# Central Queensland Coal Project

## Chapter 10 – Groundwater

Environmental Impact Statement

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# Central Queensland Coal Project
# Chapter 10 - Groundwater

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# 10 Groundwater

This chapter outlines the existing groundwater environment within and surrounding the Central Queensland Coal Project (the Project) area and discusses potential impacts and mitigation measures.

## 10.1 Project Overview

The Project is located 130 km northwest of Rockhampton in the Styx Coal Basin in Central Queensland. The Project will be located within Mining Lease (ML) 80187 and ML 700022, which are adjacent to Mineral Development Licence (MDL) 468 and Exploration Permit for Coal (EPC) 1029, both of which are held by the Proponent.

The Project will involve mining a maximum combined tonnage of up to 10 million tonnes per annum (Mtpa) of semi-soft coking coal (SSCC) and high grade thermal coal (HGTC). Development of the Project is expected to commence in 2018 and extend for approximately 20 years until the current reserve is depleted.

The Project consists of three open cut operations that will be mined using a truck and shovel methodology. The run-of-mine (ROM) coal will ramp up to approximately 2 Mtpa during Stage 1 (Year 1-4), where coal will be crushed, screened and washed to SSCC grade with an estimate 80% yield. Stage 2 of the Project (Year 4-20) will include further processing of up to an additional 4 Mtpa ROM coal within another coal handling and preparation plant (CHPP) to SSCC and up to 4 Mtpa of HGTC with an estimated 95% yield. At full production two CHPPs, one servicing Open Cut 1 and the other servicing Open Cut 2 and 4, will be in operation.

A new train loadout facility (TLF) will be developed to connect into the existing Queensland Rail North Coast Rail Line. This connection will allow the product coal to be transported to the established coal loading infrastructure at the Dalrymple Bay Coal Terminal (DBCT).

The Project is located within the Livingstone Shire Council (LSC) Local Government Area (LGA). The Project is generally located on the "Mamelon" property, described as real property Lot 11 on MC23, Lot 10 on MC493 and Lot 9 on MC496. The TLF is located on the "Strathmuir" property, described as real property Lot 9 on MC230. A small section of the haul road to the TLF is located on the "Brussels" property described as real property Lot 85 on SP164785.

## 10.2 Relevant Legislation, Plans and Guidelines

Environmental protection is governed by several legislative Acts, plans and guidelines that are described in Chapter 1 – Introduction. Those with specific relevance to groundwater are:

- *Water Act 2000* (Qld) (Water Act);
- *Environmental Protection Act 1994* (Qld) [EP Act];
- *Environmental Protection (Water) Policy 2009* (Qld) [EPP (Water)];
- Queensland Water Quality Guidelines 2009 (QWQG) (EHP 2009);
- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) Australian and

New Zealand Guidelines for Fresh and Marine Water Quality 2000 (herein referred to as the ANZECC guidelines) (ANZECC/ARMCANZ 2000);

- National Health and Medical Research Council (NHMRC) and Medical Research Council and National Resource Management Ministerial Council (NRMMC) Australian Drinking Water Guidelines (ADWG) (NHMRC/NRMMC 2011);
- EHP Mining Guideline – Model Mining Conditions; and
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act).

This assessment has been prepared to address the requirements of the Terms of Reference (ToR) by establishing the existing groundwater environmental values (EVs) under the relevant legislation, plans and guidelines and assessing the potential impacts on the EVs by the Project.

### 10.2.1 Water Act 2000

The Water Act provides a structured system for the planning, protection, allocation and use of Queensland's surface waters and groundwater. Under Section 808 of the Water Act, a person must not take, supply or interfere with water unless authorised. Authorisation under the Water Act for the taking of water comes via a water entitlement and a development application. As the Project occurs near a watercourse and will include dewatering / depressurisation of the targeted coal seams, as well as overburden and underburden, approval will be required under Section 211 of the Water Act.

The groundwater resources of the Styx Basin are not affected by any regulations under the Great Artesian Basin.

### 10.2.2 Environmental Protection (Water) Policy 2009

The object of the Environmental Protection Act 1994 (EP Act) is to 'protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes on which life depends' (s3). Of the five pieces of subordinate legislation under the EP Act the EPP (Water) applies directly to groundwater.

The EPP (Water) provides a framework for:

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

Schedule 1 of the EPP (Water) defines EVs for waters within Queensland. EVs and water quality objectives (WQOs) are prepared for drainage basins (at the sub-basin level); however, the setting of values and objectives is at different stages of development throughout Queensland. These EVs and WQOs are set under the EP Act, and its subordinate legislation, while basin resource plans are set under the Water Act.

The Project is wholly contained within the Styx River Basin. Specific EVs and WQOs for the Styx River Basin were released in 2014 as part of the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014).

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### 10.2.3 Queensland Water Quality Guidelines 2009

The Queensland Water Quality Guidelines (EHP 2009) (QWQG) are tailored guideline values for Queensland water types and regions. The QWQG also provides a framework for deriving and applying specific guidelines that are local to the water systems in Queensland. The WQOs for a water that is not in Schedule 1 of the EPP (Water) are the set of water quality guidelines (e.g. the QWQG and ANZECC) for all indicators that will protect all EVs for the water.

### 10.2.4 Australian and New Zealand Guidelines for Water Quality 2000

The ANZECC water quality guidelines provide a baseline for monitoring and measuring water quality for different ecosystems within Australia and New Zealand. The ANZECC guidelines provide threshold values that identify water quality levels based on multiple chemical and physical parameters. For example, the level of water quality at a certain site can be determined by comparing a range of parameters (e.g. pH, turbidity and conductivity) against threshold values outlined by the ANZECC guidelines.

### 10.2.5 Australian Drinking Water Guidelines 2011

The ADWG has been developed by the NHMRC in collaboration with the Natural Resource Management Ministerial Council (NRMMC). The ADWG is designed to provide an authoritative reference to the Australian community and the water supply industry on what defines safe, good quality water, how it can be achieved and how it can be assured.

### 10.2.6 Mining Guideline – Model Mining Conditions

The purpose of the Model Mining Conditions is to provide a set of model conditions to form general environmental protection commitments for the mining activities and the EA conditions pursuant to the EP Act. The guideline states that the 'model conditions should be applied to all new mining project applications lodged after the guideline is approved', therefore the Project is subject to the groundwater conditions outlined in this guideline. Schedule E of the Model Mining Conditions provides the regulatory conditions, associated with groundwater, for mining activities.

Refer to Chapter 23 – Draft EA Conditions for the proposed groundwater conditions for the Project.

### 10.2.7 Environment Protection and Biodiversity Conservation Act 1999

The Project was identified as having the potential to impact on Matters of National Environmental Significance (MNES) and was referred to the Commonwealth Department of the Environment (DotE) now the Department of the Environment and Energy (DotEE). The Project was deemed to be a controlled action requiring approval under the EPBC Act (EPBC ref 2016/7851).

A stand-alone chapter has been prepared and assessed as part of approval under the EPBC Act; refer to Chapter 16 – Matters of National Environmental Significance. The assessment bilateral process allows for the assessment of impacts on MNES to be undertaken as part of the State EIS process, with input from the Department throughout. Assessment of the Project under the EPBC Act in Chapter 16 includes water resources related to coal seam gas and large coal mining developments as a MNES (the 'water trigger').

# 10.3 Environmental Objectives and Performance Outcomes

## 10.3.1 Environmental Objective

The environmental objective relevant to groundwater is provided in the *Environmental Protection Regulation 2008* (EP Regulation). In accordance with the EP Regulation, the Project groundwater objective is to operate in a way that protects the EVs of groundwater, and any connected surface, ecosystems.

## 10.3.2 Performance Outcomes

The main aim of the Project is for no actual or potential discharge to groundwater of contaminants that may cause an adverse effect on an EV from the operation of the activity. The following are the Project's performance outcomes for groundwater:

- There will be no direct or indirect release of contaminants to groundwater from the operation of the activity that will cause an adverse effect on a groundwater EVs;
- There will be no loss of supply caused by drawdown associated with the operations of the mine to beneficial users of groundwater;
- There will be no permanent adverse impact on GDEs; and
- There will be no actual or potential adverse effect on groundwater from the operation of the activity, or, the activity will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems.

# 10.4 Description of Environmental Values and Water Quality Objectives

## 10.4.1 Overview

For all the relevant matters, the EIS must identify and describe the groundwater EVs that must be protected. EVs are specified in the EP Act, the EP Regulation, environmental protection policies (EPPs) and relevant guidelines.

The Project is wholly contained within Styx River Basin. Specific EVs and WQOs for Styx River Basin were released in 2014 as part of the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014).

## 10.4.2 Groundwater Environmental Values

Groundwater EVs are assessed based on the hydrogeological conceptualisation presented in Section 10.5.12 utilising all available information from desktop assessment, onsite groundwater investigations and a comprehensive literature review.

Groundwater EVs are defined by their contribution to the water requirements of ecological systems and or anthropogenic water users. The suitability of groundwater for supporting dependant ecosystems and/or the purposes for which it is abstracted are key indicators of EVs. The EVs of groundwater must be protected from pollution, depletion and flow modification such that habitats are unaltered and to ensure that groundwater continues to meet the requirements of the community both in terms of quantity and quality.

To protect the aquifers of the Project area and associated EVs, WQOs are established for different indicators such as pH, nutrients and toxicants. The EPP (Water) provides provisions to protect and enhance the suitability of Queensland's ground waters for various beneficial uses and has established EVs and WQOs for a number of Basins including the Styx River Basin. The EVs considered applicable to the Project are outlined in Table 10-1, and include:

- Aquatic ecosystems – these occur where groundwater baseflow supports permanent streams and water holes to some extent (e.g. seasonally or permanently). This interaction can occur in tidal and estuarine zones, as well as in freshwater areas;
- Irrigation – where groundwater is used to grow crops and pastures for commercial purposes;
- Farm supply / use – where groundwater is used to provide domestic supply and support growing of domestic produce;
- Stock water – where groundwater is used to provide stock water supplies; and
- Cultural and spiritual – where groundwater supports both indigenous and non-indigenous values, e.g. recreational fishing, heritage, ecology. This interaction can occur in tidal and estuarine zones, as well as in freshwater areas.

**Table 10-1 Environmental values for waters associated with the Project**

| Environmental Values [1] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aquatic Ecosystems | Irrigation | Farm supply / Use | Stock water | Aquaculture | Human consumer | Primary recreation | Secondary recreation | Visual recreation | Drinking water | Industrial use | Cultural and Spiritual values |
| ✓ | ✓ | ✓ | ✓ | | | | | | | | ✓ |

Notes: ✓ indicates groundwater is suitable for the EV, and grey shading indicates groundwater is not suitable for the EV

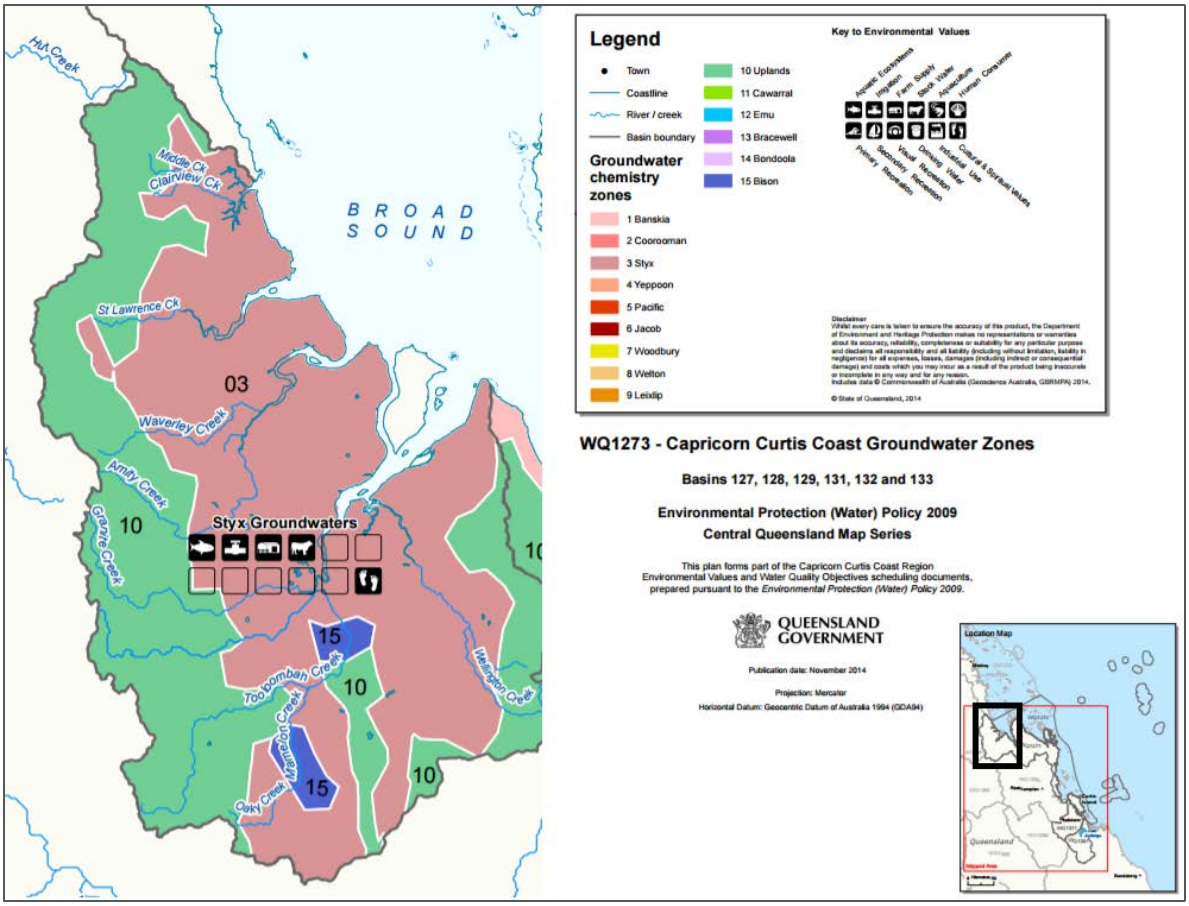
## 10.4.3 Water Quality Objectives

The purpose of defining WQOs, which are long-term goals for water quality management, is to support and protect EVs (EHP, 2009a). Notably, where groundwater and surface water interaction occurs it is important that the WQOs of either resource are not compromised by degradation of water quality in either resource. The Australian Water Quality Guidelines recommend that underground aquatic ecosystems are afforded the highest level of protection (EPPD, 2014).

WQOs vary across the Styx Basin and are defined on the basis of Groundwater Chemistry Zones (GCZs; refer Figure 10-1). The applicable GCZs for the Project are:

- Styx (zone 03);
- Uplands (zone 10); and
- Bison (zone 15).

The WQOs for these zones is presented in Table 10-2.




Source: adapted from Qld Government WQ1273

**Figure 10-1 Styx Basin WQ1273 groundwater zones**

**Table 10-2 WQOs for groundwater resources having the potential to be impacted by the Project**

| Depth[2] | Percentile | Indicator / WQO[1] | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Na | Ca | Mg | HCO3 | Cl | SO4 | NO3 | EC | Hardness | pH (units) | Alkalinity | SiO2 | F | Fe | Mn | Zn | Cu | SAR (unitless) | RAH (meq/L) |
| **GCZ** | | **Styx** | | | | | | | | | | | | | | | | | | |
| S | 20th | 781 | 95 | 163 | 326 | 1,727 | 164 | - | 6,445 | 867 | 7.5 | 272.5 | 23 | 0.32 | - | 0.035 | 0.039 | - | 7.6 | |
| | 50th | 1,296 | 222 | 209 | 583 | 2,342 | 301 | 0.00 | 7,620 | 1,346 | 7.7 | 478.5 | 30 | 0.68 | - | 0.165 | 0.140 | 0.010 | 15.3 | |
| | 80th | 1,564 | 315 | 310 | 628 | 3,607 | 653 | 3.26 | 9,887 | 1,995 | 8.0 | 524.5 | 33 | 1.07 | 0.09 | 0.478 | 12.67 | 0.041 | 22.6 | |
| M | 20th | 763 | 35 | 137 | 52 | 1,617 | 18 | 0.65 | 5,457 | 711 | 5.1 | 42.5 | 30 | 0.47 | - | 0.105 | 0.144 | 0.071 | 11.25 | |
| | 50th | 1,062 | 70 | 185 | 105 | 2,094 | 100 | 2.00 | 7,380 | 1,121 | 7.2 | 86.0 | 43 | 0.60 | - | 0.330 | 0.900 | 0.080 | 13.90 | |
| | 80th | 1,650 | 235 | 211 | 793 | 3,045 | 278 | 5.50 | 9,490 | 1,302 | 7.6 | 653.5 | 79 | 1.08 | 0.34 | 1.878 | 1.035 | 0.476 | 22.60 | |
| **GCZ** | | **Uplands** | | | | | | | | | | | | | | | | | | |
| VS | 20th | 38 | 38 | 42 | 328 | 71 | 20 | 0.62 | 774 | 330 | 7.5 | 275.0 | 28 | 0.09 | - | - | 0.010 | 0.010 | 0.87 | - |
| | 50th | 60 | 55 | 17 | 266 | 64 | 22 | 1.00 | 680 | 234 | 7.8 | 220.0 | 30 | 0.20 | 0.01 | 0.010 | 0.010 | 0.010 | 1.70 | 0.40 |
| | 80th | 100 | 84 | 39 | 506 | 97 | 44 | 7.00 | 970 | 35 | 8.1 | 417.6 | 36 | 0.50 | 0.04 | 0.010 | 0.045 | 0.015 | 2.60 | 2.31 |
| M | 20th | 85 | 56 | 34 | 449 | 49 | 13 | 2.25 | 899 | 314 | 7.5 | 370.9 | 31 | 0.35 | - | - | 0.010 | 0.010 | 1.90 | 0.51 |
| | 50th | 93 | 79 | 38 | 511 | 75 | 33 | 7.70 | 1,050 | 376 | 7.8 | 422 | 35 | 0.58 | 0.01 | - | 0.020 | 0.020 | 2.10 | 1.43 |
| | 80th | 108 | 98 | 64 | 590 | 111 | 38 | 11.27 | 1,225 | 431 | 8.0 | 486.2 | 51 | 0.60 | 0.03 | 0.010 | 0.068 | 0.030 | 2.60 | 1.84 |
| **GCZ** | | **Bison** | | | | | | | | | | | | | | | | | | |
| S | 20th | 137 | 45 | 31 | 332 | 180 | 29 | - | 1,060 | 240 | 6.8 | 272. | 30 | 0.20 | 0.02 | - | - | - | 2.20 | 1.31 |
| | 50th | 245 | 75 | 52 | 560 | 330 | 49 | - | 1,800 | 401 | 7.6 | 465.0 | 30 | 0.30 | 0.02 | - | - | - | 4.20 | 1.53 |
| | 80th | 289 | 402 | 106 | 605 | 995 | 153 | - | 3,675 | 1,441 | 8.0 | 500.0 | 38 | 0.50 | 0.02 | - | - | - | 5.3 | 1.74 |
| M | 20th | 384 | 542 | 327 | 210 | 2,200 | 189 | 12.90 | 6,570 | 2,699 | 7.2 | 173.0 | 29 | 0.23 | - | - | - | - | 3.10 | - |
| | 50th | 390 | 582 | 344 | 237 | 2,337 | 202 | 23.55 | 7,035 | 2,869 | 7.4 | 195.0 | 31 | 0.27 | - | - | - | - | 3.15 | - |
| | 80th | 396 | 623 | 361 | 263 | 3,474 | 215 | 34.20 | 7,500 | 3,038 | 7.5 | 217.0 | 33 | 0.30 | - | - | - | - | 3.20 | - |

Notes:
1. All as g/L unless otherwise indicated; "-" not designated
2. VS = very shallow; S = shallow; M = moderate

# 10.5 Existing Environment

## 10.5.1 Climate

The average climatic conditions of the study area for each month is presented in Figure 10-2. Mean climatic data has been obtained from the Bureau of Meteorology (BoM) Station 039083, located at the Rockhampton Aero, approximately 112 km from the Project. This weather station has the most comprehensive amount of climate data dating back to 1939 (78 years). Key climatic data indicates that the study area experiences a distinct wet season with the highest rainfall occurring during the summer months (December to March) with more rainfall in January and February and drier periods predominating in the winter and early spring months (June to September). Total evaporation is considerably higher than average annual rainfall.

Further climatic data is provided in Chapter 4 – Climate.

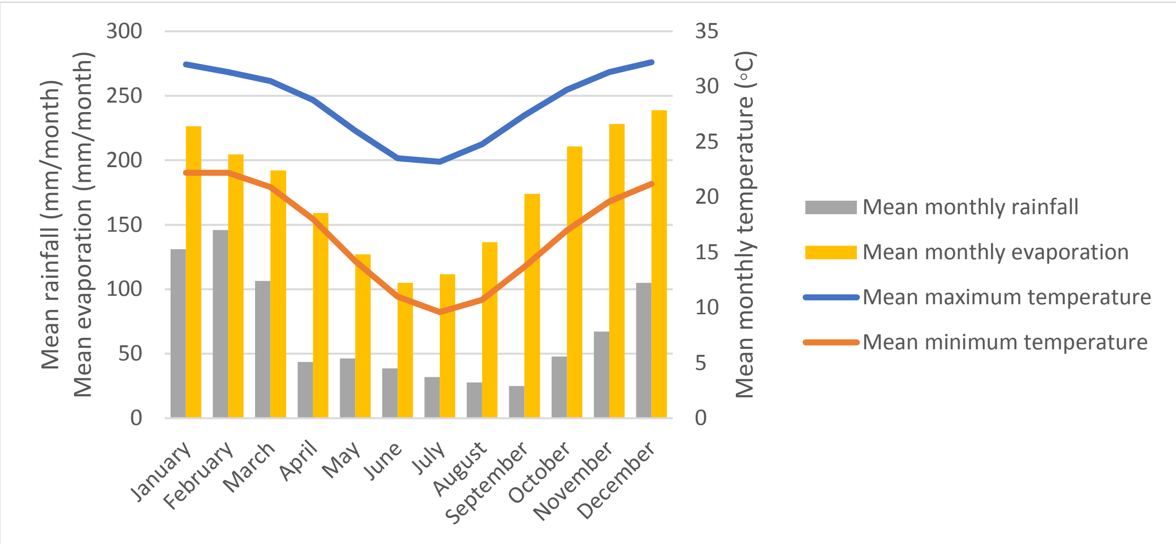



**Figure 10-2 Mean climatic conditions**

## 10.5.2 Topography

Topography at the Project predominantly comprises flat or undulating lands, draining via several smaller creeks and tributaries to the Styx River and estuary, and into the Coral Sea. The land within the Project area is described as gently undulating. A LiDAR survey was conducted of the EPC 1029 area. Based on this data, elevations within the ML area vary between 4.5 and 155 m AHD, with the Project area located between 11.4 and 43.8 m AHD. Further information on the topographical features of the Project is provided in Chapter 5 – Land.

## 10.5.3 Geology

### 10.5.3.1 Styx Basin

The Styx Basin is described as a small, elongate, Early-Cretaceous, intracratonic sag basin containing less than 1,000 m of siliciclastic sediments and coal measures (Geoscience Australia 2017a; Malone et al. 1969). Intracratonic sag basins are typically 'saucer like' in geometry and are developed by depositional infill of a sag in the Earth's crust, which generally forms by gradual subsidence. The infill sediments of Styx Basin are known collectively as the Styx Coal Measures. The stratigraphic relationship between Styx Basin and the underlying older Permian rocks is summarised in Table 10-3. The regional geology of the Styx River Basin is shown on the geological map and cross section presented in Figure 10-3 and Figure 10-4.

The west-east geological cross section shown in Figure 10-4 is at the approximate latitude of the Project. An extended west-to-east geological cross section located to the south of the Project is shown on the Saint Lawrence 1:250,000 Geological Series map sheet (Bureau of Mineral Resources 1970). The relationship between geological units shown in Figure 10-4 is based on the geological interpretation and cross section from the Saint Lawrence map sheet.

**Table 10-3 Stratigraphy of Styx River Basin**

| Age (Ma) | Group | Formation | Description[1] |
|---|---|---|---|
| Cenozoic (0 to 66) | - | Cenozoic deposits | Alluvium, colluvium, soils, estuarine deposits, etc. |
| *Unconformity* | | | |
| Early Cretaceous (100 to 145) | - | Styx Coal Measures | Quartzose sandstone, mudstone, conglomerate and coal |
| *Unconformity* | | | |
| Late to Early Permian (251 to 268) | Back Creek Group | Boomer Formation | Lithic sandstone, siltstone, mudstone, rare conglomerate |
| | | | Quartzose to lithic sandstone, siltstone, mudstone, carbonaceous shale, calcareous sandstone and siltstone, conglomerate, coal, limestone and sandy coquinite |
| Early Permian (284 ± 7) | Lizzie Creek Volcanic Group | Carmila beds | Siltstone and mudstone, volcanilithic sandstone and conglomerate and minor altered basalt; local rhyolitic to dacitic ignimbrite and volcaniclastic rocks |
| *Unconformity* | | | |
| Early Permian to Late Carboniferous (300 to 306.5 ± 1.6) | Connors Volcanic Group | | Felsic to mafic volcanic rocks; rhyolitic to andesitic flows, high-level intrusives, and volcaniclastic rocks including ignimbrite |

[1] Australian Stratigraphic Units Database; http://www.ga.gov.au/data-pubs/data-standards/reference-databases/stratigraphic-units

In total, Styx Basin covers an area of approximately 2,000 km$^2$ and extends offshore to seawater depths of up to 100 m. The maximum known thickness of sedimentary rocks within the basin is reported as 387 m in an onshore coal exploration drillhole (Geoscience Australia 2017). However, magnetic data suggest that the basin thickens offshore to the north. The basin is thought to have developed by subsidence of the Strathmuir Synclinorium, an older (deeper) feature containing Permian strata of the Bowen Basin. Styx Basin sediments unconformably lap onto Permian rocks of the Back Creek Group in the west and are faulted against them in the east. The basin plunges gently to the north under the waters of Broad Sound but the general dip of the Styx Coal Measures is to the east, with outcrop and sub-crop beneath surface Cenozoic deposits occurring along the west and central side of the basin.

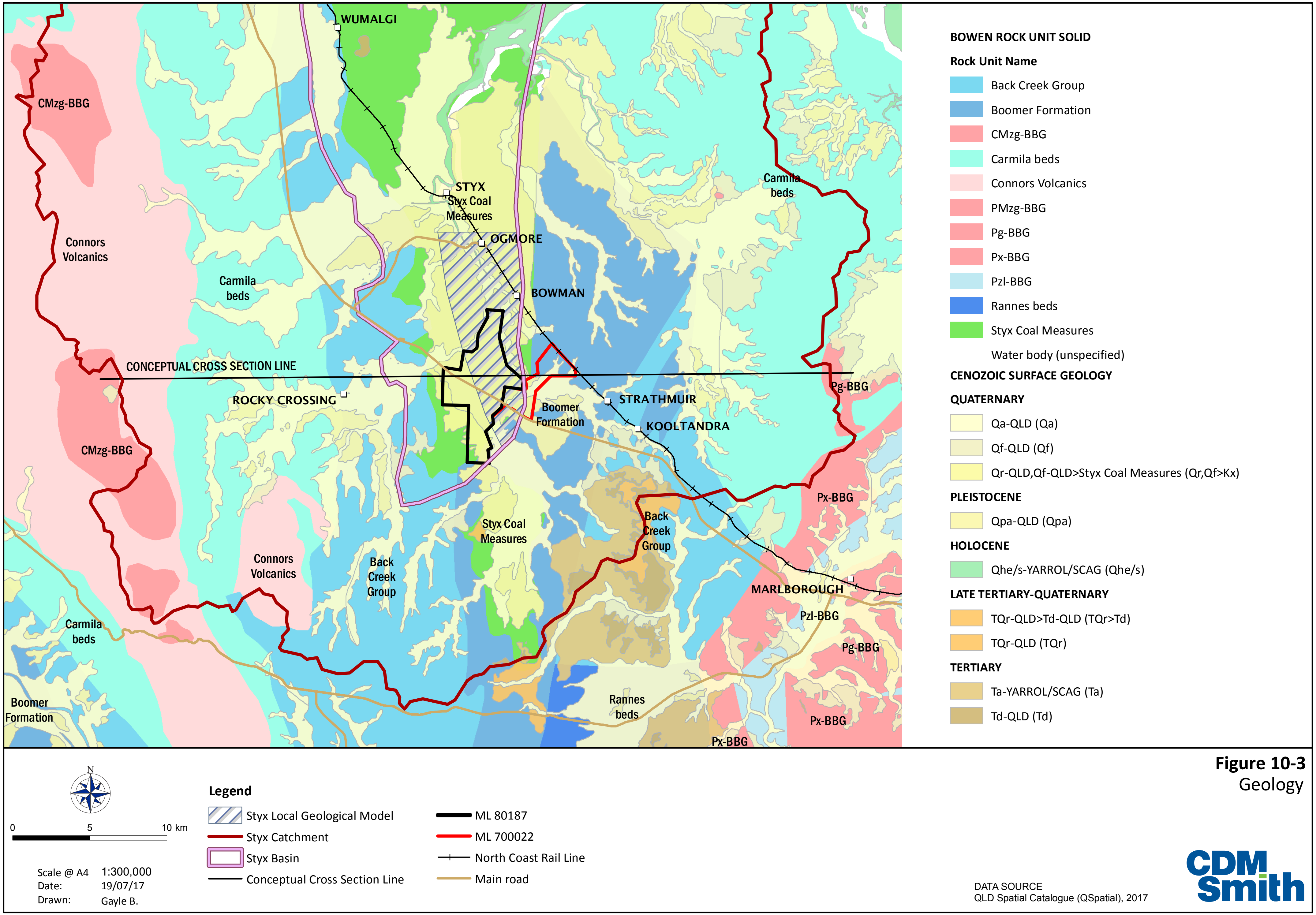



**Figure 10-3**
Geology

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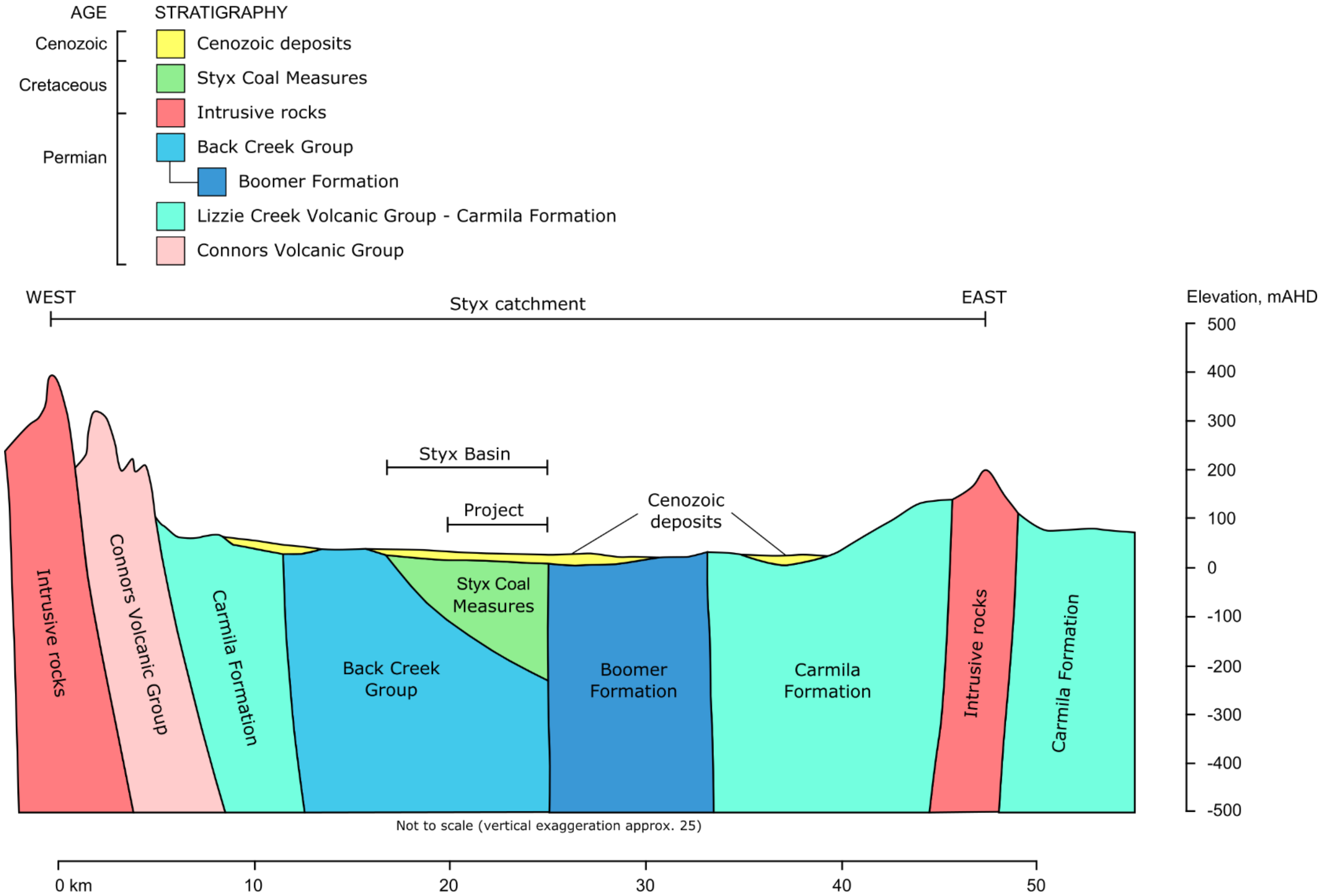


Refer alignment presented in Figure 10-3

**Figure 10-4 Schematic geological cross section**

The southern part of Styx Basin, where the Project is located, is bounded to the east by a post-depositional, high-angle reverse fault. Adjacent to the fault, the Cretaceous sedimentary rocks are folded and faulted. The sediments of the Styx Coal Measures are described in the Australian Stratigraphic Units Database as quartzose sandstone, mudstone, conglomerate and coal (Geoscience Australia 2017). The environments of sediment deposition were freshwater, deltaic to paludal (marsh) with occasional marine incursions.

