VITRINITE
BRIGHTER COAL

UNDERGROUND WATER IMPACT REPORT

VULCAN COAL MINE

Final

Tenure number: ML700060

October 2023

Prepared for:	Office of Groundwater Impact Assessment
Prepared by:	Mining and Energy Technical Services Pty Ltd
EA holder:	Queensland Coking Coal Pty Ltd and QLD Coal Aust. No 1 Pty Ltd
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+ 61 7 3174 4816 | info@vitrinite.com.au
vitrinite.com.au

PO Box 87, Morningside Q 4170
+ 61 7 3174 4816 | info@vitrinite.com.au

Suite 2, Level 6, Blue Tower
12 Creek Street, Brisbane Q 4000

VITRINITE PTY LTD
ABN 46 167 744 578

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1 Introduction

The Vulcan Coal Mine (VCM) is an open-cut coal mining operation developed by Vitrinite Pty Ltd between Dysart and Moranbah, in the Bowen Basin of Central Queensland. It is located on lot 10SP325345 and mining lease (ML) ML700060 presented in **Figure 1-1**.

Vitrinite holds an Environmental Authority (EA0002912) and ML authorising the extraction of black coal, quarry material, crushing and screening activities. The VCM is approved to operate for approximately four years extracting six million tonnes (Mt) of Run of Mine (ROM) hard coking coal at a rate of 1.95 Mt per annum. The VCM currently targets the Dysart Lower Lower (DLL) coal seam, with plans to target the Matilda (MAT) coal seam in future operations. The VCM project layout currently approved by the EA as well as proposed additional infrastructure (subject to approvals) is presented in **Figure 1-2**.

1.1 Purpose and Legislative requirements

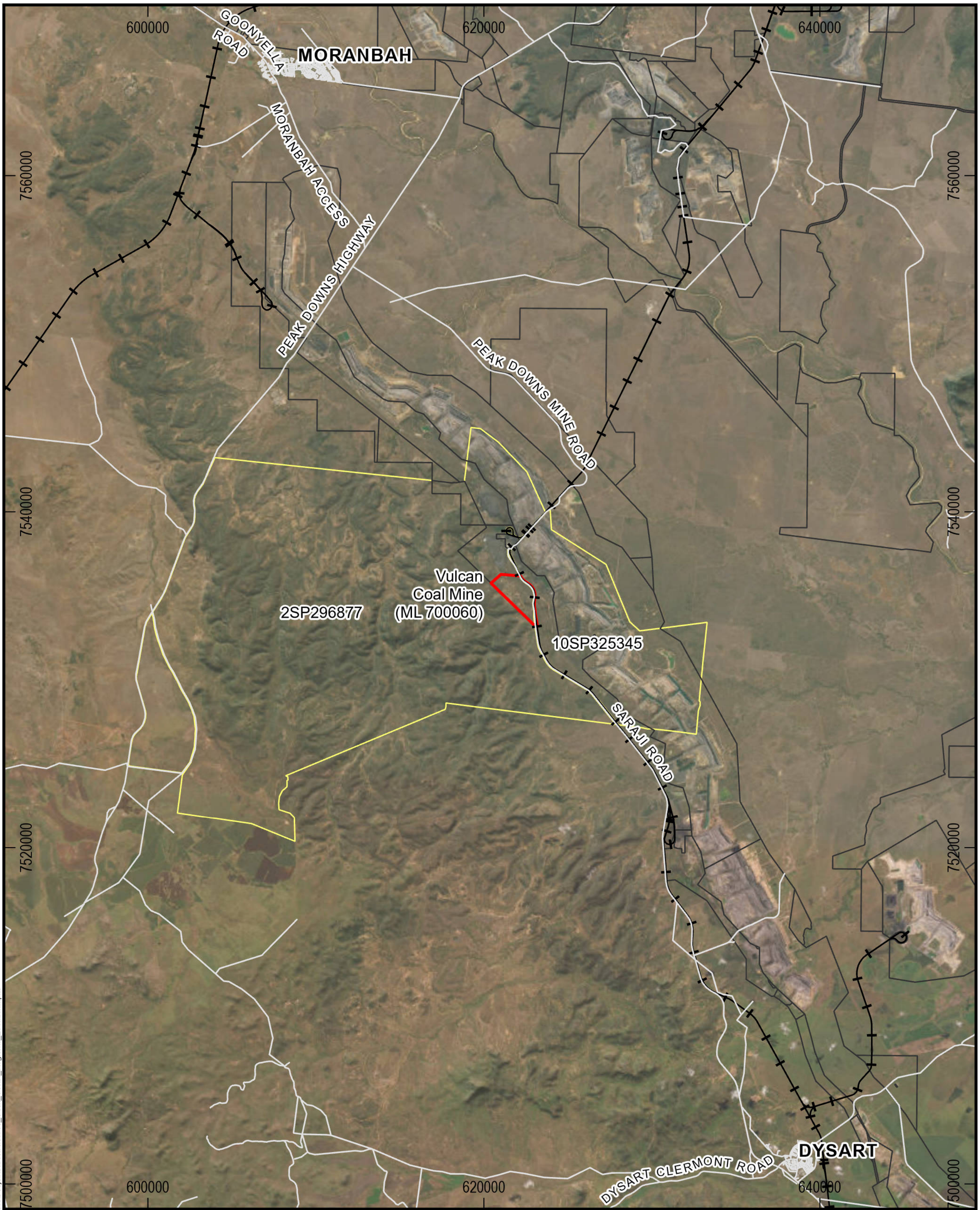
The purpose of this report is to fulfil the legislative requirements of an Underground Water Impact Report (UWIR) in accordance with Chapter 3 of the Water Act. This UWIR has been prepared as an addendum to the pre-existing Groundwater Impact Report for Vulcan Coal Mine prepared by hydrogeologist.com.au (2020).

The requirements for the management of impacts on underground water caused by the exercise of underground water rights are detailed in Chapter 3 of the Water Act. Underground water rights and obligations upon ML700060 are regulated through the Mineral Resources Act 1989, Water Act and approved EA conditions. The main purpose of a UWIR is to describe, make predictions about and manage the impacts of underground water extraction by the resource tenure holder. A summary of the UWIR requirements under the Water Act and the relevant sections of this report in which they are addressed are included in **Table 1-1**.

Table 1-1 Chapter 3 Water Act Provisions

Water Act Provision	Sub-Provision	UWIR Section
s 376		
1 (a) For the area to which the report relates -	**i.** The quantity of water produced or taken from the area because of the exercise of any previous relevant underground water rights; and	3.1
	ii. An estimate of the quantity of water to be produced or taken because of the exercise of the relevant underground water rights for a 3-year period starting on the consultation day for the report;	3.2
1 (b) For each aquifer affected, or likely to be affected, by the exercise of the relevant underground water rights -	**i.** A description of the aquifer; and	4.1
	ii. An analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and	4.1, 4.2
	iii. An analysis of the trends in water level change for the aquifer because of the exercise of the rights mentioned in paragraph (a)(i); and	4.3
	iv. A map showing the area of the aquifer where the water level is predicted to decline, because of the taking of the quantities of water mentioned in paragraph (a), by more than the bore trigger threshold within 3 years after the consultation day or the report;	5.2
	v. A map showing the area of the aquifer where the water level is predicted to decline, because of the exercise of relevant underground water rights, by more than the bore trigger threshold at any time;	5.3
1 (c) A description of the methods and techniques used to obtain the information and predictions under paragraph (b);		5.1
1 (d) A summary of information about all water bores in the area shown on a map mentioned in paragraph (b)(iv), including the number of bores, and the location and authorised use or purpose of each bore;		5.4
1 (da) A description of the impacts on environmental values that have occurred, or are likely to occur, because of any previous exercise of underground water rights;		6.1
1 (db) An assessment of the likely impacts on environmental values that will occur, or are likely to occur,	**i.** During the period mentioned in paragraph (a)(ii); and	6.2
	ii. Over the projected life of the resource tenure;	6.2

because of the exercise of underground water rights -		
1 (e) A program for -	**i.** Conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and	5.5
	ii. Giving the chief executive a summary of the outcome of each review, including a statement of whether there has been a material change in the information or predictions used to prepare the maps;	5.5
1 (f) A water monitoring strategy; as provided in s378.		7
1 (g) A spring management strategy;		Not applicable
1 (h) If the responsible entity is the office -	**i.** A proposed responsible tenure holder for each report obligation mentioned in the report; and	Not applicable
	ii. For each immediately affected area – the proposed responsible tenure holder or holders who must comply with any make good obligations for water bores within the immediately affected area;	
1 (i) Other information or matters prescribed under a regulation.		Not applicable
2 However, if the underground water impact report does not show any predicted water level decline in any area of an affected aquifer by more than the bore trigger threshold during the period mentioned in subsection (1)(b)(iv) or at any time as mentioned in subsection (1)(b)(v), the report does not have to include the program mentioned in subsection (1)(c).		
<u>s 378</u>		
1(a) Water Monitoring Strategy	**i.** Strategy for monitoring the quantity of water produced or taken from the area because of the exercise of relevant underground water rights; and	7
	ii. Changes in the water level of, and the quality of water in, aquifers in the area because of the exercise of the rights;	7
(b) The rationale for the strategy;		7.1
(c) A timetable for implementing the strategy;		7.2, 7.3
(d) A program for reporting to the office about the implementation of the strategy.		7.4
2. The strategy must include:	a) the parameters to be measures; and b) the locations for taking the measurements; and c) the frequency of the measurements.	7.2, 7.3
3. If the strategy is prepared for an UWIR, the strategy must also include a program for the responsible tenure holder or holders under the report to undertake a baseline assessment for each water bore that is:	a) Outside the area of a resource tenure; but b) Within the area shown on the map prepared under section 378 (b)(v).	Not applicable
4. If the strategy is prepared for a final report, the strategy must also include a statement about any matters under a previous strategy that have not yet been complied with.		Not applicable



Legend

- Roads
- Railway
- ML 700060
- Mining Lease
- Cadastral Boundary

Source: State of Queensland (Department of Resources) 2021-2022, Vitrinite 2022, METServe 2022, Earthstar Geographics.

Vulcan Coal Mine

Regional Location

0 3 6 12 Kilometers

Scale: 1:330,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 1-1

VITRINITE BRIGHTER COAL

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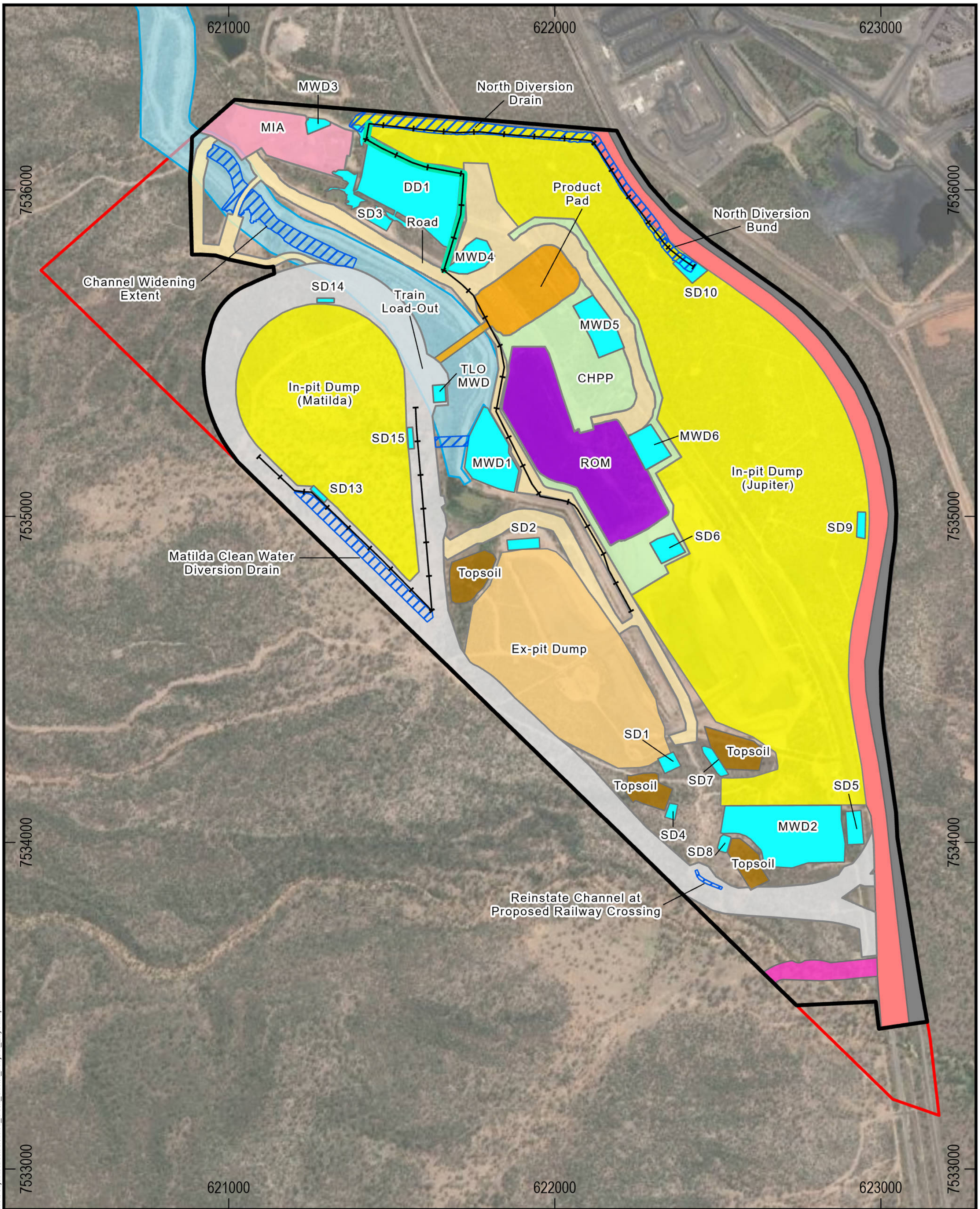

Legend

- ML 700060
- Revised Maximum Disturbance Footprint (Matilda Amendment)

Infrastructure as proposed in Matilda Amendment

- Dam Wall
- Proposed Flood Levee
- Water Pipeline Corridor
- CHPP
- Ex-pit Dump
- In-pit Dump
- MIA
- Dam
- Existing Rail
- ROM
- Rail Loop
- Road
- Saraji Road
- Stockpile (Topsoil)
- Train Load-Out Product Pad
- Magazine Road
- Water Management Infrastructure

Source: State of Queensland (Department of Resources) 2021-2022, Vitrinite 2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_Project_Layout.aprx

Vulcan Coal Mine

Project Layout

0 150 300 600

Meters

Scale: 1:17,000 (A4)

6/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 1-2

VITRINITE BRIGHTER COAL

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1.1.1 Bore trigger thresholds

Sections 376(b)(iv) and 376(b)(v) of the Water Act refers to bore trigger thresholds. As defined in the Water Act, a bore trigger threshold for an aquifer means a decline in the water level that is:

- five metres (m) for consolidated aquifers (e.g. sandstones); and
- two metres for unconsolidated aquifers (e.g. sand/alluvial aquifers).

The area within which water levels are predicted to be lowered in an aquifer by more than the bore trigger threshold within three years, due to water extraction, is referred to as the Immediately Affected Area (IAA).

The area within which water levels are predicted to be lowered by more than the bore trigger threshold in the long term, due to water extraction, is referred to as the Long-term Affected Area (LTAA).

1.2 Report structure

The structure of this UWIR has been prepared in accordance with that outlined in the Guideline: (Water Act 2000) Underground Water Impact Reports and Final Reports (DES, 2021) (UWIR Guideline). This guideline specifies that a UWIR must contain information that has been outlined in each of the following parts of the guideline:

- Part A: Information about underground water extractions resulting from the exercise of underground water rights;
- Part B: Information about aquifers affected, or likely to be affected;
- Part C: Maps showing the area of the affected aquifer(s) where underground water levels are expected to decline;
- Part D: An assessment of the impacts to the environmental values from the exercise of underground water rights;
- Part E: A water monitoring strategy;
- Part F: A spring impact management strategy; and
- Part G: For a CMA, assignment of responsibilities to resource tenure holders.

It is noted that Part G is not required as part of this UWIR as the VCM is not located within a cumulative management area (CMA).

The relevant Water Act requirements for each part of the UWIR Guideline above are listed at the beginning of the relevant sections in this report. The approved EA (EA0002912) is also referenced to with regards to the groundwater monitoring program which is currently implemented at the VCM.

1.3 Report consultation day

Section 322(1) of the Water Act defines the consultation day of a UWIR as '*the day a notice is first published about the proposed report'*. The commencement date of the UWIR will be the date that it is approved by the Chief Executive.

Vitrinite is required to provide a UWIR for its predicted take for the period of three years from the Consultation Day and then subsequent reports within 10 days of the day which is three years after the Commencement Date.

The exercise of underground water rights associated with the VCM will commence in Q1 2023.

2 Background

2.1 Project description

The VCM will operate for approximately four years and will extract approximately six million tonnes (Mt) of Run of Mine (ROM) hard coking coal at a rate of up to 1.95 million tonnes per annum (Mtpa). The VCM targets the ALEX and multiple Dysart Lower coal seams as well as the Matilda coal seam (currently subject to approvals). Current VCM activities are focused around a single open-cut pit targeting the Jupiter hard coking coal target (ALEX and DLL seams). The VCM has proposed an additional, small open-cut pit to the east of the existing pit to extract an outcrop of Matilda coal seam. Approval of this additional pit is currently subject to an EA amendment and will not be commenced until all relevant approvals have been granted.

The removal of overburden waste rock was required to access the target coal seams, by which waste rock was stored in the adjacent Ex-pit waste rock dump. Current operations implement in-pit dumping, progressively backfilling exhausted areas of the open-cut pit reducing the need to store waste rock in out-of-pit areas.

Coal is extracted using truck and shovel mining methods whereby coal is hauled to the ROM pad and processed through dry crushing and screening mobile plant equipment. Processed coal is then placed on the ROM stockpile for haulage. Rejects from the crushing and screening process are stockpiled separately and placed within the relevant active dumping area. No coal washing activities or processing waste storage is currently occurring at VCM.

As part of the EA amendment currently subject to approval, Vitrinite has proposed the following infrastructure additions to the VCM:

- Coal Handling and Preparation Plant (CHPP);
- Train Load-out facility (TLO) and dedicated rail loop; and
- Matilda open-cut pit.

The Matilda pit will be a small, shallow (maximum depth of 40 m) open-cut pit within the proposed rail loop alignment. It will target the Matilda (MAT) coal seam which underlies the ALEX and multiple Dysart Lower coal seams mined in the Jupiter pit to the east. The Matilda pit will be mined concurrently with the Jupiter pit and will provide supplementary coal to the ROM stockpile. Despite the development of an additional pit, an increase of the approved production rate (1.95 Mtpa) is not required. The proposed Matilda pit is considered not to have a significant impact on the life of the project. The extent of mining at the Matilda pit is shown in **Figure 1-2** as well as the footprints for the additional VCM infrastructure proposed.

2.2 Climate

Climate plays a major role in defining two characteristics of groundwater systems; recharge and evapotranspiration. Bureau of Meteorology (2016) classifies the area around the VCM as subtropical, with mostly hot dry summers and mild winters. In terms of rainfall, the area is classified as summer rainfall dominant with annual rainfall generally between 550 mm and 650 mm, with majority of the rain falling between November and March. **Table 2-1** and **Figure 2-1** presents the local climatic data obtained from SILO point climate data (Queensland Government, 2020) for the VCM (latitude -22.35°, longitude 148.20°, time period January 1889 to January 2020), showing the long-term rainfall and evaporation averages.

The average monthly rainfall varies between 16 mm/month in autumn to 109 mm/month in summer. The average annual rainfall is 590 mm, and when comparing precipitation with evaporation (estimated Actual

Aerial Evapotranspiration – AAET (Chiew et al., 2002)), average evaporation exceeds average precipitation for all months of the year, potentially leading to groundwater recharge deficit.

Table 2-1 Average monthly precipitation and evaporation

Month	Mean monthly precipitation (mm)	Mean monthly evaporation (mm)
Jan	109.33	137.43
Feb	99.57	120.71
Mar	65.18	118.57
Apr	31.06	86.62
May	27.98	57.23
Jun	31.23	39.59
Jul	22.05	43.74
Aug	20.14	64.72
Sep	16.77	85.54
Oct	31.47	109.47
Nov	50.28	120.87
Dec	85.35	136.32
Total	590.41	1,120.80
Min	16.77	39.59
Max	109.33	137.43

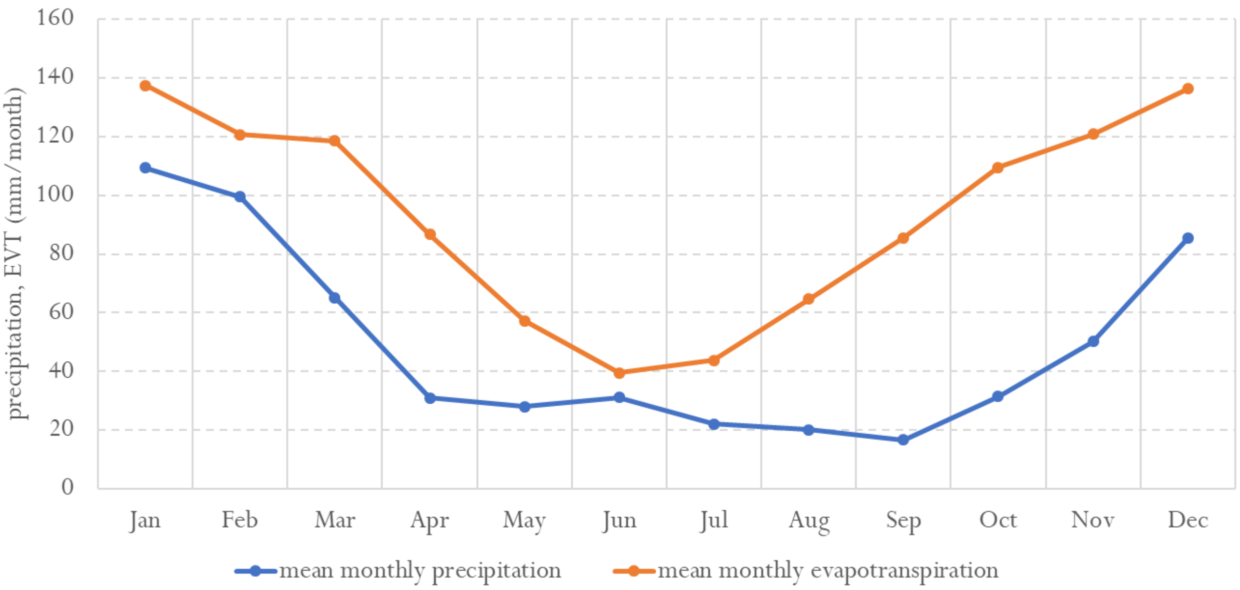


Figure 2-1 Average monthly precipitation and evaporation

One of the indicators describing long-term precipitation trend is a 'cumulative rainfall departure' – CRD (Xu & Tonder, 2001). The CRD indicates 'drier' periods (periods of below average rainfall) by downwards direction of the indicator line. Conversely, 'wetter' periods (periods of above average rainfall) are indicated by upward direction of the indicator line. The CRD calculation was based on the monthly averages calculated over the full time period of available data (131 years – see **Table 2-1**).

The trends represented by CRD analysis (**Figure 2-2**) show long-lasting dryer than average conditions between 1918-1940, 1960-71 and 2001-2007 and above average rainfall between 1953-1960, 1973-1979, 2007-2011.

Periods of approximately average rainfall can be observed between 1941 and 1944, 1970 and 1973, 1982 and 1988, and 2011– 2017. The area around the VCM has recently (beginning of 2018 until 2020) gone through a lower-than-average precipitation period.

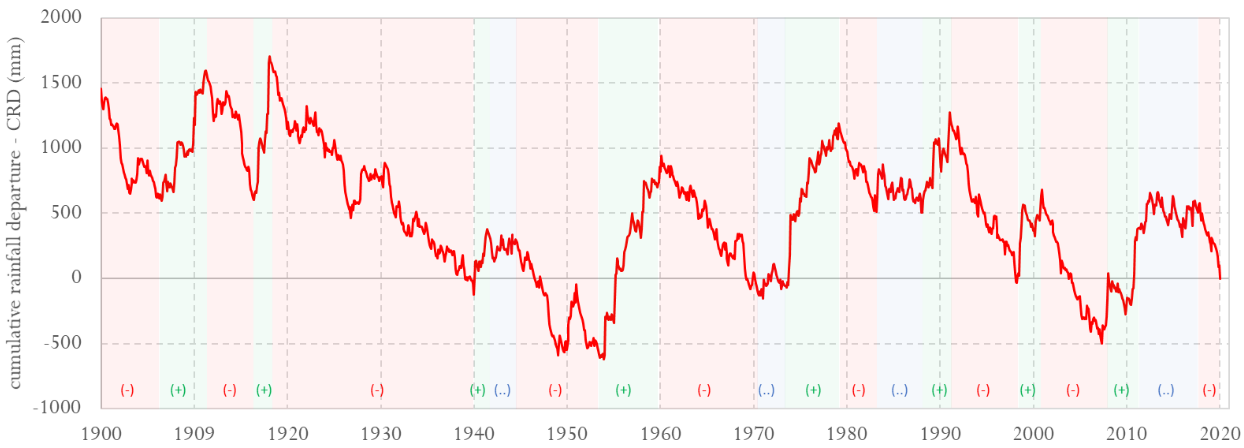


Figure 2-2 Precipitation trend – cumulative rainfall departure (CRD)

2.3 Topography and drainage

The VCM area slopes from the Harrow Range in the west to the Isaac River east of the VCM (**Figure 2-3**). Surface elevations reach approximately 500 mAHD approximately 25 km to the west of the VCM. The surface elevation within the VCM is generally between 225 mAHD and 280 mAHD.

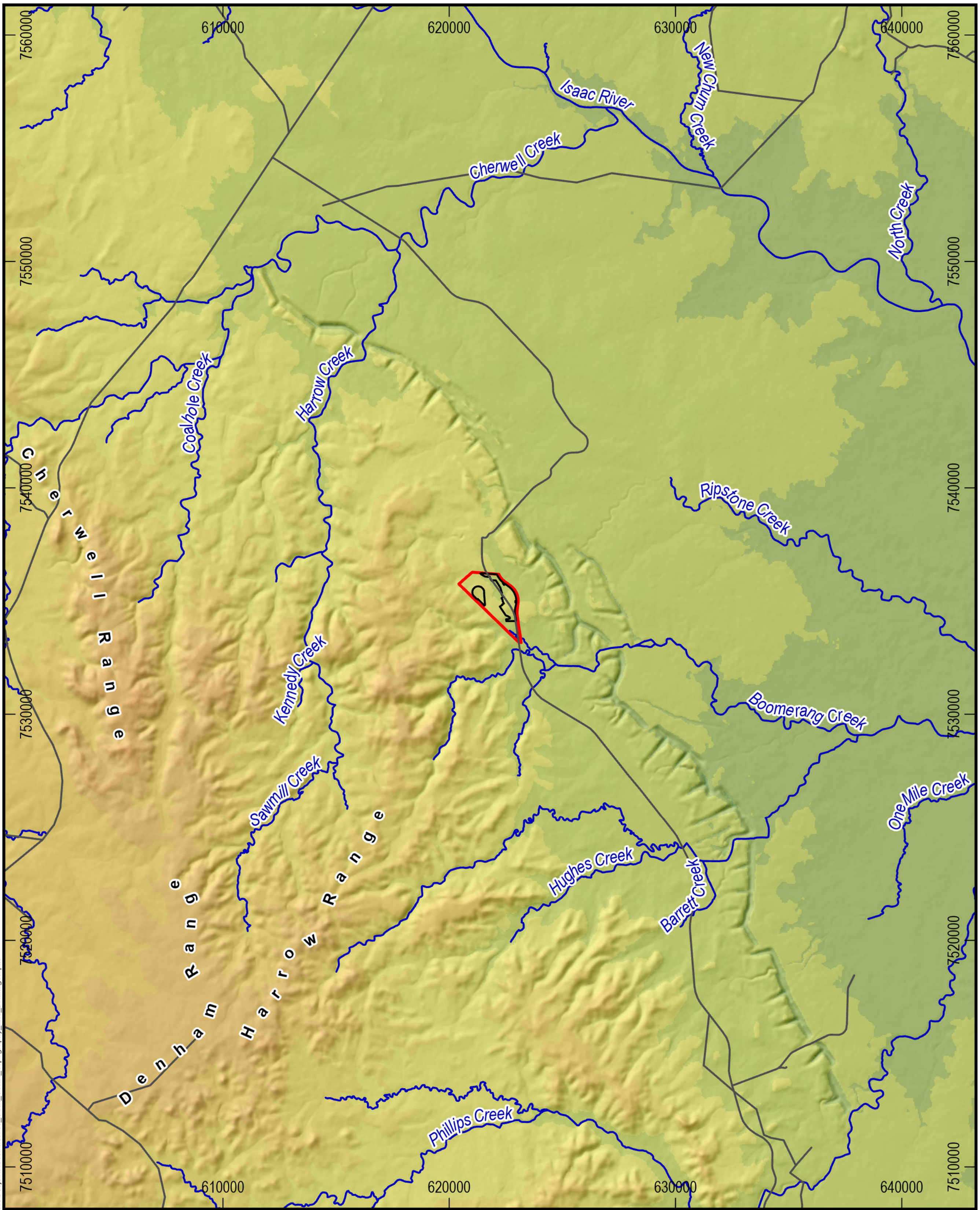
The VCM is surrounded by a number of ephemeral catchments (**Figure 2-3**) which drain from west to east, including the following creeks:

- Harrow Creek;
- Boomerang Creek;
- Hughes Creek;
- Barrett Creek;
- Phillips Creek; and
- Campbell Creek.

A tributary of Ripstone Creek flows through the VCM to the east, extending through the neighbouring Saraji Mine.

Several surface water diversions have been constructed in association with the existing coal mines to the east of the VCM. Tributaries / creeks which have had diversions constructed include Ripstone Creek, Harrow Creek, Boomerang Creek and Hughes Creek. An existing diversion bund was originally constructed by BHP to the west of the Jupiter Pit at the VCM. This diversion intersects the VCM ML diverting the drainage line of Ripstone Creek into the drainage line of North Creek in the southern part of the VCM ML. Other diversions associated with Harrow Creek, Boomerang Creek and Hughes Creek are all located downstream of the VCM, again constructed by BHP prior to the VCM. Surface water flow data captured and maintained by BHP indicates these creeks are all ephemeral.

The ephemeral creeks surrounding the VCM have limited flow, and typically only discharge after heavy rainfall events. The largest local surface water catchment near the VCM is Phillips Creek (20 kms to the south), which flows into the Isaac River. The confluence of these two surface water systems is located approximately 25 km to the east of the VCM.



Legend

- Watercourse
- Roads
- ML 700060
- Pit Shells

Elevation (mAHD)

- 121 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550

Source: Geoscience Australia 2011, State of Queensland (Department of Resources) 2021-2022, Hydrogeologist.com.au 2022, Vitrinite 2022, METServe 2023. *Basemap uses the hydrologically conditioned and drainage enforced 30m DEM-H Geoscience Australia product.*

Vulcan Coal Mine

Topography and Drainage

0 2.5 5 10

Kilometers

Scale: 1:245,000 (A4)

8/02/2023

Datum: GDA2020
Projection: MGA55

FIGURE 2-3

VITRINITE BRIGHTER COAL

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Whilst Hughes Creek and Boomerang Creek are much closer to the VCM area, Phillips Creek is the only watercourse with publicly available stream flow data. **Figure 2-4** and **Figure 2-5** presents data from the DRDMW Water Monitoring Information Portal (WMIP) (https://water-monitoring.information.qld.gov.au/), visited on 14 June 2022. **Figure 2-4** shows discharge and water level data for the historic gauging station (130409A) on Phillips Creek at Tayglen. **Figure 2-4** shows that flows within Phillips Creek are ephemeral, with short-duration flows generally occurring over the summer months. Based on daily flow data between 1968 and 1988 (only available data period), **Figure 2-5** shows that Phillips Creek flows less than 25 % of the time, with less than 10 % probability of flows exceeding 0.1 m^3/s (8.64 ML/day) and less than 2 % probability of flows exceeding 10 m^3/s (864 ML/day).

For further information regarding the VCM surface water systems, refer to the Vulcan Coal Mine – Surface Water Assessment (WRM 2020).

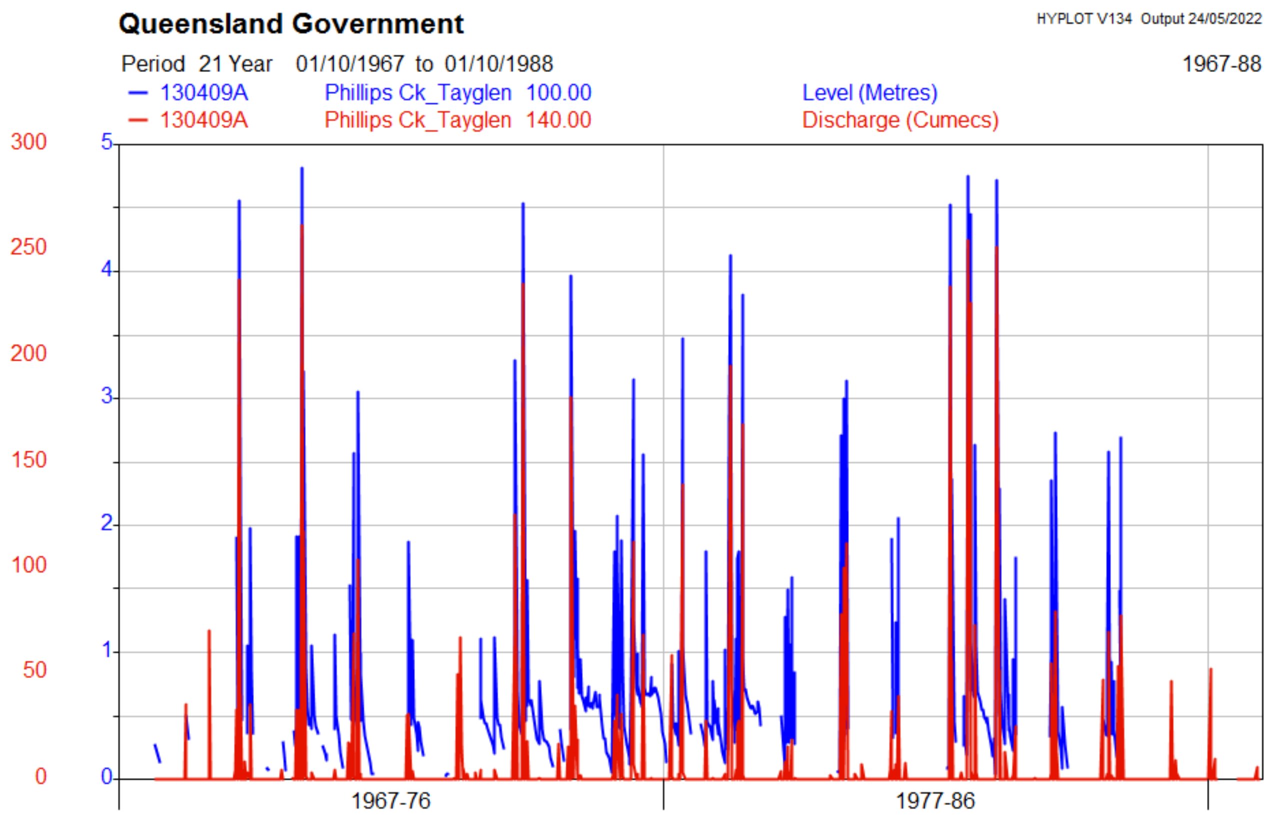


Figure 2-4 Discharge and water level, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal).

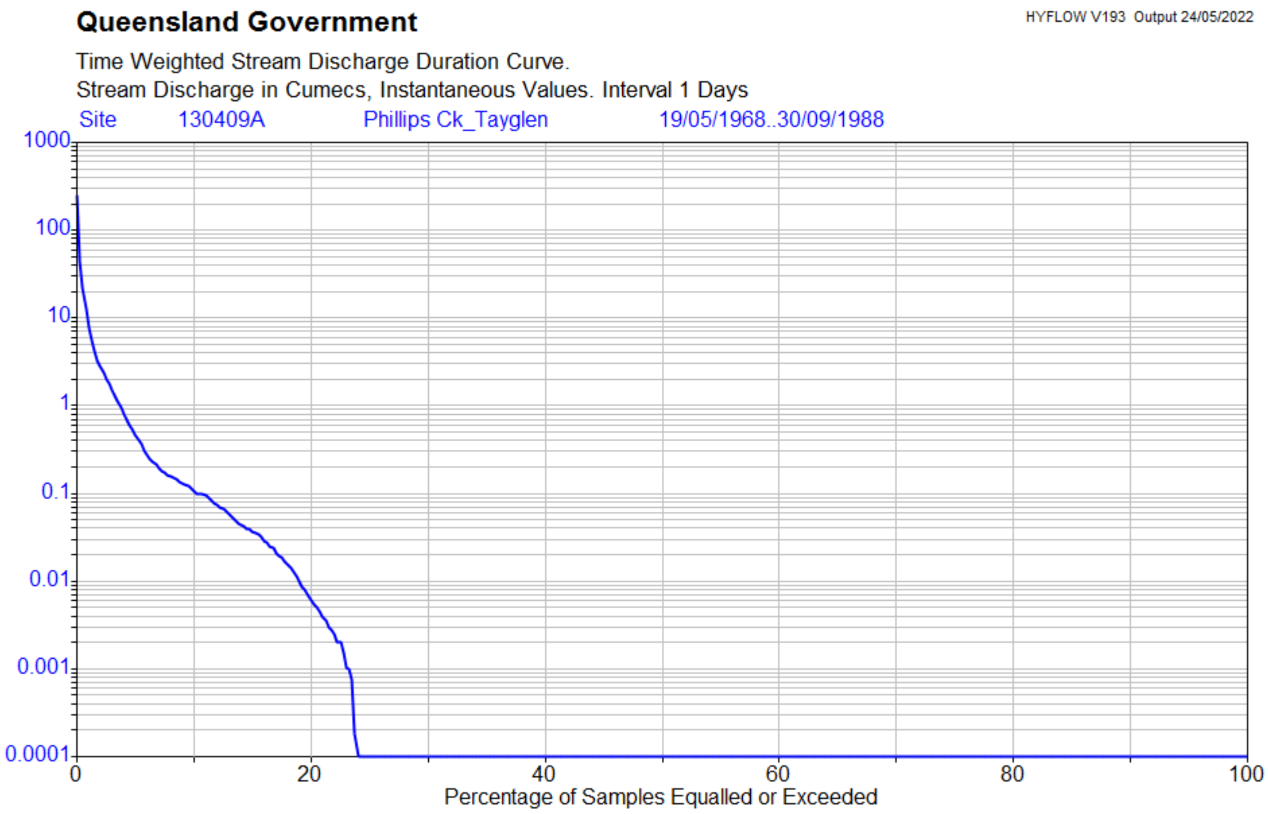


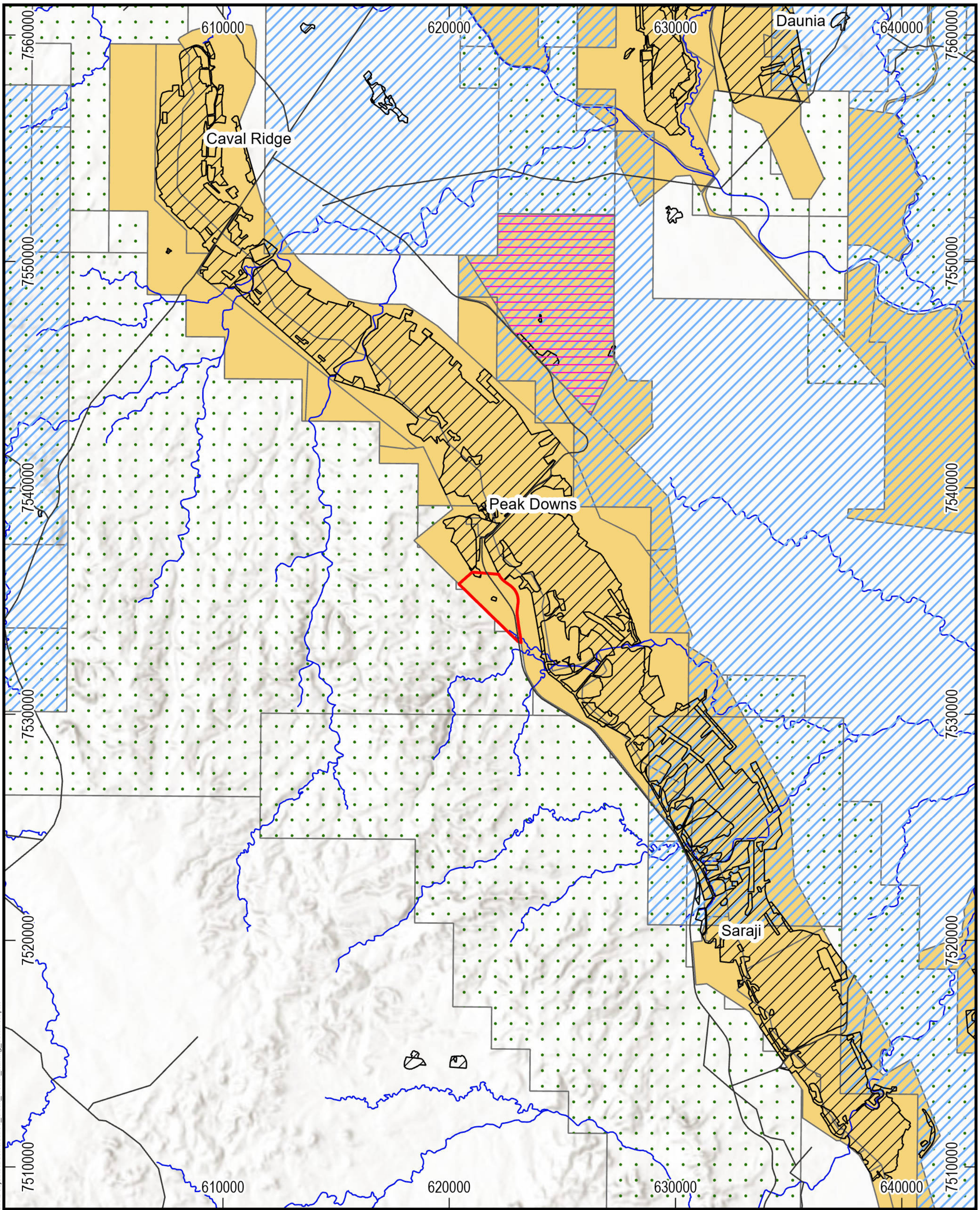
Figure 2-5 Daily flow duration, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal).

2.4 Land Use

Land use surrounding the VCM is dominated by coal exploration and mining, beef cattle grazing, and coal seam gas (CSG) exploration and operations. The VCM's neighbouring coal mines in close proximity to the ML are BHP Saraji Mine and BHP Peak Downs Mine (**Figure 2-6**). Caval Ridge Mine is located to the north of Peak Downs Mine and Norwich Park Mine is located to the south of Saraji Mine. These series of coal mines are owned by BHP, however, Norwich Park Mine is currently in care and maintenance (in the process of re-start).

Peak Downs Mine and Saraji Mine commenced coal production in the early 1970s with mining covering an area some 50 km in length and 2 km to 5 km in width across the respective MLs. These mines generally follow the strike of the coal seams within the Moranbah Coal Measures and extract coal seams that are stratigraphically higher in the Moranbah Coal Measures than the coal seams mined as part of the VCM.

Lake Vermont Mine is located to the south-east of Saraji Mine and is owned by the Jellinbah Group. Lake Vermont currently has a production capacity of 8 Mtpa and was last expanded in 2012/2013.



Legend

- Roads
- Watercourse
- ML 700060
- Exploration Permits for Coal (EPC)
- Exploration Permits for Petroleum (EPP)
- Mining Lease (ML)
- Petroleum Lease (PL)
- Established Mining Operation

Source: State of Queensland (Department of Resources) 2020-2022, Hydrogeologist.com.au 2022, Vitrinite 2022, METServe 2023, Esri, Geoscience Australia, NASA, NGA, USGS.

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Vulcan Coal Mine

Mining Tenure

0 2.5 5 10

Kilometers

Scale: 1:245,000 (A4)

8/02/2023

Datum: GDA2020
Projection: MGA55

FIGURE 2-6

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Mining & Energy Technical Services Pty Ltd

3 Part A: Underground water extraction

This section addresses the requirements under Section 376(a) of the Water Act and requirements summarised in **Table 3-1** below.

Table 3-1 Requirements under Section 376(a) of the Water Act

Section 376(a) Requirements	UWIR Section
To meet the requirements under Section 376(a) of the Water Act, a UWIR must include the following: The quality of underground water produced or taken from the area because of the exercise of underground water rights; and	3.1, 3.2
An estimate of the quantity of water to be produced or taken because of the exercise of underground water rights for a three-year period starting on the consultation day for the report.	3.2

3.1 Quantity of water already produced

Underground water rights have not been exercised at the VCM to date. No significant amount of groundwater has been produced or extracted from the operation of the Jupiter pit or other ancillary activities. Since mining commenced in late 2020, an estimated groundwater inflow of less than 3 ML/year (> 11 m^3/day) has been produced in the Jupiter pit from the target DLL coal seam. This is a conservative estimate and has been produced through predictive modelling owing to inflow volumes being so minimal that accurate measurements of inflow volumes is not possible. Current operations at the VCM do not require the dewatering of groundwater from the pit, nor requires the extraction of groundwater to drawdown the water table to facilitate mining. Groundwater inflows which currently report to the Jupiter pit considered negligible and are evaporated from the mining surface or is contained moisture within the mined coal.

No groundwater has been produced by the Matilda pit to date as construction of this pit has not yet commenced and is subject to additional approvals.

3.2 Quantity of water to be produced in the next three years

Estimated groundwater inflow volumes have been calculated by predictive modelling and are presented in **Table 3-2** along with **Figure 3-1**. **Figure 3-1** and **Table 3-2** show the predicted groundwater inflows for the Jupiter and Matilda pits from the consultation day of 22 February 2023 for a three year period (22 February 2026). A predicted total of produced groundwater at VCM over this period is also provided in **Table 3-2** (combination of both pit inflows). Groundwater pit inflows are expected to be sourced from the target coal seams in each pit, namely the DLL coal seam in the Jupiter pit and the MAT coal seam in the Matilda pit.

Table 3-2 Estimated groundwater inflow volumes

Year	Jupiter Pit Produced Groundwater Predicted (ML)	Matilda Pit Produced Groundwater Predicted (ML)	Total Produced Groundwater Predicted (ML)
2023	13.6	0.5	14.1
2024	8.0	0.8	8.8
2025	0	0.7	0.7
2026	0	0.3	0.3

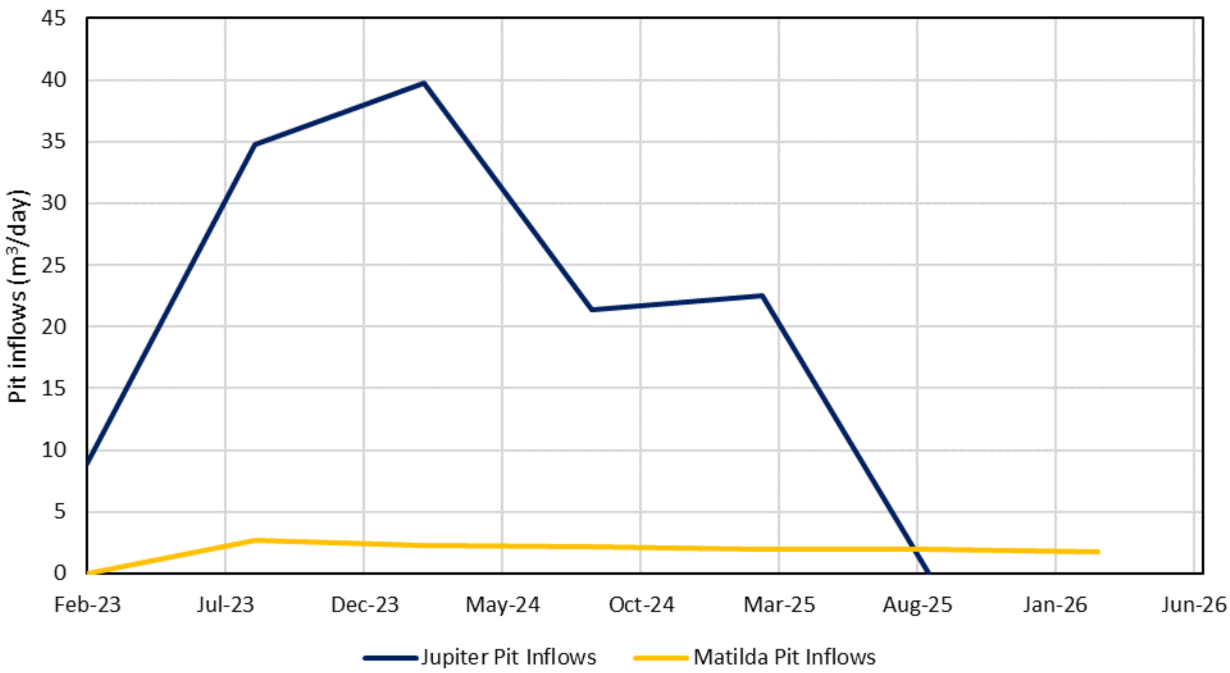


Figure 3-1 Predicted VCM pit inflows

Maximum groundwater pit inflows are expected in 2023 owing to the progression of the Jupiter pit to the north into more weathered strata along with the commencement of the Matilda pit. Despite the increase in groundwater inflows expected in 2023, the volume of produced groundwater is considered low and will not require dewatering action. Any produced groundwater is expected to be lost to evaporation or to mined coal moisture as currently occurs within the Jupiter pit.

