Australasian Groundwater and Environmental Consultants Pty Ltd

Report on

Underground Water Impact Report Ironbark No.1 Mine

Prepared for
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Project No. G1915F September 2019
www.ageconsultants.com.au ABN 64 080 238 642

Document details and history

Document details

Project	G1915F
Document title	Underground Water Impact Report Ironbark No.1 Mine
Site address	
File name	G1915F_UWIR_v02.01.docx

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Report on

Underground Water Impact Report
Ironbark No.1 Mine

1 Introduction

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) was commissioned by Hansen Bailey on behalf of Fitzroy Australia Resources Pty Ltd (Fitzroy) to prepare an Underground Water Impact Report (UWIR) for the Ironbark No.1 Mine (the mine).

This section provides an overview of the mine, explains the background to the UWIR and describes the scope and structure of the UWIR.

1.1 Mine overview and setting

The project involves the development of an underground coal mine approximately 35 km north-east of Moranbah Township (Figure 1). Fitzroy acquired the mine in November 2016 and obtained an Environmental Authority (EA0001299) for the mine on 13 July 2018.

Construction of the mine is currently scheduled to commence in April 2019. The mine life will be approximately 20 years.

The mine will produce up to approximately 6 Million tonnes per annum (Mtpa) of Run of Mine (ROM) coal. Coal will be extracted from the Leichardt coal seam using longwall and bord and pillar mining methods.

ROM coal will be hauled by truck to the existing Carborough Downs Coal Mine (CDCM) coal handling and preparation plant (CHPP). Product coal will be loaded onto trains at the CDCM train loading facility for transport to port, and exported to overseas markets.

The project site is located adjacent to the Burton open cut coal mine to the north and west, and the Broadlea open cut coal mine to the south (Figure 1).

The topography of the mine site consists of low-lying gently undulating terrain generally of less than 2% gradient (Figure 3). Ephemeral drainage lines cross the site from east to west with the majority of the project site located within the catchments of Bullock Creek, Spade Creek and Alpha Creek (Figure 3).

The geology of the mine site comprises the Permian Rangal Coal Measures and overlying Triassic Rewan Group sediments. These sediments outcrop at the surface or are overlain by Tertiary sediments. Localised deposits of unconsolidated alluvium occur within the creek beds that traverse the mine site.

1.2 Background

Fitzroy acquired the Ironbark No.1 Project (the project) from Ellensfield Coal Management Pty Ltd, a subsidiary of Vale, in November 2016. Prior to this time an Environmental Impact Statement (EIS) had been prepared by Ellensfield Coal Management Pty Ltd, an EIS Assessment Report was issued in 2012 and the project approval process had subsequently been placed on hold by Vale. The EIS included a groundwater impact assessment (discussed in Section 3.1.3).

Fitzroy recommenced the EA approval process in 2017 and obtained an EA for the project on 13 July 2018.

Fitzroy subsequently completed a feasibility assessment and detailed mine design in preparation for the commencement of mine construction. The detailed design process resulted in minor changes to the project. The proponent submitted an application for a minor EA amendment to address these changes. The DES approved the minor EA amendment on 17 January 2019. The EA amendment application was supported by a groundwater assessment (discussed in Section 3.1.3).

The current EA (EA0001299) therefore authorises the mining activities and the associated groundwater impacts described in the EIS and subsequent EA amendment application. It was issued by the Department of Environment and Science (DES) under the *Environmental Protection Act 1994* (EP Act). The EA imposes environmental management conditions on mining activities undertaken on the mine site. The EA conditions set the environmental performance requirements that the project must comply with. Failure to comply with the EA conditions is a breach of the EA and there are various compliance enforcement actions available to DES under the EP Act.

1.3 UWIR scope and structure

The UWIR is a requirement of the groundwater management framework legislated under Chapter 3 of the *Water Act 2000* (Water Act). The main purpose of the UWIR is to describe the groundwater take due to mining (and any associated impacts) over a three-year period (the UWIR period).

This UWIR addresses the initial three years of the project from the commencement of construction. Construction is currently scheduled to commence on 1 April 2019. The planned mining activities during this UWIR period include the construction of a single box cut in the north-west corner of the mine site in the area where the coal seam is shallowest, and the extraction of coal from the longwall and bord and pillar mining areas shown in Figure 2. The mine has not produced any groundwater or exercised its rights to take groundwater prior to this UWIR period.

The UWIR has been prepared in accordance with Section 376 of the Water Act and the Department of Environment and Science (DES) guideline *Underground water impact reports and final reports* (the UWIR guideline), where relevant.

Consistent with the UWIR guideline, the information supplied in support of the EA approval process under the EP Act has been used as the basis for the UWIR. Hence, the scope of work for the UWIR is generally limited to a minor update of the existing approved groundwater assessments to allow information specific to the UWIR period to be presented. The specific scope of the UWIR includes:

- A review of relevant groundwater, project development, geological and environmental reports from the mine site to develop an appreciation of the hydrogeological setting of the project;
- An updated review of hydrogeological data held on the Department of Natural Resources, Mines and Energy's (DNRME's) Groundwater Database to identify water supply bores;
- An updated census of water supply bores to confirm the extent of groundwater use in the area and collect relevant groundwater monitoring data;
- Confirmation of the conceptual model of the groundwater regime of the mine site and its surrounds, based on all available data;
- Refinement of the existing numerical groundwater model to allow the mining effects on groundwater levels to be presented for the first three years of mining only;
- Confirmation of the groundwater impacts over the first three years of mining;
- Confirmation of the existing approved EA groundwater monitoring program and management measures.

The UWIR includes:

- An introduction to the UWIR (Section 1);
- A description of the relevant regulatory UWIR requirements (Section 2);
- A description of the assessment method (Section 3);
- A description of the groundwater regime and sensitive environmental features (Section 4);
- An assessment of the mine's groundwater impacts (Section 5);
- A description of the groundwater monitoring program (Section 6);
- A description of the process for reviewing and updating the UWIR (Section 7); and
- The key conclusions of the UWIR (Section 8).

2 Regulatory requirements

Section 376 of the Water Act specifies the UWIR content requirements. Table 1 lists the specific content requirements and provides an explanation of where each requirement is addressed in this UWIR.

Table 1 UWIR Content Requirements

Water Act Section No.	Water Act Section Content	UWIR Cross Reference
376(1)(a)	An underground water impact report must include each of the following— 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 (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;	(i) No groundwater has been produced or taken from the mine site due to the exercise of underground water rights to date. (ii) Section 5.2 describes the estimated groundwater take over the UWIR period.
376(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 (ii) an analysis of the movement of underground water to and from the aquifer, including how the aquifer interacts with other aquifers; and (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 (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 for the report; and (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;	(i) and (ii) Section 4.1 describes the groundwater regime in the relevant aquifers. (iii) There has been no previous exercise of underground water rights. (iv) Figure 14 to Figure 16 show the areas where depressurisation due to mining is predicted to exceed the bore trigger threshold during the UWIR period. (v) Figure 17 shows the areas where depressurisation due to mining is predicted to exceed the bore trigger threshold during the life of the mine.
376(1)(c)	A description of the methods and techniques used to obtain the information and predictions under paragraph (b);	Section 0 describes the UWIR methodology.
376(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;	Sections 3.1.1 and 5.5.2 describes the water bore census undertaken for the UWIR and confirms that there are no water bores within the area of predicted depressurisation.

Water Act Section No.	Water Act Section Content	UWIR Cross Reference
376(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;	There has been no previous exercise of underground water rights and hence, no previous groundwater impacts due to groundwater take.
376(1)(db)	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— (i) during the period mentioned in paragraph (a)(ii); and (ii) over the projected life of the resource tenure;	Section 5.5 presents an assessment of potential groundwater impacts due to groundwater take.
	A program for— (i) conducting an annual review of the accuracy of each map prepared under paragraph (b)(iv) and (v); and (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;	Section 7.2 describes the UWIR review and reporting process for the affected aquifers.
376(1)(f)	A water monitoring strategy;	Section 6 describes the groundwater monitoring program.
376(1)(g)	A spring impact management strategy;	There are no springs within the mine site or its surrounds. Hence, a strategy for spring management is not justified.
376(1)(h)	If the responsible entity is the office— (i) a proposed responsible tenure holder for each report obligation mentioned in the report; and (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;	Not applicable.
376(1)(i)	The information or matters prescribed under a regulation.	No other relevant information or matters have been prescribed under a regulation.
376(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)(e).	Section 5.3 describes the UWIR review and reporting process for the affected aquifers.

Section 378 of the Water Act lists the content requirements for the water monitoring strategy. Table 2 lists the specific content requirements and provides an explanation of where each requirement is addressed in this UWIR.

Table 2 UWIR Water Monitoring Strategy Content Requirements

Water Act Section No.	Water Act Section Content	UWIR Cross Reference
378(1)	A responsible entity's water monitoring strategy must include the following for each immediately affected area and long-term affected area identified in its underground water impact report or final report— (a) a strategy for monitoring— (i) the quantity of water produced or taken from the area because of the exercise of relevant underground water rights; and (ii) changes in the water level of, and the quality of water in, aquifers in the area because of the exercise of the rights; (b) the rationale for the strategy; (c) a timetable for implementing the strategy; (d) a program for reporting to the office about the implementation of the strategy.	Section 6 describes the groundwater monitoring program.
378(2)	The strategy for monitoring mentioned in subsection (1)(a) must include— (a) the parameters to be measured; and (b) the locations for taking the measurements; and (c) the frequency of the measurements	Section 6 describes the groundwater monitoring program.
378(3)	If the strategy is prepared for an underground water impact report, 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 376(b)(v).	Not applicable. Sections 3.1.1 and 5.5.2 describes the water bore census undertaken for the UWIR and confirms that there are no water bores within the area of predicted depressurisation.
378(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.

3 Assessment methodology

This section describes the methodology adopted for the collection of hydrogeological data to inform the UWIR.

3.1 Desktop study

3.1.1 Database and government mapping reviews for water bores

A search of relevant Queensland databases was undertaken to identify the presence of current water bores within and surrounding the mine. A water bore is a groundwater supply bore.

The following databases and mapping were searched:

- The DNRME Groundwater Database of registered water bore data from private water bores and Queensland Government groundwater investigation and monitoring bores. Data accessed includes bore location, groundwater levels, construction details, stratigraphic logs, hydrogeological testing and groundwater quality.
- The Queensland Spatial Catalogue (QSpatial), via Queensland Globe. Records of petroleum and coal seam gas (CSG) exploration, production and monitoring wells are contained within this database.

These searches identified 46 registered groundwater bores within 5 km of the project mining area (Figure 4). Bore installation records available for these bores identify:

- 10 are the mine groundwater monitoring bores;
- One "water supply" bore (RN81908) located on the Burton Mine site which intersects "salty" water with bore casing into the Rewan Group. This bore was identified in the 2008 groundwater impact assessment (AGE, 2008) which concluded that there was no reliance on groundwater for stock watering; and
- 35 are Broadlea North Mine bores and include monitoring bores and water supply bores. Fitzroy is the owner of Broadlea Mine.

There are 15 records of CSG exploration and appraisal wells installed around the mine area, all of which are not operational and identified as "suspended/capped/shut-in" or "plugged and abandoned". The location of these CSG bores are shown in Figure 4.

3.1.2 Database and government mapping reviews for sensitive environmental features

The potential for groundwater dependent ecosystems (GDEs) to be present within the project site was reviewed, with the review consisting of:

- A search of the Queensland Springs Database;
- A search of the Bureau of Meteorology's (BoM) GDE Atlas;
- Groundwater field investigations; and
- A desktop review of groundwater monitoring data and modelling results.

The Queensland Springs Database indicated that no spring wetlands are located within the project site or its surrounds.

The BoM GDE mapping indicates several potential GDEs in the project site, namely:

- Terrestrial vegetation along the northern and eastern extents of the mining lease which are mapped as low to moderate potential GDEs;

- Terrestrial vegetation along Alpha Creek and to a lesser extent Bullock Creek which are mapped as low to moderate potential GDEs; and
- Aquatic wetland/riverine habitat within watercourses associated with Bullock, Spade and Alpha Creeks that are mapped as high potential GDEs.

A desktop review of the spring inventories has been undertaken using the springs database within the GDE Atlas (Queensland Wetland Data – Springs). The nearest mapped spring is located approximately 130 km northeast of the project site. No springs have been identified with 10 km of the project site. This is consistent with field observations from the creeks which show that there are no perennial pools associated with creeks traversing the project site and its surrounds. On the basis, springs are extremely unlikely to be affected by the project mining activities. Hence, there is no technical justification for a spring management strategy.

3.1.3 Previous groundwater studies

The hydrogeology of the Ironbark site was first assessed by AGE as part of feasibility studies and approvals for the former owner of the project (Vale). This assessment included a field program to investigate the local hydrogeology and numerical modelling to assess the project impacts. Monitoring bores were installed adjacent to the ephemeral drainages that traverse the mining lease and indicated an alluvial aquifer does not occur on the project site, with groundwater occurring within the weathered zone of the underlying Rewan Group. Laboratory analyses indicated the groundwater was brackish to saline limiting the beneficial use of the water. No usage of groundwater was identified.

In 2012, additional investigation of groundwater was undertaken by URS. This work included installing two bores and conducting pumping tests to measure yields and estimate hydraulic properties of the Leichardt Seam. This work indicated the Leichardt Seam forms a low yielding groundwater system confined by the overlying Permian overburden and Triassic Rewan Group. Further groundwater modelling provided refined estimates of groundwater take to the project during operations.

In 2018, additional groundwater investigations were undertaken in response to queries from the DES. This work included measuring groundwater levels, collecting water samples and further groundwater modelling. The fieldwork confirmed previous conclusions that groundwater occurred primarily within the weathered bedrock and was brackish to saline. As part of this work, the numerical model was recalibrated and updated to ensure it represented the influence of subsidence induced fracturing as accurately as possible. This included utilising an empirical method to estimate the height of the fracture network above longwall mining areas. The updated numerical model predicted a reduced seepage rate of groundwater into the mining areas. Updated maps indicating the zone of depressurisation within the coal seam and shallow overburden were developed as part of this work.

3.1.4 Review of groundwater monitoring data

All relevant data was collated and analysed to develop a conceptual understanding of the groundwater regime. Groundwater data collected from the mine monitoring bores has been used to inform this groundwater conceptualisation.

3.1.5 Fitzroy groundwater monitoring network

The groundwater monitoring network for the project site originally comprised eight narrow diameter bores at five sites (EFGW series) and two test pumping bores (PT series). Four bores are screened within the alluvium, four within the Triassic Rewan Group and one in the Leichhardt Seam. Fitzroy recently installed two reference bores (Ref Bore #1 and Ref Bore #2) in October 2018. Ref Bore #1 targets is in the shallow overburden and Ref Bore #2 targets the alluvium. Table 3 summarises the bore construction details with Figure 5 showing the location of the monitoring bores at the project site.

Table 3 Groundwater bore details

Bore ID	Screened stratigraphy	Ground Elevation (mAHD) Ground	Screen interval (mbGL)	Bore depth (mbGL)
EFGW1S	Alluvium	288	8.7 - 11.7	11.7
EFGW2S	Alluvium	323	1.9 - 4.9	4.9
EFGW2D	Overburden sediments	326	25.6 - 28.6	25.6
EFGW3S	Alluvium	310	1.2 - 4.2	4.2
EFGW3D	Overburden sediments	310	27.4 - 30.4	30.4
EFGW4S	Alluvium	302	1.5 - 4.5	4.5
EFGW4D	Overburden sediments	305	37.5 - 40.5	40.5
EFGW5D	Overburden sediments	325	56 - 59	59.1
PT1	Leichardt Seam	*	126 - 138	138
Ref Bore #1	Overburden sediments	*	41 – 47	50
Ref Bore #2	Alluvium	*	18 - 24	30

Notes: *Coordinates are GDA 94 zone 55 – note the site historically used ADG84 and coordinates in previous reports have used this datum.*

** No elevation recorded.*

Spatially distributed groundwater level data were used to characterise groundwater flow directions, gradients and velocities. In addition, time variant variations in groundwater level were used to interpret the rate and distribution of recharge/discharge, depressurisation influence from mining, and pre-development variability in groundwater level.

Groundwater quality data provides useful information on the hydrogeological regime, as it is influenced by interaction with the aquifer matrix, and groundwater recharge/discharge processes.

Salinity is a key constraint to the usability of groundwater resources for productive applications such as potable supply, irrigation, stock watering and industrial applications. If waters with elevated salinity levels are used for incompatible purposes or applications it may result in impacts to agricultural productivity, health and the environment.

A categorisation scheme for salinity proposed by FAO (2013) is presented in Table 4. Groundwater salinity in each project monitoring bore sampled during the field campaign has been categorised using these criteria. DNRME bores within 5 km of the project mining area with available groundwater quality data were also categorised.

There are no records indicating that 'fresh' groundwater has been encountered near the project site.

Table 4 Salinity Classification Scale

Salinity	Range (TDS mg/l)	# project bores with corresponding salinity	# DNRME-registered bores within 5 km with corresponding salinity data
Fresh	<500	0	0
Brackish	500 – 1,500	1	20
Moderately saline	1,500 – 7,000	3	7
Saline	7,000 – 15,000	3	0
Highly saline	15,000 – 35,000	0	0
Brine	>35,000	0	0
Total		**7**	**27**

Major ion data for water quality data collected to date from the project monitoring bores are summarised on a Piper plot (Figure 6) which categorises water type based on the normalised, relative proportion of each major cation and anion. The data shows minimal variation the groundwater quality within the project area which can be classified as sodium-chloride type water. The piper diagram is based on the relative proportions of the major cations and anions. The results of the groundwater quality data collated for the project are summarised in Appendix A.

3.2 Numerical modelling

The mine has an existing 3D numerical groundwater model that was developed as part of the previous groundwater impact assessments described in Section 3.1.3. The groundwater model results have been used to support the EA application and subsequent EA amendment.

The groundwater model has also been used to inform the UWIR. The model has specifically been used to predict groundwater take and resulting groundwater depressurisation. These predictions have been used to identify Immediately Affected Areas (IAA) and Long Term Affected Areas (LTAA) and assess the impacts of the project on groundwater users and the surrounding environment.

To increase the accuracy of the UWIR, the model was updated to incorporate additional details of the mine layout over the first 3 years of mining (as shown in Figure 2). No other changes to the existing groundwater model have been made as part of the UWIR.

The key aspects of the model are detailed as follows:

- The numerical groundwater model was developed from the collated dataset (described in Sections 4.2 to 4.5) using MODFLOW software and represents the conceptual groundwater regime described in Section 4.1.
- The model represents the key geological units using 23 model layers and extends 35 km north-south and 27 km east west. The project mining area was located in the centre of the model domain.
- Model development was supplemented by published geological maps, digital geology surfaces and information from mining operations near the project mining area and data from the DNRME groundwater database.

- The Australian Groundwater Modelling Guidelines (Barnett et al., 2012) were used to frame the calibration process. A detailed description of the calibration method is provided in Appendix B. The groundwater model was initially calibrated to groundwater level records from 36 bores intersecting a variety of aquifers and aquitards; which included the monitoring bores installed during the project mining area investigation. The calibration was guided by water level measurements and site specific measurements of hydraulic conductivity from packer tests and pumping tests within the coal seam, as well as operational observations of groundwater inflow into the neighbouring Carborough Downs Coal Mine.
- A steady state calibration achieved a 13.7% scaled RMS error indicating the model can suitably replicate steady state water levels and is an acceptable calibration metric as recommended by the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). Furthermore, the calibrated groundwater levels, vertical gradients, and flow patterns replicate measured 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 project impacts on groundwater users and the surrounding environment. Section 5 describes the predictions of the groundwater model.
- The sensitivity of the model predictions to the input parameters was tested, and involved varying key model parameters in isolation and assessing the influence 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 range of likely uncertainty in key hydraulic parameters for horizontal hydraulic conductivity, vertical hydraulic conductivity, specific yield and specific storage.
- 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.
- The analysis found that predicted groundwater take was most sensitive to an increase in specific yield, while other parameters do not cause deviations as far from the baseline. The model is least sensitive to a decrease in specific storage.
- Changes to these parameters within the model was associated with an increase in the model error. This indicates that the magnitude of these changes reduced the ability of the model to reliably predict measured groundwater levels, and indicates that the changes made during the sensitivity analyses are likely to represent conservative extremes for these parameters.
- Overall, the results of the sensitivity analysis confirmed that the sensitivity of the model calibration and predictions to changes in model input parameters is in all instances acceptable and the model is fit for purpose.

Appendix B provides the model parameters.

4 Groundwater regime

4.1 Overview

The project site is located on the north-western flank of the Bowen Basin, a sedimentary basin comprising Permian to Triassic age geology (Figure 13). A veneer of more recent weathered sediments typically overlies the Bowen Basin strata (Figure 10). Localised basalt and alluvium deposits are also present within the project site and its surrounds.

The relevant hydrogeological units of the project site and its surrounds broadly comprise:

- Thin localised Quaternary alluvium associated with Bullock Creek, Spade Creek, Alpha Creek and Hat Creek;
- A thin, highly weathered and heterogeneous veneer of semi-consolidated sandstone, mudstone and other minor sediments associated with the Tertiary Suttor Formation, duricrusted palaeosols at the top of deep weathering profiles, colluvium and regolith;
- Low permeability sediments of the Rewan Group; and
- Permian sediments of the Rangal Coal Measures (including the target Leichardt Seam) and the deeper Fort Cooper Coal Measures and Moranbah Coal Measures.

Figure 7 shows a conceptual cross-section of the geology and groundwater regime within the project site and its surrounds. This illustrates the main hydrogeological processes and mechanisms relevant to the project groundwater regime, including recharge, flow directions, discharge, and anthropogenic activities (i.e. mining).