Relatively few Cretaceous coal deposits are found in Queensland (Mutton 2003). They include thin seams of high-volatile bituminous coal that are present within the Styx Coal Measures, and within the Burrum Coal Measures of Maryborough Basin, which straddles the coast southeast of Styx Basin.

#### 10.5.3.2 Back Creek Group and Boomer Formation

The Permian Back Creek Group unconformably underlies Styx Basin sediments, and overlies the Lizzie Creek Volcanic Group (Carmilla Beds) with apparent conformity (Malone et al. 1969). In the Project area, the Back Creek Group extends north-south approximately sub-parallel, beneath and to the west of Styx Basin. The sediments of Back Creek Group are described in the Australian Stratigraphic Units Database as quartzose to lithic sandstone, siltstone, mudstone, carbonaceous shale, calcareous sandstone and siltstone, conglomerate, coal, limestone and sandy coquinite.

To the east of Styx Basin, the Back Creek Group is represented by Boomer Formation, which comprises of sediments derived from a volcanic terrain. The Boomer Formation is described in the Australian Stratigraphic Units Database as lithic sandstone, siltstone, mudstone and rare conglomerate.

#### 10.5.3.3 Lizzie Creek Volcanic Group - Carmila Beds

Permian sediments of the Carmila Beds underlie the Back Creek Group and unconformably overlie the Connors Volcanic Group. The Carmila Beds outcrop on and east of Connors Range, in a large area north of Marlborough, and on both sides and the southern end of Broad Sound Range (Malone et al. 1969). Near Tooloombah homestead and farther south (near the Project area) the Carmila beds have been described by Malone et al. as mainly of volcanolithic sediments, with primary volcanics constituting only about 20 percent. The Australian Stratigraphic Units Database describes the Carmila Beds as siltstone and mudstone, volcanilithic sandstone and conglomerate and minor altered basalt; local rhyolitic to dacitic ignimbrite and volcaniclastic rocks.

#### 10.5.3.4 Connors Volcanic Group

The Connors Volcanic Group consists mainly of Carboniferous to Early Permian massive volcanics that unconformably underlie Lizzie Creek Volcanic Group. The rocks of Connors Volcanic Group outcrop in a linear zone, the Connors Arch, to the west of Styx Basin and in association with Broad Sound Range. The Connors Volcanic Group are described in the Australian Stratigraphic Units Database as felsic to mafic volcanic rocks; rhyolitic to andesitic flows, high-level intrusives, and volcaniclastic rocks including ignimbrite.

#### 10.5.3.5 Geological Models

A regional geological model covering an area of around 30,000 $km^2$ has been developed for the groundwater modelling in this EIS, and is presented in Appendix A6 – Groundwater Technical Report. The local-scale geological model developed by Central Queensland Coal for resource assessment is local to the lease and covers a smaller area of around 50 $km^2$, as shown in Figure 10-3. The local geological model contains interpreted elevations and thicknesses of coal seams and interburden strata within the Styx Coal Measures as intersected by the resource drilling program.

### 10.5.4 Surface Water

The Project is wholly contained within the Styx River Basin, which is comprised of Styx River, Waverley and St Lawrence Creeks. The Project is bordered by two watercourses as defined under the Water Act, namely Tooloombah Creek and Deep Creek. These creeks meet at a confluence downstream of the Project area to form the Styx River.

Both watercourses are located outside the Project area; however, several of their tributary drainage features reside within the Project area. These drainage features are minor in nature, are ranked as either first or second order drainage features and are classified as non-perennial. This implies that the drainage features do not continually contain water and the stream flow is seasonal in nature and directly following rainfall events.

The catchment's upper reaches are steep with the water transported in defined channels but as the water reaches the middle region of the catchment (Project area), the topography flattens out with Deep Creek overflowing into the floodplain. This is consistent with survey data for the watercourses in the Project area, i.e. immediately upstream the bed elevation of Deep Creek is around 25 mAHD, whilst downstream near Ogmore the bed elevation of Styx River is around 4 mAHD. The normal tidal limit of Styx River occurs at around five or so metres, which likely makes the interaction between surface water and groundwater a sensitive issue for the Project.

Further information on surface water is presented in Chapter 9 - Surface Water.

### 10.5.5 Groundwater

The Bureau of Meteorology's (BoM's) National Groundwater Information System reports that Styx River Basin lies outside of declared groundwater management areas, including alluvial aquifer boundaries declared by the Department of Natural Resources and Mines (DNRM) (BoM nd). The BoM database lists the purposes of all bores located within Styx catchment as "unknown". The bore census conducted for the Project in 2011 found that most bores are used for stock watering, with some domestic use (Central Queensland Coal and Fairway Coal 2012).

The Groundwater Cartography product of the Australian Hydrological Geospatial Fabric (Geofabric) classifies Styx River Basin as "unknown" water table aquifer (BoM 2017). The surficial hydrogeological units hosting the water table are shown to consist mainly of Cenozoic alluvium within surface drainage areas and associated slopes, and fractured rock outcrops along ridgelines and higher areas between the alluvial deposits.

The Hydrogeology Map of Australia defines the regional hydrogeological divisions in Australia at scale 1:5,000,000 (Geoscience Australia 2017a). The aquifer types of Styx Basin are classified as porous extensive aquifers of low to moderate productivity, and the areas surrounding Styx Basin that are located within Styx River Basin are classified as fractured or fissured extensive aquifers of low to moderate productivity.

The groundwater system is understood to provide baseflow to perennial streams in the lower elevated areas of the river basin, and it is likely that some ecosystems in the lowlands of the river basin are reliant on groundwater resources, particularly during periods of prolonged drought (Central Queensland Coal and Fairway Coal 2012).

### 10.5.6 Hydrostratigraphic Units

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

The stratigraphic sequence of rocks within Styx River Basin is summarised in Table 10-3. None of the stratigraphic units in this sequence are recognised as aquifer HSUs. However, useful supplies of groundwater are present in the Cenozoic alluvial deposits and fractured zones of Cretaceous and Permian rocks.

Coal seams are not generally classified as aquifers because of typically low hydraulic conductivity values. However, within a sequence of coal seams and typical interburden rocks (such as claystone and shale) coal seams are sometimes referred to as 'aquifers' because they are more permeable than the much less-permeable interburden layers (IESC 2014).

The Styx Baseline Study (Yeats 2011) reported from the results of resource drilling programs that "there has been very little mention of water coming from the coals, though there have been some reports of salty water flows from the alluvium in the upper 50 m. However, based on discussions and data obtained from Waratah staff, Yeates (2011) reports groundwater was encountered during drilling in most boreholes, between 0 (i.e. ground level) and 30 m below ground between July 2010 and July 2011, at an average of 16 m across the preliminary investigation area".

### 10.5.7 Existing Users - Groundwater Bores

The Groundwater Database - Queensland (GWDBQ) contains records for 69 registered groundwater bores within the portion of Styx River Basin identified in Figure 10-5 (Queensland Government 2017). Of these, 15 bores (22%) are identified as DNRM bores and the remaining 54 bores (78%) have unspecified ownership but are likely to be privately owned. Most bores are located within, or at the fringes of the mapped Cenozoic deposits (see Figure 10-5), which signifies that the alluvium, and possibly geological structure that controls the occurrence and alignment of water courses, are targeted for local groundwater supplies.

Measured yields from Styx River Basin groundwater bores recorded in the GWDBQ are shown in Figure 10-6. The GWDBQ reports bore yield values from 41 bores that range from 0.02 L/s (less than 2 kL/d) and up to 5.7 L/s (approximately 0.5 ML/d). A frequency distribution of bore yield is shown in Table 10-4. Approximately half of the bores report yield values less than 1 L/s, and roughly three quarters report yield values less than 2 L/s. The remaining quarter of bores have yields greater than 2 L/s.

**Table 10-4 Frequency distribution of bore yields**

| Bore yield, L/s | Number of bores | Percent of bores, % |
|---|---|---|
| < 1 | 20 | 48.8 |
| 1 to 2 | 10 | 24.4 |
| 2 to 3 | 4 | 9.8 |
| 3 to 4 | 2 | 4.9 |
| 4 to 5 | 2 | 4.9 |
| 5 to 6 | 3 | 7.3 |
| **Total** | **41** | **100.0** |

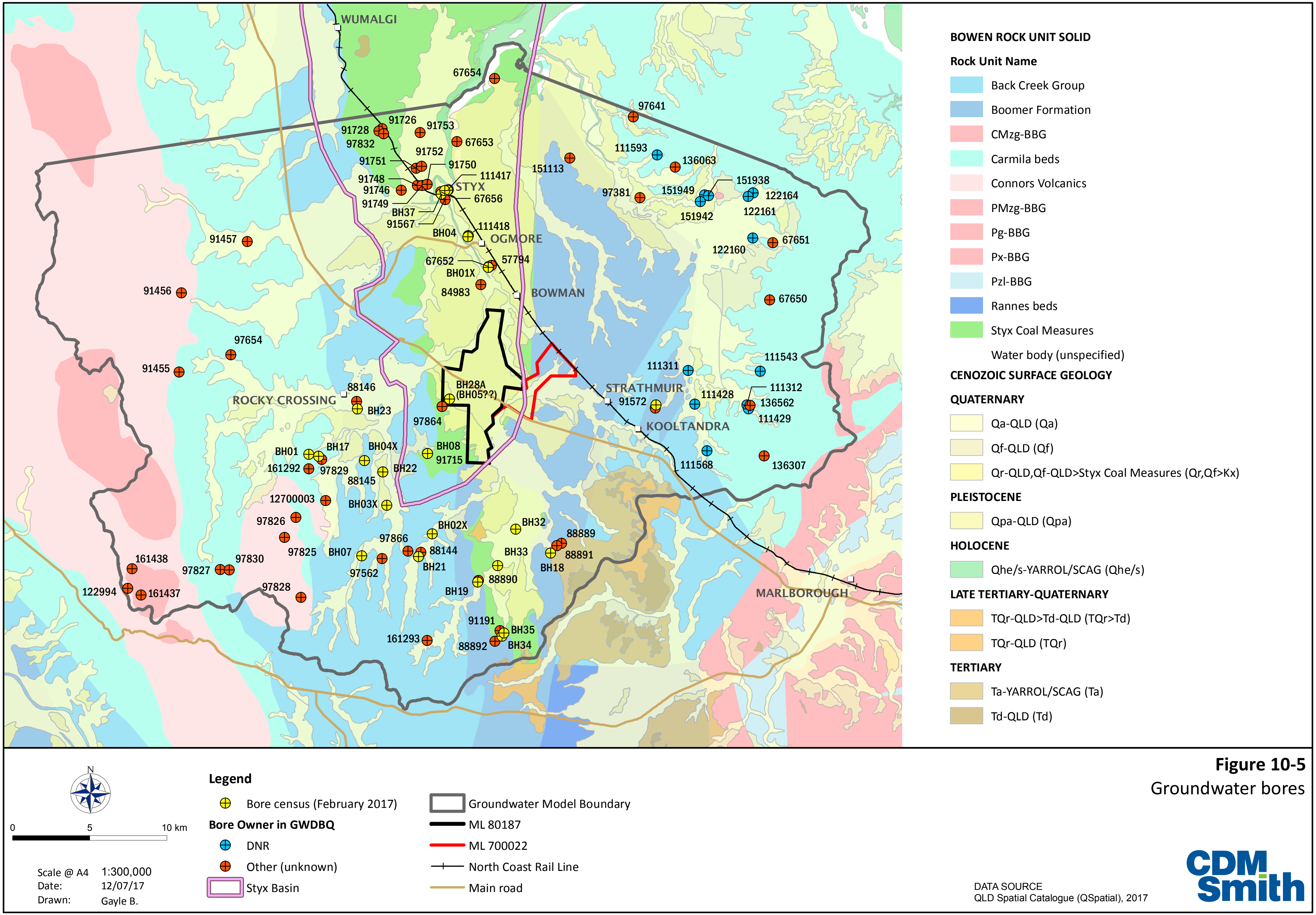


**Figure 10-5**
Groundwater bores

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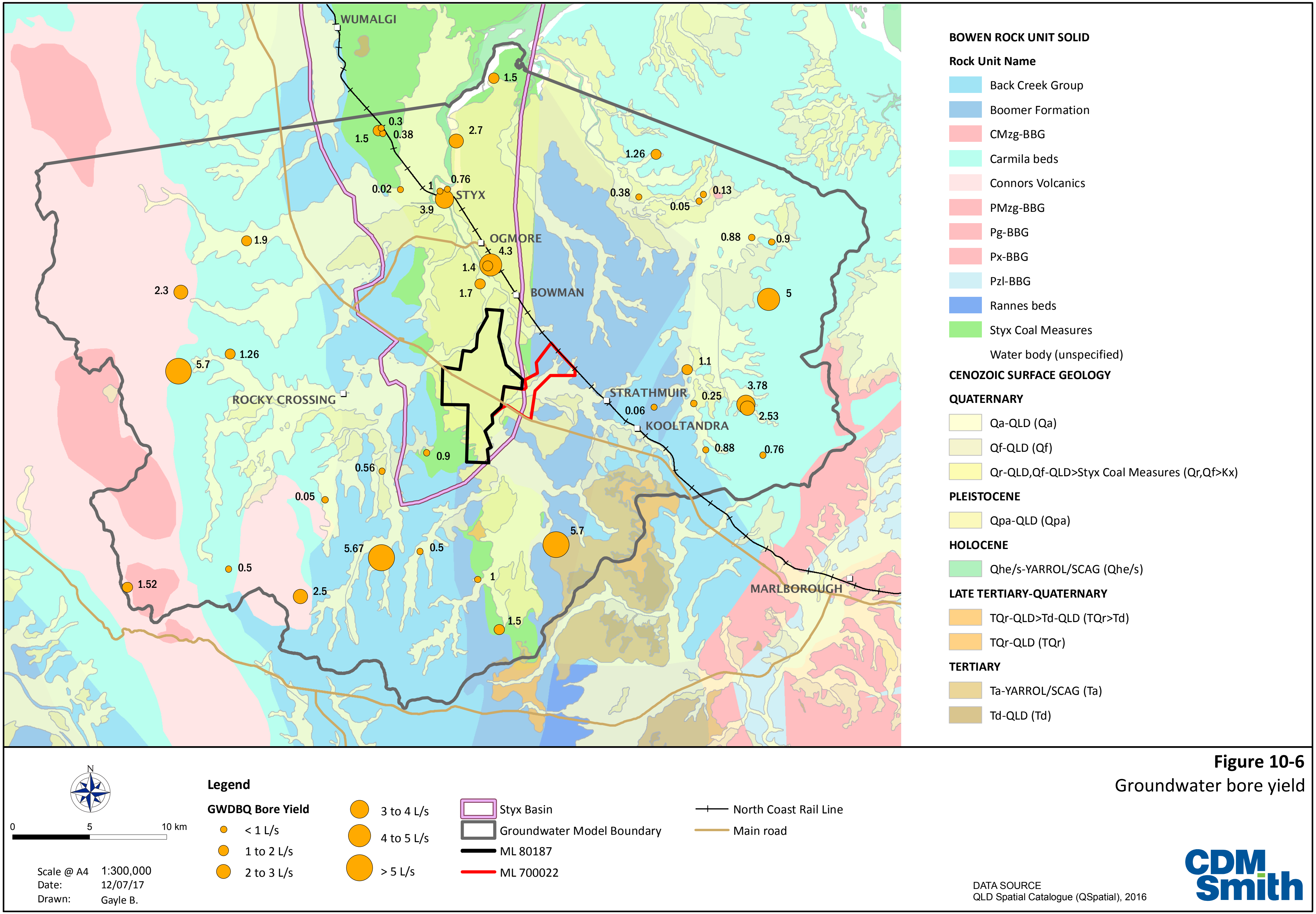


**Figure 10-6**
Groundwater bore yield

CDM Smith

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#### 10.5.7.1 Bore Census February 2017

A census of 30 regional third party groundwater bores was conducted by CDM Smith in February 2017. The bore locations are included on Figure 10-5 and a summary of the findings from the census is presented in Table 10-5 and Table 10-6. Depth to water level measurements were possible in 15 bores and collection of water samples were possible in four bores. The following general observations are made:

- Several bores identified from the GWDBQ were either found in different locations or could not be found;
- Bores that were not in use were generally in poor condition; and
- Pumping equipment present within some bores prevented access for measurement of water levels and collection of water samples.

**Table 10-5 Third party bores identified during the February 2017 bore census**

| Bore ID | GWDBQ RN | Easting, MGA55 | Northing, MGA55 | Elevation, mAHD | Field comment |
|---|---|---|---|---|---|
| BH16 | 67652? | 773592 | 749452 | 17 | One well open to air, no cap |
| BH20 | 57794? | 773592 | 749452 | 17 | Pump infrastructure installed |
| BH01X | Unknown | 773561 | 7494524 | 17 | Open well, no cap |
| BH01 | 161292? | 761920 | 7482423 | 67 | Mangled headworks |
| BH28 (BH05?) | 97864? / Windmill 10 | 771053 | 7485988 | 47 | Obstruction at 1.72 m |
| BH28A (BH05?) | 97864? / Windmill 10 | 771056 | 7485987 | 45 | Pump infrastructure installed |
| BH08 | 91715 | - | - | - | Access not approved |
| BH23 | 88146 | 765068 | 7485360 | - | Overgrown, unused, pump infrastructure installed |
| BH22 | 88145 | - | - | - | Lost or no longer exists |
| BH17 | 97829? | 762574 | 7482280 | - | Pump infrastructure installed, not accessible for measurements |
| BH07 | 97562 | 765346 | 7475831 | 198 | Solar pump installed and functional |
| BH06 | 97866/88144? | 769036 | 7475802 | 76 | Pump infrastructure installed |
| BH21 | 97866/88144? | 769040 | 7475799 | 87 | Pump infrastructure (windmill) installed |
| BH02X | Unknown | 769932 | 7477272 | 66 | Open well, disconnected pump infrastructure in well |
| BH03X | Unknown | 766972 | 7479111 | 64 | Solar pump installed and functional |
| BH04X | Unknown | 765542 | 7482007 | 55 | Pump infrastructure installed, domestic use |
| BH18 | 88891? | 777605 | 7476010 | 75 | Cement headworks, pump not in use |
| BH04 | 111418? | 772246 | 7496509 | 19 | No cap, bailer did not fit, possible surface ingress, pump infrastructure (windmill) installed, pumps to tank approx. 5 m away, not operating, stock watering |
| BH05X | Unknown | 770918 | 7499541 | 14 | Pump infrastructure installed, bailer could fit alongside pump and did not encounter obstruction, dipping also possible |
| BH38 | - | - | - | - | Could not find, lost or no longer exists |
| BH14 | - | - | - | - | Could not find, lost or no longer exists |
| BH36 | - | - | - | - | Could not find, lost or no longer exists |

**Table 10-5 Third party bores identified during the February 2017 bore census (cont.)**

| Bore | GWDBQ RN | Easting, MGA55 | Northing, MGA55 | Elevation, mAHD | Field comment |
|---|---|---|---|---|---|
| BH37 | Riverside 1 | 770505 | 7499287 | 12 | PVC casing, not used, broken stick up, cement headworks |
| BH6X | Unknown | 770732 | 7499500 | 13 | PVC casing, no cap, PVC with metal monument and concrete block, 12,000 ppm water quality (anecdotal from landowner), not in use, previously had windmill that blew over, formerly used to mix for concrete batching |
| BH33 | Neerim 2? | 774175 | 7475211 | 73 | PVC casing, no cap, not used, no headworks |
| BH32 | Neerim 1? | 775322 | 7477562 | 60 | PVC, no cap, not used |
| BH34 | Neerim 3? | 774433 | 7470634 | 109 | No cap, good condition, strong sulphurous odour, not used |
| BH35 | Neerim 4? | 774560 | 7470829 | 103 | Steel headworks, PVC casing, cement seal, headworks rusted, strong sulphurous odour, not in use |
| BH19 | New Bore 2? | 772863 | 7474143 | 84 | PVC casing, cement headworks, headworks rusted / broken, not used |
| BH13 | 91572? | 784427 | 7485608 | 84 | PVC casing, has cap, disconnected pump infrastructure, slug test attempted but obstruction encountered |

**Table 10-6 Measurements from the bore census in February 2017**

| Bore ID | Casing stick up, mAGL[1] | Casing diameter, m | Total depth, m | Depth to water, mBTC[2] | Water sample | Bore condition |
|---|---|---|---|---|---|---|
| BH16 | 0.26 | 0.147 | 9.4 | 5.37 | No | Poor |
| BH20 | | | | | No | Fair |
| BH01X | 0.3 | 0.124 | 10.8 | 6.75 | No | Poor |
| BH01 | | | | | No | Poor |
| BH28 (BH05?) | 0.2 | 0.125 | Unknown | Obstructed at 1.72 | No | Poor |
| BH28A (BH05?) | | | | | No | Fair |
| BH23 | 0.2 | | | | | Poor |
| BH17 | | | | | No | Fair |
| BH07 | 0.38 | 0.16 | NA | NA | Yes | Good |
| BH06 | 0.367 | 0.125 | 20.8 | 9.26 | No | Fair |
| BH21 | 0.72 | 0.135 | 15.2 | 9.12 | No | Fair |
| BH02X | 0.366 | 0.125 | 13.7 | 2.26 | No | Poor |
| BH03X | 0.38 | 0.15 | NA | NA | No | Good |
| BH04X | 0.35 | 0.155 | NA | NA | No | Good |
| BH18 | 0.13 | 0.14 | 14.2 | 5.95 | No | Poor |
| BH04 | 0.15 | 0.125 | 10.4 | 6.18 | No | Poor |
| BH05X | 0.16 | 0.14 | 10.8 | 6.57 | Yes | Fair |
| BH37 | 0.17 | 0.14 | 7.0 | Dry | No | - |
| BH6X | 0.24 | 0.14 | 9.2 | 6.36 | No | Poor |
| BH33 | 0.369 | 0.14 | 30.4 | 5.19 | No | Poor |
| BH32 | 0.14 | 0.14 | 9.2 | 2.24 | Yes | Poor |
| BH34 | 0.36 | 0.13 | 17.1 | 5.43 | Yes | Poor |
| BH35 | 0.295 | 0.14 | 12.1 | 2.57 | No | Poor |
| BH19 | 0.15 | 0.14 | 17.4 | 5.41 | No | Poor |
| BH13 | 0.33 | 0.14 | 31.1 | 12.9 | No | Poor |

[1] Metres above ground level; [2] Metres below top of casing

Further details of the results of the census are presented in Section 10.5.11.

## 10.5.8 Hydrogeological Properties

### 10.5.8.1 Aquifer Tests

The Groundwater Database - Queensland (GWDBQ) contains aquifer transmissivity values at the location of five bores screening the Cenozoic alluvial deposits at the locations shown in Figure 10-7. A summary of these data is presented in Table 10-7. The recorded values of transmissivity and hydraulic conductivity show moderate groundwater yields can be expected from relatively small aquifer intervals (0.7 to 4.6 m).

**Table 10-7 Results from aquifer pumping tests recorded in the GWDBQ**

| GWBDQ RN | HSU | Method | Duration, h | Interval, m | T, m²/d | K, m/d |
|---|---|---|---|---|---|---|
| 57794 | Alluvium | Pumping test | 24 | 3.4 | 412 | 121 |
| 84983 | Alluvium | Pumping test | 4.5 | 0.7 | 107 | 153 |
| 88144 | Alluvium | Pumping test | 2 | 1.8 | 59 | 33 |
| 88145 | Alluvium | Pumping test | 120 | 4.6 | 60 | 13 |
| 88146 | Alluvium | Pumping test | 2.6 | 1.9 | 6 | 3 |

GWDBQ – Groundwater Database - Queensland; T – Aquifer transmissivity; K – Hydraulic conductivity

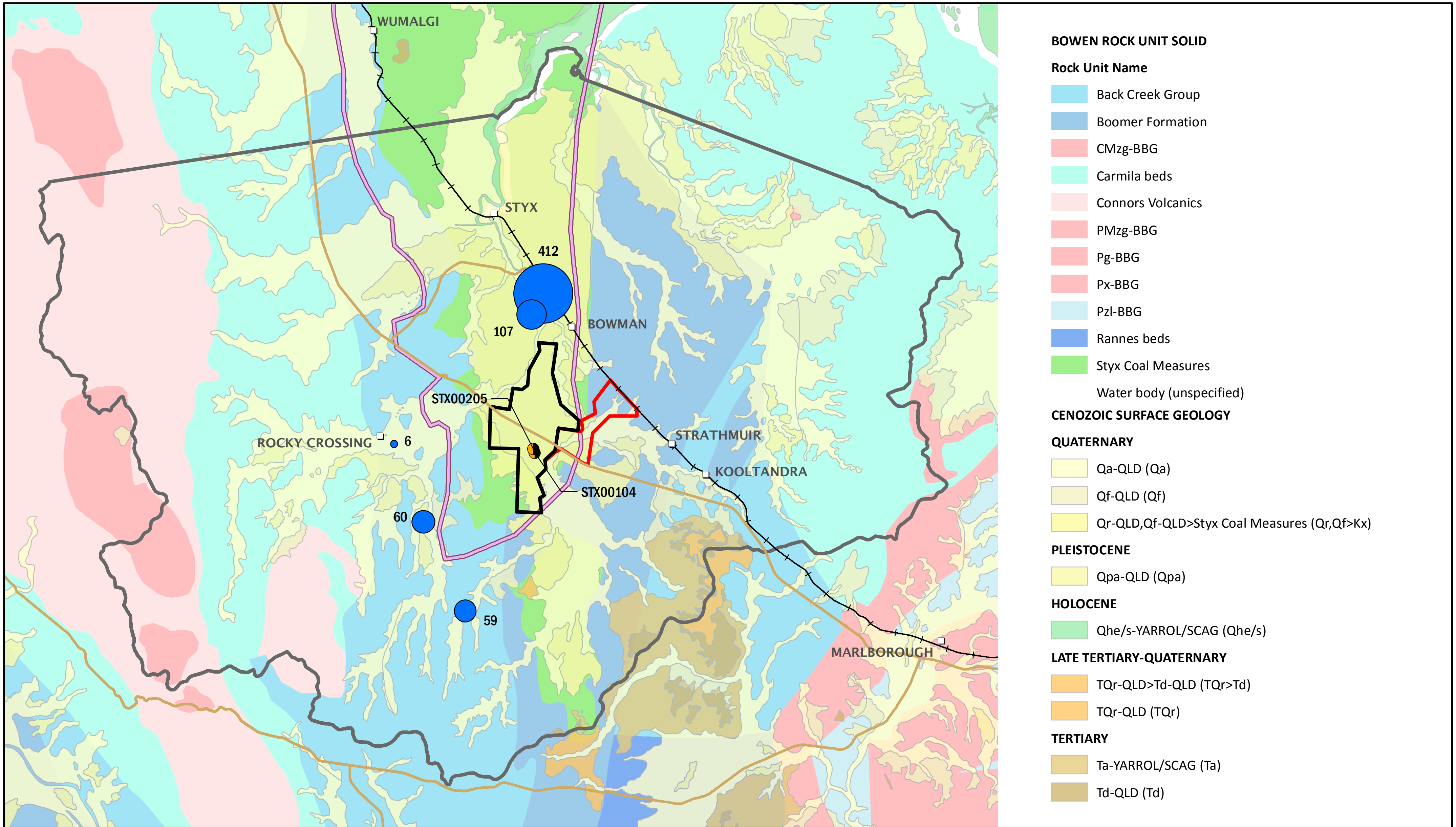
Groundwater investigations conducted for the Styx Trial Pit (AMEC 2014) included two aquifer air lift pumping tests undertaken at drillholes STX00104 and STX00205 but the results are inconclusive, likely due to the testing method, and a fault occurred during pumping of STX00205 that caused the test to be abandoned. The drillhole locations are shown in Figure 10-7 and a summary of the test results is presented in Table 10-8. In general, very low airlift yields were achieved during pumping, 0.03 L/s (approximately 2.6 kL/d) from STX00104 and 0.15 L/s (approximately 13 kL/d) from STX00205. The larger airlift rate from STX00205 was attributed to the presence of a gravel bed at the base of the "weathering" (located above the coal resource) and the presence of a 4-m thick coal seam.