Details on the development and implementation of the numerical predictive model are outlined in **Section 5.1.**

4 Part B: Aquifer information and underground water flow

This section addresses the requirements under Section 376(b)(i – iii) of the Water Act and requirements summarised in **Table 4-1** below.

Table 4-1 Requirements under Section 376(b) of the Water Act

Section 376(b) Requirements	UWIR Section
For each aquifer affected or likely to be affected, by the exercise of the relevant underground water rights, a UWIR must include: (i) a description of the aquifer(s);	Section 4.1
(ii) An analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and	Section 4.2
(iii) An analysis of the trends in water level change for the aquifer because of the exercise of underground water rights.	Section 4.3

4.1 Aquifer descriptions

The VCM is located on the western limb of the northern Bowen Basin, in a northerly plunging syncline, and at the southern end of the Collinsville Shelf (AECOM, 2016). The target coal seams are sub-cropping in a north-west to south-east direction, dipping to the north-east.

The VCM targets the Moranbah Coal Measures and Back Creek Group, specifically the Dysart Lower Lower (DLL), ALEX and Matilda (MAT) coal seams, located in the lower part of the Blackwater group's sedimentary sequence. **Table 4-2** presents the interpreted regional stratigraphy and highlights whether the regional stratigraphic units are present or absent at the VCM. Only those stratigraphic units present in the local area are described below.

Table 4-2 Interpreted regional and local stratigraphy

Period	Group	Unit	Regional context	Local context
Quaternary		Alluvium	✔	✘
Tertiary		Regolith*	✔	✔
		Suttor & Duaringa Formations	✔	✘
		Basalts	✔	✘
Triassic		Moolayember Formation	✔	✘
		Clematis Sandstone	✔	✘
		Rewan Group	✔	✘
Permian	Blackwater Group	Rangal Coal Measures	✔	✘
		Fort Cooper Coal Measures	✔	✘
		Moranbah Coal Measures	✔	✔

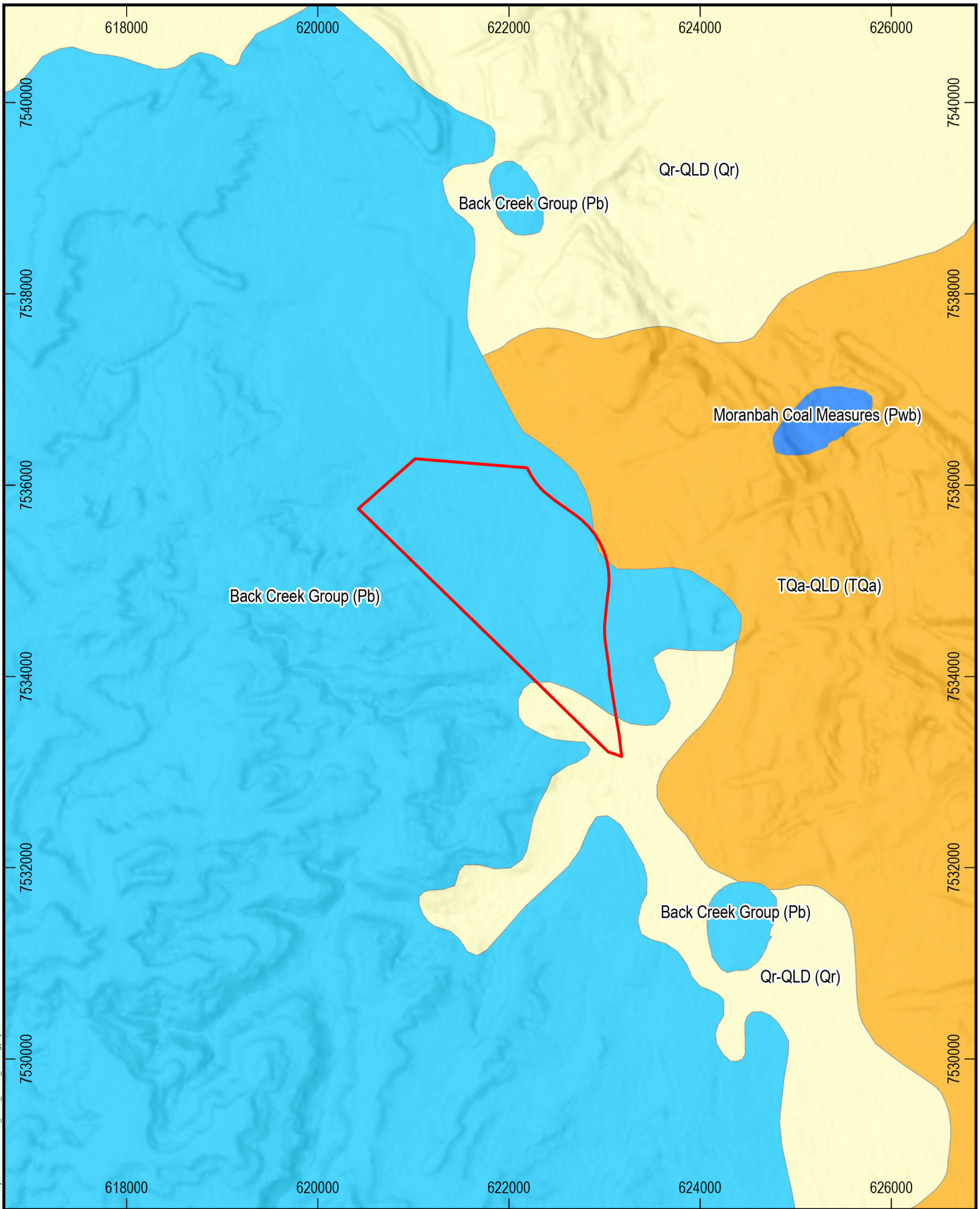
Period	Group	Unit	Regional context	Local context
	Back Creek Group	German Creek Formation	✔	✘
	Back Creek Group Exmoor Formation	Dingo Sandstone	✔	✔
		Dingo Siltstone	✔	✔
		Wallaby Hill Sandstone	✔	✔

*Notes: * Regolith concept of HydroSimulations (2018) is adopted for the weathered Permian coal measures.*

The surface geology within the VCM area is presented in **Figure 4-1**. At the VCM, groundwater typically only occurs within three hydrostratigraphic units, as outlined below in **Table 4-3**. Geological and hydrogeological characteristics of these three main units are detailed in the following sections. Publicly available surface geology mapping used in **Figure 4-1** shows Quaternary alluvium (Qr-QLD) within the VCM ML. Despite this mapping, Qr-QLD unit does not occur within the VCM ML hence is not discussed in the following sections due to its absence at the VCM.

Table 4-3 Local hydrostratigraphic units at the VCM

Age	Stratigraphic unit	Lithology	Aquifer type
Tertiary	Regolith (weathered profile)	Unconsolidated and semi-consolidated clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	Unconfined, poor aquifer, aquitard
Late Permian	Blackwater Group (Moranbah Coal Measures)	Coal, sandstone, siltstone, mudstone, carbonaceous mudstone	Confined aquifer (coal) and confining unit (interburden)
Middle Permian	Back Creek Group	Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Confining unit



Legend

ML 700060

Surface Geology

- Back Creek Group (Pb)
- Moranbah Coal Measures (Pwb)
- Qr-QLD (Qr)
- TQa-QLD (TQa)

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2022, METServe 2022, Esri, Geoscience Australia, NASA, NGA, USGS.

Vulcan Coal Mine

Surface Geology

0 0.5 1 2

Kilometers

Scale: 1:58,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 4-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_Geology.aprx

4.1.1 Tertiary regolith

Tertiary aged sediments are mapped to the east of the VCM. They are generally described as clay, silt, sand, gravel, colluvial material with a predominant clay matrix. AECOM (2016) refer to the Tertiary aged sediments as unconsolidated to consolidated fluvial, heterogeneously distributed sand deposits separated by a low permeability clay-rich matrix. There is an unconformable contact between the underlying Permian coal measures and the Tertiary sediments which represents an erosional surface prior to the deposition of Tertiary sediments.

Typically, the Tertiary sediments are less than 15 m thick although thicknesses of up to 57 m were reported at the adjacent Saraji Mine. The presence of paleo-channels and lensing of units within the Tertiary prevent correlation of discrete units; individual units are laterally discontinuous with varied thickness (AECOM, 2016).

Locally, no Tertiary sediments have been observed within the VCM, however, a regolith profile of the Permian coal measures developed during the Tertiary are present. This Tertiary weathering is evident regionally (AECOM, 2016) and the lithologies can vary from heavily leached, mottled white and maroon clays to sandy clays. The Tertiary regolith is typically unsaturated within the region, with drilling observations confirming this at the VCM.

The silts and clays are densely compacted, hard and typically dry. Sandy and gravely sections of Tertiary regolith have the potential for groundwater under unconfined or confined conditions, depending on location. Most of the sand and gravel lenses are permeable but are of limited lateral and vertical extent (URS, 2009).

Recharge to the Tertiary regolith is likely from creek flow (losing ephemeral streams), surface infiltration of rainfall and overland flow. The general recharge mechanism is presented in the schematic diagram in **Figure 4-2** below. Creek flow and surface water infiltrates through the vadose zone, into the underlying Tertiary regolith and Permian coal measures. Recharge following this mechanism is commonly observed as localised mounding beneath surface water bodies (i.e. watercourses or drainage features). Additionally, diffuse rainfall recharge occurs. The magnitude of both recharge mechanisms depends on the overlying geology. In the case of the Tertiary regolith, very low recharge rates occur due to the high clay content of the unit.

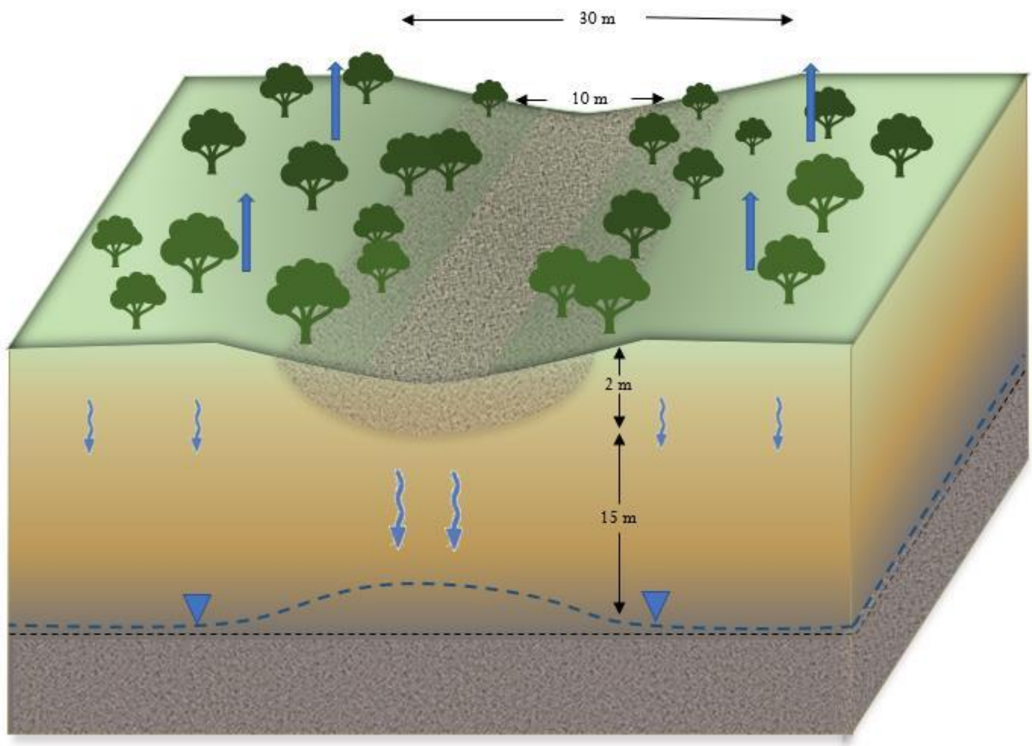


Figure 4-2 **Schematic diagram of recharge processes**

Where the water table is shallow, discharge from the Tertiary regolith occurs through evapotranspiration. The Tertiary regolith also discharges to the Permian coal measures as there is a downward vertical hydraulic gradient between the Tertiary regolith and the Permian coal measures.

Observations from the open-cut pits at the nearby Saraji Mine (AECOM, 2016) indicate that groundwater discharges relatively slowly from the sandy horizons within the Tertiary regolith. Therefore, the Tertiary regolith is considered to be a series of poorly connected aquifers of low to moderate permeability, with drainage from the upper to lower aquifers inhibited by the lower permeability horizons. As evaporation rates are higher than the seepage rate from the Tertiary regolith, the groundwater ingress rates are low and groundwater does not report directly to or require management within the pits (AECOM, 2016).

Groundwater flow in the Tertiary regolith is expected to follow topography and surface water drainage features. Groundwater levels within the Tertiary regolith from monitoring bores near the Saraji Mine were reported to be at depths shallower than the recorded water strikes from drilling and installation. This indicates that groundwater is semi-confined to confined by the clayey sediments in the upper sections of the Tertiary regolith (AECOM, 2016).

4.1.2 Permian Coal Measures

Coal seams within the Permian coal measures form the main economic resource of numerous mines in the region including the VCM. In order of increasing depth (age), the major coal measures of the Blackwater Group and Back Creek Group include the:

- Rangal Coal Measures;
- Fort Cooper Coal Measures;
- Moranbah Coal Measures; and
- Matilda Coal Measures.

The VCM currently targets the ALEX and DLL coal seams of the Moranbah Coal Measures with future operations targeting the MAT coal seam in the western extent of the VCM. To the west of the VCM, the basal section of the Moranbah Coal Measures outcrops at surface, locally mapped by Vitrinite as a sequence of sandstones and siltstones. This sequence is capped in a resistant, medium- to coarse-grained quartzose sandstone, commonly referred to as the Mesa Sandstone due to the characteristic mesa plateaus that have formed in the region. The base unit of the Moranbah Coal Measures is locally referred to as the Mesa Siltstone (Tom O'Malley Vitrinite, per.comm., 2019).

Throughout the Bowen Basin, the Blackwater group (including the Moranbah Coal Measures) are poor aquifers with the adjacent overburden and interburden sediments considered aquitards. Coal seams within the VCM area are considered dual-porosity strata where primary porosity is provided by the matrix and secondary porosity in the form of fractures such as joints and cleats. Natural cleats within the coal seams are the dominant space for groundwater storage, with groundwater movement dependent on fracture interconnectivity (AECOM, 2016; URS, 2009). The non-coal bearing overburden and interburden units are comprised of claystone, mudstone, sandstone, siltstone, and shale. These low permeability rock types have limited potential for transmitting groundwater.

The DLL coal seam forms a confined, poor-quality aquifer. The coal seam is laterally extensive along the western and eastern margins of the Bowen Basin and within the VCM area but varies in thickness. The Permian coal measures within the VCM are known to be partially unsaturated (hydrogeologist.com.au, 2019) with several VCM monitoring bores confirming this.

Groundwater recharge in the Permian coal measures is sourced from creek flow events (losing ephemeral streams), surface infiltration of rainfall and overland flow. Direct recharge of the Permian coal measures occurs where the seams are exposed (outcrops at surface), or where no substantial clay barriers occur in the shallow Tertiary regolith which overlies the coal measures. Recharge also occurs from the overlying Tertiary regolith due to a downward vertical hydraulic gradient and along faults and other structural features (AECOM, 2016).

Discharge from the Permian coal measures, where seams outcrop and the water table is shallow, occurs through evapotranspiration or along faults and by groundwater extraction from bores and mine dewatering / depressurisation (AECOM, 2016; HydroSimulations, 2018).

Within the Permian coal measures, due to the low hydraulic conductivity of the interburden material, groundwater largely flows along the bedding planes of the coal seams and within the joints and fractures present throughout the seams (HydroSimulations, 2018). Within the vicinity of an open-cut mine pit, a cone of depression forms, promoting the movement of groundwater into the pit. Although groundwater is expected to flow towards an open-cut pit (along the hydraulic gradient), the spatial extent of the cone of depression at the VCM is expected to be limited due to the observed low hydraulic conductivity and storativity of the Permian coal measures at the VCM.

4.1.3 Back Creek Group

The Back Creek Group outcrops to the west of, and in the western portion of the VCM. The Back Creek Group is interpreted to be conformably underlying the Moranbah Coal Measures. The top of the Back Creek Group is characterised by prominent coarse-grained siliceous boulder sandstone in outcrop.

The Back Creek Group is considered a semi-pervious lower boundary for groundwater flow to the overlying Blackwater Group (URS, 2012). The Exmoor Formation located at the top of the Back Creek Group is locally mapped by Vitrinite as the Dingo Sandstone, Dingo Siltstone and Wallaby Hill Sandstone (from top down) and contains recognised and laterally extensive coal seams (MAY and MAT seams).

4.1.4 Conceptual model

A conceptual regional hydrogeological cross-section from west to east is presented in **Figure 4-3** (hydrogeologist.com.au 2022).

The hydrogeological units presented in **Figure 4-3** are as follows:

- A weathered profile comprising:
  - Tertiary-aged regolith; and
  - Tertiary sediments.
- Permian coal measures, which incorporates:
  - Permian overburden comprising the Fort Cooper Coal Measures and the top of the Moranbah Coal Measures;
  - the DL coal seam (targeted at the Saraji Mine);
  - Permian interburden comprising of the Moranbah Coal Measures and the Back Creek Group;
  - the target coal seams at the VCM, namely the DLL coal seam (currently targeted) and the MAT coal seam (future target); and
  - Permian underburden comprising the Back Creek Group.

The conceptual cross-section in **Figure 4-3** lies sub-parallel to the lateral groundwater flow direction. The groundwater table is hosted by several units, from the outcropping/sub-cropping Back Creek Group in the west through the Tertiary sediments and Moranbah Coal Measures to the Fort Cooper Coal Measures in the east. As a result of the sloping groundwater table and the easterly dip of the hydrogeological units, some of the units may be partially unsaturated, particularly in the west, as is shown in **Figure 4-3**.

Rainfall provides recharge to the groundwater system. Evapotranspiration occurs where the groundwater table is close to the surface, however, the groundwater table observed at the VCM is often too deep to facilitate such a mechanism. Therefore, the only significant evaporation of groundwater occurs within the VCM pit(s) where groundwater inflows are evaporated from the pit walls. There is no interaction between surface water and groundwater within and surrounding the VCM.

The western boundary of the regional conceptual model shown in **Figure 4-3** is a catchment and groundwater divide in the Harrow Range. The eastern, regional conceptual model boundary adopted is the Jellinbah Fault Zone, which is a north-west trending zone with several easterly dipping thrust faults with throws in the order of 100 m to 500 m (URS, 2012).

The DLL coal seam at the VCM and the DL coal seam at nearby Saraji Mine shown in **Figure 4-3** have been depressurised and dewatered to a degree caused by historic mining operations. Owing to the low hydraulic conductivity and low storage of the Moranbah Coal Measures, the cones of depression surrounding both mines are considered deep (at least to current pit depth) but are laterally limited in extent.

Once mining and associated depressurisation / dewatering ceases, groundwater is anticipated to recover towards a steady state in the backfilled material within the former VCM pit(s). However, it is anticipated that a complete recovery to pre-mining conditions will not occur until the rehabilitation of nearby Saraji Mine is complete. This groundwater recovery process will largely be driven by the hydrogeological conditions discussed above and the hydraulic parameters discussed in **Section 4.2.1**.

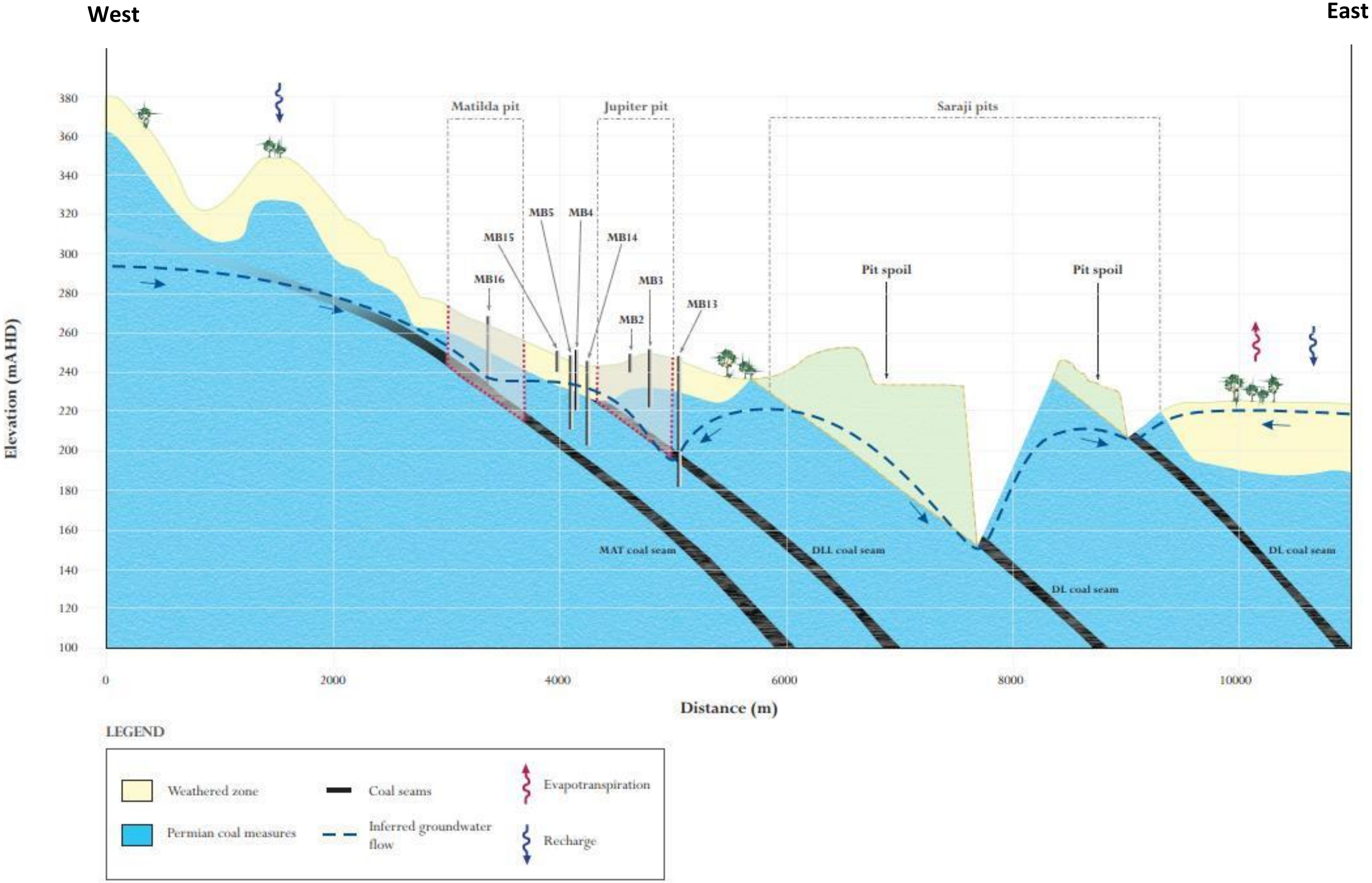


Figure 4-3 VCM Hydrogeological Conceptual Model

4.2 Underground water flow and aquifer interactions

4.2.1 Hydraulic conductivity

Hydraulic testing in the form of slug and constant head tests were conducted throughout the VCM Groundwater Monitoring Network (**Figure 7-1**) along with Vitrinite's regional monitoring bores to the south of the VCM. Slug tests (falling head tests) were completed on the monitoring bores which recorded a groundwater level, whereas constant head testing was completed on the dry monitoring bores.

For two of the dry monitoring bores (MB06 and MB08 located to the south of the VCM ML), the rate at which the bore accepted water was higher than the rate it could be fed in. Therefore, it is assumed that the hydraulic conductivity of the intersected lithology at these monitoring bores is higher than 0.1 m/day. The recovery curve method was carried out for MB12 given the slow recovery response following sampling.

The hydraulic testing of the monitoring bores indicates that generally the highest hydraulic conductivities are for the Tertiary regolith / weathered Permian overburden, moderate values for the DLL and MAT coal seams and the lowest results are for the Permian underburden. The following order of magnitude is observed in relation to hydraulic conductivities:

- Tertiary regolith / weathered Permian overburden: 10^{-1} m/day;
- DLL and MAT coal seams: 10^{-2} m/day; and
- Permian underburden / Back Creek Group: 10^{-4} m/day.

Hydraulic conductivity values derived from field testing at the VCM were compared to values reported within the region across different literature.

Tertiary regolith

The measured hydraulic conductivity value for the Tertiary regolith at VCM was comparable to values reported in other literature (10^{-3} to 1 m/day). Hence, the hydraulic conductivity in the order of 10^{-1} m/day derived from the VCM field testing is considered reasonable for the Tertiary regolith at the VCM.

Permian Coal Measures

Owing to the combination of primary and secondary porosity observed across the Permian coal seams, hydraulic conductivity varies considerably spatially and decreases with increasing depth as the fractures within the coal measures close under increasing overburden pressure (HydroSimulations, 2018). Hydraulic conductivity also varies between the overlying and underlying sediments compared to the coal seams. A range between 10^{-2} m/d and 10^{-1} m/d appears to be reasonable and consistent with the relevant literature for the upper coal seams. For the interburden, a range between 10^{-5} m/d and 10^{-3} m/d appears to be appropriate. Reported hydraulic conductivity for the Permian coal measures in other literature ranges from 10^{-4} m/day to 10^{-2} m/day. This range has been adopted in this study for the Permian coal measures in combination with results from field testing completed at the VCM.

For the coal measures (coal seams and inter- and overburden together), horizontal hydraulic conductivities between 10^{-4} m/d and 10^{-2} m/d appear to be reasonable. For the Permian Back Creek Group, horizontal hydraulic conductivities between 10^{-4} m/d and 10^{-2} m/d appear to be realistic and consistent with the material descriptions provided.

Back Creek Group

Estimated hydraulic conductivities for the fresh, Permian underburden (Back Creek Group) has been widely reported between 10^{-4} to 10^{-2} m/day. Hydraulic conductivity measured during the VCM field testing was in the order of 10^{-4} m/day and is considered reasonable for the formation.

4.2.2 Recharge and discharge estimates

While the literature generally agrees on the recharge and discharge mechanisms, rates of recharge and discharge vary significantly for numerical groundwater models developed for nearby mines. AECOM (2016) applied a recharge rate of 0.89 mm/year. URS (2012) and Arrow (2016) used a minimum of 1 mm/year for Triassic – Permian strata. HydroSimulations (2018) used model calibrated recharge rates of 0.15 mm/year for Tertiary sediments and 0.06 mm/year for outcropping Permian coal measures.

The recharge rates are summarised in **Table 4-4** together with indicative long-term average recharge/rainfall percentages.

Table 4-4 Estimates of recharge rates in the vicinity of the VCM (mm/year)

Reference	Tertiary Regolith / Sediments	Permian Coal Measures
AECOM (2016)	0.89 (0.1%)	0.89 (0.1%)
URS (2012)	1 (0.1%)	1 (0.1%)
HydroSimulations (2018)	0.15 (0.02%)	0.06 (0.009%)

HydroSimulations (2018) also refer to recharge rates used in Arrow Energy's Bowen Gas Project and other nearby projects (not sighted during the preparation of this report). According to HydroSimulations (2018), recharge at Lake Vermont was simulated as the equivalent of 2% mean annual rainfall and at Isaac Plains it was simulated as 0.5% mean annual rainfall to alluvium and 0.25% mean annual rainfall elsewhere. For the Arrow Energy Bowen Gas Project, recharge to the Tertiary sediments was simulated as 0.3 mm/year or 3 mm/year; 0 mm/year for the Rewan Group; and 0.33 mm/year to 3 mm/year for outcropping Permian coal measures.

For discharge, URS (2012) and Arrow (2016) modelled the difference between potential and actual evapotranspiration with an extinction depth of 10 m in their respective numerical models. HydroSimulations (2018) applied maximum potential evaporation rates using actual evapotranspiration values with an average value (600 mm/year) used as the calibrated evapotranspiration rate. Extinction depths were set to 2 m below ground across the model domain.

4.2.3 Groundwater flow

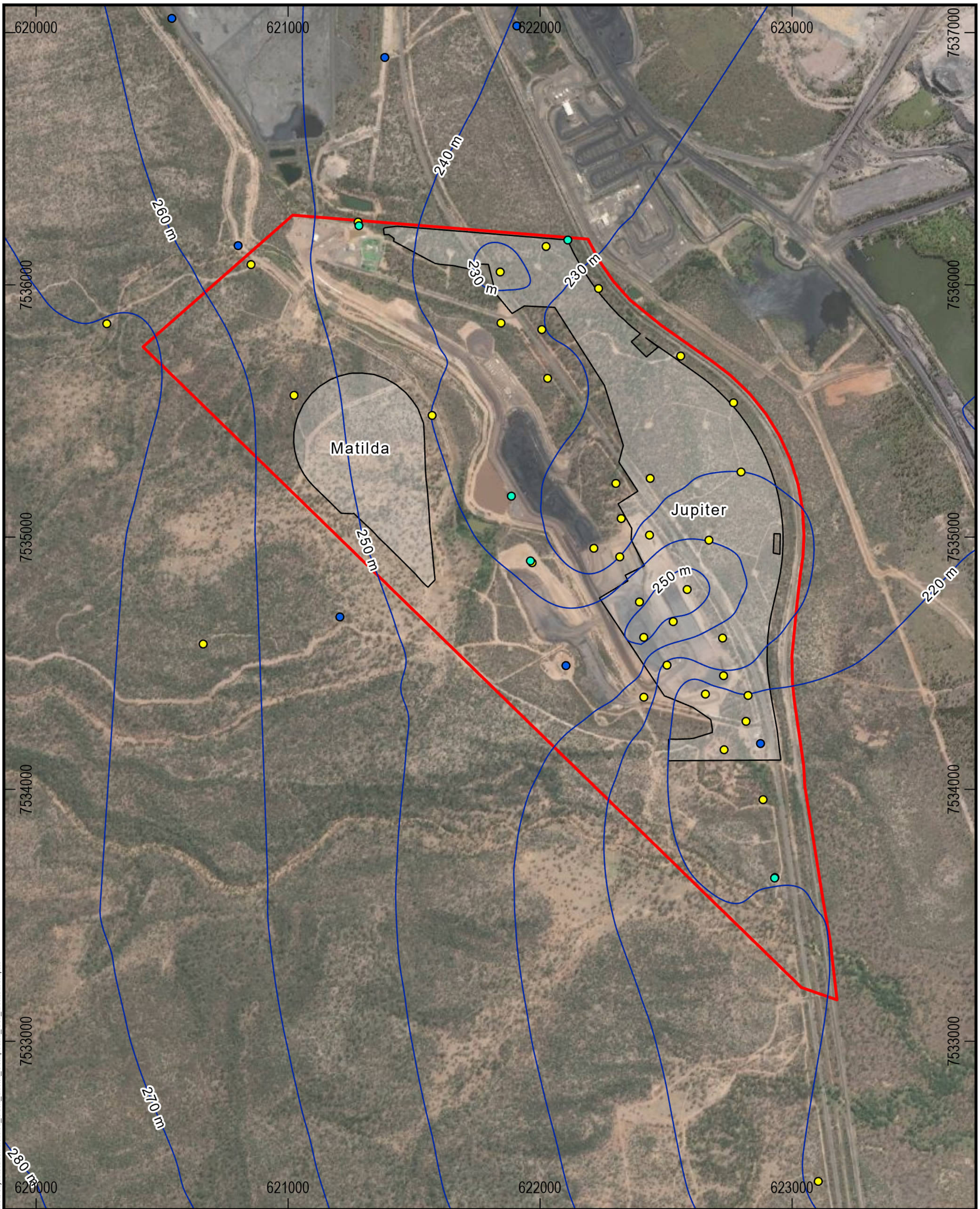
Regional groundwater flow follows the topography and the surface water drainage across all water-bearing units. However, for deeper confined units such as the Back Creek Group, groundwater flow resemblance to surface water drainage is less pronounced than that seen in the shallow unconfined aquifer.

URS (2012) presented regional groundwater elevations for the Permian Blackwater Group which indicated groundwater flows from north-west to south-east, mimicking the surface water drainage pattern. Similarly, groundwater contours produced by AGE (2012) for the Saraji Mine also indicate a west to east flow pattern. The pre-mining groundwater contours presented by AGE (2012) are typically up to 20 m different to the regional contours presented by URS (2012).

Figure 4-4 shows regional groundwater elevation contours developed by hydrogeologist.com.au (2022) using data from the Department of Regional Development, Manufacturing and Water (DRDMW) Groundwater Database (GWDB), site specific monitoring bores and exploration drill hole data at the VCM. The groundwater contours are a composite of groundwater elevations across various hydro-stratigraphic units, however, data points were collected from similar time of year (dry season).

Figure 4-4 illustrates that groundwater flows towards the east near the VCM. Further east of the VCM, groundwater flow turns towards the southeast and eventually follows the alignment of the Isaac River. This reflects the findings of HydroSimulations (2018).

The highest groundwater elevations were measured in the Tertiary units and upper Permian coal seams. Groundwater elevations also appear to decrease with depth in the Permian coal seams (URS, 2009 and AECOM, 2016). Reported vertical hydraulic gradients are downward, suggesting potential downward leakage between the hydrogeological units, specifically coinciding with the decreasing hydraulic conductivity of the coal seams with depth. However, there are limited observations to confirm such a mechanism at the VCM. Groundwater elevations measured by AECOM (2016) in nested bores located at the nearby Saraji Mine indicate downward vertical hydraulic gradients in the majority of measured bores between the Tertiary and Permian units. These observations are consistent with those made by HydroSimulations (2018).



Legend

- Exploration Boreholes
- Registered Groundwater Bores
- Groundwater Monitoring Locations
- Groundwater Elevation Contours (10 m)
- ML 700060
- Pit Shells

Source: Hydrogeologist.com.au 2022, State of Queensland (Department of Regional Development, Manufacturing and Water) 2022, Vitrinite 2022, METServe 2022, Maxar. *Groundwater modelling conducted by Hydrogeologist.com.au.*

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_Composite_GW_Contours.aprx

Vulcan Coal Mine

Composite Groundwater Elevation Contours

0 200 400 800

Meters

Scale: 1:22,000 (A4)

6/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 4-4

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

4.3 Underground water level trend analysis

Groundwater elevations measured at VCM monitoring bores range between 230 mAHD and 240 mAHD, becoming deeper towards the southern extent of the ML 700060 at MB13 (210 mAHD). Groundwater is typically 5 - 18 m below ground level within the VCM area. VCM groundwater elevations are summarised in **Table 4-5**. VCM monitoring bore locations are presented in **Figure 7-1** and construction details are outlined in **Table 7-2** (**Section 7**).

Figure 4-5 presents the groundwater hydrographs from June 2019 to October 2022 for the VCM monitoring bores installed within the Permian coal measures. The groundwater hydrographs demonstrate a static system with very little (centimetre magnitude) variations in groundwater level over time.

Monitoring bore MB02, which was installed in the shallow weathered regolith unit in 2019, was continuously dry until the bore was decommission in 2022 (owing to mining progression). This indicates the limited saturation of the shallow, unconfined weather zone within the VCM area, consistent with the observations made in other studies (HydroSimulations, 2018 and AECOM, 2016).

Limited groundwater level data has been collected from MB14, MB15 and MB16, which were installed in 2022. All three bores have since had continuous water level monitoring equipment installed. Continuous water level data is not available for MB15 and MB16 owing to equipment malfunction. This equipment has since been rectified allowing such data to be collected in due course.

Table 4-5 Manual groundwater level measurements

Site ID	Casing elevation (mAHD)	SWL (mAHD)																
		Aug-19	Sep-19	Oct-19	Dec-19	Mar-20	Jun-20	Aug-20	Oct-20	Dec-20	Mar-21	May-21	Jul-21	Sep-21	Dec-21	Mar-22	Jun-22	Oct-22
MB04	243.28	237.45	237.18	237.04	236.97	236.82	236.83	236.76	236.54	236.37	236.58	236.61	236.53	236.41	236.41	-	-	-
MB05	252.70	237.99	238.23	238.69	238.55	238.10	227.77	235.95	236.62	236.53	236.37	236.72	236.41	236.04	235.81	236.30	235.57	235.58
MB13	223.13	-	-	-	-	-	-	-	-	-	209.12	208.53	208.49	208.63	208.67	208.63	207.28	209.28
MB14	242.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	233.52	234.46
MB15	251.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	246.43	246.58
MB16	248.36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	244.09	244.23

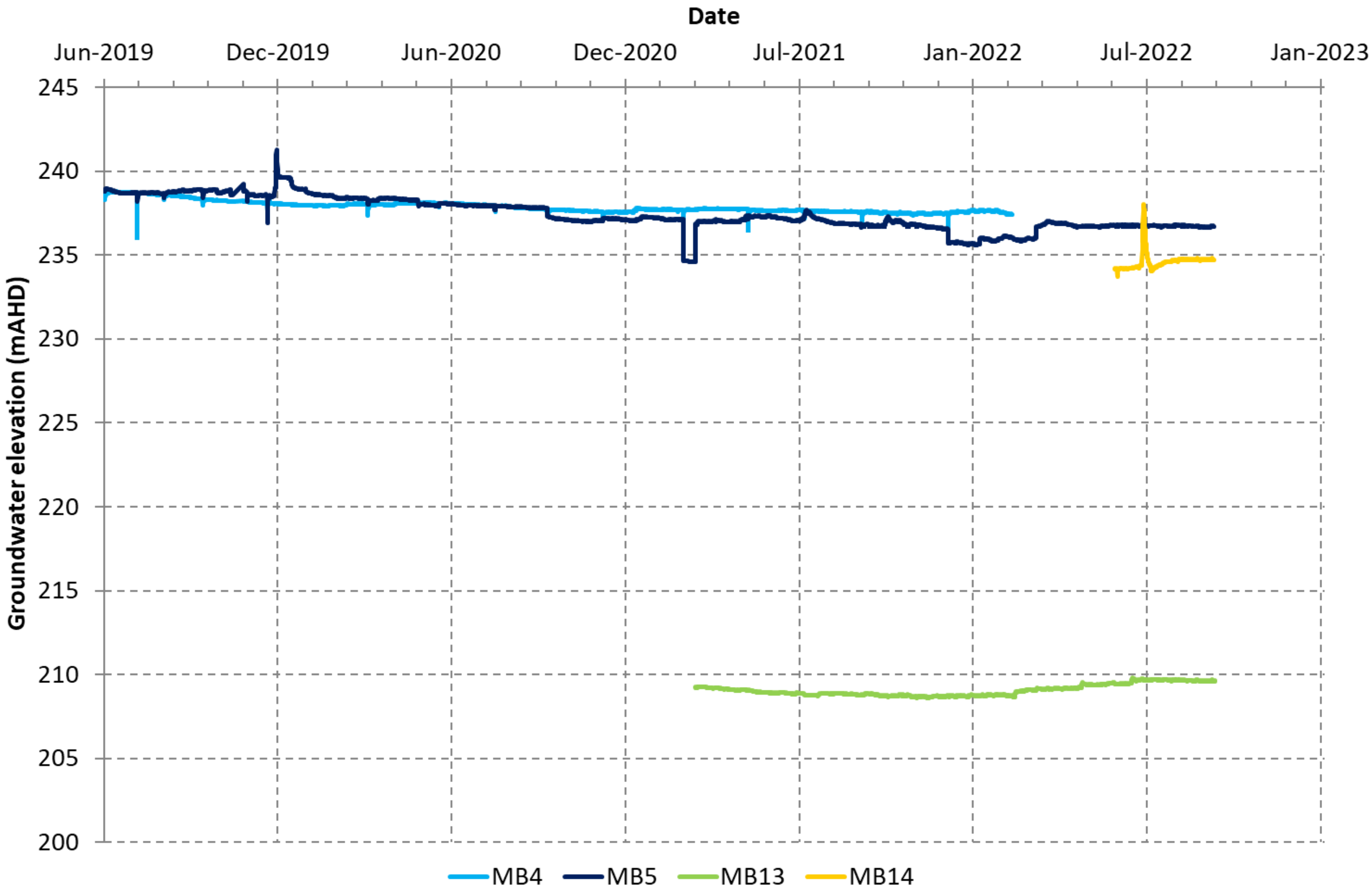


Figure 4-5 **VCM Groundwater monitoring bore hydrographs**

Measured drawdowns recorded since operations commenced

Figure 4-6 to **Figure 4-10** presents the measured groundwater elevations at each monitoring bore in comparison to the corresponding level threshold specified in the VCM EA Table E3. Groundwater elevations presented in these figures use manual dip measurements. Level thresholds applied in EA Table E3 represent the 90th percentile predicted maximum cumulative drawdown over the life of the VCM beyond any background non-mining related influence (except where specifically identified). MB05, MB13 and MB14 level thresholds are used to monitor declining / drawdown of groundwater levels. MB15 and MB16 level thresholds are used to monitor increases in groundwater level, as such bores aim to monitoring seepage downgradient of two mine water storage dams.

Please note that **Figure 4-6** to **Figure 4-10** use different x-axis date ranges corresponding to when monitoring commenced at the specific bore.

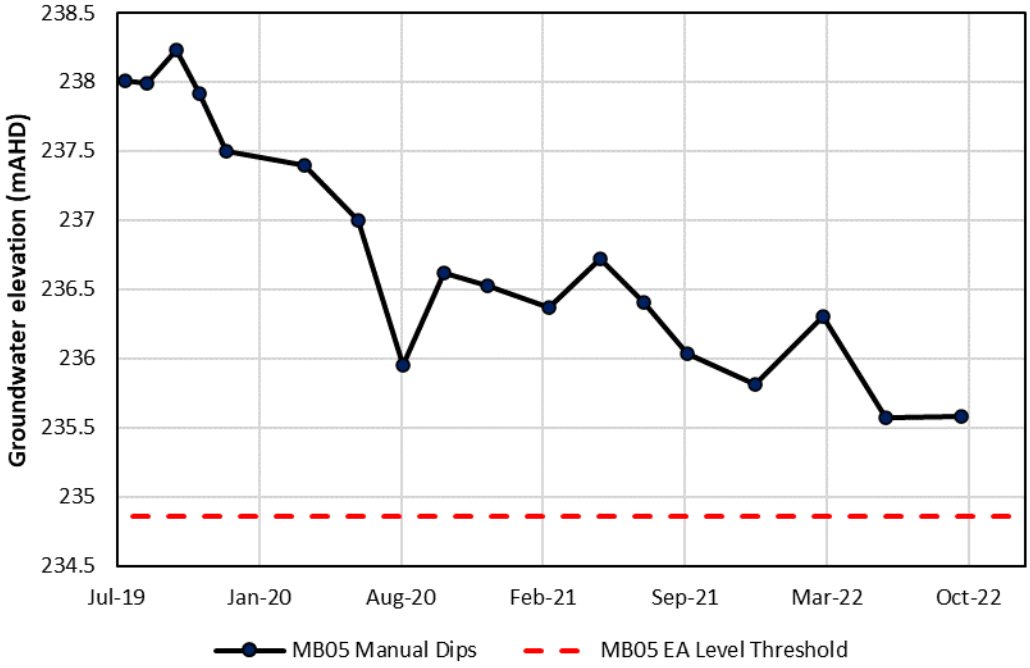


Figure 4-6 MB05 Groundwater Elevation

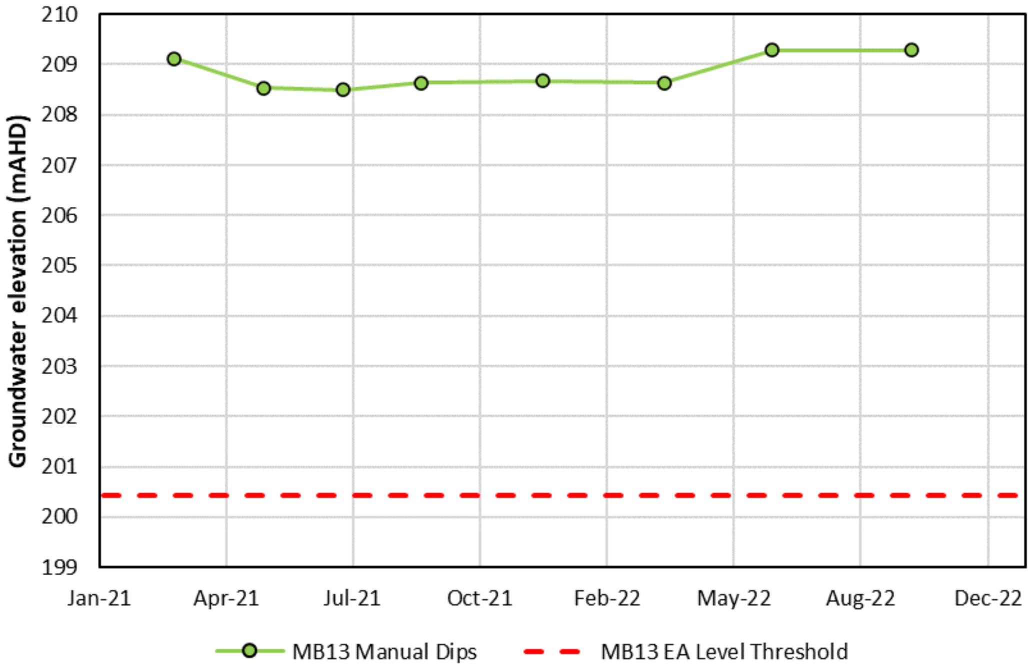


Figure 4-7 MB13 Groundwater Elevation

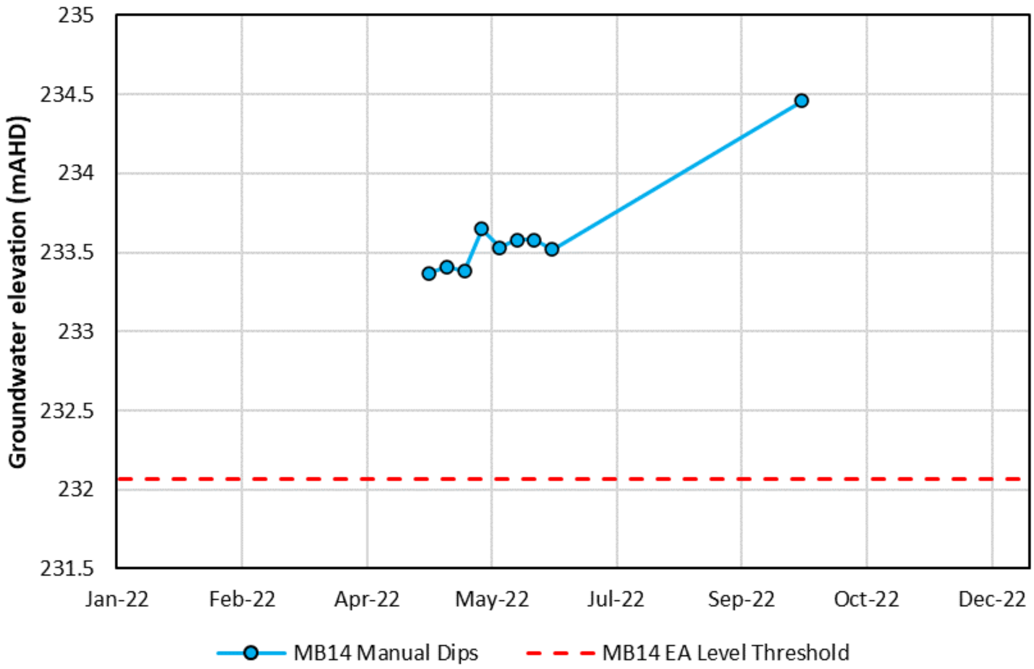


Figure 4-8 MB14 Groundwater Elevation

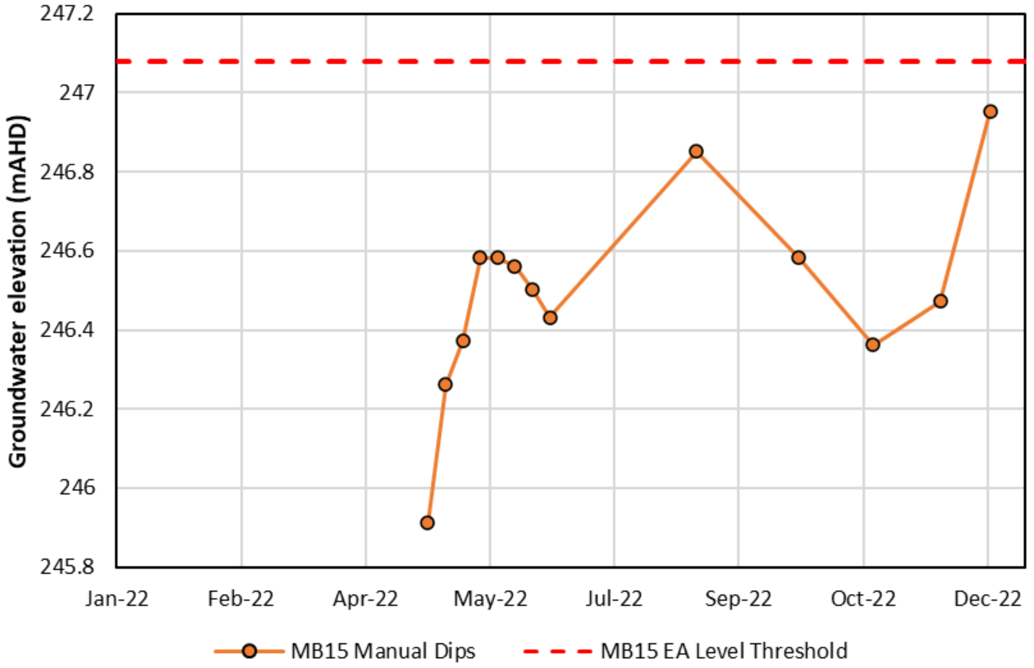


Figure 4-9 MB15 Groundwater Elevation

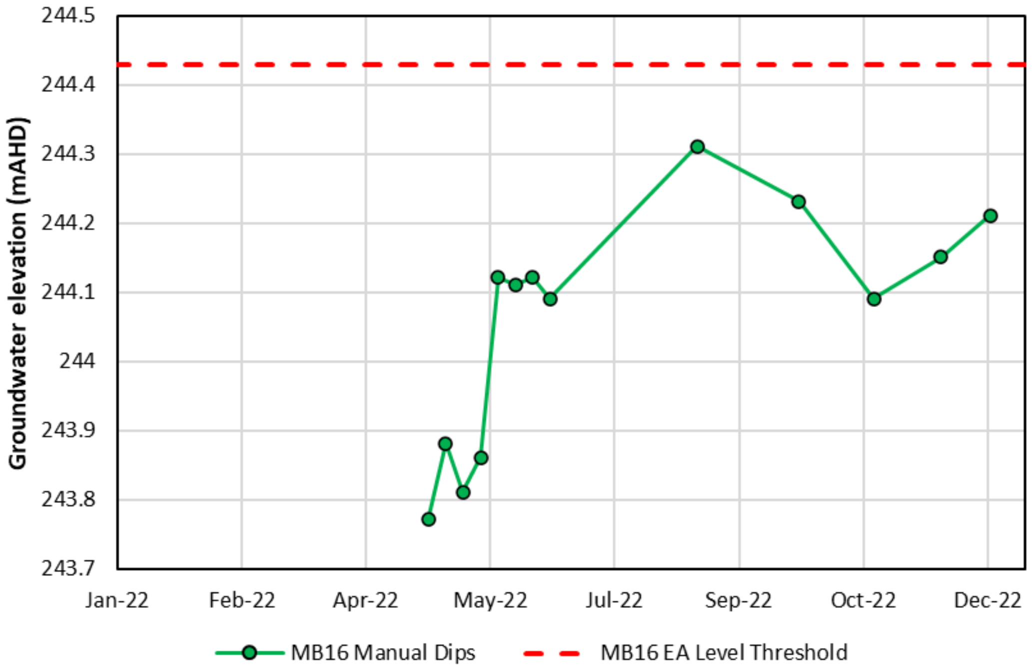


Figure 4-10 MB16 Groundwater Elevation

Evident from **Figures 4-6** to **4-10**, none of the five active monitoring bores have triggered the corresponding level thresholds.