The main groundwater-bearing formations are the coal seams of the Permian sediments. The coal seams have been significantly depressurised and impacted by mining and gas production activities at nearby operations. The Rewan Group is a low permeability formation that is a regionally recognised aquitard.

The alluvium and Tertiary sediments do not form permanent, saturated aquifers, and persistent groundwater occurs only where these sediments extend below the regional water table.

The Tertiary sediments include the Tertiary Suttor Formation which is predominantly a quartzose sandstone/conglomerate unit with minor multicoloured claystone and mudstone and bands of ironstone and silcrete. The Suttor Formation unconformably overlies the Permian and Triassic strata and forms a capping on the hills and ridges (prominent ridge escarpments), rising up to 40 m above the surrounding land surface. These escarpments occur on the eastern boundary and part of the northern and southern boundaries, and as remnant knolls within the project area. They do not form permanent, saturated aquifers, as they occur above the regional groundwater table.

The Clematis Group and basalt are not a significant feature of the local groundwater regime due to their distance from the mining activities.

Recharge occurs predominantly via direct and diffuse rainfall to the Tertiary sediments, localised areas of alluvium, and weathered Permian coal measures. A portion of the rainfall moves downwards to the groundwater table then moves through the system following the hydraulic gradient. This interaction will be enhanced during periods of creek flow (e.g. resulting from significant rain events). Recharge to the Tertiary sediments, Rewan Group and Permian sediments will occur where these units sub-crop below the alluvium.

The regional water table varies within 5 m to 13 m of the surface along the creeks where they are incised into the topography. In areas of higher topographic elevation, the water table deepens from 20 m to over 60 m below the ground surface. That is, the regional groundwater flow is a subdued reflection of the topography from northeast to the southwest (as shown on Figure 9), towards lower lying areas and the existing the Broadlea North Coal Mine to the south. A shallow groundwater gradient of approximately 0.005 has been calculated from local groundwater levels.

Groundwater quality within the project site and its surrounds ranges from moderately saline to highly saline. Regionally, groundwater generally is saline within the Triassic and Permian sediments. There are no known groundwater users in the project site or its surrounds.

Similarly, and as discussed in Section 3.1.1, there is no take of groundwater from the surrounding CSG wells which are all exploration and appraisal wells of which none are operational.

4.2 Alluvium

4.2.1 Distribution

As discussed in Section 4.1, alluvium is mapped as occurring along parts of Bullock Creek, Spade Creek and Alpha Creek. The distribution of mapped alluvium is shown on Figure 10.

However, monitoring bores drilled within the mapped alluvium extents did not intersect alluvial sediments except in EFGW2S and EFGW1S. Similarly, alluvium was not encountered elsewhere within the project site. Its occurrence is confined to a narrow band along the creeks and tributary channels and is relatively thin between <1 m and 10 m, averaging a few metres in thickness. Where alluvium is present, saturated alluvium was only intersected in the lower reaches of Alpha Creek before it flows into Bullock Creek, where it was assessed to be 10 m deep with the lower half saturated. The saturated extents of alluvium are shown in Figure 11. Figure 12 shows the variable nature of the creek beds within the project site, ranging from a sandy base to rock bars where there is no alluvium. The bed sands within the creek will be inundated during periods of rainfall and following ephemeral creek flow. However, the bed sands are thin and will dry rapidly following cessation of creek flows.

4.2.2 Hydrogeological parameters

The hydraulic conductivity of the alluvium is highly variable depending on whether the alluvium consists of clayey or silty sands or clean sands and gravels. Due to the thin saturated thickness and localized occurrence of groundwater in the alluvium, yields are very low. There are no farm bores that have been constructed in the alluvium which confirms that the saturated sections are localized and that the yield is unreliable.

4.2.3 Recharge, flow, and discharge

Recharge to the alluvium occurs via:

- Direct rainfall infiltration to the alluvium; and
- Seepage of perennial surface water flows into the river bed resulting in localised continuous recharge through the alluvium that will dissipate to the surrounding groundwater regime.

4.2.4 Groundwater quality

Groundwater monitoring data shows that the quality of groundwater in the alluvium reflects recharge by river flow and by direct infiltration of rainfall. Groundwater is typically brackish to moderately saline with a neutral to slightly alkaline pH and low concentrations of metals.

4.2.5 Groundwater yields and use

There are no water supply bores targeting the alluvium within 5 km of the project site.

4.3 Tertiary Sediments

4.3.1 Distribution

As discussed in Section 4.1, the Tertiary sediments which include remnant Tertiary sandstone that outcrop east of the project site, are elevated well above the surrounding land surface and are expected to be unsaturated. Elsewhere, these sediments therefore comprise a shallow, highly weathered and heterogeneous veneer of low permeability Tertiary sediments that do not contain any significant volumes of groundwater and are often dry. The distribution of mapped Tertiary sediments are shown on Figure 10.

The Tertiary sediments are not a significant aquifer for the purposes of this assessment.

4.3.2 Hydrogeological parameters

The Tertiary sediments have a low hydraulic conductivity range due to a predominantly low hydraulic conductivity bulk unit that is dominated by clay (regionally it would be comparable to that for the underlying weathered Rewan Group).

4.3.3 Recharge, flow, and discharge

The Tertiary sediments are recharged by direct infiltration from rainfall where these sediments are present at the surface. Recharge also occurs via seepage from the alluvium, where present. Recharge rates are low due to the predominately clayey nature of the formation. Within the project, the Tertiary sediments were assessed to be dry with groundwater not intersected in any of the monitoring bores drilled on site.

4.3.4 Groundwater quality

Where present, regional groundwater quality within the Tertiary sediments is typically brackish to saline. The groundwater quality is therefore be broadly comparable to the underlying Rewan Group.

4.3.5 Groundwater yields and use

The Tertiary sediments are commonly regarded as an aquitard and typically exhibit very low yields (less than 0.1 L/s).

No groundwater supply bores are known to target the Tertiary sediments within 5 km of the project site.

4.4 Rewan Group

4.4.1 Distribution

As discussed in Section 4.1, the Rewan Group sub-crops within the project site. The mapped extents of the Rewan Group are shown on Figure 13.

The Rewan Group is uniformly saturated at depth (i.e. below the groundwater table) and may become unsaturated where it outcrops or sub-crops above the regional groundwater table. The Rewan Group typically host the regional groundwater table in the vicinity of the project site and is therefore typically saturated within the project site and its surrounds.

The Rewan Group is a recognised regional aquitard and acts as a confining unit overlying the Permian sediments.

4.4.2 Hydrogeological parameters

In-situ permeability testing at the project site as part of the initial studies in 2008 indicated a low permeability for the Rewan Group, and hydraulic conductivity values between 0.03 and 0.08 m/d (AGE, 2008).

The Rewan Group is characterised by low primary porosity and as a result, groundwater movement is controlled by local fracture sets. Where fractures are intersected this unit shows slightly higher permeability, and conversely, where limited fractures are intersected this unit shows lower permeability associated with the primary porosity. Bulk permeability of this unit is therefore constrained by the degree of connection between any localised fractures.

4.4.3 Recharge, flow, and discharge

The Rewan Group is recharged via direct rainfall infiltration in outcropping areas and via seepage from overlying units including the Tertiary sediments and alluvium, where present.

The rates of recharge are considered to be relatively low, compared to the alluvial aquifer.

Regionally, the groundwater flow direction follows the regional topography toward the southwest where it slowly discharges to the underlying Permian sediments (Figure 9).

4.4.4 Groundwater quality

Groundwater monitoring data shows that groundwater quality at the project site and its surrounds is brackish to saline and neutral to slightly alkaline with low concentrations of metals. The groundwater quality is therefore broadly comparable to the Permian sediments. The low permeability of this formation and long groundwater residency times are reflected in the concentrations of dissolved minerals that are elevated in comparison to the alluvium.

4.4.5 Groundwater yields and use

The Rewan Group exhibits low yields within the project site and its surrounds (typically less than 1 L/s) that would commonly be regarded as characteristic of an aquitard.

No groundwater supply bores are known to target the Rewan Group within 5 km of the project site.

4.5 Permian Sediments

4.5.1 Distribution

As discussed in Section 4.1, the Permian sediments include the Rangal Coal Measures and the underlying Fort Cooper Coal Measures. The mapped extents of these Permian sediments are shown on Figure 13.

Groundwater storage and movement occurs within fractures and cleats that intersect the coal seams. Other sediments in the coal overburden and interburden sequence exhibit very low permeability and form discrete confining units between the coal seams. The Permian sediments may therefore be categorised into the following hydrogeological units:

- Hydraulically "tight" and hence very low yielding to essentially dry sandstone and siltstone that comprise the majority of the inter-burden/overburden; and
- Low to moderately permeable coal seams which are the primary water bearing strata within the Permian sediments.

The Permian sediments are uniformly saturated within the majority of the project site. Where the coal measures outcrop in the east of the project site and beyond, they may become unsaturated.

4.5.2 Hydrogeological parameters

The hydraulic conductivity within the Permian sediments is a function of fracturing and grain size within the various sedimentary units of the coal measures. The spacing and nature of cleating are the primary controls on hydraulic conductivity within the coal seams.

Regionally, the coal seams and the sediments between, above and below the coal seams have a hydraulic conductivity ranging from and 5.3 x 10-6 m/day to 0.01 m/day (AGE, 2008). The permeability data has been determined from permeability testing for the Burton Coal Mine, coal seam gas investigations at MCG Ellensfield No. 1 well and the nearby Carborough Downs Coal Mines.

4.5.3 Recharge, flow, and discharge

The Permian sediments are recharged slowly by direct rainfall on (predominantly where coal seams outcrop) and downward seepage from the overlying strata. The rate of recharge may be enhanced where the coal measures subcrop against the overlying strata. Overall, the rate of recharge remains low.

Regionally, groundwater flow is to the southwest and potentially to mining areas such as nearby Broadlea North Coal Mine (Figure 9). Groundwater discharge into overlying formations is negligible within the vicinity of the project site.

4.5.4 Groundwater quality

Groundwater quality at the project site and its surrounds is slightly alkaline to alkaline and moderately saline to saline with low concentrations of metals.

4.5.5 Groundwater yields and use

Regionally, groundwater yields from the coal seams are typically low, (i.e. less than 1 L/s).

There are no known groundwater supply bores in the Permian sediments within 5 km of the project site.

5 Groundwater impact assessment

5.1 Introduction

The project involves the development of an underground mine that utilises bord and pillar and longwall mining methods.

Both bord and pillar mining and longwall mining will involve dewatering the underground workings which will result in depressurisation of the overlying and surrounding strata.

Longwall mining will also result in subsidence of the strata above the mined longwall panels due to physical removal of coal from the target seam. Subsidence is predicted to fracture the overlying strata, and this has the potential to enhance the depressurisation effects of mine dewatering.

The bord and pillar mine layout has been specifically designed with sufficient roadway and pillar strength to ensure that there will be no caving and the underground workings will be stable and safe. Consequently, the bord and pillar mining will not result in any significant subsidence above the underground bord and pillar workings.

The following sections provide a detailed assessment of the potential impacts of these activities, as follows:

- Section 5.2 presents the predicted groundwater take over the UWIR period.
- Section 5.3 presents the groundwater drawdown during the UWIR period.
- Section 5.4 presents the groundwater drawdown over the mine life.
- Section 5.5 describes potential impacts to groundwater users and the environment.

5.2 Groundwater take

Table 5 shows the approved annual groundwater take for years 1, 2, and 3 of the UWIR period.

Table 5 Predicted volume of groundwater take

Year	Predicted Inflow (ML)
2020	7
2021	69
2022	190
Total	**264**

The gradual increase from 7 ML in year 1 to 190ML in year 3 is a result of the mine development progressing through the unsaturated sediments and intersecting the groundwater table.

The modelled groundwater take represents the theoretical volume of groundwater that could be removed from the groundwater regime. The actual volume of groundwater pumped from the underground mining area will be less that that predicted by the numerical model, as a component of the groundwater will be lost to wetting of surfaces, ventilation and retained moisture within the extracted coal. The groundwater take presented in Table 5 does not account for the above mentioned losses that will occur when converting groundwater take to mine dewatering rates.

5.3 Groundwater drawdown during the UWIR period

Figure 14 to Figure 16 show the predicted depressurisation within the target Leichardt Seam during the UWIR period. During the UWIR period, depressurisation of the Leichardt Seam is generally localised to the mining area in the northern part of the project site and its surrounds within approximately 1 km of the project site boundary. The extent of depressurisation is constrained by the physical limit of the coal seam to the west of the mining area.

Figure 16 also shows the extent of the IAA in the Leichardt Seam. The IAA encompasses the area where drawdown over the UWIR period is predicted to exceed the applicable bore trigger threshold of 5 m for consolidated aquifers.

No depressurisation is predicted to occur in the Tertiary sediments or the alluvium as a result of mining in the project mining area.

5.4 Groundwater drawdown over the mine life

Figure 17 shows the approved predicted maximum depressurisation within the target Leichardt Seam. The project will locally depressurise the Leichardt Seam within the project mining area and its surrounds by up to approximately 400 m over the life of the mine (Figure 17). Depressurisation is greatest in the southern part of the project site, where the depth of mining is greatest (approximately 450 m below ground level), and therefore the groundwater pressure is greatest.

Figure 17 also shows the extent of the LTAA in the Leichardt Seam. The LTAA encompasses the area where drawdown over the life of the mine is predicted to exceed the applicable bore trigger threshold of 5 m for consolidated aquifers.

5.5 Environmental impacts

This section describes the operational impacts of the project for the UWIR reporting period on:

- Groundwater resources;
- Groundwater users;
- Surface water features;
- Springs;
- Groundwater dependent ecosystems; and
- Groundwater quality.

The groundwater assessment also investigated potential impacts on groundwater quality due to the use of hydrocarbons and chemicals.

5.5.1 Impacts on groundwater resources

Groundwater resources within the project site and its surrounds are located within the Isaac Connors Groundwater Management Area (GMA). The Isaac Connors GMA is managed under the Water Plan (Fitzroy Basin) and comprises two groundwater units. Groundwater Unit 1 includes the Isaac River alluvial aquifer and Groundwater Unit 2 comprises all other sub-artesian aquifers.

The Isaac River alluvium is located 15 km west of the project site at its closest point. There is no drawdown within the Isaac River alluvium as a result of the project, hence there will be no groundwater take from alluvium (i.e. Groundwater Unit 1). As a result, the project will not impact on this groundwater resource.

Groundwater depressurisation is limited to the coal seam and Permian and Triassic sediments which form part of Groundwater Unit 2. Table 5 shows the predicted groundwater take associated with the project, and hence, Groundwater Unit 2. The project is predicted to result in a total groundwater take of up to approximately 264 ML from Groundwater Unit 2 over the UWIR period.

As discussed in Section 1.2, the project's groundwater take and associated groundwater impacts have been approved under the EP Act.

5.5.2 Impacts on groundwater users

A bore census was carried out to identify water supply bores within and surrounding the project site that could potentially be impacted by the project. The bore census drew upon information gathered through previous groundwater studies, consultation with landholders, advice from the proponent, and a search of the DNRME groundwater database.

The bore census was targeted towards bores and properties that could potentially be impacted by the project due to their proximity to proposed mining activities. The local hydrogeology was also taken into account in planning the bore census. The bore census included a conservative search radius of 5 km beyond the boundary of the project mining lease area.

The bore census indicated that groundwater use is uncommon in the area. Where used it is typically opportunistic and dispersed over a wide area due to the generally low yields and access to alternative supplies (i.e. surface water dams).

The bore census confirmed that there are no water supply bores within the project site. The bore census did confirm the presence of a single water supply bore (RN81908) approximately 1.3 km south of the project site southern mining lease boundary (Figure 4). As discussed in Section 3.1.1, this bore is located on the Burton Mine site, which is owned and operated by Peabody Energy Australia (Peabody). Peabody is also the owner of the land underlying the Ironbark No. 1 Mine. It is understood that the owner has access to an alternative water supply and therefore this bore is not used as a sole water supply to the property.

This bore is screened in the Rewan Group. As discussed in Section 5.3, the project is not predicted to result in any depressurisation in the vicinity of Bore RN81908. As a result, this bore is unlikely to be affected by the project.

The Broadlea water supply borefield is located to the south-east of the project site and targets the Tertiary basalt aquifer. This borefield is owned by Fitzroy. As discussed in Section 5.3, the project is not predicted to result in any depressurisation of the Tertiary basalt in the vicinity of these bores and therefore the Broadlea water supply borefield is unlikely to be affected by the project.

As discussed in Section 1.2, the project's impacts on groundwater users has been approved under the EP Act.

5.5.3 *Impacts on surface drainage*

Figure 3 shows the drainage setting of the project.

The project site is traversed by Spade Creek, Hat Creek, Alpha Creek and their tributaries. Bullock Creek is located on the western boundary of the project site and is a tributary of Teviot Brook. These creeks and their tributary drainage features are ephemeral and are characterised by short duration, surface water flows that are typically restricted to periods during and immediately after rainfall events. This is consistent with creek observations made during the 2008 and 2018 field investigations. This is also supported by surface water flow data collected from DNRME's surface water gauging stations sited downstream of the project mining area and groundwater modelling predictions, which both indicate no perennial flows in the vicinity of the project site.

Groundwater is currently located at depths of approximately 5 m to 13 m below ground level in the vicinity of the main channels of Spade Creek and the tributary of Bullock Creek, respectively. The depth to groundwater increases to approximately 30m below ground level further to the northeast of the project site.

The separating depth between the bed of these creeks and the groundwater table means that there is no direct interconnection between the groundwater table and surface water flows in this area. Groundwater does not provide baseflow to surface waters in the vicinity of the project site.

As discussed in Sections 5.3and 5.4, the project is not predicted to lower the regional groundwater table. The project will therefore not result in impacts on surface waters or any reduction in stream baseflow.

As discussed in Section 1.2, the project's impacts on surface drainage have been approved under the EP Act.

5.5.4 *Impacts on springs*

As discussed in Section 3.1.2, there are no springs within the project site or its surrounds.

5.5.5 *Impacts on groundwater dependent ecosystems*

The *Australian Groundwater Dependent Ecosystem Toolbox* (GDE Toolbox), prepared by the National Water Commission (2011), defines GDEs as:

"Ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain the communities of plants and animals, ecological processes they support, and ecosystem services they provide".

The potential for GDEs to be present within the project site was reviewed, with the review consisting of:

- A search of the Queensland Springs Database;
- A search of the Bureau of Meteorology's (BoM) GDE Atlas;
- Groundwater field investigations; and
- A desktop review of groundwater monitoring data and modelling results.

The Queensland Springs Database indicated that no spring wetlands are located within the project site or its surrounds.

The BoM GDE mapping (described in Section 3.1.2) indicates several potential GDEs in the project site, namely Bullock, Spade and Alpha Creeks and associated drainage lines.

As discussed, in Section 4.1, the main groundwater-bearing formations are the (Leichhardt) coal seams of the Permian sediments. The regional groundwater table in the project site is at least 5 m below ground level, and more typically more than 10 m below ground level. The regional groundwater table is located in the Tertiary basalt, Tertiary sediments and deeper alluvium where these units extend below the regional groundwater surface. These geological formations overlie the coal measures, including the target Leichardt Seam. The groundwater assessment predicted that the project will locally depressurise the Leichardt Seam around the project mining area, but will not affect the regional groundwater table located in the Tertiary and alluvial formations, nor will it change the depth of groundwater within these formations within the project site or surrounds.

As a result, the project is not anticipated to affect the availability of groundwater for any vegetation communities, including for any groundwater dependent communities which may be located in the project site. This conclusion is consistent with observations of vegetation communities at other local mining operations, where there has been no observed effect on riparian vegetation from mining activities. It is therefore concluded that the project will not impact GDEs.

As discussed in Section 1.2, the project's impacts on GDEs have been approved under the EP Act.

5.5.6 Impacts on groundwater quality

The project will involve the limited use of chemicals and hydrocarbons as part of the mining activities.

The storage of hydrocarbon and chemicals will be managed in accordance with the EA which requires Fitzroy resources to implement and maintain a Waste Management Plan for the mine. This will include the use of bunding and immediate clean-up of spills which are standard practice and a legislated requirement at mine sites that will prevent the contamination of the groundwater regime.

Given the limited activities proposed, and the controls that will be adopted, the project has a very limited potential to give rise to groundwater contamination as a result of hydrocarbon and chemical contamination.

As discussed in Section 1.2, the project's impacts on groundwater quality have been approved under the EP Act.

6 Groundwater monitoring program

6.1 Groundwater level and quality monitoring

The mine operates an extensive groundwater monitoring network in accordance with the Ironbark No.1 EA. The EA groundwater monitoring network comprises 11 monitoring bores located on the project site (Figure 5).

The purpose of the EA groundwater monitoring network is to monitor groundwater levels and quality in the coal seams, shallow overburden and alluvium in response to mining.

The existing EA groundwater monitoring program targets key formations in the project mining area and its surrounds. The existing EA groundwater monitoring program therefore suitable for monitoring the effects of the project on the groundwater regime and will continue to be utilised throughout the life of the project.

In accordance with the requirements of the Ironbark No.1 EA, the following monitoring will be undertaken at the EA groundwater monitoring bores:

- Groundwater levels will be recorded on a quarterly basis, which will enable natural groundwater level fluctuations (such as seasonal responses to rainfall) to be distinguished from potential water level impacts due to depressurisation resulting from mining activities. It is also designed to monitor changes in the IAA and the LTAA.
- Groundwater quality monitoring will be undertaken on a quarterly basis to enhance the existing baseline dataset available prior to commencement of the project. This will be used to detect any changes in groundwater quality during and post-mining. Water quality samples will be analysed for physico-chemical parameters including pH, electrical conductivity, alkalinity, hardness, major ions (Ca, Mg, Na, K, Cl and SO4), metals and metalloids (As, Al, Pb, Fe, Zn and Mn) and total petroleum hydrocarbons.

