Central Queensland Coal Project

Appendix 10a– Aquatic Ecology, Groundwater Dependent Ecosystems, Marine Ecology and the Great Barrier Reef

Central Queensland Coal

CQC SEIS, Version 3

October 2020

Technical Report

Groundwater Dependent Ecosystems, Aquatic Ecology, Marine Ecology and the Great Barrier Reef

Central Queensland Coal

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Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Description
AgTEM	Agricultural Transient Electromagnetic System
DAF	Department of Agriculture and Fisheries
DES	Department of Environment and Science
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GBR	Great Barrier Reef
GDE	Groundwater Dependent Ecosystem
GDEMMP	Groundwater Dependent Ecosystem Management and Monitoring Plan
GES	General Ecological Significance
HES	High Ecological Significance
IESC	Independent Expert Scientific Committee
mbgl	Metres below ground level
MNES	Matter of National Environmental Significance
MSES	Matter of State Environmental Significance
NC Act	*Nature Conservation Act 1992*
REMP	Receiving Environment Monitoring Program
SEIS	Supplementary Environmental Impact Statement
WPA	Wetland Protection Area

Executive Summary

Central Queensland Coal proposes to develop a new open cut coal mine and associated infrastructure in the Styx Coal Basin, located approximately 130 km northwest of Rockhampton, Queensland. The Central Queensland Coal Project is being assessed through an Environmental Impact Statement (EIS) process, under the Queensland *Environmental Protection Act 1994*.

An assessment of potential impacts of the Project on Groundwater Dependent Ecosystems, aquatic ecology, marine ecology and the Great Barrier Reef was completed in accordance with the Project EIS Terms of Reference, and relevant guidelines for impact assessment. A key objective of the assessment was to address comments from regulatory agencies on earlier versions of the EIS and supplementary EIS's, submitted for assessment in 2017 and 2018.

The impact assessment was informed by several newly completed technical studies, including a regional groundwater model, surface water model, a study of surface water – groundwater interactions, a sediment budget for the Project site and upstream catchment, and a study of geomorphological processes. This work supplemented the extensive baseline investigations completed since 2011 as part of the EIS studies.

A broad Study Area was defined for the impact assessment, which included all areas adjacent to and downstream of the Project, which may be physically disturbed or affected indirectly by the Project. The assessment was informed by a standardised risk assessment, and several regulatory guidelines of the Commonwealth and Queensland governments relevant to the ecological values under consideration. These included an *Explanatory Note: Assessing groundwater-dependent ecosystems* of the Independent Expert Scientific Committee, and the Net Benefit Policy of the Commonwealth Government in relation to management of the Great Barrier Reef.

The Study Area contains several national and state significant wetlands, as well as watercourses with aquatic ecology and Groundwater Dependent Ecosystem values. The ephemeral Tooloombah Creek and Deep Creek border the Project Area on the west and eastern side respectively, meeting to the north, and forming the Styx River. Important values located downstream of the Project Area include the Great Barrier Reef World Heritage Area and Marine Park and the Broad Sound Fish Habitat Area and Wetland.

A saline groundwater layer is generally present across the site at depths of 10 to 15 mbgl. Groundwater supplements the supply of water to some pools within parts of Tooloombah Creek and Deep Creek, allowing them to persist throughout the dry season. Aquatic habitats are present for a range of freshwater fauna types, including stygofauna, macroinvertebrates, fish and freshwater turtles. Riparian corridors are largely intact, though degraded by cattle grazing, and consist of a narrow band of vegetation dominated by Forest Red Gum (*Eucalyptus tereticornis*) and Melaleucas (*M. leucadendra* and *M. fluviatilis*).

All three types of GDEs are present within and adjacent to the Project Area, including stygofauna (Subterranean GDE; Type 1), groundwater fed creeks containing aquatic ecosystems (Aquatic GDE; Type 2), and groundwater dependent vegetation along the alluvial corridor of creeks and/or wetlands (Terrestrial GDE; Type 3). Mining-related drawdown of the water table aquifer is expected to result in localised impacts to stygofauna. However, the assemblages to be affected are likely to be relatively widespread throughout region, including areas unaffected by the Project.

The Project will not affect surface water flow conditions within local waterways, due to the small size of the mine catchment compared with the broader catchment upstream. However, groundwater drawdown is likely to reduce the timeframe over which some pools persist in local waterways during the dry season, particularly at Deep Creek. As the existing baseline conditions are highly variable and ephemeral, the aquatic ecosystems of the areas affected by drawdown are adapted to a variable environment, and are unlikely to be significantly affected by the Project. Recolonisation of aquatic habitats that have dried occurs rapidly following the onset of rainfall.

Groundwater drawdown along sections of Deep Creek located east of the Project Area is likely to result in some impacts to groundwater dependent vegetation. A maximum area of approximately 165 ha is predicted to be affected in the period 10 to 20 years after Project commencement. Vegetation changes may include a reduction in the ecological condition of trees that form a structural element of Regional Ecosystems, including Forest Red Gums and Melaleucas. Die-off of trees is possible in some locations during extended dry periods, as freshwater held in bank storage percolates through underlying sediments faster than occurs currently under baseline conditions, leaving less water available for vegetation.

The functional characteristics of Regional Ecosystems 11.3.25 (87.51 ha), 11.3.27 (0.59 ha), 11.3.35 (37.81 ha) and RE 11.3.4 (39.31 ha) will potentially be compromised, based on a conservative estimate of indirect Project impacts. In time, other large tree species that are more tolerant of dry conditions are likely to replace any loss of Terrestrial GDEs, and this process will be enhanced through active management and rehabilitation of the riparian zone during Project operations and rehabilitation. An environmental offsets program will also be implemented for the Project, and will offset the direct and indirect loss of vegetation and threatened species habitat. The environmental offsets delivered will be of a magnitude to provide for an overall net ecological benefit as a result of the Project.

Mapped wetlands located within the Mining Lease will not be affected by the Project. These areas are not subject to significant levels of groundwater drawdown and have vegetation communities that are dependent on surface water runoff, and in the case of Wetland 1, a perched aquifer in the unsaturated zone. Wetlands are not supported by the surface expression of groundwater, or the underlying water table and associated saturated zone.

Development of mining infrastructure will result in the permanent disturbance of approximately 8.35 km of waterways providing fish passage, as mapped by the Department of Agriculture and Fisheries (DAF) Waterways for Waterway Barrier Works Spatial Layer. These impacts are not able to be avoided and will be offset. Other impacts to fish passage associated with bridges over waterways and similar works will be managed through compliance with relevant design codes relating to the retention of fish passage characteristics.

The Project will not have any significant impact on downstream values including the Great Barrier Reef, Broad Sound Fish Habitat Area and associated wetland environments. Discharges from the mine will occur infrequently and only during and following periods of high rainfall when there is significant flow in adjacent waterways. Controlled releases will comply with the requirements of model Environmental Authority conditions, and hydrological modelling of water quality parameters with the potential to cause concern has indicated that the concentration of these parameters in the receiving environment downstream of the discharge point will be well within the bounds of existing baseline conditions.

An adaptive management and monitoring approach will be implemented for groundwater dependent ecosystems, wetlands and the receiving surface water environment. A draft Groundwater Dependent Ecosystem Management and Monitoring Plan has been developed for the Project, and outlines Project mitigation measures, triggers and corrective actions for a variety of Groundwater Dependent Ecosystem values located across the Study Area. A draft Receiving Environment Monitoring Program has also been developed and will be implemented to determine the condition of surface water, hydrology and aquatic ecological values occurring adjacent to the site, downstream, and at upstream reference sites. Results of the REMP will be reported to the Department of the Environment and Science in accordance with Environmental Authority conditions. Collectively, these measures will provide a sound basis for Central Queensland Coal to manage the construction and operation of the Project, while minimising impacts on sensitive ecological values of the region.

1. Introduction

1.1 Project Description

Central Queensland Coal proposes to develop a new open cut coal mine and associated infrastructure in the Styx Coal Basin, located approximately 130 km northwest of Rockhampton, Queensland (**Figure 1-1**). The Project is located on Mineral Development Licence (MDL) 324, and includes:

- Two open cut coal operations, associated mining activities and mining infrastructure (including waste rock stockpiles, dams, mine industrial area, coal handling and preparation plants and conveyors)
- A train loadout facility which will provide a new connection to the existing North Coast Rail Line, and
- A transport corridor to transport coal from the mine to the train load out facility.

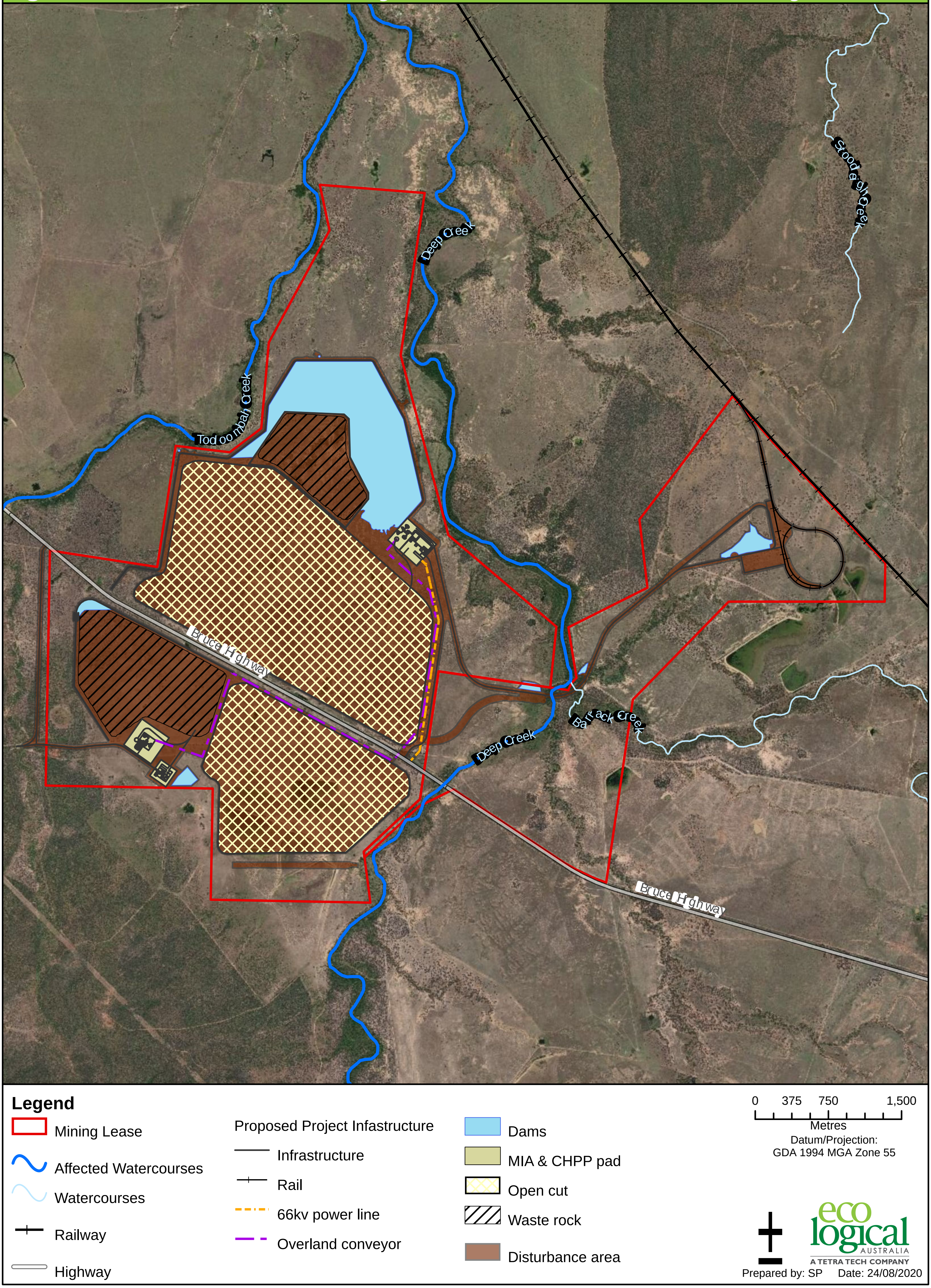
Two separate mining leases (MLs) are proposed to cover the mining areas and train loadout facility. The disturbance area within the two MLs is 1,361 ha, with an additional 11.5 ha to be disturbed outside of the MLs to facilitate the Mt Bison western mine access roads. The two open cut mine operations will produce up to 10 million tonnes per annum of run-of-mine coal, comprising semi-soft coking coal and high grade thermal coal.

Open Cut 2, located on the northern side of the Bruce Highway, will be developed first, with Open Cut 1 to the south of the highway commencing operations approximately 9 years later. Production from the Project is expected to extend for a period of approximately 19 years, after which rehabilitation and mine closure activities will occur.

The layout of key Project infrastructure is presented in **Figure 1-2**. For a detailed description of the Project, reference should be made to the Supplementary Environmental Impact Statement (SEIS), Chapter 1 – Project Introduction and Description.

Figure 1-1: Map showing location of the Project Area

Figure 1-2: Location and scale of key infrastructure associated with the Project



1.2 Summary of Impact Assessment Process to Date

The Project will be developed and operated by Central Queensland Coal and Fairway Coal, associates of Waratah Coal Pty Ltd. On 16 December 2016, Fairway Coal submitted an application to the Queensland Department of Environment and Science (DES) to undertake a voluntary Environmental Impact Statement (EIS) under the *Environmental Protection Act 1994*, which was subsequently approved on 27 January 2017.

The Project was deemed to be a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) on 3 February 2017, following referral to the former Commonwealth Department of the Environment (EPBC 2016/7851). The bilateral agreement between the Commonwealth and Queensland Governments is being used to facilitate assessment of the Project under Part 8 of the EPBC Act.

Draft Terms of Reference for the EIS were prepared under the *Environmental Protection Act 1994* and placed on public exhibition alongside an Initial Advice Statement. The final Terms of Reference were issued by DES on 4 August 2017. Following the completion of baseline technical studies and associated assessments, the EIS (CDM Smith 2017) was prepared in accordance with the final Terms of Reference.

The EIS was made available for public comment and review for the period from 6 November 2017 to 18 December 2017, during which a total of 34 properly made submissions were received. Following the receipt of regulatory comments, an SEIS (v1) was prepared and resubmitted to DES in May 2018. Additional regulator comments were received by the proponent in June 2018, and a revised SEIS (v2; CDM Smith 2018) was prepared and submitted to DES in December 2018, providing additional information on the Project and its environmental impacts. Final regulator comments on the SEIS v2 were received by the proponent in June 2019.

There were several matters identified in the regulator comments of June 2019 that required further technical investigations, involving the disciplines of groundwater, surface water, Groundwater Dependent Ecosystems (GDEs), aquatic ecology, marine ecology, the Great Barrier Reef (GBR), terrestrial ecology, offsets and social impacts. Comments generally related to uncertainties associated with the predicted effects of the Project on existing groundwater and surface water conditions, and the subsequent effects on related ecological values.

Orange Environmental was engaged by Central Queensland Coal to amend the SEIS (v3) and initiate extensive additional technical studies in key discipline areas to address outstanding comments of regulatory agencies. Such work involved a new and comprehensive range of groundwater and surface water modelling, which underpinned the reassessment of Project impacts on ecological values. A multi-disciplinary team of technical specialists was assembled to address the outstanding comments of regulatory agencies and to prepare updates to the SEIS material (v3), for submission to DES in August 2020.

1.3 Purpose and Scope of this Report

Eco Logical Australia was engaged by Central Queensland Coal on the advice of Orange Environmental to provide an updated assessment of Project impacts for the disciplines of GDEs, aquatic ecology, marine ecology and the GBR. The scope of work included the review of previously submitted Project material, review of comments from regulatory agencies, review of information associated with additional technical studies (including new groundwater and surface water modelling), and completion of an assessment of environmental impacts to address the outstanding comments of regulatory agencies for the above-mentioned discipline areas.

This Technical Report provides the results of additional assessments of Project impacts on ecological values related to GDEs, aquatic ecology, marine ecology and the GBR. The report has been drafted to be read in a standalone capacity, and has therefore included a brief summary of previous work and other information that is contained within the previously submitted EIS and SEIS's. In addition, this report will be used to inform updates to several chapters of the SEIS, incorporating the new information, analyses and assessments.

2. Methods

2.1 Nomenclature and Terminology

The Study Area for the impact assessment encompasses all areas that may be potentially impacted directly and indirectly by the Project, including adjacent terrestrial and aquatic lands and waters that may be affected by groundwater drawdown. The Study Area includes the mining tenures, adjacent watercourses, terrestrial areas containing aquatic habitats (e.g. wetlands), and estuarine and marine environments located downstream of the proposed mine, including the intertidal and subtidal areas of Broad Sound and the GBR.

The Disturbance Area is also referred to in this report, and includes the area that will be directly disturbed by construction and operation of the mine. The Disturbance Area includes all mine pits, roads, infrastructure, dams and associated constructed facilities. The Project Area generally refers to the mining leases (ML80187 and ML700022) and the surrounding local areas.

The assessment of potential Project impacts on GDEs has followed the method outlined in the GDE Toolbox (Richardson *et al.* 2011), which is derived from descriptions in Clifton *et al.* (2007) and Tomlinson (2011). The assessment has also been guided by an Explanatory Note on GDEs released by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (Doody *et al.* 2019), and the Queensland Government EIS Guideline for GDEs (Queensland Government 2019a).

GDEs are defined as ecosystems that require access to groundwater to meet all or some of their water requirements in order to maintain the communities of plants and animals, ecological processes they support, and ecosystem services they provide.

Consistent with the GDE Toolbox (Richardson *et al.* 2011) and IESC guidelines (Doody *et al*. 2019), three classes of GDEs have been adopted for the assessment:

- Subterranean GDEs. These aquifer and cave ecosystems (also known as Type 1 GDEs) provide unique habitats for living organisms, such as stygofauna and troglofauna. These ecosystems typically include karst aquifer systems, fractured rock and saturated sedimentary environments. The hyporheic zones of rivers, floodplains and coastal environments are also included in this category.
- Aquatic GDEs. These are ecosystems dependent on the surface expression of groundwater (also known as Type 2 GDEs). They include wetlands, lakes, seeps, springs, river baseflow, coastal areas and estuaries that constitute brackish water and marine ecosystems. In these situations, groundwater provides water to support aquatic biodiversity by providing access to habitat and regulation of water chemistry and temperature.
- Terrestrial GDEs. These are ecosystems dependent on subsurface presence of groundwater (also known as Type 3 GDEs). They include terrestrial vegetation that depends on groundwater fully or on a seasonal or episodic basis in order to prevent water stress and generally avoid adverse impacts to their condition. Groundwater in these cases is generally not visible on the surface. These types of ecosystems can exist wherever the water table is within the root zone of the plants, either permanently or episodically.

Further explanation of key terms utilised in the description of GDEs and associated impact assessment are provided in **Section 6.1**.

The term 'migratory shorebird' is used in this report to describe a shorebird that migrates to Australia from other parts of the world. There are 37 international migratory shorebird species that regularly visit Australia each year (DoEE 2017). While Australia has additional species of shorebird that are listed as 'Migratory' under the EPBC Act, they migrate within Australia and are not referred to as migratory shorebirds within this report.

2.2 Location and Scale of Assessment

The locations of the Study Area and Project Area for the impact assessment are shown in **Figure 2-1**. Ecological values located within the Study Area relevant to GDEs, aquatic ecology, marine ecology and the GBR are summarised in **Table 2-1**. The Study Area includes freshwater creeks, wetlands and their associated vegetation assemblages, estuarine environments, and the marine waters of Broad Sound and the GBR.

The scale of the impact assessment was determined to encompass all areas of direct impact (physical disturbance), as well as indirect impacts from the following potential modes of impact:

- Groundwater drawdown, affecting ecological values dependent on groundwater
- Discharge of contaminants to waterways, affecting water quality and ecological values downstream
- Changes to hydrological flows, affecting the location, accessibility and nature of instream aquatic habitats, and the location of the interface between fresh and salt water environments
- Erosion of catchments and stream banks, causing increased sediment discharges to aquatic systems and sediment deposition within Broad Sound and GBR.

The tidally-influenced sub-catchments of the Styx River catchment, located downstream of the confluence of Tooloombah Creek and Deep Creek, are dynamic hydrological environments where freshwaters derived from runoff from terrestrial areas mix with marine waters. This provides brackish to saline conditions that are markedly different from the higher sub-catchments.

The assessment of impacts on values located downstream of the Project, and in areas adjacent to the Project Area due to groundwater drawdown, has been informed by the results of surface water (hydrological) and groundwater modelling and associated conceptualisation of water movement across the Study Area. A study of surface water and groundwater interactions has also been undertaken, informed by the results of geological coring. Studies of geomorphology and sediment runoff to downstream areas have also informed the impact assessment. Further details of technical studies commissioned to support the updated impact assessment are provided in **Section 2.3.2**

Figure 2-1: Map showing the geographic scale of the impact assessment

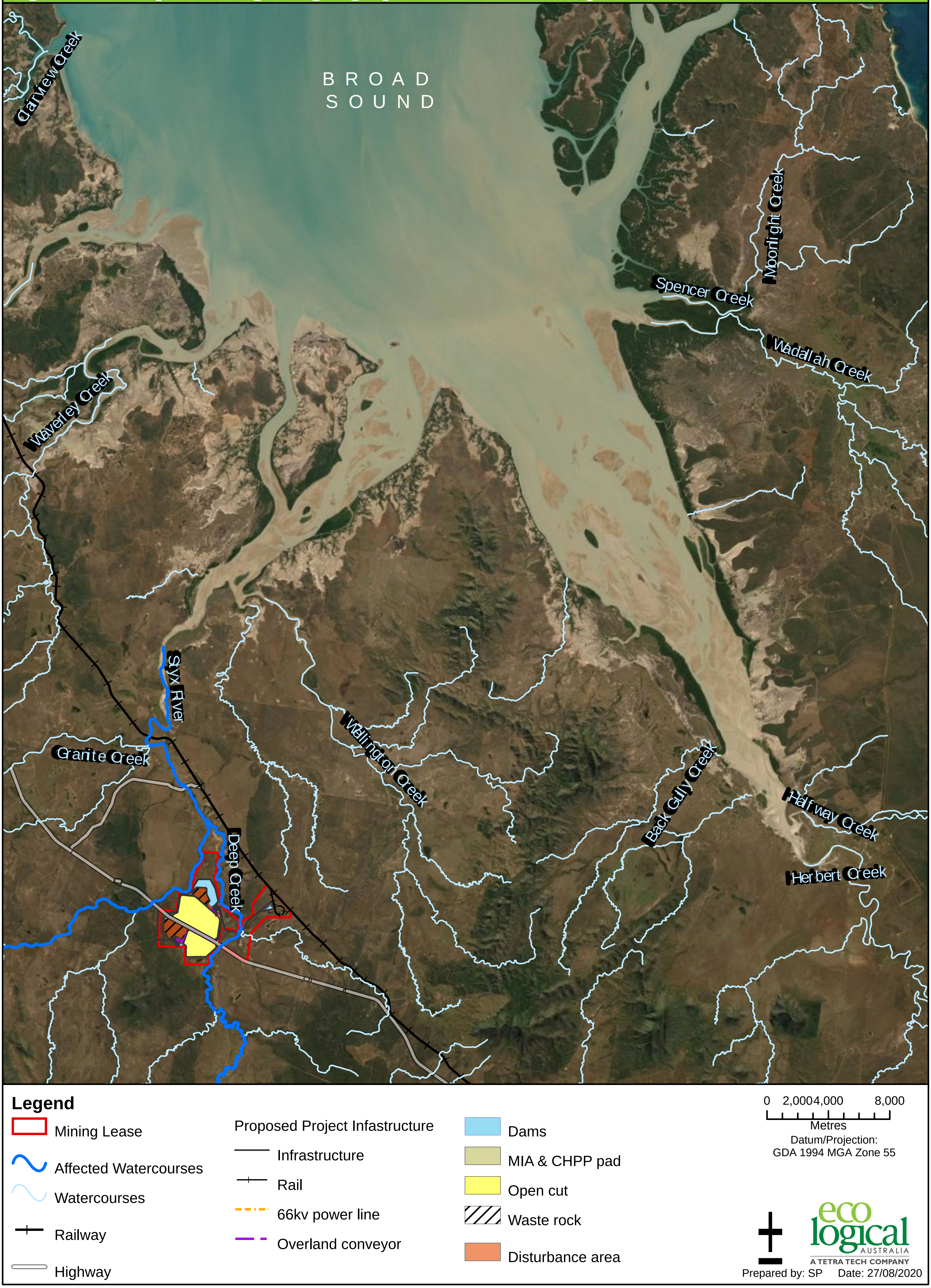


Table 2-1: Location and nature of ecological values considered with the Study Area

Description	Values	Location
Freshwater watercourses and associated aquifers Brackish watercourses Marine watercourses	Riparian vegetation, aquatic fauna habitat, aquatic fauna, groundwater fed creeks (Aquatic GDEs), waterways providing fish passage, fisheries, stygofauna (Subterranean GDEs)	Deep Creek, Granite Creek, Tooloombah Creek, Styx River and Barrack Creek
Marine and estuarine waters	Fish Habitat Area, Great Barrier Reef Marine Park, Great Barrier Reef World Heritage Area, migratory shorebird habitat, marine fauna habitat, fisheries, Directory of Important Wetlands	Broad Sound
Groundwater fed wetlands	Aquatic fauna habitat	Mining Lease and adjacent areas
Freshwater wetland (not groundwater fed)	Aquatic fauna habitat, mapped High Ecological Significance wetland	Mining Lease and adjacent areas
Terrestrial vegetation dependent on Groundwater	Terrestrial fauna habitat, Terrestrial GDEs	Mining Lease and adjacent areas

2.3 Available Information

The impact assessment has drawn upon numerous scientific studies of the ecological values of the Study Area, which includes work to inform the EIS and SEIS's, in addition to new work completed in the period 2019 – 2020. These information sources are summarised in the following sections.

2.3.1 Previous studies – EIS and SEIS

Previous baseline studies used to support the preparation of the EIS and SEIS's are summarised in **Table 2-2**. They include surveys of vegetation, aquatic fauna, water quality, stygofauna, wetlands, GDEs and groundwater quality.

Table 2-2: Summary of previous assessments and surveys in and around the Study Area

	Study	Description	Survey timing
1.	Oberonia Botanical Services & Ed Meyer 2011	Conducted for the earlier version of the proposed project. Flora and fauna surveys during both the wet season and dry season. Vegetation assessment, RE identification and targeted surveys for listed species.	21 – 25 March 2011 & 25 -29 September 2011 (5 days × 2)
2.	CDM Smith 2018	Conducted for the earlier version of the proposed project. Water quality sampling and monitoring of surrounding waterways (Tooloombah Creek, Deep Creek and Styx River).	Eight sampling events between June 2011 and March 2012 (18 days in total)
3.	ALS Water Science 2011	Comprehensive aquatic ecology survey for the earlier version of the proposed project.	1 – 6 June 2011 (6 days)
4.	ALS Water Science 2010, GHD Water Sciences 2012	Conducted for the earlier version of the proposed project. Two targeted stygofauna surveys within local and Project associated groundwater bores	21 – 24 November 2011 & 15 – 18 March 2012 (4 days × 2)

	Study	Description	Survey timing
5.	Ed Meyer 2012	Conducted for the earlier version of the proposed project. Targeted threatened fauna survey focussing on confirming presence of listed species.	7 – 10 February 2012 (3 days)
6.	CDM Smith 2018	Conducted for Project EIS. Surface water assessments including flow conditions, bank stability, water depth and water quality.	Monitoring of 11 sites between February 2017 – October 2018
7.	CDM Smith and Terrestria 2018	Conducted for Project EIS. Wet season flora survey of the ML and surrounding area. Assessed quality of vegetation communities and whether communities present aligned with RE mapping. Focussed on the boundary of the ML and potential infrastructure locations.	8 – 10 February 2017 (3 days)
8.	CDM Smith 2018	Conducted for Project EIS. Targeted wet season fauna survey of the ML and surrounding area. Focussed on confirming presence of listed species.	8 – 13 February 2017 (6 days)
9.	CDM Smith 2018	Conducted for Project EIS. Aquatic ecology survey and habitat assessment, focussing on freshwater sites previously surveyed in 2011.	11 – 13 February 2017 (3 days)
10.	CDM Smith 2018	Conducted for Project EIS. Surveys of freshwater turtles at Deep Creek and Tooloombah Creek waterholes.	June & September 2017
11.	CDM Smith 2018	Conducted for Project SEIS. Targeted vegetation survey and assessment of wetland flora located in wetlands within the Project Area	January 2018
12.	CDM Smith 2018	Conducted for Project SEIS. Broad assessment of groundwater dependent ecosystems associated with the proposed Project	February 2018
13.	CDM Smith 2018	Conducted for Project SEIS. Assessment of the relationship between surface water and groundwater in the area. Analysed radon isotopes and the stable isotopes in water samples collected from Deep Creek and Tooloombah Creek	July 2018
14.	3D Environmental	Conducted for Project SEIS. Vegetation mapping and habitat quality assessment in relation to offset requirements for the proposed project.	July – August 2018
15.	3D Environmental	Targeted assessment of groundwater dependent ecosystems associated with the proposed Project. Specifically, analysed tree water use to determine reliance on groundwater.	August – September 2018
16.	CDM Smith 2018	Flooding and stormwater drainage assessment. Field surveys were undertaken as part of this assessment. Produced a hydraulic model	N/A

2.3.2 New information

Several new technical studies have been completed in the period 2019 to 2020, to provide a detailed understanding of the potential impacts of the Project on key ecological values. These studies are summarised in **Table 2-3**, with full technical reports available in the SEIS v3 documentation.

Table 2-3: Summary of new assessments and surveys in and around the Study Area

Study Reference / Author	Description and Relevance
3D Environmental (2020)	Results of field investigations into the groundwater dependence of vegetation communities within the Study Area. The report includes the results of

Study Reference / Author	Description and Relevance
	investigations into leaf water potential, core drilling, soil moisture potential and stable isotope analysis of twig moisture. Key locations of field investigation included Wetland 1, Wetland 2, and sections of the Tooloombah Creek and Deep Creek riparian zones.
Hydro Algorithmics (2020)	Regional groundwater model considering the existing hydrogeological values and predicted changes associated with Project activities. Provides predictions on changes to the existing hydrogeological regime in response to the Project, which can inform an assessment of impacts on GDEs.
WRM (2020)	Studies of existing surface water values, including a water balance for the proposed mine, and modelling predicting the effects on the Project on surface water flows, volumes and water quality. Provides predictions on changes to the existing hydrological regime in response to the Project, which can inform an assessment of impacts on GDEs, aquatic ecology values, marine ecology values and the GBR.
Fluvial Systems (2020)	Study describing the existing geomorphological values and processes of the Study Area, with discussion of likely impacts including from erosion. This information is relevant to the assessment of impacts on GDEs, aquatic ecology values, marine ecology values and the GBR.
ELA (2020a)	Groundwater – Surface Water Integrated model providing estimation of water fluxes in the alluvial corridors of the study area. This information is relevant to the assessment of impacts on GDEs.
Engeny (2020a)	Sediment budget for the Project, describing the increases and decreases in sediment discharges to water arising from Project activities including offsets, and the net sediment discharges to the GBR. This information is relevant to assessing the effects of the Project on sediment discharges to the GBR, and the net benefit or impact of the Project in relation to sediment inputs to the GBR.
Allen (2019)	Agricultural Transient Electromagnetic System (AgTEM) study of the hydrological properties of the Project Area. This provides information on the nature, location and depth of water at various depths across the Project Area. The information is relevant to assessing potential water resources for GDEs and their suitability for use by plants (e.g. salinity).
Orange Environmental (2020)	Surface water and groundwater monitoring results from the Study Area since 2018. This information provides comprehensive data on the baseline environmental conditions to inform an updated impact assessment.
Central Queensland Coal (2020a)	Bore hole investigations of the geological properties sediments up to 20 deep in transects across Tooloombah Creek and Deep Creek. Data collected has informed assessments of the permeability of the alluvium and associated risks to GDEs from groundwater drawdown.
Astrebla (2019), C02 Australia (2019) and 3D Environmental (2019)	Field data collected September to November 2019 on location and type vegetation communities in the Study Area, including offset areas. Data were utilised to update vegetation mapping for the Study Area, where ground-truthed vegetation differed from that provided in State mapping.
Austecology (2020)	Describes the results of fauna surveys conducted in the Study Area during 2019. Includes an assessment of impacts of the Project on threatened fauna species, including those that utilise groundwater dependent vegetation, such as Koala and Greater Glider.

2.4 Impact Assessment Method

2.4.1 Overview

The impact assessment method utilised for the Project is described in Chapter 1 of the SEIS v3, and follows the approach specified in the *Environmental Protection Act 1994* and the Project Terms of Reference. To quantify the potential for an impact to cause harm, a risk analysis was undertaken using the AS/NZS IS031000 criteria.

The risk assessment sought to define the risks of any adverse outcome and was informed by identifying hazards, consequences and likelihoods. A level of risk has been determined through rating of the likelihood (**Table 2-4**) and consequence (**Table 2-5**) of a hazard occurring. The risk assessment process was completed on both unmitigated and residual (mitigated) risks. The risk matrix is provided in **Table 2-6**.

Table 2-4: Ratings for likelihood of occurrence

Probability Rating	Probability	Description#
1	Almost certain	Will almost certainly occur. Has a 95% or greater chance of occurring.
2	Likely	Probably will occur. Has a 70% to 95% chance of occurring.
3	Possible	May possibly occur. Has a 30% to 70% chance of occurring.
4	Unlikely	Could possibly occur. Has a 5% to 30% chance of occurring.
5	Rare	Only likely to occur in exceptional circumstances. Has a 5% or less chance of occurring.

modified from the SEIS criteria to delete "within a 12 month period", as the impacts of groundwater drawdown may occur over time intervals of more than 12 months.

Table 2-5: Consequence ratings

Score	Description	Maximum potential consequence (realistic) - Environment
1	Catastrophic	Significant, extensive detrimental long term impact.
2	Major	Widespread long to medium term damage to valued area
3	Moderate	Localised medium term damage to an area of local value
4	Minor	Localised short to medium term damage to an area of minor local significance
5	Insignificant	Limited damage to a localised area. No lasting effects.

Table 2-6: Risk Assessment Matrix

Likelihood	Consequence				
	Catastrophic 1	Major 2	Moderate 3	Minor 4	Insignificant 5
Almost certain 1	Extreme	Extreme	Extreme	High	Medium
Likely 2	Extreme	Extreme	High	Medium	Medium

Likelihood	Consequence				
	Catastrophic 1	Major 2	Moderate 3	Minor 4	Insignificant 5
Possible 3	Extreme	High	High	Medium	Low
Unlikely 4	High	High	Medium	Low	Low
Rare 5	Medium	Medium	Low	Low	Low

Risk levels relevant to environmental impacts are defined as follows:

- Extreme – works must not proceed until suitable mitigation measures have been adopted to minimise the risk
- High – works should not proceed without consideration of alternative options or additional controls to minimise the risk. A documented action plan is required
- Medium – Acceptable with formal review. A documented action plan is required
- Low – Acceptable with review.

The risk assessment was applied in conjunction with standard techniques for impact assessment as described for each discipline in the following sections.

2.4.2 Groundwater Dependent Ecosystems

The impact assessment for GDEs was informed by the results of revised modelling completed for surface water (WRM 2020), groundwater (HydroAlgorithmics 2020) and a study of water movement in the alluvial corridor (ELA 2020a), with a particular focus on the influence of groundwater drawdown on the:

- Presence of habitat suitable for stygofauna (Subterranean GDEs)
- Supply of groundwater to creek systems, which sustains some pools of water during the dry season (Aquatic GDEs)
- The presence and persistence of aquifers (either perched above the water table, or within the saturated zone) of the riparian corridor and at wetlands. These sources of water support some aspects of vegetation communities and their associated fauna assemblages (Terrestrial GDEs).

General information utilised for the impact assessment on GDEs is also summarised in the Central Queensland Coal Project SEIS v3 (Central Queensland Coal 2020b), specifically Chapter 10 - Groundwater, Chapter 15 - Aquatic and Marine Ecology, and the associated technical reports which form appendices to the SEIS v3. Studies described in the previous version of the SEIS (v2) were also considered. However, this information was used cautiously, with priority given to the newer and more comprehensive studies undertaken in 2019 and 2020.

The Independent Expert Scientific Committee (IESC) on coal seam gas (CSG) and large coal mines (LCM) have released explanatory notes to describe the process for assessing potential risks to GDEs (Doody *et al.* 2019). These guidelines provide a framework for assessing impacts to GDEs from large coal mining projects and have been applied in conjunction with the risk assessment protocol summarised in **Section 2.4.1**. A summary of how the Guidelines have been applied is provided in **Appendix A**.

Potential impacts of the Project on Subterranean and Aquatic GDEs were considered by examining the predicted effects of the Project on groundwater levels and quality (HydroAlgorithmics 2020), and assessing the likely implications for ecological values associated with GDEs. As stygofauna are reliant on the presence of aquifers, and Aquatic GDEs are reliant on the surface expression of groundwater, such considerations were relatively straight forward and based on the ecological implications of predicted modelling results of WRM (2020) and HydroAlgorithmics (2020), in conjunction with studies of groundwater – surface water interactions completed by ELA (2020a).

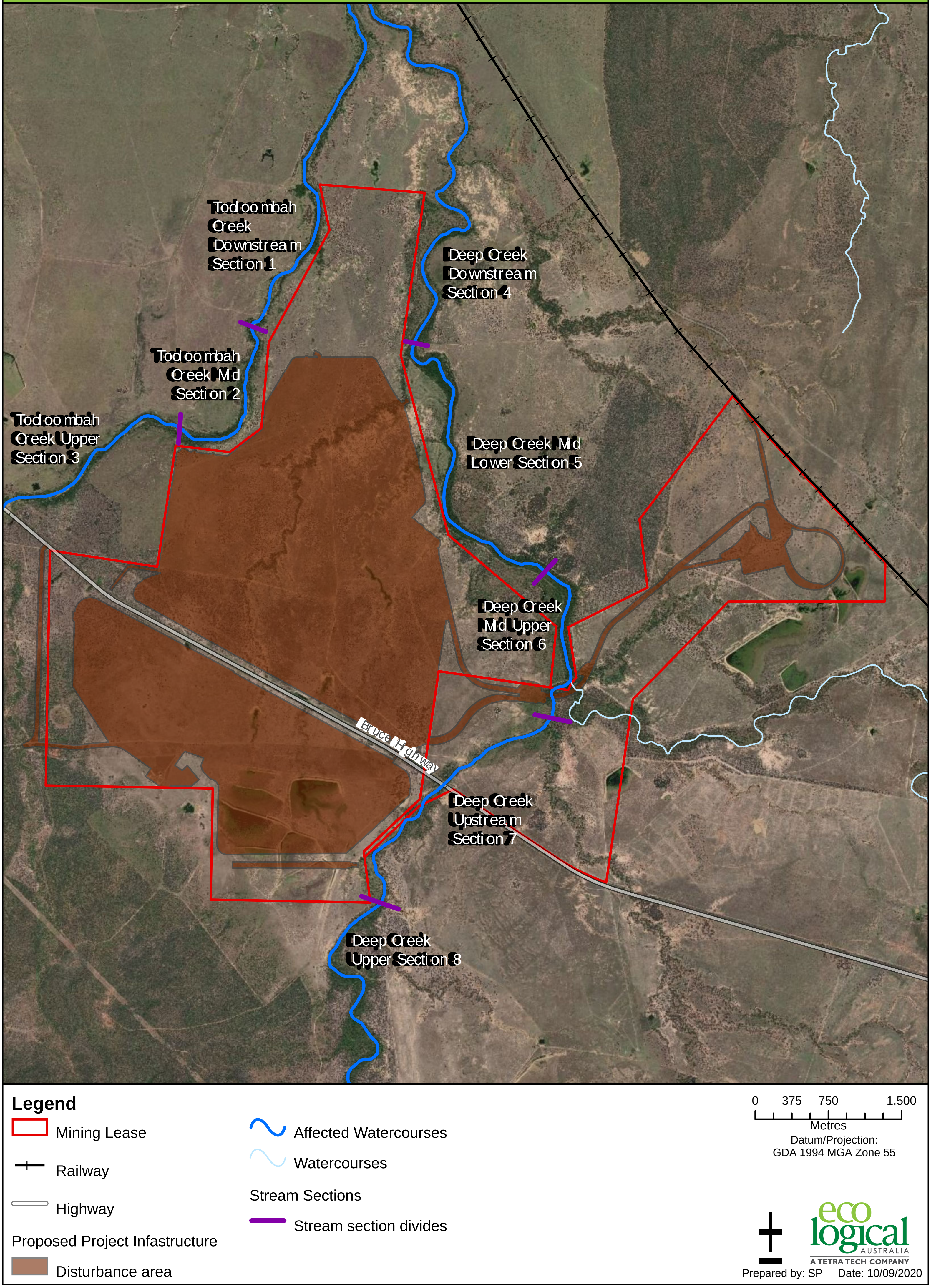
For Terrestrial GDEs, the impact assessment was more complex, as vegetation can fulfil its water requirements from multiple sources, including rainfall, stream flooding and groundwater. Assessment of the likely impacts of the Project on Terrestrial GDEs therefore considered a range of factors including:

- Predicted groundwater drawdown in metres (HydroAlgorithmics 2020) in localities where riparian vegetation occurs
- Existing groundwater level and quality (from nearby shallow aquifer bores), and therefore the suitability of groundwater for use by vegetation (Orange Environmental 2020)
- The results of TEM studies which examined the distribution of various water and geological layers throughout the soil profile of riparian areas (Allen 2019), and provided some insight into the permeability of sediments underlying the riparian zone
- The tolerance of tree species present within the riparian zone to various natural and Project-induced stressors (3D Environmental 2020; **Section 6.7.4**)
- Predicted changes to surface water flows and the frequency and duration of flood events, which may recharge stream bank water sources for riparian vegetation (WRM 2020)
- The results of boreholes drilled in transects across sections of the Tooloombah Creek and Deep Creek riparian zone, which describe the geological features of the alluvial zone and provide the results of laboratory analysis of the physical properties of alluvial sediments (Central Queensland Coal 2020a).

Tooloombah Creek and Deep Creek were divided into several stream sections with similar environmental characteristics and predicted exposure to groundwater drawdown, to facilitate a risk assessment for each stream reach (**Figure 2-2**). A series of technical workshops was convened involving specialists in the fields of groundwater, GDEs, impact assessment, geology and botany. Potential impacts of the Project were discussed and agreed, based on the collated Project information of ecological, geological and hydrogeological features.

A risk assessment was completed for each stream reach, taking into account all of the available information. As the effects of groundwater drawdown on vegetation can vary in scale, the likelihood of several scales of impact was considered for each stream reach, ranging from minimal (<10%) change to vegetation attributes, through to loss of structural integrity and ecological function of the riparian vegetation community. Further explanation of the assessment method and the field data that informed the assessment is provided in **Section 6.7**.

Figure 2-2: Location of stream sections that were subject to impact assessment for Terrestrial GDEs



2.4.3 Aquatic Ecology

The impact assessment for aquatic ecology was informed by the results of new modelling completed for surface water (WRM 2020), groundwater (HydroAlgorithmics 2020) and the riparian corridor (ELA 2020a) with a particular focus on the following modes of potential impact on aquatic ecology values:

- Changes in the natural flow regime of waterways, resulting in less or more water in the system and available to aquatic organisms and habitats
- A reduction in the size, location and persistence of pools within waterways during the dry season, as a result of groundwater drawdown
- Changes to the quality of water and other habitat features within aquatic habitats (e.g. structural integrity of stream banks, presence of woody debris, shading from riparian vegetation providing regulation of water temperature).

General information utilised for the impact assessment is also summarised in Central Queensland Coal Project SEIS v3 (Central Queensland Coal 2020b), specifically Chapter 9 - Surface Water, Chapter 15 - Aquatic and Marine Ecology, and relevant appendices. Studies described in the previous version of the SEIS (v2), including the results of field studies, were also considered. However, this information was used cautiously, with priority given to the newer and more comprehensive studies undertaken in 2019 and 2020.

For each potential mode of impact, the relevant sensitive receptors were identified from baseline studies. These generally included macroinvertebrates, fish and freshwater turtles, plus their associated habitat features, which were considered in the impact assessment using the method described in **Section 2.4**.

A desktop review was conducted on 17 February 2020 to obtain contemporary background information relating to the potential presence of aquatic ecological values. Details of the desktop review are provided in **Table 2-7**, and supplemented the desktop studies completed as part of the previous SEIS v2.

Table 2-7: Desktop searches undertaken to inform presence of aquatic values

Search	Relevant legislation	Search details
Mapping for MSES (Department of Environment and Science)	Environmental Offsets Regulation 2014	Whole of tenure
Aquatic Conservation Assessment (Department of Environment and Science)	None	Whole of tenure
Map of Great Barrier Reef wetland protection areas (Department of Environment and Science)	Environmental Protection Regulation 2008	Each Lot Plan in tenure
Map of Queensland Wetland Environmental Values (Department of Environment and Science)	Environmental Protection (Wetland and Water Biodiversity) Policy 2019	Each Lot Plan in tenure
Protected Matters Search Tool (Department of Agriculture, Water and the Environment)	*Environment Protection and Biodiversity Conservation Act 1999*	50 km buffer around central coordinate (latitude -22.7055; longitude 149.6613)

Search	Relevant legislation	Search details
Wildlife Online (Department of Environment and Science)	*Nature Conservation Act 1992*	50 km buffer around central coordinate (latitude -22.7055; longitude 149.6613)

2.4.4 Marine Ecology and Great Barrier Reef

The assessment of Project impacts on marine ecology values and the GBR considered the potential impacts of the Project on estuarine and marine habitats located downstream of the Project Area. The assessment was informed by the results of the baseline surveys described in the SEIS v3 (particularly Aquatic Ecology and Surface Water chapters and technical reports), combined with the results of revised surface water modelling (WRM 2020) and a sediment budget for the Project by Engeny (2020a).

The following potential modes of impact were a focus of the impact assessment:

- An increase or decrease in the volume and frequency of flow events within waterways, resulting in either more or less water being discharged to the estuarine environment of Broad Sound
- Discharge of mine-affected water to Tooloombah Creek and Deep Creek, resulting in an increase in the concentration and load of some water quality parameters that could cause impacts to downstream estuarine and marine environments
- Project-related changes to sediment discharges from local catchments, including from erosion arising from mining activities and from changes in land use from existing grazing activities to a combination of mining and environmental offsets (comprising revegetation of disturbed areas, protection of fauna habitats and a cessation of grazing activities across large parts of the Study Area).

Potential impacts to the GBR Marine Park and World Heritage Area were considered in the context of relevant assessment and policy frameworks, including:

- Great Barrier Reef River Basins End-of-Basin Load Water Quality Objectives (Fitzroy NRM Region: Styx River Basin; Queensland Government 2019b)
- Styx River Basin Environmental Values and Water Quality Objectives (DEHP 2014)
- Water quality objectives set in model Environmental Authority conditions (DES 2017)
- ANZECC Water Quality Guidelines (2000, 2018)
- Queensland Water Quality Guidelines (DEHP 2014)
- The consistency of potential Project impacts with Marine Park Zoning and Fish Habitat Area objectives and management principles
- Potential impacts of the Project on the Outstanding Universal Value of the GBR World Heritage Area

3. Existing Environmental Values

This section summarises the key existing environmental values of the Study Area. Information presented in this section has primarily been summarised from the SEIS v3 (Central Queensland Coal 2020b) and is referenced therein. More detailed descriptions of environmental values relevant to this assessment are provided in **Sections 6 to 8**.

The Project is predominantly located within the Marlborough Plains subregion of the Brigalow Belt North bioregion. A small portion of the western ML and the Mount Bison Road realignment occurs in the adjacent Nebo-Connors Ranges subregion. The Marlborough Plains subregion is characterised by alluvial plains and colluvial slopes, with vegetation dominated by woodlands comprising Poplar Gum (*Eucalyptus platyphylla*), Ghost Gum (*Corymbia dallachiana*), Forest Red Gum (*Eucalyptus tereticornis*) and paperbarks (*Melaleuca spp.*).

The Brigalow Belt has been subject to significant clearing of remnant vegetation for grazing, agriculture and mining, resulting in a highly fragmented landscape. Most of the remaining vegetation occurs within the hills, rocky areas, roadside vegetation and riparian areas.

The Project Area is located within the Styx Basin, with the local area having a history of mining coal, minerals and semi-precious gems. Within the Styx Basin, there are two small scale coal mines (the Ogmore and Bowman collieries) that were in operation from 1919 to 1963. Lands within the Styx Basin are currently used predominantly for cattle grazing.

The Project Area contains:

- Strategic Cropping Land (land likely to be highly suitable for cropping)
- Several wetlands of varying size including:
    - Artificial wetlands; and
    - Two wetlands mapped as Matters of State Environmental Significance (MSES)
- A section of haul road and the Bruce Highway which intersects the site
- The lower catchment areas of Tooloombah Creek and Deep Creek (sub-catchments of the Styx River catchment).

The region experiences a tropical climate with a distinct wet season (December to March) and dry season (June to September). The average annual rainfall for the region is 759 mm (Strathmuir, BoM Station 033189) with February having the highest average rainfall (143 mm) and September the lowest (16 mm). Groundwater recharge and runoff potential is highest during the wet season, and significant weather events such as tropical cyclones or tropical lows can cause substantial rainfall and surface water catchment flows (when compared with long term averages).

The average annual evaporation is approximately 2,100 mm, averaging 240 mm for summer months and 105 mm for winter months (Rockhampton Aero, BoM Station 039083). Evaporation rates are therefore significantly higher than rainfall, with net evaporation occurring in every month of the year.

Widespread clearing of lands for cattle grazing within the Styx River Catchment has resulted in significant loss of native vegetation cover. However, the Study Area contains some national and state significant wetlands, as well as watercourses and ponds. The ephemeral Tooloombah Creek and Deep Creek border the Project Area on the west and eastern side respectively, meeting at a confluence to the north, and forming the Styx River approximately 8 km downstream of the Project Area.

