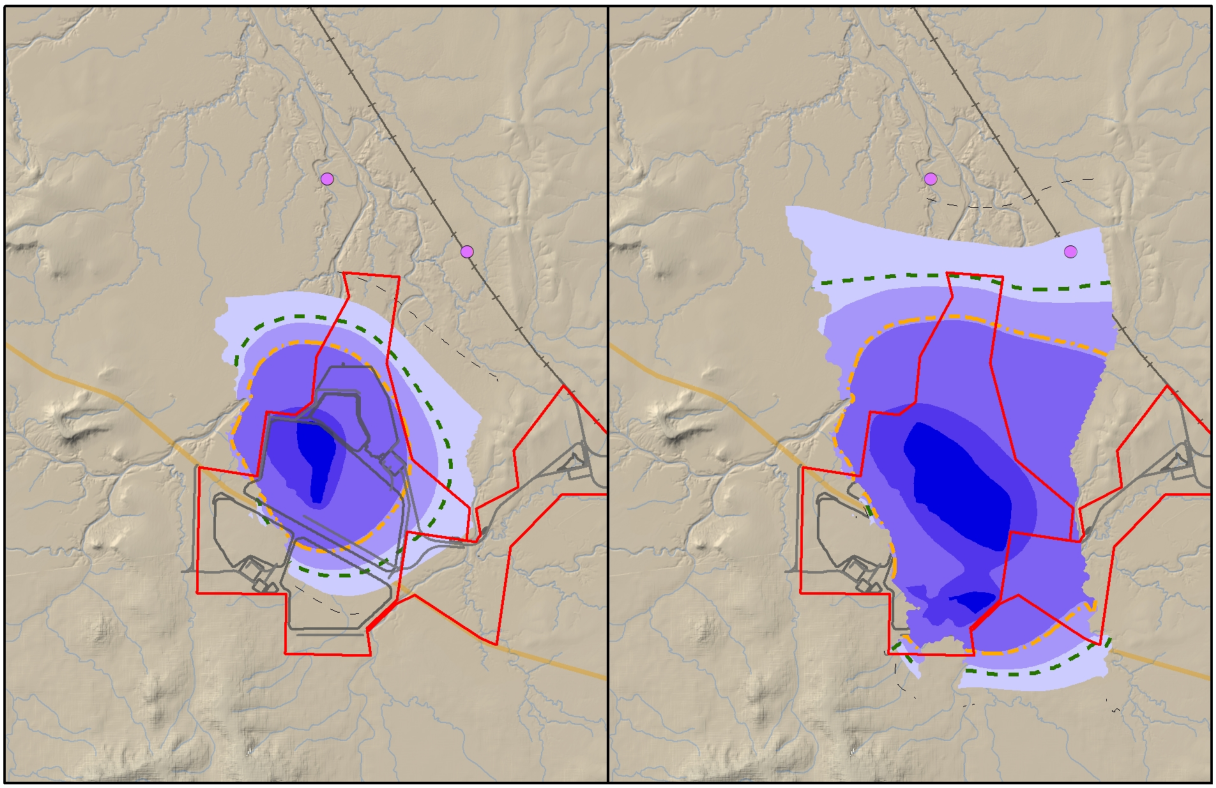
10.5.1.2.4 Summary

The predictions demonstrate substantial drawdown within the proposed open cut extent, down to the depth of the pit. Results indicated that three years after commencement of mining the drawdown was largely contained within the Styx Coal Measures (i.e. open cut with a lesser degree of observed drawdown beyond the open cut). After 10 years of mining the drawdown impacts extend towards the north, but are unlikely to extend to the downstream reach of the Tooloombah Creek or Styx River. At the end of mining there is some temporal drawdown predicted in the Cainozoic Deposits and the Back Creek Group but predicted to gradually recover to pre mining levels after about 150 years, with a further slight mounding effect occurring over the 100 years after that.

In terms of nearby sensitive receivers:

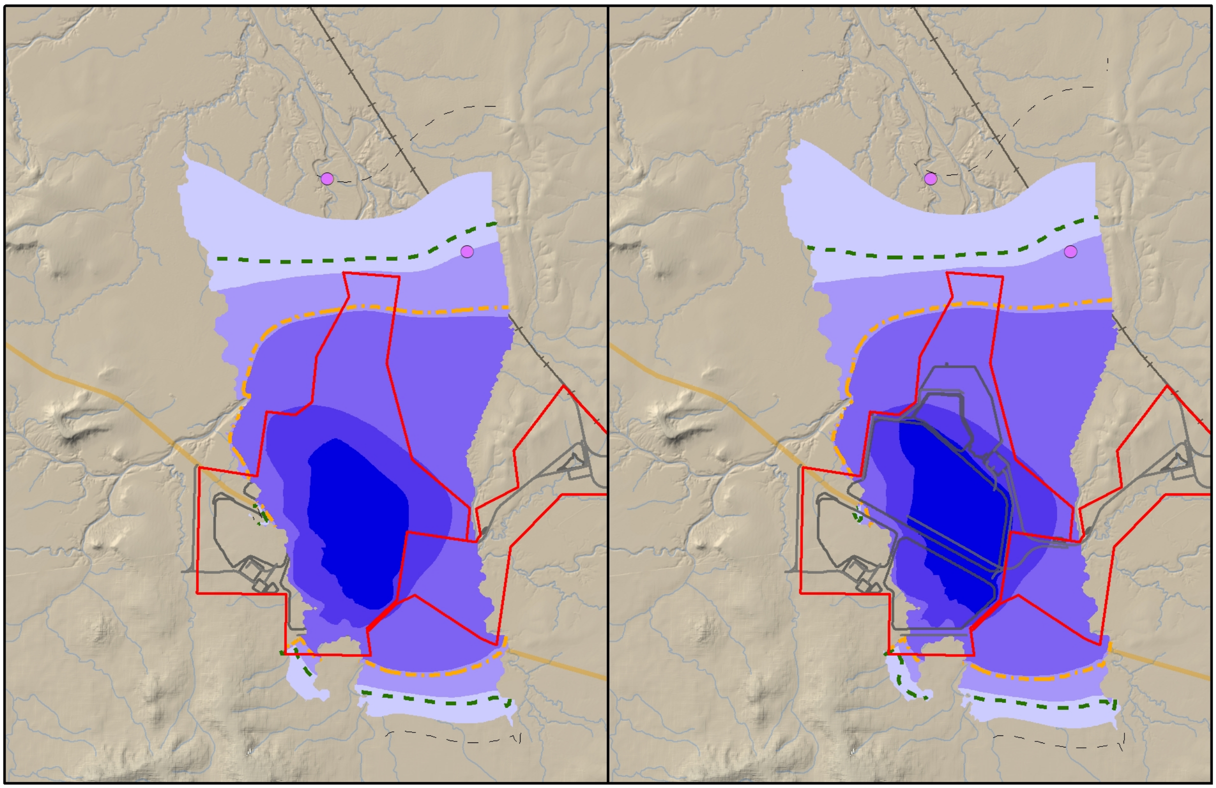
- There would be no drawdown impacts at the location of the Broad Sound declared FHA.
- Given the above, there would be no impacts to areas considered part of the Great Barrier Reef Marine Park (GBRMPA).
- There would be no drawdown impacts at the bores where stygofauna have been identified for the Project, other than at the STX093 drillhole site, which is situated on the edge of Open Cut 1 near to Deep Creek. Impacts to stygofauna are discussed further in Chapter 15 - Aquatic and Marine Ecology.

Impacts to surface water resources are discussed in Section 10.5.4.



After 3 years of mining

After 10 years of mining



At end of mining

Maximum drawdown (all years)

Legend

🟥 Mining Lease Boundaries
— Project Infrastructure
— Watercourses
—+— North Coast Rail Line
— Main Roads

Drawdown Contours (m)
– – 0.5
– – 2
– – 5

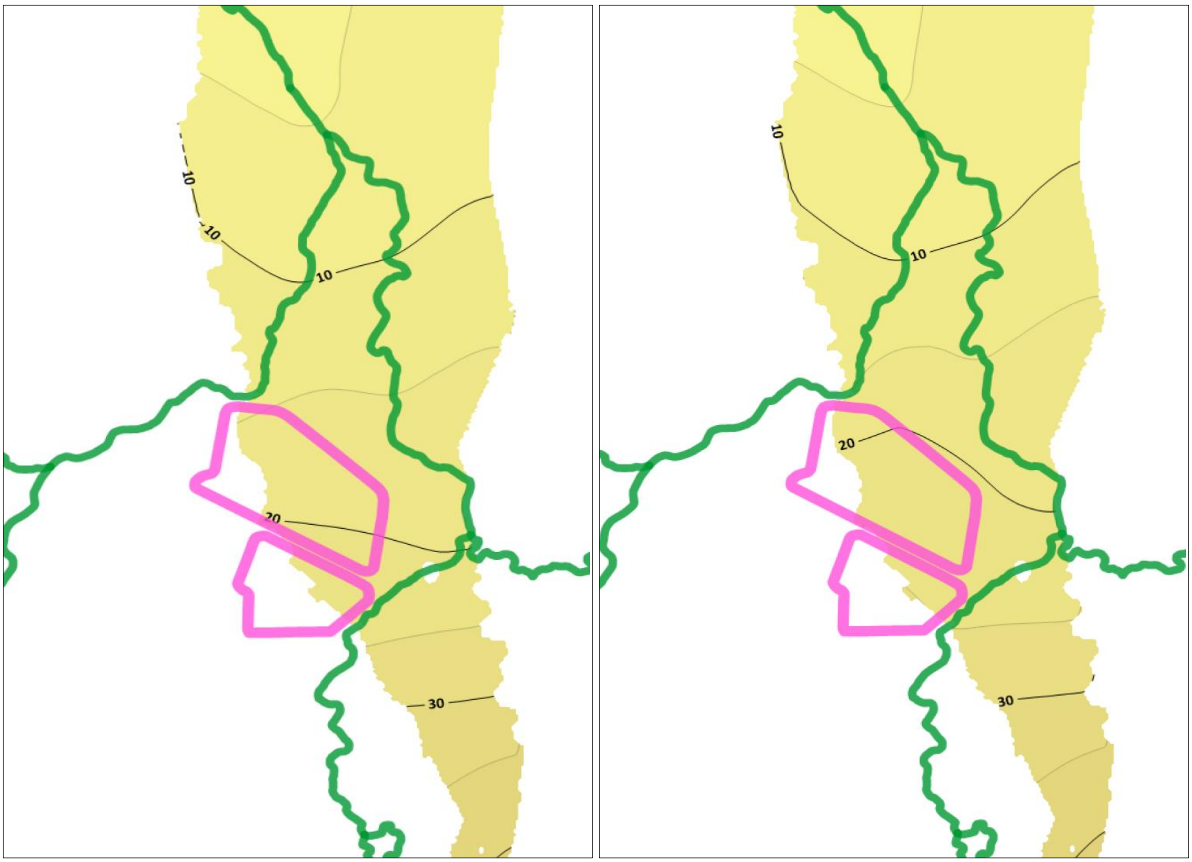
Drawdown (m)
▨ 1 - 2
▨ 2 - 5
▨ 5 - 50
▨ 50 - 100
▨ 100 - 170