All samples for groundwater quality shall be collected after the bore is appropriately purged. Groundwater samples will be collected in accordance with the relevant guidelines and conventions specified in the *"Monitoring and Sampling Manual"* (DES, 2018), and in compliance with e.g. AS/NZS 5667:11 1998 (Australian/New Zealand Standards, 2016). The samples will be preserved and forwarded to a NATA accredited water laboratory for analysis.

The groundwater monitoring data will be reviewed annually, and the groundwater monitoring program revised, as necessary.

In the event that the monitoring program identifies a significant departure from the prediction, an investigation will be undertaken to identify the cause and manage any unexpected impacts associated with the project.

No water bores are present on the project site, hence a Baseline Assessment Plan (BAP) and associated monitoring is not required.

6.2 Groundwater take monitoring

Fitzroy has an existing obligation to quantify its actual groundwater take under the *Mineral Resources Act 1999* (MR Act). The DNRME *Guideline for quantifying the volume of take of associated water under a mining lease or mineral development license* (Groundwater Take Guideline) describes the acceptable methods for monitoring and quantifying actual groundwater take under the MR Act. The acceptable methods include direct measurement, water balance modelling, and numerical/analytical groundwater flow modelling.

In accordance with the requirements of the MR Act, Fitzroy will continue to assess actual groundwater take using the acceptable methods. The method used will be reviewed annually and revised, as necessary.

The actual groundwater take assessed under the MR Act requirements will be compared to the predicted groundwater take presented in this UWIR. This comparison will be undertaken annually. If the monitoring program shows groundwater take exceeds the predictions presented in this UWIR, an investigation will be undertaken to confirm whether the actual impacts on groundwater users or sensitive environmental features are likely to be significantly greater than expected. The investigation outcomes will be considered as part of the annual UWIR review described in Section 7.

7 UWIR Review and updates

7.1 Roles and responsibilities

Fitzroy is responsible for ensuring that the UWIR is implemented.

7.2 Review and revision

As discussed in Section 5, depressurisation of the Leichardt Seam is expected to exceed the bore trigger threshold.

Hence, Fitzroy will undertake an annual review of the accuracy of the IAA and LTAA mapping, as required by Section 376(1)(e) of the Water Act.

The review process will comprise:

- An initial review of any new geology or groundwater data to identify potentially significant departures from the data used in the UWIR to develop the IAA and LTAA mapping.
- Where potentially significant departures are identified, the potential effect of these departures on the IAA and LTAA will be investigated.
- If the investigation concludes that the IAA or LTAA are likely to have been under-estimated and additional water bores are likely to be affected, the IAA and LTAA will be revised.

The UWIR has been designed to align with the current EA groundwater conditions. It is therefore necessary to review and update the UWIR in response to any material changes to the EA groundwater conditions.

7.3 Reporting and record keeping

The outcome of each annual review will be reported to the DES and the Office of Groundwater Impact Assessment following completion of each annual review. The reported outcomes will include a statement of whether there has been a material change in the information or predictions used to prepare the maps.

8 Conclusions

The key conclusions of this UWIR are as follows:

- The impacts of the project over the UWIR period and the life of the mine have been assessed and approved under the EP Act as part of the grant of the Ironbark No.1 EA.
- The approved mining operations will result in localised depressurisation of the Leichhardt Seam.
- The other potential aquifers and shallow formations (i.e. the Tertiary basalt, Tertiary sediments and alluvium) are largely unsaturated, and are not predicted to be depressurised by the project.
- The project will not impact surface waters or alluvial aquifers during the UWIR period because:
  - Alluvium is mostly absent from the project site and its surrounds;
  - Where present, alluvium is typically dry and unsaturated and does not represent a significant aquifer; and
  - The significant depth of cover over the project mining area during the UWIR period (up to 200 m) and the low permeability interburden of the Permian and Triassic sediments will reduce significant depressurisation of the shallow formations; and
- There are no groundwater users or other sensitive receptors near the mining area and therefore no significant groundwater impacts as a result of the project.
- There is a very low potential for groundwater contamination as a result of the project.

9 References

Australasian Groundwater and Environmental Consultants Pty Ltd. (AGE), 2008, "Ellensfield Coal Mine Project, Groundwater Impact Assessment", Project No. G1407 prepared by Australasian Groundwater and Environmental Consultants Pty Ltd for Ellensfield Coal Management Pty Ltd, December, 2008.

Barnett et al, (2012), Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra.

Hansen Bailey, 2018, "Ironbark No.1 Project, Response to Additional Information Request", letter report to Department of Environment and Science.

Australian/New Zealand Standards, 2016, "Water Quality – "Sampling, Part 11: Guidance on sampling of groundwaters", AS/NZS 5667.11:1998, ISO 5667-11:1993, Reconfirmed 2016.

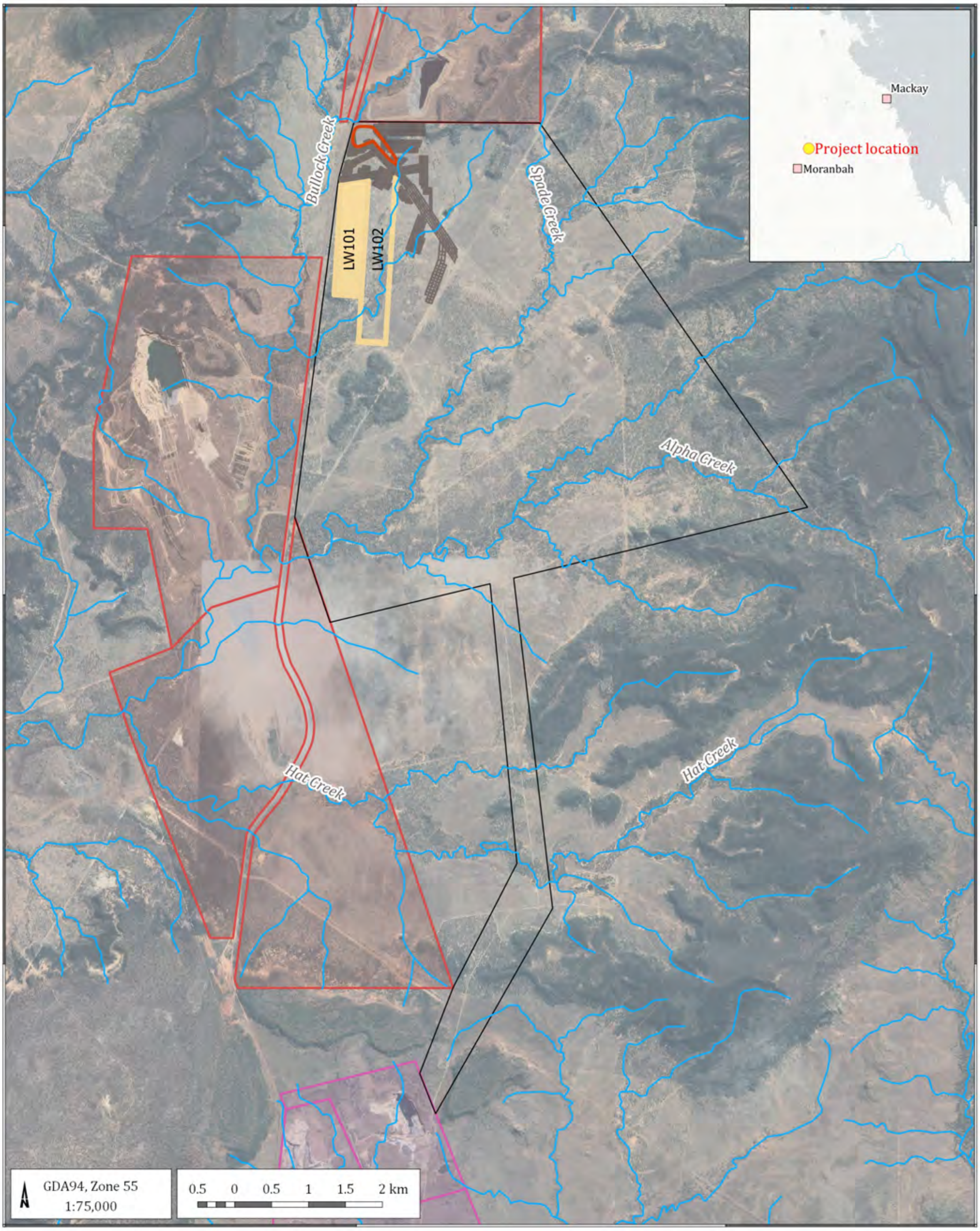
DES. 2018. Monitoring and Sampling Manual: Environmental Protection (Water) Policy. Brisbane: Department of Environment and Science Government.

Food and Agricultural Organisation of the United Nations (2013), "The use of saline waters for crop production", Chapter 2, by J.D. Rhoades, A. Kandiah and A.M. Mashali.

National Water Commission (2011), "Australian groundwater-dependent ecosystems toolbox part 1: assessment framework", Commonwealth of Australia, 2011.

Panday S., Langevin C.D., Niswonger R.G., Ibaraki M. and Hughes, J.D. (2013): "MODFLOW-USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation"; U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

HydroAlgorithmics, 2014 "Algomesh User Guide, Version 1.4", March 2014.



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads
- Box cut
- Broadlea North Coal Mine
- Burton Coal Mine

Ironbark UWIR (G1915F)

Mine location and setting

DATE 21/03/2019

FIGURE No: **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.;
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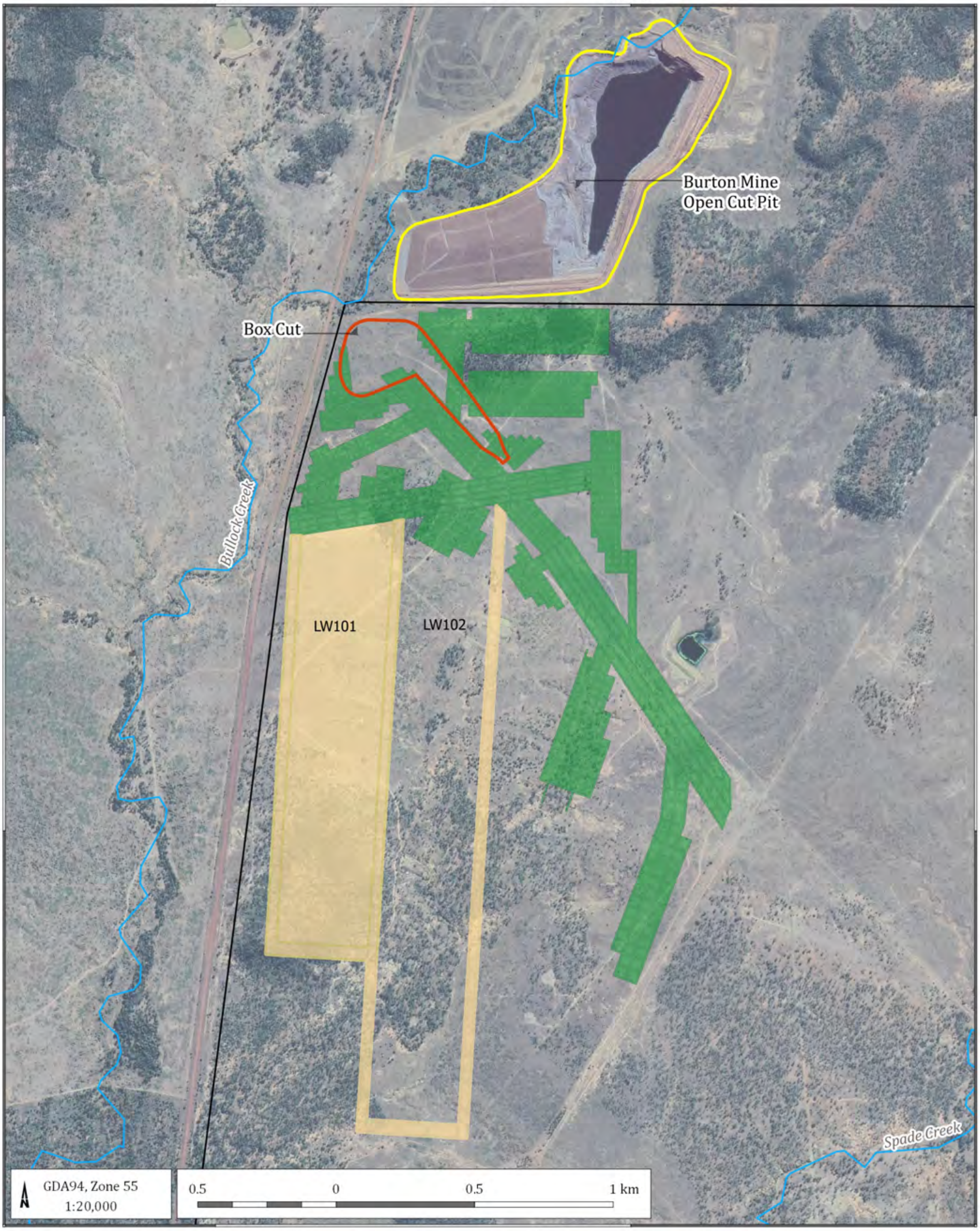

LEGEND
- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Bord and Pillar mining area
- Longwall panel /Gate roads
- Box cut

Ironbark UWIR (G1915F)

Mine layout - to end of Year 3

AGE

DATE 20/03/2019

FIGURE No: **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.;
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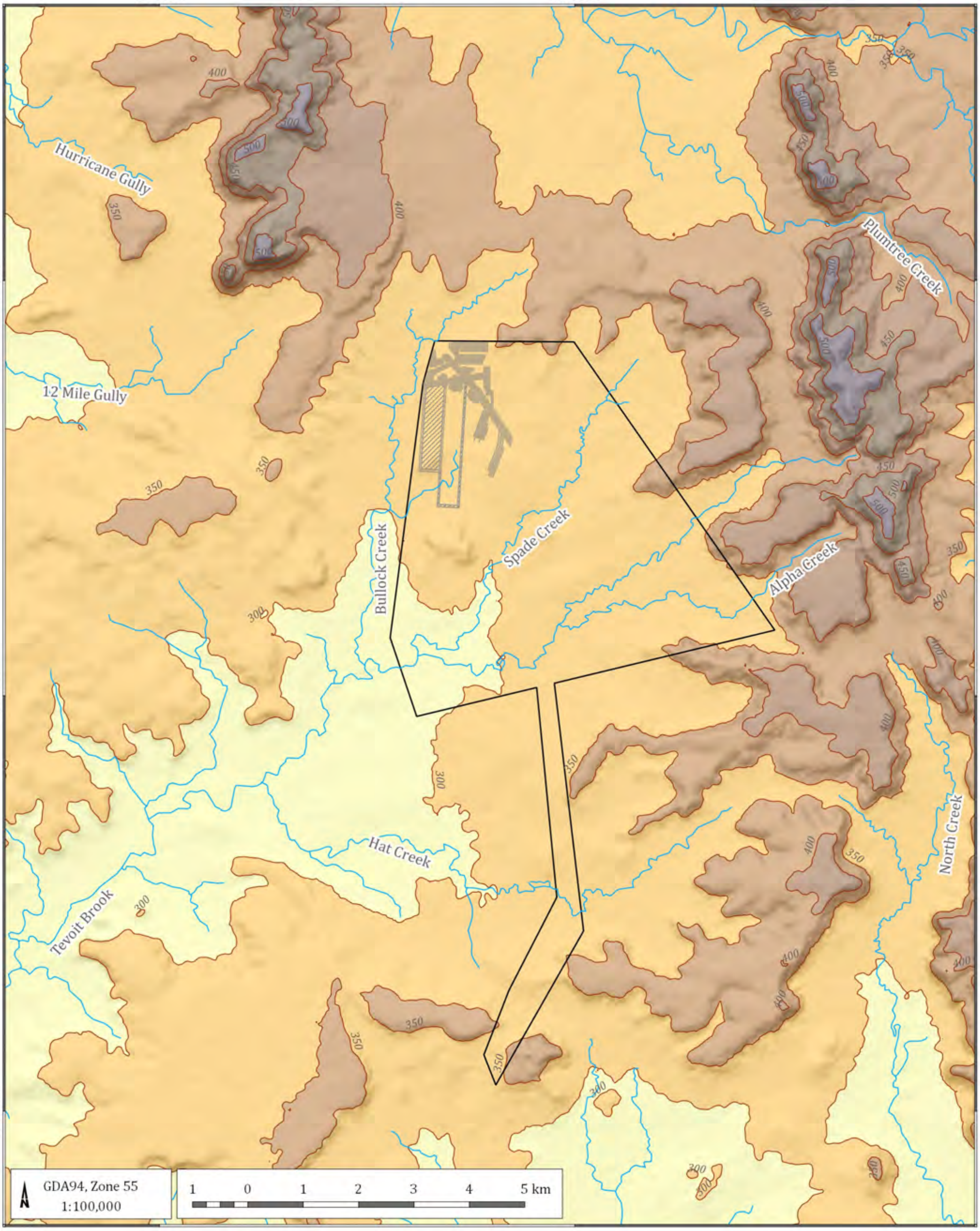

LEGEND

- Creeks
- Project Mining Lease Boundary
- Bord and Pillar mining area
- Long wall panel/Gate roads

Elevation (mAHD)

- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- Elevation contour

Ironbark UWIR (G1915F)

Topography and drainage

AGE

DATE 19/03/2019

FIGURE No: **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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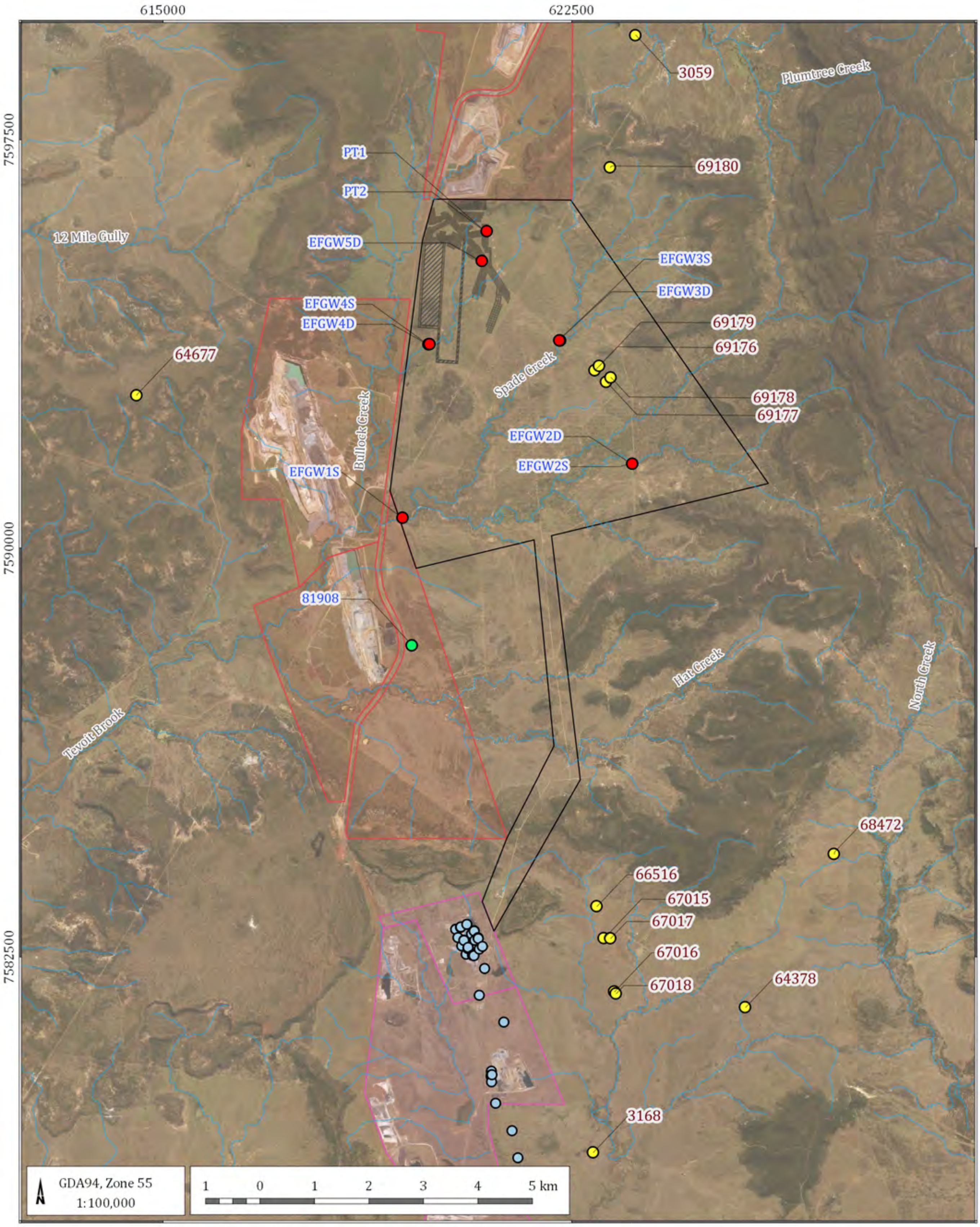

LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Long wall panel/Gate roads
- Broadlea North Coal Mine
- Burton Coal Mine
- Mine groundwater monitoring bores

EFGW1S : BoreID

- Registered watersupply bore
- Broadlea North Mine borefield groundwater monitoring network
- CSG appraisal well

3168 : BoreID

Ironbark UWIR (G1915F)