A saline groundwater layer is generally present between 10 and 15 mbgl (HydroAlgorithmics 2020), and supplements drying pools of water within parts of Tooloombah Creek and Deep Creek. Aquatic habitats are present for a range of freshwater fauna types, including stygofauna, macroinvertebrates, fish and freshwater turtles. Riparian corridors are largely intact, and consist of a narrow band of vegetation dominated by Forest Red Gum (*Eucalyptus tereticornis*) and Melaleucas (*M. leucadendra* and *M. fluviatilis*; 3D Environmental 2020). However, these riparian areas are also subject to significant levels of physical disturbance from cattle grazing, with extensive trampling of riparian zones and stream banks by cattle. There is also a high abundance of weeds along drainage lines. Rubber vine (*Cryptostegia grandiflora*) and lantana (*Lantana camara*) are common, often forming dense infestations (up to 4 m in height; Austecology 2020), which reduces the quality of existing ecological values.

The Styx River catchment discharges directly into Broad Sound Wetland, which is listed in the Directory of Important Wetlands of Australia and contains Australia's largest Fish Habitat Area, declared under the Queensland *Fisheries Act 1994*. This wetland forms part of the GBR Marine Park and World Heritage Area, and lies adjacent to Shoalwater Bay. Estuarine and marine habitats located downstream of the Project Area provide habitat for fish, sharks, turtles, dugong and migratory shorebirds, while also contributing to the Outstanding Universal Value (OUV) of the GBR.

An introductory overview of values is provided in **Table 3-1**. Detailed descriptions of ecological values associated with GDEs, aquatic ecology, and downstream marine environments including the GBR are provided in **Sections 6 to 8**. For details of other existing environmental values, reference should be made to relevant sections of the SEIS v3 (Central Queensland Coal 2020b).

Table 3-1: Overview of environmental values considered in this assessment

Feature	Overview of values relevant to the Project
Groundwater dependent ecosystems	There are a number of GDEs within the Project Area, corresponding to Subterranean, Aquatic and Terrestrial GDEs (Doody *et al.* 2019), and Type 1, 2 and 3 GDEs (as per the GDE Toolbox, Richardson *et al.* 2011) Subterranean GDEs (Type 1) Stygofauna have been collected from two locations within the Project Area and transient electromagnetic surveys indicate a lens of fresh groundwater overlying saline water in the alluvial aquifers, making it possible that stygofauna occur through much of the Styx River alluvium from the proposed mine north to the coastal margins. Aquatic GDEs (Type 2) A number of pools are present throughout Deep and Tooloombah Creeks and some of these are thought to be groundwater fed to an extent. The dominant water source of pools is surface flows during the wet season, however groundwater inputs are likely to contribute water to some pools during periods of low/no flow. Mapped wetlands (Wetlands 1 and 2) have been investigated and found to be sourced by surface water runoff, rather than groundwater (and are therefore not Aquatic GDEs). There are no known springs within the Project Area. Terrestrial GDEs (Type 3) A number of vegetation communities in the Project Area have the potential to be groundwater dependent. These occur primarily as riparian vegetation along Deep and Tooloombah Creeks, as well as vegetation associated with wetland areas.

Feature	Overview of values relevant to the Project
	Groundwater dependency in riparian and wetland vegetation is likely to be variable across the Project Area, influenced both by depth to groundwater and groundwater salinity. See **Figure 6-2** for locations of values.
Aquatic ecology	Deep Creek and Tooloombah Creek are ephemeral creeks with incised channels and predominantly sand or rocky beds. Aquatic habitat is variable throughout the creeks, with pools common, though drying out or becoming isolated during periods of low rainfall. Most sites along the creeks have multiple physical habitat features, indicating a robust environment for aquatic fauna and a healthy ecosystem. Aquatic fauna includes diverse native fish communities, freshwater turtles and macroinvertebrate taxa that are tolerant of poor water quality and periods of static or low flow. Waterways providing fish passage are mapped across the Project Area and there are two important wetlands. Wetland 1 is a Wetland of High Ecological Significance, and a Wetland Protection Area. Wetland 2 is a Wetland of General Ecological Significance. See **Figure 7-1** for locations of values.
Marine environment	The upstream tidal limit is defined as the point to which the high spring tide ordinarily flows (mean high water spring), or the downstream limit of a watercourse under the *Water Act 2000* (as identified in the *Coastal Protection and Management Act 1995*). This point is mapped approximately 3.7 km downstream of the Project Area. Coastal waters are defined under the *Coastal Protection and Management Act 1995* as extending to the limit of highest astronomical tide, which is at the confluence of Deep Creek and Tooloombah Creek. As such, a tidal transition zone occurs between 2.3 to 3.7 km downstream of the Project Area (Central Queensland Coal 2020b)From here, the Styx River estuary flows into Broad Sound, an extensive coastal embayment within the Great Barrier Reef World Heritage area. There are a number of important environmental values in the downstream marine area, including: Broad Sound Wetland, listed on the Directory of Important Wetlands (DIWA) Broad Sound Fish Habitat Area The Great Barrier Reef World Heritage Area The Great Barrier Reef Marine Park and Great Barrier Reef Coast Marine Park Habitat for marine species and communities, including marine plants and listed threatened and migratory species A number of sites within Broad Sound that are considered to be of national and international importance for migratory shorebirds. See **Figure 8-1** and **Figure 8-2** for locations of values.

4. Potential Impacts of the Project

This section describes the key potential impacts of the Project on the ecological values identified in **Section 3**. As several potential impacts are common to multiple values, key potential impacts are discussed in this section in general terms, and are carried forward to the risk assessment for each value in **Sections 6 to 9**. For some values, more detailed and specific consideration of potential impacts is also included (in addition to the key potential impacts), and incorporated into the value-specific risk assessments.

4.1 Overview

If left unmitigated, the Project has the potential to impact on a range of environmental values including, but not limited to:

- Remnant vegetation including Terrestrial GDEs and riparian communities associated with watercourses
- Wetlands, stream habitats, Subterranean and Aquatic GDEs and associated habitat for aquatic flora and fauna
- Aquatic ecosystems, including animals and plants located in or adjacent to the marine, estuarine, and fresh waters
- The Broad Sound Fish Habitat Area and fish habitats generally
- The GBR including the World Heritage Area and Marine Park areas.

Impacts from the Project can be broadly grouped as direct impacts within the Project Area and indirect impacts at associated downstream or adjoining locations (potentially affected by surface water runoff or changes to groundwater level and quality).

Each potential impact is discussed in further detail in the following sections. Discussion of mitigation measures that will be implemented to manage impacts is provided in **Section 5**.

4.2 Direct disturbance of vegetation and habitat

4.2.1 Riparian vegetation

The Project will require the clearing of some remnant vegetation during the construction phase, to facilitate the development of Project infrastructure. While the vast majority of riparian vegetation in the vicinity of the Project will not be cleared, there will be some clearing required to facilitate the construction of new mine infrastructure. Remnant riparian vegetation to be cleared may comprise GDEs and may also provide aquatic fauna habitat. Additionally, ecosystem services provided by riparian vegetation may include the shading of surface water which regulates temperature and photosynthesis, enhancement of bank stability from tree roots, and inputs of leaf litter, woody debris and fruits to instream waters, providing a source of food and shelter for aquatic organisms.

Apart from the haul road crossing over Deep Creek, clearing to facilitate the mine infrastructure will not directly impact Tooloombah Creek or Deep Creek. However, the construction of Project infrastructure will require the permanent removal of approximately 66% of a tributary of Deep Creek that runs through the centre of the mining lease, including some riparian vegetation (**Section 7.1.4**). Access tracks and other Project infrastructure may impact directly on aquatic habitats where infrastructure crosses or is located in close proximity to waterways.

4.2.2 Waterway barrier works and disruptions to fish passage

There are several waterways within and adjacent to the Project Area that are mapped according to the Department of Agriculture and Fisheries spatial data layer 'Queensland waterways for waterway barrier works'. They include a series of ephemeral drainage lines that will be permanently impacted by the Project, through construction of mining infrastructure, resulting in disruptions to fish passage.

Aquatic habitat connectivity may also be disturbed by the obstruction or movement of aquatic fauna across Deep Creek and Barrack Creek as a result of the haul road crossing. Where haul roads cross drainage gullies or Deep Creek, an appropriately sized culvert or bridge will be provided to allow for fish passage where relevant. Suitable waterway barrier designs will help to maintain habitat connectivity. Groundwater drawdown (**Section 4.3**) also has the potential to reduce connectivity along waterways, causing streams to dry up faster during the dry season than occurs under baseline conditions.

4.3 Groundwater drawdown

Mine dewatering and depressurisation will result in the depletion of groundwater storage, causing groundwater drawdown, especially in water tables near to the proposed mine. This may impact on GDEs by isolating them either from aquifers permanently, or at critical life stages. River baseflow systems and groundwater dependent wetlands can become dry, and terrestrial vegetation that once utilised aquifer water, can begin to show signs of stress if groundwater levels fall too low (Doody *et al.* 2019).

Large areas of dewatering have been modelled for the Project Area, with drawdown contours extending within the broader Study Area below parts of Deep Creek, Tooloombah Creek and Barrack Creek (HydroAlgorithmics 2020). Within the alluvial aquifer (or aquifer associated with the water table), which is the aquifer of importance for GDEs, the model predicts water levels will fall by a maximum of approximately 60 m beneath Deep Creek, 4.7 m beneath Tooloombah Creek and 12.6 m beneath Barrack Creek.

Pit progression and associated drawdown will move in a south-easterly direction, and will affect Tooloombah Creek within the first three years of operation. Drawdown will not extend below Deep Creek until the period three to five years after Project commencement. At its maximum extent, a large part of the aquifer associated with the water table between Tooloombah Creek and Deep Creek will become dry. This will isolate much of the lower Styx alluvium from its upper reaches, and may result in ecological impacts.

Invertebrates that can confidently be classified as stygofauna were collected from two bores in the Styx River alluvium during baseline studies for the EIS. The bore containing four Parabathynellidae was located north of the Project lease (GHD 2012), where the aquifer is broad. An old windmill, just inside the western lease boundary, contained two Cyclopoida. It is likely that there are stygofauna in other sections of the Styx River alluvium where water has a low Electrical Conductivity (EC), and that dewatering of the aquifer as modelled, could isolate the extensive northern part of the aquifer from the more confined southern part.

Groundwater drawdown may potentially result in longer periods over which Deep and Tooloombah creeks are dry, and impact on their riparian vegetation and aquatic ecosystems. During the 2017-2018 monitoring period of EIS baseline studies, two pools on Tooloombah Creek, two pools on the Styx River, and five pools on Deep Creek were visited. The two Tooloombah Creek pools are likely to be groundwater-fed and would be affected by drawdown in the first three years of operation (WRM 2020; HydroAlgorithmics 2020). Two of the pools in Deep Creek are also potentially connected to the alluvial groundwater, and may be affected by groundwater drawdown. The Styx River is located downstream of the area affected by drawdown, so will not be affected.

While Tooloombah Creek and Deep Creek receive some input from groundwater, the vast majority of their flow comes from rainfall and associated runoff during wet periods (WRM 2020; HydroAlgorithmics 2020). This will remain the case during mining. Pools along the affected reaches will persist after rainfall, but may dry up quicker than they currently do in areas where groundwater connectivity is lost. However, most of the biota in these pools are adapted to living in ephemeral streams, reducing the risk of significant environmental impacts. The Styx River will remain an important source for recolonisation of ephemeral creeks located upstream during periods of flow and connectivity.

The health of Forest Red Gum woodlands on alluvial plains and along drainage lines could be reduced in areas where groundwater drawdown occurs, as could the condition of the tree *Melaleuca viridiflora*. However, salinities in the alluvial aquifer (and underlying Styx Coal Measures) are generally too high for many tree species to utilise, so direct use of these aquifers may currently be minimal, with shallower roots using soil moisture associated with perched aquifers in the unsaturated zone, or diluted by freshwater retained in bank storage. Nevertheless, drawdown of the saline groundwater layer underlying freshwater stored in stream banks may indirectly reduce soil moisture available for vegetation, through enhanced leakage (HydroAlgorithmics 2020). The extent to which such processes occur depends on a range of factors, including the extent of drawdown, local geology of alluvial sediments and their permeability to water movement.

4.4 Groundwater quality

Reductions in groundwater quantity can have flow-on effects on groundwater quality. Changes in groundwater quality can occur in a number of ways including:

- Evaporative concentration of salts in temporarily open mine voids whilst they remain open (noting that all Project voids will be backfilled)
- Possible induced flow of groundwater of different quality towards depressurised parts of the groundwater system
- Infiltration of water containing elevated concentrations of metals, sulphate and salinity from waste rock stockpiles and mine water storages (Dams 1 to 4)
- Accidental release of chemicals (such as unintended fuel spills, leakage of sewage effluent, or infiltration of stormwater from disturbed areas)
- Movement in the location of the ‘saltwater-freshwater’ interface.

HydroAlgorithmics (2020) noted that with the exception of a few shallow groundwater bores located immediately adjacent to watercourses, the groundwater quality within the Mining Lease and surrounding areas is generally poor, and of limited human use, due to high salinity. Given the similarity of higher and variable salinity for the various source groundwaters, no appreciable change in groundwater salinity is expected as a consequence of mining (HydroAlgorithmics 2020).

Advancing open cuts will act as temporary and localised groundwater sinks during mining, with no deleterious effect on beneficial uses of any groundwater sources from metals. There is also limited potential for groundwater contamination to occur as a result of spills of hydrocarbons or other contaminants, due to the depth of groundwater typically being greater than 10 m below ground level (HydroAlgorithmics 2020).

The Project is not expected to result in any discernible change to the location of the freshwater-saltwater interface. HydroAlgorithmics (2020) undertook a review of available groundwater quality datasets, and found there is no idealistic freshwater-saline groundwater interface evident, which is not unexpected given the geological and geomorphological history of the region. Also, the theoretical interface depth (based on the Ghyben-Herzberg Relationship) is much deeper than areas to be disturbed or affected by the Project (HydroAlgorithmics 2020), hence outside of the zone of influence of groundwater changes as a result of the Project.

4.5 Change in surface water resources

4.5.1 Surface water hydrology

Changes to surface water hydrology can potentially reduce or increase the geographic extent of local catchments, their run-off characteristics, the intensity of flood flows and overall stability of waterways and their structural elements such as stream banks. The key changes to surface water hydrology arising from the Project relate to the installation of infrastructure, including:

- New dams to capture water runoff for use at the mine
- Drains to divert surface water runoff around the mine site to waterways
- Additional runoff as a result of the proposed mine hardstand areas
- Construction and use of mine discharge structures such as spillways and discharge drains.

The Project will have a very small impact on existing surface water flows, as mine infrastructure will decrease the size of the local catchment area, resulting in reduced rainfall runoff into creeks. Watercourse and creek crossing structures may cause a localised increase in runoff velocity due to the construction of culverts and conveyance features that eliminate natural waterway features such as meanders, and increase slope and flow velocity. However, with appropriately designed stormwater and crossing structures, such processes are unlikely to cause more than localised and very minor changes to surface hydrology.

The two major mine pit components (Open Cut 1 and Open Cut 2) will require the construction of two diversion drains to divert water runoff around the site to Deep Creek. Diversions will be constructed in a progressive manner as the pits expand, with the drain to the north of the Bruce Highway constructed first. The second drain, to the south of the Bruce Highway, will be constructed around nine years later in the second half of the Project (WRM 2020). The haul road and other infrastructure will also cross Deep

Creek and Barrack Creek, providing the potential for direct disturbance of the stream bed, and resulting in some alteration of hydraulic flows.

Access tracks and haul roads will affect natural contours of the landscape, and can act as either conduits for water, or barriers to flow. The potential impacts of these processes can be mitigated by constructing well-designed roadside drainage lines, as is specified in the Project Conceptual Erosion and Sediment Control Plan (Engeny 2020b). Spillways and discharge structures to facilitate the transfer of water from mine dams to the adjacent waterways also have the potential to change natural flow conditions. Such structures will generally only be utilised during periods of high flow, when large volumes of water are present within mine dams and the adjacent river systems.

Ecological effects from changes to surface hydrology can manifest to two ways, both of which result in less water being available for vegetation and aquatic fauna. First, surface water flow rates and volumes may be altered due to mine infrastructure, which captures water that would otherwise have entered the natural system of waterways. However, WRM (2020) undertook surface water modelling and predicted negligible changes to hydrological conditions as a result of the Project, with only minor changes to flood levels in some locations. Secondly, rainfall associated recharge and water storage within subsurface soils from rainfall infiltration may be reduced, either directly due to surface water diversion of runoff affecting infiltration and/or via groundwater drawdown increasing the rate and direction of water infiltration into underlying sediments; known as enhanced leakage.

4.5.2 Surface water quality

The Project has the potential to impact on surface water quality through an increase in sedimentation in waterways, accidental contamination due to spills or leaks, or via the controlled release of mine affected water from the mine during periods of high rainfall. Baseline water quality monitoring undertaken as part of the EIS and SEIS studies indicates that existing waterways generally have low to moderate turbidity and suspended sediment concentrations during and following flow periods. During extended dry periods with no flow, when the waterways are comprised of isolated pools, high levels of turbidity and suspended sediment concentrations have been recorded predominantly (but not solely) in Deep Creek sites.

The potential impacts of erosion and sedimentation from surface runoff, if not adequately mitigated, could result in impacts on local water quality and estuarine areas located downstream. This may in turn affect aquatic ecosystem values, including those of the marine environment. Increased concentrations and loads of suspended sediments can reduce light penetration, decreasing the photosynthesis and productivity of aquatic flora, and lowering dissolved oxygen concentrations, which are important for respiration processes of fauna.

Increased sediment loads from coastal catchments is also a key threatening process for the GBR (GBRMPA 2019). However, changes in land use at the Project Area, from the current situation of grazing to a mixture of mining and environmental offsets, is predicted to result in an overall reduction in sediment discharges to waterways through improved land management practices, despite the potential for discharge of sediment-laden water from mine dams (Engeny 2020a).

Groundwater drawdown has the potential to change the surface water quality of groundwater fed pools by reducing the volume and rate of generally saline groundwater inputs. In locations where this occurs, the associated aquatic habitats are likely to become more suitable for freshwater plants and animals, and less dominated by macroinvertebrates that have a high degree of tolerance for highly variable water quality condition.

The release of elevated metals and hydrocarbons to waterways can result in adverse impacts on flora and fauna. Such releases may occur accidentally as spills, or via controlled discharges during or immediately following intense rainfall events. The potential impacts of such releases, if not adequately mitigated, may include a reduction in local and downstream water quality, affecting environmental values related to aquatic ecosystems, irrigation, farm supply, stock water and cultural / spiritual uses.

High concentrations of metals may have toxic effects on aquatic flora and fauna, reducing their overall abundance or resulting in chronic impacts such as reduced reproductive output. However, the downstream concentrations are expected to be within the range of natural variability, and hence are not expected to cause adverse impacts to the downstream environment (WRM 2020).

Changes to water quality from the Project are unlikely to impact human consumer and drinking water values due to the distance between the Project Area and downstream extraction points. The ANZECC Guidelines (2000, 2018), local water quality guidelines and existing baseline data provide a useful reference to determine whether predicted changes to water quality are within acceptable limits.

4.5.3 Controlled releases and uncontrolled discharges

4.5.3.1 Controlled releases

Controlled releases from Dam 1 may be required over the life of the Project. This will act to prevent excessive accumulation of water within site storages and mitigate the risk of uncontrolled discharges to the receiving environment. The controlled release system will enable site water volumes to be effectively managed during wet periods when significant inflows to the site water management system are expected. Releases will only occur during flow events in Deep Creek.

The controlled release point (RP1) will be located on Dam 1 (**Figure 1-2**) and water directed along existing drainage lines into Deep Creek. The release point will be armoured and fitted with energy dissipation structures to prevent erosion and scour. A spillway will also be constructed from Dam 1 to Tooloombah Creek, and will function as a point for uncontrolled discharges in the event that water inputs exceed the capacity of the system to manage (**Figure 1-2**).

The following annual release volumes are predicted (WRM 2020):

- Between 2,790 and 2,930 ML/a during very wet climatic conditions (1st percentile annual rainfall)
- Between 780 and 1,430 ML/a during wet climatic conditions (10th percentile annual rainfall)
- Up to 40 ML/a during median climatic conditions (50th percentile annual rainfall)
- No controlled releases are projected to occur in dry and very dry climatic conditions.

The water balance model for the site (WRM 2020) has been used to simulate various release conditions and provide thresholds for when releases can occur. Releases will not be made if the conditions specified in **Table 4-1** cannot be met. These conditions have been developed based on achieving compliance with model EA conditions (DES 2017) and minimising any changes to existing water quality conditions in the Study Area. Such an approach therefore provides confidence that the concentration of water quality parameters within the release water will be diluted to such an extent that impacts to receiving waters are not anticipated.

To provide further confidence in this conclusion, the potential impact of controlled releases (and uncontrolled overflows) from the proposed water management system storages has been assessed for each of six modelled parameters, including (EC), Arsenic (As), Molybdenum (Mo), Selenium (Se), Vanadium (V) and Sulphate (SO_4). These parameters were chosen on the basis of geochemistry analysis for the site, which indicates that they are among the key parameters most likely to be present in high concentrations (RGS 2020; WRM 2020).

The results of the analysis demonstrate that the predicted concentrations of the six parameters at key points of Deep Creek, Tooloombah Creek and at the confluence of the two creeks are well within the range of the typical historical receiving water concentrations for each element examined. Indeed, the highest predicted concentrations for all heavy metals examined are an order of magnitude lower than thresholds set out in model mining EA conditions for contaminant release (WRM 2020).

4.5.3.2 Uncontrolled spillway overflows

The water balance model was used to assess the risk of uncontrolled offsite spills from the proposed water management system (WRM 2020). The mine-affected water dams that could potentially overflow directly to the receiving environment if rainfall exceeded the storage design criteria include:

- Dam 1 – spilling to Tooloombah Creek via a spillway (RP2)
- Dam 4 – spilling to Deep Creek (RP3).

Across all storages the annual risk of overflows is considered to be low (between 1 – 10%) and would only occur under wet conditions. There are no predicted overflows from Dam 1 (the largest storage) during median and dry conditions. If uncontrolled discharges do occur, modelling predictions also indicate that the concentrations of the modelled parameters at key points of Deep Creek, Tooloombah Creek and at the confluence of the two creeks will be well within the range of the typical historical receiving water concentrations for each element examined (WRM 2020).

4.5.3.3 Summary

Collectively, the information described in the preceding sections indicates that discharges of mine affected water into the receiving environment poses a low risk to instream environmental values, both within Tooloombah Creek and Deep Creek, and further downstream. The controlled release strategy will operate to minimise the risk of uncontrolled discharges. When water is released either during controlled releases or in the unlikely event of an uncontrolled spillway overflow, total water volumes will be such that metals, sulphate and electrical conductivity are diluted to concentrations below that of environmental concern. Controlled and uncontrolled discharge infrastructure will be designed such that the risk of erosion and scour of drainage lines and creeks is low.

Table 4-1: Proposed controlled release rules (WRM 2020)

Receiving Waters/Streams	Release Point (RP)	Gauging Station	GS Latitude (dec. degree, GDA94)	GS Latitude (dec. degree, GDA94)	Receiving Water Flow Criteria for Discharge (m^3/s)	Maximum release rate	Release Limits
Deep Creek	RP1	330452 Deep Creek	-22.6737°S	149.6697°E	**Low Flow**		
					0.1m^3/s (8.64ML/d)	0.018 m^3/s (1.55 ML/d)	Electrical conductivity – 1,000 µs/cm Sulphate (SO_4^{2-}) - 38 mg/L
					Medium Flow		
					4 m^3/s	0.142 m^3/s	Electrical conductivity – 2,000 µs/cm Sulphate (SO_4^{2-}) - 80 mg/L
					High Flow		
					50 m^3/s	1.09 m^3/s	Electrical conductivity – 3,000 µs/cm Sulphate (SO_4^{2-}) - 120 mg/L
					Very High Flow		
					100 m^3/s	2.02 m^3/s	Electrical conductivity – 4,000 µs/cm Sulphate (SO_4^{2-}) – 160 mg/L
					Flood Flow		
					250 m^3/s	3.07 m^3/s	Electrical conductivity – 8,000 µs/cm Sulphate (SO_4^{2-}) – 330 mg/L

4.6 Erosion of stream banks

Erosion and the resulting sedimentation of waterways can occur when vegetation is cleared and soil is exposed to overland flow. During construction and operation, sediment can be mobilised and transported by overland flow during rainfall events, ultimately discharging into watercourses within and surrounding the Project Area. An increase in sedimentation can result in negative impacts on water quality and aquatic habitats.

Tooloombah Creek and Deep Creek are highly incised waterways that are likely to be partially reliant on the retention of riparian vegetation for streambank stability. The main channel of Deep Creek has steep sided slopes that are fully vegetated and subject to minimal evident erosion. The loss of riparian vegetation in some areas, either through direct clearing or indirect impacts associated with changes in hydrology, has the potential to compromise the stability of the banks and lead to collapse. Mine water discharge also has the potential to cause local erosion of stream beds and banks, if not managed appropriately.

A description of the geomorphological values of the Study Area is provided by Gippel (2020). The geomorphology assessment concluded that while there could be isolated areas subject to somewhat higher risk of scour compared with baseline conditions, the overall risk of rapid and significant geomorphic change in Tooloombah and Deep creeks and the Styx River due to the proposed mining activity is low. Impacts from the Project on hydraulic variables will be small enough that a rapid geomorphic response would not be expected. Rather, the channel will slowly adjust over the life of the mine to the altered hydraulic conditions through minor changes in bed and floodplain levels, or channel widths (Gippel 2020).

4.7 Change in the location of the interface between fresh and saltwater

The location of highest astronomical tide is generally accepted to occur at the confluence of Tooloombah Creek and Deep Creek (Gippel 2020), and this will not change as a result of the Project. Given that there will be only minimal changes in the hydrological regime, and the large downstream influence of tides, there will be no change in the location of the freshwater – saltwater interface within surface waters of the Styx River (WRM 2020). Furthermore, groundwater modelling has demonstrated the risk of movement in the location of any freshwater-saltwater interfaces within relevant aquifers is very low due to the interface depth (based on the Ghyben-Herzberg Relationship) being much deeper than areas to be disturbed or affected by the Project (HydroAlgorithmics 2020). Therefore, potential impacts to downstream values from changes to the freshwater – saltwater interface are considered unlikely.

4.8 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 Training Area, located in a separate catchment to the North East of the Project Area. The defence project is too far away from the freshwater and groundwater resources of the Project Area to have impacts that may act cumulatively with the Project. However, as the catchment of the Shoalwater Bay Training Area also flows into Broad Sound, there is a potential for the impacts of the defence expansion project to act cumulatively with those of the Project. Potential cumulative impacts relate to changes to water quality within Broad Sound and adjacent parts of the GBR, and associated disturbance to marine habitats such as seagrass communities.

5. Mitigation and Management Measures

The previous section identified a number of unavoidable adverse impacts (e.g. vegetation clearance) and other potential adverse impacts (e.g. erosion of stream banks) that can be avoided or minimised through appropriate management and mitigation measures. The focus of mitigation and management measures to be implemented during Project construction, operation and decommissioning is to avoid or minimise impacts on ecological values.

Several documents have been developed for the Project which contain mitigation and management measures addressing a range of potential impacts. An overarching Environmental Management Plan (EMP) has been developed to provide good practice measures to avoid and reduce impacts to key environmental values. Among the other specific plans developed, the following are relevant to this assessment:

- Draft Receiving Environment Monitoring Program (REMP; ELA 2020b). The Draft REMP describes the rationale and salient aspects of a monitoring program for the receiving environment surrounding the Project Area, including the location of monitoring sites, monitoring frequency and parameters. The Draft REMP is designed to evaluate changes in the quality of the receiving environment, with a focus on surface water quality, sediment quality, aquatic ecology habitat quality, marine ecology habitat quality, macroinvertebrates and fish. Several reference and impact sites have been established upstream of, adjacent to, and downstream of the Project.
- Water Management Plan (WMP). The WMP describes the procedures that will be implemented to manage water within the Project Area, to provide sufficient water for construction and operation of the mine, while also outlining how excess water will be managed, sourced from rainfall or from groundwater seepage into the mine pits.
- Draft GDE Management and Monitoring Plan (GDEMMP; ELA 2020c). The Draft GDEMMP describes the mitigation and monitoring measures that will be implemented to manage the impacts of the Project on GDEs. A series of triggers and corrective actions have been developed for each GDE, to facilitate an assessment of the impacts of the Project during various development stages, and to inform an assessment of the suitability of mitigation measures to manage impacts. An adaptive management approach will be implemented, with the results of monitoring relevant indicators for each GDE informing the ongoing re-evaluation of Project impacts and associated mitigation measures.
- A rehabilitation framework has been developed to describe how final landforms associated with the Project will be rehabilitated after the completion of mining activities. Runoff from disturbed areas has the potential to reduce water quality in the receiving environment, with rehabilitation a key management measure to address this risk in the long term.
- Conceptual Erosion and Sediment Control Plan (ESCP; Engeny 2020b). The ESCP describes the approach to managing the risk of erosion at the site, and the methods that will be used to capture and manage sediment, to reduce discharges to the receiving environment.

Post-EIS approvals for the Project will include a range of conditions to manage environmental impacts (e.g. Environmental Authority, EPBC Act approval). In addition, relevant industry and government guidelines and codes will be followed to ensure best practice measures are undertaken. Examples of such documents include:

- The International Erosion and Control Association (IECA) Guidelines (2008)
- Austroads Guide to Road Design Part 5B: Drainage-Open Channels, Culverts and Floodways (2013)
- DAF Code for self-assessable development - Minor waterway barrier works Part 3: culvert crossings (Code number: WWBW01; 2013)
- DAF Guidelines for fish salvage (2020)
- Australian Standard for the storage and handling of flammable and combustible liquids (AS 1940—2004).

Mitigation and management measures to be implemented are classified, based on the mitigation hierarchy, which places mitigation and management measures in the following order of importance:

- Avoid – Impacts are completely avoided
- Minimise – If impacts are unavoidable, the extent of the impacts (duration, intensity) are minimised
- Rehabilitate – If impacts cannot be avoided or minimised, the environmental values that have been impacted are restored through rehabilitation methods
- Offset – If an impact results is a significant residual impact to an MNES or MSES, offsetting is required to counterbalance this impact.

The mitigation and management measures that will be implemented for the Project are outlined in the following sections in reference to avoidance, minimisation, rehabilitation and offsetting.

5.1 Avoidance

Project design and construction planning has allowed for the avoidance of impacts to environmental values through the following measures:

- Project design has been optimised and refined to avoid some areas of remnant vegetation and high ecological value
- Retained vegetation will be clearly marked to avoid damage or accidental clearing of adjacent areas
- Construction will be completed during the dry season where possible to eliminate the need to divert water around the construction area and to minimise risks to instream environmental values
- Construction works along waterways have been located to avoid impacts to permanent water sources within creeks (permanent pools)
- Wash-down areas for machinery will be clearly marked and located in areas that will prevent contaminated water leaching into soils or flowing into waterways.

5.2 Minimisation

Where impacts to environmental values cannot be avoided, minimisation of these impacts will occur via the following measures:

- Project design elements will ensure that the minimum amount of land required for operation will be disturbed and ensure that surface water flows into creeks represent natural conditions as much as possible
- Construction activities will be completed during the dry season where possible, to reduce the potential of construction-related erosion and scour

- Bank stabilisation will take place post-construction as necessary to allow for revegetation and to reduce scour potential
- Minimum culvert aperture width will be 2.4 m or span the entire channel width, reducing impacts on flow and aquatic fauna passage
- All new and replacement culvert cells will be installed at or below bed level
- The internal roof of the culverts will be >3 m above the 'commence of flow' water level
- If culvert cells are installed < 3m below bed level, the culvert floor will have a rough surface to simulate natural bed form
- Where possible, box culverts will be used to facilitate fish passage at low flow depths
- Footings over the base slabs may be used to maintain the natural bed channel through the culverts
- Apron and stream bed scour protection will be provided
- The culvert gradient will be no steeper than natural waterway bed gradient
- The design of the haul road crossings will maintain aquatic habitat connectivity
- Prior to emptying wetlands or dams, a qualified ecologist will inspect the area and if required, remove native aquatic fauna, which will be relocated to a suitable pre-determined area
- Any fish that become trapped during construction will be salvaged in accordance with the DAF *Guidelines for fish salvage* (DAF 2020). In the event of a fish kill, the appropriate steps provided in the guidelines will be followed
- Mine dams will be constructed to contain potentially contaminated mine groundwater pumped from the open cut pit throughout the life of the Project
- Early construction of the mine dams and water storage facilities will allow for the collection of water from disturbed areas from an early stage in development
- Environmental dams will collect run-off which will be transferred to the main site dams
- A water catchment system will be in place to capture rainfall runoff from the mine site including the TLF and waste rock stockpile areas
- Captured water will be treated to minimise the amount of sediment and concentration of contaminants, or treated through settlement prior to release
- Water quality release limits will be set for mine-affected water as outlined in Appendix A5a to the SEIS - Surface Water Quality Technical Report
- Baseline water quality will be monitored at the mine dam, discharge locations and locations both upstream and downstream of the Project Area
- Water will only be discharged from the mine dam during flow trigger events (during/immediately after high rainfall events when the creek is flowing) and only if the flow and water quality parameters meet the water quality release limits outlined in the Environmental Authority
- Discharge of water will be controlled to reduce the likelihood of non-compliant discharges due to overtopping
- Roads will be designed and located to minimise the amount of run-off into waterways
- Landforms such as waste rock stockpiles will be constructed using erosion-resistant materials to reduce the level of erosion
- Waste rock stockpiles are immune from the 0.1% AEP (1 in 1000 year average recurrence interval) flood event
- Removed topsoil will be placed in designated soil stockpile zones and seeded to minimise erosion
- Erosion and sediment controls will be installed and maintained in accordance with the site Erosion and Sediment Control Plan (ESCP; see draft ESCP in Appendix A15a to the SEIS)

- Clean water will be diverted around disturbed areas to avoid the mobilisation of additional sediment and contaminants
- Earthmoving activities will be minimised during rainfall events to limit sediment and contaminant runoff
- Regeneration of the vegetation and restoration of habitat on the property will create vegetation buffers to reduce sediment and nutrient run-off in a number of ways:
    - Increased capture of sediment and nutrient run-off from the property
    - Reduction of erosion as a result of vegetation restoration reducing the amount of sediment entering waterways during surface water flows
- Removal of cattle (destocking) will reduce the level of erosion and land degradation, as well as removing a source of nutrient in-put into surrounding waterways
- Vegetation regeneration and stock exclusion will continue post-operation, resulting in a permanent reduction of sediment run-off.
- Storage and handling of oil and chemicals will be in accordance with relevant Australian Standards to minimise the risk of accidental spills and leaks
- Spill control materials will be retained on site for use in the event that a substance is spilled into a surrounding waterway.

5.3 Rehabilitation

Where impacts do occur, environmental values will be restored if possible, through the following measures:

- The Mining Lease area will be destocked in the northern part during operations years 1 to 9, comprising an area of over 2,000 ha. Cattle will be removed from Mamelon South, in southern parts of the Mining Lease, during years 10 to 19 (674 ha).
- Management of destocked land on the property (presently mostly cleared) to allow for regeneration of the vegetation and restoration of habitat; focussing on riparian zones along Deep Creek and Tooloombah Creek
- Cattle will also be removed from offset areas (approximately 2,800 ha), except where light grazing is required for fuel load and weed management
- Progressive rehabilitation of disturbed areas will occur where possible to reduce the time between disturbance and rehabilitation
- Removed topsoil will be placed and seeded in designated soil stockpile areas throughout the life of the Project
- Removal of mine infrastructure and rehabilitation of all disturbed land to a stable, non-polluting and self-sustaining condition suitable for low-intensity cattle grazing
- Any riparian vegetation that is damaged during construction will be rehabilitated
- Any areas of vegetation impacted by hydrological changes will be revegetated and actively managed. Species representative of the RE(s) affected will be used in this revegetation.
- A revegetation program will be implemented in areas within the riparian corridor of Deep Creek expected to be affected by groundwater drawdown with the aim of building ecological resilience. Revegetation will include expansion of the existing riparian corridor by a width of 10 m.

5.4 Offsetting

The Project is expected to result in significant residual adverse impacts to some MSES and matters of national environmental significance (MNES) that cannot be otherwise avoided, minimised or rehabilitated; and as such offsetting will occur. Offsets will be delivered in accordance with the Commonwealth Environmental Offset Policy (2012) and Queensland *Environmental Offsets Act 2014* and Offsets Policy (2018). Offset requirements and modes of delivery are addressed in detail in the Project's Biodiversity Offset Strategy (C02 Australia 2020).

5.5 Monitoring the effectiveness of Mitigation Measures

Compliance with the requirements, agreed procedures, locations and extent of clearance in approval conditions and relevant management plans will be monitored, documented and be subject to compliance audits. A reporting schedule will be prepared and included in the management plans for both routine documentation (e.g. planned clearing) as well as incident reporting (e.g. spills, fauna mortality). If any mitigation or management measures are ineffective, corrective actions will be implemented. These procedures are described within the relevant management plan (e.g. EMP, GDEMMP).

6. Impact Assessment Groundwater Dependent Ecosystems

This section provides an assessment of potential impacts of the Project on Subterranean, Aquatic and Terrestrial GDEs. An overview of key terms used in the conceptualisation of groundwater and its relationship with GDEs is provided in **Sections 6.1** and **6.2**. This is relevant to all types of GDEs, which are summarised in relation to the Project in **Sections 6.3** and **6.4**. Following these introductory sections, a detailed assessment of GDE values and potential Project impacts is provided for Subterranean (**Section 6.5**), Aquatic (**Section 6.6**) and Terrestrial (**Section 6.7**) GDEs. The application of the IESC Guidelines is also discussed in **Section 6.8**.

6.1 Background and method

To assist with the conceptualisation of groundwater dependent ecosystems (GDEs), the key terms shown in **Table 6-1** are defined and used in this section. The definitions are consistent with those provided in the IESC Guidelines (Doody et al. 2019), GDE Toolbox (Richardson et al. 2011), and as applied by the authors of various technical studies that supported the impact assessment (e.g. 3D Environmental 2020, HydroAlgorithmics 2020; WRM 2020; ELA 2020). A conceptual representation of the definitions is provided in **Figure 6-1**.

Table 6-1 Key terms used in the discussion of GDEs

Term	Description
Alluvial corridor	A corridor comprising a creek or river, and the adjacent banks and associated riparian zone. Also referred to as the riparian corridor.
Aquifer	A geological formation or structure that stores water accessible by bores or springs. Aquifers typically supply economic volumes of groundwater.
Aquatic GDE	An ecosystem dependent on the surface expression of groundwater (e.g. river baseflow systems, springs)
Bank storage	Portion of the subsurface where water derived from infiltration associated with flooding is stored within the banks of creeks or rivers. During periods of high rainfall and associated creek flow, water levels in creeks rise, and surface water moves laterally into adjacent soils and alluvial sediments, infiltrating the stream bank (held in bank storage). There can be some uncertainty about when water held in bank storage meets the definition of groundwater, as it is applied to GDEs. Water held in bank storage may percolate downwards under gravity towards the aquifer underlying the riparian zone (if not connected to the regional water table aquifer), or be impeded by an impermeable layer of rock or clay. Once the water is captured through either of these mechanisms, the water meets the definition of groundwater as it relates to the assessment of GDEs. 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 stored in the bank for prolonged periods, where it may be accessed by Terrestrial GDEs.
Base flow	Streamflow derived from groundwater seepage into a stream.

Term	Description
Capillary fringe	The unsaturated zone above the water table containing water held by soil pores against gravity by capillary tension and in direct contact with the water table though at pressures that are less than atmospheric.
Groundwater	Those areas in the sub-surface where all soil or rock interstitial porosity is saturated with water. Includes the saturated zone and the capillary fringe. Includes water contained in perched aquifers in the unsaturated zone. Does not include soil moisture.
Groundwater dependent ecosystems (GDEs)	Ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, to maintain their communities of plants and animals, ecosystem processes and ecosystem services
Infiltration	Passage of water into the soil by forces of gravity and capillarity, dependent on the properties of the soil and moisture content.
Percolation	The downward movement of water through the soil due to gravity and hydraulic forces.
Perched aquifer	An area in the regional unsaturated zone where the soil or rock may be locally saturated following rainfall events or the wet season because it overlies a low permeability unit.
Permeability	A material's ability to allow a substance to pass through it, such as the ability of soil or rocks to conduct water under the influence of gravity and hydraulic forces.
Phreatic zone	The zone of saturation marking the uppermost unconfined aquifer, separated from the unsaturated zone by the water table.
Saturated Zone	The area below the water table in which the pore spaces between grains of sediment or soil are completely full of water.
Subterranean GDE	Ecosystems associated with aquifers and caves (e.g. containing stygofauna)
Surface water	Movement of water at or above the ground surface as overland runoff or in streams, creeks or rivers
Terrestrial GDE	Ecosystems dependent on the subsurface presence of groundwater (e.g. some riparian vegetation)
Unsaturated Zone	The unsaturated zone is the portion of the subsurface above the groundwater table. Unlike the saturated zone, the pore spaces in the unsaturated zone are not completely full of water. Also known as the vadose zone.
Water table	The upper surface of the saturated zone in the ground, where all of the pore space is filled with water.
Water table aquifer	An aquifer associated with the water table. In most parts of the Project Area, 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.
Wetting front	The boundary of soil wet by water from rainfall, and dry soil, as the water moves downward in the unsaturated zone.

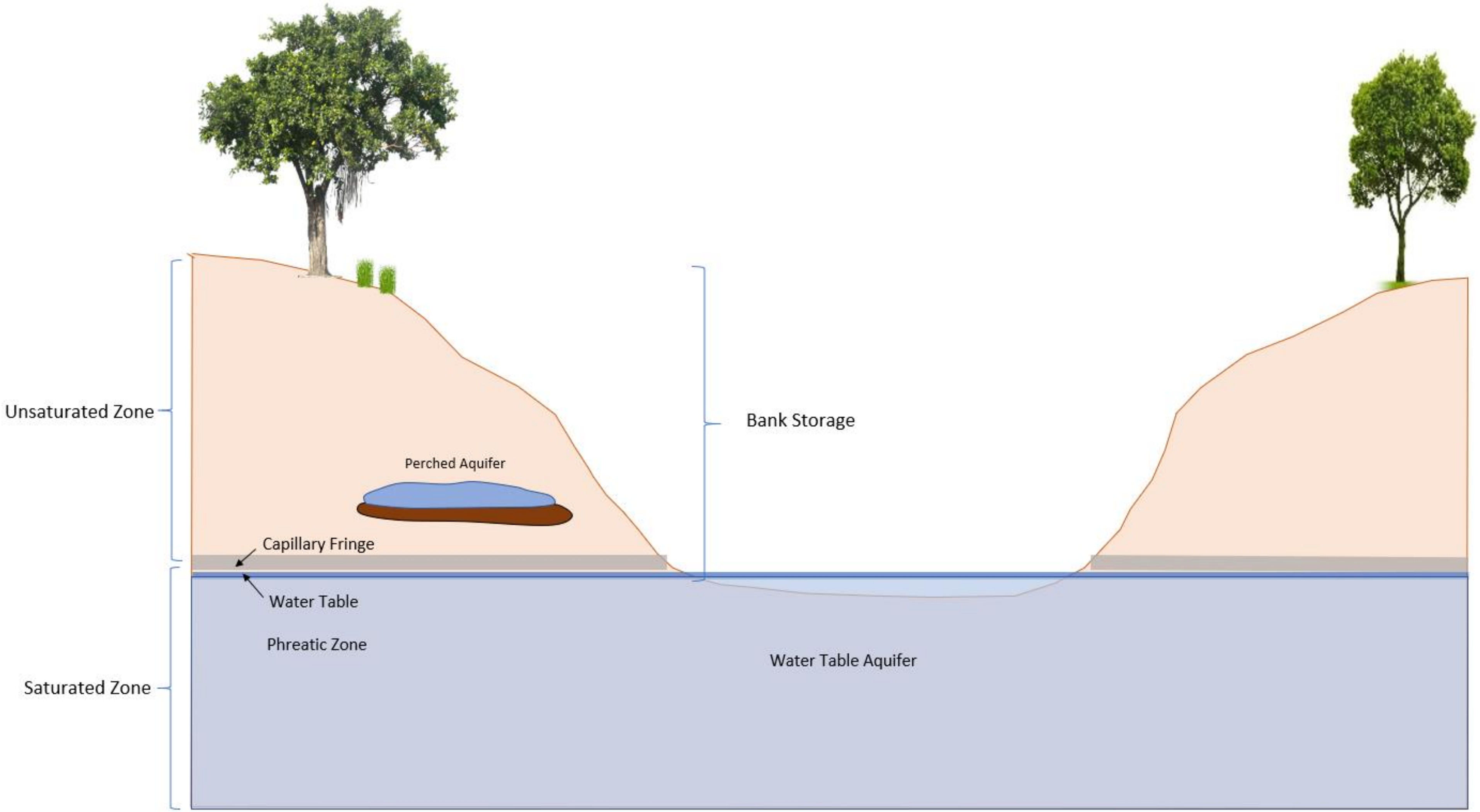


Figure 6-1 Conceptual diagram showing the location of key terms defined in relation to GDEs

Central Queensland Coal commissioned extensive new research to better understand and define the groundwater and surface water resources of the Project Area. This included a regional numerical groundwater model, completed by HydroAlgorithmics (2020), and a water balance and hydrological modelling study completed by WRM (2020). These modelling studies drew upon information collected on site since the previous SEIS (v2) was submitted, including a fluvial geomorphology study (Gippel 2020), transient electromagnetic survey to explore groundwater associated with surficial geology (Allen 2019), groundwater quality and water level data from several newly installed bores, and stream flow data collected from gauges installed at Tooloombah Creek and Deep Creek in 2019. This information collectively provided a comprehensive suite of contemporary material that could be considered in the assessment of potential Project impacts on GDEs.

In February 2020, a workshop was convened with specialists in groundwater, surface water and GDEs, to discuss the modelling findings, and to develop conceptualisations for the water resources of GDEs. During discussions at the workshop, the conceptualisation of some key hydrological and hydrogeological processes was confirmed. This provided essential elements for the GDE impact assessment, including for example, the depth to groundwater, predicted groundwater drawdown propagation (presented as drawdown contours) across the Project Area, and information on the quality of groundwater within the upper geological layers (alluvium and weathered Styx Coal Measures).

However, the workshop participants identified some uncertainty in the nature of water movement through the unsaturated zone, and the associated interactions between surface water and groundwater. This is important in the understanding of potential Project impacts on GDEs, with water movement and storage within the unsaturated zone not explicitly addressed in either the surface water or groundwater models. The unsaturated zone and the broader alluvial corridor were therefore identified as key parts of the riparian systems where further understanding of water movement and storage would be sought.

To assist in filling these identified knowledge gaps, Central Queensland Coal commissioned the following studies:

- Drilling of alluvial soil cores along transects at key locations perpendicular to the direction of flow at Tooloombah Creek and Deep Creek in April 2020 (Central Queensland Coal 2020a). The objective of this work was to identify the type and layers of sediments in these areas, and their physical properties which may affect the movement of groundwater. Once retrieved, sampling cores were logged, with subsamples sent to a laboratory for analysis of particle size distribution, moisture content and salinity. This work assisted with confirming the conceptualisation of water movement within the unsaturated zone and adjacent sections of the stream bank.
- A study of groundwater and surface water interactions, undertaken by ELA (2020a), relied on the results of the above-mentioned drilling surveys to confirm and improve the conceptualisation. The aim of the study was to provide a description of likely groundwater and surface water interactions from available information and develop the key design elements of local 2D numerical models of the interactions between groundwater and surface waters, at a higher resolution than could be accommodated by a regional hydrological or groundwater model. The future development of local-scale, 2D cross-section models was also considered to be a useful tool to assist with implementation of an adaptive management approach through the GDE Management and Monitoring Plan (GDEMMP).

The conceptualisation of groundwater movement and storage, relevant to GDEs, as described in the following sections, is based primarily on the results of these collective studies, in addition to relevant previous work from the SEIS (v2). The results of ongoing surface water and groundwater monitoring have also informed the conceptualisation, providing insight into the presence and persistence of pools throughout Tooloombah Creek and Deep Creek, and their associated water chemistry.

6.2 Overview of groundwater of relevance to GDEs

The depth to the water table across the Project Area and surrounding locations is typically in the range of 10 to 15 mbgl in floodplains. Water within the upper Quaternary Alluvium (Qa) is generally less saline than the underlying Quaternary Pleistocene Alluvium (QPa; HydroAlgorithmics 2020). Further from creeks, the depth to groundwater can be 15 metres or more.

The alluvial corridor and its associated GDEs experience a cyclic process of short-term flooding associated with high fresh surface water flows (during and immediately following significant rainfall events), followed by extended periods of little to no rainfall (WRM 2020). Variations in rainfall and associated surface water runoff drive the movement of water within creek systems, and regulate the expression of GDE values.

Groundwater sources supporting GDEs of the riparian corridors are derived from two primary sources:

- A brackish aquifer underlying the creek channel, which supplements water levels in creeks or the pools that persist within the creek channel during dry periods.
- In dry periods, groundwater held in bank storage is returned to the creek, sustaining Aquatic GDEs, or is utilised by Terrestrial GDEs when their roots access the capillary fringe and associated saturated zone of the soil profile, or a perched aquifer in the unsaturated zone.

These two sources of groundwater are discussed separately in the following sections.

6.2.1 Saline groundwater inputs from the water table aquifer

Tooloombah Creek and the lower sections of Deep Creek are influenced by a relatively small (when compared with surface water flows), yet important contribution of groundwater. This groundwater input appears to be continuous throughout the dry season in Tooloombah Creek, particularly within its lower reaches. The inflow sustains water levels within isolated pools throughout the dry season and during prolonged periods of drought, despite evaporation, resulting in a small number of permanent to semi-permanent pools along the creek.

Evidence for groundwater inflow is provided by isotopic studies completed during the EIS baseline studies, as well as comparisons of the water levels and salinity within pools with what would be expected to be mainly a response to evaporation. For example, at the Tooloombah Creek gauging station pool (ToGS1), brackish to saline groundwater inflow of several thousand litres a day is required for the pool to maintain levels and reach the observed salinity of 9,000 µS/cm EC during a prolonged dry period (WRM 2020). A trend of increasing salinity within pools with increasing distance downstream is also evident in Tooloombah Creek, based on a review of surface water quality monitoring data (Central Queensland Coal 2020b). These trends occur above the reach of tidal influences, and are thought to be explained by increasing quantities of saline groundwater inflows with distance downstream.