Groundwater Bores
● Third Party - Depth Unknown

Mining Leases: CQC 2020 | Infrastructure: CQC 2020 | Watercourses: DNRME 2018 | Roads: DNRME 2018
Groundwater Drawdown: HA 2020

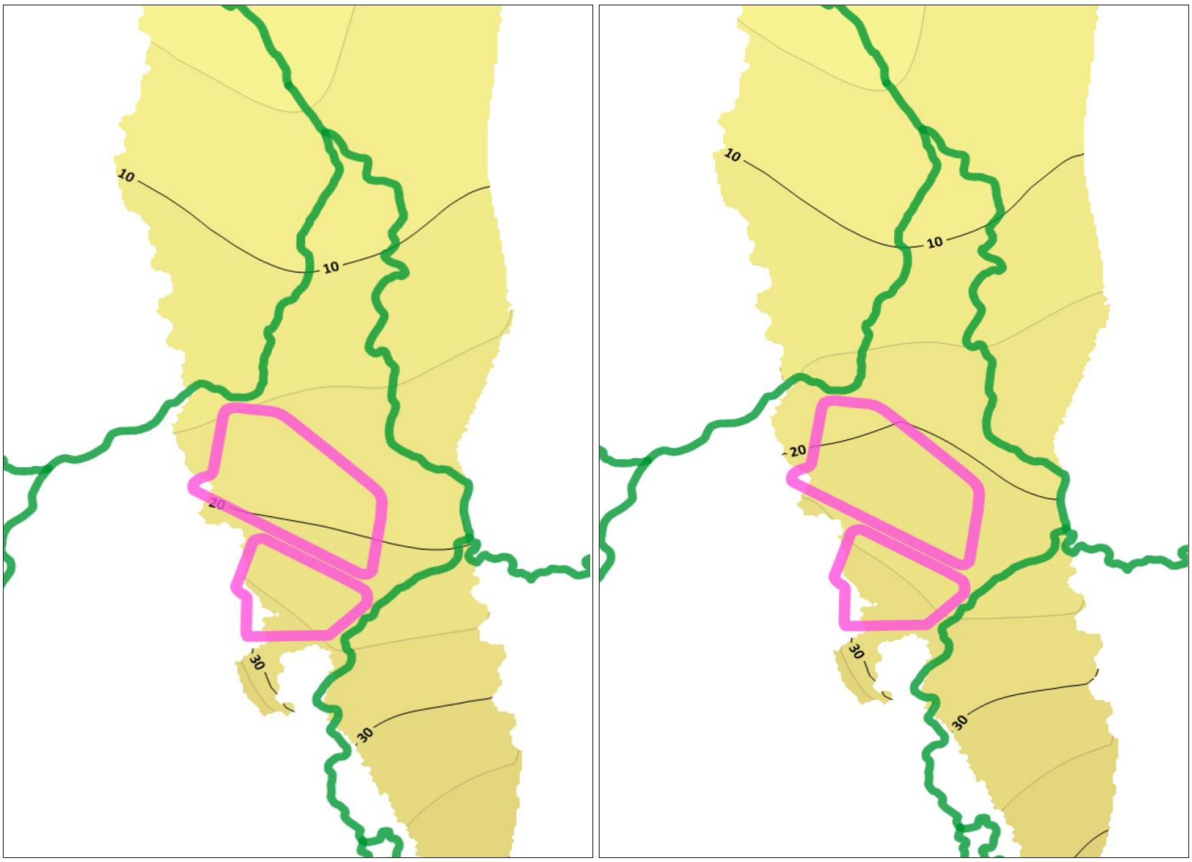
A4 Scale 1:145,000
GDA 1994 MGA Zone 55
0 1.25 2.5 km
N
CQCSCP-07-Fig10-50-DrawdownLyr8-200914, 16 Sep 2020

Figure 10-69: Drawdown contours in Styx Coal Measures (layer 8)



Layer 5 - Pre-mining (end of calibration)

Layer 5 - End of recovery period



Layer 8 - Pre-mining (end of calibration)

Layer 8 - End of recovery period

Figure 10-70: Model predicted head plots - Styx Coal Measures (Layers 5 and 8)

10.5.1.3 Impacts to Bores

With reference to Figure 10-60 and Figure 10-69, drawdown impacts to private landholder bores identified one bore within the predicted 5m drawdown trigger (RN 97864 on the south-western corner of the lease). This is located within the Back Creek Group, and therefore the 5 m trigger level defined in the *Water Act 2000* for consolidated aquifers applies.

Another bore (Og1) is located between the 2 m and 5 m drawdown trigger, however the depth is not known, so may be triggered only if it is within the top several layers. However, this bore is not anticipated to be impacted within the first 10 years of mining. Further investigation will be required if this bore is still in use.

Drawdown impacts to monitoring bores and Project drillholes are summarised in Figure 10-71. As can be seen, substantial drawdown occurs within the proposed open cut extent, and the surrounding network of groundwater monitoring bores provide varying levels of change to allow the development of appropriate triggers for investigation.

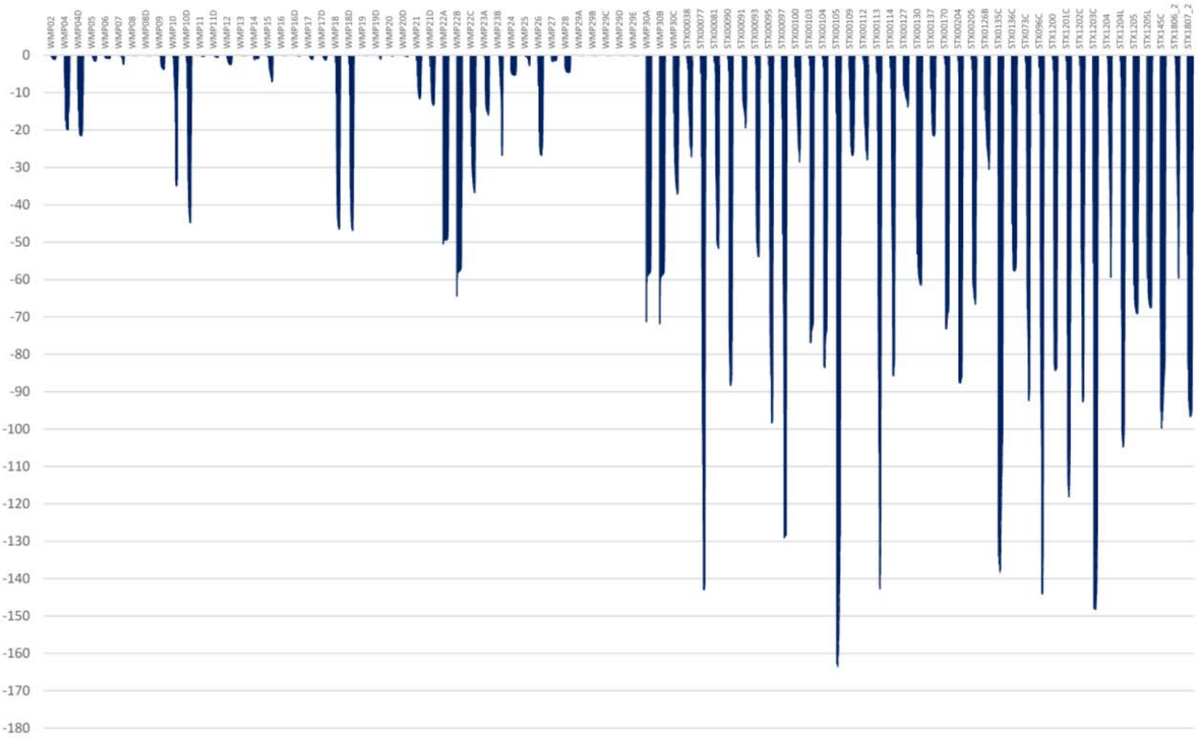


Figure 10-71: Model predicted groundwater drawdown – groundwater monitoring bores and exploration drill holes (from HA 2020)

10.5.1.4 Changes to Aquifer Storage and Inter-HSU Transfer

A change in hydraulic properties (increase) will occur across the open cut mining footprint where higher hydraulic conductivity waste rock infills the excavations, as well as the out-of-pit emplacements during mining. Therefore, recharge from rainfall is expected to be higher in these areas and there would be associated reductions in hydraulic gradients, causing subtle mounding in the final out-of-pit emplacement landform.