**Table 10-8 Results from aquifer pumping tests for the Styx Trial Pit (AMEC 2014)**

| Bore ID | Method | Hole depth, m | Interval, m | Average airlift rate, L/s | T, m²/d | S |
|---|---|---|---|---|---|---|
| STX00104 | Air lift pump out | 81.5 | NR | 0.03 | 9.5 (drawdown STX170)<br>2.1 (drawdown STX00103)<br>5.2 (drawdown STX00204)<br>0.013 (recovery) | -<br>4.4E-6<br>8.0E-7<br>2.0E-7 |
| STX00205 | Air lift pump out | 88.3 | NR | 0.15 | 0.042 (recovery) | - |

NR – Not reported; T – Aquifer transmissivity; S – Aquifer storativity (dimensionless)

Estimated values of aquifer storativity from the pumping test of STX00205 are close to, and below, the lower limit of practical values that are expected from the compressibility of water and rock—noting that values of specific storativity less than approximately 1.0E-6 $m^{-1}$ are generally not anticipated on physical grounds. The small values of storativity indicate the observed responses at the observation bores were most likely caused by depressurisation of confined strata within the sequence intersected by the drillholes rather than drawdown of the water table.




N

0 5 10 km

Scale @ A4 1:300,000
Date: 29/06/17
Drawn: Gayle B.

**Legend**

**Aquifer Transmissivity $m^2/d$**

10
25
50
75
100

Styx drillholes
Styx Basin
Groundwater Model Boundary
ML 80187
ML 700022
North Coast Rail Line
Main road

**Figure 10-7**
Aquifer Transmissivity from GWDBQ

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2016

CDM Smith

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#### 10.5.8.2 Hydrogeological Properties from Literature Review

Review of information on the hydrogeological properties of geological units found within Styx River Basin is presented in Table 10-9. Not much of this information is derived from investigations or studies conducted within the basin. Where no relevant information has been found the values in the table are sourced from the literature, with values being consistent with sediment types for those units (e.g. Boomer Formation, Carmila Beds and Connors Volcanic Group).

Estimates of hydrogeological properties for Cretaceous coal measures in Queensland are hard to find. Some information was reported for the Maryborough Basin, which has a similar setting to Styx Basin, being located to the southeast (north of Brisbane) and straddling the coast with onshore and offshore parts. There is much more public information available about the hydrogeological properties of older and deeper Permian coal measures within Bowen Basin but the relevance to Cretaceous coal measures in the Styx Basin has not been established. In general, based on experience of Permian coal measures, there is an expectation that coal measures are more permeable than the overburden and underburden sediments that do not contain coal seams (i.e. the coal seams typically have the larger permeability. There is also an expectation the permeability of coal measures diminishes with burial depth due to compaction.

Information about the hydrogeological properties of the Back Creek Group is derived entirely from studies in the Bowen Basin. No examples from Styx Basin have been found. There is almost no information about the hydrogeological properties of the Lizzie Creek Volcanic Group and Connors Volcanic Group. Part of the reason for this lack of information is that none of these stratigraphic units are recognised as aquifers. In general, they contain sediments and rocks that are expected to exhibit hydrogeological properties consistent with very poor aquifers and aquitards.

The largest estimates of hydraulic conductivity are obtained for alluvial deposits and the fractured and weathered profile of surface exposures of rocks. These zones correspond to the shallow water-table aquifer targeted by farm and pastoral bores.

The available information for estimates of specific yield and storativity suggests that primary porosity of stratigraphic units is relatively small, with specific yield less than 0.05 (5%) and typically around 0.01 (1%).

**Table 10-9 Review of hydrogeological properties**

| Stratigraphic unit | Kh, m/d | Kv, m/d | Sy | Ss, 1/m | Location | Method | Source |
|---|---|---|---|---|---|---|---|
| Alluvium and / or fractured and weathered rock profile | 3 - 121<br>0.001 - 10<br>0.25 | -<br>-<br>0.025 | -<br>-<br>0.05 | -<br>-<br>1e-4 | Styx River Basin<br>N.A.<br>Maryborough Basin | Pumping tests<br>Textbook values<br>Groundwater modelling | 1<br>7<br>2 |
| Cretaceous coal measures - overburden | 0.0075 | 0.00075 | 0.01 | 1e-5 | Maryborough Basin | Groundwater modelling | 2 |
| Cretaceous coal measures - coal | 0.001 - 0.22 | 0.0001 - 0.022 | 0.01 | 1e-5 | Maryborough Basin | Groundwater modelling | 2 |
| Cretaceous coal measures - underburden | 0.005 | 0.0005 | 0.01 | 1e-5 | Maryborough Basin | Groundwater modelling | 2 |
| Cretaceous coal measures | 0.004 - 45.7<br>0.65 - 1 | -<br>- | -<br>- | -<br>- | Maryborough Basin<br>Maryborough Basin | Falling head tests (eleven)<br>Single pumping test | 2 |
| Boomer Formation - siltstone, mudstone, sandstone | 0.00001 - 0.1 | - | - | - | N.A. | Textbook values | 7 |
| Back Creek Group | 0.002 - 0.1<br>0.0001 - 0.01<br>0.025<br>0.0108<br>0.005<br>0.000108<br>0.000358 | -<br>0.00001 - 0.001<br>0.0025<br>0.00108<br>0.0005<br>0.0000108<br>0.00000952 | -<br>0.03 - 0.18<br>-<br>-<br>0.05<br>0.03<br>0.0005 | -<br>5e-6 - 5e-4<br>-<br>-<br>1e-5<br>1e-5<br>6.07e-6 | Bowen Basin<br>Bowen Basin<br>Bowen Basin<br>Bowen Basin<br>Bowen Basin<br>Bowen Basin<br>Bowen Basin | Literature review<br>Literature review<br>Groundwater modelling<br>Groundwater modelling<br>Groundwater modelling<br>Groundwater modelling<br>Groundwater modelling | 3<br>3<br>3<br>3<br>3<br>4<br>5 |
| Carmila beds - siltstone, mudstone, sandstone | 0.00001 - 0.1 | - | - | - | N.A. | Textbook values | 7 |
| Lizzie Creek Volcanic Group | 0.0000009 | 0.000001 | 0.0001 | 1e-6 | Bowen Basin | Groundwater modelling | 6 |
| Connors Volcanic Group | 0 - 0.00001 | - | - | - | N.A. | Textbook values | 7 |

Symbols: Kh – Horizontal hydraulic conductivity; Kv – Vertical hydraulic conductivity; Sy – Specific yield; Ss – Specific storativity

Sources: 1. Groundwater Database - Queensland (GWDBQ); 2. AGE (2010); 3. URS (2012); 4. URS (2013); 5. AGE (2014); 6. Drake Coal (2014); 7. Textbook values (Bear 1972, Bouwer 1978, Freeze and Cherry 1979)

### 10.5.9 Water Table Elevation and Hydraulic Head

Observations of groundwater pressures / levels within Styx River Basin are mainly restricted to one (or several) measurements of depth to water table in individual groundwater bores. While historical time-series observations of water table elevation and hydraulic head are not identified within the river basin, a project monitoring network has been implemented and will undergo expansion during 2017 and onwards. At present the network provides a relatively comprehensive intra-annual dataset that will be complemented by inter-annual data as the monitoring progresses over time. For this reason, the model is calibrated in steady-state (see Appendix A6 – Groundwater Technical Report). A transient calibration using the acquired monitoring data network will be possible with future iterations of the modelling.

Figure 10-8 shows measurements of water table elevation in 48 bores that vary from approximately 1 mAHD near to the estuarine reach of Styx River (north of the Project) to approximately 100 mAHD near to the river basin boundary (south of the Project). In general, the elevation of the water table is a subdues reflection of regional topography, being higher in upland areas and lower in lowland areas. Multi-depth measurements of hydraulic head (e.g. nested monitoring bores) that could assist in defining vertical head gradients have not been identified.

Values of water-table elevation in Figure 10-8 are calculated by subtracting measurements of depth to water table from ground surface elevations at the bore locations, which have been extracted from 1 second (30 metre) SRTM digital elevation data (Gallant et al. 2011). Some of the variation in water table elevation seen in these derived data may be the result of inaccuracies in the bore locations, inaccuracies in the STRM data, differences between ground surface elevation and the reference elevations that was used for measuring depth at the bores, or a combination of these factors.

### 10.5.10 Groundwater Flow System

The groundwater flow system within the Styx River Basin is a combination of intermediate and local flow systems that are driven by diffuse groundwater recharge from rainfall across Styx River Basin, slow subsurface drainage of groundwater toward the ocean, and discharge of groundwater by seepage and evapotranspiration along topographic depressions associated with watercourses, and at the coast and estuarine reaches of tidal rivers and creeks.

Measurements of groundwater recharge rates specific to Styx River Basin have not been not identified in this assessment, and a review of Australian groundwater recharge studies by Crosbie et al. (2010) found there have been comparatively few published recharge studies in Queensland in the region of the Project. Based on the Method of Last Resort (MOLR) developed for data poor areas, the national map of groundwater recharge produced by Leaney et al. (2011) shows that the MOLR groundwater recharge rate within Styx River Basin is in the range 1 to 5 mm/y, which is equivalent to 0.1% to 0.7% of the long-term, mean annual rainfall of 755 mm/y at Strathmuir (BoM Station 33189), which is located approximately 8 km from the Project site.

From the available observations of water-table elevation, the regional direction of groundwater flow generally follows topography, with movement from the direction of the river-basin boundary down slope toward the ocean and water courses (refer to Figure 10-8). A saltwater interface is expected within shallow groundwater at the coast. However, there are no known measurements of deep groundwater pressure at the coast that would indicate there is flow of terrestrial groundwater offshore within Styx Basin (e.g., artesian groundwater pressure at the coast).

Local directions of shallow groundwater flow within alluvium are likely to vary in response to local topography with flow toward areas of groundwater discharge along watercourses and associated riparian vegetation. There are insufficient data to provide an interpreted contour map of the water table or to construct a meaningful groundwater flownet over the river basin. However, the calibrated groundwater model provides an impression of regional- and local-scale groundwater flow within the area of the model domain (refer to Section 10.6.2).

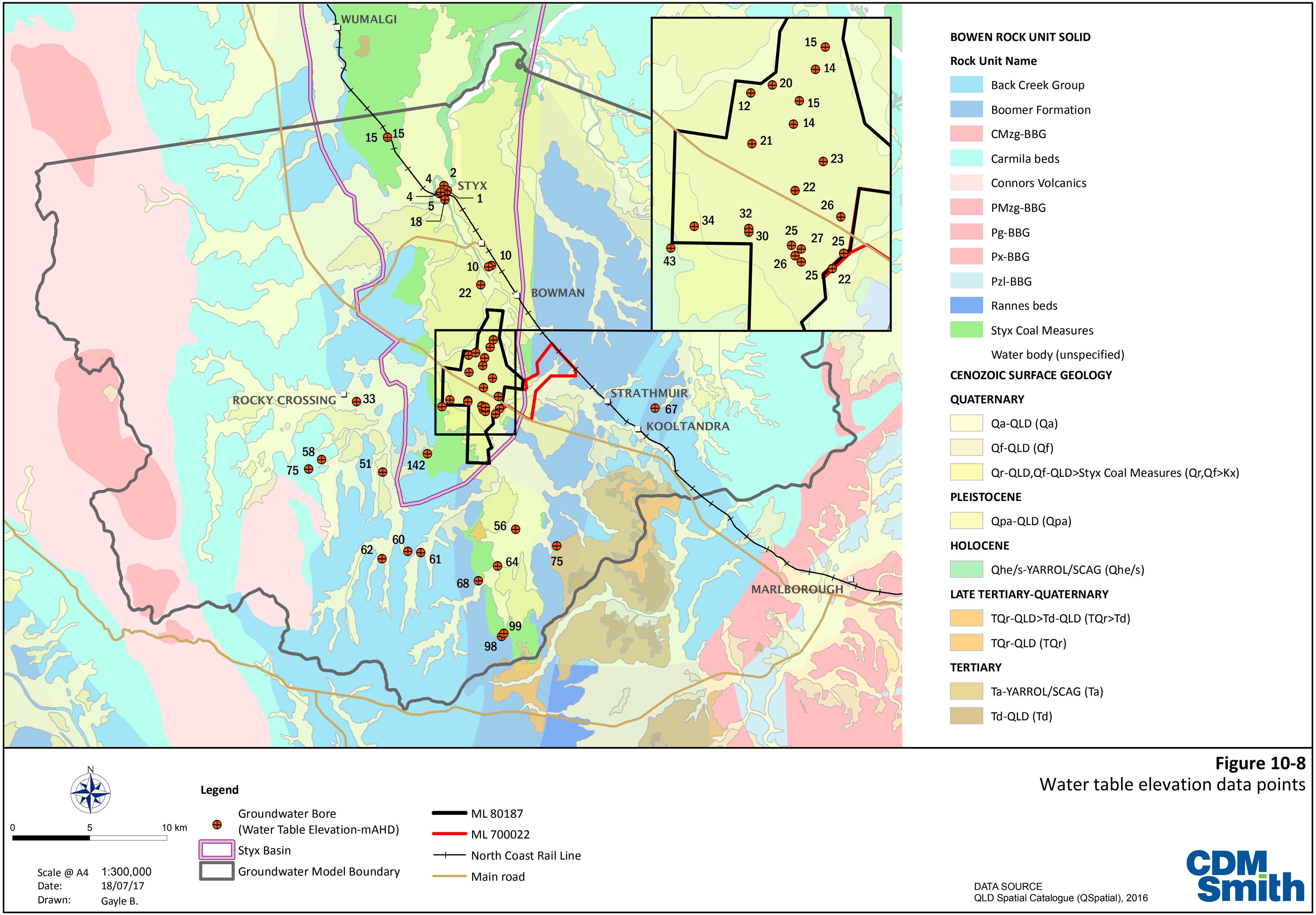


**Figure 10-8**
Water table elevation data points

## 10.5.11 Groundwater Chemistry

### 10.5.11.1 Overview

Groundwater chemistry provides an understanding of the existing baseline condition for groundwater resources and can assist in the interpretation of groundwater flow systems. Groundwater chemistry is influenced by multiple factors including hydrogeological and mineralogical properties of aquifers, sources of recharge, locations and form of discharge, groundwater flow rates and age, and anthropogenic effects.

Groundwater EVs defined as part of the Styx River, Shoalwater Creek and Water Park Creek Basins Environmental Values and Water Quality Objectives (EHP 2014) include aquatic ecosystems, irrigation, farm supply and use, and cultural and spiritual values. In this assessment., concentrations of chemicals in groundwater are compared against the Australian and New Zealand Guidelines (ANZECC Guidelines) (ANZECC and ARMCANZ 2000) that are relevant to protection of freshwater aquatic ecosystems and stock drinking water, and the Australian Drinking Water Quality Guidelines (ADWG) (NHMRC, NRMMC 2011), and WQOs set for the three GCZs within the area that may be impacted by the proposed mine.

Although there is limited information to assist in assigning aquifers to privately owned bores, Figure 10-9 indicates that the greater proportion of bores within the Styx Basin are likely to be associated with alluvial aquifers or the Styx Coal Measures. These are the two primary 'aquifers' of the study area, although it is likely the coal seams present regionally as mostly low-permeability and heterogeneous aquifers. Appendix A6 – Groundwater Technical Report presents discussion on the information and data supporting the hydrogeological conceptualisation.

### 10.5.11.2 Salinity and Major Ions

The results of a review of groundwater salinity data and major ion concentrations recorded in the GWDBQ are summarised in Table 10-10, with salinity data and major ion concentrations groundwater sampled from selected bores included in the census summarised in Table 10-11. The locations of these groundwater bores and the dominant water types are shown in Figure 10-9, with the classification of water types based on analysis using a Durov plot, which is presented in Figure 10-10. Figure 10-10 presents GWDBQ data as well as comprehensive data reported for other wells and surface water monitoring locations within the Styx Basin.

Groundwater salinity (as total dissolved solids; TDS) is variable across the Styx River Basin, ranging from drinking water quality (TDS < 600 mg/L) to water quality unacceptable for drinking (TDS > 1,200 mg/L) and even livestock (TDS > 5,000 mg/L). Figure 10-10 presents these observations as a Durov plot. More generally though, reported TDS concentrations are mostly below the salinity tolerance of most livestock (TDS <5,000 mg/L).

Dominant ion chemistry tends to be either sodium-chloride (Na-Cl) type or no dominant type. Sodium-chloride type waters are consistent with ocean derived salts mixed with rainfall recharge, or mixing of terrestrial groundwater and marine groundwater in areas of seawater intrusion at the coast. Groundwater that is not Na-Cl type typically signifies geochemical interactions between recharging groundwater and subsurface minerals. From visual inspection of the available data, definitive spatial patterns in the relationship between water type and salinity are not obvious. Locations near the estuarine reach of Styx River where there is higher-salinity groundwater of Na-Cl type may be associated with seawater intrusion. Locations reporting fresher groundwater, e.g. near the Project and non-estuarine reaches of the Styx River, may indicate areas of enhanced recharge from rainfall or infiltration of surface water.

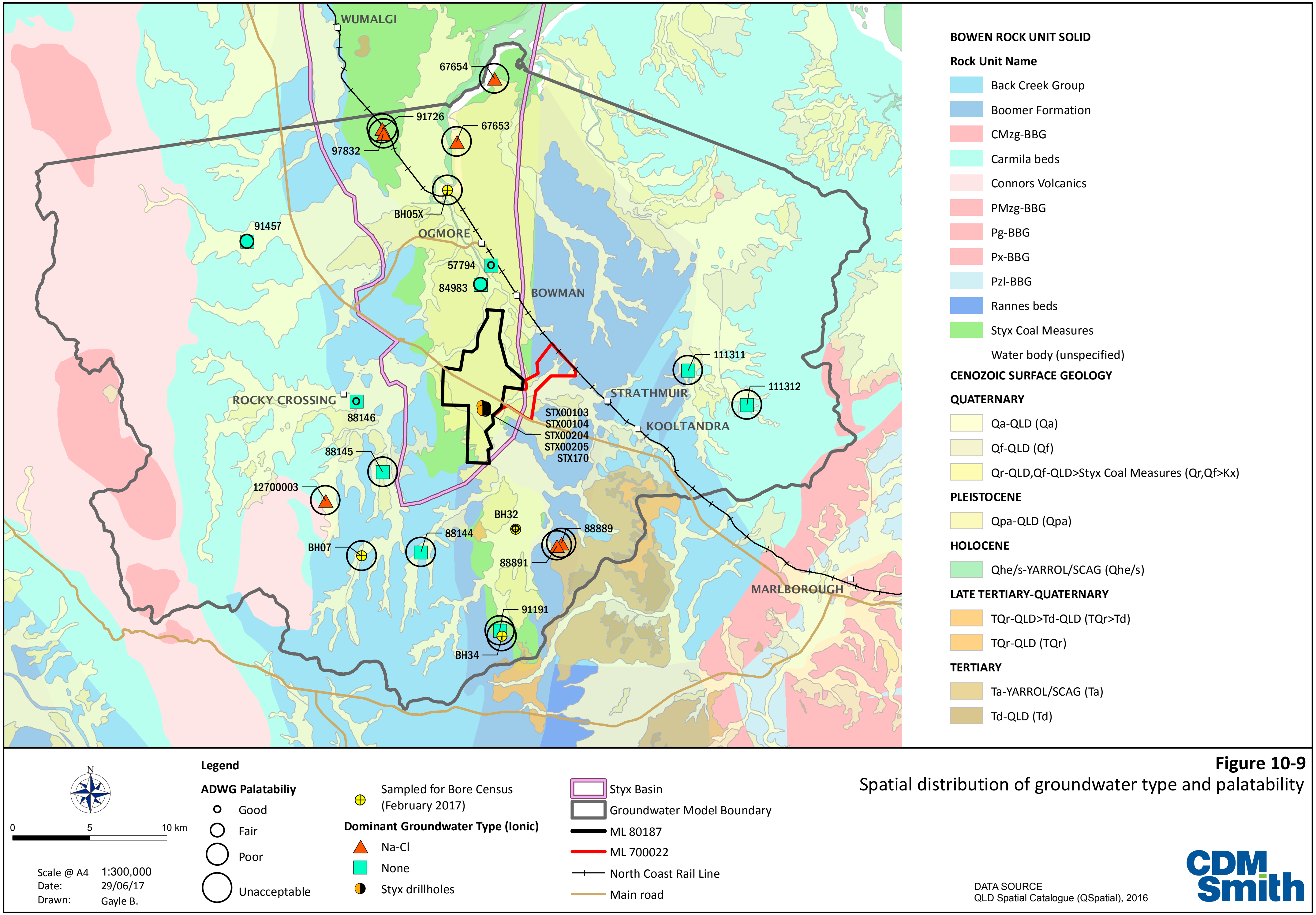


**Figure 10-9**
Spatial distribution of groundwater type and palatability

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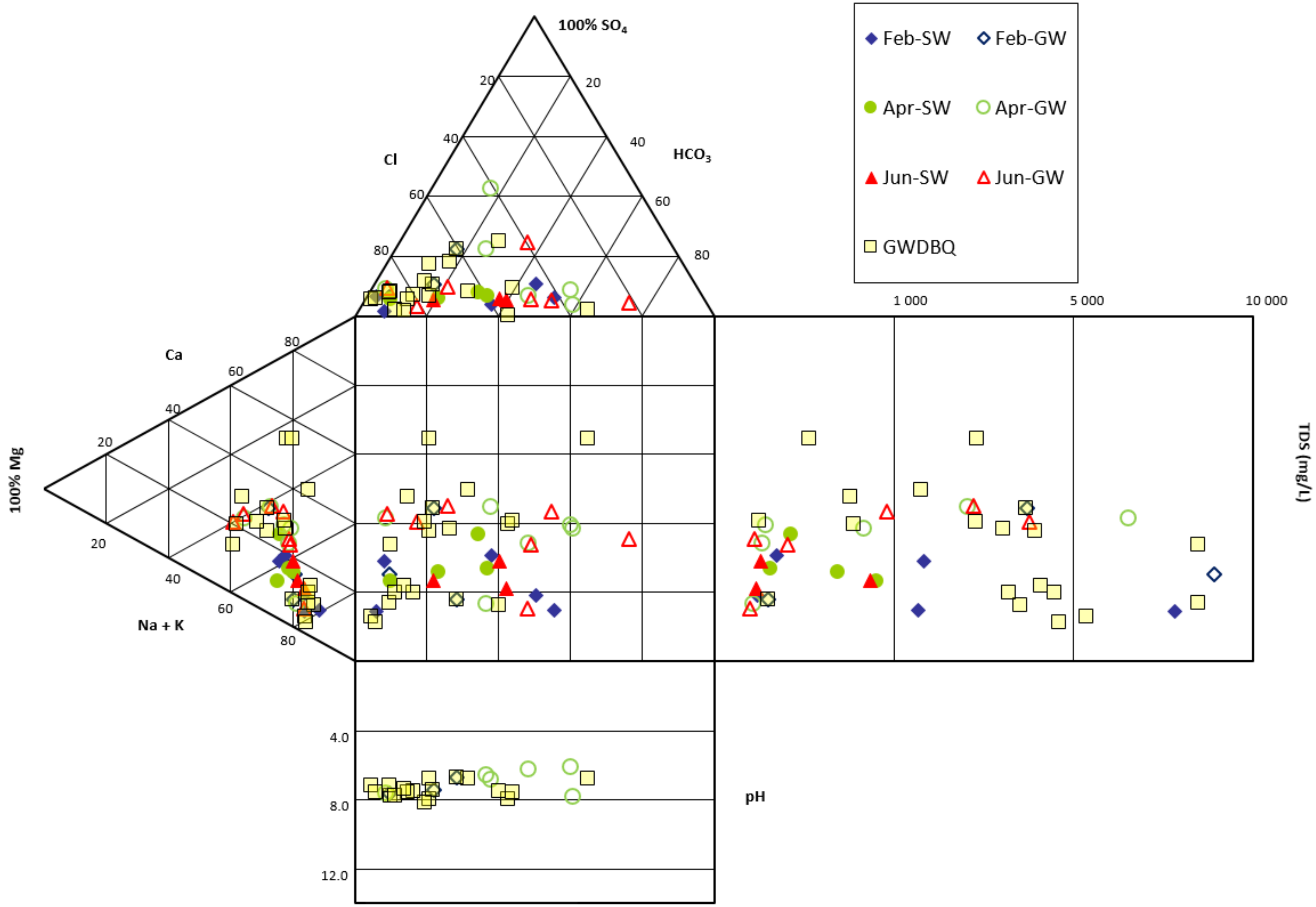



**Figure 10-10 Durov plot of regional groundwater quality from GWDBQ and 2017 sampling programs**

**Table 10-10 Reported groundwater salinity and ionic water type**

| GWDBQ RN | No. of samples | Water type (ionic) | TDS[1], mg/L | ADWG palatability[2] | ANZECC stock suitability[3] | pH |
|---|---|---|---|---|---|---|
| 57794 | 1 | None | 250 | Good | Acceptable | 7.6 |
| 67653 | 1 | Na-Cl | 3,576 | Unacceptable | Acceptable | 7.5 |
| 67654 | 1 | Na-Cl | 8,487 | Unacceptable | Acceptable | 7.2 |
| 84983 | 1 | None | 757 | Fair | Acceptable | 7.6 |
| 88144 | 1 | None | 2,863 | Unacceptable | Acceptable | 6.8 |
| 88145 | 1 | None | 1,621 | Unacceptable | Acceptable | 6.8 |
| 88146 | 1 | None | 529 | Good | Acceptable | 6.8 |
| 88889 | 2 | Na-Cl | 4,684 | Unacceptable | Acceptable | 7.6 |
| 88891 | 2 | Na-Cl | 5,370 | Unacceptable | Unacceptable | 7.2 |
| 91191 | 2 | None | 4,151 | Unacceptable | Acceptable | 8.0 |
| 91457 | 1 | None | 777 | Fair | Acceptable | 8.0 |
| 91726 | 1 | Na-Cl | 4,587 | Unacceptable | Acceptable | 7.8 |
| 97832 | 1 | Na-Cl | 4,294 | Unacceptable | Acceptable | 7.4 |
| 111311 | 1 | None | 8,487 | Unacceptable | Unacceptable | 7.8 |
| 111312 | 1 | None | 2,822 | Unacceptable | Acceptable | 8.2 |
| 12700003 | 1 | Na-Cl | 3,815 | Unacceptable | Acceptable | 7.5 |

[1] TDS – Total dissolved solids concentration
[2] ADWG palatability - Australian Drinking Water Quality Guidelines (NHMRC, NRMMC 2011): Good (TDS 0 - 600 mg/L), Fair (TDS 600 = 900 mg/L); Poor (TDS 900 – 1,200 mg/L, Unacceptable (TDS >1,200 mg/L)
[3] ANZECC stock suitability - Australian and New Zealand Guidelines (ANZECC & ARMCANZ 2000): Acceptable (2,000 – 5,000 mg/L), Unacceptable (>5,000 mg/L)

**Table 10-11 Selected groundwater salinity and pH recorded during 2017 sampling programs**

| Well ID | EC[1], µS/cm | TDS[2], mg/L | ADWG palatability[3] | ANZECC stock suitability[3] | pH |
|---|---|---|---|---|---|
| BH05X | 11,800 | 8,920 | Unacceptable | Unacceptable | 7.65 |
| BH07 | 5,419 | 3,251 | Unacceptable | Acceptable | 6.68 |
| BH32 | 430 | 300 | Good | Acceptable | 6.71 |
| BH34 | 5,220 | 3,960 | Unacceptable | Acceptable | 7.65 |

[1] EC - Electrical conductivity
[2] TDS - Total dissolved solids concentration based on approximate conversion from EC: 1 µS/cm approx. equals 0.6 mg/L TDS
[3] See Table 10-10

### 10.5.11.3 Dissolved Metals

There are few data for dissolved metals concentrations in groundwater held on the GWDBQ for Styx River Basin. Three sampling analytical programs have been undertaken specifically for the Project in 2017. These sampling events occurred in February, May and June. Dissolved metals were analysed[1] and several metals showed results above the ANZECC Guidelines and/or the ADGW. The number of exceedances is presented in Table 10-12. The groundwater results for the 2017 sampling program is provided in Appendix 5a – Surface Water and Groundwater Quality Results.

The GWDBQ contains exceedance of the ANZECC Guidelines for protection of ecosystems with 95% protection level for one aluminium, two for copper and four for zinc (see Table 10-12). Groundwater from one bore is recorded as having a dissolved zinc concentration of 18 mg/L (single measurement) which exceeds the ADWG and is close to the ANZECC Guideline value for stock water.