It is unclear whether saline groundwater inputs are caused by the stream bed level being below that of the groundwater layer (i.e. the water table), or result from upward movement of groundwater into the overlying creek. ELA (2020a) notes that water table level is generally below the creek bed across the Project Area, with intersections between the creek bed and groundwater level occurring in some locations on a seasonal basis. The regional groundwater model report (HydroAlgorithmics 2020) also notes that there is the potential for localised upward pressures from the aquifer units underlying Tooloombah Creek. This is likely influenced by surface water recharge of the groundwater system near the Tooloombah Creek 'pinch point', a geographic feature where there is a narrowing of the creek channel between Mount Brunswick and Mount Mamelon, upstream of the Project. It is hypothesised that the hydrological pressures associated with the 'pinch point' may provide a mechanism for groundwater from the water table aquifer to flow upwards into Tooloombah Creek at locations downstream of the pinch point.

Monitoring at Deep Creek suggests that this system receives far less saline groundwater inflow than Tooloombah Creek (and there is an absence of a comparable pinch point on this stream). Pools at Deep Creek are noted to be ephemeral and dry up faster during the dry season compared with Tooloombah Creek. Isotope sampling results from the EIS studies also indicated that there is less groundwater inflows to Deep Creek than to Tooloombah Creek.

Monitoring during the dry season demonstrates that pools at Deep Creek lose more water each day than pools in Tooloombah Creek (Amec 2019). Deep Creek pool levels and salinity concentrations can generally be explained by evaporation alone, rather than requiring the addition of saline groundwater. Whilst pools in the lower reaches of Deep Creek appear to be fed by groundwater at times, this does not occur to the same extent as in Tooloombah Creek (ELA 2020a).

Surveys of surface water levels in pools across both creek systems support these observations, and found only one pool in Deep Creek to be permeant or semi-permanent (in the lower reaches), while the vast majority of pools in Tooloombah Creek are categorised as permanent pools (Section 6.3).

6.2.2 Baseflow and bank storage inputs of fresh water

During periods of high rainfall and associated creek flow, water levels in creeks rise, and surface water moves laterally into adjacent soils, infiltrating the stream bank. The degree to which stream banks absorb and store water is a function of their physical structure and soil properties. Water held in bank storage may percolate downwards under gravity towards the aquifer underlying the riparian zone (if not connected to the regional water table aquifer), or be impeded by an impermeable layer of rock or clay. Once the water is captured through either of these mechanisms, the water meets the definition of groundwater as it relates to the assessment of GDEs.

At times of river flooding, groundwater is of little relevance to GDEs. Aquatic GDEs have abundant surface water to meet their environmental water requirements. Soils utilised by vegetation are also moist as a result of rainfall infiltration and stream flooding, meaning there is unlikely to be any reliance on groundwater at this time. Trees can generally adapt their water harvesting approach to suit the water sources available within the reach of their root system.

As creek levels drop and soils in the unsaturated zone begin to dry out, the use of groundwater becomes more important for GDEs. Baseflow within creeks will be supported by water seeping out of bank storage, sustaining aquatic ecosystems and shallow-rooted riparian vegetation such as the Weeping

Paperbark for an extended period of time. However, the capacity for bank storage to replenish water levels in the creek is not unlimited, and during dry periods, flow volumes and rates will reduce and cease over a duration of days, weeks or months, depending on the geological and hydraulic properties (e.g. particle size) of the stream bank sediments, which affect the volume of water that can be stored, and the rate at which this water is released to the waterway.

Transect drilling on site indicated that Tooloombah Creek has a high capacity for bank storage (ELA 2020a). The creek channel is supported by a large bank terrace in some locations, with a high clay content, particularly at the base of the alluvial sediments. This facilitates the capture and storage of flood water and the slow release of this water back to the creek during dry periods as surface water levels drop. In contrast, Deep Creek adjacent to the proposed mine follows the course of a fault, with the western bank having some clay content, as well as sand, while the eastern bank consists of coarse gravel layers with a high permeability (ELA 2020a). Bank storage is far less feasible at Deep Creek, with water likely to percolate through the coarser sediments and gravels to the east much faster than is the case at Tooloombah Creek. Such findings are consistent with the observations of pool persistence in both creeks, coupled with the above-mentioned cycle of drying.

For Terrestrial GDEs, prolonged dry periods are when access to groundwater is important. Water requirements of vegetation that cannot be met by rainfall and stream flooding during these periods will need to be met by groundwater, to avoid water stress. Forest Red Gums have a deep tap root, observed to extend to at least 9.5 m on site, which coincides with the approximate level of the creek base (3D Environmental 2020). Within this zone, fresh groundwater is present, stored after rainfall and river flooding and either captured as a perched aquifer above impermeable clay or rock layers in the bank, or connected to (sitting on top of) the alluvial aquifer in the Quaternary Alluvium layer (which is generally less saline than the underlying Quaternary Pleistocene Alluvium).

Evidence relating to the presence of this fresh source of groundwater is multi-faceted and includes:

- Transient Electromagnetic (TEM) studies of the Project Area (Allen 2019), which show that sediments within the riparian corridors surrounding the Project Area contain a layer of low conductivity signal, likely reflecting fresh water in the upper 10 m (held in bank storage). This is likely sourced directly from rainfall and high stream flow events, rather than from the underlying saline aquifers (upflow). At depths greater than 10 mbgl, the TEM conductivity increases, likely reflecting the existence of the permanent alluvial groundwater from the Quaternary Pleistocene Alluvium, which has been found to have salinities in the range 10,000 – 40,000 µS/cm EC (6,000 – 30,000 ppm).
- Field studies undertaken by 3D Environmental (2020) found that Forest Red Gums were utilising a deep and fresh water source at a time when shallow-rooted species, such as the Weeping Paperbark, were stressed from a lack of water. This fresh water source was found to be at a depth of approximately 9 mbgl.
- Salinity observations from drill holes associated with the alluvial transects show a transition in salinity from fresh to saline at approximately 10 mbgl (ELA 2020a; Central Queensland Coal 2020a).

6.3 Types of GDEs in the Project Area

GDEs of the riparian corridors of the Project Area are thus mainly supported by groundwater from two sources:

1. Saline groundwater inputs to the creek system from the underlying water table aquifer occur in Tooloombah Creek, and to a much lesser extent, in the lower reaches of Deep Creek. These inputs sustain pools of water during the dry season and extended periods of drought and result in some pools having high salinity. The creeks, pools and the flora and fauna that they support meet the definition of Aquatic GDEs. They include aquatic fauna such as macroinvertebrates, fish and freshwater turtles, plus shallow rooted vegetation which utilises water derived from infiltrations into the stream bed and banks (e.g. Weeping Paperbark).
2. The other source of groundwater comprises a layer of fresh water located in the alluvial corridor in many locations, either as a perched aquifer in the unsaturated zone of the river bank, or immediately above or within the water table aquifer, most likely the Quaternary Alluvium layer. This groundwater is generally low in salinity (although may contain some dissolved salts) and provides a source of water for deep-rooted vegetation such as the Forest Red Gum at times when other water sources from rainfall and river flooding are not available.

Stygofauna are known to occur within alluvial aquifers of the Project Area and are likely to be supported to varying extents by both types of groundwater described above. Stygofauna have a preference for water of lower salinity and are likely to be present in highest abundances in areas where the salinity of the alluvial aquifer is low, or where water derived from river flooding reduces (as a result of mixing) the salinity of the underlying aquifer.

Of those sites studied in detail from the field studies completed by 3D Environmental (2020), Wetland 1 is the only mapped wetland to be confirmed as a GDE, identifying that Melaleuca species are utilising water in the soil profile at a depth of approximately 8 mbgl. This water meets the definition of a perched aquifer, and lies approximately 4-5 m above the underlying water table. Wetland 1 is therefore classed as a Terrestrial GDE, given the structural importance of the Melaleuca trees to the wetland and its associated flora and fauna.

6.4 Desktop assessment of GDE values

The coal reserves proposed for extraction during the Project lie within the Styx Basin. This early Cretaceous, intracratonic sag basin covers an area of 2,000 km^2 and extends offshore to depths of approximately 100 m below sea level. Full geological details can be found in Central Queensland Coal (2020a) and HydroAlgorithmics (2020).

The Styx Basin is not within any declared groundwater management areas. Groundwater flow is generally towards the Styx River and the coast, varying across the system depending upon local recharge and discharge. The water table is generally within 15 m of the surface in the areas immediately adjacent to the Project Area. The water table then becomes very shallow (<5 m) towards the coastal areas of the Styx River and Broad Sound.

A total of 49 monitoring bores were installed by Central Queensland Coal between 2017 and 2018 to help improve the understanding and monitoring capability of the hydrogeological features around the Project (Orange Environmental 2020). Overall, the results of this data set and historical data collected from unregistered third-party bores show that:

- There does not appear to be a strong seasonal response to rainfall and stream flow, with the water table only varying by 3 m in distinct areas (unconsolidated alluvial deposits)
- Diffuse rainfall recharge occurs across the Styx River Basin

- Towards the confluence of Tooloombah and Deep Creeks, Styx Creek and Broad Sound there is net groundwater discharge predominantly via evapotranspiration (capillary fringe, watercourse pools, bank storage return and evaporation in low lying areas)
- Parts of Tooloombah Creek and the lower portion of Deep Creek contain pools that persist for long periods, indicating groundwater discharge and a permanent connection to the water table
- Styx River is typically a net gaining stream, except during periods of high tide
- There is no freshwater-saline groundwater interface evident in the vicinity of the Project Area, which is not unexpected given the geological and geomorphological history of the region. HydroAlgorithmics (2020) identified that the interface depth (based on the Ghyben-Herzberg Relationship) is much deeper than areas to be disturbed or affected by the Project (conservatively estimated at 500 m, compared with the deepest point of the open cut mine of -152 m AHD).

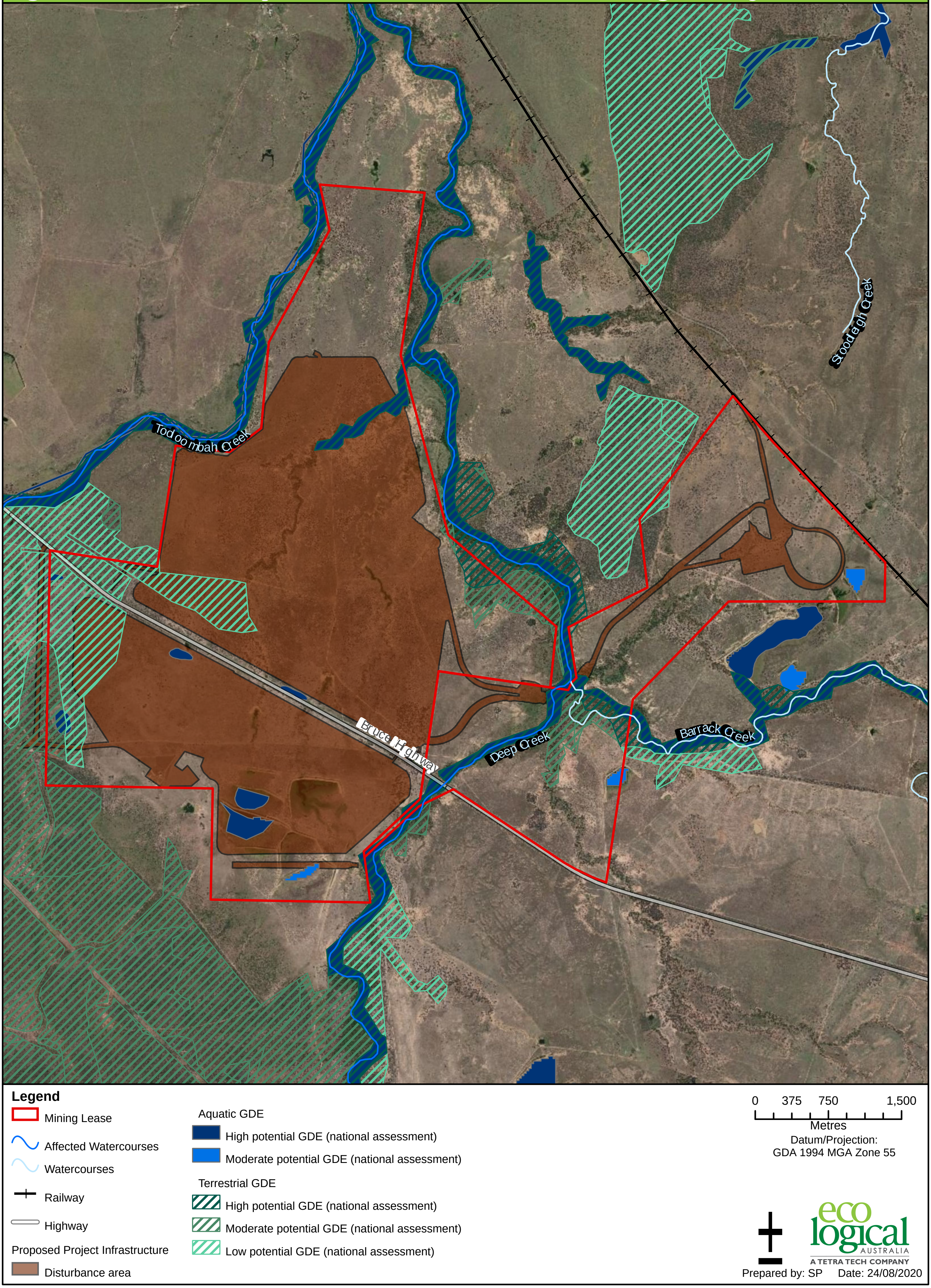
GDEs are ecosystems that rely on groundwater to maintain critical components of the ecosystem. As described in **Section 2.1**, the Australian GDE toolbox (Richardson *et al*. 2011) and IESC Guidelines (Doody *et al*. 2019) define three types of GDEs relevant to assessment of the Project:

- Subterranean GDEs (Type 1) – Aquifer systems, containing stygofauna
- Aquatic GDEs (Type 2) – Surface expression of groundwater
- Terrestrial GDEs (Type 3) – Groundwater dependent vegetation.

Previous desktop assessments, based on GDEs mapped in the online Atlas of Groundwater Dependent Ecosystems and targeted field surveys have been conducted for GDEs in the Study Area (**Table 2-2;** CDM Smith 2018, 3D Environmental 2020). An overview of the results of these studies in relation to each GDE type is provided in the following sections, with **Figure 6-2** showing the locations of potential GDEs.

Overall, there are GDEs of each type present within the Study Area and minimising impacts to surface and subsurface hydrology will be critical to maintaining water requirements for these ecosystems. Maintaining groundwater levels is of particular importance to Aquatic and Terrestrial GDEs, as they are likely to be reliant upon access to this groundwater during dry periods.

Figure 6-2: Locations of potential GDEs within and surrounding the Project Area



6.5 Subterranean GDEs – Aquifer Systems (Type 1)

6.5.1 Stygofauna habitat

The groundwater invertebrate (stygofauna) community is generally dominated by small crustaceans, occurring in aquifers with sufficient pore space to complete their life cycle, and are most common in alluvial sediments, karstic aquifers, and fractured rock (Glanville *et al*. 2016). Stygofauna were collected from bores near the Styx River during baseline studies for the EIS, but are likely to occur more broadly than the points of collection (ALS 2010, GHD 2012). The Styx River alluvium extends south from the collection bores, through ML 80187, and further south for another 12 km. This makes it unlikely that the stygofauna taxa sampled as part of the Project investigations are short range endemics.

Stygofauna are found in aquifers with relatively shallow water tables (within 20 m of the surface), and a strong hydrological connection to the surface. This is because these habitats are generally good sources of organic carbon, needed to fuel groundwater food webs. The Styx Basin contains large sections of shallow aquifer available to stygofauna, particularly the alluvial sediments associated with surface drainage and fractured or weathered rocks.

Six taxa were classified as stygofauna during baseline surveys as part of the EIS (GHD 2012):

- Bathynellacea (syncarid crustacean)
- Three Families of Oligochaeta (segmented worms)
- One species from the Subclass Copepoda
- One species from the Subclass Acari.

Of these taxa, the oligochaetes and Acari are most likely to be members of the soil invertebrate community, rather than the stygofauna community (Halse and Pearson 2014). Copepoda could be stygofauna, as groundwater copepods are known from Queensland (NRM 2004). However, there is a possibility that these could also be of surface water origin and that eggs or adult specimens have entered an open bore cavity and persisted in the bore cavity. Bathynellacea is a group of crustaceans known only from aquifers, so this taxonomic group is definitely stygofauna. This order is amongst the most diverse and widespread group of stygofauna in Australia, with little information relating to this group known from Queensland (Little *et al*. 2016).

The stygofauna collected during baseline EIS surveys came from bores close to rivers and with water of relatively low EC. Stygofauna are most commonly collected in groundwater with EC <5,000 µS/cm (Doody *et al.* 2019), although have been collected from aquifers exceeding 50,000 µS/cm on rare occasions (DES 2018). There is variability in the EC of the water table aquifers of Deep Creek, Tooloombah Creek and Styx River (HydroAlgorithmics 2020). Transient electromagnetic surveys indicate that soil moisture in upper layers to a depth of approximately 7 m is relatively fresh over most of the aquifers (EC < 4000 µS/cm), and saline below depths of approximately 12 m. EC in deeper parts of the aquifer is generally high, with alluvial bores screened between 12 and 18 m showing median ECs of 5,270 to 47,700 µS/cm.

These data suggest that there is a lens of fresh water either within or immediately above the water table aquifer overlying denser saline water. If this is the case, then it is possible that the upper parts of the aquifer are suitable for stygofauna. This is not always possible to determine from survey results, as most bores are screened beneath the fresh water layer. The Study Area is therefore likely to contain a mosaic of areas that are suitable and unsuitable for stygofauna, depending on local hydrogeological conditions and the depth of underground water resources.

Most of the bores sampled for stygofauna in the modelled drawdown area (i.e. around the pit locations), extended to depths below the alluvium, where EC was low (GHD 2012). This means that the alluvial stygofauna community was sampled from only a few locations within the impact area. Nevertheless, stygofauna were collected from two locations, and the TEM surveys indicating a lens of fresh groundwater overlying saline aquifers, make it possible that stygofauna occur throughout much of the Styx River alluvium, from the proposed mine north to the coastal margins. Styx River alluvium may also be connected to the Herbert Creek alluvium, in which case the two systems are likely to share a similar stygofauna community.

The impact assessment has been completed, based on the high likelihood that stygofauna communities extend throughout the Styx River alluvium, as well as the alluvium of Tooloombah Creek and Deep Creek, but that their distribution is generally limited to parts of the aquifer where electrical conductivity is less than 7,000 µS/cm. EC in the central part of the aquifer is higher (up to 37,400 mg/L) than in the coastal section near Broad Sound, or close to waterways (CDM Smith 2018- SEIS v2 Chapter 10), and is less suitable for stygofauna.

Likewise, there are areas suitable for stygofauna in the aquifer south of the mine, with a borehole (BH29) having EC <500 µS/cm (CDM Smith 2018- SEIS v2 Appendix 5a). Although no stygofauna were collected from bores south of the mine, it is possible that stygofauna occur in this region. The taxa living in the southern section of the aquifer would be similar to those living in the northern section, given the likely connectivity. However, numbers of stygofauna would probably be higher in the north, due to the more extensive distribution of suitable habitat in this area.

More extensive and targeted sampling of stygofauna will be undertaken as part of the adaptive management framework associated with the GDEMMP. This will provide further information on the distribution of stygofauna across parts of the Study Area that will be subject to groundwater drawdown, and allow the response of stygofauna to Project-related changes in the water table aquifer to be monitored.

6.5.2 Impact assessment

The main aspect of the Project impacting aquifer ecosystems is the dewatering required prior to and during excavation. This has the potential to remove areas of stygofauna habitat, and as the drawdown cone extends across the width of most of the water table aquifer, to isolate communities south of the mine from those in the more extensive sediments to the north. This will have a localised impact on the stygofauna community of the central Styx River alluvium, and could also reduce diversity in the southern part of the aquifer over the life of the mine, since migration pathways will be severed.

A risk assessment of potential impacts of the Project on stygofauna was completed in **Section 6.5.3**. The residual risk of impacts from groundwater drawdown on stygofauna was assessed to be Medium. The residual risk of all other modes of impact on stygofauna was assessed to be Low, as a consequence of the likely widespread distribution of stygofauna in areas adjacent to the Project Area, which will not be impacted by groundwater drawdown.

Overall, impacts on stygofauna are considered to be acceptable, as they will result in the localised loss of assemblages that are likely to be well represented in adjacent areas. Extensive monitoring of GDEs including stygofauna will be undertaken as part of the adaptive management approach outlined in the GDEMMP. Stygofauna sampling will occur ahead of groundwater drawdown occurring, targeting the upper freshwater sections of aquifers. Samples will also be collected from locations outside of groundwater drawdown areas to understand stygofauna distribution patterns across the broader Styx River basin (**Section 10.1.1**).

6.5.3 Risk Assessment

Potential impacts on Subterranean GDEs have been assessed using the risk assessment framework outlined in **Section 2.4.1**. The potential impacts considered include those common to all assessments (**Section 4**):

- Direct disturbance of vegetation and/or habitat
- Changes to groundwater level
- Changes to groundwater quality
- Changes to surface water flow (hydrology)
- Changes to surface water quality
- Erosion of sediments (not relevant to stygofauna)
- Changes in the location of the freshwater – saltwater interface.

The risk assessment for Subterranean GDEs that outlines the potential impacts, initial risk, control measures and residual risk following the implementation of control measures is provided in **Table 6-2**.

Table 6-2: Risk assessment for Subterranean GDEs

Mechanism of change	Potential impacts	Likelihood of occurrence	Consequence rating	Risk assessment rating	Proposed mitigation measures	Residual risk
Drawdown in alluvium from aquifer dewatering, resulting in direct disturbance to stygofauna habitat	Stygofauna will be lost from the area of impact around the mine, and communities upslope of the mine will be isolated from downstream communities. It is the lower reaches of the Styx alluvium, and areas adjacent to the main creeks where stygofauna diversity is likely to be highest. Any taxa living in the area modelled for drawdown are likely to also occur in the downstream reaches.	Likely	Moderate	High	Project design to minimise the area of water table aquifer drawdown. Apply an adaptive monitoring approach through the GDEMMP, involving the monitoring of groundwater and stygofauna in the alluvium. Target shallow bores that sample fresh groundwater overlying saline deeper water.	Medium
Depressurisation of lower aquifers causing change in groundwater flux and direction	Changes in the volume and quality of alluvium groundwater caused by depressurisation of deeper aquifers, which could impact stygofauna communities	Unlikely	Minor	Low	As above for aquifer ecosystems	Low
Alteration of recharge patterns for water table aquifers	Reduced infiltration from rainfall at impermeable surfaces such as roads, and an increase in infiltration along creeks during periods of drawdown.	Possible	Minor	Medium	Project design to minimise the area where water will be captured and not infiltrate to the creeks. Minimal enhanced leakage estimated from the regional groundwater model (HydroAlgorithmics 2020).	Low
Leachate from waste rock stockpiles percolating into aquifers	Leachates could percolate into aquifer, then into creeks. Change to water quality post-mining.	Possible	Moderate	High	Proper sealing of stockpile base and bunding	Low
Seepage from storage dams	Local changes to groundwater quality around dam	Unlikely	Minor	Low	Dam design to reduce the risk of seepage, including use of low permeability clay as a	Low

Mechanism of change	Potential impacts	Likelihood of occurrence	Consequence rating	Risk assessment rating	Proposed mitigation measures	Residual risk
					foundation or a liner to prevent migration of contaminants	
Change in surface water flows	Changes to the hydrology of surface water resources, affecting recharge of water table aquifers	Unlikely	Minor	Low	Design has minimised changes of surface water flows to negligible levels (WRM 2020).	Low
Discharge of mine water to creeks	Change of water quality in creeks, which may infiltrate shallow aquifers during periods of no rainfall. Released water may lack key elements if water is treated with reverse osmosis, could be low in dissolved oxygen, may cause erosion.	Likely	Minor	Medium	Water management strategy implemented to result in minimal change to water chemistry in downstream waters (WRM 2020). Fit energy dissipation structures and release water at low velocity, and over rocky substrate. Spray water to aerate. Add supplementary minerals or elements, if necessary.	Low
Erosion of sediments	Not relevant to Subterranean GDEs	Rare	Insignificant	Low	Erosion and sediment control plan will be implemented at the Project site.	Low
Change in location of freshwater – saltwater interface	Changes in the water chemistry of aquifers providing habitat for stygofauna	Unlikely	Minor	Low	Design to minimise changes in the location of the freshwater – saltwater interface as a result of Project activities.	Low

6.6 Aquatic GDEs - Surface Expression of Groundwater (Type 2)

6.6.1 Locations and types of Aquatic GDEs

Investigations undertaken as part of the EIS assessment indicate that there is potential for baseflow of groundwater into the waterways bordering the Project Area and therefore these waterways are consistent with the definition of Aquatic GDEs (3D Environmental 2020; ELA 2020a; HydroAlgorithmics 2020). Environmental isotope analysis of samples from Tooloombah Creek and Deep Creek indicate that baseflow is supported by groundwater to varying extents (HydroAlgorithmics 2020).

Throughout the wet season, flows within Tooloombah Creek and Deep Creek are primarily driven by rainfall-generated surface water runoff and associated baseflow (WRM 2020). During the dry season, groundwater is expressed within some sections of Tooloombah Creek and Deep Creek, sustaining some pools throughout part, or in some cases all, of the dry season (WRM 2020; ELA 2020a). In addition, aquatic GDEs in the lower catchment are likely have year-round access to groundwater, whereas those in the upper to middle reaches may only have seasonal connection to groundwater. From an ecological perspective, the potential effects of the Project on pools during periods of no flow is therefore the primary consideration.

Evaporative modelling from a permanent pool on Tooloombah Creek (ToGS1; **Figure 6-3**) shows that the high EC values in the pool could only be achieved through inputs of saline groundwater, rather than evaporation alone (WRM 2020). Salinity (and EC) values are generally low (<500 µS/cm) during the wet season, when freshwater runoff from the catchment is the primary source of water. During the dry season, as the pool becomes isolated, saline groundwater inputs dominate the water chemistry, with the pool achieving a salinity concentration that is higher than could be achieved by evaporation alone (WRM 2020).

There have been a range of investigations of the number and distribution of pools that receive groundwater inputs during the dry season. Pool surveys have been undertaken at various periods during the EIS and SEIS studies, with water quality sampling of the larger and more permanent pools undertaken on a regular basis (approximately monthly) in the period 2017 to August 2020. This has resulted in over 40 inspections of a sub-set of the largest pools over a period of several years, with recordings made on whether the pool was flowing or dry. The following key findings of these investigations are relevant:

- The Tooloombah Creek Gauging Station Pool (ToGS1) is permanently connected to groundwater and persists through the dry season as a permanent pool
- Other large pools on Tooloombah Creek (TO1, TO2, TO3) are also considered to be permanent or semi-permanent, with all being recorded as dry on <10% of regular inspections. These pools also likely receive groundwater inputs all year round.
- At Deep Creek and associated tributaries, the majority of pools are ephemeral, drying out at various stages during the dry season. However, there is a clear trend of increasing permanence (and likely groundwater inputs) with distance downstream. DE5 (located furthest downstream) was recorded as dry on <10% of regular inspections and has therefore been categorised as semi-permanent.

- In addition to the larger pools that have been subject to regular inspection, more than 20 other pools have been mapped. These are generally smaller (and likely more ephemeral) than the larger pools subject to regular monitoring.

The location of pools within the Study Area, and observations from field studies on whether they are persistent or ephemeral pools, are presented in **Figure 6-3** and **Table 6-3.** This work was completed as part of the baseline surveys for the EIS and SEIS's and included several inspections during the period 2017 to 2020. The presence of surface water at pools during the dry season was also examined using aerial photography. Photographs were examined over time to assess the persistence of pools over dry periods and hence make an assessment of the likely persistence of pools during the dry season, and hence the degree to which they are groundwater dependent (Central Queensland Coal 2020b).

Each pool is likely to have a differing degree of groundwater input, which may be a permanent connection (groundwater inflow) or a temporary one through the wet season and parts of the dry season. As there is spatial variability in the salinity of alluvial groundwater (as indicated through monitoring of alluvial groundwater bores), each pool is likely to have a unique pattern of water chemistry and persistence through the dry season.

Table 6-3: Summary of pools adjacent to Project Area and their potential groundwater dependence (Central Queensland Coal 2020b)

Site ID	Persistence	Comments
4	Ephemeral	Medium pool. Ephemeral (satellite imagery shows water in 2011, dry in April and September 2018).
5	Permanent	Medium-large pool. Appears permanent (satellite imagery shows water in 2011, throughout 2018, observed in February 2018, part of To1 pool).
6	Permanent	Medium pool. Appears permanent (satellite imagery shows water in 2011, April and September 2018, though drying out in September 2018).
7	Unknown	Small pool. Water observed in January-February 2018. Otherwise satellite imagery inconclusive.
11	Permanent	String of medium pools. Appears permanent (satellite imagery shows water in 2011, April and September 2018, field observations show water in May 2020).
12	Permanent	Stretch of medium to large pools leading up to confluence. Appears permanent (satellite imagery shows water in 2011, April and September 2018, field observations show water in May 2020).
13	Permanent	Permanent, tidally affected downstream from confluence. Observations, sampling and satellite imagery confirm (satellite imagery shows water in 2011, April and Sep 2018).
17	Permanent	Medium pool. Appears permanent (satellite imagery shows water in water in 2011, April and September 2018), but also appears to be the result of the damming of the creek lower down (dam present in satellite imagery 2011, 2018).
22	Ephemeral	Small pool, observed in June 2020. Satellite imagery inconclusive, likely ephemeral.
23	Ephemeral	Medium pool, observed in June 2020. Satellite imagery inconclusive, likely ephemeral.
24	Ephemeral	Medium pool, observed in June 2020. Satellite imagery inconclusive, likely ephemeral.
25	Ephemeral	Medium pool, observed in June 2020. Satellite imagery inconclusive, likely ephemeral.
26	Ephemeral	Small pool. Pool observed in June 2020. Satellite imagery inconclusive, likely ephemeral.

Site ID	Persistence	Comments
27	Ephemeral	String of small to medium sized ephemeral pools, observed in June 2020.
28	Ephemeral	String of small to medium sized ephemeral pools, observed in June 2020.
29	Ephemeral	String of small to medium sized ephemeral pools, observed in June 2020.
30	Ephemeral	Medium to large sized pool / string of pools, observed in June 2020. Satellite imagery inconclusive. Likely ephemeral.
31	Ephemeral	String of small ephemeral pools, joining at times into larger pool. Water present in satellite imagery in 2011, and perhaps in April 2018, but the sandy river bed is evident in September 2018.
32	Ephemeral	Medium pool, present in 2011 and April 2018 satellite imagery, but appears dry in September 2018 imagery. Since To1 upstream dries out, likely this is also ephemeral.
33	Permanent	Appears to be well connected to the confluence site, but Sep 2018 may show disconnection and drying up of this section.
34	Ephemeral	Medium disconnected pools apparent in 2011, disappear in 2018 (both April and September) satellite imagery.
35	Ephemeral	Small pool identified in 2011, appears to disappear in later satellite imagery (April, September 2018).
Ba1x	Ephemeral	Small pool. Dry in 2 out of 4 recorded events.
Br 15	Ephemeral	Small pool, identified in May 2020, but not apparent in satellite imagery. Given location and size, likely to be ephemeral.
De_Br 7	Unknown	Small pool visited May 2020, cannot be seen on satellite imagery.
De1	Ephemeral	Small pool. Dry on 18 of 46 inspections.
De2 Pool 1	Ephemeral	Medium pool. Observed July 2018, satellite imagery 2011, and monitored 20 May 2019 - 8 July 2019, when it went dry.
De2 Pool 8	Ephemeral	Small pool, observed in February 2018, May 2020. Likely ephemeral based on nearby pools.
De3	Ephemeral	Small pool. Dry on 13 of 45 inspections.
De4	Ephemeral	Small pool. Dry on 4 of 36 inspections.
De4 Pool 20	Ephemeral	Small pool below De4, observed in May 2020. Likely ephemeral based on nearby pools (especially De4).
De5	Semi-permanent	Small pool. Dry on 2 of 32 inspections.
De5 Pool 14	Ephemeral	Small pool below De5. Appears ephemeral (water observed in July 2018, May 2020, but appears to be dry in satellite imagery – 2011, April and September 2018).
De5 Pool 21	Ephemeral	Small pool adjacent to Deep Creek. Appears ephemeral (water observed in May 2020, but appears to be dry in satellite imagery of 2011, April and September 2018.
DCS	Ephemeral	String of small ephemeral pools, observed in June 2020. Based on surrounding pools and size, appears ephemeral (no data from satellite imagery).
Pool 19A, B	Unknown	Pair of small pools. Water in May 2020. Otherwise satellite imagery inconclusive.
St1	Permanent	Part of large pool. Water at all times during sampling, and in 2011, April and September 2018.
To Pool 10	Permanent	Large pool, observed in May 2020. Appears permanent (water in 2011, April and September 2018, May 2020).

Site ID	Persistence	Comments
To1	Semi-permanent	Part of large Pool 5 when full (January - February 2018), otherwise medium sized. Dry on 2 of 50 inspections.
To2 Pool1	Permanent	Large pool. Water present on all of 41 inspections, and in 2011, 2018 satellite imagery.
To3	Semi-permanent	Medium sized pool. Dry on 1 of 32 inspections.
ToGS1	Permanent	Medium sized pool. Gauging station, containing water January 2020 onwards, and water in 2011, April and September 2018 satellite imagery.

The primary period of interest from the perspective of assessing impacts on Aquatic GDEs is the dry season, when the aquatic ecology values of the creeks are essentially comprised of isolated pool. During the wet season, groundwater inputs have minimal influence on the amount of water in the system and the overall water chemistry. However, during the dry season, changes to the expression of groundwater to pools has the potential to result in a shorter duration of pool persistence through the dry season, as well as variation in water chemistry within pools. Overall, a reduction in groundwater inputs to pools can be expected to result in pools drying up faster during the dry season than under baseline conditions, with a less saline water chemistry overall, as saline groundwater inputs are reduced.

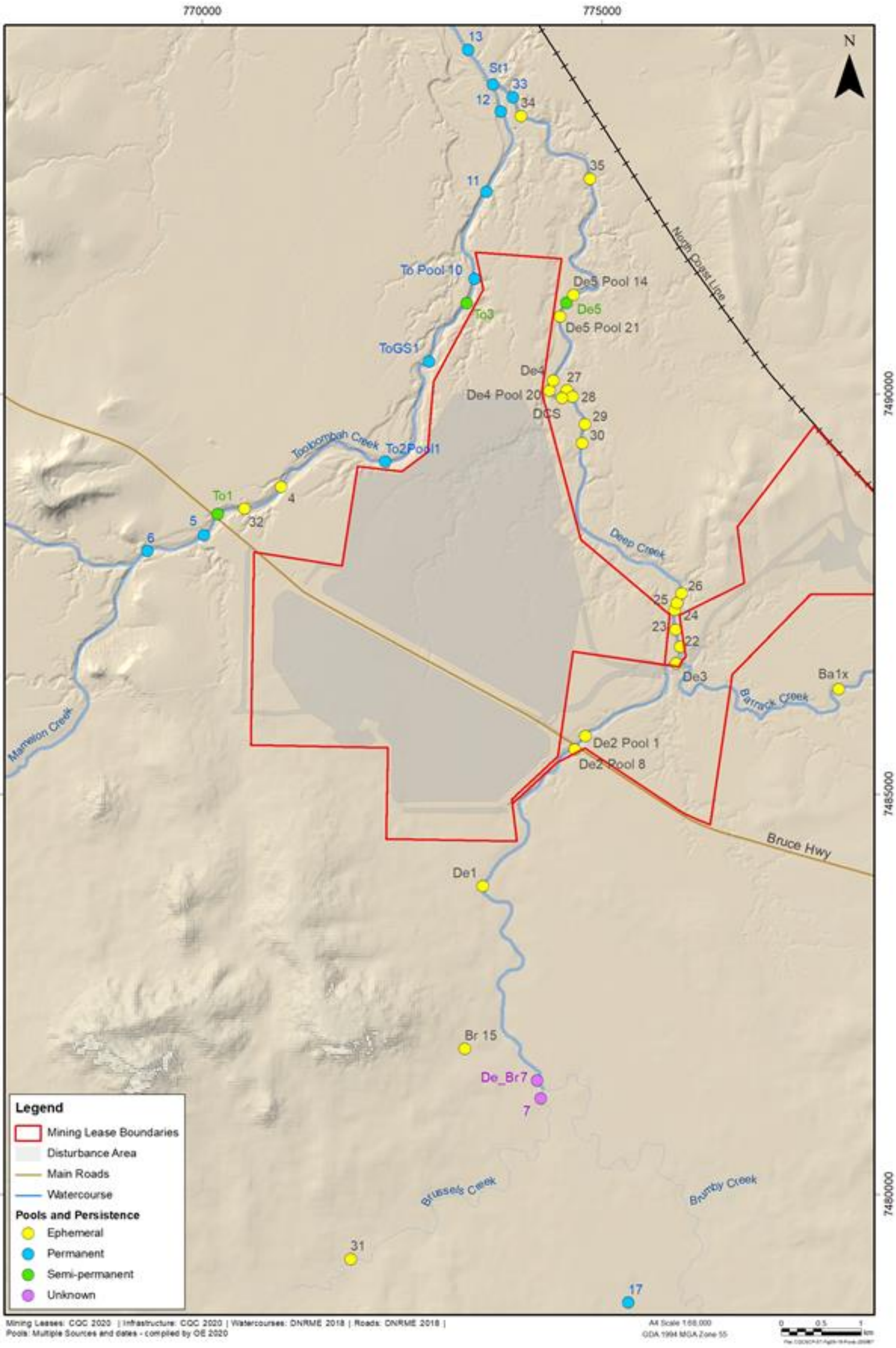


Figure 6-3: Map showing the location of pools along watercourses of the Study Area, and observations of their persistence during dry periods (Central Queensland Coal 2020b)

The desktop assessment identified two wetlands mapped on the GDE Atlas with potential to be Aquatic GDEs. These are:

- Wetland 1 - a Great Barrier Reef wetland of high ecological significance (HES) located in a GBR wetland protection area (WPA). It is identified in the GDE Atlas as a high potential aquatic GDE and moderate and low potential terrestrial GDE.
- Wetland 2 - a wetland of general ecological significance (GES). It is It is identified in the GDE Atlas as a high potential aquatic GDE and low potential terrestrial GDE.

However, field investigations of vegetation at Wetland 1 and Wetland 2 have confirmed that these areas are not supported by the surface expression of groundwater, and are therefore not Aquatic GDEs (3D Environmental 2020). Water and associated soil moisture at Wetland 1 and Wetland 2 are derived from internally draining surface water, rather than the surface expression of groundwater. Such findings are consistent with the findings of HydroAlgorithmics (2020), which noted that there are no springs known to be present with in the Project Area.

Further consideration of the potential groundwater dependence of vegetation within Wetland 1 and Wetland 2 is provided in **Section 6.7**, in the context of utilising sub-surface groundwater (Terrestrial GDE).

Field studies of 3D Environmental (2020) identified that Weeping paperbark trees occurring along the riparian fringe of Deep Creek and Tooloombah Creek, and near groundwater-fed pools, are consistent with the definition of an Aquatic GDE (3D Environmental 2020), as they are shallow rooted and utilising groundwater fed stream pools and fluvial sands.

6.6.2 Habitat features of Aquatic GDEs

As outlined above, the only Aquatic GDEs located within the Study Area that may be affected by the Project are sections of Deep Creek and Tooloombah Creek, which have connections with groundwater in some locations, the nature of which varies on a seasonal basis. The duration of time that water persists within pools during the dry season, and the quality of this water, are key considerations in assessing the habitat features of Aquatic GDEs. During periods of high rainfall, the groundwater connection is expressed as additional water inputs to the creek, which add to the water produced by catchment runoff. During the dry season, the creeks are comprised of a series of isolated pools, separated by dry creek bed, comprised of rock, gravel or sand.

HydroAlgorithmics (2020) modelled the net baseflow and/or leakage of groundwater to and from various stream sections of the Study Area, and found that sections located above the influence of tides varied from -0.19 ML/day (leakage) to 0.77 ML/day (baseflow). These ranges show that stream sections have the capacity to receive and lose groundwater from the system, based on recent climatic conditions, which influence rainfall and stream flow states.

Monitoring of pool water level and chemistry has indicated that pools that do not receive groundwater inputs tend to retain an EC of <1,500 µS/cm and lose approximately 5-10 mm of water per day during the dry season, due to evaporation (Amec 2019). In contrast, the Tooloombah Creek pool has a more stable water levels, and moves from an EC of <1,500 µS/cm at the start of the dry season, to over 15,000 µs/cm at the end of the dry season (Amec 2019; WRM 2020), as the ratio of fresh surface water to saline groundwater within the pool changes over time.

WRM (2020) completed a Tooloombah Creek pool salt and water balance. They presented a comparison of recorded and simulated water level and salinity in the pool with the addition of a constant daily groundwater inflow of 4.5kL/d with a salinity of 15,000 µS/cm. Under various inflow scenarios, it was demonstrated that an additional inflow, not dependent on rainfall, with elevated salinity was required to match the recorded water quality data (**Figure 6-4**). This led to the conclusion that there is a small groundwater source to the Tooloombah Creek pool.

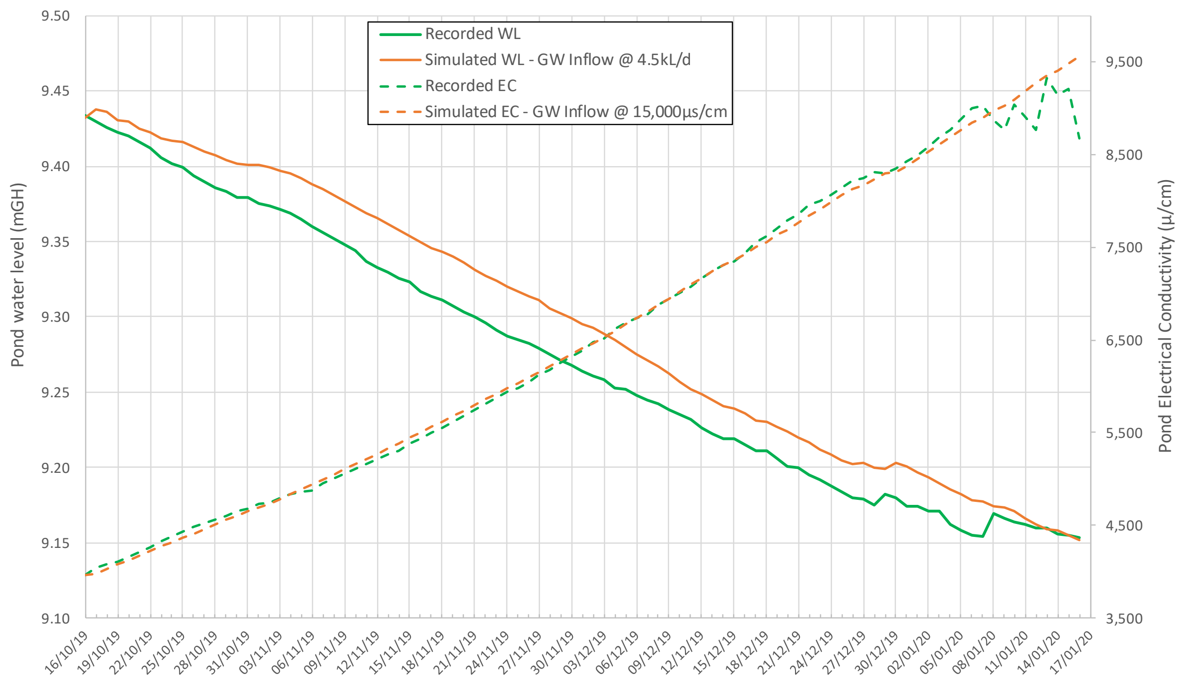


Figure 6-4: Comparison of simulated and recorded water level and salinity in Tooloombah Creek pool, inflow source 4.5 kL/d at 15,000 µS/cm (WRM 2020)

Groundwater modelling (HydroAlgorithmics 2020) has predicted a maximum drawdown of 1.5 m in the water table aquifer along approximately 4.4 km of Tooloombah Creek, and approximately 11.5 km of Deep Creek. The maximum groundwater drawdown is predicted to reach approximately 4.7 m in Tooloombah Creek, and approximately 60 m in Deep Creek. Pools along these waterway reaches are often less than 1.5 m deep, so may persist for shorter periods than currently under baseline conditions during extended periods without rainfall. However this depends on the level of connectivity a given pool has with groundwater and it is known that not all pools have this connection. These pools can also be expected to retain their freshwater chemistry <1,500 µS/cm while they persist during the dry season in the event that saline groundwater inflows are reduced or cease as a result of the Project.

Following rainfall, porous sections of creek bed may lose water through underlying sediments until the bed becomes impermeable, referred to as enhanced leakage. Modelling indicates that drawdown in the water table aquifer (model layer 2) will extend below Deep Creek and Tooloombah Creek, but what impact this will have on water levels will depend on the hydrological connectivity between the creeks and their underlying aquifers. This is influenced by a range of localised factors, including the composition of alluvial sediments.

Central Queensland Coal (2020a) completed several alluvial drilling transects in May and June 2020 to collect additional information on the permeability of sediments within the riparian corridor at key locations where groundwater drawdown is predicted. Packer and permeability tests were also completed by AMEC (2019), along with monitoring of pool water level at several locations during the dry season. Key findings of these studies are summarised as follows:

- During baseline monitoring, pools in Deep Creek lost approximately 10 mm of water per day during the dry season, compared with approximately 5 mm per day in Tooloombah Creek. The difference in loss to evaporation and seepage could possibly be attributed to higher groundwater inputs in Tooloombah Creek, and a more permeable alluvium in Deep Creek (ELA 2020a).
- Sediments of the alluvial corridor at Tooloombah Creek have a very low permeability to water, assisting to maintain high moisture content in soil held in bank storage (ELA 2020a)
- Sediments of the alluvial corridor at Deep Creek have a higher permeability and are more susceptible to the effects of drawdown reducing groundwater available to GDEs (ELA 2020a).

ELA (2020a) completed a study of groundwater and surface water interactions, informed by the result of alluvial drilling transects (Central Queensland Coal 2020a). The study identified that there is weathered clay underlying the alluvium of Tooloombah Creek, with water held in bank storage flowing towards the creek, maintaining water levels throughout the dry season. Bank storage within the alluvium is recharged through lateral flow of surface water during the wet season, causing mounding in the water table aquifer. Flows from bank storage were predicted to reach the creek for a period of approximately 150 days. Increases in salinity in some pools of Tooloombah Creek can be explained by the contribution of saline groundwater inputs, in addition to the effects of evaporation. This groundwater may be sourced from bank storage (containing some dissolved salts), or from rises in the underlying saline water table (ELA 2020a).

ELA (2020a) found that Deep Creek consists of sandier soils, with lower clay content than Tooloombah Creek. Bank storage is feasible, although water is estimated to flow away from the creek, playing a lesser role in sustaining GDEs than occurs in Tooloombah Creek. Deep Creek is not groundwater fed in many locations, leading to a loss of soil moisture and surface water in pools during the dry season. Increases in salinity within pools of Deep Creek can be explained by evaporation only. These results suggest that groundwater interactions are more important to sustain the ecological values of Tooloombah Creek, in particular the persistence of pools, than they are at Deep Creek. Such findings are consistent with field observations of pools, with the majority of pools in Deep Creek being ephemeral, while those in Tooloombah Creek are permanent or semi-permanent (**Table 6-3**).

Under baseline conditions, most invertebrate taxa present in the pools are tolerant of a hydrological regime where water is present for only a part of the year, and water chemistry fluctuates widely. Such taxa are characterised by an ability to disperse aerially (e.g. Corixidae), or are readily able to drift downstream as water levels decline (e.g. Hydropsychidae). While drawdown at Tooloombah Creek and Deep Creek is likely to result in a shorter period of pool persistence, periods of surface water flow will still occur after rainfall and remain largely unchanged from baseline conditions (WRM 2020). Invertebrates and fish will persist in the downstream reaches of the Styx River during periods of no flow, and will recolonise areas upstream when flow resumes.

One of the main risks of the Project to fish communities is a disruption in connectivity along waterways, as groundwater drawdown may cause reaches and isolated pools to dry up quicker than they do under baseline conditions. A key characteristic of migratory fish is that they move up or downstream during the wet season, when rainfall provides the water needed for hydrological connectivity (Harding *et al.* 2017). At other times of the year, the creeks are mostly dry or have only a few isolated pools of water. These pools of water have highly variable water chemistry, and are subject to impacts from existing grazing activities including access by cattle for drinking. The pools therefore constitute a harsh environment for aquatic organisms, favouring taxa that have a short life cycle or high tolerance for variable conditions. Outside of the modelled drawdown area, pools are likely to continue to hold water on a seasonable basis, so will retain their existing ecological function as suitable refuge habitats.

WRM (2020) completed modelling of three scenarios for groundwater inputs to pool:

- Continuation of existing inferred situation (small groundwater input of 4.5kL/d at 15,000 µS/cm EC)
- Zero groundwater inflow to pool
- Leakage of surface water from the pool, at a rate of 1 L per second per km, which is equivalent to the enhanced leakage estimated by HydroAlgorithmics (2020).

The 1L/s leakage was based on an assumed constant 1m depth of water in the creek, and connectivity along the entire reach (at the assumed level of streambed conductivity). Given the ephemeral nature of the waterways, this should be assumed as an upper limit based on the modelling.

Results of these three scenarios for the permanent main Tooloombah Creek Pool (ToGS1) are shown in **Figure 6-5**. The results show that in the event that groundwater inflows to the pool ceased, the water levels of the pool are reduced by approximately 0.5 m, and the salinity reduces substantially to <1,000 µS/cm EC for 95% of the time. In the event that enhanced leakage occurs, the pool becomes ephemeral, containing water for approximately 70% of the time. EC is reduced substantially and is always <1,000 µS/cm EC (WRM 2020; **Figure 6-5**).