Excavation of the alluvium within the open pit extent during mining will reduce rainfall recharge temporarily but will resume upon backfilling. The active open cut will act as a groundwater sink and cause a temporary change in groundwater flow direction until the completion of mining and the recovery of groundwater levels. Some groundwater drawdown is expected within the Cainozoic sediments in the vicinity of the open cut. Drawdown is expected to be localised in this region and predicted to gradually recover at post-mining.

As mining progresses, an increase in natural leakage of groundwater from the alluvium/regolith to the underlying Early Cretaceous/Permian rock is to be expected. The removal of alluvium/ regolith within the pit extent during mining will also reduce rainfall recharge temporarily but this will be restored upon backfilling.

All voids will be back-filled and groundwater levels will substantially recover and re-establish hydraulic gradients in the Cainozoic deposits/regolith generally equivalent to pre-mining levels. Some localised mounding is predicted to occur at the elevated final landform surfaces, and the resulting net gain effects evident in the predicted changes in baseflow and/or reduced leakage in Tooloombah Creek and Deep Creek after approximately 150 years.

10.5.1.5 Aquifer Disruption

The aquifers potentially impacted by the project are the coal seam aquifers (see Section 10.5.1.2.3) and the alluvial aquifers (see Section 10.5.1.2.1). Other components of the groundwater system, including the basement rocks, will not be intercepted and will be minimally impacted.

The rehabilitation of the mine area by backfilling of mine pits will enhance the hydraulic properties of the aquifers intersected by mining. However, given that the pits will be completely filled following mine closure, and the predictions provided in the above sections showing the system will recover in the long term, any disruption to the passage of water through these aquifers will disappear as water levels and pressures recover and stabilise.

10.5.2 Groundwater quality

Potential impacts to groundwater from the Project can be discussed in terms of the following major pathways:

- spills and leaks
- seepage from waste rock and rejects
- seepage from mine affected water dams and
- change in linkages between aquifers, and movement of poor quality groundwater into good quality aquifers.

These are discussed further below.

Spills and Leaks

The transport, handling, storage and (immediate) clean-up of all hydrocarbons and chemicals will be undertaken in accordance with industry accepted Australian Standards, as specified in the Project Environmental Management Plan (EMP) (see Appendix 12) which reduces the risk for groundwater contamination to occur. In particular, storage of fuels, chemicals and liquid waste will be undertaken in accordance with AS1940 - The storage and handling of flammable and combustible liquids. This includes storing these materials within roofed, bunded areas with a storage capacity of 100% of the largest vessel and 10% of the second largest vessel. The bunding will have floors and walls that are lined with an impermeable material to prevent leaching.

Further to this, should accidental spills or leaks occur, there is limited potential for groundwater contamination as a result of seepage of hydrocarbons and other chemical contamination, due to groundwater level depth typically being greater than 10mbgl. Nevertheless, spill control materials including booms and absorbent materials will be onsite at all times and spills cleaned up as soon as possible.

Overall, the risk to groundwater from spills and leaks is considered minimal with standard containment and incident response measures in place.

Seepage from Waste Rock and Rejects

Geochemical characterisation presented in Appendix A3b (and Chapter 8 – Waste Rock and Rejects) concluded that the overwhelming majority of the waste rock and potential coal reject materials have a very low risk of acid generation, with runoff being alkaline and having a low level of salinity. Dissolved metal/metalloid concentrations are expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources in site storages.

As the advancing open cut areas will act as groundwater sinks during mining, this would also act to intercept any groundwater affected by waste rock leachate, and as such there would be no deleterious effect in terms of water quality from waste rock and rejects on groundwater.

The quantity, quality, location, duration and timing of the potential and/or proposed surface water releases are provided by WRM Water and Environment (2020 – Appendix 5a). The Mineral Waste Management Plan (see Draft EMP – Appendix 12) also outlines spoil and coal reject disposal management requirements for the Project.

Post-mining, when the effects of dewatering cease and local mounding effects and stabilisation occurs, water would flow through the remaining elevated landforms and backfilled pits. However, as noted above, this water would still be unlikely to be contaminated and given the material is native rock, would not be anticipated to result in long term changes to groundwater quality.

Further information on the management, storage and encapsulation of waste rock and rejects is provided in Chapter 8 - Waste Rock and Rejects.

Seepage from Mine Water Dams

Mine water dams will contain dewatered groundwater from the pits, runoff from ROM and coal product stockpiles, and other runoff across the site. Salinity within Dam 1 is predicted to vary between 5,000 to 10,000 µS/cm in the first half of the Project, declining to less than 5,000 µS/cm in the second half. Given the low rate of seepage anticipated, and the salinity of groundwater, seepage from mine water dams is not anticipated to represent an impact to groundwater quality.

Mobilisation of Groundwater

As noted in Section 10.5.1.4, changes to aquifer storage and inter-HSU properties are likely to be minimal, but enhanced leakage from the overlying alluvium to the underlying coal measures could be expected to increase. This would have the effect of less saline water moving into areas of more saline groundwater, rather than the reverse. No increase in salinity is anticipated in any of the aquifers as a result of mining.

Overall, no reduction in groundwater quality as a result of mining is therefore expected to occur.

10.5.3 Seawater Interface

Section 10.3.6.7 described the closest extent of the fresh-seawater interface as being well beyond the influence of the Project, based on both theoretical and observational data.

The groundwater modelling has provided (in Figure 8-6, Attachment 3, in the SEISv3 Appendix A6a) groundwater flow directions in the Cainozoic/regolith and Styx Coal Measures layers for pre-mining, during operations, and post mining, showing that Project influence on groundwater flow directions diminishes to effectively nil at the Tooloombah – Deep Creek confluence, which is only 2.2km downstream of the Project, where the theoretical seawater interface surface would be below -280 mAHD, which is well beneath the predicted extent of drawdown. At the Ogmore bridge and WMP29 bore locations, both well outside the drawdown extent, and approximately 4km downstream of the Project, the theoretical fresh-seawater interface is still at least -40 to -80 mAHD. Any fresh-seawater interface at a shallower depth closer to the coast is well beyond the influence of the drawdown zone and any influence of the Project on groundwater flow direction.

The assessment of cumulative impacts, including impacts relating to the historic mine workings at Ogmore and Bowman (refer to the Groundwater Model and Assessment Report in Appendix A6b), concluded that the predictive cumulative modelling results demonstrate there is unlikely to be any superposition effects, thus, the predicted cumulative drawdown impacts at private landholder bores, springs, wetlands, groundwater dependent ecosystems, Broad Sound Declared FHA and on recorded groundwater fauna locations / stygofauna habitat and riparian vegetation are equivalent to the Project alone.

Therefore, there is not expected to be any discernible change to the location of the fresh-seawater interface.

10.5.4 Surface Water – Groundwater Interaction

Model predicted baseflow changes and/or enhanced leakage as a result of the Project were determined by calculating the averaged differences in flux in model cells along specific watercourse reaches (refer to Figure 10-68).

Changes in baseflow conditions were predicted to be less than 0.009 m^3/s for Tooloombah Creek, in the reach between the confluence with Mamelon Creek upstream of the Project, and with Deep Creek downstream of the Project, and the predicted change relates to a 9.3 km section of the creek, equating to ~1 L/s per km.

Changes in baseflow conditions within Deep Creek were predicted to be approximately 0.005 – 0.006 m^3/s, in the reach between the confluence with Brussels Creek upstream of the Project, and where Deep Creek joins into Tooloombah Creek downstream of the Project. The predicted change relates to a 17.5 km section of the creek, equating to ~0.3 L/s per km.

However, these predictions can be considered a worst-case prediction, unlikely to be reached in reality, since where drawdown occurs within losing zones beneath the unsaturated zones of the watercourse, the additional model predicted flux (i.e. leakage) from the watercourse would not eventuate. As described in Section 10.3.7, water tables appear to fall below the creek bed during the dry season, and direct baseflow contributions from the water table aquifer are not considered to be the source of baseflow to creeks (instead bank storage return flow).

For the Styx River, predicted baseflow changes were less than 0.0003 m^3/s. When considered in context with the large tidal range experienced within the Styx River, as well as influences from other contributing catchments, including Montrose and Granite Creeks, these changes are considered negligible.

As the invert of other drainage features across ML 80187 are generally not as incised and deep-cut as the watercourses of Tooloombah Creek and Deep Creek, and groundwater levels in lower lying topographic areas and drainages are typically greater than 8-10 m, model predicted changes in baseflow and/or enhanced leakage in the local surface water drainages across the tenement are considered to be negligible. There may be some locations where an inflow sourced from the water table or outcropping coal measures into the creek does occur, and one such pool (the Tooloombah Creek stream gauge) has been identified, although separated upstream and downstream by other pools not evidencing this reliance. Further detail including assessment of impacts of reduced pool persistence is provided in Chapter 9 – Surface Water.

No groundwater springs were identified in the Project area, and so no impacts identified. An assessment of impacts to other groundwater dependent ecosystems (GDEs) including stygofauna, wetlands, aquatic habitat and riparian zones are addressed in Chapter 15 - Aquatic and Marine Ecology and Chapter 14 - Terrestrial Ecology.

10.5.5 Assessment of Uncertainty

The numerical groundwater modelling incorporates a detailed uncertainty analysis, and a number of sensitivity runs to understand potential variation due to uncertainty in the model, and in parameter estimations. These are discussed below.