The data from the three 2017 monitoring events show levels of aluminium, arsenic, copper, lead, manganese and iron. Lead and iron are consistently elevated above the guidelines throughout the monitoring events and across sites. Bores BH30 and BH6X consistently displayed elevated arsenic levels. Manganese levels were only elevated in the May sampling event with lower levels potentially a result of increased oxygenation conditions following rain recharge events. Levels of copper were

[1] Al, As, Ba, Cd, Cr, Cu, Ni, Pb, Zn, Mn, Mb, Se, Ag, U, V, Hg

generally low although exceeded the guidelines for ecosystem protection on two occasions during different months and different wells.

**Table 10-12 Reported dissolved metal concentrations (above the level of reporting)**

| Metals | ADWG[1] | ANZECC[2] | | | Reported concentrations | | |
|---|---|---|---|---|---|---|---|
| | | Irrigation | Stock water | Ecosystems | Detection Range (mg/L) | No. of bores | No. of Exceedances |
| **GWDBQ data** | | | | | | | |
| Aluminium | 0.2 | 5 | 5 | 0.0055 | **0.01** | 1 | 1 |
| Copper | 2 | 0.2 | 0.4 | 0.0014 | **0.02 – 0.05** | 2 | 2 |
| Zinc | 3 | 2 | 20 | 0.008 | **0.03 – 18** | 4 | 4 |
| **2017 sampling events** | | | | | | | |
| Aluminium | 0.2 | 5 | 5 | 0.0055 | **0.01** | 1 | 1 |
| Arsenic | 0.01 | 0.1 | 0.5 | 0.0024 | **0.001 – 0.052** | 4 | 6 |
| Copper | 2 | 0.2 | 0.4 | 0.0014 | **0.001 – 0.002** | 2 | 2 |
| Lead | 0.01 | 2 | 0.1 | 0.0034 | **0.006 – 3.41** | 9 | 10 |
| Manganese | 0.1 | 10 | - | 0.19 | **0.006 – 2.98** | 6 | 6 |
| Iron | 0.3 | 0.2 | - | - | **0.15 – 8.91** | 6 | 10 |

[1] ADWG - Australian Drinking Water Quality Guidelines (NHMRC, NRMMC 2011)
[2] ANZECC - Australian and New Zealand Guidelines (ANZECC & ARMCANZ 2000)
Bolded values signify exceedance of the ANZECC Guideline value for ecosystems with 95% protection level, Shaded cells signify exceedance of ADWG

#### 10.5.11.4 Water Quality Objectives

A comparison of water quality data for wells located in each of the Project area GCZs (Styx, Uplands and Bison) with WQOs for those GCZs is presented in Table 10-13, Table 10-14 and Table 10-15. As shown, the available water quality data are relatively consistent with the WQOs, with the following exceptions (in terms of EC):

- Bore 111311 located in the Styx GCZ some 10 km east of the Project;
- Bores 88889, 88891 and BH34 located in the Uplands GCZ more than 8 km south of the Project; and
- Bore 111312 located in the Uplands GCZ more than 10 km east of the Project.

### 10.5.12 Conceptual Hydrogeological Model

An overview of the conceptual hydrogeological model for Styx River Basin is presented in Figure 10-11. At the broadest level, the basin contains usable but relatively low capacity groundwater supplies from shallow water table aquifers that are largely hosted in unconsolidated Cenozoic surface deposits, particularly within the alluvial infill sediments associated with surface drainages but also within fractured and weathered zones of outcropping Cretaceous rocks and older Permian rocks. The deeper sedimentary and volcanic rocks underlying the Cenozoic surface deposits and below the zone of surface fracturing and weathering have much lower permeability and are not known to yield useable groundwater supplies.

In this conceptualisation, shallow unconfined groundwater flow in Cenozoic sediments and fractured and weathered rocks within Styx River Basin is driven by diffuse groundwater recharge from rainfall within the basin. The water table slopes generally toward the ocean but locally follows topographic relief, with depth to water table typically in the range 2 to 15 m (based on gauging from existing groundwater bores dependent on location). Most groundwater discharge likely occurs by evapotranspiration from topographic lows, particularly along the surface drainage network, including evaporation from surface pools and bank seepage, and transpiration by riparian vegetation communities that access groundwater within their root zones. The main processes for interaction between groundwater and surface water are episodic groundwater recharge along flowing watercourses during wet periods, and groundwater discharge to watercourses that intersect the water table during dry periods.

## 10.5.13 Groundwater Dependent Ecosystems

### 10.5.13.1 Overview

Whilst regional groundwater systems provide water sources for pastoral and other anthropogenic uses, groundwater also supports surface (above ground) and subsurface (below ground) ecosystems that are assessed as beneficial users of these resources. The Australian groundwater dependent-ecosystem (GDE) toolbox (Richardson et al. 2011) provides a framework to assist with the identification of GDEs and the management of their water requirements. The toolbox adopts the approach of Eamus et al. (2006) and classifies GDEs based on the role groundwater plays in maintaining biodiversity and ecological condition. Three types of GDEs are defined:

- Aquifer and cave ecosystems (Type 1 GDEs) where groundwater-inhabiting ecosystems reside (e.g. stygofauna). These ecosystems typically include karst aquifer systems and fractured rock groundwater environments;

- Ecosystems dependent on the surface expression of groundwater (Type 2 GDEs), including wetlands, lakes, seeps, springs, and river baseflow systems. In these cases, surface expression of groundwater exists, providing water that can support aquatic biodiversity through access to habitat (especially when surface run-off is low) and regulation of water chemistry and temperature; and

- Ecosystems dependent on subsurface presence of groundwater (Type 3 GDEs), including terrestrial vegetation that depends on groundwater either seasonally, episodically or permanently to prevent water stress and avoid adverse impacts to their condition. Groundwater that Type 3 GDEs depend on is not visible from above ground. Type 3 GDEs can exist wherever the water table and capillary fringe is within the root zone of the plants, either permanently or episodically. The capillary fringe is the saturated zone of soil above the water table.

**Table 10-13 Styx GCZ WQOs for groundwater resources**

| Depth² | Percentile | Indicator / WQO¹ | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Na | Ca | Mg | HCO3 | Cl | SO4 | NO3 | EC | Hardness | pH (units) | Alkalinity | SiO2 | F | Fe | Mn | Zn | Cu | SAR (unitless) | RAH (meq/L) |
| **GCZ** | **Styx** | | | | | | | | | | | | | | | | | | | |
| S | 20th | 781 | 95 | 163 | 326 | 1,727 | 164 | - | 6,445 | 867 | 7.5 | 272.5 | 23 | 0.32 | - | 0.035 | 0.039 | - | 7.6 | |
| | 50th | 1,296 | 222 | 209 | 583 | 2,342 | 301 | 0.00 | 7,620 | 1,346 | 7.7 | 478.5 | 30 | 0.68 | - | 0.165 | 0.140 | 0.010 | 15.3 | |
| | 80th | 1,564 | 315 | 310 | 628 | 3,607 | 653 | 3.26 | 9,887 | 1,995 | 8.0 | 524.5 | 33 | 1.07 | 0.09 | 0.478 | 12.67 | 0.041 | 22.6 | |
| M | 20th | 763 | 35 | 137 | 52 | 1,617 | 18 | 0.65 | 5,457 | 711 | 5.1 | 42.5 | 30 | 0.47 | - | 0.105 | 0.144 | 0.071 | 11.25 | |
| | 50th | 1,062 | 70 | 185 | 105 | 2,094 | 100 | 2.00 | 7,380 | 1,121 | 7.2 | 86.0 | 43 | 0.60 | - | 0.330 | 0.900 | 0.080 | 13.90 | |
| | 80th | 1,650 | 235 | 211 | 793 | 3,045 | 278 | 5.50 | 9,490 | 1,302 | 7.6 | 653.5 | 79 | 1.08 | 0.34 | 1.878 | 1.035 | 0.476 | 22.60 | |
| **Bore** | **91726** | 1,348 | 182 | 174 | 486 | 2456 | 92 | - | - | - | 7.8 | - | - | - | - | - | - | - | - | -- |
| | **67653** | 1,002 | 138 | 131 | 574 | 1,755 | 240 | - | 6,490 | 884 | 7.5 | 471 | - | - | - | - | - | - | - | - |
| | **97832** | 1,245 | 213 | 153 | 705 | 2,228 | 70 | 0 | 7,490 | 1,161 | 7.4 | 581 | 31 | 1.14 | 0 | 0.05 | 0.06 | 0.05 | - | - |
| | **57794** | 38 | 21 | 12 | 103 | 64 | 18 | 3.1 | 420 | 102 | 7.6 | 85 | 39 | - | - | - | - | - | - | - |
| | **111311** | 1,624 | 353 | 880 | 599 | 4,608 | 682 | 0 | 13,400 | 4,499 | 7.8 | 500 | 39 | 0.4 | 0 | 0.05 | 18 | 0 | - | - |

Notes:
1. All as mg/L unless otherwise indicated; "-" not designated / not analysed
2. S = shallow; M = moderate

**Table 10-14 Uplands GCZ WQOs for groundwater resources**

| Depth[2] | Percentile | Indicator / WQO[1] | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Na | Ca | Mg | HCO3 | Cl | SO4 | NO3 | EC | Hardness | pH (units) | Alkalinity | SiO2 | F | Fe | Mn | Zn | Cu | SAR (unitless) | RAH (meq/L) |
| **GCZ** | **Styx** | | | | | | | | | | | | | | | | | | | |
| VS | 20th | 38 | 38 | 42 | 328 | 71 | 20 | 0.62 | 774 | 330 | 7.5 | 275.0 | 28 | 0.09 | - | - | 0.010 | 0.010 | 0.87 | - |
| | 50th | 60 | 55 | 17 | 266 | 64 | 22 | 1.00 | 680 | 234 | 7.8 | 220.0 | 30 | 0.20 | 0.01 | 0.010 | 0.010 | 0.010 | 1.70 | 0.40 |
| | 80th | 100 | 84 | 39 | 506 | 97 | 44 | 7.00 | 970 | 35 | 8.1 | 417.6 | 36 | 0.50 | 0.04 | 0.010 | 0.045 | 0.015 | 2.60 | 2.31 |
| M | 20th | 85 | 56 | 34 | 449 | 49 | 13 | 2.25 | 899 | 314 | 7.5 | 370.9 | 31 | 0.35 | - | - | 0.010 | 0.010 | 1.90 | 0.51 |
| | 50th | 93 | 79 | 38 | 511 | 75 | 33 | 7.70 | 1,050 | 376 | 7.8 | 422 | 35 | 0.58 | 0.01 | - | 0.020 | 0.020 | 2.10 | 1.43 |
| | 80th | 108 | 98 | 64 | 590 | 111 | 38 | 11.27 | 1,225 | 431 | 8.0 | 486.2 | 51 | 0.60 | 0.03 | 0.010 | 0.068 | 0.030 | 2.60 | 1.84 |
| **Bore** | **BH32** | 424 | 270 | 178 | 594 | 999 | 178 | - | - | - | - | 594 | - | <0.001 | <0.05 | 0.386 | <0.005 | <0.001 | - | - |
| | **BH34** | 503 | 314 | 220 | 532 | 1,420 | 324 | - | 5,220 | - | 7.46 | 532 | - | 0.8 | <0.05 | 0.642 | <0.005 | <0.001 | - | - |
| | **88891** | 1,610 | 60 | 185 | 104 | 2,930 | 275 | 0 | 9,300 | 911 | 6.6 | 85 | 49 | - | - | - | - | - | - | - |
| | **88889** | 1,503 | 52 | 175 | 183 | 2,640 | 235 | - | 7,750 | 850 | 7.6 | 150 | - | 0.8 | - | - | - | - | - | - |
| | **111312** | 495 | 230 | 231 | 469 | 1,285 | 307 | 6.5 | 4,770 | 1,524 | 8.2 | 395 | 29 | 0.18 | 0 | 0.28 | 0.22 | 0 | - | - |
| | **91457** | 131 | 52 | 80 | 455 | 290 | 0.1 | - | 1,340 | 459 | 8.0 | 373 | - | 0.4 | - | - | - | - | - | - |
| | **88146** | 55 | 108 | 32 | 435 | 110 | 10 | - | 1,000 | 402 | 6.8 | 357 | - | - | - | - | - | - | - | - |

Notes:
1. All as mg/L unless otherwise indicated ; “-“ not designated / not analysed
2. VS = shallow; M = moderate

**Table 10-15 Bison GCZ WQOs for groundwater resources**

| Depth[2] | Percentile | Indicator / WQO[1] | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Na | Ca | Mg | HCO3 | Cl | SO4 | NO3 | EC | Hardness | pH (units) | Alkalinity | SiO2 | F | Fe | Mn | Zn | Cu | SAR (unitless) | RAH (meq/L) |
| **GCZ** | **Styx** | | | | | | | | | | | | | | | | | | | |
| S | 20th | 137 | 45 | 31 | 332 | 180 | 29 | - | 1,060 | 240 | 6.8 | 272. | 30 | 0.20 | 0.02 | - | - | - | 2.20 | 1.31 |
| | 50th | 245 | 75 | 52 | 560 | 330 | 49 | - | 1,800 | 401 | 7.6 | 465.0 | 30 | 0.30 | 0.02 | - | - | - | 4.20 | 1.53 |
| | 80th | 289 | 402 | 106 | 605 | 995 | 153 | - | 3,675 | 1,441 | 8.0 | 500.0 | 38 | 0.50 | 0.02 | - | - | - | 5.3 | 1.74 |
| M | 20th | 384 | 542 | 327 | 210 | 2,200 | 189 | 12.90 | 6,570 | 2,699 | 7.2 | 173.0 | 29 | 0.23 | - | - | - | - | 3.10 | - |
| | 50th | 390 | 582 | 344 | 237 | 2,337 | 202 | 23.55 | 7,035 | 2,869 | 7.4 | 195.0 | 31 | 0.27 | - | - | - | - | 3.15 | - |
| | 80th | 396 | 623 | 361 | 263 | 3,474 | 215 | 34.20 | 7,500 | 3,038 | 7.5 | 217.0 | 33 | 0.30 | - | - | - | - | 3.20 | - |
| **Well** | **BH07** | 683 | 309 | 191 | 597 | 1,340 | 596 | - | - | - | - | 597 | - | 0.5 | 0.07 | 0.232 | 0.005 | <0.001 | - | - |
| **Well** | **88144** | 293 | 560 | 150 | 650 | 1,360 | 180 | - | 4,500 | 2,017 | 6.8 | 533 | - | - | - | - | - | - | - | - |
| **Well** | **88145** | 284 | 244 | 62 | 560 | 630 | 125 | - | 2,850 | 865 | 6.8 | 459 | - | - | - | - | - | - | - | - |

Notes:
1. All as mg/L unless otherwise indicated; "-" not designated / not analysed
2. S = shallow; M = moderate

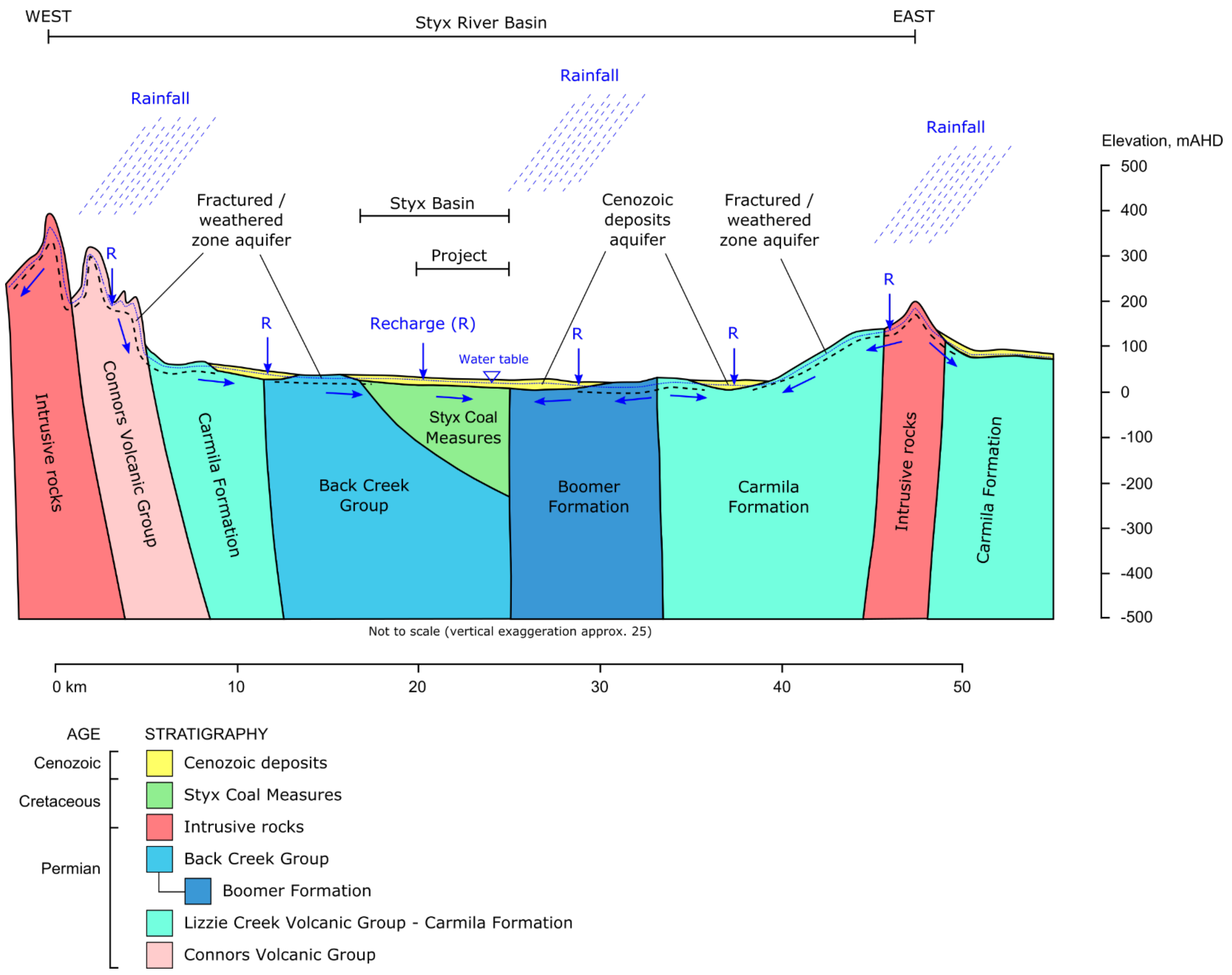



**Figure 10-11 Conceptual hydrogeological cross section**

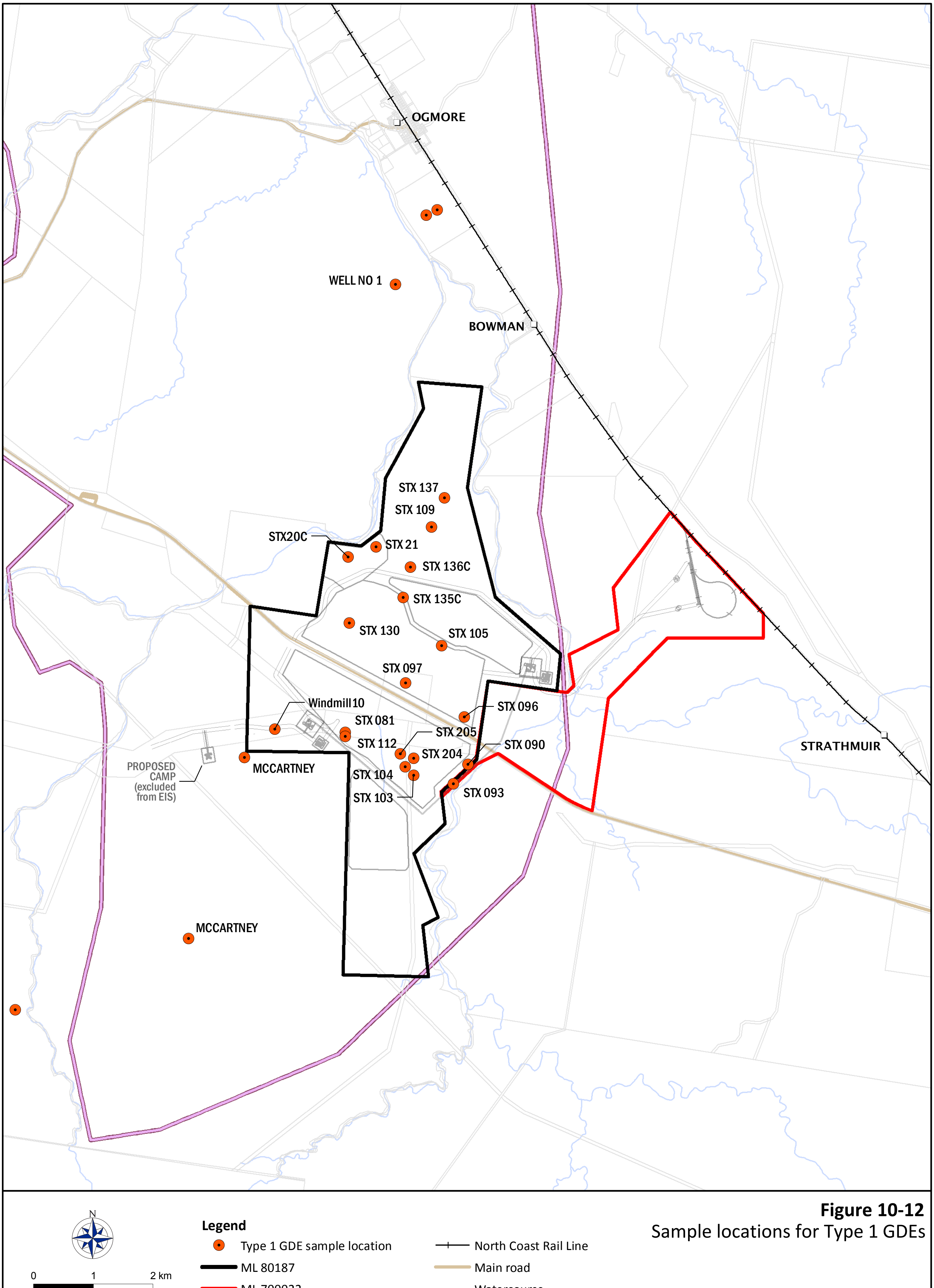
There are two sources of information pertaining to the presence of GDEs - the National Atlas of GDEs (GDE Atlas) and the Queensland Wetland GDE Layer, which provides information regarding Type 2 and 3 GDEs. The GDE Atlas presents the current knowledge of ecosystems that may depend on groundwater across Australia. The Queensland Wetland GDE Layer presents the current knowledge of ecosystems reliant on groundwater across Queensland. At the beginning of 2017, the GDE Atlas was updated with the latest information pertaining to GDEs from the Queensland Wetland GDE Layer, and therefore the GDE Atlas can be considered as the primary data source for this assessment. Information pertaining to type 1 GDEs is sourced from existing field surveys. The location of locations sampled for Type 1 GDEs are shown on Figure 10-12, whilst Figure 10-13 presents the spatial distribution of potential Type 2 and 3 GDEs.

Several ecological field surveys, whilst not specifically targeting GDEs, have been undertaken for this project to ground-truth desktop information and identify any additional flora and fauna values associated with potential GDEs. These include earlier studies carried out for the Project, which encompassed a much larger area (EPC 1029). Field surveys comprised:

- Detailed summer (wet season) fauna survey of EPC 1029 (five days) 21 to 25 March 2011 by Ed Meyer (ecological consultant);
- Summer (wet season) flora survey of EPC 1029 (five days) 21 to 25 March 2011 by Oberonia Botanical Services;
- Detailed winter (dry season) aquatic ecology survey of EPC 1029 (six days) 1 to 6 June 2011 by ALS Water Sciences;
- Detailed spring (dry season) fauna survey of EPC 1029 (five days) 25 to 29 September 2011 by Ed Meyer (ecological consultant);
- Targeted threatened fauna survey of EPC 1029 (four days) 7 to 10 February 2012 by Ed Meyer (ecological consultant);
- Stygofauna pilot survey (four days) 21 to 24 November 2011, by ALS Water Sciences;
- Stygofauna follow-up survey (three days) 15 to 18 March 2012, by ALS Water Sciences;
- Summer (wet season) flora survey of ML 80187 and immediate surrounds (three days) 8 to 10 February 2017 by Terrestria (led by Dr Andrew Daniel – Terrestria); and
- Detailed summer (wet season) fauna survey of ML 80187 and immediate surrounds (six days) 8 to 13 February 2017 by CDM Smith (led by Brett Taylor).

Surveys were designed to encapsulate seasonal variation in species' detectability, and survey sites were selected at locations representing key threatened vegetation communities and dominant habitat types present on the Project area and surrounds. All surveyed areas within the Project area have been visited at least once during the site studies.

An expansion of the groundwater and surface water monitoring network is currently underway. Information presented in the following section has been relied upon in the siting of this network, along with the effects assessment presented in Section 10.6. As the understanding of GDEs develops, it may be necessary to expand or consolidate the network in the future.



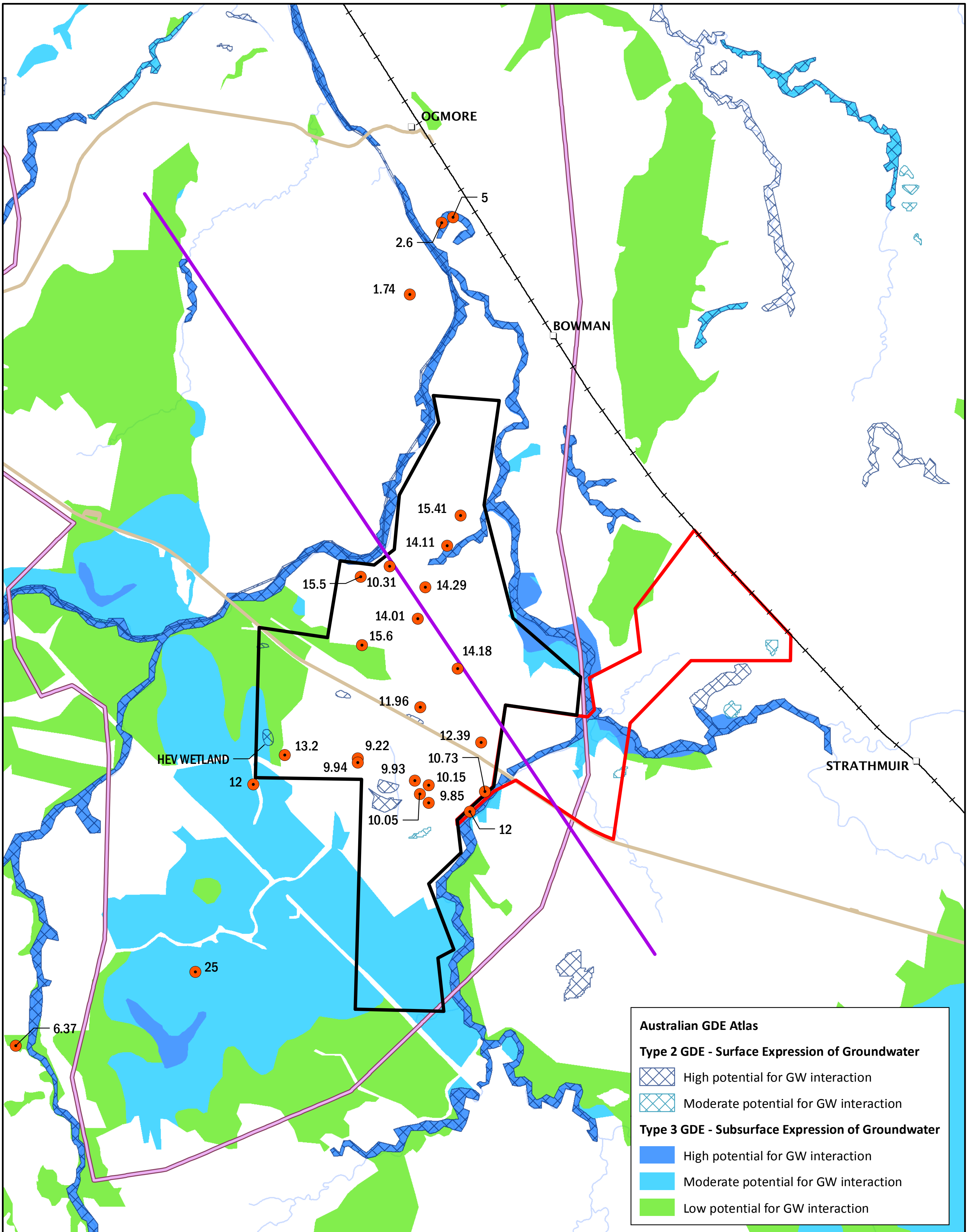

Scale @ A4 1:80,000
Date: 18/07/17
Drawn: Gayle B.

**Figure 10-12**
Sample locations for Type 1 GDEs

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-074 R1 type 1 GDE sample locations.mxd 7/18/2017




N

0 1 2 km

Scale @ A4 1:80,000
Date: 24/07/17
Drawn: Gayle B.

**Legend**

- Groundwater Bore (Depth to water table, m)
- Cross section location
- ML 80187
- ML 700022
- Styx Basin
- North Coast Rail Line
- Main road
- Watercourse

**Figure 10-13**
Mapped potential Type 2 and 3 GDEs across the study area

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\03 EIS Preparation\BES150160.03-065 R1 GDEs-gwater bores.mxd 7/24/2017

#### 10.5.13.2 GDEs Reliant on Aquifers and Caves (Type 1 GDEs)

Information relating to Type 1 GDEs has been sourced from field surveys conducted by Yeats (2012) and ALS Water Sciences, who undertook two seasonal surveys were in November 2011 and March 2012. The ALS Water Sciences surveys comprised collecting 21(2011) and 19 (2012) groundwater bore samples for examination of the presence of stygofauna. Of the bores sampled in 2012, nine were not sampled in 2011. Overall, 30 bores within the project area and surrounds have been assessed for stygofauna presence, including 20 bores established specifically for the Project and 10 landholder bores.

During the field surveys, five sites recorded the presence of subterranean fauna with four sites recording subsurface species that can be classified as stygofauna, including obligate groundwater species associated with the hypogean and permanent hyporheic environments. Stygofauna are grouped into one of several classes based on the degree of requirement for subterranean life (Tomlinson and Boulton 2008). Edaphobites are deep soil dwelling (or endogean) species that frequently display troglomorphisms and may sometimes occur in caves. These animals are not classified as stygofauna and the taxa detected at sample location STX 093 is not considered further on this basis.