As detailed in **Section 2** of this report, the VCM area has been experiencing an extending period of below-average rainfall. Periods of below-average rainfall typically reduce the amount of recharge which reports to the groundwater system. During these periods, the deficit between rainfall and evaporation is increased consequently reducing the recharge to the groundwater system. Neighbouring coal mines also have a material influence on groundwater levels at the VCM, specifically groundwater levels monitored in the Permian Coal Measures (MB05).

Recent decline in groundwater levels observed at MB05 are attributed to recent climatic variations (consecutive poor wet seasons / below average rainfall) rather than a decline caused by the VCM exercising underground water rights (which has not yet occurred). Given that not all groundwater level data currently available (and small data sets available for MB14, MB15 and MB16), a drawdown contour map has not been developed as contours based on such a small dataset would not be considered representative.

Variations in VCM groundwater levels presented in **Figure 4-6** to **Figure 4-10** are considered minimal and representative of a static system and attributed to climatic variations rather than mining activities at the VCM.

5 Part C: Predicted water level declines for affected aquifers

This section addresses the requirements under Section 376(b-e) (i – iv) of the Water Act and requirements summarised in **Table 5-1** below.

Table 5-1 Requirements under Section 376(b-e) of the Water Act

Section 376(b - e) Requirements	UWIR Section
To meet the requirements of the Water Act, a UWIR must include the following: (i) Maps showing the IAA and LTAA;	5.2 & 5.3
(ii) A description of the methods used to produce these maps;	5.1
(iii) Information about all water bores in the IAA (including the number of bores in the area, maps showing the location of these bores and the authorised use of each bore); and	5.4
(iv) A program for conducting an annual review of the accuracy of maps produced and giving the chief executive a summary of outcomes of each review, including a statement of weather there has been a material change in information or predictions used to prepare the maps.	5.5

5.1 Model development and methodology

A 3D numerical groundwater model was developed in 2020 for the VCM's EA application (as discussed in **Section 1**). The numerical model uses the MODFLOW-USG (Panday *et al*., 2015) software to represent the conceptual hydrogeological model and regime discussed in **Section 4**. The Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012) were considered throughout the modelling process. A detailed description of the modelling methodology is provided in **Appendix A** - Vulcan Coal Mine Groundwater Impact Assessment (hydrogeologist.com.au, 2022).

The groundwater model has been used to predict the groundwater take and resulting groundwater drawdown. These predictions have been used to identify the Immediately Affected Areas (IAA) and Long Term Affected Areas (LTAA) for the UWIR. These predictions have also been used to assess the potential impacts of the VCM on groundwater users and sensitive environmental values.

No changes to the groundwater model have been made as part of the UWIR.

The key aspects of the model are:

- The numerical groundwater model was developed from the collated dataset described in **Section 4** using MODFLOW-USG software and represents the conceptual groundwater regime.
- The model represents the key geological units using 11 model layers and extends approximately 46 km north-south and approximately 29 km east-west. The model domain covers a total area of 650 km^2. The VCM is located towards the centre of the model domain.
- The physical structure of the groundwater model was based on the detailed geology model developed by Vitrinite. Model development was supplemented by published geological maps, digital

geology surfaces and information from mining operations near the VCM and data from the DRDMW GWDB.
- The groundwater regime near the VCM has been impacted over time due to the presence of historic and current mining activities. For the model development, it was necessary to perform a transient (time-variant) calibration which considered the change in groundwater levels and flow.
- The Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012) were used to frame the calibration process. The groundwater model was calibrated to groundwater level records from 55 observation points (a total of 176 observations) intersecting a variety of aquifers and aquitards; this included the monitoring bores installed during the project field investigation. The calibration was guided by water level measurements and site-specific measurements of hydraulic conductivity from packer tests and slug tests.
- The calibration achieved a 4% scaled root mean squared (SRMS) error which is within acceptable limits (i.e. 10%) as recommended by the Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012). Furthermore, the calibrated groundwater levels, vertical gradients, flow patterns and mine inflows replicate measured groundwater data and groundwater trends. The model calibration is therefore considered robust.
- The numerical model was used to predict the effects of the project mining activities on the groundwater regime for the UWIR period. The modelling results were used to inform assessments of the VCM's potential impacts on groundwater users and surrounding environmental values.
- The sensitivity of the model predictions to the input parameters were tested. This involved varying key model parameters in isolation and assessing the influence of the change made on predictions of drawdown and groundwater take. Key model parameters were selected based on their potential to most influence model predictions. Sensitivity analysis included testing the key parameters for the range of likely uncertainty in key parameters. The changes used to test the model sensitivity include extremes in the potential parameter ranges and encompass the full range of relevant measured values for these parameters. Overall, the sensitivity analysis confirmed that there is a high degree of confidence in the model's calibration and predictions, and that the model is not likely to have under-predicted any significant impacts.

5.2 Groundwater drawdown during the UWIR period (IAA)

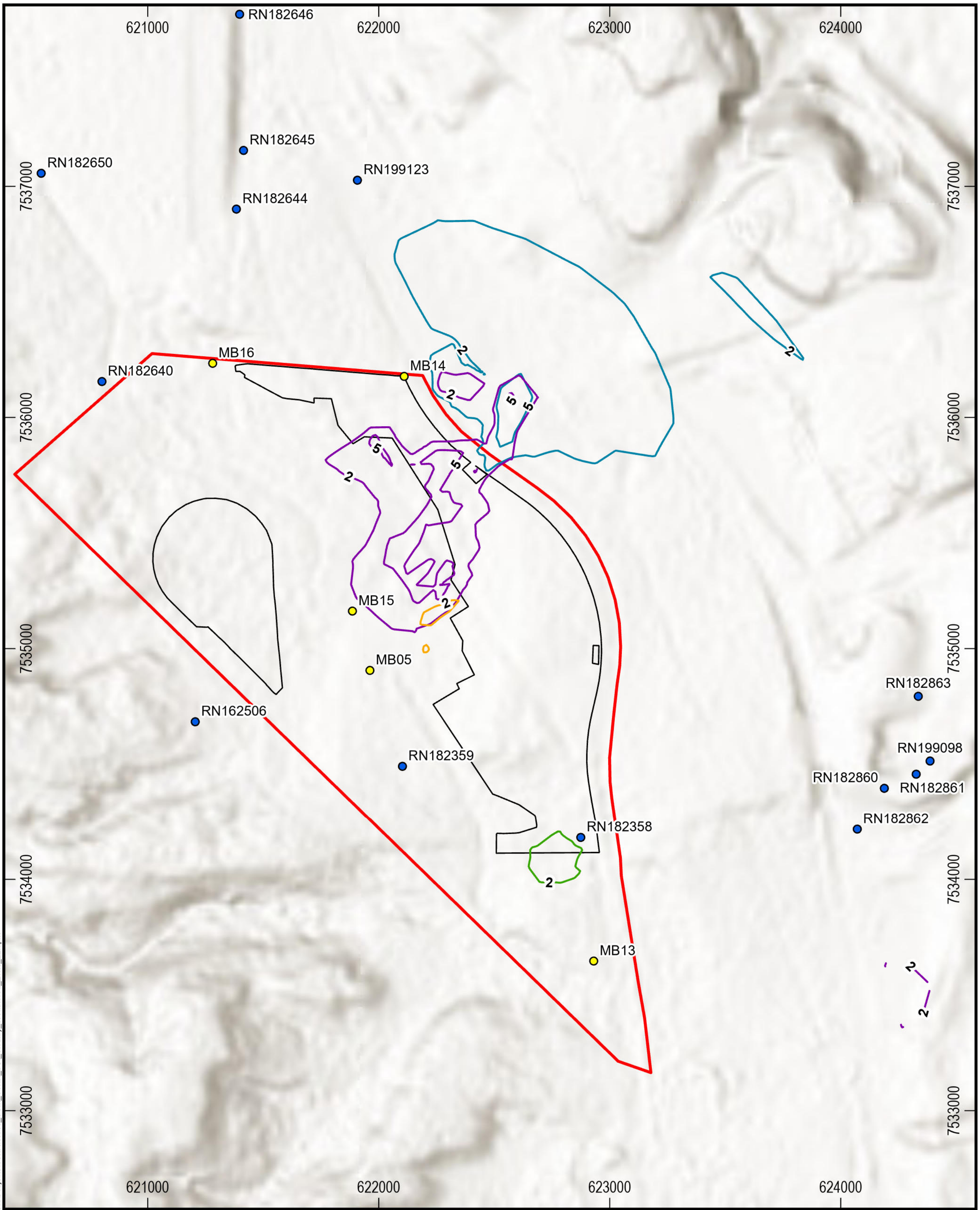
As discussed in **Section 1.1**, the Immediately Affected Area (IAA) is defined as the area of an aquifer where the water level is predicted to decline by more than the bore trigger threshold within three years (considered the UWIR period). The bore trigger threshold applicable at the VCM is 2 m for unconsolidated aquifers and 5 m for consolidated aquifers.

The extent of the predicted drawdown for the aquifers at the VCM, namely the Tertiary regolith, DLL coal seam and MAT coal seams, were extracted from the numerical model discussed in **Section 5.1**. The extent of drawdown for Year 1 (2023), Year 2 (2024) and Year 3 (2025) was limited to that associated with the VCM only (Jupiter and Matilda pits) and excludes the impacts of the nearby Saraji Mine and Peak Downs Mine.

Figure 5-1 presents the yearly drawdown predicted for the unconsolidated Tertiary regolith for the UWIR period. The modelled IAA for the Tertiary regolith over the UWIR period is predicted to be relatively limited in extent, with the largest IAA predicted in Year 3 (2025) when the Jupiter pit is mined to its full extent. No drawdown is predicted in the vicinity of the Matilda pit as this area of the Tertiary regolith is considered to be dry.

No drawdown of the DLL coal seam is predicted for the UWIR period.

Figure 5-2 presents the yearly predicted drawdown for the MAT coal seam for the UWIR period. The modelled IAA for the MAT coal seam over the UWIR period is predicted to be limited to the extent of the proposed Matilda pit. The IAA predicted for the MAT coal seam is limited to less than 100 m from the proposed pit bounds and does not vary significantly throughout the UWIR period. No drawdown is predicted within the MAT coal seam in the vicinity of the Jupiter pit as mining in this pit will not extend down to the MAT coal seam which underlies the DLL coal seam target.



Legend

- Registered Groundwater Bores
- Groundwater Monitoring Locations
- Pit Shells
- ML 700060

Drawdown (m)

- 2023
- 2024
- 2025
- 2026

Source: Hydrogeologist.com.au 2022, State of Queensland (Department of Regional Development, Manufacturing and Water) 2022, Vitrinite 2022, METServe 2022, Esri, Geoscience Australia, NASA, NGA, USGS.
Groundwater modelling conducted by Hydrogeologist.com.au.

Vulcan Coal Mine

Immediately Affected Area (IAA) - Tertiary Regolith

0 200 400 800
Meters
Scale: 1:24,000 (A4)

11/10/2023

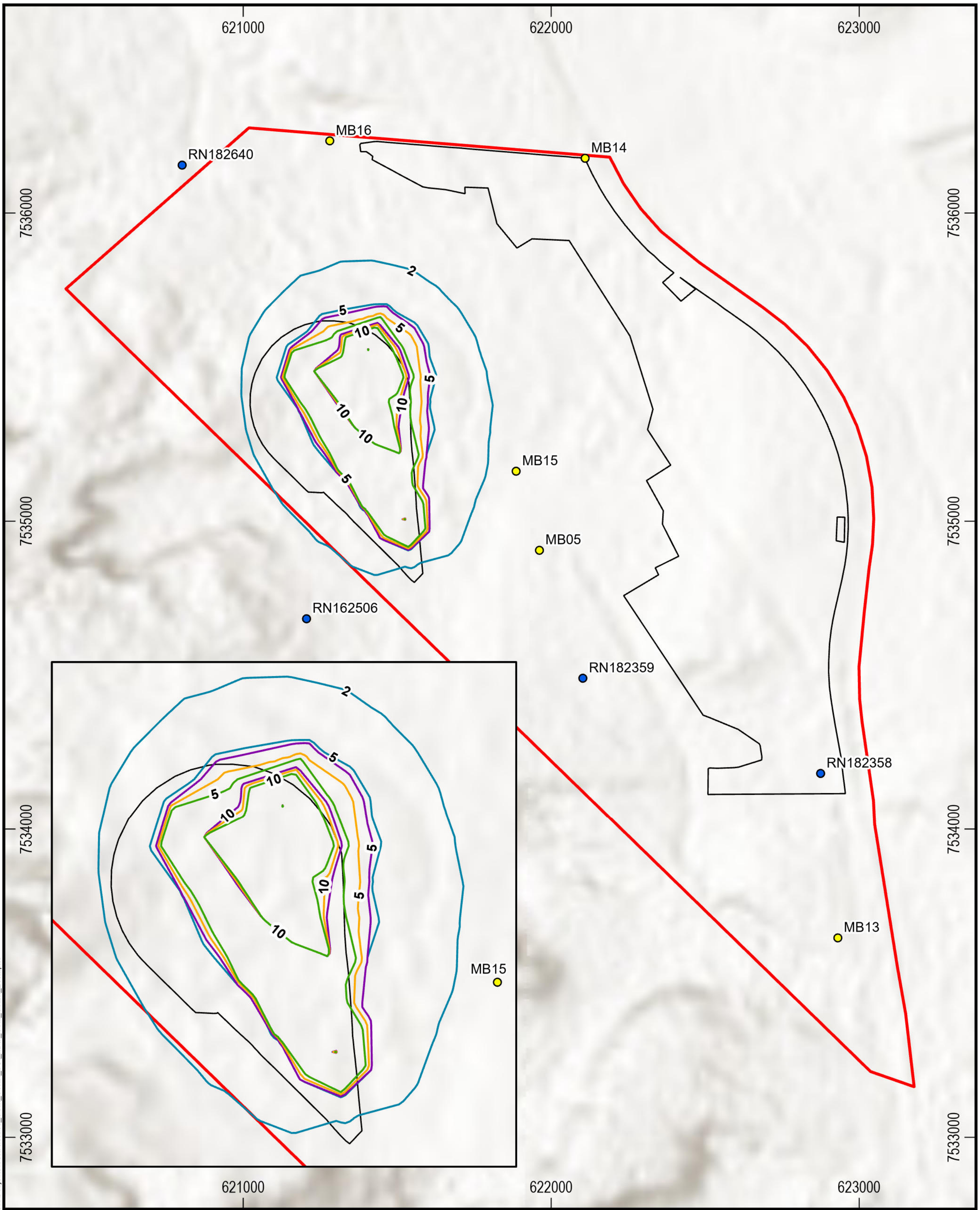
Datum: GDA2020
Projection: MGA55

FIGURE 5-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_IAA_Tertiary_Weathered_Zone_L2.aprx



Legend

- Registered Groundwater Bores
- Groundwater Monitoring Locations
- Pit Shells
- ML 700060

Drawdown (m)

- 2023
- 2024
- 2025
- 2026

Source: Hydrogeologist.com.au 2022, State of Queensland (Department of Regional Development, Manufacturing and Water) 2022, Vitrinite 2022, METServe 2022, Esri, Geoscience Australia, NASA, NGA, USGS. *Inset at different scale. Groundwater modelling conducted by Hydrogeologist.com.au.*

Vulcan Coal Mine

Immediately Affected Area (IAA) - MAT Coal Seam

0 150 300 600

Meters

Scale: 1:18,000 (A4)

11/10/2023

Datum: GDA2020
Projection: MGA55

FIGURE 5-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

5.3 Groundwater drawdown over the mine life (LTAA)

As discussed in **Section 1.1**, the Long-term Affected Area (LTAA) is defined as the area of an aquifer where the water level is predicted to decline by more than the bore trigger threshold at any time over the life of the project. The bore trigger threshold applicable at the VCM is 2 m for unconsolidated aquifers and 5 m for consolidated aquifers.

The extent of the predicted maximum drawdown for the aquifers at the VCM, namely the Tertiary regolith, DLL coal seam and MAT coal seams, were extracted from the numerical model discussed in **Section 5.1**. The maximum extent of the predicted drawdown was limited to that associated with the VCM only (Jupiter and Matilda pits) and excludes the impacts of the nearby Saraji Mine and Peak Downs Mine.

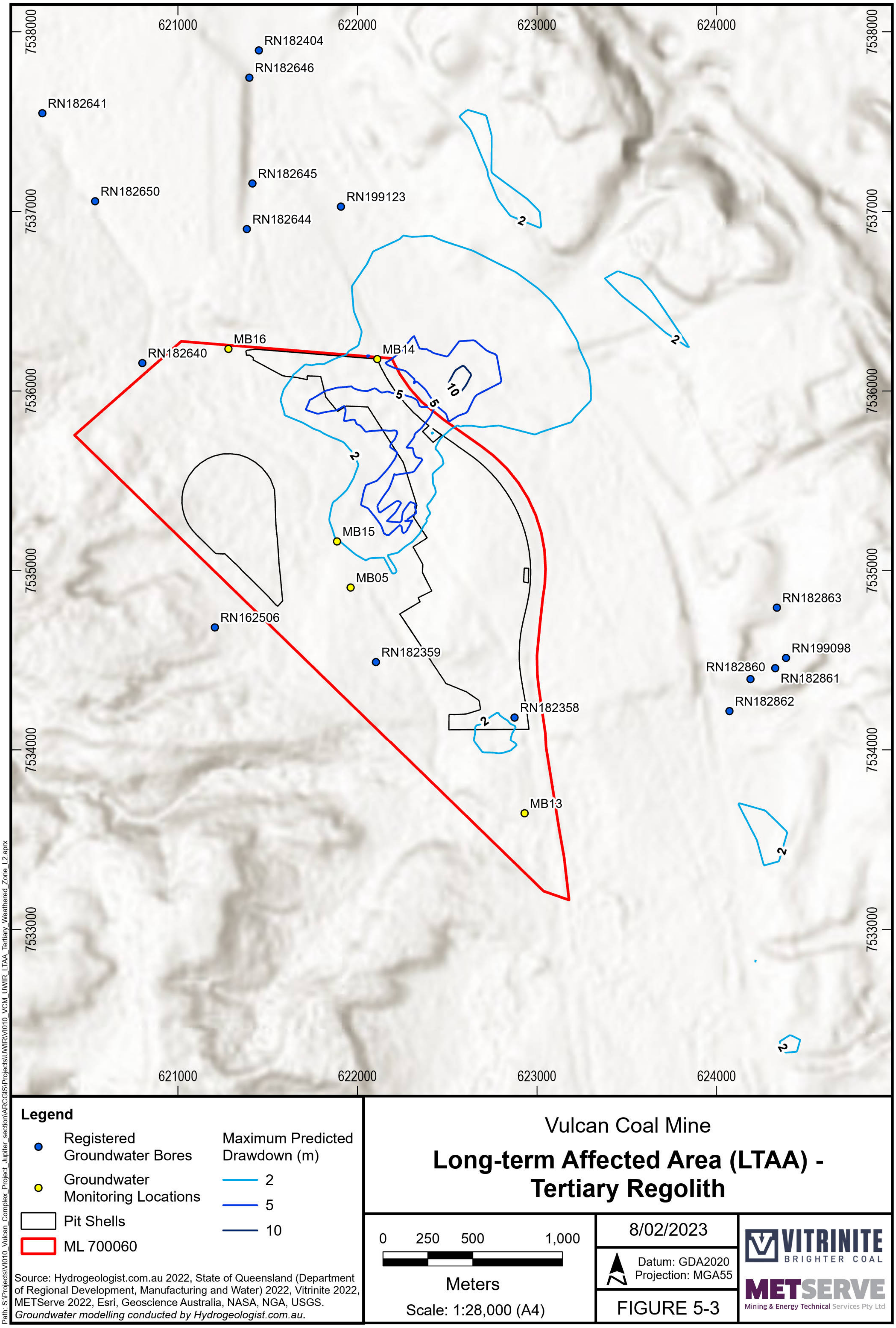
Figure 5-3 presents the predicted maximum drawdown for the Tertiary regolith throughout the life of the VCM. The depth of the predicted drawdown within the Tertiary regolith is approximately 10 m in the vicinity of the final Jupiter pit. Drawdown preferentially propagates towards the east and the existing Saraji Mine. The Tertiary regolith has the largest LTAA predicted by the model, with the LTAA extending one kilometre away from the Jupiter pit crest.

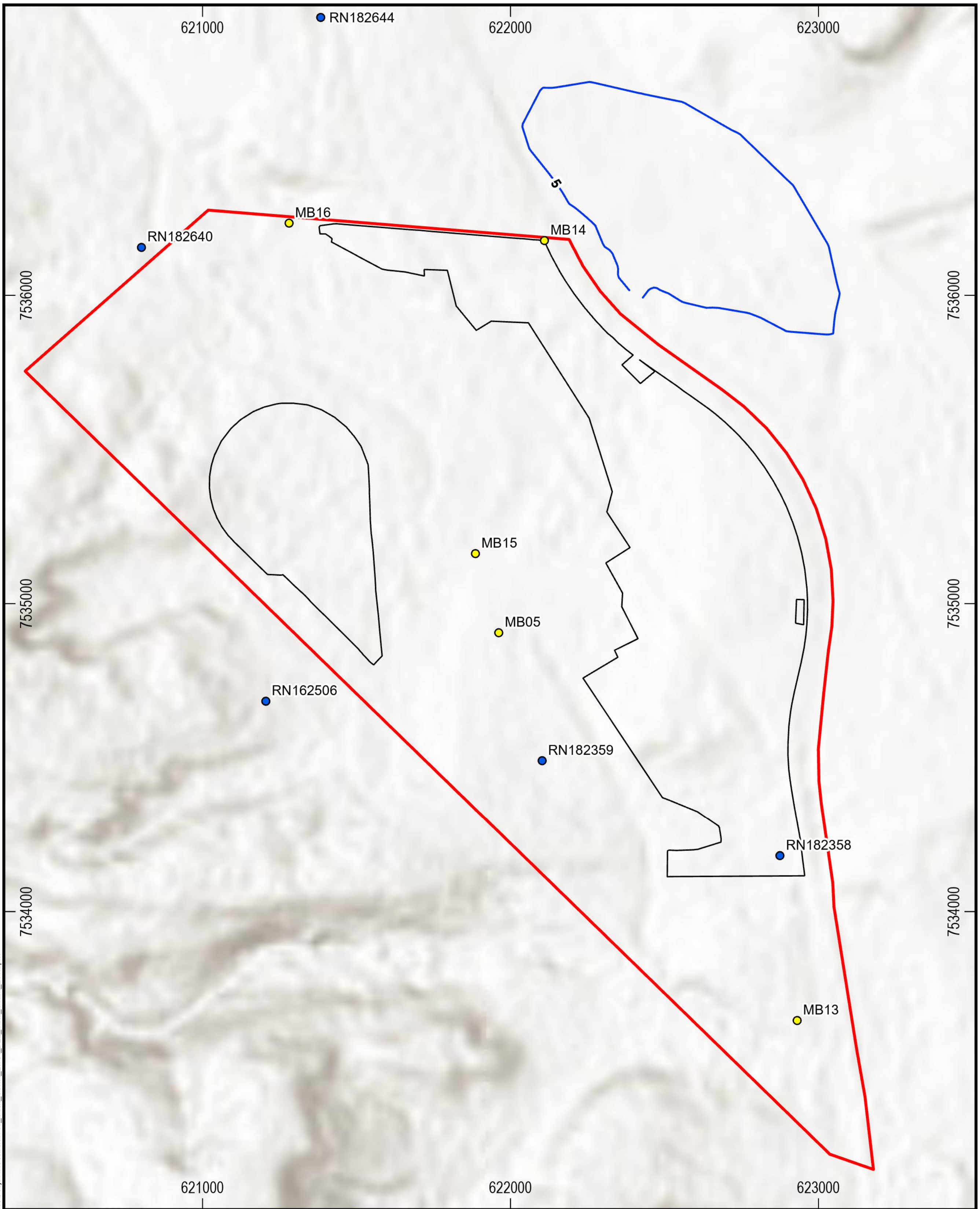
Figure 5-4 presents the predicted maximum drawdown for the DLL coal seam throughout the life of the VCM. The drawdown within the DLL coal seam is predicted to be of a similar magnitude to that predicted for the Tertiary regolith. However, as the DLL coal seam is considered a consolidated unit, a different bore trigger threshold is applied (namely, 5 m). Therefore, the LTAA extent for the DLL coal seam is smaller than that of the Tertiary regolith. The depth of the predicted drawdown in the DLL coal seam is approximately 10 m in the vicinity of the final Jupiter pit. The LTAA extends 760 m from the Jupiter pit crest in an easterly direction towards the existing Saraji Mine, indicating a limited drawdown extent.

Figure 5-5 presents the predicted maximum drawdown for the MAT coal seam throughout the life of the VCM. As with the DLL coal seam, the MAT coal seam is considered a consolidated unit, applying a 5 m bore trigger threshold for the LTAA. The MAT LTAA extends less than 200 m from the proposed Matilda pit boundary, indicating drawdown is very limited in extent, similar to the IAA for the MAT coal seam. The LTAA for the MAT coal seam does not extend over the Jupiter pit as this pit is not planned to mine the MAT coal seam.

The predicted drawdown across the three hydrostratigraphic units is limited to less than 2.5 km from both VCM pit boundaries (measured as the lateral distance between the proposed pit crests to the 1 m drawdown contour). The limited extent of the predicted drawdown is mainly due to the limited extent of saturation at the VCM, the low hydraulic conductivities and low storage coefficients of the three hydrostratigraphic units. Drawdown is predicted to extend towards the east. The predicted maximum drawdown and LTAA for the Tertiary regolith, DLL coal seam and MAT coal seam are considered highly conservative, and actual drawdowns observed at the VCM are anticipated to be less.

Both the Jupiter and the Matilda pits will be backfilled with suitable waste material following the completion of mining. Therefore, the extent of drawdown across the three hydrostratigraphic units of interest is expected to reduce once backfilling / closure is commenced. Some residual drawdown is expected owing to the continued operation of surrounding mines (for example, the Saraji Mine and Peak Downs Mine), however, the overall groundwater regime post-closure is not expected to significantly differ from baseline conditions.


621000
622000
623000
624000
7538000
7537000
7536000
7535000
7534000
7533000
RN182404
RN182646
RN182641
RN182645
RN182650
RN199123
RN182644
MB16
MB14
RN182640
10
5
2
MB15
MB05
RN182863
RN199098
RN182860
RN182861
RN182862
RN162506
RN182359
RN182358
MB13
Legend
Registered Groundwater Bores
Groundwater Monitoring Locations
Pit Shells
ML 700060
Maximum Predicted Drawdown (m)
2
5
10
Source: Hydrogeologist.com.au 2022, State of Queensland (Department of Regional Development, Manufacturing and Water) 2022, Vitrinite 2022, METServe 2022, Esri, Geoscience Australia, NASA, NGA, USGS.
Groundwater modelling conducted by Hydrogeologist.com.au.
Vulcan Coal Mine
Long-term Affected Area (LTAA) - Tertiary Regolith
0 250 500 1,000
Meters
Scale: 1:28,000 (A4)
8/02/2023
Datum: GDA2020
Projection: MGA55
FIGURE 5-3
VITRINITE BRIGHTER COAL
METSERVE Mining & Energy Technical Services Pty Ltd
Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_LTAA_Tertiary_Weathered_Zone_L2.aprx



Legend

- Registered Groundwater Bores
- Groundwater Monitoring Locations
- Maximum Predicted Drawdown (m)
- Pit Shells
- ML 700060

Source: Hydrogeologist.com.au 2022, State of Queensland (Department of Regional Development, Manufacturing and Water) 2022, Vitrinite 2022, METServe 2022, Esri, Geoscience Australia, NASA, NGA, USGS.
Groundwater modelling conducted by Hydrogeologist.com.au.

Vulcan Coal Mine

Long-term Affected Area (LTAA) - DLL Coal Seam

0 150 300 600
Meters
Scale: 1:18,000 (A4)

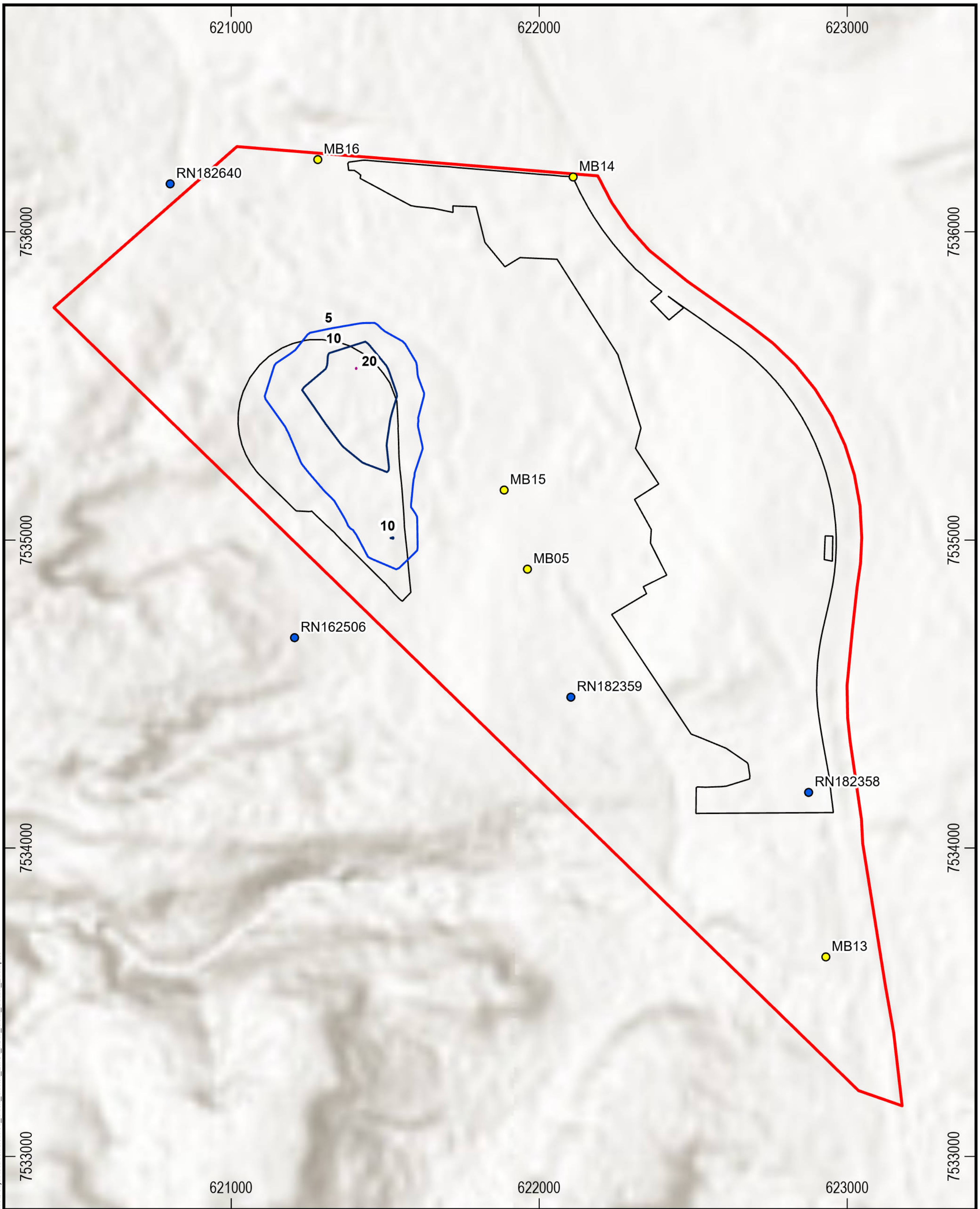
8/02/2023

Datum: GDA2020
Projection: MGA55

FIGURE 5-4

VITRINITE BRIGHTER COAL
METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_LTAA_DLL_Coal_Seam_L10.aprx



Legend

- Registered Groundwater Bores
- Groundwater Monitoring Locations
- Pit Shells
- ML 700060

Maximum Drawdown Predicted (m)

- 5
- 10
- 20

Source: Hydrogeologist.com.au 2022, State of Queensland (Department of Regional Development, Manufacturing and Water) 2022, Vitrinite 2022, METServe 2022, Esri, Geoscience Australia, NASA, NGA, USGS.
Groundwater modelling conducted by Hydrogeologist.com.au.

Vulcan Coal Mine

Long-term Affected Area (LTAA) - MAT Coal Seam

0 150 300 600
Meters
Scale: 1:18,000 (A4)

8/02/2023

Datum: GDA2020
Projection: MGA55

FIGURE 5-5

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_LTAA_MAT_Coal_Seam_L11.aprx

5.4 Water bores within IAA and LTAA

No registered or known water bores were identified within the IAA for the Tertiary regolith, DLL coal seam and MAT coal seams, as shown in the IAA maps in **Section 5.2.** Similarly, no registered or known water bores were identified within the LTAA of the Tertiary regolith, DLL or MAT coal seams (as indicated in LTAA maps in Section 5.2).

5.5 Review of maps produced

Vitrinite will conduct an annual review of the accuracy of the maps presented in **Sections 5.2** and **5.3** showing the predicted IAA and LTAA for the potentially affected aquifers. The accuracy of the maps will be assessed by comparing the predicted drawdown to actual drawdown in those monitoring bores which are accessible and predicted to be impacted.

Vitrinite will commit to providing a summary of the outcome of the annual review to the chief executive as per The annual review will include a statement of whether there has been a material change in the information or predictions used to prepare the maps.

The first annual review is scheduled to occur in February 2024.

6 Part D: Impacts on environmental values

This section addresses the requirements under Section 376(b-e) of the Water Act and requirements summarised in **Table 6-1** below.

Table 6-1 Requirements under Section 376(b-e) of the Water Act

Section 376(b - e) Requirements	UWIR Section
To meet the requirements of the Water Act, a UWIR must include the following: (i) A description of the impacts on environmental values that have occurred, or are likely to occur, because of any previous exercise of underground water rights;	Section 6.1
(ii) An assessment of the likely impacts on environmental values that will occur, or are likely to occur, because of the exercise of underground water rights – for a three-year period stating on the consultation day of the report; and over the projected life of the resource tenure.	Section 6.2

6.1 Applicable environmental values

This section identifies and describes the environmental values related to groundwater within the area of the VCM.

The quality of Queensland water is protected under the *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water). The EPP Water achieves the objective of the *Environmental Protection Act* (EP Act) to protect Queensland waters whilst supporting ecologically sustainable development. Queensland waters include rivers, streams, wetlands, lakes, aquifers, estuaries and coastal areas.

The EPP Water provides a framework for identifying environmental values (EVs) for Queensland waters and establishes the water quality objectives (WQOs) to protect or enhance those EVs. Under Schedule 1 of the EPP Water, the VCM area is covered by the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection [DEHP], 2011). Such document sets out the EVs and WQOs applicable to the VCM.

The Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011) lists the following EVs for groundwaters within the Isaac-River Sub-basin:

- aquatic ecosystems;
- agricultural use / irrigation;
- stock water;
- primary recreation;
- drinking water; and
- cultural and spiritual values.

6.2 Impacts on the groundwater quality

An assessment of groundwater quality is presented below, in terms of the applicable EVs set out in the Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011). Although EVs are not listed for the protection of industrial use, this has also been included for completeness as mine water use is an important aspect given the number of coal mines operating in the catchment.

Aquatic Ecosystems

The WQO for aquatic ecosystems within the Isaac River Sub-basin, where groundwaters interact with surface waters, is that groundwater quality should not compromise the identified EVs and WQOs for those waters. For example, Table 1 in the Sub-basin plan lists a WQO of < 720 µS/cm for Upper Isaac River catchment waters. This has been interpreted as groundwater which supports the Upper Isaac River catchment surface waters should not exceed 720 µS/cm. None of the monitoring bores or surrounding registered water bores report such low salinity; with all reporting field ECs > 2,700 µS/cm.

Given the depth of groundwater, the brackish to highly saline quality of groundwater within the VCM area, and the absence of significant groundwater-surface water interactions, groundwater is not suitable to sustain groundwater-dependent ecosystems. Groundwater at the VCM is too deep for terrestrial flora to access, and the poor groundwater quality could not support a fresh / marginal aquatic ecosystem.

Agricultural Use / Irrigation

Table 3 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011) refers to the suitability for farm supply/use WQO as "Objectives as per AWQG". The AWQG (2018) however bundles the guidelines, for irrigation and general water use. Hence, these EVs will be discussed together.

The objectives for pathogens and metals are provided in Tables 8 and 9 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011). For indicators other than pathogens and metals, the WQOs are those included in the AWQG (2018). For most pastures, loams and clays, the salinity threshold specified in the AWQG (2018) is between 1,000 µS/cm and 7,300 µS/cm.

In addition, the AWQG (2018) warns that certain combinations of salinity and sodium adsorption ratio (SAR) are likely to induce degradation of soil structure and corrective management may be required (e.g. application of lime or gypsum). Groundwater within the VCM area would be classified as "marginal quality" in accordance with the AWQG (2018), meaning soil degradation may occur if the water was used for irrigation depending on soil and rainfall. Hence, if groundwater from the VCM area was to be used for irrigation, caution would be advised.

Owing to the brackish to highly saline groundwater quality, and indications for low sustainable bore yields (low airlift rates, hydraulic conductivities, and thin coal seams) preclude the potential use of the local groundwater for irrigation supply. Neither the quantity nor the quality of local groundwater is suitable for irrigation.

Livestock watering

Review of DRDMW GWDB and the bore census data indicate that groundwater in the area may be used for livestock beef cattle watering. There are 14 registered groundwater bores located within 5 km of the extent numerical groundwater model that are classified as "water supply" bores. Some of these may be used for mine supply and others for stock and domestic which may or may not be used for livestock watering.

Water quality records from the VCM monitoring bores and surrounding registered water bores suggest that groundwater quality varies from brackish to highly saline. Although some groundwater is within the guidelines for livestock watering, the AWQG (2018) states that loss of production and a decline in animal health occurs if stock are exposed to high salinity water for prolonged periods. For beef cattle, decline or loss may occur if the electrical conductivity (EC) is between 7,463 µS/cm and 14,925 µS/cm.

Groundwater quality collected from the VCM monitoring bores has recorded an average EC of 8,666 µS/cm since monitoring began in 2019 across the Tertiary regolith and Permian coal aquifers.

Groundwater quality recorded at the nearby Saraji Mine was generally not considered suitable for livestock whereby groundwater salinity at Saraji Mine was comparable to groundwater salinity measured at the VCM (AECOM, 2016). Although the average groundwater quality at the VCM may preclude large-scale livestock watering regimes, groundwater quality from specific bores / aquifers which are below the AWQG (2018) EC guideline (7,463 µS/cm) may support livestock watering.

Recreational Use

This EV is considered not applicable to local groundwater within the VCM area. There are no groundwater features in the VCM area that could be considered for recreational use.

Drinking Water Suitability

Groundwater quality data collected from the VCM groundwater monitoring network indicates that groundwater is unsuitable for human consumption without treatment due to elevated salinity levels. The WQO specified in Table 4 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) specifies an EC of 400 µS/cm as suitable for drinking quality, whereas none of the VCM monitoring bores yield groundwater of such low EC. All reported ECs exceed 2,700 µS/cm and the average EC across all monitoring bores is 8,666 µS/cm, significantly higher than specified by Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011).

The Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) also refers to a sodium objective of 30 mg/L and a total hardness objective of 150 mg/L as $CaCO_3$ in raw water. Sodium and total hardness recorded at the VCM are well in excess of such values, with minimum concentrations across all monitoring records of 225 mg/L and 242 mg/L respectively.

Groundwater within the VCM area is therefore not considered suitable for human consumption without significant treatment.

Cultural and spiritual values

Due to the absence of significant groundwater-surface water interactions, there are no groundwater springs or seeps which supply surface water bodies at the VCM known to have significant indigenous and/or non-indigenous cultural heritage associations.

Industrial use

The Isaac River Sub-basin Environmental Values and Water Quality Objectives (DEHP, 2011) provides no defined WQOs for industrial uses:

> *"Water quality requirements for industry vary within and between industries. The AWQG do not provide guidelines to protect industries, and indicate that industrial water quality requirements need to be considered on a case-by-case basis. This EV is usually protected by other values, such as the aquatic ecosystem EV".*

The industries within the vicinity of the VCM consist of coal mines. Owing to the brackish to highly saline quality of the groundwater, it is typically utilised for dust suppression during mining activities. No other industrial users are within proximity of the VCM and the high salinity of the groundwater would likely limit other industrial uses.

Summary

Evaluation of the groundwater EVs at the VCM indicates that groundwater within this area is of no or limited value for most uses. Livestock watering and industrial dust suppression may potentially use local groundwater; however, these applications are severely limited by groundwater quality, and are not considered to impact the groundwater EVs.

6.3 Impacts on the environmental values

Impacts on nearby users

As presented in **Section 5**, the predicted maximum drawdown extents in the Tertiary regolith, the DLL coal seam and MAT coal seam are limited. There are no third-party groundwater users within the predicted extent of the IAAs or LTAAs, therefore there are no impacts on existing users.

The nearest registered third party bore to the VCM is RN162506, which is located approximately 350 m from the IAA with less than 1 m drawdown predicted over the life of the VCM. Therefore, the potential for impact to the bore is considered very unlikely. Additionally, the groundwater monitoring strategy already implemented at the VCM (**Section 7**) will ensure that third-party bores are not exposed to undue risk during the life of the VCM.

Impacts on surface drainage

Figure 4-2 illustrates groundwater recharge from surface water systems in the VCM area. No significant surface-groundwater interactions occur in the VCM area.

Creeks in the vicinity of the VCM are ephemeral and typically only discharge after heavy rainfall events. The groundwater table does not intersect the ground surface in the creek beds and there is no groundwater seepage through the creek beds and banks to provide creek baseflow.

On that basis, any localised drawdown associated with the VCM is not anticipated to impact surface water baseflow or natural flow regimes the surrounding watercourses. Therefore, impacts on nearby surface waters are considered unlikely.

Impacts on GDEs

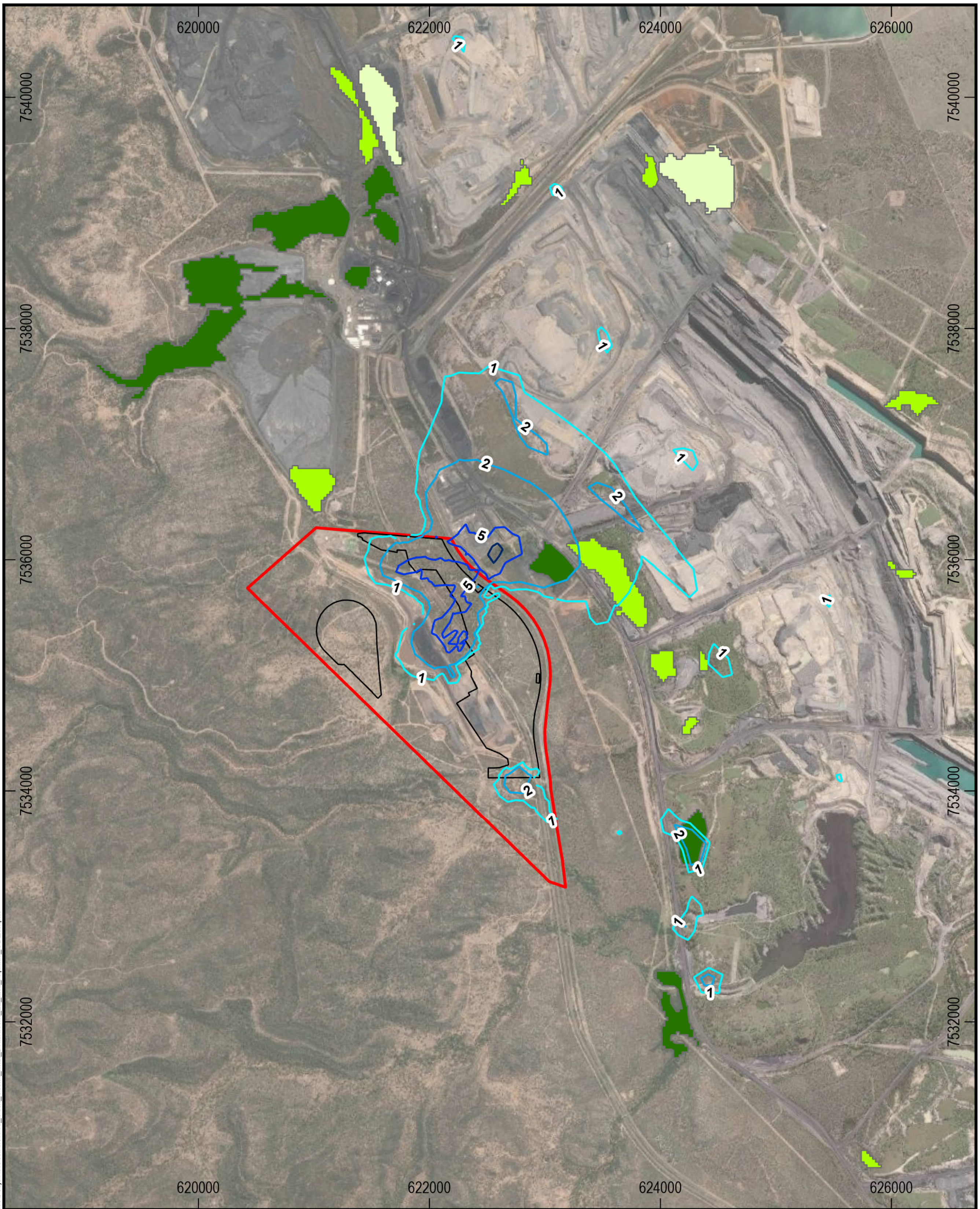
The Tertiary regolith / weathered zone is considered to have the highest potential to supply water to GDEs due to being the shallowest aquifer and potentially unconfined in some areas within the VCM. **Figure 6-1** presents the maximum predicted drawdown for the Tertiary regolith with respect to the locations of potential GDEs.