Tidal Boundary Condition Range (incorporating Sea Level Rise Predictions)

For the purposes of freshwater-seawater interface analysis, the predictive model was re-run for two scenarios to present the maximum predicted groundwater drawdown differences in Layers 2 (Cainozoic deposits/regolith) and 8 (Styx Coal Measures) with the applied fixed head boundary condition at the Styx River mouth and along the mapped estuarine reach of the Styx River (i.e. to the railway crossing):

- reduced from 3.5 mAHD to 2 mAHD and
- increased from 3.5 mAHD to 4.5 mAHD.

The bounds were determined based on the review of tidal datasets and analysis as well as consideration of sea level rise projections, based on a projected 0.8 m sea level rise by 2100 adopted by the Queensland Government from IPCC (2014). This analysis found that the differences in maximum predicted groundwater drawdown in Layers 2 and 8 are negligible despite there being a 2.5 m differential in the fixed head boundary condition.

Rainfall (incorporating Climate Change Scenario Range and Adopted Alluvium / Regolith Recharge)

For the purposes of climate change scenario analysis, the predictive model was re-run for two scenarios to present the average groundwater take/inflow changes if rainfall recharge totals applied across the model domain is:

- reduced by 20% and
- increased by 20%.

The bounds were determined based on climate change considerations from the RCP8.5[7] scenario for 2100. These broad bounds were considered appropriate when also noting the compounding maximum evapotranspiration rates and extinction depths applied.

Geological Structure (Fault) Zone of Hydraulic Conductivity [Enhanced or Reduced]

For the purposes of the geological structure (fault) zone analysis, the predictive model was re-run for one enhanced scenario to present the maximum predicted groundwater drawdown differences in Layers 2 (Cainozoic deposits/regolith) and 8 (Styx Coal Measures) with a higher (factor x 10) vertical conductivity. This found that the differences in maximum predicted groundwater drawdown in Layer 2 is very localised whilst Layer 8 is negligible.

Given the evidence of boundary effects already at the Styx Coal Measures and Permian Measures interface, and very localised changes based on the increased vertical conductivity, a reduced vertical hydraulic conductivity (i.e. less permeable barrier) scenario was not considered any further.

Maximum ET Rate and Extinction Depths

The maximum evapotranspiration extinction depth was applied to the model domain by surface geology (maximum to the Cainozoic sediments). This was reduced across the model domain so that the maximum depth was applied only where moderate and high potential GDEs had been mapped, and 3 m everywhere else within the model domain (most of which areas had groundwater at >10 m – i.e. below the maximum possible extinction depth). The results found little to no consequences on drawdown extents and key metrics.

Tooloombah Creek Fixed Stage / Water Depth ‘Boundary Condition’

As described in Section 10.2.4, each of the creeks was modelled with a set stage height, with the Tooloombah Creek section adjacent to the Project adopting a constant 1 m depth of water. This has the effect (to some extent) of a constant boundary condition and constant supply of water to the model. The effect of this feature was assessed by changing the stage height to 0 m, thereby removing this boundary effect.

The change had the effect of changing the peak mine inflow from 432 ML/a to 424 ML/a, and the peak baseflow/leakage from ~1L/s per km, to ~0.7L/s per km. While there is a notable change, in reality due to the persistent pools along Tooloombah Creek in this reach, the actual stage height would be somewhere between 0 - 1 m, and so this is unlikely to represent a significant factor.

Reduced and Enhanced River Bed Conductance

To investigate the effect of river bed conductance, both a reduced and enhanced river bed conductance scenario (with lower and higher hydraulic conductivity values applied respectively, i.e. 0.002 m/day and 0.05 m/day) was applied along Tooloombah Creek Reach 2 and Deep Creek Reach 1.

The largely unchanged predictions for annual mine inflow and peak inflow (Appendix A6b) demonstrate that direct inflows from Tooloombah Creek in the long term to the open cut pit is unlikely. This supports the concept of indirect (i.e. piston-like) groundwater movement effects, as the predicted inflows to the open cut drains still occur from water stored in the immediately surrounding rocks.

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[7] Representative Concentration Pathway (RCP) 8.5 represents a warming scenario used by climate change modellers with little curbing of emissions – i.e. the high emissions scenario - leading to radiative forcing levels of >8.5 W/m^2 by the end of the century (IPCC 2014)

The only differences occur during the first two years of the Project, when the open cut pit is nearest Tooloombah Creek, and are only 3% to 6% different for the base case. As expected, with the application of a lower river bed conductance in the model for the sensitivity scenario, peak baseflow/leakage changes are much less.

10.5.6 Impacts to Environmental Values

With reference to the potential impacts and impact assessment described in Sections 10.4 and 10.5 the potential impacts on the EVs identified in Section 10.3.6.8 are considered to be as follows:

Irrigation supply

Predicted water losses to water supplies from Tooloombah Creek and Deep Creek as a consequence of the indirect groundwater inflows are considered to be negligible.

Farm supply / stock water

Only a single bore (RN 97864) is predicted to be impacted beyond the 5m significant drawdown threshold and no appreciable change in groundwater salinity is expected as a consequence of mining. There may be an impact on another bore (Og1), and the depth of this bore would need to be confirmed to determine that impact.

Human consumption / drinking water

Recognising the generally poor quality of the groundwater in the vicinity of the project and its general low suitability for human consumption, no potential impact is expected as a result of mining.

Industrial use

Groundwaters are anticipated to be of relatively poor water quality, however they would be suitable for industrial use and therefore will be preferentially used as part of the mine site water balance.

Aquatic Ecosystems

No direct support of aquatic ecosystems is provided by groundwater in the Project area, with effects on GDEs detailed in Chapter 15 - Aquatic and Marine Ecology, and on surface water systems in Chapter 9 - Surface Water.

Cultural and spiritual values

Protection of cultural and spiritual values is essentially the same as the protection of aquatic ecosystems, described above, given the lack of springs or groundwater fed wetlands in the Project area.

10.6 Mitigation, Management and Monitoring

10.6.1 Mitigation Strategy

The potential groundwater impacts mainly relate to the change in hydraulic characteristics within the mine footprint area, and changes within the drawdown extent, resulting in changes to groundwater flow direction and potential recharge to groundwater as well as potential impacts to Deep Creek and other identified GDE’s as a result of drawdown propagation.

Management of impacts to GDEs, terrestrial vegetation and fauna and surface waters have been separately assessed and provided in Chapter 15 - Aquatic and Marine Ecology, Chapter 14 - Terrestrial Ecology and Chapter 9 - Surface Water respectively.

Management of groundwater related impacts within this Chapter are therefore associated with:

- monitoring changes to the groundwater systems throughout the Project life
- periodic review, revision and calibration of the numerical groundwater model to ensure it remains up to date and as accurate as practicable, based on continuously updated monitoring data
- development of trigger values (both quality and quantity) to provide early warning of expected and unexpected changes in the groundwater system (to provide early warning to other management programs)
- make good arrangements for impacted bores and
- general management considerations to protect groundwater quality.

10.6.2 Groundwater Management

Groundwater quality will be protected through the implementation of a number of interrelated management plans and strategies, namely:

- Detailed groundwater management and monitoring plan, a draft of which is included in the EMP in Appendix A12, which includes:
  - Groundwater monitoring program (refer to Section 10.6.5)
  - Trigger Action Response Plans (TARPs)
  - Review and Reporting and
  - Mitigation / Make Good Provisions.
- A Mineral Waste Management Plan, a draft of which is included in the EMP in Appendix A12, which includes:
  - Characterisation of waste rock and coal rejects and production quantities and volumes
  - Identification of appropriate performance measures (e.g. to prevent or minimise the migration of pollutants beyond the excavated pit extent or seepage from out-of-pit emplacements) and
  - Reject disposal management, including material handling methodologies, scheduling and water management.
- An updated and refined geo-environmental block model and detailed landform haulage schedule to optimise the construction and rehabilitation sequence, and to ensure that waste rock is backfilled and stockpiled to ensure long term stability in terms of both the landforms and the quality of runoff and leachate generated – this includes encapsulation of rejects and potential sodic materials, and/or amelioration.
- A Groundwater Dependent Ecosystem Monitoring and Management Plan and a Receiving Environment Monitoring Program, drafts of which are included in Appendices A10e and A10f respectively.
- A Progressive Rehabilitation and Closure Plan (PRCP), with the strategy for this plan provided in Chapter 11 - Rehabilitation and Decommissioning.
- Preparation of an Underground Water Impact Report as required under Queensland legislation.

The key elements relating to the groundwater monitoring and management plans are described in the following sections.

10.6.3 Groundwater Model

The numerical groundwater model will be subject to review at least every three years from the commencement of open cut mining, in line with the indicative review timeframes prescribed for UWIRs in Queensland. In addition, the model will be incorporated into other Project models to be progressively reviewed and updated as required, working as an interconnected whole, including:

- Local cross-sectional investigations and coupled numerical models linked to the numerical model regional water table aquifer predictions, to assess impacts to pools, baseflow and GDEs at specific locations – these models are described in Appendix A6d - Surface Water/Groundwater Interactions Report and
- Mine water balance model, to ensure the overall water management system is effectively managed.

10.6.4 Make Good Arrangements

As noted early, one bore has been identified that is potentially impacted by the Project, along with one other bore that may be impacted (although the depth is not known). A baseline assessment of landholder bores within the predicted impact area, to be repeated as required to update the Project UWIR, will be undertaken prior to mining activities being undertaken, and in accordance with the DES Guideline 'Baseline Assessments' (DES 2017).

Following the initial baseline assessment (informed by the current bore census data), a UWIR will be prepared for the Project. This will outline make-good water arrangements, which will include replacement or deepening of the supply bore, or of the water supply volume if this is not possible, to ensure the supply remains uninterrupted.

10.6.5 Monitoring Program

A draft Groundwater Management and Monitoring Plan is provided in Appendix 12 – EMP. As part of this, quarterly sampling will be undertaken with the view to review and revise the program as more data is collected during the life of the mine.