The results of the two surveys show most of the identified stygofauna communities were recorded in the alluvial aquifer associated with the Styx River more than 8 km away from the boundary of the Project area. A single taxon (five individuals) was identified in samples collected adjacent to the Project boundary. However, it is very unlikely the taxa will be restricted to the sample points where presence has been recorded, and a sample that does not contain taxa does not necessarily indicate complete absence in that aquifer setting.

The shallow groundwater levels (i.e. generally less than 25 mbgl; see Figure 10-8) gauged within bores constructed in alluvial sediments within or close to the riparian zone and the presence of species belonging to the (sub-)Orders Bathynellacea, Syncarida, as well as three Families of Oligochaeta and Copepoda, suggests a fine to moderate grained and unconsolidated alluvial aquifer with direct association / connectivity with the river system with an interconnected hyporheic zone (Boulton and Hancock 2006) and fresh to brackish water quality.

The absence of stygofauna from the remaining sampled locations does not indicate stygofauna are not present in the aquifers sampled, rather, it may be due to unsuitable geological conditions (low porosity, low hydraulic conductivity), poor water quality (e.g. high EC or presence of other toxicants) or sampling from a recently drilled bore that has yet to stabilise and attract stygofauna (reduced likelihood of collection).

#### 10.5.13.3 GDEs Reliant on the Surface Expression of Groundwater (Type 2 GDEs)

The GDE Atlas identifies potential GDEs that are reliant on the surface expression of groundwater (Type 2 GDEs) along extensive reaches of watercourses, both within and marginal to the Project area (i.e., Styx River, Tooloombah Creek and Deep Creek). Most of these potential Type 2 GDEs are classified as having high potential for interaction with groundwater (see Figure 10-13).

Site observations during dry season sampling suggest tributaries of the Styx River are ephemeral upstream of the confluence of Deep Creek and Tooloombah Creek (see Figure 9-2). However, a field survey in February 2017 identified several pools of water in localised depressions (i.e. at sites De1, De2, De4, To1 and To2; and Plate 10-1 to Plate 10-5) along small reaches of the two creeks that appear to be perennial, indicating that they are potentially maintained by groundwater. Downstream of the confluence, Styx River is identified as being tidally dominated based on short term water level variations and elevated electrical conductivity measurements (refer to Chapter 9 -

Surface Water). These observations suggest that any Type 2 GDEs near the Project area are likely to limited to the localised pools.

**Plate 10-1: De1 watercourse pool (February 2017)**

**Plate 10-2: De2 watercourse pool (February 2017)**

Plate 10-3: De4 watercourse pool (February 2017)

Plate 10-4: To1 watercourse pool (February 2017)

**Plate 10-5: T02 watercourse pool (February 2017)**

The Queensland Government WetlandInfo shows small areas of riverine, fresh water bodies along Styx River and Tooloombah Creek but the extent of these areas are much smaller than the extent of potential Type 2 GDEs identified by the GDE Atlas (presented as Figure 10-13). Of particular note, is the high ecological value (HEV) wetland (Ref 688938) that has been identified on the western side of the Project area (Figure 10-13), and is classified by the GDE Atlas as a potential Type 2 GDE with a high potential for groundwater interaction. However, observations during two field surveys in early-2017 suggest that surface water in the wetland (when present) is rainfall dominated. For example, the wetland was dry in February 2017 but was subsequently inundated (see Plate 10-6 and Plate 10-7) after heavy rainfall associated with Severe Tropical Cyclone Debbie, which was active in April 2017. Groundwater levels measured in bores near the HEV wetland have also been observed to be approximately 9-10 mbgl, further indicating that the wetland is unlikely to be an area of active groundwater discharge. This wetland is discussed further in the following section as a potential Type 3 GDE.

**Plate 10-6: Prior to Cyclone Debbie (February 2017)**

**Plate 10-7: After Cyclone Debbie (May 2017)**

It appears the presence of Type 2 GDEs are confined to the riverine environments of water ways (Styx River, Tooloombah Creek and Deep Creek) and that wetlands located away from riverine environments are likely to be disconnected from the groundwater system. Streamflow events supporting the shallow alluvial aquifers are likely to be the dominant source of groundwater for Type 2 GDEs in the study area.

### 10.5.13.4 GDEs Reliant on the Subsurface Expression of Groundwater (Type 3 GDEs)

The GDE Atlas identifies potential GDEs that are reliant on the subsurface expression of groundwater (Type 3 GDEs) along the drainage lines (i.e. riparian zones) associated with Styx River, Deep Creek and Tooloombah Creek. At least three of the Regional Ecosystems (REs) mapped in these areas during field surveys (refer to Chapter 14 - Terrestrial Ecology) have the potential for incorporating some component of groundwater in their water requirements, including:

- Forest Red Gum woodland fringing drainage lines (RE 11.3.25):
  – Occur along riparian areas of drainage lines. Vegetation is dominated by Forest Red Gum (*Eucalyptus tereticornis*) and Weeping Tea Tree (*Melaleuca leucadendra*). Approximate site coverage is 29.7 ha;
- Forest Red Gum woodland on alluvial plains (RE 11.3.4):
  – Occurs in patches across the eastern side of the Project area where it is associated with the alluvial plains adjacent Deep Creek. Vegetation is dominated by Forest Red Gum (*E. tereticornis*), Poplar Gum (*E. platyphylla*) with Carbeen (*Corymbia tessellaris*). Approximate site coverage is 33.2 ha;
- Poplar Box on palustrine wetland (RE 11.5.3b):
  – This is an isolated community occurring on a natural depression on the western side of the Project area (i.e. the HEV wetland). The community is characterised by Poplar Box (*E. populnea*) and a patch of Broad-leaved Paperbark (*M. viridiflora*) with a variety of low sedges and forbs on the margin, and hydrophytes in the centre when surface water is present. Approximate site coverage is 4.1 ha; and
- Areas of Semi Evergreen Vine Thicket along areas of Tooloombah Creek and Deep Creek.

Of these vegetation communities, the two Forest Gum communities (RE 11.3.25 and RE 11.3.4) and Weeping Tea Tree (*Melaleuca leucadendra*) are the most likely to be utilising groundwater to meet some or all of their water requirements because of the relatively shallower groundwater levels (approximately 2 to 5 mbgl) observed in the alluvial sediments on the margins of the drainage lines. However, these groundwater level measurements were recorded at bores located 1-2 km north of the Project area (Figure 10-8), where groundwater levels are generally shallower (no groundwater level data exist for alluvial sediments closer to the Project area).

In absence of actual groundwater data, the presence of a water table within the shallow alluvial sediments interacting with the rooting system is very likely, and suggests the classification of high potential for groundwater interaction of riparian vegetation to the east of the mine area is appropriate. However, the primary source of the groundwater that likely supports the vegetation communities is not certain, e.g. streamflow and bank storage, or groundwater moving from upgradient.

The GDE Atlas also identifies areas of potential Type 3 GDEs with low to moderate potential of groundwater interaction on the southwestern margin of the Project area. Measured groundwater levels in these areas have been observed to be approximately 10 to12 mbgl. Groundwater levels have been observed to be even deeper (25 mbgl or more) further away from the southwestern edge of the Project area. Although, these observations do not preclude deep-rooted plant species from potentially using the underlying groundwater, it is likely that groundwater is only a small component of water use during periods of limited soil water availability (i.e. droughts).

# 10.6 Groundwater Effects

## 10.6.1 Potential Direct Effects of Mining on Groundwater

### 10.6.1.1 Overview

The National Water Commission mining risk framework (Howe 2011, Moran et al. 2010) that has been adopted for the groundwater impacts assessment defines the following four direct groundwater effects arising from mining:

- Altered groundwater quantity;
- Altered groundwater quality;
- Physical disruption of aquifers; and
- Surface water – groundwater interaction.

Table 10-16 presents a brief description of each of the effects and how they arise, and further description is provided in the following sub-sections.

**Table 10-16 Possible direct effects and key mine water affecting activities**

| Direct effect | Water affecting activity | Effect causation |
|---|---|---|
| **During mining** | | |
| Quantity | ▪ Groundwater pumping for supply and development<br>▪ Stockpiling<br>▪ Backfilling<br>▪ Water storages | ▪ Water table drawdown and / or aquifer depressurisation (reduced quantity)<br>▪ Evaporative losses from open voids<br>▪ Altered recharge<br>▪ Altered hydraulic properties (backfill materials)<br>▪ Water table drawup and / or aquifer pressurisation |
| Quality | ▪ Groundwater pumping for supply and development<br>▪ Stockpiling<br>▪ Mine waste management | ▪ Mobilisation of salts from poorer water quality stores (aquifers, aquitards, surface water)<br>▪ Leaching of solutes and potential AMD issues where PAF materials occur<br>▪ Evaporative concentration of salts within mine voids |
| Groundwater – surface water interaction | ▪ Groundwater pumping for supply and development<br>▪ Water storages<br>▪ Stockpiling<br>▪ Mine waste management | ▪ Water table drawdown / drawup and aquifer depressurisation / pressurisation<br>▪ Altered baseflow regimes to water courses and wetlands<br>▪ Hydraulic loading |
| Aquifer disruption | ▪ Excavation<br>▪ Backfilling<br>▪ Waste storage | ▪ Removal of part or whole of aquifer<br>▪ Altered hydraulic properties (backfill materials)<br>▪ Hydraulic loading |

adapted from National Water Commission, 2011

### 10.6.1.2 Groundwater Quantity

Open-cut mining often extends below the water table. As overburden rocks and coal seams below the water table are removed, groundwater will seep into the mine void from the intersected saturated strata. Collection of this water, either via dewatering bores or in-floor sumps to facilitate dry mining will depress the water table immediately surrounding the pit to the approximate elevation of the pit floor. Surrounding hydrostratigraphic units will also depressurise in response to this lowering of the water table, and a zone groundwater depressurisation that decreases in magnitude with increasing distance from the mine pit will develop. Groundwater storage will be temporary depleted within the zone of depressurisation.

### 10.6.1.3 Groundwater Quality

The potential exists for groundwater quality to be altered in a number of ways:

- Evaporative concentration of salts in open mine pits and voids remaining at the end of mining, and subsequent movement of this water away from the Project due to regional groundwater flow;
- Inducing flow of groundwater of different quality towards depressurised parts of the groundwater system associated with dewatering / depressurisation;
- Infiltration of water sourced from waste storages and mine water storages; and
- Accidental release of chemicals (such as unintended fuel spill, leakage of sewage effluent, infiltration of stormwater from mine ‘contact’ areas).

#### 10.6.1.4 Physical Disruption of Aquifers

Open-cut mining involves removal and translocation of coal, overburden and interburden strata thereby creating mine-pit voids that can be progressively backfilled and rehabilitated, or left open. Backfilling of mine voids can cause permanent change of hydraulic properties of backfilled materials compared to in-situ properties (typically resulting in enhancement of hydraulic conductivity and storage capacity), but this change would not be considered particularly significant as the effect is restricted to the mine voids.

Any remaining voids that extend deeper than the pre-mine water table will become evaporative sinks that interrupt groundwater flow at the near-mine scale. Depending on the level of pit lake recovery and the surface area of the final pit lake, the voids may act as temporary or permanent groundwater sinks.

Placement of waste rock on the ground surface has the potential to cause hydraulic loading of shallow aquifers, in particular, which can give rise to compaction and reduction in of hydraulic conductivity and storage capacity and creation of a flow 'barrier'. displacement of water away from waste storages, potentially increasing baseflow discharge to watercourses and wetlands, for example.

#### 10.6.1.5 Surface Water – Groundwater Interaction

The capture of groundwater during (to meet Project water demands or allow dry and safe mining conditions) and possibly after (pits acting as evaporative sinks) mining can alter the degree and form of interaction with surface water and connected systems. For example:

- If baseflow fed water courses are located within the zone of drawdown influence of mine pits or borefields, it is probable the rate and timing of baseflow rates will diminish;
- If wetlands relying on shallow water tables or surface expression of groundwater are located within the zone of drawdown influence of mine pits or borefields, the wetlands may become disconnected from groundwater;
- Water storages, including tailings (not in the case of the Project though) and sediment ponds, may leak and cause water table mounding beneath the facilities, which may raise water tables near wetlands and terrestrial vegetation that may cause water logging, or increase rates of baseflow to nearby water courses; and
- Placement of waste rock on the ground surface has the potential to cause hydraulic loading of shallow aquifers in particular, which can give rise to displacement of water away from waste storages, potentially increasing baseflow discharge to watercourses and wetlands.

### 10.6.2 Groundwater Effects Assessment

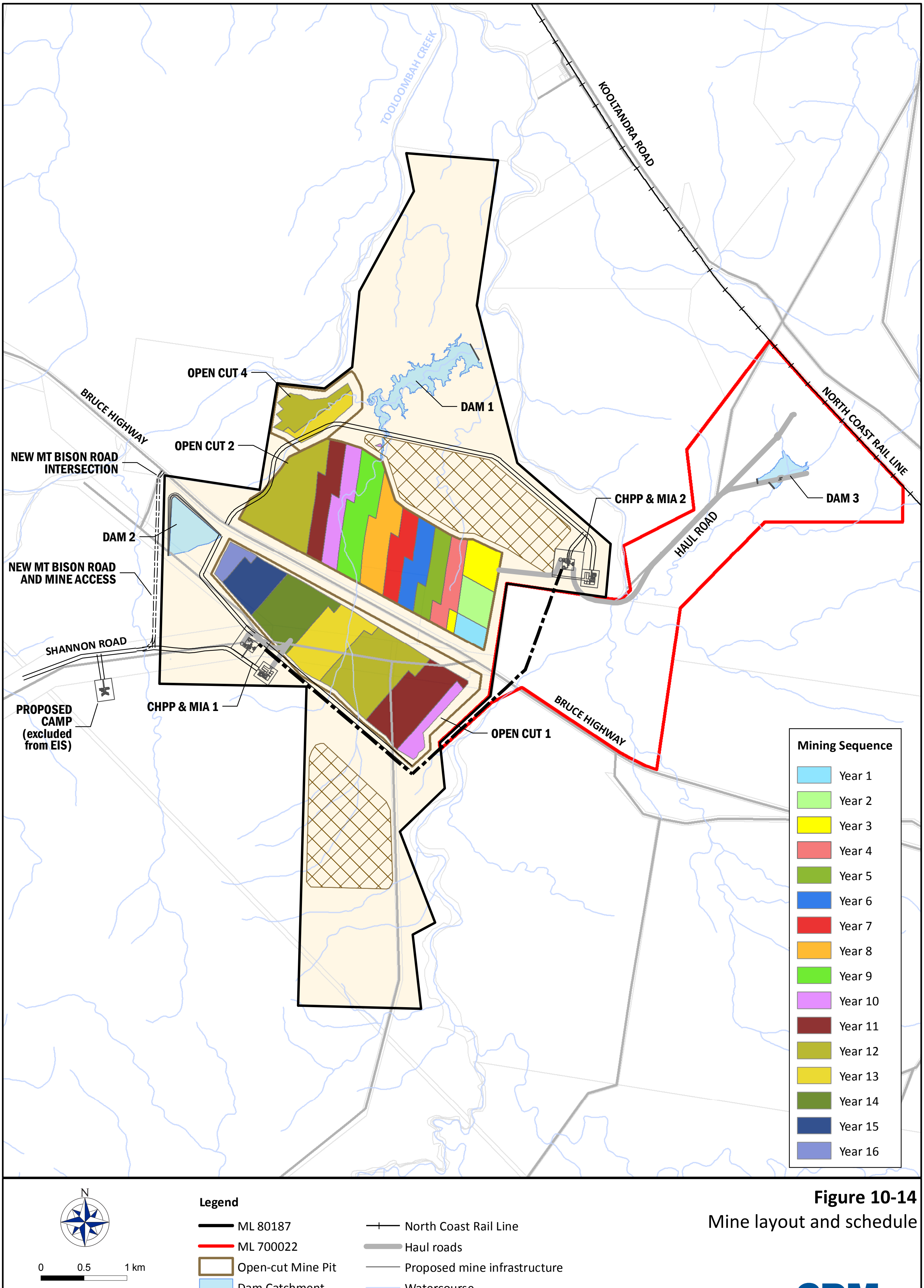
#### 10.6.2.1 Overview

Groundwater modelling is the only practical way to predict potential regional scale effects of the mine on groundwater systems in response to the Project. In this assessment, the primary objectives of groundwater modelling are to predict potential rates of mine dewatering, to facilitate planning for operational mine water management, and to predict associated effects on groundwater resources at the proposed Central Queensland Mine and surrounding areas during and after mining.

More detailed information regarding the Project numerical groundwater modelling method including guidelines, calibration, prediction, sensitivity analysis, model confidence and model limitations is provided as Appendix A6 – Groundwater Technical Report. A mine layout plan is presented as Figure 10-14.

#### 10.6.2.2 Water Affecting Activities

The water affecting activities simulated by the groundwater model include pit excavation / dewatering, pit backfill, remaining pit voids after mining is completed and mine water storages. Table 10-17 presents summary details of the water affecting activities, which have the potential to give rise to the direct effects.

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Date: 18/07/17
Drawn: Gayle B.

**Figure 10-14**
Mine layout and schedule

DATA SOURCE
QLD Open Source Data, 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-061 R2 Mine Schedule.mxd 7/18/2017

**Table 10-17 Summary details – mine water affecting activities**

| Water affecting activity | Description [1] |
|---|---|
| Mine pits and final voids | ▪ All groundwater inflow reporting to active areas of pits will be collected in sumps and pumped from the pits for use in mine water circuit<br>▪ Open Cut 1 final void – pit lake recovery is predicted occur to 15 mAHD, likely forming a semi-permanent sink approximately 15 m below pre-mine water table<br>▪ Open Cut 4 final void – pit lake recovery is predicted to occur to -40 mAHD, forming a permanent sink approximately 70 m below pre-mine water table |
| Pit backfill | ▪ Simulated hydraulic properties of K = 1 m/d, fillable porosity = 20%<br>▪ Impacts rate of groundwater recovery in backfilled materials<br>▪ No impact on groundwater inflow rate |
| Water storages | ▪ Storages operated for life of mine only<br>▪ Dam1 operated at pool level of 26 mAHD<br>▪ Dam2 operated at pool level of 38 mAHD<br>▪ Loadout facility storage operated at 36 mAHD |

1. For details see Appendix A6 – Groundwater Technical Report

### 10.6.3 Predicted Groundwater Quantity Changes

Predicted groundwater elevation contours for the Project area prior to commencement of mining and at the end of mining (year 16) are presented in Figure 10-15. The figure shows there is very little change to water table elevations upstream (south, west and east) of the proposed mine over the 16 year LOM, but there will likely be significant reduction in water table elevation in the vicinity of the mine (more than 75 m) and to the north (by up to 5 m).

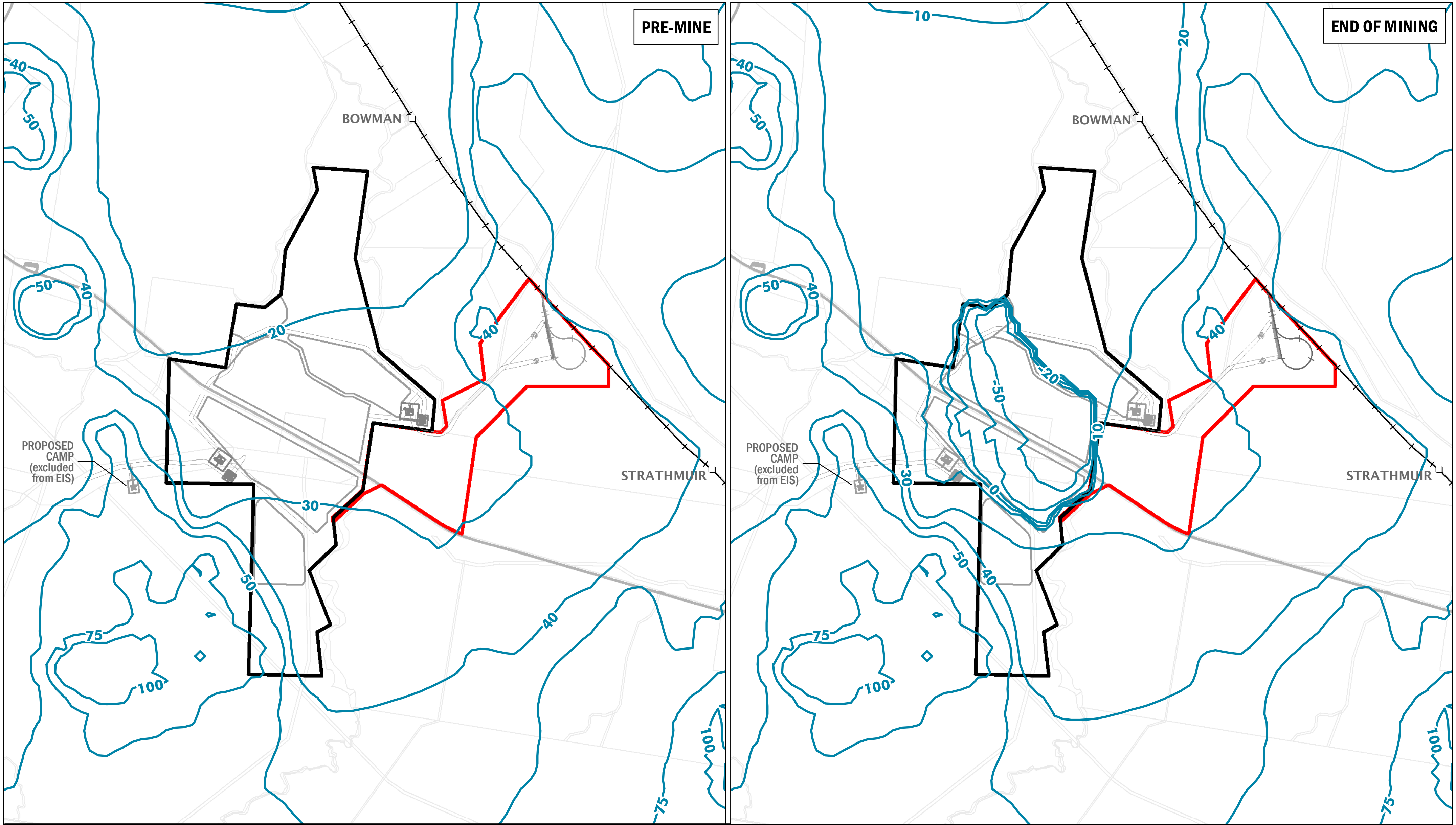
Predicted groundwater drawdown contours (compared to the pre-mine condition) at the end of mining are presented at Figure 10-16. The drawdown contours show the potential extent of changes to water table elevation (assuming the 0.5 m drawdown contour) over the LOM (14.5 km in a roughly north-south alignment and 6 km in a roughly west-east alignment).

Predicted groundwater elevation contours for the Project area 20 and 100 years after mining and rehabilitation cease are presented at Figure 10-17. As for Figure 10-15, Figure 10-17 shows there is relatively little change to water table elevations upstream (south, west and east) of the proposed mine over the closure period, and partial recovery of the water table will occur in the near vicinity of the mine (more than 50 m of groundwater level recovery). However, the groundwater recovery around the mine is likely to be offset by continued water table decline to the north (note the shift of the predicted 10 m contour toward the south) for some time until a new dynamic equilibrium is reached. This ongoing decline arises because the groundwater system further from the Project continues to seek a new dynamic equilibrium in response to mining and the establishment of a pit lake after closure.

Predicted mine-scale groundwater drawdown contours (compared to the pre-mine condition) at 20 and 100 years after mining and rehabilitation works cease are presented at Figure 10-18. The figure shows that the potential extent of changes to water table elevation, as measured by the 0.5 m drawdown contour, has the following characteristics:

- Between mining cessation and 20 years after mining, the extent increases by around 2 km in both the north and south (for an approximate overall extent of more than 16 km); and
- Between 20 and 100 years after mining, the extent of drawdown stabilises, without much additional change.

For context, Figure 10-19 presents at the catchment scale the extent of predicted drawdown (as indicated by the 0.5 m drawdown contour) for end of mine and 100 years after closure.




N

0 1 2 km

Scale @ A4 1:100,000
Date: 19/07/17
Drawn: Gayle B.

**Legend**

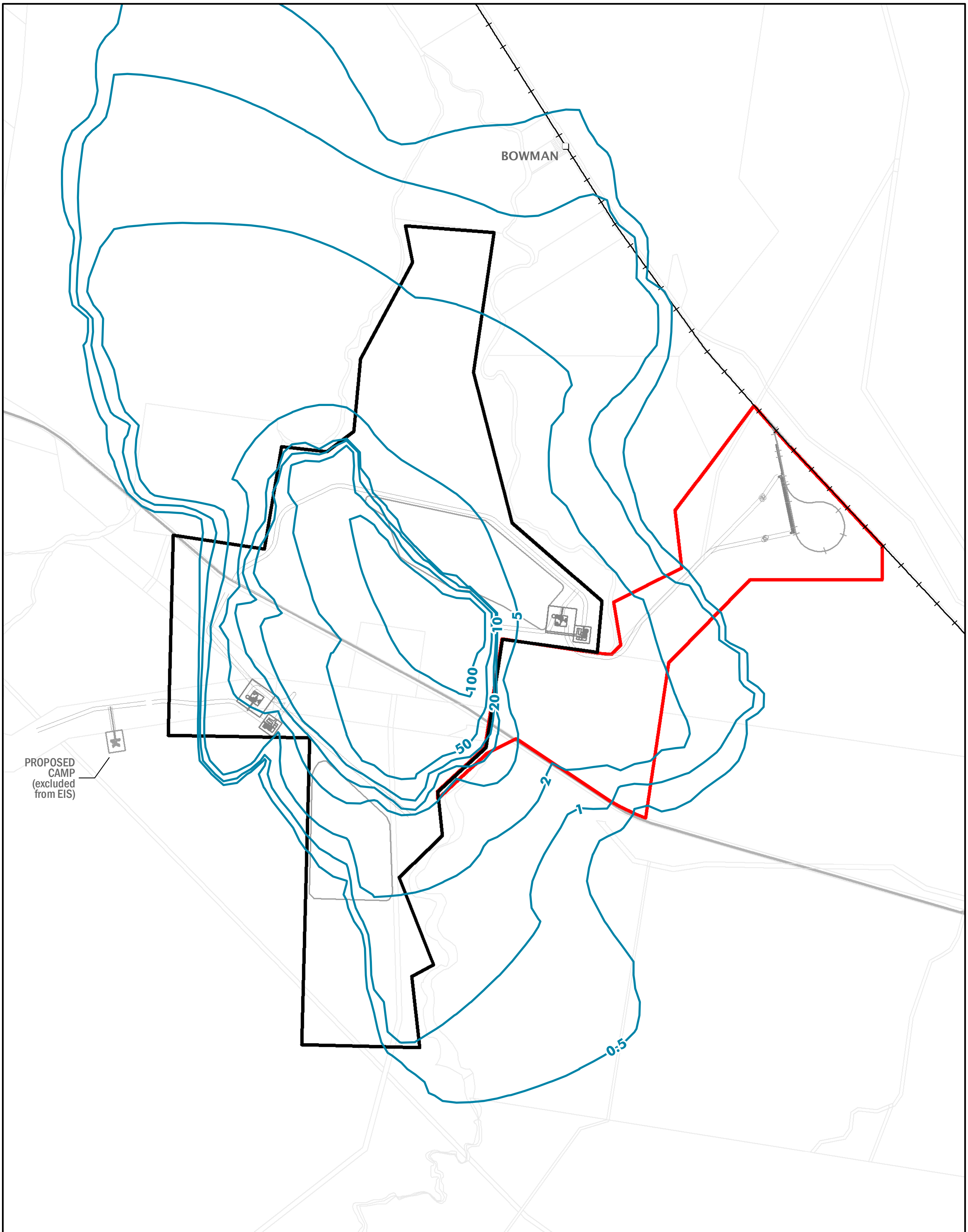
- Water table elevation contour
- ML 80187
- ML 700022
- Proposed mine infrastructure
- North Coast Rail Line
- Main road
- Cadastral boundary

**Figure 10-15**
Predicted water table elevation contours pre-mining (year 0) and at end of mining (year 16)

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-082 R1 WT pre-mine & EOM.mxd 7/19/2017




N

0 0.5 1 km

Scale @ A4 1:60,000
Date: 19/07/17
Drawn: Gayle B.

**Legend**

- Drawdown contour
- ML 80187
- ML 700022
- Proposed mine infrastructure
- North Coast Rail Line
- Main road
- Cadastral boundary

**Figure 10-16**
Predicted drawdown contours at end of mining (year 16)

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-083 R1 DD EOM.mxd 7/19/2017

The model predicts that drawdown could extend to between Ogmore and Styx. There is the potential that this could give rise to inland mobilisation of the saltwater interface (the boundary between predominantly seawater and predominantly groundwater near the coast). Modelling of potential for mobilisation of the sea water interface will be further addressed as part of the Supplementary EIS process.

Change in groundwater quantity (flux and level) associated with the mining project will have the potential to impact on all types of GDES:

- Type 1 Aquifer GDES - Reduced baseflow to streams and water pools has potential to impact hyporheic fauna inhabiting ephemeral systems, especially during dry periods when groundwater contact with pools is important in maintaining refuge. Lowering of groundwater level also has potential to dewater alluvial aquifers and impact on stygofauna inhabiting the aquifers, particularly where the thickness of sediments is limited;
- Type 2 GDEs - In-stream fauna that rely partially or entirely on baseflow to meet their water requirements have the potential to be impacted through reduction or removal of baseflow; and
- Type 3 GDEs - Ecosystems that rely on access to the water table or capillary zone to meet some or all of their water requirements (seasonally or permanently) have the potential to be impacted by a declining water table through two mechanisms; being the rate of decline and vertical extent of decline. Where stream flow is maintained, riparian vegetation might be less impacted than terrestrial vegetation because the effect on depth to water table near to a stream will be less apparent.

Further work will be completed during the Supplementary EIS stage to fully assess how these types of GDEs will respond to potential changes in groundwater quantity.

### 10.6.4 Predicted Groundwater Quality Changes

The numerical groundwater flow modelling does not directly address the issue of potential groundwater quality change in response to mining. However, model predictions of groundwater quantity change (see Section 10.6.3) provide a basis from which to assess the potential for changes to water quality associated with the primary water affecting activities (see Table 10-17) to impact on catchment scale groundwater and surface water resources.