DNRME registered bores

AGE

DATE 20/03/2019

FIGURE No: **4**

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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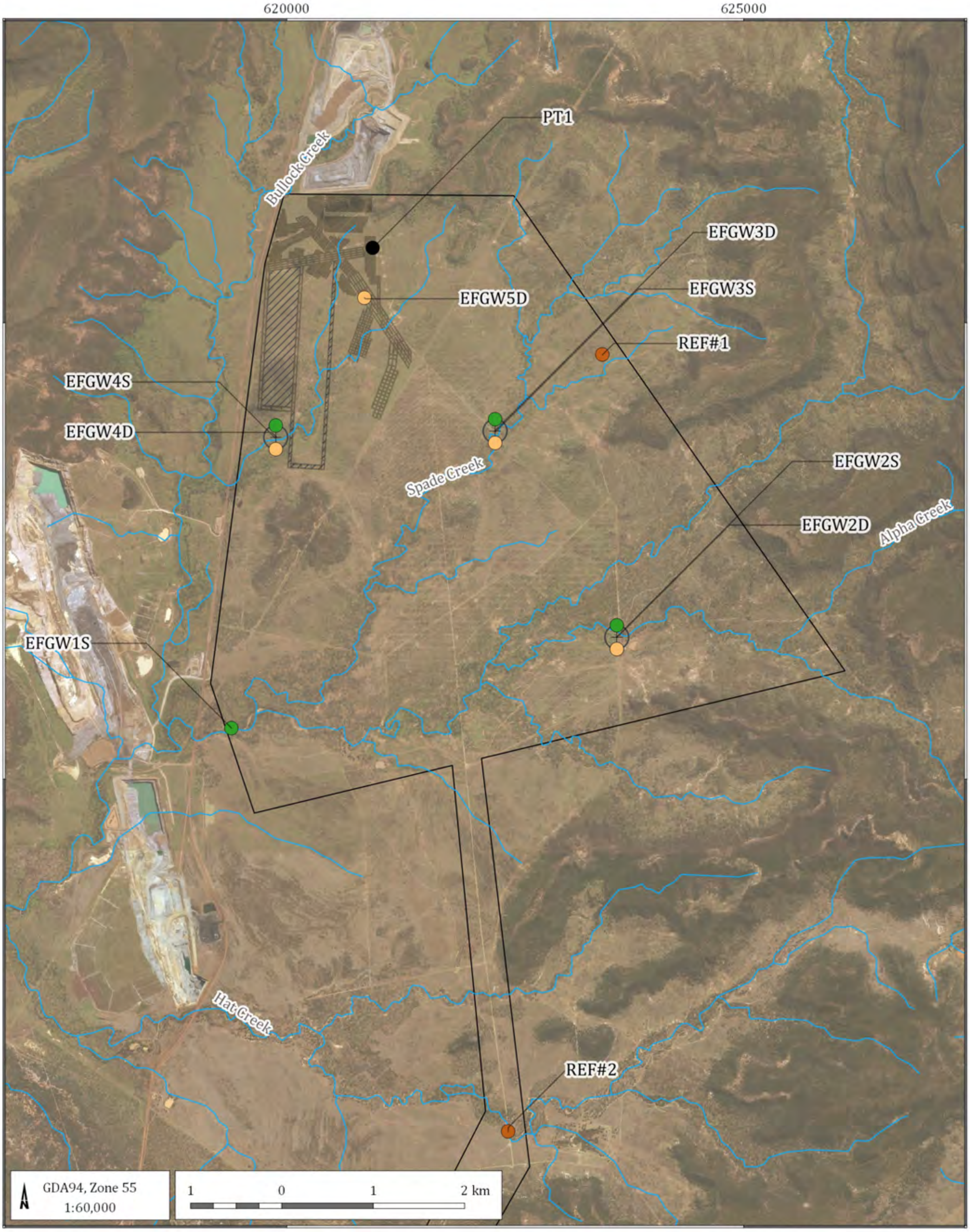

LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads

Groundwater monitoring bores

- Alluvial bores
- Shallow overburden bores
- Leichhardt Seam bores
- Reference bores

EFGW1S/REF#1 : BoreID

Ironbark UWIR (G1915F)

Mine groundwater monitoring network

AGE

DATE 20/03/2019

FIGURE No: **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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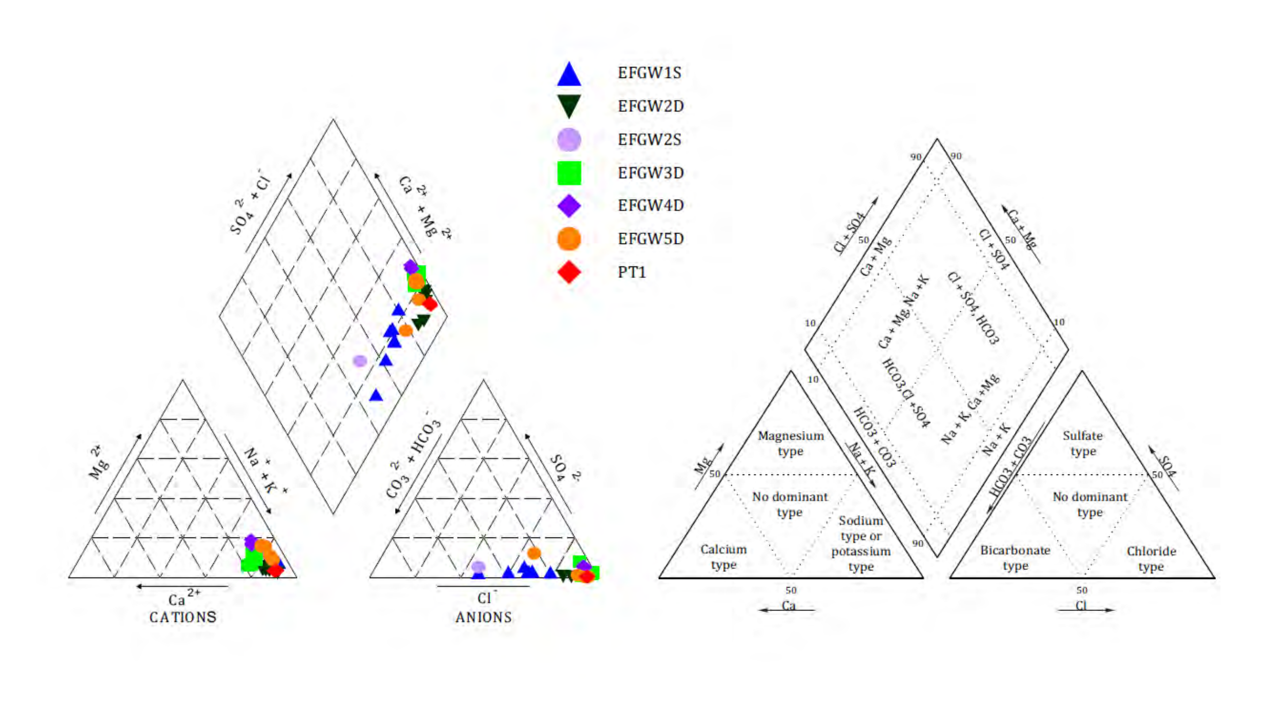
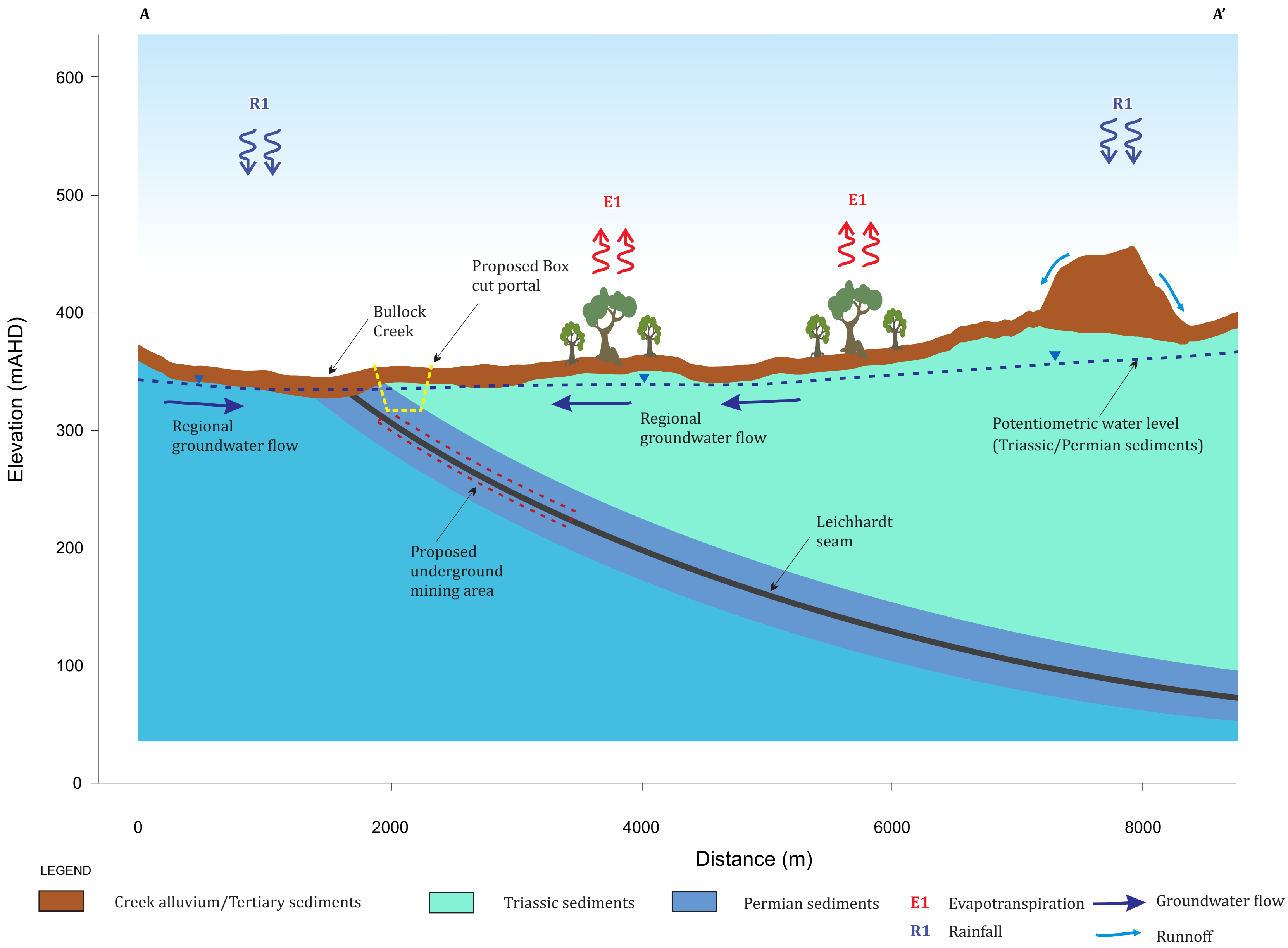


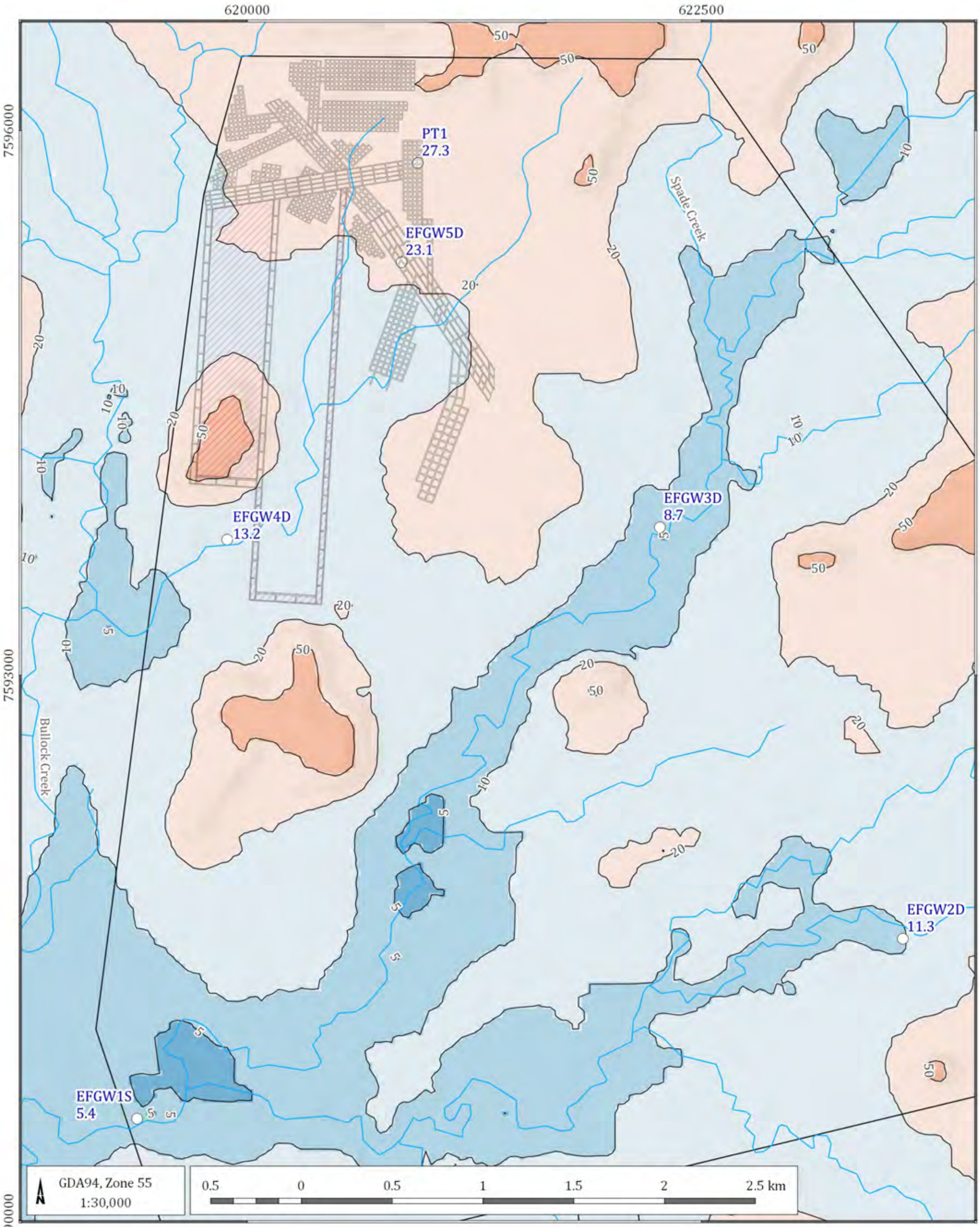
Figure 6 Piper diagram



Conceptual hydrogeological model (A - A')

Figure- 7

Ironbark UWIR (G1915F)



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads
- Mine monitoring bore
  EFGW2D : BoreID
  13.2 : Water table depth (mbgl)

Water table depth (mbgl)

- 0 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- Contour line

Ironbark UWIR (G1915F)

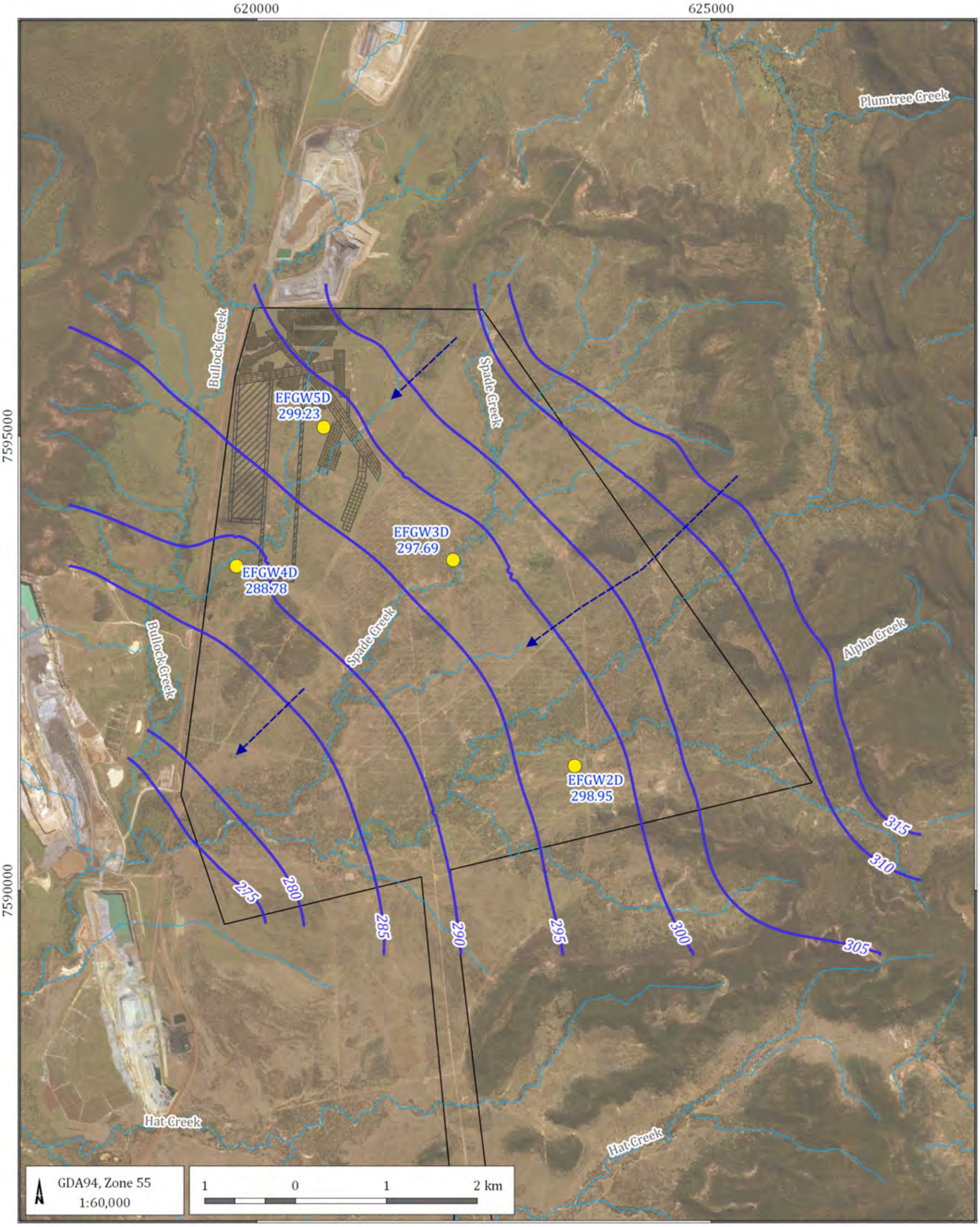
Interpreted depth to water table

AGE

DATE 19/03/2019

FIGURE No: 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.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\08.00_G1915F_Depth to regional water table.qgs.qgs



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads
- Depth bore (EFGW - series)
  EFGW2D : BoreID
  298.95 : Groundwater elevation (mAHD)
- Groundwater contour (mAHD)
- Flow direction

Ironbark UWIR (G1915F)

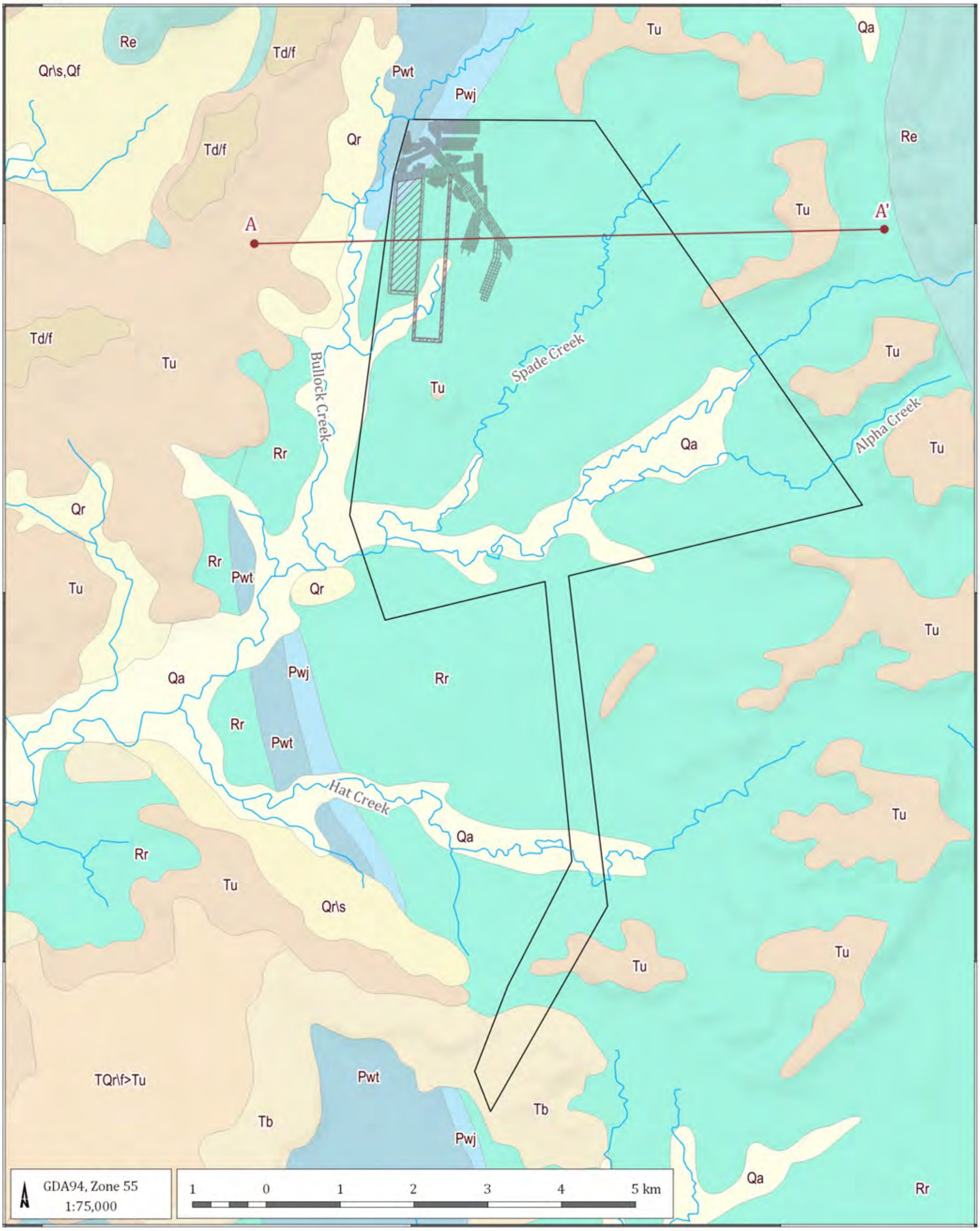
Interpolated groundwater contours

AGE

DATE 19/03/2019

FIGURE No: 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.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\09.00_G1915F_Interpolated groundwater contours.qgs