The proposed Groundwater Monitoring Program includes the following:

- Groundwater pit inflow – monitoring would include the monitoring of water levels and water quality in the pit sumps, but also record data on the volumes of water abstracted.
- Styx river (Tide monitoring – Ogmore bridge) – continuation of monitoring of depth to water surface to confirm tidal ranges encountered.
- Tooloombah and Deep Creek Surface water flow gauging – continuation of surface water level and flow measurements, to enable more refined analysis of pools and bank storage / water table influences.
- Continued monitoring of existing Project and landholder bores as summarised in Table 10-14 and Figure 10-72.
- Groundwater level triggers – preliminary triggers have been developed at each groundwater monitoring bore reflecting either a proportion (e.g. approximately 75%) of the maximum predicted groundwater drawdown, or where less than 2 m, a default trigger in the

unconsolidated aquifers of 2 m, and a default trigger in the consolidated aquifers of 5 m. These are shown in Table 10-16.

- Groundwater quality triggers – preliminary triggers have been developed as presented in Table 10-17.

Note that the quality triggers described in this Chapter are based on updated data to May 2020, whereas the Groundwater Model and Assessment Report in Appendix A6b was limited to data up to January 2020. Data is not significantly different, but some minor differences in values may be identified.

Further details on the groundwater monitoring program, including monitoring and sampling timing, methodologies and parameter suites, are provided in the draft Groundwater Management and Monitoring Plan (GWMMP) in the draft EMP, Appendix 12.

Installation of additional shallow (alluvial) groundwater monitoring bores located upstream and downstream of the identified wetland and GDE areas associated with Tooloombah Creek and Deep Creek, to monitor alluvial groundwater level and quality from bank storage at pre-mining (baseline), operations and post-mining.

Monitoring is proposed to continue at the bores nominated in Table 10-15 and Figure 10-72. When further baseline data is gathered, and after the initial 2 years of operations, the monitoring will be reviewed. An initial set of monitoring sites to continue after this point are as follows:

- Quaternary Alluvium - WMP05, WMP21, WMP29A, landholder bore BH16.
- Quaternary Pleistocene Alluvium / Regolith - WMP02, WMP04, WMP06, WMP08, WMP12, WMP17, WMP18, WMP25, WMP26, WMP29B.
- Styx Coal Measures - WMP04D, WMP08D, WMP10, WMP11D, WMP13, WMP14, WMP17D, WMP18D, WMP21D, WMP22A, WMP22B, WMP23A, WMP24, WMP28, WMP29C, WMP29D.
- Permian Measures - WMP29E, WMP22C, WMP30C, WMP16, WMP16D, WMP19, WMP19D, WMP20, WMP20D, WMP23B, WMP31 (VWP).

Finally, during the course of refined resource definition activities during operations, further mapping of the fault interface will be undertaken (east of the open cut) to delineate the fault structure with increased precision, which will feed into model reviews and updates as required.

Table 10-14: Proposed groundwater monitoring program

Element	Corresponding Programs / Reports[1]	Monitoring Locations	Parameters[2]	Frequency
Water Quality	WMP REMP GWMMP	Sites identified in Table 10-15	Phys-chem, major cations and anions, total and dissolved metals and metalloids, nutrients, organics	Quarterly
		Mine affected water dams (Dam 1, Dam 4, Environmental Dam 1C)		Quarterly
		Pit sumps		Quarterly
Water Level / Pressure	GWMMP	Sites identified in Table 10-15	Water level	Quarterly
		Pit inflows	Water level Pumped volumes to Dam 1	Quarterly Continuously
		Tide level at Ogmore Bridge	Water level	Quarterly for 2 years
		Streamflow gauges on Deep and Tooloombah Creeks	Water level, flow	Continuously
Seepage	GWMMP MWMP	At toe and existing bores	Water level	Monthly for first 2 years, Quarterly thereafter
Surface Water	Refer to Chapter 9 – Surface Water			

[1] WMP – Mine Site Water Management Plan; REMP – Receiving Environment Monitoring Plan; GWMMP – Groundwater management and monitoring plan; MWMP – Mineral Waste Management Plan

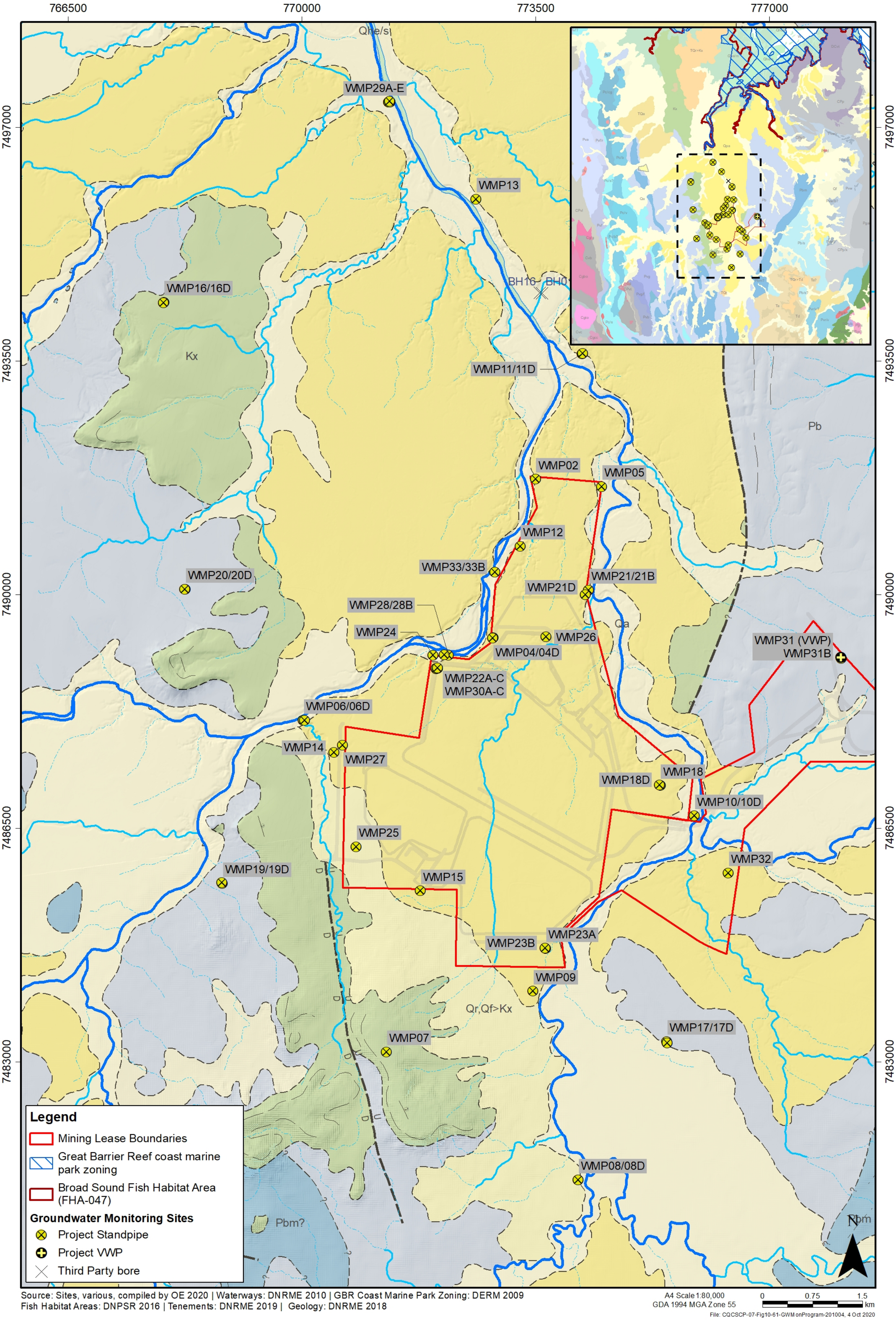
[2] Phys-chem – EC, pH, dissolved oxygen, temperature, turbidity; Major cations and anions – alkalinity (hydroxide, carbonate, bicarbonate, total) as $CaCO_3$, hardness, sulfate, chloride, fluoride, dissolved major cations (calcium, magnesium potassium, sodium); Total and dissolved metals and metalloids – aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium and zinc; Nutrients – ammonia, nitrate, nitrite, nitrate + nitrite, total kjeldahl nitrogen, total nitrogen (all as N), filterable reactive phosphorous, total phosphorous (both as P); Organics – total recoverable hydrocarbons

Table 10-15: Proposed monitoring sites

ID	Eastings	Northings	Elevation (mAHD)	Screen Depth (mbgl)	Casing Stickup (m)	Target Aquifer	Parameters
Project Monitoring Bores							
WMP02	773497	7491734	25	12 – 18	0.5	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level
WMP04	772865.3	7489359	28.33	12 – 18	0.9	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level
WMP04D	772859	7489351	28.33	18.5 – 36.3	0.9	Styx Overburden [Kx] / Weathered Regolith / Qpa [~GZ11]	Quality Level
WMP05	774487.5	7491625	17.22	9 – 12	0.48	Alluvial (Qa) [~AZ6]	Quality Level
WMP06	770020	7488120	33.98	12 – 18	0.58	Regolith / Styx Underburden [Kx] [~GZ11]	Quality Level
WMP06D	770039	7488119	34.06	38 - 44	0.52	Styx Underburden [Kx] [~GZ11]	Quality Level
WMP07	771264	7483151	131	48 – 60	0.85	Styx Underburden [Kx] [~GZ11]	Level
WMP08	774134	7481232	43.49	10 – 16	0.58	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level
WMP08D	774134	7481232	43.49	24 – 36	1	Styx Underburden [Kx] [~GZ11]	Quality Level
WMP09	773459	7484062	37.63	7.1 – 15	1	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level
WMP10	775878	7486688	29.26	12 – 18	1	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP11	774194	7493610	18.75	18 – 24	1	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP11D	774201	7493623	18.7	30 – 36	0.9	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP12	773266	7490731	26.37	11 – 17	0.9	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level
WMP13	772604	7495931	18.4	12.7 – 19.7	0.8	Styx Overburden [Kx] / Weathered Regolith / Qpa [~GZ11]	Quality Level
WMP14	770477	7487637	32.89	9 – 18	0.95	Regolith / Styx Overburden [Kx] [~GZ11]	Level
WMP15	771774	7485564	43.25	9 - 21	1.2	Regolith / Styx Underburden [Kx] / Back Creek Group [Pb] [~GZ11]	Quality Level