The two (pit) voids remaining after mine closure will capture some or all of the groundwater moving downstream from higher in the eastern part of the Tooloombah Creek catchment and much of the Deep Creek catchment. Any groundwater quality changes within this catchment zone will not impact on other parts of the Styx Basin due to the existence of the pit voids acting as permanent evaporative sinks.

South of the mine and up-hydraulic gradient, even within the expected capture zone, there is unlikely to be any change in water quality due to the mine during operation or after closure.

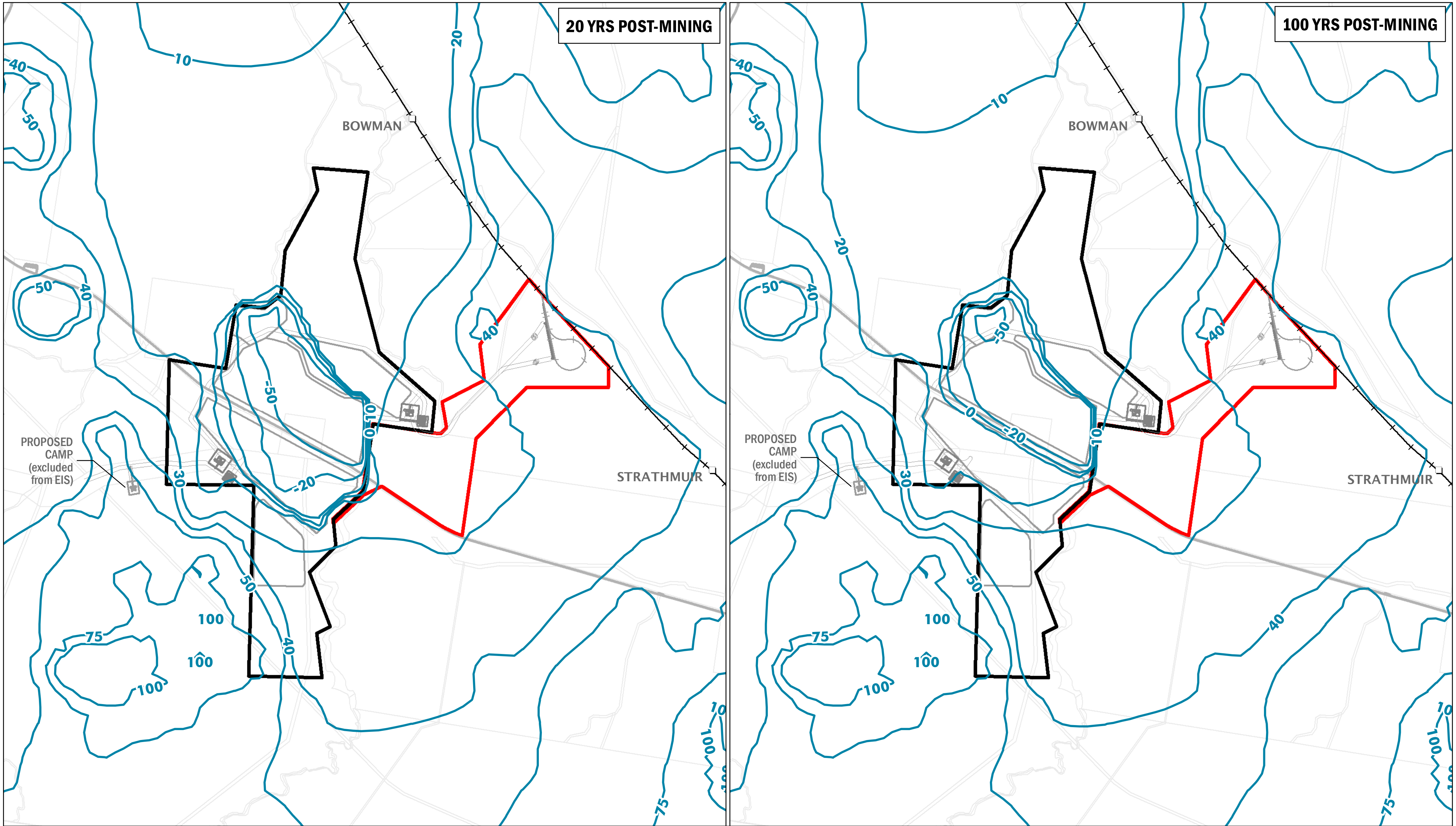
Because the mine project involves two pits being left open (noting the mine planning is currently considering the complete infill of Open Cut 4 leaving only one retained void for the Project at the completion of mining), evaporation from the pit water bodies will mean the pits will form groundwater sinks after closure. There is low potential for water quality effects associated with the mine to adversely impact on groundwater quality.

### 10.6.5 Groundwater – Surface Water Interaction

As the mine is located within parts of the Styx Basin where water table elevation is close to or at ground surface, it is expected that there will be impact on the existing interactions between groundwater and surface water, particularly in the lower parts of the valleys. Figure 10-19 shows the extent of predicted drawdown (as indicated by the 0.5 m contour) associated with long term capture and discharge of groundwater by evaporative losses from the pit voids remaining after mine closure. The extent of predicted long-term drawdown provides the basis for identifying areas where reduced baseflow is expected during dry periods. The zone of influence is predicted to extend beyond the township of Ogmore to within 5 km of Styx township. There is the potential for drawdown associated with the Project to capture some of the Styx River stream flow, in addition to flow in the tributary creeks around the Project itself. This could impact on the extent of the normal tidal influence in Styx River (i.e. extending further upstream) and brackish river water recharging the riparian zone within the predicted zone of drawdown influence. Further work will be required to assess the groundwater impacts that could arise if this were to occur.

During and following wet periods, when stream flows occur, it is probable that additional stream losses will occur within the predicted drawdown zone. In the immediate vicinity of the mine where stream reaches occur within areas having predicted long-term drawdowns of more than a few metres, it can be expected that existing baseflow may cease permanently.

Predicted changes to existing interactions between groundwater and surface water is described in Section 10.6.3. The predicted impact will be on Type 1 GDEs, where they exist. Further work is required to fully assess how these types of GDEs will respond to the potential changes in groundwater quantity.




**Legend**

- Water table elevation contour
- ML 80187
- ML 700022
- Proposed mine infrastructure
- North Coast Rail Line
- Main road
- Cadastral boundary

0 1 2 km

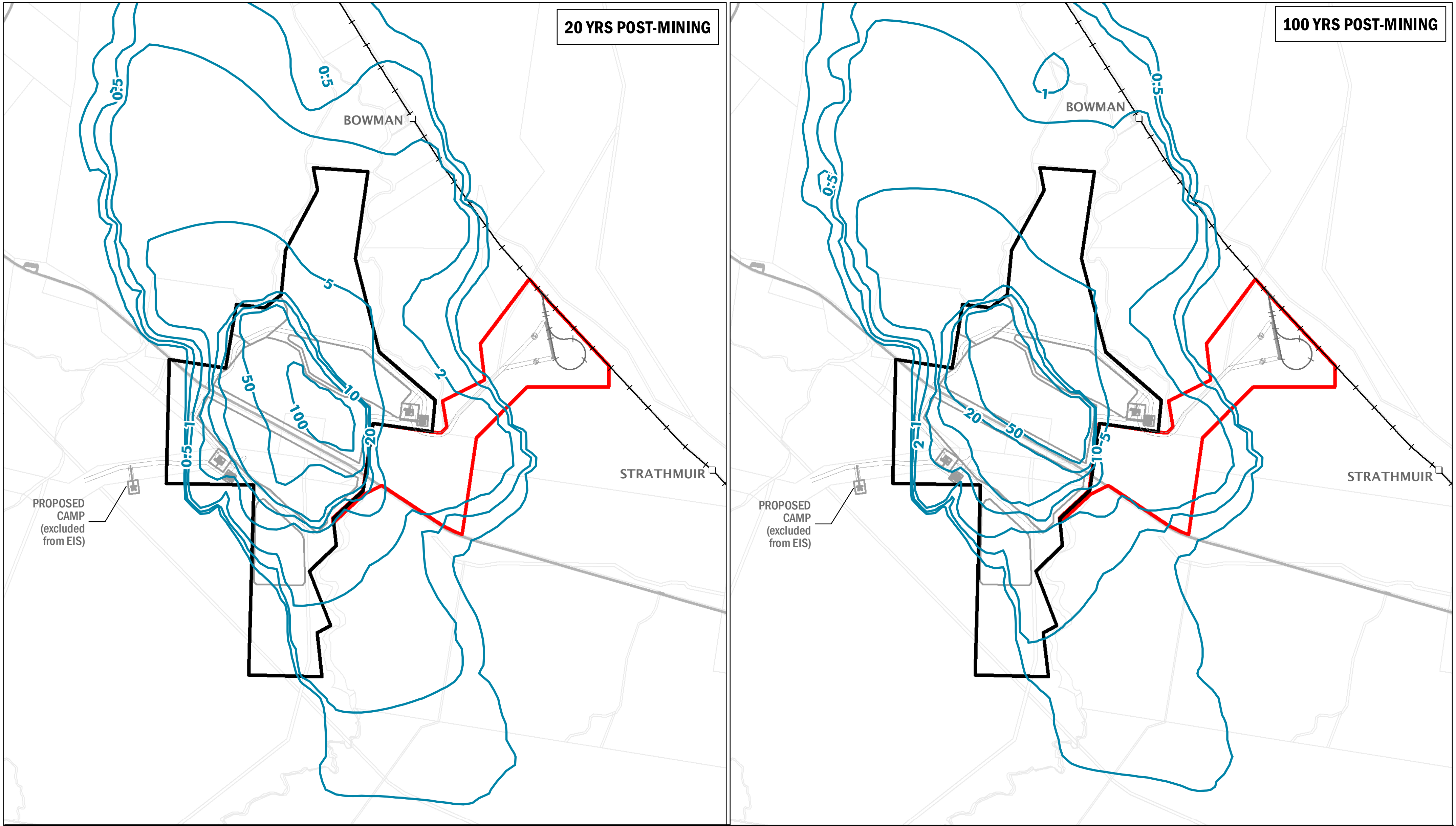
Scale @ A4 1:100,000
Date: 24/07/17
Drawn: Gayle B.

**Figure 10-17**
Predicted water table elevation contours
20 years and 100 years after mining

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\03 EIS Preparation\BES150160.03-084 WT 20&100 yrs.mxd 7/24/2017




N

0 1 2 km

Scale @ A4 1:100,000
Date: 19/07/17
Drawn: Gayle B.

**Legend**

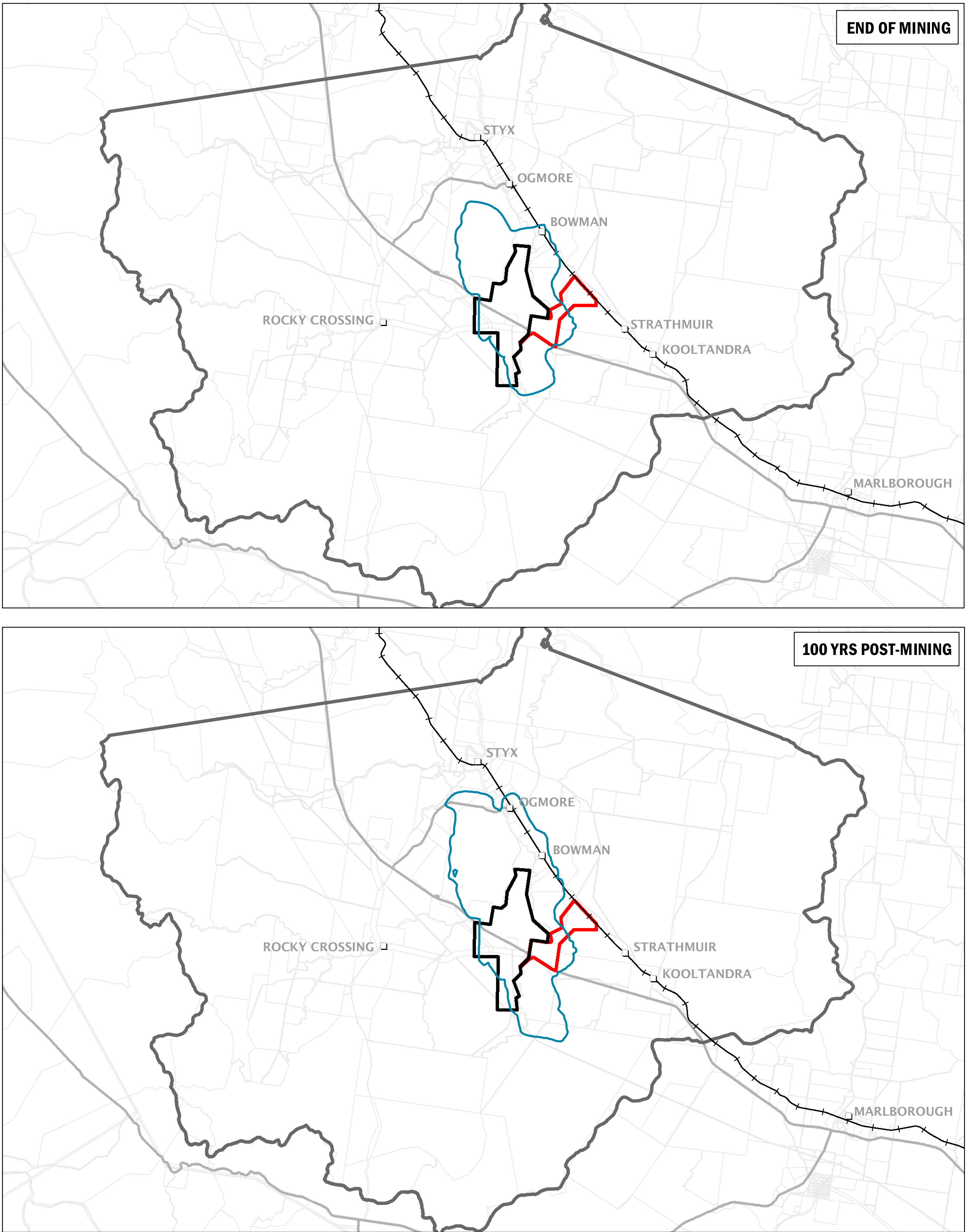
- Drawdown contour
- ML 80187
- ML 700022
- Proposed mine infrastructure
- North Coast Rail Line
- Main road
- Cadastral boundary

**Figure 10-18**
Predicted drawdown contours 20 years and 100 years after mining

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-085 DD 20&100 yrs.mxd 7/19/2017




N

0 5 10 km

Scale @ A4 1:350,000
Date: 19/07/17
Drawn: Gayle B.

**Legend**

- 0.5 m drawdown contour
- Groundwater Model Boundary
- ML 80187
- ML 700022
- Proposed mine infrastructure
- North Coast Rail Line
- Main road
- Cadastral boundary

**Figure 10-19**

Predicted drawdown contours at the catchment scale at mine closure and 100 years after mining

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-086 EOM &100 yrs-post mine.mxd 7/19/2017

### 10.6.6 Aquifer Disruption

The aquifers potentially impacted by the project are the coal seam aquifers (see Section 10.5.5 for further discussion) and the alluvial aquifers associated with the watercourses where they occur within the mining footprint. Other components of the groundwater system, including the basement rocks, will not be directly impacted.

The rehabilitation of much of the mine area by backfilling of mine pits will possibly enhance the hydraulic properties of the aquifers intersected by mining. However, the pit voids remaining after mining will disconnect the alluvial aquifers associated with Tooloombah and Deep Creek. This is unlikely to be significant as in these locations the aquifers are likely to predominantly be groundwater discharge zones rather than aquifers transferring substantial quantities of groundwater downstream.

The impact of aquifer disruption on sensitive receptors will largely be restricted to the area of rehabilitated mining and the pit voids remaining after closure. This will affect, to some extent, all three of the other direct effects, including groundwater quantity and quality, and groundwater and surface water interaction.

## 10.7 Receptor Exposure and Threat Assessment

### 10.7.1 Overview

An overview of the linkages between the potential direct groundwater effects of mining and EVs is summarised at Table 10-18. More detail is presented in the following sub-sections.

**Table 10-18 Linkage between direct effects and EVs**

| Direct effect | EVs that can be impacted | Potential effect |
|---|---|---|
| Quantity | ▪ Aquatic ecosystems | ▪ Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream |
| | ▪ Irrigation | ▪ Potential reduction in pumping rates |
| | ▪ Farm supply | ▪ Potential reduction in pumping rates |
| | ▪ Stock supply | ▪ Potential reduction in pumping rates |
| | ▪ Cultural / spiritual | ▪ Largely associated with 'aquatic ecosystems EV' |
| Quality | ▪ Aquatic ecosystems | ▪ None likely as evaporative control of poor in-pit water means there is little chance of external impact |
| | ▪ Irrigation | |
| | ▪ Farm supply | |
| | ▪ Stock supply | |
| | ▪ Cultural / spiritual | |
| Groundwater – surface water interaction | ▪ Aquatic ecosystems | ▪ Possible significant effect where baseflow is interrupted within the potential zone of drawdown impact and further downstream |
| | ▪ Irrigation | ▪ None |
| | ▪ Farm supply | ▪ None |
| | ▪ Stock supply | ▪ None |
| | ▪ Cultural / spiritual | ▪ Largely associated with 'aquatic ecosystems EV' |
| Aquifer disruption | ▪ Aquatic ecosystems | ▪ Limited |
| | ▪ Irrigation | ▪ Limited |
| | ▪ Farm supply | ▪ Limited |
| | ▪ Stock supply | ▪ Limited |
| | ▪ Cultural / spiritual | ▪ Limited |

adapted from National Water Commission, 2011

### 10.7.2 Potential EV Impact

In terms of the EVs applying to the study area, the direct effects assessment presented in Section 10.6 the following impacts to the groundwater resources on which the EVs rely are probable:

- **Aquatic ecosystems**

  *Exposure*: (i) Quantity - The extent of groundwater drawdown is predicted to not extent to with 10 km of the Styx Estuary, and most groundwater that currently discharges to Styx River, and Tooloombah and Deep Creeks is likely lost to riparian zone evapotranspiration. However, reduced baseflow along stream reaches located with the zone of (drawdown) influence could remove environmental water requirements from baseflow (Type 2 and 3) GDEs. (ii) Quality – Apart from salinization of water within the remaining pit voids there is unlikely to be significant changes to groundwater quality. (iii) Groundwater and surface water interaction – Possible reduced baseflow to stream reaches due to water table drawdown is likely to impact on beneficial use. (iv) Aquifer disruption – Possible water table drawdown and reduced baseflow to stream reaches due to water table drawdown is likely to impact Type 2 and 3 GDEs. Aquifer disruption may have local impact on Type 1 GDEs located within the immediate mine area, possibly disrupting connectivity between lower and upper catchment habitat.

  *Threat*: Moderate - High.

- **Irrigation**

  *Exposure*: (i) Quantity - The potential for irrigation supplies to be impacted by the mine (during and following closure) will be restricted to any alluvial aquifer supplies located within around 6 km upstream and downstream of the Project due to water table decline. From the information available, there may be two irrigation supplies located at the very north of the predicted zone of influence (see Figure 10-6 and Figure 10-19). (ii) Quality – Apart from salinization of water within the remaining pit voids there is unlikely to be significant changes to groundwater quality. (iii) Groundwater and surface water interaction – Possible reduced available pumping drawdown due to water table drawdown is unlikely to impact on beneficial use except within a few km of the Project. (iv) Aquifer disruption – Unlikely to cause significant impact to irrigation supply.

  *Threat*: Low to Moderate.

- **Farm supply**

  *Exposure*: Due to typically low bore yields, apart from some alluvial aquifer bores, it is probable that the farming community in the Styx Basin relies on dam water supplies. The potential for groundwater supplies to be impacted by the mine (during and following closure) will be restricted to any alluvial aquifer supplies located within around 6 km upstream and downstream of the Project due to water table decline. (ii) Quality – Apart from salinization of water within the remaining pit voids there is unlikely to be significant changes to groundwater quality. (iii) Groundwater and surface water interaction – Possible reduced baseflow to stream reaches due to water table drawdown is unlikely to impact on beneficial use. (iv) Aquifer disruption – Unlikely to cause significant impact to farm supply.

  *Threat*: Low.

- **Stock supply**

  *Exposure*: (i) Quantity - Due to typically low bore yields, apart from some alluvial aquifer bores, it is probable that the farming community in the Styx Basin relies on dam water supplies. The potential for groundwater supplies to be impacted by the mine (during and following closure) will be restricted to any alluvial aquifer supplies located within around 6 km upstream and downstream of the Project due to water table decline. (ii) Quality – Apart from salinization of water within the remaining pit voids there is unlikely to be significant changes to groundwater quality. (iii) Groundwater and surface water interaction – Possible reduced baseflow to stream reaches due to water table drawdown is unlikely to impact on beneficial use. (iv) Aquifer disruption – Unlikely to cause significant impact to stock supply.

  *Threat*: Low to Moderate.

- **Cultural or Spiritual**

  *Exposure:* (i) Quantity – Drawdown due to pit dewatering and depressurisation during mining and evaporative losses from pit voids post mining will impact on riparian vegetation and permanent pools near to the Project, and possibly further afield (within around 6 km of the project north to south). (ii) Quality – Apart from salinization of water within the remaining pit voids there is unlikely to be significant changes to groundwater quality. (iii) Groundwater and surface water interaction – See 'Quantity'. (iv) Aquifer disruption – Unlikely to cause significant impact outside Project area.

  *Threat*: Low to Moderate

## 10.7.3 Impact Assessment

### 10.7.3.1 Third Party Users

Figure 10-20 presents a locality plan for third party bore users. Also presented on Figure 10-20 is the predicted 100 year post mining extent of mine induced drawdown influence (as delineated by the 0.5 m drawdown contour). The figure shows:

- Three bores (BH28/BH28A, BH04, BH01X) are within the predicted zone of mine influence; and
- Of these, only one (BH28/BH28A) is in an area where drawdowns of more than a few metres is likely.

BH04 is reported to have a constructed depth of 10.36 m and a static water level of around 6.18 m below top of casing. There are no available data for the other bores relating to constructed depth or available drawdown. Assuming BH04 is representative of the other bores, mine induced drawdown of more than 1 m could mean that the continued use of the bores could be jeopardised depending on pumping rates and well losses.

### 10.7.3.2 Environmental and Cultural / Spiritual

EV threats associated with aquatic ecosystems, and cultural or spiritual values are addressed together in this section as they are intimately linked. The assessment of potential impact on GDEs is undertaken in line with the current national framework for assessing the environmental water requirements of GDEs. The approach utilises the GDE toolbox (Richardson et al 2011), which enables a starting point for investigating potential impacts on potential GDEs within the study area that may be exposed to threat due to reduced groundwater quantity and quality, groundwater and surface water interaction, and aquifer disruption.

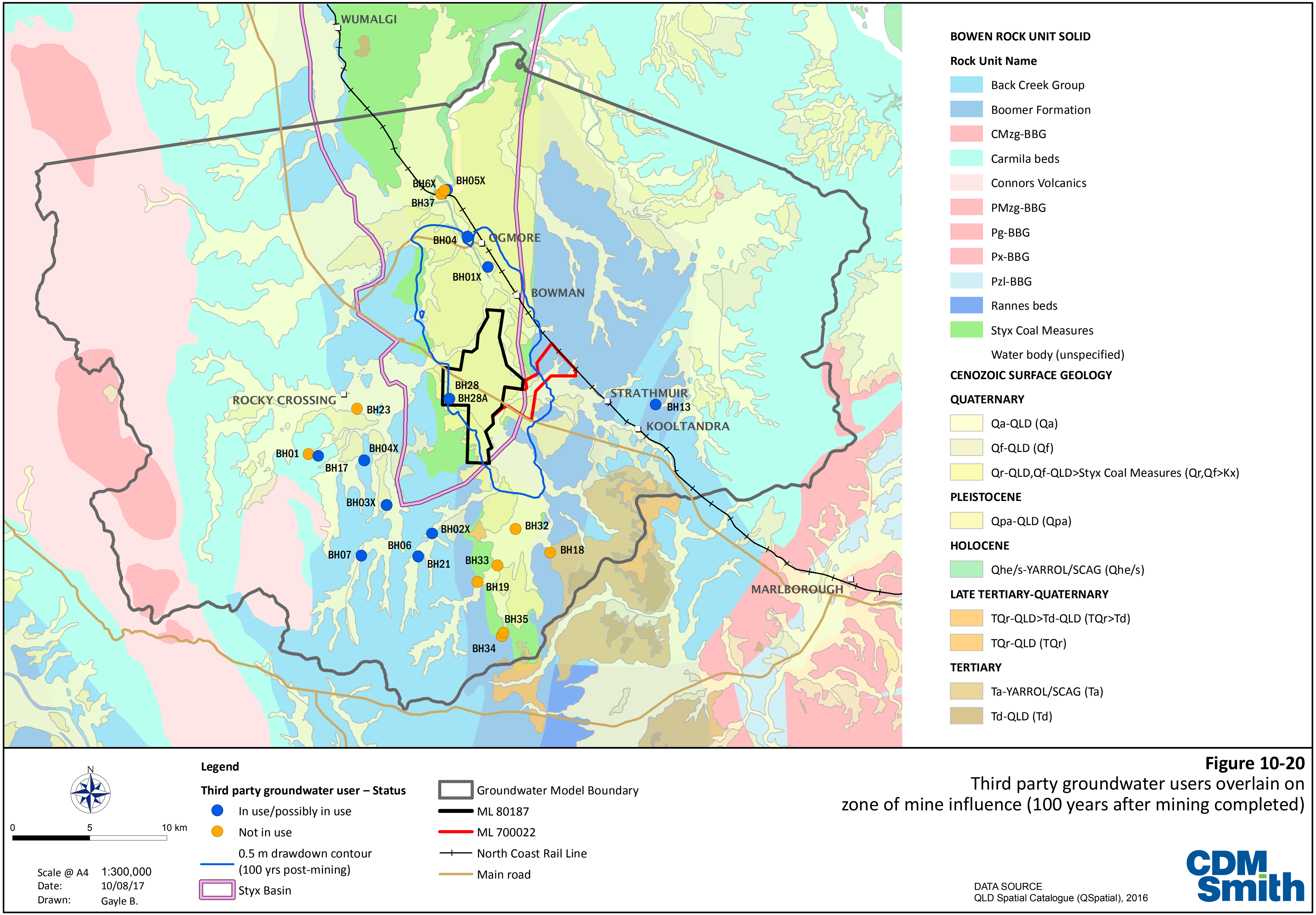



**Figure 10-20**
Third party groundwater users overlain on zone of mine influence (100 years after mining completed)

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2016

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-081 R1 third party wells.mxd 8/10/2017

The GDE toolbox allows GDEs to be considered within a staged framework that includes three levels of assessment with targeted questions. The assessment levels are related to the GDE ecological values, the level of threat posed to them, required level of certainty and data availability. The complexity of the assessment and associated data requirements increase through the assessment levels and can be summarised as follows:

- Level 1 assessment - least detailed and focuses on gaining a base understanding of where GDEs exist, the classification of processes, and basic conceptualisation of the bio-physical setting;
- Level 2 assessment - verifies the susceptibility of identified GDEs to changing hydrological setting, supported by a conceptual understanding of seasonal hydrology and groundwater interaction with the ecosystems, including the identification of ecological end points and specific components of the terrestrial vegetation that are directly related to the nature of groundwater connection; and
- Level 3 assessment - involves understanding the threats to GDEs and how a change in groundwater regime might affect GDE condition. This stage requires the development of hypotheses that are either tested through expert knowledge, modelling and / or additional field data.

Figure 10-21 presents the application of the framework to potential GDEs and current state of knowledge regarding GDEs identified within the study area. The current state of knowledge allows for all three levels of assessment to be discussed. What remain apparent as major data gaps are the:

- Lack of time series groundwater data (gaugings and water quality) that would provide insight into the temporal nature of groundwater and surface water connections;
- Lack of understanding around the groundwater environmental requirements of Type 3 GDEs; and
- General uncertainty around groundwater model outputs.

To assess the potential impacts of mining activities (level 3 assessment), drivers and stressors that influence the dynamics and health of GDEs prior to and during mining need to be considered and described within an eco-hydrogeological conceptual model based on the control and stressor model of Gross (2003). The eco-hydrogeological conceptualisation provides a schematic representation of critical processes that link GDE water requirements to the landscape, surface and groundwater systems and provides a context for hypothesising the cause-receptor pathways and likely GDE response to direct groundwater effects of mining.