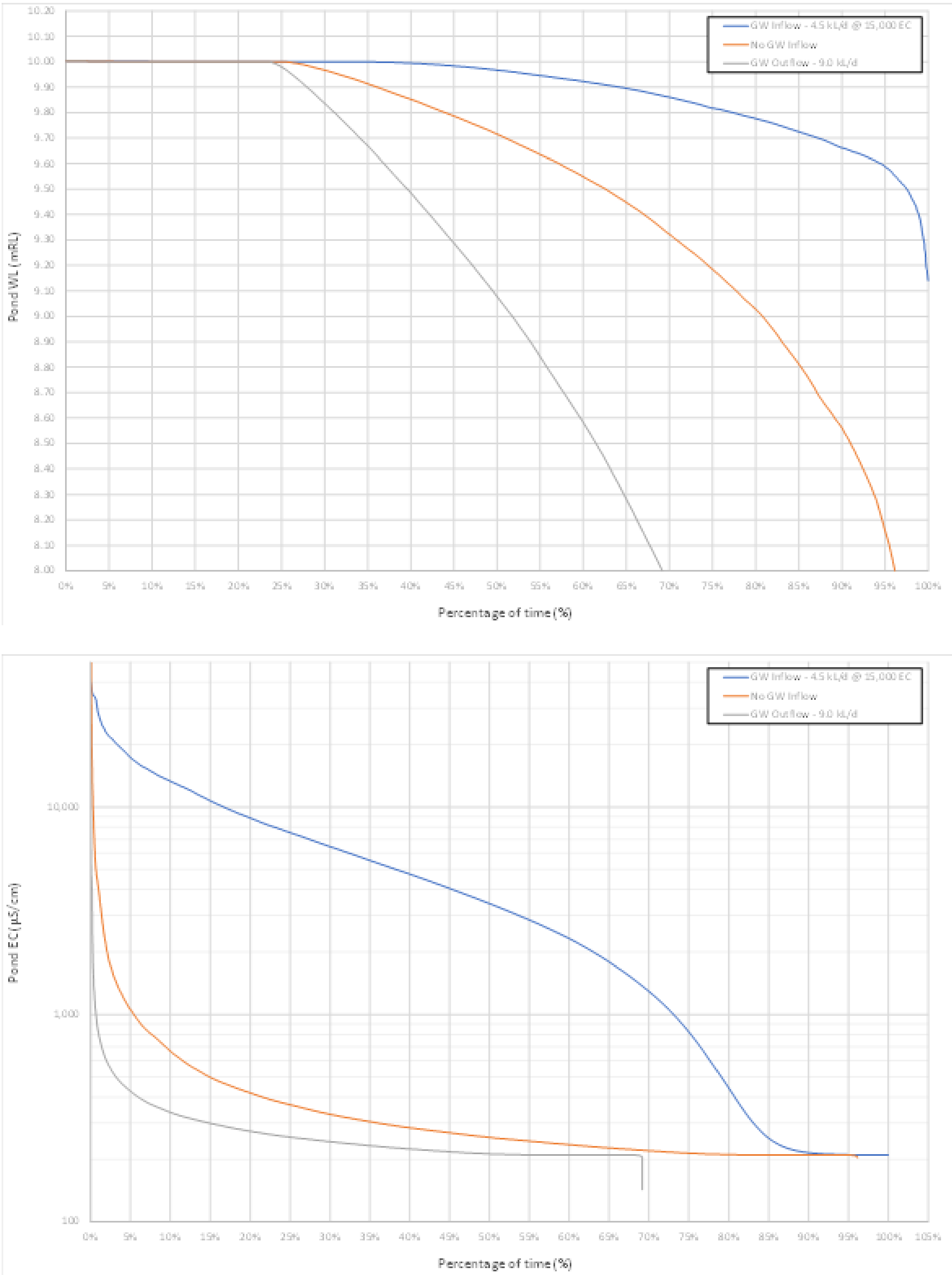


Figure 6-5: Modelled changes of Tooloombah pool water level (top) and EC (bottom) during three groundwater inputs scenarios: existing baseline (blue), zero groundwater input (orange) and enhanced leakage of 1 L per second per km of stream reach (grey; WRM 2020)

ALS (2012) collected 16 species of freshwater fish from waterways adjacent to the Project Area requiring access to the estuarine reaches at some stage of their life. Of these, Barramundi (*Lates calcarifer*) and Sea Mullet (*Mugil cephalus*) were the main species targeted by commercial fishers.

Sea Mullet occupy marine, estuarine, and fresh water environments. Mullet generally feed on zooplankton in marine and estuarine environments, and algae in freshwater. The species is able to acclimate to different levels of salinity and can move between salt water and fresh water. The species was only collected in the Styx River downstream of the Project Area (ALS 2012), but may move upstream to freshwater reaches periodically, during extended periods of flow.

Barramundi live in freshwater reaches and migrate to estuaries to spawn between September and March. Juveniles move upstream when they are approximately 200 to 300 mm in length, where they remain for three to five years before moving back to the ocean to spawn. Barramundi were collected at all sites sampled by ALS (2012), with the exception of one. This indicates that reaches of Tooloombah Creek and Deep Creek that lie adjacent to the Project Area are important migration pathways for this species.

Three species of freshwater turtle were caught during the 2011 and 2017 surveys; Kreft's River Turtle (*Emydura macquarii krefftii*), Eastern Snake-necked Turtle (*Chelodina longicollis*), and Saw-shelled Turtle (*Wollumbinia latisternum*). As pools begin to dry out, turtles are able to move across land to find more permanent water. Pools with a saline groundwater inflow may not be suitable habitat for turtles during the extended dry season, due to their high salinities.

For all fish and turtle species, regardless of whether they migrate to the estuary or not, the critical factor impacting their persistence in the ecosystem and surrounding landscape is the degree to which water drawdown affects pool permanence and water quality. As most of the waterways in the Project Area are ephemeral, the fish (and other aquatic fauna) possess life history strategies that allow them to persist through dry periods. However, if the duration of drying becomes too great, or drying occurs at critical life stages, a significant impact on aquatic ecosystems may occur.

In Tooloombah Creek and Deep Creek, the main period of flow is during the wet season, and this will continue to be the case during the period of mining, within minimal changes expected to the hydrological conditions as a result of the Project (WRM 2020). The main influence of the Project on surface water availability will occur during periods of no-flow, when baseflow to, or leakage from, stream beds may be affected by groundwater drawdown. However, HydroAlgorithmics (2020) predicted 'negligible' changes in natural baseflow to and/or leakage from surface water systems, as a consequence of the Project. Modelled enhanced leakage estimates varied per stream reach, and were generally less than 1 litre per second per kilometre of stream reach (HydroAlgorithmics 2020).

6.6.3 Impact assessment

There will be minimal physical impact to Aquatic GDEs as a result of the Project. Some localised areas of disturbance will occur due to the construction of road crossings, discharge structures and other infrastructure. Such works are likely to involve the clearing of a small area of riparian vegetation, and the placement of new structures within the in-stream habitats. These works will be small in scale, with the locations generally chosen to avoid critical features of aquatic ecology value, such as groundwater fed pools. The risk of Project impacts from physical disturbance was therefore assessed to be Low (**Section 6.6.4**).

Groundwater drawdown is the biggest Project-related threat to groundwater dependent aquatic habitats along the ephemeral Tooloombah and Deep creeks. A reduction or elimination of groundwater inputs to the creek systems during dry periods will have the resultant effect of reducing the time over which pools persist during the dry season. Changes to the water chemistry of pools is also likely to occur, resulting in a more consistent salinity profile (more freshwater) in the absence of saline groundwater inputs.

Each pool is likely to be affected in a different way, as a function of its size (length, width and depth), habitat features and types of fauna it supports, amount of groundwater drawdown predicted to occur in its location, and the degree to which groundwater currently supports the pool under baseline conditions. The greater prevalence of persistent pools along Tooloombah Creek when compared with Deep Creek (**Section 6.6.1**) is consistent with the findings of ELA (2020a) that the alluvial sediments of Deep Creek are generally not supportive of groundwater inflows to the creek system from bank storage.

WRM (2020) modelled the persistence of a typical groundwater fed pool under a range of groundwater drawdown scenarios, including no change to existing, reduction in groundwater flows, elimination of groundwater flows and loss of surface water underground (enhanced leakage). They predicted that for a typical pool fed by groundwater, if that groundwater flow stopped, the water level in the pool would drop, but the pool would remain throughout the dry season. If enhanced leakage occurred from the pool due to drawdown, the pool would become ephemeral, being present only 70% of the time, rather than permanently (WRM 2020).

It should be noted that few of the pools in adjacent waterways are considered to be permanent pools. The Tooloombah Creek pool (ToGS1) is confirmed to be permanent, and was the basis of the above mentioned scenario modelling. However other pools further upstream in Tooloombah Creek and across Deep Creek have been noted to dry up during extended dry periods (**Table 6-3**). In this context, the impacts of groundwater drawdown on Aquatic GDEs (pools) is expected to me relatively minor because:

- Drawdown at Tooloombah Creek is relatively small (<4.7 m) and the sediments in these locations have a low permeability to water (reducing the potential for enhanced leakage)
- Bank storage and associated return flows to Tooloombah Creek are likely to provide safeguards to mitigate impacts on pool persistence from drawdown of the water table underneath the creek
- Permanent pools are likely to still persist throughout most of the dry season, even under the worst case scenario, with improvements in water quality (less variation in salinity) that will make them suitable for colonisation by a wider variety of aquatic taxa
- Ephemeral pools are likely to dry up more quickly and for longer than under existing baseline conditions, especially in the middle reaches of Deep Creek. However, these pools experience a natural cycle of drying under existing baseline conditions, and the aquatic ecosystem is adapted to these cycles.
- Recolonisation of pools will occur naturally as it does under existing baseline conditions following rainfall, once the creeks begin flowing again. This occurs approximately 24% of the time and will not be affected by the Project (WRM 2020).

There will be minimal changes to the surface water quality of Aquatic GDEs arising from the Project. Discharges from the mine will only occur during significant flows, and have minimal impacts on downstream water quality (WRM 2020). During the dry season, when the ephemeral creeks form a series of isolated and contracting pools, changes to water quality of existing pools will be minimal as discharge from the mine will not occur at this time. The most significant change to pool water quality is likely to be a reduction in saline groundwater inputs for some pools, in areas affected by drawdown. Currently, EC within the pools varies considerably from <1,000 µS/cm to 15,000 µs/cm. Only a small proportion of aquatic taxa can tolerate such large variations in salinity. A reduction in groundwater inputs due to Project-related drawdown is likely to increase the suitability of pool water quality to fauna less tolerant of wide variations in water chemistry, for the periods that those pools persist. While pools will continue to increase in salinity due to evaporation, the magnitude of the increase will be much lower than occurs under baseline conditions from the input of saline groundwater.

The Project is not expected to result in any major changes to the natural hydrological conditions of Tooloombah and Deep creeks. While some runoff within the creek catchments will be captured and retained on site within the mine footprint, the amount of water involved is minimal compared with that entering the creeks as runoff from the broader catchment (WRM 2020). In this regard, the ephemeral nature of the creeks and the current flow regimes will remain unchanged, and connectivity along the creek systems for aquatic fauna will not be affected, provided that in stream works are constructed in accordance with relevant standards to facilitate fish passage. In this regard, there will be no change to the length of the period over which connectivity along stream reaches occurs, as this is a function of surface water hydrology, with only very minor influences from groundwater inputs. There will also be no change to the location of the freshwater – saltwater interface, by virtue of the absence of any change to surface water hydrological conditions (WRM 2020).

An assessment of geomorphological values and potential Project impacts found that there is minimal risk of erosion arising from the Project, provided that appropriate engineering designs and controls are utilised (Gippel 2020). The use of rock armour to avoid scouring in drains and at the location of discharge structures will prevent any material changes to the existing erosive processes at the site. Removal of cattle grazing and cattle access to waterways is also likely to assist in stabilising stream banks, reduce erosion and improve the quality of water within waterway pools.

Impacts of the Project on groundwater dependent vegetation (**Section 6.7**) may result in a reduction in the condition and number of large trees along sections of the riparian corridor, potentially affecting bank stability, erosion, and therefore instream aquatic ecology values. However, with the implementation of rehabilitation works involving suitable vegetation species, such impacts are likely to be minimal.

The risk assessment identified that following the implementation of mitigation measures, the risk of potential impacts on Aquatic GDE values was Low for all values, with the exception of impacts on pool environments, which was assessed as Medium.

6.6.4 Risk Assessment

Potential impacts on Aquatic GDEs (groundwater fed pools) have been assessed using the risk assessment framework outlined in **Section 2.4.1**. The potential impacts considered include those common to all assessments (**Section 4**):

- Direct disturbance of vegetation and/or habitat

- Changes to groundwater level
- Changes to groundwater quality
- Changes to surface water flow (hydrology)
- Changes to surface water quality
- Erosion of sediments
- Changes in the location of the freshwater – saltwater interface.

The risk assessment for Aquatic GDEs that outlines the potential impacts, initial risk, control measures and residual risk following the implementation of control measures is provided in **Table 6-4**.

Table 6-4: Risk Assessment Aquatic GDEs

Mechanism of change	Potential impacts	Likelihood of occurrence	Consequence rating	Risk assessment rating	Proposed mitigation measures	Residual risk
Direct disturbance to vegetation and habitat	There may be some disturbance to pools within Tooloombah and Deep Creek which are associated with infrastructure such as bridges, revetments or spillway construction These will be small in scale, if they occur at all in areas of GDEs.	Unlikely	Minor	Low	Design of project to minimise number of instances where works are required.	Low
Groundwater drawdown reducing or eliminating groundwater sources to pools within Tooloombah Creek and Deep Creek.	Evaporation of pools during the dry season more quickly than under baseline condition. Reduced distribution and persistence of aquatic habitat during dry season. Reduction in habitat connectivity. Changes in the water chemistry of surface water pools. Reduction of water available to Weeping paperbark	Possible	Moderate	High	Design of mine to minimise area affected by groundwater drawdown.	Medium
Change in surface water flows	Changes to the hydrology of surface water resources, affecting recharge of aquifers which sustain pools during dry season.	Unlikely	Minor	Low	Design has been completed to minimise changes to surface water flows, which are negligible (WRM 2020).	Low
Change in surface water quality Change in groundwater quality	Change of water quality in creeks, which may in turn affect the water quality of pools within creeks. Change of water quality in groundwater-fed pools, due to changes in groundwater quality.	Likely	Minor	Medium	Implement Water Management Strategy to minimise the frequency and volume of discharges and resultant changes to water quality of the receiving environment. Fit energy dissipation structures and release water at low velocity, and over rocky	Low

Mechanism of change	Potential impacts	Likelihood of occurrence	Consequence rating	Risk assessment rating	Proposed mitigation measures	Residual risk
Discharge of mine water to creeks	Cessation or reduction in saline groundwater inputs to pools, resulting in lower salinity.				substrate. Spray water to aerate. Add supplementary minerals or elements, if necessary. Changes to surface water quality in pools are likely to be suited to a wider range of aquatic fauna (i.e., less variability in salinity).	
Erosion	Degradation of bank and other habitat types within pools of creeks. Sedimentation of aquatic habitats. Increase in turbidity of water in pools.	Possible	Minor	Medium	Design has ensured minimal risk of erosion, with removal of cattle grazing likely to reduce erosion and sediment input to streams.	Low
Change in location of freshwater – saltwater interface	Changes in the water chemistry of pools within creeks.	Unlikely	Minor	Low	Design to minimise changes in the location of the freshwater – saltwater interface as a result of Project activities.	Low

6.7 Terrestrial GDEs – Groundwater Dependent Vegetation (Type 3)

6.7.1 Locations and Types of Terrestrial GDEs

The GDE Toolbox defines Type 3 GDEs as ecosystems dependent on the subsurface presence of groundwater, including terrestrial vegetation that depends on groundwater fully or on a seasonal or episodic basis. It is important to note that the two contemporary assessment guidelines for GDEs; the Australian GDE toolbox (Richardson *et al*. 2011) and IESC Guidelines (Doody *et al*. 2019); are explicit that the definition of groundwater dependency is associated with water saturation in pores, fractures in rocks and cavities, and the adjacent capillary fringe.

The definition of groundwater, and thus application to GDEs, does not include the unsaturated zone located above the water table (**Figure 6-6**). The exception to this is the presence of perched aquifers, which are formed above an impermeable layer and are included in the definition of groundwater as it applies to GDEs. This is relevant to the current assessment, as a series of monitoring bores installed across the Project Area and monitored since 2018 have demonstrated that at most locations along the riparian zone, the alluvial aquifer (or aquifer within the underlying Styx Coal Measures) is too saline to meet the water requirements of vegetation. In such locations, terrestrial vegetation would either:

- not meet the definition of a GDE, as their water requirements would be met by fresh water sourced from rainfall and river flooding alone, or
- would be considered a GDE if their water requirements were being met by perched aquifers in the unsaturated zone (**Figure 6-6**) or water held in bank storage that has been captured by the underlying water table aquifer (and thus meets the definition of groundwater).

It is also relevant to note that drawdown of a saline water table aquifer (generally unsuitable for use by vegetation) may have indirect effects on soil moisture levels in the overlying unsaturated zone, with resultant impacts on terrestrial vegetation (**Figure 6-7**). Drawdown of the water table may reduce the hydraulic support provided for water in the alluvial corridor (whether it meets the definition of groundwater or not), and result in less water available for vegetation. The potential for such impacts requires assessment, including for circumstances when the vegetation would not meet the definition of a GDE. In this context, a detailed assessment of the potential indirect impacts of the Project caused by groundwater drawdown on riparian vegetation has been completed in the following sections.

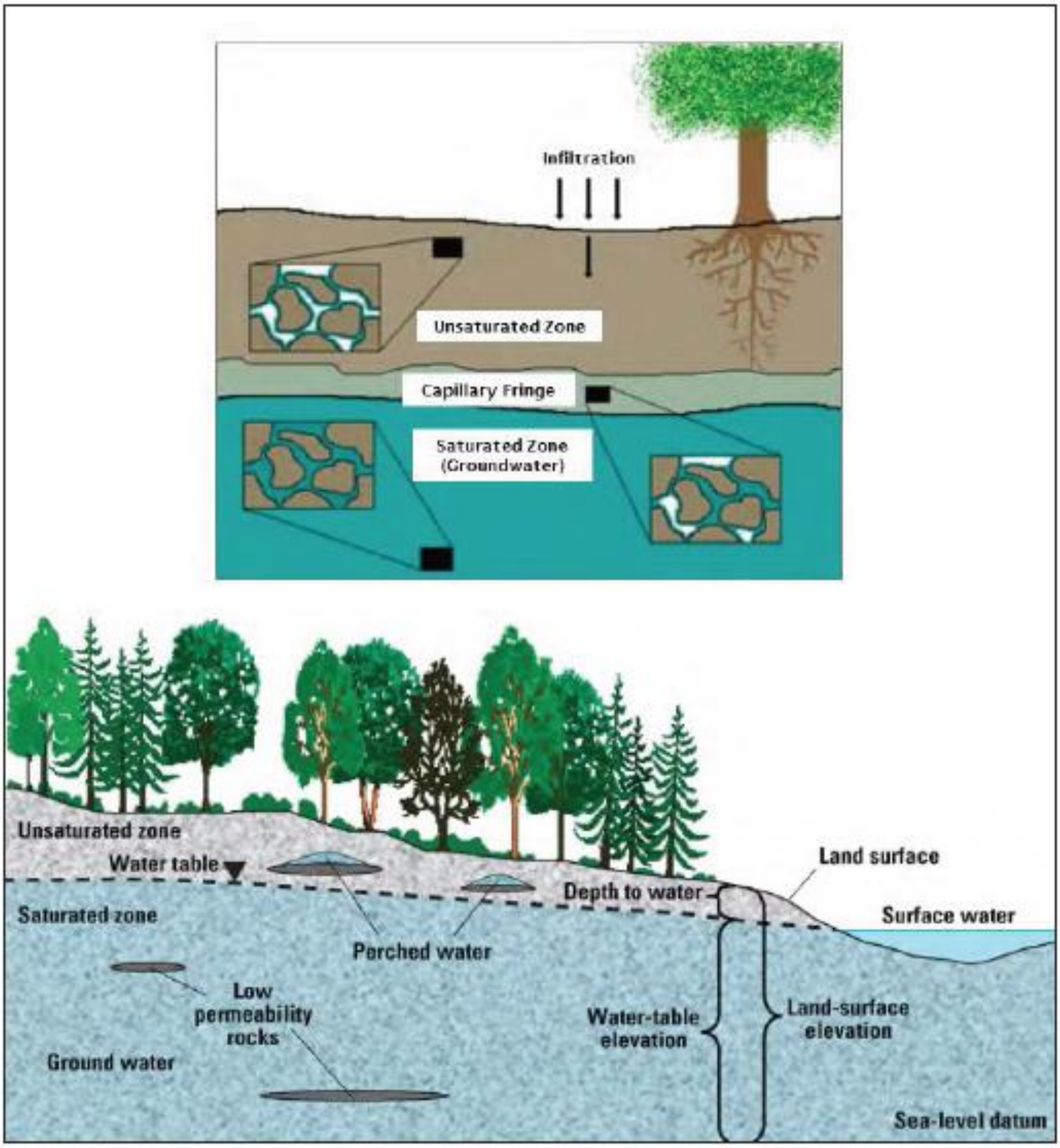


Figure 6-6: Illustration of the difference in saturation of particles in the unsaturated, capillary fringe and saturated zone (top) and perched aquifers in the unsaturated zone (bottom; Doody *et al*. 2019)

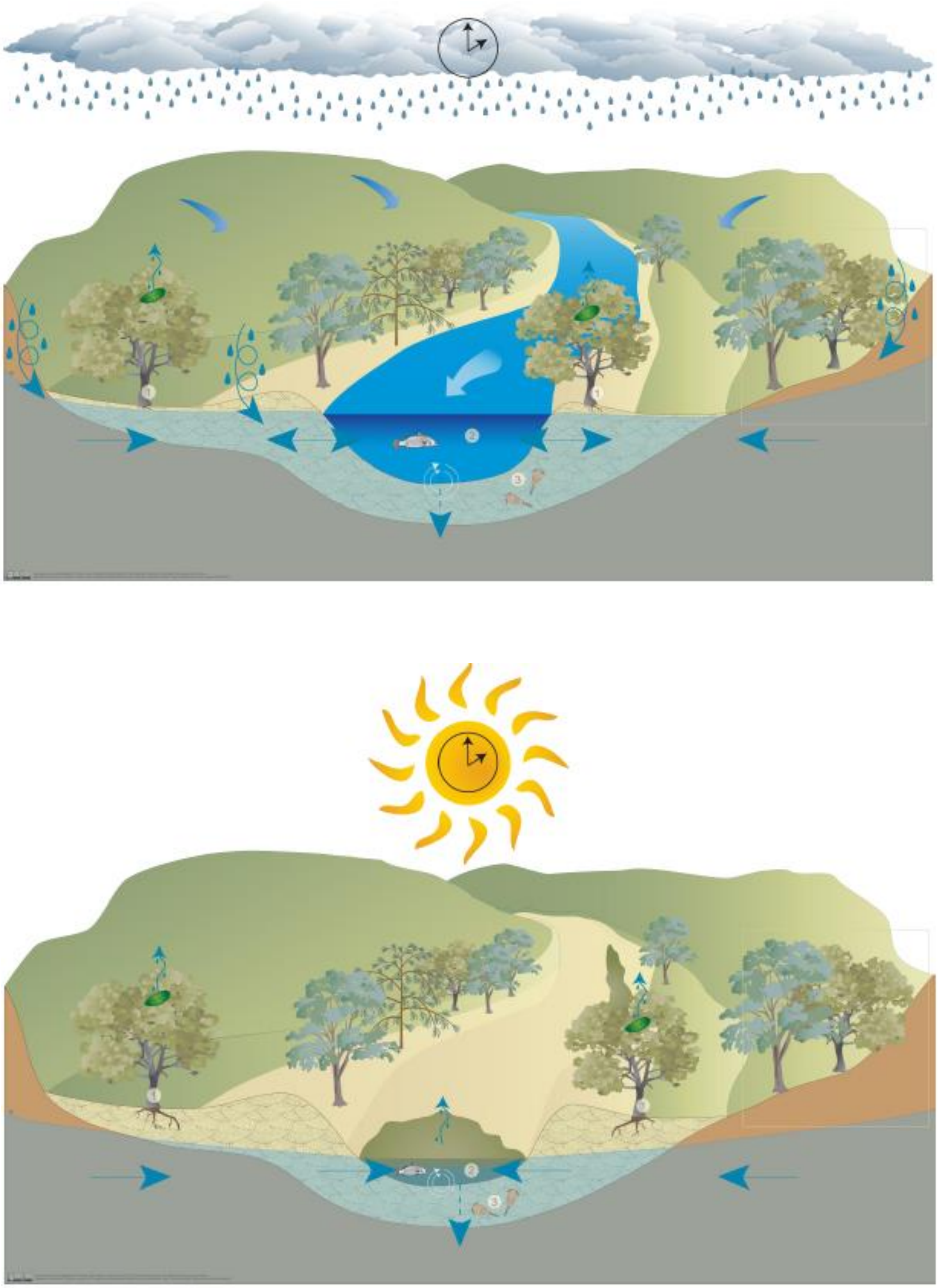


Figure 6-7: Conceptual diagram of the mid catchment alluvia during wet and dry conditions. 1 = Terrestrial GDEs, 2 = Aquatic GDEs and 3 = Subterranean GDEs (WetlandInfo 2013).

Areas with high potential for Terrestrial GDEs occur along the riparian zones of the Styx River, Deep Creek and Tooloombah Creek (**Figure 6-2**). There are also areas with low to moderate potential to be Terrestrial GDEs on the southwestern and southeastern borders of the Project Area.

Regional ecosystems mapped within the areas with potential to be Terrestrial GDEs include:

- Forest Red Gum woodland fringing drainage lines (RE 11.3.25)
- Forest Red Gum woodland on alluvial plains (RE 11.3.4)
- *Melaleuca viridiflora* on alluvial plains (RE 11.3.12)
- *Eucalyptus platyphylla, Corymbia clarksoniana* woodland on alluvial plains (11.3.35)
- Semi-evergreen Vine Thicket (RE 11.13.11) along Tooloombah Creek and the downstream portion of Deep Creek, and
- Freshwater wetlands (RE 11.3.27).

Depth to the water table across the Project Area surrounding locations is typically in the range of 10 to 15 mbgl in floodplains, overlain by freshwater and/or soil moisture within sediments of the alluvial corridor (the unsaturated zone). Vegetation along the riparian corridors is therefore likely to rely upon groundwater during dry periods only, when soil moisture derived from rainfall and river flooding has been depleted.

Field studies were completed in 2018 to examine the potential groundwater dependence of vegetation in a variety of locations across the Study Area, including Wetlands 1 and 2, and the riparian corridors of Tooloombah Creek and Deep Creeks (3D Environmental 2020). A range of survey techniques were used to examine the potential for groundwater dependence of individual trees at these locations, including:

- Measurement of leaf water potential
- Geological coring of the soil profile
- Measurement of soil moisture potential
- Stable isotope sampling and analysis.

The following key conclusions were drawn from the field studies (3D Environmental 2020):

- The saturated water source of Wetland 1 is most likely maintained by percolation of surface water from the wetland, with tree roots (Melaleuca) extending to a perched aquifer at a depth of 8 mbgl, with the underlying aquifer at 13.5 mbgl. Wetland 1 meets the definition of a Terrestrial GDE, as vegetation utilises sub-surface groundwater, in the form of a perched aquifer (3D Environmental 2020). As the groundwater dependent Melaleuca is a key component of the wetland and its associated Regional Ecosystem, the entire wetland can be considered a Terrestrial GDE.
- Wetland 2 has a shallow zone of soil moisture generated by surface water runoff, which is associated with the top 2 to 4 m of the soil profile. Any aquifer located beneath Wetland 2 is deeper than 15 mbgl and beyond the reach of tree roots. Wetland 2 is not a terrestrial GDE (3D Environmental 2020) and is not considered further in this section.
- A small patch of SEVT at Tooloombah Creek was found not to be a terrestrial GDE, with the exception of the emergent Forest Red Gums which were found to be accessing fresh water in the shallow coal measures and associated alluvial unconformity. Recharge of the soils moisture is facilitated by high

flow periods resulting in lateral water movement into bank storage. Vine thicket trees had shallower roots and were accessing soil moisture in the unsaturated zone, above the alluvial unconformity. The vine thicket component of the community is not a terrestrial GDE, as the key vegetation species comprising the vine thicket community are not groundwater dependent. However, individual Forest Red Gum trees which are scattered along the riparian corridor and around the fringe of the vine thicket community are Terrestrial GDEs (3D Environmental 2020).

- Both Tooloombah and Deep creeks had Forest Red Gums on the upper terraces that were accessing a saturated moisture source, meeting the definition of groundwater. Weeping paperbark however was utilising different water harvesting strategies reliant on access to surface water in stream pools and fluvial sands (i.e., shallow freshwater resources). The riparian corridors of Tooloombah Creek and Deep Creek contain GDEs, with Forest Red Gum meeting the definition of a Terrestrial GDE (3D Environmental 2020).

Based on the results of these field studies, the main vegetation types with potential to be Terrestrial GDEs are the riparian corridors along Deep Creek and Tooloombah Creek, which include Forest Redgum woodland, and Forest Red Gum Woodland on the alluvial plains.

Whilst Wetland 1 meets the definition of a Terrestrial GDE due to the presence of an impermeable layer and associated perched aquifer located at 8 mbgl, well above the underlying water table at 13.5 m, there is a low risk of impacts from the Project on groundwater dependent vegetation at Wetland 1. Maximum groundwater drawdown of 2.7 m at bore WMP25 near Wetland 1 (HydroAlgorithmics 2020) is unlikely to affect the percolation of surface water to the perched aquifer utilised by vegetation. In this context, the following assessment of Project impacts on Terrestrial GDEs has focussed on riparian zones, where groundwater dependent vegetation occurs in locations where groundwater drawdown in predicted to occur.

The results of drilling investigations (Central Queensland Coal 2020a) and analysis of associated data for a surface water – groundwater interactive model (ELA 2020a) indicate the following key characteristics of the alluvial corridors of Tooloombah Creek and Deep Creek which are likely to support Terrestrial GDEs:

- Soil salinity within the alluvium does not exceed 7,800 µS/cm at Tooloombah Creek and 3,060 µS/cm at Deep Creek. Therefore, moisture contained in the alluvium can be considered suitable for use by terrestrial vegetation.
- Tooloombah Creek has a higher potential for bank storage of water than does Deep Creek
- Sediments of the Tooloombah Creek alluvial corridor have a very low permeability and a greater water holding capacity by virtue of their fine sediment grain size (clay)
- Groundwater level mostly remains below the base of the creek bed.

6.7.2 Regional Ecosystems and their potential groundwater dependence

The potential for vegetation communities within and surrounding the Project Area to be groundwater dependent was examined by reviewing the predominant tree species comprising each Regional Ecosystem and investigating previous records of the groundwater dependence of those species. The primary source of information was IESC (2018), which included a list of vegetation species that are likely to be GDEs, along with a range of depths to water table derived from various published studies.

Five Regional Ecosystems in the Project Area were identified as having potential to be GDEs or otherwise susceptible to impacts from groundwater drawdown (**Table 6-5**):

- 11.3.4 *Eucalyptus tereticornis* and/or *Eucalyptus spp.* woodland on alluvial plains
- 11.3.25 *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines
- 11.3.12 *Melaleuca viridiflora M. argentea* +/- *M. dealbata* woodland on alluvial plains
- 11.3.27 Freshwater wetlands
- 11.3.35 *Eucalyptus platyphylla, Corymbia clarksoniana* woodland on alluvial plains.

These Regional Ecosystems occur along the riparian corridors comprising Tooloombah Creek and Deep Creek or as isolated wetlands (**Figure 6-8**).

Figure 6-8: The location REs with potential Terrestrial GDEs across the Project Area

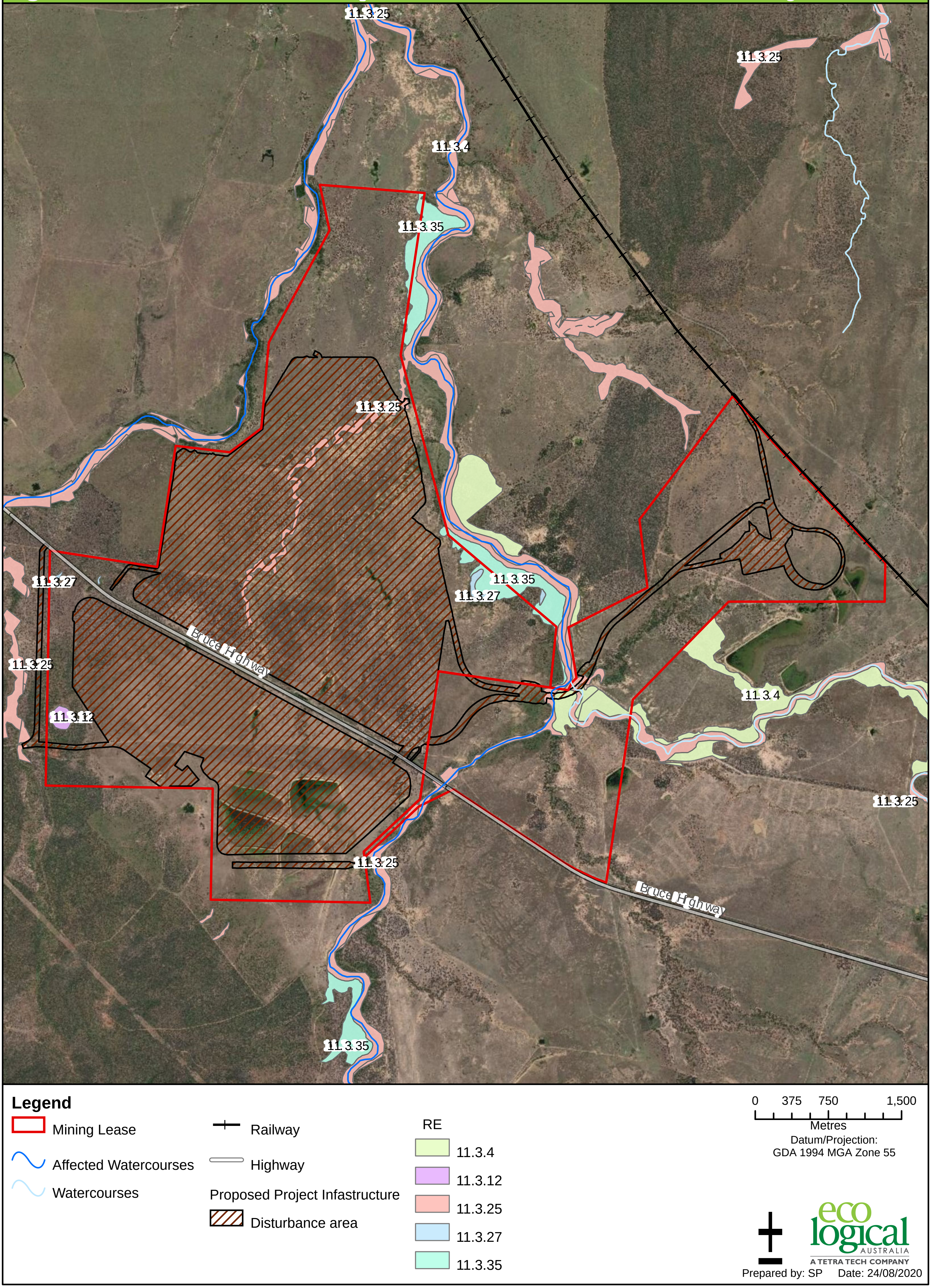


Table 6-5: Summary of the potential for each Regional Ecosystem within and adjacent to the Project Area to be a GDE

Regional Ecosystem (RE)	Predominant tree species from Regional Ecosystem description	Root depth (m)	Known to utilise groundwater?	Potential GDE?
11.3.4 *Eucalyptus tereticornis* woodland on alluvial plains	*E. tereticornis*	10+	Yes	Yes
	E. camaldulensis	12-23	Yes	
	Corymbia tessellaris		Yes	
	E. coolabah	5.7+	Yes	
	C. clarksoniana	10+	Yes	
	E. populnea			
	E. brownii			
	E. melanophloia		Yes[1]	
	E. platyphylla	10+	Yes	
	Angophora floribunda		Yes	
	E. crebra			
	Lophostemon suaveolens	10+	Yes	
11.3.11 Semi-evergreen vine thicket on alluvial plains	*E. tereticornis*	10+	Yes	No[1]
	E. raveretiana			
	Diospyros humilis			
	D. geminata			
	Brachychiton australis			
	B. rupestris			
	Geijera salicifolia			
	Lysiphyllum spp.			
	Mallotus philippensis			
	Streblus brunonianus			

Regional Ecosystem (RE)	Predominant tree species from Regional Ecosystem description	Root depth (m)	Known to utilise groundwater?	Potential GDE?
11.3.25	*E. camaldulensis*	10+	Yes	Yes
Forest Red Gum woodland fringing drainage lines	*E. tereticornis*	10+	Yes	
	E. raveretiana			
	Casuarina cunninghamiana		Yes	
	E. coolabah	5.7+	Yes	
	Melaleuca bracteata			
	M. viminalis			
	Livistona spp.		Yes	
	Melaleuca spp.		Yes	
	Angophora floribunda		Yes	
11.3.12	*Melaleuca viridiflora*	10	Yes	Yes
Melaleuca viridiflora woodland on alluvial plains	*M. argentea*		Yes	
	M. dealbata			
11.3.27	*E. tereticornis*		Yes	Yes
Freshwater wetlands	*Lophostemon suaveolens*	10	Yes	
11.3.35	*E. platyphylla*	10	Yes	Yes
Eucalyptus platyphylla, *Corymbia clarksoniana* woodland on alluvial plains	*C. clarksoniana*	10	Yes	
	C. tessellaris			
11.4.2	*Eucalyptus populnea*			No[2]
Eucalyptus spp. and/or *Corymbia* spp. Grassy or shrubby woodland on Cainozoic clay pans	*E. brownie*			
	E. melanophloia		Yes	
	C. dallachiana			
	C. tessellaris		Yes	

Regional Ecosystem (RE)	Predominant tree species from Regional Ecosystem description	Root depth (m)	Known to utilise groundwater?	Potential GDE?
	E. crebra			
	E. platyphylla	10	Yes	
11.4.9 *Acacia harpophylla* shrubby woodland with *Terminalia oblongata* on Cainozoic clay pans	*Acacia harpophylla*		Yes	No[3]
	Terminalia oblongata			
	Eremophila mitchellii			
	Casuarina christata			
	Lysiphyllum cunninghamii			
11.5.8a *Eucalyptus platyphylla*, *Corymbia intermedia* woodland on Cainozoic sand plains / remnant surfaces	*E. platyphylla*	10	Yes	No[4]
	C intermedia			
	Lophostemon suaveolens	10	Yes	
11.10.3 *Acacia shirleyi* open forest on coarse-grained sedimentary rocks - crests and scarps	*Acacia shirleyi*			No[2]
11.10.7 *Eucalyptus crebra* woodland on coarse-grained sedimentary rocks	*E. platyphyla*	10	Yes	No[2]
	C. clarksonia	10	Yes	
11.11.1 *Eucalyptus crebra* +/- *Acacia rhodoxylon* woodland on old sedimentary rocks	*Eucalyptus crebra*			No[2]
	E. melanophloia		Yes	
11.11.15a *Eucalyptus crebra* woodland on deformed and metamorphosed sediments and interbedded volcanics	*Eucalyptus crebra*			No[2]
	E. exserta			
	E. platyphyla	10	Yes	

1 Confirmed during field studies (3D Environmental 2020).
2 Species have low investment in deep root architecture, making them unlikely to utilise groundwater.
3 May possibly utilise groundwater but only in substrates where fractures in basement rock create preferential flow paths for moisture, and tree roots follow fractures.
4 On site observations show this RE occurs on sandy rises and trees were drought affected and therefore not utilising groundwater.

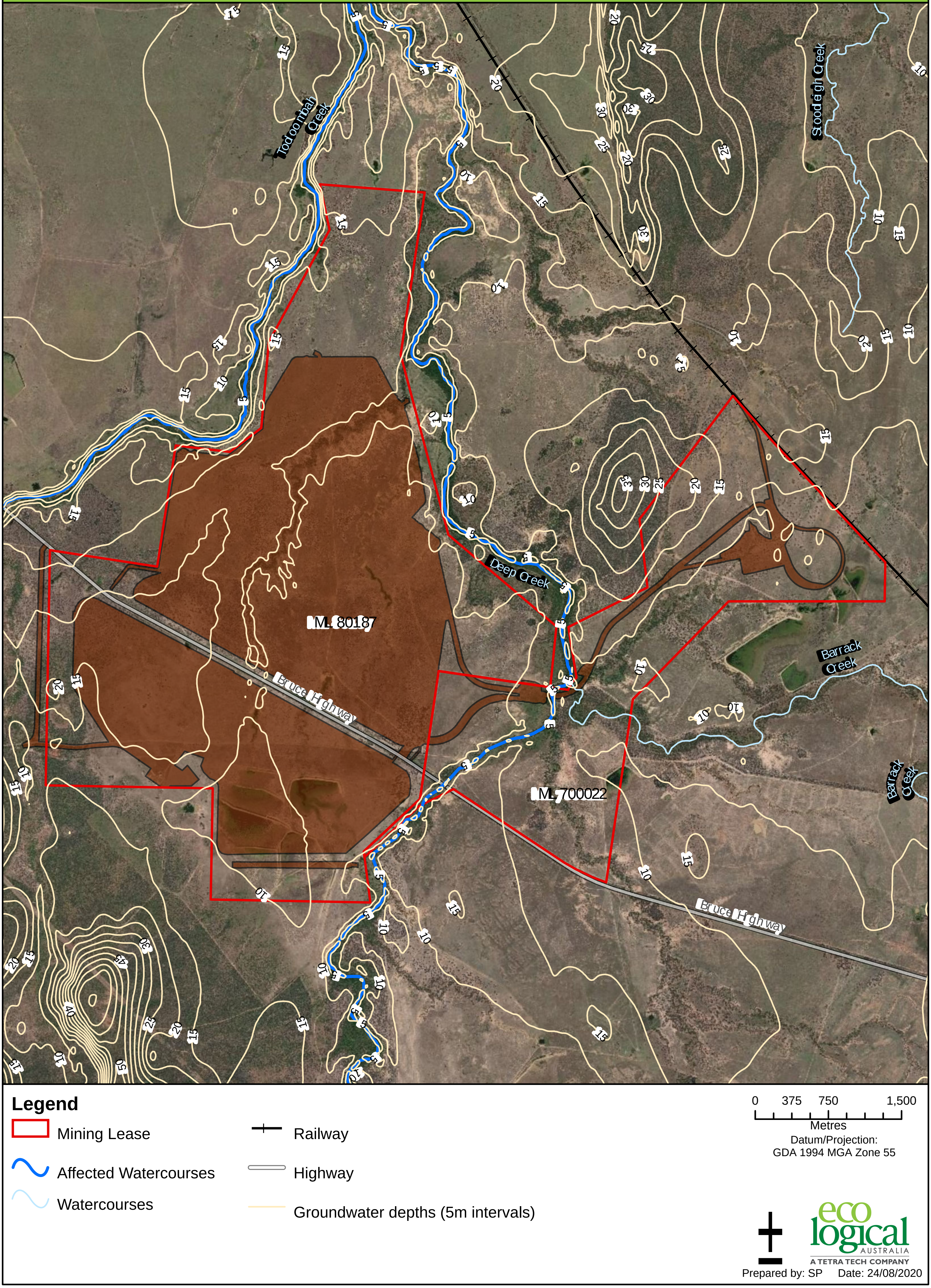
6.7.3 Depth to Groundwater

Of those Regional Ecosystems that had the potential to be groundwater dependent, the depth to groundwater was examined at locations in which they occur, to determine whether groundwater resources that may support vegetation are present. Only areas with a groundwater level deeper than 15 metres below ground level were excluded from further consideration. This approach is therefore considered to be conservative, as published depths to water table are generally a maximum of 10 m for the vegetation species present within the Study Area (IESC 2018). Depth to groundwater was found to vary from approximately 10 to 15 mbgl across the majority of the Project Area and surrounding creeks (**Figure 6-9**; HydroAlgorithmics 2020).

TEM studies of the Project Area (Allen 2019) indicate that sediments within the riparian corridors surrounding the Project Area contain a layer of freshwater in the upper 10 m (held in bank storage), which is likely to be sourced from rainfall and high stream flow events. This water meets the definition of groundwater in relation to GDEs if it is supported by the water table or has been captured by an impermeable layer in the unsaturated zone (a perched aquifer). At depths greater than 10 mbgl the salinity of groundwater increases, likely reflecting the existence of the permanent water table aquifer, which has been found to have salinities in the range 10,000 – 40,000 µS/cm EC (**Figure 6-10**; **Section 6.7.4**).

The persistence of a freshwater layer in upper sediments of the riparian corridor is likely to be critical to the maintenance of riparian vegetation during dry periods, when water from rainfall and river flooding is not readily available to vegetation.

Figure 6-9: The depth to groundwater expressed in metres below ground level (HydroAlgorithmics 2020)



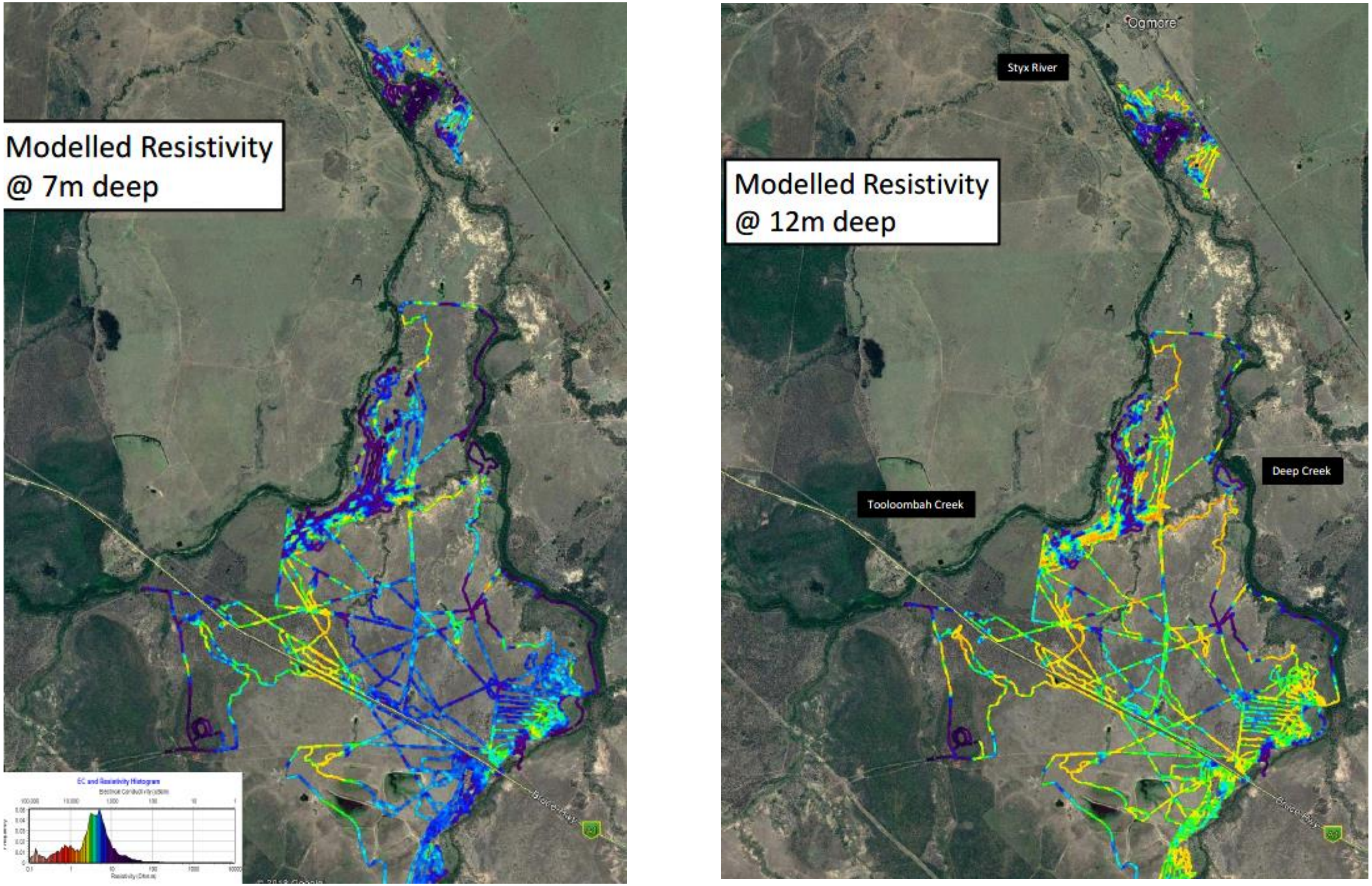


Figure 6-10: Results of AgTEM survey showing distribution of freshwater (purple and blue) along riparian zones in upper layers (7 m deep; left) and presence of saline water (yellow and green) at depths of 12 m (right; Allen 2019)

6.7.4 Groundwater quality

Groundwater quality within the alluvial aquifer (or underlying Styx Coal Measures) of the Project Area is highly variable and does not follow any consistent spatial or temporal pattern (HydroAlgorithmics 2020). Aquifers and other groundwater resources of the Project Area within 15 m of the surface commonly have high salinities (>10,000 µS/cm), which are beyond the tolerance of most terrestrial vegetation.

The upper soil salinity tolerance of key vegetation species present in the Study Area generally falls into the Moderately Saline category of DoA (2020), equivalent to an Electrical Conductivity of 4,000 to 8,000 µS/cm. This is consistent with published soil salinity tolerances that are available for vegetation species present in the Study Area (**Table 6-6**). Species in **Table 6-6** are those for which leaf water potential measurements were conducted on site (3D Environmental 2020), and represent typical species of the two major vegetation types present along Tooloombah and Deep Creeks (riparian vine thicket and tall open eucalypt woodland). Such information suggests that a conservative estimate for the maximum EC of groundwater that may sustain terrestrial vegetation at the site is 10,000 µS/cm. This is further supported by on site investigations by 3D Environmental (2020) which found that the Forest Red Gum (*Eucalyptus tereticornis*) was accessing a fresh water source (<5,000 µS/cm) during a prolonged dry period.

Some caution should be used when interpreting soil salinity tolerances, especially in relation to potential deep (i.e. groundwater) sources of water that trees may use in times of surface water scarcity. Most estimates of salinity tolerance are based on surface (0-30 cm) soil salinity. For some eucalypts, 77-90% of roots are found in the top 50 cm of soil (Eamus *et al*. 2002,; Laclau *et al*. 2013), although studies of rooting depth in natural ecosystems are lacking. In addition, the results of field-based soil salinity experiments are generally restricted to a very limited proportion of the potential genetic variation in tolerance present within a species, thereby rendering results relevant only to the provenance of seed used or location of the site.