LEGEND

- Creeks
- Conceptual cross section line (A -A')
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel (LW101)

Creek alluvium

- Qa - Quaternary alluvium
- Qa\f - Alluvial fan
- Qr\s -Residual soil/colluvium
- Qr - Residual soil/colluvium

Tertiary sediments

- TQr\f >Tu - Suttor Formation
- Tb - Tertiary basalt
- Td\f - Ferricrete
- Tu - Tertiary sediments

Triassic sediments

- Re - Clematis Group
- Rr - Rewan Group

Permian sediments

- Pwj - Rangal Coal Measures
- Pwt - Fort Cooper Coal Measures

Ironbark UWIR (G1915F)

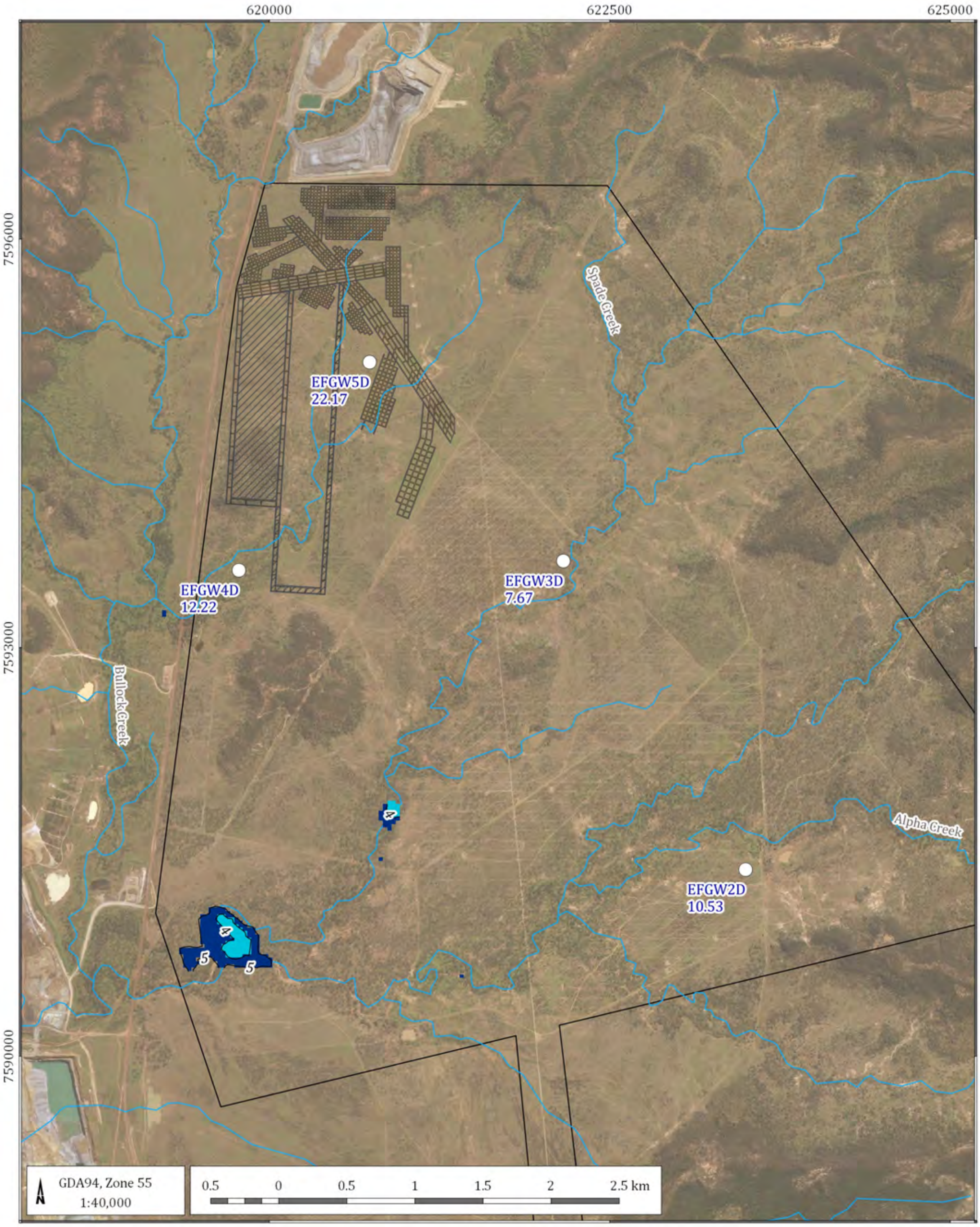
Surface geology

AGE

DATE 19/03/2019

FIGURE No: **10**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\10.00_G1915F_Surface geology.qgs



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads
- Deep bore

EFGW2D : BoreID
10.53 : Water table depth (mbgl)

Depth to water table (m)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- Contour line

Ironbark UWIR (G1915F)

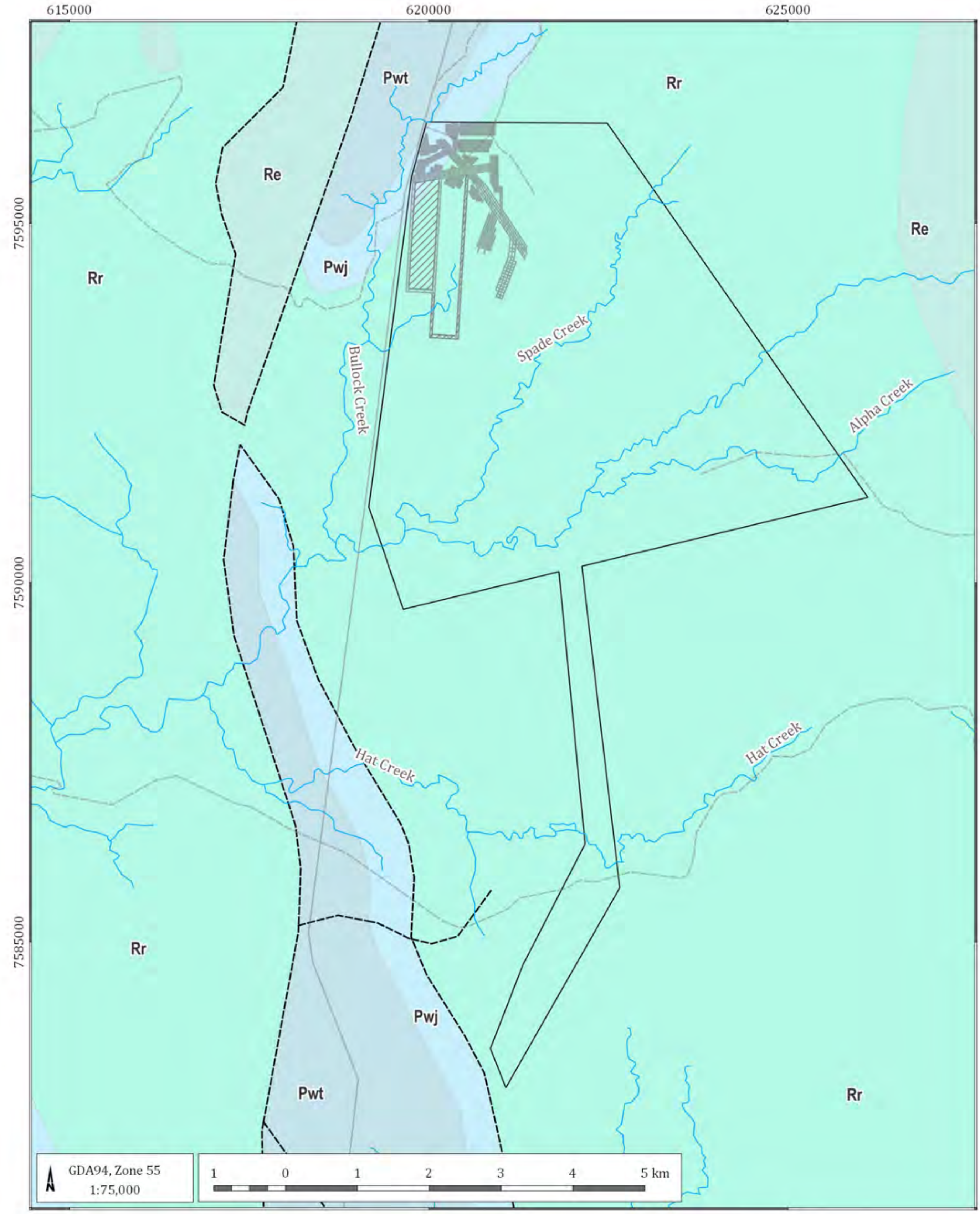
Saturated alluvium extents

DATE 19/03/2019

FIGURE No: **11**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\11.00_G1915F_Saturated alluvium extents.qgs.qgs

Figure 12 Drainage line photographs in Project area



LEGEND

- Raod
- Track
- Creeks
- Fault
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads

Solid geology

- Re-Clematis Group
- Rr-Rewan Formation
- Pwj-Rangal Coal Measures
- Pwt-Fair Hill Formation/Fort Cooper Coal Measures

Ironbark UWIR (G1915F)

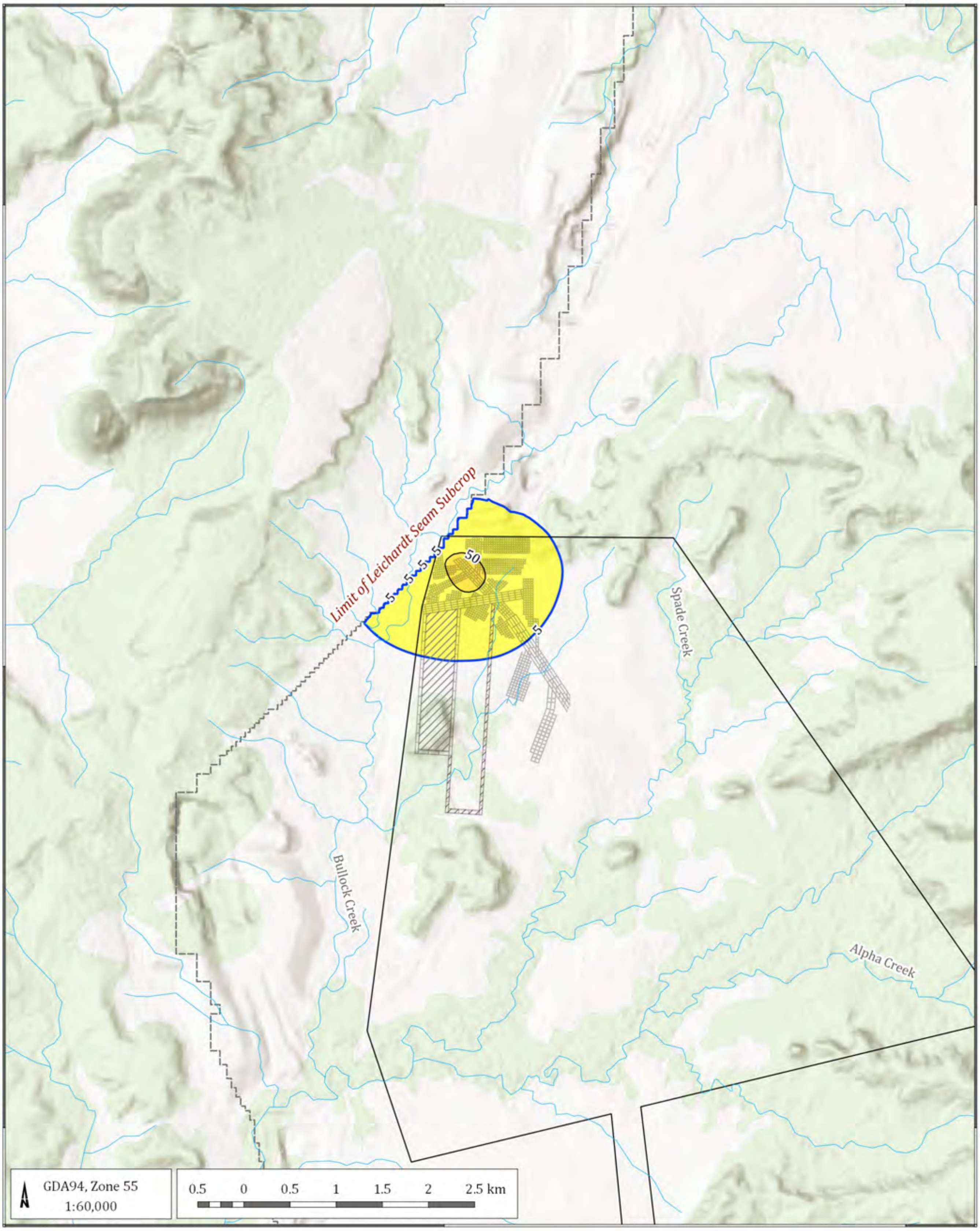
Bowen Basin geology

AGE

DATE 19/03/2019

FIGURE No: **13**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\13.00_G1915F_Bowen Basin geology.qgs



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads
- Limit of Leichardt seam subcrop
- Drawdown contour (m)
- Immediate Affected Area (IAA)

Drawdown (m)

- 0 - 5
- 5 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300

Ironbark UWIR (G1915F)

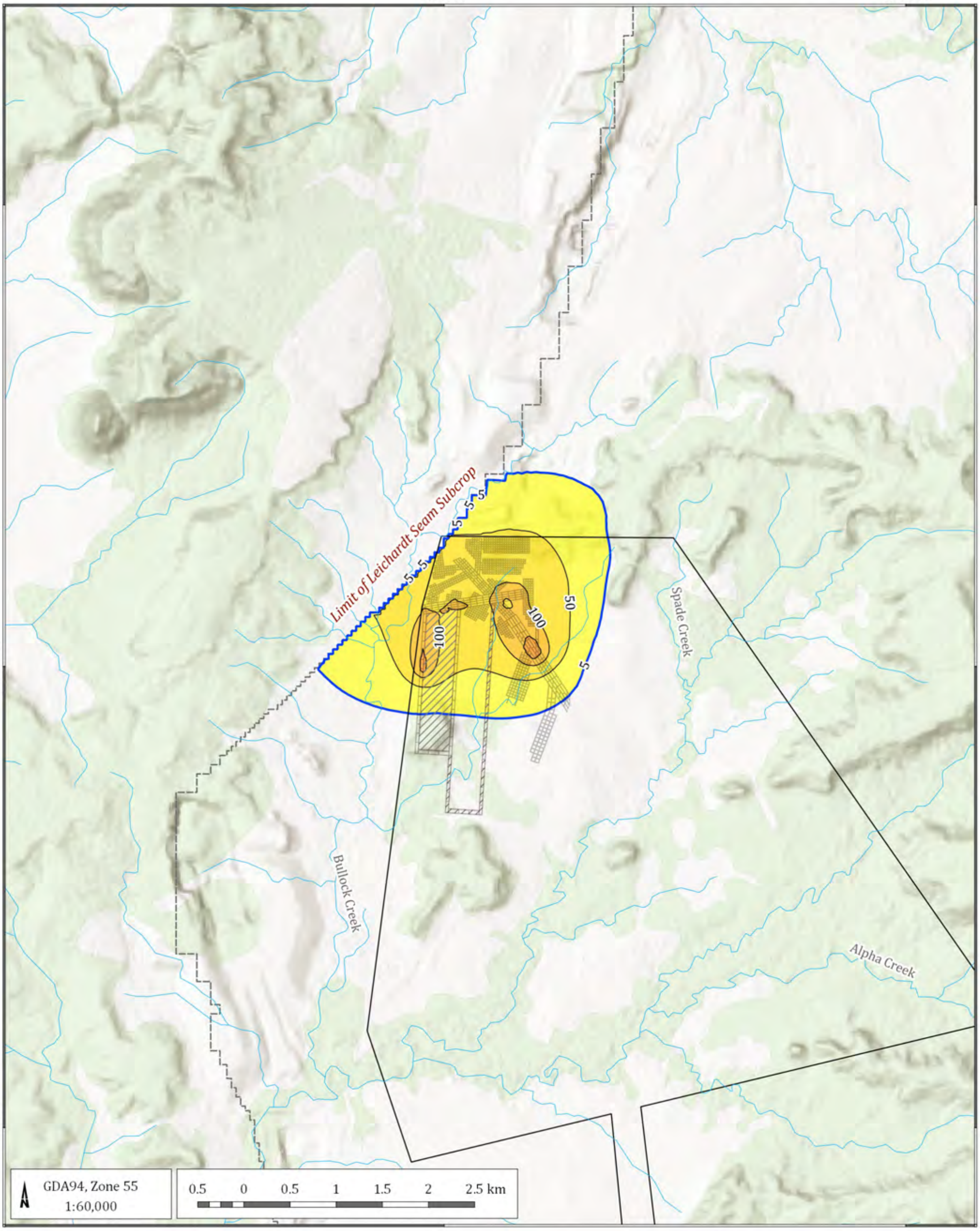
Predicted Depressurisation in the Leichardt Seam at the end of UWIR Year 1

AGE

DATE 21/03/2019

FIGURE No: **14**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\14.00 to 17.00_G1915F_Predicted drawdown.qgs.qgs



LEGEND

- Creeks
- Project Mining Lease Boundary
- Longwall panel/Gate roads
- UWIR Mining Area
- Limit of Leichardt seam subcrop
- Drawdown contour (m)
- Immediate Affected Area (IAA)

Drawdown (m)

- 0 - 5
- 5 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250

Ironbark UWIR (G1915F)

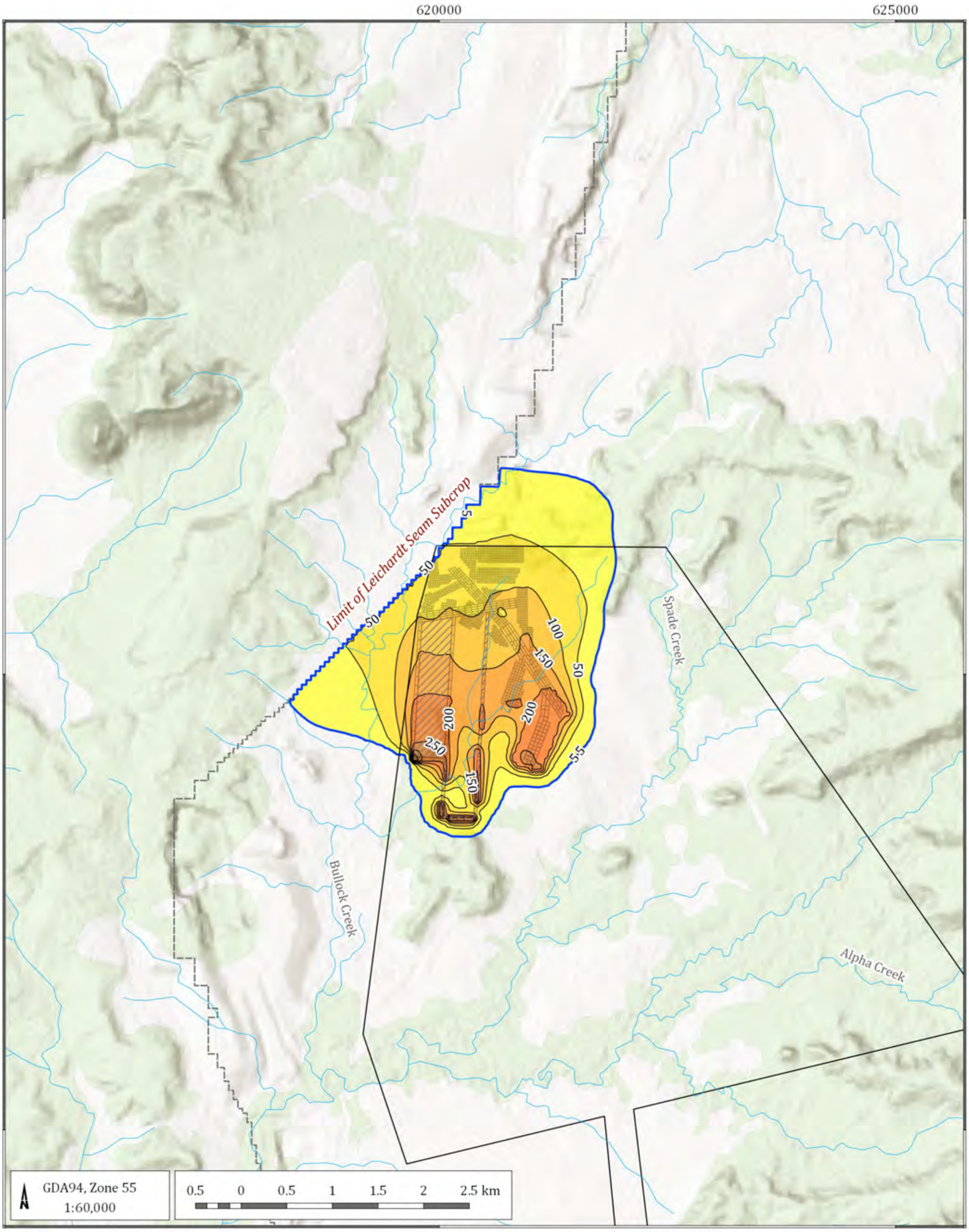
Predicted Depressurisation in the Leichardt Seam at the end of UWIR Year 2