ID	Eastings	Northings	Elevation (mAHD)	Screen Depth (mbgl)	Casing Stickup (m)	Target Aquifer	Parameters
WMP16	767930	7494387	41.91	25.5 – 31.5	0.65	Back Creek Group [Pb] [~FZ10]	Level
WMP16D	767923	7494380	41.84	35.7 – 41.7	0.75	Back Creek Group [Pb] [~FZ10]	Quality Level
WMP17	775465	7483308	42.83	9 - 12	0.77	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Level
WMP17D	775470	7483286	42.83	21 - 24	0.53	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP18	775366	7487144	30.54	9.2 - 12.2	0.56	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Level
WMP18D	775358	7487152	30.62	18.5 - 23.5	0.44	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP19	768808	7485676	41	13.1 - 16.1	0.64	Regolith / Back Creek Group [Pb] [~FZ10]	Level
WMP19D	768801	7485692	41	24.9 - 27.9	0.58	Back Creek Group [Pb] [~FZ10]	Quality Level
WMP20	768251	7490084	42.95	14.5 – 20.5	0.53	Regolith / Back Creek Group [Pb] [~FZ10]	Level
WMP20D	768246	7490082	42.98	24 – 30	0.5	Back Creek Group [Pb] [~FZ10]	Quality Level
WMP21	774294	7490072	23.79	6.9 - 9.9	0.66	Alluvial (Qa) [~AZ6]	Level
WMP21B	774294	7490072	27.99	86 - 92	0.52	Styx Underburden [Kx] [~GZ11]	Quality Level
WMP21D	774243	7490004	25.99	14 - 20	0.54	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP22A	772008	7488891	29.67	27 – 30	0.35	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP22B	772011	7488896	29.74	50 – 56	0.3	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP22C	772012	7488900	29.76	200 - 206	0.5	Back Creek Group [Pb] [~FZ10]	Quality Level
WMP23A	773651	7484701	36.38	48.5 - 54.5	0.9	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP23B	773638	7484709	36.36	187 - 193	0.9	Back Creek Group [Pb] / Carmila Beds [Pc] [~FZ10]	Quality Level
WMP24	771965	7489093	19.36	23.4 - 26.4	0.48	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP25	770812	7486227	44.21	10.1 - 13.1	0.58	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level
WMP26	773655	7489372	27.56	11.5 - 20.5	0.52	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level

ID	Eastings	Northings	Elevation (mAHD)	Screen Depth (mbgl)	Casing Stickup (m)	Target Aquifer	Parameters
WMP27	770606	7487750	33.03	14.5 - 20.5	0.85	Regolith / Styx Overburden [Kx] [~GZ11]	Level
WMP28	772192	7489099	21.91	8.9 - 11.9	0.58	Regolith / Styx Overburden [Kx] [~GZ11]	Quality Level
WMP28B	772128	7489102	21.91	5 - 7	0.52	Alluvial (Qa) [~AZ6]	Quality Level
WMP29A	771298	7497385	11.97	6.5 – 12.5	1	Alluvial (Qa/Qhe) [~AZ6]	Quality Level
WMP29B	771301	7497385	11.97	16 – 20	1	Pleistocene Alluvial (Qpa) / Regolith [~CZ2]	Quality Level
WMP29C	771318	7497394	11.97	52 – 58	1	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP29D	771317	7497387	11.97	115 – 121	1	Styx Overburden [Kx] [~GZ11]	Quality Level
WMP29E	771312	7497397	11.97	222.5 – 228.5	1	Back Creek Group [Pb] [~FZ10]	Quality Level
WMP30A	772028	7488896	29.79	27 – 30	0.9	Regolith / Styx Overburden [Kx] [~GZ11]	Level
WMP30B	772028	7488900	29.75	50 – 56	0.9	Regolith / Styx Overburden [Kx] [~GZ11]	Level
WMP30C	772029	7488905	29.72	200 – 206	0.8	Back Creek Group [Pb] [~FZ10]	Level
WMP31	778070	7489063	50.49	50; 94; 103.5; 171	0.6	Back Creek Group [Pb] [~FZ10]	Continuous Level (VWP)
WMP31B	778074	7489051	50.24	33 - 42	0.6	Back Creek Group [Pb] [~FZ10]	Quality Level
WMP32	776384	7485834	32.31	57 - 63	0.6	Styx Underburden [Kx] [~GZ11] Styx	Quality Level
WMP33	772890	7490344	22.79	6 - 8	0.6	Alluvial (Qa) [~AZ6]	Quality Level
WMP33B	772890	7490344	22.29	15 - 18	0.6	Styx Overburden [Kx] [~GZ11]	Quality Level
Landholder Bores							
BH16	773592	7494520	9.67	9.2 - 9.5	ID	Alluvial (Qa) [~AZ6]	Quality Level
BH01x	773561	7494524	11	ID	ID	Alluvial (Qa) [~AZ6]	Quality Level



Source: Sites, various, compiled by OE 2020 | Waterways: DNRME 2010 | GBR Coast Marine Park Zoning: DERM 2009
Fish Habitat Areas: DNPSR 2016 | Tenements: DNRME 2019 | Geology: DNRME 2018

File: CQCSCP-07-Fig10-61-GWMonProgram-201004, 4 Oct 2020

Figure 10-72: Groundwater monitoring program

Table 10-16: Groundwater level triggers (after HA 2020)

Monitoring Points	Preliminary Groundwater Level (Change) Investigation Trigger Threshold		
	Year 3	Interim (75% of maximum)	Maximum
WMP05, WMP08, WMP08D, WMP11, WMP11D, WMP13, WMP16, WMP16D, WMP17D, WMP19, WMP19D, WMP20D, WMP29A, WMP29B, WMP33	2.0	2.0	2.0
WMP06D, WMP29C, WMP29D, WMP29E, WMP31	5.0	5.0	5.0
WMP02, WMP06, WMP07, WMP10, WMP12, WMP14, WMP17, WMP18, WMP18D, WMP20, WMP21, WMP27, WMP28	2.0	Dry	-
WMP04, WMP22A, WMP22B, WMP30A, WMP30B	Dry	Dry	-
WMP21D	2.1	Dry	-
WMP26	5.3	Dry	-
WMP25	2.0	2.0	2.7
WMP09	2.0	2.9	3.8
WMP15	2.0	5.3	7.1
WMP23A	2.0	12.0	16.0
WMP23B	5.0	20.3	27.1
WMP24	4.5	4.5	5.3
WMP04D	13.4	16.2	21.6
WMP22C	12.4	27.6	36.7
WMP30C	12.6	27.9	37.1
WMP21B	5.0	11.0	14.6
WMP33B	5.0	5.5	7.3
WMP28B	3.3	3.2	4.2

Table 10-17: Groundwater quality triggers (80th percentiles, or 20th to 80th percentiles for pH)

	Sites	pH*	Alk	EC	TDS	Al	As	Fe	Mn	Mo	Se	V	Zn
Cainozoic Deposits - Quaternary Alluvium (1)	BH01x	6.6 - 7.1	378	1290	660	<0.01	0.0164	3.93	0.807	<0.001	<0.01	<0.01	0.0118
	BH16	6.4 - 6.8	195	1050	645	0.01	0.0044	0.262	0.917	<0.001	<0.01	<0.01	0.0146
	WMP05	7.1 - 7.5	662	2890	1770	0.22	0.0048	0.25	0.323	0.003	<0.01	0.02	0.0232
	WMP21	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP29A	7.0 - 7.2	446	8720	5610	ID	0.0056	ID	ID	ID	ID	ID	0.0252
Cainozoic Deposits - Quaternary Pleistocene Alluvium / Regolith (2)	WMP02	6.5 – 7.0	446	17400	12400	0.01	0.002	<0.05	0.381	0.002	<0.01	<0.01	<0.005
	WMP04	7.4 - 8.1	539	21900	14500	0.02	0.004	<0.05	0.0648	0.033	<0.01	<0.01	<0.005
	WMP08	6.7 – 7.0	722	27800	19800	<0.042	0.003	0.056	1.3	0.00297	<0.042	<0.042	0.0234
	WMP09	6.6 - 6.9	800	22200	15300	<0.01	0.002	<0.05	0.595	0.001	<0.01	<0.01	0.0314
	WMP12	6.9 - 7.3	391	8710	5740	0.064	0.0042	0.058	0.378	0.0056	<0.01	0.01	0.002 - 0.006
	WMP15	6.8 - 7.2	491	4720	2610	0.49	0.002	1.21	0.129	0.002	<0.01	<0.01	0.058
	WMP17	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP18	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP25	6.1 - 6.7	45.8	801	612	ID	0.002	ID	ID	ID	ID	ID	0.029
	WMP26	6.8 – 7.0	910	49700	37500	0.354	<0.005	0.218	0.601	<0.005	<0.05	<0.05	0.0584
	WMP29B	6.5 - 6.9	421	22500	15800	ID	0.029	ID	ID	ID	ID	ID	0.0586
Styx Coal Measures - Overburden (and Quaternary Alluvium [Lower] / Weathered Regolith / Underburden (3)	WMP04D	6.8 - 7.1	686	26400	17700	0.01	0.001	<0.05	0.0918	0.002	<0.01	<0.01	0.058
	WMP10	6.9 - 7.2	1290	19000	11800	0.036	0.002	0.124	0.55	0.0028	<0.01	<0.01	0.0116
	WMP13	6.2 - 6.6	524	48700	39600	<0.05	<0.005	0.88	1.84	<0.005	<0.05	<0.05	0.038
	WMP14	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP21D	6.7 – 7.0	889	42000	31800	<0.05	0.0098	0.164	0.497	ID	<0.05	<0.05	ID
Styx Coal Measures - Overburden / Coal Seams / Interburden /	WMP06	6.6 - 6.9	886	6120	4000	0.01	0.0182	2.61	2.35	0.006	<0.01	0.01	0.011
	WMP07	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP08D	7.3 - 7.5	279	14800	8820	0.026	0.004	0.35	0.306	ID	<0.01	<0.01	0.0278