Table 6-6: Published soil salinity tolerances for potential GDE vegetation species found within the Study Area

Species	Soil salinity tolerance (EC µS/cm)	Source	Notes
Acacia harpophylla	surface 400-1000 <1 m 1500-1700	Dalal *et al*. (2003)	Generally considered tolerant of moderate salinity
Brachychiton rupestris	unknown but probably low	-	Based on natural distribution and preferred soil types
Coatesia paniculata	unknown	-	Roots to 6.1 m (3D Environmental 2020)
Eucalyptus acmenoides	unknown but probably low	-	Based on natural distribution and preferred soil types
Eucalyptus coolabah	2,000-4,000 (surface) 27,000-36,000 (3-6 m depth)	DoA (2020) Costelloe (2016)	Opportunistic phreatophyte
Eucalyptus crebra	unknown but probably low	-	shallow rooted species

Species	Soil salinity tolerance (EC µS/cm)	Source	Notes
Eucalyptus tereticornis	4,000-8,000	DoA (2020), Dunn *et al.* (1994)	Survivorship high at moderate salinity: growth affected at low salinity (~1600 µS/cm). Opportunistic phreatophyte.
Flindersia australis	unknown but probably low		Based on natural distribution and preferred soil types
Melaleuca fluviatilis	unknown, possibly similar to *M. leucadendra*	-	-
Melaleuca leucadendra	2,000-8,000	Sun *et al.* (1995)	
Melaleuca viridiflora	unknown	Skull & Congdon (2008)	Adversely impacted by sea-water incursions in coastal areas
Siphonodon australis	unknown but probably low	-	Probably shallow-rooted.

Of the ten existing shallow groundwater monitoring bores in place along the Styx River, Deep Creek and Tooloombah Creek, four have a salinity concentration (EC level) that is tolerable by terrestrial vegetation. The remaining six bores have a median EC above a conservative tolerance of 10,000 µS/cm, with minimal temporal variation in salinity (**Figure 6-11**, **Figure 6-12, Table 6-7**). Water within the upper Quaternary Alluvium (Qa) is generally less saline than the underlying Quaternary Pleistocene Alluvium (QPa; HydroAlgorithmics 2020). On the basis of these results, it can be concluded that the alluvial aquifer (and in some locations, underlying Styx Coal Measures aquifer) is unsuitable for utilisation by riparian vegetation in many locations along the riparian corridor adjacent to the Project Area. Groundwater of a quality suitable for use by vegetation occurs in some locations only, and mainly in the upper (Qa) layers.

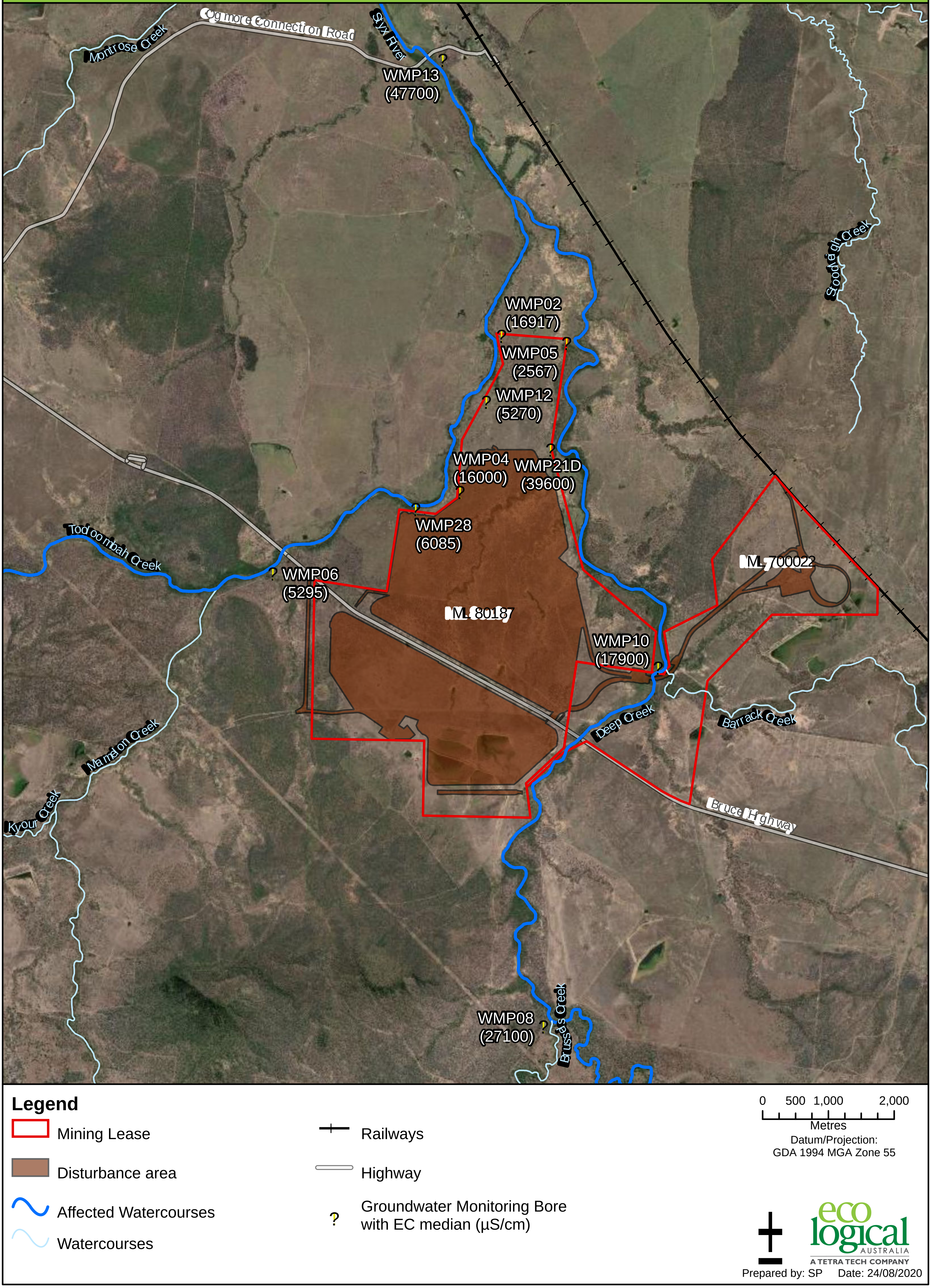
While the use of saline groundwater by riparian vegetation can be ruled out at some locations, there remains potential for indirect impacts on riparian vegetation as a result of groundwater drawdown by reducing the volumes and persistence of water in the upper soil layers (established as bank storage or perched aquifers). Also, hydraulic support for the persistence of freshwater in the unsaturated zone is possibly provided by the saline water table aquifer, particularly if sediments are permeable and groundwater drawdown causes enhanced leakage of fresh water from the stream and underlying alluvial sediments to deeper sediments beyond the reach of tree roots. Such factors are given further consideration and assessment in the following sections.

Table 6-7: Electrical conductivity (EC) of alluvial groundwater at various locations across the Project Area

Bore ID	Location	Slotted interval (mbgl)	Groundwater level metres (median)	EC (median)	No. samples	Time period
WMP13	Styx River	12.7 - 19.7	14.2	47,700	46	Jan 18 to Nov 19

Bore ID	Location	Slotted interval (mbgl)	Groundwater level metres (median)	EC (median)	No. samples	Time period
WMP05	Deep Creek	9 - 12	7.4	2,567	45	Nov 17 to Dec 19
WMP21D	Deep Creek	14 -20	14.7	39,600	5	Sep 19 to Dec 19
WMP10	Deep Creek	12 - 18	10.2	17,900	47	Nov 17 to Dec 19
WMP8	Deep Creek	10 - 16	10.1	27,100	47	Nov 17 to Dec 17
WMP02	Tooloombah Creek	12 - 18	16.9	16,917	51	Dec 17 to Dec 19
WMP12	Tooloombah Creek	11 - 17	16.4	5,270	9	Nov 17 to Apr 18
WMP04	Tooloombah Creek	12 - 18	11.4	16,000	48	Nov 17 to Dec 19
WMP06	Tooloombah Creek	12 - 18	17.3	5,295	52	Dec 17 to Dec 19
WMP28	Tooloombah Creek	8.9 – 11.9	-	6,085	4	Sep 19 to Dec 19

Figure 6-11: Location of alluvial monitoring bores with EC median (µS/cm) across the Project Area



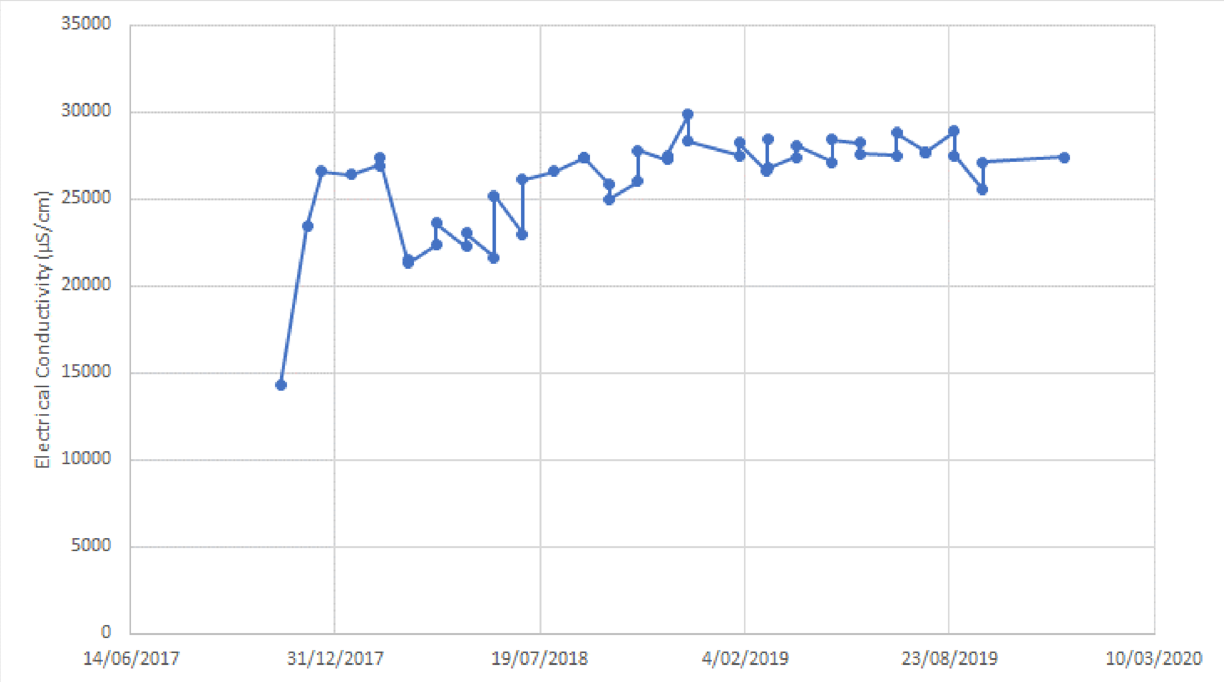


Figure 6-12: Example of time series from bore WMP08 showing variation in groundwater EC over time

6.7.5 Predicted drawdown in the water table aquifer

The timing and magnitude of predicted groundwater drawdown in the water table aquifer (Layer 2 of the groundwater model) is presented in **Figure 6-13** to **Figure 6-17** for the following time periods (HydroAlgorithmics 2020):

- Three years from Project commencement,
- 10 years from Project commencement,
- End of mining
- End of backfilling, and
- Maximum (across all Project stages).

The timing and extent of predicted groundwater drawdown varies, with a summary provided as follows in relation to riparian vegetation:

- Drawdown occurs first at Tooloombah Creek around three years after Project commencement
- The magnitude of drawdown at Tooloombah Creek is approximately 0 to 4.7 m, with areas approximately 2 km north of the Bruce Highway subject to the largest amount of drawdown on this creek
- Drawdown at Deep Creek occurs around 10 years after Project commencement, and ranges from approximately 0 to 60 m, depending on the location of the stream reach. Areas adjacent to the northern and southern bounds of the mining lease are the least affected and subject to minimal drawdown, while those areas adjacent to the central part of the mining lease are predicted to experience drawdown of between 20 and 40 m.
- A strong gradient of increasing drawdown with distance towards the mine pits is evident on the eastern side of Tooloombah Creek and the western side of Deep Creek.

Post-mining head gradient changes in layer 2 of the groundwater model reduce considerably at the period 100 years post-mining, and are consistent with other parts of the region outside of the area of groundwater drawdown after 500 years following the completion of mining (HydroAlgorithmics 2020). Groundwater drawdown is also predicted to affect baseflow through the process of enhanced leakage. This is discussed in **Section 6.6** in relation to Aquatic (Type 2) GDEs.

Figure 6-13: Predicted groundwater drawdown in the water table aquifer at Project year 3

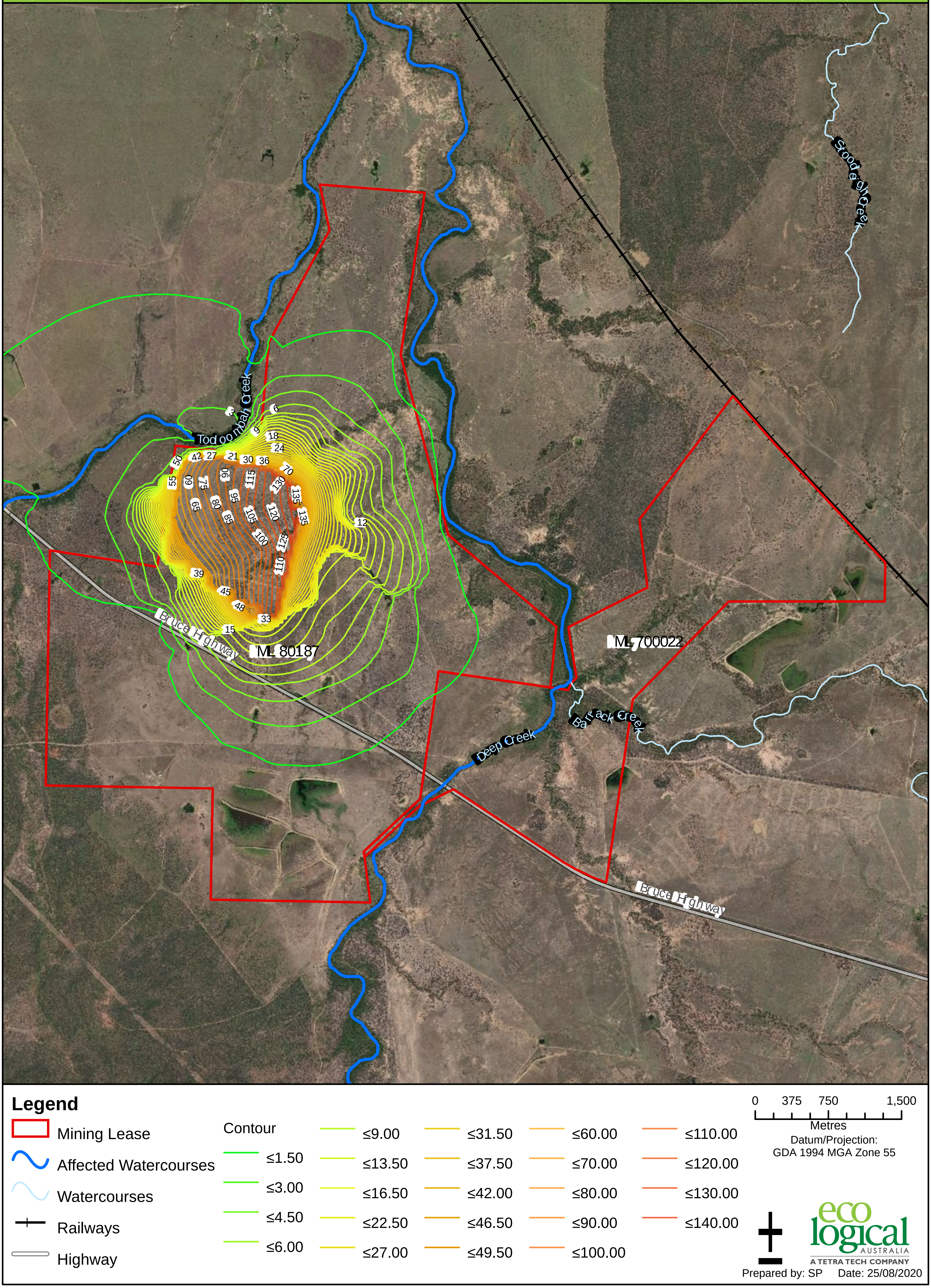


Figure 6-14: Predicted groundwater drawdown in the water table aquifer at Project year 10

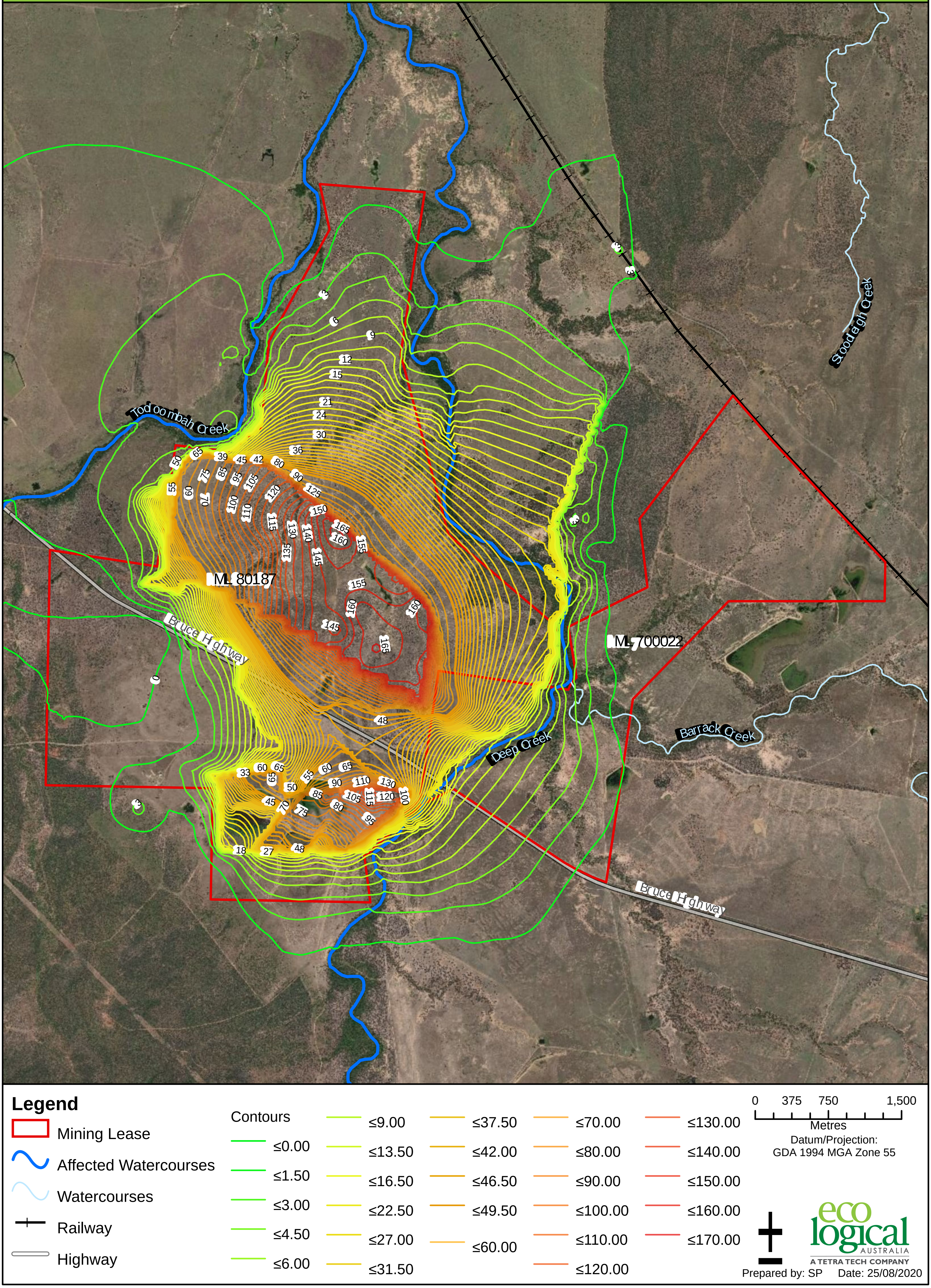


Figure 6-15: Predicted groundwater drawdown in the water table aquifer at the end of mining

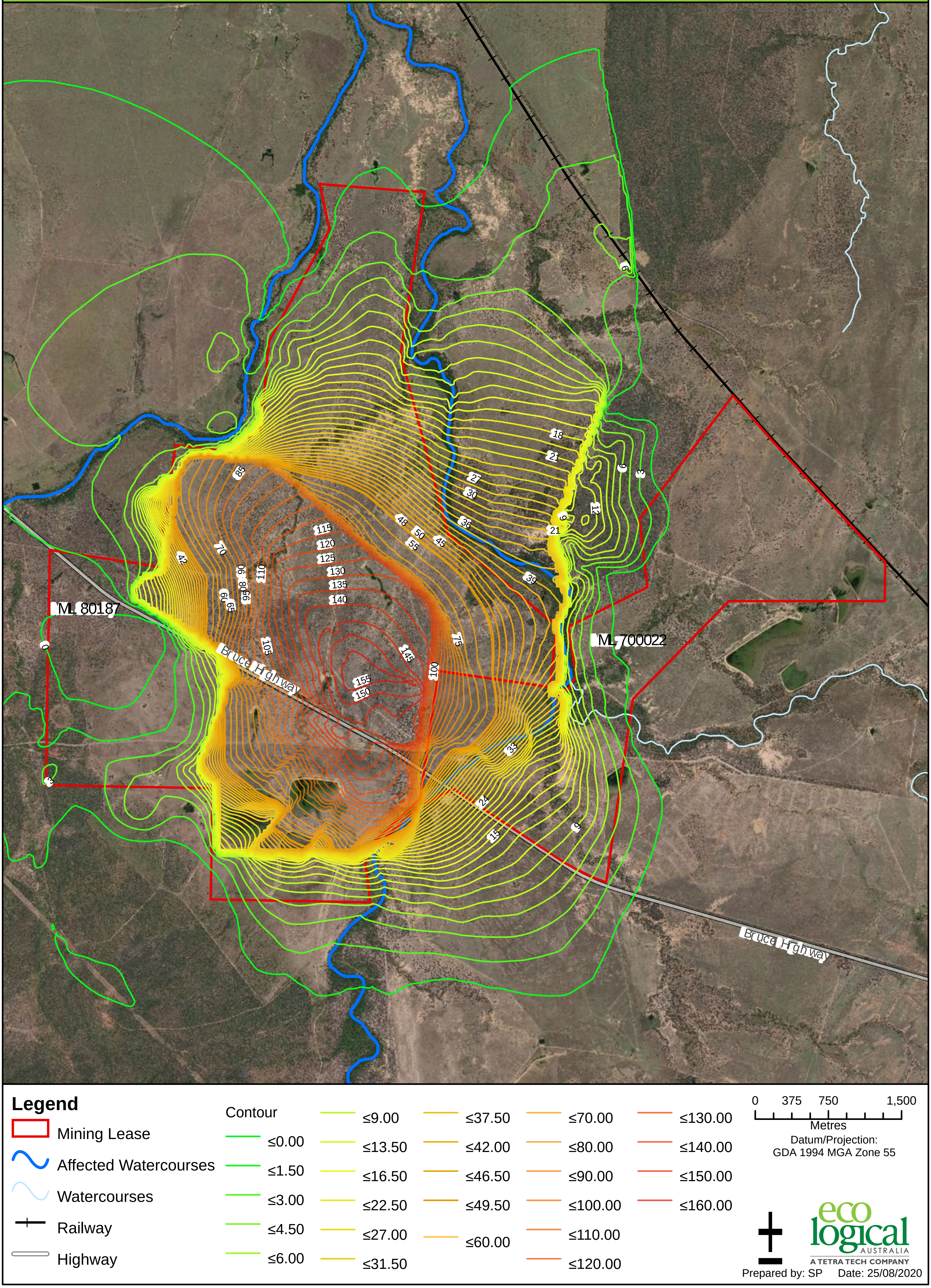


Figure 6-16: Predicted groundwater drawdown in the water table aquifer at the end of backfilling

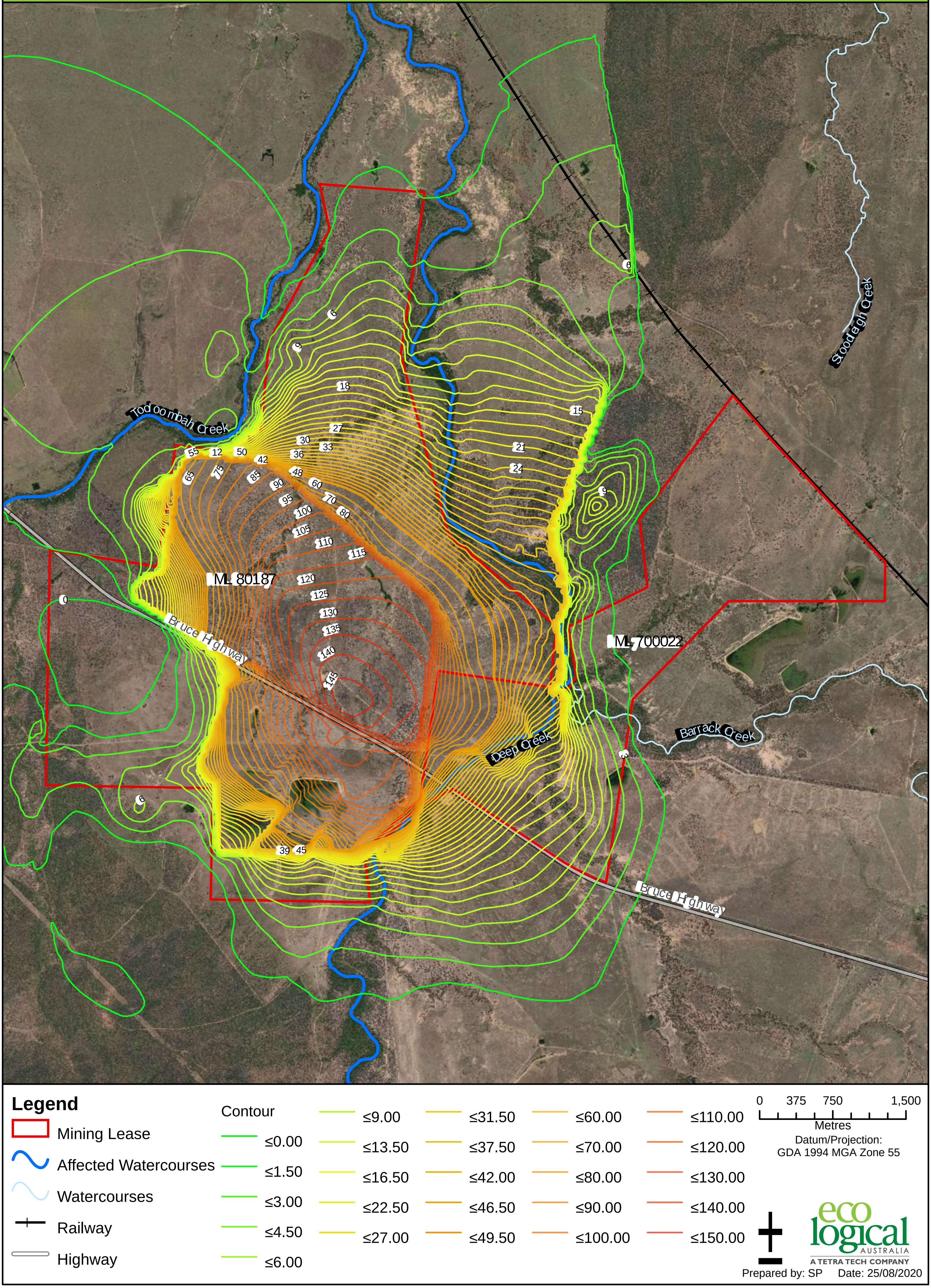
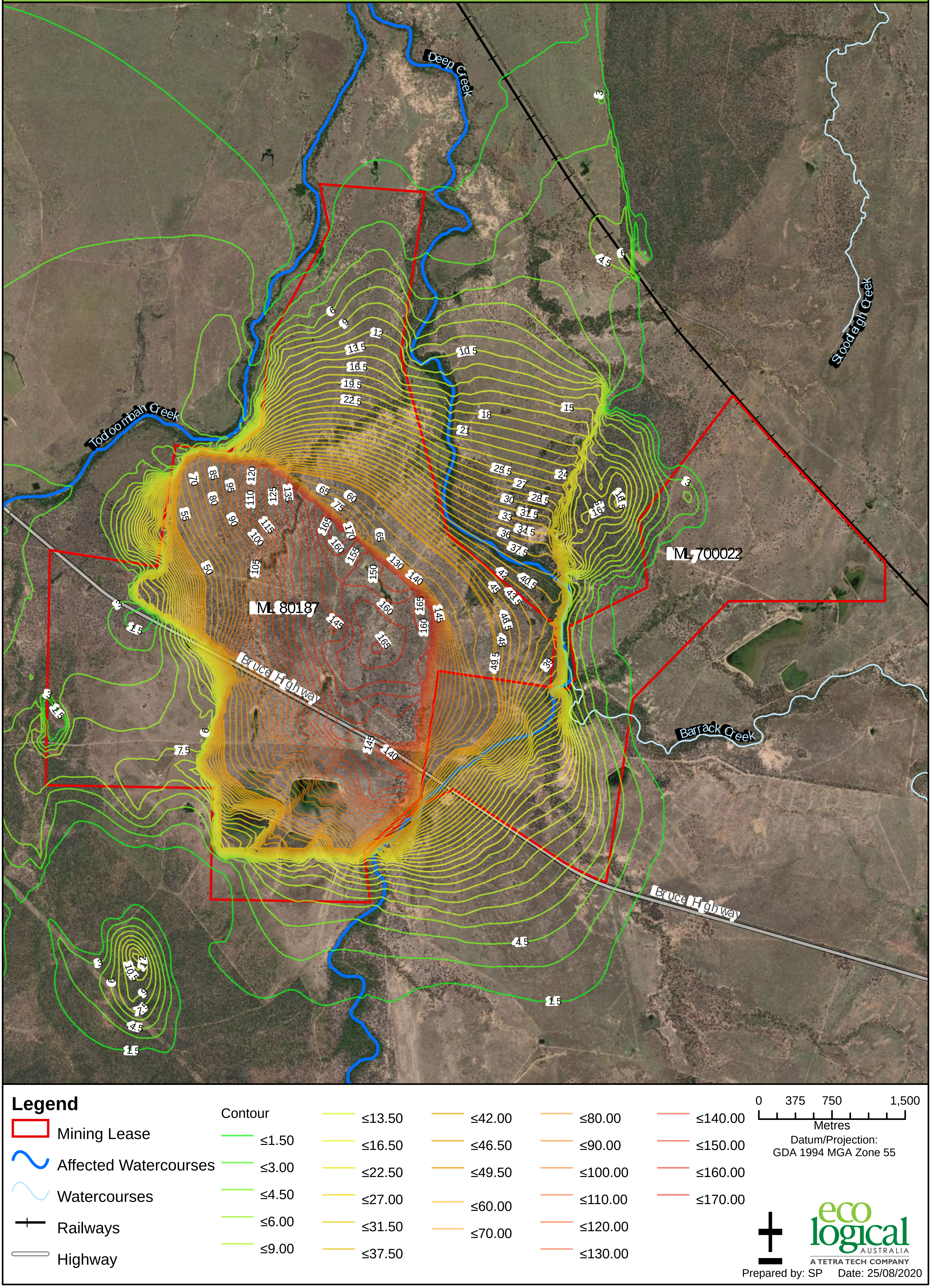


Figure 6-17: Predicted maximum groundwater drawdown in the water table aquifer (all project stages)



6.7.6 Permeability of geological layers within and below the alluvium

Groundwater drawdown has the potential to reduce moisture available to plants in the alluvium through enhanced leakage of surface water to deeper layers beyond the reach of tree roots. The degree to which enhanced leakage occurs is dependent on a range of factors, including the permeability of sediments and associated geological layers within the alluvium underlying streams. High permeabilities are consistent with increased enhanced leakage (and greater impacts on vegetation), while low permeabilities result in slower or minimal movement of water and support the retention of moisture levels in the alluvial soil profile (reducing impacts on vegetation).

Central Queensland Coal has completed drill holes to a depth of 25 metres at multiple locations across the Project Area, including areas adjacent to streams. Clay is the dominant sediment type in the upper layers of cores in most areas, and has a low permeability to water. However, silt and sand were found to dominate in sections of Deep Creek located upstream of the Bruce Highway, indicating a higher permeability to water in this area.

In order to provide additional site specific information about sediment composition and permeability, Central Queensland Coal undertook drilling of alluvial borehole transects in the period April to June 2020 to the depth of refusal at several locations, as shown in **Figure 6-18** (Central Queensland Coal 2020a). Sediments in cores were described and subsampled, with samples sent to a laboratory for analysis of moisture, salinity and grain-size. Permeability was estimated using grain size and angularity results.

Results of the drilling program show that there is sufficient clay present in the alluvium to suggest that the shallow fresh water (which meets the definition of groundwater in the context of GDEs) sits above the deeper (generally saline) system, and there appears to be little connection between the alluvium and the Styx Coal Measures. Some transmissive units exist in some locations, comprised of sands and gravels, particularly on the eastern bank of Deep Creek. Bank storage of water is most extensive in Tooloombah Creek (ELA 2020a; Central Queensland Coal 2020a).

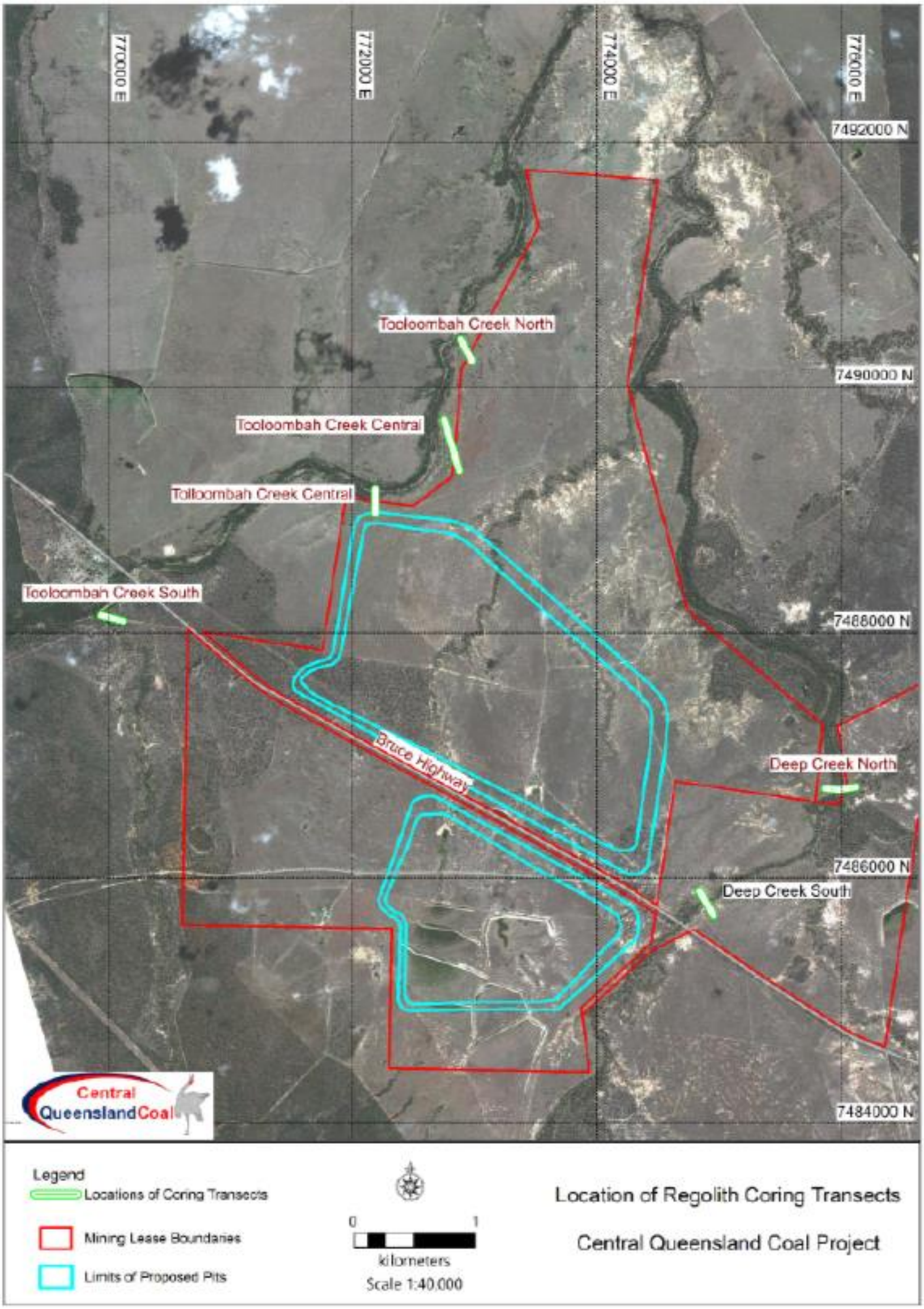


Figure 6-18: Map showing the location of borehole transects within the Study Area at Tooloombah Creek and Deep Creek (Central Queensland Coal 2020a)

6.7.7 Conceptualisation of unsaturated zone and interflow

Riparian vegetation may utilise water derived from three sources: rainfall, stream flooding and groundwater. The nature and extent of soil moisture present in the riparian zone fluctuates according to changes in stream flows and stream level, as illustrated in **Figure 6-19**. During periods of high stream flow and/or high water level, soil moisture in the stream banks is largely driven by surface water seepage from the adjacent stream.

As stream levels reduce through flows downstream, evaporation and evapotranspiration, upper levels of the stream bank dry out, and are subject to intermittent supplementation from rainfall. Impermeable layers within the alluvial zone (if present) may retain moisture in patches, increasing the period over which water is available to vegetation. Shallow aquifers may be accessed by the deeper roots of vegetation and provide a temporary or permanent water source, particularly during dry periods when soil moisture levels in upper layers are low (3D Environmental 2020).

Vegetation, and in particular phreatophytes, have an ability to exploit various sources of soil moisture and change between these sources rapidly (within hours) using their extensive root systems. During dry periods, trees may use their deep roots to obtain moisture from aquifers or within deeper sedimentary layers that have retained moisture, provided that such water is of a suitable quality for use by plants (in particular, low in salinity; Doody *et al*. 2019).

Following a rainfall event, trees can switch their exploitation of water resources from deep to shallow root systems, taking advantage of increased soil moisture in upper layers, which is typically low in salinity and of a higher quality. These seasonal patterns of water use are thought to be implemented within riparian vegetation of the Study Area, which is subject to large fluctuations in annual rainfall and associated flow states within Tooloombah Creek and Deep Creek (WRM 2020).

It is likely that the degree to which individual trees utilise groundwater will vary by location, dependent on a range of factors, including:

- Their proximity to the stream bank and local topography in relation to water flow
- The nature and scale of surface water resources within the stream at that location (e.g. presence of a pool that holds water, or riffle which is dry during periods of no flow)
- Soil type (e.g. sand or clay) and associated level of permeability to water
- The presence of impermeable soil or rock layers in the alluvium, which can result in the retention of moisture in the upper soil layers for long periods
- The depth to the water table
- The quality of water within the water table aquifer, and in particular its salinity
- The age, size and water requirements of the tree, and associated physiological requirements and processes
- The typical duration of dry periods, beyond which the environmental water requirements of trees cannot be met by rainfall and stream-based sources alone.

It is therefore prudent to assess the groundwater dependence of riparian vegetation and potential risks of groundwater drawdown at a geographic scale that is relevant to these variables, and for discrete units of the riparian corridor, within which variability among these factors is low.

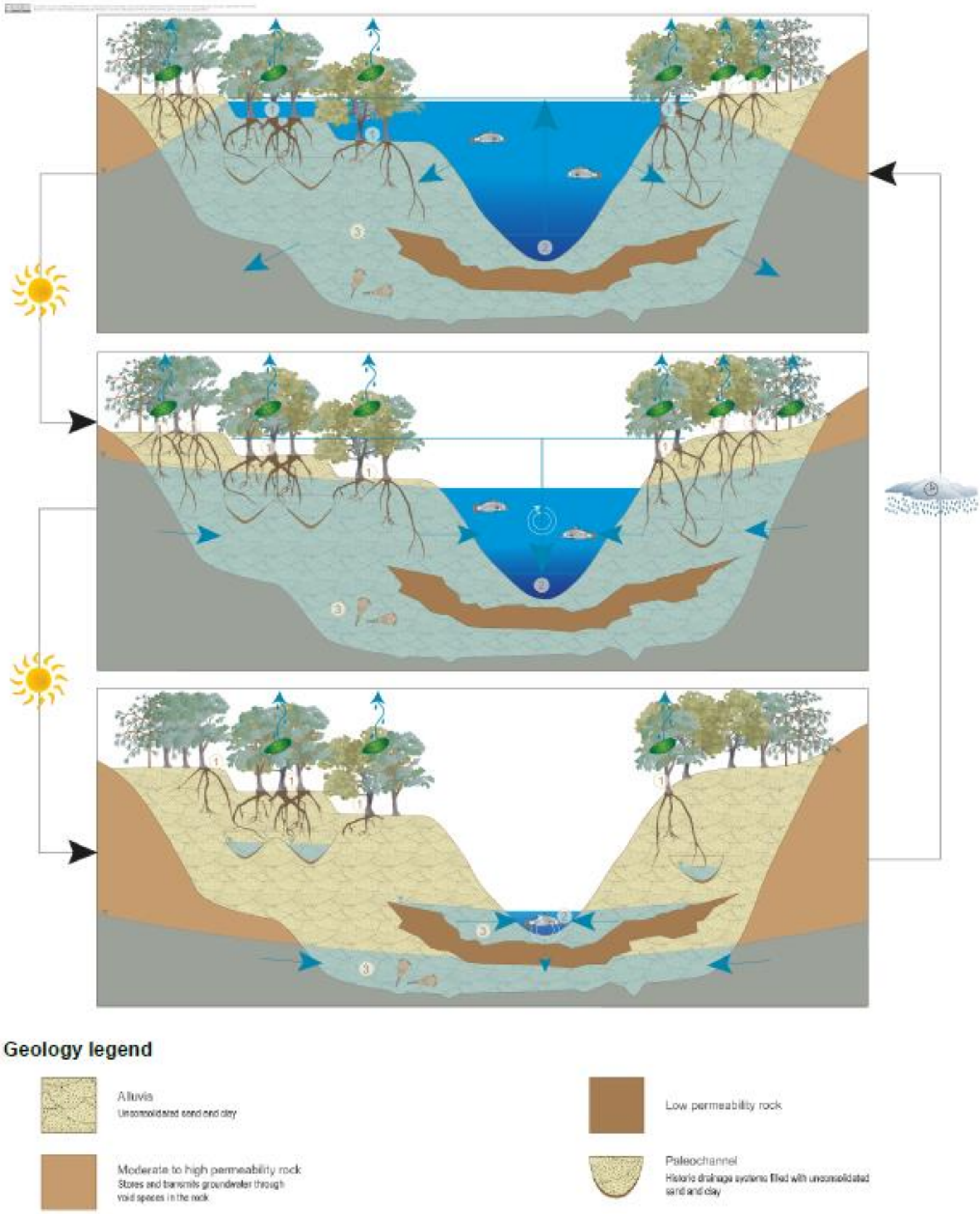


Figure 6-19: Conceptual diagram of recharge processes in the alluvial aquifer. 1 = Terrestrial GDE, 2 = Aquatic GDE and 3 = Subterranean GDE (WetlandInfo 2013).

6.7.8 Impact assessment

The primary mode of impact for Terrestrial GDEs is the drawdown of the water table aquifer, leaving less water available for use by vegetation. Other potential modes of impact will result in either small areas of vegetation clearing, or minimal impacts from erosion and other works-related issues. The following sections therefore consider in depth the potential for impacts to riparian and wetland vegetation from groundwater drawdown.

As described in **Section 2.4.2**, potential impacts of the Project on stream sections of Tooloombah Creek and Deep Creek with similar physical and environmental characteristics were assessed using a series of expert workshops. As the nature and magnitude of impacts to vegetation can vary significantly, a scaled system of potential impacts was developed and considered for each stream section, as summarised in **Table 6-8**. For example, groundwater drawdown may have minimal impacts on vegetation (insignificant impact), resulting in a small decline in vegetation characteristics such as canopy cover and height during drier years. Such impacts may result from minor drawdown in the groundwater layer, and only be visible during periods of drought when several successive years of below average rainfall occur. While the condition of vegetation may deteriorate slightly overall for some periods, a functional vegetation community remains.

At the other end of the scale, extreme impacts caused by groundwater drawdown may include widespread vegetation loss, including the loss of ecosystem services. Consequential impacts resulting from vegetation loss may include bank erosion and collapse, as well as a reduction in fauna habitat for key species. Extreme impacts could be expected for areas where groundwater is an essential source to meet the water requirements of vegetation, and where rainfall and stream flow sources are insufficient to sustain vegetation in the absence of groundwater.

Between these two extremes, there is a spectrum of variable impacts associated with the retention or loss of vegetation community structure, functional role of vegetation in providing ecosystem services, and the persistence of fauna habitat. While it is important to determine whether groundwater drawdown will result in impacts to vegetation, it is also important to understand the magnitude and nature of the predicted impact, along this sliding scale.

Table 6-8: Impact description for five categories of impact on riparian vegetation, ranging from low to extreme

Impact Rating	Impact Description
Insignificant	10% decline in the BioCondition Scores against baseline or pre-impact scores. The regional ecosystem is retained as a functional ecosystem. There are reduced numbers of microhabitat features available for fauna.
Minor	50% decline in BioCondition Scores against baseline or pre-impact scores. Canopy cover < 50% of baseline or pre-impact condition, or canopy height <70% of baseline or pre-impact condition. Vegetation no longer meets the Regional Ecosystem description. Vegetation provides ecosystem services, including minimising erosion and some fauna habitat, but with elevated weed cover. There is limited microhabitat features for fauna, such as hollows.
Moderate	90% decline in the BioCondition Scores against baseline or pre-impact scores. Vegetation no longer meets the Regional Ecosystem description. Vegetation community still existing and provides some ecosystem services in limiting erosion, but significant change in structure and composition (increased weed cover) is evident, with reduced habitat values. Limited microhabitat features for fauna.
Major	Widespread vegetation loss. Vegetation no longer meets the Regional Ecosystem description. Regional Ecosystem only remains in patches, with grasses and shrubs elsewhere. There is a high abundance of

Impact Rating	Impact Description
	weeds. Ecosystem services in limiting erosion are reduced by up to 50%, with some under cutting of banks resulting at times.
Extreme	Widespread vegetation loss. Vegetation no longer meets the Regional Ecosystem description. Grasses and shrubs dominate the riparian zone. Ecosystem services in limiting erosion are reduced by more than 50%, resulting in periodic bank collapse

The likelihood of each impact description (**Table 6-8**) occurring as a result of Project activities was assessed for each of the eight stream reaches identified as having similar environmental characteristics and exposures to Project impacts (**Section 2.4.2**). If there was a 'Possible' (or above) likelihood of there being a 'Minor' impact on vegetation within the stream reach, then there was considered to be an impact for that stream reach. Where that impact is relevant to other technical disciplines and their associated MNES and MSES (e.g. Greater Glider habitat), then an impact assessment was completed by specialists in those disciplines in accordance with significant impact criteria, to determine whether a significant residual impact would occur, and offsets would be applicable. The results of those assessments are reported in relevant technical reports for the associated discipline (e.g. Terrestrial Ecology Technical Report) and in SEIS v3.

Results of the impact assessment are presented in **Table 6-9**. An impact to riparian vegetation is expected as a result of groundwater drawdown for three stream reaches along Deep Creek (reaches 5, 6 and 7; **Figure 2-2**). These impacts can be expected to commence over timeframes of 10 to 20 years after commencement of the Project. The location of areas subject to an impact are shown in **Figure 6-20**. Some areas of freshwater wetland (RE 11.3.27) that are assessed to be surface water features have been excluded from the vegetation communities assessed to be subject to indirect impacts.

For Stream Section 1 (Tooloombah Creek downstream), the assessment team identified an 'Unlikely' likelihood of 'Insignificant' impacts to riparian vegetation, with a 'Rare' likelihood of any impact exceeding the 'Insignificant' criterion. This assessment was based on the relatively small groundwater drawdown of 1.5 m in this stream reach, and the low permeability of alluvial sediments. While there may be some decline in BioCondition scores for vegetation in this section during prolonged dry periods, the magnitude of change is expected to be small, and similar to that occurring naturally during existing climatic cycles.

For Stream Section 2 (Tooloombah Creek Mid), the assessment team identified a 'Possible' likelihood of 'Insignificant' impacts to riparian vegetation, with a 'Rare' likelihood of any impact exceeding the 'Insignificant' criterion. This assessment was based on the presence of saline groundwater unsuitable for riparian vegetation at this location, and the bores in the area logging clay within the alluvial sediments, with associated low permeability to water. Fresh groundwater held in bank storage is likely to mitigate the potential for impacts from drawdown in this location. While there is likely to be some decline in BioCondition scores for vegetation in this section during prolonged dry periods, the magnitude of change is expected to be small, and similar to that occurring naturally during existing climatic cycles.

For Stream Section 3 (Upper Tooloombah Creek), the assessment team identified a 'Rare' likelihood of any impacts to riparian vegetation. This was based on the stream section being located upstream from the Project and further away from the steep groundwater drawdown gradient located further downstream adjacent to the mine pits. Impacts to riparian vegetation arising from the Project in this area are expected to be within the bounds of natural variability.

For Stream Section 4 (Far Downstream Deep Creek), the assessment team identified an ‘Unlikely’ likelihood of ‘Insignificant’ impacts to riparian vegetation, with a ‘Rare’ likelihood of any impact exceeding the ‘Insignificant’ criterion. This was based on the low permeability of clay sediments and extensive supply of freshwater in the upper layers, as shown in TEM survey results. While there may be some decline in BioCondition scores for vegetation in this section during prolonged dry periods, the magnitude of change is expected to be small, and similar to that of natural variation.