While there are several small areas of high and moderate potential aquatic GDEs shown within the maximum drawdown extent of the Tertiary regolith, no known aquatic GDEs exist within 3 km of the VCM. Areas which are mapped as high or moderate potential aquatic GDEs are areas where seasonally high groundwater levels are close to the surface. However, surface water systems within the VCM ML lie above the groundwater table, indicating that the surface and groundwater systems are hydraulically disconnected and supply of groundwater to a GDE is unlikely.

As mentioned in **Section 6.2**, local groundwater within the vicinity of the VCM would be unable to support an aquatic GDE owing to its brackish to highly saline nature.

Similar to the potential aquatic GDE mapping, small areas of terrestrial GDEs are mapped within the maximum predicted drawdown extent of the Tertiary regolith, largely correlating to where potential aquatic GDEs are mapped. It is noted that terrestrial GDEs with high or moderate potential for groundwater interaction most likely occur in areas where depth to groundwater is less than 10 m. Interpretation of historical groundwater levels typically record levels deeper than 10 m in these areas, outside of the accessible range of terrestrial flora.

Owing to the depth to groundwater and the saline nature of groundwater in the VCM area, no valid aquatic or terrestrial GDEs exist within the maximum predicted drawdown extent and the impact to such GDEs are considered negligible.



Legend

Aquatic Groundwater Dependent Ecosystems

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment

- Pit Shells
- ML 700060

Maximum Predicted Drawdown (m)

- 1
- 2
- 5
- 10

Source: Hydrogeologist.com.au 2022, Commonwealth of Australia (Bureau of Meteorology) 2019, Vitrinite 2022, METServe 2022, Maxar. *Groundwater modelling conducted by Hydrogeologist.com.au.*

Vulcan Coal Mine

Maximum Drawdown of Tertiary / weathered zone (L2) and Aquatic Groundwater Dependent Ecosystems (GDE)

0 0.5 1 2

Kilometers

Scale: 1:48,000 (A4)

11/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 6-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_Max_Drawdown_L2_and_Aquatic_GDEs.aprx

Impacts on groundwater quality

During mining, both the Jupiter and Matilda pits at the VCM, along with the nearby Saraji Mine pit, will act as sinks for surrounding groundwater. Any local contamination of the groundwater regime at the VCM will therefore report to one of the pits. As mentioned in **Section 3**, groundwater inflows to the pits are predicted to be limited and will be evaporated or contained as mined coal moisture. Closure of the VCM will see waste rock stored areas (i.e. Ex-pit dump) fully rehabilitated, along with the complete backfill of both VCM pits. Pit backfilling during closure will remove VCM's groundwater sinks and allow groundwater levels to recover towards pre-mining levels. It is assumed that the pit voids at Saraji Mine and Peak Downs Mine will likely remain into perpetuity and will behave as regional evaporative sinks on the groundwater system, hence minimising any eastward migration of potential contaminants.

The evaluation of groundwater EVs presence at the VCM (**Section 6.2**) outlines that groundwater is of no, or limited value for the majority of EVs due to its high salinity. Local groundwater monitored at the VCM is considered brackish to highly saline; even with an 50% increase in salinity would not impact on the beneficial uses identified (livestock beef cattle watering and industrial purposes, limited to dust suppression in mining). The salinity of local groundwater is well in excess of the WQOs for aquatic ecosystems and drinking water suitability.

6.4 Impacts to formation integrity and surface subsidence

Sub-surface formation integrity issues and surface subsidence are not anticipated at the VCM due to the insignificant amount of groundwater expected to be produced at the VCM and the shallow nature of the two open-cut pits.

7 Part E: Water monitoring strategy

This section addresses the requirements under Section 378 of the Water Act and requirements summarised in **Table 7-1** below.

Table 7-1 Requirements under Section 378 of the Water Act

Section 378 Requirements	UWIR Section
To meet the requirements of the Water Act, a UWIR must include the following: (i) A rationale for the monitoring strategy;	Section 7.1 & 7.2
(ii) A timeline for the strategy;	Section 7.3
(iii) The parameters to be measured;	Section 7.3
(iv) The locations for taking measurements;	Section 7.3
(v) The frequency of the measurements;	Section 7.3
(vi) A program for the responsible tenure holder to undertake a baseline assessment for each water bore that is outside the area of a resource tenure, but within the predicted LTAA; and	N/A
(vii) A program for reporting to the OGIA about the implementation of the strategy.	Section 7.4

7.1 Rationale

The groundwater monitoring network was established at the VCM in 2019 to monitor potential impacts to groundwater caused by mining activities. Network development was based upon the general understanding of groundwater flow conditions, the geology of the region, and the available mine plan at the time. The groundwater monitoring network was also developed to satisfy the requirements stipulated in the VCM's EA.

VCM groundwater monitoring bores target the three main hydrostratigraphic units present at the VCM - the shallow Tertiary regolith / weathered zone, Permian coal measures (DLL coal seam), and the underlying Back Creek Group (MAT coal seam). The monitoring network does not target the Quaternary alluvium as there is no mapped alluvium within or surrounding the VCM area. Groundwater levels and quality are monitored across the network periodically in accordance with the VCM EA.

When establishing the monitoring network, bore locations were constrained by mining lease boundaries, future mine plans and infrastructure, as well as the orientation of the target geology with respect to the general groundwater flow conditions in the VCM area. Groundwater flows across the VCM area from west to east and given the strike orientation of the target coal seams, an up-gradient / reference monitoring bore was unable to be established. Rather, several rounds of monitoring were undertaken before mining commenced in late 2020 in order to establish a sufficient baseline reference.

All monitoring bores at the VCM were spatial distributed as far as was reasonably practicable to allow for adequate spatial spread of data across the target formations.

7.2 Monitoring strategy

A total of eight groundwater monitoring bores have been constructure across the VCM ML, whereby five bores installed in 2019 and four installed in 2022. Five active groundwater monitoring bores remain at the VCM with three bores recently decommissioned in 2022 due to Jupiter pit progression. All five active VCM monitoring bores are listed on the VCM EA.

The location of the VCM monitoring bores are presented in **Figure 7-1**. **Table 7-2** summarises the location, target formation and construction details for each of the monitoring bores in the VCM groundwater monitoring network.

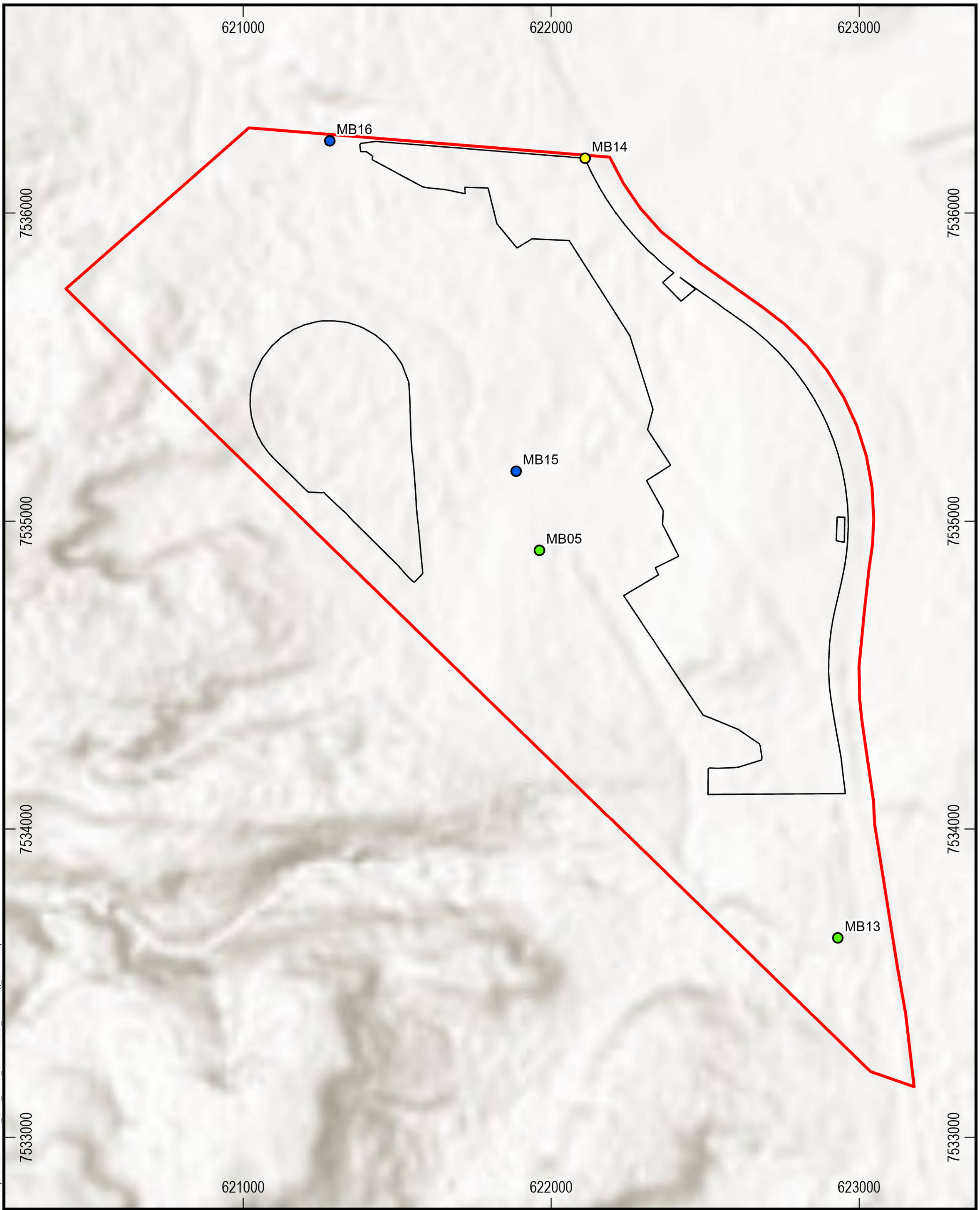
Table 7-2 VCM groundwater monitoring bore construction details

ID	Area	Easting	Northing	Target unit	Casing height (maGL)	Hole depth (mbGL)	Screen interval (mbGL)	Airlift yield (L/min)	Casing elevation (mAHD)
MB05	VCM	621964	7534905	MAT coal seam	0.77	40.9	37.9 – 40.9	0.5	252.70
MB13	VCM	622931	7533648	MAT coal seam	0.63	36.92	33.5 – 36.5	-	223.13
MB14	VCM	622111	7536181	DLL coal seam	0.6	29.5	23.5 – 29.5	-	242.38
MB15	VCM	621875	7535185	Permian interburden	0.8	10	7 – 10	-	251.55
MB16	VCM	621282	7536235	Permian interburden	0.85	10	7 - 10	-	248.36

Notes: Easting and northing coordinates are in GDA94, Zone 55

maGL – metres above ground level

mbGL – metres below ground level



Legend

- ML 700060
- Pit Shells

Groundwater Monitoring Locations

- DLL coal seam
- MAT coal seam
- Permian interburden

Source: Vitrinite 2022, METServe 2022, Esri, Geoscience Australia, NASA, NGA, USGS.

Vulcan Coal Mine

Groundwater Monitoring Network

0 150 300 600

Meters

Scale: 1:18,000 (A4)

6/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 7-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\UWIR\VI010_VCM_UWIR_Groundwater_Monitoring_Network.aprx

7.3 Monitoring frequency and parameters

In accordance with the VCM EA requirements, monitoring of groundwater level and quality at three of the five monitoring bores is conducted quarterly, whereby MB15 and MB16 is currently monitored monthly. This frequency of groundwater monitoring allows for natural fluctuations in level (such as seasonal responses to rainfall) to be distinguished from potential impacts to water level due to dewatering associated with mining activities. Monthly monitoring at MB15 and MB16 will be reduced to quarterly in August 2023 following the requirements in the VCM's EA. In addition to the manual collection of groundwater levels, pressure transducers are installed in each VCM monitoring bore to collect higher frequency, continuous data which is helpful in distinguishing impacts to groundwater level.

Groundwater quality is monitored to detect changes in water chemistry throughout mining operations and post-mining. Quarterly water quality samples are sent to a NATA accredited laboratory for the analysis of the following analytes:

- pH, electrical conductivity and total dissolved solids;
- major cations including sodium, calcium, magnesium and potassium;
- major anions including chloride and sulphate;
- total alkalinity including hydroxide, carbonate and bicarbonate;
- dissolved metals including aluminium, arsenic, iron, lead, mercury, molybdenum and selenium; and
- total recoverable hydrocarbons.

Field physico-chemical parameters such as pH, electrical conductivity, and dissolved oxygen are collected in-situ during sampling.

Groundwater samples are collected in accordance with the relevant guidelines and conventions specified in the "Monitoring and Sampling Manual" (DES, 2018), and in compliance with the relevant Australian Standard (AS/NZS 5667:11 1998 (Australian/New Zealand Standards, 2016)). Groundwater sampling at the VCM is conducted by appropriately qualified and experienced personnel. Samples are preserved and forwarded to a NATA accredited laboratory for analysis.

7.4 Reporting program

The water monitoring strategy implemented at the VCM will be reported to the OGIA upon the approval of the UWIR by the DES.

The UWIR guideline recommends six monthly reporting of the water monitoring data to the OGIA. Given the majority of the VCM groundwater monitoring network is monitored on a quarterly basis, six-monthly reporting is considered to be excessive. Therefore, reporting to the OGIA of the water monitoring data collected across the VCM groundwater monitoring network is proposed to occur on an annual basis rather than six-monthly. The proposed annual reporting frequency also aligns with the required annual review of the IAA and LTAA maps (outlined in **Section 5.5**) as per section 376(1)(e)(i) of the Water Act.

8 Part F: Spring impact management strategy

As discussed in **Section 6**, no springs or aquatic GDEs are located within the VCM. Operations at the VCM are not anticipated to cause impacts on nearby springs.

9 Conclusions

The key conclusions of the UWIR are as follows:

- The impacts of the VCM over the UWIR period and the life of the VCM have been assessed and approved under the EP Act as part of the VCM EA approval in February 2022 (amended in August 2022);
- Approved mining operations will result in localised drawdown of the Tertiary regolith, DLL coal seam and the MAT coal seam once underground water rights have been exercised at VCM (anticipated Q1 2023);
- Mining operations associated with the VCM will not impact surrounding surface waters during the UWIR period as there is no interaction between groundwater and surface water features;
- There are no groundwater users or other sensitive receptors predicted to be affected by groundwater drawdown and therefore no significant groundwater impacts are predicted as a result of the VCM; and
- There is a very low potential for groundwater contamination as a result of the VCM.

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11 Appendix A – Vulcan Coal Mine Groundwater Impact Assessment

REPORT ON

VULCAN COAL MINE EA AMENDMENT GROUNDWATER IMPACT ASSESSMENT

Project number: 4124

Date: 08/08/2022

ABN: 50 627 068 866 www.hydrogeologist.com.au info@hydrogeologist.com.au

1/149 Boundary Road, Bardon. QLD. 4065 P.O. Box 108, The Gap. QLD. 4061

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Vulcan Coal Mine EA Amendment

Groundwater Impact Assessment

Prepared for

Vitrinite Pty Ltd

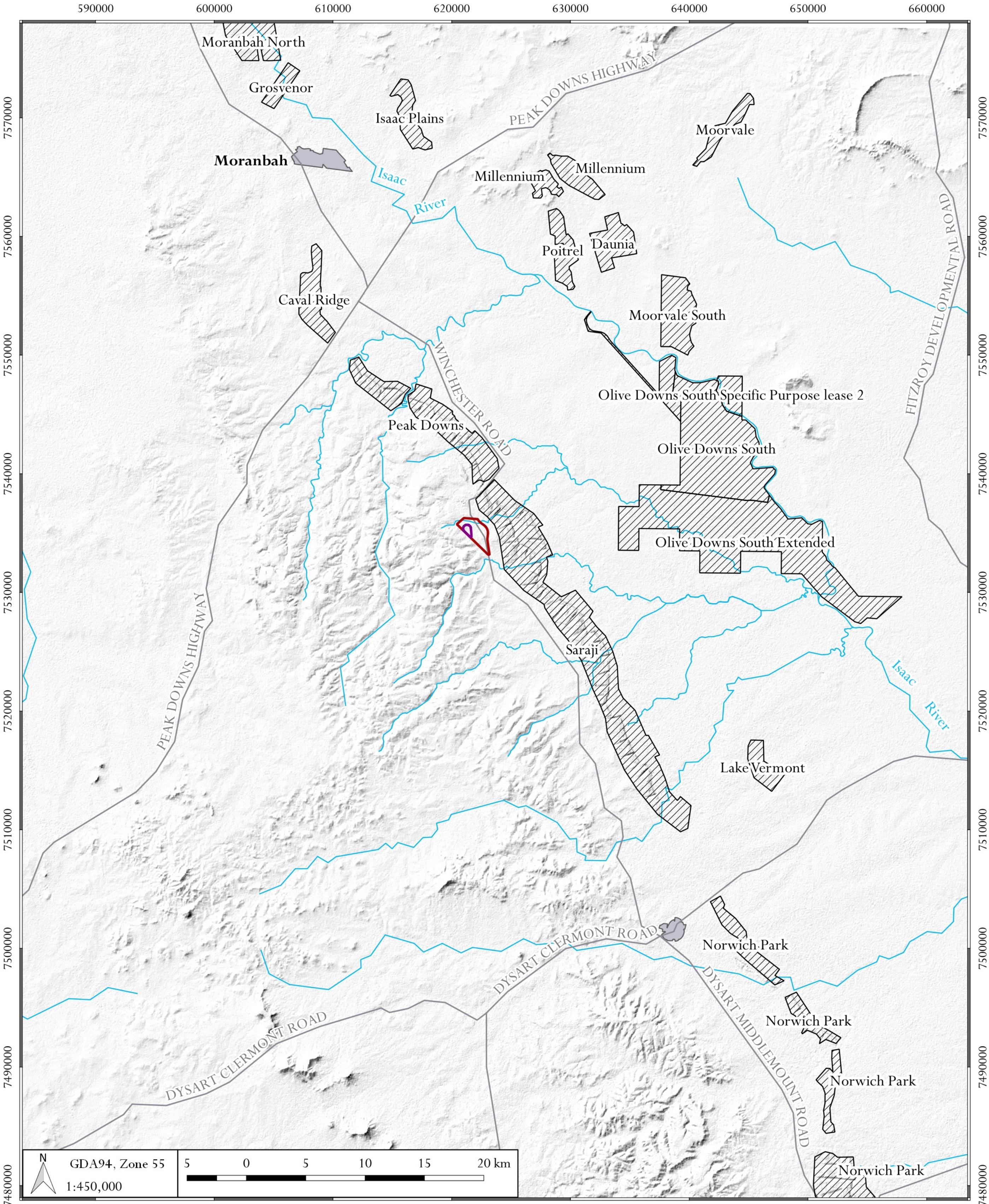
1. Introduction

hydrogeologist.com.au has been engaged by Mining & Energy Technical Services Pty Ltd (METServe) to prepare a groundwater impact assessment to support an Environmental Authority (EA) amendment for the Vulcan Coal Mine (VCM) (the Project). The Project, which is proposed to be developed by Vitrinite Pty. Ltd., owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite) is located:

- approximately 35 km south of the township of Moranbah, within Mining Lease (ML) 700060; and
- to the immediate west of the BHP Saraji Mine and nearby to several other established BHP mining operations including Caval Ridge Mine, Peak Downs Mine and Norwich Park Mine.

The Project location is presented in Figure 1-1.

METServe has been engaged by Vitrinite to manage the environmental approval process for the Project. Vitrinite has commissioned environmental assessment work for the purposes of preparing an Environmental Authority (EA) amendment. The groundwater impact assessment will also support the referral of the Project to the Commonwealth Department of the Environment and Energy (DoEE) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).



LEGEND

Combined exploration permits coal

Established mining operation

ML700060

Matilda pit

Watercourse

Major road

DATE
21/06/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Project location and surrounding mines

FIGURE No.
1.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\01_01_4124_Matilda_Vulcan South_Project location.qgz

1.1. Background

Vitrinite holds an Environmental Authority (EA0002912) and Mining Lease (ML 700060) authorising the extraction of black coal, quarry material and crushing and screening activities. The VCM is approved to operate for approximately 4 years extracting approximately 6 million tonnes (Mt) of Run of Mine (ROM) hard coking coal at a rate of up to 1.95 Mt per annum (Mtpa). The VCM currently targets the Alex and multiple Dysart Lower coal seams.

The proposed amendment primarily includes the establishment of a Coal Handling and Preparation Plant (CHPP), Train Load-out facility (TLO), a dedicated rail loop and an additional open cut pit on ML700060. The open cut pit, referred to as the 'Matilda pit' is proposed to be located within the rail loop and will provide supplementary coal to the ROM stockpile. Development of the Matilda pit will not require an increase of the approved production rate, nor have a significant impact on the life of the project.

The Matilda pit will be a small, shallow (maximum depth of 40 m) open pit within the rail loop alignment. It will target the Matilda (MAT) coal seam which underlies the Alex and multiple Dysart Lower coal seams mined in the existing open pit to the east. The Matilda pit will be mined concurrently with the existing pit to the east. The extent of mining in the Matilda pit is shown in Figure 1-2.

There is no requirement to increase the production rate or significantly alter project timeframes. This is because further planning work has been completed on the main pit and the amount of coal to be extracted has reduced from what was originally proposed and approved.

hydrogeologist.com.au (2019) established a groundwater monitoring network for the Vulcan Coal Mine in June 2019 to support baseline characterisation and impact assessment. The groundwater monitoring network has been monitored in accordance with the EA and has been supplemented overtime with additional monitoring bores where required.

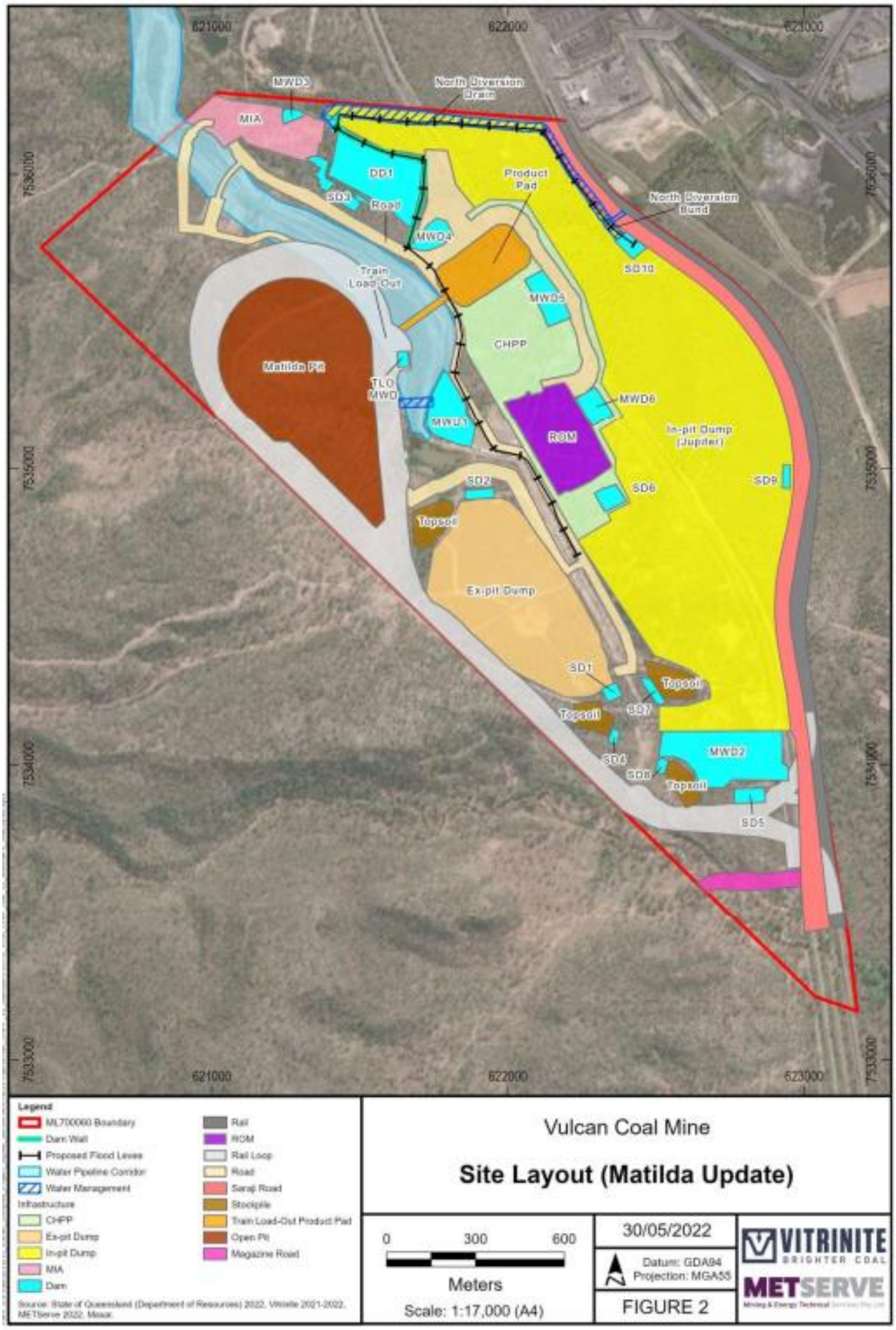


Figure 1-2 Site layout (Matilda update)

1.2. Objectives and scope

The objective of the assessment is to identify and assess the Project's groundwater impacts in a robust manner that meets the expectations of multiple stakeholders. These stakeholders include the Queensland Government, the Commonwealth Government, surrounding landholders and mining companies. The scope of work defines the following distinct activities which have been compiled into the groundwater impact assessment to support Project's approval:

- Review existing geological and hydrogeological information in the public domain and from private investigations.
- Describe the following components of the groundwater regime:
  - geology and stratigraphy, locally and regionally, including faulting;
  - depth to, and thickness of aquifers and their transmissivity;
  - relationship between local and regional groundwater flows;
  - groundwater flow directions and discharge;
  - groundwater quality and chemistry;
  - sources of recharge and recharge rates for each aquifer; and
  - surface water interactions and potential groundwater dependent ecosystems (GDEs).
- Determine the local environmental values and water quality objectives of the groundwater resource in accordance with the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity), the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection, 2009), and the ANZECC Water Quality Guidelines (AWQG, 2018).
- Predict potential drawdown of all relevant aquifers using the existing site conceptual and numerical model. The groundwater impact assessment should:
  - simulate the Project and predict groundwater level drawdown or depressurisation in each hydrostratigraphic unit during the Project and post closure;
  - predict the volumes of groundwater reporting to the Matilda pit as seepage or inflow;
  - predict residual groundwater levels and recovery rates in each hydrostratigraphic unit during post closure; and
  - include a sensitivity analysis.
- Predict and present impacts on identified third party landholder bores and potential GDEs.
- Predict and present impacts on potential interactions and connectivity between surface waters and groundwaters.
- Predict and present drawdown impacts during operations and post mining resulting from the Project.
- Predict and present cumulative drawdown impacts with other existing, known or reasonably foreseeable projects in the region during and post mining.
- Propose an ongoing groundwater management strategy including monitoring of the established bore monitoring network, any measures to manage or mitigate potential impacts and a program for the review and update of the numerical model.
- Describe potential impacts on groundwater quality from the Project (e.g., spills, contaminants).

1.3. Data and information sources

Data and information used for the purposes of this assessment has been obtained from the following sources:

- proponent provided information from METServe and Vitrinite;
- reports and publications as listed in Section 9 of this report;
- groundwater assessments from nearby mines including:
  - Caval Ridge Mine (URS, 2009);
  - Saraji Mine (AECOM, 2016); and
  - Olive Downs Coal Project (HydroSimulations, 2018).
- relevant Bowen Basin publications including:
  - CSIRO (2002);
  - Arrow Energy (2012);
  - URS (2012); and
  - Arrow Energy (2016).
- publicly available datasets including:
  - Australian Bureau of Meteorology (BoM) weather and climate data (Bureau of Meteorology, 2016);
  - Scientific Information for Land Owners (SILO) rainfall and evaporation (https://www.longpaddock.qld.gov.au/silo/);
  - Groundwater Dependent Ecosystems Atlas (GDE Atlas, BOM, 2018) (http://www.bom.gov.au/water/groundwater/gde/);
  - QLD globe (https://qldglobe.information.qld.gov.au/); and
  - Queensland Springs Database (https://data.qld.gov.au/dataset/springs/resource/4cdc89ef-b583-446e-a5c7-0836a91a3767).
- spatial mapping data from the Queensland spatial catalogue (QSpatial) (http://qldspatial.information.qld.gov.au/catalogue/custom/index.page).

2. Regulatory framework

hydrogeologist.com.au have considered the Project description and activities proposed against the various legislation and guidelines produced by the Queensland and Commonwealth Governments. Relevant legislation is described below.

2.1. Queensland

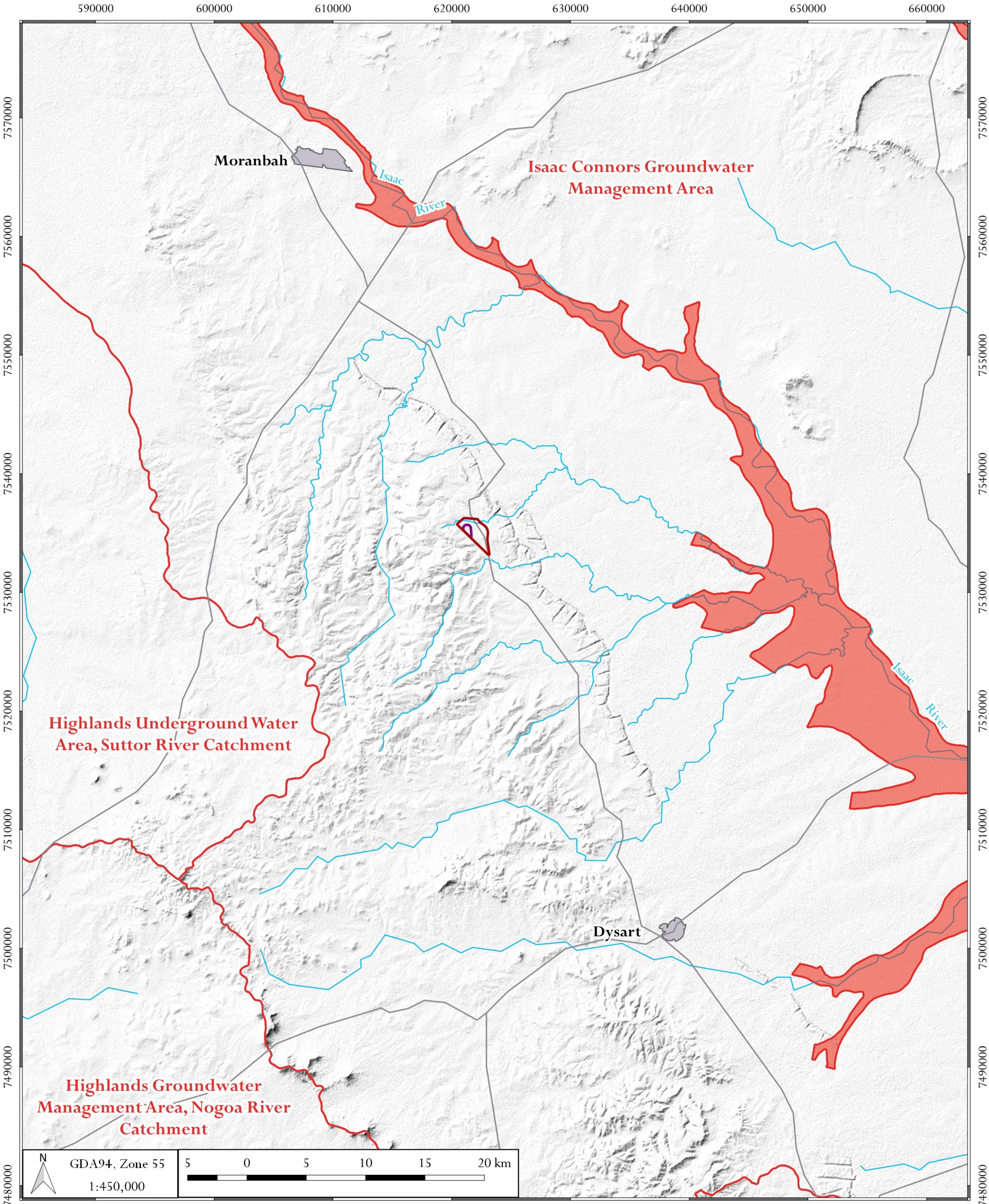
2.1.1. Water Act 2000

The *Water Act 2000* (Water Act), supported by the subordinate Water Regulation 2016, is the primary legislation regulating groundwater resources in Queensland. The purpose of the Water Act is to advance sustainable management and efficient use of water resources by establishing a system for planning, allocation and use of water. The Water Act is enacted under a framework of catchment specific Water Plans.

Water resources within the Project area are covered by the Water Plan (Fitzroy Basin) 2011 (Queensland Government, 2014) (Water Plan). The Water Plan covers surface waters (zone WQ1301) associated with the Isaac River, and groundwaters (zone WQ1310) of the Fitzroy Basin. Section 7 of the Water Plan defines the groundwater units and groundwater sub-areas, including the Isaac Connors groundwater management area, as follows:

> *(3) The Isaac Connors groundwater management area consists of the following (also each a groundwater unit)—*
>
> *(a) Isaac Connors Groundwater Unit 1, containing the aquifers of the Quaternary alluvium;*
>
> *(b) Isaac Connors Groundwater Unit 2, containing all subartesian aquifers within the Isaac Connors groundwater management area other than the aquifers included in Isaac Connors Groundwater Unit 1.*
>
> *(4) The area of Isaac Connors Groundwater Unit 1 shown on map E in schedule 4 is the Isaac Connors Alluvium groundwater sub-area for this plan.*

Map E, in Schedule 4, is reproduced as Figure 2-1 in this report. Figure 2-1 indicates that the Isaac Connors Alluvium groundwater sub-area is limited to the Isaac River and those parts of its tributaries that are adjacent to the confluence with the Isaac River. The Project area is approximately 15 km to the west of the Isaac River (Figure 2-1) and is well outside the Isaac Connors Groundwater Unit 1. It is assessed by **hydrogeologist.com.au** that the proposed open pit would take groundwater from the Isaac Connors Groundwater Unit 2, that is the sub-artesian aquifers within the Isaac Connors groundwater management area.



LEGEND

- ML700060
- Matilda pit
- Groundwater management area
- Isaac Connors Alluvium Groundwater Sub-Area
- Watercourse
- Major road

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21/06/2022

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Groundwater management areas and units

FIGURE No.
2.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\02_01_4124_Matilda_Vulcan South_Groundwater management area.qgz

2.1.2. Environmental Protection Act 1994

The quality of Queensland waters is protected under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity). The EPP Water and Wetland Biodiversity achieves the objective of the *Environmental Protection Act 1994* (EP Act) to protect Queensland waters whilst supporting ecologically sustainable development. Queensland waters include waters in rivers, streams, wetlands, lakes, aquifers, estuaries and coastal areas.

The Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) is made pursuant to the provisions of the EPP Water and Wetland Biodiversity, which is subordinate legislation under the EP Act. The EPP Water and Wetland Biodiversity provides a framework for identifying environmental values (EVs) for Queensland waters, and deciding the water quality objectives (WQOs) to protect or enhance the EV. The Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) contains EV (Section 2, Table 1) and WQO for waters (including groundwaters) in the Isaac River Sub-basin.

For Isaac River groundwaters, the EVs selected for protection are as follows:

- aquatic ecosystems;
- irrigation;
- farm supply/use;
- stock water;
- primary recreation;
- drinking water; and
- cultural and spiritual.

The water quality guidelines (Department of Environment and Science, 2022) inform the development of water quality guidelines to enhance or protect the 'aquatic ecosystem' EV for Queensland waters, in accordance with the provisions of the EPP Water and Wetland Biodiversity. The guidelines (Department of Environment and Science, 2022) outline protocols for comparing test site water quality against relevant WQO recognised under the EPP Water and Wetland Biodiversity.

Section 2.7 of the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection, 2009) provides guidance on the approach taken to identify EV, water quality indicators and guidelines (as a basis for WQO) in groundwater. Where local EV and WQO have been scheduled under the EPP Water and Wetland Biodiversity for groundwaters, these are the applicable reference source for decision making.

In the absence of scheduled data, the EPP Water and Wetland Biodiversity identifies applicable EV and potential sources for water quality guidelines to inform decision making. The EP Act identifies that groundwater quality is an EV to be protected and therefore the groundwater quality should be maintained within the range of natural quality variations. Natural quality variations should be established through baseline characterisation.

In the absence of scheduled data, the default management intent is that there should be 'no change' to the natural variation in groundwater quality. From the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection, 2009), no change in the natural variation in groundwater quality is deemed to have occurred if there are no detectable changes to the 20th, 50th and 80th percentiles of the natural distribution of values. Where review of local data indicates that some groundwater systems are clearly impacted, then in these cases, the management intent would be to improve quality, and more stringent percentiles may be used to derive guideline values.

Generally, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (AWQG, 2018) should apply to the quality of both surface waters and groundwaters since the EVs which they protect relate to above-ground uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems).

The Department of Regional Development, Manufacturing and Water (DRDMW) Groundwater Database (GWDB) contains groundwater quality data from registered groundwater bores. Where sufficient data exist, water quality guidelines are developed at aquifer/sub-aquifer level based on existing conditions, using groundwater quality data sourced from the DRDMW GWDB or from local monitoring data. Following the definition and mapping of chemistry zones, the groundwater quality data are used to calculate a range of percentiles for available indicators for each chemistry zone.

Where there is potential for groundwater to be impacted by activities such as mining, it is important to acquire localised reference (or baseline) data prior to commencement of the activity. In this situation, the local pre-development data would be used as reference data. Where the groundwater quality is slightly disturbed due to anthropogenic contamination or from naturally occurring groundwater chemistry, the slightly disturbed water guideline applies. Where groundwater is moderately or highly disturbed, more stringent percentiles may be applied as follows:

- high ecological value (HEV) groundwaters guideline: 20/50/80th percentiles of the waters in the sub-aquifer chemistry zones;
- slightly disturbed (SD) groundwaters guideline: 20/40/70th percentiles of the waters in the sub-aquifer chemistry zones; and
- waters potentially impacted by human activities – guideline: no change to the 20/50/80th percentiles of local pre-development data.

2.1.3. Environmental authority

In order to amend an EA, Section 227AA of the EP Act requires that the EA amendment application for the project must be supported by the following specific information on the exercise of underground water rights:

- *a statement describing the proposed exercise of underground water rights and a description of the timing and location of the proposed activities;*
- *a description of each aquifer and the movement of water within each aquifer affected by the proposed activities;*
- *an assessment of the extent of depressurisation in each aquifer due to the proposed activities;*
- *the predicted quantity of associated water taken from each aquifer during the proposed activities;*
- *a description of the impacts of the proposed activities on environmental values;*
- *a description of the effects of the proposed activities on groundwater quality; and*
- *a description of any strategies to manage or mitigate the impacts of the proposed activities.*

2.2. Commonwealth

The EPBC Act is administered by the DoEE and is designed to protect national environmental assets, known as Matters of National Environmental Significance (MNES). Under the 2013 amendment to the EPBC Act, impacts on groundwater resources, in relation to coal seam gas (CSG) development and large coal mining development were included and are known as the 'water trigger'.

A project may be declared a controlled action by the DoEE, with water resources being one of the controlling provisions. The Independent Expert Scientific Committee (IESC) is a statutory body under the EPBC Act that provides scientific advice to the DoEE and relevant state ministers on CSG or large coal mining development proposals. Guidelines have been developed in order to assist the IESC in reviewing these proposals. Whilst the Project is not considered to be a large coal mining development, the IESC information requirements checklist is presented in Table 2-1, with details on where aspects have been addressed and documented within the report.

Table 2-1 IESC information requirements checklist

Information requirements	Section addressed
Description of the proposal	
Provide a regional overview of the proposed project area including a description of the: ▪ *geological basin;* ▪ *coal resource;* ▪ *surface water catchments;* ▪ *groundwater systems;* ▪ *water-dependent assets; and* ▪ *past, present and reasonably foreseeable coal mining and CSG developments.*	Sections 4 and 5
Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies or regulations.	Section 2
Describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Sections 1, 5.8, 6.2, 7
Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 2
Risk assessment	
Identify and assess all potential environmental risks to water resources and water-related assets, and their possible impacts. In selecting a risk assessment approach consideration should be given to the complexity of the project, and the probability and potential consequences of risks.	Section 6
Assess risks following the implementation of any proposed mitigation and management options to determine if these will reduce risks to an acceptable level based on the identified environmental objectives.	Section 7
Incorporate causal mechanisms and pathways identified in the risk assessment in conceptual and numerical modelling. Use the results of these models to update the risk assessment.	Section 6
The risk assessment should include an assessment of: ▪ *all potential cumulative impacts which could affect water resources and water-related assets; and* ▪ *mitigation and management options which the proponent could implement to reduce these impacts.*	Sections 6 and 7
Groundwater – Context and Conceptualisation	
Describe and map geology at an appropriate level of horizontal and vertical resolution including: ▪ *definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections and any relevant field data.* ▪ *geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.*	Section 4
Define and describe or characterise significant geological structures (e.g., faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge. ▪ *Site-specific studies (e.g., geophysical, coring / wireline logging etc.) should give consideration to characterising and detailing the local stress regime and fault structure (e.g., damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays).* ▪ *Discussion on how this fits into the fault's potential influence on regional-scale groundwater conditions should also be included.*	Sections 4 and 5
Provide site-specific values for hydraulic parameters (e.g., vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	Sections 5, 5.3
Provide time series level and water quality data representative of seasonal and climatic cycles	Sections 5.2, 5.4 and 5.7

Information requirements	Section addressed
Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	Section 5.4
Provide hydrochemical (e.g., acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g., stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	Section 5.7
Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	Section 5.4
Assess the frequency (and time lags if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	Sections 5.4 and 5.5
Groundwater – Analytical and Numerical Modelling	
Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g., expert opinion, analogue sites) employed in addition to modelling.	Section 6.1
Undertake groundwater modelling in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), including independent peer review.	Section 6.1
Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g., use baseflow calibration targets where predicting changes to baseflow).	Section 6.1.3
Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	Section 6.1
Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	Sections 5.4 and 6
Describe the various stages of the proposed project (construction, operation and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	Sections 1 and 6.1.2
Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	Section 6.2.1
Undertake model verification with past and/or existing site monitoring data.	Section 6.1
Provide an explanation of the model conceptualisation of the hydrogeological system or systems, including multiple conceptual models if appropriate. Key assumptions and model limitations and any consequences should also be described.	Section 5.8
Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	Section 6.1
Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters [in press]).	Section 6.2.4
Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	Section 6.2.4
Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters [in press]).	N/A
Provide a program for review and update of models as more data and information become available, including reporting requirements. Section 8.2	Section 7
Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	Section 6.2.3
Groundwater – Impacts to Water Resources and Water-dependent Assets	
Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: ▪ *any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, interaquifer connectivity and connectivity with sea water.*	Section 6

Information requirements	Section addressed
▪ *the effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance.* ▪ *the potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units.* ▪ *the possible fracturing of and other damage to confining layers.* ▪ *for each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the proposed project, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.*	
Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	Sections 4, 5, 5.6.2, 6
For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	Section 6
Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g., water planning rules) for the groundwater basin(s) within which the development proposal is based.	Sections 2 and 5.7.2
Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Section 6.7
Describe proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	Section 7
Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 7
Groundwater – Data and Monitoring	
Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	Section 5
Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	Sections 5 and 7
Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs, the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	Section 7
Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Section 5.7
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g., QLD Government 2013).	Section 5.7
Cumulative Impacts – Context and Conceptualisation	
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 6.7
Consider all past, present and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	Section 6.7
Cumulative Impacts – Impact	
Provide an assessment of the condition of affected water resources which includes: ▪ *identification of all water resources likely to be cumulatively impacted by the proposed development;* ▪ *a description of the current condition and quality of water resources and information on condition trends;* ▪ *identification of ecological characteristics, processes, conditions, trends and values of water resources;* ▪ *adequate water and salt balances; and,*	Section 6.7

Information requirements	Section addressed
▪ *identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g., altered water quality, drawdown).*	
Assess the cumulative impacts to water resources considering: ▪ *the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally;* ▪ *all stages of the development, including exploration, operations and post closure/decommissioning;* ▪ *appropriately robust, repeatable and transparent methods;* ▪ *the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts; and,* ▪ *opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.*	Section 6.7
Cumulative Impacts – Mitigation, Monitoring and Management	
Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g., case studies) should be provided.	Section 7
Identify cumulative impact environmental objectives.	Section 7
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	Section 7
Describe appropriate reporting mechanisms.	Section 7
Propose adaptive management measures and management responses.	Section 7

3. Baseline conditions

3.1. Climate

Bureau of Meteorology (2016) classifies the area around the VCM as subtropical, with mostly hot dry summers and mild winters. In terms of rainfall, the area is classified as summer rainfall dominant with annual rainfall generally between 550 mm and 650 mm, and the majority of the rain falling between November and March. Table 3-1 (and Figure 3-1) summarises the local climatic data obtained from SILO point climate data (Queensland Government, 2020) for the VCM (latitude -22.35°, longitude 148.20°, time period January 1889 to January 2020), showing the long term rainfall and evaporation averages.

The average monthly rainfall varies between 16 mm/month in autumn or winter to 109 mm/month in summer. The average annual rainfall is 590 mm, and when comparing precipitation with evaporation (estimated Actual Aerial Evapotranspiration – AAET (Chiew *et al.*, 2002)), average evaporation exceeds average precipitation for all months of the year, potentially leading to groundwater recharge deficit.

Table 3-1 Average monthly precipitation and evaporation

Month	Mean monthly precipitation (mm)	Mean monthly evaporation (mm)
Jan	109.33	137.43
Feb	99.57	120.71
Mar	65.18	118.57
Apr	31.06	86.62
May	27.98	57.23
Jun	31.23	39.59
Jul	22.05	43.74
Aug	20.14	64.72
Sep	16.77	85.54
Oct	31.47	109.47
Nov	50.28	120.87
Dec	85.35	136.32
Σ	590.41	1120.80
min	16.77	39.59
max	109.33	137.43

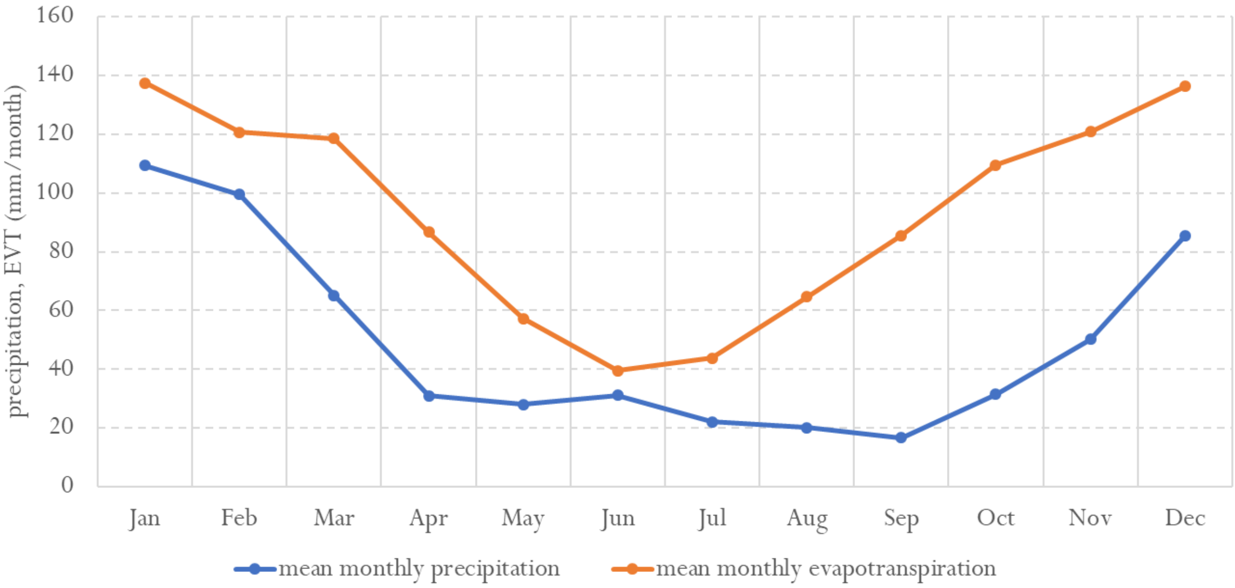


Figure 3-1 Average monthly precipitation and evaporation

One of the indicators describing long-term precipitation trend is a 'cumulative rainfall departure' – CRD (Xu & Tonder, 2001). The CRD indicates 'drier' periods (periods of lower than average rainfall) by downwards direction of the indicator line. Conversely, 'wetter' periods (periods of higher than average rainfall) are indicated by upward direction of the indicator line. The CRD calculation was based on the monthly averages calculated over the full time period of available data (131 years – see Table 3-1).

The trends represented by CRD analysis (Figure 3-2) show long-lasting dryer than average conditions between 1918-1940, 1960-71 and 2001-2007 and above average rainfall between 1953-1960, 1973-1979, 2007-2011. Periods of approximately average rainfall can be observed between 1941 and 1944, 1970 and 1973, 1982 and 1988, and 2011– 2017. The area around the VCM has recently (beginning of 2018 till end of 2019) gone through a lower-than-average precipitation period.