AGE

DATE 21/03/2019

FIGURE No: **15**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\14.00 to 17.00_G1915F_Predicted drawdown.qgs.qgs



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads
- Limit of Leichardt seam subcrop
- Drawdown contour (m)
- Immediate Affected Area (IAA)

Drawdown (m)

- 0 - 5
- 5 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350

Ironbark UWIR (G1915F)

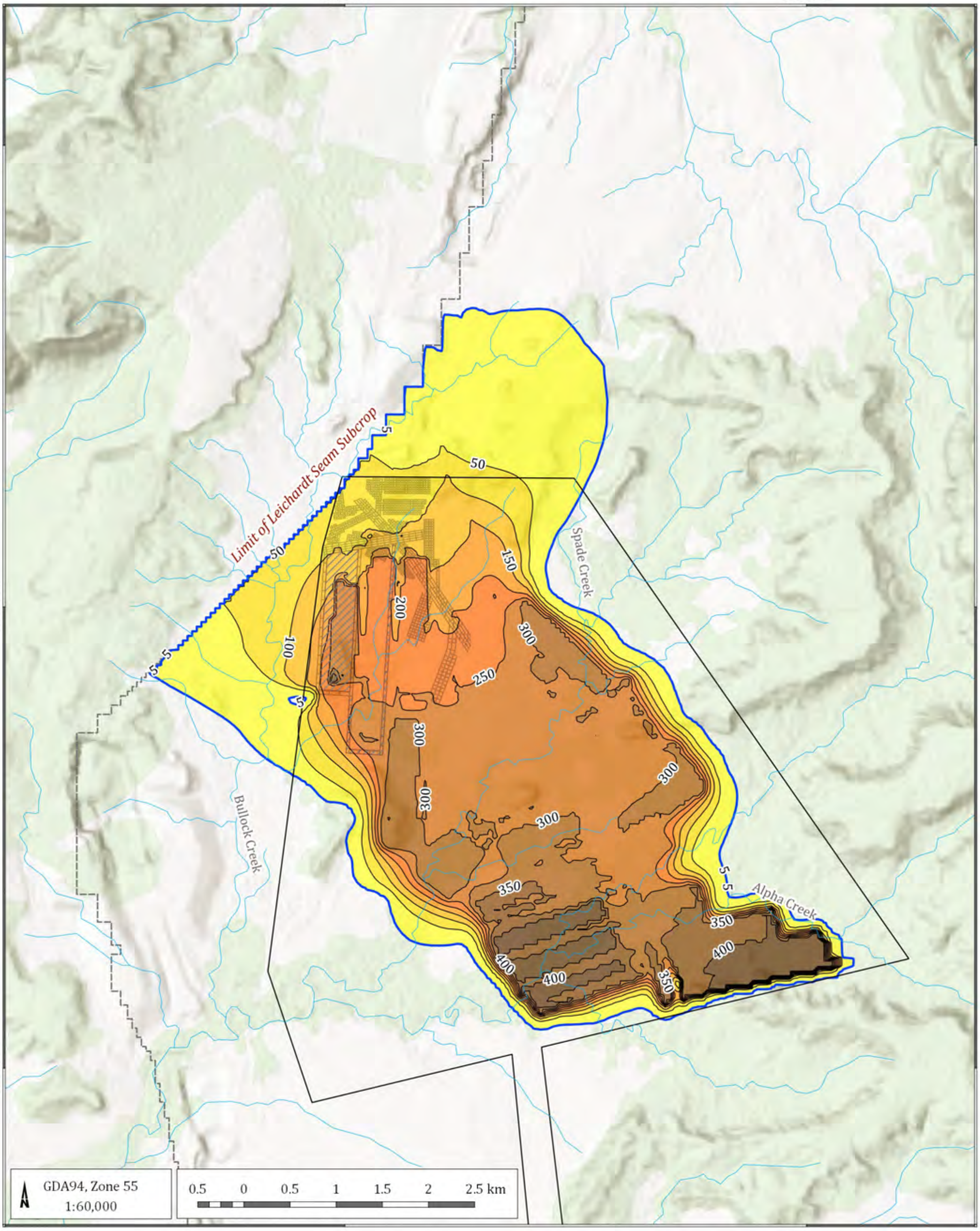
Predicted Depressurisation in the Leichardt Seam at the end of UWIR Year 3

AGE

DATE 21/03/2019

FIGURE No: **16**

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\14.00 to 17.00_G1915F_Predicted drawdown.qgs.qgs



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Longwall panel/Gate roads
- Limit of Leichardt seam subcrop
- Drawdown contour (m)
- Long-Term Affected Area (LTAA))

Drawdown (m)

- 0 - 5
- 5 - 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500

Ironbark UWIR (G1915F)

Predicted Depressurisation in the Leichardt Seam at the end of mining

AGE

DATE 21/03/2019

FIGURE No: **17**

Appendix A Laboratory analysis results

Sample ID			EFGW1S						
Sample Date			09/07/08	17/01/18	25/07/18	30/08/18	27/09/18	24/10/18	16/11/18
Aquifer			Alluvium						
Analyte	Units	LOR*							
Water Quality Indicators									
pH Value	pH Unit	0.01	7.27	7.84	7.59	7.53	7.71	7.92	7.63
Electrical Conductivity	µS/cm	1	3,550	6,360	5,500	5,700	4,050	2,320	4,560
Alkalinity									
Carbonate Alkalinity	mg/L	1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	1	466	596	777	785	728	632	649
Dissolved Major Ions									
Calcium	mg/L	1	37	102	76	83	42	17	56
Magnesium	mg/L	1	42	119	105	104	49	20	66
Sodium	mg/L	1	576	1,090	1,010	1,060	710	425	882
Potassium	mg/L	1	5	7	5	6	4	2	5
Chloride	mg/L	1	740	1,720	1,330	1,450	823	415	1,080
Sulfate	mg/L	1	78	66	68	80	44	23	55
Dissolved Metals									
Aluminium	mg/L	0.01	-	<0.01	-	-	-	-	-
Arsenic	mg/L	0.001	0.001	0.002	<0.001	0.001	<0.001	<0.001	0.003
Cadmium	mg/L	0.0001	0.0001	<0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	0.005	-	-	-	-	-
Copper	mg/L	0.001	<0.001	<0.001	-	-	-	-	-
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.685	1.73	2.78	1.27	0.256	0.364	0.24
Nickel	mg/L	0.001	0.004	0.007	-	-	-	-	-
Zinc	mg/L	0.005	0.011	0.073	0.024	0.026	0.027	0.031	0.034
Iron	mg/L	0.05	0.75	<0.05	<0.05	<0.05	<0.05	<0.05	0.14
Total Metals									
Aluminium	mg/L	0.01	-	8.64	-	-	-	-	-
Arsenic	mg/L	0.001	-	0.004	-	-	-	-	-
Cadmium	mg/L	0.0001	-	0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	0.022	-	-	-	-	-
Copper	mg/L	0.001	-	0.017	-	-	-	-	-
Lead	mg/L	0.001	-	0.011	-	-	-	-	-
Manganese	mg/L	0.001	-	2.7	-	-	-	-	-
Nickel	mg/L	0.001	-	0.028	-	-	-	-	-
Zinc	mg/L	0.005	-	0.364	-	-	-	-	-
Iron	mg/L	0.05	-	12.1	-	-	-	-	-
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	µg/L	20	-	-	<20	<20	<20	<20	<20
C10 - C14 Fraction	µg/L	50	-	-	<50	<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	-	-	<100	<100	<100	<100	<100
C29 - C36 Fraction	µg/L	50	-	-	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum)	µg/L	50	-	-	<50	<50	<50	<50	<50
Miscellaneous									
Fluoride (mg/L)	mg/L	0.1	-	0.5	-	-	-	-	-

*Laboratory limit of reporting

Sample ID			EFGW2S
Sample Date			09/07/08
Aquifer			Alluvium
Analyte	Units	LOR*	
Water Quality Indicators			
pH Value	pH Unit	0.01	7.19
Electrical Conductivity	µS/cm	1	1,040
Alkalinity			
Carbonate Alkalinity	mg/L	1	<1
Bicarbonate Alkalinity	mg/L	1	225
Dissolved Major Ions			
Calcium	mg/L	1	20
Magnesium	mg/L	1	18
Sodium	mg/L	1	150
Potassium	mg/L	1	1
Chloride	mg/L	1	148
Sulfate	mg/L	1	22
Dissolved Metals			
Aluminium	mg/L	0.01	-
Arsenic	mg/L	0.001	<0.001
Cadmium	mg/L	0.0001	<0.0001
Cobalt	mg/L	0.001	-
Copper	mg/L	0.001	<0.001
Lead	mg/L	0.001	<0.001
Manganese	mg/L	0.001	0.01
Nickel	mg/L	0.001	<0.001
Zinc	mg/L	0.005	0.011
Iron	mg/L	0.05	<0.05
Total Metals			
Aluminium	mg/L	0.01	-
Arsenic	mg/L	0.001	-
Cadmium	mg/L	0.0001	-
Cobalt	mg/L	0.001	-
Copper	mg/L	0.001	-
Lead	mg/L	0.001	-
Manganese	mg/L	0.001	-
Nickel	mg/L	0.001	-
Zinc	mg/L	0.005	-
Iron	mg/L	0.05	-
Total Petroleum Hydrocarbons			
C6 - C9 Fraction	µg/L	20	-
C10 - C14 Fraction	µg/L	50	-
C15 - C28 Fraction	µg/L	100	-
C29 - C36 Fraction	µg/L	50	-
C10 - C36 Fraction (sum)	µg/L	50	-
Miscellaneous			
Fluoride (mg/L)	mg/L	0.1	-

*Laboratory limit of reporting

Sample ID			EFGW2D						
Sample Date			09/07/08	16/01/18	24/07/18	30/08/18	27/09/18	23/10/18	16/11/18
Aquifer			Shallow overburden						
Analyte	Units	LOR*							
Water Quality Indicators									
pH Value	pH Unit	0.01	7.46	8.18	8.15	7.75	7.76	7.91	8
Electrical Conductivity	µS/cm	1	12,400	5,870	5,610	9,430	9,230	8,790	8,150
Alkalinity									
Carbonate Alkalinity	mg/L	1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	1	263	293	385	168	177	177	196
Dissolved Major Ions									
Calcium	mg/L	1	276	78	88	238	198	223	151
Magnesium	mg/L	1	81	18	20	56	44	48	37
Sodium	mg/L	1	2,070	1,130	1,100	1,830	1,660	1,650	1,490
Potassium	mg/L	1	18	6	7	11	10	10	9
Chloride	mg/L	1	4,000	1,660	1,590	3,340	3,080	2,590	2,500
Sulfate	mg/L	1	110	6	12	3	3	2	3
Dissolved Metals									
Aluminium	mg/L	0.01	-	<0.01	-	-	-	-	-
Arsenic	mg/L	0.001	0.012	0.01	0.013	0.009	0.01	0.009	0.008
Cadmium	mg/L	0.0001	<0.0001	<0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	<0.001	-	-	-	-	-
Copper	mg/L	0.001	0.002	<0.001	-	-	-	-	-
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	1.34	0.389	0.241	1.13	1.4	1	0.578
Nickel	mg/L	0.001	0.002	<0.001	-	-	-	-	-
Zinc	mg/L	0.005	0.01	<0.005	<0.005	0.006	0.008	0.023	0.012
Iron	mg/L	0.05	0.22	<0.05	<0.05	0.06	<0.05	0.08	<0.05
Total Metals									
Aluminium	mg/L	0.01	-	1.12	-	-	-	-	-
Arsenic	mg/L	0.001	-	0.01	-	-	-	-	-
Cadmium	mg/L	0.0001	-	<0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	<0.001	-	-	-	-	-
Copper	mg/L	0.001	-	0.012	-	-	-	-	-
Lead	mg/L	0.001	-	0.001	-	-	-	-	-
Manganese	mg/L	0.001	-	0.445	-	-	-	-	-
Nickel	mg/L	0.001	-	0.002	-	-	-	-	-
Zinc	mg/L	0.005	-	0.026	-	-	-	-	-
Iron	mg/L	0.05	-	1.39	-	-	-	-	-
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	µg/L	20	-	-	<20	<20	<20	<20	<20
C10 - C14 Fraction	µg/L	50	-	-	<50	<50	<50	60	<50
C15 - C28 Fraction	µg/L	100	-	-	1180	<100	140	260	140
C29 - C36 Fraction	µg/L	50	-	-	1280	<50	100	150	<50
C10 - C36 Fraction (sum)	µg/L	50	-	-	2460	<50	240	470	140
Miscellaneous									
Fluoride (mg/L)	mg/L	0.1	-	0.7	-	-	-	-	-

*Laboratory limit of reporting

Sample ID			EFGW3D						
Sample Date			09/07/08	18/01/18	25/07/18	30/08/18	26/09/18	23/10/18	15/11/18
Aquifer			Shallow overburden						
Analyte	Units	LOR*							
Water Quality Indicators									
pH Value	pH Unit	0.01	7.24	7.96	7.71	7.51	7.43	7.55	7.24
Electrical Conductivity	µS/cm	1	20,700	17,900	17,400	17,800	17,700	18,100	18,200
Alkalinity									
Carbonate Alkalinity	mg/L	1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	1	424	626	340	254	129	84	69
Dissolved Major Ions									
Calcium	mg/L	1	510	486	504	536	657	698	766
Magnesium	mg/L	1	325	222	214	228	163	160	168
Sodium	mg/L	1	3,380	3,290	3,280	3,570	3,400	3,380	3,620
Potassium	mg/L	1	48	31	32	33	34	35	37
Chloride	mg/L	1	6,750	6,410	6,100	6,570	6,410	6,540	6,420
Sulfate	mg/L	1	800	45	161	138	149	168	200
Dissolved Metals									
Aluminium	mg/L	0.01	-	0.05	-	-	-	-	-
Arsenic	mg/L	0.001	0.01	<0.001	0.001	<0.001	<0.001	0.006	0.003
Cadmium	mg/L	0.0001	0.0003	<0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	<0.001	-	-	-	-	-
Copper	mg/L	0.001	0.001	<0.001	-	-	-	-	-
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	1.9	0.96	0.964	0.955	0.751	0.585	0.542
Nickel	mg/L	0.001	0.003	0.008	-	-	-	-	-
Zinc	mg/L	0.005	0.012	<0.005	<0.005	<0.005	<0.005	0.059	0.062
Iron	mg/L	0.05	1.43	0.13	<0.05	0.49	0.3	0.19	<0.05
Total Metals									
Aluminium	mg/L	0.01	-	8.43	-	-	-	-	-
Arsenic	mg/L	0.001	-	0.003	-	-	-	-	-
Cadmium	mg/L	0.0001	-	<0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	0.007	-	-	-	-	-
Copper	mg/L	0.001	-	0.018	-	-	-	-	-
Lead	mg/L	0.001	-	0.008	-	-	-	-	-
Manganese	mg/L	0.001	-	1.27	-	-	-	-	-
Nickel	mg/L	0.001	-	0.026	-	-	-	-	-
Zinc	mg/L	0.005	-	0.166	-	-	-	-	-
Iron	mg/L	0.05	-	16	-	-	-	-	-
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	µg/L	20	-	-	480	610	300	140	<20
C10 - C14 Fraction	µg/L	50	-	-	60	120	<50	<50	<50
C15 - C28 Fraction	µg/L	100	-	-	<100	110	<100	<100	<100
C29 - C36 Fraction	µg/L	50	-	-	60	60	<50	50	<50
C10 - C36 Fraction (sum)	µg/L	50	-	-	120	290	<50	50	<50
Miscellaneous									
Fluoride (mg/L)	mg/L	0.1	-	0.6	-	-	-	-	-

*Laboratory limit of reporting

Sample ID			EFGW4D						
Sample Date			09/07/08	17/01/18	24/07/18	31/08/18	27/09/18	24/10/18	15/11/18
Aquifer			Shallow overburden						
Analyte	Units	LOR*							
Water Quality Indicators									
pH Value	pH Unit	0.01	6.87	7.52	7.93	7.11	7.1	7.48	6.9
Electrical Conductivity	µS/cm	1	34,400	25,300	24,600	22,700	28,600	16,100	28,800
Alkalinity									
Carbonate Alkalinity	mg/L	1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	1	418	376	439	445	463	442	416
Dissolved Major Ions									
Calcium	mg/L	1	557	610	602	605	632	628	656
Magnesium	mg/L	1	638	535	583	607	593	591	651
Sodium	mg/L	1	4,260	4,330	4,470	4,640	4,600	4,510	4,870
Potassium	mg/L	1	118	77	81	84	84	81	87
Chloride	mg/L	1	9,400	8,890	8,570	8,790	8,330	8,640	8,780
Sulfate	mg/L	1	692	618	636	734	631	590	698
Dissolved Metals									
Aluminium	mg/L	0.01	-	<0.01	-	-	-	-	-
Arsenic	mg/L	0.001	<0.001	0.002	0.003	0.003	0.002	0.002	0.002
Cadmium	mg/L	0.0001	0.0001	<0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	0.001	-	-	-	-	-
Copper	mg/L	0.001	0.002	<0.001	-	-	-	-	-
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.898	0.797	0.964	0.768	0.728	0.72	0.74
Nickel	mg/L	0.001	0.004	0.002	-	-	-	-	-
Zinc	mg/L	0.005	0.015	<0.005	<0.005	<0.005	0.02	0.031	0.015
Iron	mg/L	0.05	4.63	4.22	4.47	4.06	4.11	4.1	3.8
Total Metals									
Aluminium	mg/L	0.01	-	2.41	-	-	-	-	-
Arsenic	mg/L	0.001	-	0.003	-	-	-	-	-
Cadmium	mg/L	0.0001	-	<0.0001	-	-	-	-	-
Cobalt	mg/L	0.001	-	0.003	-	-	-	-	-
Copper	mg/L	0.001	-	0.004	-	-	-	-	-
Lead	mg/L	0.001	-	0.003	-	-	-	-	-
Manganese	mg/L	0.001	-	0.918	-	-	-	-	-
Nickel	mg/L	0.001	-	0.005	-	-	-	-	-
Zinc	mg/L	0.005	-	0.018	-	-	-	-	-
Iron	mg/L	0.05	-	7.81	-	-	-	-	-
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	µg/L	20	-	-	<20	<20	<20	<20	<20
C10 - C14 Fraction	µg/L	50	-	-	<50	<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	-	-	220	<100	<100	<100	<100
C29 - C36 Fraction	µg/L	50	-	-	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum)	µg/L	50	-	-	220	<50	<50	<50	<50
Miscellaneous									
Fluoride (mg/L)	mg/L	0.1	-	0.2	-	-	-	-	-

*Laboratory limit of reporting

Sample ID			EFGW5D							
Sample Date			09/07/08	16/01/18	25/07/18	31/08/18	27/09/18	24/10/18	16/11/18	18/12/18
Aquifer			Shallow overburden							
Analyte	Units	LOR*								
Water Quality Indicators										
pH Value	pH Unit	0.01	8.16	8.15	8.02	7.42	7.41	7.67	7.22	7.4
Electrical Conductivity	µS/cm	1	1,970	10,400	20,600	21,600	20,400	20,700	20,900	23,900
Alkalinity										
Carbonate Alkalinity	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	1	172	429	552	567	536	493	451	473
Dissolved Major Ions										
Calcium	mg/L	1	19	120	295	306	336	334	357	263
Magnesium	mg/L	1	18	140	444	456	451	461	520	438
Sodium	mg/L	1	304	1,870	3,860	4,020	4,030	3,950	4,440	3,920
Potassium	mg/L	1	14	41	76	78	80	78	85	80
Chloride	mg/L	1	378	3,460	7,520	7,620	7,360	7,670	7,870	7,500
Sulfate	mg/L	1	92	44	<1	2	<1	16	3	<1
Dissolved Metals										
Aluminium	mg/L	0.01	-	0.02	-	-	-	-	-	-
Arsenic	mg/L	0.001	0.003	<0.001	0.005	0.003	0.004	0.004	0.004	0.004
Cadmium	mg/L	0.0001	0.0002	<0.0001	-	-	-	-	-	-
Cobalt	mg/L	0.001	-	<0.001	-	-	-	-	-	-
Copper	mg/L	0.001	0.002	<0.001	-	-	-	-	-	-
Lead	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.063	0.23	0.25	0.332	0.307	0.256	0.261	0.238
Nickel	mg/L	0.001	0.013	<0.001	-	-	-	-	-	-
Zinc	mg/L	0.005	0.036	<0.005	0.007	0.115	0.016	0.016	0.021	0.016
Iron	mg/L	0.05	0.06	<0.05	7.37	4.34	9.44	11.1	10	9.73
Total Metals										
Aluminium	mg/L	0.01	-	0.21	-	-	-	-	-	-
Arsenic	mg/L	0.001	-	0.002	-	-	-	-	-	-
Cadmium	mg/L	0.0001	-	0.0003	-	-	-	-	-	-
Cobalt	mg/L	0.001	-	<0.001	-	-	-	-	-	-
Copper	mg/L	0.001	-	0.001	-	-	-	-	-	-
Lead	mg/L	0.001	-	0.003	-	-	-	-	-	-
Manganese	mg/L	0.001	-	0.251	-	-	-	-	-	-
Nickel	mg/L	0.001	-	0.002	-	-	-	-	-	-
Zinc	mg/L	0.005	-	0.051	-	-	-	-	-	-
Iron	mg/L	0.05	-	0.3	-	-	-	-	-	-
Total Petroleum Hydrocarbons										
C6 - C9 Fraction	µg/L	20	-	-	130	130	30	60	<20	<20
C10 - C14 Fraction	µg/L	50	-	-	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	-	-	490	140	140	140	<100	<100
C29 - C36 Fraction	µg/L	50	-	-	280	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum)	µg/L	50	-	-	770	140	<50	<50	<50	<50
Miscellaneous										
Fluoride (mg/L)	mg/L	0.1	-	0.4	-	-	-	-	-	-