For Stream Section 5 (Downstream Deep Creek), the assessment team identified a ’Likely’ likelihood of ‘Insignificant’ impacts to riparian vegetation, with a ‘Possible’ likelihood of ‘Minor’ impacts, and an ‘Unlikely’ likelihood of ‘Moderate’ impacts to riparian vegetation. ’Major’ and ‘Extreme’ impacts were assessed to be a ‘Rare’ likelihood. This assessment was based on the large drawdown depth of approximately 40 m predicted in the water table aquifer, which is expected to provide some hydraulic support to fresh water currently utilised by vegetation. As a result of groundwater drawdown, the vegetation community is expected to no longer meet the Regional Ecosystem description after a period of approximately 15 years. This outcome is assessed to be an impact on groundwater dependent vegetation.

For Stream Section 6 (Mid Deep Creek), the assessment team identified a ’Likely’ likelihood of ‘Insignificant’ impacts to riparian vegetation, with a ‘Possible’ likelihood of ‘Minor’ impacts, and an ‘Unlikely’ likelihood of ‘Moderate’ impacts. ’Major’ and ‘Extreme’ impacts were assessed to have a ‘Rare’ likelihood. This assessment was based on the large drawdown depth of 30 m predicted in the water table aquifer, which is expected to provide some hydraulic support to fresh water utilised by vegetation. As a result of groundwater drawdown, the vegetation community is expected to no longer meet the Regional Ecosystem description after a period of approximately 15 years. This outcome is assessed to be an impact on groundwater dependent vegetation.

For Stream Section 7 (Upstream Deep Creek), the assessment team identified an ‘Almost Certain’ likelihood of ‘Insignificant’ impacts to riparian vegetation, with a ’Likely’ likelihood of ‘Minor’ impacts, and a ‘Possible’ likelihood of ‘Moderate’ and ’Major’ impacts. ‘Extreme’ impacts were assessed to have an ‘Unlikely’ likelihood of occurring. This was based on the very large drawdown depth of approximately 60 m predicted in the water table aquifer, high proportion of sand and silt in sediments and the strong hydraulic gradient associated with drawdown into the adjacent mine pit. As a result of groundwater drawdown, the vegetation community is expected to no longer meet the Regional Ecosystem description after a period of approximately 15 years. This outcome is assessed to be an impact on groundwater dependent vegetation. Some increase in erosion can be expected as a result of vegetation loss, unless mitigated through revegetation with species tolerant of the predicted changes in stream bank conditions.

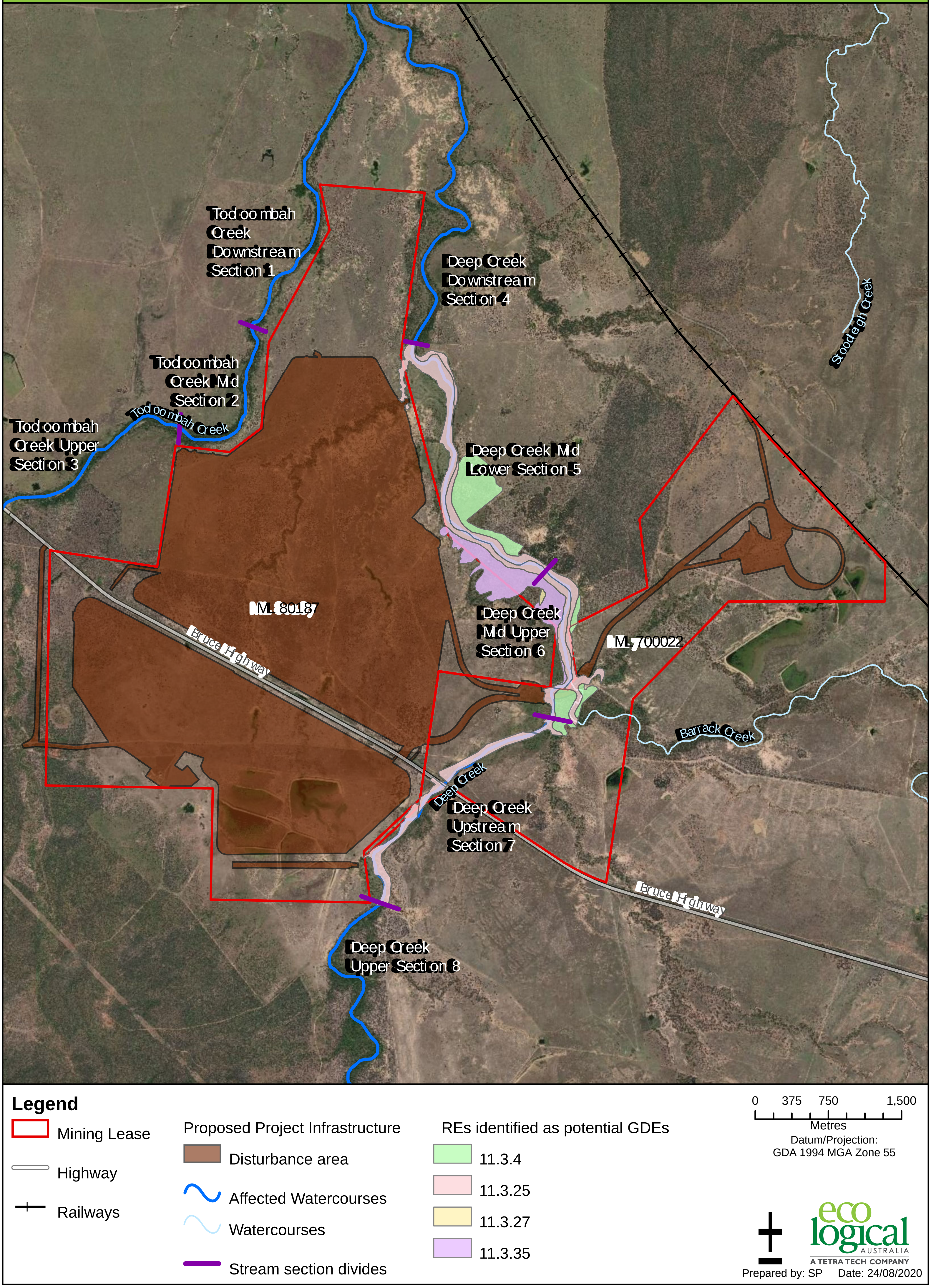
For Stream Section 8 (Far Upstream Deep Creek), the assessment team identified an ‘Unlikely’ likelihood of ‘Insignificant’ impacts to riparian vegetation, with a ‘Rare’ likelihood of any impact exceeding the ‘Insignificant’ criterion. This assessment was based on the stream section being upstream of the Project, with a relatively smaller groundwater drawdown magnitude of 4 m predicted. The shallow aquifer at this location has a median EC of 27,000 µS/cm and is unsuitable for use by vegetation. While there may be some decline in BioCondition scores for vegetation in this section, as a result of enhanced leakage of freshwater into deeper layers during dry periods, the magnitude of change is expected to be small, and similar to that occurring naturally during existing climatic cycles.

As noted in **Section 6.7.1**, impacts from groundwater drawdown are not expected for wetlands located outside of the riparian corridor. While Wetland 1 meets the definition of a Terrestrial GDE (as it utilises a perched aquifer above the water table), the magnitude of groundwater drawdown at this location is predicted to be small and unlikely to impact on vegetation.

Table 6-9: Summary of results of impact assessment for indirect impacts on Terrestrial GDEs along Tooloombah and Deep Creeks

Stream Section	Scale of Impact					Approx. Max Drawdown (m)	Approx. Timing of Max Drawdown (years)	Impact Predicted?
	Insignificant	Minor	Moderate	Major	Extreme			
Tooloombah Creek Downstream (1)	Unlikely	Rare	Rare	Rare	Rare	1.5	10	No
Tooloombah Creek Mid Section (2)	Possible	Rare	Rare	Rare	Rare	4.7	5	No
Tooloombah Creek Upstream (3)	Rare	Rare	Rare	Rare	Rare	3	5	No
Deep Creek Far Downstream (4)	Unlikely	Rare	Rare	Rare	Rare	6	10	No
Deep Creek Downstream Section (5)	Likely	Possible	Unlikely	Rare	Rare	40	15	Yes
Deep Creek Mid Section (6)	Likely	Possible	Unlikely	Rare	Rare	30	10	Yes
Deep Creek Upstream (7)	Almost Certain	Likely	Possible	Possible	Unlikely	60	15	Yes
Deep Creek Far Upper Section (8)	Unlikely	Rare	Rare	Rare	Rare	4.5	10	No

Figure 6-20: Location of groundwater dependent vegetation that is expected to be subject to an impact



6.7.9 Risk Assessment

Potential impacts on Terrestrial GDEs have been assessed using the risk assessment framework outlined in **Section 2.4.1**. The potential impacts considered include those common to all assessments (**Section 4**):

- Direct disturbance of vegetation and/or habitat
- Changes to groundwater level
- Changes to groundwater quality
- Changes to surface water flow (hydrology)
- Changes to surface water quality
- Erosion of sediments
- Changes in the location of the freshwater – saltwater interface.

The risk assessment for GDEs that outlines the potential impacts, initial risk, control measures and residual risk following the implementation of control measures is provided in **Table 6-10.**

Table 6-10: Risk Assessment matrix for Terrestrial GDEs

Mechanism of change	Potential impacts	Likelihood of occurrence	Consequence rating	Risk assessment rating	Proposed mitigation measures	Residual risk
Direct disturbance to vegetation and habitat	There may be some disturbance to vegetation associated with infrastructure such as bridges, revetments or spillway construction These will be small in scale.	Unlikely	Minor	Low	Design of project to minimise number of instances where works are required.	Low
Groundwater drawdown reducing the water available to riparian vegetation.	A varying scale of impact, from minor changes to canopy cover through to widespread loss of vegetation. See more detailed assessment above.	Dependent on stream reach – refer to above			Design to minimise impacts to aquifer characteristics. Improved management of pests and weeds in the riparian corridor, to increase ecosystem resilience.. Revegetation and rehabilitation of the riparian corridor of Deep Creek, involving expansion of the existing riparian corridor by a width of 10 m, and replacement of trees impacted by groundwater drawdown with drought tolerant species of similar ecological function.	Dependent on stream reach – refer above.

Mechanism of change	Potential impacts	Likelihood of occurrence	Consequence rating	Risk assessment rating	Proposed mitigation measures	Residual risk
Groundwater drawdown reducing the water available to Wetland 1, a Terrestrial GDE	Minor changes to canopy cover through to widespread loss of vegetation.	Unlikely	Minor	Low	Design to minimise impacts to wetland areas.	Low
Change in surface water flows	Changes to the hydrology of surface water resources, affecting recharge of aquifers which sustain soil moisture during the dry season.	Unlikely	Minor	Low	Design to minimise changes to surface water flows	Low
Change in groundwater quality Change in surface water quality Discharge of mine water to creeks	Change in groundwater quality, affecting the quality of water available to vegetation Change of water quality in creeks and wetlands, which may in term affect the water quality available to vegetation	Likely	Minor	Medium	Fit energy dissipation structures and release water at low velocity, and over rocky substrate to avoid erosion and suspension of sediment and metals. Spray water to aerate. Add supplementary minerals or elements, if necessary.	Low
Erosion	Degradation of bank and other habitat types of groundwater dependent vegetation..	Unlikely	Minor	Low	Design of water management infrastructure to reduce the risk of erosion and scour of stream banks. Revegetation and rehabilitation of the riparian corridor.	Low

Mechanism of change	Potential impacts	Likelihood of occurrence	Consequence rating	Risk assessment rating	Proposed mitigation measures	Residual risk
Change in location of freshwater – saltwater interface	Changes in the water chemistry of water available to vegetation.	Unlikely	Minor	Low	Design to minimise changes in the location of the freshwater – saltwater interface as a result of Project activities.	Low

6.8 Application of IESC Risk Matrix

Results of the impact assessment and associated risk assessments for Subterranean, Aquatic and Terrestrial GDEs are consistent with the outcomes of applying the risk matrix presented in Appendix G of the IESC Guidelines (Doody *et al.* 2019). The Project and its associated potential impacts on GDEs is consistent with a Moderate (Environmental) Value and Moderate Risk to GDEs, corresponding to Risk Matrix Box E in Doody *et al.* (2019). For Projects in this category, the following management actions are recommended (Doody *et al.* 2019):

- Protection of hotspots
- Baseline risk monitoring and mitigation actions
- Monitoring and annual assessment of mitigation actions
- Adaptive management with continuous monitoring.

Central Queensland Coal will implement the Project in a manner consistent with these recommendations, with key practices being the avoidance and minimisation of direct and indirect impacts to key values where possible (e.g. Wetland 1 and creeks adjoining the Project Area), and the implementation of a detailed adaptive management and monitoring framework, which will be established and implemented through the GDEMMP (ELA 2020c).

7. Impact Assessment Aquatic Ecology

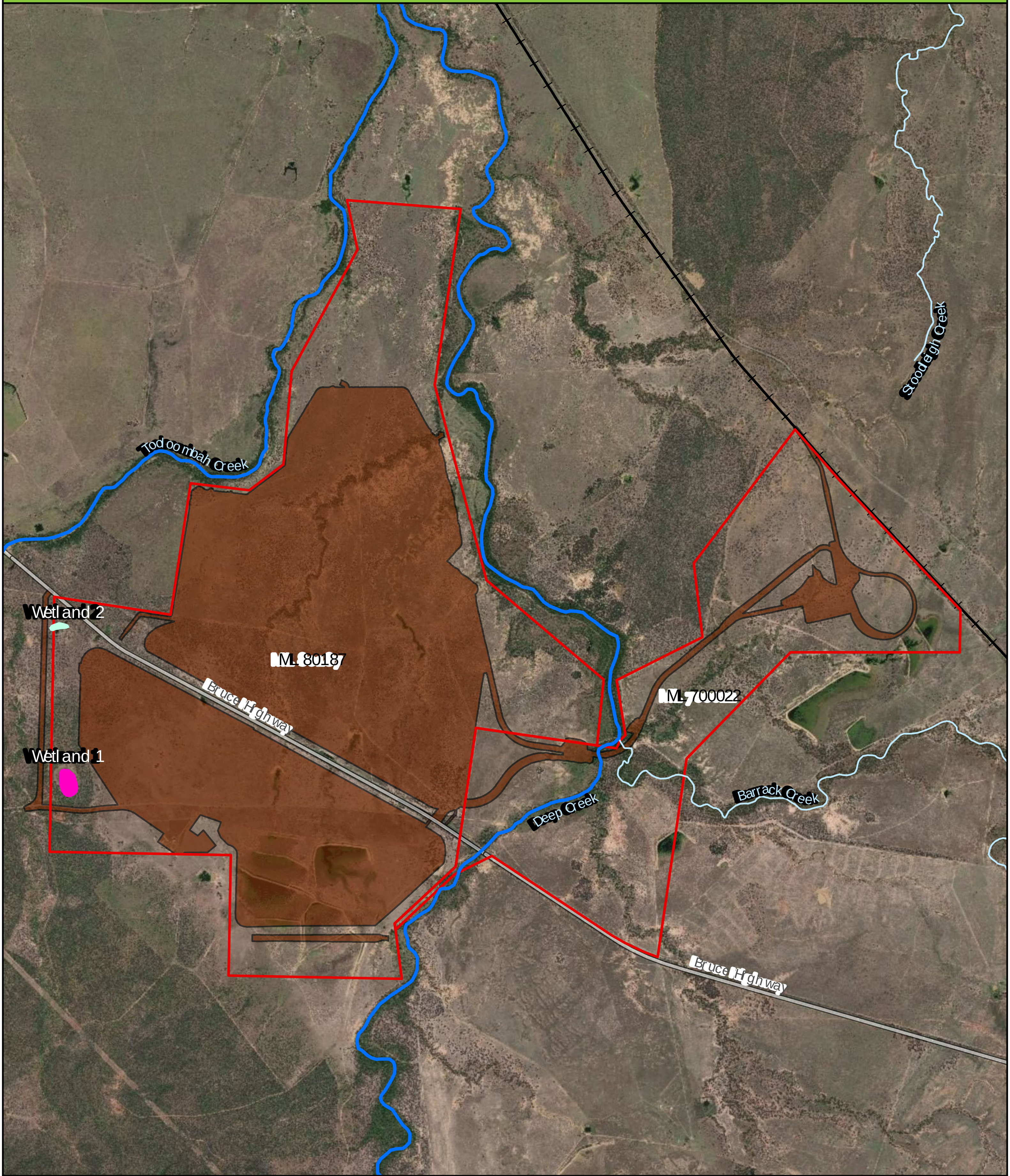
7.1 Introduction

This section describes the relevant aquatic ecological values within and surrounding the Project Area, including:

- Aquatic habitats
- Aquatic fauna
- Wetlands
- Waterways providing fish passage.

The locations of the key areas of surface water providing habitat for aquatic ecology values are shown in **Figure 7-1**.

Figure 7-1: Locations of key surface water areas providing habitat for aquatic ecology values



Legend

Mining Lease
Railways
Highway
Proposed Project Infrastructure
Disturbance area
Affected Watercourses
Watercourses
High ecological significance wetland (GBR)
General Ecological Significance

0 375 750 1,500
Metres
Datum/Projection:
GDA 1994 MGA Zone 55

Prepared by: SP Date: 24/08/2020

7.1.1 Aquatic habitats

There are two main waterways adjacent to the Project Area; Deep Creek and Tooloombah Creek, which meet at a confluence downstream of the site to form the Styx River (**Figure 7-1**). Both creeks have a range of values related to aquatic ecosystems. Deep Creek has a total catchment area of 298 km^2 and consists of a channel up to 10 m deep and 2 to 10 m wide. The creek bed is comprised of silts, clays and sand with minimal aquatic vegetation. Pooled water occurs in areas along the creek bed and this water is typically turbid. Water levels within Deep Creek change rapidly in response to rainfall. The creek is highly turbid, with areas of surface water erosion evident on the banks of the creek. Upstream and adjacent to ML80187, Deep Creek is likely to seasonally change from a losing to a gaining stream (CDM Smith 2018l; HydroAlgorithmics 2020; ELA 2020a).

The region of the Styx River Catchment surrounding the Project Area has been largely cleared for cattle grazing (80%) and during extreme rainfall events is subject to flooding and erosion. The hydrological features within the Styx River Basin are of significant value to a range of aquatic ecosystems. A total of 14% of the basin area consists of wetlands (estuarine 265.8 km^2, palustrine 89.7 km^2 and riverine 52.4 km^2; EHP 2017). Marine Couch (*Sporobolus virginicus*), which indicates the presence of brackish to saline water, is most abundant along the banks of the Styx River from 4 km downstream of the Project Area, with fewer occurrences further upstream.

Tooloombah Creek and Deep Creek are ephemeral waterways, and flow for approximately 24% of the time, predominantly during the wet season (WRM 2020). At other times, the creeks are dry or form a series of disconnected pools, which gradually reduce in size due to evaporation. Some pools are fed by groundwater, resulting in their persistence during the dry season for longer than other pools. Pools provide a refugial habitat for some aquatic fauna, which are able to tolerate the highly variable water quality conditions that occur (**Section 6.6**).

Tooloombah Creek has a total catchment area of 369.7 km^2 and runs north-easterly along the western boundary of the Project Area. The main channel is generally deeper than Deep Creek, and is 4 to 15 m wide with steep, vegetated slopes and minimal erosion. Outcropping sandstone occurs along the slopes and the creek bed is mostly rocky (gravel and boulders). On average, there are approximately three flow events per year within the creek, during which the creek has an average depth of 4 m. These flows are short-lived (a few days maximum) and occur during high rainfall events.

Low-lying areas of the Tooloombah Creek catchment are subject to flooding. Large pools of water have been observed in the creek during baseline surveys completed as part of this SEIS (v3; WRM 2020). These pools are typically less turbid than those in Deep Creek. This is likely due to a reduced amount of catchment erosion, slower flows and fewer fine-grained sediments. 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 (**Table 6-3**; ELA 2020a).

Deep Creek and Tooloombah Creek are ephemeral creeks with incised channels and predominantly sand or rocky beds. Aquatic habitats are variable throughout the creeks, with pools common, though most of them dry out or become very isolated and increase in salinity during periods of low rainfall (CDM Smith 2018). Other habitat features present in stream reaches adjacent to the Project Area are occasional riffles, large woody debris and undercut banks. Most sites monitored during baseline studies of the EIS had multiple physical habitat features, indicating a robust environment for aquatic fauna and a healthy ecosystem.

However, some natural and human-related aspects of the existing aquatic ecosystem limit the ecological condition of waterways. During dry periods surface water pools have highly variable water chemistry, influenced by evaporation, disconnection from adjacent waterways, and in some cases, saline groundwater inputs. In addition, trampling of instream habitats by cattle and associated declines in water quality (increase in suspended sediments and nutrients) creates fluctuations and declines in water quality at certain times of the year. These factors result in an aquatic environment that is highly variable, and mostly utilised by species that either have short life cycles, are mobile or are tolerant of a wide range of environmental conditions.

The main existing impact to aquatic ecosystems adjacent to the Project Area is agriculture, with the surrounding land used predominantly for cattle grazing. This activity poses a significant threat to the aquatic ecosystems, especially when cattle access waterways, causing bank erosion, disturbing stream beds, trampling aquatic habitat and increasing nutrient loads via defecation. Erosion can reduce the condition of aquatic habitat, with many areas within the Styx Catchment prone to erosion, particularly during extreme rainfall events. Turbidity within waterways of the Study Area varies. However, Deep Creek appears to be the most turbid and subject to greater levels of erosion than other watercourses.

Despite the dominant agricultural landscape and widespread erosion, the condition of riparian vegetation along the main creek lines is good in some place, and variable overall (Central Queensland Coal 2020b). Vegetation along Deep Creek is dominated by medium and large *Eucalyptus* and *Melaleuca* trees, while the riparian zone of Tooloombah Creek is dominated by rainforest species and Weeping Bottlebrush (*Melaleuca viminalis*). Granite Creek has excellent riparian vegetation, with plenty of shade provided by *Eucalyptus* and *Melaleuca* trees. Downstream of the Deep Creek junction with Tooloombah Creek, the riparian corridor of the Styx River becomes dominated by Noogoora Burr (*Xanthium occidentale*) and has fewer trees.

Overall, the aquatic habitats and ecosystems of the Study Area are in a healthy condition, with relatively good structural integrity and water quality during times of flow. During the dry season, water quality degrades, as a series of evaporating pools form which are accessed by cattle. Although erosion occurs throughout the catchment, riparian vegetation is generally in good condition, with some variation among sites. However, infestations of weeds and pest activity significantly reduce ecological condition in some riparian corridors, affecting the quality of their associated aquatic habitats.

7.1.2 Aquatic fauna

The aquatic ecosystems present within the Study Area provide habitat for a range of aquatic fauna. Key taxonomic groups include a range of native fish, freshwater turtles and aquatic macroinvertebrates. Field surveys in 2011 collected 28 native fish species from the Project Area and surrounding waterways, including 12 species that were not reported during the desktop database search (CDM Smith 2018). The most abundant taxa in the fish community were Eastern Rainbowfish (*Melanotaenia splendida*), Empire Gudgeon (*Hypseleotris compressa*), Agassiz's Glassfish (*Ambassis agassizii*), Spangled Perch (*Leiopotherapon unicolour*), and Purple Spotted Gudgeon (*Mogurnda adspersa*). The commercially important species Barramundi (*Lates calcarifer*) was also common, though was not recorded at all sites, and Sea Mullet (*Mugil cephalus*) was recorded at two sites. An unidentified eel was also collected, tentatively identified as the first record of swamp eels (*Ophisternon* sp.) in the Styx River catchment.

Three species of freshwater turtles were caught during baseline surveys in 2011 and 2017, including Kreft's River Turtle (*Emydura macquarii krefftii*), Eastern Snake-necked Turtle (*Chelodina longicollis*), and Saw-shelled Turtle (*Wollumbinia latisternum*).

Four listed aquatic animal species have the potential to occur in waterways surrounding the Project Area. Evidence of Estuarine Crocodile (*Crocodylus porosus*) was found at two Styx River sites, and the species is likely to be present in Deep Creek, Granite Creek, and Tooloombah Creek. Neither the Fitzroy Turtle (*Rheodytes leukops*), nor the Southern Snapping Turtle (*Elseya albagula*) have been recorded in the Study Area, and they are considered unlikely to occur within the Project Area (CDM Smith 2018; Central Queensland Coal 2020b). The Platypus is listed as Special Least Concern under the *Nature Conservation Act 1992* (NC Act) and has potential to occur in waterways of the Project Area. The Platypus was not observed during baseline field surveys, but is known to be cryptic and may be difficult to detect.

Aquatic macroinvertebrate communities were sampled in June 2011 and February 2017, and were represented by 48 taxa (CDM Smith 2018). Fewer taxa were collected from the Styx River than from the creek sites sampled, possibly because invertebrates are more concentrated in the smaller water bodies, and habitat diversity was higher in the creeks (CDM Smith 2018). The taxa collected are tolerant of poor water quality and periods of static or low flow. According to the AusRivAS Model for Central Queensland for riffle habitats, three sites had more taxa than reference sites, two sites had similar numbers of taxa as reference sites, and one site had significantly fewer taxa and was assessed as 'significantly impaired'.

Although the Styx River sites had fewer taxa than nearby creeks, they had permanent pools and were characterised by different invertebrate groups than the ephemeral pools. Styx River had higher abundances of the swimming families Dytiscidae and Corrixidae, as well as the snail Thiaridae. Three caddisfly (Trichopteran) families were relatively abundant in Tooloombah and Deep Creeks, but not in the Styx River. These were Hydrobiosidae, Hydropsychidae and Philipotomidae, which prefer flowing water. The blackfly family Simuliidae also requires flowing water, and while present in high numbers at the Tooloombah and Deep Creeks, was rarely detected in the Styx River. Similar patterns of occurrence were recorded for the mayfly families Baetidae and Caenidae. Such results highlight the variability of the aquatic ecosystems of the Study Area between the upper creeks and lower Styx River ecosystems.

It should be noted that while pools are an important feature of creeks within the Study Area, at least some of these receive groundwater inputs (and are therefore Aquatic GDEs). These are therefore considered in **Section 6.6**.

7.1.3 Wetlands

Wetlands throughout Queensland have varying ecological values and are classified under a number of separate pieces of legislation. Both the Project Area and the wider Study Area contain wetlands of different types and ecological value.

One Wetland Protected Area (WPA) is mapped within the Project Area (termed 'Wetland 1'), overlapping the western boundary (**Figure 7-2**). Several other WPAs also occur downstream of the Project Area and are mapped as Regional Ecosystem (RE) 11.1.3a; hypo-saline wetlands with *Melaleuca* species and / or Forest Red Gum (*Eucalyptus tereticornis*) with mangroves, saltmarsh species and Marine

Couch (*Sporobolus virginicus*) potentially occurring. Wetland 1 is identified as a wetland of high ecological significance (HES) within the GBR river catchments on the Map of Great Barrier Reef Protection Areas, as outlined in Code 9 of the State Development Assessment Provisions.

Another wetland (termed Wetland 2) occurs within the Project Area within the Tooloombah Creek catchment (**Figure 7-2**). This wetland is mapped as a wetland of general ecological significance (GES) under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019*. See **Figure 7-2** for locations of wetlands in and surrounding the Project Area.

Three small freshwater wetlands, comprising RE 11.3.27, are also located within the mining lease (Wetland 3, 4 and 5).

Broad Sound Wetland occurs approximately 8 km downstream from the Project Area and is listed on the Directory of Important Wetlands in Australia. Broad Sound also contains Australia's largest Fish Habitat Area, declared under the *Fisheries Act 1994*. Both of these values are considered MSES in Queensland. See **Section 8** for more information on Broad Sound.

Other permanent artificial wetlands such as farm dams are also present throughout the region and likely provide habitat for a number of semi-aquatic species including freshwater turtles and amphibians. However, as there is no consistent connection to waterways, these areas are unlikely to support functional populations of aquatic fauna such as fish.

7.1.4 Waterways Providing Fish Passage

Many species of fish in Queensland rely on movement through waterways and floodplains. Waterways are mapped under the *Fisheries Act 1994* to help manage the impacts to fish passage from waterway barriers (**Figure 7-3**). The Department of Agriculture and Fisheries (DAF) provides the *Accepted development requirements for operational work that is constructing or raising waterway barrier works*. This document states the requirements that must be complied with and provides guidance for conducting operational work that involves constructing or raising waterway barrier works. Waterways providing fish passage are MSES (if located outside of Urban Areas – as per Schedule 2, Section 10 of the *Environmental Offsets Regulation 2014*), and require consideration and assessment in the Project impact assessment.

Both Deep Creek and Tooloombah Creek are mapped as major risk waterways for barriers to fish passage. A number of smaller waterways are present within the Project Area and are mapped as low to moderate risk. Only one small section of waterway is mapped as high risk within the Project Area. This is a section of a drainage line to the south of the Bruce Highway. The Project lies within a highly modified landscape with many existing barriers to fish passage, including multiple dams and artificial embankments.

Approximately 13.4 km of waterways mapped under the Waterway Barrier Works for Fish Passage spatial layer occur within the Project Area. As part of the SEIS v2, Central Queensland Coal prepared a mapping revision for submission to DAF (CDM Smith 2018 – Appendix 21) limiting the impact area to approximately 8.35 km of waterway providing potential fish passage in the Project Area, on the basis that some of the waterways had been incorrectly mapped and did not provide fish passage. DAF accepted this revision in their comments on the updated SEIS (v2; March 2019), with the revised mapping displayed in **Figure 7-3**. Any works taking place in areas determined to be fish habitat will require appropriate environmental offsets.

Figure 7-2: Map showing the location of wetlands in the Study Area

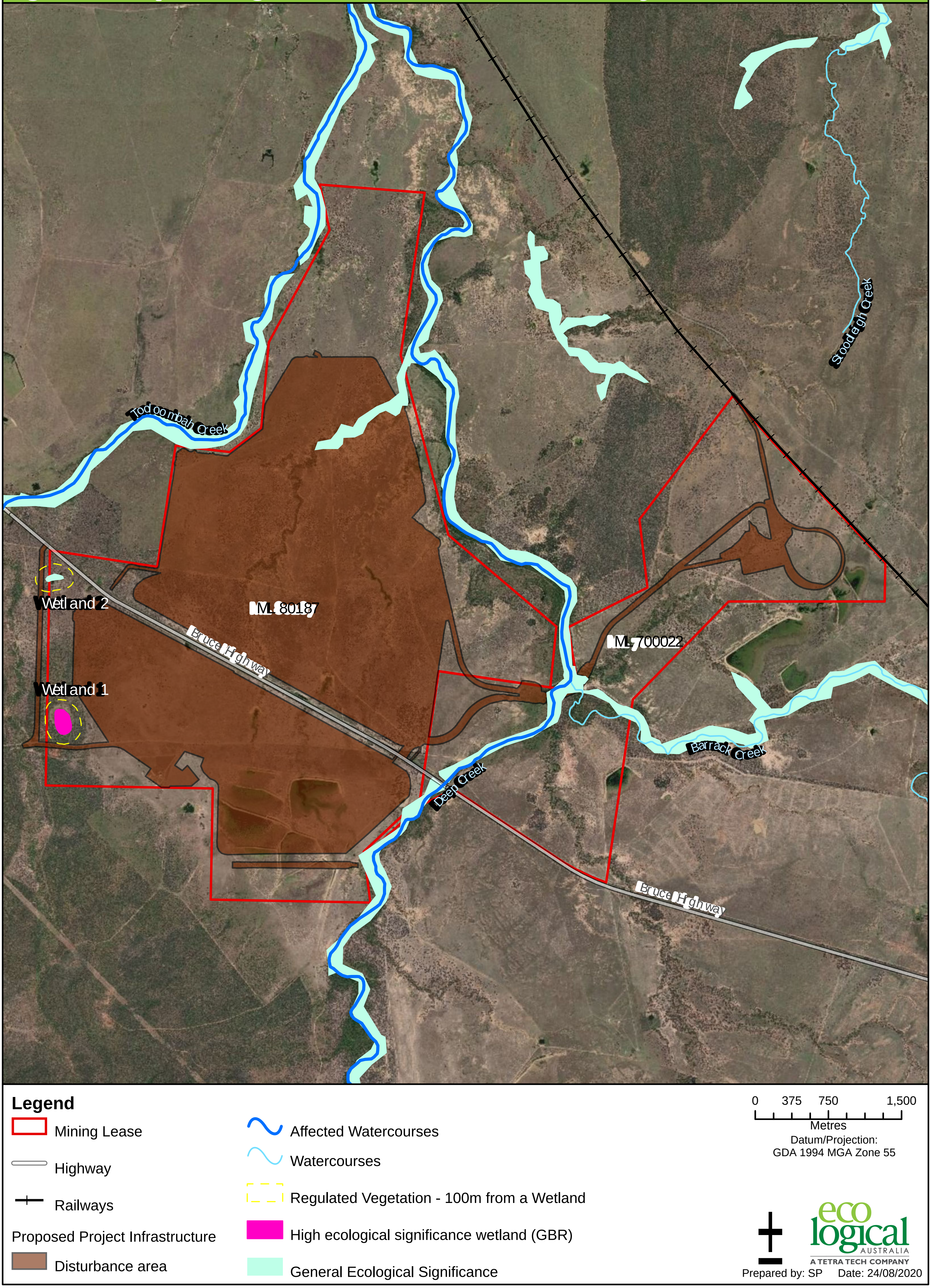
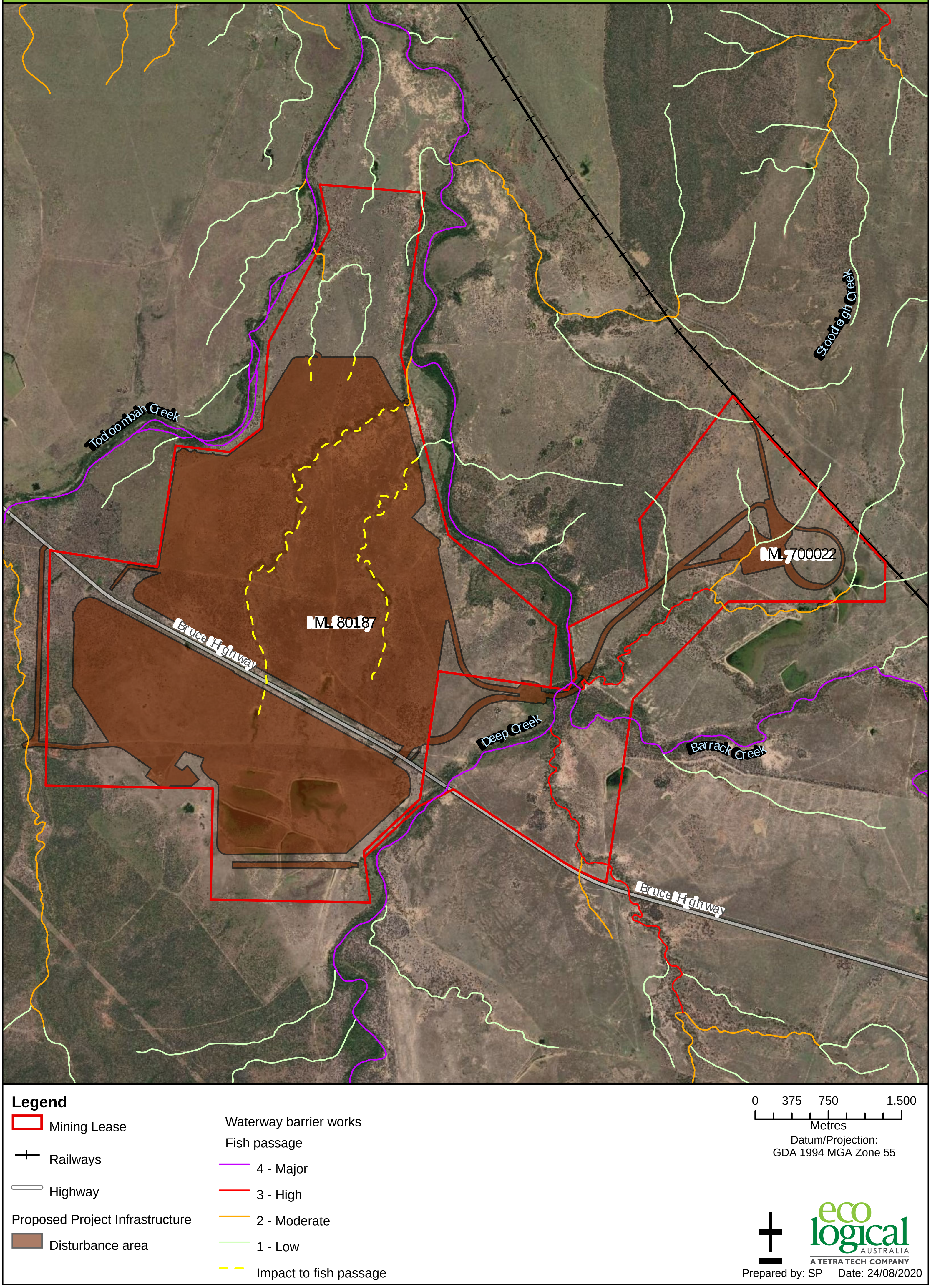


Figure 7-3: Waterway Barrier Works to Fish Passage in relation to Project disturbance areas



7.2 Impact assessment – all aquatic ecology values

Deep and Tooloombah Creeks have the potential to be impacted in a number of ways by the Project. Clearing of riparian vegetation will occur in some locations to accommodate Project infrastructure such as roads, bridges and water drainage structures. Riparian vegetation provides important ecological functions for aquatic ecosystems, such as providing shade to waterways which regulates temperature and enhancing bank stability. The small extent of watercourse vegetation (MSES) to be cleared (12.36 ha), limits the potential for significant impacts to aquatic ecology values to localised areas.

More significantly, a number of minor waterways which are tributaries of Deep Creek will be disturbed by the construction of critical Project infrastructure such as mine pits. These waterways are both highly degraded and ephemeral, and provide minimal aquatic ecology values. Their disturbance will eliminate the potential for fish passage across parts of the Project Area, while at other locations adjacent to the mining lease, infrastructure constructed within waterways will be designed to comply with DAF requirements that facilitate the continuation of fish passage.

Groundwater drawdown will result in reduced groundwater inputs to some sections of Deep Creek and Tooloombah Creek during the dry season. This will result in pools of surface water drying up faster than they do currently under baseline conditions during the dry season. Changes to water chemistry within pools are also likely to occur, with the influence of saline groundwater inputs being reduced. Water quality within pools is therefore likely to be less salty over the dry season, with the concentration of salts from evaporation a much smaller influence on the water chemistry than the saline groundwater inputs. These impacts are considered separately in **Section 6.6**, as the pools are considered to be Aquatic GDEs.

The magnitude of Project-related change to the existing hydrological regime is very minor and not expected to result in a significant impact on aquatic fauna. The existing hydrological conditions of the creeks, which flow approximately 24% of the time will remain the same (WRM 2020). There will also therefore be no change to the location of the freshwater – saltwater interface, with the baseline distribution of fresh and salt waters remaining unaffected by the Project.

The Project footprint does not intersect any freshwater wetlands and consequently, direct impacts on these wetlands and their aquatic ecology values are not anticipated. Through the water balance assessment WRM (2020) considered the impacts of the Project on surface water flows to the freshwater wetlands. The catchment areas of Wetland 1 (15.4 ha) and Wetland 2 (19.5 ha) will not be affected by mining operations (WRM 2020). They also found that the catchment of Wetland 5 would not be affected by the Project, while the catchment of Wetlands 3 and 4 will be reduced by 39 to 41% respectively. However, water level duration curves demonstrated that these catchments change will have negligible impact on water levels within the wetlands (WRM 2020). There will therefore be no substantial change to the volume, timing, duration and frequency of surface water flows to any of the wetlands.

Changes to surface and groundwater quality either from spills or controlled releases will be managed via good practice and a Water Management Plan designed to ensure that discharge occurs only during flow events of suitable magnitude to allow for appropriate dilution of any water quality parameters occurring at high concentrations. These activities will also be strictly regulated in accordance with the conditions of an EA.

Risks associated with the erosion of stream banks will be managed through the engineering design of diversion channels, drains and spillways, and through minimising the disturbance to riparian vegetation. The removal of cattle grazing from large parts of the Study Area will also assist in stabilising stream banks. Construction works will be completed predominantly in the dry season, when in-stream aquatic ecology values are generally not present or are limited in geographic scale and abundance.

Impacts related to the mortality of wildlife from construction activities, and from the creation of dust are expected to be minor. Spotter catchers will be present during all clearing activities and clearing procedures will be developed to relocate native wildlife to adjacent areas and rehabilitate any injured wildlife. Weed and pest hygiene practices will be implemented and minimise the risk of introducing exotic species to the site and surrounding areas. A detailed weed and pest management plan will also be developed and implemented to reduce the extent and severity of existing weed and pest incursions.

Aside from the direct impacts to waterways providing fish passage (MSES; **Section 7.3**), the impacts of the Project on waterways and their associated aquatic ecology values are expected to be minor. This assessment is based on the limited changes to the natural hydrological regime as a result of the Project, the implementation of sediment and water management controls to reduce discharges to the receiving environment, and a reduction in the intensity of existing grazing land use over approximately 4,000 ha (mining lease and offset areas) within the catchment of the Project Area.

7.3 Assessment against relevant MSES criteria

7.3.1 Fish passage

Any part of a waterway providing passage of fish is a MSES if the construction, installation or modification of waterway barrier works carried out under an authority will limit the passage of fish along the water. Accordingly, the impacts of the Project to fish passage have been assessed in accordance with relevant guidelines under the *Fisheries Act 1994* and *Planning Act 2016.*

A significant decrease in groundwater inputs or surface water runoff to waterways can reduce water levels and flows, impeding fish passage. Waterways include rivers, creeks, streams, watercourses and inlets of the sea, with passage meaning the natural movement patterns of fish species required to maintain the biological integrity of the species.

Approximately 13.4 km of waterways mapped under the Waterway Barrier Works for Fish Passage mapping spatial layer occur within the Project Area. As part of the SEIS, Central Queensland Coal prepared a mapping revision for submission to DAF limiting the impact area to approximately 7 km of waterway providing potential fish passage in the Project Area, on the basis that some of the waterways had been incorrectly mapped and did not provide fish passage (CQC 2018). DAF accepted this revision in their comments on the updated SEIS v2 (March 2019), with the revised mapping displayed in **Figure 7-3**. Based on changes to the Project Description since 2018, assessment of impacts on fish passage is based on the 8.35 km of waterway that is considered to provide fish passage.

The mine haul road will cross Deep Creek and Barrack Creek. Deep Creek is likely to be used for fish passage when flows occur. Barrack Creek is largely an ephemeral waterbody with highly intermittent flows. With appropriate crossing design, including culverts, no barriers to fish passage are anticipated at these crossing points. Off-lease operational works in waterways are required to adhere to accepted development requirements for operational work that is constructing or raising water barrier works, or State Development Assessment Provisions - State Code 18.

There is potential for waterholes along Tooloombah and Deep Creek to be impacted by groundwater drawdown (**Section 6.6**). Dewatering and depressurisation of aquifers may increase the period of no flow in Deep Creek and Tooloombah Creek, impairing fish passage in affected reaches. However, the changes to existing hydrology of the creeks are expected to be relatively minor, and similar to the current variability that occurs from year to year under natural conditions (WRM 2020).

Responses to the significant residual impact criteria for waterways providing fish passage are provided in **Table 7-1**. Significant residual impacts are expected in areas within the mining lease where the development will occur, and result in impacts to waterways providing fish passage, that cannot be avoided or mitigated. These are addressed in the Project Biodiversity Offset Strategy (C02 Australia 2020).

Table 7-1: Significant impact criteria – waterways providing fish passage

Significant impact criteria	Significant impact	Response
Result in mortality or injury of fish	No	A number of the waterways within the Project Area are ephemeral and highly modified, and while still meeting the definition of fish passage, are highly unlikely to regularly provide such function. This is particularly applicable for the waterways located within the footprint of the mine pits. However, in order to ensure there is no mortality or injury to fish the following measures will apply: • Prior to undertaking works in waterways, a qualified ecologist will inspect the area and if required, remove aquatic fauna. Aquatic fauna will be relocated to a suitable predetermined area (adjacent waterway containing water). • Construction will occur during the dry season to reduce the potential for injury or mortality to any species that may utilise Deep Creek during the wet season
Result in conditions that substantially increase risks to the health, wellbeing and productivity of fish seeking passage such as through the depletion of fishes energy reserves, stranding, increased predation risks, entrapment or confined schooling behaviour in fish	No	The waterways within the Project Area are ephemeral, highly modified and are unlikely to be regularly used by fish as a means of passage. Waterway barriers within the Study Area will be designed to facilitate fish passage and to minimise the chances of entrapment and stranding. There is no evidence to suggest that the Project would increase predation risks for fish species.
Reduce the extent, frequency or duration of fish passage previously found at a site	Yes	The construction of critical Project infrastructure, including mine pits, will occur directly over waterways mapped as providing fish passage. Consequently, the extent of fish passage will be reduced. Increased periods of no-flow in Deep and Tooloombah Creeks may also reduce fish passage on a limited scale.
Substantially modify, destroy or fragment areas of fish habitat (including, but not limited to in-stream vegetation, snags and woody debris, substrate, bank or riffle formations) necessary for the breeding and/or survival of fish	No	Construction of Project infrastructure will occur directly over waterways mapped as providing fish passage. However, these waterways are ephemeral, highly modified and consequently are unlikely to provide habitat necessary for the breeding and survival of fish. The waterway barriers associated with Deep Creek and Barrack Creek will be designed and constructed to avoid significantly altering instream habitat and will not result in a reduction in fish passage.
Result in a substantial and measurable change in the hydrological regime of the waterway, for example, a substantial change to the volume, depth, timing, duration and frequency of flows	No	Hydrological modelling completed by WRM (2020) found that the Project will not influence the existing hydrological conditions of local waterways. While some runoff will be captured on site in mine infrastructure, the small size of the water volumes

Significant impact criteria	Significant impact	Response
		involved, in relation to the surrounding catchment, means that no measurable changes to the hydrological conditions of the Study Area will occur. Waterways will continue to flow on average 24% of the time, consistent with baseline conditions.
Lead to significant changes in water quality parameters such as temperature, dissolved oxygen, pH and conductivity that provide cues for movement in local fish species	No	The receiving environment of the Project Area, including waterways of Tooloombah Creek and Deep Creek, will be managed in accordance with the Project EMP and a controlled release strategy for mine affected water. Controlled releases will also be regulated by the Mine EA. The effectiveness of these management measures will be determined by implementation of the REMP, which will include measures to monitor and record the effects of any release of mine-affected water on the receiving environment. No impacts to the water quality of the receiving environment are expected as a result of the Project (WRM 2020).

7.3.2 Wetland 1 and Wetland 2

The Project Area and areas immediately adjacent to it contain mapped wetlands which are classified as MSES including Wetland 1 and Wetland 2. Additional MSES wetlands associated with the Broad Sound area and GBR are located downstream of the Project Area and are discussed in **Section 8.**

As mentioned above, Wetland 1 is a wetland of high ecological significance and a wetland protection area, while Wetland 2 is a wetland of general ecological significance. The Project footprint does not intersect Wetland 1 or Wetland 2 and consequently, direct impacts on these wetlands and their aquatic ecology values are not anticipated.

Wetland 1 has a low potential to be impacted by groundwater drawdown. Wetland 1 is a Terrestrial GDE, with trees accessing a perched aquifer at a depth of 8 mbgl. However, the underlying groundwater layer is located at a depth of 13.5 mbgl. The wetland has been mapped as RE 11.3.12 under updated vegetation mapping, and occurs within the predicted zone of groundwater drawdown impact. However, maximum drawdown at the Wetland 1 monitoring bore (WMP25) is predicted to be 2.7 m below current groundwater levels. Stable isotope analysis indicated that vegetation at Wetland 1 sources water from a maximum depth of approximately 8 m. This water is generated by rainfall moving through the soil profile to an impermeable clay layer, rather than from the underlying groundwater layer (3D Environmental 2020).

At Wetland 2, the water table is approximately 20 m below ground level, and the wetland is not considered to be either an Aquatic or Terrestrial GDE. Stable isotope and water data indicate that trees at Wetland 2 access their water solely from the soil water reservoir lying above the groundwater layer at depths of 2 to 4 mbgl (3D Environmental 2020). Wetland 2 is therefore not expected to be affected by maximum groundwater drawdown of 1.9 m that will occur at the Wetland 2 monitoring bore (WMP27).

The catchment areas of Wetland 1 (15.4 ha) and Wetland 2 (19.5 ha) will not be affected by mining operations (WRM 2020). There will therefore be no substantial change to the volume, timing, duration and frequency of surface water flows to the wetlands.

Responses to the significant residual impact criteria for wetlands are provided in **Table 7-2**. The Project is not expected to result in a significant residual impact to wetlands.

Table 7-2: Significant impact criteria – wetlands and watercourses

Significant impact criteria	Significant impact	Response
Areas of the wetland or watercourses being destroyed or artificially modified	No	There is no Project infrastructure planned to intersect the wetlands within the Project Area. Consequently, these wetlands will not be destroyed or artificially modified.
A measurable change in water quality of the wetland or watercourse – for example a change in the level of the physical and/or chemical characteristics of the water, including salinity, pollutants, or nutrients in the wetland or watercourse, to a level that exceeds the water quality guidelines for the waters	No	No change to the water quality of the wetlands within the Project Area are anticipated. There will also be no change to water quality at wetlands located downstream of the Project (refer to **Section 8**).
The habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetland being seriously affected	No	No native species dependent on the wetland were identified during baseline assessments. The wetlands contain a range of fauna adapted to the ephemeral nature of the wetlands and their drying and wetting cycles. The Project will not directly impact any wetlands within the Project Area and is highly unlikely to result in demonstratable indirect impacts to the wetlands.
A substantial and measurable change in the hydrological regime or recharge zones of the wetland e.g. a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland	No	None of the wetlands in the Project Area have been identified to be Aquatic GDE (3D Environmental 2020). The wetlands are also located outside of the areas of greatest drawdown (predicted drawdown for Wetland 1 is 2.7 m (at WMP25) maximum, with natural variability of 3 m). Consequently, changes in groundwater level associated with the Project will not affect the water quality of the wetland, which is influenced by surface water runoff. The catchment areas of Wetland 1 (15.4 ha) and Wetland 2 (19.5 ha) will not be affected by mining operations (WRM 2020). There will therefore be no substantial change to the volume, timing, duration and frequency of surface water flows to those wetlands.
An invasive species that is harmful to the environmental values of the wetland being established (or an existing invasive species being spread) in the wetland	No	There is no evidence of harmful invasive species detrimental to wetlands being present in the Project Area. The Project will not create mechanisms that allow for any invasive species detrimental to wetlands to become established or spread. A weed and pest management plan will be developed and implemented for the Project, and strict hygiene measures will be utilised during Project construction activities.