	Sites	pH*	Alk	EC	TDS	Al	As	Fe	Mn	Mo	Se	V	Zn
	WMP11	6.5 - 6.9	506	32100	23800	<0.05	0.0038	3.12	1.91	0.00293	<0.05	<0.05	0.0786
	WMP11D	6.6 – 7.0	541	31600	23200	0.01	0.0108	2.82	0.379	0.00302	<0.05	<0.05	0.0794
	WMP17D	6.8 - 7.1	525	40400	28000	ID	<0.005	ID	ID	ID	ID	ID	<0.025
	WMP18D	6.8 - 7.3	908	31200	22200	ID	<0.005	ID	ID	ID	ID	ID	0.0448
	WMP21B	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP22A	6.8 - 6.9	930	24600	16300	<0.01	0.004	1.6	0.624	0.004	<0.01	<0.01	0.022
	WMP22B	7.2 - 7.4	828	35000	23200	<0.05	<0.005	<0.05	0.267	ID	<0.05	<0.05	<0.025
	WMP23A	8.0 - 12.6*	3120	25800	16200	0.188	0.0108	1.21	4.99	0.302	<0.05	<0.05	0.271
	WMP24	7.1 - 7.5	972	23200	14300	0.01	<0.001	0.344	0.0984	<0.001	<0.01	<0.01	0.0108
	WMP27	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP28	6.8 - 6.9	555	8350	5620	ID	0.004	ID	ID	ID	ID	ID	0.0222
	WMP29C	11.3 - 11.6*	297	20100	12200	1.92	0.0046	0.05	0.001	0.28	<0.01	0.01	ID
	WMP29D	9.7 - 10.7*	103	22700	14700	0.09	0.0124	<0.05	0.05	0.132	<0.01	<0.01	0.166
	WMP30A	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP30B	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Permian Measures - Back Creek Group and/or Styx Coal Measures – Underburden (5)[2]	WMP16	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP16D	7.3 - 7.5	434	8510	5060	0.02	<0.001	0.116	0.145	0.0046	<0.01	<0.01	0.12
	WMP19	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP19D	6.6 - 6.9	531	1900	1260	<0.01	0.007	0.81	0.0702	0.0048 - 0.0054	<0.01	<0.01	0.045
	WMP20	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
	WMP20D	7.1 - 7.5	784	2010	1270	0.012 - 0.016	0.006	<0.05	0.0734	0.0016	<0.01	<0.01	0.1
	WMP22C	9.9 - 10.1	273	5230	2840	ID	0.0032	ID	ID	ID	ID	ID	0.0138
	WMP29E	12.2 - 12.9	3030	16000	5560	2.4	0.0074	<0.05	<0.001	0.272	<0.01	0.026	0.0406
	WMP30C	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID

	Sites	pH*	Alk	EC	TDS	Al	As	Fe	Mn	Mo	Se	V	Zn
Permian Measures - Back Creek Group and/or Carmila Beds (6)	WMP23B	12.2 - 12.6	2350	16900	6830	0.86	0.003	<0.05	0.006	0.283	<0.01	<0.01	0.0296

Table notes:

* Bore investigations need to be conducted to determine the source of the identified high pH

Alk = total alkalinity; EC = electrical conductivity; TDS = total dissolved solids; Al = dissolved aluminium; As = dissolved arsenic; Fe = dissolved iron; Mn = dissolved manganese; Mo = dissolved molybdenum; Se = dissolved selenium; V = dissolved vanadium; Zn = dissolved zinc

10.6.6 Monitoring for Seepage

The detailed design of the environmental and water dams on site will consider and make provision for the detection and management of seepage where it may result in safety and / or water quality impacts to the receiving environment. In general, the site water management strategy indicates that mine-impacted water will be of good to moderate quality, despite having been in contact with coal and / or sediment. Seepage has been considered in the consequence category of the dams. The site water management plan (WMP) will address monitoring, including visual inspections for seepage from embankments, along with trigger and action plans based on the volume, rate and quality detected.

10.6.7 Trigger Action Response Plans

TARPs will outline actions and responses necessary should monitoring identify exceedances in the Project water quality criteria (trigger levels). In addition, the TARP will outline the criteria, monitoring and reporting measures for environmental incidents, unplanned events or cases of unauthorised discharge. Draft TARPs have been included in the Draft Groundwater Management and Monitoring Plan in the draft EMP (Appendix 12). These will be finalised once Environmental Authority (EA) conditions are finalised and will be incorporated into the overall site monitoring program.

The incident reporting processes to DES will be completed as per the EA conditions.

10.7 Cumulative Impacts

The Project may have impacts on environmental values that act cumulatively with those of other projects in the region. The contribution of past and present projects is inherent in the impact assessment, as these projects are influencing the environmental baseline upon which the impact assessment is based. However, reasonably foreseeable future projects should also be considered, in the context that these projects may have environmental impacts that act cumulatively with those of the Project.

The catchment and coastline surrounding the Project Area is relatively undeveloped, dominated by rural lands that are used for grazing. There are no known large-scale industrial or mining developments proposed within the catchment of the Project. The Commonwealth Department of Defence is currently developing an expansion of the existing Shoalwater Bay Defence Training Area. A future expansion of the existing Shoalwater Bay Defence Training Area is located partly in the catchment of Broad Sound, approximately 50 km to the north-east of the Project. However, no groundwater related impacts are anticipated that could act cumulatively with the Project.

Landholder bores involving pumping of water for water supply exist in proximity to the Project. However, these were not explicitly modelled since (as described in the Groundwater Model and Assessment Report in Appendix A6b) there does not appear to be any distinct response in groundwater levels at these bores to landholder pumping. Due to the quality of the groundwater resources, which are generally not supportive of stock watering or other uses, large scale pumping for water supply from groundwater is not practiced in the Project area.

The historic mine workings at Ogmore and Bowman were incorporated into the numerical groundwater modelling conducted as part of the Groundwater Model and Assessment Report in Appendix A6b. The report concluded that, cumulatively, since the predicted groundwater drawdown effects as a result of the CQC Project do not extend as far as the historic Ogmore mine workings (some 8 km to the north and downstream beneath the Styx River), then no superposition effects would occur – i.e. no cumulative impacts. For the Bowman workings, the report stated that the cumulative effects beyond those predicted for the CQC Project alone, are predicted to be negligible given the limited extent and continued recovery since the cessation of mining.

Overall, the Groundwater Model and Assessment Report in Appendix A6b concluded that the predicted cumulative drawdown impacts at private landholder bores, springs, wetlands, groundwater dependent ecosystems, Broad Sound Declared FHA and on recorded groundwater fauna locations / stygofauna habitat and riparian vegetation are equivalent to the Project alone.

10.8 Conclusion

The Project hydrogeological conceptual model has been reviewed and refined to inform improvements implemented in the updated numerical groundwater model. These improvements include key processes such as pit excavation, in-pit backfilling and post-mining landforms, to predict groundwater take/inflows, groundwater drawdowns and radius of influence and baseflow impacts, enhanced leakage and impacts to groundwater users and dependent assets. Implementation of each modification and/or improvement has been made progressively in consultation with DES and independent peer review by AGE Consultants.

The numerical groundwater modelling indicates the following in relation to potential groundwater impacts associated with the Project:

- The modelling predicts an average groundwater take of 0.5 ML/day during the operational life of the mine. The maximum take will be around 1.2 ML/day in the first 6 years of the mine, and this will decline thereafter.
- A substantial reduction in potentiometric head in the Styx Coal Measures (overburden and interburden) and, to a lesser extent, the underburden. This is predicted to be less than 2 m at 3.5 km, 5 km and 3km from the north, north-east and south-east of the open cut respectively. The reduction is also observed in the Back Creek Group near the vicinity of the open cut.
- Some groundwater drawdown within the Cainozoic sediments in the vicinity of the open cut. Drawdown is expected to be localised in this region and predicted to gradually recover at post-mining, with recovery to pre-mining levels over around 150 years, and a further more gradual stabilisation as the mounding effects of the elevated landforms stabilise.
- Groundwater drawdown effects within the Project area are determined to be due to the Project alone, and not affected by historic workings, which have substantially recovered.
- Changes to baseflow to and/or leakage from surface water systems are predicted to be negligible due to the predicted reductions in potentiometric head and temporal, localised drawdown in Cainozoic sediments the vicinity of the open cut.
- No appreciable change in groundwater quality due to the Project during open cut mining and long-term (post-mining).

Impacts to surface water resources and GDEs will be quantified and confirmed through the development of a 3D integrated groundwater – surface water numerical model following the study undertaken by ELA (2020a – see Appendix 6d), to support the EIS groundwater impact assessment.

10.9 Commitments

In relation to groundwater, Central Queensland Coal's commitments are provided in Table 10-18.