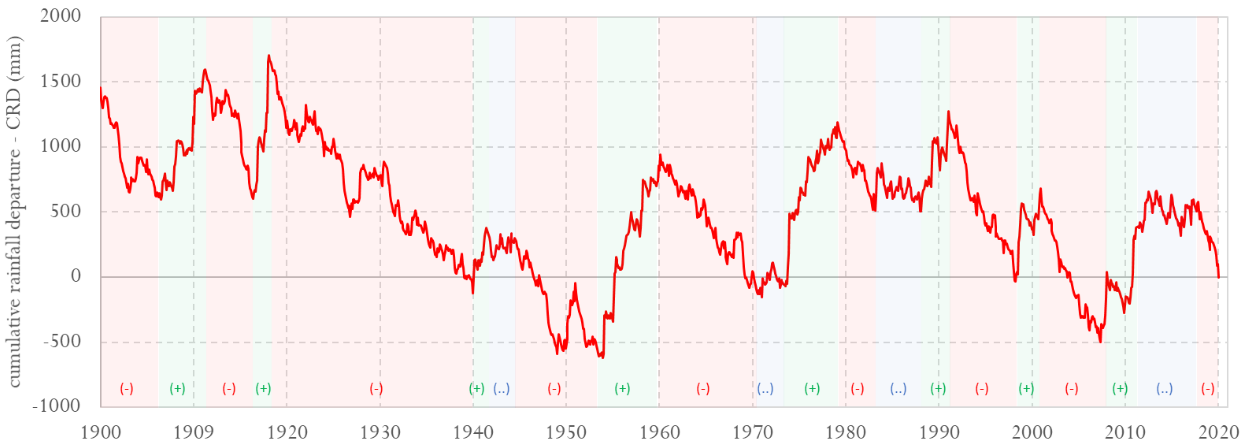


Figure 3-2 Precipitation trend – cumulative rainfall departure (CRD)

3.2. Topography and drainage

The Project area slopes from the Harrow Range in the west to the Isaac River east of the Project area (Figure 3-3). Surface elevations reach approximately 500 mAHD approximately 25 km to the west of the Project area. The surface elevation within the Project area is generally between 280 mAHD and 225 mAHD.

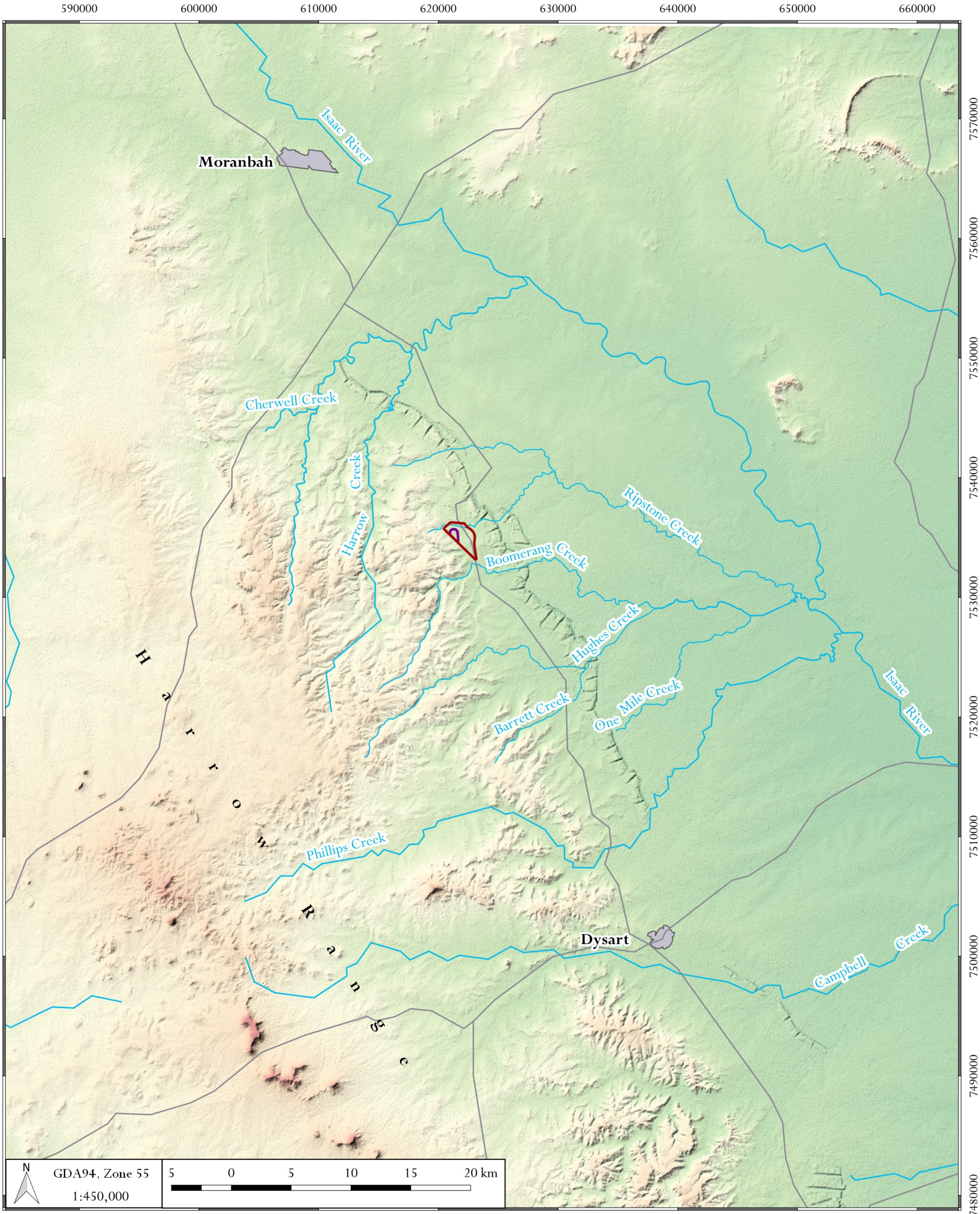
The Project area is surrounded by a number of ephemeral catchments (Figure 3-3) which drain from the west to the east, including the following creeks:

- Harrow Creek;
- Boomerang Creek;
- Hughes Creek;
- Barrett Creek;
- Phillips Creek; and
- Campbell Creek.

A tributary of Ripstone Creek flows through the Project area to the east, extending through the neighbouring Saraji Mine.

A number of surface water diversions have been constructed in association with the existing coal mines to the east of the Project area. These include diversions on Ripstone Creek, Harrow Creek, Boomerang Creek and Hughes Creek. These diversions are all located downstream of the Project area and have been constructed by BHP. Surface water flow data captured and maintained by BHP indicates these creeks are all ephemeral.

The ephemeral creeks surrounding the Project area have limited flow, and typically only discharge after heavy rainfall events. The largest local surface water catchment near the Project area is Phillips Creek (20 kms to the south of the Project area), which flows into the Isaac River. The confluence of these two surface water systems is located approximately 25 km to the east of the Project area.



LEGEND

- ML700060
- Matilda pit
- Watercourse
- Major road

Elevation (mAHD)

120	240	360	480	600	720
160	280	400	520	640	760
200	320	440	560	680	

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Topography and drainage

FIGURE No.
3.3

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
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Whilst Hughes Creek and Boomerang Creek are much closer to the proposed pit, Phillips Creek is the only watercourse with publicly available stream flow data. Figure 3-4 and Figure 3-5 are from the DRDMW Water Monitoring Information Portal (WMIP) (https://water-monitoring.information.qld.gov.au/), visited on 14 June 2022. Figure 3-4 shows discharge and water level data for the historic gauging station (130409A) on Phillips Creek at Tayglen. Figure 3-4 shows that flows within Phillips Creek are ephemeral, with short-duration flows generally occurring over the summer months. Based on daily flow data between 1968 and 1988, Figure 3-5 shows that Phillips Creek flows less than 25 percent of the time, with less than 10% probability of flows exceeding 0.1 m^3/s (8.64 ML/day) and less than 2% probability of flows exceeding 10 m^3/s (864 ML/day).

The reader is directed to the Vulcan Coal Mine – Surface Water Impact Assessment report for further information analysis and impact assessment regarding surface water systems in the Project area.

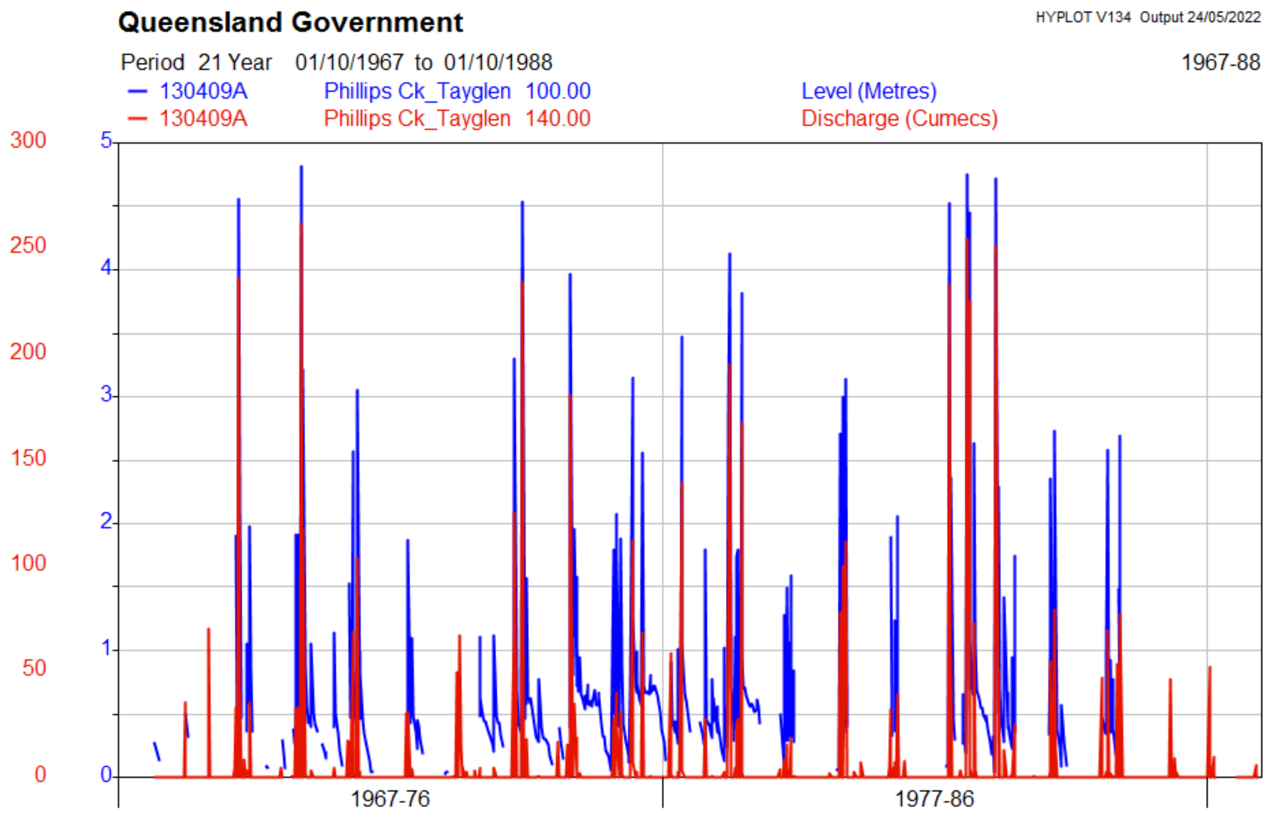


Figure 3-4 Discharge and water level, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal)

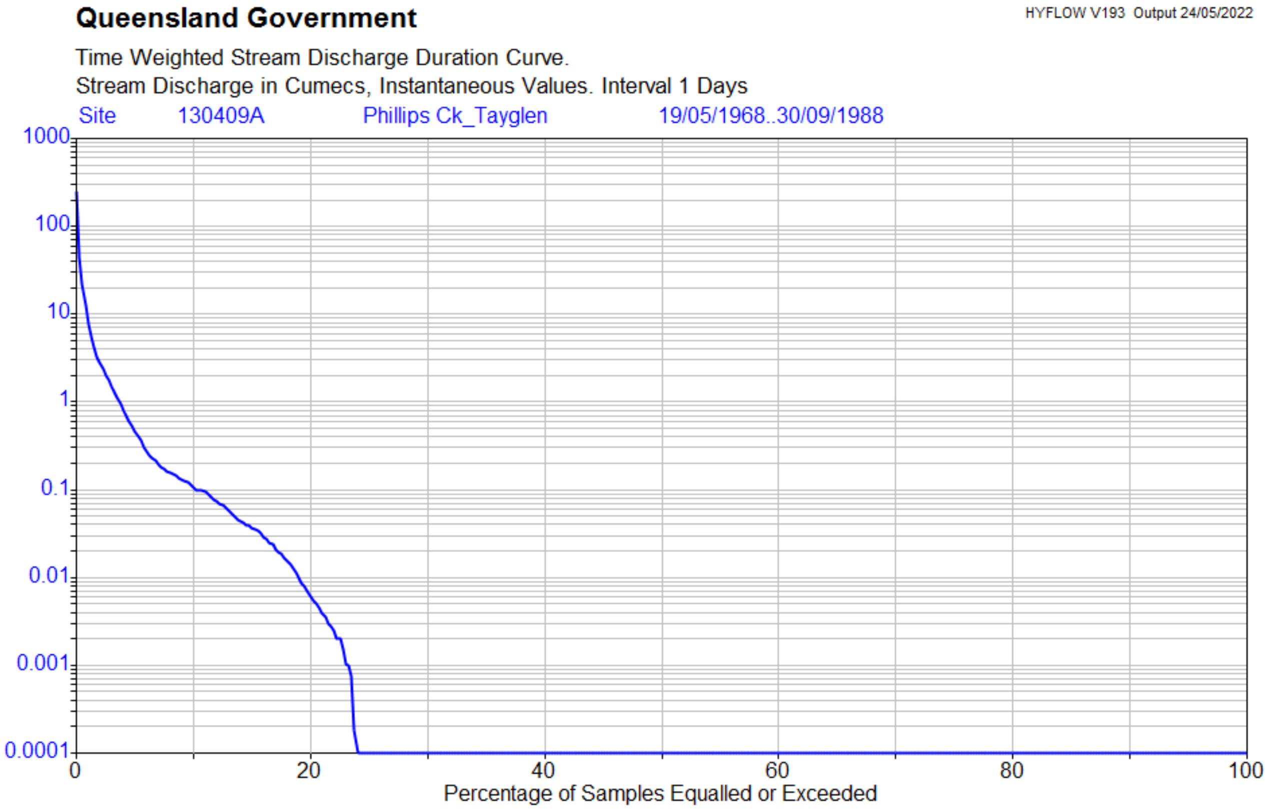


Figure 3-5 Daily flow duration, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal)

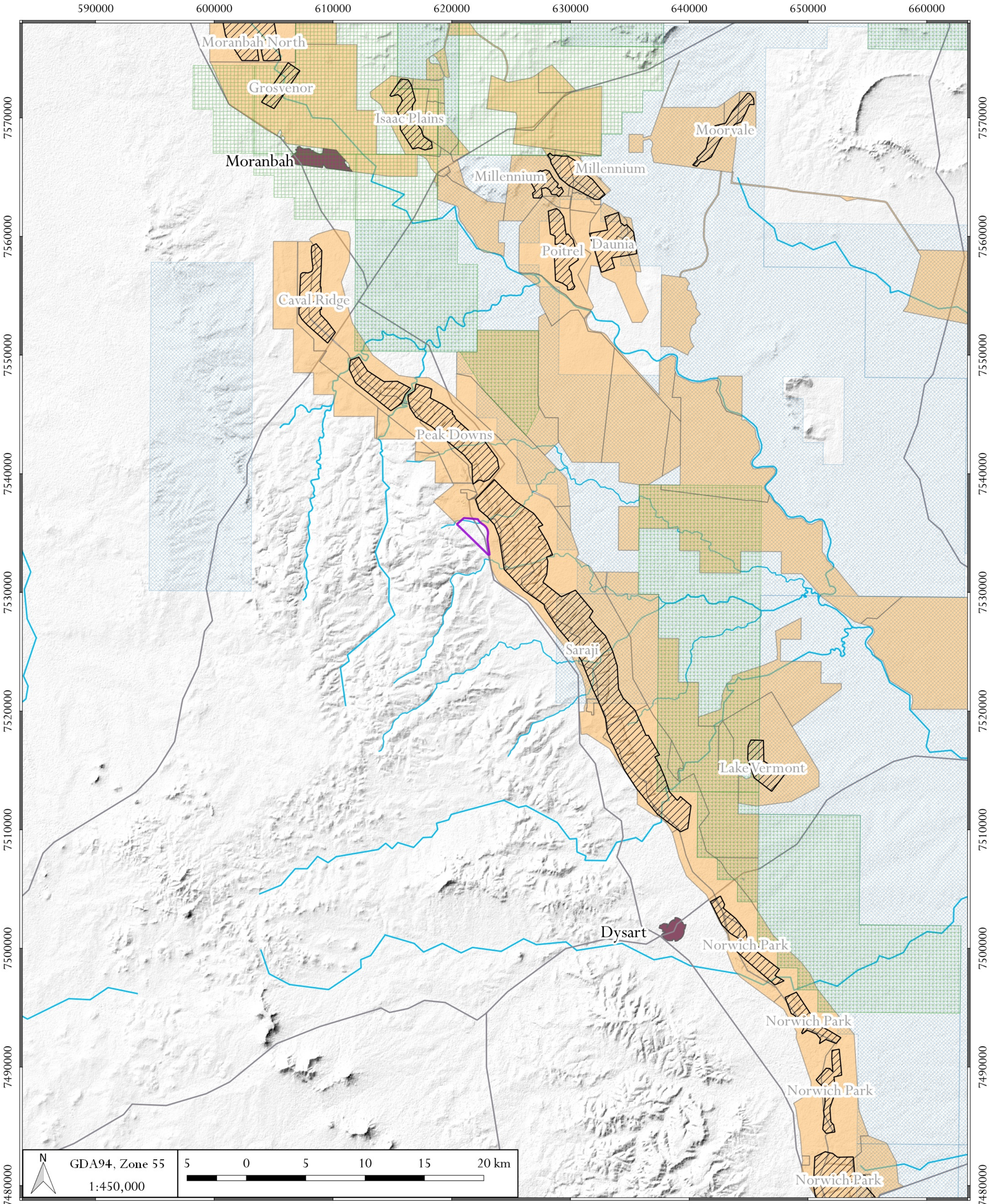
3.3. Land use

Land use is dominated by coal exploration and mining, beef cattle grazing, and CSG exploration and operations.

The individual coal mines in close proximity to the Project area are the proponents VCM, BHP Saraji Mine and BHP Peak Downs Mine (Figure 3-6). Caval Ridge Mine is located to the north of Peak Downs Mine and Norwich Park Mine is located to the south of Saraji Mine. These series of coal mines are owned by BHP, however Norwich Park Mine is currently in care and maintenance.

Peak Downs Mine and Saraji Mine commenced coal production in the early 1970s with mining covering an area some 50 km in length and 2 km to 5 km in width. The mines generally follow the strike of the coal seams within the Moranbah Coal Measures and the mines extract coal seams that are stratigraphically higher in the Moranbah Coal Measures than the coal seams to be mined as part of the Project.

Lake Vermont Mine is located to the south-east of Saraji Mine and is owned by the Jellinbah Group. Lake Vermont currently has a production capacity of 8 Mtpa and was last expanded in 2012/2013.



LEGEND

- Mining lease
- Established mining operation
- ML 700060
- Exploration permits for petroleum
- Petroleum leases
- Watercourse
- Major road

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Mining tenure

FIGURE No.
3.6

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

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4. Geology

The Project is located on the western limb of the northern Bowen Basin, in a northerly plunging syncline, and at the southern end of the Collinsville Shelf (AECOM, 2016). The target coal seams are subcropping in a north-west to south-east direction, dipping to the north-east.

Regional cross-section D-D' of URS (2012) extends near the Project area and is reproduced as Figure 4-1. The section extends from the west/south-west to the east/north-east. The Project area would plot between ~140,000 m and ~142,000 m, characterised by sub-cropping Moranbah Coal Measures beneath the surficial sediments. Beneath the Moranbah Coal Measures, the Back Creek Group forms the Permian basement and extensively outcrops to the west of the site. The Triassic units (notably the Rewan Group) are absent locally and occur further to the east. The local surface geology is shown in Figure 4-2.

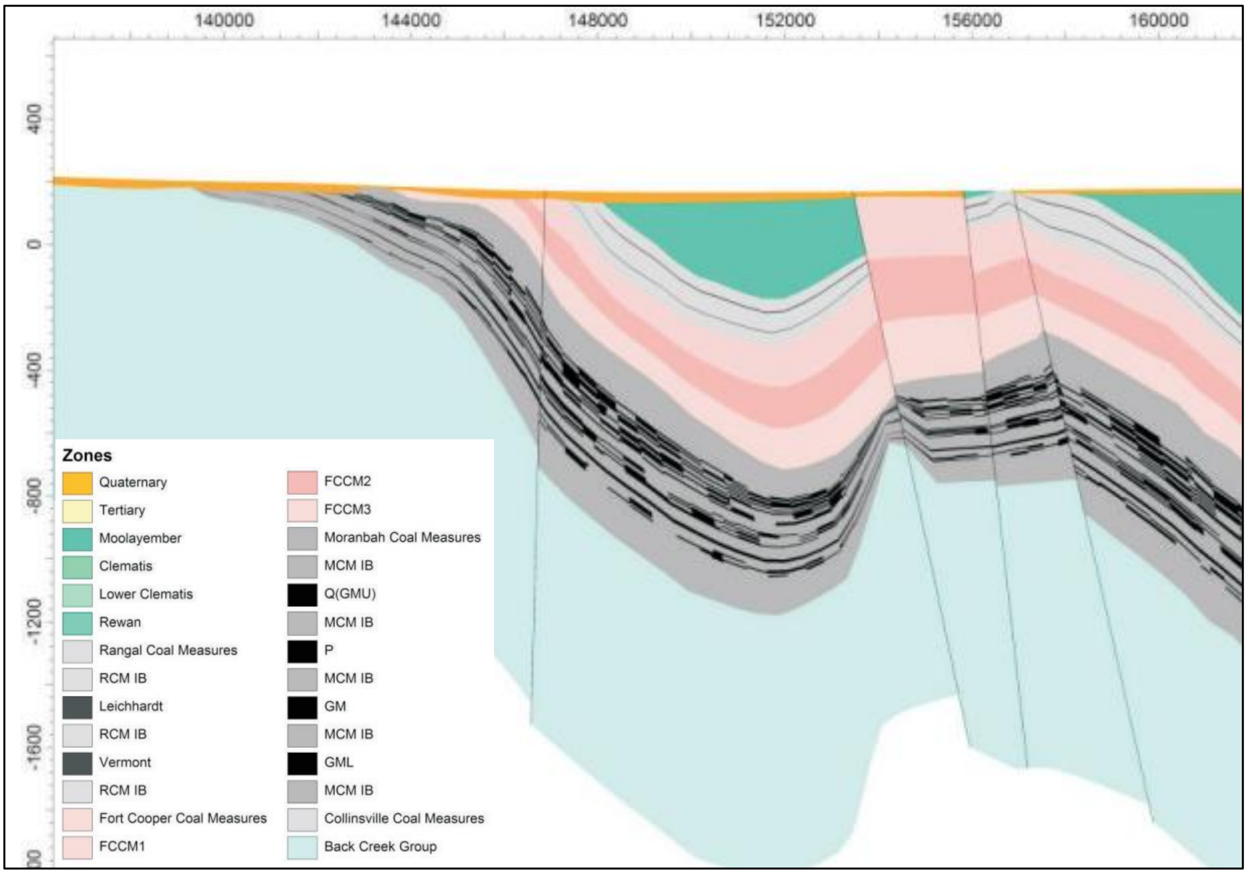
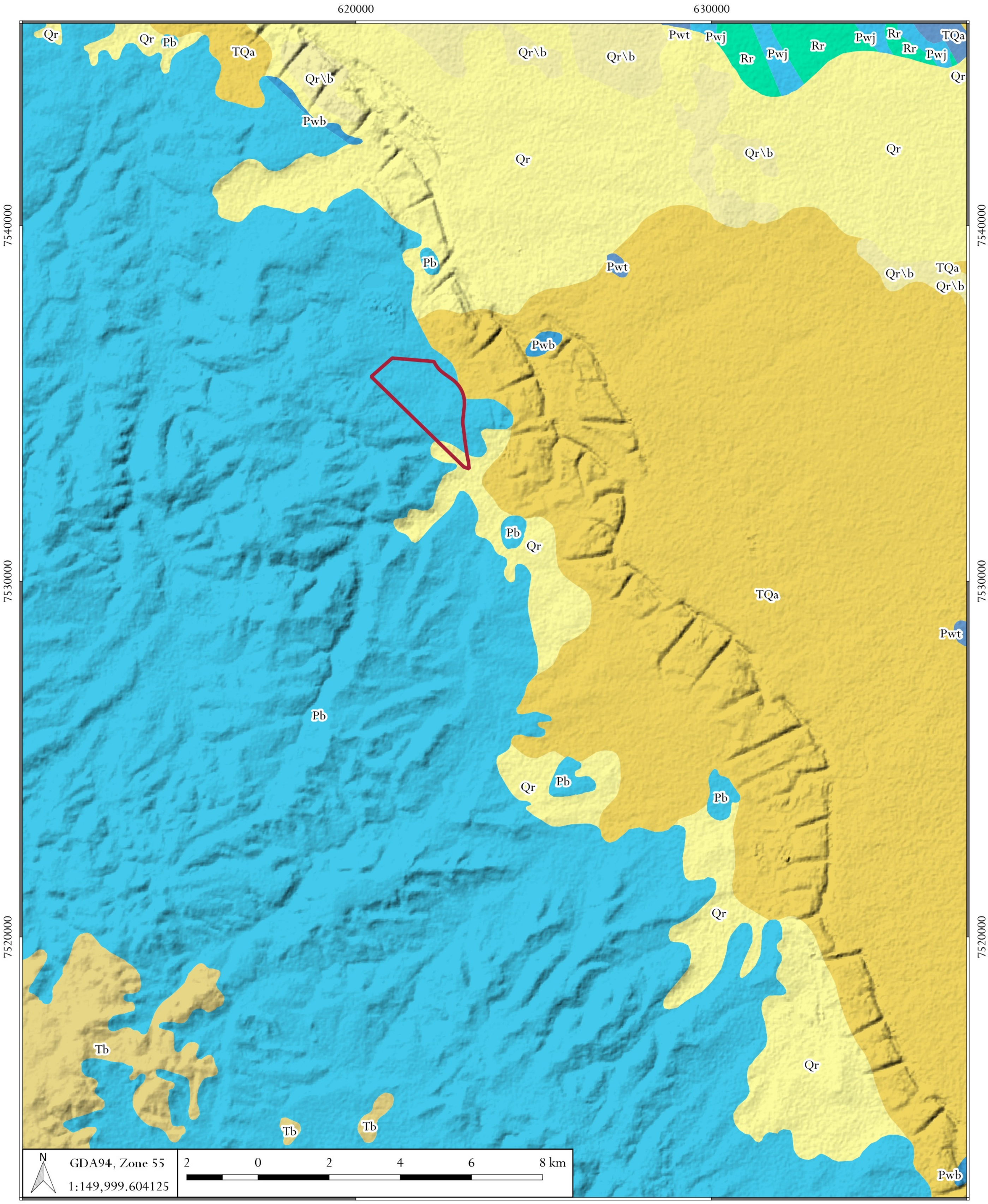


Figure 4-1 Cross-section D-D' from URS (2012)



LEGEND

Geology - surface

ML 700060	Pb - Back Creek Group	Qr\b - Colluvium	Rr - Rewan Group
	Pwt - Fort Cooper Coal Measures	Qr - Colluvium	Tb - Basalt
	Pwb - Moranbah Coal Measures	Pwj - Rangal Coal Measures	TQa - Alluvium

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Local surface geology

FIGURE No.
4.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\04_04_4124_Matilda_Vulcan South_Local surface geology.qgz

4.1. Quaternary sediments

Quaternary sediments are mapped within the Project area as sporadically exposed colluvial and residual deposits comprising clay, silt, sand and gravel soils. The closest mapped Quaternary alluvium is in excess of 10 kms to the north and south, there is no mapped Quaternary alluvium within the Project area.

4.2. Tertiary sediments

The Tertiary sediments are mapped as present to the east of the Project area. AECOM (2016) describe the Tertiary aged sediments as heterogeneously distributed lensoidal sand deposits separated by a low permeability clay-rich matrix. Lithologically, the Tertiary sediments comprise unconsolidated to consolidated fluvial sediments which include clay, silty clay, sandy clay, clayey sand, sand and gravel with clay predominant (AECOM, 2016). Weathering of the Tertiary sediments is evident (AGE, 2011) (quoted in AECOM, 2016) and the lithologies can vary from heavily leached, mottled white and maroon soils to sandy soils. The Tertiary sediments are defined by an unconformable boundary with the underlying Permian coal measures which characterises the Permian topography prior to deposition of the Tertiary sediments (AECOM, 2016).

Typically, the Tertiary sediments are less than 3 m in thickness. This is confirmed by the lithology of drill hole VSW020_C2 located in the south of the Project area (RGS, 2020). The lithology also confirms the base of weathering and the top of ALEX Seam at approximately 7 m and 8 m depth, respectively.

Furthermore, **hydrogeologist.com.au** has drilled and constructed several groundwater monitoring bores within the Project area. The term "*weathered Permian*" is used to describe the lithology intersected above the fresh Permian coal measures. It is assessed that within the Project area, the lithology intersected above the fresh Permian coal measures does not constitute Tertiary-aged sediments, rather a weathering profile that developed during the Tertiary on the Permian strata. There was no evidence of an unconformable horizon in the drill hole observations and the material intersected, graded from highly weathered, generally clay bound material at the surface to the unweathered Permian coal measures that typically occurred between 1 m to 20 m below ground level. This geological interpretation is currently supported by the exposure of geology in the VCM.

4.3. Permian coal measures

4.3.1. Blackwater Group

Coal seams within the Permian coal measures of the Blackwater Group form the main economic resource of the numerous mines in the region. In increasing depth (age) order, the major coal measures of the Blackwater Group include the:

- Rangal Coal Measures;
- Fort Cooper Coal Measures; and
- Moranbah Coal Measures.

The VCM currently mines the ALEX and Dysart Lower-Lower (DLL) coal seam of the Moranbah Coal Measures. Outcropping at surface to the west of the Project is the basal section of the Moranbah Coal Measures, locally mapped by Vitrinite as a sequence of sandstones and siltstones. This sequence is capped in a resistant, quartzose medium to coarse grained sandstone, locally referred to as the Mesa Sandstone due to the characteristic mesa plateaus that have formed in the region. The base unit of the Moranbah Coal Measures is locally referred to as the Mesa Siltstone (Tom O'Malley Vitrinite, per.comm., 2019).

The ALEX coal seam is about 1 m thick of high quality and low ash content, overlying the Mesa Sandstone. The DLL consists of a 2.5 m thick seam with four plies; and a separate basal ply, with high ash and good quality coal. An additional 1 m thick coal seam makes the entire sequence to be mined approximately 3.5 m thick. The regional sediments dip approximately eastward at about 4° in the Project area (Tom O'Malley Vitrinite, per.comm., 2019).

East of the Project area, at the Saraji Mine, the Permian coal measures are generally undisturbed and have a gentle regional dip of 2° to 5° towards the east (AECOM, 2016). Minor faults are mapped within the existing Saraji Mine which locally steepen the coal seams to approximately 9° to 10°. The Saraji South Fault is located south of the Saraji Mine, near Phillips Creek. The Saraji South Fault is a high angle, north north-west trending normal fault, with throws mapped between 10 m and 50 m (AGE, 2011 in AECOM, (2016)). The Downs Creek Fault is a north north-west trending normal fault with a maximum throw of 60 m and is located south of the Project area, near Lotus Creek Road.

At Saraji Mine, the Permian coal measures comprise overburden of sandstone, siltstone, claystone, mudstone, coal, coal parting materials and sub-coal (underburden) strata. The Moranbah Coal Measures include the Dysart series, Harrow Creek group, P, Q and R coal seams. Of these, the Harrow Creek Upper (H16) and Dysart Lower (D24 and D14) coal seams are mined at Saraji Mine (AECOM, 2016). The H16 seam is the uppermost of the two targeted coal seams and sub-crops to the west of the Saraji Mine with an easterly dip.

Near the Caval Ridge Mine, the Permian coal measures generally dip from west to east, at between 3° and 6°. The sequence within the northern extension of the Peak Downs Mine (located to the south of the Caval Ridge Mine and to the north of Saraji Mine) shows considerable deformation with strata dipping to 30° and along strike flexures in excess of 10°. Faulting and seam splitting is common, producing local steepening of the coal seams (over 10°). Minor faulting occurs in the seams in the Caval Ridge Mine area. Vertical displacement along faults ranges from less than 1 m to 36 m along the regional Harrow Creek Fault in the Peak Downs Mine (URS, 2009). Near the Olive Downs Coal Project, the coal measures dip around 7° to the east, which steepens in the south to 15° (HydroSimulations, 2018).

4.3.2. Back Creek Group

The Back Creek Group outcrops to the west of, and in the western portion of the Project area (Figure 4-2). The Exmoor and Blenheim Formations of the Back Creek Group are interpreted to be conformably underlying the Moranbah Coal Measures. The top of the Exmoor Formation is characterised by prominent coarse-grained siliceous boulder sandstone in outcrop, whilst the top of the Blenheim Formation is easily identifiable by the stratigraphic marker of the fossiliferous and worm burrowed sandstone, locally termed the Worm Burrow Sandstone.

Coal seams within the Back Creek Group (not currently targeted by the Project) include the May (MAY) coal seam that has been interpreted to be within the Dingo Siltstone of the Exmoor Formation, and the Matilda (MAT) coal seam within the MAT Siltstone of the Blenheim Formation. The MAT coal seam is the target of the Matilda pit and associated EA amendment.

5. Hydrogeology

An aquifer is generally defined as a geological unit that can transmit and store significant quantities of groundwater. Within the region, Tertiary sediments and Permian coal measures yield low volumes of groundwater and hence they would not typically be classified as aquifers in most hydrogeological settings. In reality, they would be called either poor aquifers or aquitards. However, there may be individual lithological units within these formations that have higher hydraulic conductivities than the intervening units, and as groundwater in these formations are to be assessed for the determination of impact, they are referred to as aquifers for the purposes of this report. This approach is consistent with URS (2009), URS (2012), AECOM (2016) and HydroSimulations (2018).

5.1. Hydrostratigraphy

Within the project area, the groundwater generally occurs in three hydrostratigraphic units, as outlined below and shown in Table 5-1:

- the Tertiary sediments/regolith;
- the Moranbah Coal Measures; and
- the underlying Back Creek Group.

Table 5-1 Local hydrostratigraphic units

Age	Stratigraphic unit	Lithology	Aquifer type
Tertiary	Unconsolidated, semi-consolidated sediments; weathered profile	Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	Unconfined, poor aquifer, aquitard
Late Permian	Moranbah Coal Measures	Coal, sandstone, siltstone, mudstone, carbonaceous mudstone	Confined aquifer (coal) and confining unit (interburden)
Middle Permian	Back Creek Group	Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Confined aquifer (coal) and confining unit (interburden)

The following sections define the hydrogeology of the various hydro-stratigraphic units for the Project and further discuss groundwater flow, quality and the hydraulic characteristics.

5.1.1. Tertiary sediments

The term Tertiary sediments refers to a mix of specific Tertiary aged sediments and the weathered zone or regolith material that has formed on top the Permian coal measures. As described in Section 4.2, the Tertiary sediments are sporadically distributed and consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays) with limited thicknesses. Together with the underlying weathering zone of the Permian coal measures, Tertiary sediments are not of significance in groundwater flow within the Project area.

In terms of aquifer material, the silts and clays are densely compacted, hard and generally dry. Potential for groundwater, however, exists within sandy and gravely sections, and represents an unconfined to confined aquifer depending on location. Most of the clean sand and gravel lenses are permeable but are of limited lateral and vertical extent (URS, 2009).

Historically, mining issues associated with Tertiary sediment derived groundwater at the Peak Downs Mine appear limited to pit wall instability rather than ongoing problems with groundwater inflow. This generally indicates low hydraulic conductivity and limited lateral extent of the more permeable areas (URS, 2009). It was assessed by **hydrogeologist.com.au** (2019) that the lithology intersected above the fresh Permian coal measures in the Project area did not constitute Tertiary aged sediments, rather a weathering profile that had developed during the Tertiary period on the Permian strata. Within the monitoring bores drilled for the Project, the depth of weathering typically occurred between 1 m to 20 m below ground level and the weathered profile was generally unsaturated. Current observations indicate that the Tertiary sediments in the Project area are generally unsaturated.

5.1.2. Moranbah Coal Measures

Throughout the Bowen Basin, the coal seams are considered to be poor aquifers within the Permian coal measures, and the adjacent overburden and interburden sediments are generally considered as aquitards. URS (2009) noted, in the context of overall low yields and therefore low hydraulic conductivity, that historical mining issues with groundwater in the Permian coal measures at Peak Downs Mine were limited to pit wall instability rather than ongoing problems with groundwater inflow, indicating the generally low hydraulic conductivities of the Permian coal measures on site.

The coal seams generally are considered dual-porosity strata where primary-porosity is provided by the matrix and a secondary porosity is the result of the presence of fractures (joints and cleats). Natural cleats within the coal seams are likely the dominant space for groundwater storage; the main pathway for groundwater movement is dependent on fracture interconnectivity (URS, (2009) and AECOM, (2016)). The coal seam aquifers are generally confined above and below by the low permeability interburden and overburden (AECOM, 2016).

The non-coal-bearing interburden and overburden units comprise low permeability claystone, mudstone, sandstone, siltstone and shale. They can, however, provide localised supplies of variable, generally low yielding and poor quality groundwater (AECOM, 2016). The interburden and overburden units in several mines in the northern Bowen Basin (e.g. Broadlea Coal Mine, Burton Mine and Ellensfield Coal Mine) have been described as essentially impervious to groundwater movement (AGE, 2007 in AECOM, 2016).

Within the Project area, the coal seams of the Permian coal measures (including the targeted ALEX and DLL coal seams of the Moranbah Coal Measures), are regarded as confined, poor aquifers and the interburden (including over- and under-burden) as aquitards. The Permian coal measures within the VCM are partially unsaturated.

5.1.3. Back Creek Group

The Back Creek Group comprises sandstone, siltstone, shale and minor coal; and is considered a semi-pervious lower boundary for groundwater flow to the overlying Blackwater Group (URS, 2012). The Back Creek Group is normally considered as the base layer for numerical models (the base of a model, by definition is impervious). The Exmoor Formation of the Back Creek Group is locally mapped by Vitrinite as the Dingo Sandstone, Dingo Siltstone and Wallaby Hill Sandstone (from top down) but contains recognised and laterally extensive coal seams (MAY and MAT seams) that, together with the sandstones, can potentially form poor aquifers similar to those interpreted in the Blackwater Group. The non-coal-bearing interburden and overburden units of the Back Creek Group are assessed to be aquitards. As discussed above, the Permian coal measures (which includes the Back Creek Group) within the VCM are partially unsaturated.

5.2. Groundwater monitoring network

A total of fifteen active groundwater monitoring bores have been constructed over the wider Vitrinite mining tenements, with twelve bores drilled in June 2019 and three drilled in 2022. Among them, seven active monitoring bores have been installed in the vicinity of the VCM area; the monitoring bore MB13 was drilled in early 2021, MB14 was drilled to replace MB04, and MB15 and MB16 drilled down hydraulic gradient from two VCM mine water storages.

Table 5-2 summarises the location, target unit and construction details for each VCM monitoring bore which forms the VCM groundwater monitoring network. Monitoring bores from the wider Vitrinite mining tenement (termed 'regional' bores) are also summarised in Table 5-2. The monitoring bores are shown in Figure 5-1 along with the registered groundwater bores associated with the DRDMW GWDB. MB06 and MB10 are nested monitoring bores drilled on the same site.

Table 5-2 VCM and regional monitoring bores

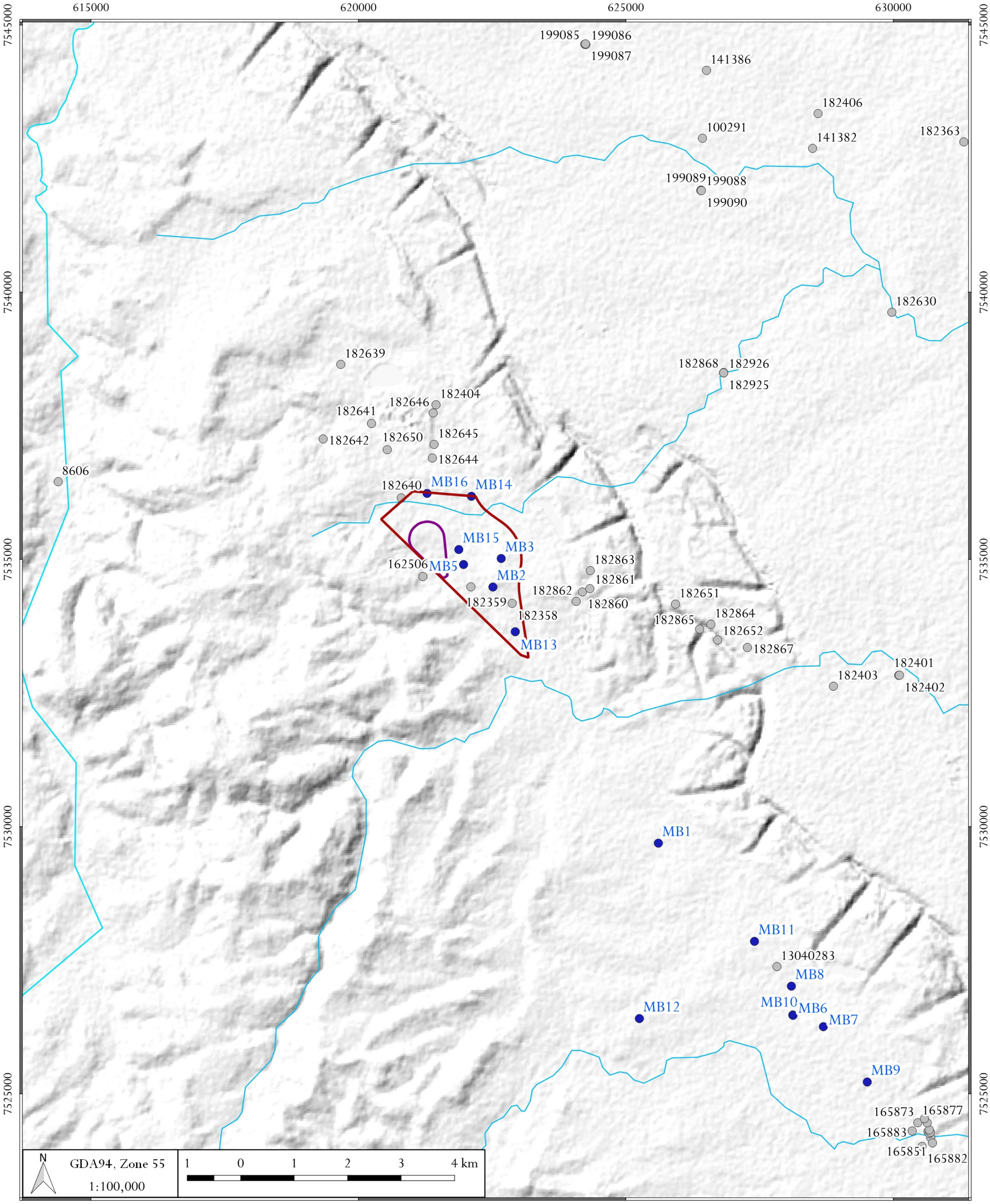
ID	Area	Easting	Northing	Target unit	Casing height (maGL)	Hole depth (mbGL)	Screen interval (mbGL)	Airlift yield (L/min)	Casing elevation (mAHD)
MB01	Regional	625606	7529691	DLL coal seam	0.70	24.9	21.9 – 24.9	Dry	222.91
MB02	VCM	622513	7534483	DLL coal seam	0.71	12.0	9.0 – 12.0	Dry	254.69
MB03	VCM	622668	7535017	DLL coal seam	0.70	33.8	30.8 – 33.8	<0.1	257.68
MB05	VCM	621964	7534905	MAT coal seam	0.77	40.9	37.9 – 40.9	0.5	252.70
MB06	Regional	628119	7526476	Weathered Permian	0.70	24.6	21.6 – 24.6	Dry	214.61
MB07	Regional	628691	7526258	Weathered Permian	0.67	43.0	40.0 – 43.0	0.1	215.99
MB08	Regional	628092	7527015	Weathered Permian	0.70	24.0	21.0 – 24.0	Dry	212.24
MB09	Regional	629511	7525222	DLL coal seam	0.65	34.4	31.4 – 34.4	0.1	208.98
MB10	Regional	628123	7526469	DLL coal seam	0.70	40.3	37.3 – 40.3	<0.1	214.60
MB11	Regional	627403	7527854	DLL coal seam	0.70	29.9	26.9 – 29.9	Dry	225.66
MB12	Regional	625251	7526409	Back Creek Group	0.66	38.2	32.2 – 38.2	1	241.43
MB13	VCM	622931	7533648	MAT coal seam	0.63	36.92	33.5 – 36.5	-	223.13
MB14	VCM	622111	7536181	DLL coal seam	TBA	29.5	23.5 – 29.5	-	242.38
MB15	VCM	621875	7535185	Permian interburden	TBA	10	7 - 10	-	251.55
MB16	VCM	621282	7536235	Permian interburden	TBA	10	7 - 10	-	248.36

Notes: *Easting and northing coordinates are in GDA94, Zone 55*

maGL – metres above ground level

mbGL – metres below ground level

The DLL coal seam (Dysart Lower Lower) is in the Mesa Siltstone (Lower Moranbah Coal measures); the MAT seam is in the Dingo Siltstone of the Exmoor Formation (Back Creek Group).



LEGEND

(red outline)	ML700060	(blue dot)	Monitoring bore
(purple outline)	Matilda pit	(grey dot)	Registered bore

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Groundwater monitoring bore network

FIGURE No.
5.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Based on or contains data provided by the State of Queensland [2019]
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_01_4124_Matilda_Vulcan South_Groundwater monitoring bore network.qgz

5.2.1. Rationale

The groundwater monitoring network was established based on available information relating to the general understanding of groundwater flow conditions (west to east), the coal resource and general geology of the region and the available mining and exploration tenure. The rationale for locating the monitoring bores was to have an upstream and downstream bore plus an understanding of groundwater conditions within the Project area and to the north and south. The groundwater within the Permian coal measures is often brackish to saline which restricts the environmental value of the groundwater (Section 5.7.2) which is typically limited to livestock watering and industrial use.

The VCM monitoring bores were designed to target the Permian coal measures and the Tertiary regolith as there is no mapped Quaternary alluvium within or in close proximity to the Project area. A number of the VCM and regional monitoring bores targeting the Permian coal measures and the Tertiary sediments have been dry since installation.

The target coal seams of the Permian coal measures (Section 4.3) generally strike in a north north-west to south south-east orientation and dip to the east. This local orientation of geology spatially constrains the groundwater monitoring network to the west of the VCM (Figure 5-1). As a result, monitoring bore MB05 has been constructed within the MAT seam of the Back Creek Group (see Section 4.3 and Section 5.1.2). The Back Creek Group underlies the Moranbah Coal Measures. The general groundwater flow conditions are from west to east and a suitable upstream monitoring site in the target coal seam(s) was not able to be practically established. However, it is assessed that MB05 will be able to provide an appropriate site for the monitoring of drawdown that may propagate through the Back Creek Group.

The Project area is adjacent to existing mining leases which are operated by BHP. The establishment of Project specific groundwater monitoring bores on the BHP mining leases to the east is not practical or achievable therefore mining tenure has spatially constrained the groundwater monitoring network to the east of the VCM. Monitoring bores MB02, MB03 and MB14 were all located and designed on existing cleared drill pads (to minimise land and vegetation clearances) to target the DLL coal seam. The three monitoring bores were spatially distributed so far as was reasonably practical to do so to provide an adequate spatial spread of the data.

The regional groundwater monitoring bores are located in association with an additional coal resource to the south of the VCM. The spatial constraints associated with local geology and mining tenure also affected the location of the southern groundwater monitoring bores.

The groundwater monitoring network is considered to be fit for purpose for this assessment. The groundwater monitoring plan (GWMP) is described in Section 5.2.2 below, and the adaptive management strategy for groundwater is described in Section 7.2.

5.2.2. Current monitoring plan

A GWMP has been developed for the VCM that lists monitoring sites, procedures, and monitoring frequencies for the groundwater monitoring network. The GWMP was developed to satisfy conditions within EA0002912. In summary, the EA approval conditions prescribe the GWMP; specifying the locations of monitoring points and sampling frequency (Table 5-3), groundwater hydrochemistry (Table 5-4), and trigger values with respect to groundwater levels and water quality (Table 5-5).

The VCM groundwater monitoring network has been designed around the following considerations:

- An existing monitoring network has been designed to observe water levels, water quality and hydrochemistry to provide baseline information for the VCM (Figure 5-1).
- The groundwater monitoring network and the GWMP is linked to various conditions within the EA (EA0002912) which prescribe the requirements for monitoring locations, frequency and parameters.
- Exceedances of groundwater quality limits and groundwater level triggers as defined in the current EA trigger a mandatory notification and investigation process.
- A GWMP has been developed and is to be updated every two years as required.
- The VCM monitoring network comprises selected bores (MB05 and MB13) from the current monitoring network, two locations based down gradient of mine affected water dams MWD1 and MWD3 (MB15 and MB16), and MB14 in the north-east of ML 700060.