7.4 Risk Assessment

Potential impacts on aquatic ecology values have been assessed using the risk assessment framework outlined in **Section 2.4.1**. The potential impacts considered include those common to all values as described in **Section 4**:

- Direct disturbance of vegetation and/or habitat
- Changes to groundwater level
- Changes to groundwater quality
- Changes to surface water flow (hydrology)
- Changes to surface water quality
- Erosion of sediments
- Changes in the location of the freshwater – saltwater interface.

Additionally, the following impacts relevant to aquatic ecology have been assessed:

- Injury to wildlife during construction works
- Increase in dust, pests and weeds during construction and operations, reducing the quality of aquatic habitats.

The risk assessment for aquatic ecology, which outlines the potential impacts, initial risk, control measures and residual risk following the implementation of control measures is provided in **Table 7-3**, with discussion in the following sections.

Table 7-3: Aquatic ecology risk assessment

Issue	Potential Impacts	Likelihood	Consequence	Potential Risk	Control Measures	Residual Risk
Direct disturbance to vegetation (clearing)	• Clearing of riparian vegetation, wetlands and associated aquatic habitat • Degradation of receiving water quality and adverse effect on supported ecosystems • Bank instability and associated follow-on impacts including riparian degradation	Almost certain	Moderate	Extreme	Project design has been optimised to reduce the need to clear remnant vegetation, particularly in riparian zones Retained vegetation will be clearly marked to avoid damage or accidental clearing Bank stabilisation will take place post-construction to allow for revegetation and reduce scour potential Apron and stream bed scour protection will be provided Regeneration of vegetation on the property during construction and operation will reduce erosion Vegetation buffers will be created to reduce sediment and nutrient run-off to waterways Post-operation mine infrastructure will be removed and rehabilitation of all disturbed land will occur. This will be to a minimum of pre-existing vegetation and habitat condition.	High
Direct disturbance to aquatic habitat, affecting connectivity	• Road crossings causing loss of connectivity in waterways that provide fish passage • Increased flow velocities in creeks due to Project related infrastructure (crossings and diversion bunds) • Reduced waterway flows, due to capture of catchment runoff in mine water storage dams	Likely	Moderate	High	Project design ensures surface water flows into creeks represent natural conditions as much as possible Construction of road crossings will be completed during the dry season to eliminate the need to divert water around the construction area Minimum culvert aperture width will be 2.4 m or span the entire channel width Culvert design and installation will be optimised to represent natural conditions and facilitate fish passage	Medium

Issue	Potential Impacts	Likelihood	Consequence	Potential Risk	Control Measures	Residual Risk
					Water will only be discharged from the mine dam during flow trigger events (during/immediately after high rainfall events when creek flow is high) and only if the water quality parameters meet the water quality release limits Discharge of water will be controlled to reduce the likelihood of discharges from overtopping	
Changes to groundwater level	Reduction in groundwater flows to pools, causing them to dry up faster than usual during the dry season	Likely	Moderate	High	Project design to minimise the areas of creeks that are subject to groundwater drawdown.	Medium
Change in groundwater quality	Change of water quality in groundwater-fed pools, due to changes in groundwater quality.	Likely	Minor	Medium	Project design to minimise the risk of changes to groundwater quality.	Low
Changes to hydrology and surface water flows	Reduction of inflows to creek lines and consequent reduction in long-term habitat persistence (waterholes)	Unlikely	Moderate	Medium	Project design will ensure that surface water flows into creeks represent natural conditions as much as possible Water from upstream of the catchment will be diverted around disturbed areas and into the creeks Tooloombah Creek and Deep Creek have naturally deep channels that confine the majority of flow within the banks. There will be minor changes to flood levels as a result of the Project, with most flow remaining contained with the system. There will be no significant increase in creek flow velocity as a result of the Project (WRM 2020). Water will be discharged from the mine dam during flow trigger events	Low

Issue	Potential Impacts	Likelihood	Consequence	Potential Risk	Control Measures	Residual Risk
Erosion of streambanks, sedimentation of waterways and sediment runoff	• Bank instability and associated follow-on impacts including degradation of the riparian zone • Degradation of instream habitat / water quality including downstream estuarine habitat in the Styx River • Degradation of important downstream habitat and values associated with Broad Sound FHA and GBR	Likely	Major	Extreme	Construction will be completed during the dry season where possible, to reduce the potential of construction related erosion and scour Bank stabilisation will take place post-construction to allow for revegetation and reduce scour potential A water catchment system and environmental dams (sediment basins) will collect run-off from the development area which will be transferred to the main site dams Captured water will be treated to minimise the amount of sediment Water will only be discharged from the mine dam during flow trigger events (during/immediately after high rainfall events when creek flow is high) Discharge of water will be controlled to reduce the likelihood of non-compliant discharges from overtopping Landforms such as waste rock stockpiles will be constructed using erosion-resistant materials and with low batter slope angles to reduce the level of erosion Removed topsoil will be placed in designated rehabilitation zones and seeded to minimise erosion Installation of sediment fences on the downslope of disturbed areas, erosion control devices and diversion drains Clean water will be diverted around disturbed areas to avoid additional sediment and contamination Earthmoving activities will be minimised during high rainfall events to limit sediment runoff	Medium

Issue	Potential Impacts	Likelihood	Consequence	Potential Risk	Control Measures	Residual Risk
					Regeneration of the vegetation and restoration of habitat on the property will create vegetation buffers to reduce sediment and nutrient runoff into waterways	
Changes to the location of the SW – FW interface	• Reductions in surface water flows causing the interface between salt water and freshwater to move upstream • Reduction in habitat for freshwater species	Unlikely	Minor	Low	Project design, to minimise the potential impacts on freshwater flows from surface water and groundwater sources	Low
Direct fauna mortality	Mortality of aquatic fauna during clearing of habitat and instream works	Likely	Moderate	High	Instream construction works will be carried out during the dry season and permanent water sources within creeks (permanent pools) are not present in the vicinity of instream construction works Prior to emptying wetlands or dams, a qualified ecologist will inspect the area and if required, remove aquatic fauna. Any fish that become trapped during construction will be salvaged in accordance with the DAF *Guidelines for fish salvage.* In the event of a fish kill, the appropriate steps provided in the guidelines will be followed	Low
Increase in dust, pests and weeds as a result of mining construction and operations	• Reduction in the condition of vegetation and habitats due to an increase in dust from construction and mining operations • Introduction of pests and weeds	Possible	Minor	Medium	All works will be undertaken in accordance with an EMP, which has extensive controls to minimise the creation of dust and the introduction of new pests and weeds A weed and pest management program will be implemented to keep existing pests and weeds at low levels throughout the Project Area	Low

8. Impact Assessment Downstream Values: Marine Environment and Great Barrier Reef

Due to the Project's location in close proximity to the Queensland coast, there is potential for impacts to downstream values, including the marine environment and the Great Barrier Reef. This section identifies those values (building on the general description in **Section 3**), and undertakes an assessment of potential indirect impacts to the values located downstream of the Project Area. Where relevant, specific assessments have been undertaken for MNES and MSES in line with applicable significant impact guidelines.

8.1 Introduction

Sections of the Styx River catchment which are tidally influenced, and are therefore relevant to the assessment of marine environments, begin at the confluence of Deep Creek and Tooloombah Creek, approximately 2.3 km downstream of the Project Area, and include all areas located downstream of this point. This area is significantly different to the upstream habitats adjacent to the Project Area.

Fresh water runoff from terrestrial areas and saline marine waters mix within the estuary, providing brackish to saline waters before reaching the coast. Salinity is highly variable among locations and seasons due to the influence of tidal cycles and upstream runoff events (EC ranges from 125 µS/cm to more than 35,000 µS/cm). The Styx River Estuary and the majority of Broad Sound are mapped as Slightly Disturbed Waters under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (SD2422), with the mapped waters commencing approximately 4.9 km downstream of the Ogmore Bridge. .

In general terms, the environmental values in this area are referred to as 'downstream values' and include:

- Broad Sound Wetland
- Broad Sound Fish Habitat Area
- The Great Barrier Reef World Heritage Area
- The Great Barrier Reef Marine Park and Great Barrier Reef Coast Marine Park
- Habitat for marine species and communities, including marine plants and listed threatened and migratory species.

8.1.1 Broad Sound Wetland

Broad Sound is listed in the Directory of Important Wetlands of Australia (DIWA) and is located approximately 8 km downstream of the Mining Lease where the Styx River forms part of the wetland catchment (**Figure 8-1**). The listed Wetland covers approximately 2,100 km^2 encompassing both tidal marine and estuarine wetlands. The area is very shallow, with depths of less than 10 m.

The head of the Broad Sound bay has a tidal range of 9 m (the largest range on the east coast of Australia) and tidal waters supply most of the water to Broad Sound. These saline waters are diluted to brackish by freshwater flooding and stream flows, particularly during extreme rainfall events. Several freshwater waterways discharge into Broad Sound, including the Styx River.

Broad Sound is comprised of a variety of habitats that are of significant ecological value to a range of species, including State and Commonwealth listed species such as migratory shorebirds, marine turtles and dugongs. These habitats include:

- Seagrass beds
- Mudflats (tidal, intertidal and supratidal)
- Mangroves
- Brackish and freshwater swamps/lagoons and
- Open depressions (streams, creeks and estuaries).

Wetland systems are also of particular importance for fish. The shallow coastal habitats such as mangroves and seagrass provide nursery resources for many species of fish, providing shelter from harsh marine conditions and predators. Broad Sound, and adjacent Shoalwater Bay, is one of the five main locations within the Great Barrier Reef for mangrove and saltmarsh communities, which provide habitat to a range of juvenile fish species. The area has historically been transformed by agriculture, with saltmarsh being converted to pasture using bund walls. This has restricted movements of juvenile fish but has also created artificial brackish wetlands that are utilised by many wetland species (Goudkamp and Chin 2006).

The nearby Shoalwater and Corio Bays are a listed as a Wetland of International Importance (RAMSAR Wetland) under the EPBC Act, and contain extensive seagrass meadows, providing significant habitat for species such as dugong and marine turtles. Broad Sound and Shoalwater Bay are also sites of international importance for migratory shorebirds as they regularly support either:

- 1% of the individuals in a population of one species or subspecies of waterbird, or
- A total abundance of at least 20,000 waterbirds.

These sites are therefore considered to be important habitat under the EPBC Act.

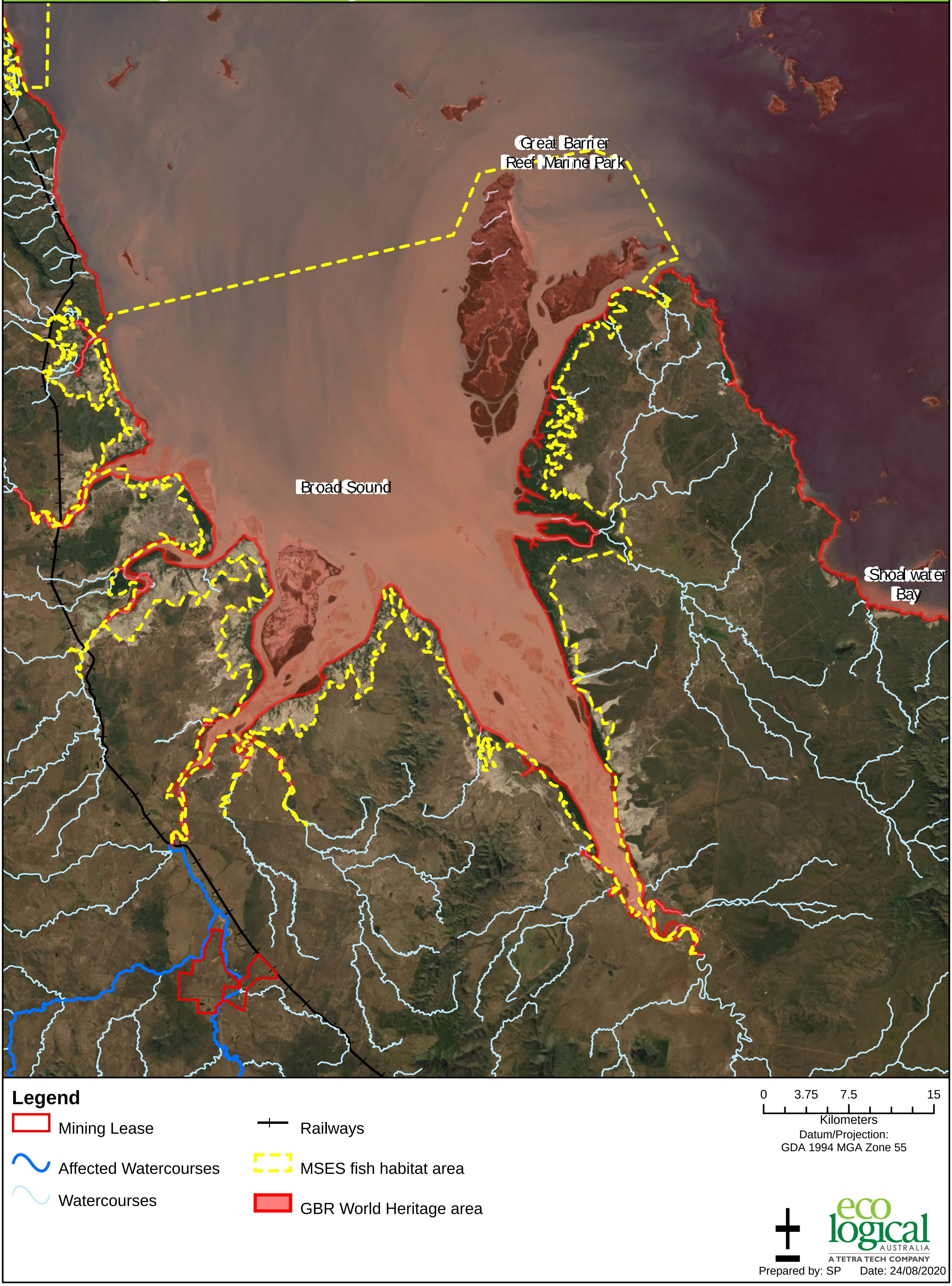
8.1.2 Broad Sound Fish Habitat Area

Broad Sound contains a variety of intertidal and estuarine habitats including mangroves and seagrass that provide key spawning and nursery areas for many species of fish. Reflecting these values, Broad Sound is afforded formal protection for its values to fish via designation as a declared Fish Habitat Area (FHA), under Queensland's *Fisheries Act 1994*.

The Broad Sounds FHA covers an area of over 170,000 ha (**Figure 8-1**) and is Australia's largest Fish Habitat Area (FHA). FHAs are protected from physical disturbance while allowing legal commercial, recreational and indigenous fishing to take place. Conservation of FHAs includes all inshore and estuarine habitats. Broad Sound is a 'key fish habitat' and is therefore classified as Management Level A; ensuring a high level of protection and management.

Fish species of fisheries value occurring in the Broad Sound area include barramundi, blue salmon, bream, estuary cod, flathead, grey mackerel, grunter, mangrove jack, queenfish, sea mullet, school mackerel, whiting, banana prawns and mud crabs (DNPSR 2014). Broad Sound FHA also overlays the Great Barrier Reef Marine Park and World Heritage Area (discussed in the following sections).

Figure 8-1: Broad Sound Nationally Important Wetland and Broad Sound Fish Habitat Area including localised overlay of GBRWHA



8.1.3 Great Barrier Reef World Heritage Area

The Great Barrier Reef (GBR) extends along approximately 2,300 km of the Queensland coast and includes intertidal areas such as Broad Sound, as well as coral reefs extending out to the continental shelf. The GBR and its ecological values are protected under the EPBC Act as well as the Queensland *Marine Parks Act 2004.*

The Great Barrier Reef World Heritage Area (GBRWHA) aligns with the boundary of Broad Sound, 8 km north of the Project Area (**Figure 8-1**). The GBRWHA extends from the low water mark on the coast of Queensland past the continental shelf outside the outer reef, covering an area of approximately 348,000 km^2.

The EPBC Act provides for the protection of World Heritage values such as the GBRWHA from actions that may have a significant impact on these values. This protection is based upon attributes of OUV outlined in the *EPBC Act referral guidelines for the Outstanding Universal Value of the Great Barrier Reef World Heritage Area* (DoE 2014).

None of the specific locations referred to in the World Heritage listing for the GBR (e.g. Green Turtle breeding on Green Island and the Cod Hole tourist attraction), occur within or near the Study Area. However, Broad Sound and the surrounding region does make a contribution to OUV under the majority of the GBRWHA's listing criteria. In all cases, this contribution is incremental, in that the area supports a subset of the features and processes (e.g. natural beauty, biodiversity, coral reef accretion) identified in the listing. However, none of the area's contributions to OUV are critical contributions at the scale of the World Heritage Area (DoE 2014).

Of the environmental values present in the Study Area, some can be considered to provide a higher contribution to the OUV of the GBRWHA than others. Broad Sound is considered one of the five main centres within the GBR for mangrove and saltmarsh communities. It is also considered to provide significant habitat for waterbirds including substantial aggregations of migratory shorebirds listed under the EPBC Act (DoE 2014; **Section 8.1.6**).

Other attributes present in the vicinity of Broad Sound that contribute to the OUV of the GBRWHA include:

- A number of reef communities including a large reef system on the edge of Long Island
- Extensive seagrass beds in the Clairview area (northwest) and in Shoalwater Bay (only small patches are present within Broad Sound Wetland)
- Inshore dolphin species, Australian Hump-back Dolphin (*Sousa sahulensis*) and Australian Snubfin Dolphin (*Orcaella brevirostris*) have been observed in Broad Sound and Shoalwater Bay
- Multiple sites of flatback turtle nesting occur in areas near Broad Sound, such as Long Island, Avoid Island and Wild Duck Island, and Broad Sound is likely to be utilised as inter-nesting habitat by some flatback turtles.

8.1.4 Great Barrier Reef Marine Park and Coast Marine Park

The Great Barrier Reef Marine Park (GBRMP) was established under the *Great Barrier Reef Marine Park Act 1975* and overlays a majority of the GBRWHA, covering approximately 344,000 km^2. The GBRMP is a MNES and protected under the EPBC Act.

The GBRMP supports a wide variety of habitats, within which there is large variation. A total of 70 different bioregions have been identified, including 30 within the reef environment and 40 in the surrounding areas (GBRMPA 2019). The Great Barrier Reef Outlook Report (GBRMPA 2019) identifies the key habitats of the GBRMP. Those present within the areas downstream of the Project include:

- Coastal habitats (including islands, beaches, mangroves, and seagrass meadows)
- Coral communities (e.g. Turtle Island and Long Island)
- Seabed including the lagoon floor
- Open water, which connects all of the GBRMP's habitats (GBRMPA 2019).

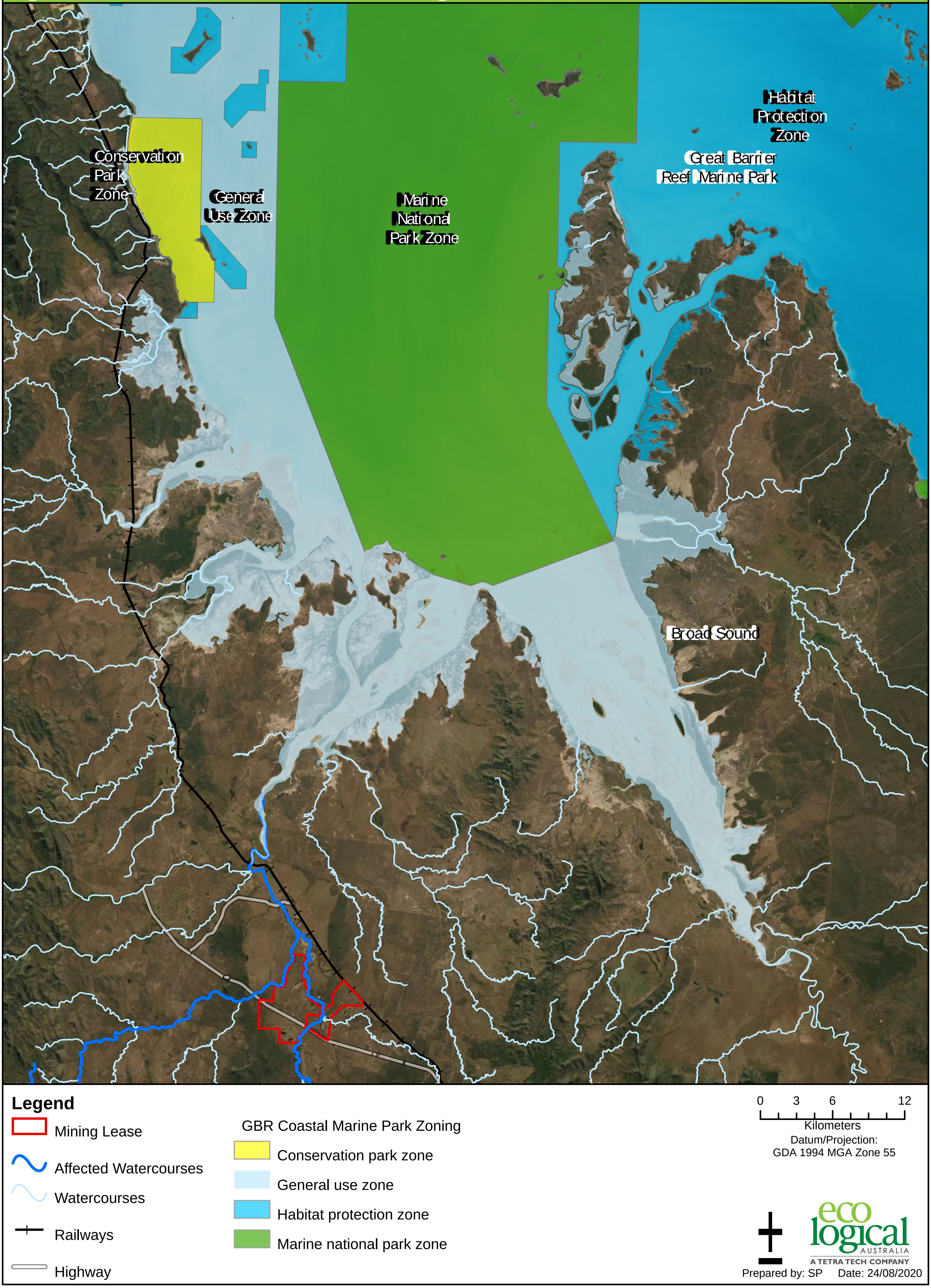
The GBRMP also supports a number of physical, chemical and ecological processes, along with social and cultural values. Those with potential to be influenced by the Project include:

- Aboriginal cultural values (e.g. connection to Sea Country and presence of culturally important species such as Dugong)
- Recreational and commercial fishing
- Tourism.

The areas of the GBRMP downstream from the Project within the Styx River estuary are zoned General Use under the *Great Barrier Reef Zoning Plan 2003*, as are other nearshore coastal areas to the north. The area beyond the Styx River estuary/coastal zone and in Broad Sound is zoned Marine National Park ('green zone').

The Great Barrier Reef Coast Marine Park (GBR Coast MP) is a State marine park administered under the Queensland *Marine Parks Act 2004*. It overlays part of the GBRMP, encompassing the tidal lands and tidal waters (an area of 62,731 km^2). The GBR Coast MP Zoning Plan maps areas of the marine park in relation to the types of activities that can occur in the various zones. Several zones occur within the Broad Sound area ranging from General Use to Marine National Park. The Styx River is mapped as General Use, providing reasonable use while allowing conservation. The GBR Coast MP is only considered a MSES where it is identified as a 'highly protected area' as defined in Schedule 2 of the *Environmental Offsets Regulation 2014*. The General Use zone is therefore not considered a MSES, unlike some other parts of Broad Sound (**Figure 8-2**).

Figure 8-2: GBR Coast Marine Park zoning



8.1.5 Condition of the Great Barrier Reef

The GBR is subject to a number of threats including land-based runoff, climate change, coastal development and direct human uses such as fishing. In recent years, the overall condition of the GBR has been declining and the latest Outlook Report published as part of the *Reef 2050 Long-Term Sustainability Plan* (Reef 2050 Plan; DoEE 2018) states that the current outlook for the GBR is very poor, unless more action is taken to address a range of threats (GBRMPA 2019).

Inshore areas of the GBR, such as Broad Sound, are also under threat, particularly due to decreased water quality. Sedimentation and levels of pollutants are high in many of these inshore areas as a result of coastal development, increased erosion, and run off from agricultural practices. Although some improvements in water quality are occurring, the rate of improvement is slow (GBRMPA 2019).

The Broad Sound region is a remote and relatively undisturbed area of the GBR. However, it is subject to the impacts of anthropogenic activities, including reductions in water quality. Water within the region is naturally turbid due to the extreme tidal range over a large shallow area, resulting in strong currents and the resuspension of sediments. Increased concentrations of suspended sediment, and pollutants (nitrogen, phosphorus and herbicides) are also present in waters of the region, likely a result of agricultural practices occurring upstream from Broad Sound, within the broader catchment. Across the GBR, several initiatives are underway to reduce sediment and nutrient inputs from agricultural activities within the catchment (Queensland Government 2018).

8.1.6 Marine species, communities and their habitats

8.1.6.1 Marine fauna

There are a number of marine fauna that are known to occur in Broad Sound and are listed as threatened and/or migratory on the NC Act and/or EPBC Act. These are summarised in **Table 8-1** and **Figure 8-3**. Full details of listed species and their likelihood of occurrence are provided in Chapter 16 of the SEIS v3 (Central Queensland Coal 2020b). As described above, Broad Sound also has significant values for fish species.

Table 8-1: Summary of listed marine fauna known to occur in Broad Sound

Species	EPBC Act status	Summary of occurrence in Broad Sound (from CDM Smith 2018 and Chapter 16 SEIS v3)
Flatback Turtles (*Natator depressus*)	V, M	Flatback Turtles are known to nest throughout the Broad Sound region, with large nesting aggregations at Wild Duck and Avoid Islands, which are both located ~75 km north of the Project Area. It is not expected that marine turtles occur upstream in the Styx River estuary much further than Rosewood Island (where the river meets the wider Broad Sound inlet). This is likely due to the shallow nature of the river (particularly at low tides) and the lack of suitable instream habitat for marine turtle.
Green Turtle (*Chelonia mydas*)	V, M	Green Turtles are known to nest in the wider region, including on several offshore islands and within Shoalwater Bay. There are ALA records of this species within the Styx River estuary, although all may be attributed to one individual. It is not expected that marine turtles occur upstream in the Styx River estuary much further than Rosewood Island (where the river meets the wider Broad Sound inlet). This is likely due to the shallow nature of the river (particularly at low tides) and the

Species	EPBC Act status	Summary of occurrence in Broad Sound (from CDM Smith 2018 and Chapter 16 SEIS v3)
		lack of suitable instream habitat for marine turtle species including a lack of seagrass resources which are particularly relevant to Green Turtles.
Dugong (*Dugong dugon*)	M	Sightings of Dugong are rare in Broad Sound. There are Dugong Protection Area (DPAs) to the north (extending from Carmilla Creek south to Clairview Bluff) and north-west (within Shoalwater Bay) of the Project Area.
Australian Hump-back Dolphin (*Sousa sahulensis*) and Australian Snubfin Dolphin (*Orcaella brevirostris*)	M	During boat-based surveys of Broad Sound carried out over two weeks in 2013 low numbers of both species were detected north of the Styx River in the channel on the western side of Rosewood Island. There are several (ALA) database records of Australian Snubfin Dolphin (only) in the wider area to the north of Broad Sound. Given the shallow nature of the Styx River, particularly at low tides, suitable habitat for these species in the river is not expected to extend upstream beyond Rosewood Island.
Estuarine Crocodile (*Crocodylus porosus*)	M	Estuarine Crocodile is anecdotally considered to occur in a large waterhole located downstream of the confluence of Deep Creek and Tooloombah Creek (2.2 km north of the Project boundary). However, it has not been observed during the ecological investigations or other monitoring associated with the Project. Habitat throughout the Styx River estuary and Broad Sound is considered suitable for this species.
Humpback Whale (*Megaptera novaeangliae*)	V, M	The Humpback Whale is known to utilise the sheltered coastal waters of central and southern Queensland, particularly while on its southern migration. Broad Sound is not ideal habitat for the species, due to its large tidal range and associated turbid waters. However, the deeper waters at the northern entrance to Broad Sound are likely to be utilised by Humpback Whales for short periods during the southern migration. This is particularly so for whales that have recently calved, with a core calving area located to the north of Broad Sound off the coast of Mackay (DAWE 2020).

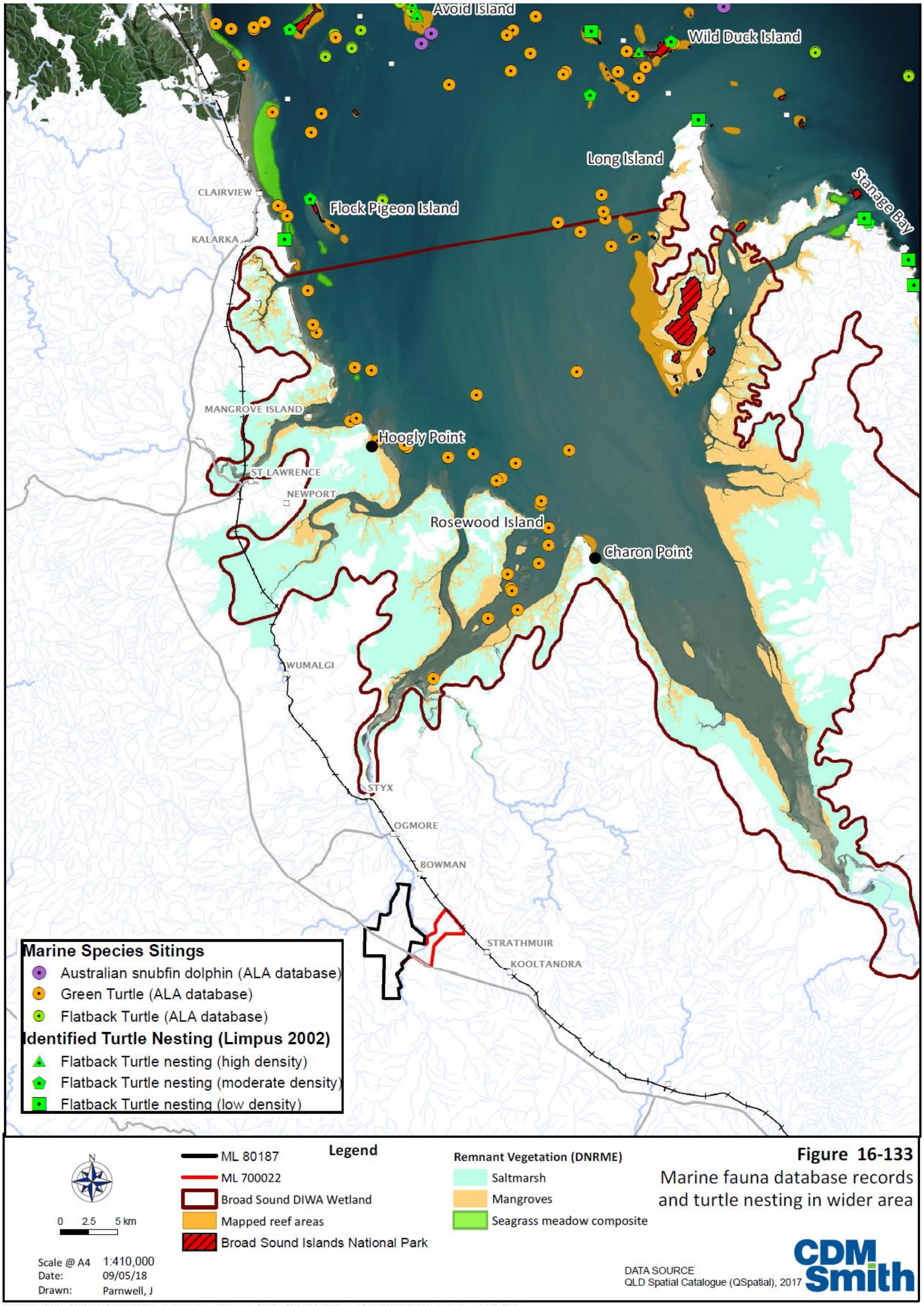


Figure 8-3: Map showing the location of marine fauna records (CDM Smith 2018)

8.1.6.2 Migratory shorebirds

Broad Sound and the adjacent Shoalwater Bay are considered sites of international importance for a number of migratory shorebirds under the EPBC Act. Shoalwater Bay typically supports larger numbers of these species than Broad Sound, with the exception of the Great Knot (*Calidris tenuirostris*; BLA 2014).

Migratory shorebirds use sheltered coasts with large intertidal mudflats or sandflats, often with seagrass beds and are also recorded in saltmarshes, mudflats and mangroves. Within Broad Sound there are five sites that regularly have large numbers of migratory shorebird roosting:

- Oyster Creek
- St Lawrence
- Bar Plain mangrove and Bar Plain beach
- Hoogley Point
- Charon Point.

At Charon Point alone there can be >2,000 individuals at one time.

A likelihood assessment for migratory shorebirds was completed as part of the SEIS (Central Queensland Coal 2020b) and included survey data for the Project. The results demonstrate at least 16 migratory shorebird species listed under the EPBC Act are known or likely to occur in the Broad Sound area, including some species that are also threatened. These are listed in **Table 8-2**, with key locations shown in **Figure 8-4**.

Table 8-2: Summary of shorebirds of the Styx River estuary and wider Broad Sound; BS – Broad Sound, SWB – Shoalwater Bay

Species	EPBC Act status	BS/SWB internationally important site	Likelihood of occurrence in Styx River estuary	Likelihood of occurrence in Wider Broad Sound
Bar-tailed Godwit (*Limosa lapponica*)	V, M	Yes	**Known**. Species recorded foraging on mudflats adjacent to the Styx River approximately 14 km north of the Project Area in February 2012.	**Known.** Recent survey records show this species occurs regularly at roost sites in western Broad Sound.
Common Greenshank (*Tringa nebularia*)	M		**Likely.** Extensive tracts of saltmarsh and brackish wetlands associated with the river will provide good foraging habitat for this species. Sandy substrate in the Styx River downstream of the rail bridge is less suitable.	**Known**. Recorded irregularly at roost sites in western Broad Sound in recent years.
Common sandpiper (*Actitis hypoleucos*)	M		**Potential.** No records from the wider area. Potentially suitable habitat is present - muddy river margins, mangrove-lined creeks and wetlands (Meyer 2011a).	**Potential.** No records from the wider area. Potentially suitable habitat is present - muddy river margins, mangrove-lined creeks and wetlands (Meyer 2011a).
Curlew Sandpiper (*Calidris ferruginea*)	CE, M		**Potential.** Sandy substrate in the Styx River downstream of the rail bridge is less suitable for this species, as it generally prefer coastal habitat.	**Known.** Survey records show this species irregularly occurs at roost sites in western Broad Sound. On

Species	EPBC Act status	BS/SWB internationally important site	Likelihood of occurrence in Styx River estuary	Likelihood of occurrence in Wider Broad Sound
			Habitat around Rosewood Island is likely to be more suitable.	one occasion recorded in 'nationally important' numbers at Oyster Creek roost site.
Eastern Curlew (*Numenius madagascariensis*)	CE, M	Yes	**Known**. Species recorded foraging on mudflats adjacent to the Styx River approximately 14 km north of the Project Area in February 2012. Also observed on associated estuarine plains 16 km north in September 2011 of the Project Area during fauna surveys.	**Known.** Survey records show this species regularly occurs at roost sites in western Broad Sound and in nationally important numbers. On one occasion (September 2013) recorded in internationally important numbers at a single roost site.
Great Knot (*Calidris tenuirostris*)	CE, M	Yes	**Potential.** Sandy substrate in the Styx River downstream of the rail bridge is less suitable for this species, as it generally prefer coastal habitat. Habitat around Rosewood Island is likely to be more suitable.	**Known.** The extensive Broad Sound wetland area is known to support nationally important populations of several migratory shorebird species including Great Knot (Bamford et al. 2008). Great Knot may regularly use the area in large numbers.
Greater Sand Plover (*Charadrius leschenaultia*)	V, M		**Likely**. Sandy substrate in the Styx River downstream of the rail bridge may be utilised by this species for foraging.	**Known.** Species has been recorded at roost sites in western Broad Sound in recent years.
Grey Plover (*Pluvialis squatorola*)	M		**Potential.** Sandy substrate in the Styx River downstream of the rail bridge is less suitable for this species, as it generally prefer coastal habitat. Habitat around Rosewood Island is likely to be more suitable.	**Known.** Recent survey records show species irregularly occurs at roost sites in western Broad Sound and generally in low numbers.
Grey-tailed Tattler (*Tringa brevipes*)	M	Yes	**Potential.** Sandy substrate in the Styx River downstream of the rail bridge is less suitable for this species, as it generally prefer coastal habitat. Habitat around Rosewood Island is likely to be more suitable.	**Known.** Recent survey records show species irregularly occurs at roost sites in western Broad Sound and generally in low numbers.
Latham's Snipe, Japanese Snipe (*Gallinago hardwickii*)	M		**Unlikely.** Prefers freshwater habitats.	**Known.** A single WildNet record adjacent to the upper reaches of Saint Lawrence Creek.
Lesser Sand Plover (*Charadrius mongolus*)	E, M		**Likely**. Sandy substrate in the Styx River downstream of the rail bridge may be utilised by this species for foraging.	**Known.** Species has been recorded at roost sites in western Broad Sound in recent years. Lesser Sand Plover has been recorded in

Species	EPBC Act status	BS/SWB internationally important site	Likelihood of occurrence in Styx River estuary	Likelihood of occurrence in Wider Broad Sound
				'nationally important' numbers on at least one occasion.
Marsh Sandpiper, Little Greenshank (*Tringa stagnatilis*)	M		**Likely.** Extensive tracts of saltmarsh and brackish wetlands associated with the river will provide good foraging habitat for this species. Sandy substrate in the Styx River downstream of the rail bridge is less suitable.	**Known.** One record approximately 37 km to the north-west of the Project Site within Saint Lawrence Creek and the Broad Sound.
Pectoral Sandpiper (*Calidris mealnotos*)	M		**Potential.** Most records in Qld are from Cairns region, with scattered records elsewhere. Suitable habitat present.	**Potential.** Most records in Qld are from Cairns region, with scattered records elsewhere. Suitable habitat present.
Red Knot (*Calidris canutus*)	E, M		**Potential.** Sandy substrate in the Styx River downstream of the rail bridge is less suitable for this species, as it generally prefer coastal habitat. Habitat around Rosewood Island is likely to be more suitable.	**Known.** Species has been recorded at roost sites in western Broad Sound in recent years. Red knot has been recorded in 'nationally important' numbers on at least one occasion.
Red-necked Stint (*Calidris ruficollis*)	M		**Likely.** Extensive tracts of saltmarsh and brackish wetlands associated with the river will provide good foraging habitat for this species. Sandy substrate in the Styx River downstream of the rail bridge is less suitable.	**Known.** Recorded regularly at roost sites in western Broad Sound in recent years. Recorded in 'nationally important' numbers on at least one occasion.
Sharp-tailed Sandpiper (*Calidris acuminate*)	M		**Likely.** Extensive tracts of saltmarsh and brackish wetlands associated with the river will provide good foraging habitat for this species. Sandy substrate in the Styx River downstream of the rail bridge is less suitable.	**Known.** Recorded irregularly at roost sites in western Broad Sound in recent years Recorded in 'nationally important' numbers on at least one occasion.
Terek Sandpiper (*Xenus cinereus*)	M	Yes	**Potential.** Sandy substrate in the Styx River downstream of the rail bridge is less suitable for this species, as it generally prefer coastal habitat. Habitat around Rosewood Island is likely to be more suitable. May occur along estuaries.	**Known.** Recent survey records show species irregularly occurs at roost sites in western Broad Sound and generally in low numbers.
Whimbrel (*Numenius phaeopus*)	M	Yes	**Known.** Recorded foraging on mudflats adjacent to the Styx River approximately 14 km north of the Project Area in February 2012.	**Known.** Recorded regularly at roost sites in western Broad Sound in recent years.

Species	EPBC Act status	BS/SWB internationally important site	Likelihood of occurrence in Styx River estuary	Likelihood of occurrence in Wider Broad Sound
Wood Sandpiper	M		**Unlikely.** Prefers freshwater wetlands and rarely use brackish wetlands or coastal flats.	**Unlikely.** Prefers freshwater wetlands and rarely use brackish wetlands or coastal flats.

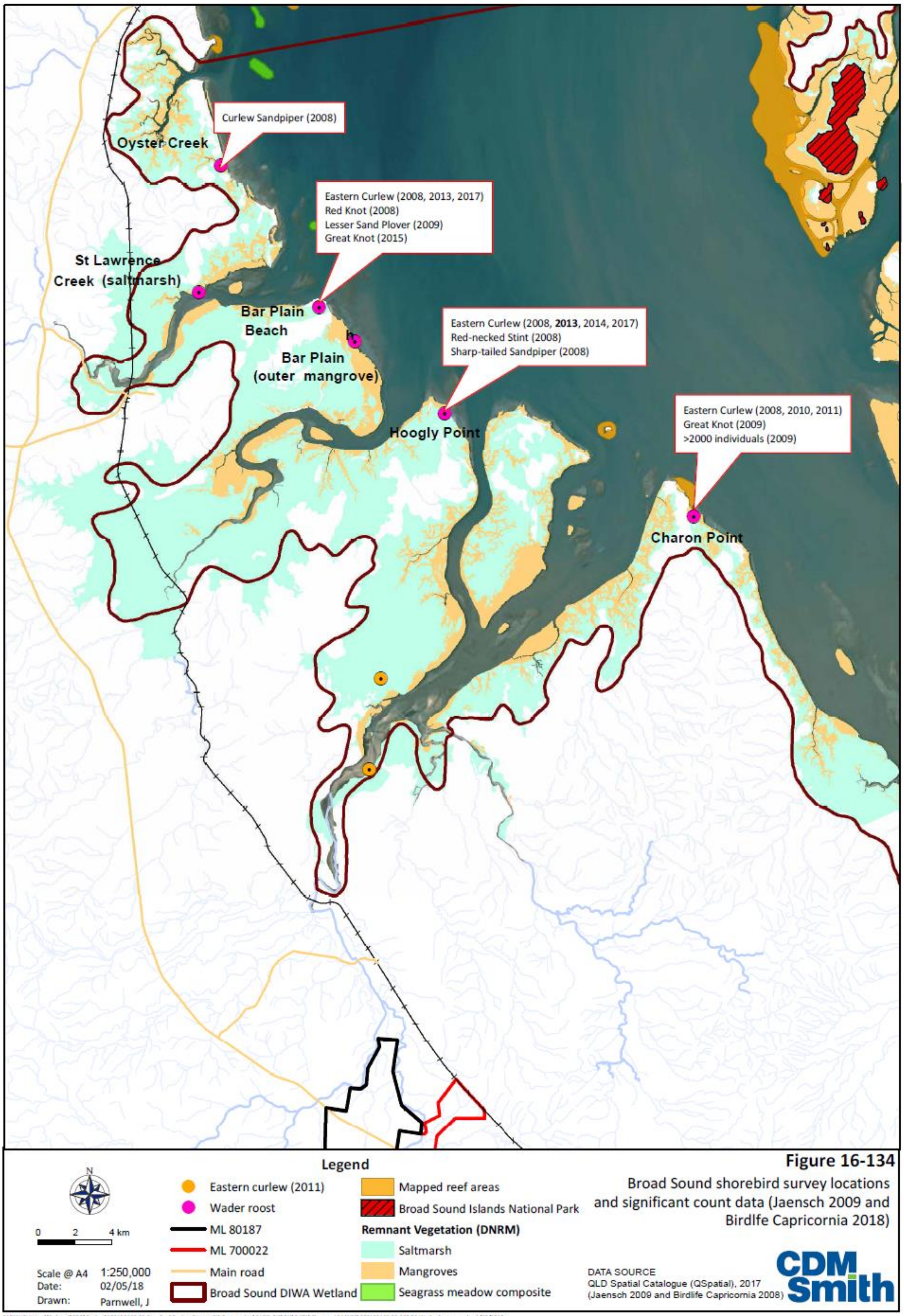


Figure 8-4: Map showing the location of key migratory shorebird sites in the Study Area (CDM Smith 2018)

8.1.6.3 Marine plants

Marine plants are defined under the Queensland *Fisheries Act 1994* and include:

- a plant (tidal plant) that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing or fallen
- material of a tidal plant, or other plant material on tidal land
- a plant, or material of a plant, prescribed by regulation to be a marine plant.

Marine Couch (*Sporobolus virginicus*) was identified along the edge of the Styx River approximately 2.5 km downstream of the Project boundary and is considered a marine plant. Extensive stands of saltmarsh and mangrove species occur downstream of the Project (14 km and 21 km downstream respectively) along the margins of the Styx River and Broad Sound (CDM Smith 2018).

8.2 Impact assessment for downstream values

The Project will not result in direct impacts to downstream values. However, connectivity between the Project Area and downstream values occurs along Tooloombah and Deep Creeks and via the Styx River. Therefore downstream values may be indirectly impacted by the Project. The indirect impact mechanisms for all downstream values are the same and are discussed in detail in the following sections. There are also some additional considerations relevant to the Great Barrier Reef.

Assessments of the significance of potential impacts against relevant criteria are provided in **Section 8.3** (for MNES) and **Section 8.4** (for MSES).

8.2.1 Impact assessment – all values

The Project is not expected to result in any major changes to the natural hydrological conditions of Tooloombah and Deep Creeks, and therefore nor to the Styx River. While some runoff within the creek catchments will be captured and retained on site within the mine footprint, the amount of water involved is minimal compared with that entering the creeks as runoff from the broader catchment (WRM 2020). In this regard, the ephemeral nature of the creeks and the current flow regime will remain unchanged, and connectivity along the creek systems and into the downstream environments will not be affected.

Surface water modelling shows that there will be no substantial change to the number of no flow days in the system under a mining scenario (WRM 2020). Downstream areas will continue to be primarily influenced by the tidal regime of the Styx River estuary and Broad Sound marine environment.

Groundwater drawdown is not predicted to occur beneath the Styx River (HydroAlgorithmics 2020) and therefore loss of potential baseflow from groundwater sources in downstream areas is not considered to be a potential impact of the Project. Further upstream, there is the potential for loss of baseflow from reduced groundwater inflows into pools in Deep and Tooloombah Creeks (WRM 2020). Loss of baseflow to pools is only relevant in the context of downstream impacts while there is connectivity between the pools and downstream areas (i.e. when the rivers have stream flow). While drawdown in the vicinity of Tooloombah Creek and Deep Creek is likely to result in a shorter period of pool persistence at some locations, periods of surface water flow will still occur after rainfall and remain largely unchanged from baseline conditions (WRM 2020).

The location of highest astronomical tide is generally accepted to occur at the confluence of Deep and Tooloombah Creeks (Gippel 2020) and modelling does not suggest this will change as result of the Project. This, combined with the minimal reduction in hydrological regime and the large downstream influence of tides, suggests there will be no change in the location of the freshwater – saltwater interface within surface waters of the Styx River. Furthermore, groundwater modelling has demonstrated the risk of movement in the location of the saline wedge within relevant aquifers is very low (HydroAlgorithmics 2020). Therefore, potential impacts to downstream values from changes to the freshwater – saltwater interface are considered unlikely.

Changes to water quality as a result of the Project present a potential risk to downstream values. This is particularly relevant in a Great Barrier Reef catchment, where sediment and other contaminants are known to present a significant risk to inshore biodiversity values. A number of assessments have been undertaken to consider the risks to downstream environments from changes to water quality and a number of mitigation and management measures will be implemented to ensure these risks are appropriately addressed.

Increased sediment loads are a significant issue for nearshore environments within the Great Barrier Reef. In the context of the Project, sediment may enter the marine environment either as a result of increased instream erosion and/or directly within mine site runoff and discharges. The geomorphology assessment (Gippel 2020) concludes that while there could be isolated areas subject to somewhat higher risks of scour compared with the existing situation, the overall risk of rapid and significant geomorphic change in Tooloombah and Deep creeks and the Styx River due to the proposed mining activity is low. Impacts from the Project on hydraulic variables would be small enough that a rapid geomorphic response would not be expected. Rather, the channel will slowly adjust over the life of the mine to the altered hydraulic conditions, through minor changes in bed and floodplain levels or channel widths (Gippel 2020).

As described in **Section 6.7.8**, some loss of riparian vegetation is expected to result from the Project over time. Riparian vegetation plays a key role in stabilising banks and therefore its loss may contribute to localised instream erosion and increased sediment loads. Loss of riparian vegetation is predicted to be most pronounced on Deep Creek and primarily include the loss of large trees, as their access to groundwater resources is diminished over time. However, it is expected that shrubs and grassy vegetation will remain and if required, the riparian vegetation will be enhanced with suitable species via active rehabilitation. This will ensure that ecosystem processes relating to bank stability are retained, and risks of increased sedimentation are low.

An overall sediment budget has been prepared for the Project Area and demonstrates that the presence of the Project will reduce the sediment inputs to downstream areas (Engeny 2020a). This is primarily due to the water management and sediment and erosion control systems for the Project being designed such that sediment-laden water is captured and treated on site. Additionally, current land use practices (cattle grazing) will cease across a large area, both on the mining lease and within the upstream offset areas, thereby also reducing existing sediment loads to downstream waters. Overall, existing sediment discharges to the GBR will be reduced by approximately 50% as a result of the Project and associated sediment and land management practices (Engeny 2020a). Proposed water storages under average climatic conditions in addition to the destocking of the undisturbed Mining Leases and Mamelon offset areas will reduce the estimated baseline sediment generation rate of 5,037 t/year to approximately 2,297 t/year.

The Project will require controlled releases of mine affected water, particularly if wet climatic conditions are experienced, and there is a small risk of uncontrolled releases during periods of very high rainfall (**Section 4.5.3**; WRM 2020). Such releases can also contribute to increased sediment and contaminant loads in downstream areas. Importantly, any releases will be appropriately managed and timed to coincide with high creek flow events and therefore, high concentrations of sediment and/or water quality parameters will be substantially diluted and short-lived. These risks have been assessed in detail and the results of this analysis demonstrate that the predicted concentrations of water quality parameters at key points of Deep Creek, Tooloombah Creek and at the confluence of the two is well within the range of the typical historical receiving water concentrations for each parameter examined.