*Laboratory limit of reporting

Sample ID			PT1						
Sample Date			18/01/18	25/07/18	30/08/18	27/09/18	24/10/18	15/11/18	18/12/18
Aquifer			Coal seam						
Analyte	Units	LOR*							
Water Quality Indicators									
pH Value	pH Unit	0.01	8.03	8.09	7.71	7.8	7.91	7.61	7.83
Electrical Conductivity	µS/cm	1	11,600	11,200	11,000	11,100	10,900	10,800	11,000
Alkalinity									
Carbonate Alkalinity	mg/L	1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity	mg/L	1	236	233	231	224	235	213	206
Dissolved Major Ions									
Calcium	mg/L	1	178	146	168	179	181	189	141
Magnesium	mg/L	1	50	50	51	49	51	56	51
Sodium	mg/L	1	2,250	2,190	2,260	2,230	2,230	2,420	2,160
Potassium	mg/L	1	10	10	10	10	10	10	10
Chloride	mg/L	1	4,050	3,800	3,880	3,810	3,290	3,560	3,390
Sulfate	mg/L	1	1	<1	<1	<1	<1	18	2
Dissolved Metals									
Aluminium	mg/L	0.01	<0.01	-	-	-	-	-	-
Arsenic	mg/L	0.001	0.014	0.013	0.01	0.012	0.013	0.012	0.01
Cadmium	mg/L	0.0001	<0.0001	-	-	-	-	-	-
Cobalt	mg/L	0.001	<0.001	-	-	-	-	-	-
Copper	mg/L	0.001	<0.001	-	-	-	-	-	-
Lead	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.032	0.028	0.028	0.029	0.028	0.028	0.033
Nickel	mg/L	0.001	<0.001	-	-	-	-	-	-
Zinc	mg/L	0.005	0.008	<0.005	0.01	0.011	0.01	0.005	0.007
Iron	mg/L	0.05	0.28	0.65	0.15	0.6	0.76	0.7	0.44
Total Metals									
Aluminium	mg/L	0.01	0.06	-	-	-	-	-	-
Arsenic	mg/L	0.001	0.015	-	-	-	-	-	-
Cadmium	mg/L	0.0001	<0.0001	-	-	-	-	-	-
Cobalt	mg/L	0.001	<0.001	-	-	-	-	-	-
Copper	mg/L	0.001	<0.001	-	-	-	-	-	-
Lead	mg/L	0.001	<0.001	-	-	-	-	-	-
Manganese	mg/L	0.001	0.049	-	-	-	-	-	-
Nickel	mg/L	0.001	<0.001	-	-	-	-	-	-
Zinc	mg/L	0.005	0.013	-	-	-	-	-	-
Iron	mg/L	0.05	0.75	-	-	-	-	-	-
Total Petroleum Hydrocarbons									
C6 - C9 Fraction	µg/L	20	-	<20	<20	<20	<20	<20	30
C10 - C14 Fraction	µg/L	50	-	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	-	140	<100	<100	<100	<100	<100
C29 - C36 Fraction	µg/L	50	-	<50	<50	<50	<50	<50	<50
C10 - C36 Fraction (sum)	µg/L	50	-	140	<50	<50	<50	<50	<50
Miscellaneous									
Fluoride (mg/L)	mg/L	0.1	0.3	-	-	-	-	-	-

*Laboratory limit of reporting

Appendix B Numerical modelling

B Numerical modelling

The predicted impact on the groundwater regime from groundwater abstraction in relation to mine development has previously been assessed through development and simulation of a numerical groundwater model (Hansen Bailey, 2018). The focus of this part of the assessment is identification of impact above the trigger drawdown levels in the IAA and the LTAA.

B.1 Model code

Simulation of groundwater flow for the Project site was undertaken using the MODFLOW-USG code (Panday *et al*., 2015), referred to as USG for the remainder of the report.

The input files for the USG model were created using Fortran code and a USG edition of the Groundwater Data Utilities by Watermark Numerical Computing. These were used to allow for the additional capabilities of USG. The mesh was generated using Algomesh (HydroAlgorithmics, 2014).

B.2 Model domain

The model grid domain was designed to account for the future likely drawdown attributable to the project. The model boundaries are sufficiently distant to the project and its surrounds, such that there is no undue influence on the model predictions from the boundary assumptions. Where necessary, natural hydrogeological boundaries such as geological units and regional catchment boundaries, have been adopted in the model.

The model domain is ranges between approximately 27 km wide (west to east direction) and 35 km long (north to south direction) as shown in Figure B 1.

Grid spacing across the model domain is variable, with refinement around the Project mine site and locations of groundwater level observations. The model cell size becomes larger away from these key areas. The model domain was discretised into 23 layers comprising 40,596 cells (31,259 active cells, 9,337 inactive cells) for the whole model. Cell sizes range from approximately 50 m by 50 m within the mining area around, up to 500 m by 500 m outside the project site (Figure B 1).

The vertical discretisation of the model is described by the geological layers. Geological surfaces have been extrapolated across the numerical model extent from the Leichhardt Seam structure determined from exploration drilling data. To the east of the project area, the coal seam dips towards the axis of the Nebo Syncline where it becomes relatively deep. The actual depth of the coal seam aquifer in this area is uncertain as there has been no coal or gas exploration east of the project area. For the purposes of the model, a constant dip based on that observed in the project area was assumed and projected from the mapped subcrop/outcrop areas to the axis of the syncline. An average seam thickness of 4.5m is assumed in the model.

The hydraulic properties of the model are based on the initial parameters established from data collected in Section 4 of the main report. The parameters have been calibrated for a better fit to the available data. In addition, the range of regional parameters were used as a reference to set the valid ranges of the model calibration.

B.3 Model boundary conditions

The model domain is surrounded by "no flow" boundaries marked by the outcrop/subcrop of the Rangal Coal Measures, and the thrust fault zone to the east of the Carborough Range. The base of Layer 23 in the model was also assumed to be a "no flow" boundary, which does not allow any exchange of water between the model domain and the surrounding areas.

B.4 Recharge and evapotranspiration

A uniform recharge was applied to the uppermost layer in the model that represents the topographic surface. The rate of recharge to the aquifers was determined from model calibration at 0.3mm/year/m^2, which is equivalent to approximately 5% of average annual rainfall.

Evapotranspiration was applied to the same uppermost model layer at a constant rate of 2,366.60 mm/year/m^2, or 6.48 mm/day/m^2. An "extinction depth" of 3 m was applied, below which evapotranspiration does not occur.

B.5 Rivers

Creeks are represented using the river package. The river bed is incised into the land surface, and the river water level is always equal to the river bed elevation. This means the river is dry and will remove groundwater from the system when groundwater head rises above river bed elevation.

B.6 Mining progression

Mining progression was modelled using drain (DRN) boundary condition. Drain cells were placed at the base of the mined layer with cell conductance set to 100 m^2/day.

B.7 Hydraulic parameters

The horizontal hydraulic conductivity (K_h) and vertical hydraulic conductivity (K_v) for interburden (layers 2 to 21 and layer 23), and coal seams (layer 22) were set as depth-dependant Figure B 2. Storage parameters (specific yield S_y and specific storage S_s) were set as constant per each hydrostratigraphic unit. All hydraulic properties across the model domain are summarized in Table B 1 which presents the hydraulic parameters adopted for the model following calibration process.

Table B 1 Hydraulic parameters

Layer	Parameter	Value
Layer 1 Weathered Material (Regolith)	Horizontal Hydraulic Conductivity [kh]	0.5 m/day
	Vertical Hydraulic Conductivity [kv]	10% of k_h
	Specific Yield [S_y]	5 %
	Specific Storage [S_s]	5 x 10^{-5}
Layers 2 to 21 Rewan Group	Horizontal Hydraulic Conductivity [kh]	variable with depth (exponential dependence): $K_h = K_0 \times e^{(slope \times depth)}$; where: $K_0 = 1.94\times10^{-2}$ slope = -2.70×10^{-2} upper limit = 2.50×10^{-3} lower limit = 1.00×10^{-6}

Layer	Parameter	Value
	Vertical Hydraulic Conductivity [kv]	variable with depth (exponential dependence): $0.01 \times K_h$
	Specific Yield [S_y]	1 x 10^{-2}
	Specific Storage [S_s]	1 x 10^{-6}
Layer 22 Rangal Coal Seams	Horizontal Hydraulic Conductivity [kh]	variable with depth (exponential dependence): $K_h = K_0 \times e^{(slope \times depth)}$; where: $K_0 = 3.814 \times 10^{-1}$ slope = -2.70×10^{-2} upper limit = 5.00×10^{-2} lower limit = 1.00×10^{-6}
	Vertical Hydraulic Conductivity [kv]	variable with depth (exponential dependence): $0.1 \times K_h$
	Specific Yield [S_y]	5 x 10^{-2}
	Specific Storage [S_s]	5 x 10^{-5}
Layer 23 Fort Cooper Coal Measures (Model Base)	Horizontal Hydraulic Conductivity [kh]	1 x 10^{-4} m/day
	Vertical Hydraulic Conductivity [kv]	1% of kh
	Specific Yield [S_y]	1 x 10^{-2}
	Specific Storage [S_s]	1 x 10^{-6}

B.8 Modelling results

Results of the predictive model run were evaluated at the end of the UWIR period (15/3/2022). For the prediction of mining impacts heads in layers 1 (weathered surface zone) and 22 (Leichhardt Coal Seam) were extracted together with model flow budgets. Comparison between mining and null scenarios (no mining) was used to produce drawdown extents for each year.

B.9 Hydraulic heads

The hydraulic head in layer 1 is unaffected by mining at the end of the model run. Figure B 3 shows that potentiometric gradients descend downstream along mapped creeks. Any mining-induced drawdown in layer 1 is predicted to be less than 1 m.

Hydraulic head after mining in layer 22 is shown in Figure B 3. A steep potentiometric gradient is predicted around the southern mine areas, and a shallower gradient in the north.

B.10 Water budgets

The differences between calculated model inflows and outflows at the completion of the calibration run, expressed as percent of discrepancy was 0.1%, indicating an accurate numerical solution and overall stability of the model. Table B 2 presents the water budget inputs and outputs for the steady state phase of the model. Table B 3 summarizes total flows through different boundary conditions throughout the full UWIR period of 3 years.

Table B 2 Groundwater budget – steady state model (ML/day)

Parameter	Input	Output
Rainfall recharge (RCH)	0.47	0
Evapotranspiration (EVT)	0	0.17
Storage	0	0
Mining (DRN)	0	0
River leakage (RIV)	0	0.31
Totals	**0.47**	**0.48**

Table B 3 Groundwater budget – transient model (ML total)

Parameter	Input (ML)	Output (ML)
Rainfall recharge (RCH)	520	0
Evapotranspiration (EVT)	0	185
Storage	265	1.2
Mining (DRN)	0	264
River leakage (RIV)	0	335
Totals	**785**	**785.2**

B.11 Model Setup for Impact Assessment

The predictive simulation required the steady state model to be converted to transient flow conditions to predict the zone of depressurisation induced by dewatering the coal seams. The transient simulation includes the period from April 2019 to March 2022 with the initial starting conditions being those determined from the steady state analysis. Depressurisation of groundwater from the numerical model is simulated using the Drain package (DRN) to represent the underground mining progression. The drain cells representing mining extent the entire thickness of the Leichhardt Coal Seams represented by Layer 22.

B.12 Sensitivity

The predicted drawdown extents are dependent on the hydraulic properties of the geological layers that have been adopted in the model. These are based on calibrated aquifer parameters, however the sensitivity of the predicted drawdown extents to changes in the properties was assessed.

Each parameter was increased (+) or decreased (-) by half order of magnitude. Since hydraulic conductivity is depth-dependent, the value that was increased and decreased was K_0 (initial hydraulic conductivity at depth of 0 m). It should be noted that changes to these parameters impacts the calibration of the model, therefore changes that cause significant deviations from the baseline prediction are considered unlikely.

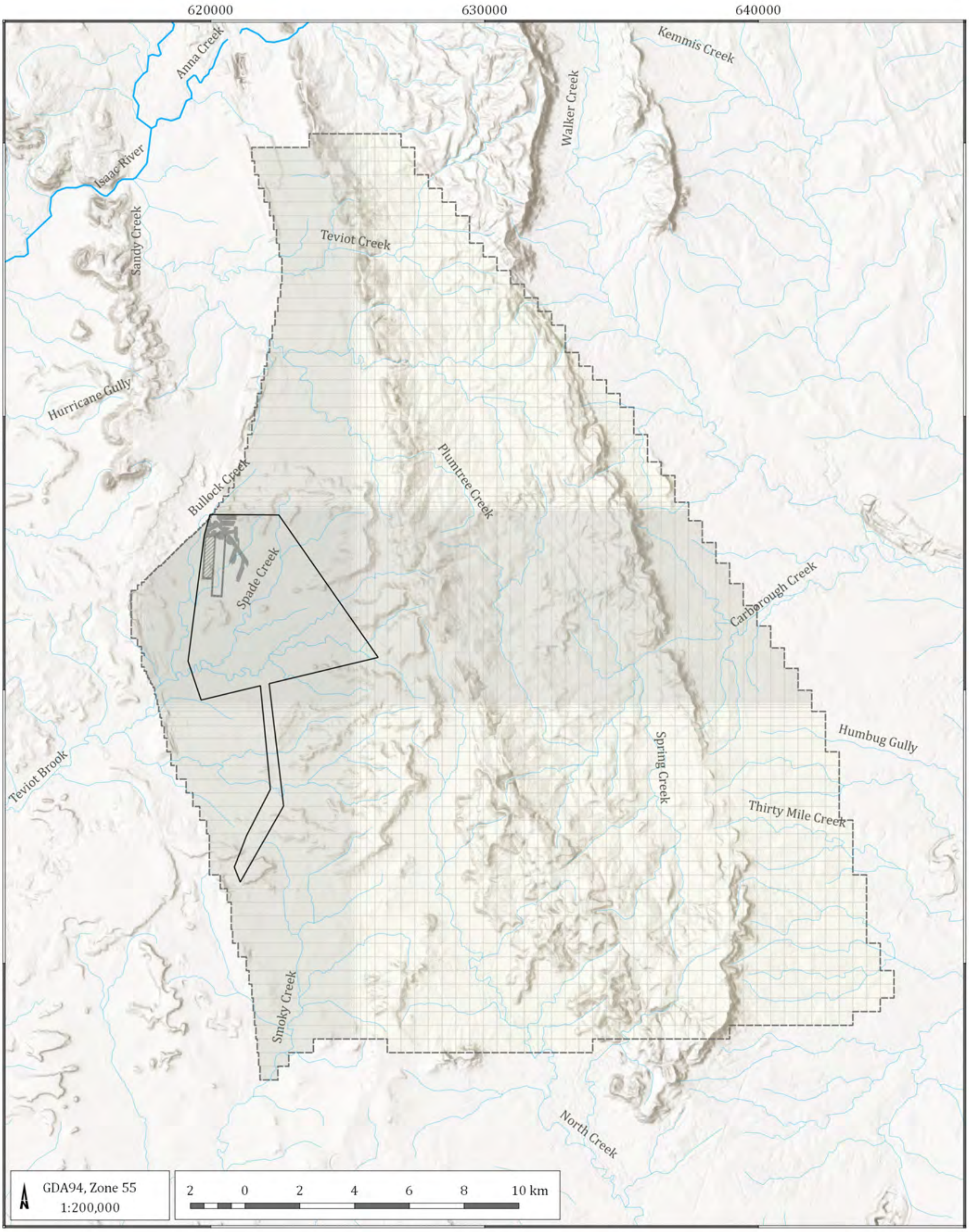
Figure B 4 shows the predicted UWIR mine inflows. Figure B 5 shows the rates of groundwater inflow over time for the multiple sensitivity scenarios. The model is most sensitive to an increase in specific yield, while other parameters do not cause deviations as far from the baseline. The model is least sensitive to a decrease in specific storage.

Table B 4 summarises the cumulative inflow volume (ML) for each sensitivity scenario.

Table B 4 Cumulative inflow volumes for sensitivity scenarios

Sensitivity scenario	Cumulative inflow volume (ML)
Baseline	263.5
K+	316.6
K-	242.6
Ss+	292.0
Ss-	259.7
Sy+	652.3
Sy-	217.0

Changes to the post-mining drawdown caused by each sensitivity scenario are shown in Figure B 6.



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Limit of Leichardt seam subcrop
- Model mesh
- Longwall panel/Gate roads

Ironbark UWIR (G1915F)

Numerical model domain

DATE 20/03/2019

FIGURE No: **B-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.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\B-01_G1915F_Numerical model domain.qgs