Table 10-18: Commitments – Groundwater

Commitment
Undertake further monitoring and model refinement work, including further investigation of the Og1 site to determine if it is potentially impacted (is it still used), monitoring of newly installed alluvial bores in proximity to creeks, and further transect work to determine local surface-groundwater interactions.
Store and manage all hydrocarbons, chemicals and waste oils in accordance with accepted industry and Australian standards, including with AS1940 - The storage and handling of flammable and combustible liquids. Spill containment and control equipment will be on-site at all times.
Finalise and implement the GWMMP, MWMP, GDEMMP, REMP, PRCP and EMP - implement the groundwater monitoring program described in Section 10.6.5
Continue to update the baseline statistics up until mining commences to refine the baseline dataset for the Project. Review the data prior to commencement and rationalise the monitoring sites where justified.
Undertake an initial baseline assessment, and from this prepare and implement a UWIR for the Project prior to works commencing on-site, including the development of make-good arrangements for potentially impacted bores.
Develop the geo-environmental block model and detailed haulage schedule to ensure that material is managed on-site to avoid erosion, leaching and contamination of surface and groundwaters (i.e. backfilling and final landforms will be stable and non-polluting long term).
Review the numerical groundwater model prior to mining commencing on-site, and every three years from commencement of mining, and revise and update as required. Include ongoing refinement through coupled surface water-groundwater models developed as part of this SEIS (or improved versions).
Maintain the mine water balance model and update as required to ensure it matches Project operations, and is validated (and re-calibrated) against data from the site.
Undertake further fault delineation works, including drilling, to better locate and understand the local north-south fault line.
Include seepage monitoring and control in the design of site water dams.

10.10 IESC Cross-Reference Tables

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) is a statutory body under the EPBC Act. The IESC has developed Information Guidelines that outline what types of information a proposal for a CSG or large coal mining project should include. This information is needed to enable the IESC to provide robust scientific advice to government regulators on the potential water-related impacts of such proposals.

The general guidance requirements are addressed variously throughout the SEIS v3. The description of the Project is provided in Chapter 1 – Introduction and Project Description. Risk assessments are provided in each of the technical chapters and reported in the associated technical reports. The descriptions of impacts to water resources and water-dependent assets are, in addition to this Chapter, discussed in detail in Chapter 10 – Groundwater, Chapter 14 – Terrestrial Ecology, Chapter 15 Aquatic Ecology and Chapter 16 – Matters of National Environmental Significance.

Specific information needs relevant to groundwater are discussed in Table 10-19.

Table 10-19: Groundwater - IESC compliance checklist

Checklist Item	Addressed?	Comments
Context and conceptualisation		
Describe and map geology at an appropriate level of horizontal and vertical resolution including: - Definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections and any relevant field data. - Geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.	Y	Geology is summarised in Section 10.3.3, including mapping at a suitable scale, and is described in more detail in Chapter 5 – Land, with detail on the coal resource in Chapter 1 – Introduction and Project Description. The Groundwater Model and Assessment Report in Appendix A6b provides a detailed analysis of the geology of the area, including faulting and other structural components, which was used to develop the conceptual and numerical models.
Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	Y	A description of the hydrostratigraphic units (hydrogeological units) is provided in Section 10.3.6, including Sections 10.3.6.2 (Hydrostratigraphy) and 10.3.6.3 (groundwater level, including data), Figure 10-7 (water table level and depth, flow directions). Most of the bores have been surveyed, with the remainder determined from LiDAR capture. An assessment of such is provided in the Groundwater Model and Assessment Report in Appendix A6b (section 8.12.3)
Define and describe or characterise significant geological structures (e.g. faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge. Site-specific studies (e.g. geophysical, coring / wireline logging etc.) should give consideration to characterising and detailing the local stress regime and fault structure (e.g. damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays). Discussion on how this fits into the fault's potential influence on regional-scale groundwater conditions should also be included.	Y	The Groundwater Model and Assessment Report in Appendix A6b provides a detailed analysis of the geology of the area, including faulting and other structural components, which was used to develop the conceptual and numerical models. This included analysis of a range of existing data, and new data commissioned by the Project.
Provide hydrochemical (e.g. acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g. stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	Y	Water quality data is provided in Section 10.3.6.6, with tracer analysis summarised in Section 10.3.7, and in the Groundwater Model and Assessment Report in Appendix A6b.

Checklist Item	Addressed?	Comments
Provide site-specific values for hydraulic parameters (e.g. vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	Y	This is detailed within the Groundwater Model and Assessment Report in Appendix A6b.
Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	Y	This is detailed within the Groundwater Model and Assessment Report in Appendix A6b, and summarised in Section 10.3.6.4.
Provide time series groundwater level and quality data representative of seasonal and climatic cycles.	Y	Sections 10.3.6.3 and 10.3.6.6 for level and quality respectively.
Assess the frequency (and time lags if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	Y	Section 10.3.7 discusses surface-groundwater connectivity, and groundwater recharge/discharge in Sections 10.3.6.4 and 10.3.8. The freshwater-seawater interface is discussed in Section 10.3.6.7.
Analytical and numerical modelling		
Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Y	The methods used are summarised in Section 10.2.4 and detailed in the Groundwater Model and Assessment Report in Appendix A6b.
Provide an explanation of the model conceptualisation of the hydrogeological system or systems, including multiple conceptual models if appropriate. Key assumptions and model limitations and any consequences should also be described.	Y	The methods used are summarised in Section 10.2.4 and detailed in the Groundwater Model and Assessment Report in Appendix A6b. The conceptual hydrogeological model is described in Section 10.3.8.
Undertaken groundwater modelling in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), including independent peer review.	Y	Section 10.2.4.3, with the peer review provided in the Numerical Groundwater Model Peer Review in Appendix A6e.
Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	Y	The methods used are summarised in Section 10.2.4 and detailed in the Groundwater Model and Assessment Report in Appendix A6b.
Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g. use baseflow calibration targets where predicting changes to baseflow).	Y	The methods used are summarised in Section 10.2.4 and detailed in the Groundwater Model and Assessment Report in Appendix A6b.
Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters [in press]).	Y	The methods used are summarised in Section 10.2.4 and detailed in the Groundwater Model and Assessment Report in Appendix A6b.

Checklist Item	Addressed?	Comments
Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters [in press]).	Y	The methods used are summarised in Section 10.2.4 and detailed in the Groundwater Model and Assessment Report in Appendix A6b.
Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	Y	The methods used are summarised in Section 10.2.4 and detailed in the Groundwater Model and Assessment Report in Appendix A6b. Key descriptions of the HSUs are provided in Section 10.3.6.2 and the water level and quality data is described in terms of these HSUs.
Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	Y	Summarised in Section 10.2.4.2 and detailed in the Groundwater Model and Assessment Report in Appendix A6b (particularly sections 8.10, 8.11 and 8.12).
Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	Y	Groundwater recharge/discharge is discussed in Sections 10.3.6.4 and 10.3.8, and changes to the existing units during and after the Project are described in Section 10.5.
Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters [in press]).	Y	Groundwater Model and Assessment Report in Appendix A6b (attachment 11).
Describe the various stages of the proposed project (construction, operation and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	Y	This is detailed within the Groundwater Model and Assessment Report in Appendix A6b, and summarised in Sections 10.2.4 (model development), 10.3.6 (existing conditions), and 10.5.1 (drawdown impacts and changes to water level and flow). Attachments 13, 14 and 15 in Appendix A6b provide head level plots of existing conditions, during mining conditions, and post-mining / recovery conditions for each relevant layer.
Provide a program for review and update of models as more data and information become available, including reporting requirements.	Y	Section 10.6
Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	Y	Section 10.5.1.1 provides the modelled groundwater ‘take’ due to dewatering, and concludes that minimal water would be taken from units other than the Styx Coal Measures.
Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	Y	Section 10.5.1.2
Undertake model verification with past and/or existing site monitoring data.	Y	This is detailed within the Groundwater Model and Assessment Report in Appendix A6b, particularly section 7.7.

Checklist Item	Addressed?	Comments
Impacts to water resources and water-dependent assets		
• Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: - Any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water. - The effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance. - The potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units.	Y	Section 10.5 (impact assessment), particularly Section 10.5.1 (Groundwater Quantity). Section 10.3.6.7 describes the freshwater-seawater interface, and further assessment of GDEs and impacts on surface waters are described in Chapters 15 – Aquatic and Marine Ecology, and 9 – Surface Water respectively.
Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	Y	Section 10.5.1.
For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	Y	Section 10.5 (impact assessment), particularly Section 10.5.1 (Groundwater Quantity). Further assessment of GDEs and impacts on surface waters are described in Chapters 15 – Aquatic and Marine Ecology, and 9 – Surface Water respectively.
Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	Y	Section 10.1.3.2.1 describes the EPP (Water and Wetland Biodiversity) values and guidelines that apply, and Section 10.1.3.5 the NWQMS and other guidelines that apply. Section 10.3.6.6 describes water quality and comparison with key guidelines, which are detailed within the Groundwater Quality Data Summary report in Appendix A6c.

Checklist Item	Addressed?	Comments
Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Y	Section 10.7.
Describe proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	Y	Section 10.6.
Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Y	Section 10.8.
Data and monitoring		
Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	Y	This is detailed within the Groundwater Model and Assessment Report in Appendix A6b, with data on groundwater levels summarised in Section 10.3.6.3.
Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Y	Long term statistics for the available data, and an assessment of the data itself, is provided in the Groundwater Quality Data Summary in Appendix A6c. This is summarised within Sections 10.2 and 10.3.6.6.
Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	Y	Section 10.6.5.
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	Y	The relevant guidelines and the NWQMS are described in 10.1.3.5. Monitoring is designed in accordance with the ANZG (2018) guidelines and QWQGs (EHP 2013).
Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs, the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	Y	Section 10.6.5.