Figure 10-22 presents the essential components of the Central Queensland Mine eco-hydrogeological conceptual model including:

- Baseline (pre-mining) natural and anthropogenic drivers that influence the landscape, and groundwater and surface water systems controlling the presence of GDEs in the landscape;
- Stressors and ecological endpoints (key physico-chemical elements of the system) that provide an indication of the overall GDE condition; and
- Direct effects of mining on GDEs.

| Question | Outcome |
| --- | --- |
| **Level 1 Basic conceptualisation** | |
| Has the hydrogeological setting been established | Preliminary conceptualisation of the hydrogeology (groundwater and surface water interactions) is established through a numerical GW model. Large uncertainties exist due to lack of field data |
| Has the location of GDEs been established | Maps of the potential Type 2 and 3 GDEs exist, with field validation regarding the absence or presence of Type 1 GDEs |
| Has the registered value of the GDEs been established | Yes |
| **Level 2 Verification of the susceptibility of vegetation to changes in groundwater** | |
| Has the temporal nature of groundwater connection been established | Currently only a snapshot understanding of the temporal nature of connection is established due to the lack of time series GW data. Although there is likely permanent connection to Type 2 GDEs (riverine environments) |
| Has the dominant influence on the GW system been established | An evaluation of the recharge and discharge dynamics of the GW system is established through modelling (did the model illustrate surface discharge ) |
| **Level 3 Understanding the response of the GDEs to changes in GW** | |
| Has the critical service provided by GW been identified | Critical linkages between GDEs and GW have been identified through eco-hydrogeological conceptualisations. Some uncertainties remain |
| Has the threats to the GW system been established | The potential effects of mine dewatering is established through modelling |
| How will the current ecosystems change under the threats | There is likely to be significant impact to Type 2 GDEs, impact to Type 3 GDEs remain uncertain |

Source: Richardson et al 2011

**Figure 10-21 GDE assessment framework**

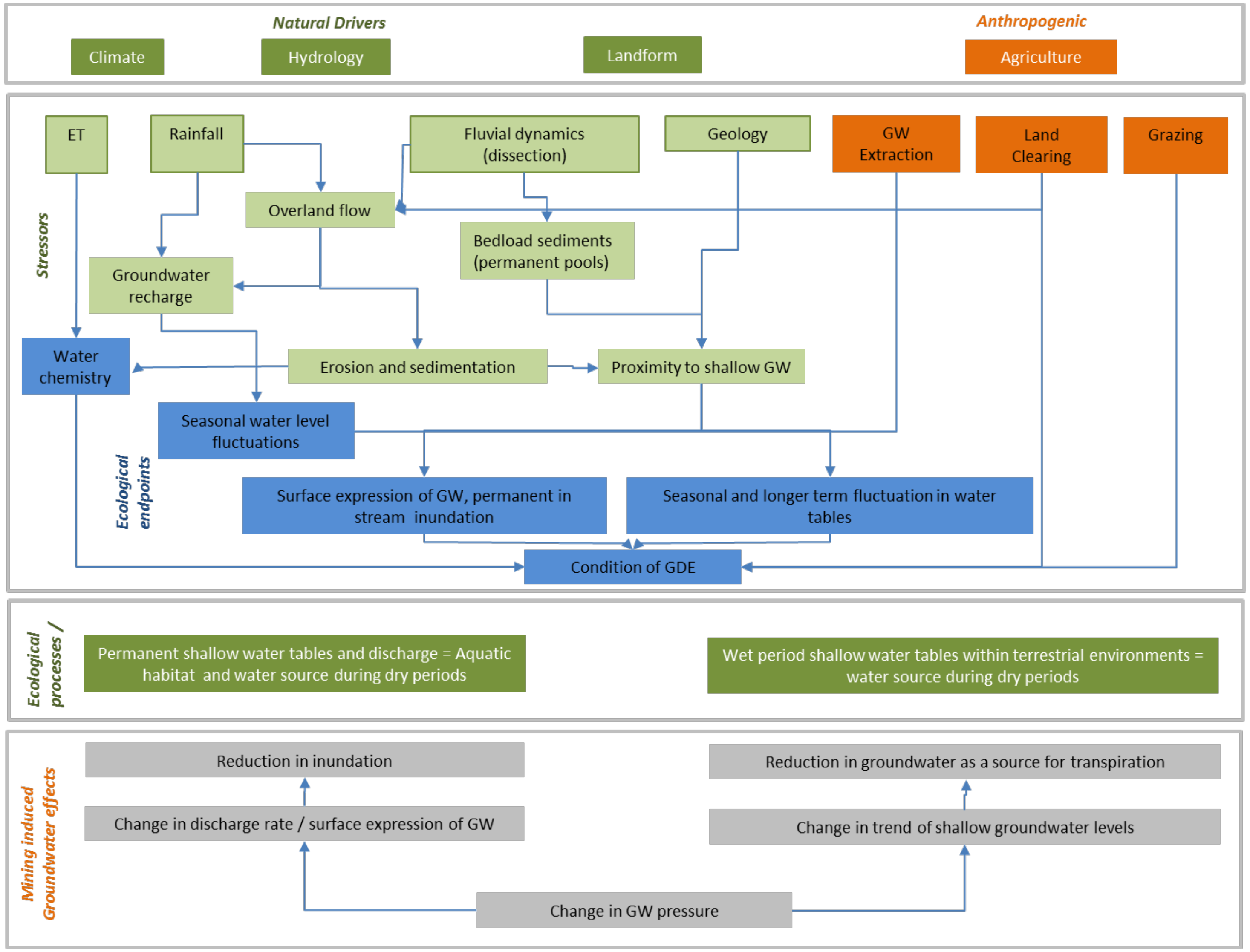



**Figure 10-22 Driver stressor diagram for GDEs**

Further description of the components of the eco-hydrogeological conceptual model are provided in Table 10-19. Several of the critical linkages that require understanding around the likely impact to GDES are:

- The role surface water flow plays in recharge to the alluvial aquifer associated with major drainages, as opposed to recharge from the broader landscape; and
- The role ground water plays in maintaining in-stream inundation.

Potential impacts on GDEs will depend on the magnitude of the alteration to groundwater connection as well as the positive or negative influences additional drivers might have on GDE condition. The direct effect of mining on groundwater of most importance to GDE condition has been determined as 'change in quantity', i.e. drawdown of water tables and reduced baseflow to water courses.

**Table 10-19 Eco-hydrogeological conceptual model components**

| Type | Driver | Stressor | Hypothesised ecological effects |
|---|---|---|---|
| Natural | Climate | Evapotranspiration | Groundwater discharge, lowering of water table and evaporative salt concentration. |
| | | Rainfall | Recharge and seasonal water table fluctuations. |
| | Landform | Fluvial dynamics – stream dissection | Steep slopes lead to run-off, flatter area encourages ponding and recharge. The depth of stream dissection will partially control proximity to shallow groundwater. |
| | | Overland flow | Contribute to recharge down gradient, can mobilise sediments and contaminants. |
| | | Geology | Type 2 GDEs associated with alluvial aquifer only, the shape of drawdown controlled by contact geology. |
| | | Bedload sediments (remnant pools) | The distribution of bedload sediments will influence size and connectivity of pools within the stream |
| | | Proximity to shallow groundwater | Depth to water table is shallower in low lying areas with local seasonal discharge. |
| | | Erosion and sedimentation | Impacts the quality of in stream water |
| | Hydrology | Groundwater recharge | Rainfall-derived recharge causing seasonal water table fluctuations within the Quaternary Sediments settings. Stream based recharge provides additional water source to Riparian Vegetation. |
| | | Seasonal water table fluctuations | Controlled by rainfall and stream flow recharge with unknown seasonal fluctuation. Water table may locally reach rooting depth around riparian zones and maintain water holes after wet periods. |
| | | Surface expression of groundwater | Permanent discharge into major waterways creating permanent inundation and flow following wet periods, consistent with mapped Type 2 GDEs. |
| Anthropogenic | Agriculture | Groundwater extraction | Unlikely groundwater extraction occurs to significantly reduce groundwater pressure and lower water tables. |
| | | Land clearing | Increased susceptibility to erosion/sedimentation, reduced water availability due to stock water use. |
| | | Grazing | Physical damage due to trampling, pugging within GW discharge zones. |
| | Mining | Change in groundwater pressure | Reduced groundwater discharge and water availability to GDEs due to drawdown of water table.<br>Reduction in period of surface water inundation within water ways. |

The magnitude of drawdown around the mine ranges up to 100 m during mining (due to dewatering and depressurisation activities), after which recovery commences such that over the next 100 years groundwater pressures recover by more than 50 m. The water table is very unlikely to recover back to pre-mine conditions around the pit voids remaining after mining due to evaporative losses from the pit water body that begins to form after mining ceases. Further afield, whilst groundwater recovery occurs around the mine, groundwater pressures / levels will continue to decline until a new dynamic equilibrium develops in response to the ongoing evaporative loss of water from the pit voids. The spatial relationship between GDEs and the time of maximum predicted drawdown is presented in Figure 10-23 and Figure 10-24 for Type 2 GDEs, and Figure 10-25 and Figure 10-26 for Type 3 GDEs.

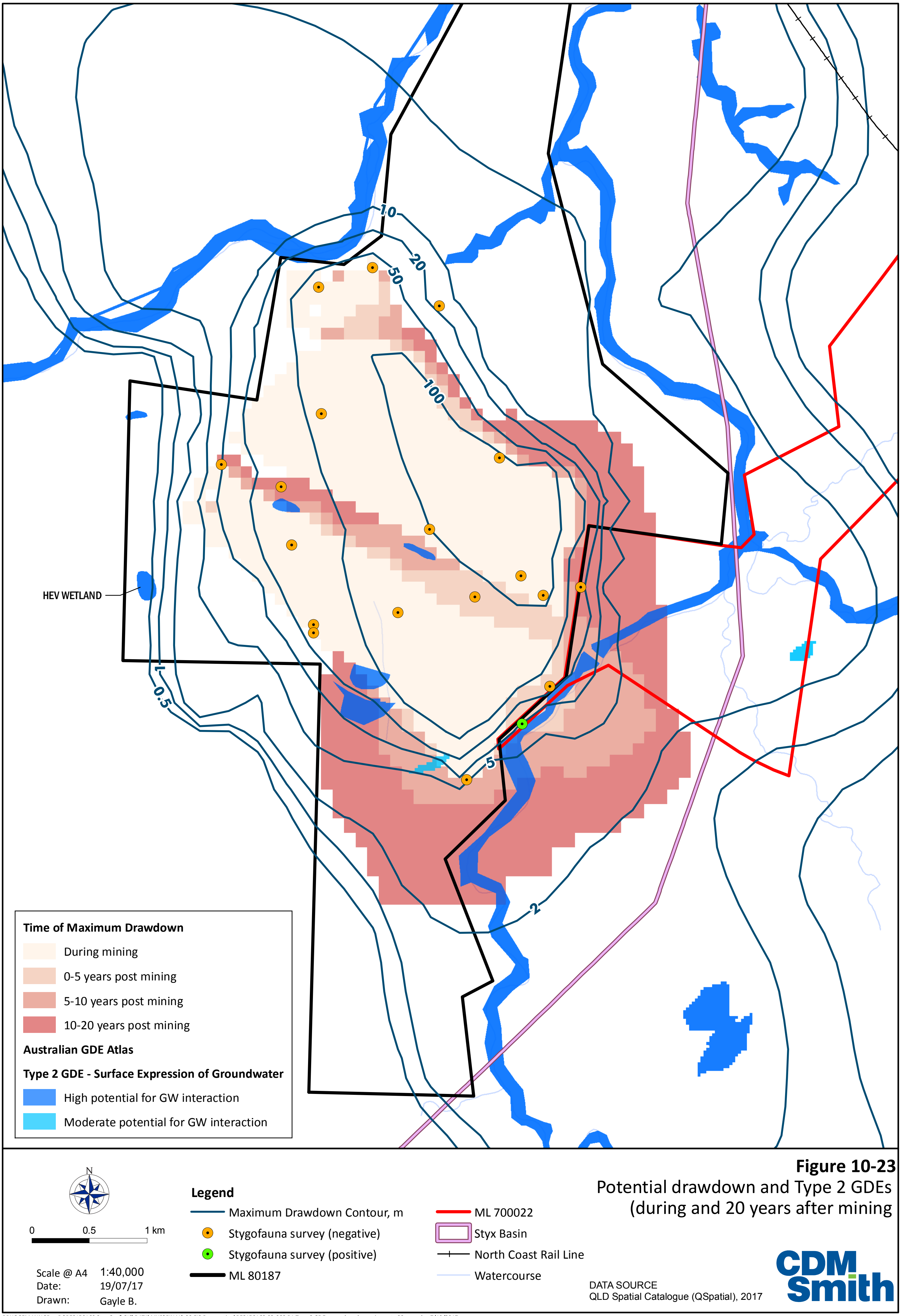
The change in groundwater pressures / levels will impact both annual and longer-term (years or decades) groundwater and surface water connections, thereby impacting on GDEs that may exist within the zone of influence (see Figure 10-19), i.e.:

- **Type 1 GDEs -** The presence of stygofauna has been verified by field sampling in a zone where it is predicted up to 10 m of drawdown will occur. As discussed previously, the taxa identified is unlikely to exist just with the zone and is likely to be more pervasive within the alluvial sediments of the broader Styx Basin; and
- **Type 2 GDEs -** As discussed previously, Type 2 GDEs are likely to be confined to the riverine environment of Tooloombah and Deep creeks. While several small wetlands are mapped as having a high potential for groundwater connection, existing bore data suggest limited connectivity as gauged depth to the groundwater is around 10 metres in many locations where wetlands occur. However, Figure 10-19 suggests that around 15 km of the major drainages could be prone to reduced baseflow (having the potential to impact on in-stream aquatic ecosystems).

The groundwater system associated with the creeks is hosted by Quaternary alluvial sediments. Recharge to this system occurs from direct rainfall, leakage from the creek during surface flow events and from deeper lithologies. During dry periods when there is little to no stream flow, it is likely the dissection of the landscape by water courses has intercepted shallow water tables such that groundwater is exposed as pools, rather than groundwater discharge occurring as flowing springs.

While no time series groundwater data exist for the Project area, it is likely that upstream of tidal influence within Styx River the nature of groundwater connection will vary spatially and temporally. The depth to the groundwater associated with Tooloombah and Deep Creeks will increase further upstream away from the coast. The lower reaches of Styx River are tidal and likely to be permanently connected to groundwater. Upstream of the confluence of Tooloombah and Deep Creeks the nature of groundwater connection is likely to vary depending on the magnitude of the rise and fall of groundwater levels in response to recharge events. It is likely water ways will vary between gaining and losing conditions. During prolonged periods of dry weather, when little to no surface flow occurs groundwater levels will fall such that the water table becomes disconnected from stream beds.

Within the first 20 years or so after mining is completed draw down of 20 m is predicted at sections of Tooloombah and Deep Creeks closest to the mine area (Figure 10-23). Further up and downstream of the Project the change in groundwater levels is predicted to be less and occurs over longer time frames of up to 80 years (Figure 10-24).




Scale @ A4 1:40,000
Date: 19/07/17
Drawn: Gayle B.

**Figure 10-23**
Potential drawdown and Type 2 GDEs (during and 20 years after mining)

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\03 EIS Preparation\BES150160.03-062 R1 Type 2 GDEs-max drawdowns impacts-20 yr.mxd 7/19/2017

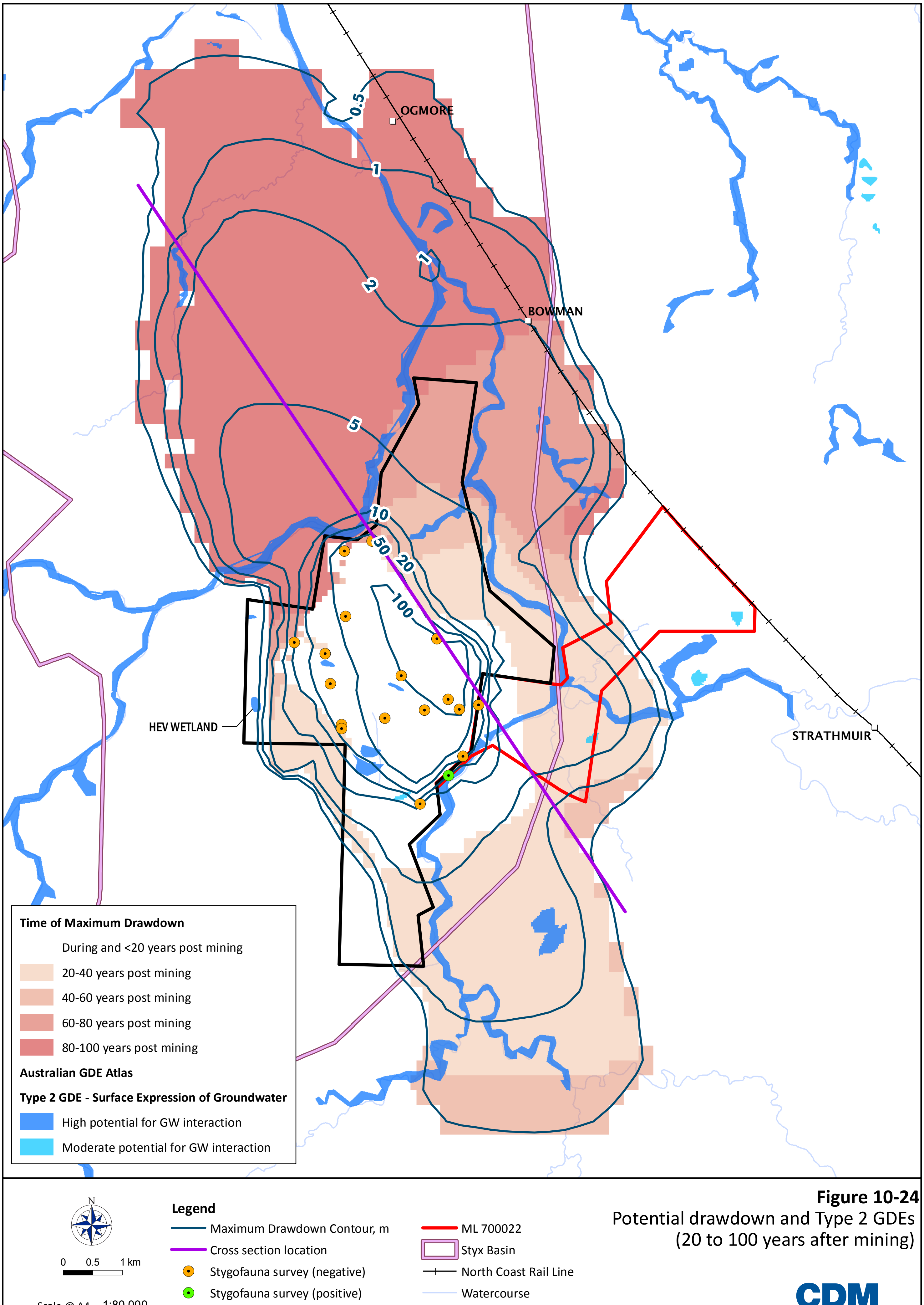



**Figure 10-24**
Potential drawdown and Type 2 GDEs (20 to 100 years after mining)

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\03 EIS Preparation\BES150160.03-057 R1 Type 2 GDEs-max drawdown impacts.mxd 7/19/2017

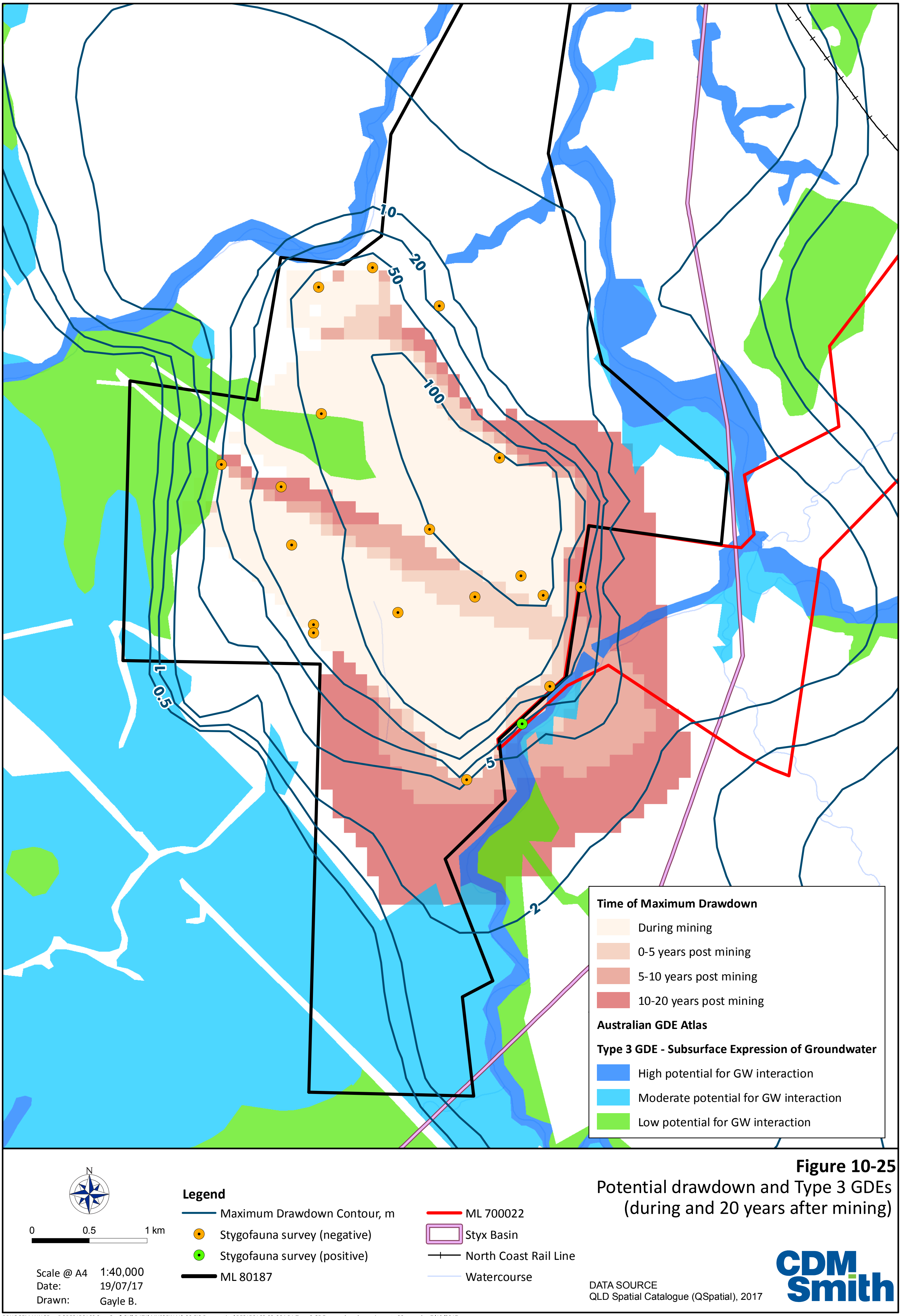



**Figure 10-25**
Potential drawdown and Type 3 GDEs (during and 20 years after mining)

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-064 R1 Type 3 GDEs-max drawdowns impacts-20 yr.mxd 7/19/2017

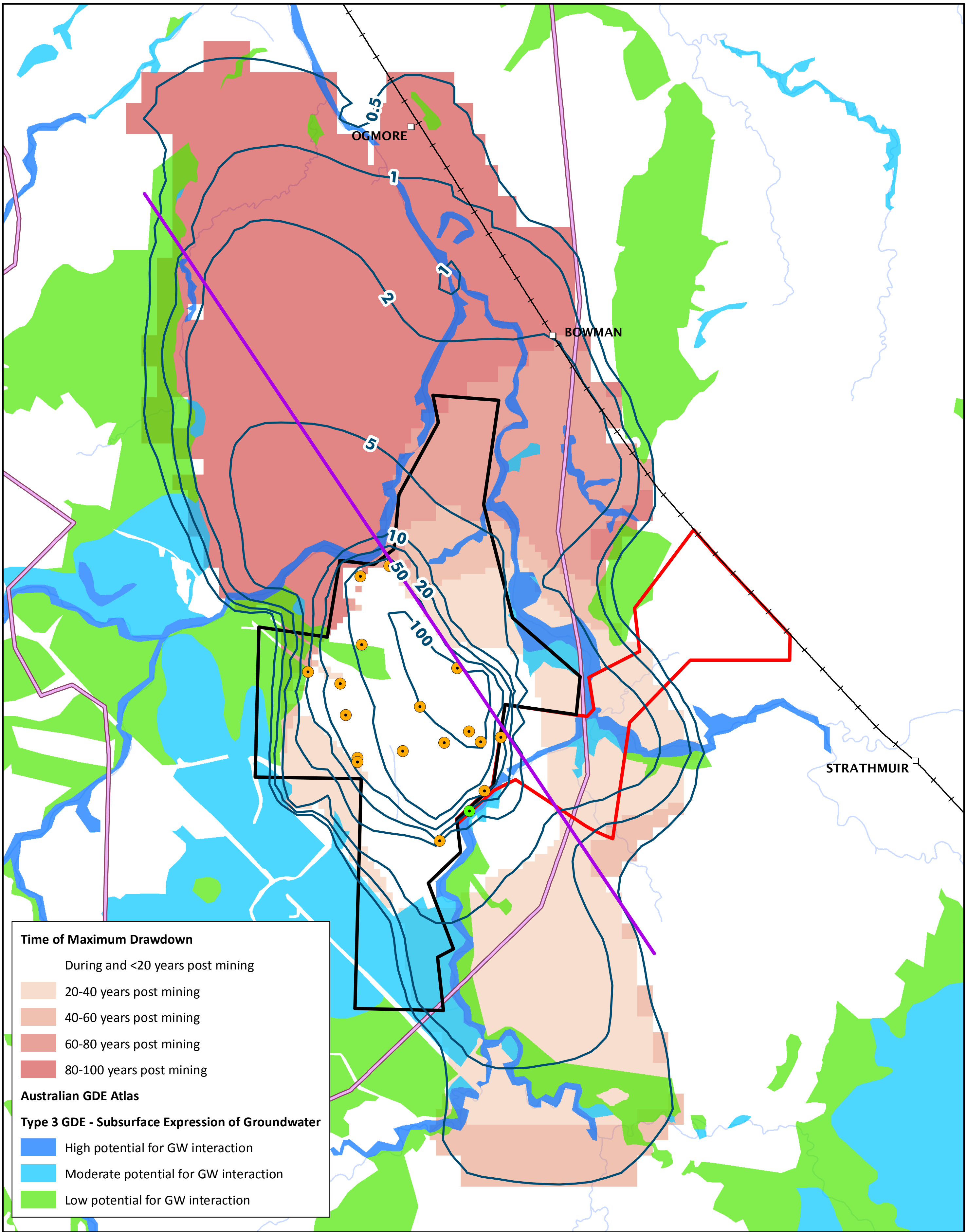



**Figure 10-26**
Potential drawdown and Type 3 GDEs
(20 to 100 years after mining)

N

0 0.5 1 km

Scale @ A4 1:80,000
Date: 19/07/17
Drawn: Gayle B.

**Legend**

- Maximum Drawdown Contour, m
- Cross section location
- Stygofauna survey (negative)
- Stygofauna survey (positive)
- ML 80187
- ML 700022
- Styx Basin
- North Coast Rail Line
- Watercourse

DATA SOURCE
QLD Spatial Catalogue (QSpatial), 2017

CDM Smith

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\03 EIS Preparation\BES150160.03-063 R1 Type 3 GDEs-max drawdown impacts.mxd 7/19/2017

Due to the uncertainty associated with numerical model predictions (CDM Smith, 2017) a simplified approach to considering the impacts of drawdown on Type 2 GDEs is undertaken, where any change in groundwater levels of greater than 5 m will inevitably disconnect the Creeks from the water table, irrespective of any seasonal recharge that may cause episodic rise in water tables. Changes less than 5 m are expected to cause a shift in the natural cycle of gaining and losing phases, but may or may not cause permanent disconnection.

Disconnection of the streams from the water table is not likely to impact surface flow events downstream. The impact is related to the persistence of permeant pools within the riverine environment during low or no flow periods. A surface flow event will fill pools, that when connected to groundwater will persist longer due to the lack of drainage through the stream bed. An important note here is that groundwater may not provide a measurable volume of water within the pools, but may act to mitigate downward leakage losses.

The change in the persistence and volume (depth) of the pools will likely adversely impact any present aquatic species. Of most ecological concern is the Southern Snapping Turtle as the pools provide critical habitat.

What remains unclear is the rate of loss of water from pools if groundwater levels were to drop and creeks were to become disconnected, and the time required to dry a pool that is no longer connected to the water table. Understanding these influences will help determine impact to aquatic ecosystems and provide information for potential mitigation options.

Sections of Deep Creek upstream of the immediate mine area are less likely to be connected to the groundwater system (see Figure 10-8), with predicted changes to groundwater levels of only several metres occurring over many decades likely to have little impact to aquatic habitat.

Downstream of the confluence of the two creeks, changes in groundwater levels may be buffered by tidal influences that may maintain riverine water levels and support aquatic ecosystems, irrespective of the changing nature of water table connection above the confluence.

**Type 3 GDEs** – These GDEs are likely to be confined to the riparian zones of the major drainages, where the depth to groundwater will generally be less than 5 m. While several areas of terrestrial GDEs are mapped as having a high potential for groundwater connection, existing bore data suggest the water table in many locations is around 10 m deep, or more (Figure 10-8). While it is possible the trees may have deep rooting systems, it is probable the soil water reservoir is the dominant source of water that meets environmental water requirements. Figure 10-19 suggests that around 7 km of the stream reaches centred around the Project could be prone to more than 5 m of drawdown over the long-term.

In general, there is a substantial data gap regarding water use patterns of terrestrial ecosystems. The presence of shallow water tables, does not necessarily equate to a viable source of water for vegetation. The complication is that Type 3 GDEs can have multiple sources of water, including direct rainfall seasonal runoff recharge that maintains the soil water reservoir and groundwater. The ratio of water requirements from these sources dictates to a degree how sensitive these vegetation types are to changes in groundwater levels. In some cases, terrestrial GDEs have a level of reliance greater than Type 2 GDEs within ephemeral systems as they have evolved to temporal changes in water sources, where small gradual declines in groundwater levels may not adversely impact the plant water requirements but large sudden shifts in groundwater levels may cause water stress depending on the availability of other water sources. For example, if stream flow and rainfall maintain sufficient soil water stores, a change in the groundwater level may be inconsequential but, if during a dry period, soil water stores were to become depleted and groundwater levels were to decline the onset of water stress may occur.

As with Type 2 GDEs, the area of most concern for Type 3 GDEs is related to areas of greater than 5 metres drawdown, which may result in long-term impacts to the riparian Forest Red Gum communities, Melaleucas and Semi-evergreen vine thicket along sections of Tooloombah and Deep Creeks that are located close to open cut mining operations. It is likely these vegetation communities will, to some degree, suffer adverse impacts in the long-term if groundwater levels decline below the necessary rooting depth required for tree species within these communities, particularly saplings and juvenile trees. It is uncertain what impact this may have on this community as most species are expected to obtain water requirements from multiple sources.

Any impact to the plant communities will also have the potential to reduce the extent of habitat for fauna species in the area including that suitable for koala, and at its worst may impact riparian connectivity along these sections of the creeks.

The mining risk framework developed by the National Water Commission states that cumulative effects in relation to mining can arise from the compounding effects of a single mining operation, interference effects between multiple mining operations, and interaction between mining and non-mining activities (Moran et al. 2010). There are no other mines operating within the Styx Basin, and as the compounding effect of the Project and its interaction with non-mining activities are assessed in the preceding sections, there is no need to undertake a cumulative impact assessment.

## 10.8 Mitigation and Management Measures

### 10.8.1 Overview

Central Queensland Coal commits to responsible resource recovery, including mitigation of unacceptable potential impacts on groundwater and connected systems. Central Queensland Coal will prepare and implement a detailed Water Management Plan (WMP) to describe how groundwater resources will be managed to achieve this objective, the WMP will also describe adverse impact mitigation works and activities.

Whilst this chapter of the EIS has focused on the key groundwater direct effects of mining on groundwater and connected systems having the potential for large-scale impact (mine pit development and post-closure pit voids), other direct effects will also be addressed by the WMP including (but not limited to) hazardous goods storages, water storages and sediment ponds.