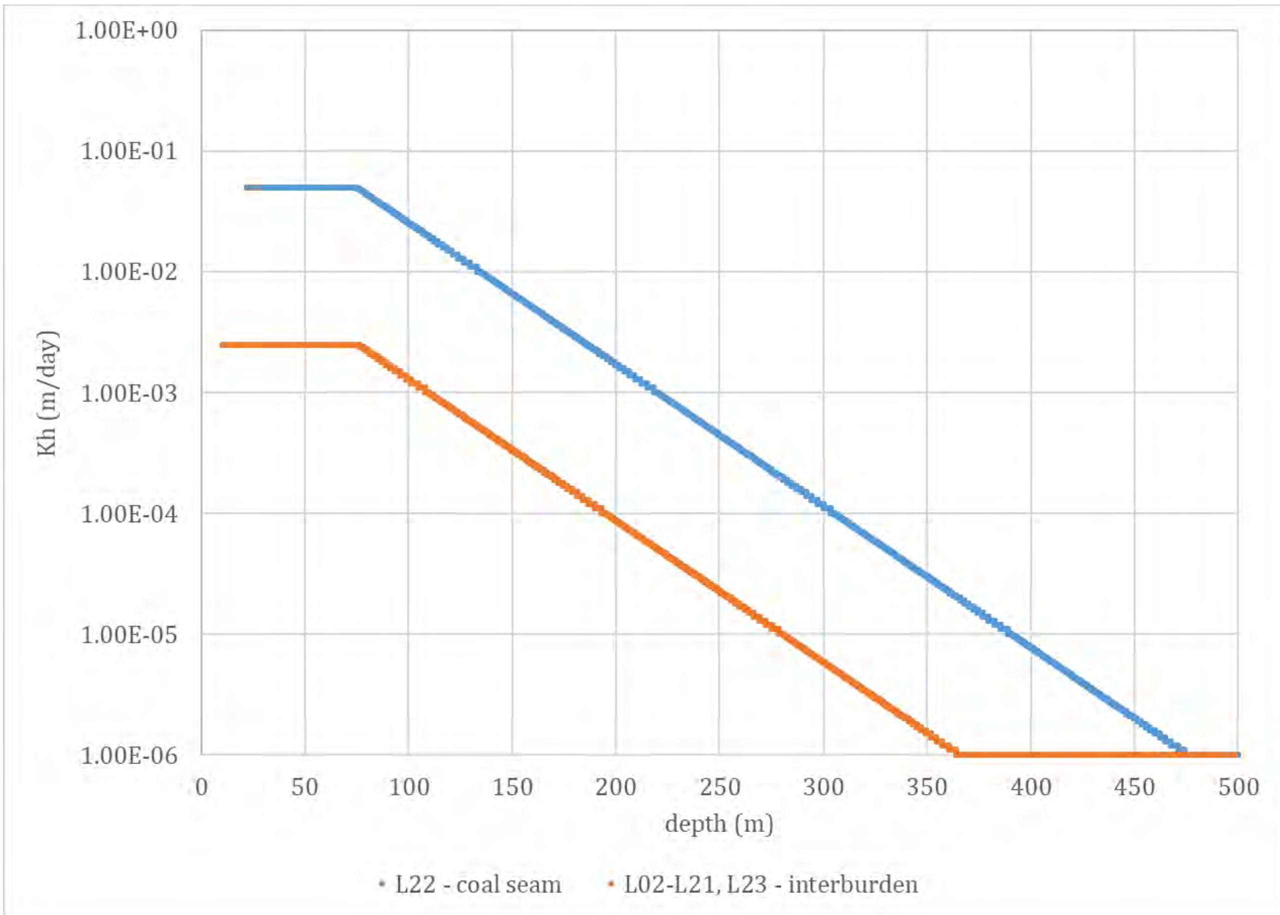
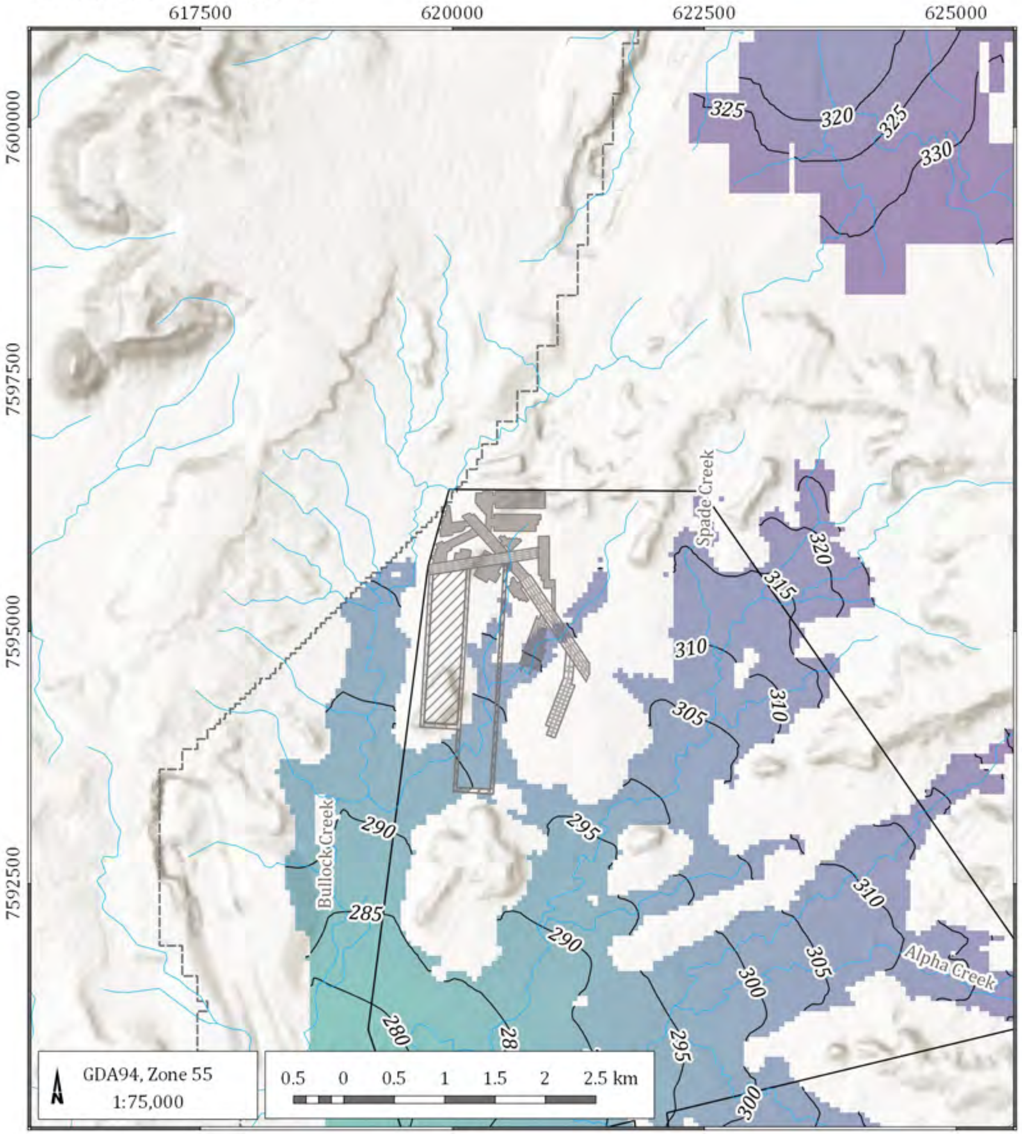
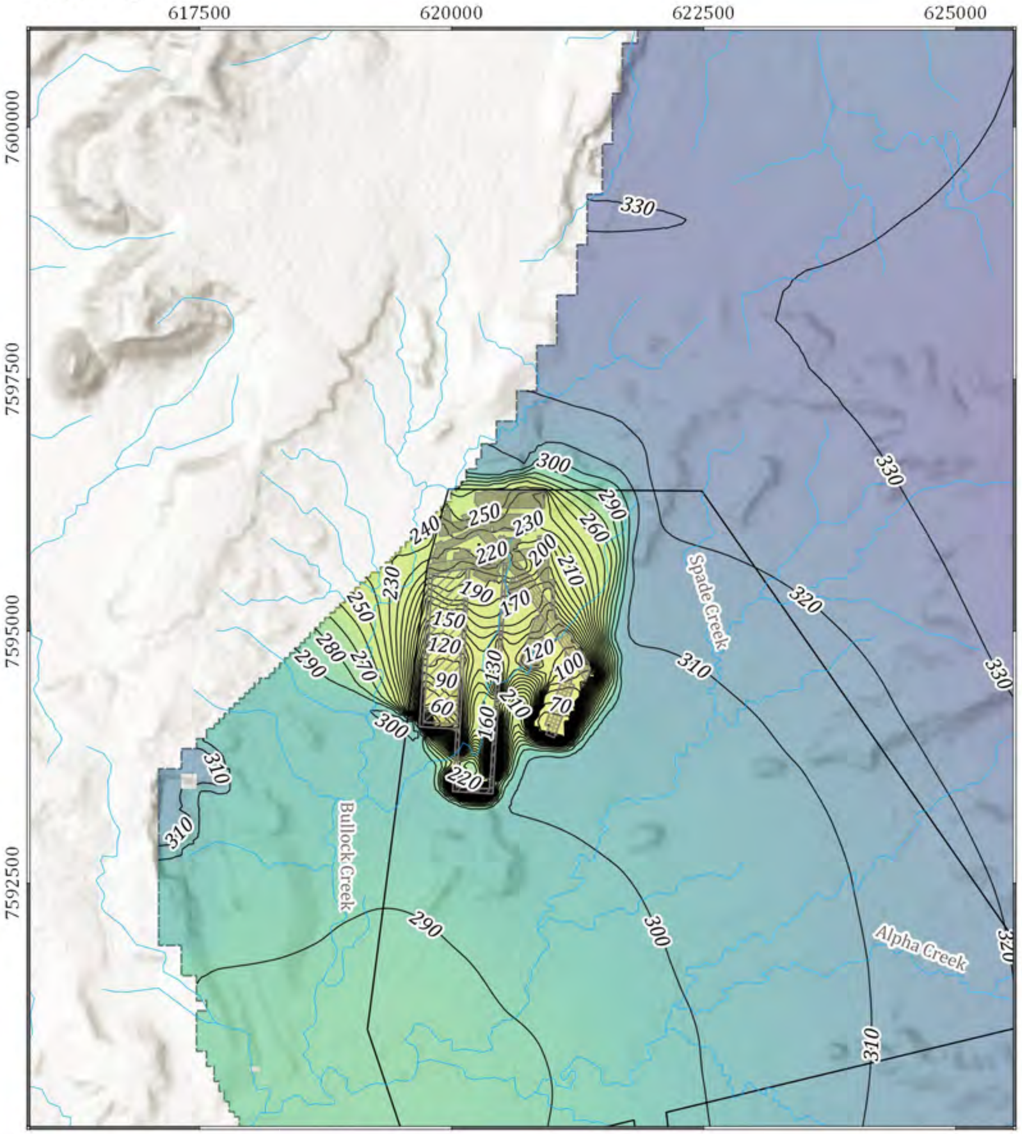


Figure B 2 Depth dependence of horizontal hydraulic conductivity – Interburden (layers 2-21 and 23) and coal seams (layer 22)

Saturated heads - Layer 01



Head - Layer 22



LEGEND

- Creeks
- Project Mining Lease Boundary
- UWIR Mining Area
- Limit of Leichardt seam subcrop
- Longwall panel/Gate roads

Heads (mAHD)

- -100
- 0
- 100
- 200
- 300
- 400

Ironbark UWIR (G1915F)

Predicted Layer 1 and Layer 22 groundwater heads at end of year 3

DATE
21/03/2019

FIGURE No:
B-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.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\B-03_G1915F_Predicted Layer 1 and Layer 22 groundwater heads at end of year 3.qgs

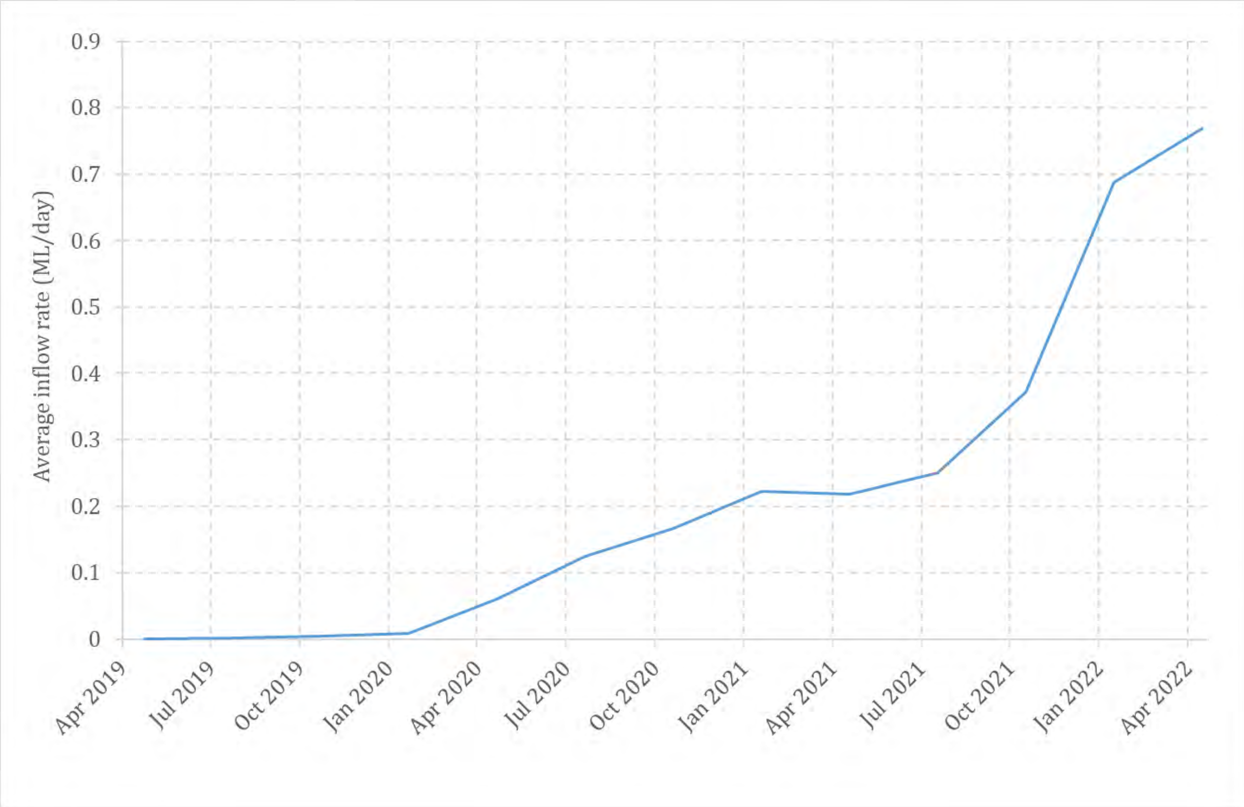


Figure B 4 Predicted UWIR mine inflows

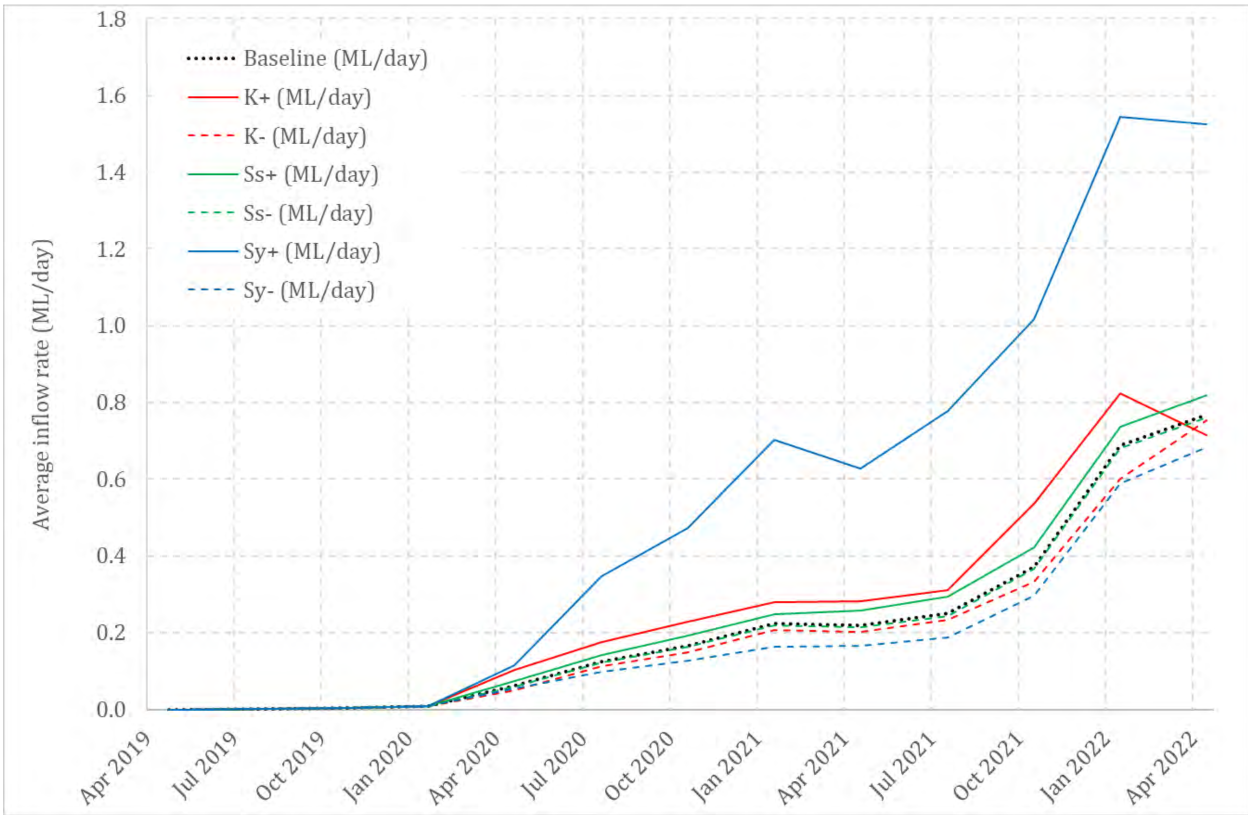
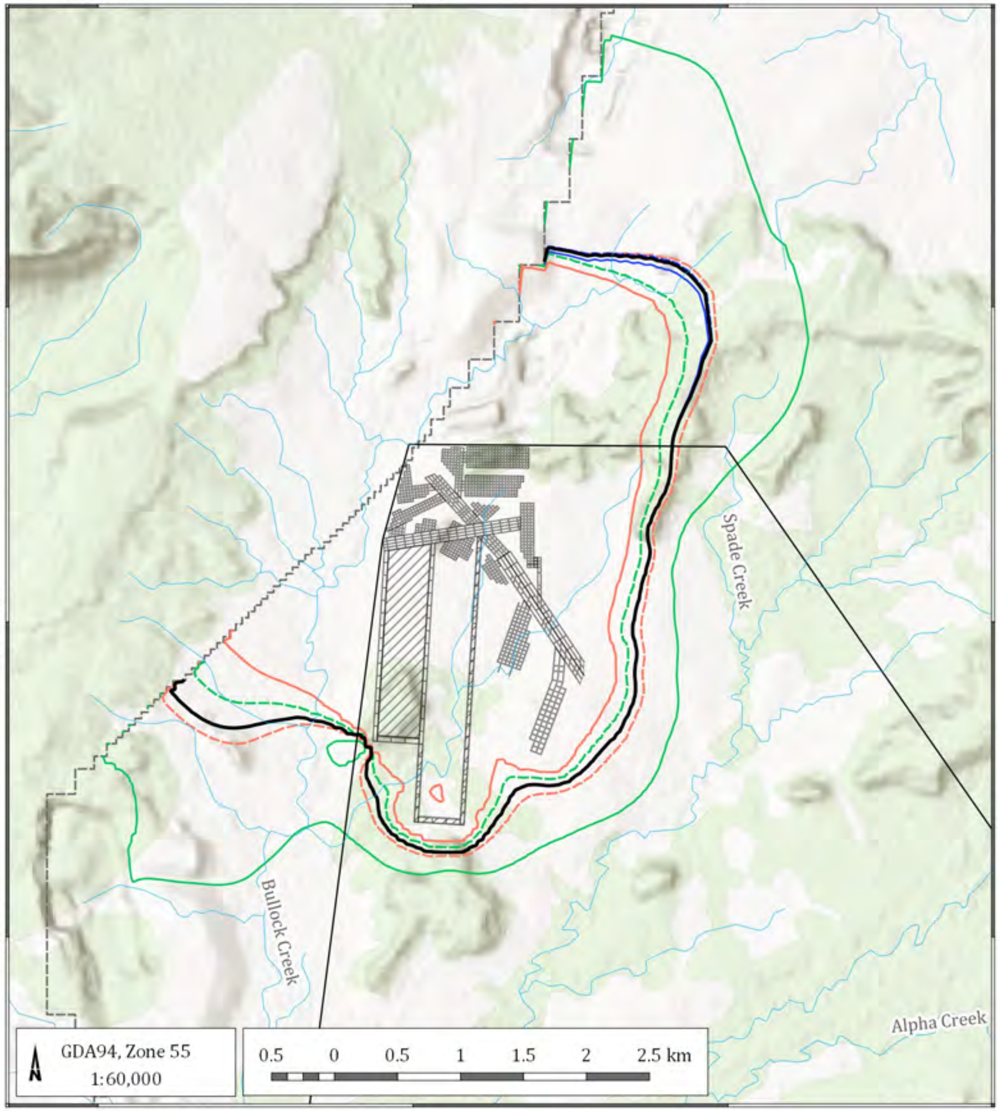
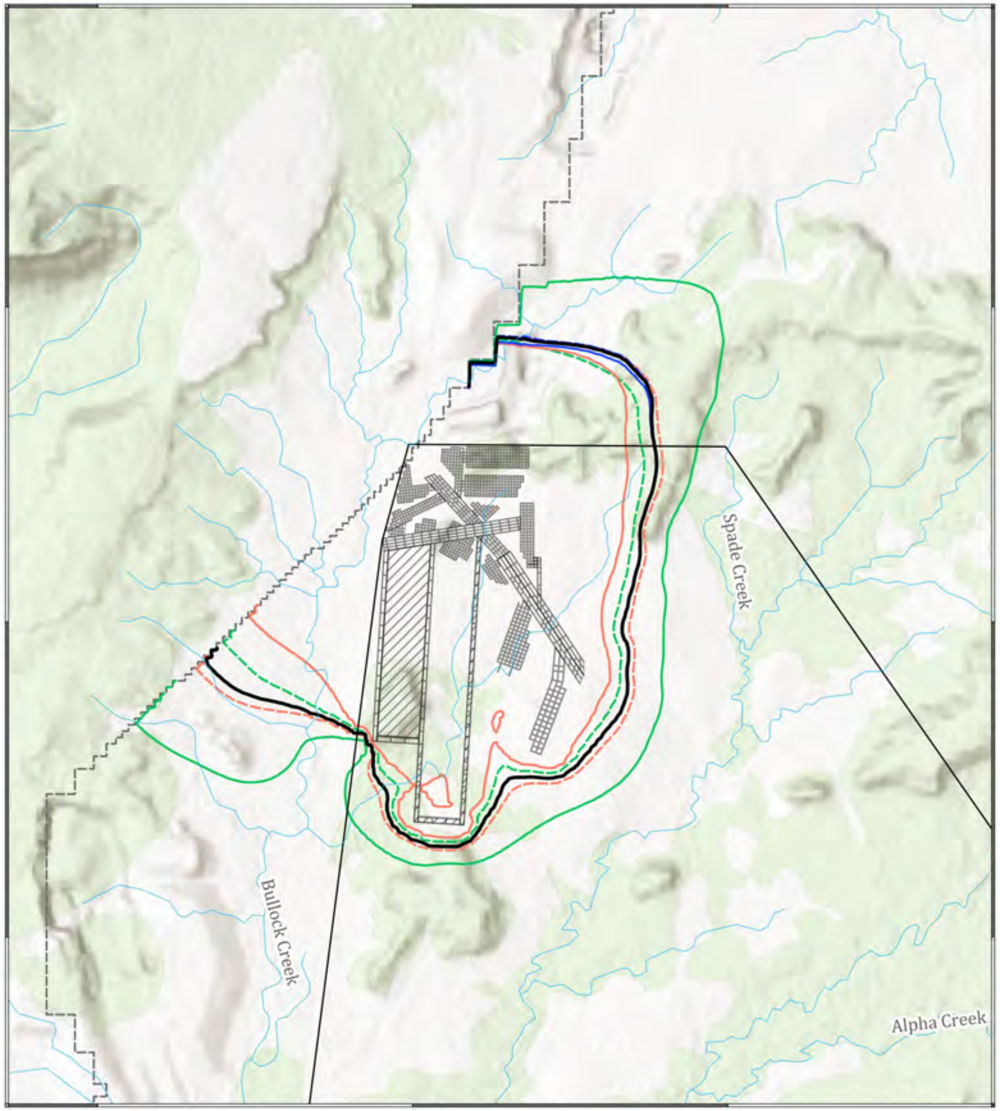


Figure B 5 Average inflow rates for sensitivity scenarios

Drawdown sensitivity (1 m)



Drawdown sensitivity (5 m)



LEGEND

- Creeks
- Project Mining Lease Boundary
- Limit of Leichardt seam subcrop
- UWIR Mining Area
- Longwall panel/Gate roads
- Vegetation

Baseline (1m & 5m drawdown)

Drawdown sensitivity

- Sy+
- Sy-
- Ss+
- Ss-
- K+
- K-

Ironbark UWIR (G1915F)

Predicted drawdown - Sensitivity analysis layer 22 drawdown contours

DATE
21/03/2019

FIGURE No:
B-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.;
G:\Projects\G1915F.Ironbark UWIR\3_GIS\Workspaces\001_Deliverable1\B-06_G1915F_Predicted drawdown - Sensitivity analysis layer 22 drawdown contours.qgs