The highest predicted concentrations for all heavy metals that were modelled are also an order of magnitude lower than thresholds set out in model mining EA conditions for water releases (WRM 2020). A similar result applies to uncontrolled releases. This suggest that the risks to downstream environments from sediments and/or high concentrations of water quality parameters contained in controlled or uncontrolled releases from the mine are low.

A number of control measures will also be in place to reduce sediment production and run-off from the development as part of the EMP. Discharge of sediment and/or high concentrations of water quality parameters would only occur during periods of high rainfall and in accordance with EA conditions. Preventative and remediation controls will also be in place to address any onsite spills, which may run off into waterways.

8.2.2 Additional considerations for the Great Barrier Reef

8.2.2.1 Consistency with Marine Park Zoning

As discussed in **Section 8.1**, the Styx River portion of the GBRMP is mapped as General Use Zone. East of the entrance of the river extending into Broad Sound, the area is zoned as Marine National Park and bordering this zone to the west is Habitat Protection Zone adjacent to Long Island. Actions occurring within the GBRMP need to be evaluated in regard to their consistency with the activities that are allowed in each of the Marine Park Zones. As the Project occurs more than 8 km upstream from the GBRMP, the Marine Park Zoning is not relevant to any actions taking place. The existing environmental values of the Great Barrier Reef are not expected to be impacted by the Project.

8.2.2.2 Net benefit to downstream water quality

The Great Barrier Reef Ministerial Forum approved the Reef 2050 Cumulative Impact Management Policy and the Net Benefit Policy on 20 July 2018. These two documents, along with the Good Practice Management for the Great Barrier Reef document, are part of a suite of guidance materials to support implementation of the Reef 2050 Plan.

Net benefit is defined in the Net Benefit Policy (GBRMPA 2018) as *an overall improvement in the condition and/or trend of a Great Barrier Reef value, or those actions which result in the net improvement*.

The objective of the Policy is to *ensure decisions and actions to reduce pressures and impacts on the Great Barrier Reef deliver a positive change in the condition and trend of Great Barrier Reef values, regardless of whether they occur within or outside the Great Barrier Reef, including internationally.*

The Project has been considered in regard to the potential impact it may have on downstream values including the GBR as a result of decreased water quality via sediment run-off (erosion and ground disturbance) and increases in water quality parameters in the surrounding waterways which flow into downstream habitats. Although this impact been assessed as unlikely to result in any significant impacts to environmental values, the Project is predicted to provide net benefit to water quality in the downstream areas, with a reduction in the existing sediment loads to the Styx River estuary. This is consistent with the objectives of the Reef 2050 Plan (DoEE 2018) which guides the overarching protection and management of the GBR.

Decreased water quality is a significant threat to the GBR, highlighted in the Outlook Report (GBRMPA 2019); particularly for inshore areas such as Broad Sound. Sedimentation and levels of pollutants are elevated in many of these inshore areas as a result of coastal development, increased erosion and run off from agricultural practices. Although some improvement in water quality is occurring, the rate of improvement is considered to be too slow (GBRMPA 2019).

Engeny (2020a) prepared a sediment budget for the Project and provided an assessment of the Project against the Reef 2050 Water Quality Targets (**Table 8-3**). The Project is consistent with the Water Quality Target of achieving at least a 20% reduction in anthropogenic end-of-catchment loads of sediment, on the way to achieving up to a 50% reduction by 2025. A reduction in cattle grazing associated with the Project is also likely to result in reduced concentrations of nutrients and herbicides in local waterways, which flow to Broad Sound and the GBR.

Table 8-3: Assessment of Reef 2050 Water Quality Target (Engeny 2020a)

Water Quality Target	Assessment
At least a 20% reduction in anthropogenic end-of-catchment loads of sediment in priority areas, on the way to achieving up to a 50% reduction by 2025.	Under average climatic conditions it has been determined that the Project will result in a positive contribution to this target through the expected reduction in sediment load reporting to Tooloombah Creek and Deep Creek in comparison to baseline (current) conditions. Under average climatic conditions it was determined the total worst-case sediment budget (i.e. comparison of baseline to operational period) for the Project is a reduction of about 50%. That is that the proposed water storages under average climatic conditions in addition to the destocking of the undisturbed MLs and Mamelon offset areas will reduce the estimated baseline sediment generation rate of 5,037 t/year to approximately 2,297 t/year. Under wet or very wet climatic conditions, there is potential for an increase in sediment loss through increased frequency of uncontrolled releases from Dam 1 and ED1B, however the additional sediment loss is not expected to approach or exceed the baseline generation rate where effective erosion and sediment controlis implemented on site including potentially flocculation of the water storages (if determined to be required).

8.3 Assessment against relevant significant impact criteria – MNES

8.3.1 Great Barrier Reef World Heritage Area and Marine Park

The significant impact criteria for World Heritage properties are listed as follows (Commonwealth of Australia 2013):

- Cause one or more of the attributes to be lost
- Cause one or more of the attributes to be degraded or damaged
- Cause one or more of the attributes to be notably altered, modified, obscured or diminished
- Impact on the integrity of the property.

Responses to the significant impact criteria for the GBRWHA have been assessed via the significant impact criteria for 'World Heritage properties with natural heritage values' provided in the *EPBC Act Significant Impact Guidelines 1.1* (Commonwealth of Australia 2013) and considering advice provided in EPBC Act referral guidelines for the *Outstanding Universal Value of the Great Barrier Reef World Heritage Area* (Commonwealth of Australia 2014). Responses to these criteria are provided in **Table 8-4**. The Project is not expected to result in a significant impact to the GBRWHA.

The GBRMP is assessed via an additional suite of significant impact criteria. Responses to the significant impact criteria for the GBRMP are provided in **Table 8-5**. The Project is not expected to result in a significant impact to the GBRMP.

Table 8-4: Significant impact assessment – Great Barrier Reef World Heritage Area

Values	Significant impact considerations	Significant impact (Y/N)	Response
Criteria from EPBC Act Significant Impact Guidelines 1.1. (Commonwealth of Australia 2013)			
Values associated with geology or landscape	Damage, modify, alter or obscure important geological formations in a World Heritage property Damage, modify, alter or obscure landforms or landscape features, for example, by excavation or infilling of the land surface in a World Heritage property Modify, alter or inhibit landscape processes, for example, by accelerating or increasing susceptibility to erosion, or stabilising mobile landforms, such as sand dunes, in a World Heritage property Divert, impound or channelise a river, wetland or other water body in a World Heritage property Substantially increase concentrations of suspended sediment, nutrients, heavy metals, hydrocarbons, or other pollutants or substances in a river, wetland or water body in a World Heritage property	No	As the Project does not occur directly within the GBRWHA, it will not: • Damage, modify, alter or obscure important geological formations; • Damage, modify, alter or obscure landforms or landscape features, for example, by excavation or infilling of the land surface; or • Modify, alter or inhibit landscape processes, for example, by accelerating or increasing susceptibility to erosion, or stabilising mobile landforms, such as sand dunes in the GBRWHA. The Project will not divert, impound or channelise a river, wetland or other water in the GBRWHA. The Project has the potential to increase concentrations of suspended sediment and other contaminants in the GBRWHA via inputs from the mine site and adjacent areas flowing from Deep and Tooloombah Creeks. As discussed in Section 8.2, these inputs will be managed in such a way as to ensure sediment and contaminant loads remain within acceptable levels at all times. In particular, with the implementation of the site water management and release rules that have been devised for the Project (WRM, 2020), the overall sediment budget for the Project is expected to decrease sediment inputs from the catchment into the downstream GBR (Engeny 2020a), thereby delivering a net benefit from the Project.
Biological and ecological values	Reduce the diversity or modify the composition of plant and animal species in all or part of a World Heritage property Fragment, isolate or substantially damage habitat important for the conservation of biological diversity in a World Heritage property Cause a long-term reduction in rare, endemic or unique plant or animal populations or species in a World Heritage property	No	As discussed above, there are a number of biological and ecological values present in the downstream environment, including threatened and migratory species and marine plant communities. Of particular note are the aggregations of migratory shorebirds within the nearshore environments of Broad Sound, which are considered important in both a national and international context. Importantly, there will be no direct impacts to these ecological values from the Project. However, they do have the potential to be indirectly impacted by the Project, primarily via potential reductions in water quality, which may in turn reduce habitat values. As discussed above, the risk of these impacts occurring is

Values	Significant impact considerations	Significant impact (Y/N)	Response
	Fragment, isolate or substantially damage habitat for rare, endemic or unique animal populations or species in a World Heritage property		considered low and alterations to habitat, or population level impacts to values are highly unlikely.
Wilderness, natural beauty or rare or unique environment values	Involve construction of buildings, roads, or other structures, vegetation clearance, or other actions with substantial, long-term or permanent impacts on relevant values Introduce noise, odours, pollutants or other intrusive elements with substantial, long-term or permanent impacts on relevant values	No	As the Project does not involve works within the GBRWHA, construction works will not result in any significant impact. The Project has the potential to increase concentrations of suspended sediment and other contaminants in the GBRWHA via inputs from the mine site and adjacent areas flowing from Deep and Tooloombah Creeks. As discussed in **Section 8.2**, these inputs will be managed in a such as way as to ensure sediment and water quality parameter loads remain within acceptable levels at all times. In particular, the overall sediment budget for the Project is expected to decrease sediment inputs from the catchment into the downstream GBR (Engeny 2020a), thereby delivering a net benefit from the Project.
Criteria from EPBC Act referral guidelines for the *Outstanding Universal Value of the Great Barrier Reef World Heritage Area* (Commonwealth of Australia, 2014)			
Attributes	Will the proposed action of itself, or in combination with other relevant impacts, result in loss or degradation of areas that are essential for maintaining the beauty of the property? Will the proposed action of itself, or in combination with other relevant impacts, impact on the key interrelated and interdependent elements in their natural relationships? Will the proposed action of itself, or in combination with other relevant impacts, result in the loss of necessary elements that are essential for the long-term conservation of the area's ecosystems and biodiversity? Will the proposed action of itself, or in combination with other relevant impacts, result in the loss or degradation of habitats required for maintaining the diverse fauna and flora of the region?	No	The nearshore areas of the GBRWHA that are downstream of the Project do not include areas that are essential for maintaining the beauty of the property. However, there are a number of important ecological features. Importantly, there will be no direct impacts to these ecological values from the Project. However, they do have the potential to be indirectly impacted by the Project, primarily via potential reductions in water quality, which may in turn reduce habitat values. As discussed in Section 8.2, the risk of these impacts occurring is considered low and alterations to habitat, or population level impacts to values are highly unlikely.
Wholeness	Will the proposed action of itself, or in combination with other relevant impacts, result in the loss of any elements necessary for the property to express its Outstanding Universal Value?	No	The Project will not result in the loss of any elements necessary for the GBRWHA to express its OUV, nor will there be any reductions in size or boundaries of the property.

Values	Significant impact considerations	Significant impact (Y/N)	Response
	Will the proposed action of itself, or in combination with other relevant impacts, reduce the size or change the boundary of the property? Will the proposed action of itself, or in combination with other relevant impacts, impact on any of the features and processes that convey its Outstanding Universal Value?		
Intactness	Will the proposed action of itself, or in combination with other relevant impacts, result in a 'greenfield' development or the fragmentation, loss and/or degradation of any ecological, physical or chemical processes or of the key features, processes and attributes of the property that express its Outstanding Universal Value? Will the proposed action of itself, or in combination with other relevant impacts, impact on the key interrelated and interdependent attributes or their natural relationships within the property?	No	The Project is located outside of the GBRWHA and will not result in a 'greenfield development' or fragmentation of key features of the property. Water quality is a key attribute that underpins the overall health of the GBRWHA and therefore requires consideration in terms of interrelatedness and interdependence of natural values. The Project has the potential to increase concentrations of suspended sediment and water quality parameters in the GBRWHA via inputs from the mine site and adjacent areas flowing from Deep and Tooloombah Creeks. As discussed in Section 8.2, these inputs will be managed in such a way as to ensure sediment and water quality parameter loads remain within acceptable levels at all times. This will ensure the intactness of the GBRWHA is not affected by the Project.
Threats	Will the proposed action of itself, or in combination with other relevant impacts, result in increased adverse effects of development, neglect or any other degrading process? Will the proposed action of itself, or in combination with other relevant impacts, result in an increase in processes that may cause deterioration?	No	Increased sediment and water quality parameter loads are a significant issue for nearshore environments within the GBRWHA. In the context of the Project, additional sediment/water quality parameters may enter the marine environment either as a result of increased instream erosion and/or directly within mine site runoff and discharges. Therefore, there is a risk the Project will exacerbate threats to the GBRWHA. However, as discussed in **Section 8.2**, these inputs will be managed in a such as way as to ensure sediment and water quality parameter loads remain within acceptable levels at all times. In particular, the overall sediment budget for the Project is expected to decrease sediment discharges from the catchment into the downstream GBR by approximately 50% (Engeny 2020a), thereby delivering a net benefit from the Project.

Table 8-5: Significant impact assessment – Great Barrier Reef Marine Park

Significant impact criteria	Significant impact (Y/N)	Response
Modify, destroy, fragment, isolate or disturb an important, substantial, sensitive or vulnerable area of habitat or ecosystem component such that an adverse impact on marine ecosystem health, functioning or integrity in the Great Barrier Reef Marine Park results	No	The nearshore areas of the GBRMP that are downstream of the Project include areas that contain important ecological features and sensitive environments e.g. migratory shorebird roosting areas. Importantly, there will be no direct impacts to these ecologically sensitive area from the Project. However, these areas do have the potential to be indirectly impacted by the Project, primarily via potential reductions in water quality, which may in turn reduce habitat values and/or ecosystem health. As discussed in Section 8.2, the risk of these impacts occurring is considered low and alterations to habitat or population level impacts to values are highly unlikely.
Have a substantial adverse effect on a population of a species or cetacean including its life cycle (for example, breeding, feeding, migration behaviour, life expectancy) and spatial distribution	No	A number of species are known to occur within the area downstream of the Project, including migratory shorebirds, inshore dolphins, humpback whale and marine turtles. Of these species, migratory shorebirds have the most extensive habitat and undertake key lifecycle activities (i.e., overwintering and building condition for the northern migration). Other species are less common and generally only forage close to the Styx River estuary. Importantly, there will be no direct impacts to these species from the Project. However, these species do have the potential to be indirectly impacted by the Project, primarily via potential reductions in water quality, which may in turn reduce habitat values and/or ecosystem health. As discussed in Section 8.2, the risk of these impacts occurring is considered low and alterations to habitat or population level impacts to species are highly unlikely.
Result in a substantial change in air quality or water quality (including temperature) which may adversely impact on biodiversity, ecological health or integrity or social amenity or human health	No	Increased sediment and water quality parameter loads are a significant issue for nearshore environments within the Great Barrier Reef Marine Park. In the context of the Project, additional sediment/water quality parameters may enter the marine environment either as a result of increased instream erosion and/or directly within mine site runoff and discharges. This may in turn, adversely impact biodiversity, ecological health or integrity or social amenity or human health. However, as discussed in Section 8.2, these inputs will be managed in a such as way as to ensure sediment and water quality parameter loads remain within acceptable levels at all

Significant impact criteria	Significant impact (Y/N)	Response
		times. In particular, the overall sediment budget for the Project is expected to decrease sediment discharges from the catchment into the downstream GBR by approximately 50% (Engeny 2020a), thereby delivering a net benefit from the Project.
Result in a known or potential pest species being introduced or becoming established in the Great Barrier Reef Marine Park	No	The GBRMP is greater than 8 km downstream from the Project Area. The estuarine and intertidal areas in this region are substantially different to the upstream habitat within and immediately surrounding the Project Area. The Project Area is highly modified (largely due to grazing of cattle) and weeds are commonly observed along the watercourses such as Deep Creek and Tooloombah Creek. Pest species present in the Project Area include feral pigs, cane toads, rabbits and cats (CDM Smith 2018). Given the differences in environment between the Project Area and nearshore GBRMP, many of the threats from weeds and pests are not relevant in the downstream areas. For those species that may be present in nearshore areas (e.g. feral pigs), local populations are likely already established and the presence of the Project will not affect the number or extent of individuals. The Project will not result in the introduction or establishment of a pest species in the GBRMP.
Result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, or social amenity or human health may be adversely affected	No	In the context of the Project, high concentrations of water quality parameters may enter the marine environment via mine site runoff and discharges of mine affected water, with both sources being potentially high in chemicals and heavy metals. This may in turn, adversely impact biodiversity, ecological health or integrity or social amenity or human health. However, as discussed in **Section 8.2** and **Section 4.5.3**, these inputs will be managed in such a way as to ensure water quality parameter loads remain within acceptable levels at all times. A number of mitigation and management measures will be in place to collect water with high concentrations of parameters from the Project, divert clean water around the site and reduce the likelihood of run-off containing high concentrations of parameters. Water with high concentrations of parameters will be stored on site in dams and will only be released if water quality release limits are met and at an appropriate time to allow dilution into the natural flows. Discharge of water will be controlled to reduce the likelihood of non-compliant discharges from overtopping. Any increase in the concentration of water quality parameters in the waterways as a result of discharge will be very short-lived and substantially diluted and will therefore be unlikely to result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine

Significant impact criteria	Significant impact (Y/N)	Response
		environment. Uncontrolled discharges are only expected during times of heavy rainfall, when there is also likely to be significant dilution of any water quality parameters at high concentrations.
Have a substantial adverse impact on heritage values of the Great Barrier Reef Marine Park, including damage or destruction of an historic shipwreck	No	The Project does not occur directly within the GBRMP and therefore any heritage values within the GBRMP such as Commonwealth heritage places, lighthouses or shipwrecks will not be impacted by the Project.

8.3.2 Threatened marine fauna

Threatened marine fauna relevant to the assessment are Humpback Whale and marine turtles. A number of migratory shorebirds known to occur in Broad Sound are also listed as threatened. These are addressed in **Section 8.3.4**.

Responses to the significant impact criteria for threatened marine fauna have been assessed via criteria provided in the *EPBC Act Significant Impact Guidelines 1.1* (Commonwealth of Australia 2013) and responses to these criteria are provided in **Table 8-6**. All relevant species are listed as vulnerable and the applicable criteria have been considered. The Project is not expected to result in a significant impact to threatened marine fauna.

Table 8-6: Significant impact criteria – threatened marine fauna

Significant impact criteria	Significant impact (Y/N)	Response
Lead to a long-term decrease in the size of an important population	No	Important populations of marine turtles do not occur in the vicinity of the Styx River estuary and adjacent marine environments. There are limited records of green turtle foraging, however, nesting for this species and flatback turtles occurs at least 75 km to the north.
Reduce the area of occupancy of an important population	No	As above
Fragment an existing important population into two or more populations	No	As above
Adversely affect habitat critical to the survival of a species	No	Habitat critical to the survival of marine turtles does not occur in the vicinity of the Styx River estuary and adjacent marine environments. There are limited records of green turtle foraging, however, nesting for this species and flatback turtles occurs at least 75 km to the north.
Disrupt the breeding cycle of an important population	No	As above
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	No	Habitat for marine turtles relevant to this assessment includes the downstream marine environment of Broad Sound, where foraging may occur. These areas have the potential to be indirectly impacted by the Project, via potential reductions in water quality, which may in turn reduce habitat values. As discussed in Section 8.2 above, the risk of these impacts occurring is considered low and alterations to habitat or population level impacts to marine turtles are highly unlikely.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	No	The Project will not result in the establishment of an invasive species in the marine environment.
Introduce disease that may cause the species to decline	No	The Project will not introduce disease into the marine environment.
Interfere with the recovery of the species	No	Interim recovery objectives for marine turtles are (Commonwealth of Australia 2017): • Current levels of legal and management protection for marine turtles are maintained or improved both

Significant impact criteria	Significant impact (Y/N)	Response
		domestically and throughout the migratory range of Australia's marine turtles. • The management of marine turtles is supported. • Anthropogenic threats are demonstrably minimised. • Trends at index beaches, and population demographics at important foraging grounds are described. The Project will not interfere with these objectives.

8.3.3 Migratory marine fauna

Migratory marine fauna (that are not threatened) relevant to the assessment are Dugong, inshore dolphins and the Estuarine crocodile. Migratory shorebirds are addressed separately in **Section 8.3.4**.

Responses to the significant impact criteria for migratory marine fauna have been assessed via criteria provided in the *EPBC Act Significant Impact Guidelines 1.1* (Commonwealth of Australia 2013) and responses to these criteria are provided in **Table 8-7**. The Project is not expected to result in a significant impact to migratory marine fauna.

Table 8-7: Significant impact criteria – migratory marine fauna

Significant impact criteria	Significant impact (Y/N)	Response
Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species	No	Important habitat for marine migratory does not occur in the vicinity of the Styx River estuary and adjacent marine environments. Sightings of Dugong and inshore dolphins are rare, and suitable habitat for Estuarine Crocodile is prevalent along the Queensland coast.
Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species	No	The Project will not result in the establishment of an invasive species in the marine environment.
Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species	No	There is no evidence that an ecologically significant proportion of Dugong, inshore dolphins or Estuarine Crocodile occurs the vicinity of the Styx River estuary and adjacent marine environments. In particular, sightings of Dugong and inshore dolphins are rare in this area.

8.3.4 Migratory shorebirds

There is specific policy guidance that can be applied to determine the likely significance of impacts from a project to migratory shorebirds. These are contained in the *EPBC Act Policy Statement 3.21 - Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species* (DoE 2015).

Under this policy advice, the Styx River estuary and the wider Broad Sound area are considered to be important habitat for migratory shorebirds. The following impact assessment has undertaken on this basis and responses to the significant impact criteria for the migratory shorebirds are provided in **Table 8-8**. The Project is not expected to result in a significant impact to these species.

Table 8-8: Significant impact assessment – migratory shorebirds

Significant impact criteria	Significant impact (Y/N)	Response
Loss of important habitat	No	Important habitat for migratory shorebirds occurs both within the Styx River estuary and nearshore/intertidal environments on Broad Sound (**Figure 8-4**). The Project will not have direct impacts on these areas and no loss of important habitat will occur.
Degradation of important habitat leading to a substantial reduction in migratory shorebird numbers	No	Important shorebird habitat areas have the potential to be indirectly impacted by the Project, via potential reductions in water quality, which may in turn reduce habitat values. As discussed in Section 8.2, the risk of these impacts occurring is considered low and alterations to habitat or population level impacts to shorebirds are highly unlikely.
Increased disturbance to important habitat leading to a substantial reduction in migratory shorebird numbers	No	As above
Direct mortality of birds substantial reduction in migratory shorebird numbers	No	No direct mortality of shorebirds will result from the Project.

8.4 Assessment against relevant significant impact criteria – MSES

There are a number of MSES relevant to this assessment, including:

- the Great Barrier Reef Coastal Marine Park
- Broad Sound Fish Habitat Area
- marine plants
- protected wildlife habitat.

Protected wildlife habitat is defined as habitat for an animal that is Endangered or Vulnerable wildlife or a Special Least Concern animal (as listed in the NC Act). For this Project, these species include marine fauna (threatened and migratory) and migratory shorebirds. Given the consistency between EPBC Act and *Environmental Protection Act 1994* significant residual impact guidelines, the assessments for MNES in **Sections 8.3.2** to **8.3.4** are considered applicable to MSES. Therefore, the Project is not expected to result in a significant impact to protected wildlife habitat. Assessments for other MSES are provided below.

8.4.1 Great Barrier Reef Coastal Marine Park and Broad Sound Fish Habitat Area

As noted above, only the areas of Broad Sound zoned Marine National Park are considered MSES (highly protected zones of State marine parks). The entire Broad Sound Fish Habitat Area (FHA) is also considered a MSES. These values are assessed via the same significant impact criteria.

As per the Significant Residual Impact Guidelines (DES 2014), works are considered to result in a significant residual impact to a declared FHA or highly protected zone of a marine park if:

- The works are not for a specific[1] purpose or structure, and
- The works will result in a residual disturbance footprint within the declared FHA and/or highly protected zone of a marine park of 40 m^2 or greater in area.

The Project will not have a direct impact on the FHA or highly protected zone of a marine park as it does not involve any direct disturbance within the boundary of these areas. As such, there will not be any significant residual impacts to a declared FHA or highly protected zone of a marine park from the Project.

8.4.2 Marine plants

Responses to the significant residual impact criteria for marine plants (DES 2014) are provided in **Table 8-9**. The Project is not expected to result in a significant residual impact to marine plants.

Table 8-9: Significant impact assessment – marine plants

Significant impact criteria	Significant impact	Response
Result in private infrastructure works impacting more than 17 m^2 of fish habitat or public infrastructure works impacting more than 25 m^2 of fish habitat; **and**	No	Marine Couch was identified downstream of the Project boundary, however this will not be directly impacted by the Project.
Temporary impacts are expected to take 5 years or more for the impact area to be restored to its predevelopment condition; or	No	Temporary impacts from the Project associated with construction of infrastructure will not result in significant disturbance to marine plants or fish habitat. Temporary impacts will cease after the construction period.
A proposed reduction in the extent of marine plants through removal, destruction or damage of marine plants; or	No	Marine Couch was identified downstream of the Project boundary, however this will not be directly impacted by the Project. Indirect impacts to the receiving environment (including marine plants) are considered unlikely with the implementation of management measures such as a controlled release strategy and sediment and erosion control plan.
Fragmentation or increased fragmentation of a marine ecological community; or	No	There are no marine ecological communities located in the direct disturbance footprint of the Project. Important marine ecological communities are associated with the Styx River, Broad Sound FHA and GBR, all located downstream of the Project Area.

[1] Purposes and structures are provided in the Significant Residual Impact Guidelines and do not include the activities that will be undertaken as part of the Project.

Significant impact criteria	Significant impact	Response
		Indirect impacts to the receiving environment (incl. marine plants) are considered unlikely with the implementation of management measures such as a controlled release strategy and sediment and erosion control plan.
Adverse changes affecting survival of marine plants through modifying or destroying abiotic (non-living) factors (such as water, nutrients, or soil) necessary for a marine plant's survival; or	No	The Project has the potential to impact on marine plants located downstream of the Project Area through changes in hydrology and changes in water quality (including increases in sedimentation). However, such indirect impacts to the receiving environment (incl. marine plants) are considered unlikely with the implementation of management measures such as a controlled release strategy and sediment and erosion control plan..
Alteration in the species composition of marine plants in an ecological community, that causes a decline or loss of functionally important species; or	No	There are no marine ecological communities located in the direct disturbance footprint of the Project. Important marine ecological communities are associated with the Styx River, Broad Sound FHA and GBR, all located downstream of the Project Area. Indirect impacts to the receiving environment (incl. marine plants) are considered unlikely with the implementation of management measures such as a controlled release strategy and sediment and erosion control plan.
Interference with the natural recovery of marine plant communities	No	The Project has the potential to impact on marine plants located downstream of the Project Area through changes in hydrology and changes in water quality (including increases in sedimentation). However, such indirect impacts to the receiving environment (incl. marine plants) are considered unlikely with the implementation of management measures such as a controlled release strategy and sediment and erosion control plan.

8.5 Risk Assessment

Potential impacts on the marine environment and Great Barrier Reef have been assessed using the risk assessment framework outlined in **Section 2.4.1**. The potential impacts considered include those common to all assessments (**Section 4**):

- Direct disturbance of vegetation and/or habitat
- Changes to groundwater level
- Changes to groundwater quality
- Changes to surface water flow (hydrology)
- Changes to surface water quality
- Erosion of sediments
- Changes in the location of the freshwater – saltwater interface.

The risk assessment for marine ecology that outlines the potential impacts, initial risk, control measures and residual risk following the implementation of control measures is provided in **Table 8-10**.

Table 8-10: Risk assessment for marine ecology

Issue	Potential Impacts	Likelihood	Consequence	Risk rating	Control Measures	Residual Risk
Direct disturbance to marine habitat	Not applicable					
Changes to groundwater level and quality	Reduction in groundwater in flows to estuarine and marine areas Changes in the quality of groundwater flowing to estuarine and marine areas	Unlikely	Moderate	Medium	Project design to minimise the areas of creeks that are subject to groundwater drawdown Implementation of groundwater monitoring and management plan with appropriate triggers and corrective actions if groundwater drawdown exceeds predicted levels and/or extents	Low
Changes to hydrology and surface water flows	Reduction of inflows to creeks and changes to the hydrological dynamics of estuarine areas	Unlikely	Moderate	Medium	Ensure water regime for the Project is designed such that impacts to hydrological regime are minimised Implementation of receiving environment monitoring plan (REMP) to detect and respond to any unexpected downstream changes	Low
Increased sedimentation in downstream areas resulting from: Erosion of streambanks from riparian vegetation dieback Mine site runoff Water releases from mine site (controlled and uncontrolled)	Bank instability and associated follow-on impacts including degradation of the riparian zone Degradation of instream habitat / water quality including downstream estuarine habitat in the Styx River Degradation of important downstream habitat and values associated with Broad Sound e.g. FHA and GBR	Almost certain	Moderate	Extreme	Construction will be completed during the dry season where possible, to reduce the potential of construction related erosion and scour Implementation of the site ESCP Bank stabilisation will take place post-construction to allow for revegetation and reduce scour potential A water catchment system and environmental dams (sediment basins) will collect run-off from the development area which will be transferred to the main site dams Captured water will be treated to minimise the amount of sediment Water will only be discharged from the mine dam during flow trigger events	Medium

Issue	Potential Impacts	Likelihood	Consequence	Risk rating	Control Measures	Residual Risk
					(during/immediately after high rainfall events when creek flow is high) Discharge of water will be controlled to reduce the likelihood of non-compliant discharges from overtopping Landforms such as waste rock stockpiles will be constructed using erosion-resistant materials and with low batter slope angles to reduce the level of erosion Removed topsoil will be placed in designated rehabilitation zones and seeded to minimise erosion Installation of sediment fences on the downslope of disturbed areas, erosion control devices and diversion drains Clean water will be diverted around disturbed areas to avoid additional sediment and contamination Earthmoving activities will be minimised during high rainfall events to limit sediment runoff Regeneration of the vegetation and restoration of habitat within the riparian corridor of Deep Creek will create vegetation buffers to reduce sediment and nutrient runoff into waterways. Revegetation will include expansion of the existing riparian corridor by a width of 10 m. Destocking and grazing reduction will occur both within the mining lease and upstream offset property	
Release of mine affected water into downstream areas	Degradation of water quality including downstream estuarine habitat in the Styx River	Almost certain	Moderate	Extreme	A water catchment system and environmental dams (sediment basins) will collect run-off from	Medium

Issue	Potential Impacts	Likelihood	Consequence	Risk rating	Control Measures	Residual Risk
	Degradation of important downstream habitat and values associated with Broad Sound e.g. FHA and GBR				the development area which will be transferred to the main site dams Captured water will be treated to minimise the amount of contamination Water will only be discharged from the mine dam during flow trigger events (during/immediately after high rainfall events when creek flow is high) Discharge of water will be controlled to reduce the likelihood of non-compliant discharges from overtopping Clean water will be diverted around disturbed areas to avoid increases in the concentration of suspended sediment and water quality parameters	
Changes to the location of the SW – FW interface	Reductions in surface water flows causing the interface between salt water and freshwater to move upstream Reduction in habitat for freshwater species Movement of saline wedge in groundwater aquifers impacting groundwater quality	Rare	Minor	Low	Implementation of groundwater monitoring and management plan with appropriate triggers and corrective actions as required Implementation of receiving environment monitoring plan (REMP) to detect and respond to any unexpected downstream changes	Low

9. Cumulative impacts

As discussed in **Section 4.8**, 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. There is therefore some potential for the impacts of the Project to act cumulatively with those of the Defence project. However, the potential for cumulative impacts is considered to be very low, because:

- Impacts of the Project on downstream values including water quality are not expected, particularly as far downstream as Broad Sound (**Section 8.2**)
- Broad Sound and Shoalwater Bay are subject to a very large tidal influence, reducing the risk of cumulative impacts to water quality from both projects
- The Defence project will be implemented in accordance with environmental guidelines to mitigate impacts on the environment, including local water quality values
- The Project will result in a net reduction in sediment discharges to the GBR, reducing the risks of impacts from sediment discharges acting cumulatively with any that should arise from the Defence project.

10. Monitoring and Reporting

A series of detailed monitoring programs have been developed for implementation to quantify impacts of the Project on environmental values during construction and operations, and provide further information to assist in adaptive management and mitigation of Project impacts. These programs will build on the existing extensive data set that has been established for the Study Area since 2011, and facilitate active management of environmental impacts during the construction and operation phases of the Project.

This section provides an overview of the monitoring programs that have been developed for each of the ecological values discussed in this report. For a more detailed description, reference should be made to the following reports:

- GDEMMP (ELA 2020c), which describes the program for monitoring GDEs, including stygofauna, groundwater fed pools and associated aquatic habitats, riparian vegetation, and their associated groundwater resources. Triggers are outlined which will be evaluated, with corrective actions identified for implementation in response to the monitoring results.
- REMP (ELA 2020b), which describes the key potential sources of contamination of the receiving environment, and outlines a program to monitor environmental variables at reference sites and at impact sites located adjacent to and downstream of the Project. Relevant environmental variables include surface water quality, sediment quality, macroinvertebrates, fish and estuarine habitat quality.

10.1 GDEs

10.1.1 Stygofauna

Stygofauna surveys will be completed in the shallow aquifers where dewatering is planned, and in adjacent areas to the south of the mine. Surveys will target the shallow lens of freshwater depicted in Allen (2019), and their associated stygofauna communities. The objective of the surveys will be to confirm the impacts of the Project on the stygofauna community, and collect further information on stygofauna in the broader region, and the environments in which they occur. Further details are provided in the GDEMMP (ELA 2020c), with a summary of key monitoring variables and indicators provided in **Table 10-1**.

Table 10-1: Summary of key aspects of the monitoring program for stygofauna

Monitoring Variable	Indicator	Sites	Timing and Frequency	Method
Stygofauna	Taxonomic composition and abundance	A total of 18 bores located across the Study Area within and outside the drawdown area.	Six monthly initially, then reviewed	As per Guideline for the Environmental Assessment of Subterranean Aquatic Fauna (DSITI 2015)
Aquifer water level and quality	Water level (mbgl), EC, pH, dissolved metals	All sites sampled for stygofauna, plus the remaining network of bores	Monthly	As per the Groundwater Monitoring Plan in the EMP

Monitoring Variable	Indicator	Sites	Timing and Frequency	Method

Dewatering of the alluvial aquifer is required for the Project, so a large section of the aquifer ecosystem will be lost. Although no stygofauna were found in the impact area during previous surveys, it is possible that they will occur there in locations where the water is of suitable quality. This is more likely close to the creeks where alluvial water is fresh.

10.1.2 Groundwater fed pools

The key hydrological features of Tooloombah and Deep Creeks will be monitored to assist in the interpretation of biological data, to provide inputs into future recalibrations of the surface water and groundwater models, and to examine changes to the distribution and persistence of aquatic ecology habitats, particularly pools, and the effects of the Project. The program will include continuous stream flow and water level monitoring at the existing Tooloombah Creek and Deep Creek gauging stations, which will be implemented as part of the REMP (**Table 10-2**).

The physical attributes of pools will be surveyed at the end of the dry season (October) each year. A total of14 pools will be surveyed (within and outside of the drawdown area), with their upstream and downstream boundaries mapped using DGPS. Water level within each pool will be monitored using a marked temporary post which will be installed during the June survey and removed during the October survey, avoiding loss during high flows of the wet season. EC, pH and turbidity will be measured during each survey, to assist in identifying the presence of saline groundwater and monitoring of evaporative processes. Biological monitoring of a representative selection of pools will also be completed.

Table 10-2: Summary of monitoring for groundwater fed pools

Monitoring Variable	Indicator	Sites	Timing and Frequency	Method
Stream flow and level	Water level at gauge Water flow at gauge	1 Deep Creek 1 Tooloombah Creek	Data collected continuously, analysed monthly	Stream flow station
Pool size, fish abundance and species composition at end of dry season	Pool length, width, depth Fish species present and abundance	13 sites subject to fish monitoring in REMP where pools are present	Once at the end of the dry season (October)	As per REMP and GDEMMP

10.1.3 Riparian vegetation and wetlands

Vegetation within the riparian corridor of Tooloombah and Deep creeks and at Wetland 1 will be monitored to confirm the results of the impact assessment and provide early identification of water stress and early signs of die off from groundwater drawdown, should this occur. Monitoring will be completed through the GDEMMP with a focus on Forest Red Gums and *Melaleuca* sp. The following key measures will be monitored (**Table 10-3**):

- BioCondition variables
- Leaf Water Potential, Isotopes, SMP
- Groundwater level at nearest bores (WMP06, WMP04, WMP02, WMP28, WMP12, WMP05, WMP21, WMP10, WMP09, WMP08, WMP25)

- Groundwater quality at nearest bores (WMP06, WMP04, WMP02, WMP28, WMP12, WMP05, WMP21, WMP10, WMP09, WMP08, WMP25).

Monitoring will be completed annually at the end of the dry season (September), when water stress and groundwater dependence is likely to be highest. The monitoring will assist in verifying the conclusions of the EIS in relation to groundwater dependence and impacts on vegetation, and provide opportunities for adaptive management of impacts.

Table 10-3: Summary of monitoring for groundwater dependent vegetation

Monitoring Variable	Indicator	Sites	Timing and Frequency	Method
Vegetation condition	BioCondition and CORVEG Foliage cover Normalised Difference Vegetation Index (NDVI) Weed and pest surveys	13 sites along Tooloombah Creek and Deep Creek	Twice per year until drawdown commences, then annually	As per GDEMMP
Water usage and stress	Leaf Water Potential, Isotopes	13 sites along Tooloombah Creek and Deep Creek	Twice per year until drawdown commences, then annually	As per 3D Environmental (2020)
Groundwater level	Mbgl at bore	WMP06, WMP04, WMP02, WMP28, WMP12, WMP05, WMP21, WMP10, WMP09, WMP08, WMP25	Quarterly	As per Groundwater Monitoring Plan
Groundwater quality	EC	WMP06, WMP04, WMP02, WMP28, WMP12, WMP05, WMP21, WMP10, WMP09, WMP08, WMP25	Quarterly	As per Groundwater Monitoring Plan

10.2 Aquatic and Marine Ecology

Aquatic ecology values will be monitored as part of the REMP, with a focus on the assessment of instream habitat values, water quality, sediment quality, macroinvertebrates and fish. The objective of the monitoring will be to determine the actual impacts of Project activities, with reference to those predicted in the EIS, and to provide information to inform decision making on the effectiveness of mitigation measures. Operational practices such as implementation of the Water Management Strategy and the treatment and discharge of mine affected water will be informed by the results of the monitoring program.

The Project has the potential to influence sensitive receptors of the receiving environment in estuarine and marine environment downstream. While the impact assessment has concluded that the risk of such impacts is minimal, values of intertidal foreshores in the lower Styx Estuary / Broad Sound will be monitored as part of the REMP, to verify these findings and assist in monitoring the condition of the receiving environment during Project construction and operations. This will include examining of sediment particle size and quality, to monitor for potential changes associated with the change in land use from grazing to a combination of mining and environmental offsets.

The REMP will be implemented and evaluated in accordance with conditions of an Environmental Authority. Details of the key indicators, monitoring frequency, location and number of sites are provided in **Table 10-4**.

Table 10-4: Summary of key monitoring variables for aquatic ecology

Monitoring Variable	Indicator	Sites	Timing and Frequency	Method
Surface Water quality	EC, pH, Dissolved Oxygen, Temperature, Turbidity Major Cations and Anions Total and dissolved metals Organics	8 reference sites, 13 impact sites	Monthly Marine sites quarterly	*In situ* and sample collection of laboratory analysis as per DES Manual
Sediment quality	Particle Size Distribution, Metals (< 2mm fraction), Total Organic Carbon	8 reference sites, 13 impact sites	Six monthly (pre-wet and post-wet seasons)	Composite samples from pool areas
Aquatic habitat values	AusRivAS physical habitat assessment	4 reference sites, 8 impact sites	Six monthly (pre-wet and post-wet seasons)	AusRivAS physical habitat assessment (DNRM 2001), examining bottom substrate, embeddedness, velocity/depth, channel alteration, bottom scouring, pool/riffle/run/bend ratio, bank stability, bank vegetative stability and streamside cover.
Macroinvertebrates	Taxonomic composition, abundance and AusRivAS variables PET taxa, Signal2 scores and OE50 (biological diversity)	4 reference sites, 8 impact sites	Six monthly (pre-wet and post-wet seasons)	Dip netting of edge and bed habitats as per Queensland AusRivAS manual
Fish	Taxonomic composition and abundance	4 reference sites, 9 impact sites	Six monthly (pre-wet and post-wet seasons)	Electrofishing, fyke netting and seine netting.
Mangrove habitat area	Area (ha) occupied by mangroves using satellite imagery	4 sites	Once every three years.	Assessment of extent of mangrove edge in comparison with previous years using satellite imagery

11. Conclusions

An assessment of likely environmental impacts of the Project on GDEs, aquatic ecology and downstream values was completed, in response to comments from regulatory agencies on the previously submitted EIS and SEIS material. The impact assessment was supported by extensive technical studies, including hydrological (surface water) modelling, a regional groundwater model, field studies on GDEs, and the geological properties of the alluvium of Tooloombah and Deep creeks, a sediment budget for the site, and a fluvial geomorphology study. In addition, ongoing monitoring of surface water and groundwater quality has facilitated the collection of extensive baseline information, to further support analyses associated with the impact assessment, and the continuation of baseline monitoring programs.

The assessment has concluded that the Project will have an impact on groundwater dependent vegetation occurring along sections of Deep Creek, of which some of the vegetation is classified as a MNES or MSES. Separate assessments have been undertaken to determine whether this impact is a significant residual impact, by consideration of MNES and MSES significant impact criteria. The area to be impacted comprises 165.23 ha of riparian vegetation in total, comprising the following REs:

- RE 11.3.25 (87.51 ha)
- RE 11.3.27 (0.59 ha)
- RE 11.3.35 (37.81 ha)
- RE 11.3.4 (39.31 ha).

The impacts are likely to be manifest through a reduction in the condition of structural elements of the vegetation communities, such as Forest Red Gums and Melaleuca trees. Impacts are expected to occur approximately 10 to 20 years after Project commencement, and may be effectively mitigated through a range of processes, including improved management of weeds and pests to increase ecosystem resilience, removal of access to waterways by cattle and revegetation of riparian areas with drought tolerant species. Impacts to vegetation will also be mitigated by widening the existing vegetated riparian corridor by 10 m along areas to Deep Creek to be affected by groundwater drawdown. This will involve the planting and establishment of plant species similar to adjacent areas, to build ecological resilience.

The indirect impacts are in addition to the 12.36 ha of watercourse vegetation to be disturbed by Project infrastructure such as road crossings and drainage structures. An offset approach has been developed to address the significant residual impacts on vegetation classified as MSES or MNES.

Approximately 8.35 km of waterways providing fish passage mapped by the DAF spatial layer will be disturbed as a result of the Project. These areas are comprised of highly ephemeral drainage lines that would provide ecological function by facilitating fish passage during periods of high rainfall and flood. The impact to this MSES is unavoidable, as the areas involved are required for establishment of critical mine infrastructure, so an offset will be applied in accordance with the relevant Queensland offset policy.

The Project is also likely to results in changes to the existing pools that occur along Tooloombah and Deep creeks during the dry season. Changes are most likely to be pool-specific, and include a reduction in the number of days that pools persist throughout the dry season, and a decrease in the salinity of water held within the pools. Such changes are likely to reduce the extent and persistence of aquatic habitats in parts of the Study Area during the dry season, and their associated assemblages of fauna, which are tolerant of the harsh environmental conditions that generally persist in pools under present conditions. During the wet season, affected reaches of local waterways will be recolonised by aquatic species, minimising the significance of impacts.

The Project is predicted to have minimal impacts on the existing hydrological conditions of the Study Area, with stream flow patterns generally remaining unchanged. Impacts on water quality of both surface water and groundwater are also expected to be minimal. During periods of high rainfall, some controlled releases of water from the mine storage dam will be required, and these will have minimal changes to water quality of the receiving environment. Significant wetlands located within the Project Area are sustained by surface water runoff, and will not be affected by the Project.

While there are extensive environmental values located downstream of the Project, including nationally listed wetlands and the Great Barrier Reef World Heritage Area, the impacts on such areas were assessed to be minimal, as a consequence of little change to the hydrology and water quality conditions of local waterways. The removal of grazing from several thousands of ha of agricultural lands, and the implementation of a water management system for water held within the mine site, will result in a 50% reduction in sediments discharged to the Great Barrier Reef. Such as reduction is consistent with Water Quality Targets in the Reef 2050 Plan and the GBR Net Benefit Policy. A summary of the outcomes of the assessment in relation to MNES and MSES relevant to the scope of this report is presented in **Table 11-1** and **Table 11-2**.

Table 11-1: Summary of MNES relevant to the Project and addressed in this assessment

Protected matter	Presence in the Project Area or downstream	Significant residual impacts
World Heritage Properties	Yes – present downstream	No
National Heritage Places	Yes – present downstream (as the GBRWHA)	No
Wetland of International Importance (Ramsar sites)		NA
Great Barrier Reef Marine Park	Yes – present downstream	No
Commonwealth Marine Areas	Not present	NA
Threatened Ecological Communities	Yes – only SEVT as potential GDE is relevant to this assessment	TECs assessment in SEIS (v3)
Threatened Species	Yes – habitat for a number of threatened species (e.g. koala, greater glider) is present within riparian vegetation that can be considered GDEs; also located downstream in association with Broad Sound intertidal area	Terrestrial threatened fauna assessed in SEIS (v3) No for threatened marine species
Migratory Species	Yes – located downstream in association with the Broad Sound intertidal area	No

Protected matter	Presence in the Project Area or downstream	Significant residual impacts
A water resource, in relation to coal seam gas development and large coal mining development	Yes – water resources present, and the Project is a large coal mining development. Values relevant to this assessment include Subterranean, Aquatic and Terrestrial GDEs.	Water trigger assessment in SEIS (v3)

Table 11-2: Summary of MSES relevant to the Project and addressed in this assessment

Protected matter	Presence in the Project Area or downstream	Significant residual impacts
Regulated vegetation under the VM Act: • Prescribed regional ecosystem that are endangered and of concern regional ecosystems • Prescribed regional ecosystem intersecting a watercourse or drainage features • Prescribed regional ecosystems intersecting a wetland shown on the vegetation management wetlands map • Containing mapped essential habitat for endangered or vulnerable plants or wildlife	Yes – regulated vegetation is present as riparian vegetation that can be considered GDEs	Assessed in SEIS (v3)
Wetlands and watercourses: • A wetland in a wetland protection area • A mapped wetland of high ecological significance • A wetland or watercourse in high ecological values waters	Yes – Wetland 1 is a wetland of high ecological significance, and is in a wetland protection area	No
Protected wildlife habitat: • An area containing endangered of vulnerable plants • An area of habitat for an animal that is endangered, vulnerable or special least concern • A koala habitat area	Yes – habitat for a number of threatened species (e.g. koala, greater glider) is present within riparian vegetation that can be considered GDEs; also located downstream in association with Broad Sound intertidal area	Terrestrial wildlife habitat assessed in SEIS (v3) No for marine and aquatic wildlife habitat
Highly protected zones of State marine parks	Yes – areas of Broad Sound zoned Marine National Park	No
Fish habitat areas	Yes – Broad Sound Fish Habitat Area	No
Waterway providing for fish passage	Yes – present within and adjacent to Project Area	Yes
Marine plants	Yes – present in downstream areas	No

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Appendix A Application of IESC Guidelines for GDE Assessment

The IESC Explanatory Note for assessing GDEs (Doody *et al.* 2019, p. 1) lists a logical sequence of steps to assist proponents prepare an appropriate environmental impact assessment for GDEs . These are summarised in the following table, with reference to sections of this report.

Guideline step	Comment with respect to the Project	Section of this report (or elsewhere in SEIS material)
Define the likely area of impact of the proposed project (including the disturbance footprint of surface infrastructure and the extent of groundwater depressurisation).	The area of impact of the proposed project has been defined, including the area of direct impact and groundwater depressurisation.	Section 2.2 Section 6
Use a desktop assessment of reports, maps, databases and other resources to list potential GDEs in the Project impact area, and make a preliminary assessment of possible risks to these GDEs from each stage of the proposed project.	A desktop assessment was completed as part of the original EIS and SEIS material. This has been updated to remain contemporary, with additional field and technical studies carried out since this time. The risks to each type of GDE has been considered (Subterranean, Aquatic and Terrestrial).	Sections 6 to 8
Apply conceptual models and other tools described in the Explanatory Note to assess the level of groundwater dependence for each GDE and the likely pathways (e.g. disruption of groundwater connections, reduction in groundwater quality) by which the Project might impact on GDEs.	Conceptual models have been applied to the assessment of impacts on GDEs. These are informed by the results of field studies, regional groundwater model, hydrological mode, integrated surface water – groundwater model and on site coring investigations.	Sections 6 to 8 3D Environmental (2020) HydroAlgorithmics (2020)
Determine baseline ecological condition and ecosystem value of each GDE, including GDEs to be used as reference sites to assess changes over time that are not associated with the Project. Field surveys will be needed to obtain site-specific data that can be supplemented with information from remote sensing and other techniques.	Baseline studies of ecological values have been completed, including studies focussed on assessing GDEs. These studies will continue into the pre-impact phase of the Project (before groundwater draw-down occurs) to establish a long term baseline for the Project. Site-specific monitoring plans have been developed.	3D Environmental (2020) Draft GDEMMP (ELA 2020c) Draft REMP (ELA 2020b)
Conduct a systematic risk assessment to estimate the likelihood and consequences of potential impacts on GDEs arising from the proposed project, including cumulative impacts. Tools such as the GDE Risk Matrix and the associated matrix of management options are useful here.	A systematic risk assessment tool has been applied to assess risks for GDEs. This included a more detailed tool which was developed for Terrestrial GDEs, given the range of potential impacts that may have resulted from the Project.	Section 2 Sections 6 to 8

Guideline step	Comment with respect to the Project	Section of this report (or elsewhere in SEIS material)
Using the risk assessment and other information from the preceding steps, specify options to avoid or mitigate impacts on GDEs and establish a monitoring plan to assess the effectiveness of mitigation. This monitoring plan should include sampling variables that will provide 'early warning' of impending impacts on GDEs so that appropriate action can be taken to avoid or minimise harm.	Mitigation measures have been developed and described to reduce impacts on GDEs. These have included optimisation of the Project design to minimise potential impacts on sensitive areas, where possible. An adaptive monitoring program has been developed, with an early warning of impending impacts on GDEs.	Section 5 Section 10 GDEMMP (ELA 2020c) REMP (ELA 2020b)

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