Table 5-3 summarises the current monitoring locations and frequencies as defined in the current EA. Table 5-4 and Table 5-5 summarises the proposed groundwater quality triggers and limits and groundwater level triggers as defined in the current EA.

Table 5-3 Groundwater monitoring location and frequency (Table E1)

Bore	MB05	MB13	MB14	MB15	MB16
Latitude (GDA94)	-22.28721	-22.2985	-22.2757	-22.2848	-22.2752
Longitude (GDA94)	148.1839	148.1934	148.1852	148.1831	148.1772
Aquifer	Back Creek Group	Back Creek Group	Moranbah CM	Moranbah CM	Moranbah CM
Monitored unit	MAT coal seam**	MAT coal seam**	DLL coal seam*	Permian interburden	Permian interburden
Surface RL (mAHD)	252.70	223.13	242.38	251.55	248.36
Depth (mbGL)	40.9	35	38.2	10	10
Monitoring Frequency	Quarterly			Monthly	

*Notes: *DLL = Dysart Lower Lower coal seam*
***MAT = Matilda coal seam*
mbGL = metres below ground level
mAHD = metres above the Australian Height Datum
Surface RL = Reduced Standing Water Level

Table 5-4 Proposed groundwater quality triggers and limits (Table E2)

Parameter	Bores	Limit	Comments
pH (field) (pH units)	All bores	5.5 - 8.0	Broad range to encompass all bores, adapted from data and ANZG (2018)
Electrical Conductivity (field) (µS/cm)	MB05	2,832*	Site specific 95th percentile
	MB13	4,373*	Site specific 95th percentile
	MB14	12,849*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Metals and Metalloids			
Sulphate (mg/L)	MB05	284*	Site specific 95th percentile
	MB13	577	Deep WQO
	MB14	176*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Aluminium (dissolved) (mg/L)	MB05	6.2*	Site specific 95th percentile
	MB13	6*	Site specific 95th percentile
	MB14	4.8*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Arsenic (dissolved) (mg/L)	All bores	0.013	ANZG (2018)
Iron (dissolved) (mg/L)	MB05	2.9*	Site specific 95th percentile
	MB13	2.8*	Site specific 95th percentile
	MB14	288*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Lead (dissolved) (mg/L)	All bores	0.008	ANZG (2018)
Mercury (dissolved) (mg/L)	All bores	0.0006	ANZG (2018)
Molybdenum (dissolved) (mg/L)	MB05, MB14, MB15, MB16	0.034	ANZG (2018)
	MB13	0.06	Site specific 95th percentile
Selenium (dissolved) (mg/L)	All bores	0.005	ANZG (2018) 99th percentile
**TRH C6-C9 (µg/L)	All bores	< 20	LOR
**TRH C10-C36 (µg/L)	All bores	< 50	LOR

Notes: * *Site specific values using 95th percentiles*

** *Total Recoverable Hydrocarbons (TRH)*

Table 5-5 Groundwater level monitoring (Table E3)

Monitoring location	Monitored unit	Pre-mining baseline level (mAHD)	Level threshold (mAHD)
MB05	MAT coal seam	237.13	234.86
MB13	MAT coal seam	202.71	200.44
MB14	DLL coal seam	233.50	232.07
MB15	Permian interburden	246.40	247.08
MB16	Permian interburden	243.97	244.43

Note: [1] 90th percentile predicted maximum cumulative drawdown over the life of the Project beyond any background non-mining related influence, except where specifically identified.

Groundwater level monitoring

The groundwater level monitoring of the groundwater monitoring network was initially carried out monthly, then quarterly thereafter. All monitoring bores were equipped with data loggers or pressure transducers, which automatically collect readings every four to six hours. The use of dataloggers will continue as part of on-going groundwater level monitoring. The manual groundwater level measurements collected at the site are summarised in Table 5-6.

From Table 5-6, it is observed that the groundwater elevations are generally between 230 mAHD and 240 mAHD in the Project area. The depth to groundwater measurements indicates that, except for MB04, the depth to groundwater is between 14 m to 37 m below ground level. Groundwater elevations are generally a subdued reflection of topography, that is deep beneath high land elevation (hills) and shallow beneath low land elevation (valleys). The ground elevation at MB04 is approximately 10 m below the other monitoring bores in the Project area which explains the shallow groundwater observed in this bore.

In some instances (e.g., MB03), the depth to groundwater measurement collected after airlift development was influenced by the drilling and construction process, and in other instances the low permeability of the intersected formation (e.g., MB12). For this reason, the earlier measurements in Table 5-6 may not be representative. Figure 5-2 shows the groundwater elevation hydrographs at the six monitoring bores (note that the hydrographs for MB04 and MB05 overlap) over a 12-month period from June 2019 through to September 2021. Except for the spikes in data observed at MB04, MB05 and MB12, the groundwater elevation hydrographs demonstrate a static system with no or very little (~centimetre magnitude) temporal variations in groundwater level. The notable spikes in data in mid-July, mid-August and mid-September are associated with the groundwater sampling events. The bores with the spikes (MB04, MB05 and MB12) are constructed within low hydraulic conductivity formations and the groundwater is slow to recover following purging.

Table 5-6 Summary of manual groundwater level measurements

Site ID	Casing elevation (mAHD)	Standing Water Level (mAHD)																
		Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Dec 2019	Mar 2020	Jun 2020	Aug 2020	Oct 2020	Dec 2020	Mar 2021	May 2021	Jul 2021	Sep 2021	Dec 2021	Mar 2022
MB1	222.91	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB2	254.69	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB3	257.68	239.38	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB5	252.70	238.17	238.01	237.99	238.23	238.69	238.55	238.10	227.77	235.95	236.62	236.53	236.37	236.72	236.41	236.04	235.81	236.30
MB6	214.61	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB7	215.99	181.19	179.71	179.77	179.79	180.31	180.12	180.40	189.79	179.92	179.87	179.91	179.99	179.91	179.96	180.03		
MB8	212.24	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB9	208.98	181.57	181.34	181.36	181.39	181.81	181.48	182.12	181.88	181.24	180.98	181.29	181.35	181.33	181.32	181.43		
MB10	214.60	182.09	182.15	182.20	182.29	183.04	183.00	183.04	188.10	182.49	182.50	182.55	182.60	182.56	182.61	182.65		
MB11	225.66	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB12	241.43	215.36	216.22	216.41	216.66	218.00	218.39	216.94	215.71	216.55	216.56	216.53	215.85	215.60	215.61	214.85		
MB13	223.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	209.12	208.53	208.49	208.63	208.67	208.63

Notes: *Easting and northing coordinates are in GDA94, Zone 55 from differential GPS*

SWL – standing water level

mAHD – metres above Australian Height Datum from differential GPS

mbTOC – metres below top of casing (PVC)

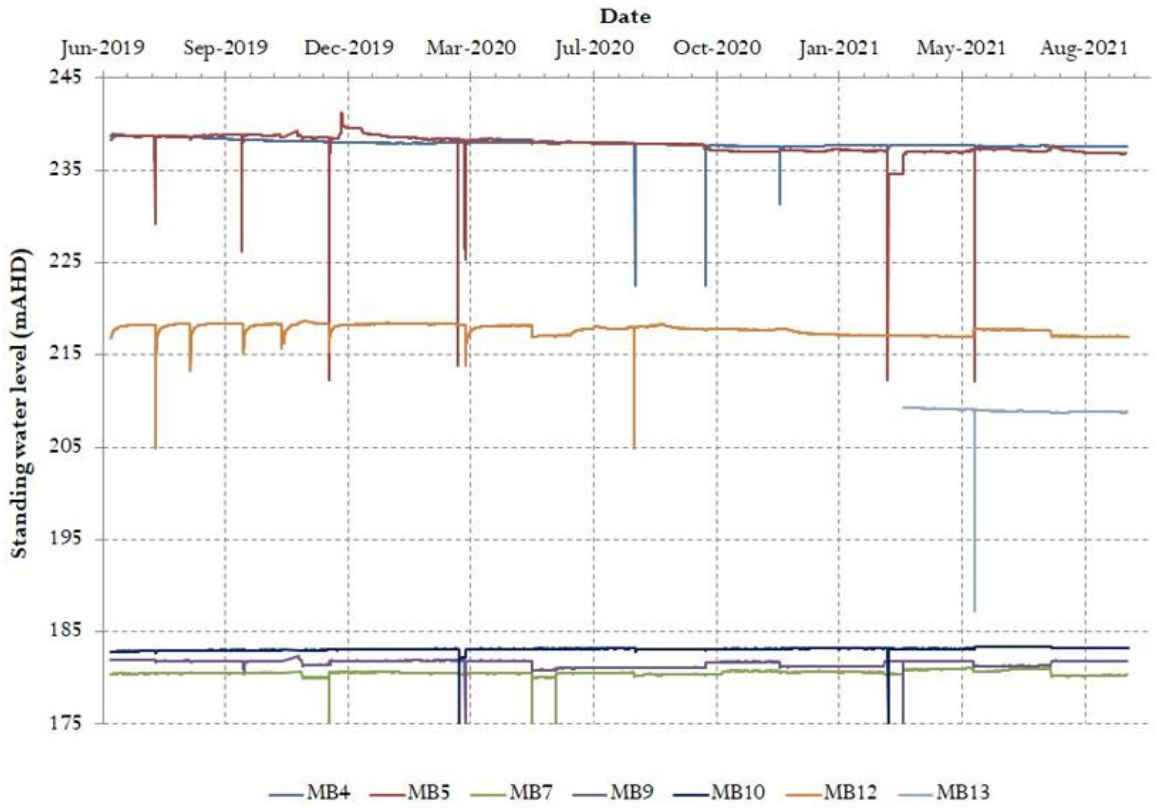


Figure 5-2 Groundwater hydrographs for Vulcan Coal Mine monitoring bores

Groundwater sampling

Groundwater sampling is also regularly carried out (on a quarterly basis) across the monitoring network to collect representative samples for baseline characterisation and for the derivation of trigger levels and contaminant limits (DES, 2021). The groundwater quality parameters monitored are consistent with those provided in the DES (2017) Guideline: Model mining conditions. The monitoring and sampling of the groundwater monitoring network is planned for and carried out in consideration of the Queensland Monitoring and Sampling Manual (DES, 2018a).

Section 5.7 provides further discussion on groundwater quality including site specific data.

5.3. Hydraulic properties

Hydraulic testing in the form of slug testing and constant head testing was performed on the VCM and regional groundwater monitoring network summarised in Table 5-2. Slug testing (falling head tests) was completed on the monitoring bores recording a groundwater level, whereas constant head testing was completed on the dry monitoring bores. The recovery curve method was carried out for MB12 given the slow recovery response following sampling. The results of the testing are summarised below in Table 5-7.

Table 5-7 Summary of hydraulic testing from the VCM and regional monitoring bores

Site ID	Area	Target unit	Test method	Hydraulic conductivity (m/d)
MB01	Regional	DLL coal seam	Constant head	3.9×10^{-2}
MB02	VCM	DLL coal seam	Constant head	5.3×10^{-2}
MB03	VCM	DLL coal seam	Constant head	3.2×10^{-2}
MB05	VCM	MAT coal seam	Slug test (Hvorslev, 1951)	2.4×10^{-2}
MB06	Regional	Weathered Permian	Constant head	>0.1
MB07	Regional	Weathered Permian	Slug test (Hvorslev, 1951)	0.21
MB08	Regional	Weathered Permian	Constant head	>0.1
MB09	Regional	DLL coal seam	Slug test (Hvorslev, 1951)	2.0×10^{-2}
MB10	Regional	DLL coal seam	Slug test (Hvorslev, 1951)	0.41
MB11	Regional	DLL coal seam	Constant head	2.9×10^{-2}
MB12	Regional	Back Creek Group	Recovery test	2.8×10^{-4}

For two of the dry monitoring bores (MB06 and MB08), the rate at which the bore accepted water was higher than the rate it could be fed in. Therefore, it is assumed that the hydraulic conductivity of the intersected lithology at these monitoring bores is higher than 0.1 m/d.

The hydraulic testing of the monitoring bores indicates that generally the highest hydraulic conductivities are for the weathered Permian, moderate values for the DLL and MAT coal seams and the lowest results are for the Permian underburden. The following order of magnitude is observed in relation to hydraulic conductivities:

- Weathered Permian: low 10^{-1} m/d;
- DLL and MAT coal seams: 10^{-2} m/d; and
- Permian underburden: 10^{-4} m/d.

The horizontal hydraulic conductivities collated from various studies in the Moranbah-Dysart region are summarised in Table 5-8. Spatial variability, local geology, the different methods used to acquire data and uncertainties in interpretation explain the wide range of values which in some instances cover three or four orders of magnitude. Notwithstanding the above, the results in Table 5-7 are consistent with the description of the hydrogeology (Section 5.1) and the majority of hydraulic conductivity ranges presented in Table 5-8.

Table 5-8 Horizontal hydraulic conductivity estimates (m/d) from studies in the Moranbah-Dysart region

Formation	URS (2009)	URS (2012)*	CDM Smith (2013)*	URS (2014)	AECOM (2016)	HydroSim. (2018)	Arrow (2016)
Tertiary sediments/regolith	-	0.1 to 10**	-	-	1×10^{-3} to 1×10^{-2}	1×10^{-1} to 6×10^{-1}	0.1 to 1
Triassic (Rewan F.)	-	5×10^{-4} to 5×10^{-2}	1×10^{-5} to 1×10^{-1}	-	-	2×10^{-6} to 5×10^{-3}	-
Permian coal measures	-	1×10^{-4} to 5×10^{-2}	-	-	-	-	0.2 to 1
Permian coal seams	1×10^{-2} to 5×10^{-1}	-	1×10^{-6} to 5	0.002 to 0.16	1×10^{-3} to 1×10^{-2}	5×10^{-4} to 1×10^{-1}	-
Permian interburden	2×10^{-2} to 3×10^{-2}	-	1×10^{-4} to 1×10^{-1}	-	-	6×10^{-7} to 6×10^{-3}	-
Permian Back Creek Group	-	1×10^{-4} to 1×10^{-2}	1×10^{-3} to 1×10^{-2}	-	-	-	-

*Note: *Collated data from literature ** (0.005 to 0.5 m/d for Duaringa Formation)*

The following sections provide commentary on the hydraulic parameters collated in Table 5-8.

Tertiary sediments

As discussed in Section 4.2, on-site observations during the construction of the VCM monitoring bores indicate that the lithology intersected above the fresh Permian coal measures did not constitute Tertiary aged sediments, rather a weathering profile that had developed during the Tertiary on the Permian coal measures. As stated in Section 5.1.1, for the purposes of this report, Tertiary regolith are defined as a mix of specific Tertiary aged sediments and the weathered zone or regolith material.

For a mix of specific Tertiary aged sediments and the weathered zone or regolith, hydraulic conductivities are in the order of 10^{-1} m/d appear reasonable (as provided by HydroSimulations, 2018, and Arrow Energy, 2016; in Table 5-8).

Permian coal measures

Throughout the Bowen Basin, the Permian coal seams are understood to be the main water bearing horizon within the Permian coal measures and the confining overburden, underburden and interburden strata are considered to be aquitards. Table 5-8 therefore lists the horizontal hydraulic conductivities for the coal measures (coal and over- and interburden), coal seams, and interburden (including overburden).

The coal seams are considered dual-porosity strata where primary-porosity is provided by the matrix and a secondary porosity is the result of the presence of fractures (joints and cleats). These secondary porosity features within the coal seams likely dominate groundwater storage; and the main pathway for groundwater movement is dependent on the interconnectivity of these fractures (URS, 2009 and AECOM, 2016). Hence, the hydraulic conductivity of the coal seams is expected to vary considerably spatially and also decrease with increasing depth of burial as the fractures close under increasing overburden pressure (HydroSimulations, 2018).

For the reasons listed above, the horizontal hydraulic conductivities in Table 5-8 cover a wide range. A range between 1 x 10^{-2} m/d and 1 x 10^{-1} m/d appears to be reasonable and consistent with the descriptions provided in Section 4.3 for the upper coal seams. For the interburden, a range between 1 x 10^{-5} m/d and 1 x 10^{-3} m/d appears to be realistic. For the coal measures (coal seams and inter- and overburden together), horizontal hydraulic conductivities between 1 x 10^{-4} m/d and 1 x 10^{-2} m/d appear to be reasonable. For the Permian Back Creek Group, horizontal hydraulic conductivities between 1 x 10^{-4} m/d and 1 x 10^{-2} m/d appear to be realistic and consistent with the material descriptions provided.

5.4. Groundwater flow, recharge and discharge

5.4.1. Tertiary sediments

Recharge to the Tertiary regolith is likely from creek flow (losing ephemeral streams) events and from surface infiltration of rainfall and overland flow. The general recharge mechanism is presented in Figure 5-3 below. The schematic diagram represents the infiltration of surface waters through the vadose zone and into the underlying Tertiary regolith and Permian coal measures involved within the Project area. This would be observed as localised mounding beneath the creeks and surface water systems. Otherwise, diffuse rainfall recharge would be expected to occur over a large area. The clayey nature of the Tertiary regolith would result in very low recharge rates.

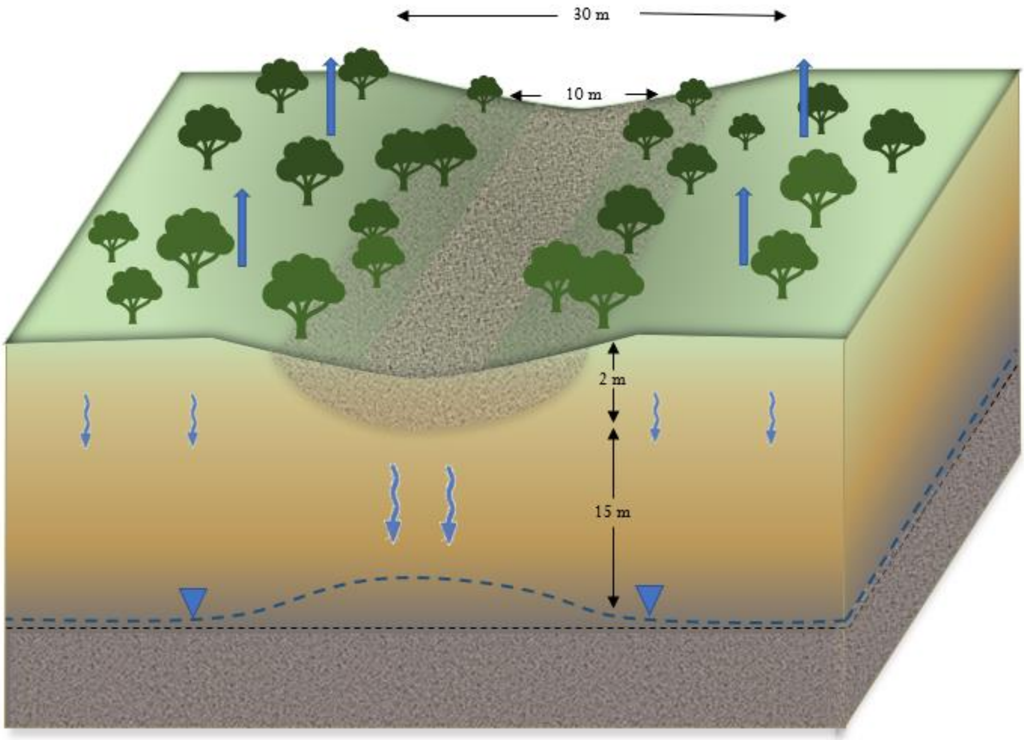


Figure 5-3 Schematic diagram of recharge processes

Discharge from the Tertiary sediments, where they outcrop and the water table is shallow, may occur through evapotranspiration. The Tertiary sediments may also discharge to the Permian coal measures as, in general, there is a downward vertical hydraulic gradient between the Tertiary sediments and Permian coal measures.

Observations from open pits at Saraji Mine (AECOM, 2016) indicate that groundwater discharges relatively slowly from the sandy horizons within the Tertiary sediments. Based on these observations, the Tertiary sediments were considered by AECOM (2016) to contain a series of poorly connected aquifers of low to moderate permeability, with drainage from the upper to lower aquifers delayed by lower permeability horizons. Groundwater ingress rates are low as evaporation rates are higher than the seepage rate, hence groundwater does not report directly or require management in the pits (AECOM, 2016).

Groundwater flow in the Tertiary sediments is expected to follow topography and surface water drainage patterns. Groundwater levels within the Tertiary sediments from monitoring bores near the Saraji Mine were reported to be at depths shallower than the recorded water strikes from drilling and installation, interpreted by AECOM (2016) to indicate that groundwater is semi-confined to confined by the clayey sediments in the upper sections of the sequence (AECOM, 2016).

5.4.2. Permian coal measures

Within the Project area, the Permian coal measures are known to be partially unsaturated and site-specific monitoring bores have confirmed this. Figure 5-4 illustrates the groundwater table in the Permian coal measures over the Project area from the south-west, to the north-east.

As for the Tertiary sediments, groundwater recharge to the Permian coal measures is likely from creek flow (losing ephemeral streams) events; and from surface infiltration of rainfall and overland flow, where the Permian coal measures are exposed, and no substantial clay barriers occur in the shallow sub-surface. Recharge may also occur from overlying Tertiary sediments under downward vertical hydraulic gradient and along faults and other structural features (AECOM, 2016).

Discharge from the Permian coal measures, where they outcrop and the water table is shallow, may occur through evapotranspiration or along faults and by groundwater extraction from bores and mine dewatering/depressurisation (AECOM, 2016 and HydroSimulations, 2018).

As for the Tertiary sediments, groundwater flow in the Permian coal measures is expected to follow topography and surface water drainage patterns, although the similarity to surface water drainage for the deeper confined units will be less pronounced than that for a shallow unconfined aquifer. Within the Permian coal measures, due to the low hydraulic conductivity of the interburden material, groundwater would largely flow along the bedding planes of the coal seams (HydroSimulations, 2018). In the vicinity of active mine dewatering sites, groundwater would flow into the pits but the spatial extent of the interference zone of individual pits would be limited because of the low hydraulic conductivity and storativity of the coal measures.

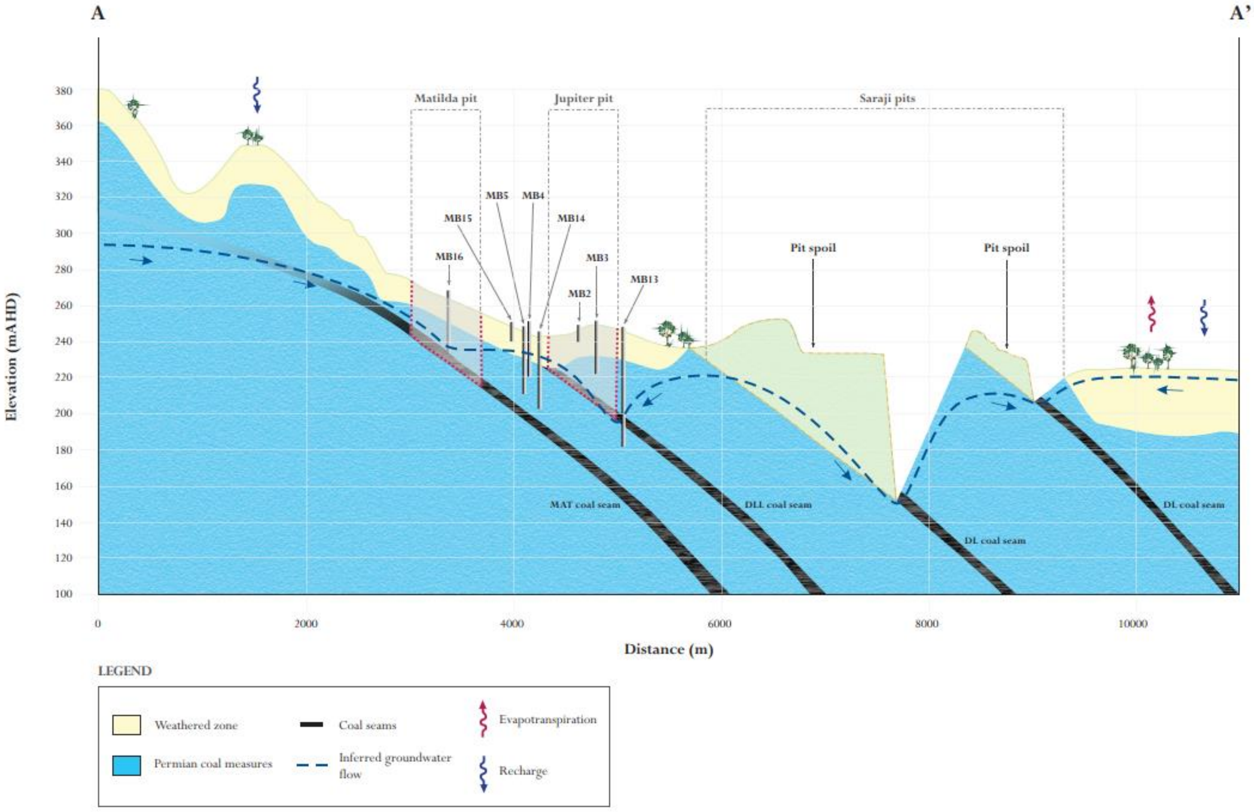


Figure 5-4 Hydrogeological cross section showing the saturation extent of the Permian coal measures in the Project area

5.4.3. Recharge and discharge rates

While the literature generally agrees on the recharge and discharge mechanisms, the rates of recharge and discharge vary significantly. AECOM (2016) used a recharge rate of 0.89 mm/yr for their model domain. URS (2012) and Arrow (2016) used a minimum of 1 mm/yr for Triassic/Permian strata (Arrow Energy, 2016).

HydroSimulations (2018) used model calibrated recharge rates of 0.15 mm/yr for Tertiary sediments and 0.06 mm/yr for outcropping Permian coal measures. These recharge rates are summarised in Table 5-9 together with indicative long-term average recharge/rainfall percentages.

Table 5-9 Estimates of recharge rates (mm/yr)

Reference	Tertiary sediments	Permian coal measures
AECOM (2016)	0.89 (0.1%)	0.89 (0.1%)
URS (2012)	1 (0.1%)	1 (0.1%)
HydroSimulations (2018)	0.15 (0.02%)	0.06 (0.009%)

Note: Value in brackets is the percent of recharge assuming an annual rainfall of 660 mm/yr.

HydroSimulations (2018) also refer to recharge rates used in Arrow Energy's Bowen Gas Project and other nearby projects (not sighted during the preparation of this report). According to HydroSimulations (2018), recharge at Lake Vermont was simulated as the equivalent of 2% mean annual rainfall and at Isaac Plains it was simulated as 0.5% (mean annual rainfall) to alluvium and 0.25% (mean annual rainfall) elsewhere. For the Arrow Energy Bowen Gas Project, recharge to the Tertiary sediments was simulated as 0.3 mm/yr or 3 mm/yr, 0 mm/yr for the Rewan Group and 0.33 mm/yr to 3 mm/yr for outcropping Permian coal measures.

For discharge, URS (2012) and Arrow (2016) modelled the difference between potential and actual evapotranspiration with an extinction depth of 10 m in their respective numerical models. HydroSimulations (2018) applied maximum potential evaporation rates using actual evapotranspiration values with an average value (600 mm/yr) used as the transient calibration evapotranspiration rate. Extinction depths were set to 2 m below ground across the model domain.

5.4.4. Groundwater flow

Based on the literature reviewed in this report, and published groundwater contour maps, horizontal (lateral) regional groundwater flow is expected to follow the same patterns as topography and the surface water drainage from all hydrogeological units, although the resemblance to surface water drainage for the deeper confined units will be less pronounced than that for the shallow unconfined aquifer.

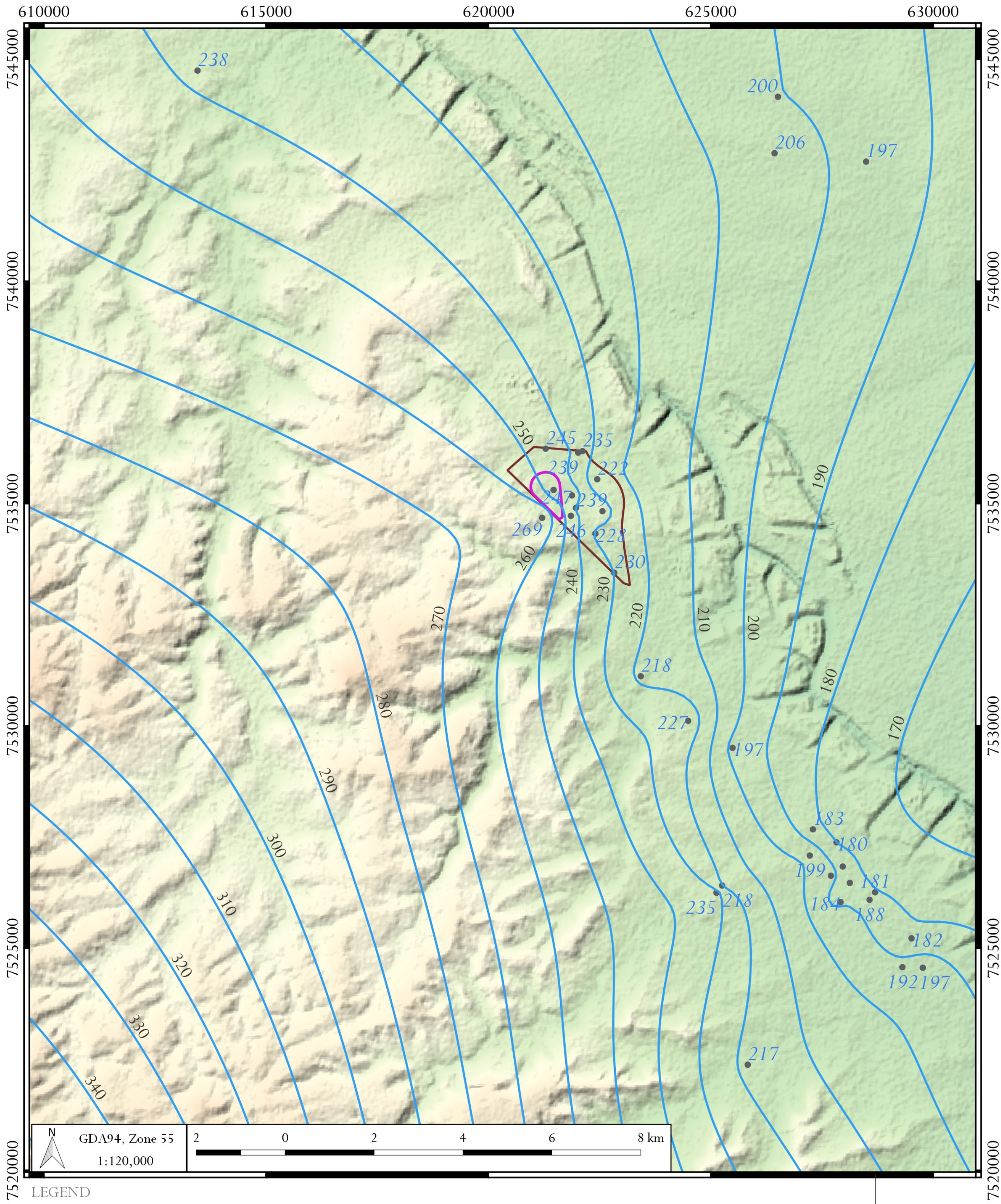
URS (2012) presented regional groundwater elevations (not reproduced in this report) for the Permian Blackwater Group. Average groundwater "levels" (i.e., elevations) were used to create the map, both from non-coal units and coal seams, hence both temporal and vertical changes (within the Blackwater Group) in groundwater elevation were disregarded. URS (2012) indicated, in general, that groundwater flows from the west (north-west) to the east (south-east), mimicking the surface water drainage pattern. URS (2012) commented that groundwater flow may also be constrained by major N-S strike fault systems. The interpretation of **hydrogeologist.com.au** is that there may be an indication for such influence on groundwater flow, however, it is difficult to say with certainty at the scale provided.

Groundwater contours by AGE 2012a (a memorandum on predicted inflows and drawdown for the Saraji East Underground Mine) in AECOM (2016; Saraji Mine) indicate generally west to east flow pattern, similar to the URS (2012; Bowen Gas Project) interpretation. The pre-mining groundwater contours are model generated, and the elevations are typically up to 20 m different to the regional contours presented by URS.

Figure 5-5 shows composite regional groundwater elevation contours, prepared by **hydrogeologist.com.au**. The groundwater elevation contours are based on 50 individual datapoints collated from the DRDMW GWDB, site specific monitoring bores and Project exploration drill holes and groundwater elevations summarised as part of neighbouring projects (AECOM, 2016). For each datapoint, the depth to groundwater measurements were considered and corrected to an elevation based on surveyed or reported elevations or derived from an STRM (one second) digital elevation model (DEM). Notwithstanding that, the contours represented in Figure 5-5 are a composite groundwater elevation map (groundwater elevations from different times and from various hydro-stratigraphic units), it clearly indicates groundwater flow to the east near the Project area. To the east of the Project area, the inferred direction of groundwater flow turns to the south-east and eventually follows the alignment of the Isaac River, in agreement with the findings of HydroSimulations (2018).

Based on the literature reviewed and presented in this report, horizontal (lateral) regional groundwater flow is expected to follow the same patterns as topography and the surface water drainage for all hydrogeological units, although the resemblance to surface water drainage for the deeper confined units will be less pronounced as for the shallow unconfined groundwater systems. Near the Project area, the statement above would suggest a west to east groundwater flow, and this is consistent with the data assessed.

Vertically, the highest groundwater elevations were measured in the Quaternary and Tertiary units and upper Permian coal seams. Groundwater elevations also appear to decrease with the depth within the coal seams (URS, 2009 and AECOM, 2016). Vertical hydraulic gradients, where reported, are downward, suggesting potential downward leakage between the hydrogeological units (although HydroSimulations (2018) reported a single observation deep in the Permian where the vertical hydraulic gradient within the Permian coal measures reversed, coinciding with a decrease in hydraulic conductivity with depth). Groundwater elevations measured by AECOM (2016) in nested bores indicate downward hydraulic gradients in all measured bores between the Tertiary and Permian units and within the Permian units in all but one bore. These observations are consistent with those made by HydroSimulations (2018).



LEGEND

- Matilda pit
- ML700060
- Groundwater elevation contours
- Groundwater elevation points

DATE
15/07/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Groundwater elevation contours

FIGURE No.
5.5

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
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Effect of mining

AECOM (2016) noted that:

"Groundwater levels in the alluvium (MB2), Tertiary (PZ02A and PZ04A) and Permian (MB31, MB33 to MB37) strata, measured over time, do not indicate any impacts of mine dewatering even though coal mining at Saraji Mine has been undertaken since 1974". The monitoring bores referred to above are located between 600 m (MB2) and 1,500 m (MB33 and MB34) of the existing Saraji Mine open cut pits. The monitoring data would indicate that the zone of influence (or interference) is restricted to an area immediately adjacent to the open cut pit. This is likely due to low permeability of the mined strata and Permian overburden. AECOM (2016) therefore considered that the long term mine activities do not markedly impact on regional groundwater resources.

hydrogeologist.com.au concurs with this interpretation. The low hydraulic conductivity / transmissivity for most units, combined with low storage, would result in mine interference zones limited in lateral extent, except in areas where secondary porosity (fractures) opened extensive preferential pathways in the coal seams.

Structural control

CSIRO (2002) presents the distribution of faults, dykes and sills within the Project area and this is reproduced as Figure 5-6. In Figure 5-6, red lines represent thrust faults with > 3m throw, blue lines indicate normal fault with 1 m to 3 m throw, and turquoise lines show normal faults with > 3 m throw, and purple rectangles signify inferred basement structures. The approximate location of the Project area is indicated on the figure to show the location relative to the Jellinbah Thrust Fault Zone and the structures mapped at Saraji Mine and Peak Downs Mine. The VCM may be influenced to some degree by local structure mapped at the adjacent Saraji Mine and Peak Downs Mine. However, it is understood that no significant faults have been intersected by mining at the VCM.

The main geological structure in the region is the Jellinbah Thrust Fault Zone. The Jellinbah Thrust Fault Zone is highly faulted with several easterly dipping thrust faults. It is a north-west trending zone of thrust faults with throws in the order of 100 m to 500 m (URS, 2012). The Olive Downs Coal Project (HydroSimulations, 2018) is located within the Jellinbah Thrust Fault Zone and discusses several regional fault structures with a dominant north-north-west trend, including the Iffley Fault Zone (up to 100 m displacement). On the western side of the Olive Downs Coal Project is the Isaac Thrust Fault, which has up to 500 m vertical displacement.

The Jellinbah Thrust Fault Zone is truncated by the Tertiary unconformity, with little to no fault activity during the Cainozoic (CSIRO, 2002 and HydroSimulations, 2018). Faulting can result in higher permeabilities within strata parallel with the fault plane, and lower permeabilities within strata perpendicular to the fault plane. However, this can be dependent on whether faults are currently active or not. Faulting has been inactive within the Bowen Basin for over 140 million years, indicating that the fault zones are less likely to act as conduits to flow (HydroSimulations, 2018). This relates to filling of the fractured pore spaces over time through hydrothermal alteration and mineralisation. Drill core logs from the Olive Downs Coal Project show that where fractures and faults have been geologically logged, many fractures are "healed" with calcite and siderite. This indicates that, although the system is a fractured network, many of the existing fractures are cemented with the likely effect of reducing effective permeability when compared to any open fracture network.

The behaviour of faults was also assessed as part of the Bowen Gas Project using the movement of water and gas across a series of faults utilising stable isotope and water quality analyses. Higher gas production rates were observed on either side of a major fault, with differences in isotopic compositions of produced water for wells north and south of a major fault line at similar depths, implying little communication across the fault boundary, and suggesting that the fault acts as a barrier to water and gas flow. The results of the study showed that compartmentalisation was evident and that this was due to the structural geology (faulting) in the basin (HydroSimulations, 2018).

The Jellinbah Thrust Fault Zone occurs some 10 km to 15 km to the east of the VCM and would be extremely unlikely to influence groundwater flow at the VCM. On a regional scale, however, the presence of the Jellinbah Thrust Fault Zone would act as a low permeability zone in the regional flow system of the Permian strata. The experience of **hydrogeologist.com.au**, with the Jellinbah Thrust Fault Zone, is that lateral groundwater flow within the fault zone is to the east (north-east). To the west of the fault zone, the presence of 'dense' groundwater head/elevation contours suggest a steep horizontal hydraulic gradient while to the east of fault zone the gradient is flatter, indicating that the fault zone is acting as an impediment, i.e., the hydraulic conductivity of the fault zone is lower than that of the host rocks.

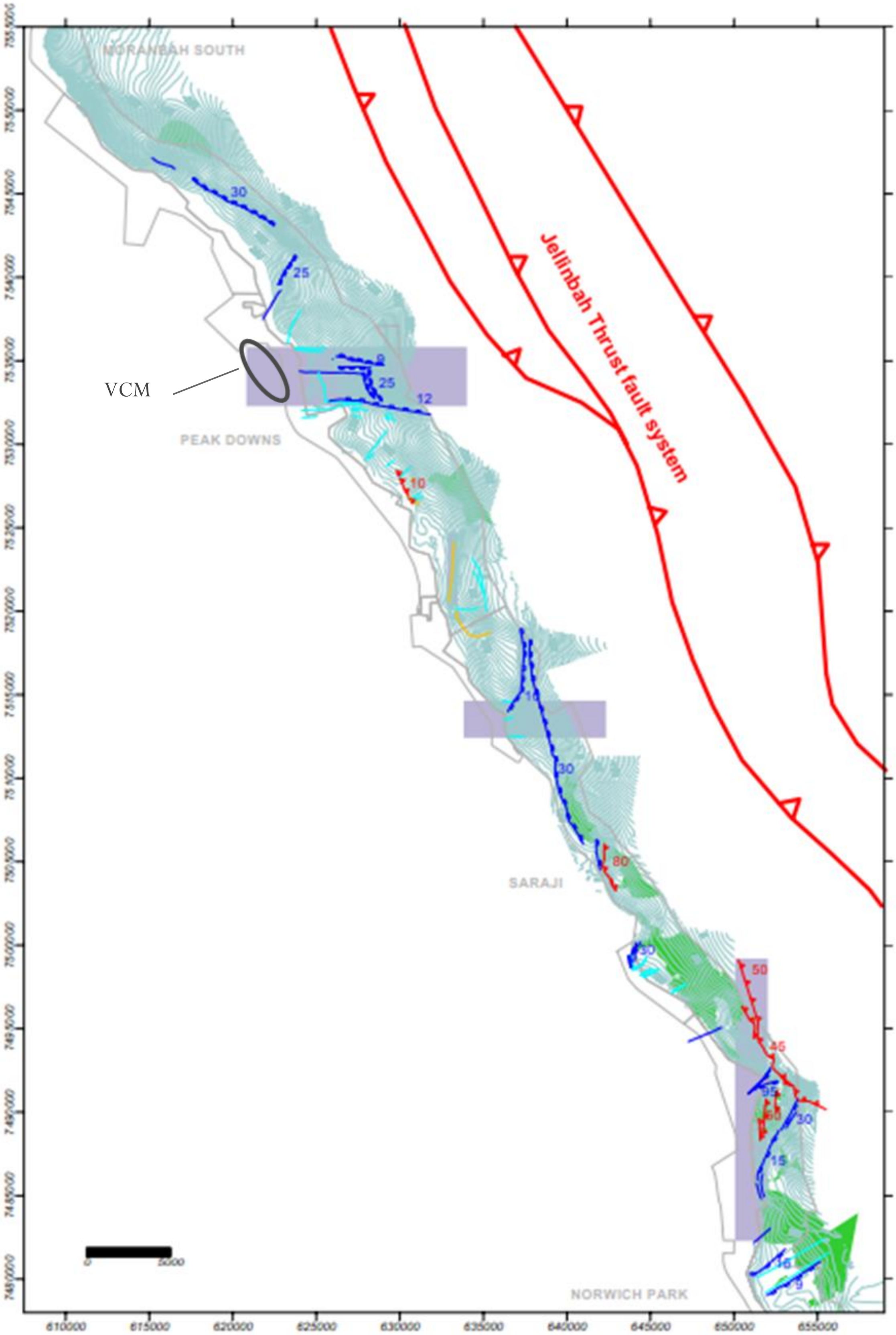


Figure 5-6 Faults with >1 m throw mapped in the Dysart seam of the Middle Tile, after CSIRO (2002)

5.5. Surface-groundwater interaction

Surface-groundwater interaction was investigated for the Olive Downs Coal Project (HydroSimulations, 2018), approximately 20 km to the north-east of the Project area. Despite the distance between the projects, the assessment appears to be directly transferable because the numerical groundwater model domain of HydroSimulations (2018) extends westward sufficiently enough to cover all important watercourses in the Project area.

In addition, HydroSimulations (2018) have:

- developed a conceptual hydrogeological model that is consistent with that presented in this report in Section 5.8;
- addressed surface water-groundwater interaction with the same or similar modelling tools used and described in Section 5.5;
- relied on a dataset almost identical to that available for this report because the most important stream gauging station, Phillips Creek at Tayglen (Figure 3-3) was closed in late 1988 (https://water-monitoring.information.qld.gov.au/, visited 21 August 2019); and
- the groundwater report and model of HydroSimulations (2018) appears to be the most recent and comprehensive groundwater assessment in the vicinity of the Project area.

Further, a careful evaluation of the differences between the Olive Downs Coal Project and the Project area suggests that surface and groundwater interact to a lesser degree at the Project area than at Olive Downs Coal Project:

- the Project area is to the west and at higher elevation than the Olive Downs Coal Project, resulting in generally deeper groundwater table and less flow in the watercourses than those at the Olive Downs Coal Project;
- the Quaternary alluvium of the Isaac River, through which most surface-groundwater interaction at the Olive Downs Coal Project occurs, is absent in the Project area; and
- the importance of the Isaac River (and its associated alluvium) on the groundwater regime of the Project area is significantly less, not just because of the distance, but because of the Jellinbah Thrust Fault Zone which is situated in between the Isaac River and the Project area, compartmentalising groundwater flow in the Permian strata.

In Section 5.4 (Figure 5-3), the mechanism of recharge from surface water systems in the Project area is presented. The ephemeral nature of the surface water systems means that the creeks are dry for the majority of time. The groundwater table beneath the creeks occurs within either the Tertiary regolith or Permian coal measures at depth (greater than 10 m below ground level) and forms part of the regional groundwater table. There is a significant thickness (generally greater than 10 m) of unsaturated material beneath the creek and above the groundwater table. For the reasons stated above, it is assessed that there is no significant surface-groundwater interaction in the Project area.

5.6. Groundwater use

Groundwater users in the vicinity of the Project area include mining companies (industrial use), private users (livestock beef cattle watering) and, potentially GDEs (springs, surface water, stygofauna, wetlands etc).

5.6.1. Third party users

Third party groundwater use has previously been assessed through two mechanisms:

- consideration of the registered bores within 5 km of the numerical flow model domain on the DRDMW GWDB; and
- discussion with private landholders within 5 km of the proposed open pit.

The Groundwater Database – Queensland (DRDMW GWDB) stores registered water bore data from private water bores and Queensland Government groundwater investigation and monitoring bores. Data includes bore location, water levels, construction details, strata log and water quality. As such the DRDMW GWDB is the most reliable source of desktop information on groundwater use for the Project area.

The previous search (2020) of the DRDMW GWDB considered records within a 5 km distance of the numerical model domain (Section 6.1). Of the 83 DRDMW GWDB records within 5 km of the numerical flow model domain, the following was concluded:

- 65 (78%) were existing;
- 11 (13%) were abandoned and destroyed; and
- 7 (8%) were abandoned but still useable.

There were 69 records classifying bore use or purpose within 5 km of the numerical flow model domain. These records suggested that the overwhelming use of bores is for mining:

- 51 (74%) were for monitoring (41 for mine, 5 for petroleum or gas and 5 for sub-artesian monitoring);
- 14 (20%) were for water supply (these may be for mine supply or private supply as water supply is used as a broad term); and
- 4 (6%) were for investigation (stratigraphic, exploration or water resources investigation).

It is the experience of **hydrogeologist.com.au** that the name of a bore may also reveal its purpose, i.e., bore names containing long numbers, company abbreviations or sequences such as "MB" or "INV" or "PIEZO" are for monitoring or investigation while private bores are named after the farm or local features. Of the 62 records with names available, 52 (84%) appeared to be for the purpose of mine investigation and monitoring.

Groundwater quality is an important consideration for groundwater use because high salinity will generally preclude or limit certain uses. For this reason, groundwater salinity data was also analysed. For the 5 km vicinity of the numerical flow model domain, most of the groundwater salinity information in DRDMW GWDB is provided as field electrical conductivity (EC). Using the classification of Mayer *et.al*. (2005) that is provided in Table 5-10, the 153 field EC records could be summarised as:

- none were fresh;
- one was marginal;
- 29 were brackish;
- 91 were saline; and
- 32 were highly saline.

The above statistics on field EC may somewhat be biased towards bores that are represented by several results (at different dates). The interpretation of **hydrogeologist.com.au** is that most bores in the vicinity of the Project area are for monitoring and investigation purposes (mostly for mining) and only a small fraction may be used for private groundwater use, probably for limited stock watering because of the high salinity of the groundwater.

A contemporary search of the DRDMW GWDB was carried to ensure no additional water supply bores have been drilled and constructed within the likely area of project impact. Additional bores were identified within 5 km of the project mining lease, however all of these additional bores were assessed to be mine monitoring bores associated with the existing BHP coal mining operations. No additional water supply bores were identified within the likely area of project impact.

The registered bores on the DRDMW GWDB are shown in Figure 5-1. Private landholder bore (RN162506) is the only bore situated within 3 km of the VCM, the next closest is RN13040283, a Queensland government monitoring bore approximately 8 km to the south-east of the proposed pit. The remaining bores shown on the map have been drilled by BHP for the purposes of mine monitoring.

Discussions have been held with the owners of the following property descriptions and Vitrinite to understand whether there are any groundwater bores on the property that may not be registered on the DRDMW GWDB:

- Lot 10 SP208611;
- Lot 2 SP296877;
- Lot 59 SP235297;
- Lot 7 CNS144;
- Lot 11 CNS394;
- Lot 14 CNS382; and
- Lot 9 SP235297.

The outcomes of the discussions indicate that there are no other groundwater supply bores in the Project area that are used by the local landholders. Potential impacts to third party groundwater users are discussed in Section 7.

5.6.2. Groundwater dependent ecosystems

A GDE is an ecosystem that requires access to groundwater on a permanent or intermittent basis to meet all, or some of its water requirements. For GDEs such as springs, wetlands, rivers and vegetation, groundwater plays an important role in sustaining aquatic and terrestrial ecosystems. A GDE therefore is a plant and/or animal community that is dependent on the availability of groundwater to maintain its structure and function.

The GDE Atlas (GDE Atlas, Bureau of Meteorology, 2016) was developed as a national dataset of Australian GDEs to inform groundwater planning and management. It is the first and only national inventory of GDEs in Australia. The GDE Atlas web-based mapping application allows the visualisation, analysis and downloading of GDE information for an area of interest (http://www.bom.gov.au/water/groundwater/gde/, visited 21 August 2019).