### 10.8.2 Groundwater Depressurisation and Drawdown of Water Table

The proposed open-cut mining method will physically disrupt and drain saturated rocks within the subsurface resulting in groundwater depressurisation and decline of water-table elevation surrounding the open-cut pits (both during and after mining). Apart from alteration of the volume of coal resource to be extracted, the magnitude and extent of groundwater depressurisation will be controlled by the hydrogeological properties of the surrounding rocks, with no practical measures available to mitigate these effects.

If access to groundwater for stock watering is compromised by effects from the Project, the following mitigation measures may be implemented:

- Lowering of the existing pump or fitting with a new pump if sufficient saturated thickness (available drawdown) remains in the bore;
- Deepening or relocation of the bore to an area outside of the area of impact;
- Provision of surplus water from mine dewatering, if the quality is deemed suitable for the current groundwater use; and

- Provision of an alternative water supply of comparable quantity and quality to the current stock water use.

To address the potential for GDEs to be adversely impacted, further investigation of the hydrological response of the groundwater system to mining and the degree to which ecosystems may rely on groundwater, and how, to meet environmental water requirements will be undertaken. The outcome of these investigations will further inform how GDE water requirements can be maintained.

It is likely though, where access to groundwater for GDEs is compromised due to drawdown and this is identified to be due to mining, then environmental flows (sourced from mine dewatering) will be provided down waterways to provide additional local recharge (waterways are predominantly losing) in sensitive GDEs. The practice of supplementary surface water flow to maintain the riparian vegetation health is widely used as a management tool in providing environmental flow requirements to waterways and wetlands across Australia. In most cases, environmental flow programs are established where the 'natural flow' of a system has been altered by water diversion, reservoir or dam constructions.

The implementation of the WMP will consider the intermittent nature of connection between groundwater and terrestrial GDEs. The WMP will aim to simulate the natural pattern of environmental flows or offset drawdown of the water table by providing additional recharge to the root zone of riparian vegetation to replenish the shallow groundwater stores at times when groundwater is intermittently accessed by the vegetation. This process would require an evaluation of the frequency and size of flows that would generate sufficient infiltration and recharge to the water table, as to maintain appropriate groundwater levels necessary to maintain the riparian condition.

The WMP will consider the tolerance ranges of the riparian vegetation to changes in the quality of root zone water. It is likely the quality of supplementary groundwater will be different, and potentially more saline. Further investigations will be required to define the water quality tolerance ranges of the riparian vegetation, and depending on the outcome, provisions for treatment and or shandying with existing surface water stores (dams) may need to be considered to obtain the required water quality.

The success of the mitigation strategy can be measured by monitoring the condition of the target 'end point' of the system, in this case the riparian vegetation communities. The hypothesis proposed is that a portion of the water requirements of the riparian vegetation is provided by shallow groundwater (water table), predominantly during dry periods when stream flows are absent. Key components of the monitoring program may include:

- A baseline water source study of the riparian vegetation to determine the nature of groundwater uptake. This would require a combination of soil, water and tree analyses to assess water use patterns, and the seasonal source of water; and

- Condition monitoring of the vegetation to ensure the mitigation measures are maintaining the pre-mining conditions, taking into account non-mining related stressors.

As drawdown depends on a range of factors, its impacts will need to be managed adaptively. Adaptive management will involve monitoring groundwater impacts and, based on the severity of impacts, implement appropriate mitigation measures to minimise impacts on existing groundwater EVs as mining takes place. Central Queensland Coal will liaise with the landholder with the aim of reaching arrangements that will ensure provision of water of adequate yield and quality during and after mining until the aquifers are replenished or access to groundwater for stock water is no longer deemed compromised.

### 10.8.3 Change in Groundwater Quality

Even though the pit voids remaining after mine closure will capture any groundwater whose quality might be impacted by the mine operation, careful management and control measures of potential pollutants and contaminant sources will be maintained to prevent uncontrolled discharge to groundwater. These will include:

- Provision of appropriate spill control materials including booms and absorbent materials at refuelling facilities to contain spills;
- Ensure all refuelling facilities and the storage and handling of oil and chemicals to comply with relevant Australian Standards. Management and mitigation measures for wastewater are discussed in Chapter 7 - Waste Management;
- Ensure all staff are made aware of the potential for groundwater quality to be impacted and the requirement to report any spills; and
- Establish procedures to ensure safe and effective fuel, oil and chemical storage and handling. This includes storing these materials within roofed, bunded areas to contain spills and prevent uncontrolled discharge to the environment.

All uncontrolled discharges will be reported to the EHP under legislative requirements of the EP Act. If groundwater quality impacts are identified, mitigation measures will include:

- Investigation to identify and rectify any activity / facility that has caused uncontrolled discharge; and
- Containment or interception of the impacted groundwater / pollutant source e.g. cut-off trenches.

Control of surface water discharges and dirty water management systems, including storage of mine dewatering water, are discussed in Chapter 9 – Surface Water.

### 10.8.4 Groundwater Monitoring and Evaluation Program

#### 10.8.4.1 Water Table Drawdown and Groundwater Depressurisation

Monitoring of groundwater drawdown and depressurisation will comprise:

- Gauging of hydraulic head in shallow groundwater monitoring bores and landholder bores located within the predicted zone of mine influence;
- Automated pressure transducers will be installed at selected monitoring bores to provide daily observations that can be used to distinguish short-term changes, such as seasonal recharge, from potential long-term effects form the Project; and
- Gauging hydraulic head in selected locations outside of the predicted area of impact to confirm the extent of impact and to assess baseline conditions away from potential mining effects.

The location / configuration of monitoring bores, together with the landholder bores, will be designed to provide sufficient coverage for the Project and surrounding area to detect and monitor groundwater effects from the Project. Indicative groundwater monitoring bore locations are shown at Figure 10-27 and described in Table 10-20. The final location of the monitoring bores will be finalised after additional groundwater modelling is completed and prior to the issue of the EA. Based on the information collected during the first few years of mining, a need for expansion or rationalisation of the monitoring network may be identified.

**Table 10-20 Indicative location of groundwater management boreholes**

| Monitoring point | Location | | | | Monitoring frequency |
|---|---|---|---|---|---|
| | Latitude (DD) | Longitude (DD) | Easting MGA55 | Northing MGA55 | |
| Reference bores | | | | | |
| MB-1 | -22.620430 | 149.644795 | 771863 | 7496083 | Bi-annual |
| MB-2 | -22.636283 | 149.636453 | 770974 | 7494342 | |
| MB-3 | -22.640842 | 149.661582 | 773549 | 7493791 | |
| Compliance Bores | | | | | |
| MB-4 | -22.659227 | 149.661198 | 773473 | 7491755 | Quarterly for field parameters<br><br>Bi-annual for complete suite of analytes |
| MB-5 | -22.666968 | 149.643469 | 771635 | 7490930 | |
| MB-6 | -22.666479 | 149.665519 | 773903 | 7490944 | |
| MB-7 | -22.659821 | 149.671587 | 774540 | 7491670 | |
| MB-8 | -22.680958 | 149.655596 | 772854 | 7489358 | |
| MB-9 | -22.686061 | 149.643417 | 771592 | 7488815 | |
| MB-10 | -22.676173 | 149.690431 | 776445 | 7489824 | |
| MB-11 | -22.694871 | 149.623720 | 769550 | 7487875 | |
| MB-12 | -22.718091 | 149.675296 | 774805 | 7485208 | |
| MB-13 | -22.704498 | 149.685442 | 775875 | 7486695 | |
| MB-14 | -22.728669 | 149.662413 | 773460 | 7484060 | |
| MB-15 | -22.738088 | 149.633303 | 770450 | 7483070 | |
| MB-16 | -22.758418 | 149.670193 | 774200 | 7480750 | |
| MB-17 | -22.738096 | 149.703520 | 777665 | 7482939 | |

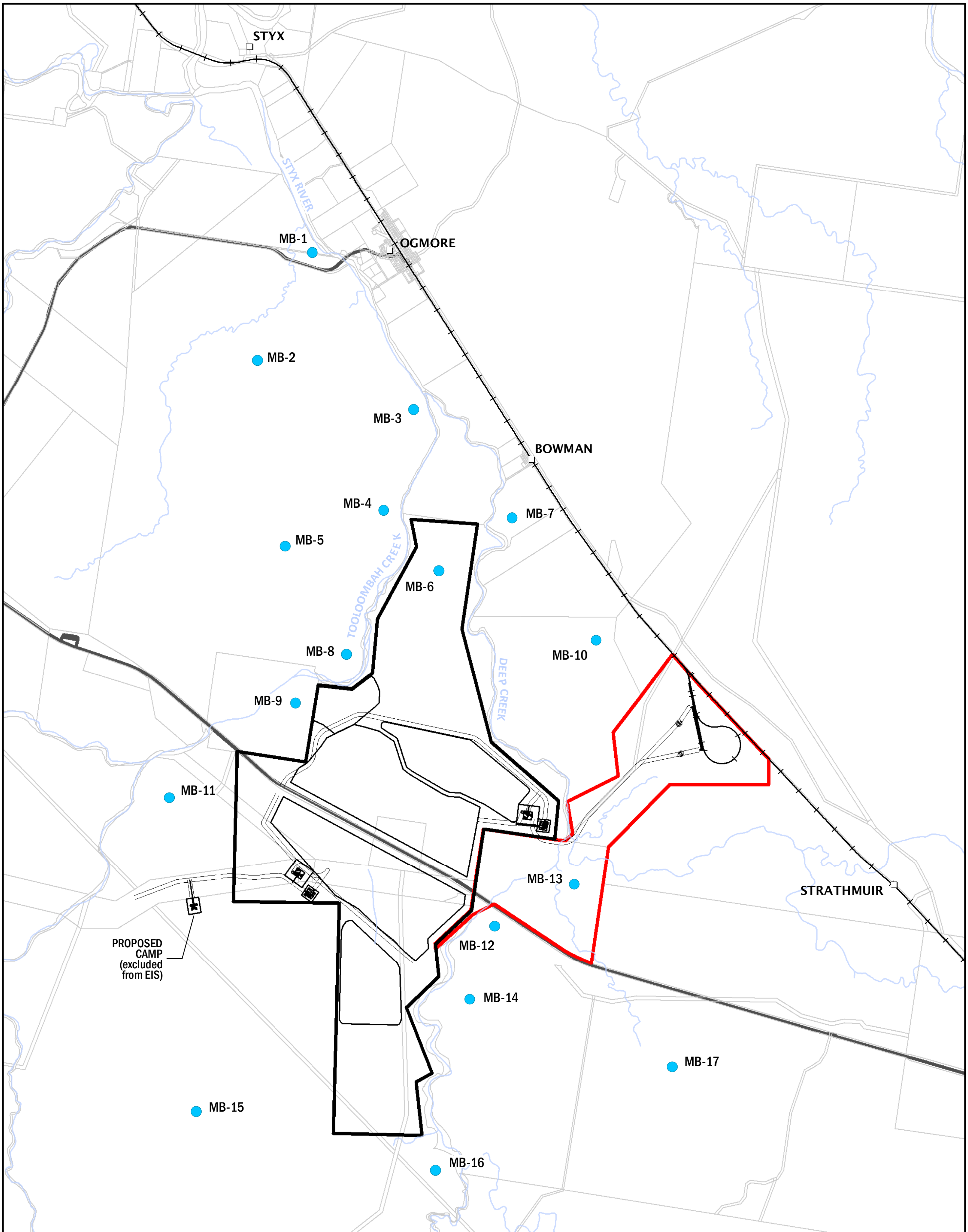



**Figure 10-27**
Indicative groundwater monitoring bore location

BRUGGEMANNGD B:\BES150160 Styx Coal\GIS\DATA\MXD\FINAL\.03 EIS Preparation\BES150160.03-096 R1 monitoring bore locations.mxd 7/27/2017

### Mine Water

Mine water inflow monitoring will consist of daily measurements of all water pumped from the mine pit using a suitable gauging method.

### Groundwater Quality

Regular monitoring of groundwater quality will take place during the life of mine, consisting of:

- Quarterly field measurements of EC and pH and total petroleum hydrocarbons of groundwater from the monitoring bores located on the mine lease and monthly field measurements of the same parameters for water pumped from the mine;
- Quarterly field measurements of EC and pH of groundwater from the monitoring bores located off the mine lease;
- Six monthly sampling of groundwater from monitoring bores and selected landholder bores for laboratory analyses of major ions, TDS and metals using methodologies that are suitable for comparison with the baseline monitoring; and
- Where groundwater quality impacts are identified, monitoring may be intensified to include the analysis of potentially harmful substances associated with oil, fuel and chemical handled onsite (e.g. benzene, toluene, ethylbenzene and xylenes).

Groundwater chemistry data will be analysed graphically for trends (e.g. using Piper plots and Stiff patterns) and any correlation with observed groundwater levels, mine inflow and rainfall.

### Frequency and Reporting

Groundwater monitoring reports will be prepared to facilitate the transfer of monitoring data to relevant regulatory authorities. The frequency of reporting will be decided in consultation with the relevant regulatory authorities and will be outlined in the WMP. Issues relating to groundwater samples that are reported by the landholder or mine staff will be recorded and documented in the monitoring report, including corrective actions.

### 10.8.4.2 Validation and Updating of the Groundwater Model

Data collected from newly installed (2017) and planned (2018) monitoring and test wells will be assessed and evaluated for incorporation into the numerical model (described in Appendix A6 – Groundwater Technical Report). The new data will include groundwater pressure and estimates of aquifer properties. The new assessment will examine whether there are distinct seasonal variations in well hydrographs that assist in describing recharge-discharge mechanisms that need to be incorporated in the numerical model.

Future improvements to the numerical model are likely in the first years of mining as new data associated with groundwater system response to mining become available to audit model predictions and, if necessary, recalibrate the groundwater model. As mining progresses, a need for further model updates will be assessed every twelve months based on quarterly reviews of groundwater monitoring data and findings of impact verification. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater from the monitoring program. Updated predictive results from the groundwater modelling will be available for updating of the eco-hydrogeological conceptualisation.

## 10.9 Qualitative Risk Assessment

Potential impacts on ecological values have been assessed utilising the risk assessment framework outlined in Chapter 1 - Introduction.

For the purposes of risk associated with groundwater EVs, risk levels 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 until suitable mitigation measures have been adopted to minimise the risk;
- Medium – Acceptable with formal review. Documented action plan to manage risk is required; and
- Low - Acceptable with review.

A qualitative risk assessment is outlined in Table 10-21. It outlines: the potential impacts, the initial risk, proposed control measures (as detailed in the previous section), and the residual risk following the implementation of those measures.

**Table 10-21 Potential impacts to groundwater**

| Issue and associated Project Phase | Potential impacts | Potential risk | Mitigation measures | Residual risk |
|---|---|---|---|---|
| **Drawdown due to Mining Activities (mine pits during and following mining)** | Drawdown due to mining has a number of potential impacts, including:<br>▪ Predicted reduction in the yield of bores due to reduced available pumping water level drawdown, including BH01X, BH04 and BH28/28A where long-term drawdown of between 0.5 and 1 m is predicted<br>▪ Reduction in groundwater quantity as depressurisation of the surrounding HSUs occur (depletion of groundwater in storage)<br>▪ Loss of discharge or drying of riverine pools during dry periods due to water table decline / drawdown<br>▪ Impact on GDEs (particularly riparian and aquatic) due to declining baseflow (important during dry periods) and water tables | High | Where access to groundwater for irrigation, farming and stock watering is compromised due to drawdown due to mining, the following mitigation measures may be implemented:<br>▪ Lowering of the existing pump or fitting with a new pump if sufficient saturated thickness (available drawdown) remains in the bore;<br>▪ Deepening or relocation of the bore to an area outside of the area of impact; and<br>▪ Provision of an alternative water supply of comparable quantity and quality to the current stock water use.<br>Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring and selected landholder bores will take place during the life of mine.<br>Further investigations relating to understanding potential GDE interactions with groundwater (timing, form of interaction) will be implemented to assist in assessing long-term impacts on potential GDEs. | Medium |
| **Reduced water quality due to Mining Activities (mine pits during and following mining)** | Dewatering of mine pits (during mining) and remaining pit voids (post-mining) will result in permanently lowered groundwater levels. Evaporative losses from the pit voids will result in gradual salinization of the pit water bodies. Permanent groundwater capture means that any accidental release of potential contaminants will be captured by the mine pits. | Low | Regular monitoring of groundwater quality will take place during the life of mine, comprising the following:<br>▪ Quarterly field measurements of EC and pH of groundwater from the monitoring bores and monthly field measurements of the same parameters for water pumped from the mine; and<br>▪ Twelve monthly sampling of groundwater from monitoring bores and selected landholder bores for laboratory analyses of major ions, total dissolved solids and metals, as per the baseline monitoring. | Low |

| Issue and associated Project Phase | Potential impacts | Potential risk | Mitigation measures | Residual risk |
|---|---|---|---|---|
| **Excavation resulting in Aquifer disruption (mine pits during and following mining)** | Disruption to the physical properties of the water table aquifer is likely. Backfilling of the majority of pits will alleviate this impact to some degree, but remaining pit voids will result in permanent capture of groundwater from around the mine (elongated capture zone controlled by geological structure and hydraulic properties. Apart from the impact of pit voids remaining after mining, the impact of excavation will be restricted to the backfilled pits. | High | Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring and selected landholder bores will take place during the life of mine to assist in understanding the extent of influence of aquifer disruption on regional (Basin) scale. | Medium |
| **Watering during Dust Suppression Activities (construction and operation)** | Watering activities to suppress dust may be required. However, it is considered unlikely that sufficient watering and wetting of the soil will be required to encourage infiltration and contamination of shallow groundwater. If this were to occur, the risk of impacts is negligible because the mine dewatering and post-closure pit voids will control / capture groundwater movement. | Low | Management and mitigation measures for the operational phase of the mine will include the following:<br>▪ Routinely inspect haul trucks for potential leaks / sources of contaminant and ensure appropriate maintenance; and<br>▪ Make available spill kits with appropriate spill control materials to all personnel in the event of a spill or leak. | Low |
| **Accidental Release of Contaminants (construction and operation)** | The potential exists for groundwater quality to be impacted by accidental release of contaminants to shallow groundwater. This may be caused in the event of major hydrocarbon spills from haul trucks or fuel tankers, the likelihood of which is considered low. If this were to occur, the risk of impacts is negligible because the mine dewatering and post-closure pit voids will control / capture groundwater movement. | Low | Management and mitigation measures will include the following:<br>▪ Ensure the use of appropriately designed laydown areas for vehicles and machinery and storage areas for chemicals, oils and fuels;<br>▪ Make available spill kits with appropriate spill control materials to all personnel in the event of a spill or leak; and<br>▪ Store and handle hazardous substances and chemicals in a controlled manner, in accordance with an established procedure, to prevent accidental release of contaminants. | Low |
| **Excavation resulting in Aquifer disruption (mine pits during and following mining)** | Disruption to the physical properties of the water table aquifer is likely. Backfilling of the majority of pits will alleviate this impact to some degree, but remaining pit voids will result in permanent capture of groundwater from around the mine (elongated capture zone controlled by geological structure and hydraulic properties. Apart from the impact of pit voids remaining after mining, the impact of excavation will be restricted to the backfilled pits. | High | Regular monitoring and evaluation of groundwater levels / pressures at on-lease and off-lease monitoring and selected landholder bores will take place during the life of mine to assist in understanding the extent of influence of aquifer disruption on regional (Basin) scale. | Medium |
| **Watering during Dust Suppression** | Watering activities to suppress dust may be required. However, it is considered unlikely that sufficient watering and wetting of the soil | Low | Management and mitigation measures for the operational phase of the mine will include the following: | Low |

| Issue and associated Project Phase | Potential impacts | Potential risk | Mitigation measures | Residual risk |
|---|---|---|---|---|
| **Activities (construction and operation)** | will be required to encourage infiltration and contamination of shallow groundwater. If this were to occur, the risk of impacts is negligible because the mine dewatering and post-closure pit voids will control / capture groundwater movement. | | ▪ Routinely inspect haul trucks for potential leaks / sources of contaminant and ensure appropriate maintenance; and<br>▪ Make available spill kits with appropriate spill control materials to all personnel in the event of a spill or leak. | |
| **Accidental Release of Contaminants (construction and operation)** | The potential exists for groundwater quality to be impacted by accidental release of contaminants to shallow groundwater. This may be caused in the event of major hydrocarbon spills from haul trucks or fuel tankers, the likelihood of which is considered low. If this were to occur, the risk of impacts is negligible because the mine dewatering and post-closure pit voids will control / capture groundwater movement. | Low | Management and mitigation measures will include the following:<br>▪ Ensure the use of appropriately designed laydown areas for vehicles and machinery and storage areas for chemicals, oils and fuels;<br>▪ Make available spill kits with appropriate spill control materials to all personnel in the event of a spill or leak; and<br>▪ Store and handle hazardous substances and chemicals in a controlled manner, in accordance with an established procedure, to prevent accidental release of contaminants. | Low |

# 10.10 Conclusions

## 10.10.1 Detail

Apart from alluvial aquifers associated with major watercourses, the Styx River Basin is typified by low permeability coal measures and basement rocks. In low elevation areas, the water table is hosted by alluvial and colluvial deposits, but in higher elevation areas the water table is hosted by fractured and weathered rocks.

In elevated areas, groundwater flow is driven by rainfall recharge from rainfall, whilst in lower lying elevations associated with drainages there may be localised recharge to alluvial aquifers during stream flow events. The water table slopes toward the major drainage lines and ultimately toward the ocean. Based on available data, the depth to water table across the Basin is typically in the range 2 to 15 m. Most groundwater discharge likely occurs by evaporation from topographic lows, particularly along the surface drainage network where there is an expression of surface water or where the water table occurs at depths less than around 2 m, as well as by evapotranspiration by riparian vegetation that can access groundwater within their root zones.

A number of third party bores are also located within the Styx River Basin, most of which appear to source water from alluvial aquifers, one of these bores is located close to the Project property boundary. In general, groundwater salinity is suitable for most livestock but is unsuitable for potable use without treatment. A bore census undertaken in 2017 suggests that the wells are used for stock water supply, and there may be small-scale irrigation development around 16 km downstream of the proposed mine.

The Queensland Government has identified the following Environmental Values for groundwater in the Styx River Basin– aquatic ecosystems, irrigation, farm supplies, stock water, and cultural and spiritual. Of these, only the aquatic ecosystem EV has relevance in regards to groundwater, noting that other types of ecosystems may have some form of indirect reliance on groundwater. GDE surveys have been undertaken in the broader study area. The following presents brief details of the results:

- Stygofauna (aquifer fauna) exist within alluvial aquifers associated with the major watercourses;
- Baseflow likely supports ephemeral and permanent flowing reaches of watercourses in some areas of the Styx River Basin particularly above the confluence of Deep and Tooloombah Creeks, and so it can be expected that aquatic GDEs will also occur near to the Project;
- A number of wetlands occur in the vicinity of the Project but it is apparent that they are unlikely to be highly dependent on groundwater discharge if at all; and
- A small number of Regional Ecosystems are likely to have terrestrial / riparian vegetation that has some degree of groundwater dependence, these include Forest Red Gum and Poplar Box woodlands, and semi-evergreen Vine Thicket.

There are four direct effects of mining on groundwater resources that need to be considered for any mining operation –altered groundwater quantity, quality and surface water / groundwater interactions, and aquifer disruption. A numerical groundwater flow model has been used to assist in assessing the extent to which mining will give rise to direct effects. The mining activities that have the most potential to significantly result in direct groundwater effects include:

- Quarrying of mine pits (during operation); and

- Remnant pit voids (following closure).

Other activities associated with mining that may have the potential to impact on groundwater resources include, for example, water storage dams, storage and use of hazardous chemicals and dust suppression. Strict handling, use and storage controls will reduce the risks of pollution affecting groundwater quality.

The following presents a summary of the groundwater effects assessment undertaken for the Project:

- **Groundwater quantity**
  During mining, it is predicted there will be very little change to water table elevations upstream (south, west and east) of the proposed mine but there will likely be significant reduction in water table elevation in the vicinity of the mine (due to dewatering that is required to provide efficient and safe conditions for mining) and to the north along the alignment of the alluvial aquifers associated with the major watercourses.

  After mining is completed, small final voids will be left in Open Cut Pit 1 and Open Cut 4. Open Cut 2 will be backfilled and no void will remain. There is expected to be little change to water table elevations upstream (south, west and east) of the proposed mine after closure, and partial recovery of the water table will occur in the near vicinity of the mine with pit lakes forming in the two voids to an elevation below the pre-mine water table. Downstream of the proposed mine water table elevations will continue to decline with stabilisation predicted to occur around 100 years after mining with water table drawdown extending to around 16 km downstream of the proposed mine.

  The pit lakes formed within the remaining pit voids will act as groundwater sinks into perpetuity due to evaporative losses exceeding rainfall and groundwater inflows.

- **Groundwater quality**
  The expectation that the pit voids act as permanent groundwater sinks means groundwater quality will unlikely be impacted by the key mine water affecting activities (mining of pits and remaining pit voids) as the pits will capture groundwater, i.e. any water quality effects will not migrate away from the pit voids.

- **Groundwater and surface water interaction**
  Water table drawdowns associated with dewatering during mining and evaporative losses after mining will give rise to reduced interaction between groundwater and surface water with the area where drawdown occurs, particularly during dry periods. The zone of influence is predicted to extend to within 5 km of Styx township and 15 km of the Styx estuary.

- **Aquifer disruption**
  The pit voids remaining after mining are unlikely to disrupt aquifers to any significant extent.

The direct groundwater effects described above will impact to some extent on existing groundwater users. The following presents a summary of the receptor exposure, threat and impact assessment:

- GDEs – the assessed threat level is considered at present to be moderate to high, particularly regarding riparian zone vegetation and any alluvial aquifer ecosystems in areas where water table drawdown occurs. Further work will be undertaken as part of the Supplementary EIS stage to refine the actual risk profiles, which includes identifying environmental water requirements of GDEs, establishing the conductance properties of the stream bed material and water budget of the permanent pools. Once these aspects are better understood, the threat assessment will be reconsidered and mitigation measures further refined;

- Irrigation – the assessed threat level is low to moderate as little irrigation is apparent in areas where water table drawdown occurs;
- Farm and stock supply - the assessed threat level is low to moderate as little the information available indicates there are few groundwater supplies located within the areas where water table drawdown of more than 5 m occurs; and
- Cultural and spiritual values - the assessed threat level is moderate to high largely due to the real possibility that these values are closely linked to ecological effects.

### 10.10.2 Further work to be undertaken during Supplementary EIS phase

The following provides details of further work to be completed to support the groundwater studies that will be reported during the supplementary EIS phase:

- Further explore the potential for groundwater and surface water interaction, both at a spatial scale that is suitable to determine losing and gaining stream reaches, and at a temporal scale suitable to identify seasonal patterns within the Styx Basin, and particularly within the project area. This work will occur over an area commensurate with the predicted zone of drawdown influence and include the installation of groundwater monitoring bores near to watercourses for gauging of groundwater levels, surveying the bed elevation of watercourses, stream gauging, and collection of groundwater and surface water chemistry data (e.g. major ions, stable isotopes of water). The groundwater monitoring data will be used to provide a basis for updating and recalibrating the groundwater model (see Section 10.6.2);
- Further assessment will be undertaken to assess the extent terrestrial and riparian vegetation within the predicted zone of groundwater drawdown influence is dependent on groundwater to meet environmental water requirements. This work will include establishing thickness of the vadose zone, likely soil water reservoir (plant available water capacity), leaf water potential studies and plant / soil / groundwater chemistry; and
- Undertake additional groundwater studies including the drilling, construction and testing of bores targeting alluvial, Styx Coal Measures and some basement rocks, to provide additional stratigraphic data and aquifer testing data to assist in updating the numerical groundwater flow model.

## 10.11 Commitments

In relation to managing groundwater, Central Queensland Coal's commitments are provided in Table 10-22.

**Table 10-22 Commitments – groundwater**

| Commitment |
|---|
| Responsible resource recovery, including mitigation of unacceptable potential impacts on groundwater and connected systems. |
| Prepare and implement a Water Management Plan that outlines the monitoring and management measures for surface water and groundwater. |
| Prepare and implement a water management network to manage impact to water resources. |
| Ensure all staff are aware of the potential for groundwater quality to be impacted and the requirement to report any spills. |
| Liaise with the landholder with the aim of reaching arrangements that will ensure provision of water of adequate yield and quality during and after mining until the aquifers are replenished or access to groundwater for stock water is no longer deemed compromised. |

# 10.12 ToR Cross-reference Table

**Table 10-23 ToR cross-reference**

| Terms of Reference | Section of EIS |
|---|---|
| Describe present and potential users and uses of water in areas potentially affected by the project, including municipal, agricultural[2], industrial, recreational and environmental uses of water. | Section 10.5.7 |
| Provide details of any proposed changes to, or use of, surface water or groundwater. | Section 10.6 |
| Identify any approval or allocation that would be needed under the *Water Act 2000*. | Section 10.2.1 |
| Describe all aquifers that would be impacted by the project, including the following information:<br>• nature of the aquifer/s | Section 10.5 |
| • geology/stratigraphy - such as alluvium, volcanic, metamorphic | Section 10.5 |
| • aquifer type - such as confined, unconfined | Section 10.5 |
| • depth to and thickness of the aquifers | Section 10.5 |
| • groundwater quality and volume | Sections 10.5.8 and 10.5.11 |
| • current use of groundwater in the area | Section 10.5.7 |
| • survey of existing groundwater supply facilities (e.g. bores, wells, or excavations) | Section 10.5.7.1 |
| • information to be gathered for analysis to include:<br>○ location | Sections 10.1 and 10.5.8 |
| ○ pumping parameters | Section 10.5.8 |
| ○ drawdown and recharge at normal pumping rates, and | Section 10.5 |
| ○ seasonal variations (if records exist) of groundwater levels | Section 10.7.2 |
| • proposal to develop network of groundwater monitoring bores before and after the commencement of the project. | Section 10.8.4 |
| Describe how 'make good' provisions would apply to any water users that may be adversely affected by the project. | Section 10.8 |
| Describe the practices and procedures that would be used to avoid or minimise impacts on water resources. | Sections 10.8 and 10.9 |
| Quantify the volume of all takes from the groundwater system (including pit dewatering, degassing, etc.) and assess the impacts on groundwater levels, quality and ecosystem interactions for each aquifer and any implications for surface-groundwater interactions. | Section 10.6 |

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