The GDE Atlas classifies ecosystems based on the potential for dependence on groundwater. Classification is based on multiple lines of scientific evidence, with categories for high, moderate or low potential, allocated as follows:

- high potential for groundwater interaction (indicating a strong possibility the ecosystem is interacting with groundwater);
- moderate potential for groundwater interaction; or
- low potential for groundwater interaction (indicating it is relatively unlikely the ecosystem will be interacting with groundwater).

BOM (2018) maps areas for both aquatic and terrestrial GDE's and indicates that the following are mapped in the vicinity of the Project area:

- Aquatic GDEs rely on the surface expression of groundwater, including surface water ecosystems which may have a groundwater component such as rivers, wetlands and springs. Aquatic GDEs associated with a number of separate wetlands along the Moranbah – Dysart Road, between Phillips Creek and Boomerang Creek and close to the Project area, are mapped as having a low, moderate or high potential to be associated with the surface expression of groundwater (Figure 5-7). These wetland features all appear to be manmade impoundments associated with Saraji Mine or pastoral properties.
- Terrestrial ecosystems rely on the subsurface presence of groundwater. This includes all vegetation ecosystems. Terrestrial GDEs to the west of Moranbah – Dysart Road are mapped generally as having a low to moderate potential to be dependent on the subsurface expression of groundwater (Figure 5-8). No subterranean GDEs (cave and aquifer ecosystems) have been identified by BOM (2018) in the vicinity of the Project.

Aquatic GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where the seasonally high groundwater potentiometric heads are above or close to the corresponding surface water heads. This is necessary to maintain a hydraulic gradient from the groundwater to surface water, or at least have a hydraulically 'connected' system. Within or adjacent to the Project area, the surface water systems are generally well above the groundwater table (see Section 5.5) and the surface water system is hydraulically disconnected from the groundwater system.

In addition, groundwater in the Project area is brackish to saline and therefore unsuitable for the maintenance of freshwater GDEs (see Section 5.7 for further information on groundwater quality).

The depth to groundwater table map in Figure 5-9 was produced by subtracting the groundwater elevation grid (compiled and generated from publicly available information – see Figure 5-5) from the ground surface (SRTM data used for the regional area and LIDAR used for the local Project area) grid.

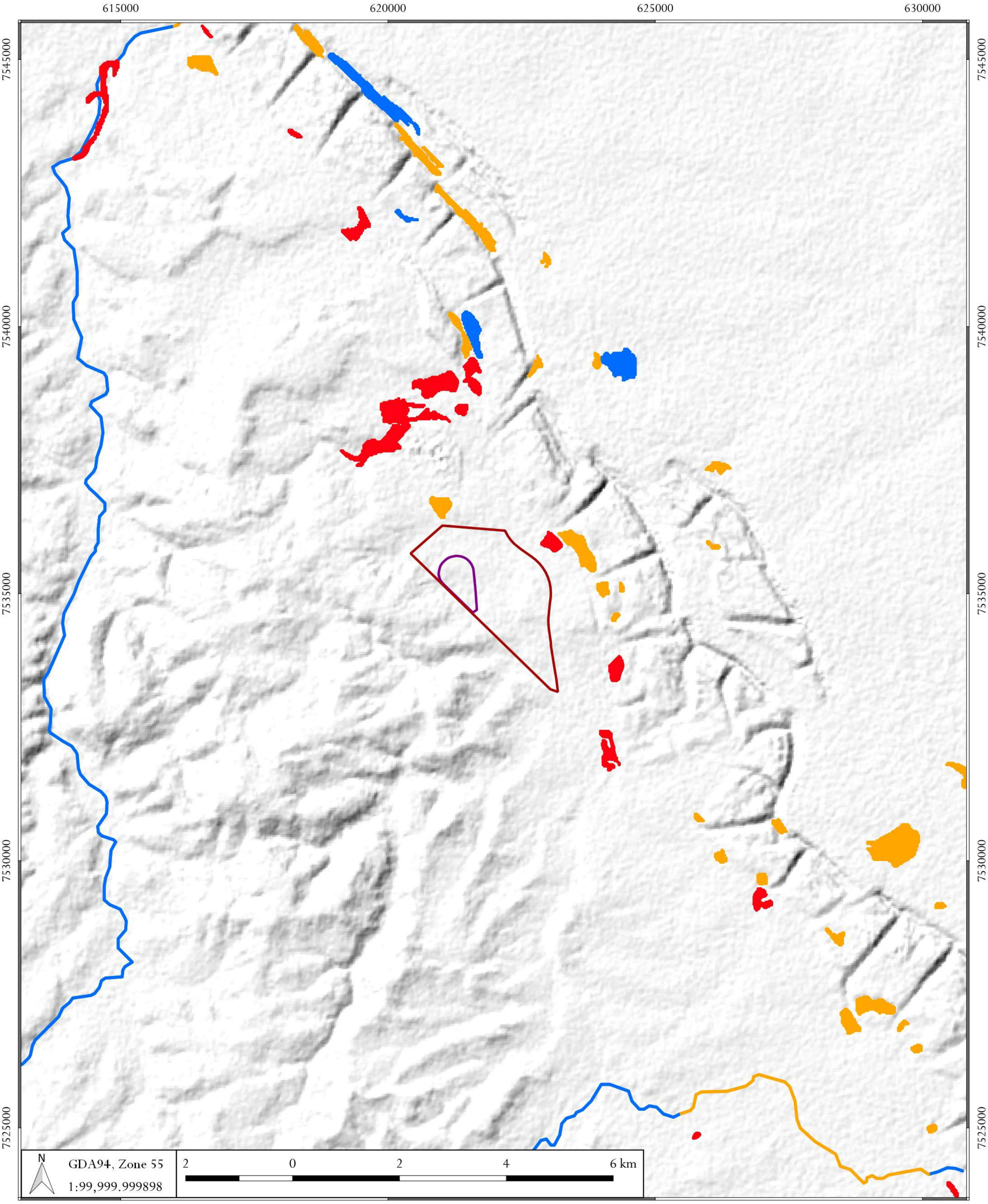
Figure 5-9 indicates that groundwater is between 5 and 30 m deep at the VCM. The nearest areas with depth to groundwater less than 5 m (orange colours) are on the northern Project area boundary and to the immediate south-west of the Project area. These areas of shallow depth to groundwater do not correlate with the aquatic GDEs presented in Figure 5-7.

In the experience of **hydrogeologist.com.au**, terrestrial GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where depth to groundwater is less than 10 m (i.e., the groundwater table is shallow, including alluvial deposits) and likely to be outside of the accessible reach of Eucalypt vegetation (Zolfaghar *et al*. 2014).

For the reasons stated above, it is the interpretation of **hydrogeologist.com.au** that there are no aquatic or terrestrial GDEs within 3 km of the VCM. The reader is directed to the Vulcan Coal Mine – Ecological Impact Assessment report for further information regarding the presence of aquatic or terrestrial GDEs.

In addition, the Queensland Government maintains an inventory of identified springs in the Queensland Springs Database (https://data.qld.gov.au/dataset/springs/resource/4cdc89ef-b583-446e-a5c7-0836a91a3767, visited 21 August 2019) that can also be reviewed through QLD globe. No springs have been identified in the vicinity of the Project area; with the nearest spring being situated at a distance greater than 100 km to the west.

A search of the EPBC Act 'Protected Matters Report' (http://www.environment.gov.au/epbc/pmst/index.html, visited 21 August 2019) found that there are no internationally or nationally important wetlands within 50 km of the Project area. Lake Elphinstone is the closest nationally important wetland, located approximately 100 km north of the Project area.



LEGEND

- ML700060
- Matilda pit

Aquatic groundwater dependent ecosystem

- High potential GDE - from national assessment
- High potential GDE - from regional studies
- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment

DATE
21/06/2022

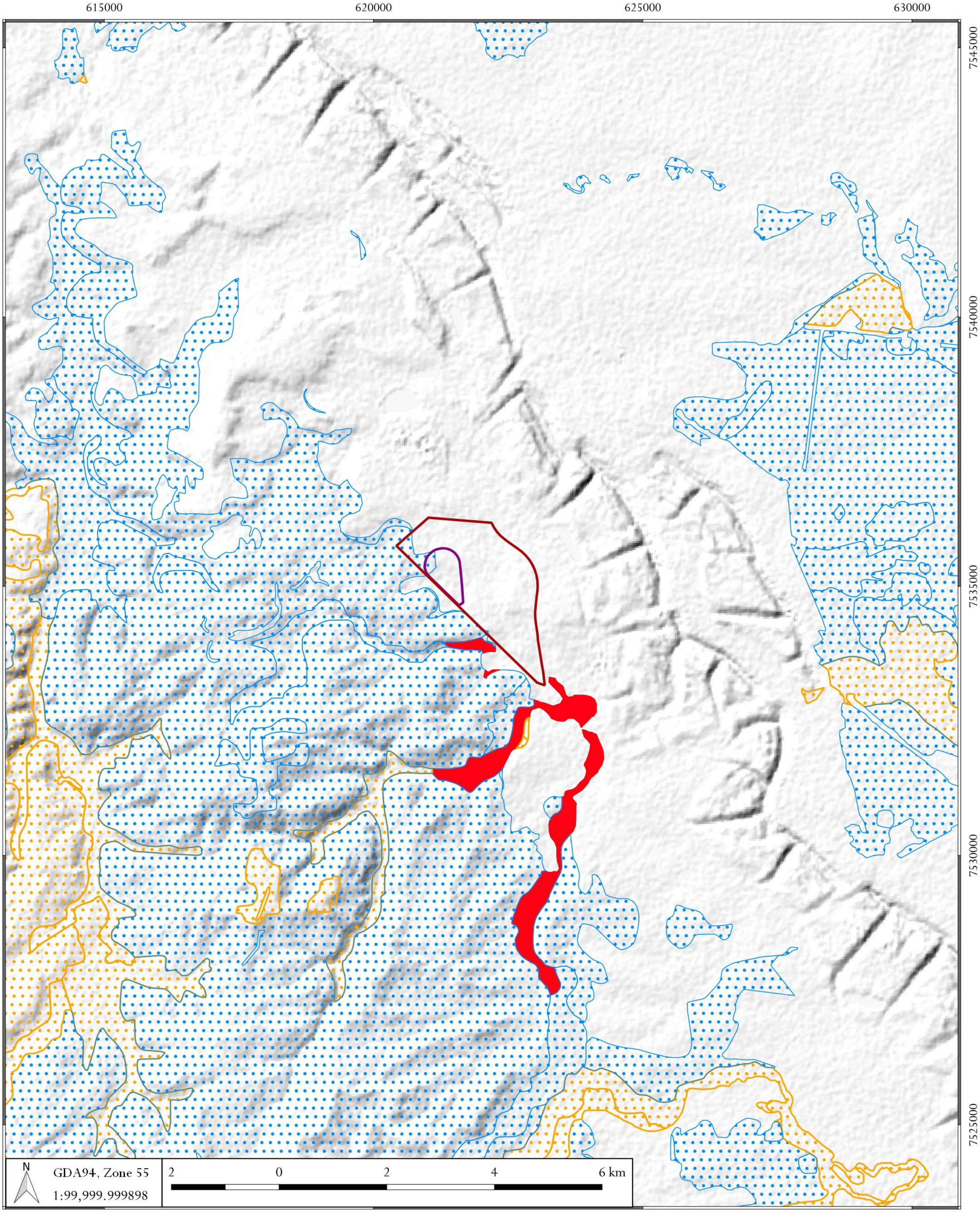
hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Aquatic groundwater dependent ecosystems

FIGURE No.
5.7

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_08_4124_Matilda_Vulcan South_Aquatic GDEs.qgz



LEGEND

ML700060

Matilda pit

Terrestrial groundwater dependent ecosystem

High potential GDE - from national assessment

Moderate potential GDE - from national assessment

Moderate potential GDE - from regional studies

Low potential GDE - from national assessment

DATE
21/06/2022

hydrogeologist.com.au

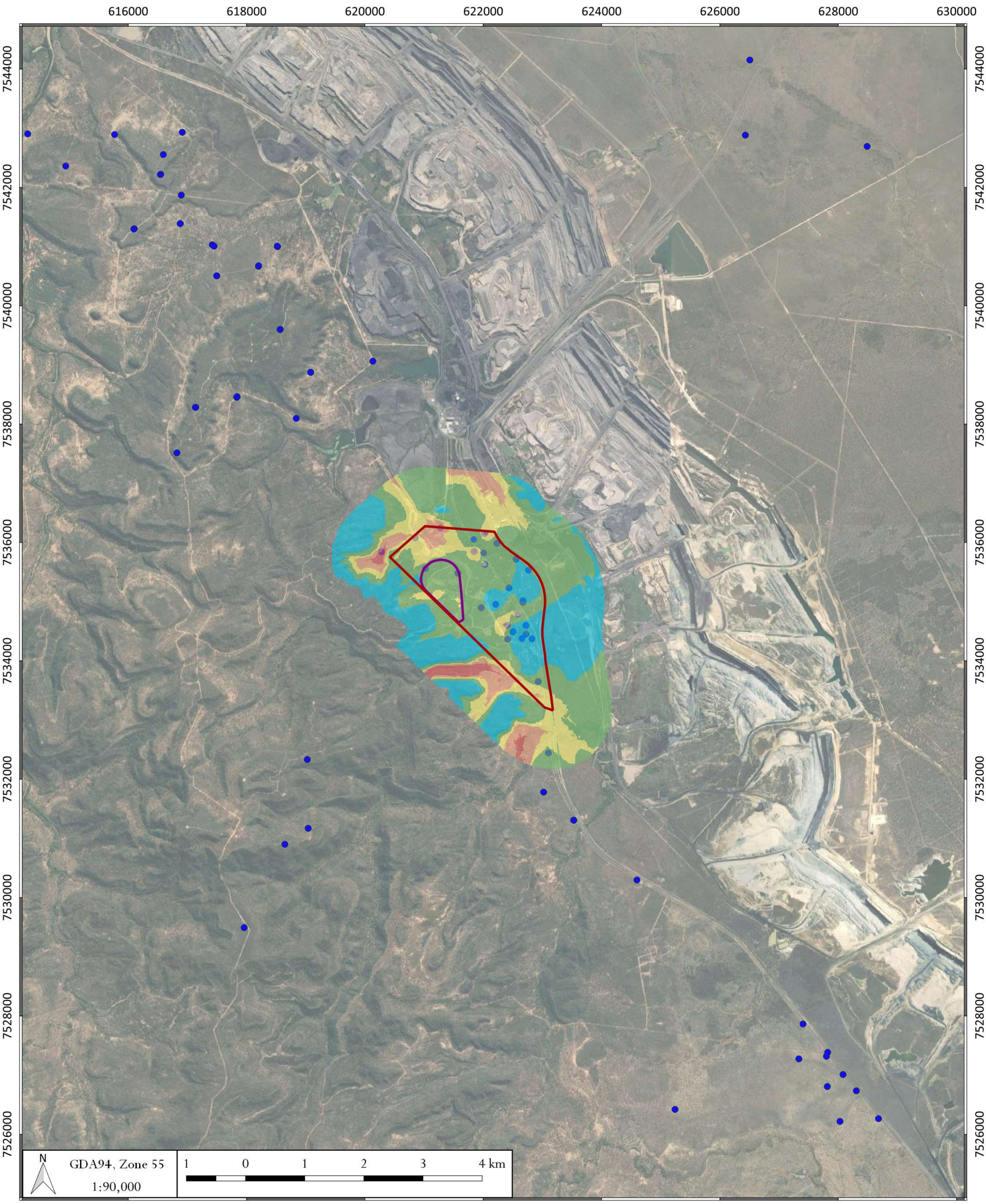
Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Terrestrial groundwater dependent ecosystems

FIGURE No.
5.8

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_09_4124_Matilda_Vulcan South_Terrestrial GDEs.qgz



LEGEND

ML700060

Matilda pit

Groundwater elevation data point

Depth to groundwater (m)

<= 0

0 - 5

5 - 10

10 - 20

20 - 50

DATE
21/06/2022

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Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Depth to groundwater

FIGURE No.
5.9

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_10_4124_Matilda_Vulcan South_Depth to Groundwater.qgz

5.7. Groundwater quality

5.7.1. Site specific data

At the time of completing this report, seventeen rounds of analytical laboratory and field results were available from the VCM groundwater monitoring network (see Section 5.2 and Table 5-2). The monitoring and sampling of the groundwater monitoring network is carried out in consideration of the Queensland Monitoring and Sampling Manual (DES, 2018a).

Groundwater salinity was classified by **hydrogeologist.com.au** (2019) using a system based on local experience. In this report, however, the classification of Mayer *et.al*. (2005, http://www.water.wa.gov.au/water-topics/water-quality/managing-water-quality/understanding-salinity, visited on 14 June 2022) will be used because it is more widely used and contains more categories, especially a 'marginal' category between fresh- and brackish water (Table 5-10).

Table 5-10 Groundwater salinity classification based on Mayer *et.al*. (2005)

Salinity status	Electrical Conductivity* (µS/cm)	Description and use
Fresh	<750	Drinking and all irrigation
Marginal	750 – 1,500	Most irrigation, adverse effects on ecosystems become apparent
Brackish	1,500 – 3,000	Irrigation certain crops only; useful for most stock
Saline	3,000 – 15,000	Useful for most livestock
Highly saline	15,000–52,000	Very saline groundwater, limited use for certain livestock
Brine	>52,000	Seawater; some mining and industrial uses exist

Note: **converted from total dissolved solids (TDS in mg/L) using a conversion factor of 0.67; rounded values*

The field EC and pH of groundwaters are summarised in Table 5-11 and Table 5-12. None of the samples are assessed as fresh or marginal, with all samples returning a field EC above 2,600 µS/cm and some above 20,000 µS/cm (MB12). Using the classification of Mayer *et al*. (2005), groundwater from the Project area is brackish (MB05); to saline (MB04, MB07, MB09, MB10 and MB13) to highly saline (MB12).

Table 5-11 Historical summary of field electrical conductivity (µS/cm)

Bore ID	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Dec 2019	Mar 2020	Jun 2020	Aug 2020	Oct 2020	Dec 2020	Mar 2021	May 2021	Jul 2021	Sep 2021	Dec 2021	Mar 2022	Salinity status*
MB04[1)]	~~2,520~~	9,510	9,346	10,409	10,703	11,709	12,913	12,734	12,782	12,752	12,048	11,122	10,904	12,592	10,901	11,800	-	Saline
MB05	2,960	3,042	2,737	2,753	2,739	2,719	2,720	2,720#	2,840	2,757	2,754	2,651	2,858	2,712	2,625	2,760	2,790	Brackish to saline
MB07	5,680	6,091	5,739	5,819	5,882	5,830	-	5,184	5,141	5,383	5,393	5,358	5,196	5,307	5,412	5,547	6,132	Saline
MB09	~~5,520~~	13,758	15,130	13,909	13,566	11,582	12,117	11,989	11,933	11,909	11,845	11,735	11,506	12,064	11,403	12,438	11,737	Saline to highly saline
MB10	-	5,668	4,846	4,322	4,353	4,034	4,170	4,121	4,028	3,980	3,876	3,881	3,818	3,806	3,762	3,852	3,794	Saline
MB12	22,800	19,469	17,854	17,231	20,878	16,725	15,644	22,200#	22,444	22,178	22,840	22,533	21,998	21,953	21,470	22,094	22,851	Highly saline
MB13	-	-	-	-	-	-	-	-	-	-	-	4,110	4,021	4,084	3,970	4,230	4,450	Saline

Notes: ** from the classification of Mayer et al. (2005) and excluding the initial June samples for MB04 and MB09*

 # laboratory data substituted for field data

Strike through text (e.g., ~~2,520~~) is considered anomalous data or outliers

1) MB04 has been decommissioned, and has been replaced by MB14

Table 5-12 Historical summary of field pH

Bore ID	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Dec 2019	Mar 2020	Jun 2020	Aug 2020	Oct 2020	Dec 2020	Mar 2021	May 2021	Jul 2021	Sep 2021	Dec 2021	Mar 2022
MB04	~~7.92~~	5.93	5.90	5.79	5.84	5.73	5.54	5.75	5.57	5.66	5.53	6.04	6.31	6.29	5.84	5.13	-
MB05	~~8.55~~	7.00	7.02	6.92	6.94	6.89	6.96	7.49[#]	6.84	6.90	6.67	7.21	7.63	7.44	6.92	7.65	7.81
MB07	~~8.78~~	7.04	7.00	6.75	6.93	6.78	-	6.74	6.72	6.91	6.86	7.08	7.23	7.42	6.94	6.77	6.53
MB09	~~8.58~~	6.90	7.00	6.90	6.87	6.93	7.08	6.78	6.64	6.72	6.71	7.26	7.21	7.51	6.96	6.87	6.91
MB10	-	6.78	6.94	6.88	6.97	6.81	7.03	6.89	6.86	6.91	6.89	7.20	7.29	7.43	7.07	6.93	6.76
MB12	~~8.29~~	6.86	6.79	6.66	6.57	6.62	6.78	7.08[#]	6.38	6.37	6.57	7.08	6.96	7.01	6.61	6.61	6.22
MB13	-	-	-	-	-	-	-	-	-	-	-	7.04	6.97	6.99	6.69	7.38	7.7

Notes: Strike through text (e.g., ~~2,520~~) is considered anomalous data or outliers

[1)] MB04 has been decommissioned, and has been replaced by MB14

The Durov diagram (Figure 5-10) is best considered as a series of joint diagrams with the right side of Figure 5-10 being a scatter graph of sodium (as a percentage of all cations) vs TDS. The bottom diagram is a scatter of chloride (as a percentage of all anions) vs pH. The innermost square is the projection of the two scatters, i.e., it shows sodium (as a percentage of all cations) vs. chloride (as a percentage of all anions). The two ternary diagrams are for anion percentages (top) and cation percentages (left).

Figure 5-10 indicates that most of the site's groundwater is strongly dominated by sodium (Na) and moderately to strongly dominated by chloride (Cl). All the site-specific groundwater would fall into the sodic waters of marine origin category of Raymond and McNeil (2011). Chloride, as a percentage of anions, varies between 40% and nearly 100%; however, some samples (MB05, MB10 and MB07) indicate the presence of moderate bicarbonate (HCO_3). There does not appear to be a simple relationship between the hydro-stratigraphic unit and groundwater quality. For example, the markers for MB05, the deepest sampled coal seam (MAT), are indicating the lowest salinity and chloride percentage, contrary to the general observations made by URS (2012) and Arrow Energy (2016) indicating increase in salinity with increasing depth. There are three bores (MB04, MB09 and MB10) targeting the DLL seam, and as Figure 5-10 indicates, the markers for these bores are widely spread.

The Piper diagram in Figure 5-11 shows the major cation percentages on the left and the anion percentages on the right, the observations from the ternary diagram are next projected to the top rhomboid. The rhomboid indicates that all groundwater is of sodium-potassium (Na_K> 50%) and sulphate-chloride (SO_4-Cl (>50%) type. The ternary diagrams provide further breakdown, i.e., that the groundwater is dominated by sodium-potassium cations combined with mostly chloride as the dominant anion; although the MB05 samples contain 30-40% bicarbonate (HCO_3).

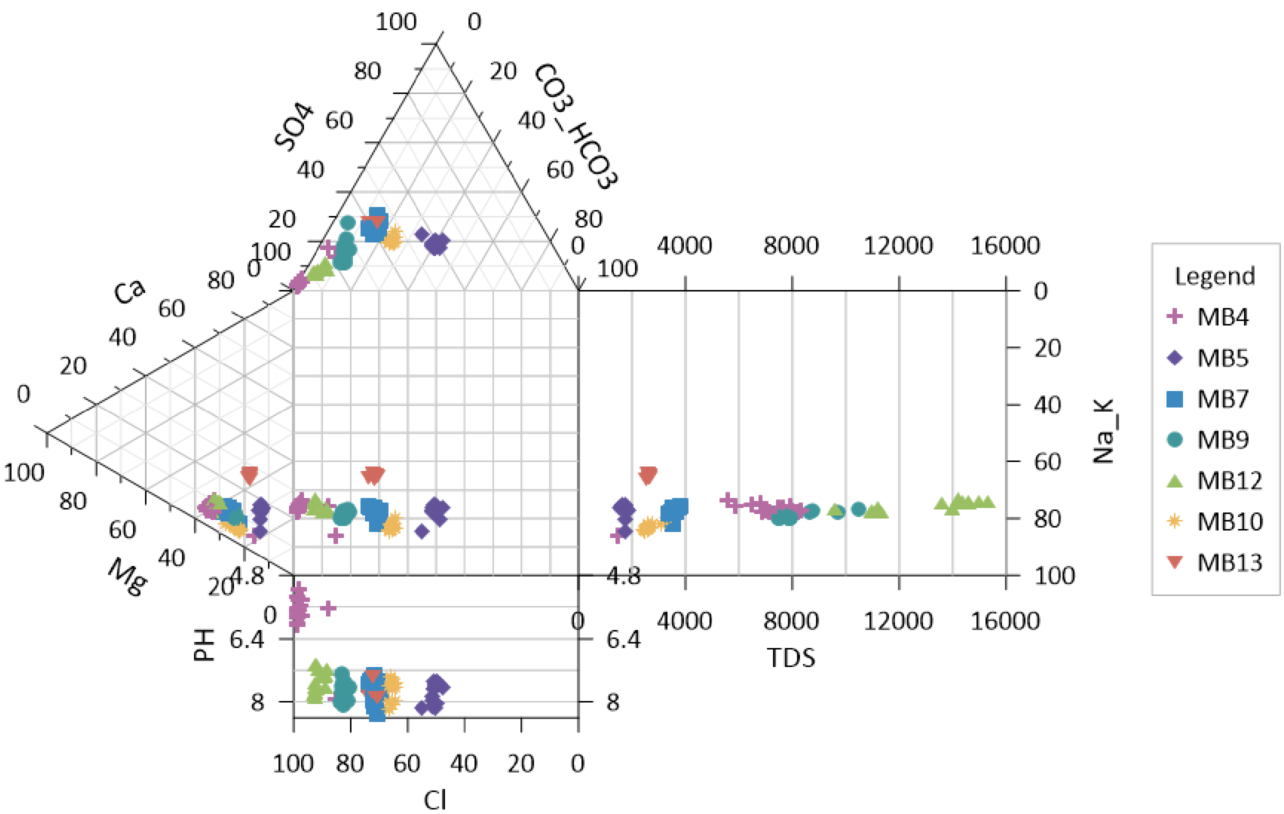


Figure 5-10 Extended Durov diagram for site specific monitoring bores

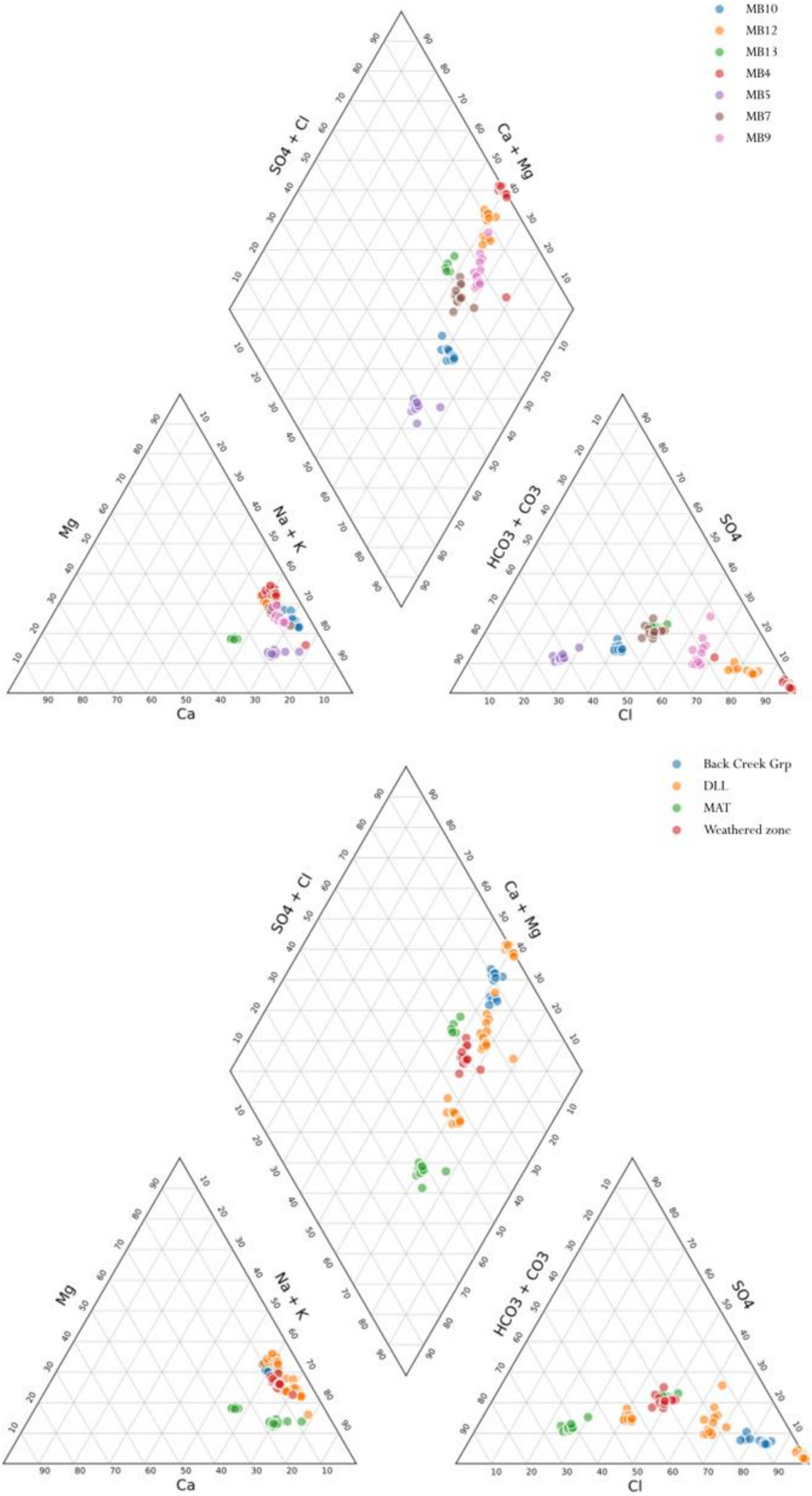


Figure 5-11 Piper diagram for site specific monitoring bores

5.7.2. Environmental values

As described in Section 2.1.1, the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) is made pursuant to the provisions of the EPP Water and Wetland Biodiversity, which is subordinate legislation under the EP Act. The EPP Water and Wetland Biodiversity provides a framework for identifying EVs for Queensland waters, and deciding the WQO to protect or enhance those EV. The Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) document contains EV (Section 2, Table 1) and WQO for waters (including groundwaters) in the Isaac River Sub-basin.

For Isaac groundwaters, the EVs selected for protection are listed as follows:

- aquatic ecosystems;
- irrigation;
- farm supply/use;
- stock water;
- primary recreation;
- drinking water; and
- cultural and spiritual.

An assessment of groundwater quality is presented below, in terms of the relevant EV used in the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011). Although the EVs are not selected for protection of industrial use, this has also been included for completeness as mine water use is an important aspect given the number of coal mines operating in the catchment.

Aquatic ecosystems

The WQO, for aquatic ecosystems, where groundwaters interact with surface waters, is that groundwater quality should not compromise the identified EV and WQO for those waters. For example, Table 1 lists a WQO of <720 µS/cm for Upper Isaac River catchment waters. **hydrogeologist.com.au** interprets that groundwater that is identified to support the Upper Isaac River catchment surface waters should not exceed 720 µS/cm. None of the site monitoring bores reported such a low salinity; with all reporting field ECs > 2,700 µS/cm.

The deep groundwater (Section 5.2) in all bores with the exception of MB05, in addition to the brackish to highly saline groundwater quality and the absence of significant groundwater-surface water interaction in the Project area (Section 5.5) would render almost all the local groundwater unsuitable for use for GDEs because it is mostly out of reach (too deep for terrestrial flora) and its quality could not support fresh or marginal water ecosystems.

Farm Use / Irrigation

Table 3 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) refers to the suitability for farm supply/use WQO as "*Objectives as per AWQG*". The AWQG (2018), however, bundles the guidelines, in Section 4.2, for irrigation and general water use. Hence, these EVs will be discussed together.

The objectives for pathogens and metals are provided in Tables 8 and 9 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011). For indicators other than pathogens and metals, the WQOs are those included in the AWQG (2018). For most pastures and loams and clays, the salinity threshold in Table 4.2.5 of the AWQG (2018) is between 1,000 µS/cm and 7,300 µS/cm.

In addition, the AWQG (2018) warns that certain combinations of salinity and sodium adsorption ratio (SAR) are likely to induce degradation of soil structure and corrective management may be required (e.g., application of lime or gypsum). Groundwater within the Project area would be classified as "marginal quality" in Figure 4.2.2 of the AWQG (2018) (i.e., soil degradation may occur if the water was used for irrigation depending on soil and rainfall) and would therefore need caution if used for irrigation.

hydrogeologist.com.au interprets that the brackish to highly saline groundwater, and all the indications for low sustainable bore yields (low airlift rates, low hydraulic conductivities and thin coal seams) preclude the potential use of the local groundwater for irrigation supply. In other words, neither the quantity nor the quality of local groundwater is suitable for irrigation.

Livestock watering

The review of DRDMW GWDB and the bore census data indicate that groundwater in the area may be used for limited livestock beef cattle watering. There are 14 records within 5 km of the numerical flow model domain previously classified as "*water supply*" (Section 5.6.1). Some of these may be used for mine supply and others for private farm supply that may or may not include livestock watering.

Information (Section 5.7.1) from local monitoring bores suggests that groundwater quality (salinity) varies from brackish to highly saline. Although some groundwater is within the guidelines for livestock watering, Section 4.3.3.5 of the AWQG (2018) states that loss of production and a decline in animal health occurs if stock is exposed to high salinity water for prolonged periods. For beef cattle, decline or loss may occur if the EC is between 7,463 µS/cm and 14,925 µS/cm.

Of the local groundwater, MB05, MB07 and MB10 have EC that is less than 7,463 µS/cm, with the maximum of 5,890 µS/cm; MB04 and MB09 are mostly between 7,463 µS/cm and 14,925 µS/cm. Groundwater at MB12 is greater than 14,925 µS/cm.

At the Saraji Mine, adjacent to the Project area, the regional (Tertiary and Permian) groundwater was generally not considered suitable for livestock (AECOM, 2016). **hydrogeologist.com.au** concurs with this interpretation but notes that, although the local groundwater is generally not considered suitable for livestock, limited livestock watering may occur and therefore should be recognised as an EV because of the three monitoring bores that returned EC less than 7,463 µS/cm.

Primary recreation

This category of EV is considered not applicable to local groundwater. There are no groundwater springs in the Project area (Section 5.6.2) that could be considered for recreational use. This EV is more common for surface water features that are readily accessible for recreation.

Drinking water suitability

The site-specific groundwater quality data, as presented in Section 5.7.1, indicates that groundwater is generally unsuitable for human consumption before treatment primarily due to elevated levels of salinity. The WQO in Table 4 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) specifies an EC of 400 µS/cm as suitable for drinking quality and none of the site monitoring bores yield groundwater of such low EC. All reported field ECs are greater than 2,700 µS/cm and the median field EC for all local samples (Table 5-11) is 5,752 µS/cm, 14 times higher than specified by Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011).

Table 4 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) also refers to a sodium objective of 30 mg/L and a total hardness objective of 150 mg/L as $CaCO_3$ in raw water. The local groundwater contains both sodium and total hardness well in excess of such objectives. The minimum concentration of sodium in any of the groundwater samples to date is 389 mg/L, and the minimum concentration of total hardness is 242 mg/L.

Groundwater within the Project area is therefore not considered suitable for drinking because it would require significant treatment.

Cultural and spiritual values

There are no groundwater springs or seeps (Section 5.6.2) that supply surface water bodies in the Project area known to have significant indigenous and/or non-indigenous cultural heritage associations.

Industrial Use

Table 3 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) provides no defined WQOs for industrial uses:

"Water quality requirements for industry vary within and between industries. The AWQG do not provide guidelines to protect industries, and indicate that industrial water quality requirements need to be considered on a case-by-case basis. This EV is usually protected by other values, such as the aquatic ecosystem EV".

The nearest industries to the Project area are coal mines. **hydrogeologist.com.au** understands that Vitrinite may intend to use some of the groundwater inflow to the proposed pit, if available after evaporation, for industrial purposes as inflows will be captured within the on-site water management system. This brackish to highly saline groundwater may be used for dust suppression during mining activities. No industrial users, other than mines, appear to be within close proximity of the Project area and the salinity of the groundwater would likely impede most industrial uses. It is the view of **hydrogeologist.com.au**, therefore, that the EV associated with industrial use should be recognised in this report.

Summary

In summary, the evaluation of groundwater EV in the Project area indicates that groundwater in the Tertiary regolith and/or Permian coal measures is of no, or limited value, for most uses and may potentially have the following EVs:

- livestock beef cattle watering (limited); and
- industrial purposes, limited to dust suppression in mining.

5.7.3. Water quality objectives

The Project area is adjacent to the Isaac-Dawson groundwater quality zone (No. 34) of Raymond and McNeil (2011). Groundwater within Zone 34 is described as slightly to moderately saline ('shallow' groundwater, within 30 mbgl) or slightly to very saline ('deep' groundwater, deeper than 30 mbgl). Groundwater within Zone 34, both shallow and deep, is of sodium-chloride (Na-Cl) type; that is, sodium is the dominant cation and chloride is the dominant anion.

WQOs have been developed to maintain or improve the quality of groundwater within the zone, i.e., maintain or reduce salinity. The percentile statistics provided in the WQOs are broad and it is expected by **hydrogeologist.com.au** that local groundwater within the Project area would naturally differ somewhat from the percentiles provided for the entire Zone 34. The statistics and percentiles presented in the WQOs provide a general indication of expected groundwater quality and are not to be used as triggers or exceedance criteria.

The WQOs for Zone 34 (Table 14 - Fitzroy groundwater: water quality objectives (aquatic ecosystem) according to water chemistry zones), provides the following EC percentiles for deep groundwaters in Zone 34:

- 20^{th} percentile:3,419 µS/cm EC;
- 50^{th} percentile or median: 6,100 µS/cm EC; and
- 80^{th} percentile: 16,000 µS/cm.

Table 5-13 lists the statistics for Zone 34 (deep) for EC and other analytes. The data for Zone 34 (deep) are compared with the median of all data (maximum of 95 counts, from 17 rounds and up to seven bores in each round). Although the EC for these bores spans a wide range, the median for EC, 5,575 µS/ cm, is below the 50^{th} percentile statistics provided for Zone 34 (deep), 6,100 µS/cm.

Of the major constituents and physical measures, the median of local monitoring data compares well with the Zone 34 statistics for Ca; while total hardness, observed alkalinity, Mg, SO_4 and HCO_3 are in excess of the 50^{th} percentile statistics provided for Zone 34. The observed median lab pH, Cl, Na and SAR are below those of the Zone 34 statistics.

Of the minor constituents, the median of local monitoring data is below the Zone 34 statistics for observed silicon (as SiO_2). The results for dissolved metals (Cu, Fe, and Zn) are probably unduly affected (biased towards the small values) by the large proportion of less than detectable results (for the purposes of Table 5-13, a value equivalent of less than the detectable limit was ignored).

Table 5-13 Zone 34 deep percentiles and medians of preliminary local monitoring data

Analyte	Unit	20th	50th	80th	Median of local monitoring data*	Comments
EC	(µS/cm)	3,419	6,100	16,000	5,575	Lab EC excluding the initial results for June 2019# for MB04 and MB09
pH		7.4	7.8	8.03	7.60	Lab pH excluding the initial results for June 2019# for MB04 and MB09
SO_4	(mg/L)	25	138	398	560	
Fe	(mg/L)	0	0.05	0.246	0.64	As dissolved Fe, influenced by large number of less than detectable, <0.05 results

Note: **From 18 preliminary monitoring rounds*

 # As per Table 5-11, these values are considered anomalous.

5.8. Conceptual model

The southwest to northeast conceptual hydrogeological cross-section of **hydrogeologist.com.au** is presented in Figure 5-4. This conceptual cross-section is based on the review of various reports, data and information, as summarised in Sections 3 to 5.7 of this report.

The hydrogeological units shown in Figure 5-4 are as follows:

- Tertiary sediments / weathered zone / regolith (extensive, generally between 1 m to 30 m);
- Fort Cooper Coal Measures – Permian overburden;
- Moranbah Coal Measures – Permian overburden;
- DL coal seam (extracted at Saraji Mine);
- Moranbah Coal Measures – Permian interburden;
- DLL coal seam (extracted at VCM);
- Back Creek Group – Permian interburden;
- MAT coal seam (proposed to be extracted at the matilda pit); and
- Back Creek Group – Permian underburden.

The west to east section in Figure 5-4 is sub-parallel to the lateral groundwater flow direction (Section 5.4.4). The groundwater table is hosted by several units, from the outcropping/sub-cropping Back Creek Group in the west through the Tertiary sediments and Moranbah Coal Measures to the Fort Cooper Coal Measures in the east. As a result of the sloping groundwater table and the easterly dip of the hydrogeological units, some of the units may be partially unsaturated, particularly in the west, as is shown in Figure 5-4.

A minor component of rainfall recharge (Section 5.4) acts on the top of the land surface. Evapotranspiration occurs from groundwater that is situated within the extinction zone above the deeper groundwater table. Significant evaporation (Figure 5-9) is only likely to occur from the proposed and existing nearby mine pits. There is no interaction between surface and groundwater within and surrounding the Project area.

The western boundary in Figure 5-4 is a catchment and groundwater divide in the Harrow Range. The eastern, regional conceptual model boundary adopted is the Jellinbah Fault Zone, which is a north-west trending zone with several easterly dipping thrust faults with throws in the order of 100 m to 500 m (URS, 2012).

As can been seen from Figure 5-4, the DLL coal seam at the VCM and the DL coal seam at the Saraji Mine, have been depressurised and dewatered. Because of the low hydraulic conductivity and the low storage of the units within the Moranbah Coal Measures, the cones of depression surrounding the mines are expected to be deep (to pit depth) but laterally limited.

Once mining, depressurisation and dewatering cease, groundwater will start to recover and eventually will reach steady state in the backfilled material within the former pit. The recovery processes will largely be driven by the boundary conditions discussed above and the hydraulic parameters discussed in Section 5.3.

6. Impact assessment

6.1. Summary of numerical modelling

6.1.1. Objectives

The conceptual model presented in Section 5.8 has been used as the basis to develop a numerical groundwater flow model. This process, including model build, calibration and predictions is summarised in this section.

The objectives of the numerical model are to assess the quantitative impacts of the Project both in terms of drawdown and groundwater fluxes. Due to the existence of numerous coal mines, especially Saraji Mine within close vicinity of the Project, groundwater impacts will need to be quantified with respect to the Project only and cumulatively.

6.1.2. Design

The numerical groundwater flow model was originally developed to support the EA application for the Vulcan Coal Mine. The full model development and calibration has been previously presented and is summarised below.

The MODFLOW-USG (Panday *et al.*, 2015) code, based on the U.S. Geological Survey MODFLOW-2005 groundwater modelling code, was used. MODFLOW-USG simulates groundwater flow using a finite-difference approach and allows non-orthogonally structured grids to be used for groundwater flow simulations (Panday *et al.*, 2013). Model calibration and parameter sensitivity analysis was undertaken using Model-Independent Parameter Estimation and Uncertainty Analysis (or PEST, Doherty, 2019a and 2019b) and BEOPEST (or efficient parallel run management version of PEST, Doherty, 2012).

The model domain consists of a maximum of 22,492 cells per layer extending over a total area of 650 km^2. The area of individual cells varies between 5,000 m^2 and 911,000 m^2. In general, this area is small for cells close to the proposed pit (50 m x 100 m), existing mines (150 m x 250 m) and main surface water drainages; and is large towards the outer margins of the model (Figure 6-1). This is to improve the convergence and resolution of the numerical model in places with the most potential to present changes in groundwater drawdown and flux.

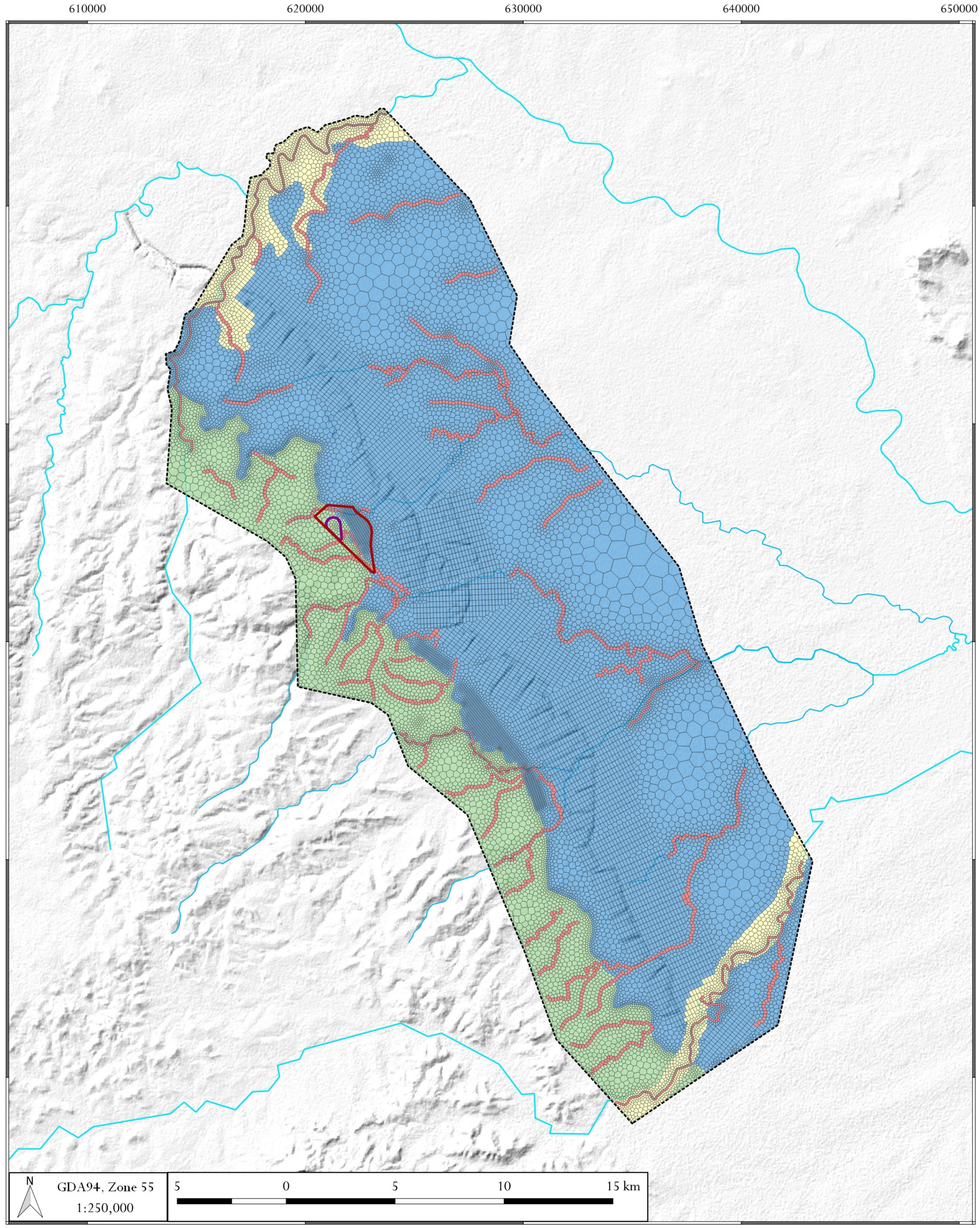
The temporal discretisation adopted consists of a pre-calibration steady state model leading into 48 year-long calibration period (1972 – 2019) and predictive (mining) period (Table 6-1).

Table 6-1 Temporal discretisation – calibration and predictive models

No. of stress periods	Stress period length	Dates	Modelling phase
Steady state	N/A	N/A	Pre-calibration
1 - 47	1 year	01/01/1972 – 31/12/2018	calibration
48 - 51	3 months	01/01/2019 – 31/12/2019	
52 - 55	3 months	01/01/2020 – 31/12/2020	prediction - mining
56 – 78	6 months	01/01/2021 – 30/06/2032	

The boundary conditions selected for the model are based on the description of the hydrogeology (Section 5, the numbers refer to Figure 6-2):

1. NW no-flow boundary (parallel to regional groundwater flow (Section 5.4.4) system in the north-west;
2. Jellinbah Fault Zone boundary;
3. SE no-flow boundary (parallel to regional groundwater flow (Section 5.4.4) system in the and south-east; and
4. SW no-flow boundary.



LEGEND

ML700060

Matilda pit

Watercourse

Recharge zones

1 - Regolith

2 - Alluvium

3 - above DLL outcrop

4 - River cell

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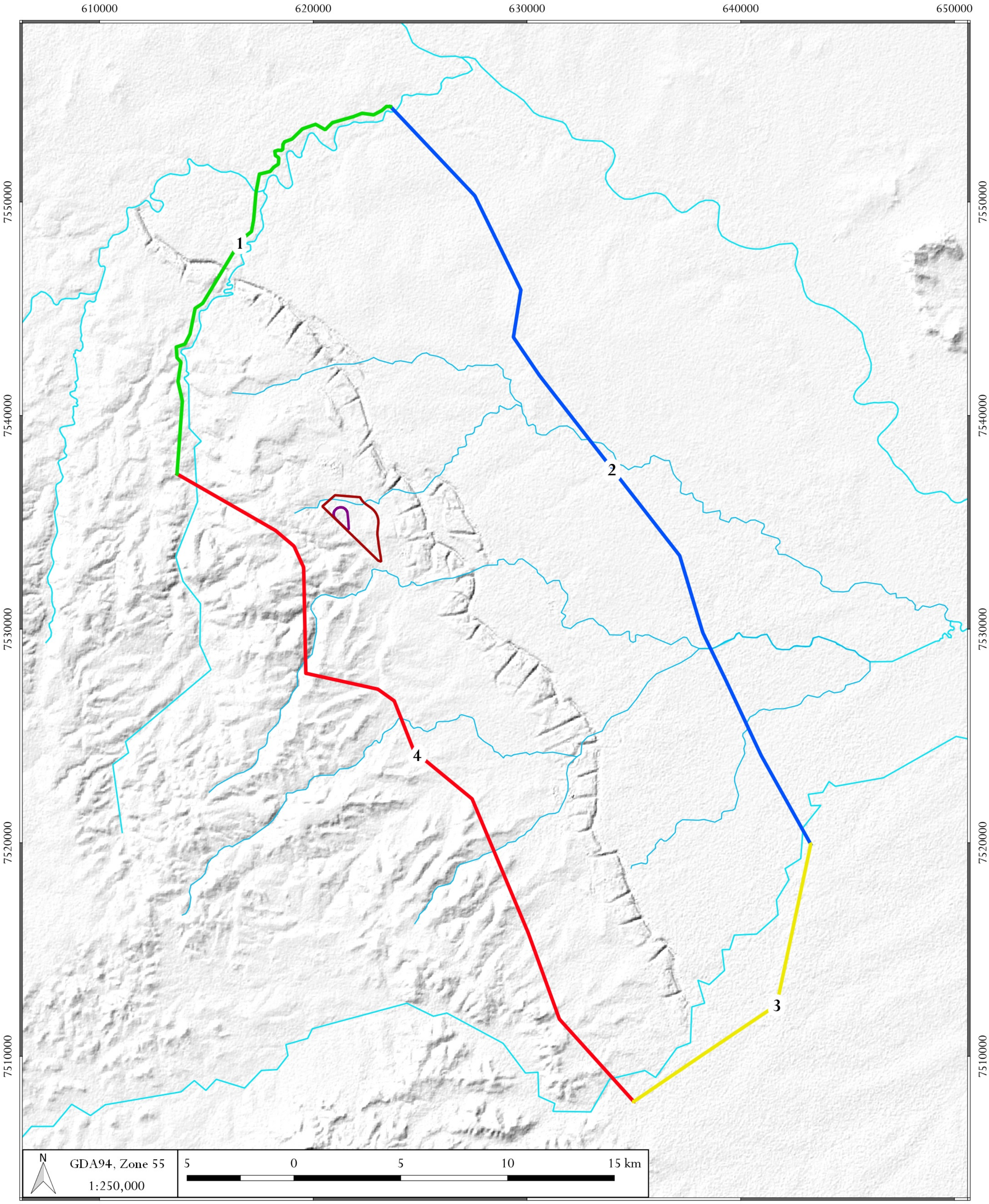
Model mesh and recharge zones

FIGURE No.
6.1

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\06_01_4124_Matilda_Vulcan South_Model mesh_recharge zones.qgz



LEGEND

ML700060

Matilda pit

Watercourse

Model boundaries

1 - NW no-flow boundary

2 - Jellinbah Fault Zone boundary

3 - SE no-flow boundary

4 - SW no-flow boundary

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21/06/2022

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Boundaries of the model domain

FIGURE No.
6.2

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\06_02_4124_Matilda_Vulcan South_Model domain boundaries.qgz

The hydro-stratigraphic units (Section 5.8) are represented by a total of eleven layers (Table 6-2), from discrete and isolated zones of Quaternary alluvium through to the lowermost and extensive Permian Back Creek Group. Several hydro-stratigraphic units (Fort Cooper Coal Measures and overburden, and the Moranbah Coal Measures interburden between the DL and DLL coal seams) are represented by two (split) layers to improve model convergence.

Key model layers for this assessment include layer 2 (Tertiary sediments) and layer 11 (representing mining from the Matilda pit). Model layer 7 represents the DL coal seam which is mined at Saraji Mine and model layer 10 (DLL coal seam) represents mining from the approved VCM pit.

Table 6-2 Model layering

Hydro-stratigraphic unit	Model layer
Quaternary alluvium	1
Tertiary sediments / weathered Zone / regolith	2
Fort Cooper Coal Measures	3
	4
Moranbah Coal Measures overburden	5
	6
DL coal seam	7
Moranbah Coal Measures interburden	8
	9
DLL coal seam	10
Back Creek Group	11

Surface water

Surface watercourses are represented by the MODFLOW-USG river (RIV) package. If the head (groundwater elevation) in the cell connected to the river drops below the bottom of the river bed, water enters the groundwater system from the river at a constant rate. If the head is above the bottom of the river, water will either leave or enter the groundwater system depending on whether the head is above or below the head in the river. The calculated water flux is proportional to the difference between the groundwater and river heads.

Recharge/discharge

Groundwater recharge from rainfall was applied to the uppermost saturated model layer as a percentage of rainfall. Zonation was applied to the modelled recharge to represent the following key areas (Figure 6-1, numbers correspond to the recharge zones) or systems:

1. regolith (east of DLL subcrop);
2. Quaternary alluvium (associated with major creeks);
3. regolith (west of DLL subcrop); and
4. river cells.

Recharge to the steady state model was applied as a percentage of the annual average rainfall from the SILO data (Section 3.1, 582 mm/yr). Recharge for the transient calibration period of 1972-2019 (Table 6-1) was applied as a percentage of actual rainfall data (SILO data) accumulated over the stress period[1]. Recharge for the predictive model was applied as a percentage based on long-term (1900-2018) averages (SILO data) for the stress period length. Evapotranspiration was not explicitly modelled as it was incorporated into the rainfall recharge applied to the model.

[1] Stress periods are used to define time intervals during which the inputs for the model remain constant.

Initial hydraulic parameters

The initial hydraulic parameters (starting values, upper bound and lower bound) were based upon the values derived from existing reports, site specific data and a general knowledge and experience in the region. These values were applied on a trial and error basis initially to inform the general behaviour of the model, then applied using PEST to develop the calibrated solution.

Drains

Mining (both historical and proposed) was simulated using the drain (DRN) package. Site specific information on the Project enabled an accurate representation of mine progression in accordance with the proposed mining schedule. The drains were applied to the Tertiary sediments (layer 2) and the MAT seam (layer 11) in the Matilda pit area.

For the representation of the Saraji Mine, historical mine development was captured in five yearly images downloaded from Landsat then digitised. The general extent of mining was then formulated into an annual sequence to approximate historical mine progression. The DRN cells were generally applied to the base of the DL coal seam (layer 7) for Saraji Mine. For the approved VCM, drains were applied to the DLL coal seam (layer 10).

6.1.3. Transient calibration

The numerical model includes a steady-state and a transient calibration (1972 to 2019). The transient calibration captures historical development at Saraji Mine and Peak Downs Mine which was based upon an interpolated mine progression assessed from Landsat imagery.

In accordance with the Australian groundwater modelling guidelines (Barnett *et al.*, 2012), the objective of a model calibration is to replicate the groundwater levels measured in the site monitoring network and other bores. A set of 55 selected observation points (and a total of 176 observations) were used in the calibration process, some with single values and some with time-series observations. The observation points included historical observation data from mining investigations (AECOM, 2016), publicly available sources (AECOM, 2016; Department of Natural Resources, Mines and Energy, 2019), and on-site data collected from open drill-holes and data collected from the new monitoring bores (**hydrogeologist.com.au**, 2019).

A scatter diagram of observed vs. modelled groundwater elevations (Figure 6-3) indicates that most points are situated close to the 1:1 line (perfect fit). While outliers do exist, most of the observations are within ±5 m of the 1:1 line. It is important to note that no significant or obvious trends or systematic departures appear to occur from the 1:1 line (the various colours representing different hydrogeological units scatter around the 1:1 line in a generally random pattern).

An overall (all observations and all time steps) transient calibration was achieved with an RMS (root mean square error) of 3.6 m and an SRMS (scaled root mean square error) of 4%. The SRMS value of 4% (3.6 m / 90.5 m=0.04 or 4%) indicates a good fit between measured and modelled data. Notwithstanding that, other criteria (such as good correlation between measured and modelled hydrographs and contour maps) also apply, an SRMS that is less than 10% may be acceptable (Barnett *et al.*, 2012) while an SRMS < 5% represents generally good calibration in the experience of **hydrogeologist.com.au**.

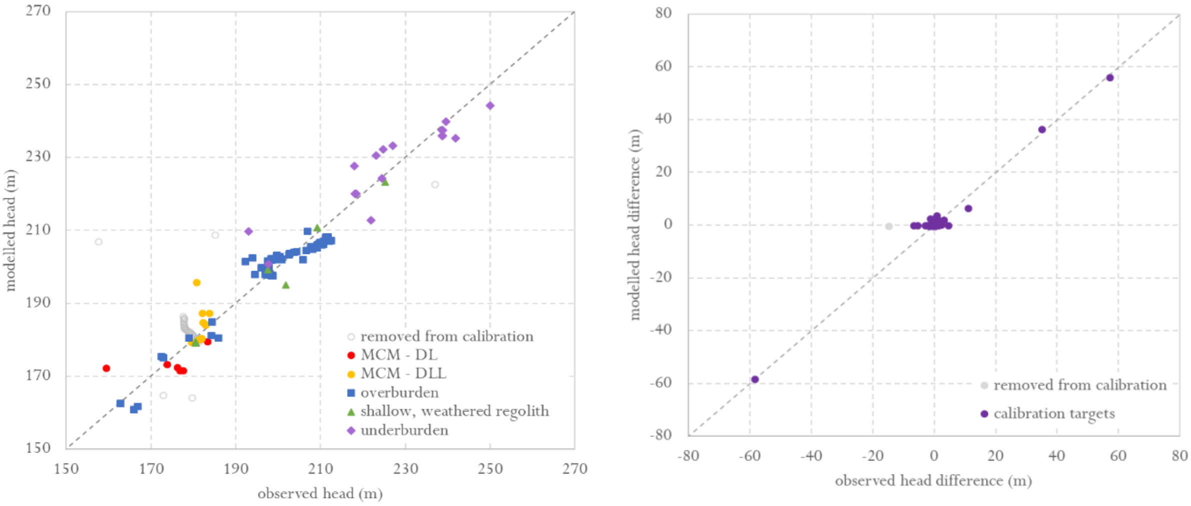


Figure 6-3 Model calibration scatter diagrams – observed and modelled heads and head differences

6.2. Predictions

The model predictions presented below are based upon 'mine' vs 'no mine' model scenarios to determine the true impact of the Project on the groundwater system. The 'mine' scenario simulates the Project (Matilda pit) along with the approved Vulcan Coal Mine, Saraji Mine and Peak Downs Mine; the 'no mine' scenario simulates the approved Vulcan Coal Mine, Saraji Mine and Peak Downs Mine only. The differences in drawdown and fluxes, between the 'mine' and 'no mine' scenarios, represent the impact of the Project on the groundwater system.

6.2.1. Mine inflows

Figure 6-4 shows the predicted inflow to the proposed Matilda pit. The prediction shows a maximum inflow of less than 3 m^3/d occurring in Year 1 (or 2023) of mining and gradually reducing thereafter.

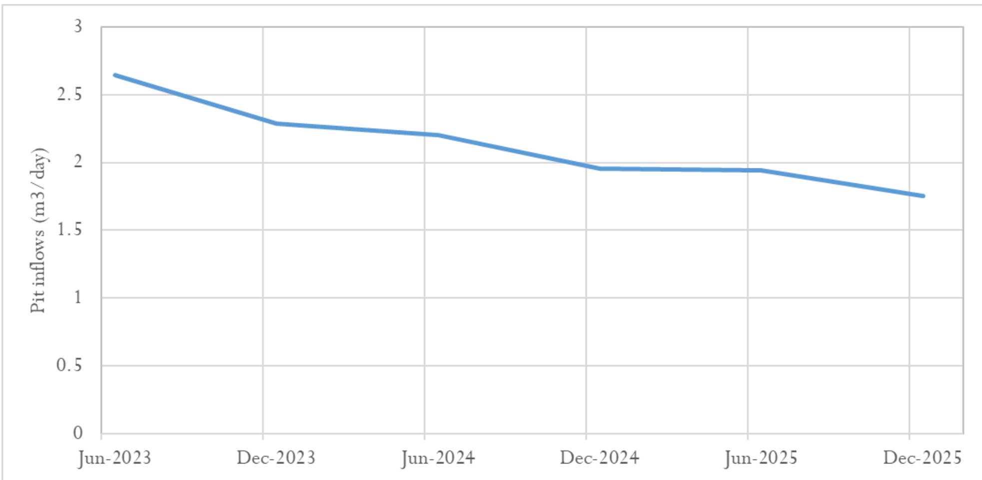


Figure 6-4 Predicted mine inflow rates

Table 6-3 summarises the predicted inflows rates and volumes for the proposed Matilda pit. The rate of inflow to the Matilda pit is consistent with Figure 6-4 and shows that the maximum inflow is less than 3 m^3/d occurring in Year 1 (or 2023) of mining. The maximum annual volume of predicted inflow to the Matilda pit is less than 1 ML/yr.

Table 6-3 Numerical model – zone budget – predicted inflow rates for the Project

SP	days	SP end	DRN inflow (m^3/day)	Volume (ML/year)
60	181	30/06/2023	2.648	0.900
61	184	31/12/2023	2.288	
62	182	30/06/2024	2.201	0.760
63	184	31/12/2024	1.952	
64	181	30/06/2025	1.945	0.675
65	184	31/12/2025	1.756	

Overall, the predicted groundwater seepage to the proposed pit is very low and will very likely be lost through evaporation on the pit face or as entrained moisture within the mined coal. Hence, seepage to the pit is very unlikely to be observed during the Project.

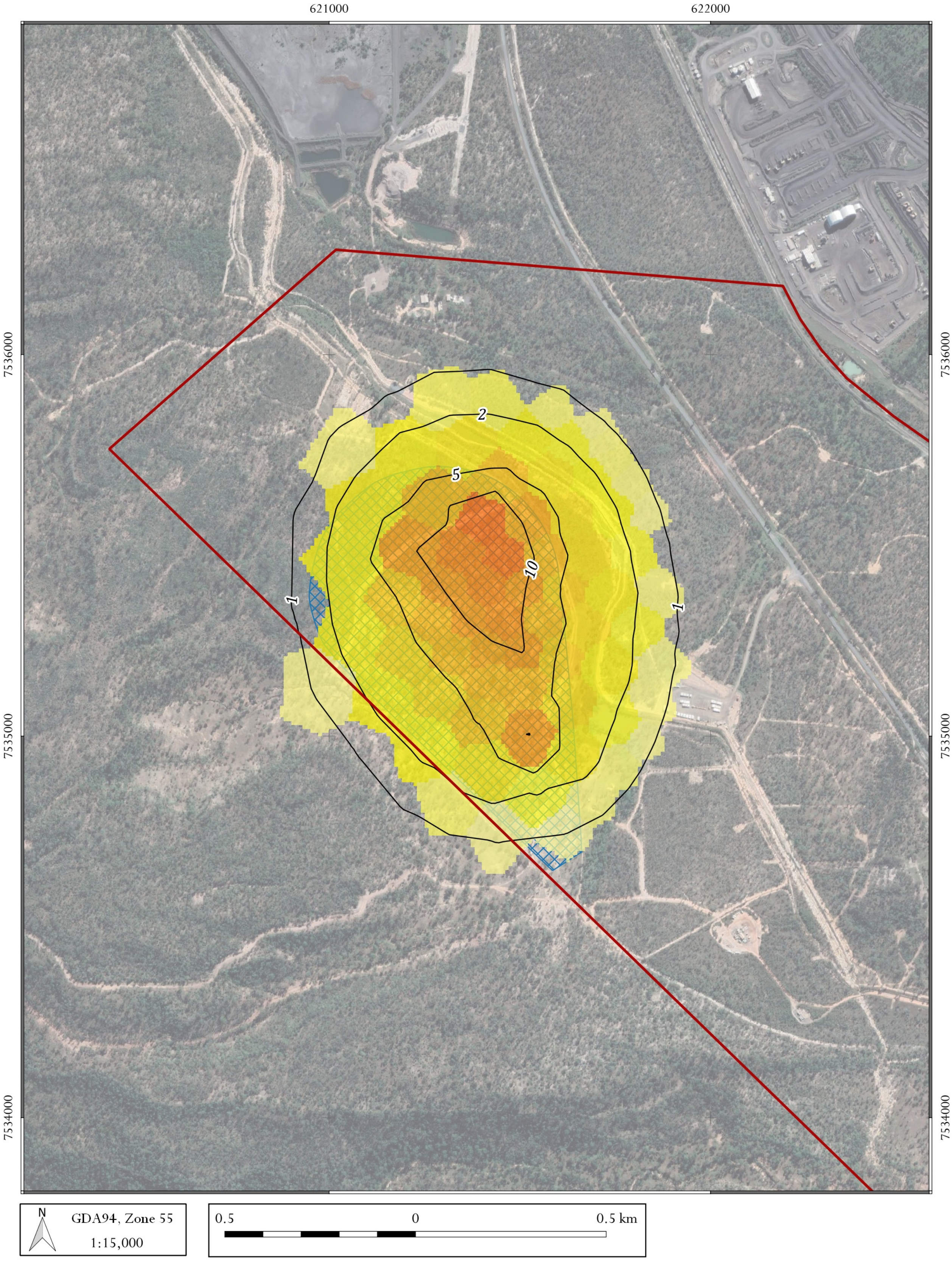
6.2.2. Drawdown

There is no predicted drawdown in the Tertiary / weathered zone (layer 2) as this layer is already dewatered in the 'no mine' scenario.

The predicted drawdown in the MAT seam (layer 11) is shown in Figure 6-5. The figure shows the maximum predicted drawdown throughout the model simulation. The drawdown represents the Project only drawdown and does not include the impacts of Saraji Mine, Peak Downs Mine, or the approved VCM pit.

The maximum predicted drawdown in layer 11 is less than 20 m in the vicinity of the proposed pit. The 1 m drawdown extent reaches up to 300 m from the proposed pit crest, indicating drawdown is very limited.

The proposed pit is to be backfilled following mining and therefore no residual drawdown is expected to occur post closure. There may be some minor change to the local groundwater elevations and flow directions post closure, however these are expected to the negligible and will not result in impact to the groundwater regime.



LEGEND

- ML700060
- Matilda pit
- 1
- 2
- 5
- 10

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05/08/2022

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Predicted drawdown in MAT coal seam (L11)

FIGURE No.
6.5

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\4124_matilda_sensitivity_max drawdown in L11.qgz

6.2.3. Sensitivity analysis

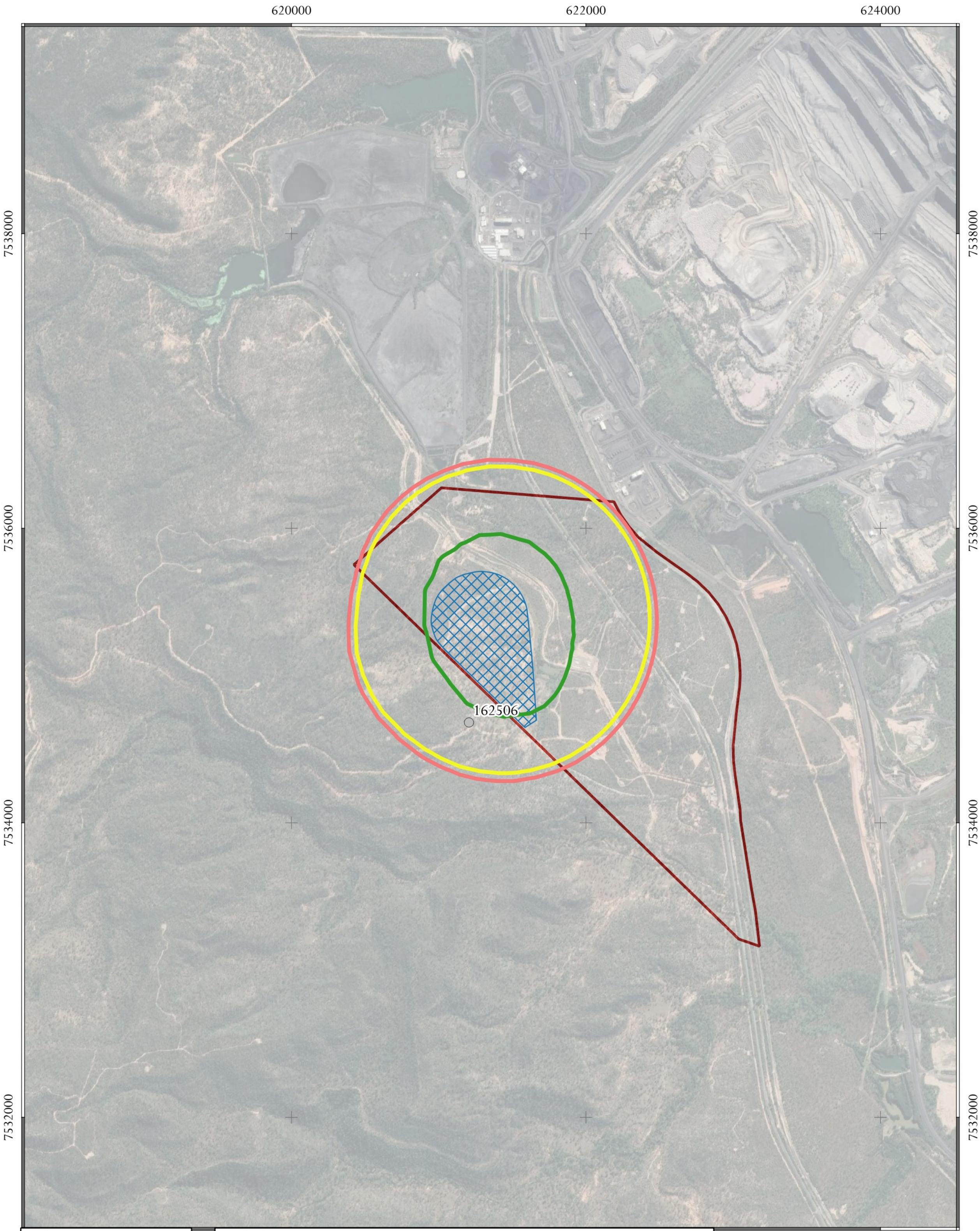
Sensitivity analysis was carried out to understand the possible change of inflows and drawdown from the model by adjusting some key model parameters of the Project. Two changes were considered:

1. the horizontal hydraulic conductivity of layer 11 was increased by one order of magnitude, denoted as the 'K+'; and,
2. the specific yield and specific storage of layer 11 was decrease by one order of magnitude, denoted as the 'S-'.

Both models were run using with the 'mine' and 'no mine' scenarios. The predicted pit inflows and drawdown were then processed and compared with the 'basecase' model (with calibrated parameters) to analyse the model sensitivity.

The maximum drawdown (represented by a 1 m contour) generated from the sensitivity analyses for the MAT coal seam (layer 11) are shown in Figure 6-6 along with the 'basecase' model predictions. The K+ and S- scenarios result in comparable maximum drawdown extents. The 1 m contour for the sensitivity analyses (Figure 6-6) predicts drawdown extending up to 800 m from the Matilda pit crest.

The K+ scenario shows a higher inflow with over 13 m^3/d at the beginning of mining (Figure 6-7), while the predicted inflow in the S- scenario is around half of that in the basecase scenario.



GDA94, Zone 55

1:40,000

1.5 0 1.5 km

LEGEND

- ML700060
- Matilda pit
- 1 m maximum drawdown - basecase
- 1 m maximum drawdown - K+
- 1 m maximum drawdown - S-

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Sensitivity analysis – maximum drawdown (L11)

FIGURE No.
6.6

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\06_08_4124_matilda_sensitivity max drawdown in L11.qgz

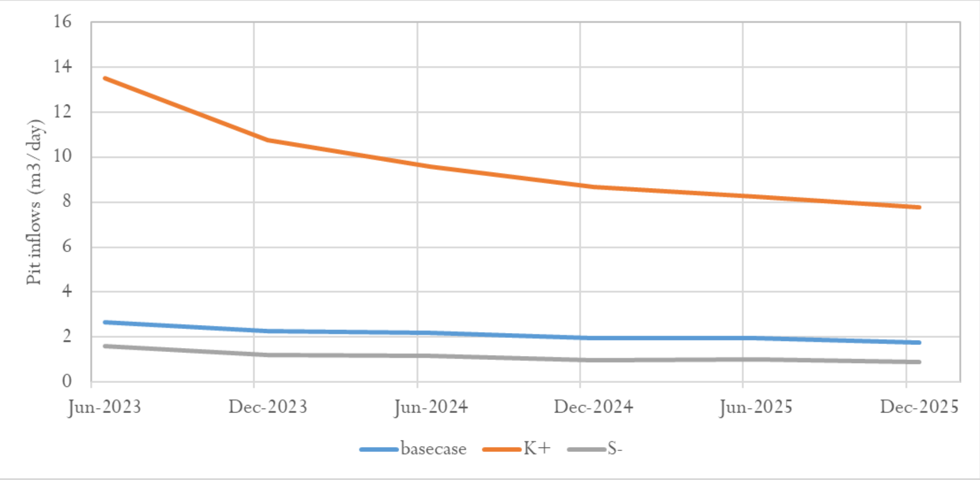


Figure 6-7 Sensitivity analyses - predicted mine inflow rates

6.3. Impacts on users

As Figure 6-5 indicates, the predicted extent of maximum drawdown in the MAT coal seam (layer 11) is limited. There are no third-party groundwater users within the predicted extent of drawdown, hence impacts on existing users are considered very unlikely. The nearest third party bore to the proposed pit is RN162506, at a distance of 100 m from the 1 m predicted drawdown contour line. However, the sensitivity analysis shows that RN 162506 falls within the 1 m extent of maximum probable drawdown (Figure 6-6) and could be impacted by the Project. Vitrinite should confirm the presence of RN 162506 with the landholder and this bore should be monitored for future impact (Section 7).

6.4. Impacts on surface drainage

In Section 5.4 (Figure 5-3), the mechanism of recharge from surface water systems in the Project area was presented. Further discussion of the surface – groundwater interaction followed in Section 5.5 and it was concluded that there was no significant surface-groundwater interaction in the Project area.

The predicted changes in modelled groundwater in- or out-flow from/to river (RIV) cells due to the Project only are generally less than 0.13 m^3/d (or 130 L/d) over the entire model domain and are therefore considered negligible. For these reasons impacts on surface waters are considered extremely unlikely.

6.5. Impacts on GDEs

Figure 6-8 shows the maximum predicted drawdown in layer 11 anytime during the modelling and the location of mapped aquatic GDEs. There are no mapped potential aquatic GDEs within the maximum predicted project drawdown.

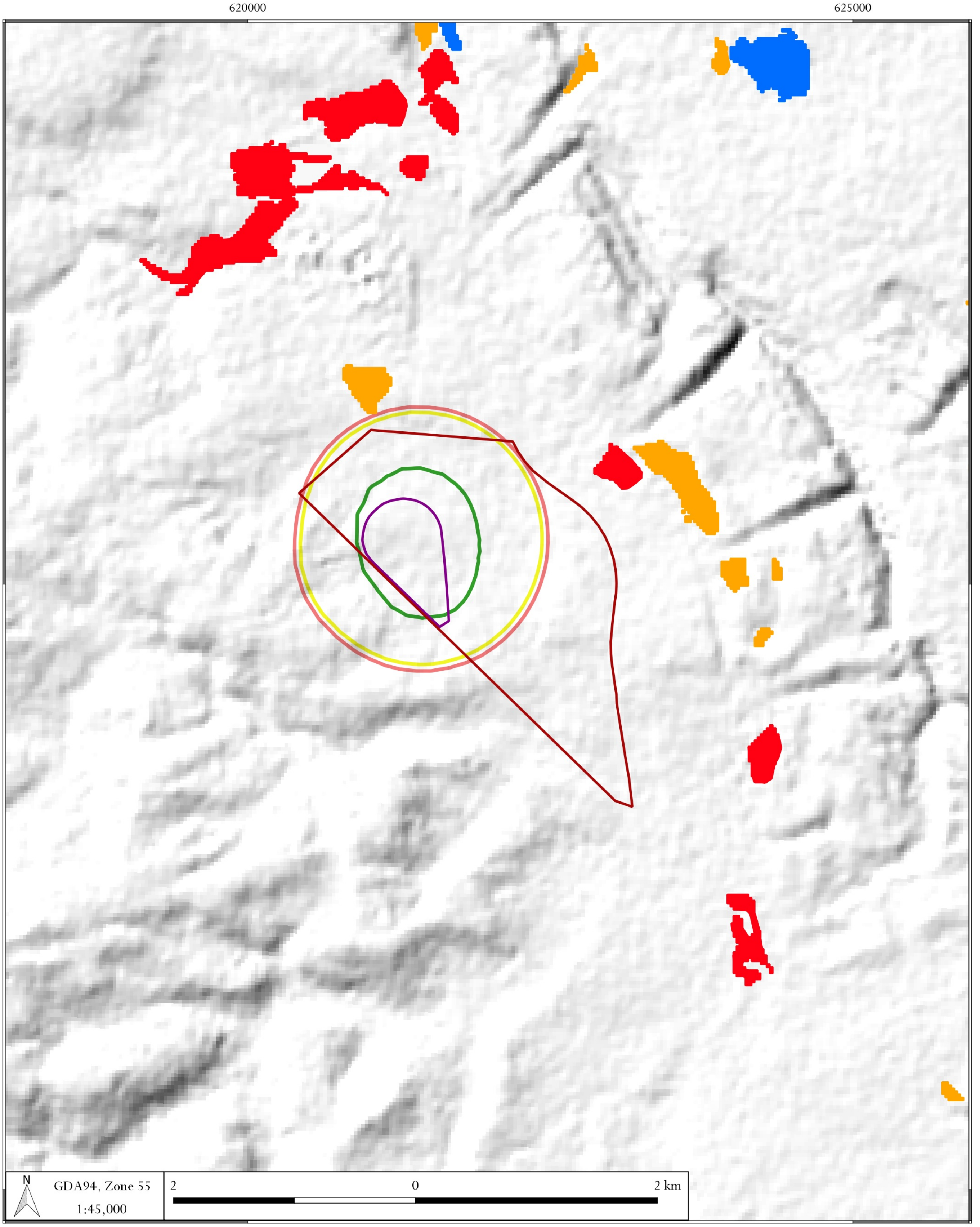
In Section 5.6.2, it was the interpretation of **hydrogeologist.com.au** that there were no valid aquatic GDEs within 3 km of the VCM. This is because aquatic GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where the seasonally high groundwater potentiometric heads are above or close to the corresponding surface water heads. This is necessary to maintain a hydraulic gradient from the groundwater to surface water, or at least have a hydraulically 'connected' system. Within or adjacent to the Project area, the surface water systems are above the groundwater table (see Section 5.5) and the surface water system is hydraulically disconnected from the groundwater system.

In addition, groundwater in the Project area is brackish to saline and therefore unsuitable for the maintenance of freshwater GDEs (see Section 5.7 for further information on groundwater quality). Further, aquatic GDEs associated with a number of separate wetlands along the Moranbah – Dysart Road, between Phillips Creek and Boomerang Creek, all appear to be manmade impoundments associated with Saraji Mine or pastoral properties.

Figure 6-9 shows maximum predicted drawdowns anytime during the modelling and the position of mapped terrestrial GDEs. Figure 6-9 indicates very small and insignificant overlaps between the drawdown affected areas and mapped terrestrial GDEs adjacent to the proposed Matilda pit.

As stated in Section 5.6.2, it is the experience of **hydrogeologist.com.au** that terrestrial GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where depth to groundwater is less than 10 m. Analysis of the depth to groundwater data surrounding the Project area identified that groundwater was typically recorded at levels deeper than 15 m (Figure 5-9) and likely to be outside of the accessible reach of Eucalypt vegetation. The nearest areas with depth to groundwater less than 10 m (red or orange colours that are not associated with the artefact of gridding near Saraji Mine) are approximately 3 km to the south-west of the proposed pits and even these areas are associated with aquatic features (Hughes Creek) not terrestrial ones.

For the reasons stated above, **hydrogeologist.com.au** interprets that there is no valid aquatic or terrestrial GDEs within the maximum drawdown zones and impacts on GDEs are considered highly unlikely. The reader is directed to the Vulcan Coal Mine – Ecological Impact Assessment report for further information regarding the presence of aquatic or terrestrial GDEs.



LEGEND

- ML700060
- Matilda pit
- 1 m maximum drawdown - basecase
- 1 m maximum drawdown - K+
- 1 m maximum drawdown - S-

Aquatic groundwater dependent ecosystem

- High potential GDE - from national assessment
- High potential GDE - from regional studies
- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment

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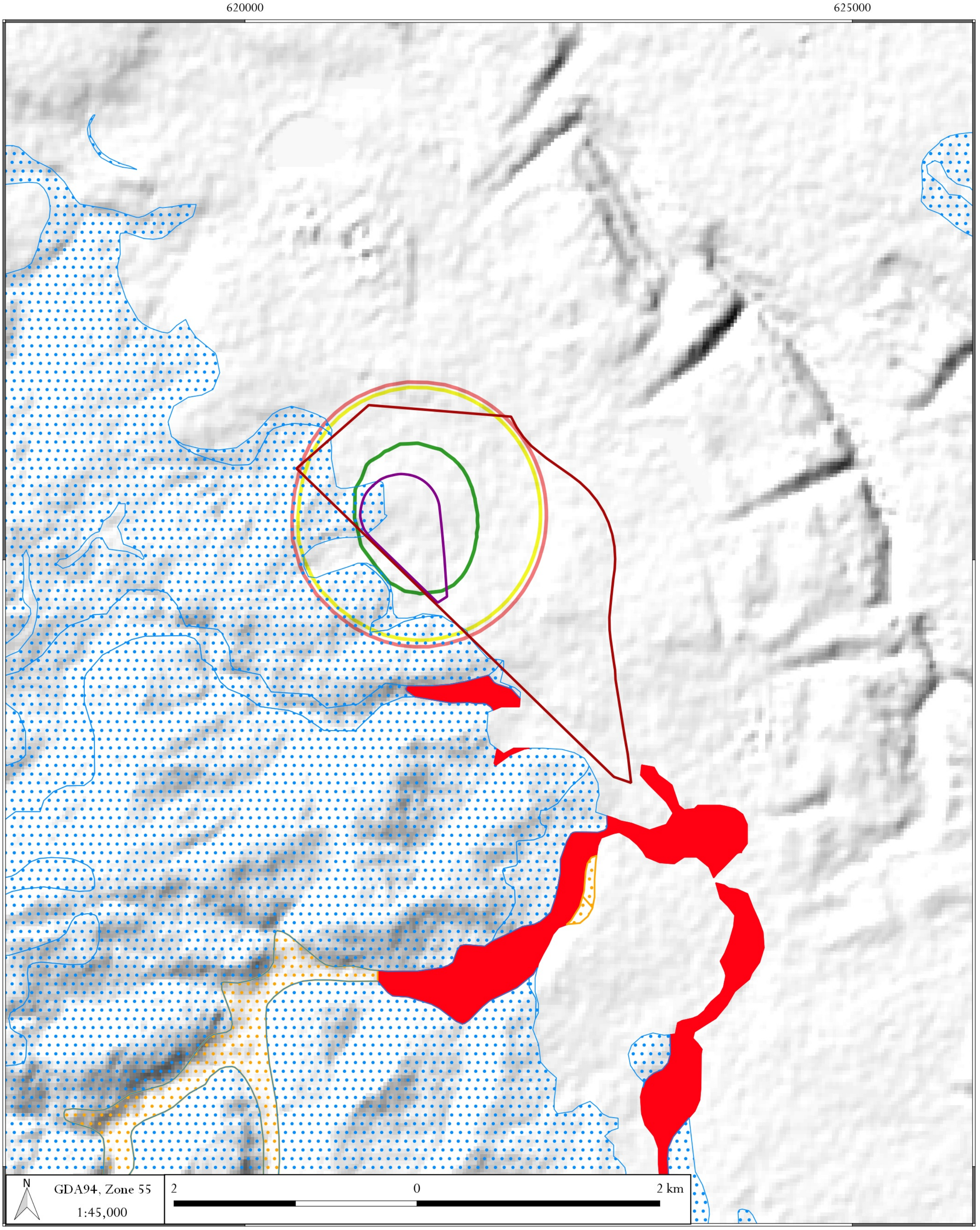
Maximum drawdown and aquatic GDEs

FIGURE No.
6.8

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_08_4124_Matilda_Vulcan South_Aquatic GDEs.qgz



LEGEND

- ML700060
- Matilda pit
- 1 m maximum drawdown - basecase
- 1 m maximum drawdown - K+
- 1 m maximum drawdown - S-

Terrestrial groundwater dependent ecosystem

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Moderate potential GDE - from regional studies
- Low potential GDE - from national assessment

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Maximum drawdown and terrestrial GDEs

FIGURE No.
6.9

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_09_4124_Matilda_Vulcan South_Terrestrial GDEs.qgz

6.6. Impacts on groundwater quality

During mining, the proposed Matilda pit, VCM and the Saraji Mine pits will act as sinks for surrounding groundwater. Any local contamination of groundwater will report to the mine pit and be contained during operations. The ex-pit and in-pit waste rock emplacement areas will be progressively rehabilitated during mine development and therefore no final voids or evaporative sinks will remain in the Project area. Groundwater is predicted to recover towards the pre-mining groundwater levels, subject to mining plans that include the adjacent Saraji and Peak Downs Mines. It is assumed that the pit voids at Saraji Mine and Peak Downs Mine will likely remain into perpetuity and will behave as regional evaporative sinks on the groundwater system, hence minimising any eastward migration of potential contaminants.

The evaluation of groundwater EV in the Project area (Section 5.7.2) indicated that groundwater is of no, or limited value for most uses because of the high salinity. Local groundwater was found to be brackish to highly saline and even an unprecedented 50% increase in salinity would not impact on the beneficial uses identified (livestock beef cattle watering (limited); and industrial purposes, limited to dust suppression in mining). This is because the salinity of local groundwater is well in excess of the WQOs for aquatic ecosystems and drinking water suitability.

All mine infrastructure areas such as workshops, fuel and chemical storage areas will be developed in accordance with current Australian Standards, including adequate bunding and spill kits. These engineering and administrative controls will assist in preventing groundwater contamination. Impacts on groundwater quality, associated with local contamination from mine activities are considered highly unlikely.

6.7. Cumulative impacts

Cumulative impacts have been assessed by representing historical and proposed mining for Saraji Mine, Peak Downs Mine and VCM. The Saraji Mine and Peak Downs Mine have been active since the 1970s. The VCM has been in operation since 2021. The impacts of these approved mines (Saraji Mine, Peak Downs Mine and the VCM) have been predicted in isolation of the Project and in a cumulative sense through the development of the 'mine' vs 'no mine' model scenarios. For the purposes of this assessment, the cumulative impact on groundwater is represented in Figure 6-10.

The graph shows the long-term model predicted inflows (on a log scale) to the Saraji Mine and Peak Downs Mine with recent and proposed average annual inflow rates in the order of 3,000 m^3/day to 5,000 m^3/day. The proposed mining inflow rates at the Saraji Mine and Peak Downs Mine correlate with AECOM (2016). The model predicted inflows to the approved VCM are also shown in Figure 6-10 with predicted inflows between 0.9 m^3/day and 40 m^3/day. The minimal inflow rates predicted for the Project (maximum inflow rate of 2.65 m^3/d) represent less than a 0.1% increase in groundwater seepage within the model domain.

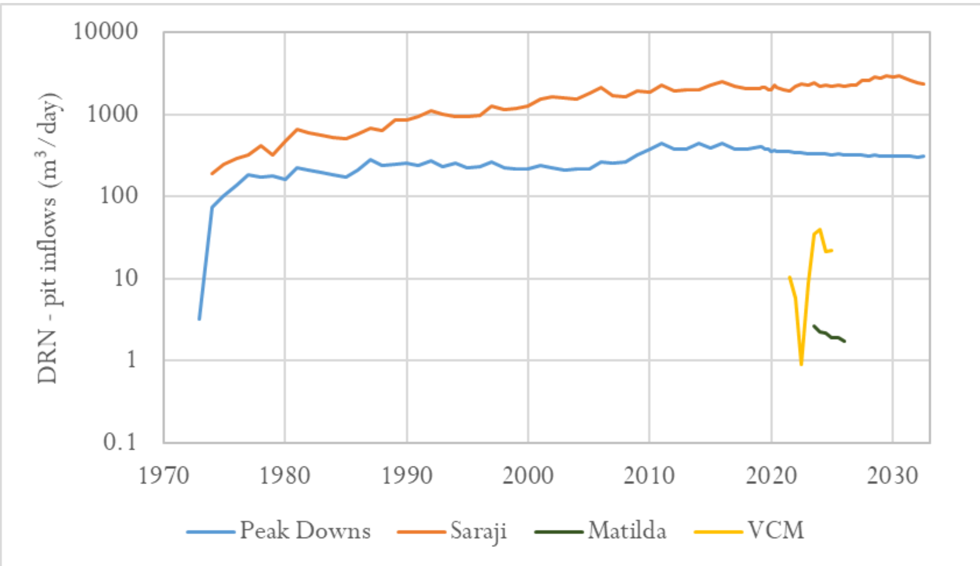

Figure 6-10 Predicted inflow rates – Saraji Mine, Peak Downs Mine and Matilda pit

7. Management and mitigation

7.1. Licensing

The proposed pit will intercept groundwater from Groundwater Unit 2 (sub-artesian aquifers) under the Water Plan (Fitzroy Basin) 2011. The predicted take of groundwater, based on the numerical model (Section 6.2.1) and the life of the Project, will involve allocation of up to 0.9 ML/year from Groundwater Unit 2. This annual inflow rate was calculated as the product of the maximum daily inflow, 2.65 m^3/d (Table 6-3) over an annual period.

The predicted take of groundwater for the approved VCM, involves up to 14.6 ML/year from Groundwater Unit 2 (based on the maximum predicted daily inflow of 40 m^3/d). Combined, the predicted take of groundwater from the VCM will be 15.5 ML/year from Groundwater Unit 2.

Post mining, there will be no requirement for a perpetual water licence as the pit will be progressively backfilled. No final void will remain in the Project area and therefore no evaporative sink will act on the groundwater regime. Groundwater is predicted to recover towards the pre-mining groundwater levels, subject to on-going mining that may occur at Saraji Mine and Peak Downs Mine.

7.2. Adaptive management strategy

The following section summarises the proposed framework for the on-going Groundwater Management Strategy to be developed to assist with the management and mitigation of drawdown and potential water quality impacts. An adaptive management strategy is proposed to assist with the management and mitigation of drawdown and potential water quality impacts. The framework of the adaptive management strategy includes the following components which will be defined in the EA.

7.2.1. Drawdown

The predicted drawdown resulting from the Project is shown in Figure 6-5 and Figure 6-6. Section 6.2.2 discusses and summarises the extent and magnitude of drawdown, and Section 6.2.3 through to Section 6.7 discuss the resulting impacts of this predicted drawdown on the surrounding environment.

The current groundwater monitoring network (Section 5.2) implemented at the VCM is considered fit for purpose for this assessment and will form the basis for ongoing drawdown monitoring and management through the life of the Project. The groundwater monitoring network may be regularly amended to ensure it remains representative of groundwater conditions and fit for purpose.

Monitoring of groundwater levels from the groundwater monitoring network will enable natural groundwater level fluctuations (such as responses to rainfall recharge) to be distinguished from potential groundwater level impacts (drawdown) due to dewatering/depressurisation resulting from proposed mining activities. Automatic data loggers are currently installed in the groundwater monitoring network and they will continue to be used to enable daily measurements. These data loggers should be downloaded regularly to coincide with groundwater quality sampling.

Some of the site-specific monitoring bores are situated adjacent to the predicted drawdown zone. Groundwater level data from all monitoring bores within the groundwater monitoring network will be assessed in a biennial comparison between actual and modelled drawdowns. This annual comparison and assessment will be completed in consideration of the DSITI (2017) guidelines for *using monitoring data to assess groundwater quality and potential environmental impacts*. This assessment will allow for verification of the numerical model predictions.

Private water supply bore RN 162506 is the nearest third party bore. The bore is located 100 m from the predicted extent of drawdown. Pending agreement to access the bore, quarterly groundwater level monitoring of this bore would provide benefit in understanding the regional behaviour of the groundwater regime in relation to mining. Any Project related impacts at RN 162506 would be mitigated through Make Good Provisions under the Water Act (see Section 2.1.1).

There is merit in a groundwater data sharing arrangement between Vitrinite and BHP. Routine groundwater level and quality monitoring from Saraji Mine and Peak Downs Mine would provide Vitrinite with a greater understanding of the hydrogeological system responses during mining.

Given the low pit inflow predictions, limited extent of drawdown and unlikely impacts on the groundwater regime, regular updates to the numerical model are not likely to be required. However, it will be important to compare and assess on a biennial basis the groundwater level observations against the modelled predictions to verify that observations are consistent with model outputs.

Every three years, consideration will be given for the redevelopment and or recalibration of the numerical groundwater model. Any such redevelopment or recalibration of the numerical groundwater model may require an iterative review of the conceptual hydrogeological model. This may result from measuring hydraulic responses that are inconsistent with the conceptual understanding or model predictions, changes to the mine plan, or modification of potential contamination sources.

The reporting obligations proposed as part of on-going Groundwater Management Strategy will be defined as conditions in the EA.

7.2.2. Groundwater quality

Groundwater quality monitoring and sampling of the groundwater monitoring network will continue in order to comply with EA conditions and to collect further information on the groundwater system. Groundwater quality parameters monitored at the VCM will continue to comply with the parameters specified in the EA. The monitoring and sampling will be carried out in consideration of DES (2018a).

Interim groundwater quality limits have been developed from site-specific data collected to date and are conditions in the EA. If site-specific data is not available, default guidelines have been implemented until data allows for site-specific limits to be developed. Following further data collection, current groundwater quality limits are required to be updated in April 2023 to better reflect the site-specific water quality at each monitoring bore conditioned in the EA.

7.3. Mitigation measures

No mitigation measures are currently proposed or required as part of the Project. There are no impacts predicted for third party groundwater users and surface water systems. Impacts to GDEs are considered highly unlikely as are impacts on groundwater quality and EV. Should monitoring and subsequent assessment determine potential impacts, mitigation strategies would be considered commensurate with the level and risk of environmental impact.

8. Conclusions

hydrogeologist.com.au has prepared a groundwater impact assessment to support the EA amendment for the Vulcan Coal Mine. The EA amendment involves the open cut mining of coal from the MAT coal seam of the Permian Back Creek Group from a single pit (the Matilda pit).

The main hydro-stratigraphic units occurring at the Project area include the Tertiary sediments or weathered zone (regolith) and the Permian coal measures. There is no Quaternary alluvium present within the Project area. The Permian MAT coal seam is partially / variably saturated over the Project area and the Matilda pit will intersect the regional groundwater table which has been historically depressurised by mining at Saraji Mine and Peak Downs Mine. A portion of mining will occur above the regional groundwater table.

Groundwater quality within the mined coal seam (and within other hydro-stratigraphic units) is generally brackish to saline and this is consistent with other mine sites in the region. The groundwater quality within the Project area has limited or no environmental value and potentially may be used for livestock beef cattle watering and / or industrial purposes (such as dust suppression for mining operations).

The groundwater quality is considered too saline to support aquatic GDEs and the depth to groundwater is considered too deep to support terrestrial GDEs. There are limited third party groundwater users in the region and Vitrinite has developed a clear understanding of where these third-party groundwater bores are located.

A numerical groundwater flow model has been modified to support the groundwater impact assessment and has been undertaken in accordance with relevant Australian guidelines. The model is assessed to be a reliable and acceptable simulator of historical mining activities and of groundwater level behaviour in and surrounding the Project area. Future predictions have been made by representing proposed mining at Saraji Mine and Peak Downs Mine, and the proposed mining schedule for the VCM.

The model predictions show limited pit inflows (less than 3 m^3/day) to the Matilda pit and it is likely that most of the predicted inflows would be lost through evaporation on the pit face or as entrained moisture within the mined coal. Hence, seepage to the pit is unlikely to be observed during the Project's life. The drawdown predicted from the Project is limited in extent (maximum up to 300 m) and magnitude (up to 20 m in the deepest part of the proposed pit).

The extent of predicted drawdown does not encroach on any of the third-party groundwater users in the region and therefore impacts in this regard are considered very unlikely. Impacts on surface waters and are considered very unlikely. It is the assessment of hydrogeologist.com.au that there is no recorded aquatic or terrestrial GDEs within the maximum drawdown zones and impacts on GDEs are considered very unlikely. Furthermore, impacts on groundwater quality are assessed to be very unlikely and there would need to be an unprecedented change in salinity to affect the current beneficial use and environmental values of the groundwater regime.

An adaptive management strategy is proposed for the Project to assist with the management and mitigation of drawdown and potential water quality impacts. The framework of the strategy includes iterative components which will be defined as conditions in the EA.

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